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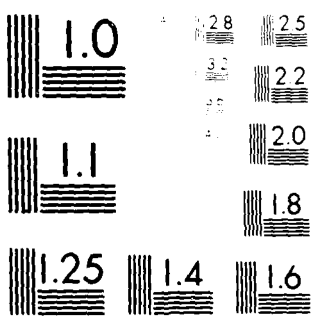

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Federal Aviation Administration
Office of Aviation Policy and Plans
Washington, D.C. 20590

Terminal Information Display System Benefits and Costs

Final Report

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March 1982

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16. Abstract

This document presents an analysis of benefits and costs expected to accrue from FAA's Terminal Information Display System (TIDS). TIDS is an electronic data processing system intended to replace (1) present flight data entry and printing equipment and (2) several devices currently used to display meteorological and operational information within towers and terminal radar control facilities.

A description of the Terminal Information Display System is presented first. Major sources of both quantifiable and non-quantifiable benefits are then discussed in some detail. It is shown that the installation of TIDS would improve terminal controller productivity by ten to fifteen percent and would result in a substantial reduction in maintenance costs.

The study provides information in present value (1981) dollars for the equipment life cycle. Over the twenty year service life of TIDS, the analysis indicates that the benefit/cost ratio is 1.74 and the net present value of FAA savings by installing TIDS at thirty major terminal facilities is about $26 million.

The report also includes a sensitivity analysis of key assumptions.

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EXECUTIVE SUMMARY

The purpose of the study described in this report was to conduct a general benefit/cost analysis of the FAA's Terminal Information Display System (TIDS). The TIDS is an electronic data processing system that will replace (1) present flight data entry and printing equipment and (2) several devices currently used for displaying meteorological and operational information within the tower and terminal radar control environments. The assumptions, analyses, and results presented in this report can be summarized as follows:

(1) Controller productivity improvement due to TIDS is estimated to be up to 15% in tower cabs and up to 10% in instrument flight rule (IFR) room departure sectors, depending on traffic levels and site-specific conditions. Other sectors may experience a productivity improvement of up to 5%.

(2) Using a discount rate of 10% and constant 1981 dollars, the present value of wage cost savings obtained by installing TIDS in 30 major terminal facilities is estimated to be $51,003,000. This value is based on 1981 controller salaries and the FAA's traffic forecasts for the 20-year period 1981 through 2000.

(3) The present value of the savings in operations and maintenance costs of the flight data entry and printing (FDEP) system and associated equipment to be replaced by TIDS is estimated to be $8,851,940. The cost savings associated with FDEP's spare parts are estimated to be $846,000. Savings in display equipment maintenance costs are estimated to be $561,000.

(4) The estimated present value (1981) of TIDS hardware for 30 major terminal facilities is $21,976,000. The present value of TIDS maintenance costs is estimated to be $6,732,460 and of spare parts cost, $921,000.

(5) The present value of the estimated research and development (R&D) costs for TIDS during the years 1982 through 1986 is $5,410,900.

(6) The benefit/cost ratio with R&D costs included in total TIDS costs is calculated to be 1.74 over the 20-year TIDS service life. This is based on a 15% productivity improvement in tower cabs, 8% in IFR room departure sectors, 5% in combined arrival/departure and satellite sectors, and 2% in final and arrival sectors. If R&D costs are excluded, the benefit/cost ratio is 2.06.

(7) The present value of net savings is $26.2 million.

The results of the TIDS benefit/cost analysis are summarized in Table ES-1.

Table ES-1

SUMMARY OF TIDS BENEFIT/COST ANALYSIS RESULTS
FOR 30 TERMINAL FACILITIES

	1981 Dollars
1. Present value of benefits	
• Saving in controller wage costs	$51,003,000
• Saving in FDEP maintenance costs	8,851,940
• Saving in display equipment maintenance costs	561,038
• Saving in FDEP's spare parts cost	846,000
Present value of total benefits	$61,261,978
2. Present value of costs	
• TIDS hardware costs	$21,976,000
• TIDS maintenance costs	6,732,460
• TIDS spare parts costs	921,000
• TIDS R&D costs	5,410,900
Present value of total costs	$35,040,360

3. Benefit/cost ratio = 1.74

4. Net saving (rounded off) = $26.2 million

The wage cost savings mentioned under item (2) above are based on the productivity improvement factors mentioned in item (1) and on the staffing standard formulas given in the FAA's "Air Traffic Standard System," Order 1380.33B (March 10, 1980). We understand that the FAA is revising these standards in the aftermath of the professional air traffic controllers' (PATCO) strike to account for the reduced number of controllers and changed traffic levels. The present FDEP and other display equipment will still be used, however, and as such, the productivity improvements due to TIDS should still be applicable. TIDS installation is expected to be initiated in 1985 or 1986; by that time the air traffic control system is expected to reach its prestrike capacity. It is therefore our judgment that the analysis presented in this report will not be significantly affected by the revisions in the staffing standard. It will be prudent, however, to check the results of the benefit/cost analysis for validity after the revisions in the staffing standards are finalized.

Based on the above results and discussion and realizing that there are several other significant qualitative benefits of TIDS as discussed in the report, it is concluded that the investment in and development of TIDS is justifiable.

1.0 INTRODUCTION

This report describes a general non-site-specific benefit/cost analysis of the FAA's Terminal Information Display System (TIDS). The analysis was conducted by SRI International for the FAA's Office of Aviation Policy and Plans from July 1981 through January 1982, under Modification No. 4 to FAA Contract No. DOT FA-79 WA-4344. The work already done by SRI under the original contract in relation to the Terminal Information Processing System (TIPS) and Consolidated Cab Displays (CCD) was used as much as possible to conduct the general benefit/cost analysis of TIDS.

1.1 Background

TIDS is an electronic system that is being developed to replace (1) the existing semiautomatic flight data entry and printing (FDEP) system that uses paper flight strips and (2) the large and increasing number of separate displays, indicators, and processors currently used in tower cabs and IFR rooms.

The motivation to replace the currently used paper flight strips and associated FDEP equipment with TIDS stems from such problems as high mechanical failure rate, low data communication rates, and a substantial workload in the manual handling of paper flight strips. Reduction in the routine and mechanical work associated with FDEP will improve the productivity of controllers.

The motivation to replace various displays, indicators, and processors with TIDS is the result of the following situation: Terminal facilities have to monitor and control a multitude of equipment and systems such as instrument landing systems, runway visual range indicators, approach lights, visual approach slope indicators, altimeter setting indicators, airport surface detection equipment, low level wind shear alert system, runway lights, wind direction and velocity indicators, automated terminal information system, and weather information displays. Associated controls and displays have created a cluttered console situation that causes inefficiencies in the controllers' work environment and uses available space haphazardly. Consolidation and improved arrangement of the information and operational equipment using modern electronic devices and displays and placement of these displays at optimal locations will facilitate controllers' activities and improve their productivity. Furthermore, TIDS provides certain other benefits that are not easily amenable to quantification; these are discussed in Section 3.5.

Although the engineering requirements of TIDS are still being developed, many of its functional characteristics are essentially established. Hence, it seemed feasible to conduct a preliminary benefit/cost analysis of TIDS equipment with reference to a large number of major terminal facilities using the best available information regarding traffic forecasts, TIDS design features, and estimated costs.

1.2 Method of Approach

SRI's approach to conducting the benefit/cost analysis of TIDS consisted of the following steps:

(1) Study past research work and relevant documents related to TIDS (References 1-19).

(2) Visit a few terminal facilities to gain a better understanding of the present FDEP system and various displays and operational equipment.

(3) Discuss with controllers and supervisors the problems associated with FDEP and various other equipment and how the proposed TIDS system might improve controller productivity and produce other benefits.

(4) Estimate controller productivity improvement factors based on steps 1 through 3 and use these factors to project manpower savings over the projected 20-year life of TIDS equipment. Estimate the savings in operation and maintenance (O/M) costs of FDEP and other equipment currently in use.

(5) Estimate the research and development (R&D), facilities and engineering (F&E), and O/M costs associated with TIDS in consultation with manufacturers and the FAA.

(6) Calculate the benefit/cost ratio of TIDS by comparing the dollar value associated with projected manpower savings plus savings in FDEP and other equipment with the dollar value of

TIDS investment and O/M costs on an equivalent basis. In this report the equivalent basis used is the "present value" (1981) of all benefits and costs as explained below.

(7) Conduct a sensitivity analysis.

(8) Present conclusions and recommendations.

The analysis presented in this report is based on the present values of costs and benefits expected to result from implementing TIDS at 30 major terminal facilities equipped with the ARTS III System,* including the associated satellite towers currently using FDEP equipment. The present value of those benefits and costs that are distributed over time, for example, controller wage cost savings and O/M costs of TIDS and FDEP, were calculated using the relationship

$$\text{Present value} = \sum_{N=1}^{20} \frac{\text{year N cost}}{\left(1 + \frac{d}{100}\right)^{N-1}}$$

where d is the percentage discount rate--10% in accordance with the FAA's standard practice. The parameter N is assigned a value of 1 for the year 1981, a value of 2 for 1982, and so on.

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*ARTS III is a semiautomated air traffic control system suitable for application to radar terminal facilities with varying traffic densities and complexities.

The 30 major terminal facilities and their primary and satellite towers are listed in Table 1.1. This list was established originally in consultation with the FAA to develop and apply establishment criteria for the TIPS. A substantial amount of useful data related to these 30 facilities was readily available to conduct the benefit/cost analysis of TIDS. Furthermore, these 30 facilities have historically accounted for about 70% of total U.S. enplanements and will be among the first candidates to receive TIDS equipment. As such, consideration of these 30 facilities for an initial benefit/cost analysis appeared to be quite adequate at the present stage of system development. The analysis method and techniques can be easily extended to cover a larger number of facilities later.

Table 1.1

TRACONS, PRIMARY TOWERS, AND IMPORTANT SATELLITE TOWERS FOR 30 MAJOR TERMINAL FACILITIES

	Primary Towers			
TRACONS	Collocated	Remote	Number of Satellite Towers	
1. Atlanta	x		2	(DeKalb Peach Tree, Fulton County)
2. Baltimore	x		0	
3. Boston	x		1	(Bedford)
4. Chicago	x		1	(Midway)
5. Cleveland	x		1	(Burke Lakefront)
6. Dallas/Ft. Worth	x		1	(Love Field)
7. Denver	x		1	(Buckley)
8. Detroit	x		3	(Detroit City, Willow Run, Oak/Pontiac)
9. Houston	x		1	(W.B. Hobby)
10. Jacksonville	x		0	
11. Kansas City	x		1	(Downtown)
12. Las Vegas	x		0	
13. Los Angeles		x	0	
14. Miami	x		1	(Ft. Lauderdale)
15. Minneapolis/St. Paul	x		0	
16. New Orleans	x		0	
17. Oakland		x	2	(San Francisco, San Jose)
18. Philadelphia	x		3	(Wilmington, N. Philadelphia, Mercer)
19. Pittsburgh	x		1	(Allegheny)
20. Phoenix	x		0	
21. Sacramento		x	1	(Sac Executive)
22. Seattle	x		1	(Boeing Field)
23. San Antonio	x		0	
24. St. Louis	x		0	
25. San Juan	x		0	
26. Tampa	x		1	(Sarasota)
27. Washington (N)	x		0	
28. Washington (D)	x		0	
29. New York		x	3	(LaGuardia, Newark, Long Island)
30. Honolulu	x		0	
Total	26	4	25	

Total number of TRACONS = 30.
Total number of towers = 55 (primary and satellite).
Total number of remotely located primary towers = 4.
Satellite towers considered = 25.

2.0 TERMINAL INFORMATION DISPLAY SYSTEM

2.1 General

The major objectives of TIDS development are to improve controller productivity, reduce the O/M costs associated with FDEP, and enhance the capabilities of air traffic control terminal facilities. Replacement of mechanical FDEP equipment with electronic TIDS will obviate or reduce much of the routine and mechanical work associated with paper flight strips and reduce the substantial O/M costs mainly associated with FDEP. Furthermore, replacement of various displays and operational equipment (e.g., runway visual range indicators, altimeter setting indicators, visual approach slope indicators, wind direction and velocity indicators, runway light operational keyboards, and instrument landing systems) with TIDS consolidated electronic displays will eliminate the large and increasing number of separate indicators and processors that are currently scattered at various controller positions. This will not only improve controller productivity but will also enable the establishment of modernized and space-effective work environments in TRACONS and towers.

2.2 Major TIDS Subsystems

The major subsystems of TIDS for a typical terminal facility are shown in Figure 2.1. A brief description of each subsystem is given below.

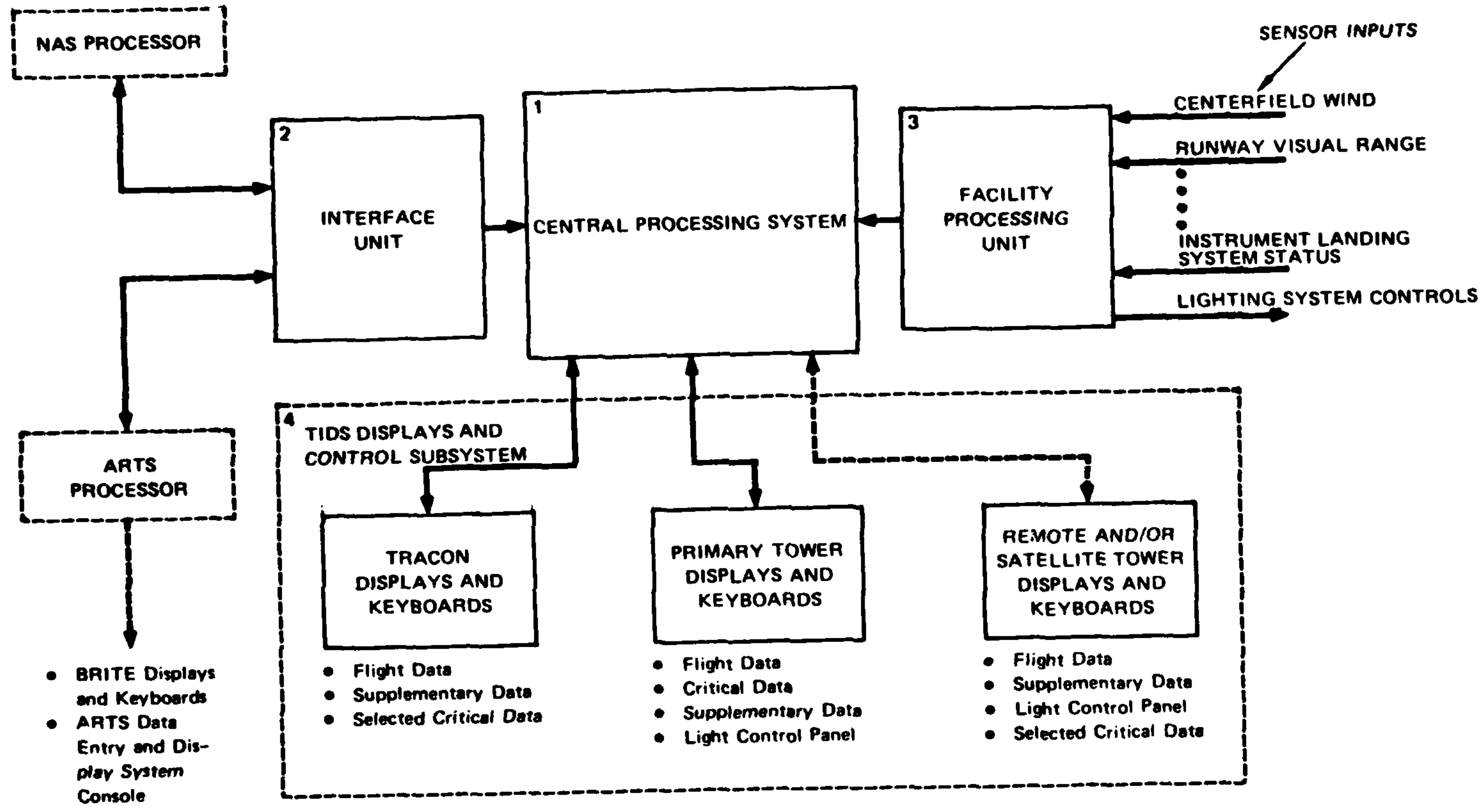

FIGURE 2.1 BASIC SUBSYSTEMS OF TERMINAL INFORMATION DISPLAY SYSTEM

2.2.1 Central Processing Subsystem

The central processing subsystem will collect and maintain a centralized terminal data base for flight, operational, meteorological, and status information entered locally by controller input actions and remotely from sensors, interfaced computer systems, and controller input actions. It will also supply flight data to the ARTS and National Airspace System (NAS) en route data bases, flight and supplementary data to the subscriber terminals and display subsystem, and control signals to lighting units.

2.2.2 TIDS/ARTS/NAS Interface Unit

The TID/ARTS/NAS interface unit will provide interfaces between the TIDS central processing subsystem and the ARTS and NAS processors for the exchange of pertinent data. These will be direct, system to system interfaces in which the TIDS/NAS interface will be used for exchange of Instrument Flight Rule (IFR) flight plans and control data, and the TIDS/ARTS interface will be used for the exchange of Visual Flight Rule (VFR) as well as IFR flight plan and control data. In addition to these initial interfaces, other systems will probably exchange data with TIDS. These include subscriber (aircraft operator) computer systems/terminals for TIDS transmission of limited data relevant to the aircraft operator, the Center Weather Service Unit for the exchange of weather data with the associated air route traffic control centers, and the Flight Service Station computer system for the exchange of VFR flight plan, Notice to Airman (NOTAM), and weather data.

2.2.3 Facility Processing Unit

The facility processing unit (FPU) will provide the interface with various sensors, lighting systems, and navaids located in the terminal area. The external systems to be interfaced with TIDS through the FPU include:

- Wind direction and velocity sensors
- Barometric pressure sensors
- Runway visual range sensors
- Low level wind shear alert system
- Vortex advisory system
- Airport lighting system (approach, threshold, sequence flasher, etc.)
- Visual approach slope indicator system
- Instrument landing system
- Terminal VHF omnidirectional range system.

2.2.4 Display and Control Subsystems

These subsystems consist of display processors/modems and various types of displays, data entry, and control devices placed at suitable locations for use by controllers and supervisors. Typically, the following displays and control keyboards will be provided:

- Flight data displays and keyboards--These will display the information currently contained in flight strips. The controller will be able to make changes, rearrange flight data, magnify specific information, and so forth through suitable keyboard operations.

- Critical data displays--These will display such critical data as time (hours, minutes, and seconds of real time), barometric pressure, center-field wind direction velocity, wind gusts, runway designations, runway visual range, levels of approach lights, and low level wind shear boundary location, velocity, and direction. Most real-time inputs will be provided from remote sensors via the FPU.

- Supplementary data displays--These will display such supplementary data as NOTAM, satellite weather, navaid status, runway visual range for all runways, instrument landing system status, field lighting status, phone numbers, special messages, daily log page, and any other data a facility might want to include. Twelve pages of displays will be provided, one of which will be a back-up page containing the critical data.

- Lighting control and status panels--These new panels will be provided to consolidate the control panels associated with runway lighting. The panels will include provisions to operate the approach lighting system, sequence flasher lights, runway edge and centerline lights, and touch-down zone lights. Through software control, the panels will allow selection (on-off control) and intensity setting for the lighting associated with each assigned runway.

The exact nature, format, attributes, and configuration of the display and control subsystems have not been finalized. The number and location of various displays and control subsystems in a tower and in a TRACON will depend on site-specific conditions, such as room layout, number and arrangement of controller positions, and traffic levels.

For the purpose of the present study, certain representative average numbers of different kinds of display and control subsystems have been assumed for a typical ARTS III facility as indicated in Section 4.0, Table 4.2. These average numbers were selected on the basis of discussions with various facility supervisors during SRI team visits to the terminal facilities in Denver, Chicago, Cleveland, Las Vegas, Los Angeles, San Francisco, Oakland, Sacramento, and Houston.

3.0 ANALYSIS OF BENEFITS

3.1 Introduction

The benefits of TIDS can be analyzed conveniently by observing that, functionally, TIDS consists of two systems: one that will replace the FDEP system and its associated equipment with an electronic data processing, distribution, and display system, and the other that will replace the various tower cab and IFR room displays and existing operational equipment with consolidated electronic displays and improved operational equipment. The potential benefits of these two aspects of TIDS are discussed below.

3.2 The Benefits of Replacing FDEP with TIDS Flight Data Related Capabilities

The two major potential benefits of replacing FDEP equipment with the TIDS electronic processing and display of flight data are:

- Improvement in controller productivity
- Reduction in O/M costs.

3.2.1 Improvement in Controller Productivity

Improvement in controller productivity is expected to result from the following sources:

- Reduction in routine and mechanical work associated with FDEP.
- Enhancement and improved timeliness of information needed by controllers.

- Increased support for VFR traffic.
- Improved flexibility in tower manning level adjustments.
- Improved IFR room and tower cab environments.

3.2.1.1 Reduction in Routine and Mechanical Work Associated with FDEP

Many controller activities of a routine and mechanical nature in an FDEP environment are expected either to be eliminated or to require less time in a TIDS environment. Table 3.1 presents a comparison of the two environments.

During a shift, the controllers in tower cab and TRACON generally take turns performing the activities indicated in Table 3.1. Hence, the controller workload reduction in a TIDS environment will be realized not in terms of any particular controller position but in the form of relieving every controller of some routine and mechanical coordination work. The time thus saved could therefore be used for other work requiring decisionmaking skills.

3.2.1.2 Enhancement and Improved Timeliness of Information

Flight data from FDEP are available only for IFR flights and are occasionally delayed due to FDEP's low data communication speeds and maintenance problems. Furthermore, the ARTS computers contain only abbreviated flight data (aircraft identification, altitude, and ground speed) on IFR flights. TIDS design features include a centralized terminal flight data base, containing both IFR and VFR flight data.

Table 3.1

STATUS OF ROUTINE AND MECHANICAL
CONTROLLER ACTIVITIES IN AN FDEP AND A TIDS ENVIRONMENT

FDEP Environment	TIDS Environment
1. Tear strips from printer	Not needed--time will be saved
2. Put strips in holders	Not needed-time will be saved
3. Mark strips in longhand	Through keyboard entry actions--experience in realistic environments will be needed to find out if time savings are feasible
4. Physically move strips from one position to another (i.e., from flight data to clearance delivery to ground to local controller positions)	Simple, single keyboard entry actions--some saving in time should result
5. Arrange strips in some convenient order	Suitable computer software could be developed to present the flight plans in standard patterns--some saving in time should result
6. Drop strips in drop tubes (from tower cab to IFR room in collocated facilities)	Simple, single keyboard entry actions--some saving in time should result
7. Remove strips from holders	Not needed--time will be saved
8. Collect and bundle strips	Not needed--time will be saved
9. Collect strip holders	Not needed--time will be saved
10. Develop statistical data	Software could be developed to tabulate data--time will be saved

Full flight plan data (which typically include aircraft identification, aircraft type/transponder equipment, computer identification number, assigned beacon code, requested and assigned altitudes, route designation, expected departure/arrival times) can be displayed for all IFR and VFR flights as soon as the information is entered into the centralized terminal flight data base. This enhancement and improved timeliness of information will help controllers in making better and quicker control decisions and thereby increase their productivity.

3.2.1.3 Increased Support for VFR Traffic

At present, several controllers may independently request the same basic information from VFR pilots; the VFR-related flight strips are frequently prepared manually. With increased demand for VFR flight services, the process of independent information collection will become more time consuming and inefficient. TIDS will be designed so that VFR and IFR flight plans can be entered into the system at any designated display position and stored in the computer. Once entered, the flight plans will be available at any controller position for control, amendment, or transfer. Flight status changes, such as IFR to VFR, can be readily made by simple controller actions. Thus, TIDS will contribute to reducing the VFR-related workload.

3.2.1.4 Improved Flexibility in Tower Manning Level Adjustments

It is expected that in response to increases or decreases in flight activity, controller positions in towers could be more easily modified in a TIDS than in an FDEP environment. The flight data position and clearance delivery position in a tower are frequently combined under low levels of flight activity, even in an FDEP environment. In view of the removal of flight-strip handling activities in the TIDS environment, a single controller at the combined flight data/clearance delivery post should be able to handle relatively higher levels of traffic activity before it becomes necessary to separate the two positions.

3.2.1.5 Improved Tower Cab and IFR Room Environments

In many tower cabs, and occasionally in IFR rooms, equipment of diverse designs is arranged in an ad hoc manner because each terminal facility has acquired various kinds of equipment on an "as needed" or "whatever is readily available" basis. In general, the working environment in tower cabs does not produce a feeling of modernity and efficiency. It is very likely that the replacement of haphazardly organized and outmoded equipment with well-organized and modern electronic equipment in tower cabs and IFR rooms will have an overall positive effect on controller productivity.

3.2.2 Estimation of Productivity Improvement in Tower Cabs

Previous studies (References 5-8) based essentially on theoretical considerations projected controller productivity improvement factors of 1.1 to 1.2 due to the automation of flight data handling activities.* For example, in Ref. 8, p. 3-45, the total staff for Atlanta (1986 traffic) is estimated to be 164 in the present ARTS III environment and

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*A controller productivity improvement factor of 1.1 implies that a controller can handle 10% higher traffic levels due to the equipment under consideration (e.g., automated flight data handling system) or, alternatively, that a given level of traffic can be handled by approximately 10% fewer controllers.

149 in an automated flight data handling system environment. Thus, the controller productivity improvement factor due to the flight data related automation and display features of TIDS is 164/149 = 1.1. In Ref. 7, p. 6-5, the controller productivity gains due to an automated flight data handling system have been estimated as 1.2 to 1.22 for various types of TRACON/tower facilities. Similar inferences can be made by studying Table S-1 in Ref. 5 and Tables 38, 39, and 46 in Ref. 6.

After familiarizing itself with relevant theoretical considerations, the SRI team visited terminal facilities at the San Jose tower, San Francisco tower, Oakland TRACON, Los Angeles TRACON/tower, Denver TRACON/tower, Chicago TRACON/tower, and Cleveland TRACON/tower and observed the activities associated with flight data handling. Discussions were also held with supervisors and controllers regarding the possibilities of workload reduction if flight strips were replaced by TIDS electronic displays. Controllers were shown schematic diagrams of the proposed equipment, and the sources of potential benefits due to TIDS, as mentioned above, were pointed out to them.

Without having the equipment on site and without having had the time to adapt themselves to the new equipment, the controllers could not be expected to indicate in quantitative terms the projected improvement in their productivity. However, there was general consensus on the following:

- Cab controllers spend 15% to 20% of their time and effort on activities related to flight data handling, in high-activity environments. Activity levels producing 500 cab workload (CWL) units or more are considered high. The method of calculating CWL units is included in Appendix A.

- If such mechanical activities as tearing the strips, moving the strips physically from one section to another, dropping the strips in drop tubes, writing the various information items on strips in longhand, and so on could be eliminated or simplified, the work associated with flight data handling may be approximately halved. This implies an improvement in productivity of about 7.5%. For example, if the total controller workload in an FDEP environment is assigned a value of 100 points, then a minimum of 15 points is currently being used for mechanical and routine activities related to flight data. With TIDS, it is projected that only 7 or 8 points (i.e., half of 15 points) will be used for activities related to flight data. Thus, the total workload will be reduced from 100 points to 93 points, and the controller productivity improvement factor under high activity levels will be 100/93 = 1.075.

- Improvement in the timeliness and accuracy of information as well as inclusion of VFR flight data in the data base would improve controller productivity by 2% to 3%.

- Overall improvement in productivity due to modernized and standardized environments could be 1% to 2%.

- Under low-activity conditions the work associated with flight strips is minimal; therefore, replacing the paper strips with electronic displays will not significantly affect controller productivity.

Based on these observations, the SRI team concluded that under high-activity conditions (i.e., 500 CWL units or higher) the overall controller productivity improvement due to automation of mechanical and routine FDEP activities, timeliness and accuracy of information, and modernization and standardization of tower cab environments will be about 10% (7% due to automation, 2% due to timeliness and accuracy, and 1% due to modernization and standardization).

3.2.3 Estimation of Productivity Improvement in IFR Rooms

The activities of various controllers in different types of IFR room sectors were observed in the Oakland, Los Angeles, Denver, Chicago, and Cleveland TRACONS. Discussions were also held with supervisors and controllers regarding the possibilities of workload reduction due to TIDS in IFR rooms. Controllers and supervisors were again reluctant to indicate in quantitative terms the projected improvement in their productivity without having had sufficient experience with the new TIDS equipment. However, there was general consensus on the following:

- Flight strips are used in the arrival sector (Type 1) and final sector (Type 5) mainly as backup, and some terminal facilities (e.g., Chicago) do not even use flight strips in their arrival and final sectors. Hence, TIDS capabilities related to automatic display of flight data will not have any impact on the productivity of controllers attending arrival and final sectors.

- In collocated TRACON/tower facilities--e.g., Denver, Chicago, and Cleveland--controllers attending departure sectors (Type 2) spend up to 10% of their time and effort on mechanical and routine activities related to flight strips at high activity levels (30 aircraft or more per hour). TIDS equipment should reduce this percentage to about 5%, implying a productivity improvement factor of 5%. The improvement in productivity for controllers attending the combined arrival/departure sectors (Type 3) and satellite sectors (Type 4) should be 3% to 4%.

- In separately located TRACON facilities, the departure strips are separately printed in the IFR room (instead of being dropped via a tube from the tower as in the case of collocated facilities). A controller has to attend the printer, tear the strips, and distribute them to respective sector controllers. The overall equivalent percentage of time spent in activities related to flight strips in a departure sector is estimated to be 15% at high activity levels. TIDS equipment should reduce these percentages to about half the present value, implying an improvement in productivity of about 8%. For satellite and departure/arrival sectors, the improvement in productivity should be about 6%.

On the basis of these observations the SRI team concluded that:

- In the IFR rooms of TRACONS collocated with towers, the improvement in the productivity of controllers in departure sectors will be 5%, and in combined arrival/departure sectors and satellite sectors, 3%.

- In the IFR rooms of separately located TRACONS, improvement in the productivity of controllers in departure sectors will be 8%, and in arrival/departure and satellite sectors, 6%.

- No significant improvement in productivity is expected for controllers in arrival or final sectors.

The above-noted productivity improvement factors for tower cabs and IFR rooms will be combined later with productivity improvement factors due to consolidation and modernization of other cab displays to develop overall productivity improvement factors (see Section 3.4, Table 3.2).

3.2.4 Reduction in Maintenance Costs

The present FDEP system is mostly mechanical and therefore requires considerable maintenance in terms of routine servicing and replacement of worn-out parts, particularly in the printers. This has resulted in significant maintenance costs and frequent delays in information dissemination. Because the TIDS will have few moving or mechanical parts, the maintenance requirements associated with TIDS equipment are expected to be considerably less than those of FDEP equipment.

The TIDS O/M costs used in this study were derived from estimates by the TIDS contractors and Airway Facilities Service based on their experience with similar processors, displays, and data entry devices.

3.3 The Benefits of Replacing Various Tower Cab and IFR Room Displays with TIDS

3.3.1 General Discussion of Benefits

Observations and conversations with controllers and supervisors at Denver, Chicago, Sacramento, San Jose, Houston, San Francisco, Los Angeles, and Las Vegas tower/TRACON facilities have revealed the following potential benefits to be derived from installation of TIDS:

- All critical display information in the facility will be available to all controllers. Currently such items as runway visual range and low level wind shear alert system displays are located strategically throughout the facility. Finite console space and a limited number of displays prohibit the exhibition of all information at each console. Controllers only have access to the information pertinent to their operation. Controllers would like access to all critical display items for general informational purposes and for advising pilots.

- All information will be consolidated in front of the controller in a nonchanging position. Currently, in some facilities, the status board is located behind or off to the side of the controllers and requires turning up to 180° for full view. In some tower facilities the automated terminal information system (ATIS) information is handwritten on a piece of paper and pinned up in a location most easily seen by everybody. Because the staffing changes, the optimal location will change, and therefore the paper will not always be pinned up in the same place. Having all information directly in front of the controller will eliminate distraction.

- The TIDS displays will have alerting features to tell of status changes. Currently, for example, when a VHF omnidirectional radio range goes out of service or the ATIS code is changed, the supervisor must walk around to each controller and orally confirm that the new information has been received.

- Procedures will be standardized from facility to facility. The dissemination of weather information in particular is handled differently from facility to facility. Some supervisors feel that it may take up to 4 hr for a new controller from another facility to learn the system.

- Consoles will be more standardized from position to position. Midnight consolidation in the TRACON could be done more easily at any of the radar positions. In cases of equipment failure, a position could be moved to another console without much difficulty.

- Automatic weather transmission will result in speeded up data transmission and the elimination of legibility problems and of manual gathering and dissemination of weather information, thereby freeing personnel for other duties.

- The information displayed via the TIDS may be more accurate. Currently much of the information (wind speed, wind direction, and altimeter readings) are analog displays. These displays are generally located at an angle above the radar scope, presenting a slightly distorted view to the controller. The TIDS presents digital information, which is much more precise and leaves less room for error.

- The TIDS will permit more immediate response by a controller to a pilot's request for flashing or dimming of approach lights. Currently in many facilities a combination of numbers must be entered to change intensity levels. This combination is different for every intensity level. The combinations are posted, but they are complicated, time consuming to enter, and a nuisance to controllers. In a TIDS environment the combinations will be determined by the computer so that the controller need only enter the intensity level.

- The TIDS will make identification and response to alarms of equipment failure much simpler by eliminating the need to walk around the facility.

- The TIDS environment allows for more controller autonomy. Presently a controller must rely on a supervisor or other personnel to provide him with information on weather, ATIS, flow, runways, and the like. With TIDS, controllers have all that information at their fingertips, which likely would improve their morale and increase their efficiency.

- In facilities with both a tower and a TRACON, there is often a need for telephone communication to confirm that information is consistent between the two facilities. For example, in the Las Vegas facility, the tower prepares the approach ATIS and the TRACON broadcasts the departure ATIS. Each hour both facilities check to make sure they are using the same ATIS code. This could be eliminated by simply glancing at the TIDS displays.

- Presently much information that is not vital for ordinary operations is stored in binders and notebooks. In an emergency, much time is lost while the controller searches for the appropriate information. If such information could be stored on a page of the TIDS displays and brought to the screen by simply touching a button, much confusion could be avoided, and air traffic safety would be improved.

- In many facilities the digital clocks lose some time and need to be adjusted regularly. With the TIDS the time displayed at all consoles will be synchronous.

- Most facilities have a section where such information as Pilot Reports, NOTAMS, and weather forecasts are posted. This information can be reviewed by controllers before they come on duty and at breaks. With the TIDS these data could be displayed at the console as desired.

- In the current FDEP environment, all equipment must be checked at least once a day by the supervisor for accuracy. With the TIDS all data will be contained in a centralized terminal data base.
- In a TIDS environment, a few pieces of modern equipment will replace many outmoded displays and many pieces of paper, resulting in a less cluttered and more modern environment. This will undoubtedly improve the morale and productivity of controllers.
- The TIDS capability for record keeping and retention of data will allow for more effective analyses of incidents.

3.3.2 Estimation of Productivity Improvement Factors in Tower Cabs and TRACONS

The supervisors and controllers at the tower/TRACON facilities visited could not indicate, in quantitative terms, the projected improvements in controller productivity due to consolidation and modernization of cab displays and operational equipment without having the new equipment on site and the time to adapt themselves to it. The general consensus was that the benefits of equipment consolidation and other capabilities of TIDS mentioned above will be noticeable essentially in tower cabs, and a projection in controller productivity improvement of 5% to 6% in the tower cabs under high activity levels will not be unreasonable. It was generally agreed that controllers in IFR room sectors would experience a small improvement in their productivity, perhaps 2% to 3%. Based on these discussions and its own observations, the SRI team selected a 5% improvement in productivity for tower cab controllers and a 2% improvement in productivity for IFR room controllers.

3.4 Quantification of TIDS Productivity Benefits

The projected improvements in controller productivity due to TIDS under high activity levels are summarized in Table 3.2 to facilitate the discussion of quantifying TIDS productivity benefits--that is, controller wage cost savings. Lists of productivity improvement factors for various traffic levels associated with tower cabs and IFR room sectors are included in Appendix A.

To quantify TIDS productivity benefits, the number of controllers required in the primary towers, IFR rooms, and associated satellite towers both without and with TIDs were calculated for the 30 major terminal facilities for 1981 through 1995 using traffic forecast data readily available for the 30 facilities from the FAA's Tape VSN: 81313 prepared by Information Systems Branch (APO-130) in November 1981.* The results for each year were then summed for the 30 facilities. A summary of these results is presented in Table 3.3. A graphical representation of the aggregated traffic data based on the above mentioned tape is shown in Figure 3.1. The estimation of the number of controllers for primary towers, satellite towers, and IFR room sectors was based on the methodology and formulas used by the FAA as described in "Air Traffic Standard System," Order 1380.33B (March 10, 1980), Chapter 9. A computer

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*As explained later in this section the saving in the number of controllers for 1996 through 2000 was estimated using extrapolation because the FAA's tape contained data up to 1995 only.

Table 3.2

SUMMARY OF PRODUCTIVITY IMPROVEMENT FACTORS DUE TO TIDS FOR FACILITIES WITH HIGH ACTIVITY LEVELS

Location	Source of Benefits: Automation and Modernization of Activities Related to Flight Data (%)	Source of Benefits: Consolidation and Modernization of Display and Operational Equipment (%)	Cumulative Percentage Improvement (%)	Cumulative Improvement Factor
Tower CAB	10%	5%	15%	1.15
Collocated IFR room				
Arrival sector	0	2	2	1.02
Departure sector	5	2	8	1.08
Combined arrival/ departure sector	3	2	5	1.05
Satellite sector	3	2	5	1.05
Final sector	0	2	2	1.02
Separately located IFR room				
Arrival sector	0	2	2	1.02
Departure sector	8	2	10	1.10
Combined arrival/ departure sector	6	2	8	1.08
Satellite sector	6	2	8	1.08
Final sector	0	2	2	1.02

Note: Facilities with high activity levels refer to those that generate 500 or more cab workload (CWL) units for towers and/or 30 or more aircraft per hour for one or more IFR room sectors on the 37th busiest IFR operations day. Further discussion of traffic levels and associated improvement factors is included in Appendix A.

Table 3.3

ESTIMATED NUMBER OF CONTROLLERS NEEDED AT
30 MAJOR TERMINAL FACILITIES WITHOUT AND WITH TIDS: 1981-1995

	Present System	With TIDS	Personnel Savings
Primary Towers			
1981	654.0	620.5	33.5
1982	662.0	627.5	34.5
1983	672.0	637.0	35.0
1984	683.0	645.0	38.0
1985	685.0	646.5	38.5
1986	698.0	660.5	37.5
1987	703.0	666.5	36.5
1988	711.5	675.5	36.0
1989	716.5	681.5	35.0
1990	717.0	681.5	35.5
1991	731.0	696.0	35.0
1992	739.0	701.5	37.5
1993	743.5	707.5	36.0
1994	751.5	713.0	38.5
1995	752.0	713.5	38.5
Satellite Towers			
1981	542.0	513.0	29.0
1982	549.5	520.0	29.5
1983	557.0	527.5	29.5
1984	565.0	534.5	30.5
1985	567.0	536.5	30.5
1986	579.0	549.0	30.0
1987	583.5	553.0	30.5
1988	588.5	559.0	29.5
1989	593.0	563.0	30.0
1990	593.5	562.5	31.0
1991	605.5	575.0	30.5
1992	611.0	580.0	31.0
1993	618.5	588.5	30.0
1994	624.0	593.5	30.5
1995	624.5	594.0	30.5

Table 3.3 (Concluded)

	Present System	With TIDS	Personnel Savings
IFR Rooms			
1981	1657.0	1628.5	28.5
1982	1707.5	1680.0	27.5
1983	1755.0	1727.0	28.0
1984	1804.0	1775.5	28.5
1985	1846.5	1818.5	28.0
1986	1874.5	1849.0	25.5
1987	1899.0	1872.5	26.5
1988	1920.5	1893.5	27.0
1989	1945.0	1917.0	28.0
1990	1962.5	1935.0	27.5
1991	1984.0	1958.0	26.0
1992	2001.5	1977.5	24.0
1993	2016.5	1993.0	23.5
1994	2034.0	2012.5	21.5
1995	2045.0	2025.0	20.0

Note: The above results were obtained by summing the number of controllers needed in each facility's primary tower, IFR room, and satellite towers. The number of controllers for individual facilities was calculated using the methodology and the computer program briefly described in Appendix A.

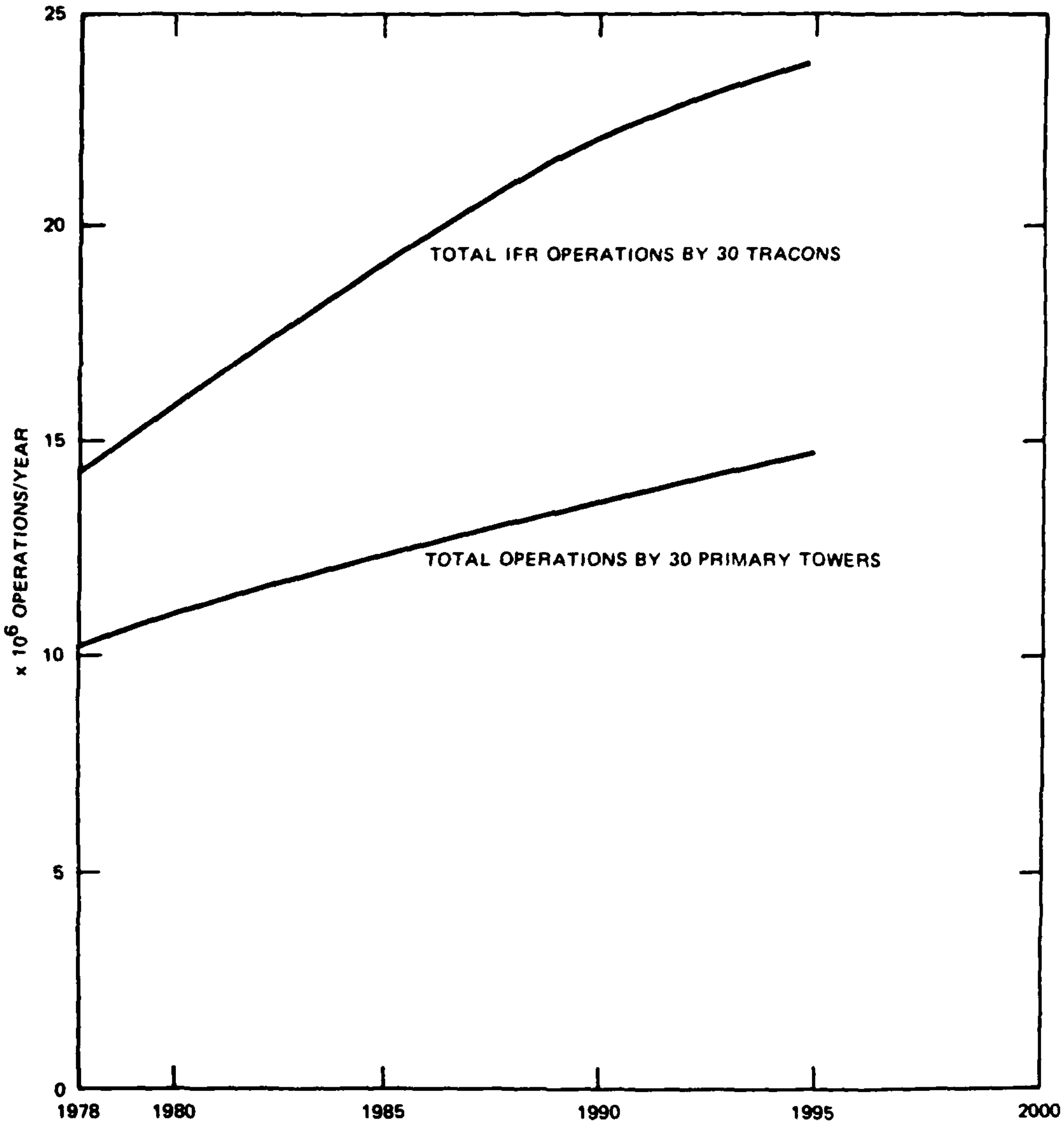

FIGURE 3.1 GRAPHICAL REPRESENTATION OF THE AGGREGATED TRAFFIC FORECAST DATA FOR 30 MAJOR TERMINAL FACILITIES

(Note: Based on FAA's Tape VSN: 81313 Supplied by Information System's Branch (APO-130) in November 1981. Controller Staffing Without and With TIDS was Estimated for 1981 Through 1995 for Each Facility Separately Using the Data for Individual Facilities Included in the Tape.)

program was developed to facilitate the extensive, albeit repetitive, calculations needed to obtain the results. A brief description of the methodology and the associated computer program are included in Appendix A.

The potential savings in the number of new controllers required with TIDS can be translated into dollar savings by using appropriate wage costs of the controllers. For the purposes of this study, five grades of controllers were considered, as shown in Table 3.4. Annual salaries (1981) for each grade are those with longevity step 4 in accordance with the FAA's guidelines. In accordance with the FAA's Office of Aviation Policy and Plans guidelines, the annual salaries were multiplied by a factor of 1.18 to account for annual leave, sick leave, and other absences and then by a factor of 1.26 to account for retirement, health, and other benefits to give equivalent annual wage costs for various grades.

To calculate the present value of the controllers' wage cost savings over the life of TIDS, the following approach was taken: The controllers in primary towers and IFR rooms were assumed to be in grade GS-14 because almost all primary towers and IFR rooms are of facility level V. The controllers in satellite towers were assumed to be in grade GS-12 because the average facility level of satellite towers is about III (some are level II, some level III, and a few level IV). This generalization seems to be justifiable in view of the planning nature of this benefit/cost study. The life of TIDS is expected to be 20 years. A discount factor of 10% was used to calculate the present value of the wage cost

Table 3.4

QUALIFIED CONTROLLER GRADES, 1981 SALARIES, AND EQUIVALENT ANNUAL WAGE COSTS FOR VARIOUS TERMINAL FACILITY LEVELS

Facility Level*	Grade of Qualified Controllers	Annual Salary+ with Longevity Step 4	Equivalent Annual Wages (= Salary x 1.18 x 1.26)
I	GS-10	$23,594	$35,080
II	GS-11	25,924	38,546
III	GS-12	31,071	46,196
IV	GS-13	36,946	54,931
V	GS-14	43,648	64,907

*Facility level is indicative of a terminal's traffic activity level. The higher the traffic activity, the higher the facility level. Facility type indicates the type of services provided by the facility. For example, facility type 1 indicates a VFR tower providing VFR services. A brief description of various facility types is given in Appendix A, Table A-1.

+According to Federal Register, Volume 46, Number 200 (October 16, 1981).

savings. The savings in the number of controllers for 1996 through 2000 were estimated using extrapolation because forecast traffic data up to the year 2000 were not available. Table 3.5 shows the year-by-year savings in number of controllers and the present value of associated wage costs due to TIDS. The present value of the total controller wage cost savings over a period of 20 years is $51,003,000.

3.5 Other Potential Benefits of TIDS

In addition to improvements in controller productivity and potential reductions in maintenance costs, there are certain other potential benefits of TIDS that are not easily amenable to quantification. However, for the sake of completeness and to provide a reasonably complete perspective of TIDS, these other potential benefits are listed below.

(1) TIDS displays and operational equipment will require less space, particularly in towers, than present displays, operational equipment, and FDEP equipment. Data on space currently occupied by various displays and flight data equipment were collected through documents, site visits, and telephone calls to the Oakland, San Jose, Stockton, Bakersfield, Houston, San Francisco, Fresno, Atlanta, and Sacramento terminal facilities. These facilities are of various sizes and levels. According to preliminary estimates, the value of space saved in major facilities due to consolidation of displays and other equipment is in the range of 5 to 15 square feet per facility. In smaller facilities, the savings are not significant because the number of displays and other equipment to be consolidated is not great.

(2) The information displayed at the control positions will be up to date and accurate, thereby lessening the potential for system errors or deviations. The equipment is expected to be less subject to outages and provide more operational reliability. These aspects will contribute to improved air traffic safety.

Table 3.5

YEAR BY YEAR SAVINGS IN NUMBER OF CONTROLLERS
AND PRESENT VALUE OF ASSOCIATED WAGE COSTS
DUE TO TIDS IN 30 MAJOR FACILITIES

Year	10% Discount Factor	Number of Controllers Saved in IFR Room and Primary Towers	Present Value of Annual Wage Cost Saved ($ x 1,000)	Number of Controllers Saved in Satellite Towers	Present Value of Annual Wage Costs Saved ($ x 1,000)
1981	1.000	62.0	$ 4,023	29.0	$ 1,339
1982	0.909	62.0	3,656	29.5	1,239
1983	0.826	63.0	3,716	29.5	1,125
1984	0.751	66.5	3,240	30.5	1,058
1985	0.683	66.5	3,947	30.5	963
1986	0.621	63.0	2,538	30.5	874
1987	0.564	63.0	2,306	30.5	794
1988	0.513	63.0	2,097	29.5	698
1989	0.467	63.0	1,909	30.0	658
1990	0.424	63.0	1,734	31.0	607
1991	0.386	61.0	1,527	30.5	544
1992	0.350	61.5	1,396	31.0	501
1993	0.319	59.5	1,232	30.0	441
1994	0.290	60.0	1,129	30.5	408
1995	0.263	58.5	998	30.5	372
1996	0.239	57.0	885	30.0	330
1997	0.217	56.0	789	30.0	300
1998	0.197	55.0	703	30.0	272
1999	0.179	54.0	627	30.0	247
2000	0.162	53.0	557	30.0	224
Cumulative factor	9.360	Total	$38,009		$12,994

Present value of total controller wage cost savings: $51,003,000

(3) The pilots will receive current information in a rapid and effective manner. This will also contribute to improved air traffic safety.

(4) Controllers will be able to sign in and out through computer messages, and a record of all transactions will be kept automatically.

(5) TIDS will have the capability of keeping a complete record of all incidents and events, such as data receipt times, acknowledgment times, outage times, and control settings. This could be useful for effective analysis of accidents/incidents and as well for legal purposes.

(6) Flexibility and adaptability to site conditions will be easily achievable through software changes.

(7) TIDS has the potential of accomplishing certain other tasks more efficiently, such as runway configuration management, event reconstruction, and processing equipment station information for certification purposes.

4.0 COSTS

The TIDS will be installed eventually at all those terminal facilities and primary and satellite towers where its installation is considered to be cost effective and desirable. For the purposes of this benefit/cost study, however, it has been assumed that the initial recipients of TIDS equipment will be the 30 major ARTS III terminal facilities and their associated primary and satellite towers shown in Table 1.1. The costs in this section refer to these 30 facilities, except that all of the R&D costs have been applied to these 30 installations in accordance with the recommendation of the Office of Aviation Policy and Plans. Thus, analysis of other installations need not include R&D costs.

4.1 TIDS Research and Development Costs

A preliminary program review paper prepared by the Systems Research and Development Service of the FAA during the month of July 1981 indicates the TIDS R&D costs shown in Table 4.1. The present value of the total R&D costs, including F&E development costs, for 1982 through 1986 is expected to be $5,410,900 as calculated in Table 4.1. The R&D and F&E development costs spent in 1980 and 1981 have been treated as sunk costs in accordance with the recommendation of the Office of Aviation Policy and Plans.

Table 4.1

ESTIMATED R&D COSTS FOR TIDS
(Thousands of Dollars)

	In House		Contracts	
	Costs in Respective Years	Present Value* (1981 dollars)	Costs in Respective Years	Present Value* (1981 dollars)
FY82	340	x0.909 = 309.0	600	x0.909 = 545.4
FY83	635	x0.826 = 524.5	1,000	x0.826 = 826.0
FY84	685	x0.751 = 514.4	1,200	x0.751 = 901.2
FY85	635	x0.683 = 433.7	1,000	x0.682 = 683.0
FY86	335	x0.621 = 208.0	750	x0.621 = 465.7
	Total	$1,989.6		$3,421.3

Present value of grand total R&D costs $5,410,900

*See Table 3.5 for appropriate discount factors.

4.2 TIDS Facilities and Engineering Costs

The total estimated costs (1981 dollars) for procuring and installing the TIDS equipment at the 30 terminal facilities and associated towers are shown in Table 4.2. The average number of subsystems per facility was selected in consultation with various facility supervisors during the SRI team's visit to a few terminal facilities. The indicated unit costs are based on large quantity orders and were estimated by the FAA Technical Center (ACT-230) and the FAA's Systems Research and Development Service (ARD-120). The estimate of 25% for installation, training, and communication lines indicated in Table 4.2 is based on the study team's judgment. The FAA's Air Facilities Radar and Automation Engineering Division (AAF-370) verified that the percentage figure is a reasonable assumption.

4.3 TIDS Maintenance Costs

The maintenance costs of TIDS equipment consist of the costs associated with labor hours needed to repair failed equipment and to perform preventive maintenance as well as the costs of certain spare parts that must be available at various facilities.

The required labor hours for repair and preventive maintenance of various subsystems of TIDS as estimated by the FAA were included in FAA's Order 1812, Subject: System Requirement Statement for Terminal Information Display System (TIDS), Appendix 3, page 2. These estimates are shown in Table 4.3 for ready reference. The grade level of maintenance personnel is typically GS-12 as indicated by the supervisors of various facilities visited by SRI. Referring to Table 3.4, the equivalent annual

Table 4.2

SUMMARY OF TIDS FACILITIES AND ENGINEERING COST CALCULATIONS FOR 30 MAJOR FACILITIES

Item	Number of Units Required	Estimated Unit Price (1981 dollars)	Total
1. Central processing subsystems (1 per facility)	30	$400,000	$12,000,000
2. Interface units (1 per facility)	30	50,000	1,500,000
3. Display processors for major remote towers*	5	20,000	100,000
4. Critical displays for towers (3 per primary tower, 1 per satellite tower)	115	6,200	713,000
5. Supplementary displays for towers (3 per primary tower, 1 per satellite tower)	115	3,400	391,000
6. TRACON displays (4 per TRACON)	120	3,400	408,000
7. Supervisory and maintenance displays (1 per TRACON, 1 per primary tower)	60	1,800	108,000
8. Lighting control panels (3 per primary tower)	90	2,500	225,000
9. Facility processing units (1 per tower)	55	6,400	352,000
10. Flight data displays with keyboards (3 per tower)	165	7,000	1,155,000
11. Modems (2 per remote primary tower, 2 per satellite tower)	58	500	29,000
12. Software (20K per facility)	30	20,000	600,000
Total			$17,581,000
Add an estimated 25% for installation, training, and communication lines			4,395,000
Grand total			$21,976,000

*Los Angeles, San Francisco, Sacramento, LaGuardia, Newark.

wages for GS-12 personnel is $46,196. The hourly wage costs are calculated by dividing this equivalent yearly wage cost by 2,080, that is,

$$\frac{46,196}{2080} = \$22.20 \text{ per hour.}$$

Thus the average person-hour cost for maintenance of TIDS equipment per facility is:

$$1,080 \times \$22.20 = \$23,976 \text{ per year,}$$

where 1,080 = total preventive maintenance hours per year (see Table 4.3). The total cost for 30 facilities will be $719,280 per year.

A preliminary list of recommended spare subsystems per facility is shown in Table 4.4 along with their unit costs. The cost of the spare subsystems per facility is $30,700. The total cost for 30 facilities is $921,000.

4.4 Costs of Existing FDEP and Display Equipment

4.4.1 Maintenance Costs

The R&D, development, and capital costs associated with existing FDEP equipment have already been spent and therefore can be appropriately treated as sunk costs. The only costs that must be considered in the benefit/cost analysis of TIDS are the maintenance costs of FDEP that will continue to be incurred if TIDS is not installed.

Estimation of maintenance labor hours for existing FDEP and display devices is inherently difficult because maintenance personnel usually do not keep a separate record of time spent on repair items. However, SRI

Table 4.3

TIDS CORRECTIVE MAINTENANCE PERSON-HOUR SCHEDULE

Equipment Type	Mean Time Between Failures (MTBF)	Hr/Yr/Device	Number of Devices	Total Hr/Yr
Processor	1,000 hr	8.7	2	17.4
Disk unit	4,000 hr	2.2	2	4.4
Tape unit	2,000 hr	4.37	1	4.4
Line printer	2,000 hr	4.37	1	4.4
Facility processing unit	1,000 hr	8.37	2	16.7
Supervisory maintenance display	4,000 hr	2.2	4	8.8
Lighting panel	4,000 hr	2.2	12	26.4
TRACON display	4,000 hr	2.2	3	6.6
Critical display	4,000 hr	2.2	3	6.6
Flight data processing display	4,000 hr	2.2	15	33.0
Remote terminals	2,000 hr	4.37	10	43.7
				179.0*
Additional repair time				35.8⁺
Subtotal 1				214.8

PREVENTIVE MAINTENANCE

Equipment Type	Hr/Mo/Device	Number of Devices	Hr/Mo	Total Hr/Yr
Processors	1	2	2	24
Facility processing unit	1	2	2	24
Displays	1	40	40	480
Peripheral equipment	2	14	28	336
Subtotal 2				864
Total of Subtotals 1 and 2				1,080**

*Based on a maximum of a 1-hr repair per failure.

⁺Assumes 5% of failures will require 4 additional hours to repair.

**Rounded.

Table 4.4

PRELIMINARY LIST OF TIDS SPARE SUBSYSTEMS PER FACILITY

	Subsystem	Unit Price ($)
1	Critical display unit	$ 6,200
1	Supplementary display unit	3,400
1	TRACON display unit	3,460
1	Supervisory and maintenance display unit	1,800
1	Lighting control panel	2,500
1	Flight data display unit	7,000
1	Facility processing unit	6,400
	Total	$30,700

obtained the following estimates from Houston, Dallas-Ft. Worth, and Las Vegas terminal facilities through telephone calls:

	FDEP Maintenance Labor Hours/Year
Houston	3,300
Dallas-Ft. Worth	1,995
Las Vegas	1,150

The FAA's Airway Facilities Service had estimated an average value of 1,420 hours/year per typical ARTS III facility for maintenance of FDEP. This average value appears to be reasonable and was reverified recently by the Air Facilities Radar and Automation Engineering Division of the FAA (AAF-370). At $22.20 per hour x 1,420 hours, the maintenance labor cost is $31,524/year per facility. For the 30 facilities, the total maintenance labor cost will be $945,720/year.

If we assume that each facility needs a spare data control communication unit, an alpha numeric keyboard, and a flight strip printer and that the total cost of this spare parts set is about $28,200, as communicated to SRI by the Houston facility, then for the 30 facilities, the total cost of the spare parts set will be:

$28,200 x 30 = $846,000.

4.4.2 Display Equipment Cost

The initial capital and installation costs of display devices associated with runway visual range, surface wind measurement systems, instrument landing systems, low level wind shear alert systems, and the like also can be treated as sunk costs. Almost all facilities supervisors indicated that this display equipment does not require much maintenance except for a daily routine checkup and minor calibrations that do not take more than 15 to 20 minutes/day on the average. This implies a total of about 90 hours/year per facility. At $22.20 per hour, this amounts to a maintenance cost for display devices of $1,998/year per facility. For the 30 facilities, the total maintenance cost for display devices will be $59,940 per year.

5.0 RESULTS

The final TIDS benefit and cost calculations are summarized below. In addition, sensitivity analyses are provided so that the effects of changes in the basic parameters can be assessed.

5.1 Present Value of Benefits

In Section 3.4, the present value of total controller wage cost savings was calculated to be $51,003,000. In Section 4.4, the yearly maintenance costs for the FDEP systems for the 30 facilities were estimated to be $945,720. Installation of TIDS will obviate the need for these maintenance costs. As such, these savings can be treated as a benefit due to TIDS. The present value (1981 dollars) of these savings over a period of 20 years with a discount factor of 10% is:

$$\$945,720 \times 9.36 = \$8,851,940,$$

where 9.36 is the cumulative multiplying factor for 20 years with a discount factor of 10% as calculated and indicated in Table 3.5.

The costs associated with the spare parts needed for FDEP also will be saved if TIDS is installed. These costs were estimated to be $846,000 (Section 4.4.1). The maintenance costs for present display equipment for the 30 facilities were estimated to be $59,940 per year. The present value (1981 dollars) of these costs over a period of 20 years is:

$$\$59,940 \times 9.36 = \$561,038.$$

Therefore, the present value of the benefits can be summarized as follows:

Controller wage costs	$51,003,000
FDEP maintenance	8,851,940
Display equipment maintenance	561,038
FDEP spare parts	846,000
Total	$61,261,978

5.2 Present Value of Costs

In Section 4.2, the total present value cost of TIDS equipment for the 30 facilities was calculated to be $21,976,000. The maintenance cost for TIDS for 30 facilities was estimated to be $719,280 per year. The present value of this cost for 20 years is:

$$\$719,280 \times 9.36 = \$6,732.460.$$

The cost associated with spare parts for TIDS was estimated to be $921,000 (Section 4.3). The present value of the total R&D costs (see Table 4.1) was $5,410,900. Therefore, the present value of costs can be summarized as follows:

TIDS hardware	$21,967,000
TIDS maintenance	6,732,460
TIDS spare parts	921,000
R&D costs	5,410,900
Total	$35,031,360

5.3 The Benefit/Cost Ratio

The benefit/cost ratio can be calculated as:

$$\frac{\text{Present value of benefits}}{\text{Present value of costs}}$$

$$= \frac{61,261,978}{35,031,360} = 1.74.$$

If the R&D costs of $5,410,900 are excluded in the cost calculations, the benefit/cost ratio will be:

$$\frac{61,261,978}{29,620,460} = 2.06.$$

5.4 Sensitivity Analyses

There are essentially three sets of sensitivity parameters:

(1) Controller productivity improvement factors.

(2) Investment and maintenance costs of TIDS hardware and software, including spare parts.

(3) Maintenance costs of FDEP equipment.

These parameters are discussed in detail below.

5.4.1 Controller Productivity Improvement Factors

Since the dollar value associated with manpower savings due to TIDS is calculated using a set of productivity improvement factors, variations in the improvement factors can significantly change the calculated manpower savings and consequently the value of the benefit/cost ratio. Hence, the productivity improvement factors are among the most sensitive parameters used in the calculations.

At the present stage of TIDS development, controller productivity improvement factors due to TIDS can only be inferred by indirect means because the equipment is still being developed. Strictly speaking, improvements in controller productivity due to TIDS can be established realistically only after the installation of TIDS equipment in a few facilities and after several controller teams have had adequate experience working in a realistic operating environment. For purposes of the initial analysis, the SRI team selected a suitable set of nominal factors after researching the relevant literature (Refs. 2-8), visiting several terminal facilities, and discussing the projected benefits of TIDS with several supervisors and controllers. A discussion of how these factors were used in calculating manpower benefits is included in Appendix A.

Results of applying the nominal factors to 30 major terminal facilities and to the calculation of a benefit/cost ratio have been presented earlier. The benefit/cost ratio with the nominal factors (e.g., a maximum of a 15% productivity improvement in tower cabs and 8% in departure sectors of IFR rooms) was calculated to be 1.74. Obviously, if the productivity improvement factors are increased, the benefit/cost ratio will become still higher, and the results might be regarded as too optimistic. As such, the sensitivity analysis should address a more critical question: What if the actual controller productivity improvement due to TIDS is not 15%, but less? To answer this question, the manpower savings for the 30 major terminal facilities were calculated using a maximum productivity improvement of 10% in tower cabs and 5% in departure sectors under moderate to heavy activity conditions. The results are shown in Table 5.1. For convenience and easy comparison, the results associated with the nominal factors are also shown.

Table 5.1

EFFECT OF REDUCING THE VALUES OF CONTROLLER PRODUCTIVITY IMPROVEMENT FACTORS

Year	Manpower Savings: Nominal Factors (e.g., 15% productivity improvement in tower cabs, 8% in departure sectors)	Manpower Savings: Reduced Factors (e.g., 10% productivity improvement in tower cabs, 5% in departure sectors)
Primary towers		
1981	33.5	26.0
1982	34.5	26.0
1983	35.0	27.0
1984	38.0	31.0
1985	38.5	31.0
1986	37.5	30.0
1987	36.5	28.5
1988	36.0	28.0
1989	25.0	26.5
1990	35.5	27.0
1991	35.0	27.0
1992	37.5	29.0
1993	36.0	26.5
1994	38.5	28.5
1995	38.5	28.5
Satellite towers		
1981	29.0	20.5
1982	29.5	20.5
1983	29.5	21.0
1984	30.5	22.5
1985	30.5	22.5
1986	30.0	23.0
1987	30.5	22.5
1988	29.5	21.5
1989	30.0	21.0
1990	31.0	22.0
1991	30.5	21.5
1992	31.0	21.5
1993	30.0	22.0
1994	30.5	22.0
1995	30.5	22.0

Table 5.1 (Concluded)

Year	Manpower Savings: Nominal Factors (e.g., 15% productivity improvement in tower cabs, 8% in departure sectors)	Manpower Savings: Reduced Factors (e.g., 10% productivity improvement in tower cabs, 5% in departure sectors)
IFR rooms		
1981	28.5	12.5
1982	27.5	14.0
1983	28.0	13.0
1984	28.5	13.5
1985	28.0	13.5
1986	25.5	12.0
1987	26.5	11.5
1988	27.0	11.0
1989	28.0	10.5
1990	27.5	11.5
1991	26.0	12.5
1992	24.0	11.5
1993	23.5	11.0
1994	21.5	10.0
1995	20.0	9.5

The present value of controller wage cost savings with nominal factors was $51,003,000 (Section 3.4). The corresponding value with reduced factors was calculated to be $29,985,000. The benefit/cost ratio with reduced factors is then calculated as follows:

Controller wage cost	$29,985,000	
FDEP maintenance	8,851,940	Assumed unchanged
Display equipment maintenance	561,038	Assumed unchanged
FDEP spare parts	846,000	Assumed unchanged
Total	$40,243,978	

The present value of the total cost of TIDS, including R&D costs, was calculated to be $35,031,360 (Section 5.2). Therefore, the benefit/cost ratio with reduced factors is:

$$\frac{40,243,978}{35,031,360} = 1.148.$$

Even with a reduced controller productivity improvement of, for example, 10% in tower cabs and 5% in departure sectors of IFR rooms, and even if all R&D costs are allocated to the 30 facilities, the benefit/cost ratio is still greater than 1.

5.4.2 Investment and Maintenance Costs of TIDS Hardware and Software, Including Spare Parts

The unit costs associated with various subsystems and the average maintenance costs of TIDS equipment were established in consultation with the manufacturers, the FAA Technical Center, and Systems Research and Development Service staff monitoring the TIDS development program.

The number of subsystems needed for various facilities can be established fairly accurately on the basis of controller positions in respective towers and IFR rooms. However, there may be variations in the estimated costs of (1) various subsystems and (2) TIDS maintenance because the equipment is under development and stable prices in large quantities are difficult to estimate. Variations in unit prices of various subsystems and maintenance costs will have a direct effect on the benefit/cost ratio because the value of total TIDS costs is directly affected by unit prices and maintenance costs. If the actual value of TIDS costs is, say, 25% higher than assumed, but the assumed productivity factors and FDEP-related costs are correct, then the benefit/cost ratio will be:

$$\frac{61,261,978}{(35,031,360) \times (1.25)} = 1.39,$$

which is still significantly greater than 1. Hence if TIDS costs have been underestimated by as much as 25%, but productivity improvement factors and FDEP-related costs have been correctly estimated, the benefit/cost ratio will still be significantly greater than 1. Even if the costs were underestimated by 50%, the benefit/cost ratios will be 1.16. If TIDS costs have been overestimated, then the benefit/cost ratio will have a higher value.

5.4.3 Maintenance Costs of FDEP Equipment

The present value of the FDEP maintenance cost saving for the 30 facilities was estimated to be $8,851,940 (Section 5.1). The critical question is: What if these costs have been overestimated? Assuming that the costs were overestimated by 25%, the actual savings would amount to $8,851,940 x 0.75 = $6,638,955, and the benefit/cost ratio would then be calculated using:

Controller wage costs	$51,003,000	(as before)
FDEP maintenance	6,638,955	
Display equipment maintenance	561,038	(as before)
FDEP spare parts	846,000	(as before)
	$59,048,993	

The benefit/cost ratio will be: $\frac{59,048,993}{35,031,360} = 1.68.$

It can be seen that the benefit/cost ratio is not as sensitive to FDEP maintenance cost estimates as it is to controller productivity factors and TIDS costs. This is understandable as FDEP-related benefits are relatively small compared to controller wage cost savings.

In summary, the two critical parameters in the benefit/cost analysis of TIDS are controller productivity factors and TIDS costs. The productivity improvement factors should be carefully estimated. The nominal values selected by SRI provide a good starting point. However, these values were established on the basis of limited site visits, subjective judgments by supervisors, controllers, and SRI, and some theoretical considerations.

5.5 Summary of Results

The results presented above are summarized in Table 5.2.

Table 5.2

SUMMARY OF TIDS BENEFIT/COST ANALYSIS RESULTS FOR 30 TERMINAL FACILITIES

	1981 Dollars
1. Present value of benefits	
• Saving in controller wage costs	$51,003,000
• Saving in FDEP maintenance costs	8,851,940
• Saving in display equipment maintenance costs	561,038
• Saving in FDEP's spare parts cost	846,000
Present value of total benefits	$61,261,978
2. Present value of costs	
• TIDS hardware costs	$21,976,000
• TIDS maintenance costs	6,732,460
• TIDS spare parts costs	921,000
• TIDS R&D costs	5,410,900
Present value of total costs	$35,040,360

3. Benefit/cost ratio = 1.74

4. Net saving (rounded off) = $26.2 million

6.0 CONCLUDING REMARKS

This report presents the results of the work done by SRI International in conducting a general benefit/cost analysis of TIDS. The study was performed at a time when TIDS equipment was still in a developmental stage and when its engineering requirements were still undergoing changes. Therefore the benefit/cost analysis was conducted on the basis of whatever information was available at the time of the study.

The benefits and costs identified in this study may be verified by operational testing after TIDS equipment is installed in a few facilities. The benefits claimed for TIDS can be realized essentially through manpower savings and reduced maintenance costs.

The methodology used in this study provides a basic framework for conducting a TIDS benefit/cost analysis for various terminal facilities. Such important parameters as controller productivity improvement factors, controller salaries and wage costs, investment and maintenance costs of TIDS equipment, and maintenance costs of present equipment have been used as input parameters in the methodology. Nominal values of these and other related parameters were developed by SRI International on the basis of discussions with several field controllers, facility supervisors, FAA staff members, and TIDS equipment developers. These nominal values can be modified as more accurate information becomes available and as more experience is gained with TIDS equipment. The methodology is conceptually straightforward and easy to modify.

Based on the initial analysis, the investment in and development of TIDS appear to be justifiable because the potential benefits outweigh the estimated costs.

Appendix A

ESTIMATION OF THE NUMBER OF CONTROLLERS NEEDED WITHOUT AND WITH TIDS

Appendix A

ESTIMATION OF THE NUMBER OF CONTROLLERS NEEDED WITHOUT AND WITH TIDS

The estimation of the number of controllers needed in a terminal facility without and with TIDS was made using the method described in Chapter 5 of FAA's document "Air Traffic Staffing Standard System," Order 1380.33B, dated March 10, 1980 and the controller improvement productivity factors due to TIDS. Table A-1 shows the nominal factors selected by SRI for tower cabs in facilities of various types. An improvement factor of 1.15 was selected for high activity levels [500 cab workload (CWL) units and above; see Table 3.2]. For 0-500 CWL units, four levels of improvement factors were selected: 1.025; 1.05; 1.075; 1.00. These were distributed consistently in four stages for various facility types. For example, for up to about 135 CWL units, the factor is 1.025, and so on. Finer gradation did not seem worthwhile because the factors are already inherently small. Table A-2 shows the productivity improvement factors selected for various sectors in the IFR room. For high activity levels (about 30 aircraft/per hour or more) the factors are those that were already included in Table 3.2. For lower activity levels, gradually decreasing factors were chosen.

For completeness and convenience, a brief summary of the methodology is presented below. Sample calculations for Baltimore are also presented to illustrate the methodology further.

Table A-1

NOMINAL CAB CONTROLLER PRODUCTIVITY
IMPROVEMENT FACTORS DUE TO TIDS

Facility Type 1,2		Facility Type 5		Facility Type 7		Facility Type 8	
Cab Workload Units	Factors	Cab Workload Units	Factors	Cab Worklaod Units	Factors	Cab Workload Units	Factors
0-10	1.025	0-50	1.025	0-45	1.025	0-97	1.025
11-39	1.025	51-59	1.025	46-90	1.025	98-105	1.025
40-74	1.025	60-75	1.025	91-134	1.025	106-114	1.025
75-107	1.025	76-93	1.025	135-159	1.05	115-125	1.025
108-140	1.025	94-113	1.025	160-185	1.05	126-136	1.025
141-171	1.05	114-135	1.025	186-213	1.05	149-162	1.05
172-202	1.05	136-158	1.05	214-240	1.05	163-174	1.05
203-232	1.05	159-183	1.05	241-266	1.05	163-174	1.05
233-261	1.05	184-210	1.05	267-301	1.075	175-190	1.05
262-289	1.075	211-238	1.05	302-333	1.075	191-207	1.05
290-317	1.075	239-269	1.05	334-365	1.075	208-226	1.05
313-344	1.075	370-301	1.075	366-399	1.1	227-245	1.05
345-371	1.075	302-335	1.075	400-434	1.1	246-267	1.05
372-397	1.1	336-371	1.075	435-468	1.1	268-291	1.075
398-422	1.1	372-408	1.1	469-506	1.1	292-315	1.075
423-447	1.1	409-447	1.1	507-537	1.15	316-344	1.075
448-472	1.1	448-448	1.1	538-564	1.15	345-376	1.075
473-496	1.1	489-530	1.15	565-596	1.15	377-407	1.1
497-520	1.15	531-574	1.15	597-639	1.15	408-444	1.1
521-543	1.15	575-620	1.15	640-668	1.15	445-484	1.1
544-566	1.15	621-668	1.15	669-711	1.15	485-526	1.15
567-589	1.15	669-717	1.15	712-762	1.15	527-572	1.15
590-and up	1.15	718-768	1.15	763-817	1.15	573-624	1.15
		769-821	1.15	818-884	1.15	625-678	1.15
		822-875	1.15	885-961	1.15	679-737	1.15
		867-931	1.15	962-1054	1.15	738-798	1.15
		932-989	1.15	1055-1165	1.15	799-874	1.15
		990-1048	1.15	1166-1303	1.15	875-951	1.15
		1049-1109	1.15	1304-1479	1.15	952-1035	1.15
		1110-1172	1.15	1480-1707	1.15	1036-1127	1.15
		1173-1237	1.15	1708-and up	1.15	1128-and up	1.15
		1238-1303	1.15				
		1304-1371	1.15				
		1372-1441	1.15				
		1442-1513	1.15				
		1514-1587	1.15				
		1588-and up	1.15				

Note: Facility types are as follows [see FAA Order 1380.33B, "Air Traffic Staffing Standard System" (March 10, 1980), p. 73]:
1-VFR tower (cab only)
2-VFR combined station/tower
3,4-Nonradar approach control combined station/tower (not relevant to present study)
5-Radar approach control terminal
6-Unused
7-Limited radar approach control tower
8-Terminal radar approach cab.

Table A-2

NOMINAL IFR ROOM CONTROLLER PRODUCTIVITY IMPROVEMENT FACTORS DUE TO TIDS

Part 1

Collocated TRACON/TOWER Facilities

Sector Type	Destination	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor
1	Arrival	19	1.02	23	1.02	27	1.02	>27	1.02
2	Departure	25	1.02	30	1.04	33	1.06	>33	1.08
3	Arrival/departure	27	1.02	31	1.03	37	1.04	>37	1.06
4	Satellite	20	1.02	24	1.03	29	1.04	>29	1.06
5	Final	25	1.02	28	1.02	33	1.02	>33	1.02
	Staffing		1.0		1.5		2		2.5

Part 2

Separately Located TRACON/Tower Facilities

Sector Type	Destination	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor	Max Aircraft per Hour	Factor
1	Arrival	19	1.02	23	1.02	27	1.02	>27	1.02
2	Departure	25	1.02	30	1.06	33	1.08	>33	1.1
3	Arrival/departure	27	1.02	31	1.04	37	1.06	>37	1.08
4	Satellite	20	1.02	24	1.04	29	1.06	>29	1.08
5	Final	25	1.02	28	1.02	33	1.02	>33	1.02
	Staffing		1		1.5		2		2.5

Control Tower (Cab) Staffing

1. Cab workload units for year i are calculated using the appropriate formula of the form:

$$C_i = \frac{1}{1000} (X_i + K_1 Y_i + K_2 Z_i + K_3 V_i),$$

C_i = Cab workload units for the tower in year i
X_i = Annual itinerant operations in year i
Y_i = Annual local operations in year i
Z_i = Annual instrument operations in year i
V_i = Annual primary airport instrument operations.

K_1, K_2 and K_3 are constants with the following values for different types of facilities (see Table A-1 for definitions of facility types):

- For facility types 1, 2, 3, 4 and 7: $K_1 = 0.5$, $K_2 = 1$, $K_3 = 0$.
- For facility type 5: $K_1 = 0.5$, $K_2 = 0$, $K_3 = 0.5$
- For facility type 8: $K_1 = 0.5$, $K_2 = 3.5$, $K_3 = 0$.

The above-noted formula is actually a concise representation of the three formulas given in the FAA's Order 1380.33B, "Air Traffic Staffing Standard System" (March 10, 1980), p. 57.

2. The combined day and evening shift staffing requirement is determined by applying the cab workload units calculated above to the appropriate cab type in Table A-3 for the present system (without TIDS) and in Table A-4 for the TIDS scenario. Table A-4 was developed from Table A-3 by multiplying the CWL numbers in Table A-3 with the corresponding productivity improvement factors from Table A-1.

3. Two additional positions are allowed for midnight shift.

Table A-3

CONTROLLERS NEEDED VERSUS CAB WORKLOAD UNITS BY FACILITY TYPE UNDER PRESENT SYSTEM

Combined Day and Evening Staffing	Facility Type 1, 2	Facility Type 5	Facility Type 7	Facility Type 8
3.0	0.- 10.	0.- 50.	0.- 45.	0.- 97.
3.5	11.- 39.	51.- 59.	46.- 90.	98.- 105.
4.0	40.- 74.	60.- 75.	91.- 134.	106.- 114.
4.5	75.- 107.	76.- 93.	135.- 159.	115.- 125.
5.0	108.- 140.	94.- 113.	160.- 185.	126.- 136.
5.5	108.- 140.	114.- 135.	186.- 213.	137.- 148.
6.0	172.- 202.	136.- 158.	214.- 266.	163.- 174.
6.5	203.- 232.	159.- 183.	241.- 166.	163.- 174.
7.0	233.- 261.	184.- 210.	267.- 301.	175.- 190.
7.5	262.- 289.	211.- 238.	302.- 333.	191.- 207.
8.0	290.- 317.	238.- 269.	334.- 365.	208.- 226.
8.5	318.- 344.	270.- 301.	366.- 399.	227.- 245.
9.0	345.- 371.	302.- 335.	400.- 434.	246.- 267.
9.5	372.- 397.	336.- 371.	435.- 468.	268.- 291.
10.0	398.- 422.	372.- 408.	469.- 506.	292.- 315.
10.5	423.- 447.	409.- 447.	507.- 537.	316.- 344.
11.0	448.- 472.	448.- 488.	538.- 564.	345.- 376.
11.5	473.- 496.	489.- 530.	656.- 596.	377.- 407.
12.0	497.- 520.	531.- 574.	597.- 639.	408.- 444.
12.5	521.- 543.	575.- 620.	640.- 668.	445.- 484.
13.0	544.- 566.	621.- 668.	669.- 711.	485.- 526.
13.5	567.- 589.	669.- 717.	712.- 762.	527.- 572.
14.0	590.-and up	718.- 768.	763.- 817.	573.- 624.
14.5		769.- 821.	818.- 884.	625.- 678.
15.0		822.- 875.	885.- 961.	679.- 737.
15.5		876.- 931.	962.-1054.	738.- 798.
16.0		932.- 989.	1055.-1165.	799.- 874.
16.5		990.-1048.	1166.-1303.	875.- 951.
17.0		1049.-1109.	1304.-1479.	952.-1035.
17.5		1110.-1172.	1480.-1707.	1036.-1127.
18.0		1173.-1237.	1708.-and up	1128.-and up
18.5		1238.-1303.		
19.0		1304.-1371.		
19.5		1372.-1441.		
20.0		1442.-1513.		
20.5		1514.-1587.		
21.0		1588.-and up		

Source: FAA Order 1380.33B, "Air Traffic Staffing Standard System" (March 10, 1980), p. 59, Table 5-1.

Table A-4

CONTROLLERS NEEDED VERSUS CAB WORKLOAD UNITS BY FACILITY TYPE UNDER TIDS

Combined Day and Evening Staffing	Facility Type 1,2	Facility Type 5	Facility Type 7	Facility Type 8
3.0	0.- 10.	0.- 51.	0.- 46.	0.- 99.
3.5	11.- 40.	52.- 60.	47.- 92.	100.- 108.
4.0	41.- 76.	61.- 77.	93.- 137.	109.- 117.
4.5	77.- 110.	78.- 95.	138.- 167.	118.- 128.
5.0	111.- 144.	96.- 116.	168.- 194.	129.- 139.
5.5	145.- 180.	117.- 138.	195.- 224.	140.- 155.
6.0	181.- 212.	139.- 166.	225.- 252.	156.- 170.
6.5	213.- 244.	167.- 192.	253.- 279.	171.- 183.
7.0	245.- 274.	193.- 220.	280.- 324.	184.- 199.
7.5	275.- 311.	221.- 250.	325.- 358.	200.- 217.
8.0	312.- 341.	251.- 282.	359.- 392.	218.- 237.
8.5	342.- 370.	283.- 324.	393.- 439.	238.- 257.
9.0	371.- 399.	325.- 360.	440.- 477.	258.- 280.
9.5	400.- 437.	361.- 399.	478.- 515.	281.- 313.
10.0	438.- 464.	400.- 449.	516.- 557.	314.- 339.
10.5	465.- 492.	450.- 492.	558.- 618.	340.- 370.
11.0	493.- 519.	493.- 537.	619. 649.	371.- 404.
11.5	520.- 546.	538.- 610.	650.- 685.	405.- 448.
12.0	547.- 498.	611.- 660.	686.- 735.	449.- 488.
12.5	599.- 624.	661.- 713.	736.- 768.	489.- 532.
13.0	625.- 651.	714.- 768.	769.- 818.	533.- 605.
13.5	652.- 677.	769.- 825.	819.- 876.	606.- 658.
14.0	678.-and up	826.- 883.	877.- 940.	659.- 718.
14.5		884.- 944.	941.-1017.	719.- 780.
15.0		945.-1006.	1018.-1105.	781.- 848.
15.5		1007.-1071.	1106.-1212.	849.- 918.
16.0		1072.-1137.	1213.-1340.	919.-1005.
16.5		1138.-1205.	1341.-1498.	1006.-1094.
17.0		1206.-1275.	1449.-1701.	1095.-1190.
17.5		1276.-1348.	1702.-1963.	1191.-1296.
18.0		1349.-1423.	1964.-and up	1297.-and up
19.0		1499.-1577.		
19.5		1578.-1657.		
20.0		1658.-1740.		
20.5		1741.-1825.		
21.0		1826.-and up		

4. Total cab controller positions are determined by adding the midnight, day, and evening shift positions and multiplying the total position requirements by 1.6 to provide for the 7-day work week and normal leave usage. Computed fractional positions are rounded to the next highest half number.

IFR Room Staffing

IFR room staffing is calculated by applying the standardized data in Tables A-5 and A-6 or A-7 (A-6 for collocated tower/TRACON facilities and A-7 for separately located tower/TRACON facilities) to the complex's projected hour-by-hour traffic profile on the 37th busiest IFR operations day and averaging the two peak hours of aircraft handled for each shift. Tables A-6 and A-7 were developed by multiplying the "Max aircraft count per hour" numbers in Table A-2 by corresponding productivity factors from Table A-2, Parts 1 and 2, respectively.

The hour-by-hour traffic profiles on the 37th busiest day in 1978 were available for various positions in the 30 facilities. The projected hour-by-hour traffic profiles for future years were estimated by assuming that the hourly counts will be proportional to annual IFR operations.

The total controllers' positions are then multiplied by 1.6 to provide for the 7-day work week and normal leave usage. Computed fractional positions are rounded to the next highest half number.

An Example

Certain representative calculations for the Baltimore facility are presented below to elaborate on the methodology described above. Baltimore is a Type 5 facility with three arrival sectors and 2 departure sectors in the IFR room, collocated with the primary tower.

Table A-5

MAXIMUM HOURLY AIRCRAFT COUNT VERSUS SECTOR STAFFING
UNDER PRESENT SYSTEM

Sector Type		Aircraft Handled per Hour			
1	Arrival	19	23	27	40
2	Departure	25	30	33	50
3	Arrival/departure combined	27	31	37	52
4	Satellite	20	29	29	45
5	Final	25	28	33	50
	Staffing	1.0	1.5	2.0	2.5

Source: FAA Order 1380.33B, "Air Traffic Staffing Standard System" (March 10, 1980), p. 66, Table 5-2.

Table A-6

MAXIMUM HOURLY AIRCRAFT COUNT VERSUS SECTOR STAFFING UNDER TIDS
(Collocated Tower and TRACON)

Sector Type		Aircraft Handled per Hour			
1	Arrival	19	23	28	41
2	Departure	26	31	35	54
3	Arrival/departure	28	32	38	55
4	Satellite	20	25	30	47
5	Final	26	29	34	51
	Staffing	1.0	1.5	2.0	2.5

Table A-7
MAXIMUM HOURLY AIRCRAFT COUNT VERSUS SECTOR STAFFING UNDER TIDS
(Separately Located Tower and TRACON)

Sector Type		Aircraft Handled per Hour			
1	Arrival	19	23	28	41
2	Departure	26	32	36	55
3	Arrival/departure	28	32	39	56
4	Satellite	20	25	31	49
5	Final	26	29	34	51
	Staffing	1.0	1.5	2.0	2.5

Step 1: Establishment of Traffic Data

The following traffic data for Baltimore are extracted from the FAA's tape VSN: 81313 prepared by Information Systems Branch (APO-130):

ANNUAL AIRCRAFT OPERATIONS FOR BALTIMORE

Year	Itinerant Operations	Local Operations	Primary IFR Operations	Total IFR Operations
1978	208,265	13,572	210,597	329,282
1985	276,444	16,663	279,787	479,736
1990	325,399	18,411	333,200	587,918
1995	380,081	19,976	380,294	707,505

The following maximum hourly counts on the 37th busiest IFR day in 1978 for various sectors in the IFR room are established from FAA's Terminal Staffing Standards computer printout prepared by the Office of Management Systems (AMS-560).

MAXIMUM HOURLY AIRCRAFT OPERATIONS ON THE 37TH BUSIEST IFR DAY (1978) FOR BALTIMORE

Sector	Type	Shifts Midnight	Shifts Day	Shifts Evening
Arrival I	1	16	27	31
Arrival II	1	11	29	31
Arrival III	1	0	19	20
Departure I	2	6	25	22
Departure II	2	5	20	23

Step 2: Selection of Manpower Tables

Appropriate tables of cab workload units versus controllers and maximum hourly versus controllers are selected. Since Baltimore is a collocated type 5 facility, the following tables are applicable:

- o Table A-3, column heading "Facility type 5," for tower cabs under present system.
- o Table A-4, column heading "Facility type 5," for tower cabs under TIDS.
- o Table A-5 to calculate number of IFR room controllers under present system.
- o Table A-6 to calculate number of IFR room controllers under TIDS.

Step 3: Calculation of the Number of Controllers Needed in Various Years

The number of controllers needed in tower cabs is calculated by first calculating the cab workload units for the year under consideration. The formula for facility type 5 is applicable. Considering, for example, the year 1985:

$$CWL(1985) = \frac{(276,444) + (0.5)\ (1,663) + (0.5)\ (279,787)}{1,000}$$
$$= 425.$$

Referring to the facility type 5 columns in Tables A-3 and A-4, the combined number of day and evening shift controllers is 10.5 under the present system and 10 in a TIDS environment. Adding 2 controllers for the midnight shift to each number and then multiplying by a factor of 1.6 to provide for the 7-day work week and normal leave usage, the total number of controllers needed for the tower cab in 1985 is calculated to be 20 under the present system and 19.2 under TIDS; 19.2 is rounded to the next half number 19.5.

The number of controllers needed in the years 1978, 1990, and 1995 is calculated in a similar manner. The number of controllers needed in the intermediate years is calculated by linear interpolation between the end point years, for example, for 1987, the end point year will be 1985 and 1990.

The number of controllers needed in IFR rooms is calculated by first calculating the projected maximum hourly count on the 37th busiest day in the year under consideration for various sectors.

Considering again the year 1985, the projected maximum yearly counts in various sectors are obtained by multiplying the respective maximum counts in 1978 by the factor:

$$\frac{\text{Total IFR operation in 1985}}{\text{Total IFR operations in 1978}}$$

$$= \frac{479736}{329282} = 1.457.$$

Multiplying the maximum hourly counts for 1978 by the above factor, the following projected maximum hourly counts for 1985 are obtained:

MAXIMUM HOURLY AIRCRAFT OPERATIONS PROJECTED FOR BALTIMORE IN 1985

		Shift		
Sector	Type	Midnight	Day	Evening
Arrival I	1	23	39	45
Arrival II	1	16	42	45
Arrival III	1	0	28	29
Departure I	2	9	36	32
Departure II	2	7	29	34

Referring now to Table A-5 and matching the hourly counts with the staffing needs for corresponding sector types, the number of controllers needed in various shifts under the present system is found to be as follows:

STAFFING NEEDS FOR BALTIMORE IFR ROOM IN 1985 UNDER PRESENT SYSTEM

Sector	Type	Shifts: Midnight	Day	Evening
Arrival I	1	1.5	2.5	2.5
Arrival II	1	1.0	2.5	2.5
Arrival III	1	0.0	2.5	2.5
Departure I	2	1.0	2.5	2.0
Departure II	2	1.0	1.5	2.5
	Total	4.5	11.5	12.0

Adding the totals for each shift and multiplying by a factor of 1.6, the total staffing needs under the present system are (4.5 + 11.5 + 12) = 28 x 1.6 = 44.8. This is rounded to 45 controllers.

Referring now to Table A-6, the staffing needed for various shifts under TIDS is found to be as follows:

STAFFING NEEDS FOR BALTIMORE IFR ROOM IN 1985 UNDER TIDS

Sector	Type	Shift: Midnight	Day	Evening
Arrival I	1	1.5	2.5	2.5
Arrival II	1	1.0	2.5	2.5
Arrival III	1	0.0	2.0	2.5
Departure I	2	1.0	2.5	2.0
Departure II	2	1.0	1.5	2.0
	Total	4.5	11.0	11.5

The total number of controllers is calculated by adding the totals of midnight, day, and evening shift controller numbers and multiplying by a factor of 1.6:

$$(4.5 + 11.0 + 11.5) \times 1.6 = 27 \times 1.6 = 43.2.$$

This is rounded to the next half number, 43.5 controllers. The staffing needs in the IFR room for the years 1978, 1990, and 1995 are calculated in a similar manner. The number of controllers needed in the intermediate years is calculated by interpolation between appropriate end point years.

The calculations presented above were performed by a computer program for all the 30 facilities. The results were then summed to obtain aggregate controller needs for all facilities for the years 1981 through 1995. The controller needs for the years 1996 through 2000 were estimated by extrapolation.

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