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ABSTRACT

The report reviews the evolution of existing national programs for air traffic controller training, estimates the number of persons requiring developmental and supplementary training, examines present controller selection and training programs, investigates performance measurement methods, considers standardization and quality control, discusses the capabilities and limitations of existing simulation devices for air traffic controller training, and identifies and compares on a cost basis developmental training alternatives. It also considers: simulators and centralized and noncentralized training, the training budget, future requirements of training, research and development for training, hiring practices, and the training load at the Federal Aviation Administration Academy. Over 200 pages of the document consist of the following appendixes: statement of work; field facility survey on training; simulation for air traffic controller training, selection of air traffic controllers; performance measurement in air traffic control; review of present training; cost analyses of air traffic controller training, FY 1974, and of alternative training methods; alternative developmental training programs; and budgetary and fiscal control training. (NTIS/JR)

TRAINING OF U.S. AIR TRAFFIC CONTROLLERS

(IDA Report R-206)

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FINAL REPORT

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16. Abstract

After a brief review of the evolution of existing national programs for air traffic controller training, an estimate is prepared of the number of individuals who will require developmental and supplementary training. The present controller selection and training programs are then examined, leading to an investigation of the methods available to measure performance and to establish competence on the job. The role of standardization and quality control is then addressed. The capabilities and limitations of existing simulation devices for air traffic control training are considered. Alternative ways of meeting the training needs of developmentals are identified and compared on a cost basis. Finally, attention is given to (a) simulators and centralized and noncentralized training, (b) the training budget, (c) future requirements of training, (d) R&D for training, (e) hiring practices, (f) standardization, and (g) the training load at the FAA Academy.

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FOREWORD

The FAA has been increasingly concerned about the National Training Programs for development of En Route and Terminal controllers. Divergent views have been expressed concerning location and duration of this training, the order and content of the curriculum, the use and capabilities of simulators and the degree of centralization that is desirable. This report addresses these questions. Where answers are not available now, a way of obtaining the answers is offered. Cost is the dominant measure used in comparing alternatives.

In addition to the authors, several people helped in the study and the preparation of this report. James J. Bagnall performed an early investigation of the simulation capabilities of the existing ATC systems and the associated improvement program. Vernon I. Weihe, consultant, of Arlington, Va., reviewed the capabilities of digital computer simulators, particularly as they could be used for the ARTS II system. The data obtained in the facility survey that was performed were processed and developed by Elizabeth Ratigan of the IDA Computer Group. Beth A. McClain helped to prepare the survey data and also helped in using the results to develop program costs. Their efforts are gratefully acknowledged.

A draft of this report was reviewed by Joseph G. Colmen, president of Education and Public Affairs, Inc., and by Stuart H. Starr and John J. Metzko, both of IDA. Their helpful suggestions and revisions have made an important contribution to this report.

Finally, the assistance and support of Arnold Corradino, James I. Moore, and H. Douglas French, Office of Personnel and Training, FAA, are greatly appreciated. Gratitude is due for their efforts to obtain much of the necessary information for this study.

CONTENTS

ABBREVIATIONS AND ACRONYMS

A/N	Alphanumeric
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ARTCT	Air Route Traffic Control Tower
ARTS	Automated Radar Terminal System
ASR	Air Surveillance Radar
ATB	Air Traffic Branch
ATC	Air Traffic Control; Air Traffic Controller
ATCBI	Air Traffic Control Beacon Interrogator
ATCC	Air Traffic Control Center
ATCRBS	Air Traffic Control Radar Beacon System
ATCS	Air Traffic Control Specialist
ATS	Air Traffic Service
B DAS	Beacon Data Acquisition System
BRITE	Bright Radar Indicator Tower Equipment
CAA	Civil Aeronautics Administration
CAMI	Civil Aeromedical Institute
CARI	Civil Aeromedical Research Institute
CCC	Central Computer Complex
CDC	Computer Display Channel
CED	Computer Entry Device
CIFRR	Common IFR Room
CODE	Controller Decision Evaluation
CONUS	Contiguous United States
CPM	Controller Performance Measurement

CRD	Computer Readout Device
CSC	Civil Service Commission
CUE	Computer Update Equipment
CUM	Cumulative
DABS	Discrete Address Beacon System
DAS	Data Acquisition Subsystem
DCC	Display Channel Complex
DEDS	Data Entry and Display System
DPS	Data Processing Subsystem (or System)
DS	Dynamic Simulation; Dynamic Simulator
DSF	Digital Simulation Facility
DSS	Data Systems Specialist
EAR	Employee Appraisal Record
EEO	Equal Employment Opportunity
EPA	Education and Public Affairs, Incorporated
EPDO	Evaluation and Proficiency Development Officer
EPDS	Evaluation and Proficiency Development Specialist
ETG	Enhanced Target Generator
ETS	Educational Technology and Standards (Branch)
FAA	Federal Aviation Administration
FAM	Familiarization (Flight)
FDB	Full Data Block
FSS	Flight Service Station
FY	Fiscal Year
GCI	Ground-Controlled Intercept
GS	General Schedule
IDA	Institute for Defense Analyses
IFR	Instrument Flight Rules
IOP	Input-Output Processing
IPC	Intermittent Positive Control

LSI	Large-Scale Integrated (Circuit)
MLS	Microwave Landing System
MTS	Management Training School
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NAS-A	National Airspace System, Stage A
NATO	North Atlantic Treaty Organization
NR	Non-Radar
NTDS	Navy Tactical Data System
OJT	On-the-Job Training
O&M	Operation and Maintenance
OTS	Over-the-Shoulder
PATCO	Professional Air Traffic Controller's Organization
PC&B	Personnel Compensation and Benefits
PCD	Production Common Digitizer
PDB	Partial Data Block
PEM	Position Entry Module
PPI	Plan Position Indicator
PRE	Pre-Control
PVD	Plan View Display
QUAL	Qualification
RAPCON	Radar Approach Control
RATCC	Radar Air Traffic Control Center
RATCF	Radar Air Traffic Control Facility
RBI	Radar Beacon Interrogator
R&D	Research and Development
R DAS	Radar Data Acquisition System
REM	Remedial (Training)
RML	Radar Microwave Link
RNAV	Area Navigation

SAGE	Semi-Automatic Ground Environment
SDC	System Development Corporation
SET	Simulated Environmental Training
STP	System Training Program
TDC	Technical Development Center
TPAP	Technical Performance Appraisal Program
TRACAB	Tower Radar Automation Cab
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules

SUMMARY

A. OBJECTIVE

The objective of this study is to provide information useful for improving the air traffic controller training system of the U.S. Federal Aviation Administration (FAA). Special consideration is given to the cost and duration of training and to the ability of the training system to handle various loads. Key issues are the benefits of centralized and noncentralized training and the need for simulators.

B. FINDINGS

The principal findings of the study are summarized here, grouped according to the tasks assigned by the agreement for the study. Evidence in support of each finding appears in the report on the pages cited in parentheses.

Task 1. Training Load

1.1. The hiring requirement for new air traffic controllers is highly dependent on the separation rate of controllers and the attrition rate of trainees. The present attrition rate of trainees (FY 1974) is 43 percent for the en route option and 38 percent for the terminal option. The average annual separation rate for the last 13 years has been 5.1 percent for en route controllers and 3.3 percent for terminal controllers. Should these latter separation rates prevail into the future, the new hires needed to fill FAA projections of required controller positions are:

Trainee Attrition Rate	FY 1975		FY 1980	
	En Route	Terminal	En Route	Terminal
Present Rate	1110	1350	1160	1480
1/2 Present Rate	810	1040	840	1130
1/4 Present Rate	710	920	740	1000

(pp. 11-21)

Task 2. Training Process

2.1. Improved selection criteria are available that could reduce the number of controllers who fail during training. If failures could be eliminated completely, the cost of training would be reduced 33 percent for the en route option and 22 percent for the terminal option. (pp. 25-26)

2.2. Objective measures of performance of air traffic controllers have been developed by the FAA but are not in use at present. These measures are important for determining the competence of controllers during and after training. (pp. 27-30)

2.3. The present curriculum provides the information needed by controllers to do their work. However, questions about the amount of time given to various segments of training, the order of training (e.g., non-radar training followed by radar training), and the value of training on prototype sectors can be resolved best by an experimental approach which would use the foregoing objective performance measures. (pp. 26-27)

2.4. There is substantial evidence of lack of standardization throughout controller training. An FAA office should be vested with a positive role of certification of both field facility training programs and the qualification of individual trainees. (pp. 26-27, 61)

Task 3. Simulation

The simulators in the National Airspace System, Stage A (NAS-A) and the Automated Radar Terminal System (ARTS) III

appear sufficiently realistic and adequate for radar training of controllers, although they have some limitations, e.g., analog information cannot be simulated on the ARTS III system. These limitations could be remedied by development of inexpensive software and hardware, some of which is already under way. The simulators at the facilities are usable for proficiency, remedial, and supplemental training. Because performance is not measured objectively at present, a program of software development to accomplish this should be introduced. A simulation capability for proficiency testing and supplemental training should be introduced in the ARTS II. (pp. 35-41)

3.2. The cost of air traffic control simulators is a small part of the training cost for developmentals (less than 5 percent). A full simulation capability should be introduced at a centralized training facility, presumably the FAA Academy. (pp. 53-55)

3.3. The training requirements introduced by improvements in future systems should be identified early in the development cycle. This is important in order to procure hardware and software for simulation and to develop proper training programs in a more timely fashion. (pp. 57-58)

Task 4. Training Method

4.1. Within the accuracy of the study's cost estimation and training program specification, there is little difference in the costs of actual trainir of developmentals on a centralized or noncentralized basis for either controller option.

The duration of the developmental period has a strong impact on the cost of training, and shortening of this period can save as much as $48,000 for training each controller. With full-time academic training, screening can be accomplished sooner, and developmentals' unproductive

time can be reduced. A centralized facility would have greater capability for full-time training than an operating control facility. (pp. 43-51)

5. General Findings

5.1. The total controller training budget is substantially greater than is explicitly identified at present. The actual amount should be determined and the application to purposes of training should be reviewed regularly. (pp. 55-56)

5.2. New R&D on controller selection, performance measures, order of training, and training techniques is warranted. A focal point should be established to coordinate all personnel-related R&D in FAA, including ongoing research, and to respond to findings. (pp. 58-59)

5.3. Fluctuations in hiring can and should be reduced. More efficient use of the Academy would result. At current staffing and training loads, approximately $1 million could be saved annually by smoothing trainee enrollments. (pp. 59-62)

I. INTRODUCTION

A. OBJECTIVE AND TASKS

The objective of this study is to provide information useful for improving the air traffic controller training system of the U.S. Federal Aviation Administration (FAA). Special consideration is given to the costs and duration of training and to the ability of the training system to handle various loads. Key issues are the benefits of centralized and noncentralized training. The study addresses the following tasks (paraphrased from the work statement reproduced in Appendix A):

- Review the evolution of the existing national programs for the qualification, refresher, proficiency maintenance, and supplementary training of en route and terminal control specialists.

1. Develop estimates of the number of individuals who will require various types of qualification and supplementary training.
2. Access the adequacy of current specifications for training. Compare (a) the content and relevance of present training courses and (b) the methods used to establish competence at course completion and the current specifications for training. Examine the extent to which the current specifications for training are based upon analyses of on-the-job performance and the degree to which qualification standards have been validated against operational performance data. Included would be an analysis of the need for, and a description of, the requirements for standardization and quality

control in terms of the implication or impact, or the lack thereof, on training.

3. Appraise the capabilities and limitations of the state of the art of simulation devices relevant to air traffic control training. Describe and analyze the applicable simulation, on-line, and classroom facilities that may be required for training the anticipated loads. Include the influence of such factors as number, type, and complexity of equipment, location of the training facilities, and sequence of progression through training blocks upon the number of individuals who may be trained per unit time, the duration of training, and the total annual cost of the training program. The purpose of the analysis is to provide information needed to make decisions concerning the number, type, and location of training facilities and equipment.
4. Identify and evaluate the alternative methods currently and potentially available in which training needs could be satisfied.

B. METHODOLOGY AND MANNER OF PRESENTATION

Standard research procedures were used for much of the study; e.g., training materials were examined, visits were made to FAA facilities, interviews and discussions were held, regional and headquarters reports were reviewed, research reports were studied, statistical information was collected. Later, a survey was undertaken of all en route and terminal facilities because specific data on training at these facilities were needed. A seven-page questionnaire was constructed and disseminated. All the centers and over 80 percent of the terminal facilities responded. These responses became an important source of data for this study and may have value to other FAA activities.

The main body of this report consists of chapters arranged in the order of the tasks listed above, followed by a chapter that covers a number of important aspects developed in the process of performing the study. Nine appendices contain much of the supporting data and information.

C. THE AIR TRAFFIC CONTROL SYSTEM

The purpose of air traffic control (ATC) is to ensure safe and efficient movement of aircraft. Control of aircraft in the National Airspace System (NAS) is done from the ground, and it is designed to keep aircraft separated from each other and to expedite the flow of traffic. Control facilities develop information from a variety of sources, including long-range surveillance radars, local airport radars, adjacent control areas, and by direct vision from towers. Air traffic control is exercised at terminals and between terminals. Control between terminals is called en route control. En route control in the continental United States is distributed among 20 air route traffic control centers (ARTCCs) for aircraft operating on instrument flight rules (IFR). Terminal control facilities can be divided into those capable of handling traffic operating on IFR and those that can handle only aircraft operating under visual flight rules (VFR). Controllers are usually classified by the kind of facility in which they operate, i.e., en route, IFR terminal, and VFR terminal. Training programs for controllers are designed for each of these specialties.

II. EVOLUTION OF THE NATIONAL TRAINING PROGRAM

This chapter reviews the evolution of the existing national program for the qualification, refresher, proficiency maintenance, and supplementary training of en route and terminal control specialists.

The objective of the national training program is to equip and retain controllers who can make the ultimate decisions necessary to maintain the safe, expeditious, and orderly flow of air traffic. At times the controllers who operate this man-machine system perform under great stress; often they operate under great boredom. The character of this workload provides the basis for selecting and training air controllers.

ATC services were initiated in November 1941. The training program started in the same year and, in the next two years, seven training centers were established in key locations throughout the country. Wartime flying demands caused the service to be considerably expanded. Women were also recruited, and by the end of World War II they comprised one-third of the controller work force. In contrast, only 2.2 percent of enrollments for ATC training in 1969 were women (Cobb et al., 1972). The pay of women has always been the same as that of men in the Air Traffic Service (ATS).

After World War II, the regional training schools were closed, and many instructors moved to the Aeronautical Center established by the Civil Aeronautics Administration (CAA) in 1946 at Oklahoma City. However, most training reverted to an on-the-job training (OJT) method. Centralized training was authorized in 1956 by the CAA at what became in 1959 the FAA Academy. When the ATC work force expanded in 1959-63, this centralized training comprised

some 4 to 8 weeks of training on the so-called basic airman subjects (e.g., flight navigation, communication, maps and flight plans). At that time the Academy program performed a primary screening function by determining the aptitude of prospective air traffic controllers while at the school.

By 1963, enrollment at the Academy had declined to 76 percent of capacity. Although plans were developed to increase the depth and amount of centralized training, ATC training at the Academy was discontinued in 1963 when recruitment of new controller candidates fell to a low level. The primary function of the Academy then became the preparation and distribution of training materials to the facilities which conducted the qualification, refresher, and suplementary training programs.

Centralized training of the 6- to 8-week variety was reinstituted in 1968, primarily for screening purposes. In 1970, a major part of the Phase II portion of the en route training program was inaugurated at the Academy, and radar control training was accomplished by using the simulation facilities at NAFEC. This latter expedient was discontinued in 1972. Comparable portions of terminal control specialist training were performed at the Academy beginning in 1971. However, lack of adequate simulation facilities prevented effective radar control training, and it still does. The present Terminal Training Program was adopted in 1972.

Refresher, proficiency maintenance, and supplementary training have always been under the control and operation of each facility. The standards are established at the Academy, which also prepares self-study materials. For example, supplementary training associated with the introduction of automation has generally been performed on an expediency basis at each facility.

III. PROJECTED TRAINING LOAD

This Chapter develops estimates of the number of individuals who will require various types of qualification and supplementary training. Estimates are provided for three classes of training--en route, terminal, and supplemental. A variety of data sources have been used, including the recent IDA survey of training at centers and terminals described in Appendix B. The estimates are based on the relationship between controller positions, attrition, and training losses and reflect controller productivity improvements. Some problems inherent in translating the necessary hiring to an efficient training program are presented.

A. METHOD

The method used to develop the estimates of the developmental training load was as follows:

a. Determine from FAA (1973b) and FAA (1974f) the linear trend of traffic handled by centers and terminals.

b. Take the linear trend through the actual number of controller positions in the last 6 years (FAA RIS MIN 3300-5 reports) and the estimates of requirements through 1985 (Office of Aviation Economics, FAA, 1974c). The projected productivity improvements can be observed.

c. Examine the history of the separation rates of controllers (FAA, 1971b and RIS MN 3300-5 reports) to estimate a future separation rate.

d. Estimate the attrition of air traffic controllers from the IDA survey for FY 1974. [Similar attrition rates

were reported in the Corson Report (Corson et al., 1970) and more recently in the Great Lakes Region (Hollinger, 1974).]

e. Use an elementary difference equation to predict necessary hires, and hence the future developmental training load.

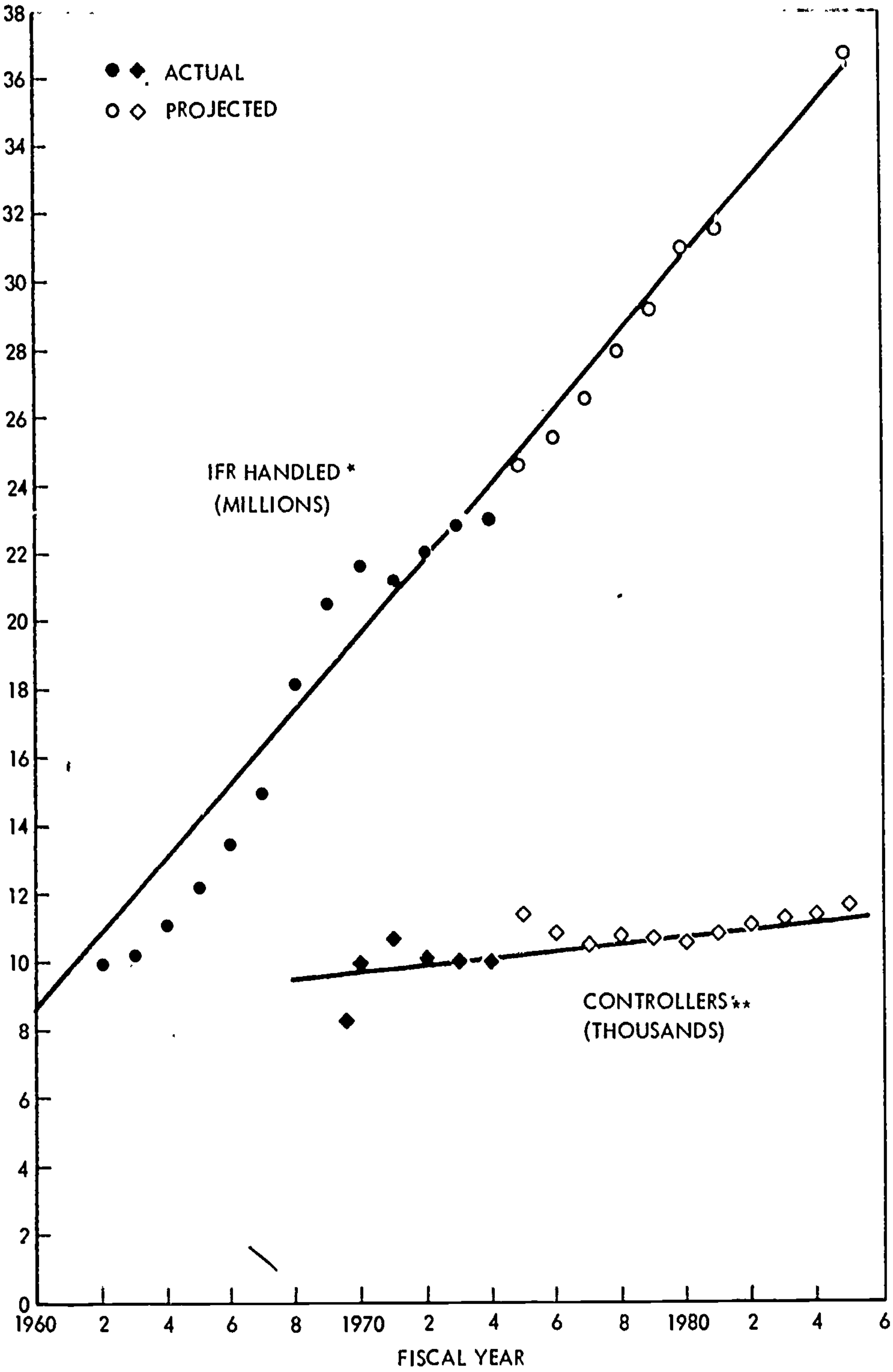
Another method of estimation was initially tried. In that method, an attempt was made to construct an estimate from the sum of the requirements at each individual facility and thereby reflect their present situation and trends. However, there was such variability in the facility data (Appendix B) that consistent projections were infeasible. This approach is unworkable without detailed knowledge of the separation, hiring, and training situation prevailing at each facility.

B. EN ROUTE

The history and latest projection of IFR traffic handled (overflights plus departures multiplied by two) for the United States is shown in Fig. 1. The straight line is a least-squares fit to these data. Also shown are the numbers of all en route controller positions for past years and the provisional estimates for future years. These data apply to the end of the fiscal year. A straight line is again fitted to the controller data for smoothing purposes. The data smoothed by the linear fits are recorded in Table 1.

The straight-line fit avoids the discontinuities in the estimates of controller numbers developing from different sources at different times and from changes in productivity estimates.

Experience concerning ARTCC separations for the en route controllers is shown in Fig. 2. Considerable fluctuation occurs from year to year (from 2.1 percent in FY 1965 to 11.2 percent in FY 1970). The average separation rate is 5.1 percent.



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* FAA "Aviation Forecasts 1975 - 1986"

**FAA AMN-22 reports and Office of Aviation Economics forecast

FIGURE 1. En Route Traffic Load and Controller Positions

TABLE 1. SMOOTHED TRAFFIC AND EN ROUTE CONTROLLER ESTIMATES[a]

Year	IFR Traffic (millions)	All En Route Controllers (thousands)	Gross Productivity (IFR/Controller)	Annual Productivity Increase (percent)
1970	19.2	10.0	1920	--
1972	21.5	10.2	2108	4.9%
1974	23.8	10.4	2288	4.2
1976	26.0	10.6	2453	3.6
1978	28.3	10.8	2620	3.4
1980	30.5	11.0	2773	2.9
1982	32.8	11.2	2929	2.8

[a]Data Source: Least-squares fit in Fig. 1.

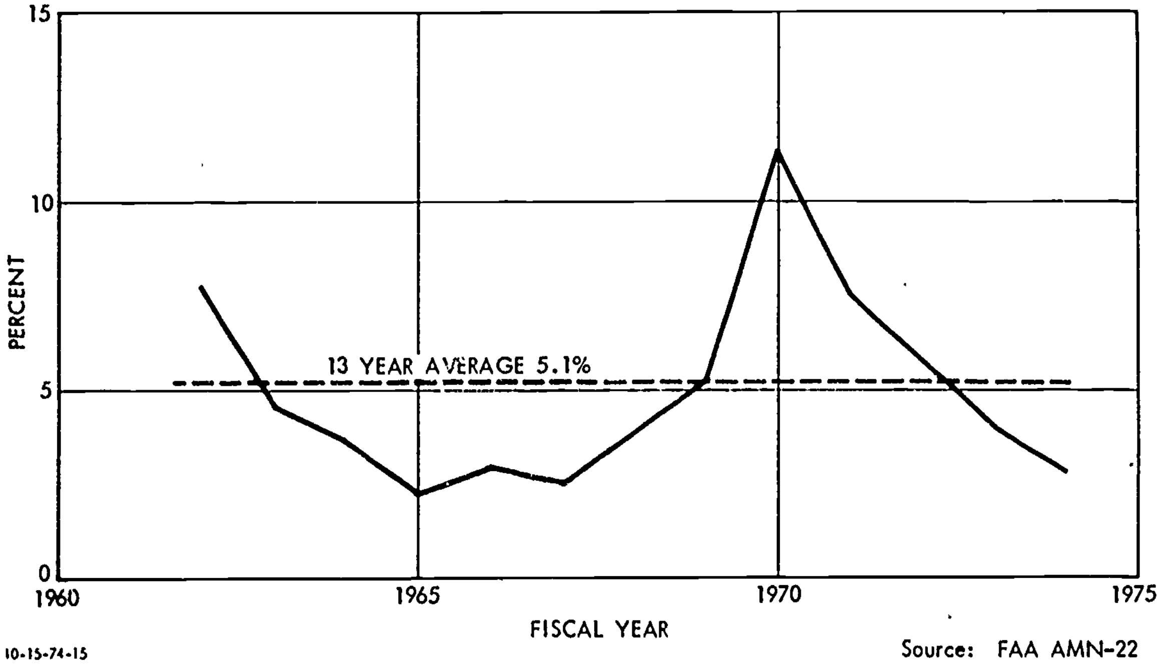

FIGURE 2. ARTCC Controller Separation Rate

The loss rate of developmentals during the training period is substantially larger than the later loss rate of journeymen. The Corson Committee (Corson et al., 1970) reported attrition as a percentage of hires to be:

Year	Attrition
1967	17.4%
1968	17.8
1969	22.4

The IDA survey found an overall attrition (all phases) to be somewhat lower--14.3 percent for en route in FY 1974. This corresponds to a loss rate of approximately 43 percent over the entire developmental period (Appendix G, Table G-13).

A projection to the future training load can be made by using a difference equation relating hires with numbers of controllers required and separation and training losses,

$$H_y = [(1 + r) C_{y+1} - C_y]/(1 - s), \qquad (1)$$

where H_y represents the number of new hires in year y

r is the separation rate of journeyman controllers

s is the loss rate of developmentals during training

C_y is the number of controllers required in year y. This reflects changes in controller productivity in year y. The number of controllers required is shown in Table 1.

The required hiring to meet retirement, training losses, and traffic controller position increases is derived for en route centers by using Eq. 1 and is shown in Fig. 3. The smoothed controller requirements are used. To meet the increasing traffic demands, 103 additional positions per year are required. To meet training losses alone, 181 employees must be hired for these additional 103 positions. The remaining hires are to replace separation losses. Also shown in Fig. 3 are the effects of reduced attrition

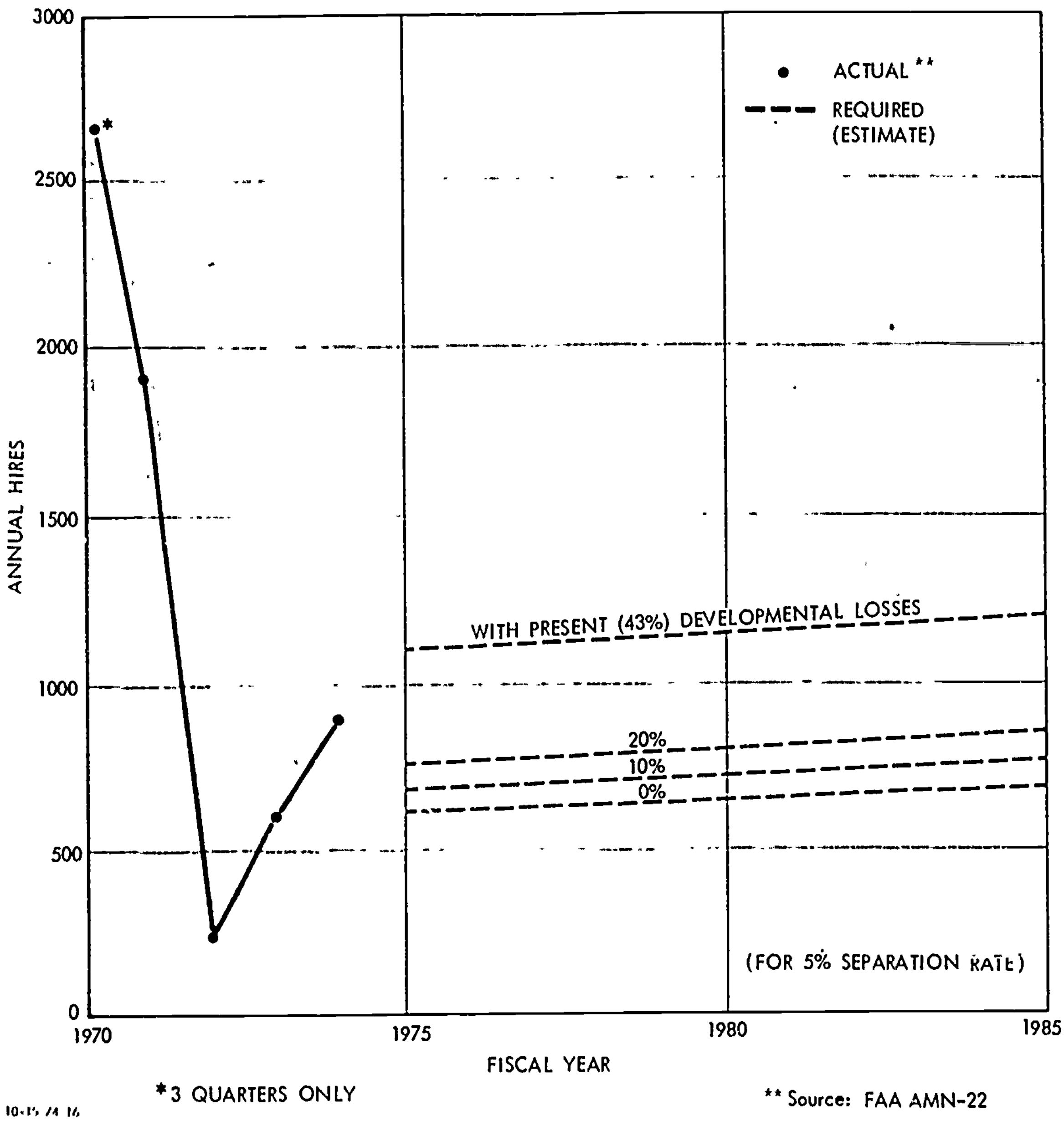

FIGURE 3. Required Hires for En Route Developmentals for Various Developmental Loss Rates

during training, from the FY 1974 rate of 43 percent to assumed values of 20 percent, 10 percent, and zero (with separation rate kept constant at the present 5 percent). The training load obviously is much more sensitive to separation rate. In Fig. 4, the necessary hires to meet 7.5 percent, 5.0 percent, 2.5 percent, and zero separation rates are shown (in this case, with developmental loss rate kept constant at its present 43 percent.) Also shown, as individual points, are the actual en route controller hires for the last 5 fiscal years. Although the latter vary greatly, the prediction is within the historical range.

The great sensitivity of the training load to separation rates and developmental loss rates is important. A training load of less than 1100 new developmentals each year would seem feasible for the en route option as long as the separation rate of journeyman controllers does not exceed 5 percent. Productivity changes have a small effect on the number of new hires required.

C. TERMINAL

In the same manner, projections have been made for controllers in the terminal option. Figure 5 shows the history and latest projection of total terminal operations in the United States. Again, the straight line is a least-squares fit to these data. Also shown, are the history and projections of IFR operations at terminals. It is evident that most of the growth of terminal operations will be of the IFR type, VFR increases being considerably less. Finally, the history of controller positions is shown along with the recent FAA estimates. The data, smoothed by the linear fits, are recorded in Table 2. The changes in controller productivity are also shown.

The experienced separation rate of terminal controllers is shown in Fig. 6. Fluctuation has been less than for en route controllers, and the average separation rate of 3.3 percent is also less.

The loss rate of developmentals in the IFR terminal option in FY 1974 was 38 percent.

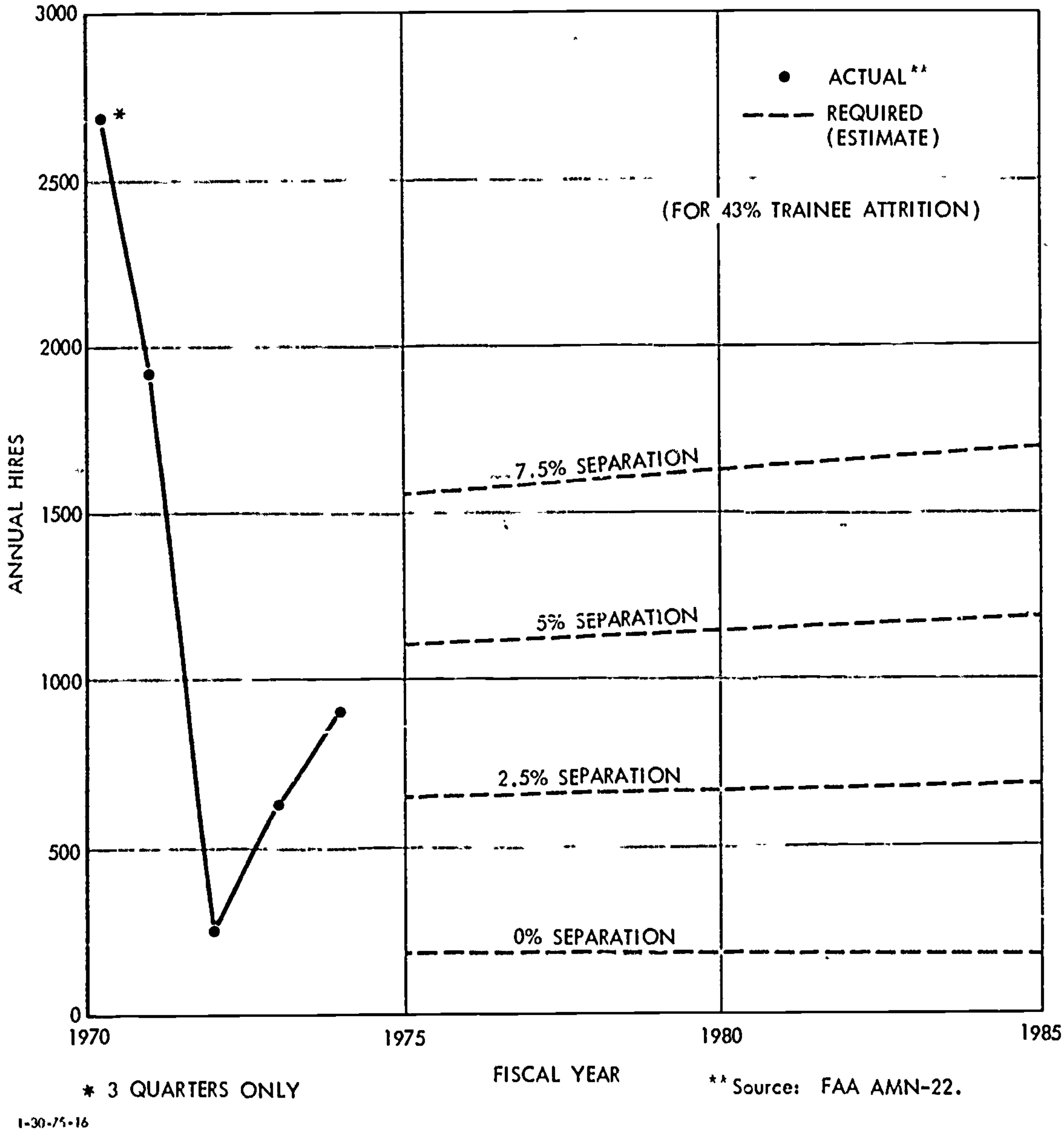

FIGURE 4. Required Hires for En Route Developmentals for Various Separation Rates

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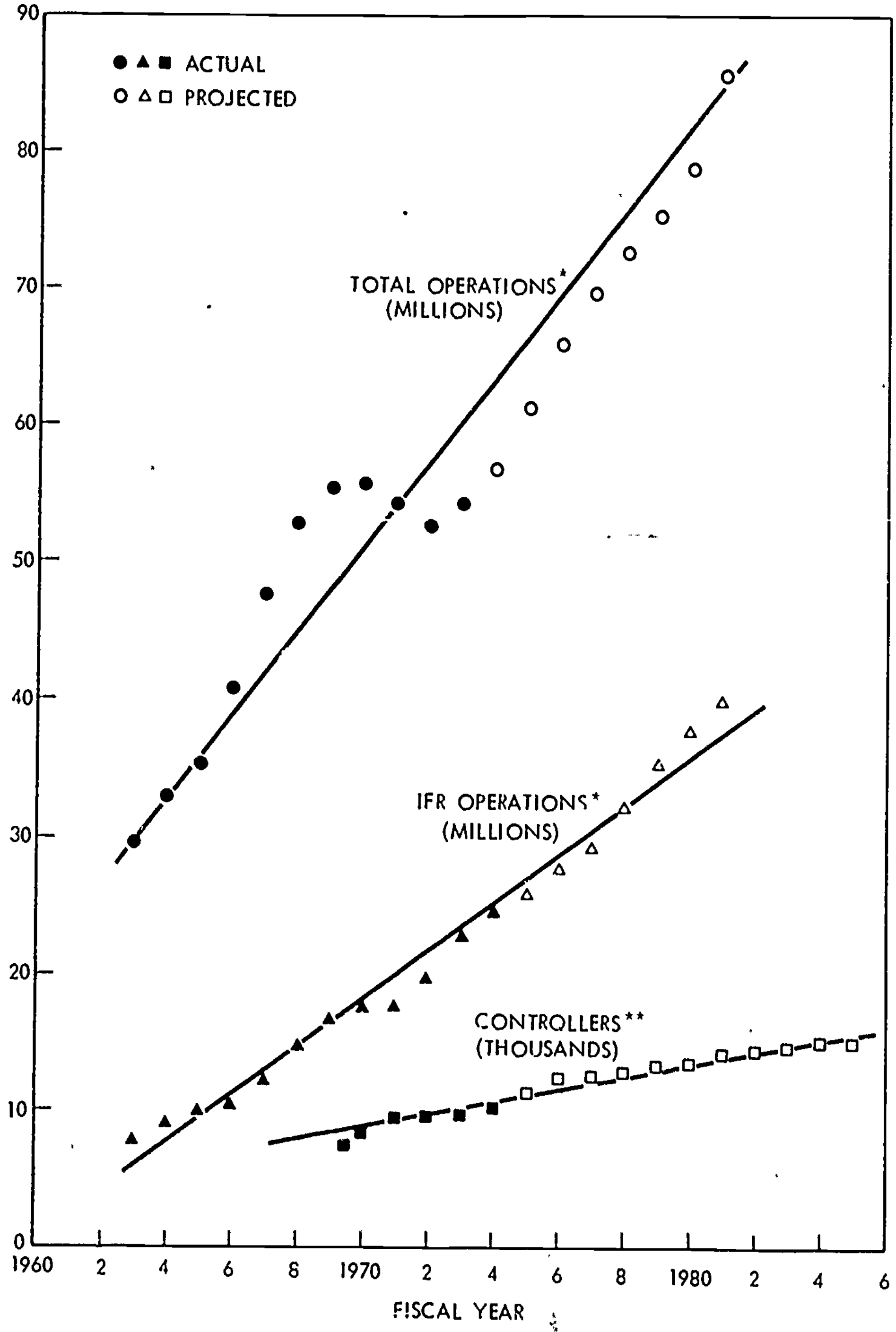

*FAA "Aviation Forecasts 1975-1986"

**FAA AMN-22 reports and Office of Aviation Economics Forecast

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FIGURE 5. Terminal Traffic Load and Controller Positions

TABLE 2. SMOOTHED TRAFFIC AND TERMINAL CONTROLLER ESTIMATES[a]

Year	Total Operations (millions)	IFR Operations (millions)	All Terminal Controllers (thousands)	Gross Productivity (all operations/ controller)	Annual Productivity Increase (percent)
1970	51.5	18.0	8,578	6,004	--
1972	57.7	21.5	9,535	6,051	0.39%
1974	63.8	25.1	10,491	6,081	0.25
1976	70.0	28.7	11,447	6,115	0.25
1978	76.1	32.2	12,404	6,135	0.25
1980	82.3	35.8	13,360	6,160	0.20
1982	85.4	39.3	14,317	6,172	0.20

[a]Data Source: Fig. 5.

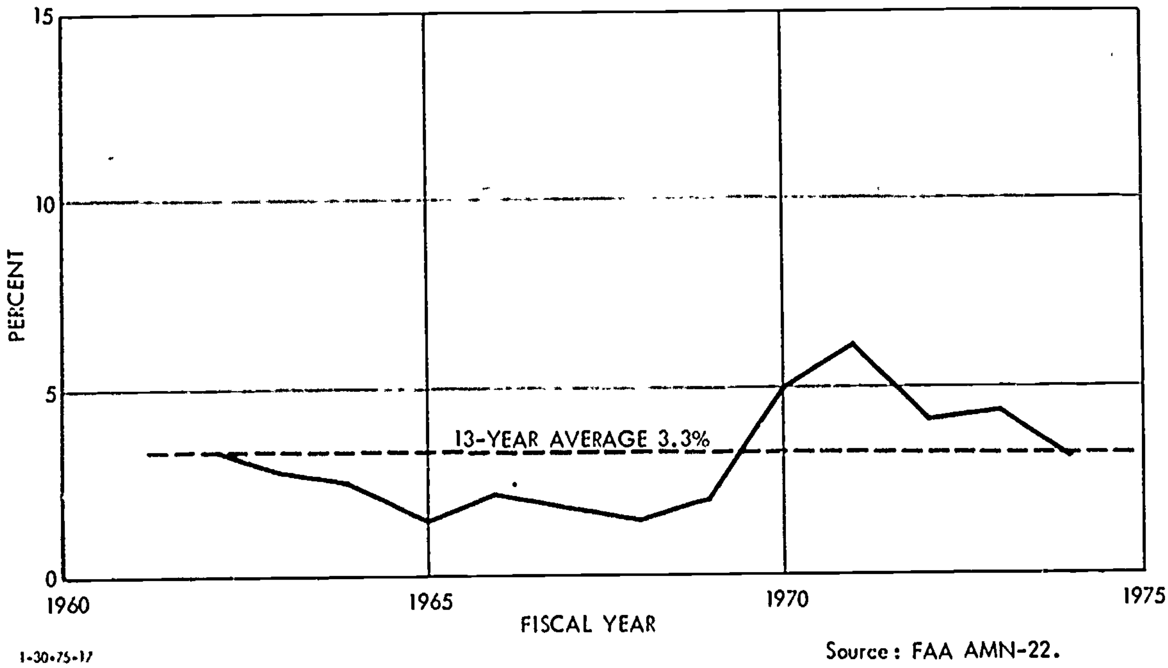

FIGURE 6. Terminal Controller Separation Rate

From Eq. 1, the projections for new hiring to meet separations, training losses, and expanded operations, with allowance for expected productivity improvements, are shown in Figure 7. The projections have been smoothed. To meet traffic expansion alone, approximately 480 additional terminal positions are required each year. When FY 1974 developmental loss rates (38 percent) are introduced, this requirement rises to 771. The remaining hires are to replace controller separations.

Figure 8 shows the significance of separations for hiring requirements. The training load projection is very sensitive to the separation rate.

As has already been observed, growth of controller complement at VFR towers is expected to be slower. As approximately 20 percent of controllers operate at VFR facility, it can be expected that approximately 250 VFR controllers will be needed in FY 1975 and about 300 in FY 1980.

With present separation and developmental loss rates, a terminal option training load of 1300 in FY 1975 and 1500 in FY 1980 can be anticipated. As will be seen in later sections, these estimates can be significantly modified.

D. SUPPLEMENTAL

As specified, and as confirmed by the IDA survey, nearly all controllers undergo supplemental proficiency training during a year. In FY 1974, 94 percent of en route controllers and 92 percent of IFR terminal controllers undertook such training. The average duration of such training as performed at each facility was 42 hours for centers and 53 hours for terminals, averaging over a week for each controller. Refresher training involved 90 percent of en route controllers and essentially all terminal controllers.

Some form of remedial training in FY 1974 was required for approximately 4 percent of en route controllers and 10 percent of IFR

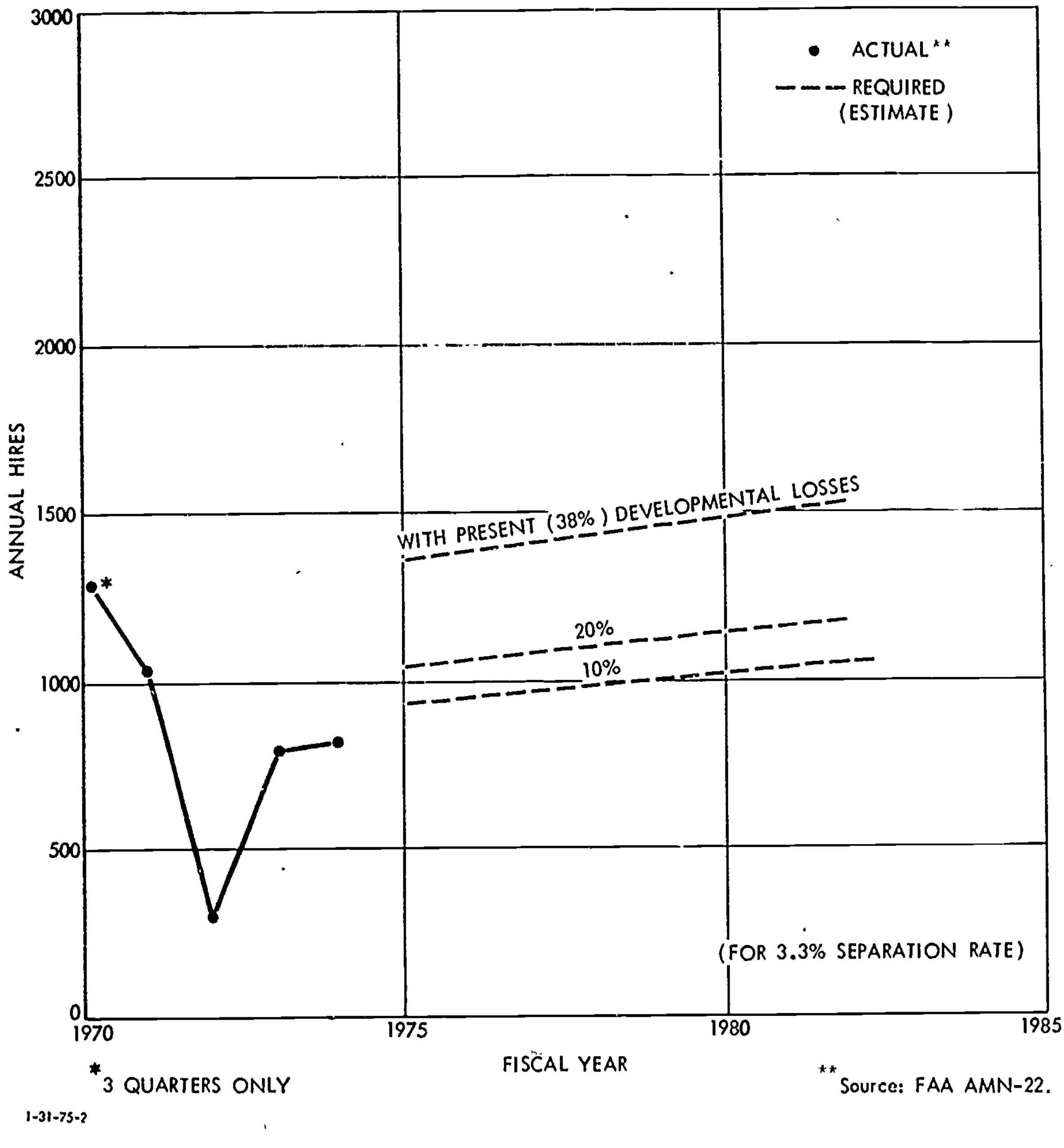

FIGURE 7. Required Hires for Terminal Developmentals for Various Developmental Loss Rates

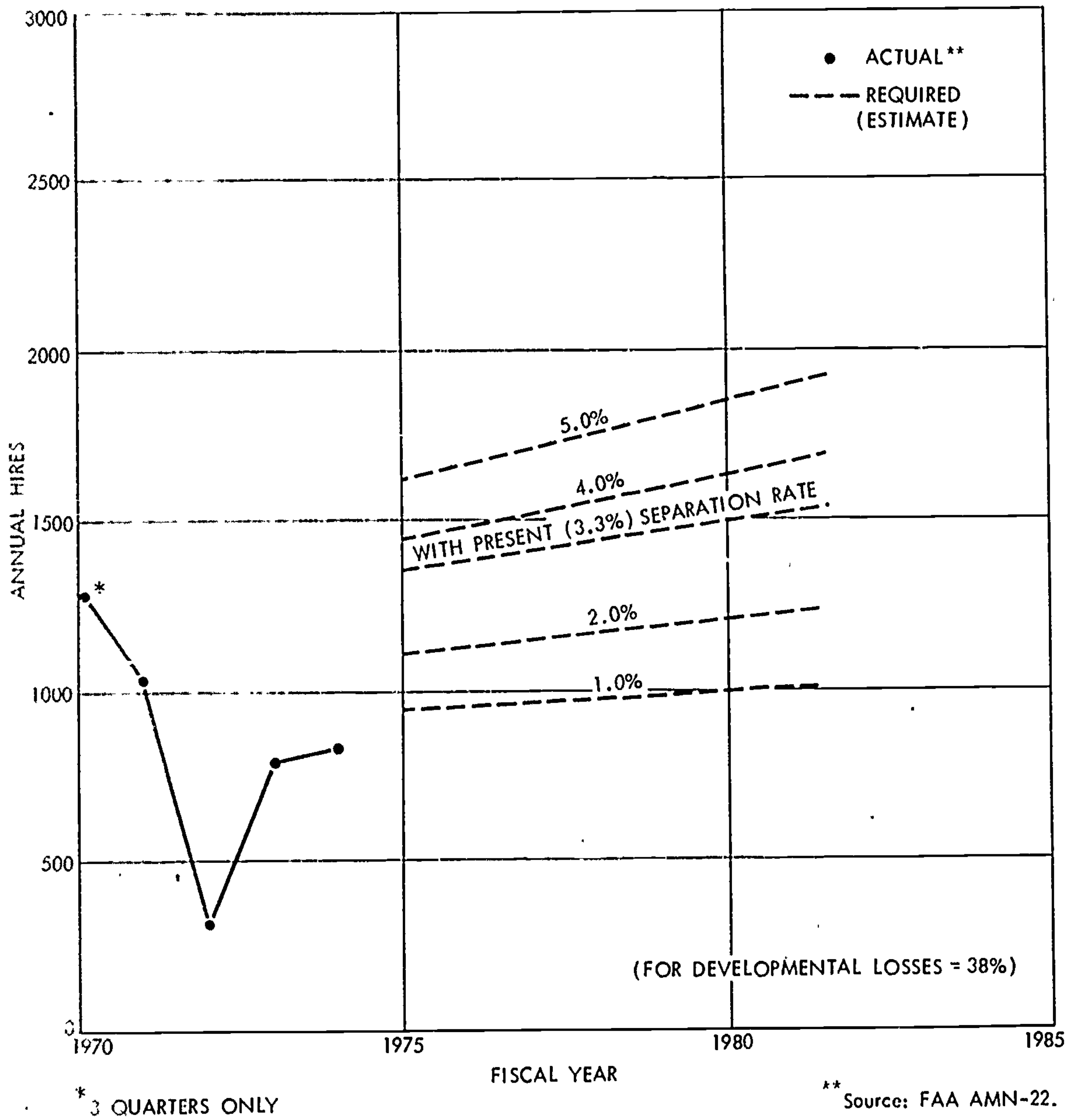

FIGURE 8. Required Hires for Terminal Developmentals for Various Separation Rates

terminal controllers, averaging 22 and 14 hours, respectively (Appendix G, Tables G-13, G-14, and G-15).

In sum, the equivalent of one to two weeks of proficiency training is given to the average journeyman controller each year.

E. FINDINGS

The hiring requirement for new air traffic controllers is very sensitive to the separation of controllers and the attrition rate of trainees. The average annual separation rate for the last 13 years has been 5.1 percent for en route controllers and 3.3 percent for terminal controllers. Should these separation rates prevail into the future, the new hires needed are as follows:

	FY 1975		FY 1980	
	En Route	Terminal	En Route	Terminal
Present Student Attrition	1110	1350	1160	1480
One-Half Present Attrition	810	1040	840	1130
One-Quarter Present Attrition	710	920	740	1000

The present student attrition (FY 1974) is 43 percent for en route controllers and 38 percent for terminal controllers.

IV. PRESENT CONTROLLER TRAINING PROGRAMS

This Chapter examines the adequacy of current specifications for training, the content and relevance of present training courses, and the methods used to establish competence at their completion. At the outset, selection procedures are reviewed because of their impact upon the likelihood that a new hire can successfully complete his training, as well as upon the quality of his performance on the job. Then, attention is given to the relevance of present training courses to the work actually performed by air traffic controllers.

This leads to an investigation of the methods used to measure performance and to establish competence on the job. The role of standardization and quality control is also addressed.

A. SELECTION

The FAA has long recognized the importance of selecting qualified controller candidates and has conducted many studies to improve its selection criteria. The present selection procedure includes a Civil Service Commission aptitude test, evaluation of amount and type of experience, an age limitation of 30 years, reference and background checks, medical examinations (both physical and psychological), and an interview. A number of studies have examined the relation of test scores at time of selection to success in training and to length of service. Unfortunately, little effort has been made to relate selection criteria to objective information about the performance of journeyman controllers.

FAA studies (by Education and Public Affairs, Inc., and the Civil Aeromedical Institute, for example) indicate, however, that selection procedures can be improved by incorporating tests which

measure behaviors required of controllers on the job. Experiments show that tests which measure skills in psychomotor coordination and ability to perform several tasks simultaneously would select superior journeymen, as judged by supervisors (Education and Public Affairs, 1972, and Chiles et al., 1972). Further improvements are possible by assigning newly hired personnel to the en route, IFR, or VFR option on the basis of their test scores. Such improved selection procedures would be expected to reduce the number of candidate controllers who fail to complete their training. (See Appendix D.)

Improved selection methods have monetary implications. Cost savings can accrue from improved selection and assignment (Appendix G, p. 242). If the attrition losses during training could be completely eliminated, the cost of en route controller training would be reduced by 33 percent and the cost of terminal controller training would be reduced by 22 percent. If the trainee losses could be reduced by 50 percent, training cost reductions of approximately 16 percent for en route training and 11 percent for terminal training would result.

B. RELEVANCE (see Appendix F)

The curricula of both the National En Route and the Terminal Air Traffic Training Programs specify in great detail the information and procedures to be taught during training and the methods of assuring their accomplishment at each phase. These programs have frequent and vigorous reviews. At the same time, there is evidence (e.g., p. 184) that training is not standardized at the facilities, that training times given to various topics differ between facilities, that some procedures specified by the curriculum are inconsistent with others in the curriculum, that qualification standards are interpreted differently at various facilities, and that some teaching materials do not conform to current operational practices. Such a situation will continue as long as there does not exist a fully supported mechanism to ensure adherence to program standards or to ensure uniform changes in the program across the system.

The relevance of training to operational requirements is maintained in several ways. Only experienced controllers constitute the training corps. Evaluation surveys of courses are conducted by the Air Traffic Branch (AAC-930). Corrections are generally implemented when within program budget. Improvements to the present curriculum and training procedures are possible, as discussed in the next section. These can be tested and appraised in an objective fashion by means of valid measures of performance also discussed in the next section. Questions about present training include:

1. Is the time allocation appropriate for each training segment?
2. Is the order of training appropriate? In particular, if radar is less complex to learn than non-radar, should radar training follow non-radar training, as at present? Learning theory strongly suggests that one learns more effectively when proceeding from simple to complex tasks, rather than in the reverse order.
3. What is the value of training on prototype sectors (e.g., Tango) rather than on actual ones?

The FAA training program can be made more efficient and effective by adopting an experimental method to evaluate alternative concepts about what has to be taught and how to do so. The associated measurement capability needed for such evaluations is now close at hand within the FAA (Appendix E). This could substantially improve the commendable effort, now primarily subjective, that is accorded the resolution of major issues about how best to train new controllers and how to assure competence among journeymen.

C. MEASURING THE EFFECTIVENESS OF TRAINING AND PERFORMANCE (see Appendix E)

Objective performance measures have important implications for the evaluation of alternative methods of training. They also have important applications, as mentioned above, in the selection of air traffic controllers, in the evaluation of controllers' performance on the job, in determining controllers' maximum useful workload for

purposes of sector design, and for testing controllers' performance on proposed improvements to the air traffic system. Despite such value, objective performance measures are not in use at present, although their feasibility has been demonstrated in work at the National Aviation Facilities Experimental Center (NAFEC) (Buckley et al., 1969, 1972).

As journeymen, controllers are assessed for proficiency by periodic written examinations, over-the-shoulder evaluations, and the Employee Appraisal Records (EARs) required by the Civil Service Commission. The purpose is to determine whether proficiency is acceptable; the criterion is pass or fail. Failure would indicate the need for refresher, remedial, or supplemental training, or, in the extreme case, elimination from the service for unacceptable performance. This method of measuring performance, however, does not establish the level or degree of proficiency. All controllers who pass the tests are not equivalent in performance. Such measures make it difficult, if not impossible, to establish whether one method of training is more effective than another, quite apart from considerations of accuracy, reliability, or objectivity of measurement. There are no scores (except, perhaps, in written tests) which can measure actual performance on the job. Among the results of inadequate measures of performance are possible inefficiencies if developmentals are trained longer than really required. Training is oriented to provide the required number who can just qualify.

There are several reasons to believe that there are significant limitations to the present use of ratings in general and to the over-the-shoulder rating in particular. These relate to the subjective nature of the rating procedure and problems of inter-rater agreement. A rating describes one person's judgment of another, and it can be influenced by a variety of causes, such as the extent of the supervisor's knowledge of the employee's performance, differing standards between supervisors about what constitutes adequate performance, and, in a subtle way, social and personality factors (Appendix E). In addition, the lack of standardization in the traffic samples used to

evaluate controllers' performance makes comparisons between persons, or comparisons of the same person over time, of questionable utility. Variability in conditions of observation, including such factors as the density and complexity of traffic, and in the duration of the observation period have also been shown to degrade over-the-shoulder ratings (Buckley et al., 1969).

Recent studies for the FAA by the System Development Corporation (SDC, 1971, 1972a-d, 1974a-f) have developed new controller rating procedures that are more carefully specified and more relevant to the important aspects of the controller's job than are those used up to now. To the extent that controllers are evaluated on behavior that is directly observable, explicitly described, and truly related to job performance, improved reproducibility of subjective measures can be expected, although this has not yet been demonstrated.

It is feasible to measure a controller's performance in an objective way; that is, in a way that produces quantitative scores, uncontaminated by human error, on various characteristics of performance. Such major characteristics as speed and accuracy of response, maximum number of aircraft handled, maintenance of separation standards (measured in time and distance), and the like can be measured. The prototype for doing this is a recording and scoring module attached to a dynamic simulation of the air traffic controller's console and work environment. It could also be attached to the operational equipment. The simulator is, of course, precisely the equipment used for training, provided that means exist to repeat selected samples of air traffic without variation and to record and score various characteristics of the controller's performance.

Simulators capable of measuring the performance of air traffic controllers have been developed by the FAA. A radar air traffic simulator was developed at the Civil Aeromedical Research Institute (CARI) in 1965 that was useful for research on training, selection, controller proficiency, and workload as functions of the number and speeds of targets, the display design, and the like. The NAFEC

simulator (1969) had greater track-handling capabilities than the one at CARI. Situations of greater complexity could therefore be simulated. The NAFEC simulator clearly demonstrated the feasibility of measuring the performance of air traffic controllers objectively and reliably. This work at NAFEC is still going on, and the current NAFEC Digital Simulation Facility (DSF) is improved over the simulator used in the initial study. Among other improvements, the current DSF provides virtually real-time scoring.

Thus, it has been shown that the performance of air traffic controllers can be measured in an objective way. It is necessary to use representative samples of air traffic carefully standardized for level of difficulty, i.e., in density, complexity, and potential conflictions. The duration of the observations must be reasonably long, probably an average of at least two one-hour periods. Objective performance data are needed to evaluate the effectiveness of various types of training. They would also have great value for the purposes of selection, establishing qualification standards, evaluating the proficiency of developmental and journeyman controllers, and determining controller workloads at various levels of traffic, thereby contributing to the design of sectors.

D. FINDINGS

- Relevance. The present curriculum provides the information needed by controllers to do their work. However, questions about the amount of time given to various segments of training, the order of non-radar training followed by radar training, and the value of training on prototype sectors (e.g., Tango) can be resolved best by an experimental approach based on objective performance measures. (Appendix F)
- Methods used to establish competence. Objective tests used for classroom or textbook subjects are thoroughly appropriate and relevant to the instructional material in the training program. However, determining the proficiency of performance

at the ATC console (i.e., over-the-shoulder evaluations) is a subjective procedure which has been demonstrated experimentally to have limited reliability. The feasibility of objective performance measures has been demonstrated at NAFEC but such measures are not in use at present. (Appendix E)

- Selection. FAA studies show that selection procedures could be improved by incorporating performance tests that measure behaviors required of controllers at work. Further improvements are possible by assigning candidates to the en route, IFR, or VFR option on the basis of their test scores. Such improved selection procedures would be expected to reduce the number of candidate controllers who fail to complete their training. (Appendix D)

V. SIMULATION DEVICES FOR AIR TRAFFIC CONTROL TRAINING

The capabilities and limitations of the state of the art of simulation devices for air traffic control training are considered here. After a brief review of the history of simulators, their capabilities for training controllers are addressed. The training simulation capabilities of the automated systems, National Airspace System, Stage A (NAS-A), Automated Radar Terminal System (ARTS) III, and ARTS II, and the prospects for their use in training are then examined, and strengths and deficiencies are identified. The need for more systematic planning for future simulation requirements is also discussed.

The purpose of this analysis is to provide information needed to make decisions concerning the number, type, and location of training facilities and equipment. Appendix C provides a more extensive discussion.

A. HISTORY

For this study, the simulators of interest are those that reproduce under controllable conditions air traffic situations likely to occur in actual practice and to do so in a fashion suitable for training. Simulation of air traffic for training has a long history, both for military applications and for air traffic control. It has been exploited for both training and research for the Airborne Combat Information Centers and Tactical Data Systems of the Navy, the radar stations and the Semi-Automatic Ground Environment (SAGE) System of the Air Force, and major national command and control systems, including those of the Joint Chiefs of Staff and the Strategic Air Command. It is used widely for air traffic control training in foreign countries and for training military controllers in the United

States. Substantial simulation work has been done for the FAA, first at the Technical Development Center in Indianapolis and later at NAFEC in Atlantic City (Vickers, 1959, 1972). The simulators at these facilities have been used to investigate such problems as simultaneous dual approaches, combining of approach control facilities, traffic flow patterns, and airport sector selection. And, as mentioned in the previous Chapter, they have been used in system performance investigations.

B. CAPABILITIES

Some of the obvious benefits in the use of simulators for air traffic control training are:

- They permit experiences with air traffic to be arranged in an order of increasing complexity that is optimally useful for training purposes
- They permit immediate review and assessment of each training experience
- They provide as much repetition of any type of traffic problem as is required to achieve mastery
- They need not interfere with actual operations
- They permit students to experience uncommon but important events or situations without having to wait for their occurrence in real life
- Scheduling is flexible and can be tailored to the overall training program and for periods appropriate to the subject's importance
- Safety is preserved
- The duration of overall training time is reduced.

There is no serious debate about the usefulness of simulation for training air traffic controllers. The value of simulation equipment for training purposes has been demonstrated beyond question in pilot training, air defense radar operation, malfunction detection for electronic equipment, sonar operation, and the like (e.g., pp.

96-98). It should be expected that simulators would also be effective in training air traffic controllers, although statistical data to this effect have not been collected.

C. ABOUT REALISM

As the word implies, simulation is the process of representing a real task or event; by implication, the simulation is not a complete duplicate of the real thing, although parts of what is being represented may be duplicated. Depending on the purpose to be served, the degree of simulation, the portions of the system to be included, and the fidelity of simulation should vary. For example, it has been found that high fidelity of simulation is not important when training a person to perform tasks with fixed procedures (Prophet, 1966, and Cox et al., 1965). Precise sensory cues are important in training for tasks which require precise motor skills, such as accurate feedback (or "control feel") on aileron and rudder controls in aircraft simulators. Only that part of air traffic control that is a precise sensory-motor skill requires high fidelity in the simulation. On the other hand, if the critical skills are mostly in the areas of decision making and communication, completeness rather than precise realism of the display on the scope will probably be most significant. In the final analysis, the validity of a simulation has to be proven by research and experiment.

D. CAPABILITY OF SIMULATORS IN OPERATIONAL SYSTEMS

NAS-A and ARTS III were initially delivered with a limited simulation capability to permit equipment checkout, to facilitate maintenance, and to be used for initial facility shakedown. In the realization that these simulation capabilities would also be useful for training, the staffs of two facilities (Houston ARTS III terminal and Washington NAS-A center) were tasked to develop "patches" to the operational programs that would permit flexible training at designated positions without interfering with operational positions. The results

are the Enhanced Target Generator (ETG) for the ARTS III and the Dynamic Simulator (DS) for NAS-A, and both have been demonstrated.* These simulators need not interfere in any way with the use of operational positions, although there is a question about the capacity of the computer and display facilities to handle training and certain volumes of operational traffic at the same time.

The ARTS II has no simulation capability in the present specifications.

These simulations can provide realistic representations of traffic for digital operations but not for broadband or analog radar. All "static" data available in the facility computer memories, as well as live operational traffic, can be presented at the simulation (i.e., training) positions. The "static" data include: sector boundaries, airport positions, navigation aid positions, holding patterns, airways, and weather contours (NAS-A only), all of which can be displayed optionally at any of the simulation positions. Essentially all of the operations required for operational control of aircraft can be simulated and outputs can also be generated for the support positions (data man and handoff man), as needed. As part of a simulation problem, tapes of scheduled simulated traffic can be prepared and entered into the computer before the problem begins, and flight strips will be printed out at the appropriate simulated support position. Also, simulated traffic entered into the simulated areas by the "aircraft pilots" will be associated with the stored traffic data, and tracks will be started automatically on targets that pass the system association rules. All positions will be connected by the standard level 300 communications system and "pilots" will control simulated targets in accordance with the trainee controller's instructions; thus, the pilot-controller communications are also simulated.

*The program for the computer display channel (CDC) of NAS-A was not completed as of October 1974.

The principal limitations of these simulations are: (1) limited availability of positions and capacity in an operational facility; (2) the ability of "pilots" to generate and control adequate numbers of simulated targets; (3) inability to simulate adequately interactions with adjacent facilities; and (4) the lack of recording capability designed for training purposes. In addition, the simulations have limited flexibility in that they can be interrupted but cannot be "backed up" or have parts repeated in the middle of a simulation problem to point out a control error or a deviation from control rules or standard practices.

As mentioned above, neither the NAS-A nor the ARTS III simulation capabilities include broadband radar. As discussed in Appendix C, it is possible to use symbology to represent the analog return, but this results in an unrealistic display. This is clearly a limitation, particularly with ARTS III, since the analog display is an integral part of the operational mode in that system. Since the developmental has ample opportunity to observe real displays, this lack of realism should not be a problem, but special efforts will be required to minimize any negative transfer that might occur because of this lack. For future broadband simulation requirements, discussed below, the feasibility of adding a simple radar target generator to ARTS III might be explored. A number of companies (Raytheon, Hydrosystems, Litton, Sanders Associates, and others) have off-the-shelf broadband simulators in the $25,000 price range that could be used to augment the ETG capability.

The concern about capacity is that the simulation will overload the computer system, requiring it to be cut back (NAS-A) or taken off (ARTS III) so as not to interfere with ongoing operations. Table 3 shows the track capacity of the NAS-A system at each center and the traffic in the peak hour of the peak day in 1973. More than half the centers have the capacity to handle such extreme traffic loads. Further, there is substantial variation of traffic load throughout the day. For example, Fig. 9 shows the load pattern by hour for Los Angeles during the peak air traffic day of 1973. Track capacity was

exceeded for less than 8 hours on this peak day. It is evident that ample opportunity is available for scheduling simulation training in NAS-A centers.

TABLE 3. TRAFFIC (PEAK HOUR OF PEAK DAY, 1973) AND TRACK CAPACITY AT CENTERS

	9020 VERSION & DISPLAY		1973 IFR (millions)	PEAK HOUR OPERATIONS	TRACK CAPACITY	SECTORS	PVD's	AUTHORIZED CONTROLLERS
ALBUQUERQUE	A	CDC	0.91	275	300	29	46	280
ATLANTA	D	CDC	1.44	365	400	46	54	469
BOSTON	A	CDC	0.97	305	300	27	58	415
CHICAGO	D/E	DCC	1.65	410	500	38	69	566
CLEVELAND	D/E	DCC	1.73	535	400	43	65	573
DENVER	A	CDC	0.64	200	300	30	44	273
FT. WORTH	D/E	DCC	1.23	430	350	39	57	338
HOUSTON	A	CDC	1.15	600	300	38	60	424
INDIANAPOLIS	D	CDC	1.29	340	400	33	49	450
JACKSONVILLE	A	CDC	1.08	375	400	35	57	407
KANSAS CITY	D	CDC	0.99	335	400	36	52	365
LOS ANGELES	D	CDC	1.05	325	250	34	48	361
MEMPHIS	A	CDC	1.09	394	250	30	42	348
MIAMI	A	CDC	1.05	365	350	29	50	293
MINNEAPOLIS	A	CDC	0.91	264	250	28	41	316
NEW YORK CITY	D/E	DCC	1.61	421	450	37	62	576
OAKLAND	A	CDC	0.91	278	250	29	44	346
SALT LAKE CITY	A	CDC	0.41	105	250	18	43	183
SEATTLE	A	CDC	0.60	163	250	16	35	185
WASHINGTON, D.C.	D/E	DCC	1.37	400	400	34	63	482
TOTAL			22.07			649	1039	7650
AVERAGE			1.10			32.5	56.0	382.5

Sources: FAA Sizing Committee, FAA Air Traffic Activity, IDA Survey, FAA AAT-110.

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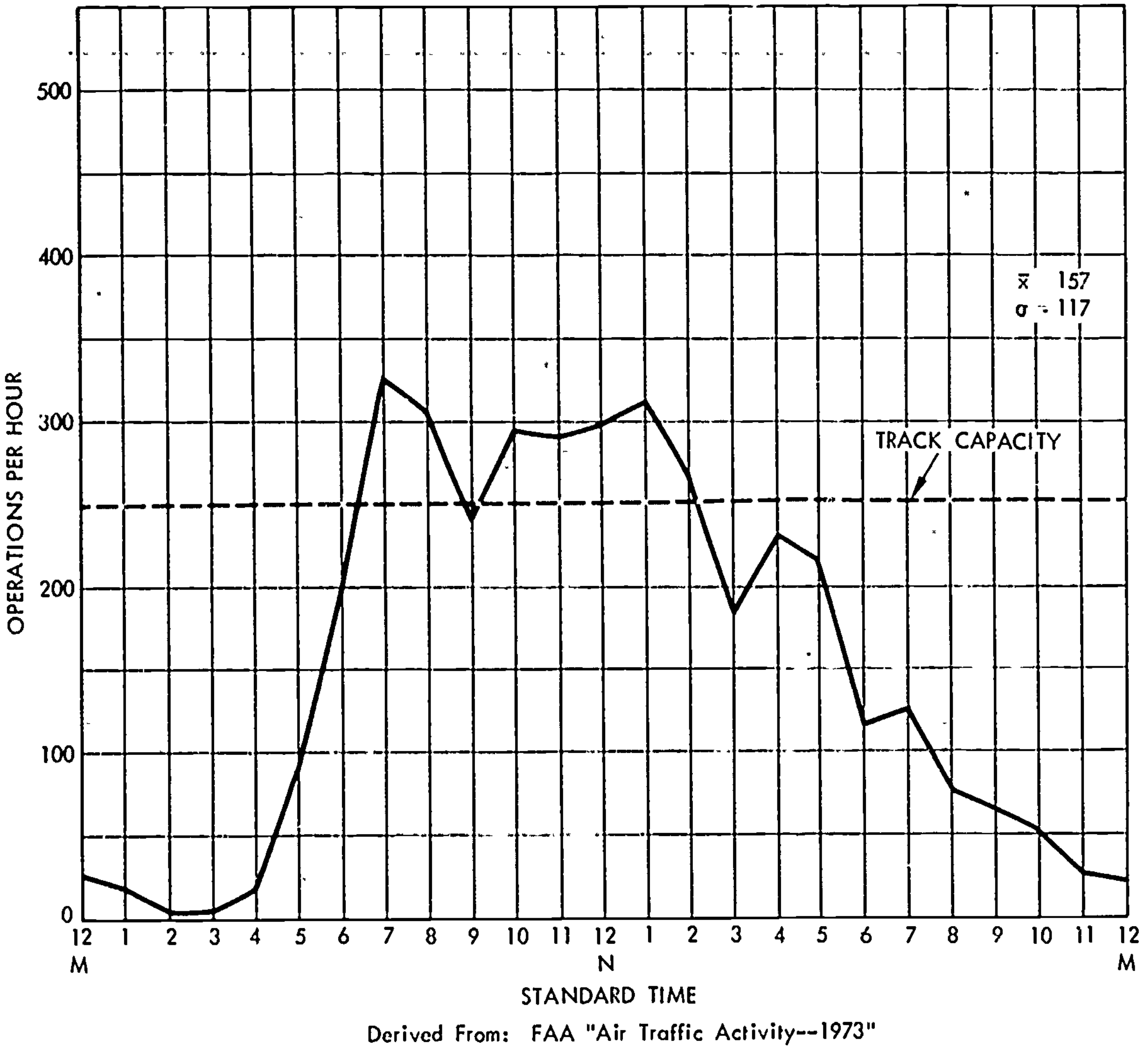

FIGURE 9. Los Angeles Air Traffic on Peak Day, 1973

E. ACADEMY SIMULATION REQUIREMENTS

Since the simulation capabilities of NAS-A and ARTS III appear to be adequate for facility training, at least for the near future, it follows that separate simulators at field locations are not required. The needs of the Academy are a different matter. Both the existing but obsolete Servonics equipment, which is expensive to operate, and the Sylvania modules should be replaced if there is to be any significant radar training done at the Academy. Some modules could be scavenged for a successor simulation installation. If all radar training could be done in the field, no simulation capability would be needed at the Academy. However, as will be discussed in later sections, there are important cost savings to be had from early screening, and this can most readily be done at the Academy. In fact, for the smaller IFR terminals centralized training is almost mandatory, because these terminals, with only a few controllers on duty at any one time, have only limited training opportunities.

If at least some IFR terminal training should be done at the Academy, a simulation capability is required. Installing the NAS-A or ARTS III simulation hardware necessary to operate in a simulation mode would be costly ($4 million to $5 million for NAS-A) and would result in a simulation lacking broadband capability.

The long-range simulation requirements for the Academy should be considered in the overall context of system planning discussed in the next section, but for the short term it seems clear that a simulator should be acquired as soon as possible. A number of questions, such as whether the simulator should be configured for both terminal and en route training, can be answered after alternative training locations are examined (see next Chapter).

F. FUTURE SIMULATION REQUIREMENTS

Training requirements seem to have played a negligible role in the specifications for NAS-A and ARTS III. Recognition of training requirements as legitimate design considerations could have resulted

in much more powerful simulation tools than were actually produced. Further, improvements that are feasible, such as realistic speed changes, are not being included in the rewrite of the dynamic simulation program that is under way at the present time. It is important for future system effectiveness that the need for training simulation be included in the design of future versions of the National Airspace System.

A systems approach to simulation appears to be essential. Requirements for future simulation involving processes such as conflict detection, conflict resolution, and intermittent positive control can cause ATC displayed information to be quite different from what exists at present. Effective simulation of these processes can be difficult and expensive if it is done as an afterthought isolated from the main system development program. A centralized group with knowledge of training needs, available ATC operational hardware and software, and competence in minicomputer applications could provide the systems approach to applications of simulation in training which is needed to cope with future simulation requirements.

G. FINDINGS

- The NAS-A and ARTS III simulators appear sufficiently realistic but have some limitations. Present and future deficiencies, however, can be remedied by target-generating software and inexpensive hardware and recording capabilities.
- These present simulators can be used at most scheduled times, particularly for proficiency, maintenance, and refresher and supplemental training.
- A program of software for installation of performance measurement should be initiated.
- A simulation capability for ARTS II equipment is warranted and needed now. The modular structure of ARTS II facilitates the introduction of this capability before the hardware is installed.

- As will be seen in later sections, a simulation capability is required at the Academy.

VI. ANALYSES OF ALTERNATIVE DEVELOPMENTAL TRAINING PROGRAMS

The purpose of this Chapter is to identify and evaluate alternative methods currently and potentially available to meet the training needs of developmentals. The alternatives which are considered reflect differences in degree of centralization and differences in the duration of training, both issues of concern to the FAA.

A. DESCRIPTION OF ALTERNATIVES

The following options are significant in determining the possible restructuring of the FAA training system:

• Location of training	Academy or facility
• Duration of training	Related to curriculum (6-9 months) or to necessary time for experience and associated Civil Service progression (3.5-4.5 years)
• Need for separate simulators	Academy and/or facilities
• Responsibility for final screening	Academy or facility.

To analyze these options, it was assumed that five alternative training programs would be considered, each containing some combination of the main features shown above. One of the alternatives to be considered is the present program. All are summarized in Table 4 and explained below.

TABLE 4. DEVELOPMENTAL TRAINING ALTERNATIVES
(GS-7 to GS-12/13)

	Alternatives				
	Accelerated Academy	Extended Academy	Present Program	Extended Facility	Accelerated Facility
Training Duration, months	6-9	7-10	7-10	7-10	6-9
Elapsed Time, years	0.5-0.75	3.5-4.5	3.5-4.5	3.5-4.5	0.5-0.75
Final Screening	Academy	Academy	Facility	Facility	Facility
Separate Simulator	At Academy	At Academy	No	No	Terminal simulation at Academy

Some aspects of training are not at issue and, in the analysis that follows, it is assumed that these aspects are treated in the same way in all five alternative programs. This applies, for example, to the contents of the curriculum, the order of presentation of topics, the amount of time devoted to each phase of training, and the methods used to establish competence. The Academy would be responsible for developing lesson plans, training materials, and tests and for keeping them up to date.

Common to each alternative would be the adoption of the improved entrance selection criteria discussed in Chapter IV. Revised procedures and reordering of course materials to reflect present automation and radar capabilities, improved pedagogical concepts, and performance measures would be incorporated as available in each alternative. The advantages of simulators would be exploited throughout. The present Civil Service grade structures could be retained. Revisions of job assignments and responsibilities would be required for several of the options examined.

1. Accelerated Academy

In this alternative, the student would receive all his academic training at a centralized facility such as the Academy at Oklahoma

City. The training would be continuous and completed over a period estimated to be from 6 to 9 months (as curriculum, measurements, and experience indicate) and would include simulation to prepare the student for final sector or position qualification at his home facility. A capability to simulate both en route and terminal facilities would be maintained at the Academy. Separate courses would be scheduled for controllers destined for en route, IFR, and VFR facilities. Screening would be done at the Academy and not take more than 9 months or so, and it would be done before the trainee achieved status as a civil servant. Entry into the ATS would not occur until after successful completion of Academy training, when status in a Civil Service grade would be assigned. The first sector or position qualification would normally take another several months at the home facility. Progression to fully qualified journeyman controller would take place as the necessary experience and seasoning are gained.

2. Extended Academy

As above, all formal training would be given at the Academy, but the training for each phase would be followed by service and on-the-job training (OJT) at the home (or nearby) facility. The overall time would approximate the 3.5- to 4.5-year period of the present schedule and the present Civil Service ATC grade structure. Screening would be done at the Academy at the completion of each training phase. Time to reach final or position qualification for journeyman status would presumably be shorter than for the first alternative because of greater familiarity with facility operations.

3. Present Program

This is the present prescribed training program, in which the training load is shared by the Academy and the facilities. Screening would be primarily done at each facility.

4. Extended Facility

This alternative features the possibility of accomplishing all training at each facility (or in local groupings, where more appropriate). The training plan and progression would be centrally developed and standardized, as would the scheduling and performance of regular inspections. After completion of each phase of developmental training, facility service and OJT would follow at the facility. As in the "Extended Academy" option; the elapsed time to qualification would take 3.5 to 4.5 years. Final qualification would be similar to present procedures, screening responsibilities resting with the facilities.

5. Accelerated Facility

This case is similar in pace to the "Accelerated Academy" option but is done in a continuous, decentralized fashion at centers and terminals (or groups of terminals, as appropriate). This reflects the objective of completing formal academic training before proceeding to OJT and before Civil Service status is achieved. Again, course materials, plans, and final examinations would be centrally prepared. Upon passing, the student would be admitted to the ATS with the appropriate Civil Service grade. The initial period would take approximately 6-9 months, as in the "Accelerated Academy" case. Thereafter, the student would commence to gain final sector and position training and experience, and he would normally qualify in another few months.

B. TRAINING SPECIFICATIONS FOR EACH ALTERNATIVE

Underlying the five foregoing alternatives are a number of detailed specifications for the training programs for en route and terminal controllers. These include the time and location of each phase and subphase of the training, the mode of training (i.e., classroom/laboratory, OJT, simulation), student/staff ratios, Civil Service grade classification, and the elapsed time while in developmental status. As far as possible, procedures and times that apply

to present training are used. For facilities, averages were derived from the results of the IDA survey of field facility training and then applied consistently to the several alternatives. All the details are recorded in Appendix H. As an example, Table 5 shows the specifications for training of en route controllers; the level of detail is evident.

C. TRAINING COSTS FOR EACH ALTERNATIVE

An extensive effort has been made to develop cost estimates for each of the five alternatives. The costs of training are based on the workload and practices in FY 1974. The cost data base underlying all estimates derives from FAA budget submissions and data specifically collected for this study from the FAA Academy and the en route and terminal facilities. Many of these data are new.

The principal measure used for comparison of alternatives is the variable training cost per year per one thousand graduates. Variable costs consist of wages and benefits of instructional and support staffs, student travel and per diem, and wages and benefits of students during their period of actual instruction. Capital costs, while not unimportant, approximate ten percent of these variable costs. All the details of the costing process are contained in Appendix G and are an important part of the comparison.

Table 6 shows the costs for each alternative way of training for each controller option.

The cost differences among alternatives are caused by a complex set of differences in the specification of each training program of the sort illustrated in Table 5. However, one major difference between the costs of Academy training and facility training is the per diem and travel costs of the former. The per diem cost could be reduced with residential facilities operated by the Academy. More importantly, however, "accelerated" training costs could be more than compensated by savings from possible reduced training time. These and similar considerations suggest that with present knowledge only

TABLE 5. SPECIFICATIONS FOR TRAINING, EN ROUTE PROGRAMS[a]

Alternative	Phase[b]	Location	Hours by Mode: Classroom/Laboratory	OJT	Simulation	Student-to-Staff Ratio	Failure/Drop-Out Rate	Student GS Grade Level	Cumulative Elapsed Time From Initial Entry	Remarks
Accelerated Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	IIN	Academy	304	--	--	1.7	0.14	7	--	
	IIR	Academy	40	--	--	8.0	0.00	7	--	
	IIR	Academy	--	--	200	2.0	0.05	7	--	
	IIIN	Academy	--	--	100	2.0	0.13	7	--	
	IIIR	Academy	--	--	200	2.0	0.15	7	~6 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	
Extended Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	
	IIR	Academy	40	--	--	8.0	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	--	100	2.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Present Program	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	25% of students
	IIN	Facility	350	--	--	1.7	0.14	9	--	75% of students
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.6	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Extended Facility	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Facility	350	--	--	1.7	0.14	9	--	
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.3	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Accelerated Facility	I	Facility	340	--	--	2.9	0.05	7	--	
	IIN	Facility	350	--	--	1.7	0.14	7	--	
	IIR	Facility	40	--	--	2.9	0.00	7	--	
	IIR	Facility	--	--	200	2.0	0.05	7	--	
	IIIN	Facility	--	--	100	2.0	0.13	7	--	
	IIIR	Facility	--	--	200	2.0	0.15	7	~3 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	

[a] Derived from IDA survey.

[b] "N" and "R" signify non-radar and radar, respectively.

TABLE 6. VARIABLE TRAINING COSTS PER THOUSAND GRADUATES (dollars in millions)

Alternative	En Route	Terminal IFR	Terminal VFR
Accelerated Academy	$33.6	$25.8	$10.6
Extended Academy	32.3	29.5	15.7
Current Program	29.9	24.2	12.8
Extended Facility	29.4	22.9	12.5
Accelerated Facility	27.2	18.7	8.2

minor cost differences can be assuredly distinguished among alternatives.

At current rates, about 900 en route controllers are hired each year. Thus, the overall training costs each year greatly exceed the one-time cost of simulation necessary for the facilities and for the Academy.

D. TRAINEE SALARIES

The cost estimates in Table 6 include the full salaries of trainees while actually engaged in training. In Alternatives 2, 3, and 4 the trainee spends a considerable portion of his developmental period performing at his facility those supporting tasks for which he is qualified. Since these opportunities are limited, some portion of his salary should be considered as a training cost, yet just what fraction should be assessed against salary is uncertain. Table 7 shows the variable costs when 0, 25, 50, 75, and 100 percent of the nontraining time salaries are included as a training cost for the en route, IFR, and VFR options.

The data in the table show the effect that stretching out the training period has on cost. In fact, a major cost factor is the duration of training.

Because of such considerations, the cost implications of selection procedures that are inferior to those now available and of late recognition of the inability of a developmental to be a capable journeyman controller have been determined in this study. Also, the

additional costs introduced by the great fluctuations in student enrollments at the Academy have been estimated. The details of these costs are given in Appendix G.

TABLE 7. VARIABLE TRAINING COSTS OF ALTERNATIVE WAYS OF TRAINING AIR TRAFFIC CONTROLLERS

(dollars in millions per 1000 controllers trained)

Option & Alternative	Percentage of Nontraining Time Salaries Charged to Training				
	0%	25%	50%	75%	100%
En Route Centers					
Accelerated Academy	$33.6	--	--	--	--
Extended Academy	32.3	$43.4	$54.5	$65.6	$76.7
Present Program	29.9	41.3	52.6	64.0	75.4
Extended Facility	29.4	41.1	52.9	64.6	76.3
Accelerated Facility	27.2	--	--	--	--
IFR Terminals					
Accelerated Academy	25.8	--	--	--	--
Extended Academy	29.5	39.9	50.2	60.6	70.9
Present Program	24.2	34.3	44.3	54.4	64.5
Extended Facility	22.9	33.0	43.1	53.1	63.2
Accelerated Facility	18.7	--	--	--	--
VFR Terminals					
Accelerated Academy	10.6	--	--	--	--
Extended Academy	15.7	22.9	30.2	37.4	44.7
Present Program	12.8	19.8	26.9	33.9	41.0
Extended Facility	12.5	19.6	26.7	33.7	40.7
Accelerated Facility	8.2	--	--	--	--

Accelerated training and consequent earlier screening could reduce the cost of training as much as $42,000-$48,000 for an en route controller, $39,000-$46,000 for an IFR terminal controller, and $30,000-$33,000 for a controller at a VFR terminal facility.

Improved selection procedures to reduce the losses of developmentals during training could reduce training costs a maximum of 33 percent for en route controllers and a maximum of 22 percent for terminal controllers. These figures represent a perfect selection process and are unachievable. A 50 percent reduction of trainee losses, however, would provide cost reductions of 16 percent in en route training and 10 percent in terminal training.

Smoothing out the flow of students at the FAA Academy and staffing the Academy to deal with a steady training load could produce a saving of between 20 and 30 percent of the cost of Academy controller training operations. This would have meant something between $0.9 million and $1.4 million in FY 1974.

E. FINDINGS

- Within the accuracy of cost estimation, the cost differences between training at the FAA Academy and at the field facilities are small, and their significance is masked by uncertainties associated with the details of the various alternative training programs.
- Smoothing the enrollments of developmental controllers at the Academy could result in cost benefits of approximately $1 million each year, in addition to improved training performance.
- An 11 to 16 percent cost reduction could result from selection procedures that reduce trainee attrition by 50 percent.
- A major cost factor is the duration of training. Accelerated training and resultant earlier screening could reduce training costs as much as $48,000 per developmental.
- Simulation costs, whether at a facility or at the Academy, are small compared to the training costs.

VII. IMPLICATIONS

The purpose of this Chapter is to consider the significance to the FAA of the findings of this study and to develop some suggestions for action. Attention is given to (a) simulators and centralized or noncentralized training, (b) the training budget, (c) future requirements for training, (d) R&D for training, (e) hiring practices, (f) standardization, and (g) the training load at the Academy.

A. SIMULATORS AND CENTRALIZED OR NONCENTRALIZED TRAINING

Since the Corson Report (Corson et al., 1970), the FAA has been concerned with how to implement recommendations that simulation equipment should be procured for training en route and IFR terminal controllers at a centralized location. The findings of this study bear directly on this problem. As presented in the previous Chapter, the major part of training costs is the variable cost (i.e., that due to wages and benefits of instructors and students, travel and per diem). This cost is about $24,000 to $30,000 per qualified developmental, depending on controller option. In addition, a charge should be added to reflect the nontraining time salary while not a fully qualified journeyman.

To train 1000 controllers costs from $24 million to $30 million. A full-fledged simulator for a central location would cost less than $10 million and would be available to more than 10,000 controllers over 5 years; thus, it would cost less than $1000 per controller. Simulator costs are therefore small compared to actual controller training costs.

There are not significant cost differences between centralized and decentralized training modes--between training at the Academy and training at a facility.

Major cost factors are introduced by the duration of training and by any delay in screening. These can account for more than half the training cost to produce a qualified controller. Centralized training has inherent advantages in these cost areas. A centralized training facility can train a student full time, a capability possible at only the largest of operating facilities. Thus, screening can take place most quickly. Standardization of training, measurement of training effectiveness, and application of uniform screening procedures can all be done easily and objectively at a central facility. Obviously, such a centralized facility must be fully equipped to accomplish its mission, and this would include an air traffic control simulator fitted for training. This should be provided in the very near future.

Proficiency, remedial, supplemental, and other testing and training can be done more easily at a facility, particularly with central support. The simulated training and measurement capabilities possible in the NAS-A, ARTS III, and ARTS II equipment is important in this aspect of the controller training program. Some capability for training almost exists in the existing NAS-A and ARTS III equipment. As an interim measure, the "patches" required to make these equipments useful for training can and should be extended immediately to the entire system. These "patches," of course, are the Dynamic Simulator (DS) for NAS-A, demonstrated at the Leesburg Center, and the Enhanced Target Generator (ETG) for ARTS III, demonstrated at the Houston Terminal. Provision should also be made soon for "pilot" consoles to conserve PVDs,* and for recording and playback equipment to permit the review of performance so important for training. All of these steps should be regarded as readily feasible, near-term steps to realize the current almost-present capability for training.

*For NAS-A.

Dedicated simulators for training might well be needed in the longer term, although a strong case cannot be made for them at the present time. The long-term case rests upon (1) the growth of traffic and the addition of new control features which might reduce the availability of the NAS-A and ARTS for training, (2) the specification of required performance measures and recording and analytical capability to provide training scores (which depends on work still under way at NAFEC), and (3) management arrangements to ensure adherence among centers and terminals to the curriculum and standards promulgated by the national training program. Planning for the characterization of the required simulators should start immediately. The "patches" suggested above as feasible and relatively inexpensive in the near term cannot be regarded as an ideal solution. The simulators in NAS-A and ARTS III were designed for purposes of maintenance, but they can and should be adapted now to training as well. When this is done, there will still be a need for more competent and flexible simulation capabilities for training, and steps to specify and install these, over the next 3 to 5 years, should also be started immediately.

B. THE TRAINING BUDGET

The sources of training funds and their control are spread among a number of offices within the FAA. As a result, it is difficult to identify all the points in the budget which relate to training and hence to identify the full costs of training. Of more importance, the dispersion and diffuse control of training funds in the present budget structure makes it difficult, if not impossible, to administer a uniform national training system. Appendix I discusses the budgetary sources of controller training and coincidentally derives an estimate of ATC training cost--about 5 to 8 percent of FAA operating expenses. It also discusses problems inherent in the present method of funding training activities with respect to coherence of the program and standardization of its content and quality.

Funds are allocated from the FAA appropriation to organizational offices and institutions (i.e., the Aeronautical Center, Regions, etc.) without binding functional application. For example, funds to the Regions, budgeted for training, travel, and per diem can be--and often are--used for other operating functions at the discretion of field administrators. Variations among facilities in the conduct of the training program, as reported in this study, are probably related to this method of budgeting. Consequently, planning for training and control of its application becomes almost impossible, and utilization of training resources becomes highly variable.

Further, sizable amounts of money are involved in the air traffic controller training system. Table 8 shows the FY 1974 funds related explicitly to controller training. The total approaches 7 percent of the FAA operating accounts, increasing to 10 percent if developmental nontraining time salaries are included. Centralization of fiscal authority for controller training activities does not exist at present. If it is warranted, as is probably the case, a plan for a new training budget structure, together with organizational responsibilities, will have to be developed.

TABLE 8. AIR TRAFFIC TRAINING COSTS, FY 1974
(dollars in millions)

Centralized Training Budget Costs		$18.9
Allocation of Centralized Training Support & Travel	$8.2	
Allocation of Management Training School (MTS)	4.1	
Air Traffic Branch (ATB)	6.6	
Field Facility Training Staffs		13.1
Trainee Salaries[a]		46.7
TOTAL		$78.7

[a]Includes periodic training of full-performance controllers.

C. FUTURE REQUIREMENTS

The "Ten Year Plan, 1973-1982" (FAA, 1973a) and FAA Engineering and Development Programs (FAA, 1974b) project many improvements to the National Airspace Traffic Control System. Many of these will have significant implications for training and for new features not present in any training equipment contemplated so far. The following operational improvements must be considered in this category:

1. Air Route Traffic Control Center (ARTCC)
   a. Conflict detection
   b. Conflict resolution
   c. Intermittent positive control (IPC)
   d. Discrete address (tactical) data link of discrete address beacon system (DABS)
   e. DABS interrogation hierarchy control.
2. Terminal Radar Approach Control (TRACON)
   a. Automatic radar level tracking with tagged targets
   b. Metering and spacing
   c. Conflict prediction
   d. Conflict resolution
   e. Fail safe/Fail soft/Auto standby switch
   f. Multiradar
   g. Multiprocessing
   h. DABS data link.
3. Tower Radar Automation Cab (TRACAB)
   a. Radar level tracking
   b. Noise abatement pattern control
   c. Wake turbulence separation control
   d. Multisegmented approach and departure routings to exploit the characteristics of area navigation (RNAV) and microwave landing system (MLS)
   e. Upgrading ARTS II from beacon data level to beacon tracking level.

Attention is directed to the importance of including the training implications of these improvements early in the development cycle.

D. R&D FOR TRAINING

This section presents several research projects that would support further improvements in the selection, performance measures, and training of air traffic controllers. The FAA has supported and is supporting research that has direct application to training. However, the current level of support is so modest that it will take a long time before the needed results become available. Therefore, several research areas have been identified in this study as worthy of immediate attention:

- Selection. Little is known about how the criteria used during selection affect assignment to controller option or the quality of performance after completion of training. Improved selection procedures would be expected to reduce attrition during training and thereby save some of the expenses due to attrition (Appendix D).
- Performance Measures. These are very important to the FAA because, together with other factors such as cost and flexibility, they provide the means needed to evaluate the ultimate effectiveness of alternative methods of training air traffic controllers. Performance measures are also needed for many other purposes of interest to the FAA, such as determining, for example, the controller's maximum useful workload, the distribution of traffic loads among sectors, the impact of new or proposed types of ATC equipment, and the significance of various tests and criteria for the selection of controllers (Appendix E). Such research should be focused on objective performance measures that could be employed in conjunction with the automated equipment at centers and terminals.

- Training. The present national programs for air traffic controller training specify in great detail the information and procedures that are to be taught during each phase of training and the goals to be accomplished before the developmental can move from one phase to the next. Yet it is evident that there are substantial variations in the training programs at the many facilities. Substantial questions are outstanding about the content and method of training. Experiments designed to evaluate the significance of different ways of training are warranted (Appendix F).

Research and development related to selection and training are conducted on behalf of the FAA, variously, by CAMI, the Academy, NAFEC, the Office of Aviation Medicine, the Office of Personnel and Training, the Systems Research and Development Service, and the Air Traffic Service. Although there is a clear interdependence between many of these efforts, there are no ready means for coordinating the various perograms. It is suggested that a focal point be established to coordinate these research efforts and to respond to findings. Initially, an Advisory Committee on Personnel Research and Training, reporting to the FAA Administrator, could be established for a trial period.

E. HIRING PRACTICES

The history of ATC hiring is shown in Fig. 10. The present practice is to delegate hiring to the Regions and the facilities they control. As a result, there is little or no synchronization of hiring across the country. Most hiring now takes place during the fourth quarter, when availability of funds is more certain and fiscal year expenditures are thereby less, without the loss of the authorization for controller positions. This results in large fluctuations in input to the training system and resultant saturation of the system for extended periods. There are further implications for scheduling and sequencing of the units of training. And, as already

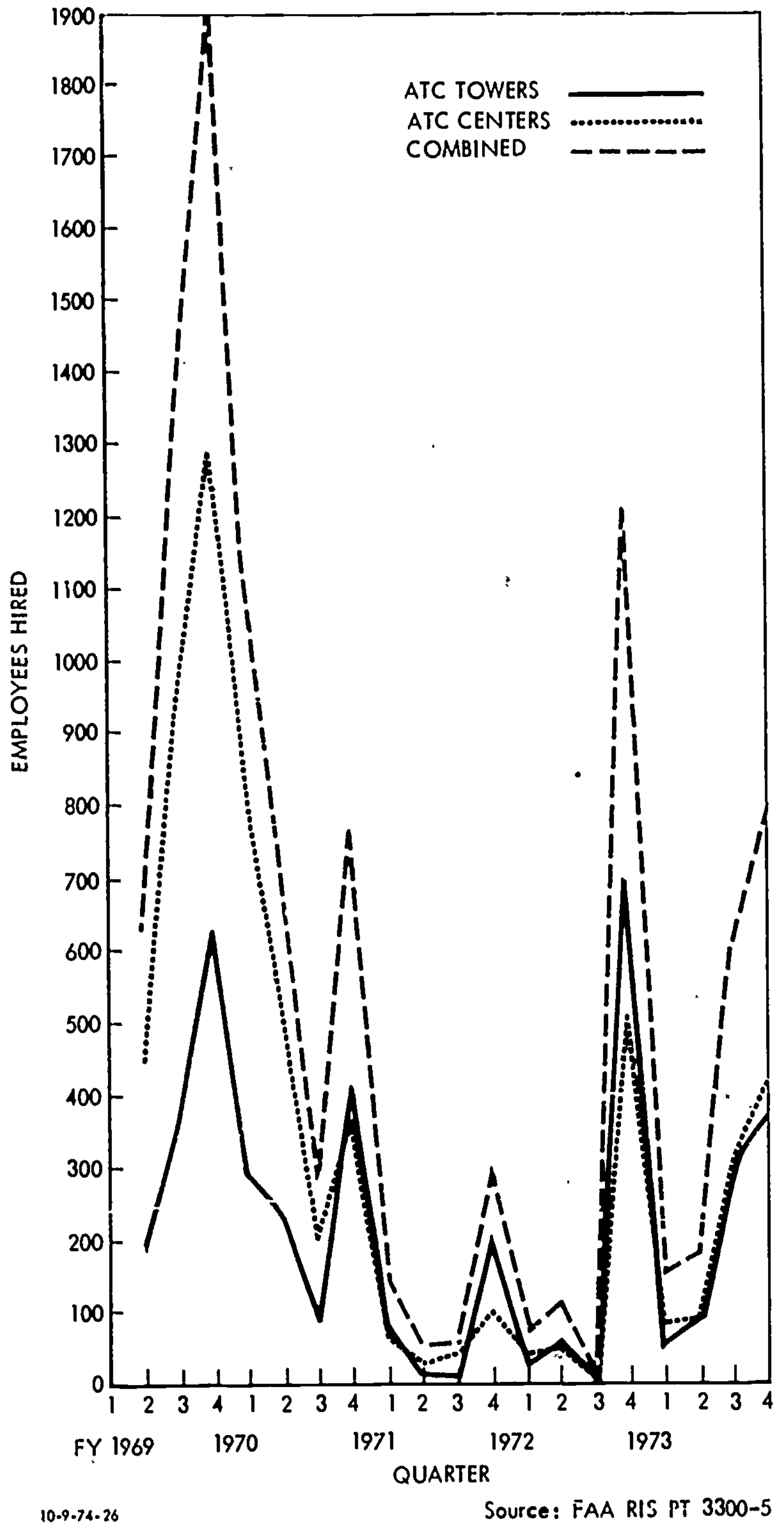

FIGURE 10. ATC Quarterly Hires, FY 1969-1973

discussed and as shown in Appendix G, this practice leads to inefficient use of training resources.

There are a number of standard management procedures that would resolve this problem without disturbing the decentralized operations of the National Airspace System. In this study, the important details of the hiring problem have not been examined, but it is very evident that improved planning and execution of the recruitment effort is needed. This, also, was a finding of the Corson Report (Corson et al., 1970).

F. STANDARDIZATION

As mentioned before, there is substantial evidence of lack of standardization in training, use of training resources, and operating practices.

It might be thought that standardization could be achieved by vesting the Academy with sole jurisdiction over all training, or at least over portions of the training program to be standardized. The Academy has had exclusive responsibility for portions of the training program in the past, but no such arrangement has survived for an appreciable length of time or over large changes in the numbers to be trained. Other requirements for a viable centralized training program have not been met in the past. One of these requirements has to do with budgeting, as discussed above. Another has to do with hiring, also discussed above. Standardized training requires central and systematic hiring on the basis of projected needs.

Finally, standardization of training without centralization could be achieved, but the requirement for centralization of other functions remains, and some office must be vested with a positive and absolute role of certification of both field facility training programs and the qualifications of individual trainees. In some way, the independence and responsibility of this certifying office would have to be ensured.

G. THE TRAINING LOAD AT THE ACADEMY

Figure 11 shows the number of residents in air traffic controller courses at the Academy for the period FY 1968-1974. Large fluctuations are evident, but, in this case, they are not cyclical and thus could not be anticipated long in advance. Over this period the Academy staff size has remained relatively stable. Thus the staff at the Academy is generally either overloaded or overmanned and is only occasionally in proper balance with the student load. As a practical matter, development of new course materials and surveys of training effectiveness are set aside at the Academy when there is a large influx of students. Since the dominant cost at the Academy is maintaining instructional staff, unused capacity implies high unit cost and inefficiency, as discussed in Chapter VI and Appendix G.

It is estimated that the cost of centralized training can be significantly reduced by smoothing the flow of training. The resultant savings in FY 1974 could have been about $1 million.

H. FINDINGS

- Centralization. The full-time training done at a centralized facility permits the earliest screening of developmentals and the fastest development of productive controller capabilities. Great cost benefits accrue to such a training procedure as well as the desirable application of uniform training procedures, performance measurement, and screening. All the full-time training necessary to ready a developmental for qualification should be done at a centralized facility. Exceptions could be large facilities where the developmental could receive full-time training. Qualification and seasoning through experience would be done at the home facility.
- Simulations. The centralized facility, presumably the Academy, should be equipped with a fully capable air traffic control simulator designed specifically for training. NAS-A

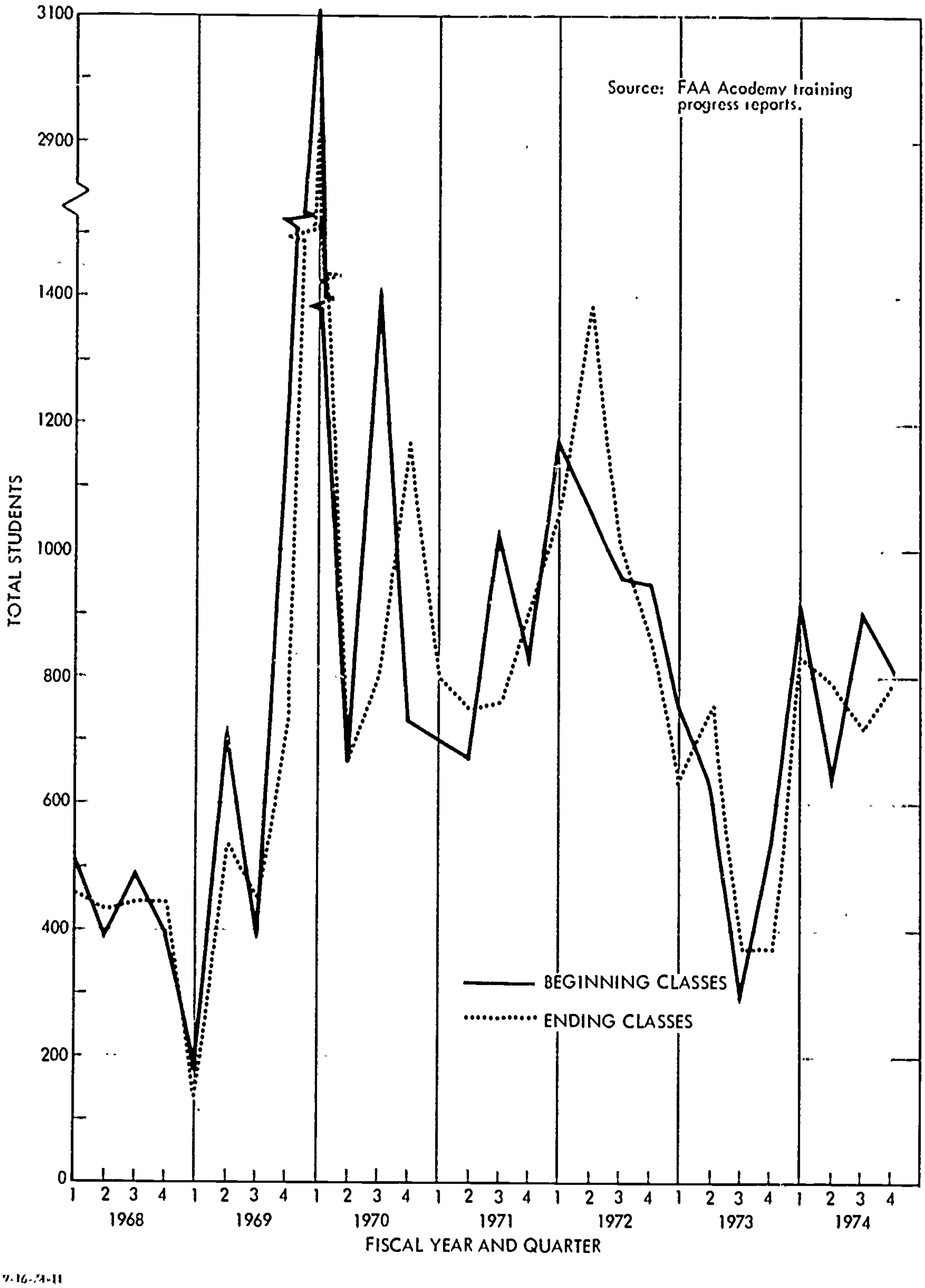

FIGURE 11. Training Load at the Academy

and ARTS III simulation, can serve training and proficiency testing where NAS-A and ARTS III are installed. The training limitations of these equipments should be upgraded as quickly as possible. Simulation capabilities should be introduced in the new ARTS II equipment currently under procurement.

- ATC Training Budget. A system to ensure that budgeted funds are used for controller training is indicated. These funds account for 7 to 10 percent of FAA operating accounts.

- Future Requirements. The training and simulation implications of the many improvements to the National Airspace Traffic Control System should be identified early in the development cycle. This is important in order to procure hardware and software and to develop proper training programs in a timely fashion.

- R&D for Training. Further research should be undertaken in controller selection, controller performance measures, and training alternatives. Improved coordination of and responsiveness to all personnel-related R&D, including ongoing research, is required.

- Hiring. A mechanism to smooth recruiting and hiring should be adopted.

- Standardization. There is substantial evidence of lack of standardization in training. An FAA office should be vested with a positive and absolute role of certification of both field facility training programs and the qualification of individual trainees.

- Academy Training Load. Substantial cost benefits (about $1 million in FY 1974) and efficiencies could result from smoothing the flow of training.

APPENDIX A

STATEMENT OF WORK

To successf ly accomplish this requirement the Contractor shall identify and evaluate alternative ways of improving the air traffic controller training system. Alternative methods of training will be evaluated in terms of (a) system costs, (b) length of training time, (c) system capacity, (d) flexibility to accommodate to changes in training loads, and (e) flexibility for incorporating new training specifications.

Tasks. The following tasks will be undertaken in an effort to identify and resolve the main issues which influence the training of en route and terminal air traffic specialists:

Task 1. Review the evolution of the existing national programs for the qualification, refresher, proficiency maintenance, and supplementary training of en route and terminal control specialists. Develop estimates of the number of individuals who will require various types of qualification and supplementary training, identify alternative methods of accomplishing the required training, and establish the questions which must be answered in order to evaluate the various ways in which training needs could be satisfied.

Task 2. Assess the adequacy of current specifications for training. Compare (1) the contents and relevance of present training courses and (2) the methods used to establish competence at their completion to the current specifications for training. Examine the extent to which current specifications for training are based upon analyses

of on-the-job performance and the degree to which qualification standards have been validated against operational performance data. Included would be an analysis of the need for, and a description of, the requirements for standardization and quality control in terms of the implication or impact of the lack thereof on training.

Task 3. Appraise the capabilities and limitations of the state-of-the-art of simulation devices relevant to air traffic control training.

Task 4. Establish, for the purpose of analysis, the alternative methods currently and potentially available for training en route and terminal control specialists. This shall, in general, describe the applicable simulation, on-line, and classroom facilities that may be required for training the anticipated loads. The analysis shall examine the influence of such factors as the number, type, and complexity of equipment, location of the train-facilities, and the sequence of progression through training blocks upon the number of individuals who may be trained per unit time, the duration of training, and the total annual cost of the training program. The purpose of the analysis is to provide information needed to make decisions concerning the number, type, and location of training facilities and equipment.

APPENDIX B

FIELD FACILITY SURVEY ON TRAINING

CONTENTS

A. INTRODUCTION

The purpose of this Appendix is to describe a survey that was performed to determine the numerical characteristics of the air traffic controller training performed at facilities during FY 1974. The survey was undertaken after it was found that little was known about the overall effort that is directed to developmental and proficiency training. The information solicited in the survey was needed for a variety of purposes, a few of which are: determining temporary training assignments and training losses; determining the costs of training for FY 1974; and determining the timing of losses.

A copy of the questionnaire used in the survey and a sample of the results are presented in this Appendix.

It should be emphasized that the survey was concerned with training activities during FY 1974. It offers a snapshot of the situation prevailing at that time. Applications to other periods should obviously be made with care. The results, however, may be useful to activities other than training.

B. FIELD FACILITY SURVEY QUESTIONNAIRE

The survey was intended to cover every facility performing air traffic control. This included air route traffic control centers (ARTCCs), airport traffic control towers, combined stations/towers, common IFR room RAPCONs/RATCCs, RAPCONs/ATCCs, and RAPCONs/ARTCTs. The addresses were obtained from the FAA's National Field Office Directory. All the ARTCCs submitted responses, but a few questionnaires for terminal facilities were returned because of improper

address. Most of the terminals responded. Overall, 78 percent of IFR terminals and 70 percent of VFR terminals responded. The results, therefore, are an extensive sample of FAA air traffic control facilities. The support of these facilities is gratefully acknowledged. Filling out the questionnaire involved substantial effort, as the data requested were of a kind not normally collected about training operations. More information on the results is given in Section III of Appendix G.

A copy of the survey questionnaire follows. Essentially the same form was sent to both ARTCCs and terminal facilities; the sole difference lay in the designations of sequential training phases.

FIELD FACILITY TRAINING SURVEY
(LEVEL & CHARACTERISTICS OF TRAINING OPERATIONS)

Type of Facility (1)______

(En Route	= 1)
(VFR Tower	= 2)
(IFR Tower (Non-radar)	= 3)
(Tower/TRACON	= 4)
(TRACON	= 5)

Facility Sequence Number (2)____________

Region Number 1/ (7)_______

Operations Level Classification 2/ (8)_____

Automated Traffic Control Equipment - Scheduled or In-place (9)______

Key:	En Route:	CDC	= 1
		DCC	= 2
	Tower/Terminal;	ARTS III	= 3
		ARTS II	= 4
		Radar Only	= 5
		Non-Radar	= 6

Note: Footnotes are found at the end of questionnaire.

Card No.			Number	Average GS Grade Level	
	I.	CONTROLLER COMPLEMENT AS OF YEAR END, FY 1974			
(01)	A.	Authorized Controllers	(11)_____		
	B.	Other 2152 Series Required to Maintain Facility Currency	(16)_____		
	C.	Assigned & On-Board			
		Full Performance	(21)_____	(26)_____	
		Pre-Developmental	(31)_____	(36)_____	
		Phase I	(41)_____	(46)_____	
		Phase II, Non-Radar	(51)_____	(56)_____	✓✓✓
(02)		Phase II, Radar	(11)_____	(16)_____	
		Phase III, Non-Radar	(21)_____	(26)_____	
		Phase III, Radar	(31)_____	(36)_____	
	D.	Assigned & On Detail to FAA Academy			
		Pre-Developmental		(41)_____	
		Phase II, Non-Radar		(46)_____	
		Phase II, Radar		(51)_____	
				(56)_____	✓✓✓

II. NUMBER OF DEVELOPMENTALS AND PRE-DEVELOPMENTALS DETAILED TO FAA ACADEMY DURING FY 74

(03)	A.	Pre-Developmentals	(11)_____
	B.	Developmentals;	
		Phase II, Non-radar	(16)_____
		Phase II, Radar	(21)_____
			(26)_____

III. NEW HIRE DEVELOPMENTALS REPORTING ON-BOARD DURING FY 1974, BY QUARTER 3/

	New To FAA	Transfers From ARTCC & FSS	
1st Quarter	(31)_____	(36)_____	
2nd Quarter	(41)_____	(46)_____	
3rd Quarter	(51)_____	(56)_____	
4th Quarter	(61)_____	(66)_____	✓✓✓

Card No.

IV. TRAINING PERSONNEL COMPLEMENT

(04) A. Average Full Time Staff During FY 1974 (EPDO+EPDS) (11)________

B. Part Time or Temporary Detail Personnel; "Full Time Equivalent" 4/ Man-Months During FY 1974 (16)________

V. NUMBER OF CLASSROOMS/LABORATORIES MAINTAINED BY FACILITY (21)________ ///

VI. NUMBERS OF DEVELOPMENTALS AND PRE-DEVELOPMENTALS LEAVING TRAINING PROGRAM DURING FY 1974, BY PHASE

Card No.		While Failing Program	While Progressing Satisfactorily	
(05)	Pre-Developmentals	(11)________	(16)________	
	Phase I	(21)________	(26)________	
	Phase II, Non-Radar	(31)________	(36)________	
	Phase II, Radar	(41)________	(46)________	
	Phase III, Non-Radar	(51)________	(56)________	
	Phase III, Radar	(61)________	(66)________	///

VII. QUALIFICATION TRAINING CONDUCTED (By Phase), FY 1974 5/

A. Classroom (and Laboratory) Training

Card No.		Number of Persons Entering Training Phase	Number of Classes Begun	Length of Course (Classroom & Laboratory Hours)	Average Student-Teacher Ratio	Planned Student Study Hours Per Class Hour 6/	Typical Instructor Preparation Time Per Class Hour	Number of Failures	
(06)	Pre-Developmental	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///
(07)	Phase I	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///
(08)	Phase II, Non-Radar	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///
(09)	Phase II, Radar	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///
(10)	Phase III, Non-Radar	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///
(11)	Phase III, Radar	(11)_____	(16)_____	(21)_____	(26)_____	(31)_____	(36)_____	(41)_____	///

B. Self Study

Card No.		Number of Persons Entering Training Phase	Length of Course	Number of Failures	
(12)	Pre-Developmental	(11)_____	(16)_____	(21)_____	///
(13)	Phase I	(11)_____	(16)_____	(21)_____	///
(14)	Phase II, Non-Radar	(11)_____	(16)_____	(21)_____	///
(15)	Phase II, Radar	(11)_____	(16)_____	(21)_____	///
(16)	Phase III, Non-Radar	(11)_____	(16)_____	(21)_____	///
(17)	Phase III, Radar	(11)_____	(16)_____	(21)_____	///

VII. QUALIFICATION TRAINING CONDUCTED (By Phase), FY 1974, (Continued) 5/

C. O.J.T.

Card No.		Number of Persons Entering OJT Phase	Average Length of OJT Training (Hours) 7/	Number of Failures	
(18)	Pre-Developmental	(11)_____	(16)_____	(21)_____	///
(19)	Phase I	(11)_____	(16)_____	(21)_____	///
(20)	Phase II, Non-Radar	(11)_____	(16)_____	(21)_____	///
(21)	Phase II, Radar	(11)_____	(16)_____	(21)_____	///
(22)	Phase III, Non-Radar	(11)_____	(16)_____	(21)_____	///
(23)	Phase III, Radar	(11)_____	(16)_____	(21)_____	///

VIII. ACTIVITIES OF DEVELOPMENTALS/PRE-DEVELOPMENTALS OTHER THAN TRAINING AND OJT, BY G.S. GRADE LEVEL, FY 1974 5/

Card No.		Number of Persons Engaged	Average Man-Months Spent (Omit Leave Periods)	Task Assignments (Use Additional Sheets as Necessary)	
(24)	G.S. 4	(11)_____	(16)_____	(21)_____	✓✓✓
(25)	G.S. 5	(11)_____	(16)_____	(21)_____	✓✓✓
(26)	G.S. 7	(11)_____	(16)_____	(21)_____	✓✓✓
(27)	G.S. 9	(11)_____	(16)_____	(21)_____	✓✓✓
(28)	G.S.10	(11)_____	(16)_____	(21)_____	✓✓✓
(29)	G.S.11	(11)_____	(16)_____	(21)_____	✓✓✓
(30)	G.S.12	(11)_____	(16)_____	(21)_____	✓✓✓
(31)	G.S.13	(11)_____	(16)_____	(21)_____	✓✓✓

IX. OTHER TRAINING CONDUCTED, FY 1974 (BY TYPE)

Card No.		Remedial	Supplemental [a]/	Refresher	Other/General	
	A. Full Performance Controllers					
(32)	Number Entering Training	(11)_____	(16)_____	(21)_____	(26)_____	
	Average Duration of Training (Hours) [6]/	(31)_____	(36)_____	(41)_____	(46)_____	√√√
(33)	B. Developmental/Pre-Developmental Controllers					
	Number Entering Training	(11)_____	(16)_____	(21)_____	(26)_____	
	Average Duration of Training Hours [6]/	(31)_____	(36)_____	(41)_____	(46)_____	√√√

X. CHARACTERIZATION OF THE USES OF THE TOTAL TRAINING PERSONNEL MAN-HOURS SHOWN IN PART IV

Percentage of Total Man-Hours Shown in Part IV Devoted To

Card No.			
(34)	A. Formal (Classroom/Laboratory) Initial Training of Developmental and Pre-developmental Controllers, Including Time Spent in Preparation: Section VIIA	(11)_____	
	B. Other Training Assistance Devoted to Qualification Training Including Assistance to Controllers Engaged in OJT of Developmentals: Section VIIB, VIIC	(16)_____	
	C. Other Training and Evaluation of Full Performance and Developmental Controllers, Including Time Spent in Preparation: Section IX	(21)_____	
	D. Supervision, Administration, Management of Facility Training Program	(26)_____	
	E. Other; Please Comment on Nature of Activity	(31)_____	√√√

(35) Comments: (11)____

____

____

FOOTNOTES

1. Region number key:

Eastern	(EA) = 1
New England	(NE) = 2
Southern	(SO) = 3
Great Lakes	(GL) = 4
Central	(CE) = 5
Southwest	(SW) = 6
Rocky Mountain	(RM) = 7
Northwest	(NW) = 8
Western	(WE) = 9

2. Operations level classification key:

ARTCC level 1	= 1
ARTCC level 2	= 2
Terminal/tower level 1	= 3
Terminal/tower level 2	= 4
Terminal/tower level 3	= 5
Terminal/tower level 4	= 6

3. Include only personnel new to the ATS.

4. A full time equivalent man-month is the number of hours per month worked by a full time employee. A specialist devoting an average of one-half time to training would be counted at a rate of one-half full time equivalent man-months per month.

5. Persons initially entering combinations of classroom, self-study, OJT, and other than training activities during the year should be counted once in each applicable category. For example, a person who first enters phase III non-radar classroom, phase III non-radar OJT, phase III radar classroom, and who is promoted to GS 11 during FY 1974 would be included in each of the counts for phase III non-radar classroom, phase III radar classroom, phase III non-radar OJT, and GS 11 other than training. He would not, however, be included in counts for those categories to which he had been assigned prior to the first day of FY 1974, e.g., phase II training or GS 9.

6. Include only on-duty (paid) time.

7. Include time spent in qualification check-out.

8. Exclude FAM trips.

C. SOME SURVEY RESULTS

This section presents some results of the survey coupled with some statistical data from FAA Air Traffic Activity publications (e.g., FAA, 1974a). More of the survey data, particularly those relating to costs of training, are presented in Appendix G, particularly Tables G-13, G-14 and G-15.

Manning and training at each center are obviously related. Each center has a number of sectors, and the number of personnel assigned to a center depends on the volume and complexity of traffic in the various sectors. This feature is examined herewith because of its significance to future training loads.

Table B-1 shows some ratios between the numbers of controllers and indices of traffic load at 20 en route centers listed in decreasing order of traffic volume (as measured by annual IFR aircraft handled in 1973).

These ratios are plotted in Fig. B-1 against traffic volume, with a least-squares line fitted for each to assist in appraising the trend. From both the table and the plot, it is evident that each center has a unique set of operational characteristics, presumably deriving from its own peculiar situation.

The number of trainees at each center was also examined, based on data derived from the IDA survey. Table B-2 shows that there are very wide differences in the distribution of trainees according to their phase at each center.

TABLE B-1. SOME BASIC STATISTICS ABOUT CONTROLLERS AT 20 ARTCCs

	Sectors	Authorized Controllers	Controllers per Sector	IFR Handled Per Controller	Controllers Per PVD
Cleveland	43	573	13.3	3017	8.8
Chicago	38	566	14.9	2915	8.2
New York	37	576	15.6	2801	9.3
Atlanta	46	469	10.2	3065	8.7
Washington, D.C.	34	482	14.2	2850	7.7
Indianapolis	33	450	13.6	2861	9.2
Ft. Worth	39	338	8.7	3636	5.9
Houston	38	424	11.2	2723	7.1
Memphis	30	348	11.6	3119	8.3
Jacksonville	35	407	11.6	2652	7.1
Miami	29	293	10.1	3590	5.9
Los Angeles	34	361	10.6	2906	7.5
Kansas City	36	365	10.1	2700	7.0
Boston	27	415	15.4	2346	7.2
Oakland	29	346	11.9	2629	7.9
Albuquerque	29	280	9.7	3248	6.1
Minneapolis	28	316	11.3	2865	7.7
Denver	30	273	9.1	2347	6.2
Seattle	16	185	11.6	3228	5.3
Salt Lake City	18	183	10.2	2225	4.3
Average	32.5	382.5	11.8	2886	7.3

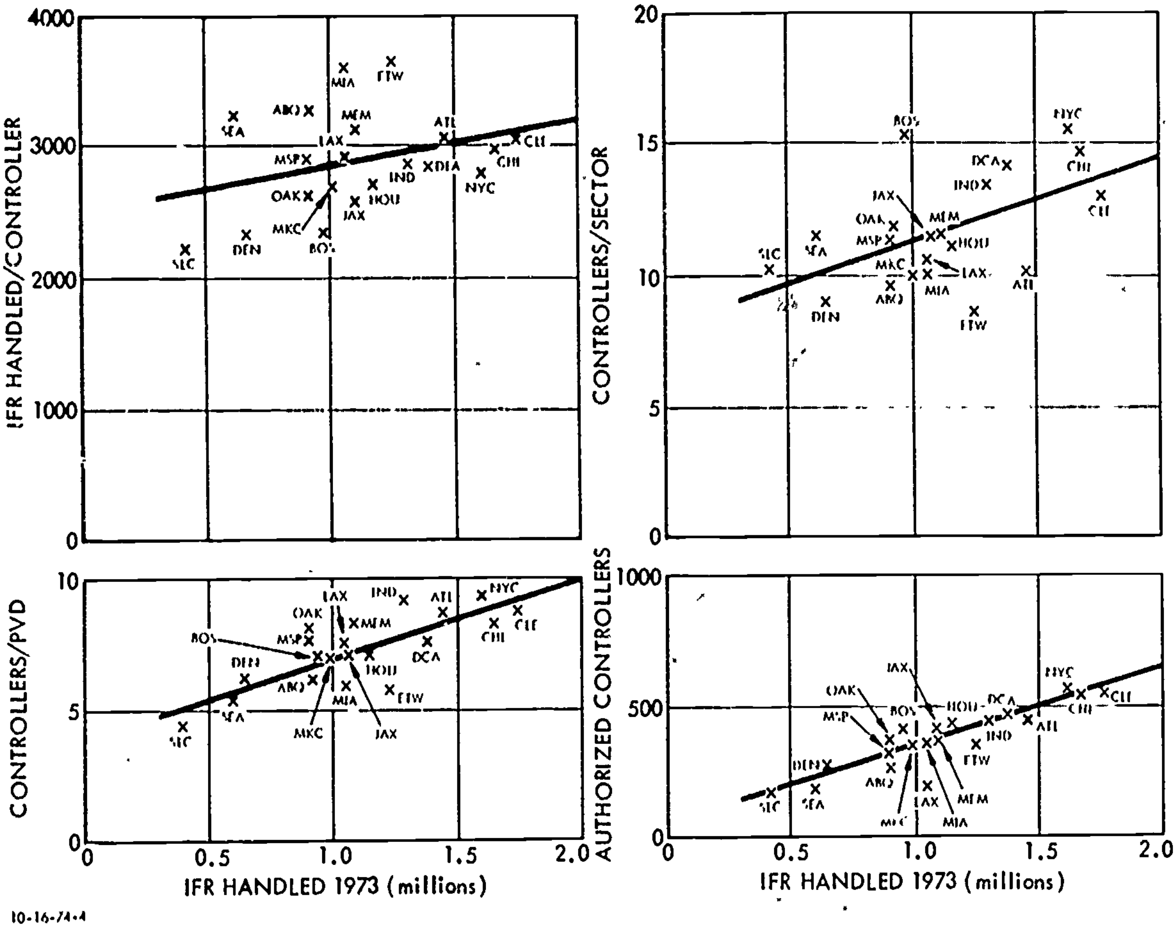

FIGURE B-1. Operational Characteristics of Centers

TABLE B-2. NUMBER OF TRAINEES/DEVELOPMENTALS BY TRAINING PHASE AT 20 ARTCCs

	Phase						
	PRE	I	II NR	II R	III NR	III R	Total
Cleveland	0	28	3	3	38	24	96
Chicago	5	132	30	0	69	18	254
New York	0	93	10	21	101	30	255
Atlanta	12	96	28	0	28	55	219
Washington, D.C.	4	13	28	0	49	64	158
Indianapolis	0	68	0	7	14	37	126
Fort Worth	15	48	3	0	8	33	107
Houston	4	65	0	1	0	24	94
Memphis	3	86	0	0	14	2	105
Jacksonville	6	50	87	0	9	6	158
Miami	8	24	24	0	1	10	67
Los Angeles	0	8	35	12	19	60	134
Kansas City	9	57	0	0	10	17	93
Boston	20	0	0	0	7	57	84
Oakland	15	26	25	0	1	34	101
Albuquerque	14	29	8	8	3	0	62
Minneapolis	0	64	10	0	11	8	93
Denver	0	8	16	5	9	10	43
Seattle	12	15	1	0	2	3	38
Salt Lake City	10	5	0	0	15	1	31
Total	137	918	308	57	409	493	2322

NOTE: R = radar; NR = non-radar.

An associated consideration concerns the fraction of controllers who are fully qualified and the instructional resources at each center. Table B-3 shows the relationship. The fraction of fully qualified controllers ranges from 54 percent at Chicago to 85 percent at Denver. The relationship of instructional capabilities to apparent requirements is not obvious. (In fact, there seem to be more training resources where there are fewer developmentals to train.) It seems inadequate, for example, at Chicago. The relationship between "student/teacher" ratio to fraction of qualified controllers is shown in Figure B-2.

TABLE B-3. INSTRUCTIONAL RESOURCES, HIRES, AND ATTRITION DURING TRAINING AT 20 ARTCCs[a]

En Route Center	Percentage of Operational Controllers that are Fully Qualified	Developmentals per Instructor	Hires	Developmental Losses Number	Developmental Losses Percentage
Cleveland	83%	6.9	56	11	11%
Chicago	54	9.4	109	24	9
New York	56	12.4	98	36	14
Atlanta	60	20.7	111	12	5
Washington	69	8.3	4	6	4
Indianapolis	72	8.0	45	16	13
Fort Worth	70	7.7	31	13	12
Houston	75	4.7	61	10	10
Memphis	67	17.0	69	13	12
Jacksonville	64	13.9	102	23	15
Miami	72	5.4	49	24	36
Los Angeles	60	12.2	25	18	13
Kansas City	77	6.9	21	9	10
Boston	81	3.3	20	14	17
Oakland	70	6.2	29	21	21
Albuquerque	77	3.0	76	17	27
Minneapolis	69	8.9	39	17	18
Denver	85	2.9	38	11	26
Seattle	81	3.6	0	7	18
Salt Lake City	83	2.3	29	24	77

[a]Source: IDA Survey.

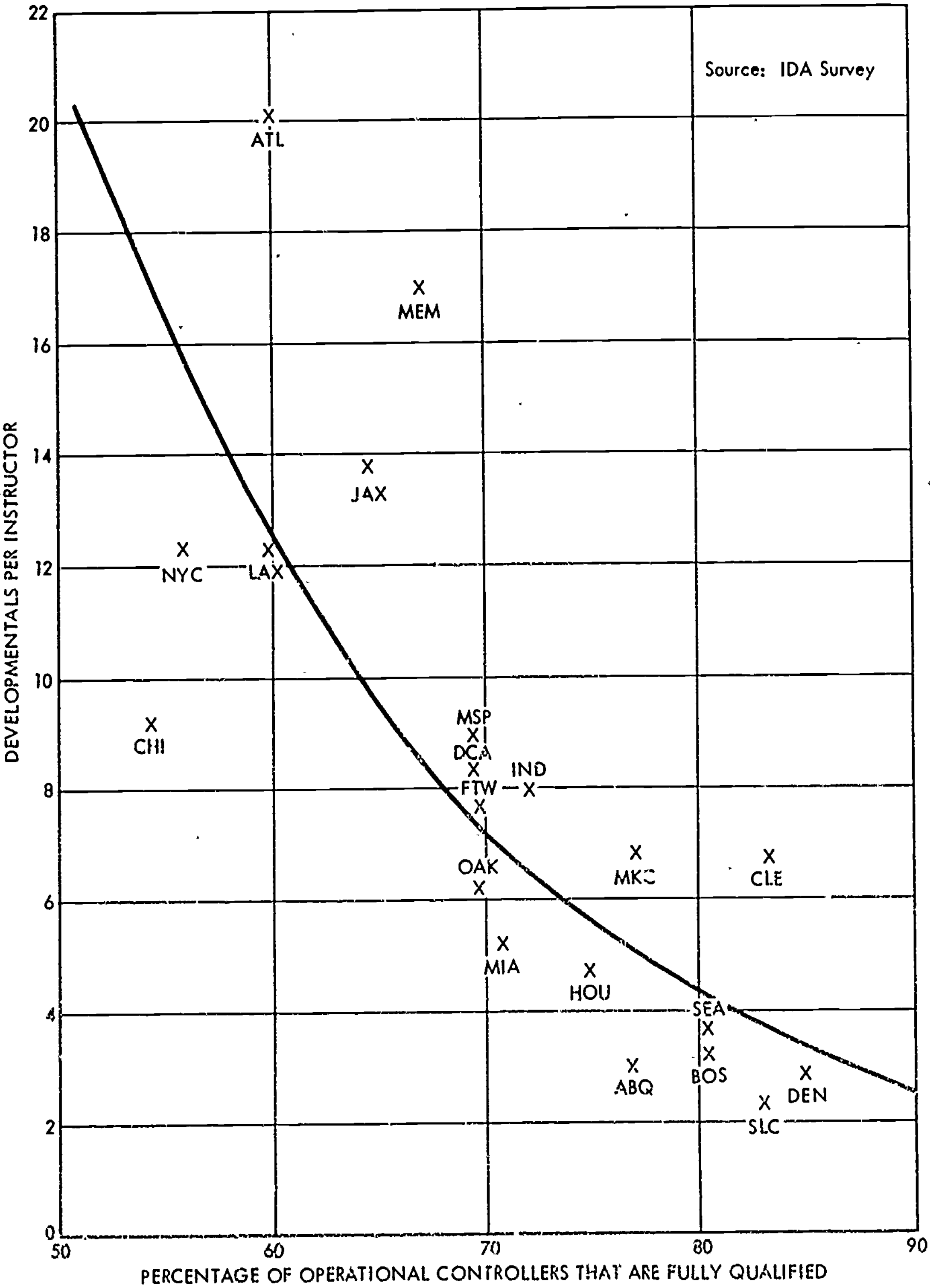

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FIGURE B-2. Relation Between Instructional Resources at Centers and Percentage of Controllers that Are Fully Qualified

In addition, the data show wide variations in training at terminals also. Table B-4 shows data for some of the major IFR terminals, where the average number of developmentals per instructor is 7.3; this ratio varies from 0.86 to 20.8. An average of 76 percent of the entire staff are fully qualified journeymen, but this varies with facility from 54 to 92 percent. There seems to be no consistent relationship between the fraction of the staff needing developmental training at these terminal facilities and the training resources. The situation is shown graphically in Fig. B-3.

The history of separations and hires was also examined. These are shown in Figs. B-4 and B-5. The pattern of substantial fluctuation is evident. (It should be remembered that training programs are less than a quarter of a year in duration, and hence quarterly data are appropriate.) Again, it is difficult to use these data as a basis for future projections.

D. REMAINING SURVEY RESULTS

As mentioned, the primary purpose of the survey was to obtain the data necessary to help in the development of program costs. The data for this purpose are given in Appendix G (starting at p. 218), where they are used.

TABLE B-4. INSTRUCTIONAL RESOURCES, HIRES, AND ATTRITION DURING TRAINING AT 21 MAJOR TERMINALS[a]

En Route Center	Percentage of Operational Controllers that are Fully Qualified	Developmentals per Instructor	Hires	Developmental Losses: Number	Developmental Losses: Percentage
New York (CIFRR)	82%	3.2	33	4	15%
Chicago	54	17.0	5	16	31
Atlanta	56	17.4	0	1	1
Miami	81	5.2	20	2	12
Dallas/Ft. Worth	67	9.3	0	4	14
Los Angeles	92	2.0	0	3	50
Washington National	68	20.8	13	1	4
Detroit	75	4.7	6	7	64
Boston	69	15.0	5	6	30
Houston	83	0.86	2	0	0
San Antonio	92	4.3	0	0	0
Tampa	68	9.6	6	4	20
Denver	89	3.4	0	8	100
Memphis	80	8.3	5	0	45
Pittsburgh	66	7.4	13	1	5
St. Louis	72	16.3	10	4	21
Cleveland	75	4.7	6	7	64
Minneapolis	76	7.3	6	6	46
Kansas City	84	8.0	1	1	13
Columbus	92	2.0	3	0	0
Indianapolis	78	9.4	5	3	27

[a] Source: IDA Survey.

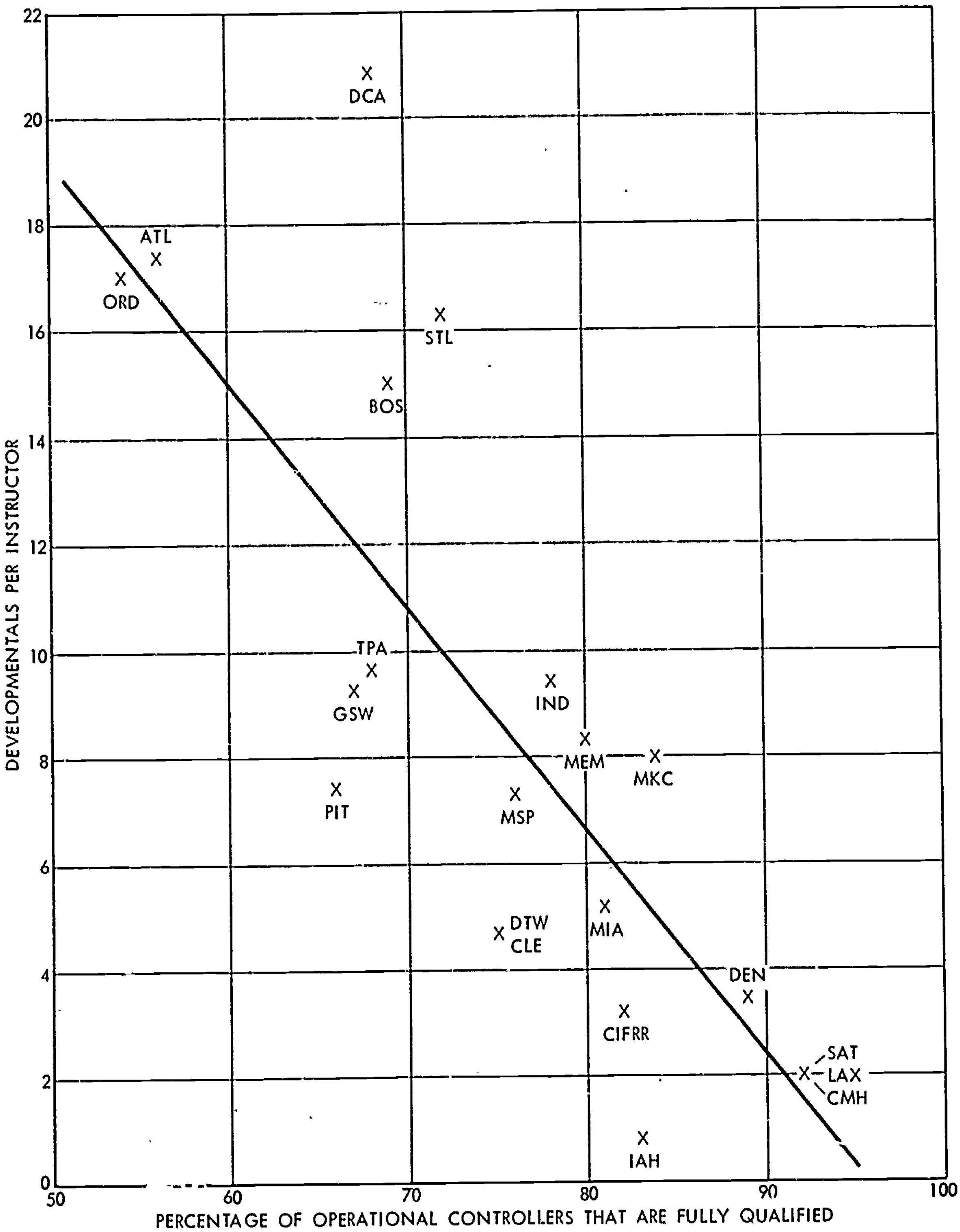

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FIGURE B-3. Relation Between Instructional Resources at Selected Terminals and Fraction of Controllers that are Fully Qualified

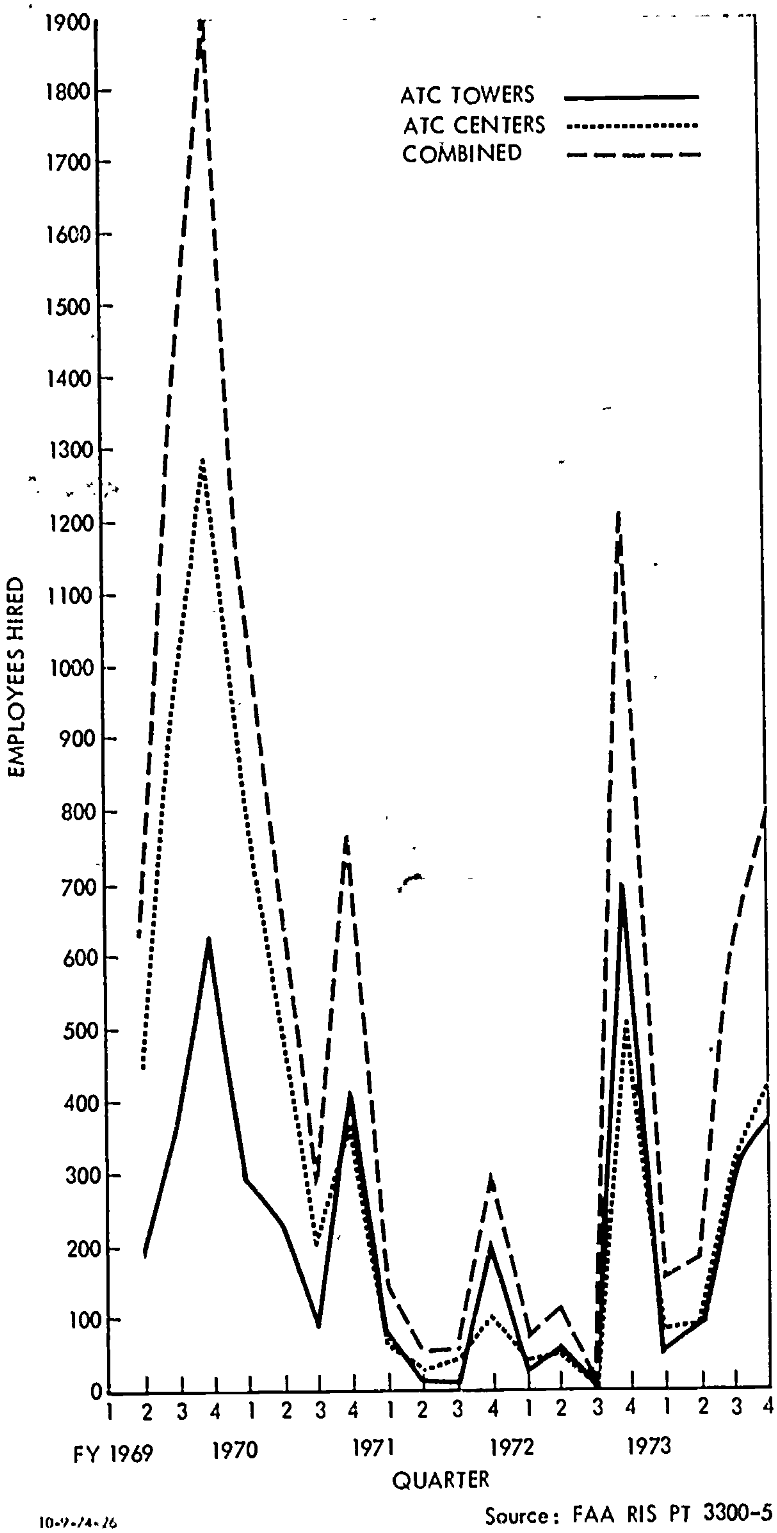

FIGURE B-4. History of ATC Hirings

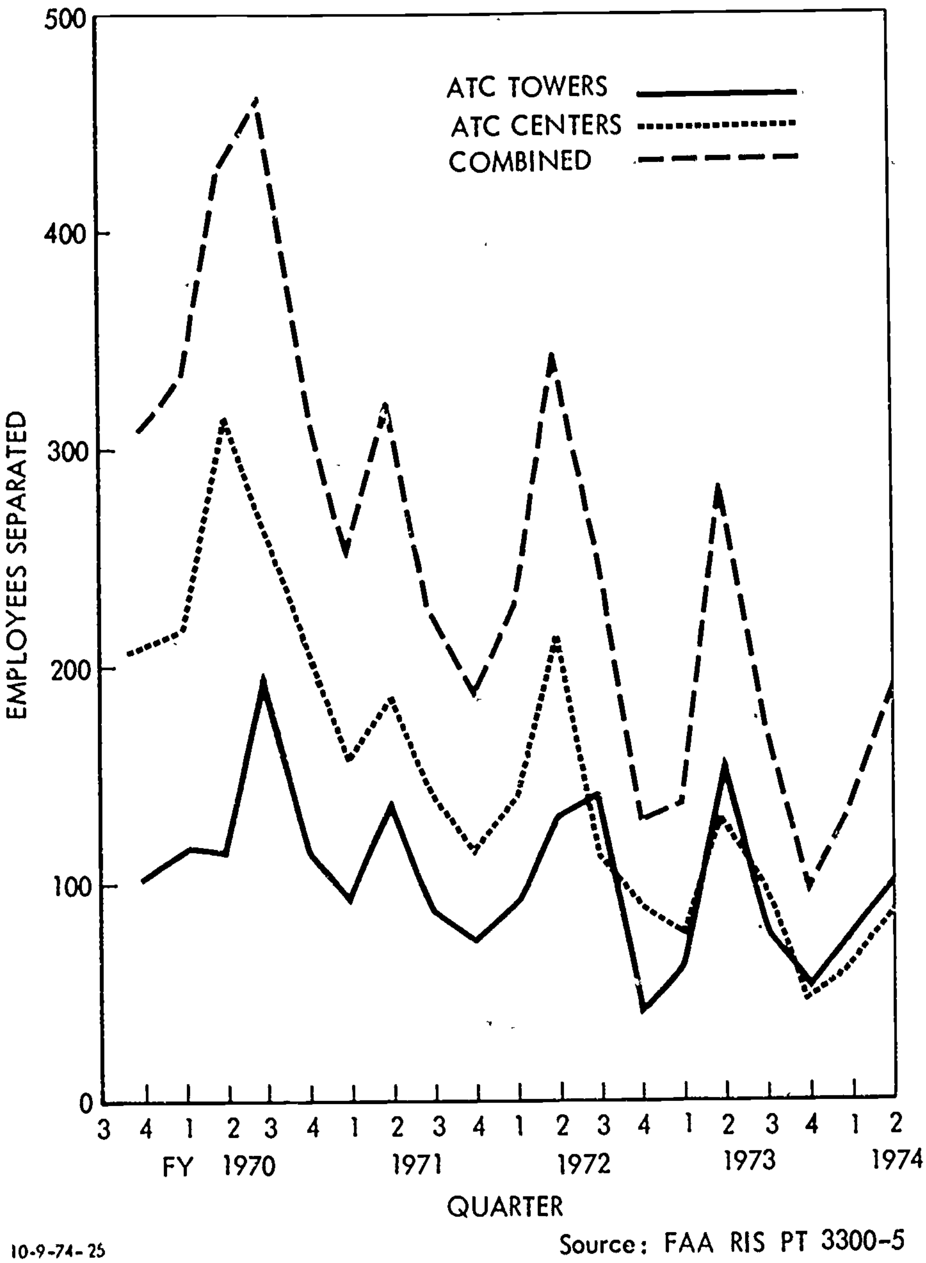

FIGURE B-5. History of ATC Separations

APPENDIX C

SIMULATION FOR AIR TRAFFIC CONTROL TRAINING

CONTENTS

I. INTRODUCTION

This Appendix is concerned with the capabilities and limitations of simulation devices relevant to air traffic control training. For background, the history of air traffic control simulation is reviewed, and fidelity of simulation--a concept that is central to the use of simulators for training--is discussed. Then, the functions of National Airspace System, Stage A (NAS-A), Automated Radar Terminal System (ARTS) III, and ARTS II are briefly described, and the simulation capabilities and limitations of those systems are discussed. There follows a discussion of the need for dedicated simulators at the FAA Academy and an examination of future simulation requirements. Finally, a summary and conclusions are presented.

II. HISTORY OF AIR TRAFFIC CONTROL SIMULATION

The term "simulation" has a variety of meanings, all centering around the idea of representing something--an object, a condition, a process--in some manner. What is simulated can vary from the simplest device to complex systems involving sophisticated electronic components, communication networks, and human decision makers. The purpose of the simulation, and thus the method used, can vary as well. When the purpose is system design, the simulation may be completely mathematical, often utilizing a computer, or it may involve an electromechanical mockup. The literature on mathematical simulation and on engineering simulation is extensive (e.g., Naylor et al., 1966, and Flagle et al., 1960) but is not particularly relevant when the purpose of simulation is training, performance assessment, or development of standard operational procedures and doctrine for existing systems. There is also extensive literature in this area, perhaps the most comprehensive recent source being Parsons (1972).

The idea of using simulation for training is an old one; the game of chess is said to have evolved from ancient oriental war games, and training with mockups of military equipment (e.g., wooden swords) is centuries old. The use of complex equipment for simulation has occurred principally since World War II, the aircraft simulator being the best-known example.

Simulation of air traffic for training has a long history, for both military and air traffic control (ATC) purposes. Vickers (1959) mentions an ATC simulation study in Australia in 1948. Parsons (1972), in his study of man-machine experimentation, discusses more than 40 major applications of the technique, many of them for training. Some of the more relevant studies are discussed in the following paragraphs.

Project Cadillac was conducted for the Navy by New York University from 1948 to 1955 using several radar consoles and associated communication networks with thirty 15-AM-1 target generators. The project investigated aircraft surveillance, display, and communication problems experienced by operators in Navy Airborne Combat Information Centers.

The Navy in the late 1950s set up a center to be used to train personnel for the Navy Tactical Data System (NTDS), a system used for aircraft surveillance and intercept direction aboard ship. The NTDS computer could generate simulated targets and record system performance. Larger, multioperator, computer-based simulation facilities for NTDS training were established at the Fleet Anti-Air Warfare Training Centers in San Diego and Norfolk.

In 1952-54, the Rand Corporation's System Research Laboratory embarked on a study of the behavior of operators in complex systems of the Air Force. An early by-product was the realization that laboratory subjects improved rapidly in performing their assigned tasks in a simulated air defense environment. The radar simulation was extremely simple--multifold paper was passed in front of a light source which revealed printed digits that represented positions of

blips on a particular radar sweep. After a series of experiments, first with students and then with military crews, a field training program called the System Training Program (STP) was developed and installed in all Air Force radar stations and in the radar stations of the North Atlantic Treaty Organization (NATO) countries. The STP, as implemented in the field, utilized a film device for feeding the plan position indicator (PPI) scopes a simulated air environment, including permanent echoes and weather, and used 15-J-1-C target generators controlled by pseudo-pilots. The program was based on a combination of well-known and, in theory, at least, generally accepted principles, among which were: training a team as a whole, stressing the system (in this case, in a simulated mode), and providing the participants with knowledge of the results (in this case, through an immediate discussion-type debriefing after each exercise.)

During the 1950s, the Semi-Automatic Ground Environment (SAGE) system was developed and installed as the primary air defense system for the United States. It had a more than superficial similarity to NAS-A and deserves some attention, particularly with respect to simulation and training. SAGE consisted of 20 or so direction centers that were fed digitized radar data from long-range radars which were processed by the SAGE computer and displayed on scopes. This man-machine system carried out surveillance, identification, and intercept control functions. The system training program that originally focused on the radar site was adapted to SAGE and eventually included coordinated exercises that involved all radars, SAGE direction centers, early-warning aircraft, and appropriate higher headquarters. The basic SAGE STP simulation consisted of two parts: (1) pseudo-pilots in a special room controlling computer-generated targets that appeared on the consoles in the direction center, and (2) a training-problem magnetic tape containing simulated inputs from the long-range radars as well as weather information from adjacent sectors and civil flight plans from the Federal Aviation Administration (FAA). The performance of the system during an exercise was recorded, the data were reduced by the computer, and additional observations were made

by monitors in a training operations report. Numerous studies were made of how to improve the quality of the simulation and, more importantly, of the training program. While the general approach of stressing the overall system through varying the complexity of the air defense scenarios proved beneficial, it was also necessary to develop ways to stress particular subsystems. For example, to gain tighter control over the inputs to the weapons direction section, special problems were designed in which the output of the surveillance section was simulated instead of the radar inputs. This made it possible to present the weapons section with situations that it would otherwise face only when the surveillance section made mistakes.

Most of the simulation of air traffic control has, of course, been done by or for the FAA, but a number of studies have been oriented toward military problems. One series of studies was carried out at Ohio State University in the late 1950s under Air Force sponsorship. An electronic simulator was built to display up to 30 controllable targets incorporating altitude effects on speed, wind effects on speed and headings, and various aircraft identification arrangements. The experiments dealt primarily with human engineering and system design considerations and did not deal directly with training.

The work on simulation, first at the Technical Development Center (TDC) in Indianapolis and then at the National Aviation Facilities Experimental Center (NAFEC) in Atlantic City, has been extensive and is presumably well known within FAA. Consequently, only a few of the most relevant studies will be mentioned here.

The first real-time simulation activities at Indianapolis used a simple device that mechanically integrated speed and heading to produce a realistic approach path in the form of a small spot of light which traveled across the surface of a simulated radar scope. This device, which simulated a single aircraft, was followed by the "Navascreen" in 1950, which projected six controllable targets on a

large translucent screen. Each target was operated by a person acting as pilot. Navascreen was superseded in 1952 by an Air Force experimental device known as Teleran, a system using a television camera and eight projectors. The projectors were equipped to integrate speed and heading to produce realistic curved paths on a large viewing screen. Using a television camera and a specially designed flying-spot scanner, the images on the screen were presented on scopes in plan position with a rotating sweep. A number of improvements were made over several years. For example, in the TDC simulation, 1.5-deg turns in addition to 3-deg turns were simulated, and wind drift was introduced. The final configuration had 42 controllable targets. Most of the work with the simulator had to do with terminal ATC problems--developing measures of system performance and studying problems occasioned by the introduction of new equipment.

From 1950 to 1958, approximately 50 technical reports were prepared from the simulation work at Indianapolis, but apparently none of this activity dealt with the use of simulation for training controllers (Vickers, 1959).

The simulation equipment used at TDC was transferred to NAFEC in Atlantic City and used there until 1962. In 1960, a new simulator, Model A, was acquired from Aircraft Armaments, Inc., and in 1961, a second one, Model B, was acquired from the same company. Model A could simulate three radars; Model B, four. Model A had 48 pilot positions; Model B, 60. These simulators and their digital successors were used in numerous studies investigating such problems as simultaneous dual approaches, combining of approach control facilities, traffic flow patterns, and airport site selection. Some of the later work on investigating system performance measurement is discussed in Appendix E. As was the case at TDC, however, no experimental work was done on simulation for training.

A very significant development began at NAFEC in 1970, partly as a consequence of the Corson Committee's strong recommendation that adequate simulation be used for training (Vickers, 1972). In a NAFEC

program, groups of about 18 students, accompanied by their instructors (all from the same en route center), took over the NAFEC Model B simulator for assigned three-week training periods. The displays were arranged to duplicate two en route sectors from the home facility. The traffic samples which were used during this training were based on actual recorded traffic for the two sectors. During the final week, the traffic density was increased to 110 percent of the recorded peak-day density.

The main object of the customized training was to carry a group of students as far along as possible toward checkout as radar controllers on the two sectors being simulated. The training also stressed the development of the team concept in sector operation.

The NAFEC program was discontinued in 1972.

The following comments on the program are quoted from Vickers (1972):

> The results have been rather spectacular; but because no formal statistical study has yet been completed, the FAA Technical Training Division is reluctant to give out any figures comparing the progress of students who get this customized training with those who do not. However, unofficial reports from several sources indicate that this three-week simulation course shortens the amount of on-the-job training required for radar checkout by about six months. In one case, a group of students from the Oakland Center was able to check out as radar controllers, on the two sectors simulated at NAFEC, immediately after their return to Oakland, without further on-the-job training.

That such an approach would be successful should come as no surprise to those familiar with technical training, but it is unfortunate that statistical data are not available to support this finding. It is also unfortunate that it was not possible to continue the effort longer, even though it is recognized that the Model B simulator was expensive to operate and that NAFEC had other missions than to provide training.

III. FIDELITY OF SIMULATION

A major consideration in the use of simulation for training is called "transfer of training." That is, how well a person performs on the job after being trained on a simulator. "How well" is often measured in terms of quality of performance or amount of training time and cost required to reach some level of performance, generally by comparing those trained on a simulator with those trained on operational equipment. In the training of pilots this issue has been under study since 1929, studies becoming increasingly frequent after World War II.

In 1949, a study (Williams and Flexman, 1949) showed that using simulators cut training cost by 50 percent and flight hours by 62 percent. Other studies in the 1950s (Payne et al., 1954, and Creelman, 1955) demonstrated that students trained in simulators were as proficient on flight checks as students trained in aircraft, made 74 percent fewer errors, and showed superior ability in approach and landing. In the 1960s, numerous studies addressed the effectiveness of different degrees of completeness of the simulation and the roles in flight training to be played by various part-task training devices and operational flight simulators. As the name implies, a part-task trainer is limited to some part of an entire task to be learned (e.g., trainers for pilot navigation or radio procedures rather than a complete cockpit simulation). Questions about what training could be done most effectively in cockpit procedures trainers and in instrument and contact flight simulators, rather than in complete operational flight simulators, were raised and answered. In the interest of safety and economy, the amount of training in flight was minimized.

Between 1966 and 1971, American Airlines reduced flying time for Boeing 707 captain transition training from 18.3 to 3.1 hours (Moran, 1971). The comparable reduction for the Boeing 727 was from 20.6 to 3.5 hours. In 1971, captain transition training for the

Boeing 747 averaged 5.3 aircraft flying hours and 22.1 flight simulator hours; such training for the DC-10 averaged 2.1 aircraft flying hours and 19.5 flight simulator hours. The other major airlines have had similar success; and the FAA Flight Standards Service now permits almost all transition training for the airlines to be accomplished in simulators.

The central importance of simulation in flight training is well accepted. Considering the fact that air traffic control radar simulation is technically much simpler, it seems strange that it has not played a similar role in the training of FAA controllers. Each of the three military services uses simulation extensively in controller training, and, as has been mentioned, the technique is an integral part of air defense training.

While simulation is the process of "representing" something, it is clearly implied that a simulation need not be a complete duplicate of the real thing. The degree of simulation, what portions of a system are included, and the fidelity of simulation will vary with purpose. A key element in using simulation for training is the nature of the task or tasks to be learned. Training to impart precise motor skills gives rise to requirements different from those of teaching general procedures. In the former case, it might be critical that the sensory cues in the simulation be very realistic, and it might not be so important to include parts of the system not directly associated with the sensory motor activity of the operation. Another consideration is the stage of training for which a device will be used; early stages of learning are often best done in a simplified environment, the complexity to be found in real operations being introduced later. Just what features of the real world should be included sometimes can be answered only by research. A question such as what degrees of freedom of motion should be built into a flight simulator does not lend itself to answer by analysis alone.

Prophet (1966) compared a procedures trainer that cost $100,000 with a plywood mockup of a cockpit with a photographic instrument

panel that cost $100. The static mockup was as effective as the expensive trainer in teaching cockpit procedures. It was also as effective on tasks such as reading instruments and making precise control settings.

Cox et al. (1965) investigated transfer of training in a study that involved 12 different devices, each of which simulated a complex control console in a missile system. The most realistic device, the "hot panel," was the same size and shape as the real console, with every light, switch, meter, intercom, and telephone functioning. A "cold panel" was the same, except that no electrical power was used. Other variations were a panel made of cardboard, a full-size black-and-white photo of the face of the console, a line drawing of the panel, and panels differing in size. The results were that for training in fixed-procedure tasks, the fidelity of the simulation did not matter. Grimsley (1969) later verified these findings by using three versions of the console--high, medium and low fidelity. This time the emphasis was on retention and retraining time. There were no differences in initial training time, in retention after four and six weeks, or in time to retrain to the criterion.

An interesting study was done recently (Koonce, 1974) in which statistically significant results were obtained indicating that better simulation does not necessarily mean better transfer of training. The experiment involved testing a pilot's instrument flight skills on successive days. Training was in simulators on the first two days and in an aircraft on the third day. There were three groups of pilots. For one group the motion system in the flight simulator was turned off; the other two groups were trained under two different levels of sophistication with respect to motion cues. There was the usual finding that motion cues, simple or complex, make the simulator easier to fly. But when the groups were tested in the aircraft, the group that had experienced less realism--no motion in the simulator--was significantly better. Apparently the motion cues in the simulator were misleading, even though the motion system had apparent or "face" validity; that is, pilots thought it realistic.

Chapanis (1972), in commenting on the dangers of assuming validity of a simulation, gave a striking illustration of how "realistic" simulations sometimes have unintended features. Many highly realistic driving simulators induce motion sickness even in people who never experience motion sickness in driving real automobiles. The curious thing is that all attempts to isolate and remove the cause or causes of this have been largely unsuccessful.

> The results obtained from simulation have to be interpreted and extrapolated to real world situations with great caution. In the final analysis, the validity of a simulation has to be proven experimentally. It cannot be taken for granted, no matter how impressive, internally consistent or elegant the simulation. (Chapanis, 1972, p. 726)

Thus, realism does not necessarily mean good training. What is important is that the right aspects of the real environment be present for the task to be learned. In the case of the radar portion of controller training, the realism of the display itself is probably not as important as having all functional aspects of the system represented, so that communication procedures and other basic skills can be practiced in safety. It is probably obvious that if the simulation is too poor, motivational problems will arise and the benefit that comes from a student's becoming thoroughly involved with a problem will be lost.

An important consideration is stimulus control and the ability of a trainer to create situations in which the proper behavior can be taught. This makes it possible to present situations that occur infrequently in real life and to give practice unobtainable in a reasonable period of time on the job. It also makes it possible for the simulation experience to be ordered coherently in terms of the materials to be learned.

It seems clear that using a simulator in early phases of training would be effective even if it is lacking in realism and specificity. Military experience with complex command-and-control systems

certainly suggests that working with the actual system, but in a simulated mode, is an effective final stage of training and is the indicated way to maintain or to increase proficiency after becoming qualified. In the case of both NAS-A and ARTS III, utilizing the built-in simulation capability as a final stage of radar training obviates the problem of keeping the simulation current, a problem faced by separate simulators as new features, particularly features of a decision-aiding nature, are added to a system. This will be important. There are problems with utilizing operational equipment for training, however. These problems will be discussed in later sections of this Appendix.

IV. FUNCTIONAL SYSTEM DESCRIPTIONS

A. NATIONAL AIRSPACE SYSTEM, STAGE A (NAS-A)

NAS-A uses air route surveillance radars (ARSRs) (200-mile) and their associated air traffic control (ATC) radar beacon interrogators (RBIs) in a CONUS network in which the wideband (video) data is digitized at the sensor and transmitted over voice-quality circuits to central computer complexes at 20 air route traffic control centers (ARTCCs). Aircraft tracks are computed for all aircraft and sent to the display console (Fig. C-1).

The system includes flight plan entry, progress reports, flight plan updating and forwarding, plan position and tabular displays, and semiautomatic transfer of control between facilities.

NAS-A technically represents the highest level of ATC automation by reason of the radar level and beacon level tracking, the multi-sensor and multiprocessor capability, and the automation of flight plan functions. The Automated Radar Terminal System (ARTS) III is less automated, and the ARTS II is even less automated.

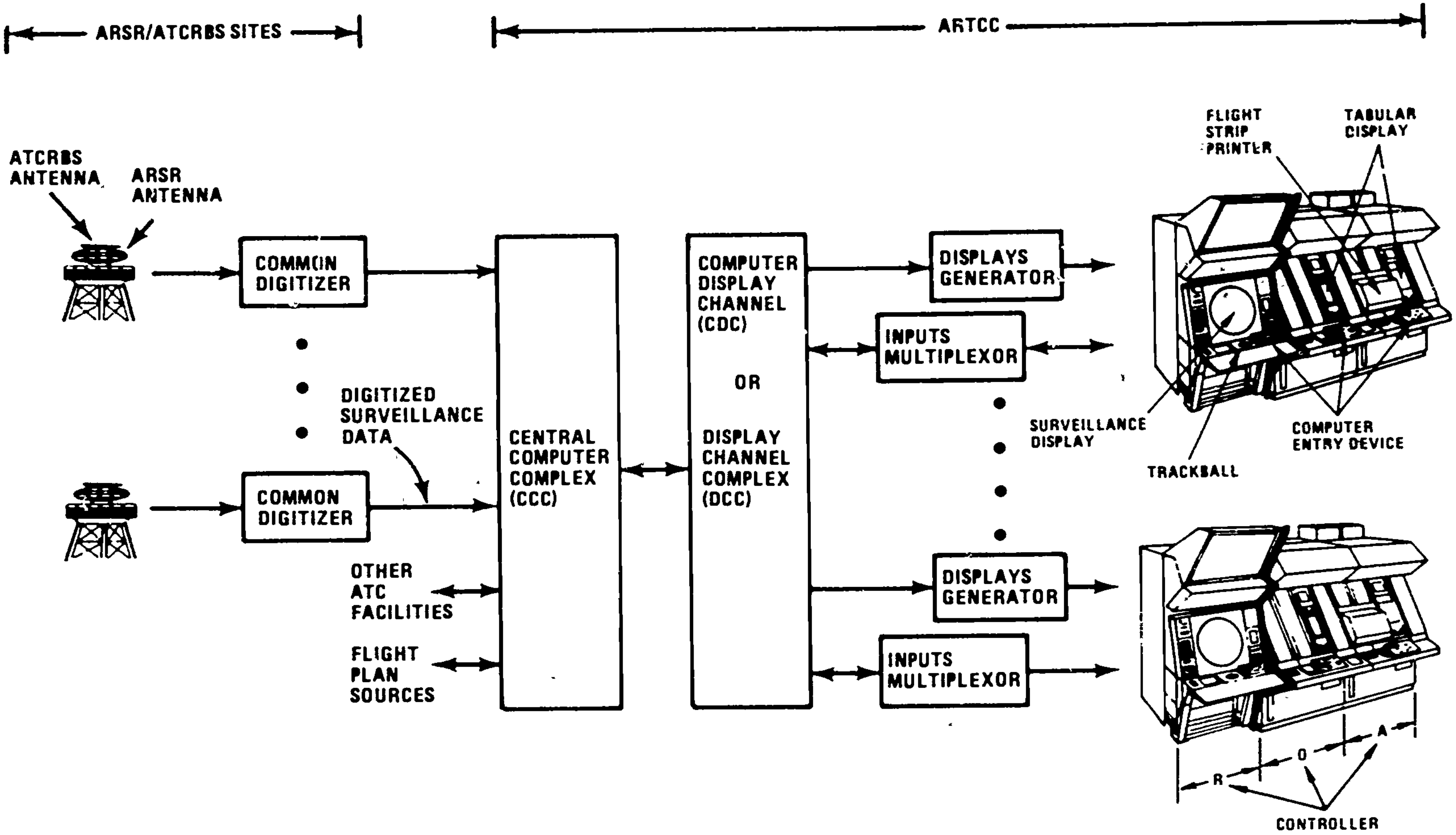

FIGURE C-1. Simplified Block Diagram, NAS-A (Source: FAA, 1974b)

B. AUTOMATED RADAR TERMINAL SYSTEM III (ARTS III)

The basic ARTS III (Fig. C-2) is based upon system work initially started at the Atlanta terminal and now programmed for full operation at 61 terminals. The terminal radar approach control (TRACON) system functions at instrument flight rules (IFR) rooms with tower cab (TRACAB) displays where appropriate.

The block diagram shows that beacon-equipped aircraft are automated to beacon tracking level, while non-beacon-equipped aircraft are not tracked. When the radar video is digitized, all aircraft can be tracked, as in NAS-A.

C. AUTOMATED RADAR TERMINAL SYSTEM II (ARTS II)

For less busy terminals, the level of automation and the size of the facility are constrained by basic economics to be somewhat less than those of ARTS III. See the simplified block diagram of ARTS II (Fig. C-3). ARTS II employs beacon data level (not tracking level) sensor inputs to a minicomputer which, in basic form, is expected to handle up to six displays.

ARTS II is in procurement, and to date there has been no program development for training purposes such as the enhanced target generator (ETG) of ARTS III. While ARTS II is much smaller and cheaper than ARTS III, it could very likely support training at most, if not all, of the locations where it is installed. The low traffic count, the small number of ATC displays, and the modular expansion capability of the minicomputer support this view.

D. ENHANCEMENT PROGRAMS

From a simulation viewpoint, there are three levels of sensor input: beacon data level (in ARTS II), beacon tracking level (in ARTS III), and both beacon and primary radar tracking level (in NAS-A). Plans and programs to provide tracking level on all aircraft (as in NAS-A) will materialize as program priorities, technical capabilities, and operational capacity will allow.

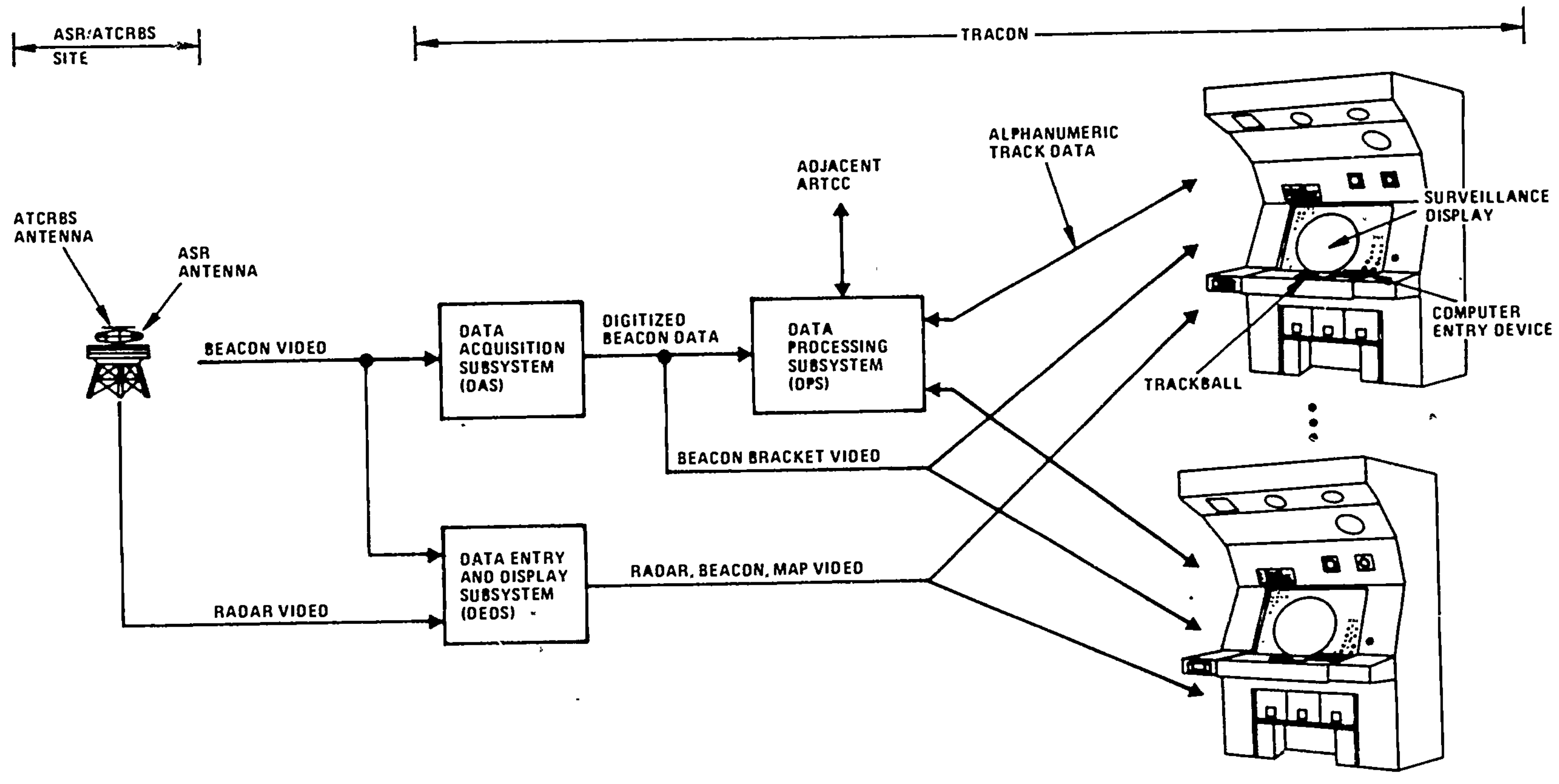

FIGURE C-2. Simplified Block Diagram, ARTS III (Source: FAA, 1974b)

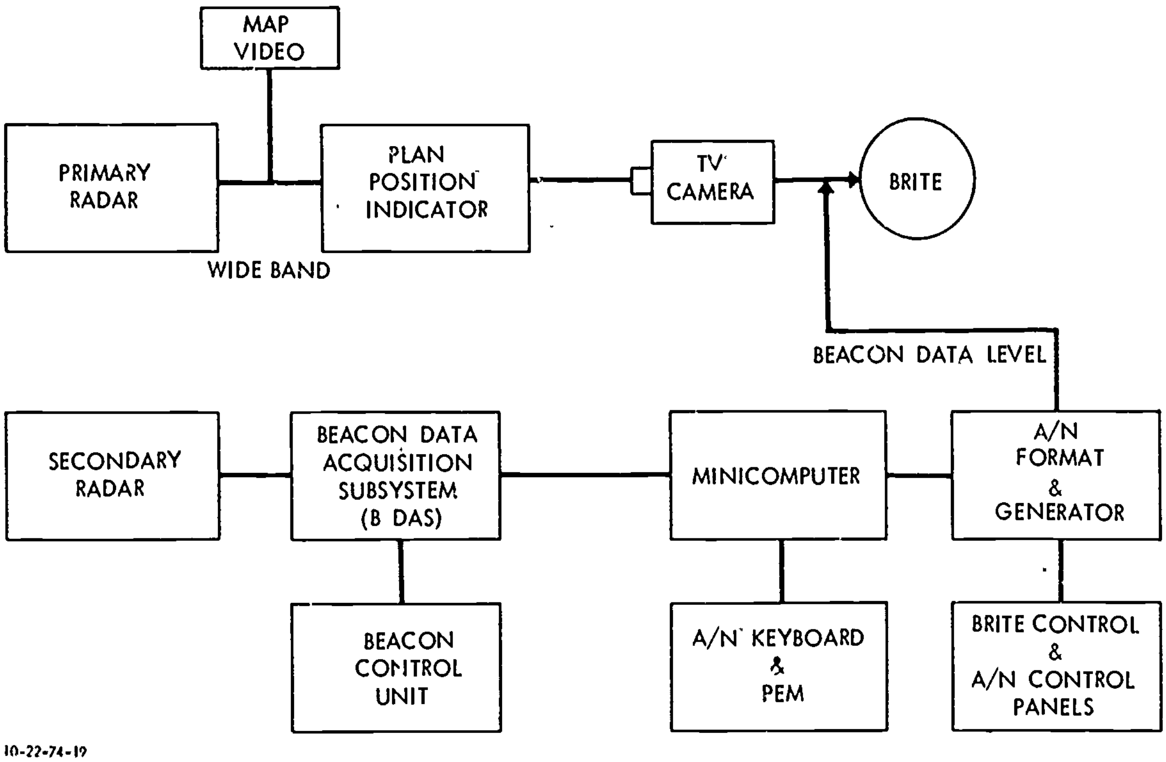

FIGURE C-3. Simplified Block Diagram, ARTS II

As the system evolves into the "upgraded third-generation" phase, the surplus capacity at many locations is expected to gradually diminish until competition for main frame time militates against use for training and requires reconfiguration of the system.

Projected operational improvements which may be very demanding on processing capability are exemplified as:

1. <u>ARTCC</u>

   a. Conflict detection
   b. Conflict resolution
   c. Intermittent positive control (IPC)
   d. Discrete address (tactical) data link of discrete address beacon system (DABS)
   e. DABS interrogation hierarchy control.

2. <u>Terminal Radar Approach Control (TRACON)</u>

   a. Automatic radar level tracking with tagged targets
   b. Metering and spacing
   c. Conflict prediction
   d. Conflict resolution
   e. Fail safe/Fail soft/Auto standby switch
   f. Multiradar
   g. Multiprocessing
   h. DABS data link.

3. <u>Tower Radar Automation Cab (TRACAB)</u>

   a. Radar level tracking
   b. Noise abatement pattern control
   c. Wake turbulence separation control
   d. Multisegmented approach and departure routings to exploit the characteristics of area navigation (RNAV) and microwave landing system (MLS)
   e. Upgrading ARTS II from beacon data level to beacon tracking level.

Thus it would appear desirable to view the training situation within the context of both short- and long-term needs. The short-term needs are discussed in Section V, where the simulation capabilities of NAS-A, ARTS III, and ARTS II are reviewed, and in Section VI, where dedicated simulators are considered. The longer term situation is discussed in Section VII, where a systems approach to simulation is advocated to cope with training requirements in the evolving National Airspace System.

V. SIMULATION CAPABILITY OF NAS-A, ARTS III, AND ARTS II

NAS-A and ARTS III were initially delivered with a simulation capability designed to permit equipment checkout, to facilitate maintenance, and to be used for initial facility shakedown. This simulation capability, however, did not permit operation of the equipment in training and operational modes at the same time because the simulated targets appeared simultaneously on all operating scopes in the facility. Because of these limitations, staffs of two facilities (Houston ARTS III terminal and Washington NAS-A center) were authorized and tasked to develop "patches" to the programs that would permit flexible training at designated positions without interfering with operational positions. The ARTS III patch, known as the Enhanced Target Generator (ETG), has been approved and is now being implemented; the NAS-A patch to the Dynamic Simulation (DS) program* is developed but has not as yet been approved for implementation at all centers.

With the Enhanced Target Generator (ETG ARTS III) and the Dynamic Simulator (DS NAS-A), designated positions called "pilot" positions can be used to generate simulated targets which can be displayed at other designated positions independent of all other operational

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*Not yet completed for computer display channel (CDC) version of NAS-A as of October 1974.

positions being used for control of real traffic. The simulated targets will not appear on any of the operational scopes, and the simulation will not interfere in any way with the use of the operational positions. The simulation programs (ETG and DS) utilize part of the equipment capability of the installed ARTS III and NAS-A, however, and in certain circumstances reduce the capacity of these systems to handle operational traffic. For example, should the operational traffic load in NAS-A increase to the point where it equalled the number of tracks for which a particular center was adapted, the system would gradually reduce the number of simulated tracks available, but there would still be an impact on processing times.

The simulations can provide realistic representations of real traffic for digital operations but not of analog radar. All "static" data that are available in the facility computer memories as well as live operational traffic can be presented at the training positions. The "static" data includes: sector boundaries, airport positions, navigation aid positions, holding patterns, airways, and weather contours (NAS-A only), all of which can be displayed optionally by operator selection at any of the simulation positions. Essentially all of the operations required in operational control of aircraft can be simulated, and outputs can also be generated for assistant controller and support positions, as needed. As part of a simulation problem, tapes of scheduled simulated traffic can be prepared and entered into the computer before the problem begins, and flight strips will be printed out at the appropriate simulated support position. Also, simulated traffic entered into the simulated areas by the "pilots" will be associated with the stored traffic data, and tracks will be started automatically on targets that pass the system association criteria. All positions will be connected by the standard level 300 communications system, and "pilots" will control simulated targets in accordance with the trainee controller's instructions; thereby, the pilot-controller communications are also simulated.

Apart from the analog radar presentation, the principal limitations of the simulations are: (1) availability of positions and capacity in an operational facility; (2) the ability of "pilots" to generate and control adequate numbers of simulated targets; (3) the inability to simulate adequately the interactions with adjacent facilities; and (4) the lack of a recording capability designed for training purposes. In addition, the simulations have limited flexibility in that they can be interrupted but cannot be "backed up" or have parts repeated in the middle of a simulation problem to point out a control error or a deviation from control rules or standard practices.

The present simulations do not include a capability to display broadband radar data. In NAS-A, broadband simulation could be obtained by suppressing all alphanumeric and other symbology, other than a symbol representing each target position, e.g., a slash (/). For ARTS III, for which the normal mode of operation is mixed digital and analog data, the position of each controlled target could be represented by several symbols: the usual alphabetic symbol for the controller position and additional symbols [e.g., a slash (/)] in proximity for the analog radar and beacon return.

Although complete system fidelity may not be required for training, the use of a slash for broadband returns departs considerably from realism. The true analog return is an arc, concentric with the center of the display. Its length will vary with distance from the sensor, and it may be broken, depending upon the sensor's antenna pattern and the suppression of individual beacon replies. In addition, deleterious effects such as "ring-around" (i.e., a circle, or broken circle, arising from sidelobe effects) and "spiraling" (arising from asynchronous interference from neighboring beacon interrogators) may occur under actual operational conditions and may degrade the controller's display.

Table C-1 summarizes the capabilities of the two simulation programs.

TABLE C-1. CHARACTERISTICS OF SIMULATION

	Dynamic Simulator (NAS-A)	ETG (ARTS III)
Functions		
Simulation terminate (manual/automatic)	Yes	Yes
Separate, independent operational and simulated traffic	Yes	Yes (no live data blocks)
Mixed live and simulated traffic at simulated positions only	Yes	Yes
Target entry/termination	Yes, "pilot"/trainee positions	Yes, "pilot"/trainee positions
Track initiate	Yes	Yes (beacon only)
Voice communication-"pilot"/trainee	Yes	Yes
Computer association--trackball/keyboard/flt. plan[a]	Yes	Yes (no flight plans)
Hand-off	Yes	Yes
Holding pattern	No	Yes
Flight plan enter/modification	Yes	No
Data block: Full (FDB)	√	√
Partial (PDB)	√	
None	√	√
Offset data block	√	√
Emergency/radio failure	√	√
Radar Modes		
Analog radar/beacon[b]	No	No
Digital radar/beacon	Yes/Yes	Yes/Yes
Radar/beacon noise (blip/scan)	Yes/Yes	No/No
Target number	100	32
Beacon: Mode C	√	√
Mode 3/A	√	√
None	√	√
Position (plan)	Alphabetic symbol	Alphabetic symbol
Altitude	Mode C (FDB) only	Mode C (FDB) only
Climb/dive rate	Yes, including symbol in FDB (↑↓)	Yes
Altitude, commanded	Yes (FDB)	Yes (not in FDB)
Identity	Modes C, 3/A (FDB/PDB)	Modes C, 3/A (FDB/PDB)
Speed	Vector line	FDB only
Acceleration	No (step change to cmd. speed)	Yes
Heading	Yes (vector)	Yes
Turn rate/new heading	Yes, speed dependent	Yes, speed dependent
Noise: plan position	No	Yes
Windage	No	Yes
Past target history[b]	Yes	No

[a]Can initiate targets and tracks from flight plans.

[b]Simulation override mode--may be intended for wide-band simulation.

Using DS and ETG for training clearly requires special efforts to minimize any negative transfer caused by the lack of realism of the broadband display. Since the developmental has ample opportunity to observe real displays, however, this should not be a great problem.

The evolution of the ATC system and the introduction of the enhancement programs listed in Section IV-D of this Appendix may overload the automated systems and change training capabilities. An analysis of the present air traffic volume with respect to current capacities (FAA, 1974a) does not indicate any system capacity problem with using DS and ETG for training in facilities. In Table C-2 some of the pertinent characteristics of the NAS-A system at centers are tabulated. As an example of the distribution of operations during the day, Los Angeles is cited and shown in Figure C-4. The data shown are for the peak day of 1973 (traffic was less on all other days). There may be scattered occasions when training would be interrupted, but in general, with the possible exception of the case where all training is done at facilities, it appears that training could be done on a scheduled basis during normal working hours.

If all radar training were done at facilities, operational changes, such as operating the automated system longer each day, would probably be needed.

The ARTS II system, based upon the prototype tested at Wilkes-Barre/Scranton Airport, uses the same beacon data acquisition system (DAS) as ARTS III and, like ARTS III, does not process the primary radar video data from airport surveillance radar (ASR).

DAS contains circuitry which can generate aircraft targets fixed in range and bearing for maintenance troubleshooting. Two modes are supplied:

1. A single aircraft generated at each pulse repetition frequency with selectable range decodes.
2. Multiple processing of 16 equally spaced aircraft in 360 deg of azimuth but all at the same range.

Provisions are made on the maintenance panel for generating simulated azimuth data pulses and mixed aircraft pulses in the maintenance mode. Either beacon Mode 3/A (identification) or C (altitude) is selectable.

TABLE C-2. TRAFFIC (PEAK HOUR OF PEAK DAY, 1973) AND TRACK CAPACITY AT CENTERS

	9020 VERSION & DISPLAY		1973 IFR (millions)	PEAK HOUR OPERATIONS	TRACK CAPACITY	SECTORS	PVD's	AUTHORIZED CONTROLLERS
ALBUQUERQUE	A	CDC	0.91	275	300	29	46	280
ATLANTA	D	CDC	1.44	365	400	46	54	469
BOSTON	A	CDC	0.97	305	300	27	58	415
CHICAGO	D/E	DCC	1.65	410	500	38	69	566
CLEVELAND	D/E	DCC	1.73	535	400	43	65	573
DENVER	A	CDC	0.64	200	300	30	44	273
FT. WORTH	D/E	DCC	1.23	430	350	39	57	338
HOUSTON	A	CDC	1.15	600	300	38	60	424
INDIANAPOLIS	D	CDC	1.29	340	400	33	49	450
JACKSONVILLE	A	CDC	1.08	375	400	35	57	407
KANSAS CITY	D	CDC	0.99	335	400	36	52	365
LOS ANGELES	D	CDC	1.05	325	250	34	48	361
MEMPHIS	A	CDC	1.09	394	250	30	42	348
MIAMI	A	CDC	1.05	365	350	29	50	293
MINNEAPOLIS	A	CDC	0.91	264	250	28	41	316
NEW YORK CITY	D/E	DCC	1.61	421	450	37	62	576
OAKLAND	A	CDC	0.91	278	250	29	44	346
SALT LAKE CITY	A	CDC	0.41	105	250	18	43	183
SEATTLE	A	CDC	0.60	163	250	16	35	185
WASHINGTON, D.C.	D/E	DCC	1.37	400	400	34	63	482
TOTAL			22.07			649	1039	7650
AVERAGE			1.10			32.5	56.0	382.5

Sources: FAA Sizing Committee, FAA Air Traffic Activity, IDA Survey, FAA AAT-110.

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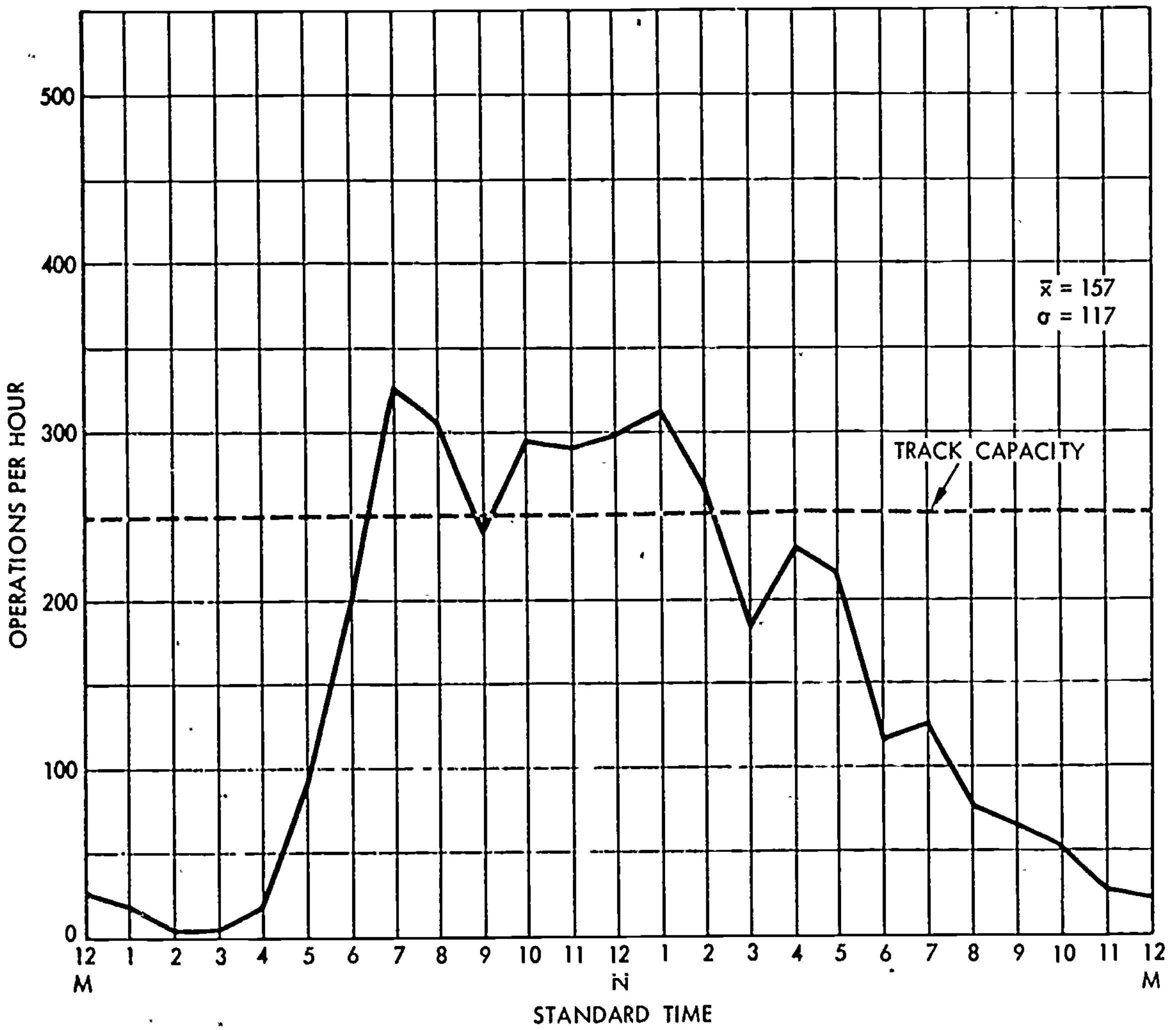


Derived From: FAA "Air Traffic Activity--1973"

10-15-74-9

FIGURE C-4. Los Angeles Air Traffic on Peak Day, 1973

Simulation for training has not been a requirement in the ARTS II prototype. Production systems are still in the early stages of procurement.

The minicomputer of the production ARTS II is of modular form, and it is unlikely that there would be an inherent system limitation to providing an enhanced target generator (ETG) similar to that of ARTS III. In its basic form, ARTS II is required to handle 256 aircraft and six display consoles, and it can operate utilizing data from (a) local ASR site, (b) remotely sited ARTS III (from DAS through Modems), or (c) NAS-A production common digitizer (PCD, beacon portion).

The position entry module (PEM) can be employed to move a single target manually across the display.

The development of programs to provide simulation equivalent to ARTS III ETG could start immediately, since the processor selected for ARTS II is an off-the-shelf commercial item.

VI. DEDICATED SIMULATORS

An alternative to using the developed simulations for NAS-A and ARTS III is a separate simulator dedicated to training. The requirement for such simulators goes beyond the simulation capabilities of the ATC systems themselves. In large part, it depends on what portion of radar training is to be done in the field. If only sector qualification and remedial and refresher training are done, dedicated simulators do not appear needed, because of the simulation capabilities of the present automated equipment and because of the problem (discussed later) of keeping separate simulators current. If all radar training is done in the field, the training load may exceed the system capacity available for simulation in the near term, particularly at terminal facilities. In fact, the alternative of full-time training at a terminal (as offered in Appendix H) is not really feasible for the large number of IFR terminals with only

two or three people, and with few, if any, instructors. For this reason and for standardization and other considerations, some degree of centralization of radar training is indicated. To do this, the FAA Academy (or regional training centers) must have a radar simulation capability.

The Servonics simulation equipment still in use at the Academy and a few other locations is quite inadequate. Its replacement could probably be justified in terms of annual maintenance costs alone, but in addition it has inadequate capacity and availability because of its low reliability and the scarcity of replacement parts.

One option for replacing the Servonics equipment can be quickly dismissed on the basis of cost, and that is installing the necessary additional hardware to be able to operate NAS-A and/or ARTS III in Oklahoma City in a simulated mode. For NAS-A hardware, this cost would be on the order of $4 million to $5 million.* The Academy would still lack an effective broadband simulation capability and would suffer from most of the limitations of the current dynamic simulation program. In addition to the hardware costs, there would be some unknown costs for software. Another unexplored area is how available the Academy's 9020 would be for controller training.

The situation with respect to using an ARTS III system at Oklahoma City is probably similar, if less expensive. Neither of these alternatives would be economical in operation, and both would require extensive manpower for pilots, hand-off, etc., as compared to a device or devices designed for training. As discussed later, training should get more attention as a design consideration in the future evolution of the ATC system. As a part of this, the FAA should explore ways of utilizing standard FAA hardware, particularly plan view displays (PVDs) and minicomputers that will be in the

*Internal FAA estimate (FAA, 1973c).

inventory, and a minimum of special-purpose equipment to achieve the simulation capability needed at various locations at various times. This would make it possible to meet shifting simulation requirements without large sunk costs.

Such an approach does not meet the immediate need for a radar simulation capability at the Academy, however. The number of trainee positions that are needed and the specific features (data blocks, for example) that should be included in the simulator depend on the extent to which radar training is centralized. As indicated above, most IFR terminal training probably should be centralized; whether en route training is done all in the field or partly at the Academy depends on factors discussed elsewhere in this report.

A simulator equipped for terminal training is needed at the Academy. Whether it should also be equipped for en route training, whether the NAS-A enhancement should be done, and whether it should be expanded beyond two-sector capability should be determined as decisions are made about further centralization (see Chapter VII in main report).

VII. FUTURE SIMULATION REQUIREMENTS

The FAA apparently did not, in the design of NAS-A and ARTS III, recognize training as a function that should be reflected in system design. In NAS-A, the dynamic simulation capability was designed for use in system checkout, not training. Although training is mentioned as a reason for the program, it seems clear that no real consideration was given to training requirements. Certainly the most cursory analysis would have indicated the necessity of being able to isolate simulated traffic from live operations. The ARTS III situation is similar. In both cases, recognizing training requirements as legitimate design considerations could have resulted in much more powerful simulation tools than were actually produced. Support for this statement can be drawn from the fact that it was possible to patch both programs in such a way as to make them useful for training.

Furthermore, even though it is now recognized that the enhanced target generator and dynamic simulation programs as modified are valuable training tools, no effort is being made to improve them in future releases. There are modifications, such as more realistic speed changes, that could be included at little cost in the rewrite of the dynamic simulation program that is presently under way.

Unfortunately, the same oversight seems to obtain in the case of ARTS II. A brief analysis of the system specifications again indicates an absence of training considerations. The simulation capability is even more limited than in ARTS III, although the nature of the processor would make it relatively simple to have a sophisticated simulation program.

It is important for future system effectiveness that simulation for training be included in the design of future versions of the National Airspace System. The problem is more complicated than that of procuring dedicated simulators or including on-line simulation programs.

From the viewpoint of the national program, it would be an oversimplification to assume that dedicated off-line special ATC simulators can retain currency and accomplish optimum training results. It probably would be equally fallacious to assume that training programs can succeed based solely on the allocation of time and hardware modules within existing operational ATC systems. In the future it may be impossible to maintain training schedules at many locations when the traffic levels are too high, when the equipment maintenance status is too low, or when enhancement programs are behind schedule.

With the ever-increasing power and flexibility of minicomputers and their dramatically decreasing cost per computational function, one needs to review very carefully the long-term advantages of competing for time on a central computing facility. This is especially true when such a facility has an architecture predating that of current multiple-access distributed modular systems and, in particular, may lack asynchronous bus and bus controller performance capabilities.

For reasons of economy and realism, ATC controller training should take place on standard FAA consoles out of the inventory rather than on special simulator consoles which might be quite different. The "pilot," instructor, and support positions, however, need not be FAA standard operating consoles. Target control and monitoring, "pilot" air/ground voice subsystem, and video generation for standard FAA displays can be independent modules not normally in use in the ATC system.

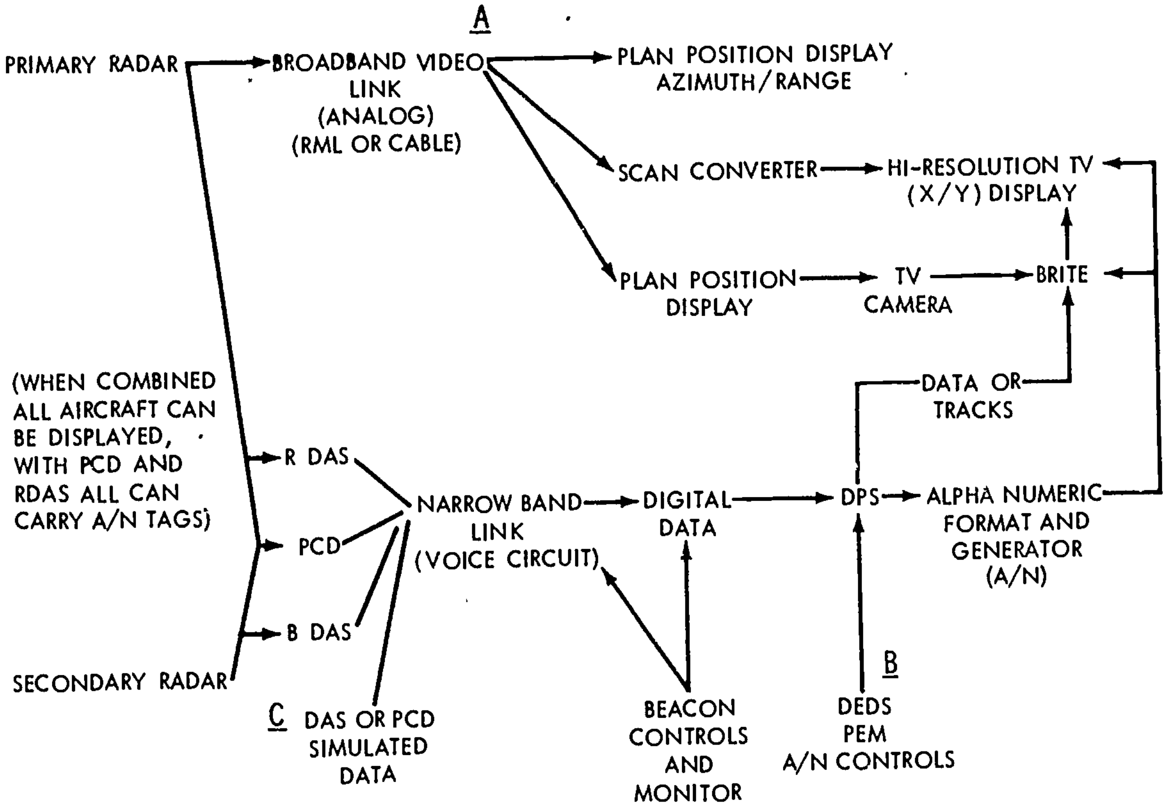
Because of planned upgrading and enhancement programs, the subsystems should be modular, so that add-on modules can be utilized to upgrade the training as automation and its related new training requirements develop.

The simplified diagram in Fig. C-5 shows the alternatives available in the present ATC system. Broadband, hardware-generated video information can be fed at position A for use in the three categories of display shown. This information can be controlled via a target control and monitoring subsystem connected to a video generation subsystem, or it can be input from storage via video tape, film, or TV camera. Map overlays can utilized at the camera or on the final display itself.

At position B the controls are available to simulate live targets using software programs of the data processing system, such as the enhanced target generator (ARTS III) and dynamic simulation (NAS-A).

Position C identifies the fact that digital data in R DAS, PCD, or B DAS digital content and format can be fed from a voice-bandwidth source and appear on the displays as simulated aircraft with alphanumeric data blocks.

It is recommended that ATC hardware implementation schedules include extra standard subsystems and items to cover training needs, that these items be inventoried with normal operational equipment, and that training subsystems be withdrawn, configured, utilized,



LEGEND

RML - Radio Microwave Link
BRITE - Bright Radar Indicator Tower Equipment
R DAS - Radar Data Acquisition System
B DAS - Beacon Data Acquisition System
PCD - Production Common Digitizer
DPS - Data Processing System
DEDS - Data Entry and Display System
PEM - Position Entry Module

10-22-74-20

FIGURE C-5. Alternative Simulated Data Paths Available in Present ATC System

and returned to the operational inventory as the training load increases and decreases.

Future simulation requirements to cover many of the projected operational improvements in the ATC system cited in Section IV-D of this Appendix can be met by utilizing standard subsystems of the ATC system with appropriate software packages and target generation and control equipments.

Processing for simulation can take three compatible forms: (1) on-line NAS-A and ARTS III, (2) on-line NAS-A and ARTS III supplemented with "smart" consoles containing "naked mini" computer cards to unburden the on-line ATC processors, and (3) off-line or dedicated training simulators utilizing the same "naked mini" computer elements packaged as an identifiably separate minicomputer. Use of ARTS II processing and interface components would simplify the subsequent logistic and maintenance problems while maintaining reliable simulation.

ARTS II subsystems are modular, their floorspace requirements are small, and the equipment is readily transportable. With flexible cabling and appropriate plugs and receptors, the hardware could be placed at the position selected and operated whenever classroom simulation needs develop. This practice, of course, would be impractical with the NAS-A or ARTS III processing complexes.

Requirements for future simulation involving processes such as conflict detection, conflict resolution, and intermittent positive control could cause the ATC displayed information to be quite different than present NAS-A and ARTS III. Placing an automatic or semi-automatic data link in operation to reduce and change the functions of air/ground voice circuits would also result in display changes. However, each enhancement or change usually relegates the older processes to a backup role. Hence, the simulator's load increases, and the number of backup modes the prospective controller must deal with increases. A systems approach to designing the required simulation equipment appears to be essential.

Thus, there will be a continuing need to utilize live, taped, and controlled target analog video in training simulation. Each step in digitizing, tracking, and using the processed data and tracks will be required in simulation at some stage of the controller's curriculum.

As the ATC enhancement programs mature and new features become available, single-thread processing will give way to multiprocessing. This provides increased reliability to some extent by reserve and available reserve capacity with automatic changeover when trouble develops. This factor allows one, on a long-term basis, to plan for increased on-line simulation training with some confidence that competition for frame time for operational purposes will not interfere with training schedules.

Changes in the state of the art of information processing have caused equipment costs to run counter to prevailing inflationary trends for several years. The new large-scale integrated-circuit (LSI) systems are quite powerful, yet comparatively low in cost. Since the equipment is reliable and has a long life, the overall training costs reside primarily on the personnel side. This was not true a decade ago. From an overall FAA viewpoint, it is probable that program cost-effectiveness can be enhanced through the procurement and utilization of compatible simulation hardware and software supported at a much higher priority than in the past.

A centralized group with knowledge of training needs, available ATC operational hardware and software, and competence in minicomputer applications could provide the systems approach to applications of simulation in training which is needed to cope with future simulation requirements..

VIII. SUMMARY AND CONCLUSIONS

The following statements summarize this Appendix and present its conclusions:

- Analysis of training by means of simulation in a wide variety of fields indicates the danger of making generalizations that are not based on careful research. It does appear, however, that for training purposes, completeness of a simulation--what elements of a system are included--is more important than the fidelity or precise realism of any particular element.
- ATC simulation has been extensive in the FAA, but evaluation of its use for training has not been done, and should be.
- Simulation required for training was given little or no apparent consideration in the design of NAS-A and ARTS III. The same lack of understanding of the importance of an operational simulation capability appears to apply in ARTS II. Effort should begin immediately to provide an operational simulation capability in ARTS II.
- The simulation capability that now exists in NAS-A and ARTS III, while less than ideal, appears to be adequate for training in the near term. Because of the importance of broadband in ARTS III, special consideration needs to be given to integrating simulation training with OJT involving live radar.
- If the FAA Academy is to play any role in radar training, an improved simulation capability there is imperative. In the case of IFR terminal training, it seems clear that some degree of centralization is needed. If this training were done at regional locations instead of

the Academy, simulation capability would be required at those locations.

- Evolutionary changes in air traffic control and possible future traffic loads require that future simulation requirements be addressed. It is recommended that this be done as an integral part of future system development. A promising approach is to investigate a modular system involving standard FAA equipment including minicomputers such as those being procured for ARTS II, interchangeable software, and a minimum of special-purpose hardware.

APPENDIX D

SELECTION OF AIR TRAFFIC CONTROLLERS

CONTENTS

A. INTRODUCTION

The purpose of this Appendix is to review procedures currently in effect for the selection of air traffic controllers.

Certain characteristics of the individuals accepted for training will affect their ability to complete their training, how well they perform on the job, and how long they continue to work as controllers. Some tradeoffs can be made between the selection standards, the method and amount of training, and the qualification standards for a journeyman controller. Some of the interactions between selection and training will be considered here. Fortunately, the Federal Aviation Administration (FAA) has long recognized the importance of selection and has conducted many studies in this area. This Appendix draws on an outstanding series of reports prepared for the FAA by Education and Public Affairs, Inc. (EPA) in 1970-1972 as well as many studies done by the Civil Aeromedical Research Institute/ Civil Aeromedical Institute (CARI/CAMI) since 1961.

B. METHOD OF SELECTING CONTROLLERS

The selection of controllers uses the following procedures and criteria:

1. Civil Service Commission (CSC) Air Traffic Control (ATC) Aptitude Tests

   These include tests in

   - Computations
   - Special patterns
   - Following oral directions
   - Abstract reasoning and letter sequences
   - Air traffic problems.

   Duration: about 2.5 hours.

   Minimum acceptable score: 210.

2. Rating of Experience and Education

Various combinations of education and experience are graded as follows:

GS-4: 2 years undergraduate study or experience

GS-5: 4 years undergraduate study or 3 years experience

GS-7: 1 year graduate study or specialized experience as controller or pilot

GS-9: 2 years specialized experience as controller.

3. Age

Not over 30 years (no such limitation before 1972).

4. Reference Checks

Written inquiries to verify claimed employment and to solicit evaluation of candidate on 15 items such as job interest, cooperation, and emotional stability.

5. National Security Check and Investigation

Security investigation by Government agencies to determine suitability for employment.

6. Medical Examinations

- Physical. To detect presence of disabling illness or abnormality. Includes a questionnaire on 24 conditions, some of which relate to psychological conditions.
- Psychological. Applicant completes a psychological inventory (Cattell 16 P-F) which yields a profile on 16 personality factors, e.g., outgoing versus reserved, casual versus controlled.

7. Interview

Candidate is evaluated in areas of oral expression, poise and self-reliance, resourcefulness and decisiveness. Interview Record and Evaluation Form is prepared by panel consisting of a controller and a personnel specialist.

C. DISCUSSION

The trainee, then, is an applicant who, having been judged eligible by these procedures, accepts an appointment at the GS grade level offered to him. The process of selection and appointment is not distinguished by its speed, and some candidates have taken other jobs by the time an appointment is offered. The numbers of men selected for training have fluctuated widely over the years.

Whether each step in this procedure is necessary and whether each criterion contributes to selecting controllers who will perform well on the job are pragmatic questions. An EPA study was commissioned because the Air Traffic Controller Career Committee (the Corson Committee) pointed out in its report, The Career of the Air Traffic Controller (Corson et al., 1970), that selection and training were inefficient and expensive procedures. At that time, the attrition rate was 30 percent during formal training and an additional 20 percent during on-the-job training (OJT). EPA found that the selection procedures could be improved and reported new results on selection and training that confirm findings made earlier by CAMI. In FY 1974, the failure rate was about 43 percent for en route trainees and about 38 percent for terminal trainees.

The significance of each selection criterion (e.g., scores on the CSC tests, amount and type of experience, maximum eligible age) or of any combination of criteria can be determined by what it predicts and how well it does so. For example, what is the relationship between CSC test scores and ability to complete initial training, or to be qualified as a journeyman controller, or to perform well on the job? The relationship between the selection criterion and some later measure is called the "validity" of the selection criterion. Among the selection criteria, it is known that scores on the CSC aptitude tests predict a candidate's ability to complete training. There is little relationship between CSC test scores or the other criteria used for selecting prospective controllers and success in training or performance on the job. The research which has been accomplished

reflects the fact that CSC test scores are readily available for analysis, and information about success in training is more readily available than information about success on the job. After training, one must wait various amounts of time before job performance data can come into existence. The job performance data, so-called, consist of supervisors' ratings which are subjective and generally unreliable, at least for statistical purposes, for comparison with predictors of success on the job. It is regrettable that little effort has yet been made to collect more objective information about the performance of journeymen controllers.

The CARI/CAMI reports* show that individuals with higher CSC aptitude test scores show a lower failure rate during training at the FAA Academy; they receive higher grades in academic and laboratory work; they also receive higher ratings from their training supervisors. Correlations between aptitude test scores and these criteria, on which there is much data, rarely exceed 0.35. A correlation of 0.35 means that CSC test scores predict about 12 percent, i.e., $(0.35)^2$, of the variation observed between CSC scores and the later measures. A few studies which go beyond training show that individuals with higher CSC scores also remain longer with FAA (qualified by data for those remaining with FAA up to 7 years). This suggests that selection and training actually find, to some extent, candidates who are well suited to the journeyman's job. These studies, summarized here very briefly, provide the factual basis for establishing for prospective controller trainees a minimum acceptable score of 210 on the CSC test battery and a maximum age of 30 years. Identical prior experience in air traffic work predicts success in training. Experience in communications and ground-controlled intercept (GCI) and as a pilot have little value in predicting performance in training, although they are used to justify a higher civil service grade at time of entrance. Data have not been collected to support

*These studies are listed under the names of their authors in the references; see Chiles, Cobb, Trites.

or reject the validity of the other criteria used in the selection procedure. Undoubtedly, the medical examination identifies significant disabilities among candidates, because few controllers leave the FAA for medical reasons.

A better understanding of what controllers do on the job shows that new criteria should be added to the selection system. Thus, a pilot study on ATC trainees by Chiles, Dean, Jennings and West (1972) at CAMI shows that a battery of tests which involve skills in physical coordination and which also require the candidate to work on several tasks at the same time can predict supervisors' ratings of trainees at the Academy (validations with training in the pilot study range from 0.24 to 0.54). Cobb and Mathews (1972) find that a new aptitude test called "Directional Headings" correlates 0.41 with training performance. This test requires the subject to rapidly interpret letters, symbols, and degrees in order to determine directional headings while being exposed to aural distraction. In the Controller Decision Evaluation (CODE) test devised by Buckley and Beebe (1972), the candidate judges possible conflictions in a simplified air traffic display presented in a sound motion-picture film. Education and Public Affairs (1972) shows that a combination of psychomotor tests, including CODE, correlates 0.50-0.75 with supervisors' ratings. Thus, a case can be made that selection would be improved by including tests of spatial abilities, psychomotor performance, and ability to monitor several tasks simultaneously.

Another possible route for improving selection, with its corollary effect on training, is to act on the fact that terminal and en route controllers perform somewhat different jobs. This is demonstrated in the task analyses performed for FAA by System Development Corporation (1971, 1972a-d, 1974a-f). On the basis of aptitude tests, training performance, and experimental performance ratings, Trites, Miller and Cobb (1965) concluded that en route, terminal, and flight service station (FSS) personnel differ in the characteristics required for job performance. This is strongly confirmed with a much larger

battery of experimental tests in the EPA (1972) study. This shows that the inclusion of new tests, including psychomotor ones, could increase accuracy of assignment between IFR, VFR, Center, and FSS from 25 percent (a random possibility of success when no special criteria are used in selecting personnel for these four options) to 58 percent. Within the IFR and Center options, accuracy levels of 75 to 80 percent could be achieved. Even better selection should become possible when Buckley's work at the National Aviation Facilities Experimental Center (NAFEC) produces useful objective performance measures for controllers on appropriately designed traffic samples.

Improved selection procedures should reduce attrition in training and attrition due to inappropriate job assignments. Reduced attrition can, of course, produce significant reductions in the costs of training, and this issue is considered in Appendix G.

The process of selecting controllers includes not only the tests and procedures which have been considered here but also the screening which occurs as the candidate succeeds or fails at each phase of training from novice to full journeyman status. In terms of cost and time alone, it is clearly preferable to improve selection by testing rather than by hiring. For the same reasons, it is also preferable to screen personnel at the Academy rather than by OJT. Among the various ways of reducing costs and improving the efficiency of training, a premium must be placed on improving the selection procedures. The evidence addressed in this Appendix is that improved selection is possible by adding perceptual and psychomotor tests to the battery of selection tests. In addition, candidates should be selected by criteria specifically relevant to the ATC specialty to which they will be assigned, rather than by the general criteria now applicable to all controllers.

D. SUMMARY

The procedure for selecting controllers includes a battery of aptitude tests, a medical examination, reference and security checks, and an interview. There are also requirements for education, experience and age (not to exceed 30 years). To qualify for employment, a candidate must meet minimum conditions or scores at each step in this procedure. Studies performed for the FAA show that the aptitude tests predict, to a modest extent, a candidate's ability to complete training and to continue working as a controller. The medical examination appears relevant because few controllers leave their jobs for medical reasons. There is no evidence to show that any of the other criteria used during selection predict success in training. There is little evidence to show that selection criteria predict job performance, i.e., quality of performance after completion of training. The inability to determine relationships between training and on-the-job performance is due principally to the absence of reliable measures of job performance. There is evidence that selection procedures could be improved by the addition of a variety of psychomotor performance tests, including one which uses samples of simplified air traffic situations. Improved selection procedures would be expected to reduce attrition during training and thereby save some of those expenses.

E. CONCLUSIONS

Among the selection criteria presently in use, only aptitude test scores predict success in training (to a modest extent), while the maximum age standard appears to reduce attrition after training. No significant relations have been demonstrated between success as a controller and either the initial selection criteria or performance during training. Significant improvements in selection and reduced training costs are feasible by incorporating psychomotor and controller-like tests into the selection battery.

APPENDIX E

PERFORMANCE MEASUREMENT IN AIR TRAFFIC CONTROL

CONTENTS

A. INTRODUCTION

The purpose of this Appendix is to review current methods of measuring the performance of air traffic controllers. The review is based on descriptions of the present procedures, many studies of air traffic controllers conducted by the Federal Aviation Administration (FAA), and a large background of knowledge about performance measurement in systems, both simulated and operational in nature, with functions identical or similar to those in the FAA air traffic control (ATC) system.

Performance measures are very important to the FAA because they provide the means needed, together with other factors such as cost and flexibility, to evaluate the ultimate effectiveness of alternative methods of training air traffic controllers. Performance measures are also needed for many other purposes of interest to the FAA such as, for example, determining the controller's maximum useful workload, the distribution of traffic loads among sectors, the impact of new or proposed types of ATC equipment, and the significance of various tests and criteria used for the selection of controllers. It is a matter of some interest that objective performance measures are not in use at present, although their feasibility has been demonstrated in experimental work conducted at the National Aviation Facilities Experimental Center (NAFEC) (Buckley, O'Connor and Beebe, 1969).

Objective performance measures would describe a controller's performance in such objective terms as, for example, the number of aircraft handled, the average delay per aircraft instruction, and the number of control instructions and average communication times--in each case, probably as a function of traffic load. Measures of this type must be contrasted to subjective rating schemes, such as over-the-shoulder evaluations, which are presently in use and which will be discussed below.

The ingredients needed to develop objective measures of the controller's performance have been present in FAA for a long time. Task analyses, needed to describe precisely what the controller does

on the job and thus to train him appropriately and to evaluate his performance afterwards, were developed by Nagay (1949, 1950) and by Courtney and Company, 1960a-c). The duties of a controller have also been described, more or less precisely, in many other reports, e.g., Jacksonville Air Route Traffic Control Center (ARTCC) (1970), Civil Service Commission (1968), Arad (1964), Warskow, Hooton and Burns (1969), Kuprijanow (1970) and Ratner et al. (1972). However, there has been a general lack of detailed, up-to-date job information about what the controller actually does until the recently completed work by System Development Corporation (SDC, 1971, 1972a-d, 1974a-f). This extensive effort, which is based on detailed and verified descriptions of the work performed by controllers, will be discussed later in this Appendix.

The development of objective performance measures at FAA can be seen in the work of Anderson and Vickers (1953) and Vickers (1959) at Indianapolis, Pearson et al. (1965) at Oklahoma City, and Buckley et al. (1969) and Buckley and Beebe (1972) at NAFEC. Closely related work on air traffic control, concerned with both training on system simulators and the objective measurement of performance was done at Ohio State University in 1952-1961 for the Air Force, at the Mitre Corporation for the FAA in 1969-1973 and at the Rand Corporation and SDC on the SAGE System for the Air Force, starting in 1952. A history of these interesting and important efforts, including many FAA studies not cited here, may be found in Parsons (1972). Despite the evidence of extensive previous efforts at FAA and elsewhere, objective performance methods are not in use now by FAA.

B. SUBJECTIVE PERFORMANCE MEASURES

At present, the FAA assesses the performance of air traffic controllers in several ways. Trainees are judged on the basis of grades achieved on academic tests and laboratory exercises. During on-the-job training, there are written examinations on rules and procedures and over-the-shoulder evaluations by the supervisors. The ultimate

performance measure for the developmental's training is his pass or fail status. As a journeyman, the controller is assessed for pro ciency by periodic written exams, over-the-shoulder evaluations, and the Employee Appraisal Record (EAR), required by the Civil Service Commission.

The explicit purpose of these tests is to determine the proficiency of the developmentals and the journeymen, but not to grade their performance. Besides the essential purpose of qualification, the various tests and evaluations are used largely for diagnostic purposes so that remedial training may be specified as required, and the controller reexamined accordingly. In the extreme case, of course, the developmental or journeyman may be eliminated for an unacceptable performance. But the criterion is still one of pass or fail.

Except for determining whether remedial training is needed, this method of measuring performance does not establish the level or degree of proficiency which distinguishes individual air traffic controllers. Although it would be difficult to believe that all air traffic controllers are equivalent in performance, the use of "pass or fail" performance measures makes it appear that this is indeed the case.

The use of categorical performance measures also makes it difficult to establish whether one method of training is more effective than another, even if it is assumed that the measures are reliable and valid. The essential reason is that these measures have no dispersion, i.e., normal distribution in the statistical sense. In effect, such measures cannot be used to detect differences between alternative methods of training because, according to the measures, most students appear to perform equally well, although this cannot be the case. As for those who fail, we do not know by how much. The limitation is due, obviously, to a matter of policy which determines whether deficiencies exist and not whether there are quantitative differences in levels of performance. Another consequence of this policy is that the training system is inefficient if it trains some men longer than is

really required. That is because training is oriented to provide the required number who can just qualify.

However, the major issue is whether the pass-fail grades, EARs, and over-the-shoulder evaluations are suitable measures of an air traffic controller's performance. There are several reasons to believe that there are significant limitations to the present use of ratings in general, and to the over-the-shoulder rating in particular. These relate to the subjectiveness of the rating procedure and to the lack of standardization in the traffic samples used to evaluate a controller's performance.

It is of interest to note that this point has been made strongly within FAA, but to little noticeable effect, by a Southwest Region staff study of the training program (Curliss et al., 1974, p. 25):

> The reason for having a technical training program is to meet an operational need. The test of the training lies in the degree that personal skills are acquired or enhanced through that process. Performance on the job is the final and best measure of the effectiveness of training.
>
> Unfortunately, the FAA has yet to devise reliable objective measures of the controller. The "over-the-shoulder" evaluations required by the TPAP program are at best subjective judgments by peers and supervisors using varying standards. The absence of objective, relevant measures of individual performance makes it difficult to know what improvements are truly required.

It may or may not be obvious that the over-the-shoulder evaluation is, at its heart, a subjective procedure. What "subjective" means is that this method of evaluation represents one person's view of another, i.e., the supervisor's judgment of how well the controller performs his job. Supervisors often differ in their appraisal of an employee for a variety of reasons such as, for example, differences in the extent of their knowledge about the employee's performance, different standards concerning the nature of an adequate performance, and because social and personality factors may intrude in a subtle way into the judgment of on-the-job performance. This evaluation has an "absolute" quality only as long as it is made by one supervisor.

Its subjective nature would be demonstrated directly if journeymen were evaluated independently at the same time by two or more supervisors, rather than by one. The FAA procedure reserves over-the-shoulder evaluation of each controller to the one supervisor who knows him best.

The extent to which subjective factors may influence over-the-shoulder ratings of controllers by supervisors is not known directly, but it can be estimated from studies conducted for FAA and its predecessors since 1950. These are studies in which performance ratings of a controller have been reported on more than one occasion. The agreement between the ratings provides an estimate of the reliability (or repeatability or consistency) of that method of evaluating performance. Most of the studies use a supervisor's rating form and are subjective in nature, but a few have used objective measures, such as number of aircraft handled, number of delays, and the like.

Nagay (1949, 1950) developed a rating form on which supervisors identified significantly effective or ineffective behavior observed while evaluating a controller's performance.* The form was tested experimentally by 48 senior controllers who observed 42 controllers at work in the New York, Washington, and Chicago Centers. At that time, the method of control was nonradar. The nature of the experiment permitted comparison between supervisors' ratings of one controller, i.e., estimates of the reliability of the ratings, as follows:

Comparison	Number of Comparisons	Reliability (Correlation) Observed	Reliability (Correlation) Adjusted
Between supervisors' ratings at the same time	80	0.43	0.94
Between supervisors' ratings at different times	156	0.22	0.85

*This account is based on information in Education and Public Affairs, Inc. (1970), pp. 19-20, and Buckley, O'Connor and Beebe (1969), pp. 1-1 to 1-2.

The observed correlations are based on a limited number of observations, i.e., controllers worked in 12 watches, and each senior controller made only an average of 6.5 observations. It is possible to estimate what the reliability coefficient would be if more observations were made. The adjusted reliabilities, above, show what would be expected if the controllers were observed continuously for one year (237 watches). Of course, no one would realistically argue that supervisors could or should spend so much time observing controllers in order to generate reliable evaluations, but it should be obvious that reliable ratings would require an extensive series of observations.

Trites, Miller and Cobb (1965) summarize various studies concerned with job performance measures for controllers conducted at CARI from 1961 to 1965. The job performance data consisted of ratings made by supervisors on controllers on 16 items, such as "ability to understand and apply controller procedures", "display of good judgment", and "demonstrated aptitude for air traffic control activities". The ratings were on a five-point scale, with "excellent" and "unsatisfactory" at opposite extremes. The reliability (correlation) of ratings made by supervisors in various studies was as follows:

Group	N	r
En route controller	468	0.58
Terminal controller	262	0.78
En route controller	367	0.43
Terminal controller	244	0.47

The two higher reliabilities are for ratings made at about the same time; the two lower reliabilities are between the earliest and the most recent ratings of the same individuals. From the text, it appears that "at about the same time" signifies within about two months; the time interval for the smaller reliabilities is not specified.

In a paper concerned with attrition-retention rates of air traffic controllers during 1960-1963 and 1968-1970, Cobb, Mathews and Nelson (1972, p. 1) comment upon the reliability of FAA performance-rating methods as follows:

> Moreover, experimental performance-rating procedures were developed and employed in several follow-up studies (references given) because the officially derived ratings (e.g., those based on the "Employee Appraisal Record," and others which were rendered primarily for remedial or diagnostic purposes) offered little potential for individual differentiation. The experimental ratings submitted by supervisors, crew chiefs, and peers of the subjects were somewhat less "haloed" than those rendered for official purposes but, like the latter, they did not possess a very high degree of reliability.

Cobb (1968) reports a survey of 568 controllers at four ARTCCs, of whom about half were rated either two or three times. Rating Form C contained 33 items which were verbatim copies of the performance indicators or appraisal standards specified in the semiannual over-the-shoulder ratings of each controller. Form B contained 14 items of a more general and less technical nature than Form C. Reliability, based on the average intraclass correlations between the several ratings, was:

Form B	0.35
Form C	0.29.

Cobb believes that the low reliabilities may be due to the fact that although many of the ratings were made by the controller's immediate supervisor, other supervisors participated who may have had less direct knowledge of the controllers. Cobb and Harshaw (1967, unpublished) were able to find EARs (Employee Appraisal Records, Form 3693) that gave findings similar to those of the Form B and Form C ratings with age and length of experience. Cobb and Harshaw say that supervisory ratings of performance rarely attain a high degree of reliability.

Cobb, Nelson and Mathews (1973) examined several types of performance evaluation ratings collected on 614 terminal area traffic

controllers at 17 terminal facilities. The experimental Air Traffic Control Specialist (ATCS) Performance Evaluation Form contained 29 aspects of performance for evaluation, very similar in content and wording to the over-the-shoulder rating; eight of the items came from an experimental form developed by CAMI relating to teamwork, tactfulness, and adaptability. Ratings were made, variously, by coworkers, crew chiefs, and supervisors. The following findings relate to reliability:

Comparison	Range of Correlations	Average Correlation[a]
Between coworkers	0.21-0.47	0.39
Between crew chiefs	0.40-0.54	0.46
Between supervisors (ratings on 121 controllers)	0.62	

[a]Based on z-coefficient transformation.

The new controller performance rating procedures developed by System Development Corporation (1971, 1972a-d, 1974a-f) have been reserved for separate treatment. These incorporate significant features which would probably improve the reliability of performance ratings, although the extent to which this may be true cannot be determined from the various reports about the procedures' development and field tests. The SDC report was submitted recently, and the procedures it proposes have not been implemented at the present time (December 1974).

The SDC performance rating system consists of Over-the-Shoulder Training Reviews and Extended Performance Ratings for en route and terminal controllers, and it may be summarized briefly as follows:

	Over-the-Shoulder Performance Review	Extended Performance Rating
Purpose	Identifies need for additional training.	Determines level of proficiency.
Suggested Frequency	Four reviews a year.	Twice a year.
Number of Items Rated	27 in 7 skill areas.	73 in 4 skill areas.
Basis of Review	Specific observations when traffic is adequate (moderate or higher).	Review of over-the-shoulder and other data.
Duration	Four 10-min segments for each review.	
Scoring	Dots identify the areas in which the controller is deficient.	Numerical. Rating from 1 to 7 for proficiency on each item; from "unacceptable" to "excellent."
Results	Number of deficiencies, i.e., areas in which additional training is required.	Profile: average of above ratings in four areas plus overall rating.

The method of performance evaluation developed by SDC incorporates the following significant features:

- The controller's job has been determined through direct observation of the way in which controllers perform their duties at the present time. The results are contained in a series of detailed job analyses and flow diagrams not previously available.
- Controllers are rated in those aspects of their job duties which are regarded as significant for effective performance and on which their behaviors are observable. These job duties were identified jointly with controllers and modified in a series of trial applications. Manuals were developed to explain how the ratings are made, to define terms, to show how scores are developed, and so on.
- The conditions of observation are more carefully defined and are more standardized than in previous rating procedures used by FAA. This applies to number and duration of observations, peak traffic count and degree of complexity, and training of observers. Minimum traffic requirements

were specified numerically in the preliminary version but not in the final one. Attention is given also to discussing the results of the evaluations with the controllers.

These methods of rating are more carefully specified but are not necessarily less subjective than those followed previously. To the extent that the controller would be evaluated on behaviors which are directly observable, which are more carefully described for consideration by the raters, and which are truly relevant to job performance, one would expect improved reliability, i.e., better agreement between supervisors making the ratings.

The minimum length of observation is given as four 10-minute periods. Although longer periods of observation tend to increase the reliability of ratings, the selection of a 40-minute total length appears to have been done arbitrarily. The summary report indicates that there was significant agreement between raters, i.e., high reliability, but no data are presented (SDC, 1974a, pp. 25, 31, 35, 51). The overall inter-rater reliability for tests run earlier at two locations was 0.65 and 0.67 (private communication from D. L. Dickson, SDC, 9 September 1974). Inter-rater reliability for the final over-the-shoulder procedure was not determined, in accordance with guidelines received from FAA (SDC, 1974a, pp. 66-67).

One of the major reasons for the low reliability of over-the-shoulder ratings is variability in the conditions of observation, which includes such factors as the density and complexity of the traffic sample being observed and the duration of the observation period. Buckley, O'Connor and Beebe (1969) used the NAFEC simulator to present traffic samples which differed in levels of density from 6 to 12 aircraft under simultaneous control. A total of 36 journeyman controllers worked two runs at each of three levels of traffic density. Traffic was built up in a 15-minute period which preceded each run. Three controllers, specially trained as observers for this experiment, independently rated the performance of each controller on each run.

The median reliability in observing the same man on the same run was 0.53. Using average ratings, the median reliabilities of nine types of observer ratings at three different traffic densities were 0.75, 0.70 and 0.56; reliability decreased as density increased. The agreement between judges in judging conflictions was 0.83.

Buckley, O'Connor and Beebe (1969) show a higher reliability for performance ratings than those found in other FAA studies because of the control they had over the traffic samples and because of the training their observers received. Excluding their data, the median reliability is 0.43 for other FAA studies on performance ratings which appear in this Appendix. Since the magnitude of variance explained by a correlation is r^2, this accounts for about 18 percent (0.43^2) of the relationship between supervisors' ratings; the remainder remains unexplained or uncontrolled. Though these reliabilities are regarded here as being low, they are about as high as one finds for subjective rating scales. Thus, improved performance evaluation schemes must be sought by appealing to methods of measurement other than subjective rating scales.

C. OBJECTIVE PERFORMANCE MEASURES

It is feasible to measure a controller's performance in an objective way, that is, in a way that produces quantitative scores on various characteristics of an operator's performance. Measurable performance characteristics of major interest include speed and accuracy of response, maximum number of aircraft handled, maintenance of separation standards (measured in time and distance), and the like.

The primary device needed to develop objective performance measures is one which records the flight histories of aircraft and the actions taken by the controller to direct their progress. The capability of recording this information already exists in the National Airspace System, Stage A (NAS-A) and it will exist in the Automated Radar Terminal System III (ARTS III), when Package One, Enhanced Target Generator (ETG), is introduced. At present, however,

these records are used primarily for diagnostic purposes and not for performance measurement. Performance could be recorded simply by a TV camera with recording tape. In this case, analysis of the record would be accomplished, in a most tedious manner, at a later time. On the NAFEC ATC simulator, the recording, data processing, and reporting of performance measures are now being accomplished virtually in real time. Similar on-line data processing functions will be performed in future ATC systems which monitor traffic automatically and which give warnings of potential conflictions. Air traffic control simulators provide the means for repeated observations of performance on traffic samples with known characteristics. Most (but not all) simulators include some means of recording performance. Finally, objective performance measures and ATC simulators provide the means, by observing the actions of many controllers on the same traffic samples, of establishing statistical norms for evaluating the performance of controllers in an objective manner in precisely controlled situations.

Objective performance measures, no matter how exquisite, would not be useful for evaluating some significant characteristics of a controller's performance such as phraseology, leadership qualities, and participation in teamwork. Subjective rating schemes would still be needed to evaluate these attributes.

Simulators capable of measuring the performance of air traffic controllers have been used by the FAA for many years. Pearson, Hunter and Neal (1965) describe a radar air traffic simulator at CARI useful for research on training, selection, controller proficiency, workload as a function of targets and speed, display design, and the like. Target motion is derived from film strips which advance one frame every 10 seconds. Individual control of each aircraft via a pseudo-pilot is not possible with this equipment. Scoring was limited to the speed and accuracy of response to key events programmed on selected frames, e.g., entries of new aircraft into the sector, intersection crossings, airway changes, voice transmissions, and hand-offs. The Pearson report describes preliminary experiments which show

different rates of learning radar control by terminal and flight service station (FSS) personnel. Reliability data are not reported. No reports showing further use of this device have been found.

The NAFEC simulator used by Buckley, O'Connor and Beebe (1969) has much greater capabilities than the one described by Pearson, Hunter and Neal. The pioneering work of Buckley, O'Connor and Beebe clearly demonstrates that it is feasible to measure the performance of an air traffic controller in an objective and reliable way. Here, some of the major results of their unusually comprehensive "preliminary" investigation are noted. This work is still going on, and the current NAFEC simulator is improved over that used in the initial study.

The NAFEC Air Traffic Control Simulator (Model A) used by Buckley can present up to 48 aircraft, each controlled separately by a "pilot" who can communicate with the controller via "radio" and who can alter the aircraft's speed and flight path. The simulated airspace contains radars, beacons, and communication equipment. The performance of four controllers can be recorded separately on the following basic measures:

- Number of conflictions
- Number of delays
- Delay time
- Number of aircraft delayed
- Aircraft time in system
- Aircraft time in system for completed flights
- Flight time deviation for completed flights
- Number of completed flights
- Number of control instructions
- Number of contacts
- Communication time
- Number of aircraft handled.

Since this was an exploratory investigation, other data were also collected such as heart rate and galvanic skin response,

biographical data, experimental performance ratings in the field from a previous study, scores on a personality test, the most recent Employee Appraisal Records (Civil Service ratings), and controller's opinions. Three observers independently rated each controller's performance on 27 measures. The ratings on all 27 measures proved to be so voluminous that ratings on only nine measures were analyzed. Data on another type of simulation, called Controller Decision Evaluation (CODE), were also collected and will be described below.

A significant effort was given to developing samples of traffic which were representative and which increased in difficulty so that all controllers could handle the easiest, while the most difficult samples would probably overload the best controllers. A total of 36 journeyman controllers was tested twice at each of four levels of density for a total of eight runs containing 340 flights. Each run lasted 1 hour, not counting a 15-minute period during which traffic built up. Since each controller was tested twice on the same 1-hour task, this provided the basic data needed to determine reliability, i.e., the repeatability of various measures at different levels of traffic density. This study is the first one to make such a determination.

The data were analyzed to determine the statistical significance, if any, of various combinations of the basic measures at various levels of traffic density, e.g., number of conflictions/number of aircraft in sample, and so on. One would expect that some but not all measures or combinations of measures would be found to be significant.

The following findings are particularly significant for the prospect of developing reliable and objective performance measures:

- The median reliability of all objective measures was 0.65. Reliability increased from about 0.60 at low traffic density to about 0.70 at high density. This trend is contrary to the reliability of observers' ratings, reported earlier in this Appendix, which decreased from 0.58 to 0.39 as density increased.

- Multiple correlations of about 0.45 were found between performance measures in the simulator and various combinations of job performance ratings made previously by supervisors of these controllers, peer nominations, and observer ratings made during the study. This is taken to mean that simulator scores have some validity, i.e., that they produce scores not unlike those provided by presently accepted methods.

- A factor analysis was undertaken to identify the least number of common elements needed to account for the variability in the great number of measures used in this experiment. Four dominant types of factors, with these key elements, emerged from the statistical analysis:

  1. Delay-Volume Factors

     - Expedition of high density traffic
     - Minimization of delays, low and moderate density traffic
     - Expedition and maximization of com··leted flights, moderate density
     - Random high average delay time, low density

  2. Separation-Confliction Factors

     - Failure to separate aircraft, low and moderate densities
     - Violation of separation, high density
     - Random high density conflictions

  3. Communications Factors

     - Frequency vs. duration of contacts
     - Volume of control instructions, low and moderate densities
     - Transmission time

4. Non-Simulation Factors

- Experience
- Heart rate
- Supervisory rating
- Current age and age at entry on duty.

The following performance measures are recorded for use in further studies:

- Conflicts per aircraft handled
- Conflicts per delay
- Delays per aircraft handled
- Delay time per aircraft scheduled
- Aircraft time in system per aircraft scheduled
- Proportion of complete flights schedule actually completed
- Contacts per aircraft handled
- Communication time per contact
- Proportion of aircraft scheduled that were handled.

The Buckley study clearly demonstrates that it is feasible to develop objective performance measures for air traffic controllers, and the study has performed the important service of identifying the most promising measures from a much larger number of candidates.

Equally important are two conditions which must be satisfied in order to measure the performance of controllers: (1) standard traffic samples constructed with specified levels of difficulty based on such features as density, angles of convergence between traffic lanes, number of hand-offs, proportion of climbing and descending aircraft, and mix of aircraft performance characteristics in the sample; and (2) extended periods of observation, probably on the order of two 1-hour runs for each test.

The Controller Decision Evaluation (CODE) test, which is included in the study by Buckley, O'Connor and Beebe (1969), does not use the NAFEC Model A simulator. In the CODE test, the controller observes a radar display which shows the positions of aircraft along

airways. The scope displays come from a previously prepared film strip. The controller also receives information via a headset and keeps flight progress strips and aircraft identity up-to-date as new frames appear. The controller's task is to indicate when action should be taken to avoid any possible confliction that may arise. Each run contained six or seven conflictions. Each subject was tested twice at each of three densities of traffic, for a total of six runs. The basic data for each controller were the number of conflictions correctly detected, and the false conflictions, i.e., reports of confliction when there were none. Because of problems with the equipment only 18 of the 36 controllers were tested, and it appears that the runs were not long enough. Under these conditions, the following repeat reliabilities (between runs at the same level of density) were found:

	Level of Density		
	2	3	4
Number of correct detections	0.24	0.43	0.63
Number of false positives			0.54

Certain CODE scores showed some significant correlations (about 0.70) with some of the performance measures obtained in the dynamic simulations on the Model A simulator. The areas of high correlation suggest that CODE measures assess a controller's ability to forecast the future positions of the various aircraft under observation. Increased delays, as found for some controllers, appear to result indirectly from an inability to forecast potential conflictions rather than directly as a result of higher volumes of traffic. At present, these findings are incomplete and only suggestive at best.

The CODE test was modified for projection by motion picture film with a sound track (Buckley and Beebe, 1972). Instructions for taking the test are also on film. The new films were made with the NAFEC Digital Simulation Facility which gives an alphanumeric tag to aircraft and a table, updated as required, with altitude, speed, and

route data. As previously, the controller is supposed to identify, as soon as possible, pairs of aircraft that may violate separation standards. The modified test can be administered simultaneously to groups of men (ten in this study). In a study of 19 controllers, the median reliability was 0.75 (ranging from 0.60 to 0.90 for five measures tried here).

The obvious advantage of the CODE test is its ease of administration. Presumably, traffic samples of various levels of difficulty could be developed for testing at various stages of training, for illustrative purposes in connection with training, and, if not too complicated, as a selection test for prospective controllers. It is not inconceivable that it could also be developed into an instrument, with new versions from time to time, to test selected aspects of the proficiency of journeyman controllers.

Buckley's current work at NAFEC is directed toward the development of a Controller Performance Measurement (CPM) test package which would include procedural instructions, scoring methods, and normative data (NAFEC Agreement No. 21-254, dated 22 June 1973). This is a research and development effort planned to continue over several years. An improved CODE test, intended for validation of selection procedures, will also be developed under the program. Progress reports are not yet available at the time of this writing (December 1974).

D. SUMMARY

Present procedures for evaluating the performance of controllers center around the over-the-shoulder evaluation, are subjective, and show low consistency on repetition, i.e., low reliability. FAA studies, which are still continuing at NAFEC, show that the performance of air traffic controllers can be measured in an objective way. The objective measures show a higher reliability than the subjective ones. For performance measures to be reliable, it is necessary to observe controllers performing on samples of air traffic carefully

standardized for level of difficulty, i.e., density, complexity, and potential conflictions. For reliability, it also appears necessary to observe a controller's performance over reasonably long periods of time, so as to provide a measure which is the average of at least two 1-hour periods of observation. Objective performance data are needed to evaluate the effectiveness of various methods of training. They would also have great value in selecting controllers, establishing qualification standards, evaluating the proficiency of developmental and journeyman controllers, determining controller workloads at various levels of traffic, and thereby contributing to the design of en route and terminal sectors.

E. CONCLUSIONS

Studies at NAFEC have shown that the performance of controllers can be measured in an objective manner. These measures show a higher reliability than the over-the-shoulder rating methods currently in use. Objective performance measures are needed to assess various methods of training controllers, the proficiency of controllers, and optimum workloads, and for similar applications concerned with the overall efficiency of the air traffic control system.

APPENDIX F

REVIEW OF PRESENT TRAINING

CONTENTS

A. INTRODUCTION

The purpose of this Appendix is to describe briefly the present training programs for centers and terminals, and to consider the relevance of the curricula to present operational practices, standardization in methods of training among the Regions, and ways of improving the training program. Information used for this purpose comes from many documents and reports of the Federal Aviation Administration (FAA), visits to the FAA Academy and field installations, and from a survey of training at field facilities based on analysis of answers to a questionnaire prepared by the Institute for Defense Analyses (IDA).

B. TRAINING A CONTROLLER

This section describes the training program which transforms an apprentice controller into a fully qualified journeyman in a period of four years. The training of en route and terminal specialists is considered here; the flight service station option is not considered. The selection procedure is described fully in Appendix D, which also suggests that trainees should be assigned to the en route or terminal option on the basis of their test scores, a procedure not being followed at present. The typical trainee is a high school graduate, not older than 30 years, who achieves a score of at least 210 on the Civil Service Commission (CSC) air traffic control (ATC) aptitude test, and who is rated as a GS-7. Only 40 to 50 percent of all applicants attain the qualifying score (Cobb and Mathews, 1972). Because of relevant experience in previous employment, about 10 percent of the applicants are given GS-9 ratings. In a special program for disadvantaged groups, a limited number of individuals are given a GS-4 or GS-5 rating and 17 weeks of predevelopmental training at the FAA Academy before entering the regular developmental training program.

1. En Route Option

En route ATC training is conducted in three phases (FAA, 1972). Phase I, called Indoctrination and Pre-Control, is conducted at en

route facilities. The approximate course time is 340 hours, and programmed lesson plans developed at the FAA Academy are used. In Phase I the developmental specialist learns about the air traffic control system, the functions of centers, towers, and flight service stations, the regulations, the navigational aids, and the communications used in air traffic control. He is also taught FAA personnel policies. He learns to perform, under supervision, such air traffic control functions as drawing area maps, processing flight plans, distributing flight progress strips, encoding and decoding weather information, operating the communications switching system, entering messages into the computer, and transmitting flight plans and estimates. Associated with all these "doing" capabilities is a long list of "knowledges" that the trainee must acquire.

When nearly a year has elapsed, the developmental specialist becomes eligible to move up a grade and to initiate Phase II training. Before entering Phase II, he takes 120 hours of training in prefamiliarization, which must be given in the eight-week period immediately preceding entry into Phase II training. In this course he learns about strip marking and about the synthetic area sectors and letters of agreement that will be used for simulated environmental training. He must be able to work low-complexity demonstration exercises on the simulated environmental sectors.

Phase II is entitled Radar and Non-Radar Control. The non-radar control training course is conducted at the FAA Academy as well as at the en route facilities. Each Region determines where its developmentals will be trained. The course includes procedures laboratory preparation and simulated environmental training in a non-radar laboratory. The length of the course is approximately 304 hours. This training permits a developmental specialist to perform under immediate supervision as a member of a sector team on two sectors in his assigned facility, to record clearances and control information on flight strips, issue clearances, record control information, and perform other tasks.

Phase II radar control is supposed to be taught at the FAA Academy after completion of the non-radar control course. It takes about 240 hours. However, since the Academy does not have adequate radar simulation equipment, this training is given at the National Aviation Facilities Experimental Center (NAFEC) or in the operational environment of the facility. The trainee is taught to align and adjust radar equipment, interpret the radar display, hand off aircraft to the next sector, operate the radar sector, and provide traffic advisories on request.

Phase III, Sector Qualification Training, is conducted by the facilities as on-the-job application of previously learned skills and knowledges utilized for the purpose of qualification in the specific sectors to which the developmental will ultimately be assigned. A maximum of 60 hours of training is given for each position for which qualification is required. The specialist must demonstrate his ability to control traffic by the use of applicable radar separation standards, procedures, and techniques in a variety of situations. After this training is completed, he will be able to perform independently all the functions of a full-performance (journeyman) controller, under general supervision as a member of a sector team on the required number of sectors in his assigned facility.

2. Terminal Option

Terminal controllers enter the system in the same way as en route controllers and follow the same Civil Service procedures. After selection, they are given Phase I indoctrination and orientation in a 40-hour course of instruction at a facility. When this training is completed, the trainee will be able to describe the air traffic control system, the functions of centers, terminals, and flight service stations, applicable Federal Air Regulations, navigational aids, and communications, as well as FAA personnel policies.

Following the completion of Phase I, the trainee is sent to the FAA Academy where he is given Phase II, called Pre-Control. This 260-hour course teaches the trainee to operate the interphone system,

operate flight data entry and printout equipment, prepare and distribute flight data strips, receive and relay weather information, and perform a number of other tasks as noted in the Air Traffic Training Handbook (FAA, 1971a). After the training at the Academy is completed, the trainee returns to his assigned facility for position qualification.

Phase III, Visual Flight Rules (VFR) Control, requires 400 hours of training at the facility. Of this time, 160 hours is devoted to procedures training and 260 hours to position qualification. When this training is completed, the trainee will be able to perform ground control and local control functions independently under general supervision.

Phase IV, Instrument Flight Rules (IFR) Non-Radar Control, consists of two parts. Developmental procedures is a 240-hour course conducted at the FAA Academy. Position qualification requires 80 hours per position and is conducted at the facility. Upon completing this training, the developmental specialist should be able to control IFR non-radar traffic at a complexity factor equivalent to 15 operations per hour, under immediate supervision. After position qualification, he should be able to perform under general supervision all functions of non-radar control at his assigned facility.

Phase V consists of 200 hours of developmental procedures training and 80 hours of position qualification for each radar position. Procedures training is taught at the Academy, and position qualification is taught at the facility. After completion of training, the specialist should be able to control traffic using radar separation standards, procedures, and techniques. As a member of a traffic control team, the specialist should be able, under immediate supervision, to control traffic at a complexity factor equal to 25 operations per hour. After completing facility position qualification, the specialist should be able, under general supervision, to perform all radar controller functions as specified in the Air Traffic Training Handbook and as modified to meet operational requirements unique to the facility to which he is assigned.

In a recent evaluation of the Academy's training programs, instructors were sent from the Academy to a number of facilities. The following problems were noted:*

- The existing radar simulation is unsatisfactory, and the capabilities of Automated Radar Terminal System (ARTS) III are needed for training purposes.
- The centers do not have proper radar training; they do not use the Academy curricula but rather rely primarily on on-the-job training (OJT).
- The predevelopmental training program to be discussed in the next section is turning out better controllers than the regular program.

(No data were provided to support these observations, however.)

C. PREDEVELOPMENTAL TRAINING

The FAA has been conducting a program for individuals who cannot be hired at the GS-7 entry grade and are thus ineligible for entry into the developmental training program. They enter, instead, into the predevelopmental training program, which is aimed at assisting members of minority groups to enter the ATC career field. A 17-week course at the Academy and post-Academy training in the field facilities give these individuals fundamental knowledge of aviation and the National Airspace System. Individuals in this program enter on duty at grades of GS-4 or GS-5 and, upon completing training and meeting minimum time-in-grade requirements, are promoted to GS-7 and enter the developmental training program.

Two aspects of the training need some comment here. First, the program does not fully reach the people for whom it was designed. Many in the program are either not from minority groups or have sound

*Based on a discussion with the Evaluation Officer at the FAA Academy, May 7, 1974.

educational backgrounds and would appear not to be in need of this type of training. Thus, many individuals enter the service through the cellar door, so to speak, and while they enter at a lower grade and therefore lose some time and pay, they do get into the system.

The second aspect of the program has to do with its success. It generally appears to be successful, in that it does get members of minority groups into the service, and they seem to be performing capably. What is not yet known is how well these people are being accepted by the controllers who came in through the normal channels. Moreover, since the program is not always reaching those individual minority members who might be considered to need the most help, the methods of recruiting and selection might be examined. There is some evidence of a high drop-out rate in the program (Appendix G).

D. PROFICIENCY TRAINING

Proficiency training is conducted to reinforce previously learned skills or to develop new skills required because of new or revised procedures, regulations or equipment.* Proficiency training is a continuous program which results from the administration of job-centered evaluations and examinations. At least one refresher unit (1 hour) per month and one facility-developed refresher training package (2 hours) per quarter are to be covered in the minimum 20-hour annual skill maintenance program required of each ATC specialist. This training might increase to as much as 60 or more hours annually for an individual, depending on how his supervisor assesses his needs. This training covers new procedures, remedial training, and reviews of air traffic matters, as required.

*Much of the following material is taken directly or paraphrased from FAA (1971c).

1. Refresher Training

Refresher training is given to systematically review current operational procedures and techniques. It consists of self-study units as well as classroom and briefing sessions. The self-study units, designed to take about 1 hour each, are developed by the FAA Academy generally, or by the facility when training in local operational procedures is required. Each specialist is expected to complete an average of at least one study unit per month. The units are chosen by the facility chief.

2. Supplemental Training

Supplemental training is conducted to develop new skills to maintain proficiency at assigned operational positions whenever a significant change occurs in procedures, regulations, or equipment. Each specialist is briefed on national and local changes before they become effective. The facilities use a combination of classroom training, briefings, and self-study to accomplish supplemental training. Training materials are developed centrally or locally, depending on the nature of the change.

3. Remedial Training

Remedial training is given to correct specific operational deficiencies, either in response to a disciplinary need (e.g., a system error) or in response to appraisals of a controller's performance under the Technical Performance Appraisal Program. Under this program all controllers are required to take a performance test and a written test. Performance is judged by the supervisor or by someone he designates, who watches the controller while he is controlling traffic of a specified minimum density. This is the well-known over-the-shoulder evaluation. If the controller is judged to be weak in some area and remedial measures cannot be taken on the job by the first-line supervisor, the controller is required to take remedial training. Such training may include classroom training, on-the-job training, or both, as decided upon by the facility chief or the first-line supervisor.

Depending on the nature of the requirement for remedial training, requalification of the controller through appropriate written examinations and performance tests may be required.

E. ACADEMY TRAINING SUPPORT

In addition to training developmentals in residence at the Academy, the FAA Academy fulfills a major role in the national training program, as follows:

- Provides advice and assistance to field facilities in planning, developing and standardizing air traffic training programs and courses, and in developing objectives, curricula, and schedules for air traffic training.
- Develops personnel standards for admission to air traffic training courses.
- Develops methods for evaluation of personnel performance and progress in training.
- Reviews training at facilities, and reports on the adequacy and effectiveness of the programs.
- Identifies and recommends desirable training for air traffic career progression.
- Develops and updates, as necessary, standardized training procedures and materials for facility training programs.
- Develops and updates, as necessary, a recording method to reflect the status of air traffic control training throughout the agency.

F. FIELD PROGRAM SUPPORT

The Air Traffic Training Branch of the Academy supports the field training program by providing the following services:

Developmental Training

- Develops instructional programmed learning techniques and distributes the program of instruction with the National Air Traffic Training Program for each option.
- Develops and distributes the written examinations on the instructional plans.
- Develops and distributes the National Air Traffic Training Program, prescribing the phases of developmental training and establishing the criteria for successful completion of each phase.
- Develops and distributes training manuals, including reference manuals, directed study manuals, and programmed learning manuals.

Proficiency Training

- Develops and distributes self-study materials.
- Develops and distributes interpretive instructional materials and aids in support of new procedural documents for use in training situations when appropriate.
- Develops and distributes instructional materials in special training projects in support of immediate requirements of the Air Traffic Service.
- Administers special prototype programs in selected air traffic facilities.
- Develops and distributes the appraisal documents used in the Performance Appraisal Program.

Review

- Reviews, from reports and records, the training accomplished at air traffic facilities, and provides reports on the adequacy and effectiveness of the training in meeting requirements. This work is conducted by three sections in the Training Branch:

1. Qualification Section. The Qualification Section handles parts of the terminal and en route qualification courses as described previously. It also handles the predevelopmental program, special training, advanced radar training, facility management training, military training, and training for controllers in private industry.

2. Automation Section. The Automation Section develops, reviews, and teaches courses in new hardware. This year (1974), the Section is scheduled to complete the courses on the National Airspace System, Stage A (NAS-A) and the Automated Radar Terminal System (ARTS) III.

3. Development and Revision Section. The Development and Revision Section develops new curricula and new training materials, changes manuals regularly, and develops tests.

The numbers of personnel involved in each of these functions in 1974 are shown in Table F-1.

TABLE F-1. AIR TRAFFIC PERSONNEL AT THE FAA ACADEMY, 1974

		Number
Instructors (GS-11 to GS-13)		122
En Route (Phase II)	27	
Terminal (Phases II, IV, V)	46	
Special (Initial and Indoctrination)	7	
Predevelopmental	7	
Other (Includes FSS, etc.)	35	
Supervisors (GS-12 to GS-15)		34
Clerical (GS-3 to GS-5)		37
Total		193
Educational Technology Branch[a]		27
Resident Students (Daily Average)		405

[a]Educational Technology Branch has 27 professional educators and 12 support staff for entire Academy. Air Traffic students this year are about one-third of all resident Academy students.

G. TRAINING OF NON-FAA PERSONNEL

The FAA provides orientation and familiarization training at facilities to persons not employed by the agency. Those who have successfully completed programs equivalent to FAA Academy developmental training courses may participate in operational activities and training programs related to the performance of duties of developmental positions. Persons who possess a certificate recognized by the FAA as comparable to the FAA air traffic control specialist (ATCS) certificate may participate under supervision in facility training programs and activities at any employee level.

The FAA Academy trains both military and foreign personnel. Recently, most of the military students have been Army personnel, since the other two Services have their own air traffic training facilities.

Since 1967, the maximum number of non-FAA students at the Academy (the sum of beginning and ending classes) was 424 (fourth quarter, 1968). The minimum number was 38, occurring a year later. More recently, the number has fluctuated between 50 and about 150. Figure F-I shows these data graphically and also shows the percentage of all students at the Academy that the non-FAA students have represented. Generally, non-FAA students make up about 10 percent or less of the entire student body, but there were two quarters (1968-69) when non-FAA students made up more than 50 percent of all students at the Academy. The number of non-FAA students correlates negatively (r = -0.375) with the number of FAA students; if the surge of FAA students in the first quarter of 1970 is deleted from the data, the correlation coefficient becomes -0.575. Thus, in the general case, the attendance of non-FAA students tends to smooth the load at the Academy. Since non-FAA students are usually only a very minor fraction of the entire student population, however, the magnitude of smoothing is minor.

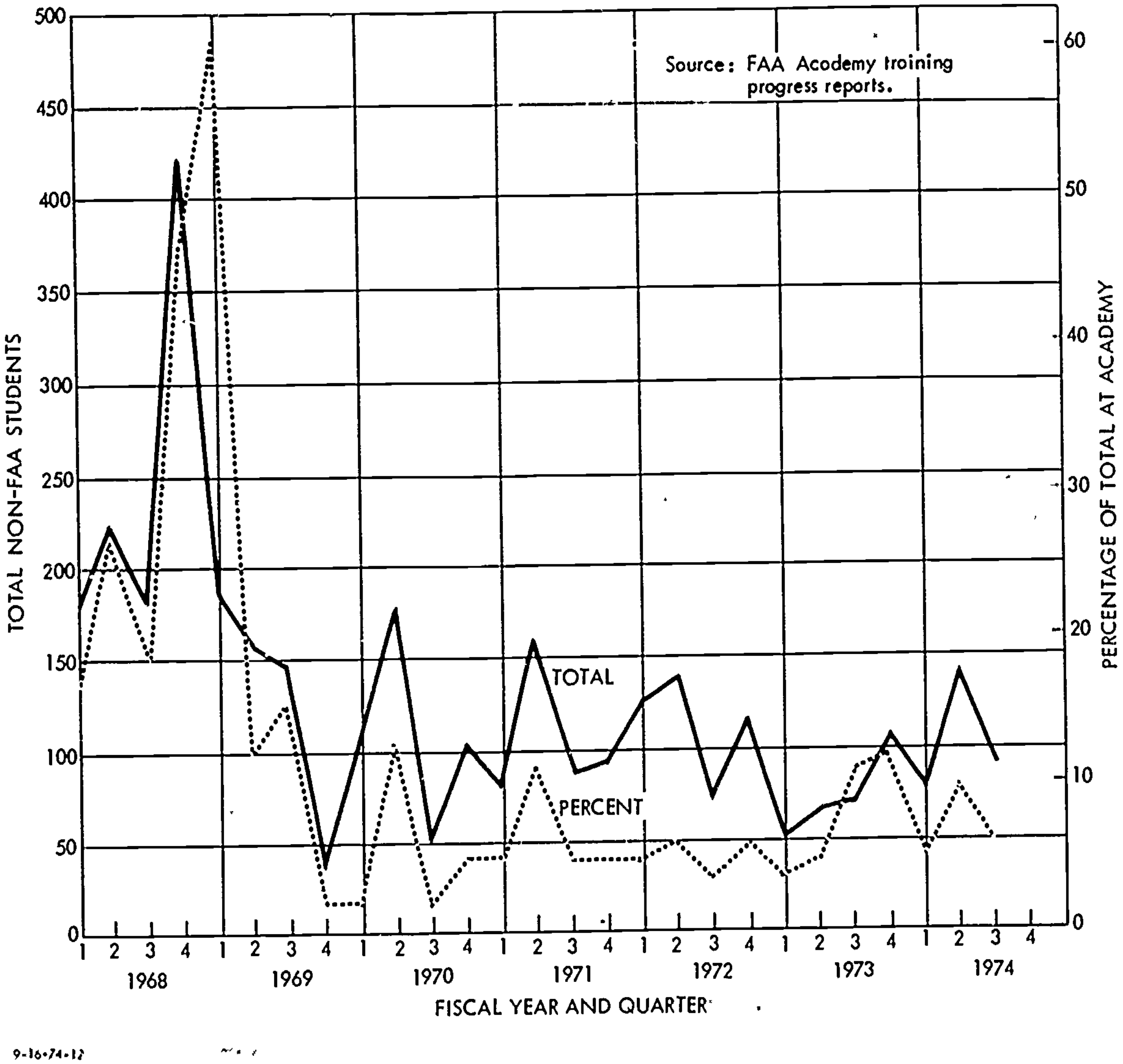


FIGURE F-1. Number of Non-FAA Air Traffic Students Attending FAA Academy and their Percentage of All Students at Academy (Sum of Beginning and Ending Classes by Quarter), FY 1968-1974

H. TRAINING LOADS AND COSTS

Marked fluctuations in the numbers of developmentals hired by the FAA each quarter since 1967 have led to wide variations in the training loads at the Academy. Figure F-2, taken from the Corson Report (Corson et al., 1970), showed the situation in 1970 which that Report said should be remedied.* As shown in Figure F-3, the training loads at the FAA have continued to fluctuate into the present time frame. From FY 1971 to FY 1974, the number of students in residence at any time has varied from about 300 to almost 1200.

The percentage of students who failed to graduate from the Academy has not exceeded 2 percent since the fourth quarter of FY 1971 (Fig. F-4). Earlier, during FY 1970, it had reached as much as 22 percent. Overall air traffic student attrition is considerably higher, however (Appendix G).

The cost of training is considered in detail in Appendix G. In formal FAA budget submissions, training is estimated to cost \$43.7 million for FY 1974 and \$55.9 million for FY 1975. To these figures one should add an estimate for the pay and allowances of the developmentals during training and some provision for the overhead costs for training at the facilities. A case is made, in Appendix I, that the total annual cost of air traffic training could approach \$120 million.

*See also Fig. 10, p. 60.

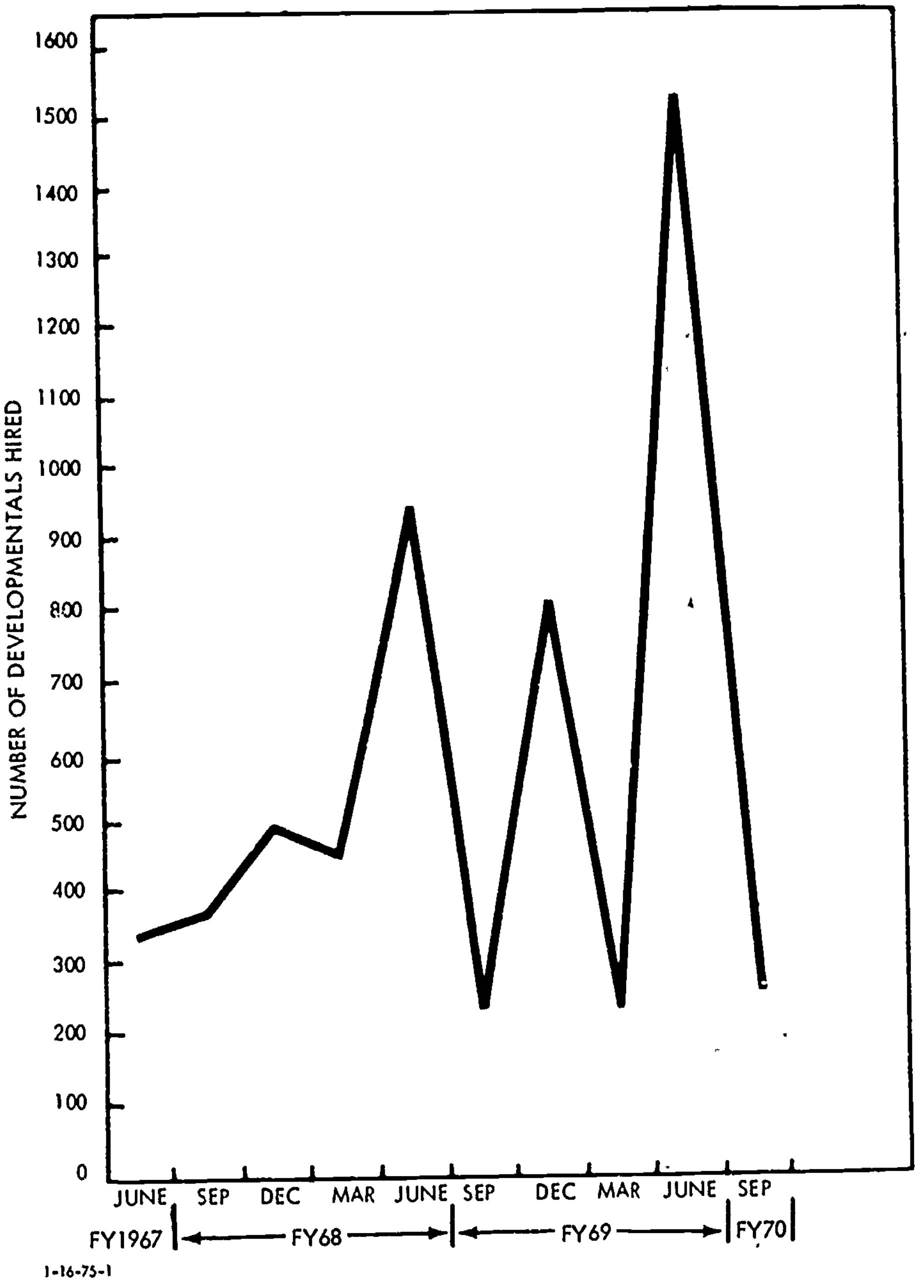
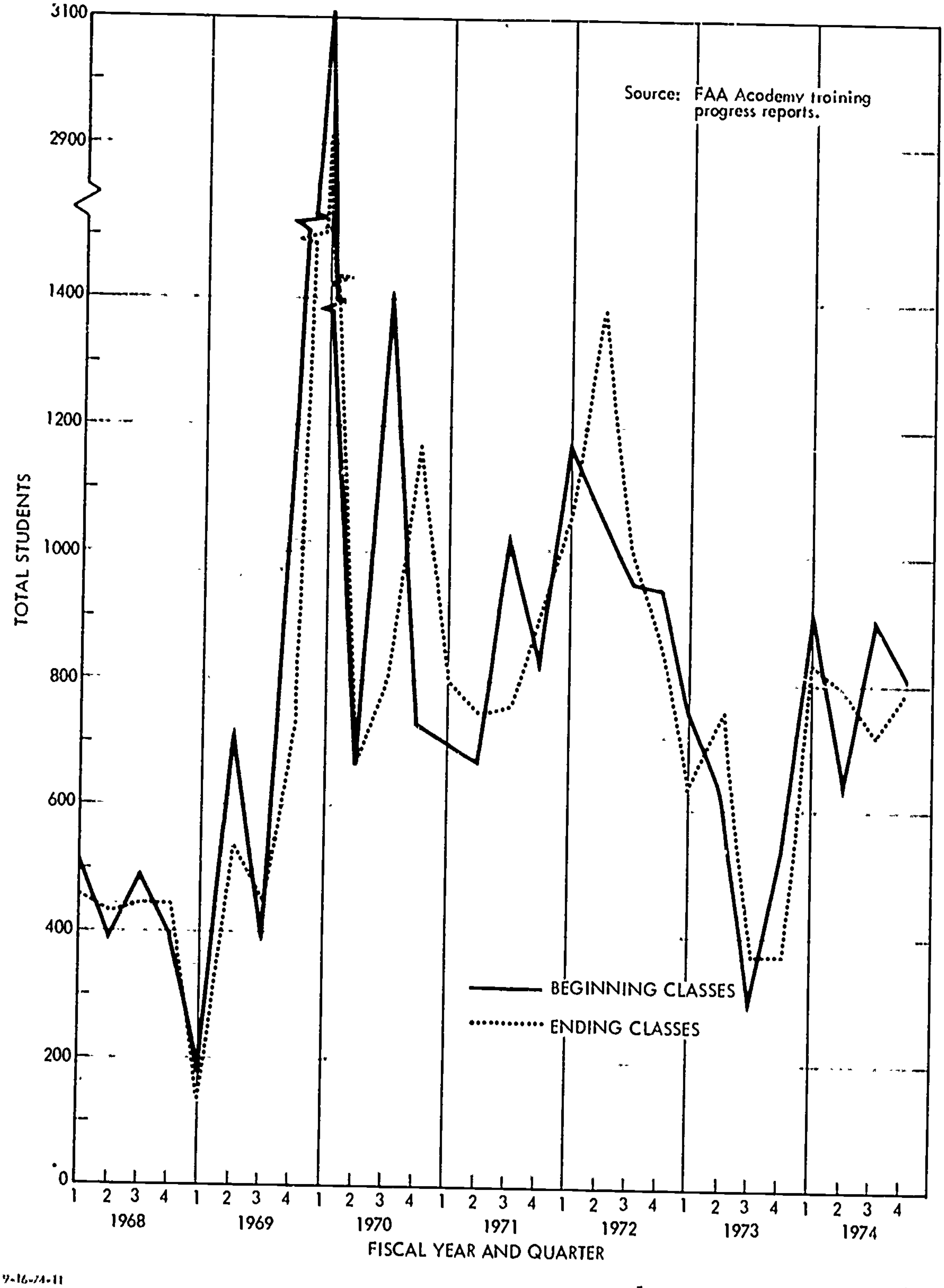


FIGURE F-2. Fluctuations in the Number of Developmentals Hired by the FAA, FY 1967-1970 (Source: Corson et al., 1970)



9-16-74-11

FIGURE F-3. Fluctuations in the Number of Students at the FAA Academy, FY 1968-1974

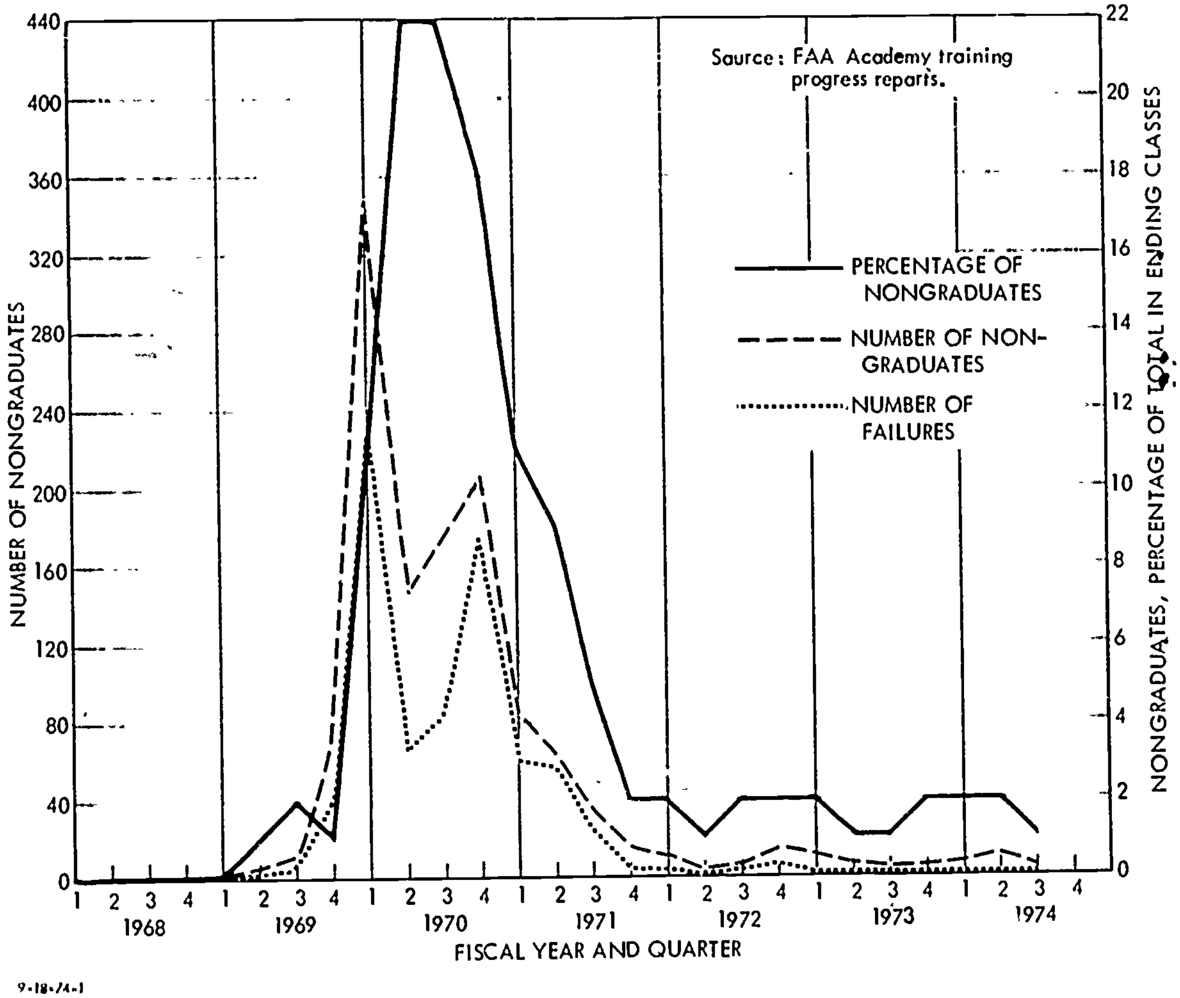


FIGURE F-4. Academy Nongraduates

I. CAREER PROGRESSION OF AIR TRAFFIC SPECIALISTS

Figure F-5 diagrams the career of a terminal air traffic specialist. The chart is drawn so as to indicate possible alternatives in light lines, while the current system is depicted with heavy lines. The screening examination, an aptitude test, may have several outcomes. In the general case, the individual is put on the roster in order of his score on the test. If he has some relevant experience (say, as a military controller or pilot) he may be eligible for higher placement on the list. A few experienced individuals may qualify for higher ratings which permit them to proceed immediately to Phase III training with a GS-9 rating. On the other hand, members of minority groups who do not make a minimum score may be permitted to enter at a lower level through the predevelopment (or "150") program. The training program has been described earlier, and it will not be redescribed here. Several aspects of the diagram in Fig. F-5 that are relevant to the current training program should be noted, however. The first is the limited role of the Academy in screening. The Academy does part of the training, and the facility does the remainder. The Academy has virtually no role in selecting or washing out trainees, however, although it does test them during and at the completion of each course. The Academy provides a rating of the student--"Outstanding," "Pass" or "Fail"--but cannot dismiss him. Rather, he is permitted to return to his facility, where he may be tested and given remedial training if it is considered desirable. However, some trainees do leave the FAA voluntarily while they are students at the Academy. Also, it must be noted here that once a controller starts his career, he is required to continue it to the highest journeyman grade at the facility that employs him. Thus, a non-radar qualified controller cannot stop at that level if he works for a radar facility, even though he could be useful. And a GS-12 journeyman must continue to study to rise to GS-13 if he works for the class of facility that has GS-13 controllers. This is called the "up or out" policy.

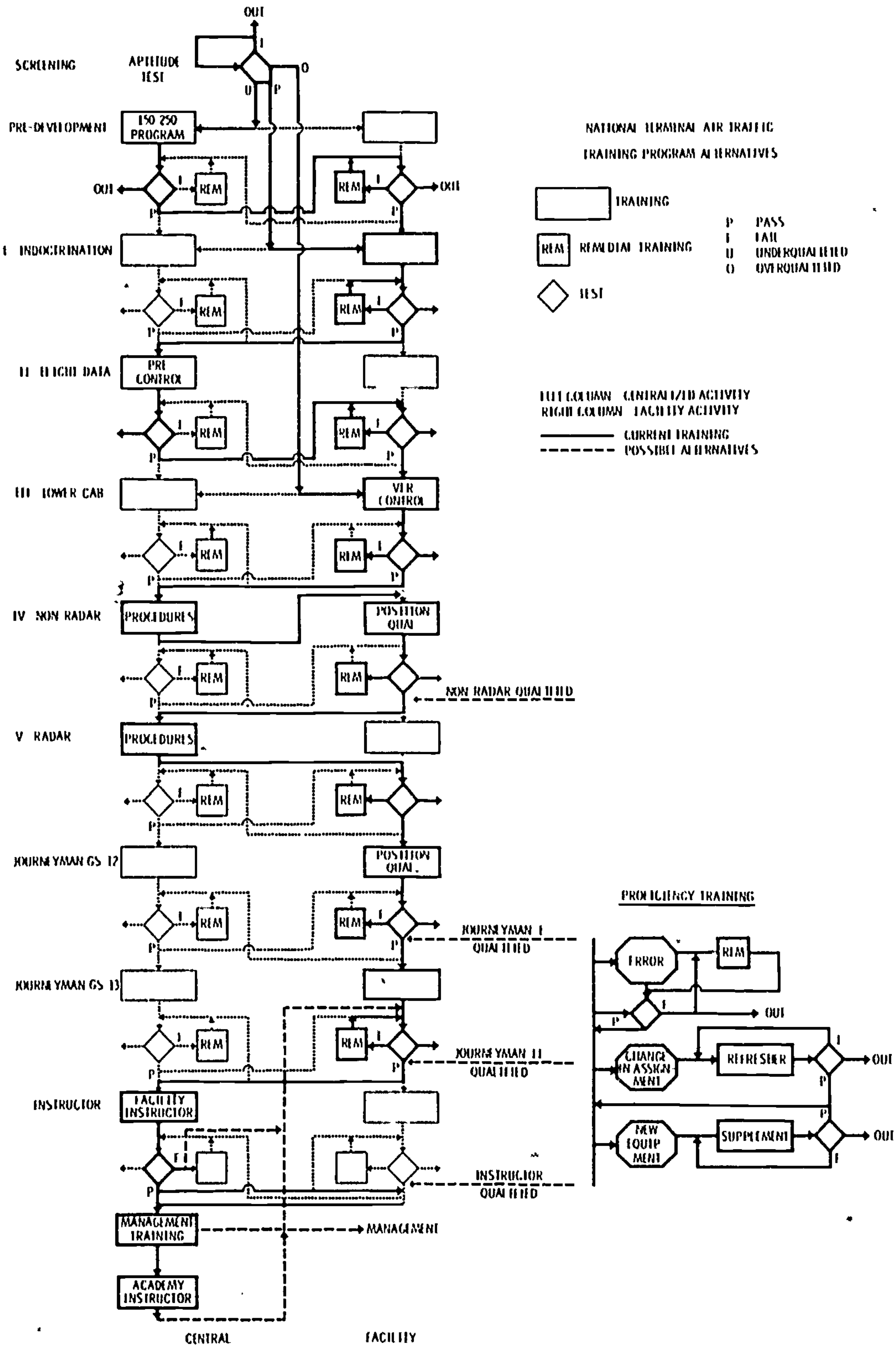


FIGURE F-5. Typical Career Progression for a Terminal Air Traffic Specialist

Following his arrival at full journeyman status, the specialist may elect to become a facility instructor. This requires that he take an instructor's course at the Academy. In some cases where the need is justified and the resources exist, the Office of Training will give a Region a waiver to do its own instructor training. In any case, once an instructor is qualified by the Academy or by his Region, he is not tested further before he undertakes instructor duties at a facility. His work, however, is monitored by the Evaluation and Proficiency Development Officer (EPDO) at the facility. There is still one further step that is available to the air traffic specialist--Academy instructor. Academy instructorships are bid for by the journeyman personnel in the Air Traffic Service, and they must be recommended by their facility and regional supervisors. Generally this is considered to be a desirable step because it usually means a promotion, since an Academy instructor is considered to be a prime candidate for a managerial position after his return to his facility. For this reason, all Academy instructor candidates are required to take the management training course before they take the Academy instructor course.

Figure F-6 shows the career of an en route controller. The general scheme is the same, although it can be seen that the en route controller receives a relatively small proportion of his training at the Academy--only the part involving non-radar procedures and laboratory. Since the Academy radar facilities are inadequate, radar training occurs at the facilities or, sometimes, where new equipment is involved, at NAFEC. After he arrives at the journeyman level, the career and options for the en route controller are similar to those for the terminal controller.

We shall mention here one other career aspect of the air traffic specialist, the "Second Career." In 1972, legislation was passed requiring the FAA to set up a scheme for providing training for controllers who could not continue their work due to disability. To qualify for this training, a controller must have at least 5 years'

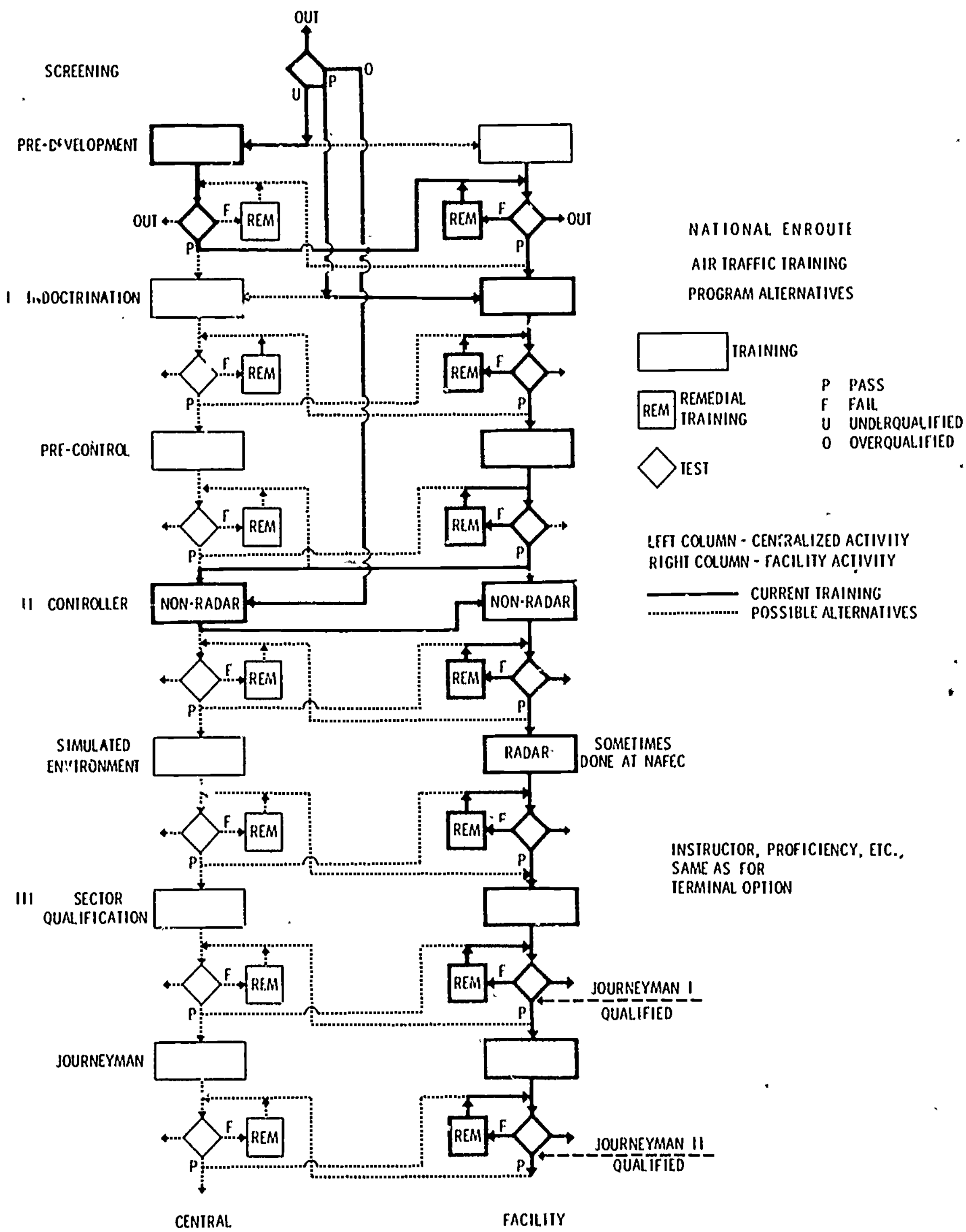


FIGURE F-6. Typical Career Progression for an En Route Air Traffic Specialist

service as a journeyman. Then, for medical reasons such as hypertension or ulcers, or an "operational" reason specified by his supervisor, the controller will be considered for Second Career training. It might be noted that there is available a separate federal program for job-related disability for any civil servant, but the Second Career program is preferred because the benefits are significantly better. The primary benefit is 2 years at full salary plus tuition and travel to a school for further education. Counseling is used to assist the individual in selecting a second career, but there are no particular restrictions on the choice of new occupation. Each case is considered individually, and judgment is used to decide whether a controller qualifies for the program and whether a Second Career program choice is reasonable and wise.

Approximately 500 controllers are in the Second Career program now. It is expected that the number will increase to about 850 by the end of FY 1976. Since the cost in current dollars is something like $24,000 per year per man, the total annual cost of this program can be expected to reach more than $20 million. This cost is considered to be part of the FAA air traffic training budget, but it is not included in the comparisons of alternative training programs discussed in Appendix H.

J. RELEVANCE OF TRAINING CURRICULUM TO OPERATIONS

The National En Route and Terminal Air Traffic Training Programs are designed to provide controllers with the knowledges and skills they need to provide identical ATC services throughout the nation. Standardization of procedures across the national airspace is a fundamental requirement of the national air traffic control system. Therefore, consistency in the content and method of training by the Academy and the region is virtually an end in itself. Thus, the national programs specify, in great detail, the information and procedures that are to be taught during each phase of training and the goals to be accomplished before the developmental can move from one phase to the next. Means are provided by periodic review, survey, and feedback between the Academy and the regions for modifying the

course content and training methods as new needs arise. Whatever problems have been encountered in assuring standardization between the regions or in keeping the curriculum up-to-date are due more to the constraints under which training must operate than to limitations in the design of the training programs. Training operates, as everyone knows, under such constraints as the size of the annual FAA budget, fluctuations in the number of trainees from time to time, the priority of operations over training, and the impact of the Civil Service Commission, the Whitten Amendment, and the Equal Employment Opportunity (EEO) program. The training programs receive frequent and vigorous reviews within the FAA (e.g., Southwest Region, June 1974; Eastern Region, February 1970; Great Lakes Region, November 1973; Western Region, May 1973; Corson Committee, 1970; Academy Survey, April 1974), and it is not likely that any critical comment could be made for the first time. There is substantial evidence, from the reports noted above, that training is not standardized between centers, that the amounts of training time given to various topics differ notably between centers, that some procedures specified by the curriculum are inconsistent with others, that some qualification standards are open to differences in interpretation, and that the national program specifies training in procedures that do not agree with current operational practices. The resolution of such problems associated with training, which have been identified by the FAA itself, would seem to require either adherence to program documents or changing training requirements that have outlived their usefulness. In either case, the matter rests with the FAA.

Results of the IDA survey, which was addressed to statistics about training activities, suggest but do not prove that training practices at centers and terminals are not standardized. The evidence consists of data on the resources available for training at 20 centers which responded to the questionnaire. Table F-2 shows that, on the average, there are 8.2 developmentals per instructor at centers; the ratio varies from 2.3 to 20.7. An average 72 percent

of the entire staff are fully qualified journeymen; this percentage varies from 54 to 85 percent. On the average, 18 percent of the developmentals do not complete their training; the range is 4 to 36 percent loss (an extreme value of 77 percent loss has been excluded from both the average and the range). The relation between the instructional resources and the fraction of qualified controllers at these centers is shown in Fig. F-7. There is a wide variation in both parameters, strongly suggestive of a lack of standardization in training resources.

TABLE F-2. INSTRUCTIONAL RESOURCES, HIRES, AND ATTRITION DURING TRAINING AT 20 EN ROUTE CENTERS[a]

En Route Center	Percentage of Operational Controllers that are Fully Qualified	Developmentals per Instructor	Hires	Developmental Losses	
				Number	Percentage
Cleveland	83%	6.9	56	11	11%
Chicago	54	9.4	109	24	9
New York	56	12.4	98	36	14
Atlanta	60	20.7	111	12	5
Washington	69	8.3	4	6	4
Indianapolis	72	8.0	45	16	13
Fort Worth	70	7.7	31	13	12
Houston	75	4.7	61	10	10
Memphis	67	17.0	69	13	12
Jacksonville	64	13.9	102	23	15
Miami	72	5.4	49	24	36
Los Angeles	60	12.2	25	18	13
Kansas City	77	6.9	21	9	10
Boston	81	3.3	20	14	17
Oakland	70	6.2	29	21	21
Albuquerque	77	3.0	76	17	27
Minneapolis	69	8.9	39	17	18
Denver	85	2.9	38	11	26
Seattle	81	3.6	0	7	18
Salt Lake City	83	2.3	29	24	77

[a]Source: IDA Survey.

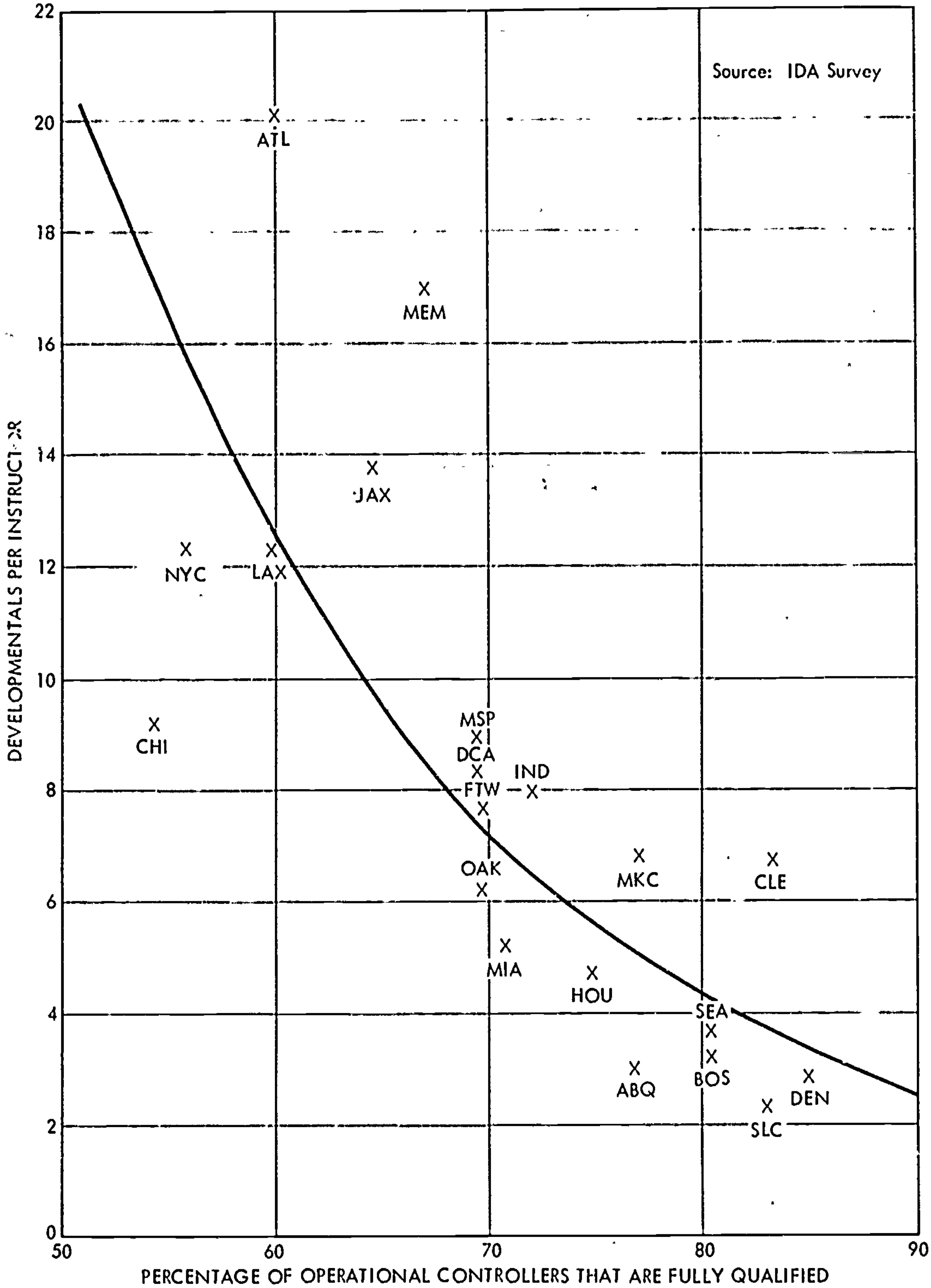


FIGURE F-7. Relation Between Instructional Resources at Centers and Percentage of Controllers that Are Fully Qualified

In addition, the data show wide variations in training resources at terminals also. For 21 major terminals, the data in Table F-3 show that the average number of developmentals per instructor is 7.3; this ratio varies from 0.86 to 20.8. An average 76 percent of the entire staff are fully qualified journeymen, but this varies from 54 to 92 percent. There seems to be no consistent relationship between the fraction of the staff needing developmental training at these terminal facilities and the training resources. The relationship is shown graphically in Fig. F-8. Again, such data suggest that there is a lack of standardization in training resources and hence in the training itself.

TABLE F-3. INSTRUCTIONAL RESOURCES, HIRES, AND ATTRITION DURING TRAINING AT 21 MAJOR TERMINALS[a]

En Route Center	Percentage of Operational Controllers that are Fully qualified	Developmentals per Instructor	Hires	Developmental Losses	
				Number	Percentage
New York (CIFRR)	82%	3.2	33	4	15%
Chicago	54	17.0	5	16	31
Atlanta	56	17.4	0	1	1
Miami	81	5.2	20	2	12
Dallas/Ft. Worth	67	9.3	0	4	14
Los Angeles	92	2.0	0	3	50
Washington National	68	20.8	13	1	4
Detroit	75	4.7	6	7	64
Boston	69	15.0	5	6	30
Houston	83	0.86	2	0	0
San Antonio	92	4.3	0	0	0
Tampa	68	9.6	6	4	20
Denver	89	3.4	0	8	100
Memphis	80	8.3	5	0	45
Pittsburgh	66	7.4	13	1	5
St. Louis	72	16.3	10	4	21
Cleveland	75	4.7	6	7	64
Minneapolis	76	7.3	6	6	46
Kansas City	84	8.0	1	1	13
Columbus	92	2.0	3	0	0
Indianapolis	78	9.4	5	3	27

[a]Source: IDA Survey.

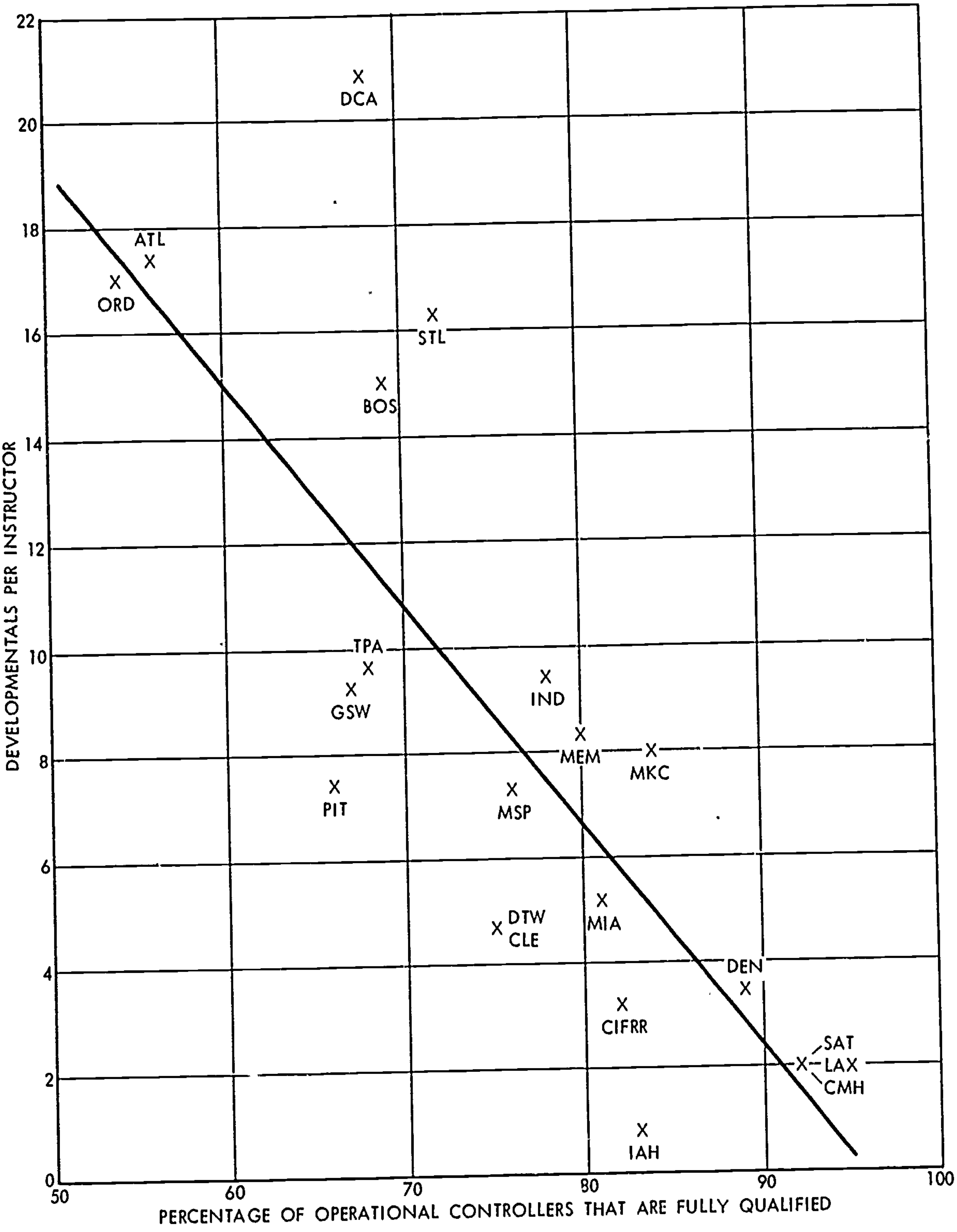


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FIGURE F-8. Relation Between Instructional Resources at Selected Terminals and Fraction of Controllers that are Fully Qualified

The relevance of the training material to present operations is now considered. On the one hand, the flow of controllers and supervisors between operational and training duties ensures a high degree of relevance between the two, as do the formal surveys conducted by the Air Traffic Branch (AAC-930) to evaluate the courses developed by the Academy.* The evidence suggests that efforts are made to correct the deficiencies which come to light as a result of such surveys. The remedy for some deficiencies, however, might require substantial additions to the Academy staff (e.g., to review the complexity of problems used in simulated environmental training) or revisions in the Program Control Document (which requires, for example, training on a two-man basis at the Academy, while the controllers are evaluated on a one-man basis at their field facility). Action on such problems can only be referred to the FAA Headquarters.

Many of the opposing views about training which reflect the perceived needs (primarily but not exclusively operational and training needs) of various segments of the FAA family are not readily resolved by debate and have, in fact, persisted for long periods of time. Rather, an objective method is required to provide the information that may be used to resolve understandable differences in views about the utility of various aspects of training.

For example, is two-man training at the Academy detrimental to the controller's performance at the field facility? The determination is made presently by subjective means, i.e., primarily by the supervisor's evaluation of the controller's performance, despite the fact that NAFEC studies have shown that objective measurement of the controller's performance is feasible. The significance of the NAFEC work is discussed at length in Appendix E. Here, it remains to be said that a variety of problems encountered in current training procedures can be resolved by objective means associated primarily with valid measures of the controller's performance. These measures still

*In accordance with FAA Order 3000.18A, Chapter 8, Section 1.

require some development, but their reliability has been demonstrated beyond question. They are needed to answer such questions about training as the following:

- What is the appropriate amount of time required to achieve qualification at each phase of training? What is the appropriate mix of effort in formal training and OJT?
- In what order should air traffic problems be presented for optimum training? The issue is to determine proper increments in level of complexity between problems.
- Is the order of non-radar training followed by radar training the correct one? At issue here is the relative difficulty of learning the two operations. Learning theory strongly suggests that one learns more effectively when proceeding from simple to complex tasks, rather than in the reverse order.
- What is the value of training on prototype sectors (e.g., Tango) rather than on actual ones? This question can be resolved by an experimental comparison and not by further discussion based on insufficient information.

A substantial basis for standardizing the training of controllers may be found in the reports submitted by the System Development Corporation (1971, 1972, 1974). These contain comprehensive descriptions of what en route and terminal controllers actually do on the job. These task analyses have been confirmed by field trials. They provide the means for reviewing and modifying the current curriculum of instruction to ensure its relevance to actual operations. It is not anticipated that such review should produce major changes in the content of training.

Where questions may arise, it should be pointed out that the FAA does not have available the means to resolve key issues which may affect the content and format of the training program. Means for doing so are potentially available (in primitive form) at NAFEC now,

although their further and rapid development would be most desirable. The training problems identified here require an experimental approach for their solution. In such an approach the general question is, "Is this way of training more effective than that?" Partisan points of view are helpful in identifying problem areas, but not for resolving them. Except for the absence of an experimental point of view for dealing with training problems, the FAA shows a commendable, although primarily subjective, concern for the improvement of its methods of training controllers. It is not too much to say that the FAA training program can be made more efficient and effective by adopting experimental methods, now close at hand, for resolving some of the key issues in the present method of training.

K. SUMMARY

The various phases of training that in four years transform an apprentice into a fully qualified journeyman, as an en route or terminal specialist, have been described. Other types of training, for predevelopmentals and for proficiency purposes, were also considered. The role of the Academy in direct training and in support of training at the facilities has been described, and an estimate of current training loads and costs has been made. The career progressions of en route and terminal specialists have been outlined.

Because of periodic review, the present training curriculum is generally relevant to current operations. Nevertheless, some of the reviews suggest that training is neither standardized nor completely relevant to actual operational practice. This case is also supported by data which show marked variations in the number of qualified personnel who could serve as instructors and in the ratio of developmentals to instructors, which also varies among the facilities. Questions about the content and/or method of training could be resolved by experiments using objective performance measures, a course not now being pursued by the FAA.

L. CONCLUSIONS

Training is generally relevant to current operations, although some questions exist about the content and method of training. These could be resolved by experiments designed to evaluate the significance of different ways of training. To be useful, such experiments should incorporate objective measures of the controller's performance. Such objective measures have been demonstrated at NAFEC (Appendix E).

APPENDIX G

COST ANALYSES OF AIR TRAFFIC CONTROLLER TRAINING, FY 1974, AND OF ALTERNATIVE TRAINING METHODS

CONTENTS

This Appendix presents the costs of training air traffic controllers in both the en route and terminal options. It also presents estimates of the costs of several alternative training programs.

I. MEASURES OF COST

Resources devoted to Federal Aviation Administration (FAA) training are dominated by manpower, and therefore training costs occur almost entirely as salary and benefit expenses. This is also true of the alternative training methods considered by this study, even for those cases assuming procurement of dedicated simulators. Therefore, in this analysis, costs of alternative training systems will be considered to consist only of (1) student travel costs, including per diem, and (2) personnel compensation and benefits (PC&B) calculated at Civil Service pay rates in effect at the end of FY 1974. Facility costs such as rent, utilities, and maintenance are not included.

Criticisms of FAA controller training practices have arisen during periods of system expansion due to the seeming incapacity of the system to expand its output of qualified controllers. This suggests two additional related measures of cost for evaluating alternative systems. The first is the elapsed time of controller training from accession to qualification. The second is the amount of trainer manpower required on the average to qualify new entrants--a measure of the labor intensity of the training process. Neither will suffice independently as a measure of training cost, but each offers further means of assessing the net attractiveness of different training schemes.

The question of manpower required to qualify new controllers has not been studied in detail. It is clear that the process is heavily manpower intensive, and there may be some ways in which the manpower required might be reduced; for example, better selection procedures to reduce losses during training, more intensive use of simulators using standardized problems and automatic recording of performance, and reduction of fluctuations in training load. It is believed, however, that there is no good way of evaluating training until the FAA develops and places in use an objective method of evaluating controller performance. Two of the alternative schemes of training presented in this report (Appendix H) indicate considerable savings through a reduction of elapsed time. There are some institutional traditions against making such changes, but this problem can be resolved. The changes need reflect on the quality of neither journeyman controllers nor their training. An informal sampling of the opinions of informed FAA personnel involved in training elicited no dissents from the idea that the training period could be substantially shortened. The costing in this Appendix shows the potential savings of this and other possible changes in training arrangements.

II. COSTING METHOD

Training of controllers occurs both at facilities and at the FAA Academy. Since each facility type uses only one controller option, there is no problem of cost allocation between en route and terminal types of training here. In the case of Academy training and training support functions funded through the centralized training budget, allocations between the two options must be made. In some cases, arbitrary allocations of joint costs have been made.

Table G-1 lists those activities contributing to costs of training of FAA en route and terminal traffic control specialists. The last three columns in the table indicate whether the costs are wholly identifiable with either terminal or en route controller training, or whether the available data do not permit separation.

TABLE G-1. ELEMENTS OF TRAINING COST

Element	Scope of Training Activities Supported	En Route	Terminal	Joint
A. FIXED COSTS				
1. Instructor Training (Educational Technology and Standards Branch)[a]	All training	x	x	
2. Management Training School (Lawton)	Agency-wide management training	x	x	
3. FAA Academy administration and services	All initial training	x	x	x
4. Aeronautical Center support of FAA Academy	All initial training	x	x	x
5. Office of Training	All training	x	x	
6. Regional training offices	All field facility training	x	x	
7. Air Traffic Branch (ATB) Development Revision Section	Initial and post-qualification for en route and terminal options			
Non-Radar Support Unit[b]				x
Radar Support Unit[b]				x
B. VARIABLE COSTS				
1. En Route Unit of Qualification Section of ATB	Initial training for en route option	x		
2. Terminal Unit of Qualification Section of ATB	Initial training for terminal option		x	
3. Predevelopmental Training Unit of Qualification Section of ATB	En route, terminal, and flight service			x
4. Field facility training staffs (evaluation and proficiency development officer/specialist staffs at en route centers and terminals) and controllers on temporary detail to training staffs	Initial and post-qualification for a single facility	x	x	
5. Developmentals in training at Academy	Initial and post-qualification at Academy	x	x	x
6. Developmentals in training at facilities	Initial and post-qualification at field facilities	x	x	
7. Full-performance controllers engaged in training and evaluation	On-the-job, self-study, and classroom training and evaluation	x	x	
8. Temporary and part-time facility training staff	On-the-job, self-study, and classroom training and evaluation	x	x	
9. Developmental controllers; time not engaged in training	None	x	x	

[a] Also provides predevelopmental training program instructors for flight service option.

[b] Costs are totally in support of en route and terminal controller training. However, they cannot be allocated between the two and are considered as a joint cost.

In the latter case, all costs incurred have been classified as joint costs of en route and terminal controller training.

The items in this list are defined as the explicit costs of training for terminal and en route traffic control specialists. Summed up, they are the total of costs of those resources and activities that can be unambiguously associated with training for these specialties. They are also classified as variable or fixed costs, depending upon whether they change greatly or little with changes in the training workload. Elements classed as variable costs are limited to those that will change both significantly and predictably with changes in the numbers of persons trained and in the nature of the training programs. For variable cost items, functional relationships have been formulated for examining the cost implications of alternative training programs.

The bulk of training costs arises from two elements that are not associated with the training function in the FAA budget. These elements are the field training staffs (including controller personnel on temporary detail to training departments) and controllers engaged in training. The total salary bill of all field training staffs is roughly twice that of the FAA Academy's Air Traffic Branch (ATB). Both terminals and en route centers assign controllers to training staffs on a temporary or part-time basis. These salary costs are approximately equal to those of the permanent training staffs.

The salaries earned by developmental controllers while actually engaged in training activities are an unambiguous cost of training, regardless of the mode of training--classroom, self-study, or on-the-job. When in the classroom or in self-study, the student is engaged full-time and is not available for control duties. In on-the-job training (OJT), the requirement for continual monitoring by a controller qualified for the particular position implies double manning of the position. One of the two salaries accruing is redundant to manning of the position and cannot be considered as a cost of traffic control operations. Similarly, the other salary cannot be considered a training cost, since it would accrue in the absence of training.

The amount of remedial, refresher, and supplementary training of full-performance controllers varies widely between facilities. In the aggregate, these areas of training constitute 30 percent of total trainee man-hours and 5 percent of on-duty time. Facility manpower authorization must be large enough to permit manning of control positions as well as assignment of qualified controllers for training. It is theoretically possible to schedule training during times of light traffic, thereby offsetting at least some of the need for qualified controllers. However, this can result in a requirement for continuous assignment of instructors to night or weekend work. For purposes of this study it is assumed that the increased manpower authorization is necessary for training during peak times.

An additional source of training cost is the salary bill of developmental controllers during periods when they are not engaged in training. The present training procedures and schedules of training extend the period required to attain journeyman status beyond the time that is actually required for training. The result is that trainees spend some portion of their qualification period in operating control positions for which they are qualified by virtue of experience and amount of training completed and in performing other facility operating functions. However, the functions they perform might be accomplished more cheaply by other means (even if one accounts for the lower salary levels of developmentals), and there is some question whether some of these functions should be performed at all. To the extent that facility operating costs are increased by constraints on the use of developmentals, training costs are increased, and it is clear that some portion of the salaries earned by trainees while they are at a facility but are not in training should be considered as a training cost.

The value of trainees to a facility will vary with the characteristics of the facility (size, type of traffic controlled, etc.), the traffic control procedures employed (including control equipment used), and the characteristics of the training program itself. For

example, in terminal facilities the introduction of National Airspace System, Stage A (NAS-A) equipment has significantly decreased the requirement for flight data positions previously filled by developmentals. What portion should be charged as an implicit cost of training is uncertain and can change over time. However, past FAA testimony in Congressional hearings supports a contention that some part of trainee wages should be considered a cost of training.* Table G-2 shows costs both with and without this particular implicit cost of training.

A. FIXED COSTS

1. Instructor Training

The costs of instructor training consist of personnel compensation and benefits (PC&B) for students, teachers, and support staff plus student travel and per diem. The data used here were supplied by the Educational Technology and Standards (ETS) Branch at the FAA Academy as displayed in Table G-3.

With a teaching staff of 16 and a support staff of two, PC&B for the staff are

$$1.28[(16)(\$19{,}829) + (2)(\$6836)] = \$406{,}098,$$

*House of Representatives Hearings, 92nd Congress, Second Session, Department of Transportation and Related Agencies, Appropriations for 1973, Part 3, p. 832:

> Mr. Conte. What do you feel that you have invested in that person by that time?
>
> Mr. Flener. We figure 3 years and we probably have $45,000 wrapped up in him, including his base pay.

Mr. Flener went on to say that some productivity was obtained from trainees, though he gave no specific value.

TABLE G-2. COST OF EN ROUTE AND TERMINAL CONTROLLER TRAINING, FY 1974 (PERSONNEL COMPENSATION & BENEFITS, TRAVEL, AND PER DIEM)[a]

	En Route	Terminal	Joint[b]
A. FIXED COSTS			
1. Instructor training[c]	$ 526	$ 416	$ --
2. Management training (Lawton)[c]	1,995	1,995	--
3. FAA Academy Administration and Services	55	154	99
4. Aeronautical Center Support of Academy	170	476	306
5. Office of Training	224	216	--
6. Regional Training Offices	512	495	--
7. ATB Development/Revision Section			
Non-Radar Support Unit	--	--	979
Radar Support Unit	--	--	--
Total Fixed Costs	$ 3,482	$ 3,752	$ 1,384
B. VARIABLE COSTS			
1. En Route Unit, ATB	$ 638	$ --	$ --
2. Terminal Unit, ATB	--	1,663	--
3. Predevelopmental Training Unit, ATB	--	--	181
4. Field facility training staffs	4,077	3,018	--
5. Developmentals at Academy[d]	821	2,894	1,115
6. Developmentals in training at facilities[e]	9,284	17,008	--
7. Full-performance controllers engaged in training and evaluation	5,636	9,965	--
8. Temporary and part-time facility training staff	2,728	3,317	--
9. Developmental controllers; time not in training	25,179	19,184	--
Total Variable Costs (excluding B.9)	$ 23,184	$ 37,865	$ 1,296
(including B.9)	$ 48,363	$ 57,049	$ 1,296
Total Training Costs (excluding B.9)	$ 26,666	$ 41,617	$ 2,680
(including B.9)	$ 51,845	$ 60,801	$ 2,680
Sum of en route, terminal, and joint training costs			
(excluding B.9)		$ 70,963	
(including B.9)		$115,326	

[a] This is a summary table. The derivation of all individual entries is explained in correspondingly numbered sections of this Appendix.

[b] Includes Predevelopmental Training by the FAA Academy.

[c] Includes student PC&B, travel, and per diem.

[d] Includes travel and per diem.

[e] Includes qualification, remedial, refresher, and supplemental training.

TABLE G-3. INSTRUCTOR TRAINING, FY 1974

	Number of Classes	Air Traffic Enrollments	Total Enrollments	Course Duration (Days)	Student Class Days: AT	Student Class Days Total	Instructor Class Days
Academy Oriented							
Achievement Testing	1	5	12	5	25	60	5
Basic Instructor Training	16	105	224	15	1575	3360	240
Advanced Instructor Training	6	22	51	10	220	510	60
Instructional Materials	6	28	47	15	420	705	90
Total		160	334		2240	4635	395
Facility Oriented							
Facility Instructor Training	11	152	178	15	2280	2670	165
OJT Techniques	12	134	167	5	670	835	60
Total		286	345		2950	3505	225
TOTAL		446	679		5190	8140	

where

1.28 represents salary plus a 28 percent benefit rate,
$19,829 is the GS-12 salary, and
$6,836 is the GS-3 salary.

Since there were 8140 student class days, this amounts to $50 per student day.

Student travel and per diem averages $31 per day, calculated as follows:

a. Travel Costs

Number of facility-oriented enrollments x average trip cost =

$$(286)(\$200) = \$57,200$$

(NOTE: $200 is the estimate, used throughout this study, for average trip cost to the FAA Academy.)

b. Per Diem Costs

$$(\text{Per diem}) \left(\frac{\text{days per week}}{\text{instructional days per week}}\right) (\text{student class days})$$

$$= (\$25)(7/5)(2950) = \$103,250$$

Thus, total travel and per diem = $57,200 + $103,250 = $160,450. Since there were 5190 student instructor days at the Academy, this is an average of $160,450/5190 = $31 per day.

Finally, PC&B for air traffic students is for grade GS-13:

$$1.28(\$23,433)/230 = \$130,$$

where 230 is the approximate number of working days per year.

The total cost of instructor training, then, is

Staff PC&B	$ 50
Student Travel & Per Diem	31
Student PC&B	130
	$211 per student day.

This amounts to \$211 x 446 = \$1.095 million for all air traffic students during FY 1974. This is allocated to terminal and en route specialties on the basis of the FY 1974 proportion of total Air Traffic Branch (ATB) instructors and facility Evaluation and Proficiency Development Officers and Specialists (EDPOs and EPDSs) found in each specialty as indicated in Table G-4--48 percent in en route centers and 38 percent in terminals:

\$1,095,000 x 0.48 = \$526,000

\$1,095,000 x 0.38 = \$416,000.

2. Management Training School (MTS)

The total cost of MTS in FY 1974 consisted of \$1.607 million for student travel and per diem and \$2.725 million for contract and FAA support. This data is based on information provided to IDA informally and characterized as part of the FY 1974 FAA budget submission.

The contract and support effort amounts to

\$2,725,000/42,080 = \$65 per student day.

(There were 42,080 MTS student class days, according to Table G-5.)

Travel costs are calculated as follows:

$$\frac{\text{(Number of enrollments)(average cost of travel)}}{\text{total daily attendance}} =$$

$$\frac{(2287)(\$200)}{19{,}459}(1 - 0.17) = \$20 \text{ per student day.}$$

The basic formula is multiplied by (1 - 0.17) since about 17 percent of the total air traffic enrollments at MTS are air traffic students enrolled at the Academy and can be considered to be the same personnel. Therefore, this fraction will not incur any travel cost at MTS.

The other relevant costs are student PC&B as calculated in item 1 above, \$130 per student day, and per diem, (\$25)(7/5) = \$35 per student day. The total, then, is \$65 + \$20 + \$130 + \$35 = \$250 per student day, or \$250 x 19,459 = \$4.865 million for all air traffic

TABLE G-4. ALLOCATION OF INSTRUCTORS AND EPDOs/EPDSs

	En Route	Terminal	Flight Service Station (FSS)	Data Systems Specialist (DSS)	Total
Academy Instructors					
Terminal	--	47	--	--	47
En Route	17	--	--	--	17
FSS	--	--	9	--	9
Predevelopmental	(3.5)[a]	(3.5)[a]	--	--	7
Special	(3.5)[a]	(3.5)[a]	--	--	7
Development/Revision					
Radar/Non-Radar	(12)[a]	(12)a	--	--	24
FSS	--	--	4	--	4
Automation	--	--	--	52	52
Facility EPDOs/EPDSs	225	139	15	--	379
Total	261	205	28	52	546
Percentage[b]	48%	38%	5%	10%	100%

[a]Figures in parentheses are arbitrary allocations between en route and terminal options.

[b]Individual entries do not total 100% because of rounding.

TABLE G-5. MANAGEMENT TRAINING SCHOOL ENROLLMENTS AND TRAINEE CLASS DAYS, FY 1974

Course	Course No.	Air Traffic Enrollments (Actual)[a]	Total Enrollments (Authorized)[b]	Course Duration (Class Days)	Total Daily Attendance (Trainee Class Days)	
					Air Traffic	Total
Supervisory	01200	876	1,780	13	11,388	23,140
Managerial	01300	127	380	13	1,651	4,940
Supervisory, Recurring	01201	850	1,940	5	4,250	9,700
Managerial, Recurring	01301	110	500	5	550	2,500
Labor Relations	01202	324	360	5	1,620	1,800
Total		2,287	4,960		19,459	42,080

[a]Source: Management Training School.
[b]Source: FAA Office of Training.

students in management training during FY 1974. This has been allocated to terminal and en route specialties in the same proportions as for total controller personnel authorized to field facilities in the FY 1974 budget--41 percent for each (Column D, Table G-6):

$$\$4,865,000 \times 0.41 = \$1,995,000.$$

3. FAA Academy Administration and Other Services

The FAA budget submission to Congress for FY 1974 requested \$1.573 million for support functions of the Academy and operation of the General Training Branch. This value has been allocated to terminal and en route controller training (and to common support, including the predevelopmental training program) as the product of two allocation rates. The first rate is the number of staff positions requested for the Air Traffic Branch (ATB) as a percentage of the staff positions requested for all specialty branches (35%, from Table G-7). The second rate is derived from the numbers of instructional staff positions in the en route unit of the qualification section, the terminal unit, and the predevelopmental program unit plus the radar and non-radar units of the development/revision section expressed as percentages of total instructor staffing of the ATB (Table G-8). The products are as follows:

En route: (0.35) (0.10) (\$1,573,000) = \$55,000
Terminal: (0.35) (0.28) (\$1,573,000) = \$154,000
Common Support: (0.35) (0.18) (\$1,573,000) = \$99,000.

4. Aeronautical Center Support of the Academy

The FAA budget submission to Congress for FY 1974 requested \$4.858 million for this item. That amount has been allocated to terminal and en route training in the same manner as the amount for Academy administration (Section I-A-3 above).

5. Office of Training Support

The FAA budget submission to Congress for FY 1974 requested \$829,000 for this item. That amount has been allocated to terminal

TABLE G-6. TOTAL PERSONNEL AUTHORIZATIONS REQUESTED FOR TRAFFIC CONTROL FACILITIES AND MAJOR OPERATIONAL PROGRAMS, FY 1974

	A Total Positions Authorized		B Positions Authorized for Traffic Control at Centers & Terminals		C Positions Authorized for Traffic Control, Maintenance, & Flight Standards		D Controller Positions Authorized for Field Facilities	
	Personnel	%[a]	Personnel	%[a]	Personnel	%[a]	Personnel	%
Traffic Control	28,859	55						
Centers	10,969		10,969	30	10,969	27	10,969	41
Terminals	10,850		10,850	29	10,850	26	10,850	41
Flight Service Stations	4,689		4,689	13	4,689	11	4,689	18
Centralized Training	347		--	--	--	--	--	--
Other	2,004		--	--	--	--	--	--
Maintenance	13,135	25						
Field Maintenance	10,565		10,565	29	10,565	26	--	--
Centralized Training	402		--	--	--	--	--	--
Other	2,168		--	--	--	--	--	--
Flight Standards	6,230	12						
Centralized Training	320		--	--	--	--	--	--
Flight Programs & Systems O&M	4,032		--	--	4,032	10	--	--
Other	1,878		--	--	--	--	--	--
Installation & Materiel Services	2,084	4						
Centralized Training	17		--	--	--	--	--	--
Other	2,067		--	--	--	--	--	--
Airports Program	976	2						
Operations	680		--	--	--	--	--	--
Centralized Training	12		--	--	--	--	--	--
Other	284		--	--	--	--	--	--
Other	726	1						
Centralized Training	2		--	--	--	--	--	--
Other	724		--	--	--	--	--	--
TOTAL	52,041	100	37,073	100	41,105	100	26,508	100

[a]Individual entries do not add to 100% because of rounding.

TABLE G-7. PERSONNEL AUTHORIZATIONS AT FAA ACADEMY BY BRANCH, FY 1974

Branch	Number of Positions	Percentage Distribution
Air Traffic	273	35%
Airway Facilities	324	41
Flight Standards	178	23
Airports	6	1
TOTAL	781	100%

TABLE G-8. PERSONNEL POSITIONS OF AIR TRAFFIC BRANCH BY SECTION AND UNIT, FY 1974 MONTHLY AVERAGES

	Number of Instructor Positions		Percentage of Branch[a]	
Qualification Section		87		51%
En Route Unit	17		10%	
Terminal Unit	47		28	
Predevelopmental Training Unit	7		4	
Flight Service Station Unit	9		5	
Special Unit	7		4	
Development/Revision Section		28		16
Radar/Non-Radar Units	24		14	
Flight Service Station Unit	4		2	
Automation Section		52		31
		167		100%

[a]Individual entries do not total 100% because of rounding.

and en route training on the basis of the number of positions requested for FY 1974 for traffic control in en route centers and terminals. As percentages of the authorization for traffic control and maintenance in all field facilities plus those authorized for operations of the flight standards program, these allocation figures are 27 percent for en route centers and 26 percent for terminals (Column C, Table G-6).

6. Regional Training Office Support

The FAA budget submission to Congress for FY 1974 requested $1.707 million for training program support by regional headquarters and NAFEC. That amount has been partly allocated to terminal and en route training on the basis of the number of positions authorized for traffic control at centers and terminal facilities. Table G-6, Column B, indicates that the centers have 30 percent of the total personnel and the terminals have 29 percent. Thus, for this item the costs are $512,000 and $495,000, respectively.

7. Development/Revision Section of ATB

Information concerning the characteristics of the radar and non-radar support units of the Development/Revision Section was obtained by conversations with the current section chief. For both Priority 1 and Priority 2 tasks (currency of documentation of the national programs and currency of proficiency evaluation and remedial training materials, respectively), commonality between terminal and en route training is almost complete, so that allocation of costs between them cannot be justified. Furthermore, the section's workload is determined primarily by characteristics of the training program and not by numbers of controller trainees at either the Academy or field facilities, thus making the cost of this section a fixed cost.

The instructional staff for FY 1974 numbered 24, supported by a staff of 4 technical writers, 10 clericals, and 2 unit chiefs. In the section chief's judgment, a staff of this size is adequate for Priority 1 tasks under the current national program but permits no

effort to be devoted to Priority 2 work. (In FY 1974 less than 1 man-year was devoted to Priority 2.) His further judgment was that Priority 2 tasks require an average of 10 instructional man-years plus support personnel.

Identifiable costs for this section consist solely of PC&B of the staff. These costs have been calculated on the basis of actual staffing of the section during FY 1974, as follows:

GS-13	24 x $23,433 =	$562,392
GS-3	10 x $ 6,622 =	66,220
GS-7	4 x $ 9,969 =	39,876
GS-14	3 x $29,095 =	87,285
Total		$755,773
Total plus 28% benefits		$967,389

B. VARIABLE COSTS

Variable costs of instruction at the Academy are based on the same procedures for both the en route and terminal options and the predevelopmental training program. Costs incurred consist of PC&B of the instructional and support staffs, student travel and per diem, and the PC&B of students during their period of Academy instruction.

Tables G-9, G-10, and G-11 display operating levels and cost-generating characteristics during FY 1974 for the three relevant units of the Qualification Section. They are derived from detailed data provided by the section chief. PC&B costs for the staff were developed from the monthly staffing (Table G-12) of each unit by GS grade level. Student per diem and PC&B are based on total daily attendance (the latter at salary rates for the GS level normally associated with each phase). Travel costs are allocated at a rate of $200 per enrollment, except in Phase V of the terminal option. Here, no travel is allowed, on the assumption that all students enroll in Phases IV and V sequentially. An implicit assumption associated with these costs is that enrollees remain in training for the full term of each course, and that no failures are recorded by the Academy.

TABLE G-9. EN ROUTE OPTION, PHASE II NON-RADAR

FY 1974 Academy Operations

Class Days Conducted	608
Enrollments	202
Average Daily Attendance	32
Total Daily Attendance	7,676
Classes Begun	16
Length of Course, days	38
Average Class Size	12.6
Average En Route Unit Staff (including Supervisors)	19.1
Student Hours per Direct Instructor Hour	3.6
Average Daily Attendance per Staff Member	1.7
Cost per Student Day	$193
Course Cost per Student	$7,338

Class Operating Characteristics (Based on Class Size of 12)

	Instructional Hours	Students per Instructor	Instructors	Student Hours	Instructor Hours
Classroom	80	12	1	960	80
Class/Laboratory	20	6	2	240	40
Laboratory Recap	50	3	4	600	200
SET Laboratory	114	3	4	1,368	456
Non-Radar Tango Lab	40	2	6	480	250
				3,648	1,016

TABLE G-10. TERMINAL OPTION, PHASES II, IV, AND V

FY 1974 Academy Operations

	Phase II 2 Week	Phase II 4 Week	Phase IV	Phase V	All Phases
Class Days Conducted	350	256	788	405	
Enrollments	535	288	400	408	
Average Daily Attendance	65[a]	31[a]	46	24	109
Total Daily Attendance	5,330	4,608	11,200	6,120	27,258
Classes Begun	35	16	28	27	
Length of Course, days	10	16	28	15	
Average Class Size	15.3	18.0	14.2	15.1	
Average Terminal Unit Staff (including Supervisors)					51.6
Student Hours per Direct Instructor Hour	6.0	7.5	5.6	4.3	
Average Daily Attendance per Staff Member					2.1
Cost per Student Day	$179	$168	$170	$170	
Course Cost per Student	$1,793	$2,689	$4,766	$2,554	

Class Operating Characteristics

	Instructional Hours	Students per Instructor	Instructors	Student Hours	Instructor Hours
Phase II, 2 Week (Based on Class Size of 15)					
Classroom	50	15	1	750	50
Laboratory	30	3	5	450	150
				1,200	200
Phase II, 4 Week (Based on Class Size of 18)					
Classroom	92	18	1	1,656	92
Laboratory	36	3	6	648	216
				2,304	308
Phase IV (Based on Class Size of 15)					
Classroom	134	15	1	2,010	134
Laboratory	90	3	5	1,350	450
				3,360	584
Phase V (Based on Class Size of 15)					
Classroom	46	15	1	690	46
Laboratory	74	3	5	1,110	370
				1,800	416

[a] During that part of year class was taught. Whole-year values are 21 and 18.

TABLE G-11. PREDEVELOPMENTAL TRAINING PROGRAM

FY 1974 Academy Operations

Class Days Conducted	680
Enrollments	164
Average Daily Attendance	57
Total Daily Attendance	13,940
Classes Begun	8
Length of Course, days	85
Average Class Size	20.5
Average Staff Size (including Supervisors)	8
Student Hours per Direct Instructor Hour	20.5
Average Daily Attendance per Staff Member	7.1
Cost per Student Day	$93
Course Cost per Student	$7,923

TABLE G-12. QUALIFICATION SECTION STAFFING, FY 1974 (EXCEPT FLIGHT SERVICE AND SPECIAL PROJECTS UNITS)

	Supervisors/Instructors		
	En Route Unit	Terminal Unit	Predevelopmental Training Unit
July	1/9	3/40	1/7
August	1/5	3/47	1/7
September	1/7	4/49	1/7
October	1/7	5/52	1/7
November	1/16	5/47	1/7
December	2/21	5/49	1/7
January	2/22	5/48	1/7
February	2/24	5/48	1/7
March	2/23	5/49	1/7
April	3/23	5/46	1/7
May	3/25	5/47	1/7
June	3/25	5/42	1/7
Total Man-Months	22/207	55/564	12/84
Average Staffing	1.8/17.3	4.6/47	1/7

The variable costs are divided into nine categories and calculated as follows:

1. Academy En Route Unit (Table G-9)

The Academy en route unit provides Phase II non-radar training to developmental controllers in the en route option. The unit is assumed to have 1.8* GS-14 supervisors and 17.3* GS-13 instructors assigned to this option. Hence, costs are

$$1.28[(1.8)(\$29,095) + (17.3)(\$24,811)]\ 1.035 = \$638,025,$$

or \$638,025/7676 = \$83 per student day, where 7676 is the number of student days.

2. Academy Terminal Unit (Table G-10)

The Academy provides training in Phases II, IV, and V of the terminal option. At staff costs of \$61 per student day, the total cost of this unit's staff is

$$\$61 \times 27,258 = \$1,662,738.$$

3. Academy Predevelopmental Training Unit (Table G-11)

The predevelopmental training unit has 7 GS-11 instructors and 1 GS-12 supervisor. With a 5% allowance for clerical, this amounts to \$13 per student day. Since there were 13,940 student days, one has the total for this unit as

$$\$13 \times 13,940 = \$181,220.$$

4. Field Facility Training Staff

The costs of the full-time field facility training staff are calculated by using data from the IDA facility survey as shown in Tables G-13, G-14, and G-15 (pp. 221-226). The basic calculation is

$$(\text{PC\&B})(\text{proportion of controllers involved})\left(\frac{1}{\text{sample size}}\right).$$

*Average over the year (Table G-12).

Option	Number of Controllers	Total Controllers	PC&B, thousands	Sample Size	Cost, thousands
En Route	1937	3233	$6,465	0.95	$4,077
Terminal IFR	791	2110	$3,553	0.78	$1,708
Terminal VFR	602	818	$1,246	0.70	1,310
Total Terminal					$3,018

5. Developmentals at Academy

The cost of developmentals at the Academy is calculated as

PC&B + Travel + Per Diem.

For the en route unit, assuming GS-9 Step 2 salary, one has the following:

PC&B	$67
Per Diem	35
Travel = 200/38	5
	$107 per student day.

Since there were 7676 student days, the total cost is

$107 x 7676 = $821,332.

For the terminal option, one has the following daily costs (Table G-10):

Phase	Rating	Daily Cost	Student Days	Total Cost
Phase II (2 weeks)	GS-7	$108	5,330	$ 575,640
Phase II (4 weeks)	GS-7	$101	4,608	465,408
Phase IV	GS-9	$107	11,200	1,198,400
Phase V	GS-9	$107	6,120	654,840
Total				$2,894,288

For the 150 students, the cost of PC&B, travel, and per diem amounts to $80 per student day (GS-5). Since there were 13,940 student days, one has the total cost as

$13,940 x 80 = $1,115,200.

6. Developmentals at Facilities

The cost of developmentals at the facilities is calculated as the sum of PC&B for (classroom time + self-study time + on-the-job training time + other training time) divided by the sample size.

For the several options, these data are taken from Tables G-13, G-14, and G-15, as appropriate.

Training Mode	PC&B, thousands		
	En Route	Terminal IFR	Terminal VFR
Classroom	$3,525	$1,966	$ 359
Self-Study	390	2,069	1,079
OJT	3,818	4,145	1,395
Other	1,087	890	933
Total	$8,820	$9,070	$3,766
Sample Size	0.95	0.78	0.70
Corrected Total	$9,284	$11,628	$5,380
Total Terminal		$17,008	

7. Full-Performance Controllers in Training and Evaluation

These data are presented in Tables G-13, G-14, and G-15 and are adjusted for sample size to give total cost.

Option	Cost, thousands	Sample Size	Cost, thousands
En Route	$5,355	0.95	$5,636
Terminal IFR	$6,753	0.78	$8,658
Terminal VFR	$ 915	0.70	1,307
Total Terminal			$9,965

8. Temporary and Part-Time Facility Training Staff

The cost of the temporary and part-time facility training staff is calculated as

$$(\text{PC\&B})(\text{proportion of controllers involved})\left(\frac{.1}{\text{sample size}}\right).$$

Option	Controllers Participating	Total Controllers	PC&B, thousands	Sample Size	Cost, thousands
En Route	1296	3233	$6,465	0.95	$2,728
Terminal IFR	1319	2110	$3,553	0.78	$2,847
Terminal VFR	216	818	$1,246	0.70	470
Total Terminal					$3,317

9. Developmental Controllers, Time Not in Training

Data on nontraining time costs are shown here, but since there is some question about whether they should be included, either fully or partly, in training costs, the total estimated training costs will be shown later both with and without this component. It seems that some portion of nontraining time costs should be allocated to training, but just what portion cannot be specified from the available information (see discussion, p. 199). The calculation here simply involves correcting the nontraining time costs, as shown in Tables G-13, G-14, and G-15, for sample size:

Option	Cost, thousands	Sample Size	Corrected Cost, thousands
En Route	$23,920	0.95	$25,179
Terminal IFR	$12,102	0.78	$15,515
Terminal VFR	$ 2,568	0.70	3,669
Total Terminal			$19,184

III. DATA

In this Section the several sources of data that were used in preparing this Appendix are described and discussed.

A. DISCUSSIONS WITH FAA AND ACADEMY PERSONNEL

Face-to-face discussions were held with a number of personnel in the Air Traffic Branch at the FAA Academy and in the FAA Office of

Training. From such discussions data were obtained on the numbers of instructors and support personnel in different assignments at the Academy. Also obtained were the distributions of Civil Service grades, numbers of students by option and phases, numbers of class days, attendance, class sizes, course descriptions, and course lengths. From budget discussions and from unpublished documents relating to budget requests, information was extracted on general allocations to the Academy, the Office of Training, and the Aeronautical Center.

Some of these data represented the actual situation at the time they were received. However, variations through the year in personnel complement and other factors would tend to change the numbers somewhat from those used. An attempt was made to use average data for the year rather than for a single instant in time, but this was not always possible. The error introduced by using snapshot data rather than average data is believed to be inconsequential.

B. IDA SURVEY OF FAA EN ROUTE CENTER AND TERMINAL FACILITIES

1. Interpretation Problems

Because the FAA data that were readily available were insufficient for the purposes of this study, the IDA study group undertook to make a survey of the FAA traffic control facilities. A survey questionnaire (Appendix B) was developed and mailed out to all field facilities in September 1974. This was a first effort to collect data of this type. The results should be interpreted with caution because the field facilities do not maintain data in the form that was requested, and therefore the completion of the form required extensive interpretation by the facility personnel charged with filling it out. The resources available to the study team have permitted a limited field test of the form and verification of the data.

The survey returns of 19 large en route centers were reviewed in detail. Follow-up conversations with their training department personnel revealed wide variations both in training programs and in

program administration. Such differences led to differing interpretations of the data requested. The returns from terminals were not given a similar review and follow-up, but one would not expect to find greater homogeneity among them than among the returns from the en route centers.

Another reason for treating the results cautiously is that they represent only a cross section or snapshot of the situation at the time the survey was made. The results provide little information on structural relationships in the program, and they do not indicate how costs will respond to changes in training requirements and procedures. Despite its deficiencies, however, the current survey provides the only data base available for assessing the impact of training system changes. Its errors appear to be nominal and should not vitiate the essential findings of this study.

2. Data

The data derived from the survey are shown in Tables G-13, G-14, and G-15. They include both costs and training program characteristics according to phase; the data were used to derive the 1974 facility training costs presented in Table G-2 and the cost estimating relationships used to estimate the costs of alternative training programs.

3. Completeness of Survey Sample

A total of 26 questionnaires was sent to en route centers, including the 20 large continental centers. Replies were received from 19 large centers* and three small centers in time to be included in the data sample. Table G-13 shows the accumulated data for the 22 responding centers. If one compares this sample with the personnel complements of the centers as reported in the Air Traffic Field

*One reply arrived too late to be included in the computations in this Appendix.

Facility Employment Report of April 30, 1974, one gets results as shown on Table G-16. In this table, the survey data have been adjusted upward by 5 percent, since the total number of full-performance controllers as represented in the sample is 95 percent of the number

TABLE G-13. TRAINING HOURS AND COSTS, EN ROUTE OPTION, FY 1974 (95 PERCENT SAMPLE)

	Full Performance	Pre-Developmental	Phase I	Phase II Non-Radar	Phase II Radar	Phase III Non-Radar	Phase III Radar	Total Developmental
Complement Assigned								
Number	5,221	181	854	371	57	398	485	2,346
Average G.S. Grade	12.8	4.4	6.9	8.0	9.6	10.2	11.9	--
Salary Rate-Annual	22,710	7,540	8,870	11,400	13,750	14,550	18,360	12,576
PC&B-Annual*(000)	151,788	1,747	10,789	5,413	1,004	7,412	11,498	37,764
PC&B-Hourly	14.98	4.61	6.07	7.01	8.46	8.06	11.30	7.74
Total Man-Hours**(000)	9,388	340	1,606	697	107	748	912	4,410
Classroom Training								
Student Hours (000)	---	37.7	325.6	163.5	26.1	.2	.4	553.3
Instructor Hours (000)	---	5.9	57.4	47.6	4.6	.2	.2	115.9
Student-Instructor Ratio	---	6.35	5.68	3.43	5.63	1.00	1.83	4.77
Student-Staff Ratio	---	3.18	2.85	1.72	2.83	.50	.92	2.40
Student PC&B (000)	---	171	1,978	1,146	221	2	4	3,525
Number of Students	---	105	1,010	422	256	20	12	---
Number of Classes Begun	---	21	119	51	27	5	7	---
Avg. Length of Training (Hrs)	---	238	318	347	89	8	24	---
Weighted Avg. Lngth of Trng (Hrs)	---	359	322	387	102	10	33	---
Avg. Class Size	---	5.0	8.5	8.3	9.5	4.0	1.7	---
Self Study								
Student Hours (000)	---	7.4	10.5	41.9	0	0	0	59.7
Instructor Hours (000)	---	.9	1.2	1.8	0	0	0	6.9
Student Hrs/Instructor Hrs	---	---	---	---	---	---	---	8.60
Student PC&B (000)	---	34	65	295	0	0	0	390
Number of Students	---	42	141	172	0	0	0	---
Avg. Length of Trng. (Hrs)	---	200	90	161	0	0	0	---
Weighted Avg. Lngth of Trng (Hrs)	---	176	74	244	0	0	0	---
OJT								
Student Hours (000)	---	5.8	123.5	8.3	36.5	77.7	175.2	426.9
Instructor Hours (000)	---	.7	14.2	1.0	1.2	9.0	20.2	48.1
Student Hrs/Instructor Hrs	---	---	---	---	---	---	---	8.69
Student PC&B (000)	---	[illegible]	750	58	309	606	1,920	3,819
Number of Students	---	32	858	71	246	430	764	---
Avg. Length of Trng. (Hrs)	---	273	141	121	166	239	212	---
Weighted Avg. Lngth of Trng (Hrs)	---	181	144	117	148	181	229	---
Detailed to Academy During Yr.	---	97	---	218	0	---	---	315
Student Hours (000)	---	66.0	---	66.2	0	---	---	132.2
Student PC&B (000)	---	406	---	405	---	---	---	771
Non-Training Time								
Total Man-Hours (000)	---	340	1,606	687	107	748	912	4,410
Less Classroom Hrs (000)	---	---	---	---	---	---	---	553
Academy Hours (000)	---	---	---	---	---	---	---	132
Self-Study Hours (000)	---	---	---	---	---	---	---	60
OJT Hours (000)	---	---	---	---	---	---	---	427
Other Training Hrs (000)	---	---	---	---	---	---	---	147
Non-Training Hours (000)	---	238	1,126	489	75	524	639	3,091
Non-Training PC&B (000)	---	1,105	6,866	3,420	654	4,896	6,721	23,920
Leaving Training Program	---	28	49	57	12	55	115	---
In Passing Status	---	24	40	15	9	11	60	---
In Failing Status	---	4	9	42	3	44	55	---
Training Failures								
Classroom	---	2	11	45	0	0	0	---
OJT	---	1	2	0	2	33	46	---
Discrepancy	---	1	-1	-3	1	11	9	---
Drop-Out Rate (%)	---	27	5	14	6	13	15	---
Primarily During	---	Classroom	Classroom	Classroom	OJT	OJT	OJT	---
Cumulative Drop-Out Rate (%)	---	--	5	18	22	32	43	---

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TABLE G-13. (Continued)

	Remedial	Supplemental	Refresher	General	Total
Other Training					
Full Performance	202	5,116	4,932	1,553	11,804
Avg. Length of Training (Hrs)	22.1	41.5	28.7	75.8	---
Weighted Avg. Length of Trng. (Hrs)	5.0	42.5	18.9	46.2	32.5
Student Hours (000)	1.0	217.2	93.1	71.8	383.1
Instructor Hrs (000)	*.3*	*66.2*	*28.4*	*21.9*	*116.8*
Student Hrs/Instructor Hrs	---	---	---	---	*3.28*
Student PC&B (000)	*14*	*3,036*	*1,301*	*1,004*	[illegible]
Developmentals					
Number Entering	218	1,370	1,051	346	---
Avg. Length of Training (Hrs)	48.1	61.5	20.7	127.2	---
Weighted Avg. Length of Trng. (Hrs)	44.5	53.5	21.5	118.5	49.1
Student Hours (000)	9.7	73.3	22.6	41.0	146.6
Instructor Hours (000)	*3.0*	*22.3*	*6.9*	*12.5*	*44.7*
Student Hours/Instructor Hours	---	---	---	---	*3.28*
Student PC&B (000)	*78*	*513*	*168*	*301*	*1,087*

	Total	Classroom Qualification	Other Qualification	Other Training	Administration	Other
Instructor Man-Months						
Full Time (EPOS/EPOO)	1,937	---	---	---	---	---
Part Time/Temporary Detail	1,296	---	---	---	---	---
Total	3,233	---	---	---	---	---
Allocation by Function (%)	100	39.7	9.6	27.7	15.3	7.7
Man-Hours by Function (000)	*448.2*	*192.6*	*46.8*	*135.0*	*73.8*	---
Adjusted Man-Hours by Function (000)	*448.2*	*230.6*	*56.0*	*161.6*	---	---
PC&B by Function (000)	*6,163*	[illegible]	*507*	[illegible]	---	---

*Includes benefits at 28 percent.

**Man-Year: Full Performance 1800 hours
Developmental 1880 hours

Note: *Italics*: Derived Values.

TABLE G-14. TRAINING HOURS AND COSTS, TERMINAL OPTION, IFR TOWERS, FY 1974 (78 PERCENT SAMPLE)

	Full Performance	Pre-Developmental	Phase I	Phase II	Phase III	Phase IV	Phase V	Total Developmental
Complement Assigned								
Number	3,553	43	91	208	444	270	446	1.502
Average G.S. Grade	11.8	5.1	9.0	8.1	8.6	9.4	10.8	--
Salary Rate-Annual	19,190	8,147	12,170	11,510	12,100	13,490	15,370	13,13[illegible]
PC&B-Annual* (000)	87,282	448	1,418	3,064	6,877	4,662	8,774	25,2[illegible]
PC&B-Hourly	11.81	5.08	7.48	7.09	7.44	8.30	[illegible]	8.08
Total Man-Hours** (000)	8,395	80.8	171.1	491.0	834.7	507.6	838.5	2,823.8
Classroom Training								
Student Hours (000)	--	4.4	28.3	53.4	67.3	36.9	57.7	248.1
Instructor Hours (000)	--	4.6	28.1	33.4	44.7	46.7	49.5	206.9
Student-Instructor Ratio	--	.96	1.01	1.60	1.51	.79	1.17	1.20
Student-Staff Ratio	--	1.97	2.07	3.28	3.09	1.62	2.40	2.46
Student PC&B (000)	--	[illegible]	212	878	501	306	510	1,906
Number of Students	--	89	701	796	835	582	581	--
Number of Classes Begun	--	76	434	496	541	472	353	--
Avg. Length of Classes (Hours)	--	71	43	73	81	81	84	--
Weighted Avg. Lngth of Classes (Hours)	--	50	42	67	81	63	99	--
Avg. Class Size	--	1.2	1.0	1.6	1.5	1.2	1.6	--
Self Study								
Student Hours (000)	--	2.4	38.8	48.3	99.6	56.9	22.4	268.4
Instructor Hours (000)	--	.3	5.0	6.2	12.8	7.3	2.9	34.4
Student Hours/Instructor Hour	--	--	--	--	--	--	--	7.8
Student PC&B (000)	--	12	200	512	741	475	211	2,069
Number of Students	--	52	664	682	808	455	398	--
Avg. Lngth of Training (Hrs)	--	122	75	97	218	205	63	--
Weighted Avg. Lngth of Trng (Hours)	--	47	58	72	123	125	56	--
OJT								
Student Hours (000)	--	5.1	17.4	87.7	182.5	69.1	152.1	513.9
Instructor Hours (000)	--	.6	2.2	11.2	23.4	8.9	19.5	65.9
Student Hours/Instructor Hour	--	--	--	--	--	--	--	7.8
Student PC&B	--	25	130	621	1,868	573	1,458	4,115
Number of Students	--	56	450	1,059	1,127	700	762	--
Avg. Lngth of Training (Hrs)	--	107	49	110	184	136	196	--
Weighted Avg. Lngth of Trng (Hours)	--	91	39	83	162	99	200	--
Detailed to Academy	--	41	--	498	--	327	297	--
Student Hours (000)	--	27.9	--	48.2	--	73.2	35.6	185.0
Student PC&B (000)	--	110	--	842	--	607	350	1,42[illegible]
Non-Training Time								
Total Man-Hours (000)	--	80.8	171.1	391.0	834.7	507.6	838.5	2,823.8
Less-Classroom Hours (000)	--	--	--	--	--	--	--	248.1
Academy Hours (000)	--	--	--	--	--	--	--	185.0
Self Study Hours (000)	--	--	--	--	--	--	--	268.4
OJT Hours (000)	--	--	--	--	--	--	--	513.9
Other Trng. Hours (000)	--	--	--	--	--	--	--	110.1
Non-Training Hours (000)	--	42.9	90.8	207.5	442.9	269.3	444.9	1,498.3
Non-Training PC&B (000)	--	215	680	1,471	3,29[illegible]	[illegible]	1,[illegible]	12,10[illegible]
Leaving Training Program	--	27	71	90	125	62	85	--
In Passing Status	--	27	69	84	82	57	53	--
In Failing Status	--	0	2	6	43	5	32	--
Training Failures								
Classroom/Self Study	--	2	0	4	10	3	3	--
OJT	--	0	1	5	34	6	31	--
Discrepancy	--	-2	1	-3	-1	-4	-2	--
Drop-Out Rate (%)	--	21	10	7	11	7	10	--
Primarily During	--	Classroom	Classroom	Classroom		OJT	OJT	--
Cumulative Drop-Out Rate (%)	--	--	10	16	26	31	38	--

TABLE G-14. (Continued)

	Remedial	Supplemental	Refresher	General	Total
Other Training					
Full Performance					
Number Entering	356	3,266	3,549	1,702	--
Avg. Duration (Hours)	14	53	53	82	--
Weighted Avg. Lngth of Trng. (Hrs)	*23*	*79*	*47*	*81*	--
Student Hours (000)	8.3	258.2	167.9	137.4	571.8
Instructor Hours (000)	*1.1*	*34.0*	*22.1*	*18.1*	*75.2*
Student Hrs/Instructor Hrs	--	--	--	--	*7.6*
Student PC&B (000)	*98*	*3,049*	*1,983*	*1,623*	*6,[illegible]*
Developmentals					
Number Entering	151	1,524	1,188	528	--
Avg. Duration (Hours)	16	21	76	21	--
Student Hours (000)	1.8	21.5	79.6	7.1	110.1
Instructor Hours (000)	*.2*	*2.8*	*10.5*	*.9*	*14.5*
Student Hrs/Instructor Hour	--	--	--	--	*7.6*
Student PC&B (000)	*16*	*174*	*643*	*57*	*890*

	Total	Classroom Qualification	Other Qualification	Other Training	Training Administration	Other
Instructor Man-Months						
Full Time (EPDO/EPDS)	791	--	--	--	--	[illegible]
Part Time/Temporary Detail	1,319	--	--	--	--	[illegible]
Total	2,110	--	--	--	--	--
Allocation by Function (%)	100	22.2	22.0	19.8	28.0	8.0
Training Man-Hours by Function (000)	*[illegible]91.[illegible]*	*70.3*	*69.6*	*62.7*	*88.6*	--
Adjusted Man-Hours by Function (000)	*291.2*	*101.0*	*100.0*	*90.1*	--	--
PC&B by Function (000)	*3,553*	*1,237*	*1,090*	--	--	--

*Includes benefits at 28 percent

**Man-Year: Full Performance 1800 Hours
Developmental 1880 Hours

Note: *Italics:* Derived Values.

TABLE G-15. TRAINING HOURS AND COSTS, TERMINAL OPTION, VFR TOWERS, FY 1974 (70 PERCENT SAMPLE)

	Full Performance	Pre-Developmental	Phase I	Phase II	Phase III	Phase IV	Phase V	Total Developmental
Complement Assigned								
Number	984	50	67	123	263	19	3	525
Average G.S. Grade	10.5	4.4	6.9	7.2	8.1	9.2	9.0	--
Salary Rate-Annual	15,900	7,540	9,870	10,520	11,890	13,240	12,980	10,954
PC&B-Annual* (000)	20,024	483	846	1,657	4,003	322	50	7,361
PC&B-Hourly	9.79	4.67	6.07	6.17	7.32	8.15	7.98	6.73
Total Man-Hours** (000)	1,771	94	126	231	494	36	6	987
Classroom Training								
Student Hours (000)	--	10.1	9.7	15.5	19.9	.7	.3	56.2
Instructor Hours (000)	--	2.9	7.9	11.8	16.6	.1	.1	39.4
Student-Instructor Ratio	--	3.49	1.24	1.31	1.20	5.55	3.00	1.13
Student-Staff Ratio	--	5.98	2.12	2.24	2.00	9.51	5.14	2.44
Student PC&B (000)	--	47	59	100	115	5	2	350
Number of Students	--	68	232	235	206	9	27	--
Number of Classes Begun	--	42	170	182	167	2	9	--
Avg. Lngth of Classes (Hrs)	--	77	51	71	107	58	12	--
Avg. Weighted Lngth of Classes (Hrs)	--	148	42	66	96	81	12	--
Avg. Class Size	--	1.6	1.4	1.3	1.2	4.5	3.0	--
Self Study								
Student Hours (000)	--	17.3	38.6	39.8	65.6	3.4	.1	164.8
Instructor Hours (000)	--	2.3	5.2	5.4	8.8	.5	0	22.2
Student Hours/Instructor Hour	--	--	--	--	--	--	--	7.43
Student PC&B (000)	--	80	234	258	180	28	1	1,079
Number of Students	--	84	332	336	326	25	27	--
Avg. Lngth of Trng (Hrs)	--	191	110	117	206	176	4	--
Weighted Avg. Lngth of Training (Hrs)	--	206	110	118	201	136	4	--
OJT								
Student Hours (000)	--	9.5	23.1	49.4	108.9	10.9	.5	202.3
Instructor Hours (000)	--	1.3	3.1	6.6	14.6	1.5	.1	27.2
Student Hrs/Instructor Hour	--	--	--	--	--	--	--	7.43
Student PC&B	--	14	110	323	797	83	3	1,495
Number of Students	--	60	317	430	418	44	27	--
Avg. Lngth of Trng (Hours)	--	190	87	123	296	197	20	--
Weighted Avg. Lngth of Training (Hrs)	--	168	73	115	261	248	19	--
Detailed to Academy	--	47	--	122	--	2	0	--
Student Hours (000)	--	32.0	--	11.8	--	.4	0	44.2
Student PC&B (000)	--	118	--	70	--	--	--	221
Non-Training Time								
Total Man Hours (000)	--	94.0	126.0	231.2	494.4	35.7	5.6	987.0
Less-Classroom Hours (000)	--	--	--	--	--	--	--	56.2
Academy Hours (000)	--	--	--	--	--	--	--	44.2
Self-Study Hours (000)	--	--	--	--	--	--	--	164.8
OJT Hours (000)	--	--	--	--	--	--	--	202.3
Other Trng Hours (000)	--	--	--	--	--	--	--	138.3
Non-Training Hours (000)	--	34.3	48.7	89.3	190.9	13.8	2.2	381.2
Non-Training PC&B (000)	--	166	296	578	1,397	112	17	[illegible]
Leaving Training Program	--	10	43	48	79	4	0	--
In Passing Status	--	7	42	44	66	3	0	--
In Failing Status	--	3	1	4	13	1	0	--
Training Failures								
Classroom/Self Study	--	1	3	0	3	2	0	--
OJT	--	1	3	3	10	1	0	--
Discrepancy	--	1	-5	1	0	2	0	--
Drop-out Rate (%)	--	12	13	11	19	-	--	--
Primarily During	--	Classroom	Classroom	Split	OJT	OJT	--	--
Cumulative Drop-out Rate (%)	--	--	13	23	37	--	--	--

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TABLE G-15. (Continued)

	Remedial	Supplemental	Refresher	General	Total
Other Training					
Full Performance					
Number Entering	56	949	1,276	532	
Avg. Duration (Hours)	25	34	32	57	--
Weighted Avg. Lngth of Trng. (Hrs)	15	30	24	64	--
Student Hours (000)	.8	28.1	30.6	34.0	93.6
Instructor Hours (000)	*.2*	*6.0*	*6.5*	*7.3*	*20.0*
Student Hrs/Instructor Hrs	--	--	--	--	*4.69*
Student PC&B (000)	*8*	*275*	*299*	*333*	*915*
Developmentals					
Number Entering	37	401	337	218	
Avg. Duration (Hours)	26	60	23	118	--
Weighted Avg. Lngth of Trng. (Hrs)	*50*	*116*	*40*	*350*	--
Student Hours (000)	1.9	46.5	13.6	76.4	138.3
Instructor Hours (000)	*.4*	*9.9*	*2.9*	*16.3*	*29.5*
Student Hours/Instructor Hours	--	--	--	--	*4.69*
Student PC&B (000)	[illegible]	*311*	*91*	*515*	*933*

	Total	Classroom Qualification	Other Qualification	Other Training	Training Administration	Other
Instructor Man-Months						
Full Time (EPDO/EPDS)	602	--	--	--	--	--
Part Time/Temporary Detail	216	--	--	--	--	--
Total	818	--	--	--	--	--
Allocation by Function (%)	100	14.2	30.2	30.2	24.6	.9
Training Man-Hours by Function (000)	*121.8*	*17.4*	*37.1*	*37.1*	*30.2*	[illegible]
Adjusted Man-Hours by Function (000)	*121.8*	*23.0*	*49.4*	*49.4*	--	--
PC&B by Function (000)	*1,316*	*755*	*505*	*505*	--	--

*Includes benefits at 28 percent

**Man-Year: Full Performance 1800 hours
Developmental 1880 hours

Note: *Italics:* Derived Values.

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TABLE G-16. COMPARISON OF FIELD FACILITY EMPLOYMENT REPORT OF 30 APRIL 1974 WITH RESULTS OF IDA SURVEY OF EN ROUTE CENTERS

	Field Facility Employment Report, 4/30/74	IDA Survey Returns	Projected Number for 100% Survey Returns	Projected Number as Percentage of Employment Report
Full-Performance Controllers	5,523	5,221	5,496	96%
Developmentals	2,534	2,238	2,356	96
Trainees	161	225	237	
Supervisors[a]	1,582	1,039	1,094	69%
EPDOs/EPDSs	225	161	169	75
TOTAL	10,025	8,884	9,352	93%

[a]Other than facility chiefs and deputy chiefs.

in the field facility employment report. This seems to produce a large discrepancy between the report and the survey data in the numbers of supervisors, which may be explainable in terms of definitional ambiguity, since the questionnaire did not ask explicitly for supervisory personnel. The discrepancy in EPDOs and EPDSs cannot be thus explained, however.

A total of 394 questionnaires was also sent to facilities performing tower functions (VFR towers, non-radar IFR towers, TRACONs, tower/TRACONs, RAPCONs, combined station/towers, and other facility types). A total of 339 surveys was returned, 317 of which are represented in the data contained in Tables G-14 and G-15. (Returns from 22 RAPCONs were not included in the data sample, since traffic data were not available.) The total returns were divided into two classes, VFR and IFR, on the basis of training requirements.

A comparison of the number of returns in each class with the total number of field installations leads to the conclusion that the reduced sample represents 70 percent of all VFR tower controllers and 78 percent of controllers in all other terminal facilities. These percentages were verified by projecting the total number of controllers in each class and comparing the total with that reported in the Field Facility Employment Summary of 30 April 1974. The result of this comparison was a 2 percent difference in projected controller complements (Table G-17).

4. Student-to-Instructor Ratio

Instructor hours for classroom training are based upon reported student hours and student-to-instructor ratios. The student-to-staff ratio is an adjustment of the student-to-instructor ratio to account for total instructor man-hours devoted to classroom teaching as reported by the individual facilities. For the en route centers as well as the Academy, the student-to-staff ratio is approximately one-half the student-to-instructor ratio. On the other hand, for both types of terminal facilities the student-to-instructor ratio is approximately one-half the student-to-staff ratio (Table G-18).

TABLE G-17. SURVEY RESPONSE FROM TERMINAL FACILITIES

	Facilities				Personnel		
	Population[a]	Survey Returns	Sample Size	Sample as Percentage of Population	Authorized Controllers in Sample	Average Author-izations	Projection of Controllers in Universe
VFR Towers	204	143	143	70%	1,290	9.0	1,843
Other Towers							
IFR	46	49	49				
Tower/TRACONs, TRACONs	126	84	84				
Other	50	63	41[b]				
Total, Other Towers	222	196	174	78%	4,857	27.9	6,227
SURVEY TOTAL					6,147		8,070
Total Terminal Controllers[c]					7,899		7,899
Difference					1,752		171
Percentage Difference					22%		2%

[a]Source: FAA (1974b).
[b]Excludes survey returns from 22 RAPCONs with 669 authorized positions.
[c]Source: FAA (1974a).

TABLE G-18. COMPARISONS OF STUDENT-TO-INSTRUCTOR AND STUDENT-TO-STAFF RATIOS

	FAA Academy (Table G-10)	En Route Centers (Table G-13)	IFR Terminals (Table G-14)	VFR Terminals (Table G-15)
Students per Instructor	3.6	4.77	1.20	1.43
Students per Staff Member	1.7	2.40	2.46	2.44

There is no basic reason for this reversed ratio in the case of the terminal facilities. One suspects that the reported percentage breakdown of instructor time devoted to different training functions is erroneous in the case of the terminals reported. As a result, instructor support hours devoted to self-study, OJT, and other training are suspect, since they were derived from the percentage breakdowns.

These considerations should not affect the total costs of training, however. Salaries of students in training are based upon training hours and hourly equivalent PC&B at the reported grade levels of developmentals, including a .28 percent benefit rate. Instructor salary costs are based upon reported total instructor man-hours and a similarly calculated hourly PC&B rate.

5. Training Program Length

The survey shows marked differences between facilities in training program durations for the same phases and modes of training. This is shown by the differences in weighted and unweighted averages of lengths of training in each table. The unweighted average is the average of the training period (of a given phase and mode) reported by each facility:

$$\frac{\Sigma \text{ training period reported}}{\text{number of facilities reporting}} .$$

The weighted average is the sum, across all facilities, of the product (number of students entering x length of training) for each facility divided by the total number of students entering training in all facilities:

$$\frac{\Sigma \text{ (number of students x length of training)}}{\Sigma \text{ (number of students)}} .$$

The difference between these two averages will be most pronounced when a relatively small number of students undergoes a training period quite different from that undergone by the remainder of students.

6. Mobility

Personnel in the Office of Training seem to believe that there is quite limited mobility among both qualified and developmental controllers, especially with regard to personnel transferring between facilities of the same option. The results of the survey and follow-up conversations with field personnel bring this belief into serious doubt. Unfortunately, the survey did not explicitly ask for data on this point (the origins of personnel new to the facilities or the disposition of those leaving the training programs). If interfacility mobility is, in fact, extensive, it carries implications for both program costs and program design to take advantage of it. It also resurrects an issue raised in the Corson Report (Corson et al., 1970): standardization of training and control procedures and the staffing of busy and large city facilities are still viewed as problems by a significant proportion of facility personnel contacted.

7. Developmental Time Spent in Other Than Training

The rationale for including some portion of developmentals' salaries while they are not in actual training has been discussed. In addition to the problem of assigning some fraction of these salaries to training, there is the question of the average time developmentals spend in "other than training" by phase of training. Non-training time estimates were derived indirectly. Total developmental man-years were determined on the basis of the total year-end complement of developmentals. Total training time was subtracted to arrive at total nontraining time and was allocated to training phases according to the year-end complements. Implicit in this method is the assumption that developmentals spend a total time in each phase proportional to time spent in actual training. While it is recognized that there will be differing impacts of the Whitten Amendment and of queueing to enter training by phase, the available data did not permit measurement of actual times spent.

IV. ESTIMATING COSTS OF ALTERNATIVE TRAINING PROGRAMS

In developing estimates of alternative training programs a different technique from the 1974 cost procedure discussed previously was employed. A standard entry level of GS-7 was assumed, and the Whitten Amendment was assumed to be the critical constraint. Thus, if the full-performance grade level of a certain type of facility is GS-12 or GS-13, a 3-year developmental period is assumed and non-training time is taken as the difference between 3 years and the actual training time. For facilities with full-performance GS levels of GS-10 or less, a developmental period of 2 years was assumed. Non-training time and PC&B costs were then determined on the basis of associating a "characteristic" grade level with each training phase and assuming promotions occur once a year.

This estimation process is designed to make cost comparisons between alternative training programs whose principal differences lie in where training occurs and in the length of the developmental period (from initial hiring to full qualification). In this comparison the differences in costs are considered more significant than the levels of cost.

A. FIXED COSTS

The costs of a number of organizations and activities necessary to a training program but whose levels are considered insensitive to training loads are not included in the calculations. Those activities include all fixed-cost elements of Table G-2.

B. VARIABLE COSTS

Estimates of variable costs for each alternative program are prepared by defining each program as a sequence of training blocks, each identified with location, duration, and other cost generating characteristics. Total variable costs of a program alternative equal the sum of costs of all blocks defining the program. Costs are

estimated on a "per student day" basis and are aggregated across duration of block and number of students to obtain total costs. Costs of each block are estimated in a similar manner and according to categories consistent with Table G-2. The numbers of students entering each block of training are set so that 1000 students successfully complete each of the three training programs (en route, terminal VFR, and terminal approach control), assuming the dropout rates experienced by each option during FY 1974 (Table G-18). Training program total costs for the five alternative training program concepts are based on the 1000-graduate level. Table G-19 displays the relations employed by the model. Table G-20 gives the meanings of the input terms.

C. SPECIFICATIONS OF ALTERNATIVES

Tables G-21 and G-22 list the specifications that were assumed for the alternative programs described in Appendix H. In addition to the items displayed in those tables, the following are to be noted:

- Instructor GS grades were assumed as follows:

  En route centers--GS-13
  IFR terminals--GS-12
  VFR terminals--GS-11
  All Academy--GS-13.

- A benefits rate of 28 percent was assumed for all students and instructors.

- A per diem rate of $25 was assumed, regardless of the duration of continuous training. A travel rate of $200 was assumed for each trip to the Academy. For the accelerated Academy alternative, a single trip was assumed. For the extended Academy and present program alternatives, a trip was assumed for each phase with the exception of terminal Phase V, where instruction was assumed contiguous with Phase IV.

TABLE G-19. OUTPUTS AND RELATIONSHIPS

Student PC&B per Student Day (Daily Attendance)

$$R = \left(\frac{G + 16}{G}\right)\left(\frac{1.28C}{260}\right) \text{, centralized training}$$

$$R = \frac{1.28C}{260} \text{, local training}$$

Student Per Diem per Student Day (Daily Attendance)

$$S = \left(\frac{G + 16}{G}\right)\left(\frac{7}{5}\right) E \text{, centralized training.}$$

$$S = 0 \text{, local training}$$

Student Travel Cost per Student Day (Daily Attendance)

$$T = \frac{F}{G/8} \text{, centralized training}$$

$$T = 0 \text{, local training}$$

Instructional & Support Staff Cost per Student Day (Daily Attendance)

$$Q = \left(\frac{1}{D}\right)\left[\frac{(1 - B)(1.28A)}{260}\right]$$

Training Cost per Student Day (Daily Attendance)

$$U = Q + R + S + T$$

Training Cost per Student (Successfully) Completing Training Block

$$V = \left[\frac{1}{(1 - I)}\right] U \left(\frac{G}{8}\right)$$

Training Cost of All Students (Successfully) Completing Training Block

$$W = VJ$$

Total Costs per Student Generated by Training Block, Including Student PC&B Incurred During Nontraining Time

$$Y = V + \left[\left(\frac{1 - H}{H}\right) G \left(\frac{1.28C}{2080}\right)\right] (1 - K)$$

Total Costs Generated by Training Block, Including Student PC&B Incurred During Nontraining Time

$$Z = YJ$$

Instructor Man-Year Requirements Generated by All Students in Training Block

$$X = \left(\frac{1}{1 - I}\right)\left(\frac{J}{D}\right)\left(\frac{G}{2080}\right)$$

- The terminal VFR program includes Phases I, II, and III along with the local control portion of facility check-out for the accelerated program alternatives. The terminal IFR program covers all phases, including facility check-out for both local and approach control.

TABLE G-20. INPUT TERMS AND THEIR MEANINGS

Input Term	Meaning
A	Annual salary rate of instructors
B	Support staff cost ratio--support staff cost as a proportion of instructional staff PC&B
C	Annual salary rate of students
D	Student-to-staff ratio (student hours/instructor hours)
E	Student per diem rate
F	Travel rate (travel cost per student per training block)
G	Length of training block (hours of training time)
H	Proportion of time in training (ratio of time spent in training to total time of training phase)
I	Failure/drop-out rate (ratio of students not completing training block to those beginning training block)
J	Number of students completing training block
K	Student relative value rate [proportion of student PC&B representing students' worth in traffic control; proportion (1-K) chargeable to training costs]

TABLE G-21. ALTERNATIVE EN ROUTE PROGRAMS--SPECIFICATIONS USED[a]

Alternative	Phase[b]	Location	Hours by Mode: Classroom/ Laboratory	Hours by Mode: OJT	Hours by Mode: Simulation	Student-to-Staff Ratio	Failure/ Drop-Out Rate	Student GS Grade Level	Cumulative Elapsed Time From Initial Entry	Remarks
Accelerated Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	IIN	Academy	304	--	--	1.7	0.14	7	--	
	IIR	Academy	40	--	--	8.0	0.00	7	--	
	IIR	Academy	--	--	200	2.0	0.05	7	--	
	IIIN	Academy	--	--	100	2.0	0.13	7	--	
	IIIR	Academy	--	--	200	2.0	0.15	7	~8 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	
Extended Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	
	IIR	Academy	40	--	--	8.0	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	--	100	2.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Present Program	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	25% of students
	IIN	Facility	350	--	--	1.7	0.14	9	--	75% of students
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.8	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Extended Facility	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Facility	350	--	--	1.7	0.14	9	--	
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.8	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	C.15	11	3 years	
Accelerated Facility	I	Facility	340	--	--	2.9	(.05	7	--	
	IIN	Facility	350	--	--	1.7	(.14	7	--	
	IIR	Facility	40	--	--	2.9	0.00	7	--	
	IIR	Facility	--	--	200	2.0	0.05	7	--	
	IIIN	Facility	--	--	100	2.0	0.13	7	--	
	IIIR	Facility	--	--	200	2.0	0.15	7	~8 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	

[a]Derived from IDA survey.

[b]"N" and "R" signify non-radar and radar, respectively.

TABLE G-22. ALTERNATIVE TERMINAL PROGRAMS--SPECIFICATIONS USED[a]

Alternative	Phase	Location	Hours by Mode: Classroom/Laboratory	Hours by Mode: OJT	Hours by Mode: Simulation	Student-to-Staff Ratio	Failure/Drop-Out Rate[b]	Student GS Grade Level	Cumulative Elapsed Time from Initial Entry	Remarks
Accelerated Academy	I	Academy	120	--	--	8.0	0.10/0.13	7	--	
	II	Academy	96	--	--	2.8	0.07/0.11	7	--	
	III	Academy	200	--	--	2.8	0.11/0.19	7	--	
	IV	Academy	224	--	--	2.4	0.07/--	7	--	
	IV	Academy	--	--	100	2.0	0.00/--	7	--	
	V	Academy	120	--	--	1.8	0.00/--	7	--	
	V	Academy	--	--	200	2.0	0.10/--	7	~6 months	
	Checkout	Facility	--	120	--	7.5	0.00/0.00	10	--	Local
	Checkout	Facility	--	--	50	2.0	0.00/--	10	--	Approach
Extended Academy	I	Academy	120	--	--	8.0	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Academy	96	--	--	2.8	0.00/0.00	9	--	
	II	Facility	--	90	--	7.5	0.07/0.11	9	--	
	III	Academy	200	--	--	2.8	0.00/0.00	9	--	
	III	Facility	--	190	--	7.5	0.11/0.19	9	2 years	
	IV	Academy	224	--	--	2.4	0.00/--	10	--	
	IV	Facility	--	--	100	2.0	0.07/--	10	--	
	V	Academy	120	--	--	1.8	0.00/--	10	--	
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Present Program	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Academy	96	--	--	2.8	0.07/0.11	9	--	45% of students
	II	Facility	140	--	--	2.8	0.07/0.11	9	--	55% of students
	II	Facility	--	90	--	7.5	0.00/0.00	9	--	
	III	Facility	200	--	--	2.5	0.11/0.19	9	--	
	III	Facility	--	190	--	7.5	0.00/0.00	9	2 years	
	IV	Academy	224	--	--	2.4	0.07/--	10	--	40% of students
	IV	Facility	192	--	--	1.6	0.07/--	10	--	60% of students
	IV	Facility	--	100	--	7.5	0.00/--	10	--	
	V	Academy	120	--	--	1.8	0.00/--	10	--	50% of students
	V	Facility	160	--	--	2.4	0.00/--	10	--	50% of students
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Extended Facility	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Facility	140	--	--	2.8	0.07/0.11	9	--	
	II	Facility	--	90	--	7.5	0.00/0.00	9	--	
	III	Facility	200	--	--	2.5	0.11/0.19	9	--	
	III	Facility	--	190	--	7.5	0.00/0.00	9	2 years	
	IV	Facility	192	--	--	1.6	0.07/--	10	--	
	IV	Facility	--	100	--	7.5	0.00/--	10	--	
	V	Facility	160	--	--	2.4	0.00/--	10	--	
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Accelerated Facility	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	II	Facility	96	--	--	2.8	0.07/0.11	7	--	
	III	Facility	200	--	--	2.5	0.00/0.00	7	--	
	III	Facility	--	100	--	7.5	0.11/0.19	7	--	400 hours elapsed
	IV	Facility	192	--	--	1.6	0.07/--	7	--	
	IV	Facility	--	--	100	2.0	0.00/--	7	--	
	V	Facility	160	--	--	2.4	0.00/--	7	--	
	V	Facility	--	--	200	2.0	0.10/--	7	~10 months	
	Checkout	Facility	--	50	--	7.5	0.00/0.00	10	--	Local
	Checkout	Facility	--	--	50	2.0	0.00/--	10	--	Approach

[a]Derived from IDA Survey.

[b]First value is IFR terminal rate, and second is VFR terminal rate.

V. ESTIMATION OF POTENTIAL SAVINGS FROM SEVERAL SOURCES

A. REDUCTION OF FLUCTUATIONS IN TRAINING LOAD

Table G-23 displays beginning enrollments at the Academy over a period of 28 quarters (7 years). Figure G-1 is a histogram of the quarterly data. From the histogram one can conclude there has been no typical enrollment level (or central tendency).

There are no apparent trends or longer term increases or decreases; that is, the fluctuations are short-term (one or two quarters) and present a nearly random appearance. The randomness is also evident when sequential quarters and years are rank-ordered as in the last column of Table G-23. In neither the quarterly nor the yearly enrollments are there bunchings of adjacent rank orders. The random sequence could well have resulted from drawing the numbers of enrollments from a hat.

In calculating the added costs of capacity to meet such fluctuating demand, it is assumed that Academy capacity is fixed throughout the 7-year period at a level that permits entry of all applicants for a given percentage of the time with no delay. Then, several percentage levels are chosen and capacity is calculated as follows (Fig. G-2 and Table G-24):

- 100 percent level. All applicants for entry are admitted; the Academy has a capacity to meet the maximum demand experienced (3100 per quarter). Total enrollment capacity over the 28 quarters would be 3100 x 28 = 86,800. Actual enrolments were close to 23,000, for a 26 percent average use of capacity.
- 90 percent level. All applicants are admitted in 90 percent of all quarters. Capacity is 1150 per quarter (Fig. G-2). Total enrollment capacity over the 28 quarters would be 32,200. Enrollment demands could not have been met in only three of the 28 quarters, and a total of 20,750 would have

TABLE G-23. STUDENTS ENTERING FAA ACADEMY BY QUARTER AND YEAR, FY 1968-1974[a]

Fiscal Year	Quarter	Enrollments Quarterly	Enrollments Annual	Enrollment Rank Quarterly	Enrollment Rank Annual
1968			1790		7
	1	510		22	
	2	390		25	
	3	490		23	
	4	400		24	
1969			2490		5
	1	180		28	
	2	720		15	
	3	390		25	
	4	1,200		3	
1970			5890		1
	1	3,100		1	
	2	660		18	
	3	1,400		2	
	4	730		14	
1971			3220		4
	1	700		16	
	2	670		17	
	3	1,030		6	
	4	820		11	
1972			4140		2
	1	1,180		4	
	2	1,070		5	
	3	950		7	
	4	940		8	
1973			2220		6
	1	760		13	
	2	630		19	
	3	300		27	
	4	530		21	
1974			3250		3
	1	910		9	
	2	630		19	
	3	900		10	
	4	810		12	

$\Sigma \approx 23,000$

$\overline{X} \approx 820$

[a]Source: FAA Academy training progress reports.

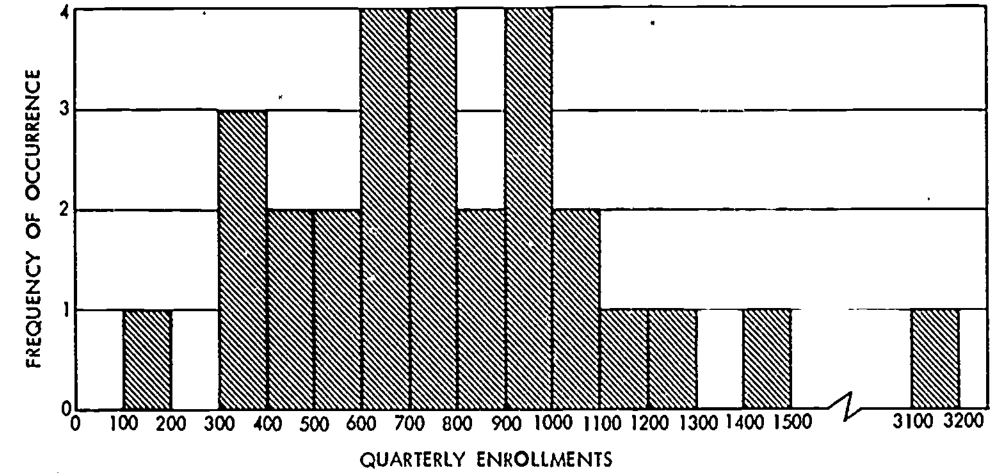

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FIGURE G-1. Frequency of Occurrence of Numbers of Beginning Enrollments at FAA Academy by Quarter, FY 1968-1974.

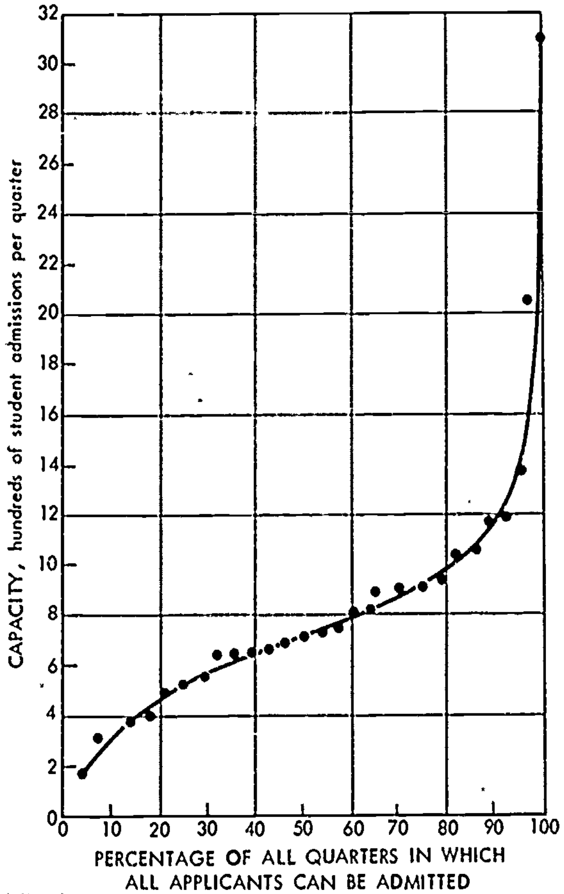

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FIGURE G-2. Capacity of FAA Academy to Admit Students Versus Percentage of All Quarters in Which All Applicants Can be Admitted, Based on Historical Data for 28 Quarters, FY 1968-1974 (Source: Table G-23).

been trained over the 28-quarter period, enrollments in those three quarters having been chopped off. The ratio of 20,750 to 32,200 indicates a 64 percent use of capacity and implies a potential for training roughly 11,500 additional students at the same Academy cost.

- 80 percent level. All applicants are admitted in 80 percent of all quarters. Capacity is 1000 per quarter (Fig. G-2). The Academy would have been sized to train 28,000 over the 28 quarters. Eliminating excesses of enrollments over 1000 in any quarter implies that 20,000 could have been trained in the 28-quarter period and that the Academy would have been used at 72 percent of capacity.
- 60 percent level. All applicants are admitted in 60 percent of all quarters. Capacity is 800 per quarter (Fig. G-2). Here, the total enrollment capacity throughout the 28-quarter period would be nearly equal to the actual enrollments. It is evident, however, that a planned capacity of 800 would involve delays in student admissions that could be avoided only by smoothing the flow of hires and demands for admission. If this were done, a planned capacity of about 800 would be a proper level for the Academy, based on the experience of the past 28 quarters.

TABLE G-24. POSSIBLE ENROLLMENTS AND QUARTERS OF UNDERCAPACITY AT FAA ACADEMY AT FOUR LEVELS OF CAPACITY, BASED ON HISTORICAL DATA FOR FY 1968-1974[a]

Capacity Level (Percentage of All Quarters in which Enrollment Demand Can Be Met)	Number of Quarters of Undercapacity (out of 28 Quarters)	Quarterly Enrollment Capacity	Total Enrollment Capacity (for 28 Quarters)
100%	0	3,100	86,800
90%	3	1,150	32,200
80%	6	1,000	28,000
60%	12	800	22,400

[a]Source: Fig. G-2 and Table G-23.

The effective (or average actual) level at which the Academy was sized during the 28-quarter period is unknown to this writer. The 80 percent and 90 percent levels appear to be reasonable guesses for upper and lower bounds. The ratios of the costs of the 80 percent and 90 percent levels to the "efficient capacity level" (i.e., 800 admissions per quarter) are as follows:

- 80 percent level. 1000/800 = 1.25 (20 percent of actual costs are attributable to fluctuating enrollments)
- 90 percent level. 1150/800 = 1.44 (30 percent of actual costs are attributable to fluctuating enrollments).

These values can be considered as minimums, since their derivation did not consider the mixes of enrollment demands or faculty qualifications by traffic control option. It can be expected that relative fluctuations by option (and hence the costs of excess capacity) would be greater when specialty restrictions are considered.

The Academy costs which are affected by these considerations are the fixed costs plus those variable costs associated with the Air Traffic Branch of the Academy (items A.1, A.3, A.4, A.7, B.1, and B.2 in Table G-2.) The total of these items in FY 1974 was $4.45 million. The savings by reduction in fluctuation, according to the calculations above, would have been somewhere between about $900,000 and $1.4 million for FY 1974.

B. REDUCTION OF LOSSES DURING TRAINING

This Section considers the potential cost savings that might accrue from improved selection and assignment. Little information is available on the actual effectiveness of various programs that might be undertaken to improve selection and assignment. Appendix D points out that the inclusion of new tests could increase accuracy of assignment from 25 percent (the random possibility of success) to 58 percent, and that assignments within the IFR terminal and en route center options could achieve accuracies of 75 to 80 percent. Even such figures are not translatable into training retention rates.

One can, however, calculate proportionate potential savings that would accrue from eliminating attrition or various proportions of it among trainees.

Attrition or loss rates include trainees who voluntarily leave the service as well as those who are dismissed for cause. The rate is the ratio of those leaving to the number entering training, by phase. These data are presented in Tables G-13, G-14, and G-15 and are summarized in Table G-25. It should be noted that the denominator of the ratio as used here depends on the particular case. In each case presented here the denominator is selected from the mode of training with the largest number of entrants as identified in the row marked "primarily during" in Tables G-13, G-14, and G-15. For en route centers, the cumulative dropout rate of the training program over the 4-year training period is over 40 percent for new hires at the GS-7 level and nearly 60 percent for those entering through the predevelopmental training program. For terminals, the dropout rates are also about 40 percent, even for VFR terminals where training ends with Phase III. These rates are as high as or higher than rates experienced in the late 1960s.

The possible cost savings through reduction of trainee losses are calculated with the following formula:

$$(\text{cost/student})[1 - (\text{failure rate})] ,$$

where the cost per student is calculated according to the method developed in Section IV of this Appendix, "Estimating Costs of Alternative Training Programs," and where the failure rate is taken from Tables G-13, G-14, and G-15, the facility survey data.

Table G-26 illustrates the calculation for the en route option. Each line is calculated according to the formula above. From the table it can be seen that cumulative losses increase the cost of training an en route controller from $22,235 to $33,163, or by approximately 50 percent. If losses could be completely eliminated,

TABLE G-25. CUMULATIVE IMPACT OF DROPOUT RATES

Phase: En Route	I	II Non-Radar	II Radar	III Non-Radar	III Radar
Phase: Terminal	I	II	III	IV	V
En Route Centers					
Dropout Rate	0.05	0.14	0.05	0.13	0.15
Rate of Success	0.95	0.84	0.95	0.87	0.85
Cum. Success Rate	0.95	0.80	0.76	0.66	0.56
Cum. Dropout Rate	0.05	0.20	0.24	0.34	0.44
Entries/1000 Completions	1,784	1,695	1,423	1,352	1,176
All Terminals					
Dropout Rate	0.11	0.09	0.13	0.07	0.09
Success Rate	0.89	0.91	0.87	0.93	0.91
Cum. Success Rate	0.89	0.81	0.70	0.66	0.60
Cum. Dropout Rate	0.11	0.19	0.30	0.34	0.40
Entries/1000 Completions	1,677	1,493	1,358	1,182	1,099
IFR Terminals					
Dropout Rate	0.10	0.07	0.11	0.07	0.10
Success Rate	0.90	0.93	0.89	0.93	0.90
Cum. Success Rate	0.90	0.84	0.74	0.69	0.62
Cum. Dropout Rate	0.10	0.16	0.26	0.31	0.38
Entries/1000 Completions	1,604	1,443	1,342	1,195	1,111
VFR Terminals					
Dropout Rate	0.13	0.11	0.19	--	--
Success Rate	0.87	0.89	0.81	--	--
Cum. Success Rate	0.87	0.77	0.63	--	--
Cum. Dropout Rate	0.13	0.23	0.37	--	--
Entries/1000 Completions	1,594	1,387	1,235	--	--

the cost of en route controller training would be reduced by 33 percent. This is the low point of the "en route" curve in Fig. G-3. Less than 100 percent reduction of attrition would increase costs as shown by the rest of the curve. Similar considerations apply to the reduction of losses of terminal controller trainees, as shown by the "terminal" curve in Fig. G-3.

TABLE G-26. CALCULATION OF COST OF DEVELOPMENTAL CONTROLLER LOSS RATES, EN ROUTE OPTION

Phase	Place	Mode	Calculation		
I	Facility	Class	\$ 4,319 x 0.95	=	\$ 4,103
I	Facility	OJT	873 x 1	=	873
II Non-Radar	Academy	Class	8,683 x 0.86 x (410/1423)[a]	=	2,152
II Non-Radar	Facility	Class	7,671 x 0.86 x (1013/1423)[a]	=	4,696
II Non-Radar	Facility	OJT	210 x 1	=	210
II Radar	Facility	Class	592 x 1	=	592
II Radar	Facility	Self-Study	3,643 x 0.95	=	3,461
III Non-Radar	Facility	OJT	2,607 x 0.87	=	2,268
III Radar	Facility	Self-Study	4,565 x 0.85	=	3,880
		Total	\$33,163 Total per Graduated Student		\$22,235

[a]Some students in this phase are trained at the Academy, the others at facilities. Proportions are used here.

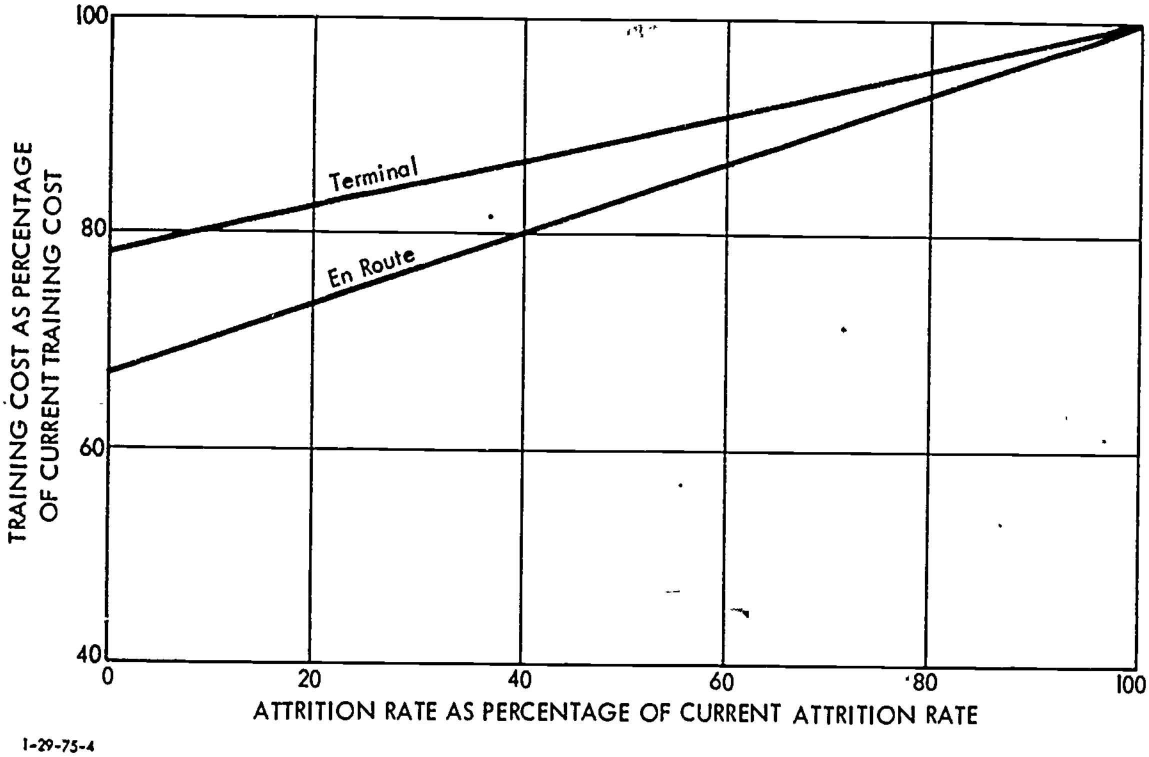

FIGURE G-3. Potential Reduction in Air Traffic Controller Training Costs through Reduction of Attrition During Training.

C. REDUCTION OF ELAPSED TIME IN TRAINING

Training of journeyman air traffic controllers is spread over 3 to 4 years of time, depending on option and kind of facility. During this period the developmental controller spends only a fraction of his time in actual training. The remainder is spent in assisting the other controllers or in doing other tasks at the facility that do not require a journeyman capability. Developmentals at facilities are underutilized now, and as automation of facilities increases the opportunities for using them productively diminish still further. Nevertheless, the developmentals continue to draw full salaries for their respective GS levels. Underutilization is therefore a cost of training that has been discussed earlier. It is a cost imposed by the present mode of performing training and seasoning, and an indication of the amount of such a cost seems useful.

In the cost analysis of alternative ways of training, two alternatives were hypothesized to be shorter than the present program, representing an elapsed training time equal to the actual training time. These data are presented in Table G-27. Subtracting the differences between the accelerated programs and the present program shown in this table gives possible savings from accelerated training (in millions of dollars per 1000 controllers trained) as shown in Table G-28.

The savings are a strong function of the proportion of developmental nontraining salary assigned to training cost. If no developmental time is so assigned, the savings are marginal and perhaps even negative. However, if all the nontraining time is considered to be nonproductive, savings of about $30 million to $48 million per 1000 controllers trained, depending on option, are indicated ($30,000 to $48,000 per trained journeyman). If nontraining time is considered to be 50 percent productive, these figures reduce to about $16 million to $26 million per 1000 controllers trained, or a saving of $16,000 to $26,000 per trained journeyman.

TABLE G-27. COMPARATIVE COSTS OF ALTERNATIVE WAYS OF TRAINING AIR TRAFFIC CONTROLLERS[a]

(dollars in millions per 1000 controllers trained)

	Percentage of Nontraining Time Salaries Charged to Training				
Option & Alternative	0%	25%	50%	75%	100%
En Route Centers					
Accelerated Academy	$33.6	--	--	--	--
Extended Academy	32.3	$43.4	$54.5	$65.6	$76.7
Present Program	29.9	41.3	52.6	64.0	75.4
Extended Facility	29.4	41.1	52.9	64.6	76.3
Accelerated Facility	27.2	--	--	--	--
IFR Terminals					
Accelerated Academy	25.8	--	--	--	--
Extended Academy	29.5	39.9	50.2	60.6	70.9
Present Program	24.2	34.3	44.3	54.4	64.5
Extended Facility	22.9	33.0	43.1	53.1	63.2
Accelerated Facility	18.7	--	--	--	--
VFR Terminals					
Accelerated Academy	10.6	--	--	--	--
Extended Academy	15.7	22.9	30.2	37.4	44.7
Present Program	12.8	19.8	26.9	33.9	41.0
Extended Facility	12.5	19.6	26.7	33.7	40.7
Accelerated Facility	8.2	--	--	--	--

[a]Formulas for calculating these costs are given in Tables G-19 and G-20.

TABLE G-28. SAVINGS OF ACCELERATED CONTROLLER TRAINING PROGRAMS

(dollars in millions per 1000 controllers trained)

Option	Percentage of Nontraining Time Salaries Charged to Training				
	0%	25%	50%	75%	100%
En Route Centers					
Accelerated Academy	-$3.7	$ 7.7	$19.0	$30.4	$41.8
Accelerated Facility	2.7	14.1	25.4	36.8	48.2
IFR Terminals					
Accelerated Academy	-1.6	8.5	18.5	28.6	38.7
Accelerated Facility	6.3	15.6	25.6	35.7	45.8
VFR Terminals					
Accelerated Academy	2.2	9.2	16.3	23.3	30.4
Accelerated Facility	4.3	11.6	18.7	25.7	32.8

D. USE OF SIMULATORS

Computers associated with simulators of the types being considered for training and refreshing traffic controllers can be programmed to provide such bookkeeping functions as grading and maintaining records. This would relieve instructors and administrators of some chores, but it is not certain that this would amount to much in cost savings. Since instructors would be likely to employ any time thus gained in additional instruction or in review of simulated problems, the major benefits of simulators are much more likely to be realized as better opportunities for improving instruction and objectively testing candidates, rather than as cost savings.

VI. SUMMARY OF FINDINGS

A. COSTS OF TRAINING CONTROLLERS

In 1974 the FAA spent something between $61 million and $115 million on developmental and proficiency training of en route and terminal air traffic controllers. These costs almost totally comprise personnel compensation and benefits, travel, and per diem, and they do not include costs associated with the procurement or rental of facilities. The range of values presented here and in the following discussion results from whatever assumption is made about the allocation of developmental controllers' pay and benefits when they are not actually receiving training. The higher cost estimate applies if it is assumed that 100 percent of these costs are applied to training; the lower cost applies if it is assumed that the developmental controllers have full productivity and utility commensurate with their grade when they are not receiving training.

The cost of training a single controller is a function of the control option, with the range of costs again due to the assumptions described above.

Option	Minimum	Maximum
En Route	$27,000	$77,000
IFR Terminal	19,000	71,000
VFR Terminal	8,000	45,000

Some portion of these costs is incurred through inefficiencies in the selection and training system, and a very significant fraction is caused by rules under which the FAA is presently operating.

B. COSTS OF ALTERNATIVE TRAINING METHODS

Of five alternative training programs for developmental controllers examined in this study, two offer an opportunity for substantial savings. The common characteristic of these two is that they are

short, taking only enough elapsed time to cover the formal training now being given over a considerably longer period of time. While this mode of training could produce substantial savings, there may be difficulties in implementing it. Perhaps, in the long run, the figures given in Section C below may be useful in helping to bring about changes.

Cost differences between training at the FAA Academy and at the field facilities are small, with whatever differences there may be favoring the facilities because of lower travel and per diem costs.

C. POTENTIAL SAVINGS FROM VARIOUS SOURCES

Three possible savings sources are the following:

1. Smoothing out the flow of students at the FAA Academy and staffing the Academy to deal with a steady load. This could produce a saving of between 20 and 30 percent of the cost of Academy operations associated with training developmental controllers, which translates into something between $0.9 million and $1.4 million in 1974. (This range of values does not result from the earlier assumptions about the productivity of developmental controllers, but rather from assumptions about the staffing level of the Academy.)

2. Improving selection procedures to reduce the losses of developmentals during training. This could reduce the cost of training (per individual trained) by a maximum of 22 percent for the terminal option and 33 percent for the en route option. Since these figures are based on 100 percent reduction of losses during training, any lesser success in reducing losses would lower these figures proportionately (e.g., a 50 percent reduction of trainee losses would provide cost reductions of about 10 percent in terminal training and 16 percent in en route training).

3. <u>Acceleration of training and earlier screening (as discussed in Section III-C above)</u>. This could reduce training costs per individual by as much as $48,000 (1974 costs), depending on the option and the assumption made about the degree of productivity of developmentals when not actually training.

APPENDIX H

ALTERNATIVE DEVELOPMENTAL TRAINING PROGRAMS

CONTENTS

This Appendix identifies and evaluates alternative procedures currently and potentially available to meet the training needs of developmentals. The alternatives reflect differences in degree of centralization and differences in the duration of training, both of which are issues of concern to the Federal Aviation Administration (FAA).

A. DESCRIPTION OF ALTERNATIVES

Five alternative approaches to the training of developmentals are postulated. The differentiating factors are training location and elapsed time of training. The training process and scheduling are not considered as significant differentiating variables. In each of the alternatives, each student is assumed to receive the same training and to undergo the same improved selection process, as proposed and discussed in Appendix D.

1. Accelerated Academy

In this alternative, the student would receive al his academic training at a centralized facility such as the FAA Academy at Oklahoma City. The initial training would be continuous and completed over a period of approximately 6 to 9 months and would include simulation to prepare the student for final sector or position qualification at his home facility. A capability to simulate both en route and terminal facilities would be maintained at the Academy. Separate courses would be scheduled for controllers destined for en route, instrument flight rules (IFR), and visual flight rules (VFR) facilities. Screening would be done at the Academy and not take more than 9 months or so, and it would be done before the trainee achieved status as a civil servant. Entry into the Air Traffic Service (ATS) would not occur until after successful completion of Academy training, when status in a Civil Service grade would be assigned. The first sector or position qualification would normally take another several months at the home facility. Progression to fully qualified

journeyman controller would take place as the necessary experience and seasoning are gained.

2. Extended Academy

As in the first alternative, all formal training would be given at the Academy, but the training for each phase would be followed by service and on-the-job training (OJT) at the home (or nearby) facility. The overall time would approximate the 3.5- to 4.5-year period of the present schedule and the present Civil Service ATC grade structure. Screening would be done at the Academy at the completion of each training phase. Time to reach final or position qualification for journeyman status presumably would be shorter than in the first alternative because of greater familiarity with facility operations.

3. Present Program

This is the present prescribed training program, in which the Academy and the facilities share the training load. Screening would be done primarily at each facility.

4. Extended Facility

This alternative poses the possibility of performing all training at each facility (or in local groupings, where more appropriate). The training plan and progression would be centrally developed and standardized, as would the scheduling and performance of regular inspections. After completion of each phase of developmental training, facility service and OJT would follow at the facility. As in Alternative 2, the elapsed time to qualification would take 3.5 to 4.5 years. Final qualification would be similar to present procedures, with screening responsibilities resting with the facilities.

5. Accelerated Facility

This alternative is similar in pace to Alternative 1, but training is done in a continuous, decentralized fashion at centers and terminals (or groups of terminals, as appropriate). This reflects the objective of completing formal academic training before proceed-

ing to OJT and before Civil Service status is achieved. Course materials, plans, and final examinations would be centrally prepared. Upon passing, the student would be admitted to the ATS with an appropriate Civil Service rating. The initial period of training would take 6 to 9 months, as in Alternative 1. Thereafter, the student would commence to gain final sector and position training and experience, and he would normally qualify in another few months.

It is recognized that this alternative would be feasible for terminal controllers only at the largest terminals. Regional training centers could serve the other cases, although centralized training would have advantages of economy and scheduling.

6. Summary

These training alternatives are summarized in Table H-1.

TABLE H-1. DEVELOPMENTAL TRAINING ALTERNATIVES (GS-7 to GS-12/13)

	Alternatives				
	Accelerated Academy	Extended Academy	Present Program	Extended Facility	Accelerated Facility
Training Duration, months	6-9	7-10	7-10	7-10	6-9
Elapsed Time, years	0.5-0.75	3.5-4.5	3.5-4.5	3.5-4.5	0.5-0.75
Final Screening	Academy	Academy	Facility	Facility	Facility
Separate Simulator	At Academy	At Academy	No	No	Terminal simulation at Academy

B. TRAINING SPECIFICATIONS FOR EACH ALTERNATIVE

Underlying the five foregoing alternatives are a number of detailed specifications. These include the time and location of each phase and subphase of training; the mode of training (i.e., classroom/laboratory, OJT, simulation); student-to-staff ratios; Civil Service grade classification; and elapsed time in developmental status. Tables H-2 and H-3 show the specifications for the training of en route and terminal controllers. As far as possible, procedures and times that apply to the present training situation of FY 1974 are used. For facilities, averages have been derived from the results of the IDA survey questionnaire and a consistent set of alternatives has been developed. It is emphasized that these averages reflect training in FY 1974, and some differences would be expected in other years. All the details are recorded in Appendix G.

C. TRAINING COSTS FOR EACH ALTERNATIVE

An extensive effort has been made to develop cost estimates for each of the five alternatives. The workload and costs incurred in training apply to FY 1974. The data base underlying all estimates derives from FAA budget submissions and data specifically collected for this study from the FAA Academy and the en route and terminal facilities. Many of these data have not been collected before.

The principal cost measure used for comparison of alternatives is the variable training cost per year per thousand graduates. Capital costs approximate 10 percent of these variable costs. All the details of the costing process are contained in Appendix G, and they are an important part of the comparison.

Table H-4 shows a comparison of the costs of the five alternatives for each controller option.

TABLE H-2. EN ROUTE PROGRAMS--SPECIFICATIONS[a]

Alternative	Phase[b]	Location	Hours by Mode: Classroom/ Laboratory	Hours by Mode: OJT	Hours by Mode: Simulation	Student-to-Staff Ratio	Failure/ Drop-Out Rate	Student GS Grade Level	Cumulative Elapsed Time From Initial Entry	Remarks
Accelerated Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	IIN	Academy	304	--	--	1.7	0.14	7	--	
	IIR	Academy	40	--	--	8.0	0.00	7	--	
	IIR	Academy	--	--	200	2.0	0.05	7	--	
	IIIN	Academy	--	--	100	2.0	0.13	7	--	
	IIIR	Academy	--	--	200	2.0	0.15	7	~8 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	
Extended Academy	I	Academy	340	--	--	8.0	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	
	IIR	Academy	40	--	--	8.0	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	--	100	2.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Present Program	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Academy	304	--	--	1.7	0.14	9	--	25% of students
	IIN	Facility	350	--	--	1.7	0.14	9	--	75% of students
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.8	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Extended Facility	I	Facility	320	--	--	2.9	0.05	7	--	
	I	Facility	--	100	--	9.0	0.00	7	1 year	
	IIN	Facility	350	--	--	1.7	0.14	9	--	
	IIN	Facility	--	20	--	9.0	0.00	9	--	
	IIR	Facility	40	--	--	2.8	0.00	9	--	
	IIR	Facility	--	--	200	2.0	0.05	9	2 years	
	IIIN	Facility	--	180	--	9.0	0.13	11	--	
	IIIR	Facility	--	--	200	2.0	0.15	11	3 years	
Accelerated Facility	I	Facility	340	--	--	2.9	0.05	7	--	
	IIN	Facility	350	--	--	1.7	0.14	7	--	
	IIR	Facility	40	--	--	2.9	0.00	7	--	
	IIR	Facility	--	--	200	2.0	0.05	7	--	
	IIIN	Facility	--	--	100	2.0	0.13	7	--	
	IIIR	Facility	--	--	200	2.0	0.15	7	~8 months	
	Checkout	Facility	--	--	128	2.0	0.00	11	--	

[a] Derived from IDA survey.

[b] "N" and "R" signify non-radar and radar, respectively.

TABLE H-3. TERMINAL PROGRAMS--SPECIFICATIONS[a]

Alternative	Phase	Location	Hours by Mode: Classroom/ Laboratory	Hours by Mode: OJT	Hours by Mode: Simulation	Student-to-Staff Ratio	Failure/ DropOut Rate[b]	Student GS Grade Level	Cumulative Elapsed Time from Initial Entry	Remarks
Accelerated Academy	I	Academy	120	--	--	8.0	0.10/0.13	7	--	
	II	Academy	96	--	--	2.8	0.07/0.11	7	--	
	III	Academy	200	--	--	2.8	0.11/0.19	7	--	
	IV	Academy	224	--	--	2.4	0.07/--	7	--	
	IV	Academy	--	--	100	2.0	0.00/--	7	--	
	V	Academy	120	--	--	1.8	0.00/--	7	--	
	V	Academy	--	--	200	2.0	0.10/--	7	~6 months	
	Checkout	Facility	--	120	--	7.5	0.00/0.00	10	--	Local
	Checkout	Facility	--	--	50	2.0	0.00/--	10	--	Approach
Extended Academy	I	Academy	120	--	--	8.0	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Academy	96	--	--	2.8	0.00/0.00	9	--	
	II	Facility	--	90	--	7.5	0.07/0.11	9	--	
	III	Academy	200	--	--	2.8	0.00/0.00	9	--	
	III	Facility	--	190	--	7.5	0.11/0.19	9	2 years	
	IV	Academy	224	--	--	2.4	0.00/--	10	--	
	IV	Facility	--	--	100	2.0	0.07/--	10	--	
	V	Academy	120	--	--	1.8	0.00/--	10	--	
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Present Program	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Academy	96	--	--	2.8	0.07/0.11	9	--	45% of students
	II	Facility	140	--	--	2.8	0.07/0.11	9	--	55% of students
	II	Facility	--	90	--	7.5	0.00/0.00	9	--	
	III	Facility	200	--	--	2.5	0.11/0.19	9	--	
	III	Facility	--	190	--	7.5	0.00/0.00	9	2 years	
	IV	Academy	224	--	--	2.4	0.07/--	10	--	40% of students
	IV	Facility	192	--	--	1.6	0.07/--	10	--	60% of students
	IV	Facility	--	100	--	7.5	0.00/--	10	--	
	V	Academy	120	--	--	1.8	0.00/--	10	--	50% of students
	V	Facility	160	--	--	2.4	0.00/--	10	--	50% of students
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Extended Facility	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	I	Facility	--	40	--	7.5	0.00/0.00	7	1 year	
	II	Facility	140	--	--	2.8	0.07/0.11	9	--	
	II	Facility	--	90	--	7.5	0.00/0.00	9	--	
	III	Facility	200	--	--	2.5	0.11/0.19	9	--	
	III	Facility	--	190	--	7.5	0.00/0.00	9	2 years	
	IV	Facility	192	--	--	1.6	0.07/--	10	--	
	IV	Facility	--	100	--	7.5	0.00/--	10	--	
	V	Facility	160	--	--	2.4	0.00/--	10	--	
	V	Facility	--	--	200	2.0	0.10/--	10	3 years	
Accelerated Facility	I	Facility	120	--	--	2.1	0.10/0.13	7	--	
	II	Facility	96	--	--	2.8	0.07/0.11	7	--	
	III	Facility	200	--	--	2.5	0.00/0.00	7	--	
	III	Facility	--	100	--	7.5	0.11/0.19	7	--	400 hours elapsed
	IV	Facility	192	--	--	1.6	0.07/--	7	--	
	IV	Facility	--	--	100	2.0	0.00/--	7	--	
	V	Facility	160	--	--	2.4	0.00/--	7	--	
	V	Facility	--	--	200	2.0	0.10/--	7	~10 months	
	Checkout	Facility	--	50	--	7.5	0.00/0.00	10	--	Local
	Checkout	Facility	--	--	50	2.0	0.00/--	10	--	Approach

[a]Derived from IDA Survey.

[b]First value is IFR terminal rate, and second is VFR terminal rate.

TABLE H-4. VARIABLE TRAINING COSTS PER YEAR PER THOUSAND GRADUATES UNDER FIVE TRAINING ALTERNATIVES, EN ROUTE, IFR, AND VFR OPTIONS

(dollars in millions)

Alternative	En Route	IFR	VFR
Accelerated Academy	$ 33.6	$ 25.8	$ 10.6
Extended Academy	32.3	29.5	15.7
Present Program	29.9	24.2	12.8
Extended Facility	29.4	22.9	12.5
Accelerated Facility	27.2	18.7	8.2

The cost differences among alternatives are caused by a complex set of detailed differences in the specification of each training program. However, one major difference between the costs of centralized Academy training and facility training is the per diem and travel costs of the former. This cost could be reduced with residential facilities operated by the Academy. This and similar considerations suggest that there may be only minor cost differences among the alternatives, except for the question of pay for developmentals when not training. That question is discussed in Appendix G and in Section D, following.

D. TRAINEE SALARIES

The cost estimates in Table H-4 include the full salaries of trainees while actually engaged in training. In Alternatives 2, 3, and 4 the trainee spends a considerable portion of his developmental period performing at his facility those supporting tasks for which he is qualified. Since these are limited, some portion of his salary should be considered as a training cost, yet just what fraction should be assessed against salaries is uncertain. As an example, Table H-5 shows the variable training costs for the en route option when 0, 25, 50, 75, and 100 percent of the trainees' nontraining time salaries are included as training costs.

TABLE H-5. VARIABLE TRAINING COST PER YEAR PER THOUSAND GRADUATES, EN ROUTE OPTION UNDER FIVE TRAINING ALTERNATIVES, WHEN VARIOUS PERCENTAGES OF TRAINEES' NONTRAINING TIME SALARIES ARE CHARGED TO TRAINING

(dollars in millions)

	Percentage of Nontraining Time Salaries Charged to Training				
Alternative	0	25	50	75	100
Accelerated Academy	$33.6	--	--	--	--
Extended Academy	32.3	$43.4	$54.5	$65.6	$76.7
Present Program	29.9	41.3	52.6	64.0	75.4
Extended Facility	29.4	41.1	52.9	64.6	76.3
Accelerated Facility	27.2	--	--	--	--

The data in the table give an idea of the cost of stretching out the training period. In fact, duration of training is a major cost factor. Further, it delays the screening process with associated expense. (This is discussed in Appendix G.)

In summary, then, considering present procedures and cost structure, there is no clear-cut choice of training location on the basis of cost. There is, however, a cost incentive to reduce the length of time over which training occurs and to reduce the time for screening.

APPENDIX I

BUDGETARY AND FISCAL CONTROL OF TRAINING

CONTENTS

The sources of training funds and control of those funds are spread among a number of offices throughout the Federal Aviation Administration (FAA). As a result, it is difficult to identify the points at which training is supported by the budget and hence to identify accurately the full cost of training. Of more importance, the dispersed origins and control of training funds may make it difficult to coordinate a national training program. This Appendix discusses budgetary sources of funds for training controllers and derives an estimate of total training cost based on the FAA's FY 1974 budget submission to Congress. Finally, problems embedded in present institutional arrangements for funding training activities are discussed in the light of stated goals.

A. METHODOLOGY

The approach adopted is to assume that the general objective of the training program is to provide for such goals as a coherent training program capable of dealing with significant fluctuations in numbers of persons to be trained, the maintenance of prescribed standards of controller training and proficiency throughout the FAA, responsiveness of the training system to new requirements, and efficient training in terms of resource requirements. Current arrangements for funding and administering various portions of the training program are examined for this purpose. The analysis is qualitative in nature.

B. FUNDING OF TRAFFIC CONTROL TRAINING

Table I-1 displays the total FAA budget submission to Congress for FY 1974, organized along functional lines. Training is not identified directly in these totals. About $51.5 million in these accounts can be identified with training, as shown in Table I-2. In addition, there are funds for supporting field facility training personnel (EPDOs/EPDSs--$9 million) and Aeronautical Center support of FAA Academy training ($5 million). This would make the total training cost appear to be near $66 million.

TABLE I-1. TOTAL FAA BUDGET SUBMISSION TO CONGRESS, FY 1974[a]

(dollars in thousands)

	Budget Request		Percentage of Total FAA[b]	Percentage of Total FAA Operating Functions.
Operating Accounts		$1,166,890	50%	77%
Operation of Air Traffic Control System	$590,514			
Maintenance of Air Traffic Control System	299,528			
Installation & Material Services	116,928			
Flight Standards Program	159,920			
Capital Accounts		250,000	11	16
Facilities & Equipment	250,000			
Research and Engineering Accounts		105,998	5	7
Research, Engineering, & Development	70,000			
Development Direction	14,636			
Engineering & Development (Regulatory Support)	13,750			
Medical Program	7,612			
Grant Accounts (Nonoperating Functions)		803,112	35	--
Airports Program	763,000			
Administration of Airports Program	22,112			
National Capital Airports	18,000			
TOTAL FAA		$2,326,000	100%	
OPERATING FUNCTIONS OF FAA		$1,522,888		100%

[a]Source: FAA budget submission to Congress for FY 1974.

[b]Individual entries do not total 100% due to rounding.

TABLE I-2. CENTRALIZED TRAINING ITEMS IDENTIFIED IN FAA SUBMISSION FOR OPERATING ACCOUNTS, FY 1974[a]

(dollars in thousands)

Operation of Air Traffic Control System			$590,514
Air Traffic Service		$537,107	
En Route Centers	$218,134		
Terminals	210,967		
Flight Service Stations	80,033		
Direct Support	27,973		
Centralized Training		24,746[b]	
Support & Administration		28,661	
Maintenance of Air Traffic Control System			299,528
Airway Facility Service		262,698	
Centralized Training		12,935	
Support & Administration (including Development Direction)		23,895	
Flight Standards Program			159,920
Operation of Program		113,436	
Centralized Training		13,255	
Support & Administration		33,229	
Installation & Material Services			116,928
Material & Procurement		48,186[c]	
Leased Telecommunications & Commercial Services		49,828[d]	
Centralized Training		539	
Support & Administration		18,375	
			$1,166,890

[a]Source: FAA budget submission to Congress for FY 1974.

[b]Includes $10,900,000 allocation for second-career training.

[c]Includes supplies, spares, repair, and overhaul for air traffic control, navigation, and agency aircraft.

[d]Predominantly in support of air traffic control.

Table I-3 lists the functions funded from this training budget. (The descrepancy of $4 million in training funds between Tables I-2 and I-3 is in part, at least, definitional).* This information, along with other data, provides an estimate of actual training costs. There may, of course, also be other methods of estimating the total cost of training. Of particular note is that the majority of training costs are not shown by budget accounts specifically associated with training.

TABLE I-3. ESTIMATED FAA TRAINING BUDGET, FY 1974[a]
(dollars in thousands)

Office of Training		$ 829
Regional Training Offices		1,475
FAA Academy		20,128
Air Traffic Branch	$6,561	
Airways Facilities Branch	6,801	
Flight Standards Branch	4,901	
Airports Branch	127	
Other Administration & Support Services	1,738	
Management Training School[b]		4,332
Traffic Safety Institute		109
Training, Travel		13,834
Air Traffic Second Career		10,900
O&M Aircraft		3,500
TOTAL		$55,116

[a]Source: FAA budget submission to Congress for FY 1974.
[b]Includes associated contractual, travel, and support requirements.

*The material contained in Table I-2 comprised part of the formal FAA submissions, while Table I-3 formed a part of informal backup materials. Since the two sets of data are structured differently, the sources of discrepancy cannot be pinpointed without additional examination.

Table I-4 displays a derivation of aggregate controller training costs for FY 1974.* The estimated training budget (of $51 million) has been adjusted by deducting items that can be associated with independent training activities (those not supported by other headings of the general training program) and by adding Aeronautical Center support of the FAA Academy (in particular, supply and facility support). From this, the operating budgets of the four specialty training branches of the Academy are deducted to define "generalized training program support" provided by the estimated training budget.

The air traffic control training support provided by the training budget comprises pro rata shares of generalized training support and the Management Training School, along with the total budget of the Air Traffic Branch. Training costs not included in the $18.9 million, and not identified with training in the FAA budget, include the salaries of field facility training staffs and the salaries of developmental and full-performance controllers engaged in training activities. Such requirements are clearly a cost of training, regardless of where they are funded in the budget. Their magnitude is clearly several times that of those training activities estimated as training costs above.

There are both logical and traditional grounds for including as a proper cost of training some part of developmental controllers' salaries earned during periods when they are not actively engaged in training. Logical grounds for this position are discussed in Appendix G. Congressional testimony in 1973 concerning the cost of bringing new hires up to facility qualification appears to have included nearly all of trainees' salaries for the full terms of their

*A detailed construction of controller training costs from Academy and field facility operating data is presented in Appendix G. The costs presented in Table I-4 rely, in part, on this material.

TABLE I-4. BUDGET SOURCES OF AIR TRAFFIC TRAINING RESOURCES, FY 1974

(dollars in millions)

Estimated FAA Training Budget		$55.1
Deductions		-18.8
O&M Aircraft	$ 3.5	
Air Traffic Second Career	10.9	
Management Training School	4.3	
Traffic Safety Institute	0.1	
Aeronautical Center Support of FAA Academy		4.9
Adjusted Training Budget		$41.2
Deductions: Academy Specialty Training Branches Budget		-18.4
Air Traffic	$ 6.6	
Airways Facilities	6.8	
Flight Standards	4.9	
Airports	0.1	
CENTRALIZED TRAINING, GENERALIZED TRAINING SUPPORT		$22.8
Air Traffic Branch as Fraction of All Specialty Training Branches	$6.6/$18.4 = 0.36	
Air Traffic Branch Portion of Generalized Training Support	0.36 x $22.8	$ 8.2
Air Traffic Branch		6.6
Air Traffic Allocation of Management Training School (includes student PC&B)		4.1
Air Traffic Centralized Budget		$18.9
Other Budget Sources of Air Traffic Training Funds		59.8
Field Facility Training Staffs[a]	$13.1	
Trainee Salaries[b]	46.7	
TOTAL		$78.7

[a]Includes temporary and part-time training personnel but not OJT trainers. See Appendix G.

[b]Includes salaries of developmental and full-performance controllers while engaged in remedial, supplemental, refresher, and general training and salaries of developmentals while engaged in qualification training. See Appendix G.

developmental status.* For FY 1974, the nontraining salaries of developmental controllers is indicated to be approximately $44 million. Total controller training cost (nearly all personnel compensation) for FY 1974 is estimated to be between $78 million and $122 million, depending upon the fraction of developmental salaries included. This is between 5 and 8 percent of the whole budget (not grant accounts) of the FAA. It is 7 to 10 percent of FAA operating accounts. Further, it is 13 to 21 percent of air traffic control personnel costs. Only $27 million can be identified explicitly with training functions in formal budget materials and in other FAA reports.**

C. IMPACT OF FUNDING PRACTICES ON TRAINING PROGRAM OPERATION

There are many FAA activities and offices that control explicit and implicit training funds and thereby influence the actual administration of the training program. Some of the influences are noted below:

- The FAA Academy is administered by the Aeronautical Center, which also controls its budget. The budget allocated to the Academy for controller training must compete for funds with all of the other diverse functions for which the Center is responsible. The amount of funds assigned to controller

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*House of Representatives Hearings, 93rd Congress, First Session, Department of Transportation and Related Agencies Appropriations for 1974, Part ., p. 100. Testimony was given confirming that "it takes about 3 years to train a controller and it costs you about $45,000 over the time period." The testimony indicates that the $45,000 figure applied to training given in FY 1972 and earlier. With Civil Service salary levels and other costs of that time, it appears impossible to accumulate unit training costs of this magnitude without including a large portion of the salaries of the trainees.

**Centralized Training Budget ($19 million) and EPDO/EPDS field facility training staffs.

training is not necessarily responsive to needs for such FAA controller training. A specific restraint on training arises from the difficulty of predicting the required number of students to be trained, since the number and schedule of new hires is controlled by the Regions and fluctuates widely. If this continues as it has in the past, it appears almost inevitable that the Academy will, from time to time, be unable to meet all FAA controller training requirements. Such administrative arrangements invite a lack of standardization in the training program and in the performance of its finished product.

- The Office of Training is the only organization within the FAA concerned with agency-wide training. It has no authority, however, over funding of training activities or certification of the training programs of field facilities. As a result, it has little or no control over the training programs administered in field facilities, in terms of enforcement of training policy, maintenance of training standards, or utilization of training resources. Responsibility for and control over these matters is vested in the regional headquarters.

- Individual facilities and the regional offices under which they operate exercise authority for hiring new controllers, and they decide when hiring and reporting shall occur. There is a seasonality in hiring which produces uneven loads for the training pipeline. This seasonality is illustrated in Fig. I-1 and Table I-5. Hirings are concentrated in the fourth quarter of each fiscal year. The fiscal implications of fluctuations in hiring are discussed in Appendix G.

- Authorizations for training staff (EPDOs/EPDSs) are the result of decisions at the facility or Regional level. There is great disparity among the Regions in the resources available for training. From the IDA survey, Table I-6 shows wide variation among the air route traffic control centers in the

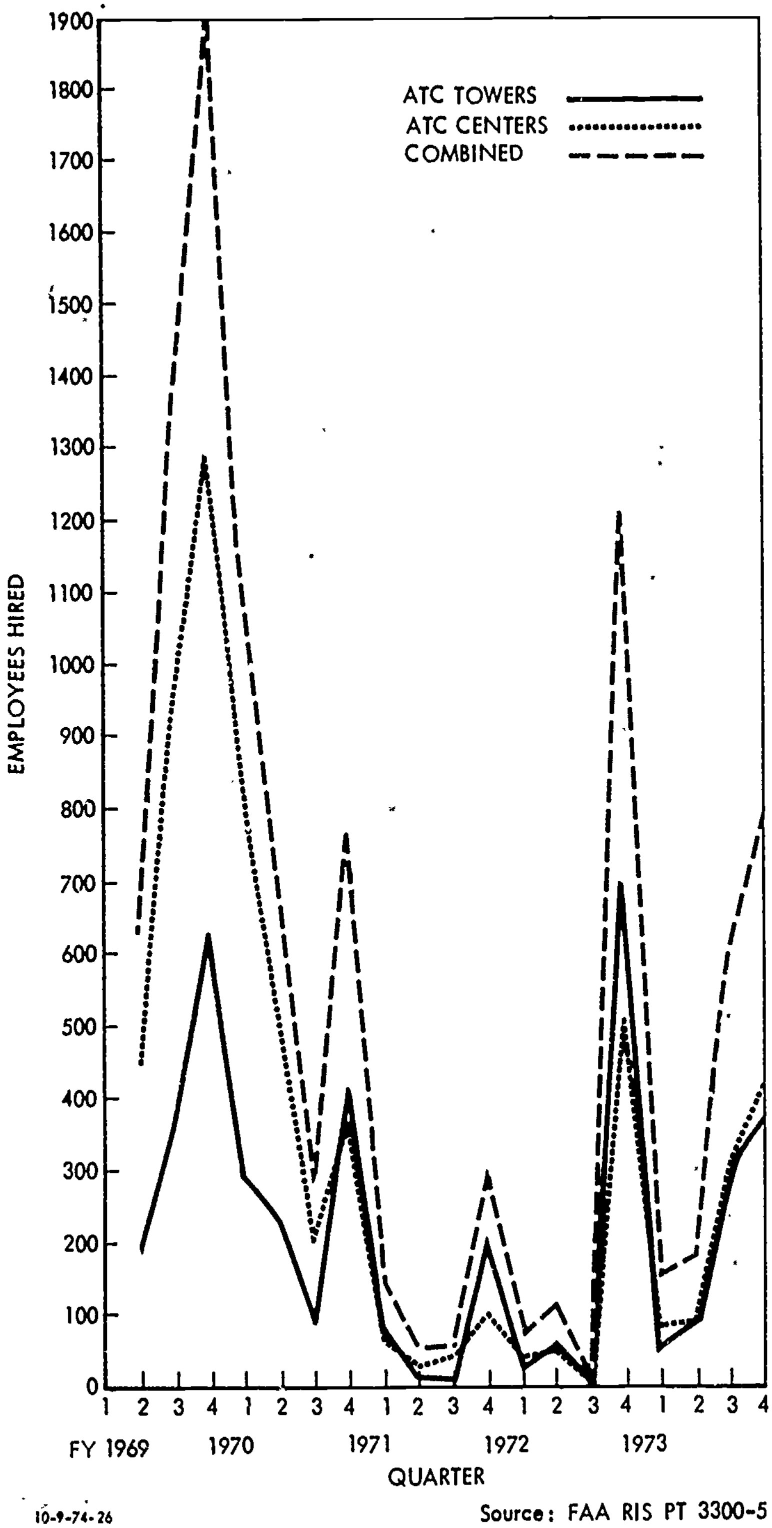

FIGURE I-1. History of ATC Hirings

TABLE I-5. SEASONALITY OF ATC HIRINGS[a]

	Quarters of FY 1969				Quarters of FY 1970				Quarters of FY 1971				Quarters of FY 1972				Quarters of FY 1973			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Towers	--	196	370	622	295	237	90	412	78	19	15	192	34	59	7	691	64	92	302	364
% Annual Hires	--	17[b]	31[b]	52[b]	29	23	9	40	26	6	5	63	4	8	1	87	8	11	37	44
Centers	--	451	958	1280	831	508	251	358	69	34	45	101	41	57	4	513	89	92	306	412
% Annual Hires	--	17[b]	36[b]	48[b]	43	26	13	18	28	14	18	40	7	9	1	83	10	10	34	46
Total	--	647	1328	1902	1126	745	341	770	147	53	60	293	75	116	11	1204	153	184	608	776
% Annual Hires	--	17[b]	34[b]	49[b]	38	25	11	26	27	10	11	53	5	8	1	86	9	11	35	45

[a]Source: FAA RIS PT 3300-5.

[b]Percentage of hires for last three quarters of FY 1969.

TABLE I-6. INSTRUCTIONAL RESOURCES, HIRES AND ATTRITION DURING TRAINING AT 20 EN ROUTE CENTERS[a]

En Route Center	Percentage of Operational Controllers that are Fully Qualified	Developmentals per Instructor	Hires	Developmental Losses	
				Number	Percentage
Cleveland	83%	6.9	56	11	11%
Chicago	54	9.4	109	24	9
New York	56	12.4	98	36	14
Atlanta	60	20.7	111	12	5
Washington	69	8.3	4	6	4
Indianapolis	72	8.0	45	16	13
Fort Worth	70	7.7	31	13	12
Houston	75	4.7	61	10	10
Memphis	67	17.0	69	13	12
Jacksonville	64	13.9	102	23	15
Miami	72	5.4	49	24	36
Los Angeles	60	12.2	25	18	13
Kansas City	77	6.9	21	9	10
Boston	81	3.3	20	14	17
Oakland	70	6.2	29	21	21
Albuquerque	77	3.0	76	17	27
Minneapolis	69	8.9	39	17	18
Denver	85	2.9	38	11	26
Seattle	81	3.6	0	7	18
Salt Lake City	83	2.3	29	24	77

[a]Source: IDA Survey.

ratio of students to qualified instructors (including temporary training complement). This ratio varies from 20.7 to 1 at Atlanta to 2.3 to 1 at Salt Lake City. Even larger variations prevail at instrument flight rules terminals. LaGuardia has a ratio of 40 to 1, whereas Newark and Houston have ratios of less than 1 to 1.

- The budget of each Region contains funds allocated for travel and per diem for training conducted at the Academy. The Regions are free to send men to the Academy for training or to train them at their own facilities, however. In the latter instance, the regions are permitted to spend the travel and per diem for purposes other than training. The discretionary nature of these funds invites inconsistency among the Regions in their use of the Academy for training. The diversion of these funds has an impact on the overall training program that is substantially greater than their magnitude would seem to indicate. This increases the problem of predicting training loads at the Academy, and perhaps it promotes a lack of standardization in training procedures among the Regions.

From a management point of view, the training program is supposed to provide standardized training. Unfortunately, the conditions required to assure this result do not exist at the present time. For a variety of reasons, there are considerable fluctuations in the rates of hiring, both within and between years. This places an uneven load on the facilities required for training, in this case primarily the Academy. The Regions follow differing, rather than consistent, practices in the extent to which they use the Academy to train their personnel. This increases the difficulty of predicting and therefore providing the required training capability at the Academy. Although there is a National Training Program, responsibility for its implementation in a standard manner is distributed between the Regions, the Academy, and the headquarters organization of the FAA. Control over all of the expenses required to train

controllers is not found in any single office. It also is distributed between the Regions, the Academy, and the FAA headquarters. Without urging that the present management structure should or should not be changed, it seems clear that the present arrangements could provide standardized and efficient training only with the greatest difficulty.

D. CONCLUSION

The sources of controller training funds are diverse and not explicitly defined in present FAA accounting procedures. About 5 to 8 percent of FAA operating expenses can be properly attributed to controller training. There is apparently great variation among the Regions in the allocation of resources to training. A system of regular reporting of all expenditures in behalf of training controllers would offer the opportunity for verification of adherence to FAA training policies and the opportunity for a more stable, standardized, and perhaps efficient training program. Whether there should be central control over these expenditures for training is a matter of management prerogative that is beyond the scope of this finding.

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