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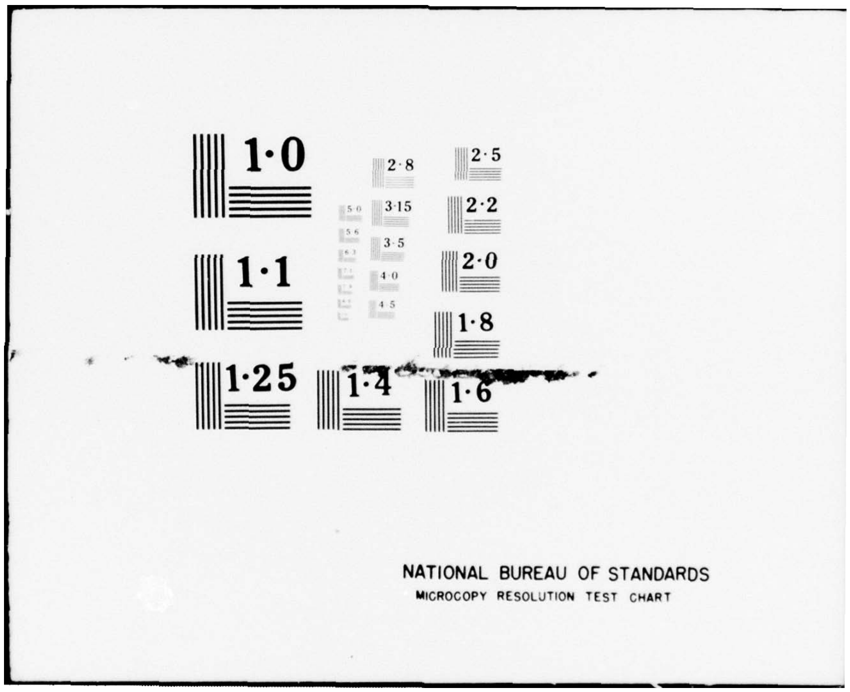
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FAA-AVP-77-18

TRAINING IMPACT OF ARTS III ENHANCEMENTS

December 1976

U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
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16. Abstract

This document examines the productivity gains attributed to the ARTS-III Enhancement program. Fundamental is the question of the impact of productivity gains upon the air traffic controllers' training needs.

A detailed productivity analysis of ARTS-III Enchancement was conducted with and without training considerations. The analysis indicated a 0.8 percent reduction in benefits due to training requirements.

The training impacts of the productivity gains shown considered the entire training cycle, including the facility on-the-job training (OJT) which was the most affected area.

In addition to the principal analysis, the effectiveness of an alternate training aid (radar simulator) was examined.

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TABLE OF CONTENTS

1.0 SUMMARY

Several of the automation functions introduced by the ARTS III Enhancement program will result in productivity improvements. This was the principal finding in the ARTS III Enhancements Costs and Benefits Study (Reference 1). Thus, fewer controllers would have to be added to the terminal work force to accommodate future traffic growth. The Enhancements which can increase productivity are:

- Terminal Information Processing System (TIPS)
- Metering and Spacing (M&S)
- Conflict Prediction and Resolution (CP&R)
- Control Message Automation (CMA)

The previous cost/benefits study of the ARTS Enhancements concluded that the largest productivity gains would be realized by the automated flight data handling capabilities of TIPS. This analysis also concluded that the costs of most of the Enhancements could be justified only at the largest ARTS TRACONs. While other sources of benefits (safety improvements and delay reductions) are larger than those due to productivity, the benefits which accrue to TIPS and CMA are predominantly productivity gains. Further, the TIPS gains are achieved primarily by eliminating the flight data (FD) positions in the TRACON and tower cab. These positions are typically the first assigned to a new trainee. Hence, there arose the question of whether the productivity gains calculated in the costs and benefits study would be largely lost due to increased training time. The training impact of these Enhancements is the principal issue addressed in this study.

A detailed productivity analysis of two Level IV ARTS facilities was conducted in support of this study. These productivity gains, with and without training impact, were extended to the candidate Enhancement sites. The results of this analysis are reflected in Table 1. The training impact of the productivity gains shown considers the entire training cycle, including the facility on-the-job training (OJT), which is the point of heaviest impact. The number of developmental controllers needed when the Enhancements are available reflects these changes. In addition, an analysis of the staff savings made possible by TIPS at ARTS satellite towers is included. These results are projected to the ARTS Enhancement candidate sites to determine overall productivity gains, including necessary modifications in the training cycle. Other data are taken directly from the previous benefits and costs analysis.

The principal conclusion of this analysis is that the training impact has a minimal effect on the earlier ARTS Enhancements Benefits analysis. Some decrease in developmental productivity will occur because of elimination of the FD position; however, this reduction is small. This small loss in developmental productivity is due to the fact that a longer time would be required to certify on the first (ground control) position after the flight data position is eliminated. This analysis was based on "worst case" assumptions regarding reduced developmental productivity. These assumptions included the elimination of flight data and clearance delivery positions.

In addition to the principal analysis, the effectiveness of alternative training aids in accelerating the training cycle was

TABLE 1

ARTS ENHANCEMENTS -
PRESENT VALUE BENEFITS AND COSTS
CURRENT DECISION DATA

	EXPECTED PRESENT VALUE ($ MILLION)
BENEFITS	
Delay Reduction	518
Equipment Savings	6
Productivity	84.6 / 88.6*
TOTAL BENEFITS	608.6 /612.6
COST	77
BENEFITS/COST	7.90 / 7.96
DIFFERENCE DUE TO TRAINING IMPACT	0.8%

* First number reflects the impact of training; second number ignores training impact.

examined. A radar simulator, or other screening technique, used to accelerate the washout rate, can save salaries paid to those developmentals who ultimately wash out. Annual salary savings of $50 - $218 thousand per year has been projected, depending on how much the washout rate could be accelerated. A facility radar simulator could reduce OJT time (which requires one-on-one supervision by a full proficiency level (FPL) controller) and thereby save time in achieving position certification. Also, using TIPS to store other facility related data (approach procedures, letters of agreement, etc.) which must be memorized by the developmental could accelerate the training process.

The time constraints imposed by the Whitten Amendment will not allow the developmental to progress to FPL any sooner regardless of reduced OJT and classroom time to achieve certification on particular positions. However, this does not present any cost disadvantages to the FAA as long as the developmental can be assigned to work those positions for which he is certified. The principal savings from reduced training time is fewer hours of FPL staff tied up in "nonproductive" OJT or classroom instruction.

Based on the data summarized in Table 1, it is concluded that the training impact of introducing ARTS Enhancements does not materially affect the quantifiable benefits or costs previously calculated.

2.0 ARTS ENHANCEMENTS PRODUCTIVITY IMPROVEMENTS

The benefits provided by ARTS Enhancements fall principally into three categories: improving safety, decreasing ATC delays at the terminal, and increasing productivity. In an earlier study (Reference 1) which calculated these benefits, the principal conclusion regarding productivity improvements was that the bulk of the improvements would come from implementation of an automated flight data handling system similar to the Terminal Information Processing System currently under development. This system would essentially eliminate the need for the flight data duties currently performed in the tower cab and the TRACON. The flight data, rather than being manually transcribed onto paper strips and physically moved about the facility, would be stored in a digital computer and automatically presented to each position as required by the air traffic control process. Other Enhancement items, such as control message automation and metering and spacing, would increase the peak capacity of the radar controller, but productivity gains would be realized only by reducing staff growth as peak hour traffic increases in the future.

The flight data position is usually that position to which the developmental is first assigned, since it requires relatively fewer skills. While performing the flight data function, the developmental also learns other necessary material about the facility, such as its geography and general operating procedures. Therefore, even though the flight data function can be eliminated by the TIPS, the question remains as to whether such elimination yields full productivity improvements since the developmental who might previously have performed the flight data function might not be capable of other productive work in the facility until he had achieved a higher level of on-the-job instruction. It is principally this question to which this study is addressed.

In addition to determining whether alternative productive assignments for a developmental are available in the TRACON, the study also investigates whether it is possible to utilize other training techniques to effectively accelerate the period spent on OJT instruction at the facility. In particular, the use of a training simulator might accelerate the washout rate of trainees and developmentals. Earlier washout saves the unproductive portion of salaries paid prior to washout.

The previous ARTS Enhancement analysis considered implementattion at only the 30 largest ARTS III facilities. A benefits analysis concluded that implementation of all Enhancements at smaller sites was not cost effective. Thus, this analysis is concerned principally with the larger ARTS III sites, which are candidates for the full Enhancement package. These sites are predominantly Level IV facilities (27 Level IV facilities in the U.S.). Level III is the lowest level activity which might be so equipped (75 Level IIIs in the U.S.). Although the full Enhancements will be limited to the larger facilities, the Terminal Information Processing System will be deployed at all ARTS III facilities, and possibly at smaller towers and TRACONs as well.

3.0 THE TRAINING CYCLE

The typical trainee air traffic controller is recruited from a Federal register, after passing certain basic skill and aptitude examinations, by a terminal or center facility. After an initial (two weeks) indoctrination at the facility, the trainee is sent to the Oklahoma City Training Academy for sixteen weeks of instruction in the basics of air traffic control and radar and non-radar techniques. The trainee is then returned to the facility from which he was recruited for continued on-the-job and classroom training. This facility training will include classroom instruction which indoctrinates the trainee in the general knowledge regarding the facility's geography, procedures, etc. The trainee then begins a qualification process which involves on-the-job instruction. He becomes a developmental controller as he begins the position certification process and begins to operate the position under direct supervision until he has demonstrated proficiency. Generally, for a new recruit, the flight data position in the tower cab is the first position assigned, since it is the easiest to master. In many smaller facilities, it is combined with the clearance delivery position. Typically, a minimum and maximum number of hours is allocated in the facility training program for the trainee to master the skills of that position. After position certification, he can be assigned to operate that position under general supervision. The developmental then progresses to more complex positions, again operating the position with direct supervision by an OJT instructor. Later, once he has demonstrated sufficient skills, he is certified on that position to operate it under general supervision. Typically, a developmental may be in the certification process on several positions simultaneously and at the same time periodically rotated to those positions for which he is already certified. This assures maintenance of proficiency on those positions already certified, and a diversity of experience on those in process. This training cycle is described in detail in Reference 2. Figure 1 shows a typical career path which leads to FPL status at a Level IV facility.

There are two important constraints on the rate at which the developmental progresses. First, when recruited at the GS-7* level, he is constrained as long as he remains in that grade to operate a limited number of positions. As he progresses to Grade 9 and subsequent grades, the number of positions for which he can be certified increases. This is an absolute constraint on the rate at which any developmental can progress through the developmental cycle. These constraints are shown in Table 2 (Reference 3).

The second constraint is that the Level IV (largest) facilities, of which there are 27 in the United States, typically do not use new recruits as developmentals; they generally recruit, if possible, a full proficiency level controller from a smaller (Level III or II) facility. The full proficiency level controller will have already developed some skills necessary for the lower level facility, and therefore in those particular positions, he will have an accelerated learning and certification process in the new, larger facility. For other skills which were not required at the earlier facility, he must start initial training for the certification

* Some recruits at the GS-5 level are taken, but they are put through a predevelopmental program to bring up basic skills and knowledge prior to entering the training cycle.

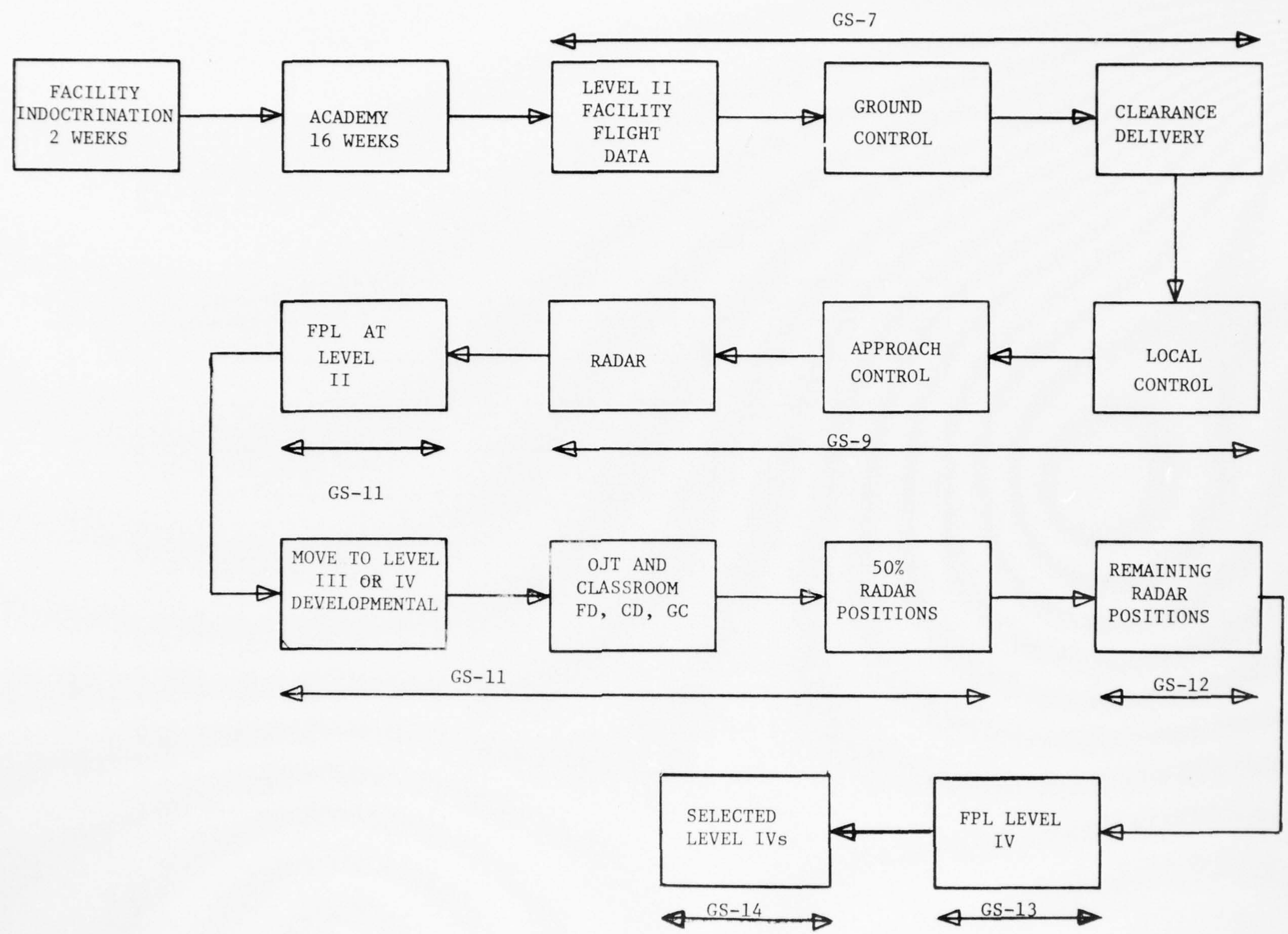


Figure 1

TYPICAL CAREER PATH - TERMINAL CONTROLLER

TABLE 2*

TERMINAL DEVELOPMENTAL POSITION
QUALIFICATION/CERTIFICATION
PROMOTION REQUIREMENTS

		Radar Approach Control (with CAB)			Radar Approach Control (without CAB)		
POSITION CERTIFICATION REQUIREMENTS	GS GRADE	LEVEL II	III	IV	LEVEL II	III	IV
Developmental Flight Data 1/	7						
Developmental Ground Control	9	X	X	X			
Developmental Clearance Delivery	9	X	X	X			
Developmental Radar-Associated	9	X			X		
Developmental Radar-Associated, Limited	9		X	X		X	X
Local	10						
Approach	10						
Local	11	X					
Radar	11	X			X		
Approach	11						
Developmental Local-Associated	11			X			
Developmental Radar-Associated	11		X	X		X	X
Developmental Local	11		X				
Local	12						
Approach	12						
Radar	12		X			X	
Developmental Local	12			X			
Developmental Radar-Limited 2/	12			X			X
Radar	13			X			X

1/ Training Received Upon Returning from the FAA Academy.

2/ Limited to working not more than 50% of the radar positions of operation which constitutes the full performance level.

* Data is from FAA Notice N 3120.45 dated 8-12-76.

process. Even then, he will have a better general feeling for the ATC system and undoubtedly progress more rapidly by virtue of his prior experience as an FPL (full proficiency level) controller in a smaller facility. Thus, the new arrival, even though he was FPL at a smaller facility, must be certified by the appropriate training personnel on each position in the new facility prior to the time he can become an FPL controller at the larger facility. Since the lower level positions, including flight data and clearance delivery, have been mastered in the lower level facility, the new arrival at a Level IV facility spends relatively little time in achieving certification at these positions. This is referred to as "subsequent" as opposed to "initial" training. Thus, very little OJT time is required or allowed for certification on the flight data or clearance delivery positions. Their elimination would have little impact on the overall training cycle at Level IV facilities. Table 3 shows the maximum OJT time allowed on each position as defined in Reference 2. The facility chief may reduce these maximums. Also, note that if a facility has several positions of one type (i.e., radar), the total OJT time is the appropriate multiple of the time shown in Table 3.

As an individual moves through this training cycle, he can "wash out" at essentially any point. It is obviously preferable to have the washouts occur early in the cycle to avoid the cost of salaries prior to washout, and also to fill the pipeline with individuals who will ultimately achieve full proficiency level. If, after expending the maximum number of allowable hours with OJT

TABLE 3*

MAXIMUM ON-THE-JOB AND CLASSROOM INSTRUCTION TIME (HOURS)
FOR TERMINAL CONTROLLER POSITIONS

POSITION	INITIAL OJT	SUBSEQUENT OJT	CLASSROOM
Flight Data	80	40	160
Clearance Delivery	50	30	20
Ground Control	150	75	80
Local Control	180	90	80
Non-Radar	80	40	120
Radar	120	90	200

* Data from the Terminal Instruction Program Guide TP-12-0-1, dated May, 1976.

instruction, it is still impossible for the individual to satisfy his supervisors that he has achieved the necessary skills, the individual cannot be certified on that position. Once achieving full proficiency level at the Level IV facility, and therefore achieving the grade of GS-13, he is still subject to periodic over-the-shoulder evaluations and proficiency training.

Since training can absorb a significant fraction of the total productive manpower in a facility, it is an important element in the overall labor cost of operating the facility. Typically, a larger burden of initial training falls on the lower level facilities. The larger facilities present a more demanding environment and thus require a full time training staff to assure that the facility will have the necessary FPL controllers available when required.

As the developmental progresses through the training cycle, he increases his productivity at the facility by qualifying on more positions, thereby being assignable to those positions under general supervision. This rate of progression is limited by the individual's capability and those function-in-grade limits defined in Table 2. Table 4, derived from an unpublished Air Traffic Service analysis of qualification rates (Reference 4), shows the average productivity of developmentals as a function of time they have been in the training cycle.

TABLE 4*

PRODUCTIVITY RATES FOR TERMINAL DEVELOPMENTAL CONTROLLERS

PERIOD (months)	PRODUCTIVITY	HOURS LOST TO TRAINING**
0 - 3	0	470
4 - 6	.10	423
7 - 9	.18	385
10 - 12	.25	353
13 - 15	.36	301
16 - 18	.48	224
19 - 21	.6	188
22 - 24	.7	141
25 - 27	.76	113
28 - 30	.82	85
31 - 33	.90	47
34 - 36	.95	24
37 - 39	.96	19
40 - 42	.98	9
43 - 45	1.00	0
46 - 48	1.00	0
	TOTAL HOURS LOST =	2802
	AVERAGE PRODUCTIVITY DURING 48 MONTHS =	.63

* Data derived from Qualification Rates for GS-2152 Air Traffic Control Specialists, Reference 4.

** 1880 hours/year

4.0 IMPACT OF ARTS ENHANCEMENTS ON PRODUCTIVITY OF TERMINAL CONTROLLER POSITIONS

The initial ARTS Enhancements study was performed prior to the time that a well-defined Terminal Information Processing System was developed. Since that time, more detailed data on TIPS specifications have been made available by a Mitre developed System Description (Reference 5); these data are used in the following analyses. In some cases, additional functional capabilities could be added. These capabilities are described in a later section. Since TIPS is the source of the largest productivity gains, it is the major factor in this analysis.

In the following paragraphs, impact of TIPS on the various positions staffed in the TRACON and tower cab will be defined. In addition to the impact on the position as staffed by an FPL controller, the impact of eliminating or modifying the position functions on the overall training cycle will also be discussed. Subsequently, these individual position analyses will be transformed into an overall staff reduction for the 1987 time period.

The other productivity improvements made possible by metering and spacing, conflict alert, and control message automation principally impact the radar positions. These Enhancements will have less impact on the training cycle since they affect only the radar positions which are typically the last positions certified.

4.1 FLIGHT DATA POSITION - TOWER CAB

One flight data position is generally located in the tower cab where the principal activity involves tearing off flight strips which are sent from the center via the FDEP printer and moving these about the facility. These printed strips are modified as necessary and inserted into plastic holders and passed on to the clearance delivery position. In those cases where clearance delivery is combined with the flight data position, the clearance delivery position delivers the appropriate clearance to the aircraft and passes the flight strip on to the ground control position. Flight data is received from the center for all IFR flight plans; VFR Stage 3 traffic has a flight strip initiated at the flight data position. While the flight data position may have some peripheral duties such as recording visibility observations and recording ATIS broadcasts, the bulk of the duties are totally eliminated by the TIPS. Any peripheral duties can easily be combined with the clearance delivery position when clearance delivery is separately staffed. In Level IV facilities and in many larger Level III facilities, separate flight data and clearance delivery positions are necessary for peak hours operations since one man cannot handle the combined workload of the two jobs.

When these positions are combined at the smaller facility, the TIPS would in some cases allow total elimination of the clearance delivery position as well as the flight data position by merging it into the ground control position. At some low level facilities, this consolidation is used presently.

In the Level IV or higher Level III facilities, where most developmental controllers in the training pipeline have previously been certified FPL at a lower level facility, elimination of the flight data position would have relatively little impact on the training cycle or on the flexibility to staff the various positions. Typically, less than 40 hours is allowed an FPL developmental to check out on the flight data and 30 hours on the clearance delivery positions (Table 3). The classroom training for the flight data position would be largely unaffected since it includes much general material specific to the facility. Table 5 briefly describes this material.

4.2 FLIGHT DATA IN THE TRACON

In many cases the flight data function in the TRACON is staffed in a more complex manner than in the tower cab. In some cases, one or more individuals are assigned purely to flight data functions; this can include initiating and modifying flight strips and distributing them to the radar positions in the TRACON. In the case of the Atlanta TRACON, for example, one flight data position is staffed full time. This individual devotes 100 percent of his effort to pure flight data functions. Clearly, this position can be totally eliminated by the introduction of TIPS. In Jacksonville, however, four flight data/handoff positions are staffed at peak operations. The fraction of the time each of these positions devotes to the flight data function varies from 90 percent to 30 percent. While all of the functions cannot be eliminated by TIPS,

TABLE 5*

FACILITY CLASSROOM TRAINING FOR
FLIGHT DATA POSITIONS

(up to 160 hours)

I. TERMINAL AREA INFORMATION

   A. Local Airport Data
   B. Airway Structure, NAVAIDS, etc.

II. EQUIPMENT

   A. Operate FDEP (replaced by TIPS)
   B. Operate Interphone System
   C. Operate Radio Communications Equipment
   D. Operate Automatic Terminal Information Service
   E. Operate NAVAID Monitoring Devices
   F. Operate Recording Equipment
   G. Operate Electrowriter
   H. Other Equipment (ARTS, Console Instruction, Lighting, etc.)

III. PROCEDURES

   A. Facility Positions
   B. Handbooks, Directives, etc.
   C. Flight Data Procedures
   D. Flight Data Handling
   E. Use of Interphone
   F. NOTAMS
   G. Records
   H. Airport Emergencies

IV. WEATHER

* Data from the Terminal Instruction Program Guide
TP-12-0-1, dated May, 1976.

the four positions could be reduced to two, with the resulting positions devoted to supporting the radar positions.

The elimination of the flight data portion of these positions likewise would have little impact on training in the Level IV and larger Level III facilities. In the smaller facilities, the larger number of developmentals might be in the GS-7 or GS-9 category, and it would be impossible to assign them to positions other than the flight data, clearance delivery, and support functions. In such instances, the elimination of these lower level positions would not allow the staff to be effectively utilized. (This is due to the constraints imposed by Agency Order 3120.45.)

4.3 IMPACT ON MANAGEMENT AND CLERICAL STAFF

The current AT staffing standard (Reference 6) specifies a number of management and clerical positions that are allowed as a function of the total controller staff. Therefore, if the elimination of positions made possible by ARTS Enhancements reduces the staff, it is also possible, in some instances, to reduce overall management and clerical staff. Table 6 defines the total support staff allowed as a function of the professional controller staff. These reductions will be taken into account in the total staff savings made possible by the Enhancements.

4.4 GROUND CONTROL POSITIONS

In the event TIPS automated all the functions of the flight data and clearance delivery positions, some additional workload

TABLE 6

TERMINAL SUPPORT POSITION STAFFING FOR TRACONS*

STAFF'G STD REQUIRED CONTROLLERS	CHIEF	DEP. CHIEF	OPS OFF	ASST. CHIEF	TEAM SUPVR	OTHER[1]	SEC/ CLERK	TOTAL
1 - 8	1							1
9 - 12	1			2			.5	3.5
13 - 18	1			3			.5	4.5
19 - 26	1			4		1	1	7
27 - 43	1	1		4	3	1	1	11
44 - 54	1	1		4	5	1	2	14
55 - 70	1	1	1	4	7	1	2	17
71 - 99	1	1	1	5	7	2	2	19
100+	1	1	1	5	14	6	3	31

[1] Includes EPDS, EPDO, PPS and PPO, where appropriate.

* Data is from the ATC Staffing Standard System, Reference 6.

would transfer to the ground control position if he were the individual contacted by a pilot requesting IFR clearance. In order to perform the ground control function, the ground controller needs from the pilot certain information, including his departure gate. The pilot must be told his assigned beacon code. Unless certain "canned" departure procedures have been agreed upon between the center and the tower, it is necessary for the clearance delivery position to get an IFR clearance. The ground control position must also handle arrivals after landing, but this would not be impacted by TIPS. The additional workload that would fall to the ground control position would be minimal, and would not be expected to significantly impact the number of aircraft the ground controller could handle.

4.5 RADAR POSITIONS

While the radar positions are not directly impacted by the implementation of TIPS, the radar controller should have available for his use a more timely coordinated flight data product than it made possible by the manual manipulation and updating of flight strips. If the TIPS utilizes the ARTS keyboard, as planned, the ARTS computer can activate TIPS flight data transfer. The use of TIPS to store and display weather data, satellite approach procedures, and letters of agreement could accelerate the position certification by the developmental and allow more rapid and safer response to unusual situations.

A minimal additional training burden would be imposed on the radar controller positions since the controller would also have to be able to manipulate the TIPS System as well as the ARTS System in order to receive his flight data. However, the training time to utilize TIPS should not be significantly greater than that required to learn to manipulate or view the flight strips as they are currently printed. There should be no change in the format or content of the data provided by TIPS unless such change is desired by the user.

The other Enhancement functions which significantly impact the radar controller include control message automation, metering and spacing, conflict alert, and conflict resolution. No experience has been gained with these to-be-developed techniques. However, an analytical technique for projecting these impacts was developed by the Stanford Research Institute (Reference 9). These studies concluded that radar position peak capacity would be increased by 10 to 45 percent if all the Enhancement automation aids were implemented. Table 7 shows the current radar complex staffing standard for peak operations rates (peak hour for the shift on the 37th busiest IFR activity day). Table 8 shows these same rates for the full Enhancements that would be projected from Reference 9. The actual gains are those derived from Level 3a of automation, which is the UG3RD level with current airspace structure. Averages for arrival and departure sectors studies (Oakland, Boston, and Washington National) are used.

TABLE 7

RADAR COMPLEX STAFFING STANDARD*

RADAR COMPLEX	AIRCRAFT PER HOUR		
ARRIVAL	0 - 14	15 - 19	20 or Greater
DEPARTURE	0 - 16	17 - 24	25 or Greater
ARRIVAL/ DEPARTURE	0 - 15	16 - 23	24 or Greater
COMPLEX STAFFING	1.0	1.5	2.0

*Data from the ATC Staffing Standard System, Reference 6.

TABLE 8

RADAR COMPLEX STAFFING
WITH FULL ARTS ENHANCEMENTS*

RADAR COMPLEX	AIRCRAFT PER HOUR		
ARRIVAL	0 - 18	19 - 24	25 or Greater
DEPARTURE	0 - 20	21 - 30	30 or Greater
ARRIVAL/ DEPARTURE	0 - 19	20 - 29	30 or Greater
COMPLEX STAFFING	1.0	1.5	2.0

*Data derived from the Air Traffic Controllers Contribution to ATC System Capacity in Automated Environments, Reference 9.

The current system would require a position to be split if the peak hour count grows beyond some maximum which depends on the complexity of the airspace. At some facilities, highly structured sectors can accommodate peak rates of 60 per hour or more, usually for periods of less than one hour.

Thus, the exact point at which sectors would have to be split, or airspace structures changed, is difficult to predict with precision. The other factor affecting maximum operations rates is the physical capacity of the airport. The two Enhancements which can significantly affect this are wake vortex avoidance (reduced separation behind heavies) and metering and spacing (more precise time control and therefore less average separation).

The training impact of these advanced automation functions on the radar controller is difficult to estimate at this time. No experience has been gained in the area of training with such a highly automated system. It seems likely that classroom and self-study time would increase somewhat simply because there would be more ARTS functions to be mastered.

4.6 RADAR ASSISTING POSITIONS

The staffing standards (Reference 6) provide for the staffing of three kinds of radar complexes. The 1.0 Complex has a single controller to operate the radar console; the 1.5 uses a shared assisting controller to support two radar controllers; and the 2.0 Complex provides a full time assisting controller to the controller operating the radar scope. The capacity of each of these complexes is defined for staffing purposes as the maximum number of aircraft per hour that can be handled by the position. The facility is to be staffed so that the available position can handle the maximum hourly workload during the 37th busiest day at the facility. Table 7 defines the capacity of the radar complexes as currently envisioned. Table 8 defines the capacity which would be possible if the full array of ARTS Enhancements were available.

The supporting positions are significantly impacted by the availability of the TIPS System. The exact functions assigned to the assisting positions depend on the specific facility and the airspace structure at that facility. Typically, these positions are defined as flight data positions, handoff positions, or coordinator positions. In all cases, the principal purpose is to support the individual manning the radar scope. Many of these duties are either simplified or eliminated by the availability of a TIPS display for the radar controller and/or his assistant. If a flight data position is staffed in the TRACON, TIPS will allow its elimination. In many cases, however, the flight data is handled by the assisting controller as one of several other duties, including handoff and coordination functions. Based on the distribution of tasks identified in the Atlanta and Jacksonville analysis, it has been concluded that if TIPS were available, the 1.5 Complex staffing would be effective in handling the largest number of aircraft per hour by the radar controller. In other words, the installation of TIPS should eliminate the need for devoting one assisting controller full time for the support of the radar controller in the busiest sectors. The productivity analysis that follows assumes that the 1.5 Complex is capable of handling the peak aircraft per hour rates which had previously been accommodated by the 2.0 Complex staffing.

5.0 PRODUCTIVITY ANALYSIS

5.1 ANALYSIS APPROACH

The previous ARTS III Costs/Benefits Study (reference 1) determined productivity improvements which could be expected from the automated flight data handling capability and with a full ARTS Enhancement program. The approach used in this present study is an analysis of productivity gains that can be expected at two large ARTS III facilities. These productivity gains have been calculated from existing staff positions and a projection of the number of positions required in the future with ARTS III alone and with the Enhancements. These calculations are based on available traffic projections and staffing in November, 1976. The analysis then determines the productivity gains per unit operation at these two facilities, and projects the average productivity gain to all ARTS facilities which were candidates for the Enhancements. The impact of training requirements on these gains is also analyzed.

Since the earlier study, new FAA traffic projections have been developed and the staff at the two facilities has changed slightly. Thus, in addition to a review and update of the productivity gains to be expected at these facilities, this study includes a correction for losses in average trainee productivity due to the elimination of flight data positions and increased classroom training time necessitated by the other ARTS Enhancement functions. For the reasons explained in the preceding chapter, no impact on overall time to achieve FPL status is expected because of the Enhancements. The constraints described in Table 2 governing the in-grade activities of the air traffic control specialist are still the pacing factor in the rate at which the developmental can progress to FPL status. Nothing visualized in the Enhancement program is expected to affect this rate of progression.

The major impacts of training are twofold: First, the productivity of the developmental controller prior to the first position certification can be expected to drop slightly; second, some additional training time, principally classroom training, will be required to teach the radar controller as well as the tower cab positions how to operate the additional automation equipments.

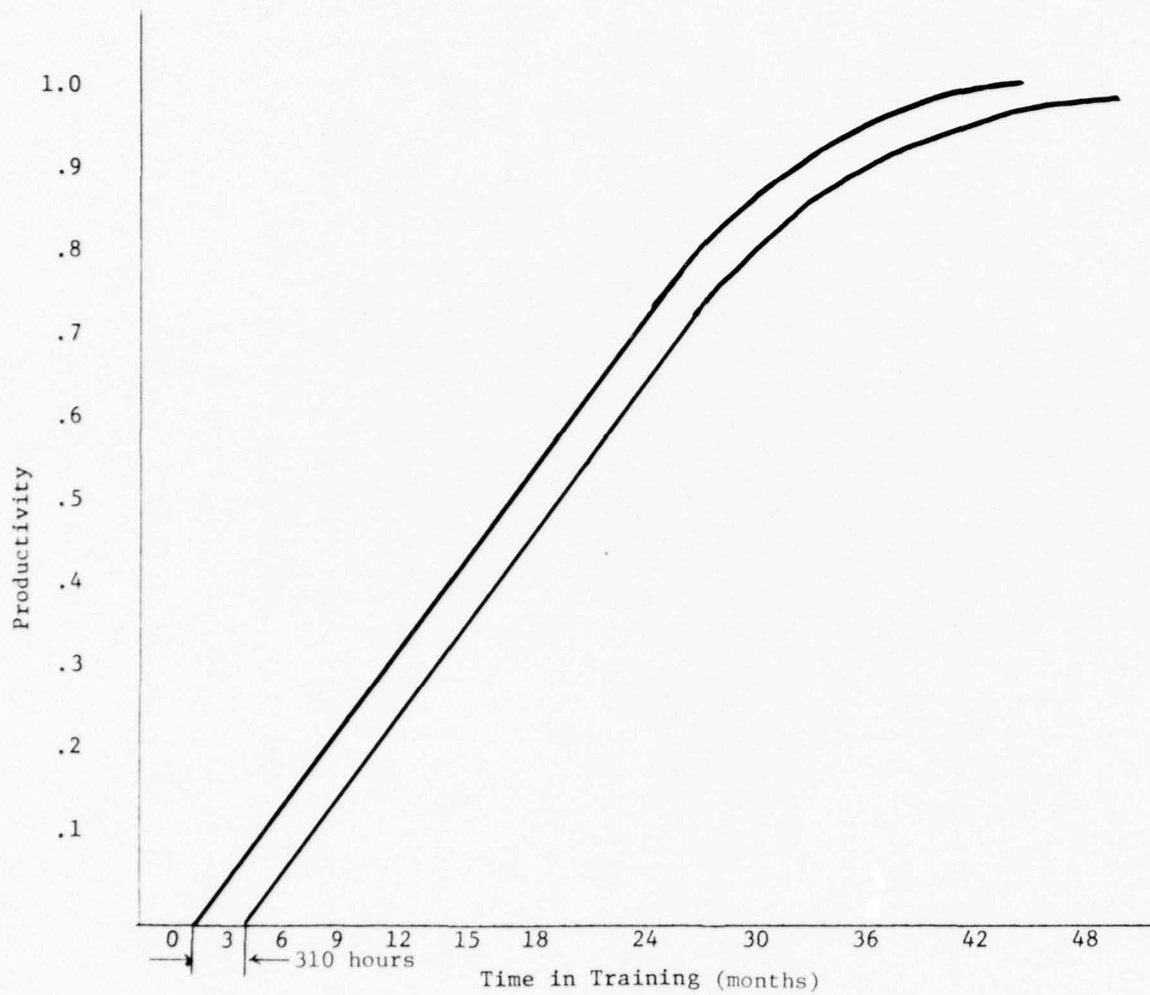
The following sections include detailed analyses of Atlanta and Jacksonville. The staff projections with the ARTS Enhancements are based on the position impact statements in the previous chapter. The future staffing required with ARTS III only, ARTS III plus TIPS, and the full Enhancements package is calculated. Then, the productivity gains are projected to a total productivity savings at the candidate ARTS Enhancement sites. The impact on the overall developmental population at these facilities is isolated and presented separately. Finally, in Section 5.4, these results are summarized.

5.2 TRAINING IMPACT

In order to assess the impact of eliminating the flight data position on developmental productivity, the data in Table 3 will be modified as follows. To determine the maximum impact, assume the full, initial OJT and classroom instruction time for flight data and clearance delivery must be completed prior to any developmental productivity. This "pushes forward" the productivity schedule (in Table 3) 310 hours, the total OJT and classroom instruction time for flight data and clearance delivery. In other words, it is assumed that the developmental must learn the flight data and clearance delivery skills but that he cannot be productive until he is certified on the next position (ground control). Figure 2 shows the original productivity data, derived from an unpublished FAA analysis of controller qualification rates (Reference 4), plotted on a graph and the same curve displaced 310 hours to the right. This productivity data is currently used in the Advanced Recruitment Model (Reference 6) to determine the number of new hires required to satisfy future staffing requirements. The number of new recruits is based, among other factors, on the rate at which the developmental's productivity increases. The faster the developmental can be assigned to positions under general supervision, the faster he can contribute to facility staffing.

The displaced curve in Figure 2 results in the modified productivity data shown in the table. This modified productivity curve is a "worst case" of the training impact created by flight data position elimination. This modified curve assumes, in effect, that the developmental must qualify on the first two positions before he begins to develop any productivity. When this delay in productivity is considered, the average developmental productivity

Figure 2. Productivity Impact of Training Changes



TIME	PROD.	TIME LOST
0- 3	0	470
4- 6	.04	451
7- 9	.11	418
10-12	.18	385
13-15	.27	343
16-18	.27	296
19-21	.5	235
22-24	.6	188
25-28	.68	150
28-30	.76	113
31-33	.83	80
34-36	.88	56
37-39	.92	38
40-42	.95	24
43-45	.96	19
46-48	.98	9

TOTAL 3,252 HOURS

AVERAGE PROD.= .56

becomes .56 over the four-year period. This implies that an increase in developmental staff of 12 percent would be required to accomplish the same work effort as is currently the case with an average productivity of .63.

In October, 1976, there were 1947 developmental controllers in the terminal work force. If TIPS were deployed over the entire system, the decrease in productivity shown by Figure 2 would require a maximum addition of 243 developmentals. The approximate total cost, if the average grade is GS-9, would be about $5.3 million per year. As will be seen later, this is a small fraction of TIPS productivity gains. Thus, the maximum increase in training time created by TIPS, and therefore, the maximum reduction in developmental productivity, will not significantly impact the *cost/benefits ratio.*

In the following sections, these developmental productivity changes will be applied to the particular facilities analyzed. These detailed results will then be extrapolated to the larger ARTS III sites.

5.3 ANALYSIS

As mentioned earlier, two Level IV facilities were analyzed in detail to determine the productivity and training impact of the Enhancements. The automation introduced by the ARTS Enhancements would eliminate, or increase the productivity of, certain positions in the facility. Therefore, it was necessary to isolate the impact of eliminating or modifying these particular positions.

Table 9 presents the current and projected staffing of the Atlanta and Jacksonville TRACONs. This staffing is broken into specific positions and the staffing standards applied and compared to the actual on-board staff.

The following methodology was used to derive these staffing projections:

1. Current FPL and developmental staff is the actual on-board as of November, 1976. These FPL numbers are in close agreement to those derived from Reference 6.

2. Projections to 1987 were used since this is the mid point of the 15-year equipment life cycle (1980-95).

3. The staff projections were made for a TIPS plus ARTS III-only environment and a fully enhanced ARTS III which includes M&S, CP&R, and CMA.

4. The TIPS + ARTS productivity impact results in eliminating the flight data position in the tower cab and reducing the assisting controllers in the TRACON to .5 per radar position.

5. The full Enhancements have the effect of the TIPS, plus increasing the peak hour capacity of the radar positions as shown in Table 8.

TABLE 9

CURRENT AND PROJECTED STAFF

CONFIGURATION/LOCATION		SUPPORT STAFF	TOWER CAB POSITIONS	RADAR POSITIONS	RADAR ASSIST POSITIONS	MIDWATCH	STAFF STD FPL	DEVELOP-MENTALS	FPL/DEV STAFF REQD.
1976 ARTS III	Atlanta	23	9	10	9	7	98	24	98/24
	Jacksonville	13	3	8	6	3	67	20	63/20
ARTS III	Atlanta	31	9	15	12	7	136	33	136/33
	Jacksonville	19	5.5	12	12	3	99	31	99/31
ARTS III + TIPS	Atlanta	19	7	15	8	7	107	26	107/29
	Jacksonville	19	4	12	6	3	75	24	75/27
ARTS III + FULL ENH.	Atlanta	19	7	11	6	7	88	22	88/25
	Jacksonville	17	4	9	5	3	63	20	63/23

6. The number of developmentals required for all cases is assumed to increase (decrease) in direct proportion to the change in total staff from the 1976 data.

7. If TIPS is implemented, then the number of developmentals is assumed to increase (beyond the number computed in 6) by an amount which reflects their reduced productivity calculated in Section 5.2. This decreased productivity results from eliminating the FD functions.

Table 10 summarizes the calculations which derive the average productivity savings per operation at the two TRACONs. For TIPS implementation only, this savings amounts to \$1.14 per operation. The full Enhancements, including TIPS, would yield \$1.82 per operation. These calculations include increases in the developmental staff due to the elimination of FD positions.

If these savings are applied to the larger ARTS III installations for traffic projections, the annual savings which would then accrue would be in proportion to the number of operations shown in Table 11.

In order to calculate the 15-year life cycle benefit, assume the average savings is applicable over the entire period. Thus, the present value benefit becomes, if the equipment is available in 1980:

$$PVB = \sum_{N=4}^{18} \frac{\text{Annual Savings}}{1.1^N}$$

TABLE 10

PRODUCTIVITY SAVINGS FOR 1987 TRAFFIC

EQUIPMENT/LOCATION	FPL SAVINGS	DEV* SAVINGS	DOLLARS PER** YEAR (X 1000)	SAVINGS PER INST. OP.	AVERAGE $/OP SAVINGS
ARTS III + TIPS					
ATLANTA	29	4/7	971/1025	.83 /.87 (.63)***	1.14/1.21 (.94)
JACKSONVILLE	24	4/7	816/870	1.45/1.55 (1.24)	
FULL ENHANCEMENTS					
ATLANTA	47	8/11	1632/1686	1.36/1.44 1.70	1.82/1.89 (1.95)
JACKSONVILLE	36	8/11	1260/1314	2.24/2.33 (2.20)	

* First number is staff savings with training impact considered; second number is savings if reduction in developmental productivity ignored.

** FPL Salary at GS-13 + 28%
DEV Salary at GS-9 + 28%

*** Numbers in parentheses are those derived in Reference 1.

TABLE 11

1987 ITENERANT OPERATIONS
AT ARTS III ENHANCEMENT TERMINALS

Terminal	1987 OPs x 1000
Atlanta	700
Baltimore	331
Boston	420
Chicago	740
Cleveland	358
Denver	499
Detroit	340
Honolulu	340
Houston	299
Las Vegas	400
Los Angeles	600
Miami	585
Minneapolis	358
New Orleans	240
Philadelphia	460
Phoenix	677
Pittsburgh	415
San Antonio	323
San Francisco	455
Seattle	275
St. Louis	413
Tampa	369
Washington	341
TOTAL	9,938

This calculation yields the results shown in Table 12.

TABLE 12

PRESENT VALUE BENEFITS
(in $ Millions)

EQUIPMENT	WITH TRAINING IMPACT	WITHOUT TRAINING IMPACT
ARTS III + TIPS	64.74	68.72
ARTS III + TIPS* + SATELLITE TIPS	84.64	88.62
FULL ENHANCEMENTS	123.26	127.24

*See Section 5.4

5.4 STAFF SAVINGS AT TOWERS

Once TIPS is installed at an ARTS III facility, it becomes relatively inexpensive to remote terminals and provide TIPS capabilities at satellite towers as well as in the tower located at the primary airport. The larger towers typically carry one flight data position on the two busy shifts, which can be eliminated by TIPS. A reasonable criterion to establish if a tower is large enough to realize such a savings is whether an FDEP printer is installed. Table 13 shows the number of tower airports served by each of the ARTS III-equipped TRACONs and indicates the number equipped with FDEP.

The ARTS Enhancements candidates are identified with an asterisk. These sites have 50 towers equipped with FEDP. If two positions per tower can be eliminated, this results in a staff savings

TABLE 13

TOWER AIRPORTS SERVED BY ARTS III EQUIPPED TRACONS

TRACON	Number of Tower Airports Served				
	Total	NFT**	Military	FAA	FAA w/FDEP
Birmingham	2			2	1
*Phoenix	4		2	2	1
Tucson	2		1	1	1
Burbank	2			2	2
*Los Angeles	4	1		3	1
Oakland	10		2	8	3
Ontario/Riverside	7		2	5	1
*Sacramento	6		3	3	2
San Diego	9		4	5	1
*Santa Ana	7		3	4	2
*Denver	4		1	3	1
Windsor Locks	2			2	1
*Washington	3		1	2	2
*Jacksonville	5		3	2	1
*Miami	8		1	7	2
Orlando	2			2	2
*Tampa	5		1	4	2
*Atlanta	4		1	3	3
*Honolulu	1			1	
*Chicago	5		1	4	3
Indianapolis	1			1	1
Des Moines	1			1	1
Covington/Gr.Cincinnati	2			2	2
Louisville	3		1	2	1
New Orleans	3		1	2	
Shreveport	3		1	2	1
*Baltimore	3		2	1	1
*Boston	5		1	4	2
*Detroit	5			5	3
*Minneapolis	4			4	1
*Kansas City	5		1	4	2
*St. Louis	3			3	1
Omaha	2		1	1	1
*Las Vegas	2		1	1	1
Albuquerque	1			1	1

TABLE 13 (Contd.)

TRACON	Total	NFT	Military	FAA	FAA w/FDEP
	Number of Tower Airports Served				
Albany	1			1	1
Buffalo	2			2	1
*New York	13	1		12	6
Rochester	1			1	1
Syracuse	1			1	1
Charlotte	1			1	1
Raleigh	1			1	1
*Cleveland	3			3	2
Columbus	3		1	2	1
Dayton	2		1	1	1
Oklahoma City	3		1	2	1
Tulsa	2			2	1
Portland	3			3	1
*Philadelphia	6		2	4	2
*Pittsburgh	3			3	2
Providence	4		1	3	1
Memphis	3		1	2	1
Nashville	1			1	1
El Paso	2		1	1	1
*Dallas/Fort Worth	7		2	5	2
*Houston	3		1	2	2
*San Antonio	4		2	2	1
Salt Lake City	1			1	1
Dulles	1			1	1
Norfolk	6		4	2	2
*Seattle/Tacoma	3			3	2
Milwaukee	2			2	1
*San Juan	1			1	
TOTALS (63)	218	2	52	164	90

*Enhancement Candidate Sites

**Non-Federal Towers

of 160. These positions would approximate the GS-11 level, and hence represent a savings of $3.5 million per year. The staff at these towers is too small to anticipate a significant training impact.

The satellite tower savings is computed as follows:

Total Positions Saved	=	50 Towers x 1 FD Position x 2 Shifts = 100
Total Staff Saved	=	100 Positions x 1.6 = 160 Staff
Total Dollars Saved	=	160 Staff x $17,000* x 1.28 Fringe Pkg. = $3.48 million/year

These staff reductions will be largely independent of traffic growth since further consolidation beyond elimination of the FD function is difficult even in the largest satellite towers.

Thus, if the TIPS capability were available in 1980 (N=4), the 15-year life cycle benefit which would accrue, using a 10 percent discount rate, is:

$$PVB = \sum_{N=4}^{18} \frac{\$3.48}{1.1^N} = \$19.9 \text{ million.}$$

*Initial GS-11 salary is $17,056.

6.0 ALTERNATIVE TRAINING MECHANISMS

The introduction of advanced automation affects the training requirements, as described in the preceding chapters. First, the elimination of some positions can affect the overall training cycle, and therefore the rate at which developmentals become productive. Second, changes in those functions that must be performed by the radar controller can affect the classroom and OJT instruction required. The radar controller must learn new ARTS III functions as well as new radar techniques to fully utilize such advanced automation functions as Control Message Automation and Metering and Spacing. New and innovative training techniques can undoubtedly assist in improving the overall training function. This section discusses several of these techniques. Since, in most cases, there is little experience with these techniques, no data is available on how the training cycle would be affected.

6.1 RADAR TRAINING SIMULATOR

The use of computer-based simulation techniques has increased in training complex system operators, and the use of aircraft simulators has been common for some time. Recently, the Air Force has procured a radar proficiency simulator for the use in RAPCONs and the more elaborate radar training simulator for initial training of air traffic controllers. Several foreign countries have procured broadband radar simulators. These devices are just coming on-line and no significant data on their use has been accumulated.

The FAA is currently in the process of procuring a radar training simulator for use at the FAA Academy. One of the goals of this simulation is to force earlier washouts. In the current terminal training program, 38 percent of those developmentals who enter at the GS-7 grade ultimately wash out before achieving full proficiency level. This means that during the earlier period prior to washout, part of the salaries expended on the individual who ultimately does wash out are wasted. Furthermore, the program requires that the capacity of the training pipeline be greater at the front end since constant attrition along the way leaves a lower flow of qualified FPL controllers at the output end. The impact of an early washout achieved through a radar training simulator, or any other effective testing technique, is exemplified by the following model.

The total output of controllers, C_{FPL}, can be expressed in terms of the input of trainees, C_T, and the washout rate during each time period, W_t:

$$C_{FPL} = C_T \, (1-W_1) \cdot (1-W_2) \ldots . (1-W_N) . \qquad (1)$$

If the salary of the developmental is S_T during each time period, the total salary lost to wash outs becomes;

$$C_T S_T \cdot \sum_{n=1}^{N} nW_n \, (1-W_1) \, (1-W_2) \ldots . (1-W_{n-1}) \cdot (1-P_n) \qquad (2)$$

where P_n is the developmental's productivity during the n^{th} period.

Using the washout data from a 1974 study by the Institute for Defense Analysis (Reference 7), the effect of earlier washout can be determined.

If it is assumed that a simulator does not reduce the total washout rate, but simply identifies the washout earlier, then the cumulative washout rate will be the same. In order to analyze this effect, a parametric variation on early washout is used. Table 14 shows the results of a 25, 50, and 100 percent increase in washout rate during the first two periods.

TABLE 14

ALTERNATIVE WASHOUT SCHEDULES

	PERIOD					
	1 (Indoctri-nation)	2 (Pre-Control)	3 (VFR)	4 (Non-Radar IFR)	5 (Radar)	CUM
1974 Term. Data	.1	.07	.11	.07	.10	.38
25% Increase 1,2	.125	.088	.081	.081	.081	.38
50% Increase 1,2	.15	.11	.064	.064	.064	.38
100% Increase 1,2	.2	.14	.034	.034	.034	.38

Data on the duration of each period was not available from Reference 7; therefore, for purposes of the sensitivity calculation, the periods will be assumed to be two quarters. Hence the average salary, S_T, is $9,000 during the period (GS-9 x 1.28).

The current (October 1976) developmental population is 1947. If the total period is 2.5 years*, then the initial population,

*The total time to achieve FPL status is longer, but earlier washout is not likely to significantly affect separation rates beyond this period.

C_T, will be 779 (= 1947/2.5). Using the productivity data in Table 4, the corresponding lost salaries for the four washout assumptions shown in Table 14 are:

SCENARIO	LOST SALARIES ($ Millions)	ANNUAL SAVINGS ($ Thousands)
Actual ('74)	3.508	----
25% Increase	3.458	50
50% Increase	3.382	76
100% Increase	3.240	218

Thus, if the current early washout rate were doubled (and the cumulative rate unchanged), a savings of $218,000 per year would be realized from reductions in lost salaries. Since classroom and Academy facilities represent predominantly fixed expenses, the earlier washout would result in few economies there.

The 15-year present value savings would then be $1.55 million if the current washout rate were doubled.

In addition to utilizing a radar simulator at the Academy, it is relatively inexpensive to add the necessary pilot consoles and software to the ARTS III computer to provide an effective radar training simulator. One or more data entry and display devices would be required for the training positions as well as the necessary software modifications to support the training functions. With a facility simulator, it would be possible to accomplish much of the OJT radar instruction without interference with live traffic. Another advantage is the ability to generate a variety of stress or emergency situations which a developmental would seldom encounter in an OJT environment. Without experiments utilizing such a simulator, it is impossible to predict with any precision how much the OJT instruction time for the radar controller could be reduced. Estimates from the training officers at the sites analyzed in the preceding chapters estimated 25 to 50 percent reduction in OJT instruction time. This, of course, is not a net gain since an instructor's time is required to utilize the simulator.

6.2 TEACHING MACHINE CONCEPTS

The TIPS System has all the basic technical capabilities required to serve the controller as a memory aid and/or teaching device as well as a distributor of flight data. The current design anticipates utilizing TIPS for distributing weather and NOTAM as well as flight data.

These, and other TIPS applications, were discussed at the 1974 National Seminar on TIPS (Reference 11).

One possible new application is to store in the TIPS System all of that data which must be learned by the developmental controller. Examples of this data include approach procedures, letters of agreement, and equipment characteristics. In many cases, even the FPL controller may require refresher training on some of this data which is seldom used, and could be greatly assisted by having the ability to recall it with TIPS. Such adaptation of TIPS would be a minor change, but could improve the rate at which the developmental assimilates the data which must be remembered to perform his function. Separate terminals could be installed to be used only as training devices and could provide a teaching machine type assistance for the trainee when he is in a classroom environment. Any acceleration of this learning process which allows earlier completion of classroom time and earlier certification on position translates into direct dollar savings by increasing average developmental productivity. To provide quantitative measures of such improvements, it will be necessary to perform experiments either at NAFEC or at the tower.

7.0 RESULTS

The results from the earlier ARTS III Enhancements Benefits and Cost (Reference 1) are summarized in Table 15.

TABLE 15

BENEFITS AND COST OF ARTS III ENHANCEMENTS

CATEGORY	EXPECTED PRESENT-VALUE ($ MILLIONS)	MAX AND MIN PRESENT-VALUE ($ MILLIONS)
BENEFITS		
Delay Reduction	518	279 - 796
Productivity	88	88 - 99
Safety	37	37 - 42
Equipment Savings	6	6
TOTAL	649	410 - 943
COST	119	119 - 148
BENEFIT/COST	5.5	3.1 - 7.9
"CURRENT DECISION CASE"		
BENEFITS	612	
COSTS	77	
BENEFIT/COST	7.95	

The largest source of benefits was due to reduction in delays. Productivity gains were the second largest source of benefits. Since the earlier analysis, part of the enhancements have been procured. This package included the Minimum Safe Altitude Warning capability which is the only significant source of safety related benefits. Therefore, the current decision will not involve these capabilities. This results in removal of the safety benefits from the current decision case, and a reduction in present value cost of $42 million, the amount of the procurement.

The productivity benefits used in the final results include only TIPS. This is because the data link capability provided by DABS is essential in achieving productivity gains from the other automation functions (M&S, CP&R and CMA). Since the cost of DABS and associated avionics was not included in the enhancement costs, the benefits are not included. The productivity benefits resulting from the full enhancements were calculated in Chapter 5.

The results of the revised productivity calculations are shown in Table 12. These results show the productivity gains with and without the decreased developmental productivity due to elimination of the Flight Data positions. The change in total benefits is quite small (less than one percent). Also, the assumptions used in the training impact calculations generate the maximum cost, and therefore the differences, even though small, are the largest likely to be encountered. Based on these results, installation of TIPS at the ARTS Enhancement sites and remote terminals at the satellite towers served is recommended.

The total present value cost of the ARTS Enhancements, minus the equipment already procured, is $77 million. This cost includes all costs required for the productivity improvements except the data link provided by the Discrete Address Beacon System. Thus, the present value benefit cost rates for the current decision case is 7.90 when the impact of training is considered, and 7.96 when the training impact is ignored. The difference is less than one percent.

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