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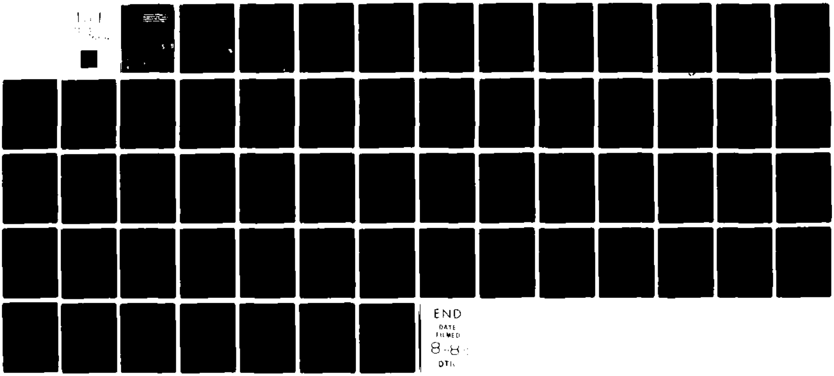

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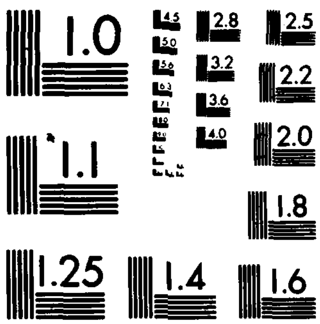

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Office of Systems Engineering
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Washington, D.C. 20591

Preliminary Analysis of the Benefits and Costs to Implement the National Airspace System Plan

An Economic Justification for the NAS Plan

June 1982

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16. Abstract

The many individual programs which comprise the National Airspace System Plan are designed to provide more air traffic control service to the aviation users at reduced operating costs to the FAA. The FAA is able to justify its investment in the NAS Plan by a cost/effectiveness argument. The benefits and costs to the aviation users are the focus of this report. By using example cases to quantify a portion of the potential dollar benefits that would be available to the aviation user as a result of the FAA's implementation of its NAS Plan, this report concludes that the added benefits to the users exceed the users' added costs in avionics equipment by a large margin.

17. Key Words FAA National Airspace System Plan; Benefit/Cost Analysis; Cost/Effectiveness Analysis	18. Distribution Statement Document is available to the public through the National Technical Information Service Springfield, Virginia 22161

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PRELIMINARY ANALYSIS OF THE BENEFITS AND COSTS TO IMPLEMENT THE NATIONAL AIRSPACE SYSTEM PLAN

TABLE OF CONTENTS

FIGURES AND TABLES

PRELIMINARY ANALYSIS OF THE BENEFITS AND COSTS TO IMPLEMENT THE NATIONAL AIRSPACE SYSTEM PLAN

I. SUMMARY: ECONOMIC JUSTIFICATION FOR THE PLAN

The programs which comprise the National Airspace System (NAS) Plan are designed to provide improved air traffic control and flight services to aviation users, while constraining and reducing the costs of providing these services. The technical basis of the Plan is discussed at length in the NAS Plan itself, but it is fair to ask about actual payback in safety, in Federal Aviation Administration (FAA) cost savings, and in cost savings and operational benefits to be achieved by the users.

FAA has undertaken a preliminary assessment of benefits and cost. While the assessment analyzes the total investment cost and payback for the NAS Plan to FAA, it calculates user benefits for only some of the programs. While it must be clear to the most casual reader of the NAS Plan that safety benefits will be a major product of NAS Plan implementation, virtually no benefits for increased safety are claimed. While the cost to the users for the implementation of the Traffic Alert and Collision Avoidance System (TCAS) are included in the costs to aviation users, no benefits are claimed.

It is recognized that both costs and benefits are projections based on judgments about equipment, in a number of cases yet to be built, and benefits to be achieved in the future. For this reason, the analysis first uses estimates we believe to be realistic, and then assumes far more pessimistic results to permit sensitivity judgments to be made.

Benefits and Costs to FAA, and Therefore to the Taxpayer

The first portion of this analysis deals with savings of costs to FAA, the manager of the air traffic control system. From an FAA-only point of view, and therefore the taxpayers', the Plan is justified economically on a cost versus effectiveness argument.

The investment in the modernization of FAA's system has been estimated at about $8 billion in 1982 dollars. The savings in operating costs over the next 20 years come to $24.3 billion dollars, for a net benefit, in 1982 dollars, of $16.3 billion.

Next, we calculated the effect of discounting to consider the effect of disparity of time flow in the benefits against the earlier expenditures for the creation of the improvements, using the OMB Circular 94 method of discounting, and our realistic estimates of costs. The cost savings to FAA and to the taxpayer come to approximately $5 billion in discounted dollars in the next 10 years, against discounted savings in operating costs over the next 20 years of about $9 billion, a net savings of $4 billion by a more efficient FAA system.

Benefits and Costs to Users

In making an assessment of benefits to users, we examined just five program areas. Benefits were estimated for: 1) the programs leading to improved fuel efficiency en route and during transition and approach, 2) the programs to improve capacity and throughput at major airports, and 3) implementation of the Microwave Landing System. Two other programs: 4) improved access to weather information, and 5) improvements in safety other than weather related, are discussed, but no dollar estimates of safety benefits are claimed.

Best estimates based on FAA's own studies of benefits and costs are given. Best estimates of avionics cost and expected equipage levels are based on FAA's own studies and consultation with industry sources. These estimates yield a 20-year total of aviation user benefits of $24.7 billion versus an added cost of $4.0 billion, a net benefit of $20.7 billion, ignoring (in this calculation) the benefits of FAA system efficiency. The $4.0 billion cost is based on assumptions of high equipage levels for Mode A, C, S and TCAS avionics.

The analysis next assumes that the estimates we consider realistic are in reality highly optimistic. We now assume that only half the benefits will be achieved by users, but that avionics costs to users will be double our estimates. Even with these assumptions, there is still a net benefit to users of approximately $4.4 billion. Next, we evaluated the effect of "discounting."

For the aviation users, again using our best cost estimates, the net *discounted* benefits come to $6.8 billion dollars against $1.1 billion in avionics cost (discounted), for a net benefit of $5.7 billion, in discounted dollars.

Finally, we analyzed the cost and benefits in a highly pessimistic way. We estimated that the investment costs for both FAA and users will be double our best estimates and that the expected benefits to both FAA and users would be half of our estimates. Discounting was then applied to adjust for time lags between achieved benefits and expended costs. Even under these conditions, a net benefit of $1.2 billion still accrues to the aviation users, but the investment costs to FAA with this very pessimistic assumption now exceed the reduction in operating costs.

It should be noted that in the more pessimistic assessments, the net benefits to general aviation go down more rapidly than those for the air carriers. There are two reasons for this. As noted, virtually no dollar benefits are claimed for safety improvements or improvements which will provide better general aviation access to the system, yet these are probably the most compelling benefits to general aviation. Further, the general aviation equipage levels (and therefore the costs) used in computing benefits versus costs are set high, e.g., at 100 percent for altitude-reporting Mode A, C, S systems and 50 percent TCAS implementation, even for single-engine propeller aircraft. Thus, the costs are set quite high and then arbitrarily doubled while benefits are arbitrarily halved in the computation.

This analysis does not include an assessment of benefits and costs for the U.S. military fleet even though the Department of Defense is an integral working part of the National air traffic control system. FAA estimates that approximately 20,000 aircraft currently fly in the continental U.S., of which 8,000 are helicopters. While FAA has the statutory responsibility to provide a common system for all users, the Department of Defense also has a requirement to maintain a level of air traffic control capability to meet wartime readiness requirements, and thus operates a major system of facilities and services for military use.

In considering benefits and costs, it is reasonable to assert that benefits achieved by the military services would be similar to those obtained by other users for the many military operations which are similar to those conducted by civil users; but this would not account for the extensive special needs of the military services. Thus, an analysis based on normal transport operations alone would be unfair in that costs might be estimated in ways similar to those discussed in this analysis, while benefits could not be readily estimated by FAA.

These preliminary estimates of cost and benefits for the NAS Plan to civil aviation show a clear benefit both to the taxpayer and to the users of aviation system. The benefits will be far greater than the benefits assumed for the few programs chosen.

A. FAA Investment and Savings in Annual Operating Costs

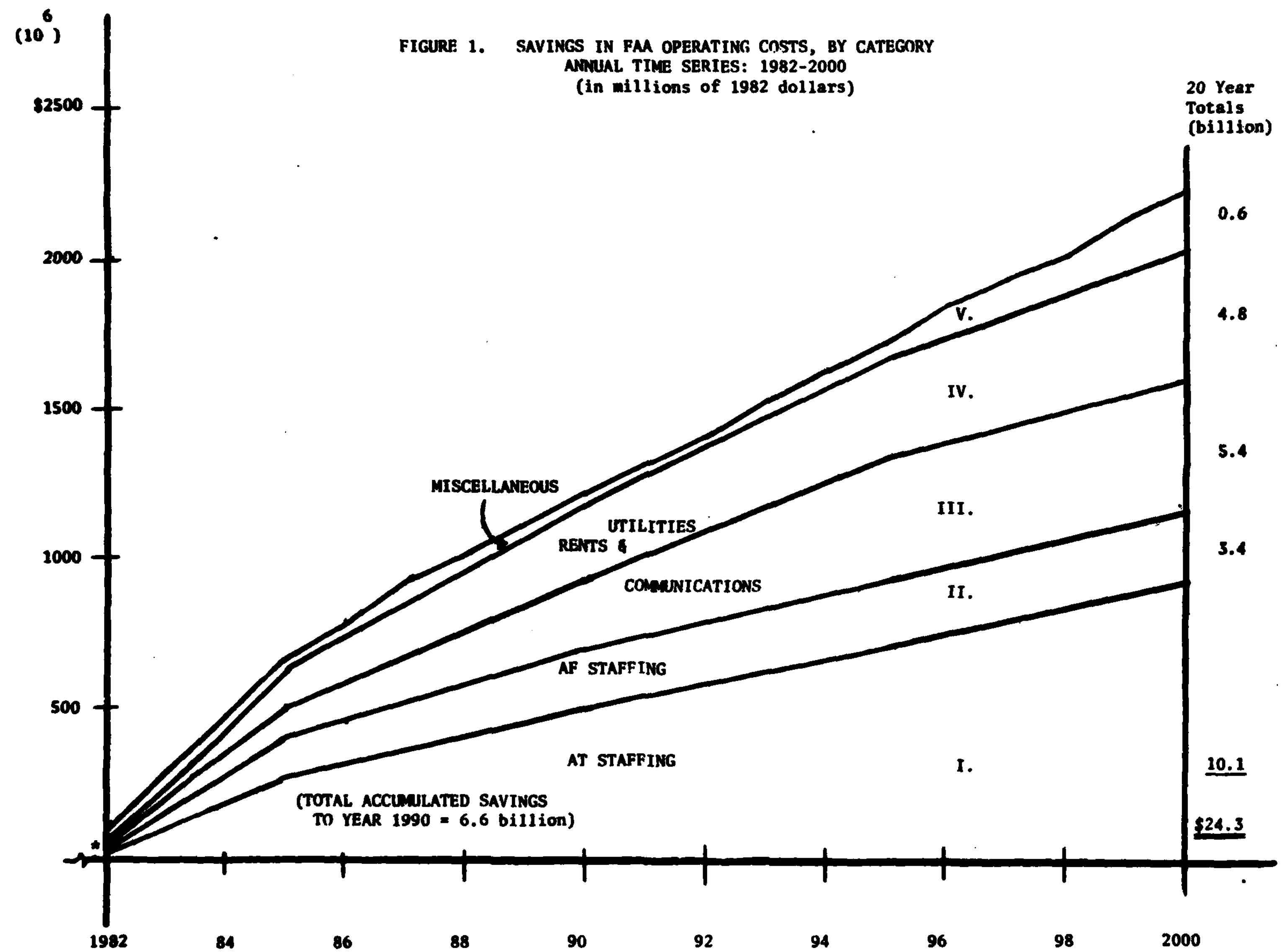
The investment programs needed to execute the modernization of the FAA system are described in the National Airspace System Plan (Chapters III through VIII). The programs will provide a higher quality of service to more aviation users, at a savings in costs to FAA--the manager of the air traffic control system. The Plan describes how these savings will be achieved by a process of consolidation, automation, modernization, and redesign of the ATC system. From an FAA-only point of view, and therefore the taxpayers', the Plan is justifiable economically on a cost versus effectiveness argument; a comparison of costs to provide, at a minimum, the same level of service under the current and the modernized system.

The basis for this argument can be seen in Figure 1, which shows an annual time series of anticipated operating cost savings resulting from the implementation of the NAS Plan.

A saving of $24.3 billion in annual operating costs has been estimated for the 17-year period ending in the Year 2000. About 40 percent of this saving results from reductions in air traffic control personnel staffing; another 40 percent is saved in the combined facility costs for rents, payments for utilities, leasing and communications.

The investment in the automation, modernization and consolidation programs needed to achieve these savings has been estimated at about $8 billion in 1982 dollars; $1 billion for engineering and development, and $7 billion to implement the facilities and equipment described in the Plan. As a rough comparison, the savings in operating costs of some $24 billion over the next 20 years appear to economically justify the expenditure of $8 billion to be spent over the next 10 years.

FIGURE 1. SAVINGS IN FAA OPERATING COSTS, BY CATEGORY
ANNUAL TIME SERIES: 1982-2000
(in millions of 1982 dollars)



*Small dollar amounts shown in 1982 reflect savings accumulated by programs already implemented in 1981.

Another comparison, recommended by OMB Circular A-94, is to calculate the present value of all future benefits and costs, discounted at a rate of return on investment of 0.10. When the future investment costs of $8 billion, and the operating savings of $24 billion are discounted to reflect present values, they are still sufficient to warrant the investment. The present, discounted, value of the $8 billion in costs to be expended over the next 10 years is approximately $5 billion. The savings in operating costs of $24 billion obtained over a period of 20 years, are $9 billion. In effect, FAA, while earning a prescribed rate of return on its investment of 10 percent, is still able to achieve a favorable ratio of benefits to costs of almost 2 to 1.

In addition to simply providing operating cost savings to FAA, the NAS Plan will consolidate and modernize ATC facilities with the latest technology and will offer increased benefits and service to the aviation user. To cite just one example, an indirect, but real benefit will accrue to the general aviation user, for example, in easier access to the ATC system. The Plan will establish a network of modern flight service stations. As a result, users will get fewer "busy" signals when they attempt to reach the system, and more timely and accurate weather information when they do reach it. While there is an obvious benefit from easier access to essential information, no dollar benefit is claimed.

There is another issue which must be considered at the outset in considering the costs to the user community. In this assessment, we have considered only costs of new avionics equipment. It can be argued that increases in fuel taxes or ticket taxes will also add cost burdens to users. Such cost increases are not considered in this analysis because they are intended to achieve cost recovery from those utilizing aviation services. However, a higher degree of cost recovery for FAA services can only make the modernization of the system to achieve cost containment and more user benefits even more attractive. Cost recovery for a more efficient system is on its face a better deal than cost recovery for a more costly one.

B. Benefits to Aviation Users

A preliminary assessment of the benefits and costs to the users of the system is contained in this report.

Rather than attempting to analyze the whole Plan, this assessment concentrates on only a few specific areas of improvement in making its point. The estimates of benefits and costs shown below have been excerpted where possible from previous studies. The example cases of benefits are presented as separate topics. An attempt was made to avoid the "double counting" of benefits when a new topic is presented. Thus, it is proper to add the estimates for each topic presented in order to arrive at a more general indication of benefits to the users. It is likely, however, that the actual benefits from the full implementation of the NAS Plan will greatly exceed the sum of the benefits for the topics selected for presentation.

A large number of the modernization and improvement programs contained in the National Airspace System Plan are expected to have a direct and beneficial effect on the safety of the aviation system. There is universal agreement in the aviation community that better weather data gathering and dissemination, approach lights, precision approach and landing guidance, better information on airport conditions, and other aids improve the safety of the aviation system. Similarly, TCAS, improvements in conflict alert and resolution systems, and reduction of ATC system errors will have a beneficial effect. This analysis contains assessments of several such benefits. As will be seen from the analysis, the Plan is justifiable without them, but its value is dramatically enhanced by the prospect of safety enhancements.

As part of this analysis, a preliminary estimate is provided of the additional costs in avionics equipment likely to be incurred by aviation users by the implementation of the NAS Plan., A comparison of the estimated benefits and costs to users provides an indication of the economic justification of the NAS Plan.

Example Cases of NAS Program Benefits to Aviation Users

1. Improved Fuel Efficiency En Route and During Transition and Approach, due to the elimination of indirect routings and altitude restrictions. Reductions in fuel costs made possible by automation functions provided by Automated En Route ATC and Integrated Flow Management.

   - Benefits available to both air carrier and general aviation user groups.
   - Reference: "En Route Air Traffic Control Computer System," DOT/FAA report No. AAP-82-3, January 1982.
   - Benefits estimated; 20-year total of savings in fuel costs: $16.4 billion (1982 dollars).

2. Reduced Delays at Major Airports; due to increases in airport throughput provided by improved technology and procedures.

   - Benefits available to aircraft which operate out of the major airports; predominantly air carriers.
   - References: FAA Study of MLS Benefits and Costs Compared to ILS, FAA report No. EM-80-7, June 1980.

     Estimates for airport capacity improvement benefits were obtained from an informal study of the projections made by FAA/Industry Airport Task Forces at five major airports. The results, developed by Peat, Marwick, & Mitchell, were reported in an FAA "Briefing on Airport Capacity," March 18, 1982.
   - Benefits estimated; 20-year total of reduced costs of delays: $8.0 billion (1982 dollars).

3. Improved Access to Weather Information; due to better dissemination of weather data through a modernized and automated network of flight service stations, and provision of better weather information by "next generation" weather radars.

- A safety-improvement benefit available to general aviation users due to better dissemination of weather data; a safety-improvement benefit to both the air carrier and general aviation user will result from better weather data.

- Reference: Table 3 based on weather-related accident record compiled by NTSB.

- Benefit of improvement in safety to users not estimated.

4. Improvements in Safety (Other Than Weather-Related)--reduced threat of mid-air collisions, improved and automated conflict advisory/conflict resolution service, reduction in ATC system errors through automation, research into human factors contributing to accidents, etc.

   - Safety improvements are intended to benefit both the air carrier and general aviation user groups.

   - References: a) NTSB accident data, Tables 3, 4, and 5; and b) 9020 Computer Replacement Program Analysis of Potential for Reduced System Errors, DOT/FAA Report No. AAP-82-3, January 1982, pages 3-23.

   - Benefit of improvement in safety to users not estimated.

II. EXAMPLE CASES OF BENEFITS TO AVIATION USERS

A. Improved Fuel Efficiency Due to Automated ATC Functions*

- o Air Carriers
- o General Aviation

Preliminary analysis based on studies conducted by and for FAA, indicate that with the introduction of further automation, a major potential savings of fuel could be realized by the users of the aviation system. These savings could be achieved from 1) optimal or direct routing of flights, 2) the elimination of altitude restrictions, and 3) the elimination of arrival delays caused by the inefficient use of available airport capacity. By better regulation of flows into the airport to fully utilize available capacity, an improvement in fuel efficiency of some 3 percent was estimated nationwide; the remaining 3 percent was estimated to accrue to the ability to make direct flights with minimal restrictions (AERA). These savings were estimated as being made possible by the introduction of the following automated functions:

1. Improved En Route Metering. The ability to better coordinate the flow of traffic into "fix" points, and provide for better sequencing of aircraft and airport runway utilization. A savings of 1.5 percent of the total fuel bill was estimated for this function.

2. Fuel-Efficient Route Planning. More direct flights with fewer altitude restrictions would be achieved. A savings of 1.5 percent in fuel was estimated for this function.

3. En Route and Terminal Flow Planning and Traffic Management. Will provide for more accurate predictions of arrival times and delays. This ATC management tool will allow delays to be handled more efficiently. A savings of 1.5 percent in fuel was estimated for this function.

4. Strategic Clearance Planning. Will provide for the separation of aircraft from other aircraft rather than achieving separation by

*This discussion excerpted from "FAA's En Route Air Traffic Control Computer System, Response to Congressional Recommendations," DOT/FAA/AAP-82-3, January 1982. This response drew upon the work performed by Edmund Koenke and Karl Seiler of FAA, and by the MITRE Corporation: Rucker, Richard A., "Potential Fuel Savings of Specific ATC System Improvements," FAA Report EM-82-11.

allocation to prescribed airspace. There will be an accompanying significant reduction in procedural restrictions. The filing of direct routes will be commonplace. A savings of 1.0 percent in fuel was estimated for this function.

5. Tactical Clearance Generation. Will provide as close to unrestricted flights as possible with no real time intervention of the controller into the control loop. A savings of 0.5 percent was estimated for this function.

To reach the level of full automation included in the functional levels described will require the replacement of the FAA computer system. Improved en route metering is scheduled for implementation in 1984. Fuel savings due to this function were, therefore, calculated to start in 1984. Functional levels two and three--Efficient Route Planning; Flow Planning and Traffic Management--are planned for inclusion in the software package of en route computer capability to be introduced in 1991. Functional level four--Strategic Clearance Planning--is estimated to be implemented in 1993, and level five--Tactical Clearance Generation--will be available when full Automated En Route Air Traffic Control (AERA) capability is introduced in 1994.

The full potential of a 6 percent savings in fuel costs is estimated to be available in 1995, after the full system envisioned in the NAS Plan is implemented. Smaller benefits accrue in the intervening time, as depicted in Table 1. Estimates are based on applying the full 6 percent benefit only in the final 5 years of the 20-year period projected in the NAS Plan. Table 1 shows the consequences of savings build-up to the 6 percent figure, but in the sensitivity analyses which are discussed subsequently, these benefits were arbitrarily cut in half. All figures are shown in 1982 dollars.

The first step of the advanced automation program is intended to relieve the present system of constraints in computer capacity which might prevent the ATC system from satisfying forecast levels of traffic activity. Hence, the dollar savings shown in Table 1 are not due to any penalties assessed to the present system due to limited capacity; these

TABLE 1

TOTAL SAVINGS IN USER FUEL COSTS DUE TO AUTOMATION
(billions of 1982 dollars)

	I. Forecast of Fuel Consumed[1/] (billions of gallons)			II. Savings Factor (.06 max.)	III. Dollar Savings[2/] (dollars in billions)			IV. Automation Levels[3/]
	Air Carrier	General Aviation			Air Carrier	General Aviation		
	(Jet Fuel)	(Jet Fuel)	(Av. Gas)		(Jet Fuel)	(Jet Fuel)	(Av. Gas)	
1986	9.8	1.2	0.6	.015	0.15	0.03	0.02	1
1987	10.0	1.3	0.6	.015	0.15	0.03	0.02	1
1988	10.3	1.4	0.7	.015	0.15	0.04	0.02	1
1989	10.5	1.5	0.7	.015	0.16	0.04	0.02	1
1990	10.8	1.6	0.7	.015	0.16	0.04	0.02	1
1991	11.2	1.7	0.8	.015	0.17	0.04	0.02	1
1992	11.5	1.8	0.8	.015	0.17	0.05	0.02	1
1993	11.8	1.9	0.8	.045	0.53	0.15	0.07	2&3
1994	12.1	2.0	0.9	.045	0.54	0.16	0.08	3
1995	12.4	2.1	0.9	.055	0.68	0.20	0.10	4
1996	12.7	2.2	0.9	.06	0.76	0.23	0.10	5
1997	13.0	2.2	1.0	.06	0.78	0.23	0.12	5
1998	13.3	2.3	1.0	.06	0.80	0.24	0.12	5
1999	13.6	2.4	1.0	.06	0.82	0.25	0.12	5
2000	13.9	2.5	1.1	.06	0.83	0.26	0.13	5
2001	14.2	2.6	1.1	.06	0.85	0.27	0.13	5
2002	14.5	2.7	1.1	.06	0.87	0.28	0.13	5
2003	14.8	2.7	1.2	.06	0.89	0.28	0.14	5
2004	15.1	2.8	1.2	.06	0.91	0.29	0.14	5
2005	15.4	2.9	1.2	.06	0.92	0.30	0.14	5
20-Year Total	250.9	49.5	18.3		$11.29	$3.41	$1.66	

1/ Forecast of Fuel Consumed:
"FAA Aviation Forecasts, 1982-1993," Report APO-82-2, page 46

2/ Fuel Costs
Air Carrier
Jet Fuel = $1.00 per gallon
General Aviation:
Jet Fuel = $1.73 per gallon
Av. Gas = $1.92 per gallon

3/ Automation Levels
1. Enroute Metering
2. Fuel Efficient Route Planning
3. Flow Planning and Traffic Management
4. Strategic Clearance Planning
5. Tactical Clearance Generation

limitations were assumed as having already been eliminated. The savings as a result of fuel efficiency shown in Table 1 represent the difference in benefits to the aviation user as the first projected improvement--improved en route metering for en route centers--evolves into the full system envisioned in the NAS Plan capable of eventually providing automated air traffic control services. The savings in fuel costs shown in Table 1 do not include any benefits resulting from improvements made in runway capacity and airport throughput at major terminal airports. These latter benefits have been estimated separately and are shown in Table 2.

Table 1 reveals that the full fuel savings potential of 6 percent will be reached by the year 1996 and will continue at this level of savings until the year 2005, the end of the 20-year planning period. By the end of this period, fuel will be consumed at an annual rate of about 20 billion gallons; 6 percent or 1.2 billion gallons will be conserved at a total dollar savings of $1.4 billion. For the entire 20-year planning period, the total savings in fuel costs are estimated as $16.4 billion; about 70 percent of these savings accruing to the air carriers, 30 percent to the general aviation user.

From a general aviation aircraft owner's point of view, a decision to purchase the avionics equipment needed to obtain the services offered by the modernized ATC system will result in an improvement in fuel efficiency at least equal to that attained by the air carriers. The service area for which the greatest improvement in fuel efficiency is expected to be achieved is below Flight Level 310, and within 150 miles of the major air terminals. Beyond these limits, it is frequently possible to provide fuel-efficient routings with today's, unimproved, ATC system, when traffic is light enough to permit controllers to provide such services. General aviation aircraft operating in the vicinity of major terminal areas will, thus, have the same potential for fuel savings as air carriers.

The above analysis deals with fuel costs only. However, from the air passenger's point of view, there is a value in not being delayed on a flight. For this reason, many studies which attempt to quantify benefits to the aviation community choose to include costs to the passenger by estimating the value of time lost in being delayed by the dollar loss in hourly income. We have not done so in this analysis.

From the air carrier's point of view, there is also a value associated with not having flights delayed by the air traffic control system. For one thing, passengers, particularly on short-range flights, won't choose to use other modes of travel. And there are savings in the cost of operating an airline when flights are not delayed. At a minimum, there is agreement that the costs of burning fuel could be avoided. For this reason, the dollar costs of delays due to indirect flight routings and other airborne delays are often estimated in the dollar value of the fuel consumed. This results in a very conservative estimate of the true costs of airline delays. In other words, "the cost of airborne delays" and "the reduced costs due to fuel efficiency" are not alternative measures of the same accomplishment of achieving improved performance; reduced fuel costs are the method selected for measuring the costs of delays. Since these costs do not reflect the passenger's inconvenience or other costs associated with a delay to the air traveler, and since they include a portion only (fuel costs) of the airline's operating costs, they understate the benefits to aviation users resulting from an ATC system that results in reduced delays.

B. Reduced Delays at Major Airports

o Improvements In Existing Airport Capacity

Reduction of inefficiencies en route and during transition to approach will result in the benefits just discussed. Inability of airports to accommodate the demand also creates delays. Programs to increase runway capacity and increase throughput also have the potential to reduce delays. These are not included in the savings in reduced fuel costs shown in Table 1, but are estimated separately and shown in Table 2.

The NAS Plan includes programs for improvement in airport capacity. (See "Airport Capacity Improvement/Delay Reduction Program," page IV-44.)

Although new runways and other improvements at existing airports are clearly the best ways to increase system capacity, significant gains also can be achieved by other means. Possibilities that have been examined include: parallel instrument (IFR) operations with reduced spacing between runways, operational solutions to avoid the hazard of wake vortices and allow shorter distances between arriving and departing aircraft, independent and dependent IFR parallel operations at reduced spacing for dual and triple runways, and construction of separate segregated short runways for commuter and business aircraft, among others.

New technologies also have been developed, including the Microwave Landing System (MLS), which allows more varied approach paths to an airport; improved surveillance capability; and the airborne collision avoidance system, Traffic Alert and Collision Avoidance (TCAS). Work is also underway on methods to improve the integrated management of air traffic flows in the terminal area and on a unique solution to the wake vortex detection and avoidance problem.

The Microwave Landing System (MLS) will provide a more accurate and stable signal that is virtually unaffected by such environmental influences as snow or slush on the runway, or other detrimental effects such as tides and costly site preparation. In addition, unlike ILS, the use of MLS equipment will protect against the uncertainties inherent in our forecasts of traffic activity and will allow for future growth, unencumbered by the problem of a shortage in available frequencies for communication.

In a study of potential benefits of MLS equipment, the FAA identified and quantified in dollar terms the additional benefits that would accrue in the alternative use of MLS to provide for delay reduction at major airports serving air carriers and already threatened by congestion (see reference shown on Table 2).

The benefit categories quantified in the MLS study which will provide benefits are shown in Table 2. The 20-year total of dollar benefits in reduced delays at major airports, in excess of what would be provided if ILS were to remain as the incumbent system, is $2.3 billion (in 1982 dollars). In addition, benefits from MLS of some $0.3 billion were estimated in the referenced study (but not claimed in Table 2) to accrue to users who receive MLS service at the smaller airports.

MLS also has the potential for increasing runway capacity at major airports by allowing the use of certain Concepts for Increased Runway Utilization (Table 2). Although a description of some of these benefits appears in the MLS studies, no attempt was made to quantify them. The MLS study employed the notion of a "worse case" analysis; the assumption being that an economic justification for replacing ILS equipment with MLS could be reached by including only a portion of the benefits--those more readily quantifiable in dollar terms.

TABLE 2

Delay Reductions at Major Airports Due to Improvements in Technology

Dollar Benefits to Air Carriers
(20-Year Totals in Billions of 1982 Dollars)

Microwave Landing Systems	$ Benefits	Case Study Locations
a. Reduced Disruptions Due to Weather Minima	0.9	Top 40
b. Lower System Outages	0.1	Top 40
c. Eliminate Airway Constrictions, Ground Signal Restrictions	1.1	JFK (NYC Area)
d. Reduced Path Lengths to Terminal	0.2	Top 40
20-Year Total 1/	2.3	
Concepts for Increased Runway Utilization		
a. Independent IFR Parallels (to 3000')	1.0	JFK/DEN/DFW/MSP MEM/PHL
b. Dependent IFR Parallels (below 3000')	0.3	DEN
c. Operational Solutions to Wake Vortex	0.3	DEN
d. IFR Approach to Converging Runways	2.0	DEN/DFW/IAH/MIA ORD/STL/JFK
e. Triple Parallels	0.3	ORD
f. Short Runways, Dedicated to G.A.	1.2	ORD/ATL/PHL/DFW JFK/DEN/STL
g. Automated Runway Configuration Management Sys.	0.6	ORD
20-Year Total 2/	5.7	

1/ These figures were estimated in FAA Study of MLS Benefits and Costs Compared to ILS; FAA No. EM-80-7, June 1980.

2/ These estimates were obtained from an informal study of the projections made by FAA/Industry Task Forces at five major airports. The results, developed by Peat, Marwick, and Mitchell were reported in an FAA Briefing on Airport Capacity, March 18, 1982.

Not all of the concepts shown on the bottom of Table 2 depend on the implementation of MLS; for example, the automated Runway Configuration Management system, in prototype development for Chicago O'Hare Airport (ORD) is not MLS dependent. Some of the operational solutions to wake vortex impact are more dependent upon MLS.

A series of FAA and industry study efforts at specific airports yielded estimates of significant benefits from potential implementation of new operational concepts. The total estimate of benefits at major airports resulting from the use of these operational concepts is shown in Table 2; a 20-year total dollar benefit of $5.7 billion has been estimated.

It should be noted, however, that where totals have been estimated for case study locations, the totals shown reflect the benefits available to the specific locations listed. Should subsequent study and evaluation reveal, for example, that some of the concepts have potential application locations other than those shown in Table 2; these benefits would be added to the totals shown in Table 2.

C. Improvements in Safety, Weather Related

o Improved Access to Weather Information

NAS Plan Program - "Flight Services and Weather"

The purpose of this program is to provide for: 1) the automation and consolidation of flight service stations to provide better and more complete flight service at constrained costs; 2) improved pilot access to file flight plans and receive information about weather and ATC system status (delays, equipment, outages, etc.); and 3) more readily available information in a network of national coverage, but tailored to individual user needs.

A special study conducted by the National Transportation Safety Board (NTSB), for the years 1964 through 1974, of a large number of general aviation accidents concluded that NTSB "is concerned about the large number of fatal accidents which are weather-involved," (accidents which the Safety Board determined that weather had been a cause or a contributing factor).

The study went on to say that "weather is the most frequently cited causal factor in fatal general aviation accidents and has been for several decades." Weather-involved accidents represent some 37 percent of the total fatal accidents for the 10-year period studied.

> "Low ceiling was the most frequently cited weather phenomenon in weather-involved, fatal, general aviation accidents. Fog and rain were the next two most frequently cited phenomena."

Table 3, shown below, has been compiled from NTSB data and includes all weather-involved general aviation accidents--fatal and non-fatal. Note that in the 10-year study of general aviation accidents, weather-involved accidents remain as a highly significant portion of the total, reaching to some 20 percent of the total number of accidents by the early 1970's (Column V). In 1979, the latest year for which NTSB data are available, the percentage of weather-involved accidents to total is shown as 21.9 percent. The NTSB study and the accident data shown in Table 3 indicate that a considerable benefit would accrue to general aviation users from FAA's effort to improve the quality and timely dissemination of weather information.

With regard to the quality of weather information made available to the general aviation pilot, the NTSB study found that:

> "In the cases studied, 74 percent of National Weather Service forecasts were considered to have been either substantially correct, or the weather was better than predicted. On the other hand, 11 percent were considered to have been worse than forecast. Of these, in only about 5.5 percent of the cases, the forecast was completely inaccurate, or the weather was considered to have been considerably worse than forecast."

TABLE 3

General Aviation Accidents; Weather-Involved* Accidents

I. YEAR	II. HOURS FLOWN (annual, in millions)	III. TOTAL ACCIDENTS (fatal/non-fatal)	IV. WEATHER-INVOLVED	V. % WEATHER/TOTAL (Col IV÷ Col III)	VI. WEATHER ACCIDENT RATE (per 100,000 hrs) (Col IV÷ Col II)
1964	N/A	5069	798	15.7%	N/A
1965	N/A	5196	669	12.9	N/A
1966	N/A	5712	909	15.9	N/A
1967	N/A	6115	1112	18.2	N/A
1968	N/A	4968	1067	21.5	N/A
1969	N/A**	4767	986	20.7	N/A
1970	26.03	4718	1014	21.5	3.9
1971	25.51	4640	947	20.4	3.7
1972	26.97	4256	983	23.1	3.6
1973	30.05	4255	976	22.9	3.2
1974	32.48	4343	1010	23.2	3.1
11-Year Average 1/	N/A	4,913	952	19.4%	N/A
1979 (Latest Year) 2/	43.34	4,023	881	21.9%	2.0

Sources: 1/ 11-Year Average Data from "Special Study of Weather-Involved G. A. Accidents; 1964-74," NTSB 1976
2/ Latest Year Data from "Briefs of Fatal Accidents, Weather a Cause/Factor, G.A., 1979," NTSB

Explanatory Notes:

*Weather-Related Accidents: NTSB determined that weather had been a cause or contributing factor.
**Data on general aviation aircraft usage compiled from FAA survey begun in 1970.

It is clear that investment programs to improve the accuracy of weather forecasts will provide important safety benefits to both the air carrier and general aviation user groups.

Through the use of a sample survey of users, started in 1970, FAA has compiled statistics on the number of hours flown annually by general aviation aircraft. If it can be assumed that "hours flown" represent a relevant measure of the exposure to the risk of an accident, then the calculation of the accident rate (shown in Column VI) indicates that a considerable improvement in general aviation safety has taken place in recent years. The accident rate for weather-involved accidents has gone down by almost one-half: from a rate of 3.9 accidents per 100,000 annual flight hours in 1970 (the first year for which data on aircraft operational use are available) to a rate in 1979 (the latest year for which accident data are available) of 2.0 accidents. The reason for this improvement is not to be found in the reduction in the absolute number of accidents recorded, but in the significant increase in the annual numbers flown by general aviation aircraft. This increase is due to the much expanded size of the general aviation fleet.

Forecasts indicate that this expansion in fleet size can be expected to continue.

If the industry is to be successful in reducing the absolute level of weather-involved accidents to general aviation aircraft, it must invest in the following programs described in the National Airspace System Plan:

Other Weather-Related Programs:

-- Flight Service Stations - NAS Plan Chapter V

Sixteen individual programs listed in Plan to assist the general aviation community by the establishment of an Automated Flight Service Automation System (FSAS).

Flight Service Stations provide:

Flight plan entries into ATC system for general aviation pilots
Briefings, including weather updates
Distress assistance
Ground-to-VFR communications

Included among the 16 individual programs shown on page V-23, are those for mass weather dissemination, automated observation and display of weather information, and for improved ground-to-air communications.

-- <u>Weather Radar Programs (Program 18), NAS Plan Chapter VI</u>

"The future aviation weather radar sensor network will provide improved weather information at 6,000 feet and above for en route areas and approaching the surface of designated airports. The sensor network will be comprised of selected FAA terminal radars with weather channels and next generation weather radars (NEXRAD)."

The safety benefit from these programs is self-evident, but we have not attempted to quantify it in assessing benefits versus costs.

D. Improvements in Safety, Other than Weather Related

1. For the General Aviation User

The National Transportation Safety Board (NTSB) special studies of both fatal and non-fatal general aviation accidents (summarized in Table 3) reveal a pattern over the last two decades of some 5,000 accidents per year; 650 (15 percent) of which were fatal. Of the total of 5,000 accidents, approximately 20 percent are weather involved; of the 650 fatal accidents, about 37 percent are weather involved. This means that even if all the weather factors contributing to an accident were eliminated, there would still be room for improvement in the safety of the aviation system.

In 1979, the latest year for which accident statistics are available, the accident rate (total number of accidents per 100,000 hours of operation) for general aviation aircraft was 9.3 (4,023 accidents recorded in 43.34 million hours of operation); the comparable rate for all U.S. air carriers (shown in Table 4, Column V) is 0.43. In other words, the accident rate for general aviation aircraft is far greater than the rate for air carriers. It can be argued, however, that the consequences of an air carrier accident are even greater than that rate differential, considering the number of passengers on airline aircraft.

There has been a recent significant reduction in the accident rate for general aviation. In 1970, the accident rate was 18.1 accidents per 100,000 airborne hours (divide the total of 4718 accidents shown in Table 3, Column III, by the 26.03 million hours flown, shown in Column II). In 1979, the latest year for which accident statistics are available, the accident rate has amost been halved, to a rate of 9.3 accidents per 100,000 airborne hours (4,023 accidents; 43.34 million airborne hours).

A similar trend to a "halving" of the general aviation accident rate has already been cited for "weather-involved" accidents. Apparently, the improvement has been a general one affecting weather-involved and total accidents equally.

FAA forecasts for the next decades indicate that traffic volumes will be greatly increased, particularly in the general aviation category. The goal of eliminating all aviation accidents will, thus, become increasingly difficult to attain. Without making significant improvements in both the quality and quantity of services made available to users, it would be wishful thinking to expect that the trend toward a significantly reduced accident rate observed in recent years for the general aviation user would continue into the future.

The NAS Plan proposes to modernize and consolidate FAA facilities, and to utilize the best technology to provide safety services more efficiently, faster, and more conveniently. This, along with better training and private pilot proficiency, represents the best hope for containing the general aviation accident level.

No dollar benefit is claimed for such safety improvements.

2. For the Air Carrier User

The accident record compiled by the NTSB for the decade of the 70's for all U.S. air carriers is shown in Table 4. There is always uneasiness in attempting to place a value judgment on the record because at the very moment that the record is being read, there may be a news bulletin announcing a commercial airline disaster.

TABLE 4

Accidents, Fatalities, Accident Rates*
U.S. Air Carriers

	Accidents		Fatalities	Hours Flown	Accident Rate
	Total	Fatal	Total	(10^5)	(per 10^5 hrs)
	I.	II.	III.	IV.	V. (I ÷ IV)
1969	63	10	158	67.4	0.94
1970	55	8	146	64.7	0.85
1971	48	8	203	63.9	0.75
1972	50	8	190	63.0	0.79
1973	43	9	227	65.0	0.66
1974	47	9	467	59.8	0.77
1975	45	3	124	60.4	0.75
1976	28	4	45	62.3	0.45
1977	26	5	655	65.4	0.40
1978	24	6	163	67.9	0.35
1979	32	6	355	72.6	0.43

*NTSB: "Annual Review of Aircraft Data," U.S. Air Carrier Operations 1979
ARC-81-1, page 34

The data shown in Table 4 reflect the latest accident statistics published by the NTSB; they include statistics through the year 1979. For the next 26 months following the record shown in Table 4, there were no fatal accidents involving air carriers. However, any euphoria was shattered in January 1982, when an Air Florida Boeing 737 crashed into the 14th Street Bridge in Washington, D.C.

The data presented in Table 4, with the additional information to bring the record up to date, provides few analytical guidelines. What is relevant to the assessment of the benefits to be obtained from implementing the investment package contained in the NAS Plan, is the comparison of the "old" Table 4 with the "new" one that would be compiled for the decade of operations <u>after</u> the NAS Plan has been implemented.

Examining the list of accidents comprising Table 4 (and the collision statistics of Table 5) and evaluating all those accidents that could have been avoided with the proposed systems is also likely to lead to misleading conclusions. The traditional procedure following an air carrier accident is to complete a comprehensive investigation of the probable cause of the accident, and when the cause has been identified, to recommend how it can be eliminated. Once an action consistent with the recommendation has been taken, the list of accidents shown in Table 4 has been modified. It may have been drained of its ability to provide inferences for future action and, thus, may no longer provide a proper guideline for future investments.

To repeat, what is required for making the proper inferences regarding future investments is a <u>forecast</u> of what Table 4 will look like both with and without the proposed investment package.

Thus, the record of accident statistics may be a poor indicator of the need or direction for improvement. For example, the 26-month safety record prior to January 1982, used as the principal guideline to investment opportunities, indicates that no improvement is needed for air

TABLE 5

Number of Fatalities From Mid-Air Collisions Involving Air Carriers*

1957	19
1958	86
1959	0
1960	152
1961	0
1962	0
1963	0
1964	0
1965	30
1966	33
1967	157
1968	69
1969	122
1970	0
1971	96
1972	41
1973	0
1974	0
1975	0
1976	0
1977	0
1978	137

Note: By comparison, in 1979, a relatively typical year, there were 4,023 general aviation accidents, of which 40 were mid-air collisions between general aviation aircraft. Nearly all of these, in a pattern common to a decade or more, occurred within a few miles of non-tower airports. Loss of life from general aviation mid-air collisions has averaged 35-40 per year over a period of 14 years.

*NTSB: "Briefs of Accidents Involving Midair Collisions, 1957-77," Report No. AMM-78-13.

(1978 data from NTSB Aircraft Accident Report; Midair Collision, San Diego, September 25, 1978).

carrier safety. Ironically, it was during this same period that the impetus to provide improved collision prevention and avoidance capability was high.

Congress, in reflecting on the views expressed to it by the aviation community--air carriers, pilots, airline passengers, and general aviation users--perceives that there is a strong desire to insure against the possibility of a mid-air collision. This perception is not subject to argument. It is the expression of a desired public goal.

The NAS Plan provides a description of the future ATC system which, in FAA's opinion, is best able to accommodate the Nation's desire for a safe system. But, in addition, the Plan calls for a separate, independent collision protection system--TCAS. This system has been designed specifically to reduce the risk of mid-air collisions, with different levels of capability, for any user who chooses to purchase the appropriate avionics equipment.

The present air traffic control system is safe; but it can be, and therefore it must be, made safer. It borders on the ghoulish to tally the costs in dollars of the losses that would occur as a result of a collision between two wide-body aircraft. If one were to place a dollar value on each human life lost at approximately $500,000, and assumed 700 passengers aboard, the total dollar loss equivalent would be $350 million. The loss of the two aircraft would add at least another $100 million, plus the tally of the loss of lives and property on the ground, the cost of investigating the accident, etc. More than one-half billion dollars would represent a reasonable estimate of the total costs.

Such a dollar accounting is odious, however, because the dollar tally isn't able to differentiate between a loss of property and human life. The more relevant contemplation is to ask if the collision could have been avoided. Did the aircraft involved in the accident have access to the best and most recent information that the latest advances in technology and research could provide?

Later in this analysis, the costs of the program to implement TCAS will be assessed. This will assume alternative levels of participation of the aviation users in the ATC system. The best estimate of how many users will choose to participate and the level to which they will upgrade their equipment is shown in Table 9. This table indicates that the total avionics bill for TCAS for aviation users to the year 2005 is as follows: $0.55 billion for commercial aviation; $1.7 billion for corporate jets (recall that all corporate jets--some 32,000 by the year 2005--are assumed to have TCAS-II); $1.4 billion for multi-engine propeller aircraft, and $0.27 billion for single-engine propeller aircraft. Looking at commercial aviation only, the cost for TCAS is about the same as the cost of a single mid-air collision between two wide-body aircraft.

The NAS Plan proposes to implement automatic air traffic control processes. There is clear indication that system errors can be significantly reduced by such automation aids. Given a current estimate of 1.5 system errors per day in the current system, it has been estimated that perhaps 80 percent of these errors can be avoided. The vast majority of system errors are not critical, they do not result in significant risk of collision; but prevention of even a single collision by such automation justifies the investment.

In the following comparison of benefits versus costs, we have not put a dollar value on the collisions prevented, but we did include the <u>costs</u> of TCAS to the users in the assessment.

E. Benefits to the Military User

This analysis does not include an assessment of benefits or costs for the U.S. military fleet even though the Department of Defense is an integral working part of the National air traffic control system. FAA estimates that approximately 20,000 aircraft currently fly in the continental U.S., of which 8,000 are helicopters. While FAA has the statutory responsibility to provide a common system for all users, the Department of Defense also has a requirement to maintain a level of air traffic control capability to meet wartime readiness requirements, and thus operates a major system of facilities and services for military use.

In considering benefits and costs, it is reasonable to assert that benefits achieved by the military services would be similar to those obtained by other users for the many military operations which are similar to those conducted by civil users; but this would not account for the extensive special needs of the military services. Thus, an analysis based on normal transport operations alone would be unfair in that costs might be estimated in ways similar to those discussed in this analysis, while benefits could not be readily estimated by FAA.

One area of benefits is common to all aviation users: improved safety. The 20-year record of mid-air collision accidents compiled by the NTSB from 1957 to 1977* indicates that there was a total of 44 such accidents between civil and military aircraft during this period; 5 of the mid-air collisions were with air carrier aircraft, 39 with general aviation aircraft. It is notable that the very first practical development of an airborne collision avoidance system was sponsored by DOD in the 1950's.

The Department of Defense has in the past endorsed FAA's efforts to improve the safety of the air traffic control system for all users. In

*"Briefs of Accidents Involving Midair Collisions," NTSB-AMM-78-13, 1977, page 1.

recent Congressional testimony on the NAS Plan,* DOD supported the intent and general outline of the NAS Plan. DOD indicated that it looks forward to continued close cooperation with FAA and the rest of the aviation community in the further definition and eventual implementation of the improvements in the Nation's airspace support system to accommodate the needs of the civil aviation community and national security.

DOD noted that its own requirements are primarily for training to use aircraft for military tasks associated with the defense of our Nation. As a result, most of DOD's flying is the opposite of predictable, point-to-point commercial flights. Various special arrangements have been made between FAA and DOD to accommodate those special requirements in the system, and these will continue to be needed under the improvements proposed by the NAS Plan.

DOD noted its need for air traffic control system improvements, especially in the regime below 10,000 feet, and that the current manual system makes information dissemination cumbersome and less effective than it should be. DOD noted its confidence that the increased automation network and data link services envisioned in the NAS Plan can improve this information transfer where IFR air traffic control service is not feasible for military operations. DOD has noted that the structure of the IFR system is often incompatible with military requirements to maneuver in a random, unpredictable, tactical training manner in the airspace, and expressed its view that the FAA enhanced automation effort may provide for more effective real-time joint use of airspace while still permitting DOD the flexibility to train "the way we plan to fight."

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*Statement by Major General R. A. Burpee (Director of Operations, Headquarters United States Air Force) to Subcommittee on Transportation, Aviation, and Materials; Committee on Science and Technology; House of Representatives; April 29, 1982

The DOD view on the NAS Plan was summarized by the DOD Representative to FAA in a letter to the FAA Administrator dated April 20, 1982:

> "Although the plan does not highlight the unique role of the DOD, both as a user of National Airspace and as a provider of air traffic services to civil as well as military aircraft, the DOD supports the intent of NASP to improve the productivity and efficiency of air traffic services to the aviation community. As the implementation of the plan progresses, close cooperation between our agencies will be necessary to assess the programming and funding necessary to interface our respective operations.
>
> Our initial review has already indicated some specific areas which require clarification and active DOD participation with FAA. Accordingly, our staffs have already been in contact with each other.
>
> In summary, the DOD endorses the FAA's effort to improve overall operations in the National airspace and looks forward to a continuing close cooperative effort to work out implementing details which will support the needs of our Nation's defense interests."

III. AVIONICS COSTS TO THE AVIATION USER COMMUNITY

- Mode A, C, S and TCAS
- MLS
- 25kHz VHF Communications Capability

Table 6 provides data on the aircraft population operating in the United States. Both the estimates for the 1980 population and the forecast level for the year 2000 have been obtained from the FAA sources referenced in the Table.

A. Transponders and TCAS

Table 7, column 1, indicates the percentage of each user group's aircraft that currently have Mode A, C transponder installations: air carriers, commuter airlines, and general aviation corporate jet user groups are virtually 100 percent equipped; general aviation owners of twin-engine propeller aircraft have 77 percent of their aircraft equipped with Mode A, C transponders; single-engine propeller aircraft are 21 percent equipped.

For 4096 code Mode A only transponders (without altitude encoding), the percentage of participation for the General Aviation multi-engine propeller aircraft is 95 percent; for General Aviation single-engine propeller aircraft, the percentage is 58 percent.

(These data were obtained from the FAA source referenced in Table 7. The data are in close agreement with estimates of transponder equipage supplied by the Aircraft Owners and Pilots Association (AOPA). These latter estimates were based on a survey conducted in 1978 of AOPA members who own aircraft.)

Table 7 provides data on the comparative unit cost of typical Mode A, C transponder equipment currently installed on user aircraft, and the type of future Mode A, C, S and TCAS avionics that FAA anticipates will be installed.

TABLE 6

Aircraft Population, By User Group
Present and Forecast Levels*

	1980	1985	2000	2005
Commercial Aviation				
Air Carriers	2,558	2,950	4,120	4,200
Commuters	1,645	2,410	4,530	5,300
General Aviation				
Corporate Jets	2,700	3,400	8,500	11,200
Multi-Engine Propellers	28,600	33,600	67,600	85,900
Single-Engine Propellers	168,400	181,700	328,700	381,600

*Long-range forecast of fleet numbers supplied by FAA/APO-100. This forecast is consistent with data shown in: "FAA Aviation Forecasts, 1982-1993," Report No. APO-82-2.

TABLE 7

Aircraft Avionics Costs, Transponders and TCAS
(in 1982 dollars)
By Aviation User Category

	Present Equipment		Future Equipment		
	% Equipped[1]	Mode A,C	Mode A,C,S	Mode A,C,S & TCAS-I	Mode A,C,S & TCAS-II
Commercial Aviation					
Air Carriers	100%	$22,000 (dual)	$ 18,000	--	$ 66,000
Commuters	100%	$10,000	--	--	$ 66,000
General Aviation					
Corporate Jets	97%	$14,500	--	--	$ 66,000
Multi-Engine Propellers	77%	$10,000 (10%) $ 1,600 (90%)	-- $ 3,000 (50%)	-- $ 3,800 (50%)	$ 63,500 --
Single-Engine Propellers	21%	$ 1,600	$ 3,000 (50%)	$ 3,800 (50%)	--

1/ Reference: "General Aviation Activity and Avionics Survey," FAA Report No. MS-81-5, December 1981.

A number of assumptions were made in order to complete the 20-year program cost calculations:

(1) The unit prices shown in Table 7 are current estimates for a typical installation appropriate to the aircraft type, and include installation costs. Prices will, of course, vary depending on such factors as production quantities, quality of equipment, and the type of installation. It should be noted that neither Mode S nor TCAS is yet commercially available, and that firm prices are not available. The figures given are based on estimates from several sources. With respect to TCAS-II, we chose to use the same cost for air carrier, commuter, and corporate jets, although that is probably conservative.

(2) The air carrier group prefers to have dual equipage of current Mode A, C transponders; the unit prices shown in Table 7 reflect installed dual units. For the future installation of TCAS-II, one Mode A, C, S transponder is part of the TCAS-II installation; the second Mode A, C, S transponder installation is separately shown.

For the corporate jet user group, the assumption was made that there would be a single TCAS-II installation including the Mode A, C, S transponder, but no second Mode A, C, S transponder.

(3) The cost calculations assume that there will be no salvage value for Mode A, C transponders replaced with Mode A, C, S transponders. It also assumed that the user would not incur any cost burden from premature replacement of Mode A, C equipment.

(4) In order to reduce the variability in the equipment costs shown for the General Aviation multi-engine propeller aircraft, it was recognized that this group includes several separate aircraft populations; multi-engine propeller aircraft range from large

transports which use an air carrier type of avionics equipment, to light-twin aircraft with avionics equipment similar to the installations made on single-engine aircraft. A survey sponsored by the FAA* indicated that in 1978, 90 percent of the multi-engine propeller aircraft in the general aviation fleet were of the light-twin (under 12, 500 #) variety. In Table 7, therefore, the assumption is made that 90 percent of this general aviation user category would choose avionics equipment of the same type as selected by the owners of single-engine propeller aircraft. All of the smaller variety of general aviation aircraft would be equipped with Mode A, C, S transponders; 50 percent of this fleet would install TCAS-I in addition to Mode A, C, S.

(5) The installation of new avionics equipment was estimated to begin during the year identified in the NAS Plan for initial implementation. All programs whose costs and benefits are presented as example cases in this report have 1985 as the common date for the initial implementation of avionics equipment. The replacement of current Mode A, C transponder equipment is estimated to be completed, at a linear rate, by the year 1995; ten years after initial installation begins. Additional costs beyond 1995 are included to reflect fleet growth. The analysis horizon is assumed to be 20 years after the start of the program, or until the year 2005.

(6) Separate cost calculations were made for MLS avionics equipment and for the installation of radio receivers providing voice communications 25kHz capability (see below).

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*"United States General Aviation, 1959-78", FAA Report No. DOT-FA79WH-4383.

COST CALCULATIONS: TRANSPONDERS AND TCAS

The first cost calculation, shown in Table 8, is the estimate of the added investment costs required to install Mode A, C, S transponders to the same level of participation as Mode A, C transponders in the present aircraft fleet.

For TCAS, it assumes the following participation:

o	100% air carriers, commuters, corporate jets	TCAS-II
o	100% (of the 77% now equipped with Mode A, C) multi-engine propeller general aviation aircraft--the heavy transport type	TCAS-II
o	50% (of the 77% now equipped with Mode A, C) of all remaining multi-engine propeller general aviation aircraft	TCAS-I
o	50% (of the 21% now equipped with Mode A, C) single-engine propeller general aviation aircraft	TCAS-I

The total avionics cost for all users to equip to present levels of participation in Mode A, C transponder equipment, over a 20-year period, is shown in Table 8 as $1.72 billion, in 1982 dollars.

The second cost calculation, shown in Table 9, assumes a higher level of equipage. For this calculation, we have assumed all aircraft carry a Mode A, C, S transponder.

For TCAS, it assumes the following participation:

o	100% air carriers, commuters, corporate jets	TCAS-II
o	10% multi-engine propeller general aviation aircraft--the heavy transport type	TCAS-II
o	50% of all remaining multi-engine propeller general aviation aircraft	TCAS-I
o	50% of all single-engine propeller general aviation aircraft	TCAS-I

TABLE 8
SUMMARY: AVIONICS INVESTMENT COSTS
20-YEAR TOTALS, in thousands of 1982 dollars
by User Group

First Cost Calculation - Based on Current Mode A/C Equipage

	MODE A/C/S	TCAS/1 & MODE A/C/S	TCAS/2 & MODE A/C/S	TOTALS
Commercial Aviation				
Air Carrier	55,800		204,600	260,400
Commuters			296,800	296,800
Totals	55,800		501,400	557,200
General Aviation:				
Corporate Jets			559,496	559,496
Multi-engine Propellers	41,670	65,482	353,865	461,017
Single-Engine Propellers	56,095	98,150		144,245
Totals	97,765	153,632	913,361	1,164,758
Total All Users	153,565	153,632	1,414,761	1,721,958
Accumulated Value - All Users Discounted to Program Start	49,737	78,156	744,184	872,077

TABLE 9
SUMMARY: AVIONICS INVESTMENT COSTS
20-YEAR TOTALS, in thousands of 1982 dollars
by User Group

Second Cost Calculation - Based on Full Mode A/C/S Equipage

	MODE A/C/S	TCAS/1 & MODE A/C/S	TCAS/2 & MODE A/C/S	TOTALS
Commercial Aviation				
Air Carrier	55,800		204,600	260,400
Commuters			296,800	296,800
Totals	55,800		501,400	557,200
General Aviation:				
Corporate Jets			576,800	576,800
Multi-engine Propellers	54,117	85,041	459,565	598,723
Single-Engine Propellers	267,120	419,760		686,880
Totals	321,237	504,801	1,036,365	1,862,403
Total All Users	377,037	504,801	1,537,765	2,419,603
Accumulated Value - All Users Discounted to Program Start	144,863	227,641	796,545	1,169,049

The total avionics cost for all users to equip to 100 percent participation in Mode A, C, S and the high level of TCAS equipment indicated, over a 20-year period, is shown in Table 9 as $2.42 billion, in 1982 dollars.

This higher avionics cost estimate for Mode A, C, S and TCAS is used in the benefit versus cost comparison shown in Table 13.

Tables 10A thru 10E present the 20-year total of avionics costs, by year and individual user category, using the second (higher equipage level) cost calculation.

TABLE 10A

AVIONICS INVESTMENT COSTS
(in thousands of 1982 dollars)

USER GROUP: AIR CARRIERS   FUTURE EQUIPMENT: Mode A/C/S (Dual) and TCAS-II (100%)

YEAR	
1986	22,165
1987	22,165
1988	22,165
1989	22,165
1990	22,165
1991	22,165
1992	22,165
1993	22,165
1994	22,165
1995	22,165
1996	3,875
1997	3,875
1998	3,875
1999	3,875
2000	3,875
2001	3,875
2002	3,875
2003	3,875
2004	3,875
2005	3,875
TOTALS	260,400
ACCUMULATED VALUE DISCOUNTED TO PROGRAM START	145,374

TABLE 10B

AVIONICS INVESTMENT COSTS
(in thousands of 1982 dollars)

USER GROUP: COMMUTERS

FUTURE EQUIPMENT: Mode A/C/S (Dual) and TCAS-II (100%)

YEAR	
1986	21,588
1987	21,588
1988	21,588
1989	21,588
1990	21,588
1991	21,588
1992	21,588
1993	21,588
1994	21,588
1995	21,588
1996	8,092
1997	8,092
1998	8,092
1999	8,092
2000	8,092
2001	8,092
2002	8,092
2003	8,092
2004	8,092
2005	8,092
TOTALS	296,800
ACCUMULATED VALUE DISCOUNTED TO PROGRAM START	151,819

TABLE 10C

AVIONICS INVESTMENT COSTS
(in thousands of 1982 dollars)

USER GROUP: CORPORATE JETS FUTURE EQUIPMENT: Mode A/C/S (Dual) and TCAS-II (100%)

YEAR	
1986	37,332
1987	37,332
1988	37,332
1989	37,332
1990	37,332
1991	37,332
1992	37,332
1993	37,332
1994	37,332
1995	37,332
1996	20,348
1997	20,348
1998	20,348
1999	20,348
2000	20,348
2001	20,348
2002	20,348
2003	20,348
2004	20,348
2005	20,348
TOTALS	576,800
ACCUMULATED VALUE DISCOUNTED TO PROGRAM START	277,595

TABLE 10D

AVIONICS INVESTMENT COSTS
(in thousands of 1982 dollars)

USER GROUP: MULTI-ENGINE PROPS

FUTURE EQUIPMENT:
(10%) Heavy Transports: Mode A/C/S and TCAS-II (100%)

(90%) Light Twins : Mode A/C/S (100%) and TCAS-I (50%)

YEAR	MODE A/C/S	TCAS-I and MODE A/C/S	TCAS-II and MODE A/C/S	TOTALS
1986	3,521	5,533	29,899	38,953
1987	3,521	5,533	29,899	38,953
1988	3,521	5,533	29,899	38,953
1989	3,521	5,533	29,899	38,953
1990	3,521	5,533	29,899	38,953
1991	3,521	5,533	29,899	38,953
1992	3,521	5,533	29,899	38,953
1993	3,521	5,533	29,899	38,953
1994	3,521	5,533	29,899	38,953
1995	3,521	5,533	29,899	38,953
1996	1,891	2,971	16,057	20,920
1997	1,891	2,971	16,057	20,920
1998	1,891	2,971	16,057	20,920
1999	1,891	2,971	16,057	20,920
2000	1,891	2,971	16,057	20,920
2001	1,891	2,971	16,057	20,920
2002	1,891	2,971	16,057	20,920
2003	1,891	2,971	16,057	20,920
2004	1,891	2,971	16,057	20,920
2005	1,891	2,971	16,057	20,920
TOTALS	54,117	85,041	459,565	598,723
ACCUMULATED VALUE DISCOUNTED TO PROGRAM START	26,113	41,035	221,757	288,905

TABLE 10E

AVIONICS INVESTMENT COSTS
(in thousands of 1982 dollars)

USER GROUP: SINGLE-ENGINE PROPS

FUTURE EQUIPMENT:
Mode A/C/S (100%)
and TCAS-I (50%)

YEAR	MODE A/C/S	TCAS-I and MODE A/C/S	TCAS-II and MODE A/C/S	TOTALS
1986	14,691	23,087	0	37,778
1987	14,691	23,087	0	37,778
1988	14,691	23,087	0	37,778
1989	14,691	23,087	0	37,778
1990	14,691	23,087	0	37,778
1991	14,691	23,087	0	37,778
1992	14,691	23,087	0	37,778
1993	14,691	23,087	0	37,778
1994	14,691	23,087	0	37,778
1995	14,691	23,087	0	37,778
1996	12,021	18,889	0	30,910
1997	12,021	18,889	0	30,910
1998	12,021	18,889	0	30,910
1999	12,021	18,889	0	30,910
2000	12,021	18,889	0	30,910
2001	12,021	18,889	0	30,910
2002	12,021	18,889	0	30,910
2003	12,021	18,889	0	30,910
2004	12,021	18,889	0	30,910
2005	12,021	18,889	0	30,910
TOTALS	267,120	419,760	0	686,880
ACCUMULATED VALUE DISCOUNTED TO PROGRAM START	118,749	186,606	0	305,356

B. MLS Avionics Equipment Costs

Cost estimates for MLS unit costs are given in Table 11. The total costs for a 20-year period to implement MLS avionics equipment are shown in Table 12, categorized by aviation user groups. These costs were estimated as part of the study of the benefits and costs previously conducted by FAA. The costs are incremental, or in addition, to those that would occur if ILS equipment were to continue as the standard for precision guidance service. Implementation of MLS avionics is estimated to begin in 1985, and the data on costs (and previously, for benefits) shown in Table 12 are the totals accumulated over 20 years. For cost analysis purposes, full replacement of ILS avionics is assumed to be completed 10 years after the implementation to MLS begins; in the year 1995. The operational life of the ILS may, in fact, continue beyond 1995. The total planning period considered in the study was a typical one of 20 years. For the first 10 years of this period, the costs to continue to implement new ILS avionics equipment to accommodate the growth in the aircraft population were charged as costs to the MLS system. The total 20-year program costs for investment and operating MLS avionics equipment in place of ILS are shown in Table 12 as $580 million for commercial aviation, and about $1.0 billion for general aviation.

Other Avionics Costs To Users

The NAS Plan indicates that voice communication coverage for towers, centers, and flight service stations will be provided at or above 2000 feet. This will require the conversion of existing and future VHF communications equipment to a frequency spacing of 25kHz. It is estimated that this conversion can be made at a modest cost, and this burden is not separately costed.

TABLE 11

Estimated Avionics Costs per Aircraft
(in 1982 dollars)

ILS and MLS, Categorized by User Groups 1/

COMMERCIAL AVIATION	ILS	MLS
Air Carriers	$34,000	$47,000
Commuters	8,000	16,300
GENERAL AVIATION		
Corporate Jets	$12,000	$16,300
Multi-Engine Propellers	3,500	4,800
Single-Engine Propellers	1,300 2/	2,400 2/

Notes:

1. Equipment common to both MLS and ILS is excluded from this table. Costs shown do not include DME service for MLS under the assumption that this service will be available from equipment already on board.

2. Includes an on-board computational capability for the Air Carrier user group, and dual systems for all users except owners of single-engine propeller aircraft.

3. Reference: "--Benefits and Costs of the MLS System," FAA Report EM-80-7, Table 1.3-1, page 1-65. (Costs shown in the reference report are in 1976 dollars; an inflation factor of 1.6 was used to convert to 1982 dollars. Recent checks indicate these costs remain reasonable.)

TABLE 12

MLS AVIONICS PROGRAM COSTS*

(Investment and Operating)1/
Incremental to ILS; By User Group

20-Year Program Totals
(in millions of 1982 dollars)

User Groups	Implementation Assumption
Air Carriers (A/C)	100% MLS Equipped
Commuters (C/M)	100% MLS Equipped
General Aviation	
Corporation Jets (G/A I)	100% MLS Equipped
Multi-Engine Propellers (G/A II)	35% MLS Equipped
Single-Engine Propellers (G/A III)	35% MLS Equipped

	Total (All Users):	A/C	C/M	G/A I	G/A II	G/A III
20-Year Totals	$1630:	515	62	338	154	562
(Accumulated Value Discounted to Start of Program)	(748):	(242)	(28)	(158)	(71)	(249)

Reference: Study of Benefits and Costs--MLS Compared to ILS (see Table 2).

1/ Investment and operating costs for MLS avionics include the cost for redundant ILS equipment for the first 10 years of the total 20-year program horizon.

IV. COMPARISON OF BENEFITS TO COSTS

A. Using Best Estimates

It is now possible to compare the totals of benefits shown in Tables 1&2 accumulated for the example cases cited, with the avionics costs to users shown in Tables 10 and 12. The benefits and costs are compared in Table 13.

Table 2 shows a 20-year total of $2.3 billion in benefits resulting from the implementation of the MLS program, due to the MLS ability to reduce delays at the major airport terminals by: 1) reducing disruptions due to weather minima, 2) lower system outages for MLS equipment, 3) the elimination of airway and ground restrictions at selected airport locations, and 4) the reduction in flight path lengths to the terminal. A 20-year program total of 1,250 MLS ground systems was estimated to be installed. In addition to the MLS benefits from reduced delays at major (top 40) airports, the study identified some $240 million in benefits for MLS at all airport locations (not just major terminals). Finally, a benefit in increased safety was estimated for the MLS due to its ability to provide, at least, CAT I levels of service at those airport locations able to receive only restricted CAT I levels of service with present ILS equipment. The amount is modest, some $54 million are attributed to increased safety due to MLS.

Adding up the totals of benefits attributed to MLS, yields a dollar amount of $2.6 billion. This compares favorably with the additional costs for MLS avionics cited in Table 12, of $1.6 billion (a net dollar benefit of $1.0 billion).

The delay reductions due to implementing the new concepts identified in the NAS Plan for increasing runway capacity, shown in Table 2--some of these concepts depend on MLS, some depend on other programs shown in the NAS Plan--are estimated as a total 20-year dollar benefit, to the users of major airports, of $5.7 billion.

The benefits in increased fuel efficiency due to 1) direct routing, 2) the elimination of altitude restrictions, and 3) the improved flow and management of aircraft to utilize existing runway capacity more efficiently, result in a 20-year savings in fuel costs estimated in Table 1 as $16.4 billion; $11.3 billion for commercial aviation, $5.1 billion for general aviation.

The total benefits for the cases selected in the calculations thus come to some $24.7 billion; $2.6 billion in added benefits and $1.6 billion in added costs have already been attributed to the implementation of MLS equipment.

The remainder of the total of dollar benefits--some $22 billion without MLS--will be available to the user at an additional cost for Mode A, C, S and TCAS, as shown in Table 9.

The best estimate of the cost to implement the full aircraft population to 100 percent transponder equipage--with all users equipped to Mode A, C, S; air carriers, commuters, corporate jets and general aviation multi-engine propeller aircraft of the heavy transport type equipped with TCAS-II, the remainder of the general aviation user group equipped to a 50 percent level with TCAS-I-- is shown in Table 9 as $2.42 billion; $557 million for commercial aviation; $1.86 billion for general aviation. These costs for avionics are probably high because they assume a high level of upgrading in transponder equipment and that all (100 percent) users will participate by having at least Mode S capability. Despite this high estimate for avionics costs, there is still a net benefit (benefits less costs) of about $20.7 billion available to the aviation users.

The benefits and costs for the FAA are also summarized in Table 13. In addition, this table provides estimates of Present Discounted Values (PDV) for benefits and costs to all users.

TABLE 13

Summary: 20-Year Total of Benefits and Costs Due to NAS Plan for Aviation Users and FAA, in billions of 1982 dollars Present Discounted Values (PDV) Shown Parenthetically

	Aviation Users	I. Added Benefits	II. Added Costs	III.: II - I Net Benefits
	1. MLS Program			
	Reduced Delays at Major Airports	$ 2.3		
	Additional Benefits, All Airports	0.3	$ 1.6	$ 1.0
(PDV)		(1.0)	(0.2)	(0.8)
	2. Airport Throughput Improvement Program	5.7	*--	5.7
(PDV)		(1.7)		(1.7)
	3. Increased Fuel Efficiency	16.4	2.4	14.0
(PDV)		(4.1)	(0.9)	(3.2)
	TOTAL AVIATION USERS	$24.7	$ 4.0	$20.7
(PDV)		($6.8)	($1.1)	($5.7)
	Federal Aviation Administration			
	Operating Cost Savings	$24.3	$ 8.0	$16.3
(PDV)		($9.0)	($5.0)	($4.0)

*Avionics costs for this program are included in costs shown for the other programs.

B. Using Pessimistic Estimates ("Sensitivity Analysis")

The sensitivity analysis conducted next assumed that the above estimates were optimistic. It now assumed that only half the benefits will be achieved and that actual avionics costs will be double the estimates.

Should fuel efficiency gains not be at the 6 percent level originally estimated, but instead be 3 percent, the benefit from this source would be $8.2 billion (not $16.4 billion).

The gain from MLS estimated in the study previously conducted by FAA would be $1.3 billion (not $2.6 billion).

The capacity gains at major airport terminals due to increased runway capacity are estimated as $2.9 billion (not $5.7 billion).

The modified (halved) total of benefits is now $12.4 billion (not $24.7 billion).

The user costs, modified by doubling, are now estimated as:

- o $3.2 billion for MLS avionics (not $1.6 billion)
- o 4.8 billion for Mode A, C, S and TCAS (not $2.4 billion)

  $8.0

The total of $12.4 billion in benefits still compares favorably with the total avionics cost of $8.0 billion.

C. The Effect of Discounting

The effect of the disparity in the time flow of benefits versus those for investment costs can be estimated by the technique of "discounting."

Typically, any major investment in new facilities and equipment by FAA will occur prior to implementation of avionics by the user by a significant time interval. The method recommended by the OMB to adjust for differences in the time profile of benefits and costs is to "discount" all future benefits and costs by an annual, compounded, rate of 0.10. This method adjusts dollar flows by estimating that there is an "opportunity lost" of 10 percent a year when benefits are delayed (while waiting to receive benefits from some given program, the government could have received an annual rate of return on investment of 10 percent, from some alternative investment). In the same way, costs which can be delayed are considered to be worth 10 percent per year, compounded.

In other words, when accumulating the annual benefits or costs resulting from the implementation of a given program in this way, it is appropriate to calculate and compare the "present discounted value" of benefits and costs.

This comparison was done separately for FAA and the aviation users. The benefits to FAA in reduced operating costs was compared to the increased investment costs for FAA. The users' benefits were compared to their added costs for avionics. These comparisons are shown in Table 13. The estimates of Present Discounted Value (discounted at a rate of 0.10) are shown in Table 13 as parenthetical entries.

The savings in operating costs to the FAA of $24 billion over a 20-year period, when discounted at a rate of 0.10, come to about $9 billion, compared to FAA investment costs of $5 billion in discounted dollars to be expended over the next 10 years.

For the aviation users, the estimated cost in discounted dollars for Mode A, C, S and TCAS in the full-implementation assumption is $0.9 billion. The discounted value of increased avionics cost of $1.2 billion shown in Table 9 as being discounted to the start of the program in the year 1985, must be discounted again by an additional factor of 0.75 in order to bring it to the "present (1982) discounted value" of $0.9 billion shown in Table 13. The present discounted value for MLS avionics calculated in a similar manner, is $200 million.

The combined cost for MLS, Mode A, C, S, and TCAS is some $1.1 billion in present value discounted dollars (as shown in Table 13).

The benefit total of some $24.7 billion (undiscounted) in combined benefits for all programs described in the NAS Plan, when discounted, is equal to the $6.8 billion total shown in Table 13.

The net benefit (benefits less costs shown in Table 13, Column III) to the aviation user, in present discounted value dollars (each dollar having a fixed purchasing power equal to the 1982 dollar) is $5.7 billion.

Doubling Estimated Investment Costs, Halving Expected Benefits, and Discounting

As a final pessimistic assessment, the combined effect of doubling costs to both users and FAA, halving benefits to both, and discounting was considered. Such assumptions will have a different effect on the net benefits for the aviation users and for FAA.

The conclusion that there will be a net benefit to the aviation users from implementing the NAS Plan remains valid. The halved benefits total, in present discounted dollars, is $3.4 billion; the doubled cost (discounted) would be $2.2 billion. The result still favors the NAS Plan implementation for the aviation user by a net benefit estimated as $1.2 billion (discounted).

For FAA, halving and discounting of the operating cost savings yields a revised estimate of $4.5 billion. The doubled and discounted costs would be $10 billion. This would result in a net loss or (dis)benefit to FAA, but as noted above, not to the users.