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Final Report

ANALYSIS OF TECHNOLOGY REQUIREMENTS AND POTENTIAL DEMAND FOR GENERAL AVIATION AVIONICS SYSTEMS IN THE 1980'S

by

David M. Cohn
John H. Kayser
George M. Senko
Donald R. Glenn

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I. INTRODUCTION

A. BACKGROUND

Air travel has become a commonplace event in modern society and, in the United States, is the dominant mode of inter-city common carrier passenger transportation. Furthermore, at the present time, more than 98% of the civil aircraft fleet in the United States is represented by general aviation aircraft. Nevertheless, a recent General Aviation Manufacturers Association (GAMA) survey showed that although 41% of the total public claim familiarity with the term "general aviation" and indicate they have flown in a light aircraft, only a very small percentage are truly aware that general aviation does not refer to commercial airlines or military aircraft. Thus, the real recognition level of general aviation is quite low.

Since the end of World War II, the general aviation fleet has grown by an average of more than 5% annually and, in 1973, numbered approximately 145,000 active aircraft. The growth of general aviation, however, has not been steady. During the years immediately following the Second World War, there was a phenomenal surge in the general aviation fleet which has been unequaled since. In the 1950's, general aviation went through a prolonged slump from which it only began to recover during the Sixties. Since the early Sixties, the growth in general aviation has been steady and consistent.

Nevertheless, this growth has not been without its problems. It has been accompanied by increased air congestion and an appreciable rise in air traffic control problems. Even though only a relatively small percentage of today's general aviation air traffic flies IFR, the percentage is rising rapidly, creating new stresses on the ATC system. Consequently, in today's aviation environment, trends to more controlled airspace and a concern for safety are increasing.

In the last ten years, the Federal Aviation Administration (FAA) has been pressing for improved accuracy in navigation aids and requirements for aircraft to carry more avionics equipment than in the past. Furthermore, as changes are occurring in the regulatory environment, there is an increase in pilot workload creating a need for greater pilot proficiency.

B. ROLE OF NASA IN CIVIL AVIATION

As an extension of its activities and experience, the National Aeronautics and Space Administration (NASA) has been taking a more active role in the field of general aviation. The NASA role in general aviation technology encompasses a broad effort to improve the safety of all flight operations, and the program simultaneously tries to recognize and provide for the growing technological needs and requirements. The programs are directed to provide technology for general aviation use that will permit the design of future U.S. aircraft that are safer, more productive, and clearly superior to the rapidly growing foreign competition. It is in this context that NASA undertook a comprehensive study and analysis of the technological requirements and potential demand for general aviation avionics systems for operation in the 1980's.

C. OBJECTIVES OF THE PROGRAM

The primary objective of this program was to identify technology areas where NASA's research and development activities can make substantial contributions to the design of avionics to satisfy the future requirements of general aviation. It was established that prime considerations would be for avionics which would provide added safety, lower costs, and improved reliability across the total spectrum of the general aviation marketplace.

To support these general goals, the following subordinate objectives were defined:

- Develop a complete definition of the present general aviation avionics market
- Identify major problem areas and constraints to growth in general aviation and relate them to avionics systems and equipment
- Identify technological advances in avionics systems which would be desirable in the 1980 time frame to satisfy the requirements being placed on the general aviation industry
- Estimate the future demand for avionics equipment as a function of available funds and requirements of the evolving airspace system
- Estimate the impact and public benefits of potential technological advances

Thus, the overall intent of this study was to identify avionics systems which promise to reduce economic constraints and provide significant improvements in performance, operational capability and utility for general aviation aircraft in the 1980's.

D. METHODOLOGY

On the basis of these objectives, the approach used in this study followed the methodology outlined in Figure I-1. A combination of research techniques were utilized, including:

- DSC Data Files

  Decision Sciences Corporation has carried out more than 20 projects involving market analysis, structuring and forecasting of the general aviation market, industry, and technology. In the last year alone, DSC has carried out projects involving more than 80 man-months of study and evaluation of the general aviation market and trends for the period 1974-1985. As a result of this extensive work, DSC has acquired a considerable amount of in-depth data on:

  - The structure and evaluation of the general aviation market
  - General aviation users, products, and technology
  - Models and forecasting systems of general aviation aircraft and avionics
  - Industry buying patterns and decision factors
  - Government regulatory programs and plans

  A list of past general aviation assignments carried out by DSC is shown in the Appendix of this report.

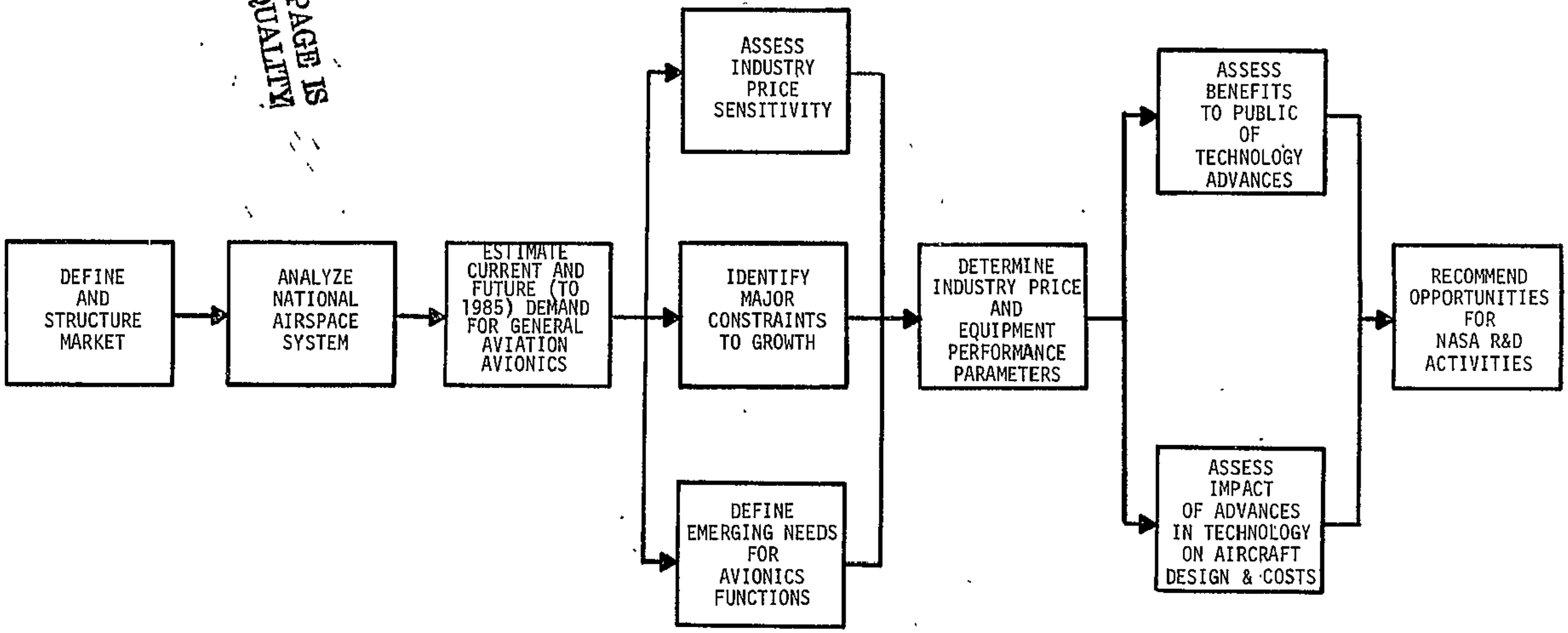
- DSC Technological Forecasting Techniques

  A number of approaches were utilized to effectively develop meaningful estimates of future technological advances. Areas of avionics technology studied included:

  - Navigation systems
  - Communication systems

FIGURE I-1

METHODOLOGY



- Flight controls
- Instrumentation
- Displays

Techniques utilized included historical growth patterns, trend curves, correlation analyses, substitution growth curves, diffusion studies, and the Delphi technique. The Delphi technique involves assembling a committee of experts in a single area who pool their knowledge about that area and prepare an intuitive, confidential forecast of future developments. The Delphi survey process is described in detail in Chapter IX of this report. It is important to note that individual responses to questioning are not revealed; thus, anonymity and privileged opinions are protected.

The following companies participated in DSC's General Aviation Technical Advisory Delphi Panel in this program:

- AIL/Cutler Hammer
- Aradar Corporation
- Atlantic Aviation Corporation
- Bendix Corporation
- Butler Aviation
- Collins Radio Corporation
- Gates Learjet Corporation
- Hamilton Standard Division, United Aircraft Corporation
- Hoffman Electronics Corporation
- King Radio Corporation
- Lear Siegler, Inc.
- Narco Avionics
- Piper Aircraft Corporation

- RCA Aviation Group
- Singer-Kearfott Division
- Wilcox Electric Company
- Wulfsberg Electronics, Inc.

° <u>In-depth Field Interviews</u>

In addition to the market forecasting models and technological forecasting techniques described above, DSC conducted over 100 interviews among knowledgeable government representatives, industry experts, aircraft owners and fleet operators, airframe manufacturers and avionics manufacturers. These interviews were conducted to obtain opinions on the requirements for technological change in the general aviation avionics industry during the 1980's, as well as to obtain specific ideas from a cross-section of the industry, under controlled conditions.

In summary, the methodology employed in this program involved a combination of techniques incorporating DSC's data files and market and technological forecasting models and approaches, coupled with the attitudes and opinions of knowledgeable people within the industry. It was extremely critical in developing the methodology for this program to recognize that while the general aviation fleet is frequently discussed as though it were one common entity, it is in fact made up of a number of very diverse groups with separate and distinct missions. When developing and analyzing the data gathered in this program, DSC defined the industry according to aircraft type as well as user characteristics. The aircraft segments used in this report were:

° Light single-engine piston, 1-3 place

° Medium/heavy single piston, 4+ place

° Light twin piston

° Medium/heavy twin piston and turboprop

° Turbine

° Other

The user segments used in this report were:

- Corporate/executive flying
- Business flying
- Personal flying
- Aerial application
- Industrial application
- Instruction
- Air taxi, charter
- Other

Each segment of the fleet has different constraints and needs which must be recognized when developing avionics. One area of significant difference relates to the ability to pay (price) for avionics. Because of varying levels of price sensitivity, technical advances which have been developed for and used by the corporate fleet occasionally have taken a considerable length of time to filter down to the pleasure flying segment of the general aviation fleet. Frequently, this is attributable to the high cost and complexity of the system. While it may be ideal to consider advancements in avionics systems and technologies in terms of providing significant performance improvements, enhanced safety, improved reliability, and lower maintenance and repair costs, these goals must also recognize the economic limitations of the major portion of the general aviation fleet to insure that the benefits of advanced technology reach across the total spectrum of the fleet. It is important to recognize that when planning for the general aviation marketplace, the problem of availability of discretionary funds is real and that more than 80% of the fleet consists of single-engine aircraft flown by pilots whose proficiency is frequently relatively low. Furthermore, to insure a healthy expansion of general aviation, it is important not to discourage pilots, especially new pilots, by making avionics too complex and too expensive.

Nevertheless, while these constraints must be considered in any analysis of technology requirements and potential for advances in general aviation avionics, total expenditures for avionics in general aviation in the next 10-15 years are likely to be quite substantial. This situation will result from the greater number of aircraft which will be operating in this environment and factors which will necessitate more precise navigation, enhanced data handling capabilities, and generally increased flexibility in the national airspace system. Each of these factors will be discussed in detail in this report.

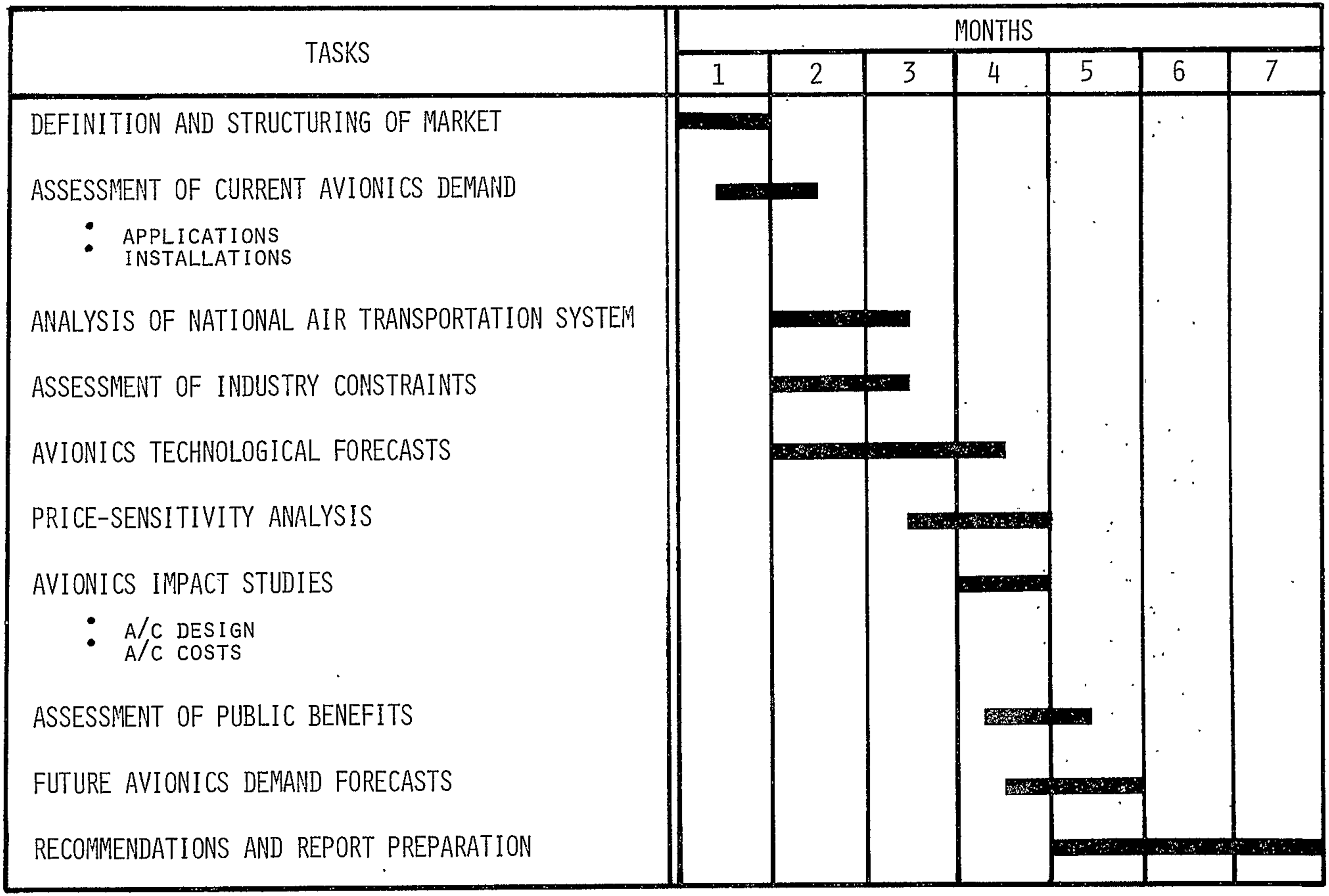
Although it is possible to forecast the shape of things to come 10-15 years hence, assuming a certain stable evolutionary pattern, it is certainly impossible to predict all of the specific events that will affect general aviation during the period. However, it is assumed that there will be some factors beneficial to the growth of the fleet in general aviation activity, just as other factors will result in periods of decline. The overall effect is expected to result in a general aviation fleet in 1985 considerably larger than today's. In analyzing avionics requirements during the 1980's, Decision Sciences Corporation has examined historic and current levels of avionics carried in general aviation aircraft, has evaluated various factors which might lead to increases or decreases in these levels, and has made forecasts of the avionics demands. Assumptions which underly these forecasts are enumerated in the chapters that follow. The project schedule followed to complete this study is shown in Figure I-2 covering a period of seven months.

E. SUMMARY OF THE REPORT

This report contains a description of the seven tasks accomplished by DSC and our recommendations under Contract NAS2-7888. Chapter II provides a comprehensive definition and structuring of the general aviation market according to aircraft type and user category. The analysis includes historical and current information available on annual sales of general aviation avionics, and describes typical systems of avionics equipment for each aircraft type and user category. Chapter III provides an analysis of the national air transportation system. The effect of planned changes in the national aviation system on future technology requirements for general aviation avionics systems is assessed. Chapter IV describes the major problem areas and constraints to growth in general aviation likely to occur during the 1980-1985 time frame. An identification of emerging general aviation avionics requirements and trends is provided in Chapter V. The probable impact on general aviation of timing and level of demand is covered. Chapter VI outlines an assessment of the impact and public benefits of prospective advances in general aviation avionics systems and equipment.

FIGURE I-2

PROJECT SCHEDULE



Estimates of the price sensitivity of demand of avionics systems are provided in Chapter VII. Chapter VIII contains the market forecast of the demand for general aviation avionics through the year 1985. Chapter IX presents our recommendations regarding technology areas where research and development could be directed by NASA to provide significant improvements in performance, safety, simplicity of operation and overall capability of general aviation aircraft.

II. DEFINITION AND STRUCTURE OF THE GENERAL AVIATION INDUSTRY

To forecast the avionics requirements in the general aviation fleet during the 1980's, it was necessary to examine the structure of the general aviation fleet. General aviation includes all non-military and non-air carrier flying, and has been divided into the following aircraft and user categories to provide a more complete understanding of the avionics requirements in the various segments of the industry:

- Aircraft classes
  - Light single-engine piston, 1-3 place
  - Medium/heavy single piston, 4+ place
  - Light twin piston
  - Medium/heavy twin piston and turboprop
  - Turbine
  - Other
- User categories
  - Corporate/executive flying
  - Business flying
  - Personal flying
  - Aerial application
  - Industrial application
  - Instruction
  - Air taxi, charter
  - Other

This chapter examines these segments of the general aviation market and estimates the current level of avionics equipment carried in the fleet.

A. THE GENERAL AVIATION FLEET

According to the 1973 Federal Aviation Administration (FAA) Statistical Handbook, the general aviation fleet totaled 131,149 active aircraft on December 31, 1971—a very slight decrease from the year before. It was, in fact, the first year since 1952 that the active fleet failed to show any growth over the previous year. However, estimates of the fleet size at the end of 1972 indicate that it had grown to over 145,000 aircraft by the end of that year.

Figure II-1 shows the growth and development of the general aviation fleet from 1959 through 1972. During this period, the total number of active aircraft increased by more than 110%. It is noteworthy that although single-engine piston aircraft have dominated the overall aircraft population, multi-engine piston, turbine and other aircraft are representing an increasingly larger portion of the fleet.

In contrast to the fairly steady growth in fleet size, shown in Figure II-1, Figure II-2 shows the erratic pattern of new general aviation aircraft deliveries from 1940 to the present day. This figure portrays the unstability of the general aviation market which is subject to rapid and dramatic reversals.

In Figure II-3, deliveries are examined by category of aircraft. While no clear trend in mix of aircraft deliveries is evident, there does appear to be an increasing proportion of twin-engine propeller aircraft, particularly medium and heavy twins, with a corresponding decrease in single-engine piston aircraft. Certainly a major contributing factor is the increase in corporate aircraft fleets.

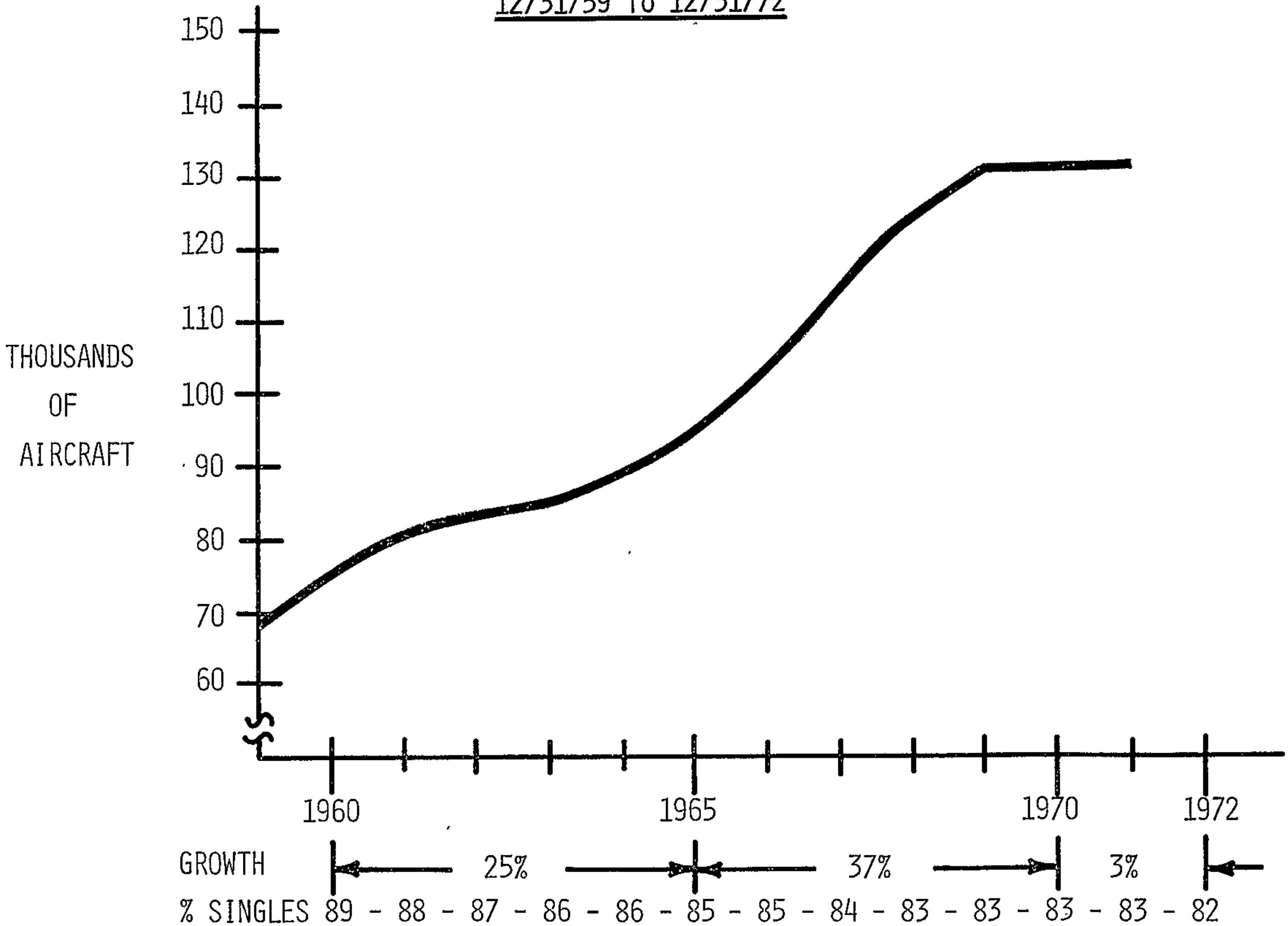
A review of the general aviation fleet by geographic region (Figure II-4) shows that although there have been slight shifts overall in aircraft distribution between 1960 and 1971, only in the southern and New England regions have the changes been of significance.

Decision Sciences Corporation examined the present age distribution of the general aviation fleet (shown in Figure II-5). In a similar study carried out some years ago using 1967 data, DSC found that approximately 43% of the aircraft were over 15 years old, as opposed to 31% in 1972. The trend shows that the general aviation fleet is currently being updated and that many older aircraft are being retired. Furthermore, it reflects the impact in recent years of increased rates of new aircraft deliveries.

FIGURE II-1

GENERAL AVIATION FLEET GROWTH AND DEVELOPMENT

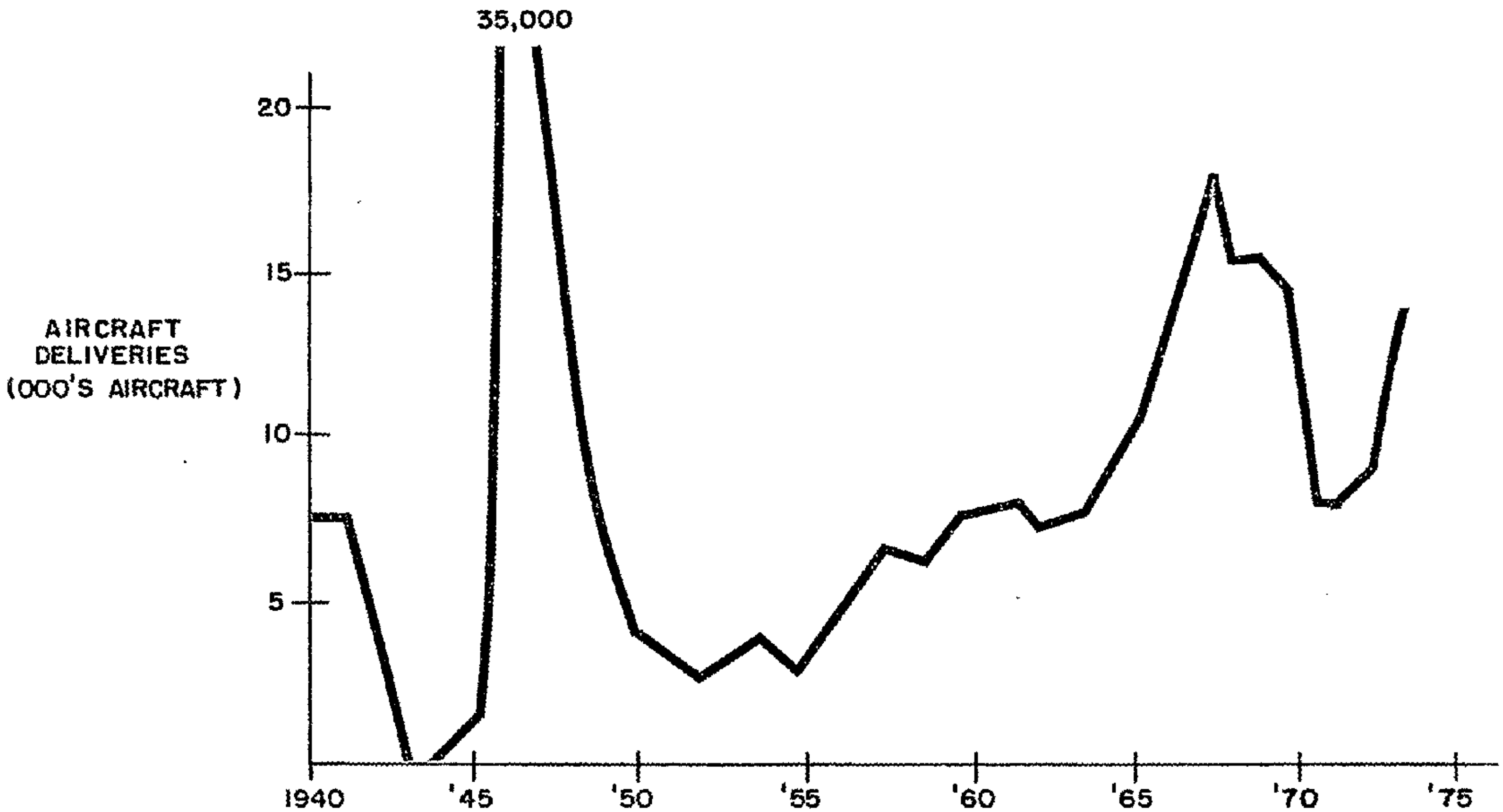
12/31/59 TO 12/31/72



SOURCE: FAA

FIGURE II-2

GENERAL AVIATION AIRCRAFT DELIVERIES



SOURCE: GAMA

FIGURE II-3

GENERAL AVIATION AIRCRAFT DELIVERIES

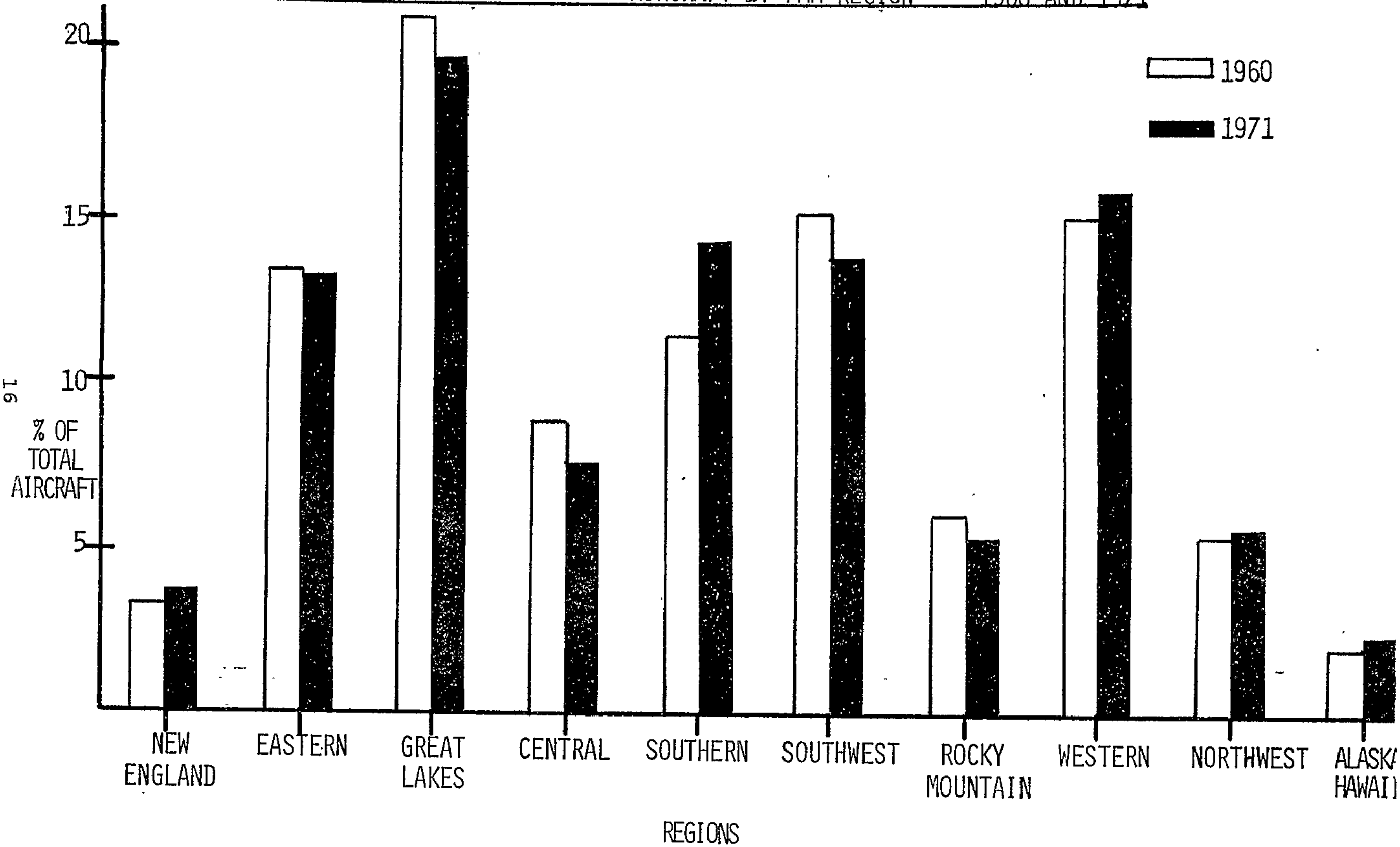
SHIPMENTS BY SEGMENT OF FLEET

1965-1973

YEAR	AIRCRAFT SECTORS					TOTAL %	TOTAL AIRCRAFT
	LIGHT SINGLES	MED.-HEAVY SINGLES	LIGHT TWINS	MED.-HEAVY TWINS	JETS		
1973	46.4	32.5	3.8	15.6	1.7	100.0	13,675
1972	45.8	35.2	5.1	12.6	1.3	100.0	9,774
1971	49.6	34.6	2.8	12.3	0.7	100.0	7,466
1970	45.5	35.4	3.3	14.9	0.9	100.0	7,292
1969	49.2	31.2	3.4	15.2	1.0	100.0	12,457
1968	56.1	27.1	2.4	13.7	0.7	100.0	13,698
1967	54.2	30.9	3.6	10.6	0.7	100.0	13,577
1966	51.2	32.8	4.4	10.5	1.1	100.0	15,768
1965	47.0	36.3	4.5	11.2	1.0	100.0	11,852

FIGURE II-4

ACTIVE U.S. GENERAL AVIATION AIRCRAFT BY FAA REGION - 1960 AND 1971



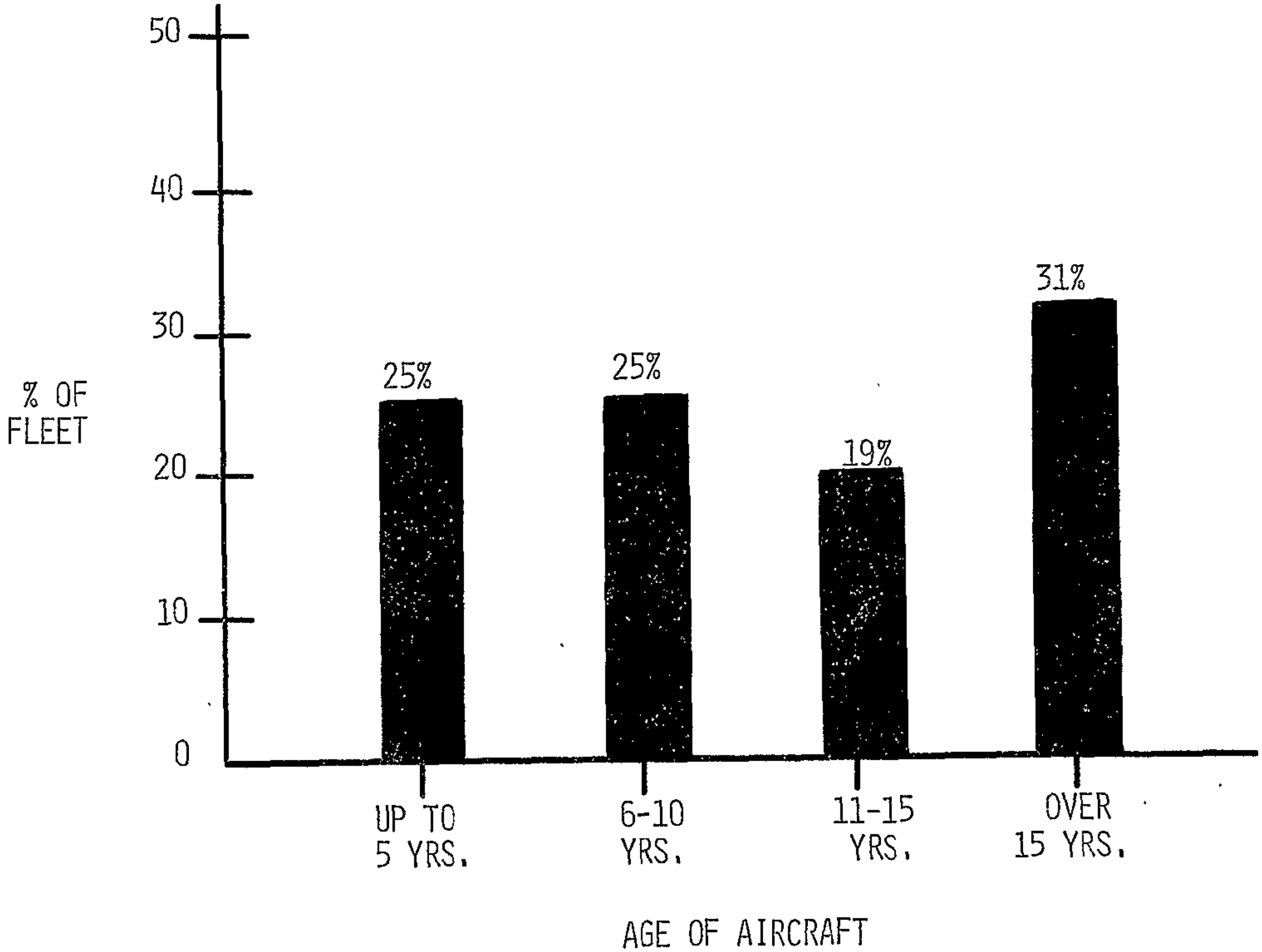
TOTAL AIRCRAFT - 78,760 (1960)
- 133,870 (1971)

SOURCE: FAA

FIGURE II-5

AGE DISTRIBUTION OF GENERAL AVIATION FLEET

1972



SOURCE: DSC

B. AIRCRAFT USAGE

Figures II-6 and II-7 analyze the general aviation fleet in two forms, i.e., by primary use of the major categories of aircraft and by aircraft type flown by the major user categories. From this data, it becomes clear that the most versatile aircraft in general aviation is the medium/ heavy single-engine aircraft which account for more than half of both personal and business aircraft and more than one-third of air taxi and instructional aircraft.

Using the data that is available from the FAA, the breakdown of hours flown by the various user categories can be seen in Figure II-8. This figure also shows the breakdown of number of aircraft by user category. While 52% of the general aviation fleet consists of personal aircraft, they only account for 29% of reported flying time. As the avionics complement carried in aircraft is a factor of the aircraft's mission, we will show in later sections of this report the estimates of avionics in the various classes of aircraft, reflecting the statistics shown here.

C. FORECAST OF THE GENERAL AVIATION FLEET - 1974-1985

In order to forecast the size of the general aviation fleet in 1985, DSC utilized our forecasting model, described in the Appendix of this report. This model considers general aviation industry-related factors such as:

- Airmen certificates
- Airports
- FAA airport expenditures
- Price of aircraft
- Aircraft mix changes
- Cost of flying
    - Training
    - Avionics costs

From DSC's forecasting activities, it has been determined that there are a number of definite issues which characterize the deliveries of new aircraft and which must be incorporated into the forecasts. In the short term, the industry is

FIGURE II-6

MATRIX OF AIRCRAFT TYPES BY USE
1972

TYPE OF FLYING	TYPE OF AIRCRAFT				
	1-3 PLACE SINGLE	4 PLACE AND OVER SINGLE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET
PERSONAL	69.2	67.2	21.4	3.3	11.8
BUSINESS TRANSPORTATION	2.7	20.2	52.6	36.9	36.6
EXECUTIVE TRANSPORTATION	0.1	0.4	8.2	31.9	46.5
AIR TAXI INSTRUCTION	28.0	12.2	17.8	27.9	5.1
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%

SOURCE: FAA

FIGURE II-7

MATRIX OF USE BY TYPE OF AIRCRAFT
1972

TYPE OF FLYING	TYPE OF AIRCRAFT					TOTAL
	1-3 PLACE SINGLE	4 PLACE AND OVER SINGLE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET	
PERSONAL	36.7	58.5	4.6	0.05	0.15	100.0%
BUSINESS TRANSPORTATION	4.7	56.4	35.9	1.6	1.4	100.0%
EXECUTIVE TRANSPORTATION	0.7	12.4	55.6	13.9	17.4	100.0%
AIR TAXI INSTRUCTION	50.2	35.5	12.8	1.3	0.2	100.0%

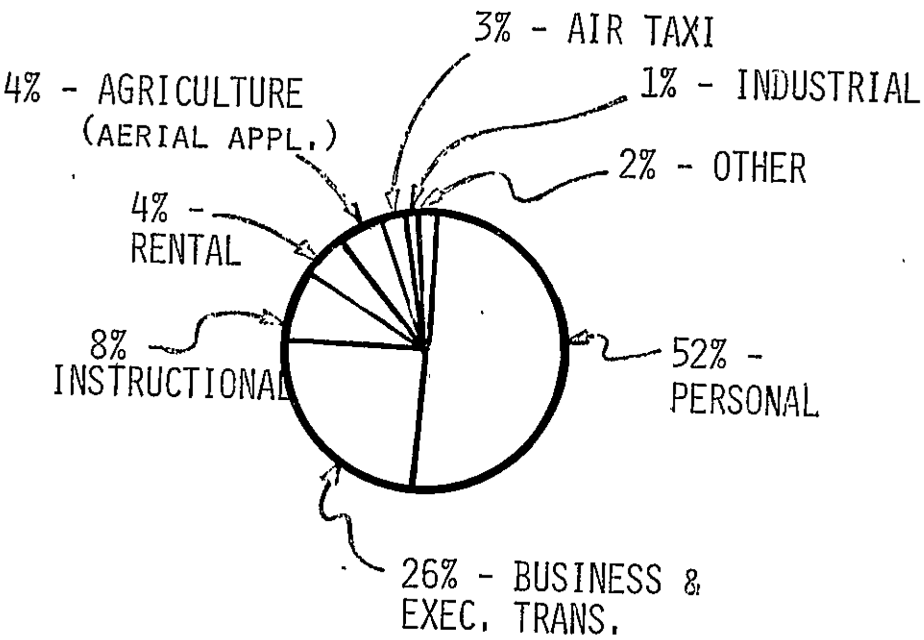
SOURCE: FAA

FIGURE II-8

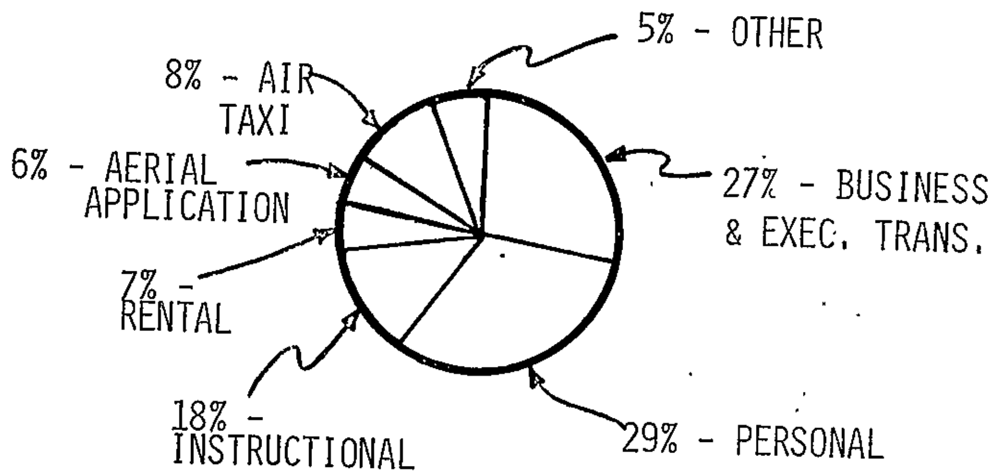
GENERAL AVIATION AIRCRAFT FLEET

BY PRIMARY USE AND HOURS FLOWN

DEC. 31, 1971



NO. OF AIRCRAFT = 129,464



TOTAL HOURS FLOWN = 25,510,000

SOURCE: FAA

very sensitive to money supply and its cost. It is strongly influenced by public attitudes. Furthermore, reactions of the airframe manufacturers to real or perceived changes in the economy greatly affect industry activity.

In the longer terms, it was found that general aviation deliveries, to a great extent, follow the patterns of the gross national product. However, government regulations, availability of other modes of transportation, and Department of Transportation expenditures for air travel facilities are all influencing factors. Among the industry-related factors of importance in long-term forecasts of general aviation are numbers of airline arrival and departure locations, airmen licenses, and the fleet composition and age.

The DSC forecast of aircraft deliveries for the 1974-1985 time frame is shown in Figure II-9. Included for comparison purposes are the actual deliveries made during the period 1965 to 1973. Although high and low forecasts were also made for the period 1974 to 1985, the medium forecast is considered by DSC to be the most probable. The medium or most probable forecast estimates total new deliveries during the same period at 210,550 aircraft for an annual average of 17,545. After taking into account exports and attrition, the new aircraft were then added to the existing general aviation fleet, resulting in a fleet forecast shown in Figure II-10. In 1980, the low, medium and high fleet forecasts are 173,000, 179,000 and 183,000 aircraft. By 1985, the range of estimates will be 214,000, 229,000 and 238,000 active aircraft. For comparision purposes, Figure II-11 shows two other industry forecasts—one made by the FAA in 1972 and one by R. Dixon Speas in 1970. The latter only went to 1980 and, although the FAA forecast is actually only to 1984, DSC projected one year further using the same rate of growth. The DSC and FAA forecasts are very close; the Speas forecast is considerably higher.

The DSC and FAA forecasts of fleet distribution by type of aircraft are shown in Figures II-12 and II-13. Although the two sets of data differ in their actual numbers, it is significant that there is agreement regarding the declining share of single-engine piston aircraft from approximately 83% of the total aircraft fleet in 1970 to 78% in 1985. Nevertheless, in absolute numbers, this represents an increase of approximately 70,000 single-engine piston aircraft, bringing the total in 1985 to more than 178,000.

FIGURE II-9

FORECAST OF AIRCRAFT DELIVERIES

PERIOD		TOTAL NUMBER OF AIRCRAFT DELIVERED	ANNUAL AVERAGE
1965 - 1969 (ACTUAL)*		67,352	13,470
1970 - 1973 (ACTUAL)*		38,385	9,596
1974 - 1985**	LOW	164,050	13,670
	MEDIUM	210,550	17,545
	HIGH	234,650	19,554

*SOURCE: GAMA

**DSC FORECAST

FIGURE II-10

GENERAL AVIATION FLEET - DSC FORECAST

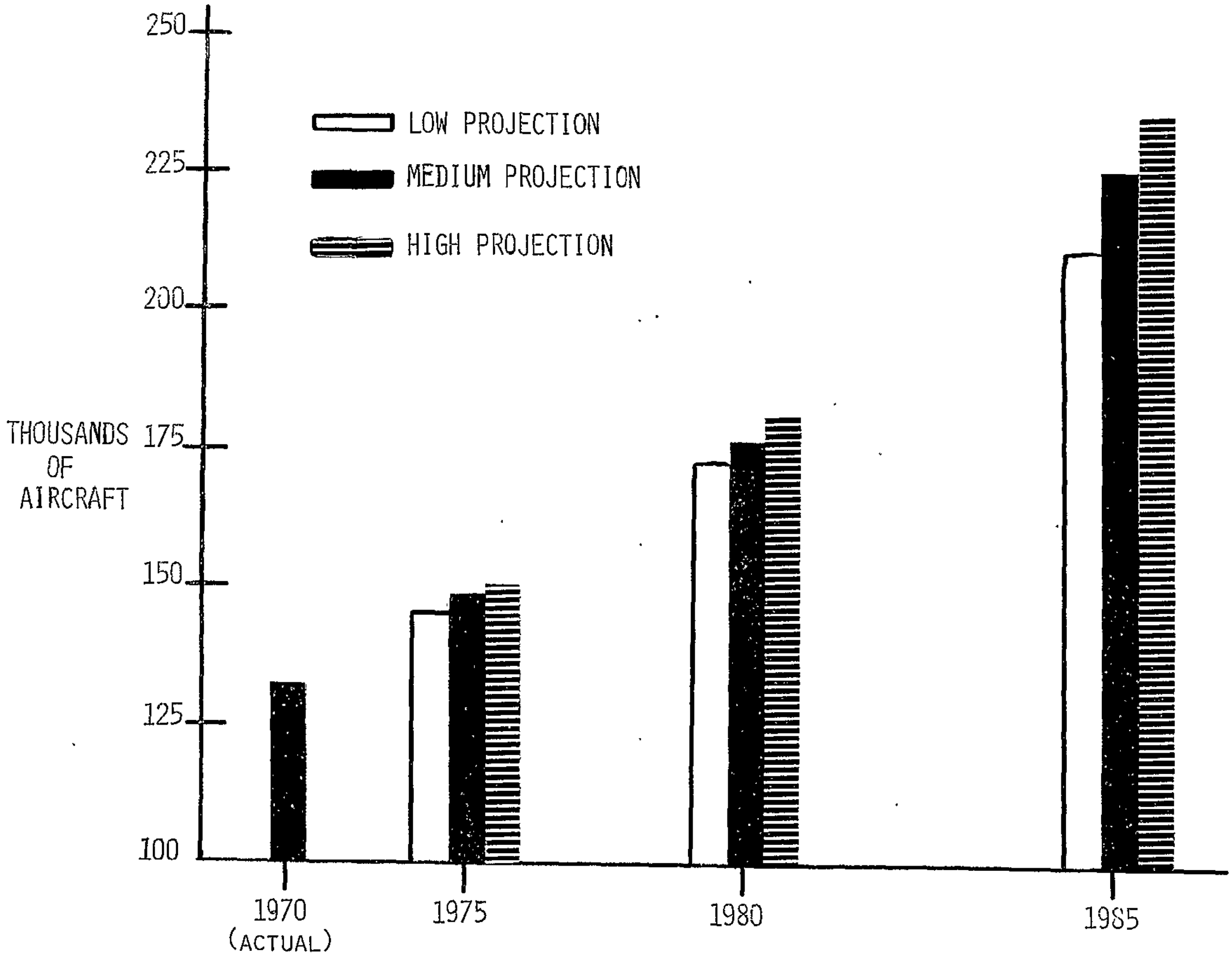


FIGURE II-11

GENERAL AVIATION - FORECASTS OF FLEET SIZE

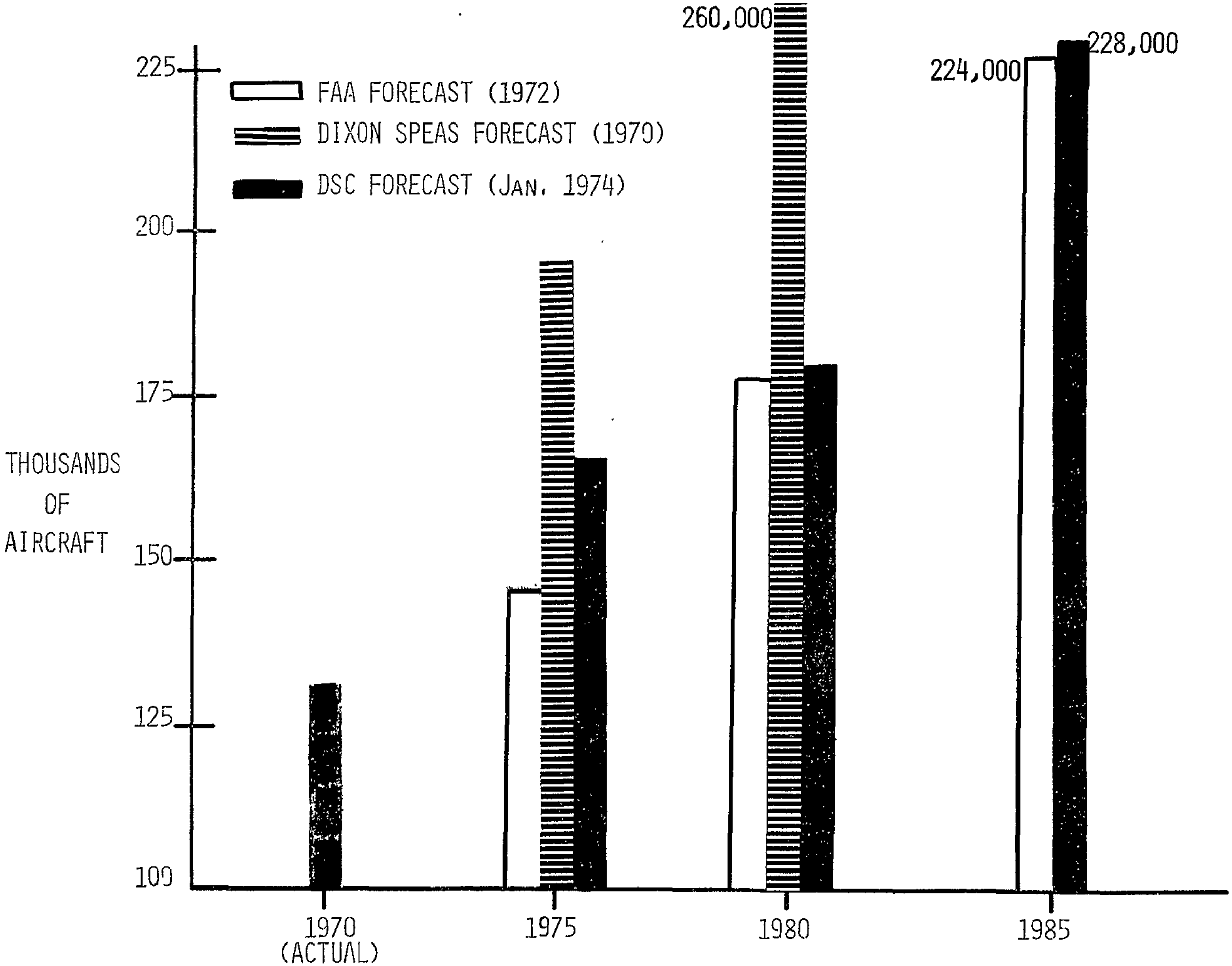


FIGURE II-12

GENERAL AVIATION FLEET DISTRIBUTION BY TYPE OF AIRCRAFT

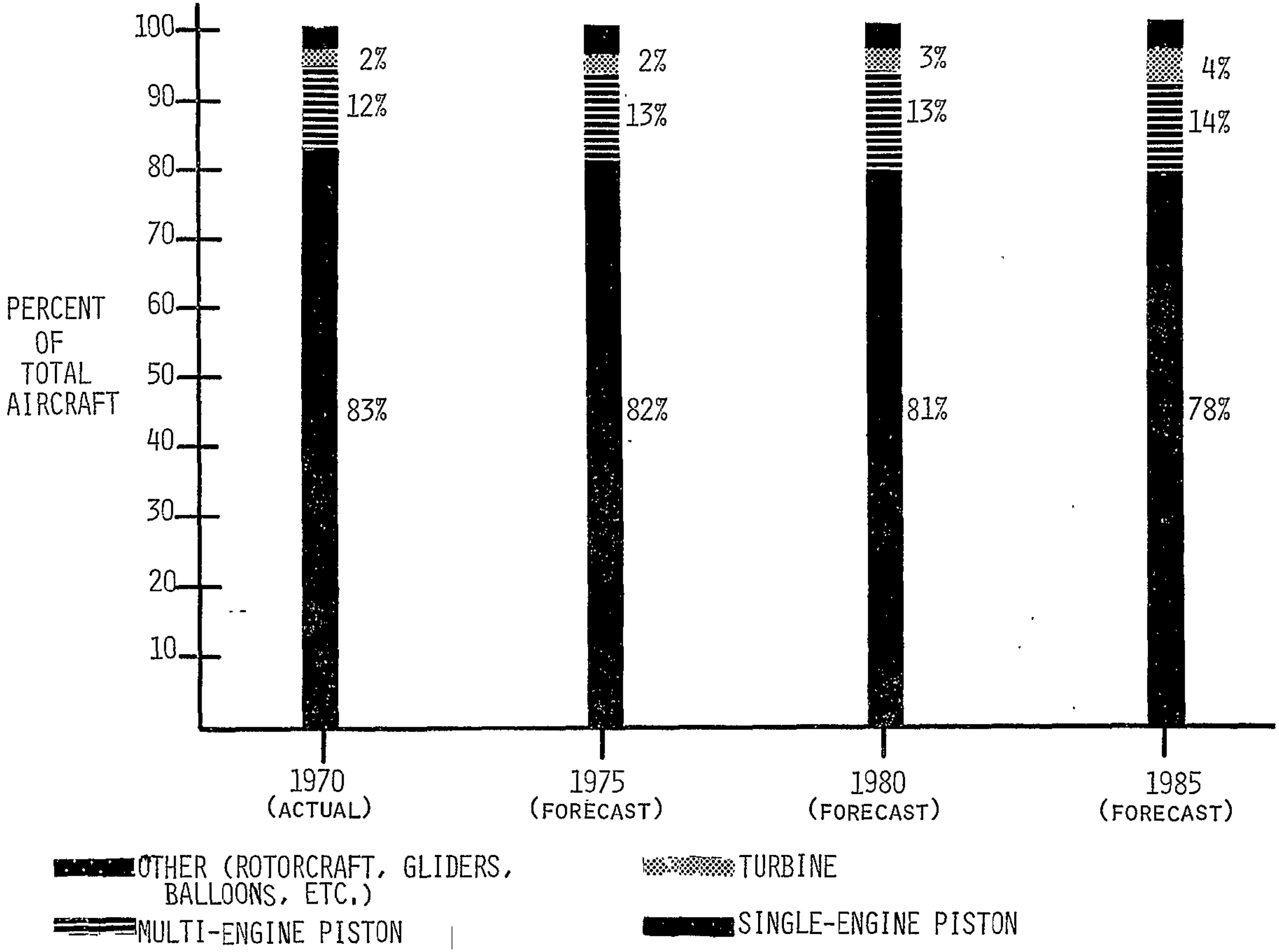
(% OF AIRCRAFT FLEET)

	1970	1975	1980	1985
SINGLE-ENGINE PISTON	83.1	81.9	79.5	77.5
MULTI-ENGINE PISTON	12.1	12.9	14.8	16.6
TURBINE	1.7	2.2	2.5	2.7
OTHER - ROTORCRAFT, ETC.	3.1	3.0	3.2	3.2

SOURCE: DSC

FIGURE II-13

GENERAL AVIATION FLEET DISTRIBUTION BY TYPE OF AIRCRAFT



SOURCE: FAA

D. GENERAL AVIATION AVIONICS INSTALLATIONS

For the purposes of this study, general aviation avionics were divided into the following six functional categories:

- Communications equipment
- Navigation equipment
- Instrumentation
- Flight controls
- Displays
- Electrical sources

1. Communications Equipment

Estimates of the current level of avionics installations in the general aviation fleet are shown in Figures II-14 through II-19. Figure II-14, communications equipment installations, shows that most fixed wing aircraft are equipped with at least one VHF communications system. A negligible percentage of light single-engine aircraft and approximately one-third of medium and heavy single-engine aircraft are equipped with dual communications. Among the heavier aircraft, on the other hand, dual installations are common. Transponders, although only required for flying in positive control areas, are installed by more than half the fleet. As of January, 1973, automatic altitude reporting (the encoding altimeter), the proximity warning indicator, and the emergency locator transmitter were still in their infancy and their use in the fleet quite limited. Of the three types of equipment, only the emergency locator transmitter has gained widespread acceptance due primarily to the government's law that every aircraft carry one. The legislation requiring aircraft to be equipped with automatic altitude reporting for aircraft using terminal control areas was recently postponed until the beginning of 1975, and it can be seen that in the early part of 1973, it was, in effect, only the heavy turboprops and turbojet aircraft that were equipped with this capability.

FIGURE II-14

AVIONICS INSTALLATIONS

COMMUNICATIONS EQUIPMENT

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JANUARY 1, 1973)										TOTAL AIRCRAFT
	SINGLE ENG. 1-3 PLACE	SINGLE ENG. 4+ PLACE	MULTI ENG. <12,500 LBS.	MULTI ENG. >12,500 LBS.	TURBOPROP <12,500 LBS.	TURBOPROP >12,500 LBS.	TURBOJET <50K LBS.	TURBOJET >50K LBS.	ROTOR	OTHER	
VHF-1	62.8	91.3	98.5	100.0	97.3	100.0	99.1	100.0	49.8	37.7	81.4
VHF-2	1.0	35.8	90.1	100.0	97.3	100.0	99.1	100.0	15.3	0.0	31.0
HF	0.0	1.1	21.0	26.7	40.3	40.0	70.8	50.0	0.0	0.0	4.1
ATCRBS (TRANSPONDER)	28.4	63.2	57.1	93.3	100.0	100.0	100.0	100.0	57.5	25.2	51.0
AUTOMATIC ALTITUDE REPORTING	0.0	0.3	1.8	26.7	26.8	80.0	75.5	100.0	0.0	0.0	1.5
PROXIMITY WARNING INDICATOR (PWI)	0.1	0.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
ELT	10.1	11.2	30.0	26.7	33.6	0.0	9.4	0.0	7.7	31.4	13.4
UHF TELEPHONE	0.0	0.0	2.8	40.0	33.6	40.0	37.7	30.0	0.0	0.0	1.2

2. Navigation Equipment

Figure II-15 shows the parallel between aircraft equipped with VHF communications and VOR navigation receivers. Approximately 80% of the general aviation fleet carries one VOR receiver, and approximately 30% carries dual installations. With the exclusion of ADF and, to some extent, ILS glideslope, the figure shows clearly that single-engine piston aircraft carry little in the way of electronic navigation equipment. Approximately 20% of the medium to heavy single-engine aircraft and a negligible percentage of the light singles are DME-equipped.

Reviewing all the classes of aircraft, it is clear that, generally, only the primary types of navigation equipment have gained widespread use. Hyperbolic, Doppler, and inertial navigation systems are necessary only for transoceanic flights and, because of their extremely high cost, are only found in turboprop and turbojet aircraft. VOR- and DME-based area navigation and VLF navigation have yet to gain major acceptance in the general aviation fleet, although they have both been the subject of much discussion in recent years. They are considered items of major expense, with a single waypoint R/NAV system representing an incremental purchase cost of approximately $2,000. However, the industry expects the use of area navigation to increase very rapidly as air traffic controllers and pilots accept the versatility of the system. Nevertheless, as of January, 1973, only approximately 17% of the aircraft were DME-equipped, thereby having the basic capability necessary to add an area navigation system. VLF navigation systems are also considered too expensive for the majority of general aviation aircraft owners relative to its value in use, with the lowest priced system currently available costing over $15,000.

3. Instrumentation

Very few general aviation aircraft are equipped with the categories of instrumentation examined for the purposes of this study, as is shown in Figure II-16. However, turboprop and turbojet aircraft are generally equipped with dual independent altitude, attitude, etc. systems, and weather radar, and a large percentage carry air data systems, recorders, and engine monitors. Approximately one-quarter of the multi-engine piston aircraft

FIGURE II-15

AVIONICS INSTALLATIONS
NAVIGATION EQUIPMENT

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JANUARY 1, 1973)									TOTAL
	SINGLE ENG. 1-3 PLACE	SINGLE ENG. 4+ PLACE	MULTI ENG. <12,500 LBS.	MULTI ENG. >12,500 LBS.	TURBOPROP <12,500 LBS.	TURBOPROP >12,500 LBS.	TURBOJET <50K LBS.	TURBOJET >50K LBS.	ROTOR	
ADF	22.7	56.5	90.1	93.3	97.3	100.0	94.3	100.0	3.8	48.3
VOR - 1	61.0	91.3	98.5	100.0	97.3	100.0	99.1	100.0	34.5	80.0
VOR - 2	0.5	34.4	87.1	93.3	97.3	100.0	99.1	100.0	7.7	29.7
DME	0.1	19.7	48.0	66.7	80.5	60.0	94.3	100.0	0.0	17.2
RADAR ALTIMETER	0.0	0.4	21.3	26.7	80.5	40.0	94.3	100.0	1.9	4.5
HYPERBOLIC (LORAN, OMEGA)	0.0	0.0	0.1	2.7	1.3	8.0	4.7	10.0	0.0	0.1
DOPPLER	0.0	0.0	0.0	0.0	0.0	20.0	9.4	20.0	0.0	0.1
INERTIAL	0.0	0.0	0.0	1.3	1.3	20.0	14.2	30.0	0.0	0.2
RNAV - 2D (VOR/DME BASED)	0.0	0.1	4.8	13.3	10.1	0.0	4.7	0.0	0.0	0.8
VNAV - 3D (VOR/DME BASED)	0.0	0.0	0.1	1.3	0.7	0.0	1.9	10.0	0.0	0.04
ILS GLIDESLOPE	1.0	32.3	90.1	100.0	100.0	100.0	100.0	100.0	3.8	29.1
VLF (OTHER THAN LORAN, OMEGA)	0.0	0.0	0.1	0.0	0.7	0.0	0.0	0.0	0.4	0.02

FIGURE II-16

AVIONICS INSTALLATIONS

INSTRUMENTATION

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JAN. 1, 1973)					TOTAL
	SINGLE-ENG. PISTON	MULTI-ENG. PISTON	TURBOPROP	TURBOJET	ROTOR	
DUAL INDEPENDENT ALT, ATT, ETC.	0.0	23.0	88.5	100.0	3.8	4.8
AIR DATA SYSTEMS	0.0	1.1	14.4	30.2	0.0	0.2
RECORDERS	0.0	0.3	17.2	25.9	0.0	0.4
ENGINE MONITORS (EXCEPT EGT)	0.0	8.0	28.7	51.7	0.0	1.7
WEATHER RADAR	0.0 (0.0008)	22.4	83.9	100.0	0.0	4.5

carry dual independent altitude and attitude, etc. systems, and weather radar, although few are equipped with air data systems, recorders, and engine monitors. This is an area where the general aviation fleet is not well-equipped, the primary reason being a low value in use.

4. Flight Control Systems

DSC's estimates of flight control installations consisting of stability augmentation systems, 2- and 3-axis autopilots, and flight directors in the general aviation fleet are shown in Figure II-17. The figure shows that stability augmentation systems are found primarily in the medium to heavy single-engine piston aircraft. Most turboprop and turbojet and, to a smaller degree, twin-engine piston aircraft carry 2- and 3-axis autopilots and flight directors.

5. Displays

With the exception of attitude gyros, displays are difficult to estimate as a separate entity, since they are usually part of a functional system such as navigation and flight control. Nevertheless, estimates have been made of the display installations found in general aviation. From Figure II-18, it is clear that only the attitude gyro is used extensively across the entire spectrum of general aviation.

6. Electrical Sources

The final functional avionics category examined was the electrical sources in Figure II-19. It can be seen quite clearly that the most common electrical source in lighter aircraft is 14 volt DC, whereas in the multi-engine pistons, turboprops and turbojets categories, 28 volt DC and 400 Hz AC tend to be the accepted standard.

To obtain a better understanding of the avionics carried in the various categories of aircraft, DSC developed the product matrix by user group shown in Figure II-20. The matrix shows that corporate-owned aircraft are fully equipped with every type of avionics and, in many cases, have dual installations. The individually-owned aircraft and aircraft belonging to fixed base operators are equipped only with basic avionics packages. Figure II-21 shows the annual avionics expenditures by customer segment and type of aircraft.

FIGURE II-17

AVIONICS INSTALLATIONS
FLIGHT CONTROLS

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JAN. 1, 1973)							TOTAL
	SINGLE-ENG. 1-3 PLACE	SINGLE-ENG. 4+ PLACE	MULTI-ENG < 12,500 LBS	MULTI-ENG >12,500 LBS	TURBO-PROP	TURBO-JET	ROTOR	
STABILITY AUGMENTATION	8.1	42.2	24.0	0.0	0.0	0.0	0.0	22.8
AUTO PILOT - 2 AND 3 AXIS	2.0	21.1	45.0	66.7	100.0	100.0	9.6	18.7
FLIGHT DIRECTOR	0.0	0.3	22.2	53.3	88.5	100.0	0.0	4.8

FIGURE II-18

AVIONICS INSTALLATIONS

DISPLAYS (NAV, POSITION, ATTITUDE)

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JAN. 1, 1973)					TOTAL
	SINGLE-ENG 4+ PLACE	MULTI-ENG < 12,500 LBS.	MULTI-ENG >12,500 LBS.	TURBOPROP	TURBOJET	
ELECTRONIC - DIGITAL	0.1	0.9	13.3	74.7	38.8	1.1
PERIPHERAL	0.0	0.3	6.7	5.7	8.6	0.2
ATTITUDE GYRO	80.0	100.0	100.0	100.0	100.0	60.1
INTEGRATED (RMI, HSI, FLT. DIR.)	2.1	27.0	66.7	98.8	100.0	6.5

35

FIGURE II-19

AVIONICS INSTALLATIONS
ELECTRICAL SOURCE

EQUIPMENT CATEGORY	AIRCRAFT CATEGORY (% EQUIPPED JAN. 1, 1973)							TOTAL
	SINGLE-ENG. 1-3 PLACE	SINGLE-ENG. 4+PLACE	MULTI-ENG. <12,500 LBS.	MULTI-ENG. >12,500 LBS.	TURBOPROP	TURBOJET	ROTOR	
14 VOLT DC	64.8	95.6	33.9	0.0	0.0	0.0	38.3	73.6
28 VOLT DC	0.0	0.7	66.1	100.0	100.0	100.0	61.7	11.6
400 HZ AC	0.0	0.3	24.0	93.3	94.8	100.0	7.7	5.5

FIGURE II-20

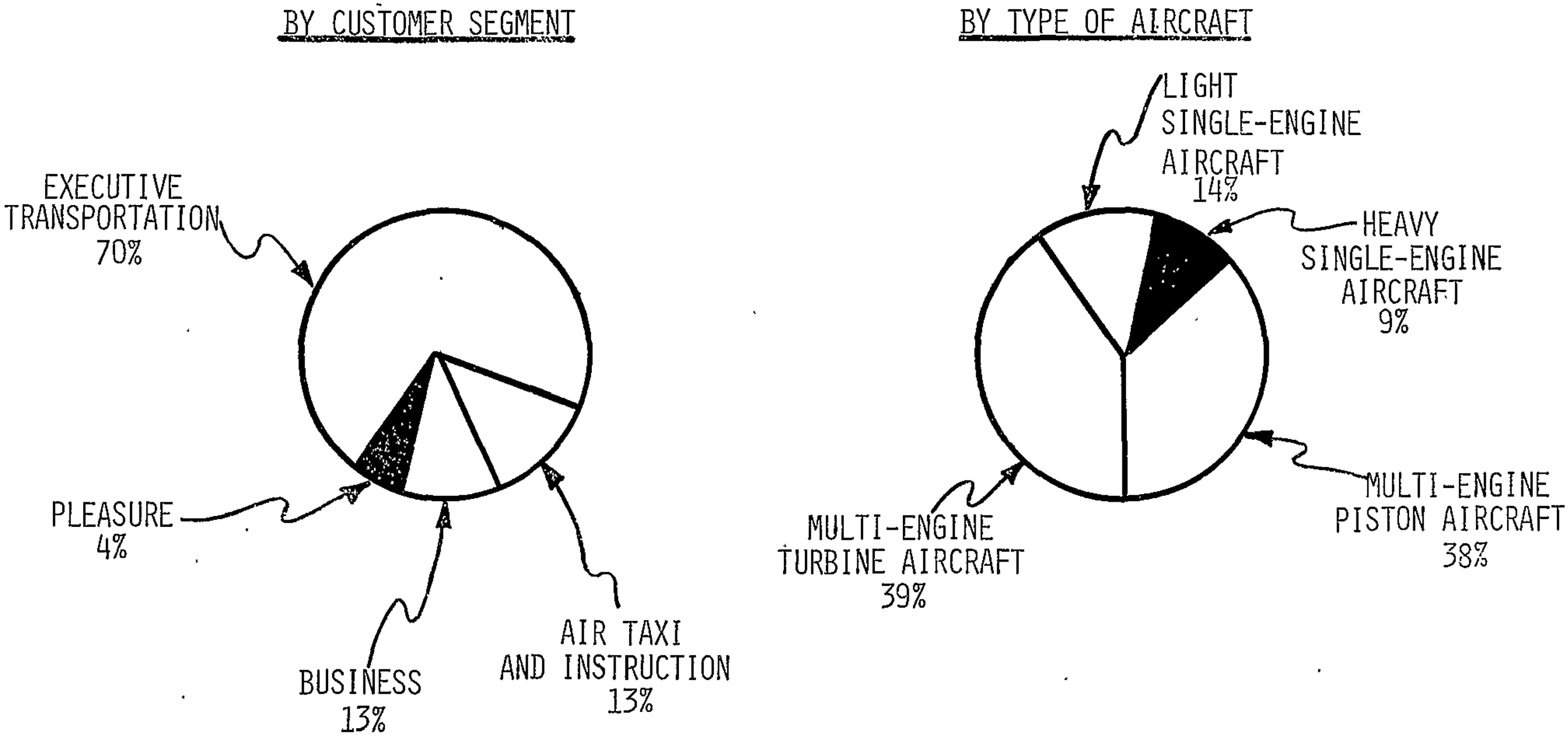
GENERAL AVIATION AVIONICS PRODUCT MATRIX BY USER GROUP

USER GROUP	EQUIPMENT CATEGORY								
	NAV/COM #1	NAV/COM #2	ADF	XPONDER	DME	GLIDE-SLOPE	AUTO-PILOT	FLIGHT DIRECTOR/HSI	WEATHER RADAR
INDIVIDUAL OWNERS									
LIGHT SINGLE	X	(x)	(x)	(x)					
MEDIUM-HEAVY SINGLE	X	(X)	X	X	(x)	(x)	X		
LIGHT TWIN	X	X	X	X	(x)	(x)	X		
COMMUTER AIRLINES	X	X	X	X	X	X	(x)	(x)	(x)
CORPORATE-OWNED A/C									
LIGHT-MEDIUM TWIN	X	X	X	X	X	X	X	(x)	(x)
HEAVY TWIN/JETS	X	X	D	D	D	D	X	D	X
FBO									
LIGHT SINGLE	X								
LIGHT-MEDIUM SINGLE	X	(x)	(x)	(x)			(x)		
LIGHT-MEDIUM TWIN	X	X	X	(x)		(x)	(x)		

X - MOST A/C EQUIPPED (x) - HALF OR LESS EQUIPPED D - USUALLY DUAL INSTALLATION

FIGURE II-21

GENERAL AVIATION AVIONICS EXPENDITURES



SOURCE: DSC

Avionics value by type of aircraft ranges from approximately $2,200 for light single-engine pistons to more than $150,000 for turbojet aircraft, as shown in Figure II-22. The average value of avionics installed in the various categories of aircraft are as follows:

- Piston engine aircraft
  - Light singles - $ 2,400
  - Medium singles - $ 3,800
  - Heavy singles - $10,000
  - Light twins - $12,000
  - Medium twins - $35,000
  - Heavy twins - $48,000
- Turbine aircraft
  - Turboprops - $90,000
  - Turbojets - $150,000 +

There is a considerable difference in the value of avionics carried in light to medium singles and in the high performance singles. There is also a substantial overlap in avionics expenditures between the high performance single-engine piston aircraft and the light twins. At the top end of the line, the turboprops and turbojets tend to identify more closely in the type of flying they do and the avionics they carry with the air carrier aircraft than with the main body of general aviation.

In order to relate these ranges of avionics to the current availability of products, DSC compiled the table shown in Figure II-23. In examining the table, it is apparent that the number of brands (makes) available of inexpensive products is far greater than for the more costly products. This reflects the manufacturers' recognition of sensitivity to price, characteristic of the pilots flying single-engine aircraft. Thus, small differences in price can have a significant impact on sales. Furthermore, the large number of products found in the less expensive categories also reflects the ease of entry available at this end of the spectrum compared to the investment and technological requirements for top-of-the-line equipment.

FIGURE II-22

AVIONICS VALUE PER AIRCRAFT

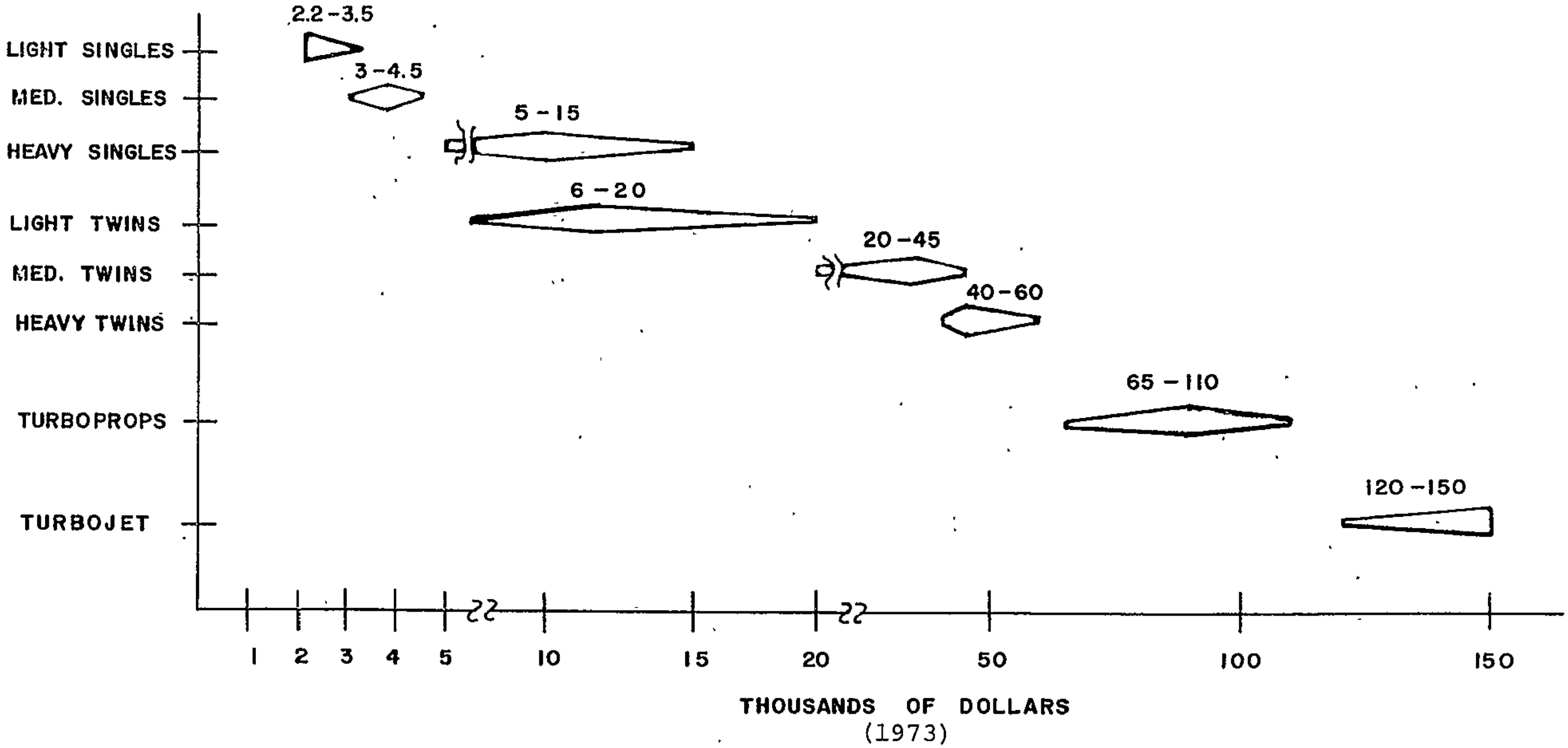
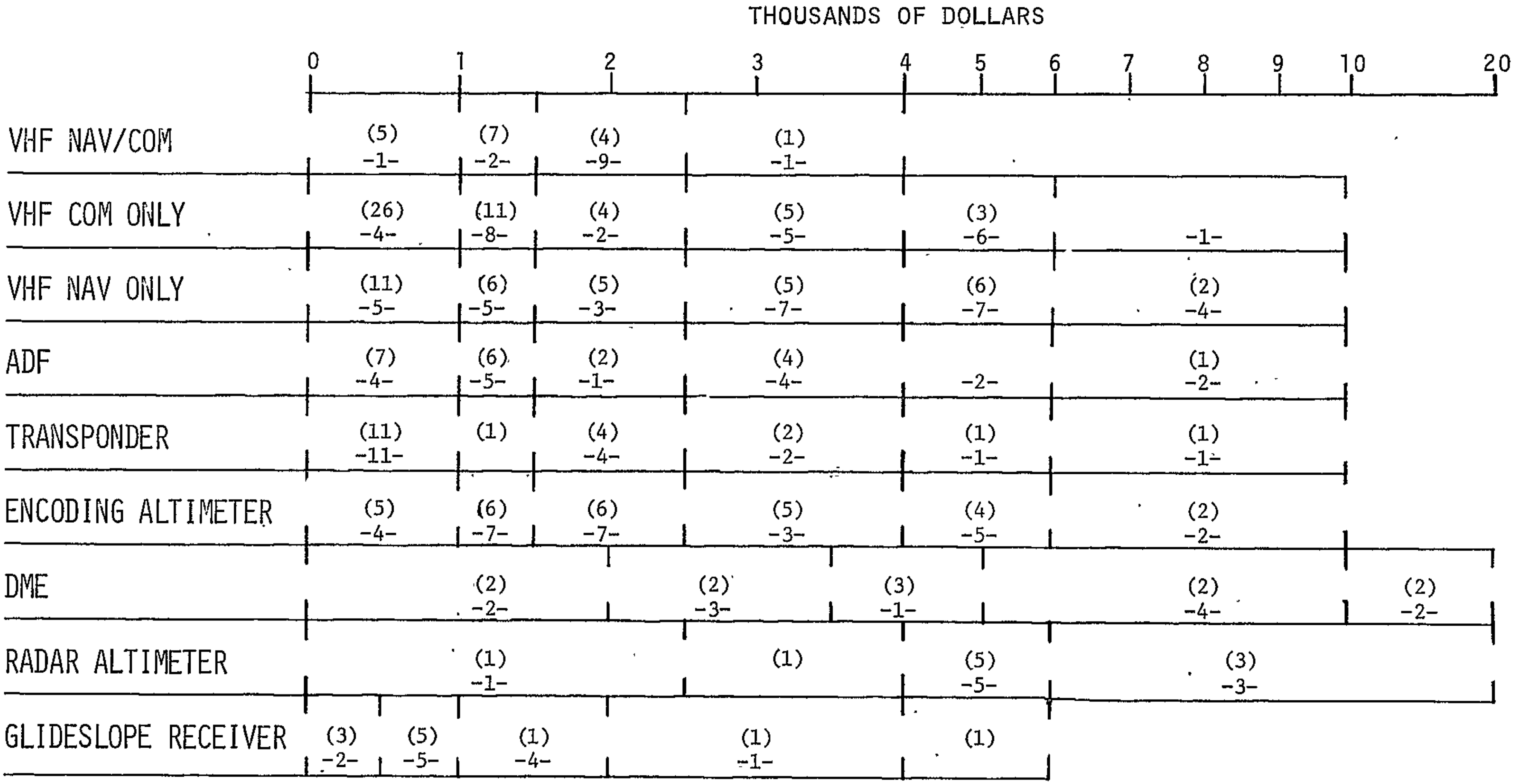


FIGURE II-23

NUMBER OF AVAILABLE AVIONICS PRODUCTS BY PRICE RANGE



SOURCE: ( ) FLYING ANNUAL & PILOTS' BUYING GUIDE 1974

- - BUSINESS & COMMERCIAL AVIATION, 1974 PLANNING & PURCHASING HANDBOOK

E. AIRMEN STATISTICS

Figure II-24 shows that the total number of active airmen in the United States more than doubled between 1962 and 1972, reaching 750,000 pilots by the end of 1972. However, since 1969, the increase in active airmen certificates has slowed considerably. This trend is substantiated by Figure II-25 which shows that the number of student starts declined continuously from 1967 to 1972. In 1973, the trend was reversed which, if continued, would be a positive indication of increasing public interest in general aviation.

If the estimated average student pilot completion rate of 35% (see Figure II-26) is applied and student starts remain at their present level or increase slightly, the total number of active airmen will increase by 45,000-50,000 annually.

The number of active airmen by type of certificate is shown in Figure II-27. It can be seen that the relative decline in growth of the total number of active airmen in the 1962-1972 time frame is accounted for by the decline in the number of student pilots. Both the number of private and commercial pilots have been increasing. The abrupt decrease in number of flight instructors in 1968 was caused by a change in the selection criteria, and it appears that since then the normal growth curve has been resumed. The number of ATR-rated pilots has increased at a very slow annual growth rate and it is not expected that this will change, as the total number of air carrier aircraft, the number of flights and hours flown have been declining.

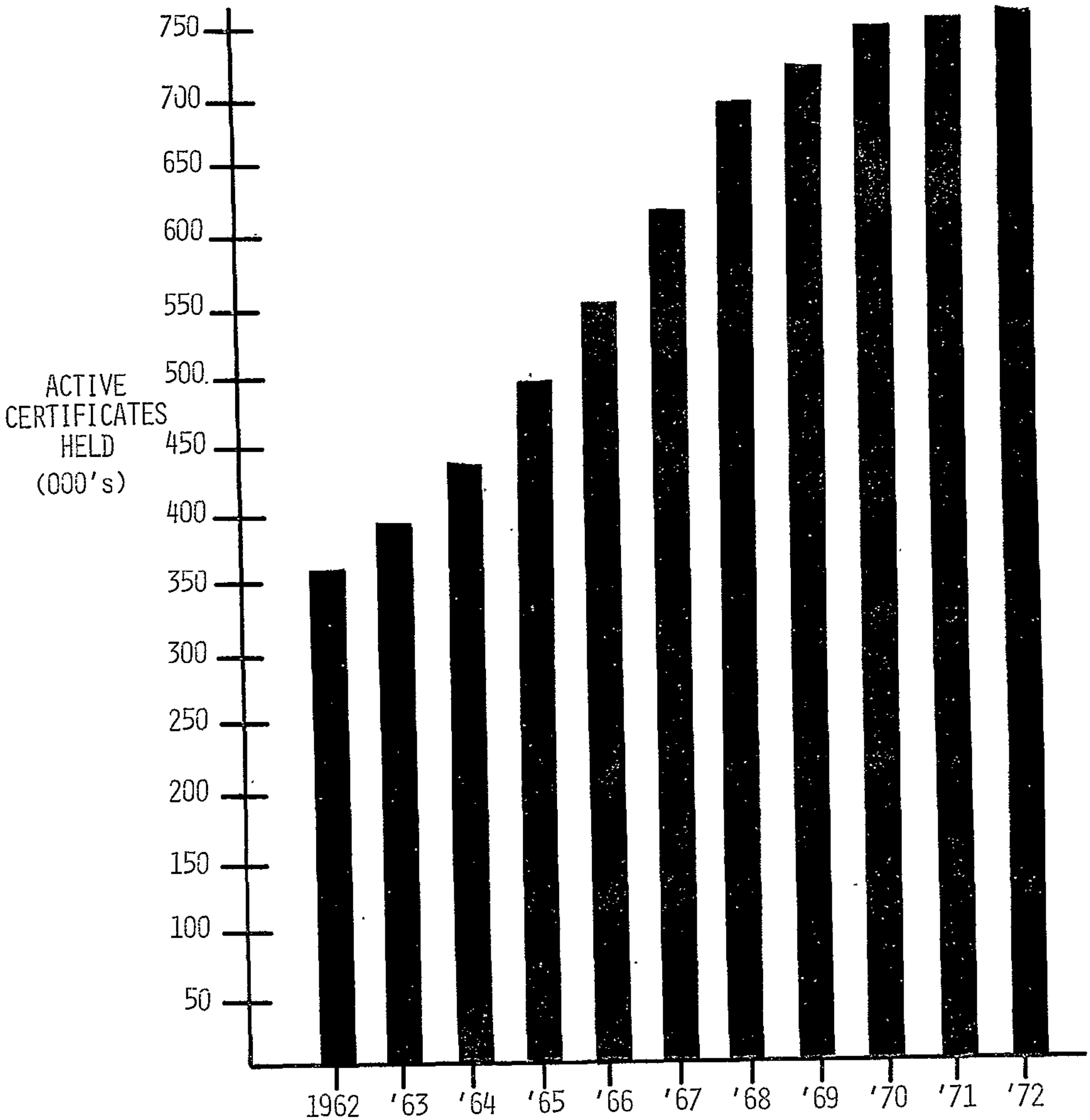
Possibly the most significant change in the airmen statistics is the considerable increase during the past ten years in the number of pilots holding instrument ratings. Figure II-28 shows that IFR-rated pilots have increased by approximately 150% between 1962 and 1972.

The FAA forecasts indicate that the total number of active airmen in 1984 will reach approximately 1.2 million, consisting of about 528,000 pilots with private licenses, 318,000 pilots with commercial licenses, and 282,000 student pilots. During the same period, the number of instrument-rated pilots as a percentage of total non-student pilots is expected to reach 44% in 1985. These FAA forecasts are shown in Figures II-29 and II-30.

FIGURE II-24

TOTAL ACTIVE AIRMEN CERTIFICATES HELD

DEC. 31, 1962 - '72



SOURCE: FAA

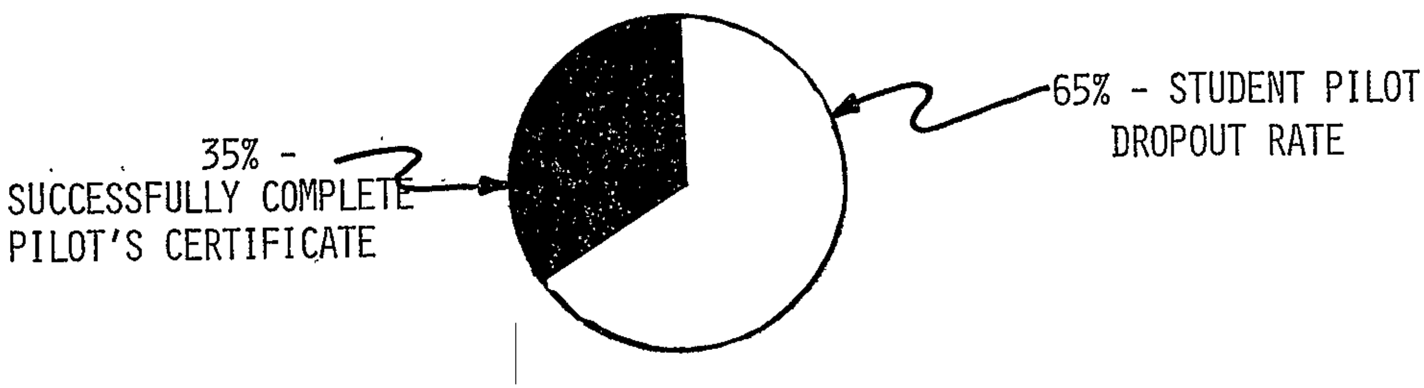
FIGURE II-25

STUDENT STARTS (1967-1973)

SOURCE: GAMA

FIGURE II-26

STUDENT PILOT COMPLETION RATE - 1973

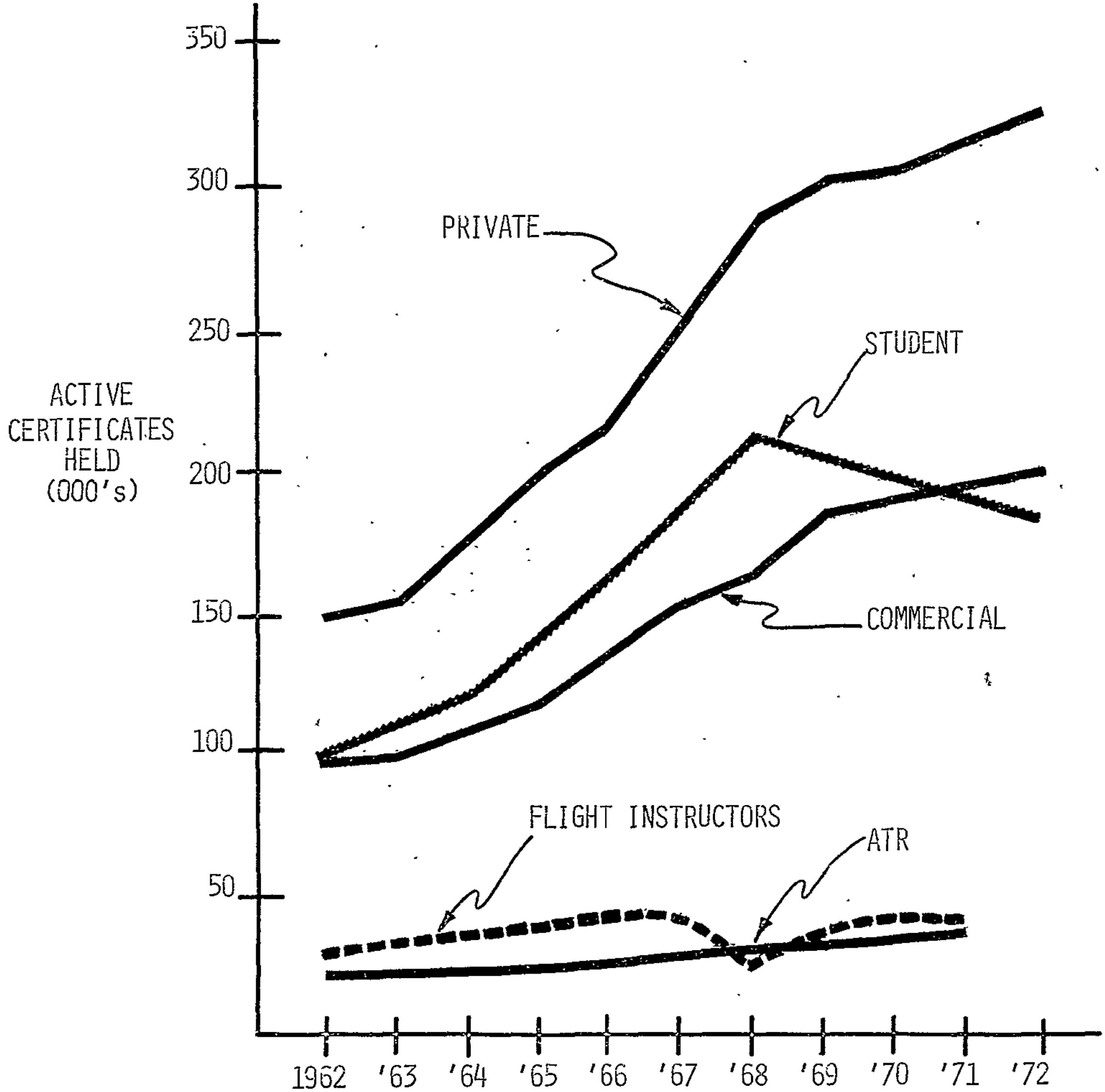


SOURCE: FAA

FIGURE II-27

ACTIVE AIRMEN CERTIFICATES HELD BY TYPE OF AIRMEN

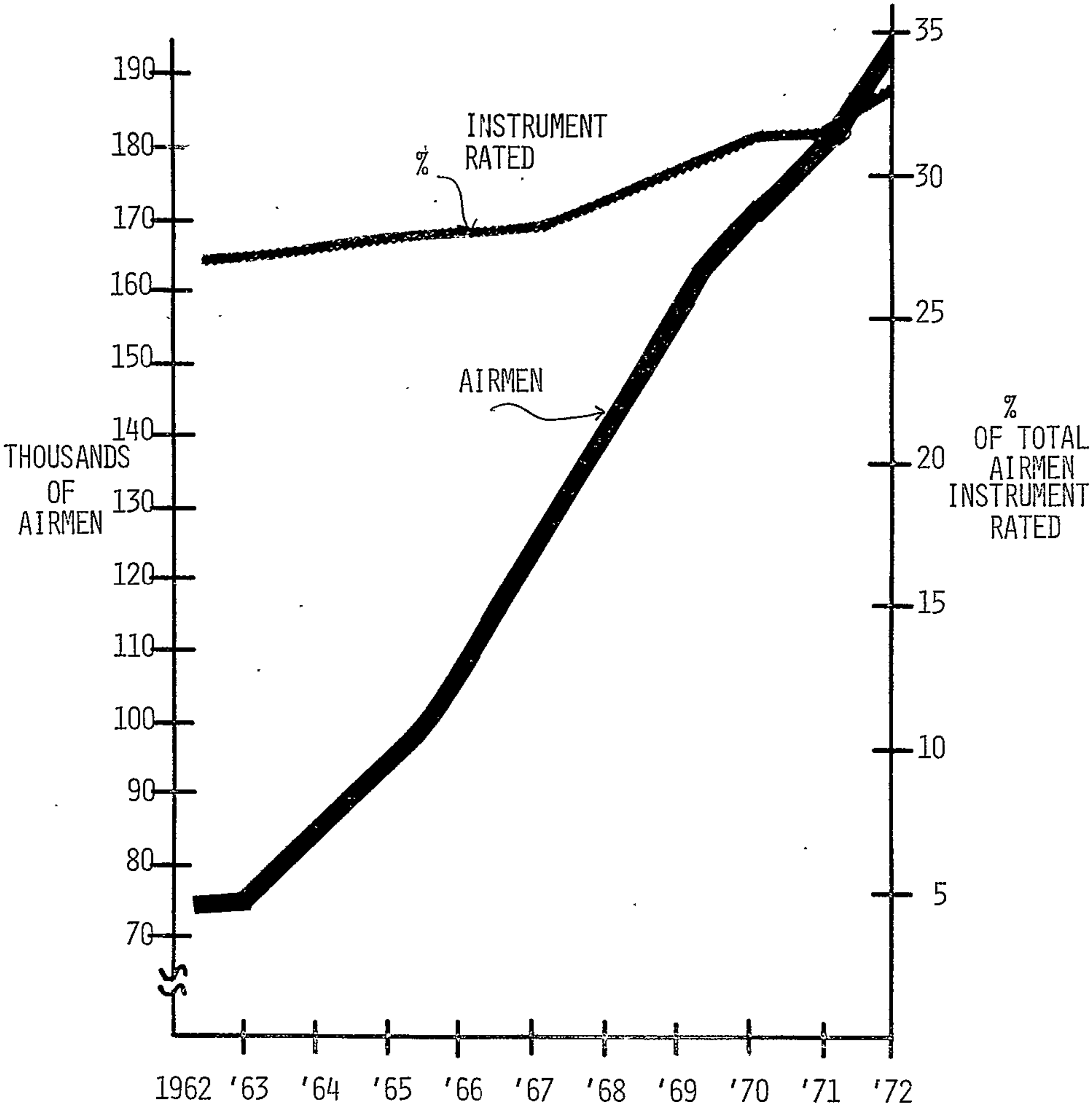
DEC. 31, 1962-1972



SOURCE: FAA

FIGURE II-28

ACTIVE AIRMEN HOLDING INSTRUMENT RATINGS
1962-1972

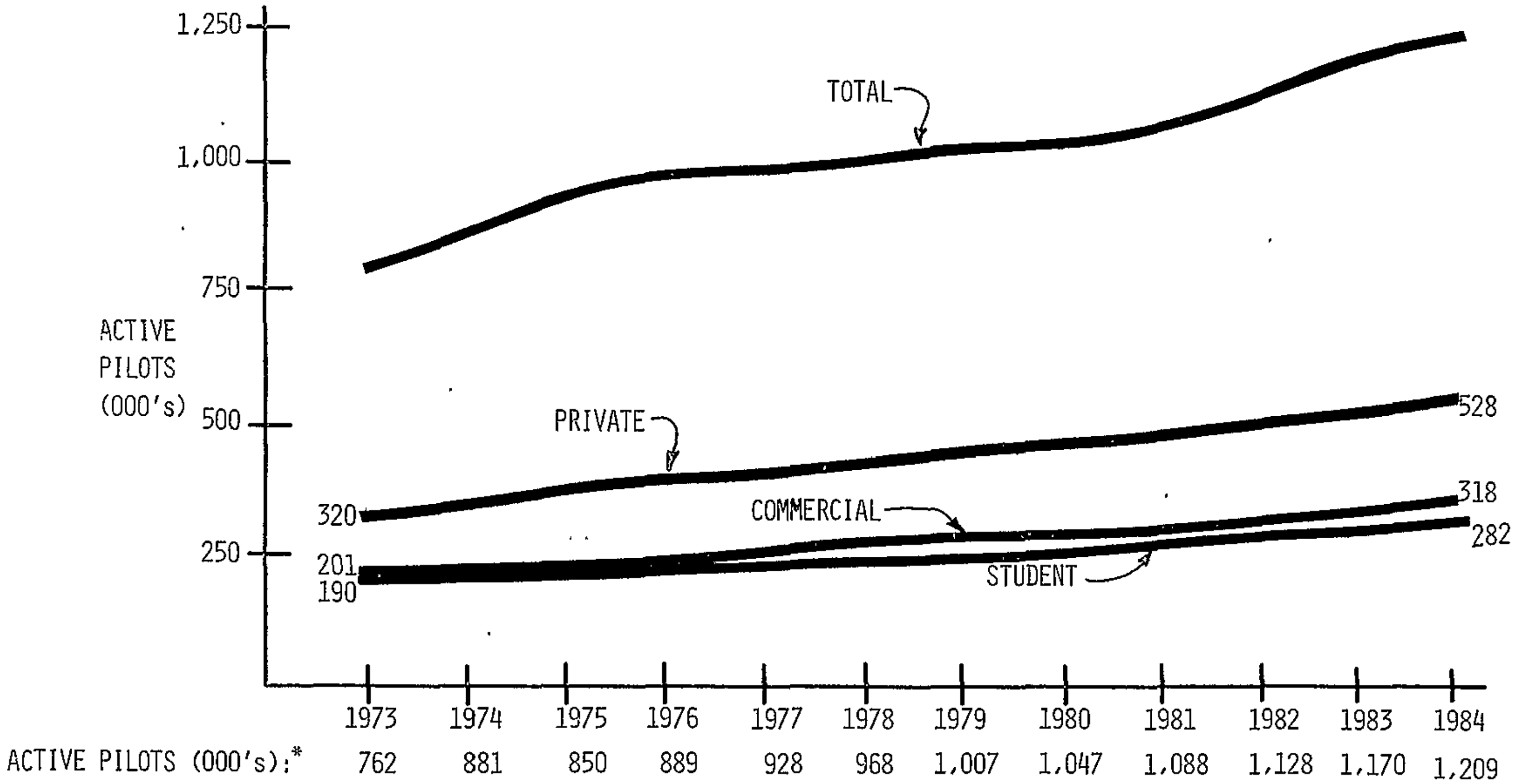


% CHANGE: 2.1 13.4 10.8 14.5 14.4 13.7 11.9 9.0 5.5 8.1

SOURCE: FAA

FIGURE II-29

FORECASTED ACTIVE PILOTS BY TYPE OF CERTIFICATE 1973-1984

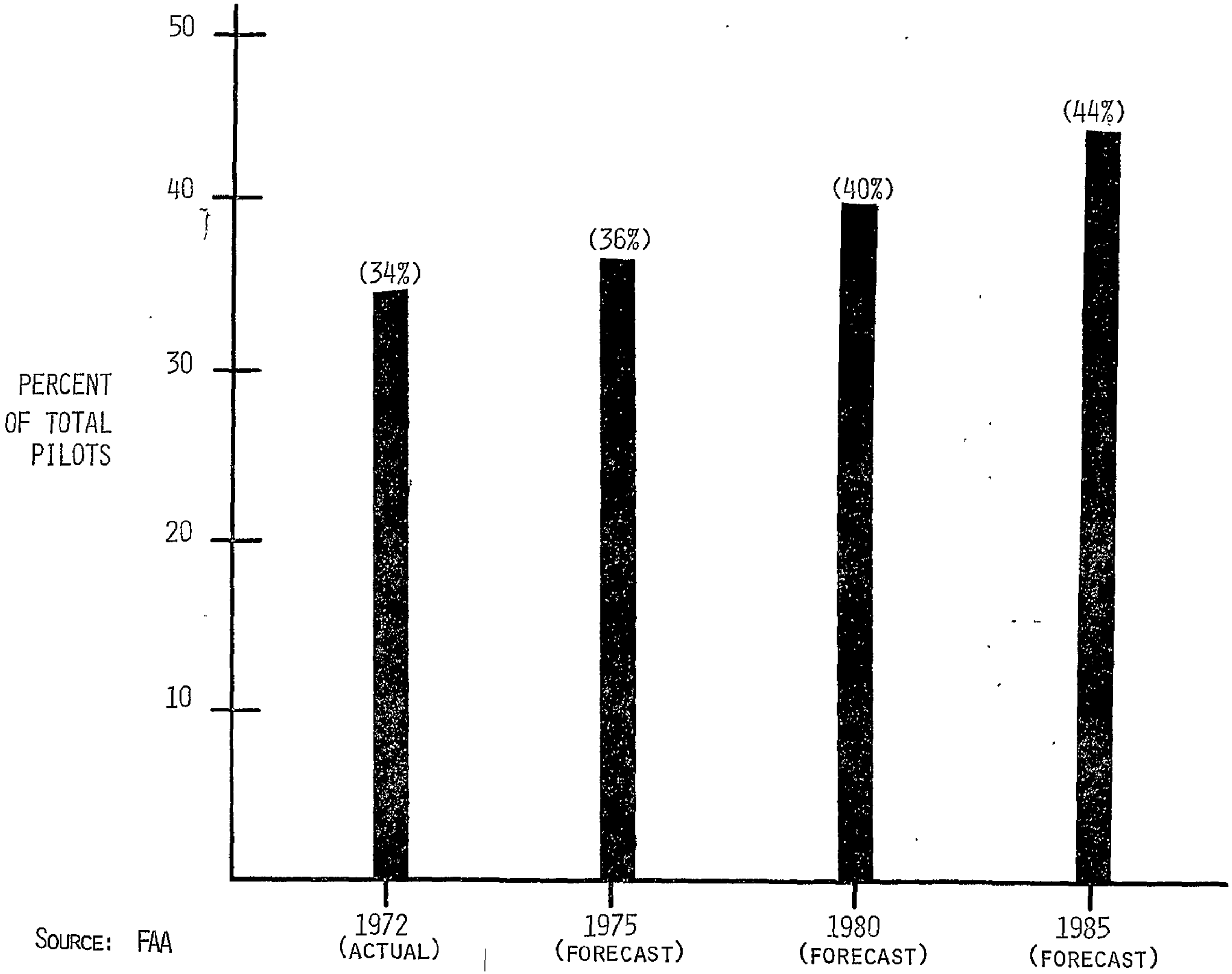


*TOTAL INCLUDES HELICOPTER AND GLIDER PILOTS

SOURCE: FAA

FIGURE II-30

INSTRUMENT-RATED PILOTS AS A PERCENTAGE OF TOTAL PILOTS



SOURCE: FAA

F. SUMMARY

In this chapter, DSC has established much of the industry framework regarding the size and composition of the fleet during the early 1980's, as well as the number of active airmen. The avionics forecasts discussed later in this report are based upon these characteristics and also upon characteristics of the airspace environment.

III. DEFINITION OF THE ENVIRONMENT AND ANALYSIS OF THE NATIONAL AVIATION SYSTEM

A. GENERAL AVIATION ACTIVITY

1. Hours Flown

The increase in the number of aircraft and equipment has led to a corresponding rise in general aviation activity. Figure III-1 shows that between 1953 and 1965, the number of hours flown in general aviation doubled, with an average annual rate of growth of approximately 5½%. This growth rate doubled during the latter half of the 1960's, with the number of hours flown in general aviation reaching a peak in 1970 estimated at more than 26 million.

It is not possible to make an accurate estimate of the changes in hours flown during the past ten years by primary use, since the data collected and reported by the FAA of the primary uses has not been in a consistent form. However, from the data that is available, it appears that there has been a significant increase in general aviation in personal and instructional flying hours as a percentage of total hours flown.

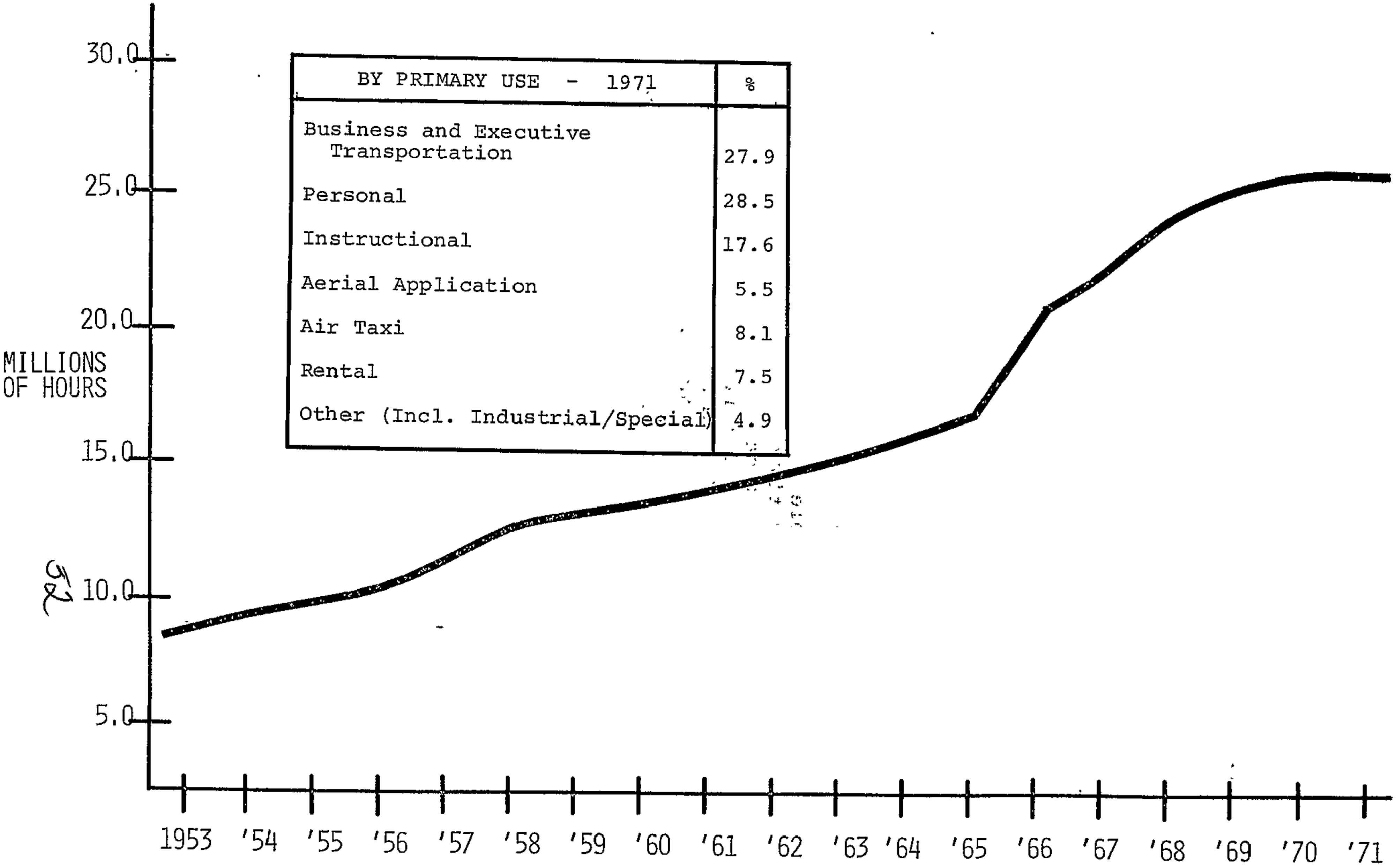
Examining the average activity of the general aviation fleet, Figure III-2 shows little change between the early Sixties and early Seventies. In terms of the average number of hours flown per general aviation aircraft between 1960 and 1965, a level of 170-180 hours per year was maintained. In 1966, the average increased significantly and then remained at approximately the same level throughout the remainder of the decade.

2. Miles Flown

Although the average number of miles flown per aircraft in 1970 was not substantially greater than in 1960, the average level between 1965 and 1969 was approximately 25% higher. Figure III-3 gives a breakdown of the average number of hours flown by aircraft type, showing that turboprop aircraft represent the most active part of the fleet in terms of hours by a margin of one-third over turbojets and more than double the usage of twin-engine piston aircraft.

FIGURE III-1

HOURS FLOWN IN GENERAL AVIATION - 1953-1971



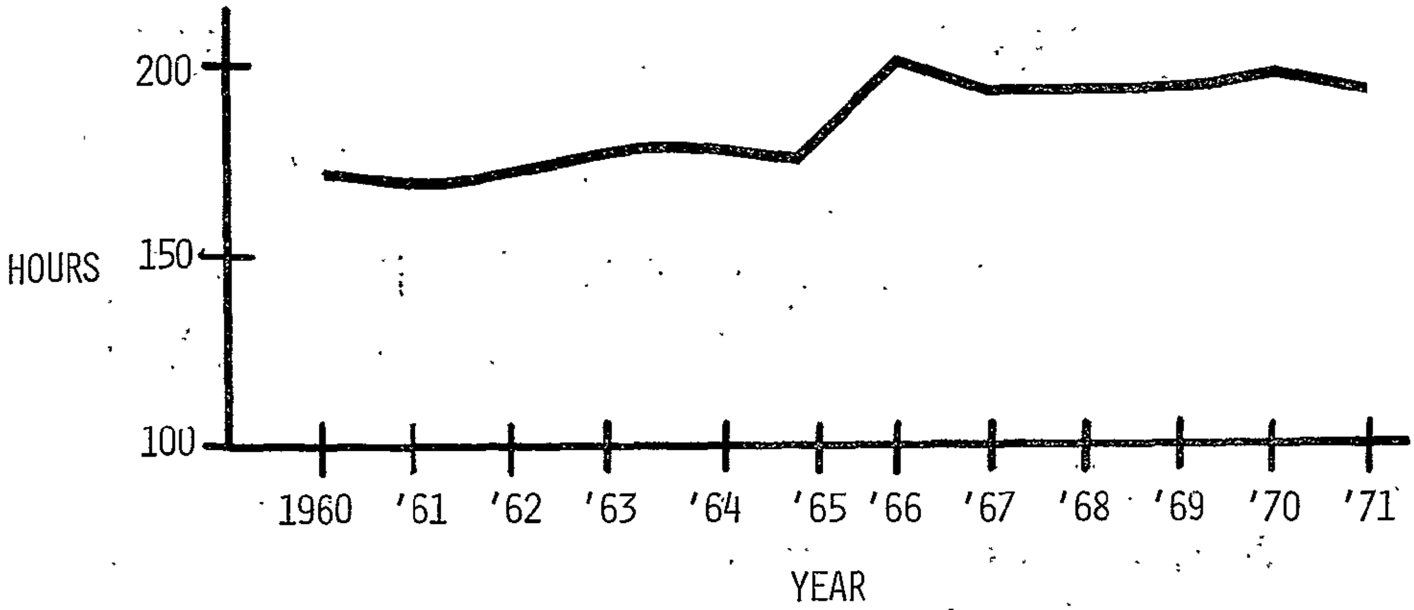
BY PRIMARY USE - 1971	%
Business and Executive Transportation	27.9
Personal	28.5
Instructional	17.6
Aerial Application	5.5
Air Taxi	8.1
Rental	7.5
Other (Incl. Industrial/Special)	4.9

SOURCE: FAA

FIGURE III-2

AVERAGE ACTIVITY PER GENERAL AVIATION AIRCRAFT

HOURS FLOWN



MILES FLOWN

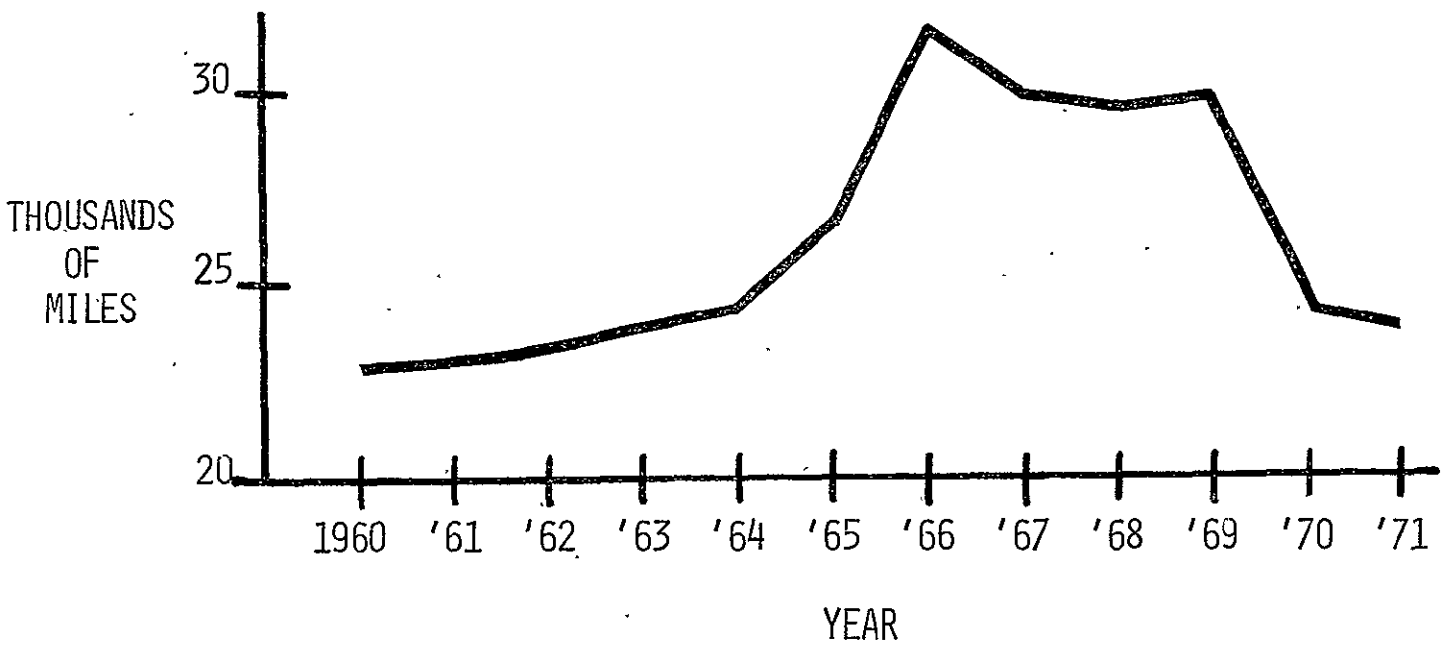
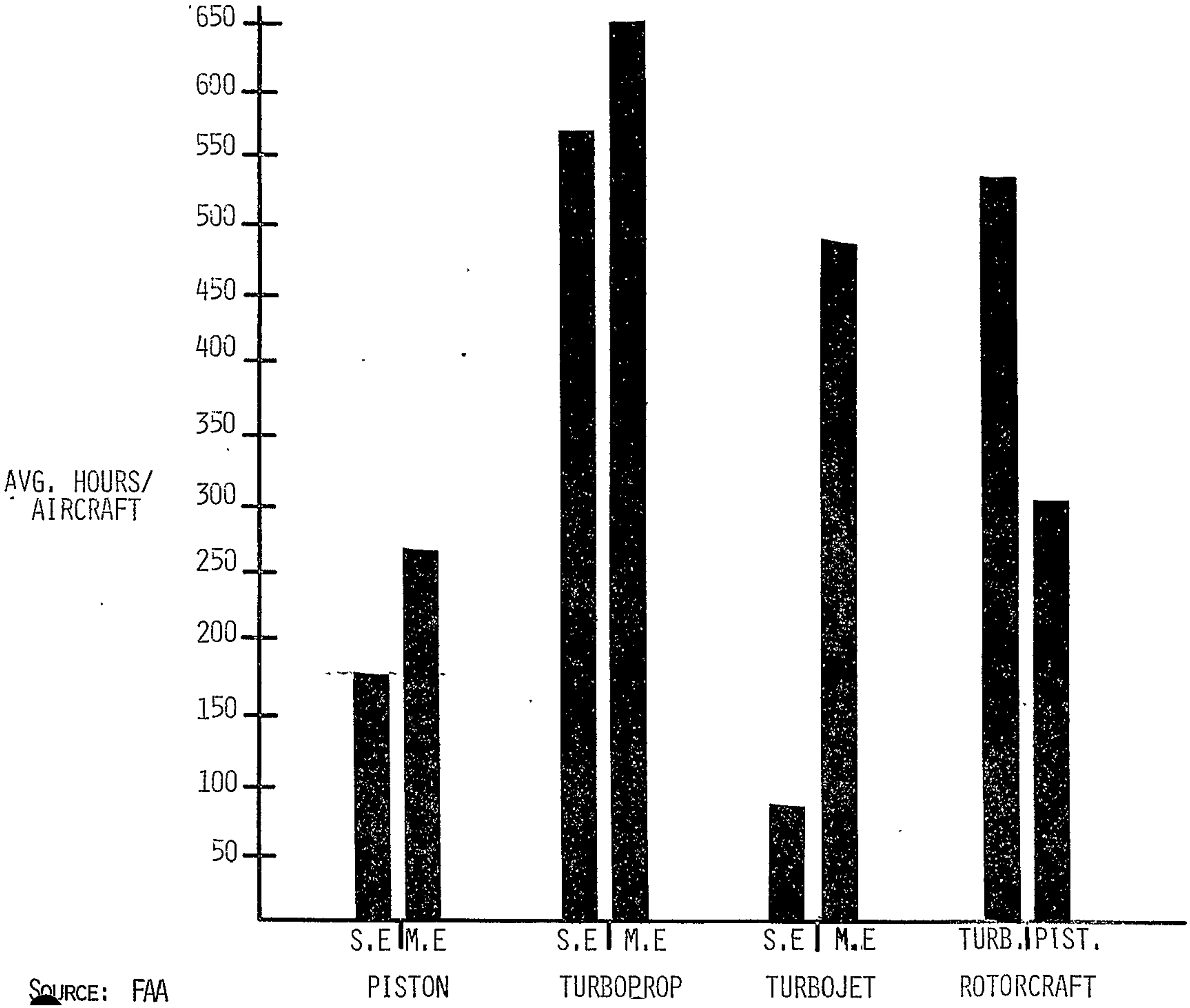


FIGURE III-3

AVERAGE HOURS FLOWN BY AIRCRAFT TYPE - 1971



SOURCE: FAA

Figure III-4 reflects a profile similar to that shown in the bottom part of Figure III-2, indicating the considerable increase in air miles flown annually during the latter half of the 1960's and the abrupt decrease in 1970 and 1971 which, due to the country's general economic situation, were repressed years for the general aviation industry.

3. IFR Flying

Although the increases in hours and miles flown are indicative of the growth in general aviation, the most notable changes have occurred in air traffic activity. Increases in IFR activity are shown in Figure III-5. With an increase of 15% in the number of general aviation IFR aircraft handled in 1971, general aviation constituted 20% of the total IFR activity at controlled airports. Furthermore, during the five-year period 1966-1971, general aviation IFR aircraft handled increased by 110%. During the same period, aircraft operations increased by 20% and instrument approaches by 77%. Since 1968, instrument operations (IFR landings and takeoffs) increased by 59% and, in 1971, general aviation accounted for 28% of all instrument operations.

Thus, there has been not only an increase in the size of the general aviation fleet and in the amount of flying, but also a change in the nature of the activity of general aviation. In the previous chapter, it was noted that there has been an increase in the number of IFR-rated pilots, and it appears that this is resulting in an increased sophistication in the use of the National Aviation System by general aviation.

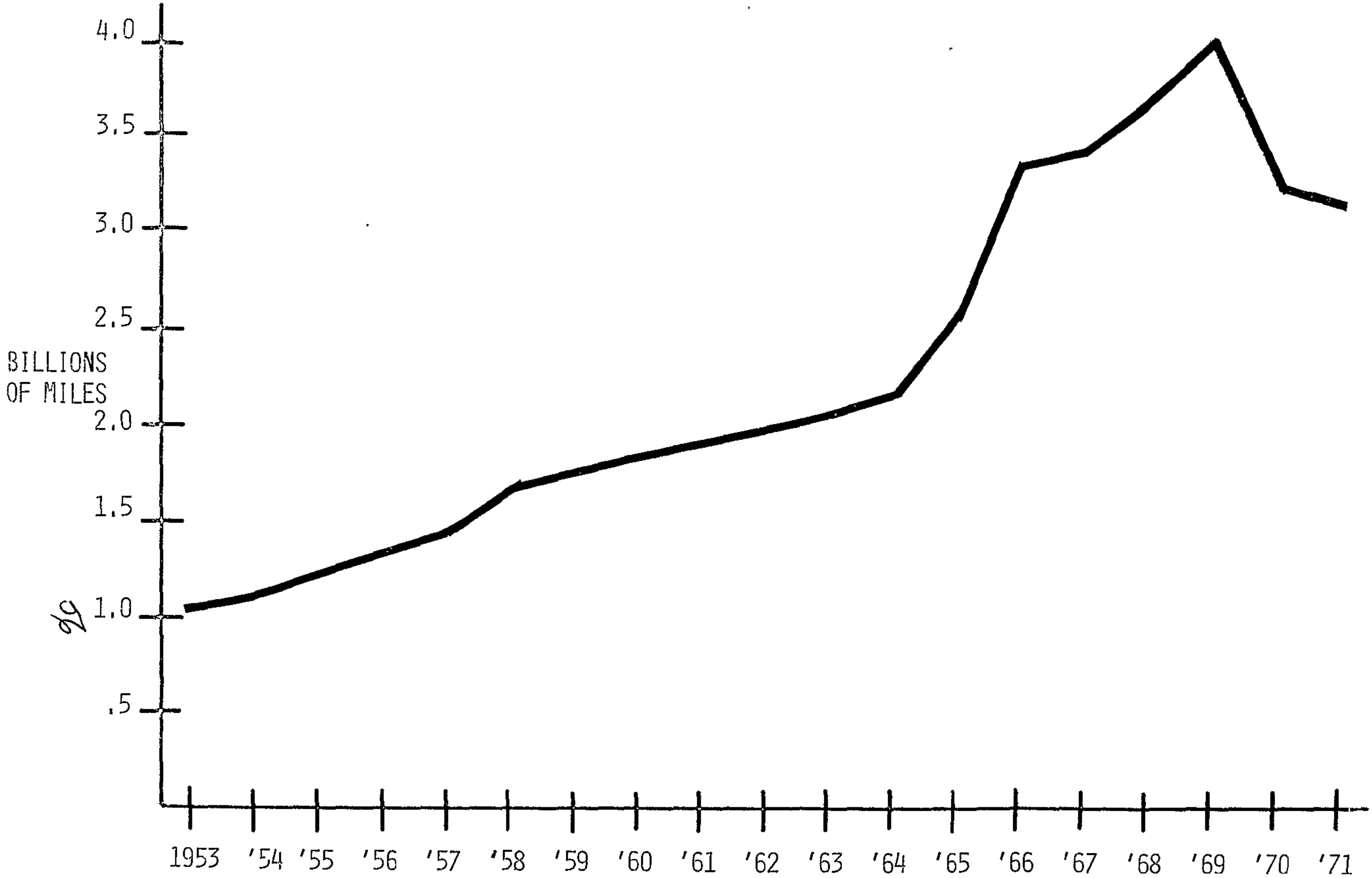
B. ACCIDENT RATES IN GENERAL AVIATION

It is unfortunate that the greatest level of public awareness of general aviation is probably generated by the accidents that occur. In a recent public attitude survey carried out for GAMA, it was found that 46% of the general public consider general aviation only "fairly safe" or "unsafe." Because of a fear for safety, it is not unusual for corporations to attempt to dissuade their executives from flying light aircraft.

In actual fact, however, the accident rate in general aviation has been improving (see Figure III-6). Whereas since 1960, the aircraft hours flown increased by more than 100%, the total accident rate per 100,000 hours flown decreased

FIGURE III-4

ESTIMATED MILES FLOWN IN GENERAL AVIATION - 1953-1971



SOURCE: FAA

FIGURE III-5

GENERAL AVIATION AIR TRAFFIC ACTIVITY

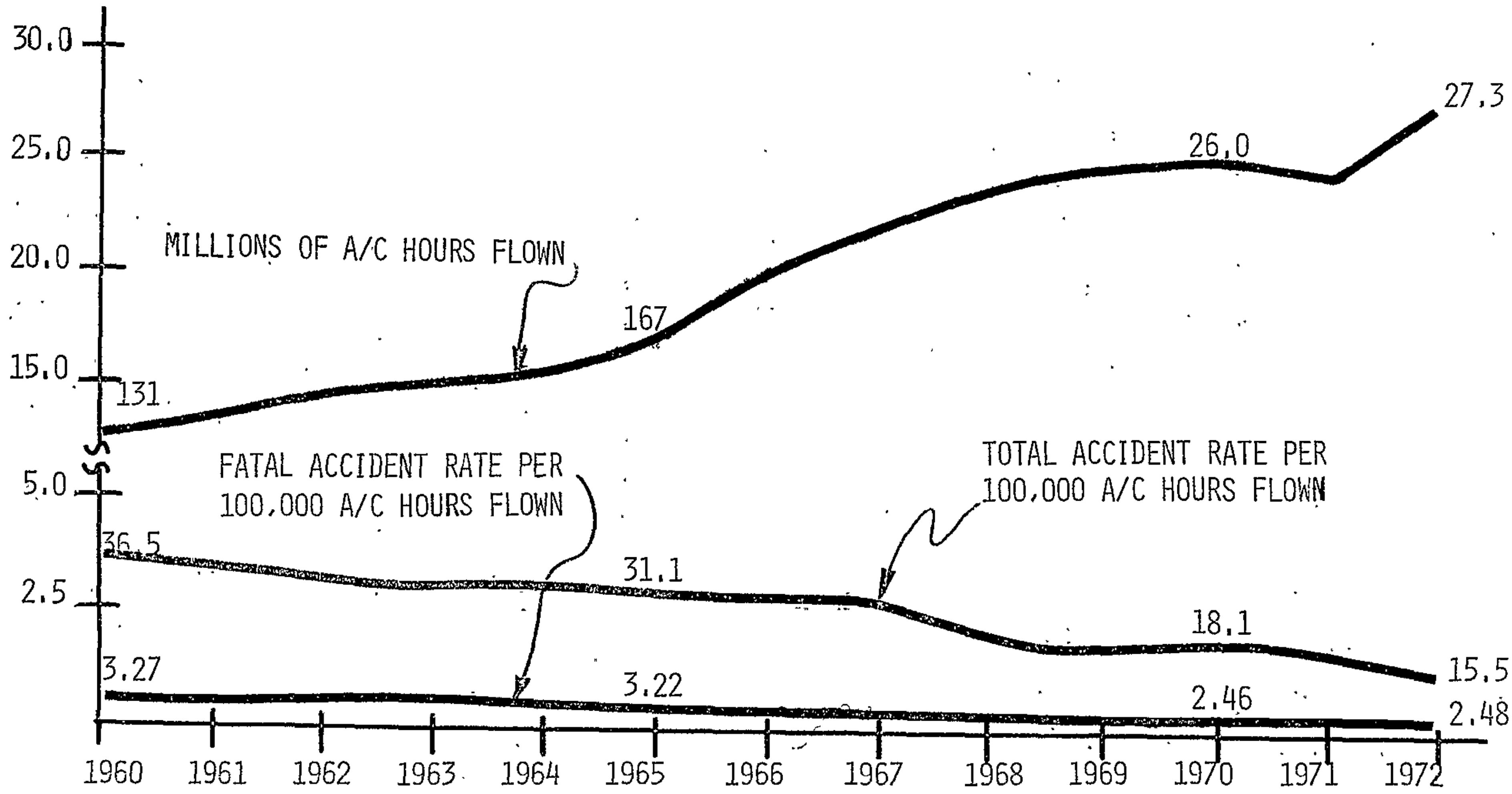
1968-1971

ITEM	% OF TOTAL AVIATION ACTIVITY (1971)	1971	% CHANGE '70-'71	1970	% CHANGE '69-'70	1969	% CHANGE '68-'69
IFR AIRCRAFT HANDLED	20%	4,246,494	+15	3,705,664	+ 7	3,473,213	+17
AIRCRAFT OPERATIONS	75%	40,400,593	- 2	41,384,006	- 1	41,952,176	+ 1
INSTRUMENT APPROACHES (ILS) AT FAA CENTERS	39%	622,354	+ 2	610,156	+ 4	587,953	+25
INSTRUMENT OPERATIONS	28%	5,174,088	+20	4,297,776	+10	3,928,093	+21
AIRCRAFT CONTACTED:							
• IFR-DVFR	66%	769,674	+ 9	719,101	+ 4	618,101	+23
• VFR	92%	8,125,797	+ 2	7,929,802	+ 1	7,794,521	+ 1
FLIGHT PLANS ORIGINATED							
• IFR-DVFR	53%	2,123,400	+ 5	2,025,150	+11	1,830,150	+26
• VFR	79%	2,353,950	- 1	2,374,200	+ 4	2,289,150	+ 3

SOURCE: FAA

FIGURE III-6

AIRCRAFT HOURS FLOWN AND ACCIDENT RATES
GENERAL AVIATION
1960-1972



SOURCE: NTSB

by approximately 57%. The fatal accident rate, however, experienced an increase between 1970 and 1972. In 1969 (the last year for which complete data is available), approximately 94% of all general aviation accidents occurred in VFR conditions and 84% of them in daylight (see Figure III-7). It is significant that approximately 72% of the accidents—6% of them fatal—occur within five miles of an airport or in the approach pattern, and, as Figure III-8 shows, 50% of all general aviation accidents take place on the airport itself.

Figure III-9 shows the accident rate by type of flying. It was seen earlier that personal/pleasure flying represented 26% of the hours flown. However, approximately 50% of general aviation accidents are recorded by pilots flying for pleasure. The figure also gives the accident rates by category, and pleasure flying has a rate considerably higher than any other type of non-commercial activity.

The data provided by the National Transportation Safety Board breaks down the accidents in causes and factors, as shown in Figure III-10. As reported by the NTSB, the overriding cause of accidents is pilot error, with a major contributing factor being the weather. This must be taken into account when evaluating new or improved equipment that would be desirable for general aviation aircraft.

C. AIRPORTS

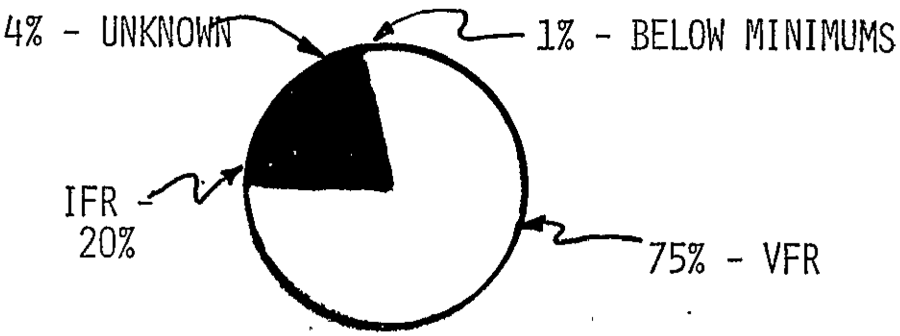
The total number of airports in the United States on record with the FAA, a key element in the aviation environment, has almost doubled since 1960, increasing from 6,865 to 12,028. In Figure III-11, the distribution of airports by private and public ownership shows that during the 1960's, privately-owned airports increased by approximately 100%, while publicly-owned airports increased by 50%. Although these numbers seem to indicate a rapid development of new airports, it should be noted that many of the privately-owned airports are nothing more than landing strips. Many of these have been in existence for some time but were not part of the official statistics until recently. Therefore, many of the airports on record are not open to the flying public. A regional distribution of airports is shown in Figure III-12. This does not indicate that any major redistribution is taking place.

FIGURE III-7

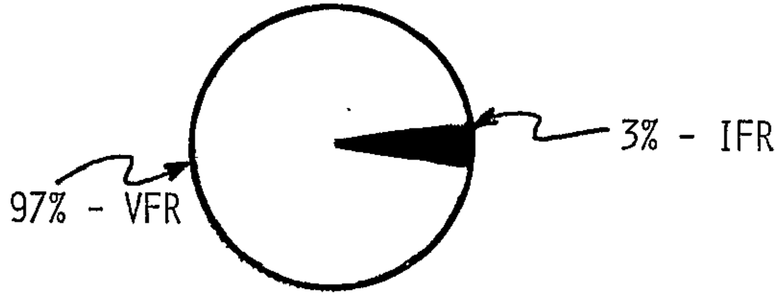
GENERAL AVIATION AIRCRAFT ACCIDENT DATA - 1969

WEATHER CONDITIONS

FATAL (647)

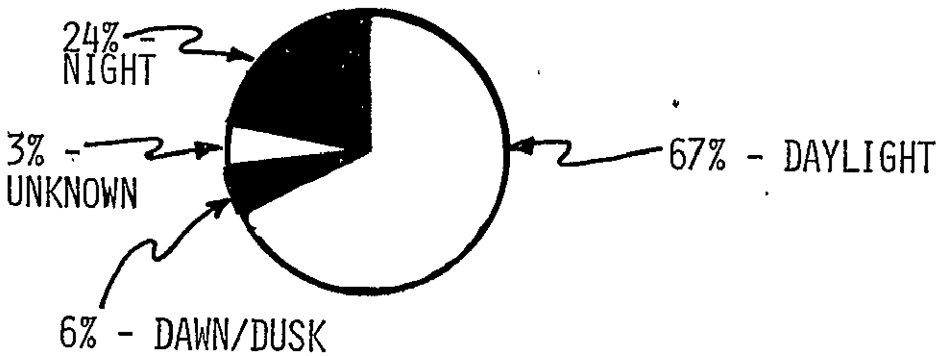


NON-FATAL (4,120)

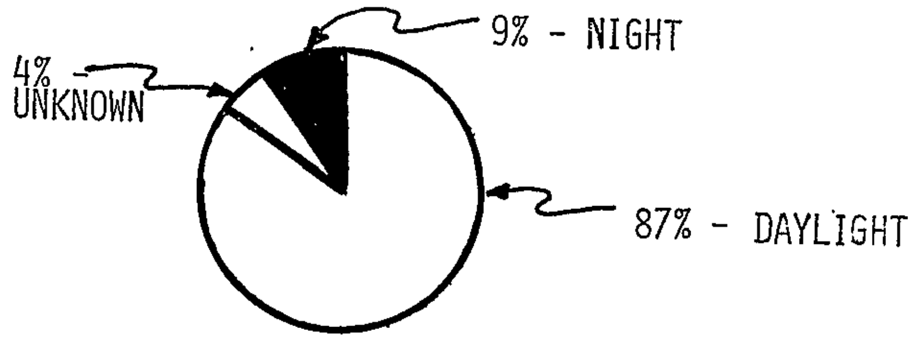


CONDITIONS OF LIGHT

FATAL (647)



NON-FATAL (4,120)

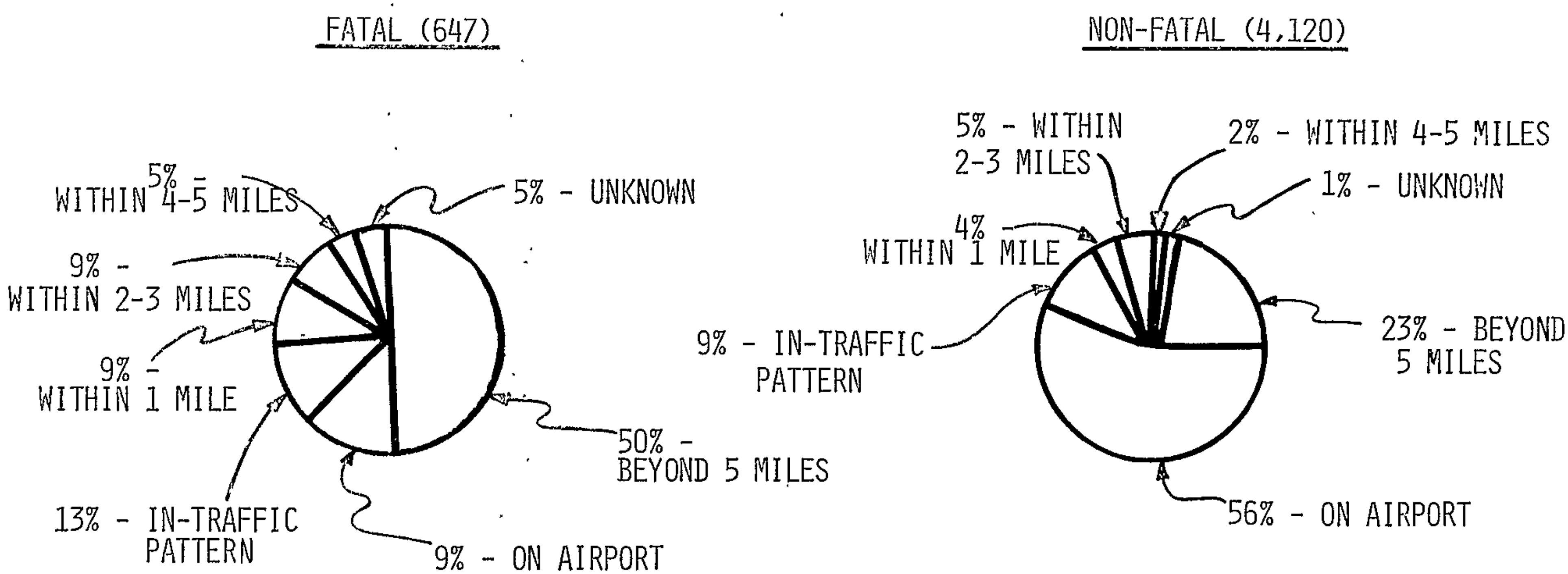


SOURCE: NTSB

FIGURE III-8

GENERAL AVIATION AIRCRAFT ACCIDENT DATA - 1969

AIRPORT PROXIMITY



SOURCE: NTSB

FIGURE III-9

GENERAL AVIATION AIRCRAFT ACCIDENT DATA BY TYPE OF FLYING - 1970

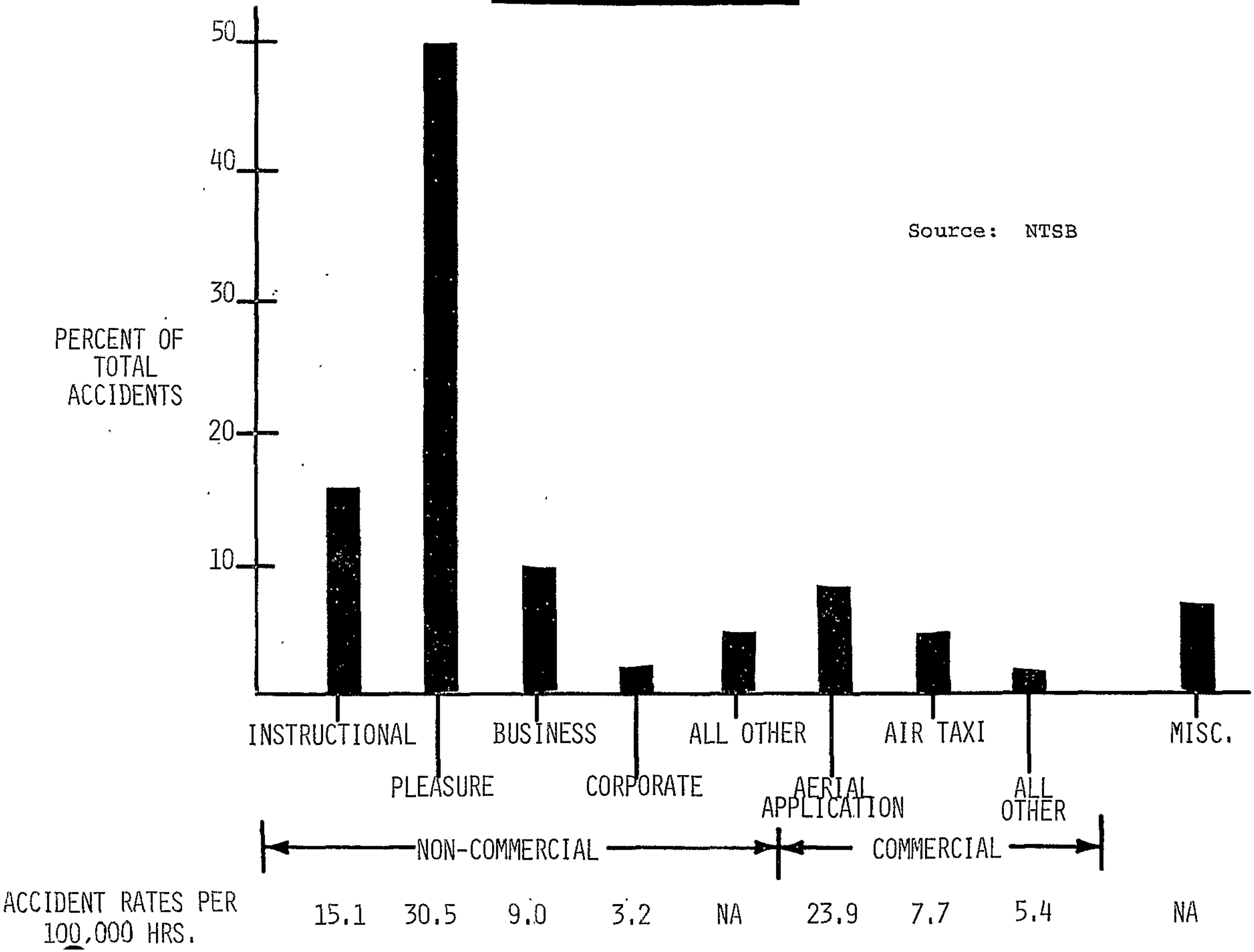


FIGURE III-10

GENERAL AVIATION AIRCRAFT ACCIDENT DATA

CAUSES AND FACTORS - 1970

(% OF A/C ACCIDENTS)

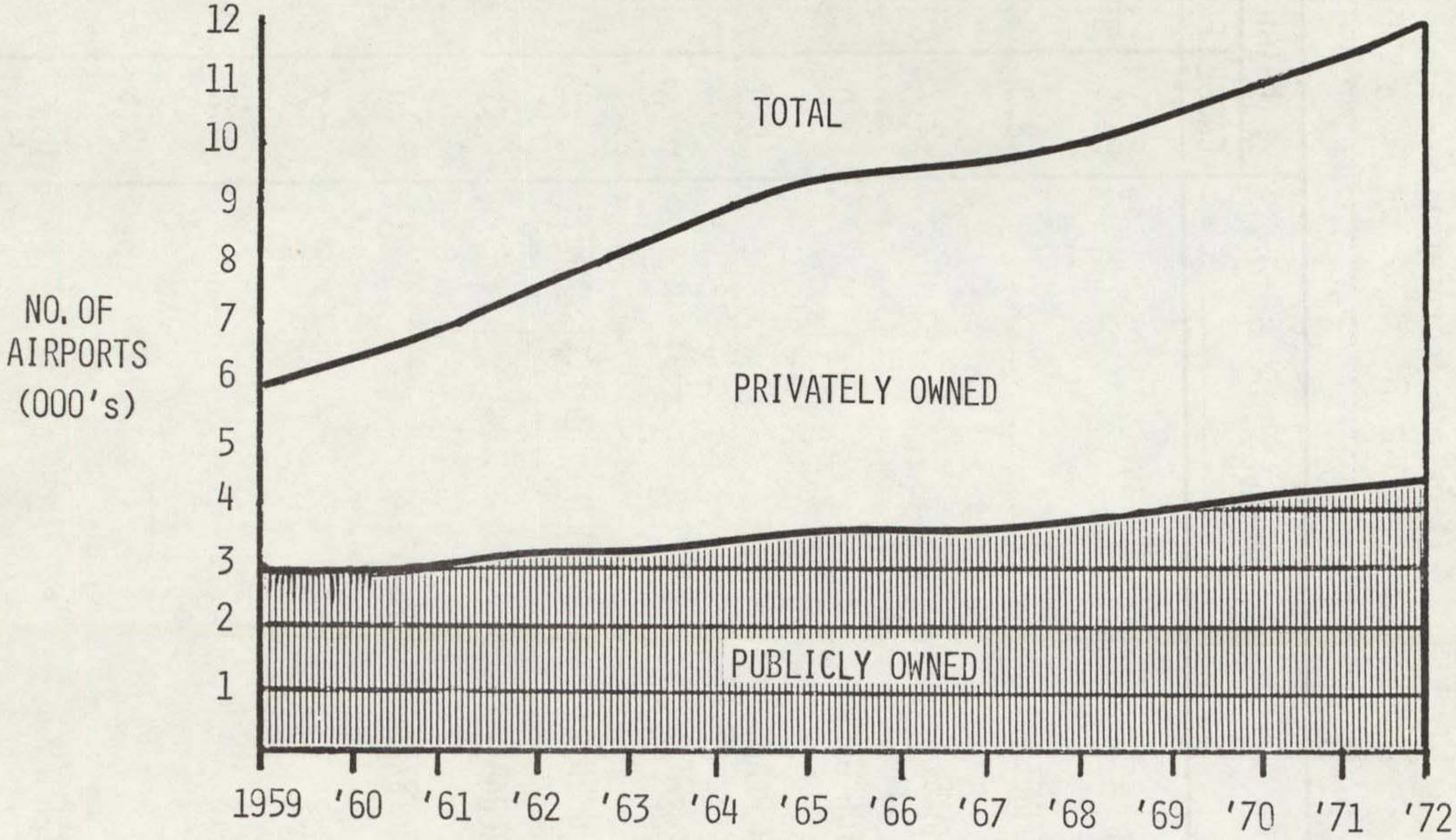
CAUSES/FACTORS	FATAL		NON-FATAL	
	CAUSE	FACTOR	CAUSE	FACTOR
PILOT	84.5	13.9	81.9	5.6
PERSONNEL	8.2	2.4	10.4	1.7
AIRFRAME	2.7	.0	.7	.0
LANDING GEAR	.0	.0	5.2	1.2
POWER PLANT	6.9	.3	12.3	.7
SYSTEMS	.8	.1	1.0	1.2
INSTRUMENTATION/EQUIPMENT AND ACCESSORIES	.2	.3	.2	.1
ROTORCRAFT	.7	.0	.4	.0
AIRPORTS/FACILITIES	.0	1.6	4.8	6.6
WEATHER	7.7	30.7	8.2	11.7
TERRAIN	4.8	8.1	14.4	9.4
MISC.	2.6	.3	3.9	.4
UNDETERMINED	10.5	.0	1.1	.0

SOURCE: NTSB

FIGURE III-11

PRIVATELY AND PUBLICLY OWNED AIRPORTS

1959-1972



SOURCE: FAA

FIGURE III-12

REGIONAL DISTRIBUTION OF AIRPORTS, AIRCRAFT AND POPULATION

1960-1970

FAA REGION	1960			1970			PERCENT CHANGE		
	AIRPORTS	AIRCRAFT	POPULATION	AIRPORTS	AIRCRAFT	POPULATION	AIRPORTS	AIRCRAFT	POPULATION
NEW ENGLAND	3.6%	3.0%	5.7%	3.8%	3.5%	5.8%	85.9	98.0	15.7
EASTERN	11.8	13.3	24.7	12.5	13.0	24.0	87.6	65.4	10.2
GREAT LAKES	19.6	20.8	22.1	18.9	19.7	21.6	69.1	61.3	11.2
CENTRAL	10.7	8.6	6.0	9.4	7.7	5.5	53.7	52.3	5.3
SOUTHERN	10.1	11.3	15.6	11.4	14.2	15.6	97.2	14.4	14.2
SOUTHWEST	14.7	14.8	10.0	15.9	13.8	10.3	90.0	58.1	16.9
ROCKY MOUNTAIN	8.8	5.8	2.8	7.2	5.3	2.7	43.7	52.5	12.4
WESTERN	8.3	15.1	9.7	8.9	15.4	10.9	85.5	73.3	28.4
NORTHWEST	7.0	5.3	2.9	5.7	5.3	3.1	42.8	70.5	17.5
ALASKA AND HAWAII	5.4	2.0	0.5	6.3	2.1	0.5	102.5	81.3	24.4
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%			
Σ TOTAL	6,865	78,760	179,323,000	12,028	134,539	203,212,000	75.2	70.8	13.3

Source: FAA, Bureau of Census

Figure III-13 shows that during the last decade, the number of airports with lighted runways averaged approximately 31% of the total. The number of airports with paved runways has been increasing steadily since 1964, from approximately 2,600 to more than 4,200 at the beginning of 1972—an increase of more than 60%. Figure III-14 summarizes the U.S. airport profile at the end of 1972 by ownership, runway surface and lighting. Assuming that all the paved and lighted unpaved airports are open to public use, it is estimated that there are approximately 5,300 airports, or 43% of the total, which can realistically be used by general aviation.

Despite the large number of airports serving general aviation, there is concern that there is a decreasing number in the proximity of the major population centers, thus discouraging the growth of general aviation in these areas. It appears that at the beginning of 1972, 92% of the known airports served areas with populations of less than 250,000, 85% of them served areas with populations of less than 50,000, and 70% served populations of less than 10,000.

As one example of the trends in airports at major metropolitan areas, the FAA regional office in New York developed the data shown in Figure III-15 for the region around New York City. It shows that during the 20-year period 1950-1970, the airports in the area decreased by approximately 30%, while the number of based aircraft tripled. However, the decrease in the number of airports occurred mainly between 1950 and 1960 and remained relatively constant throughout the remaining decade.

Airport data is also available in the data shown in Figure III-16. It gives only a partial illustration of the situation, but one fact is apparent; despite the planned increase in the number of airports in the major SMSA's, the average number of based aircraft per airport will have increased from 106 in 1961 to 231 in 1982.

The federal government supports airport development through the Airport Development Aid Program (ADAP) which replaced the Federal Aid Airport Program in 1970. During the first 18 months of its operation, ADAP funds totaling $18.6 million were provided to 176 airports throughout the United States for 180 different projects. The general aviation community depends on this aid program to expand its available facilities.

FIGURE III-13

% OF U.S. AIRPORTS WITH RUNWAY LIGHTS AND PAVED RUNWAYS

1959-1972

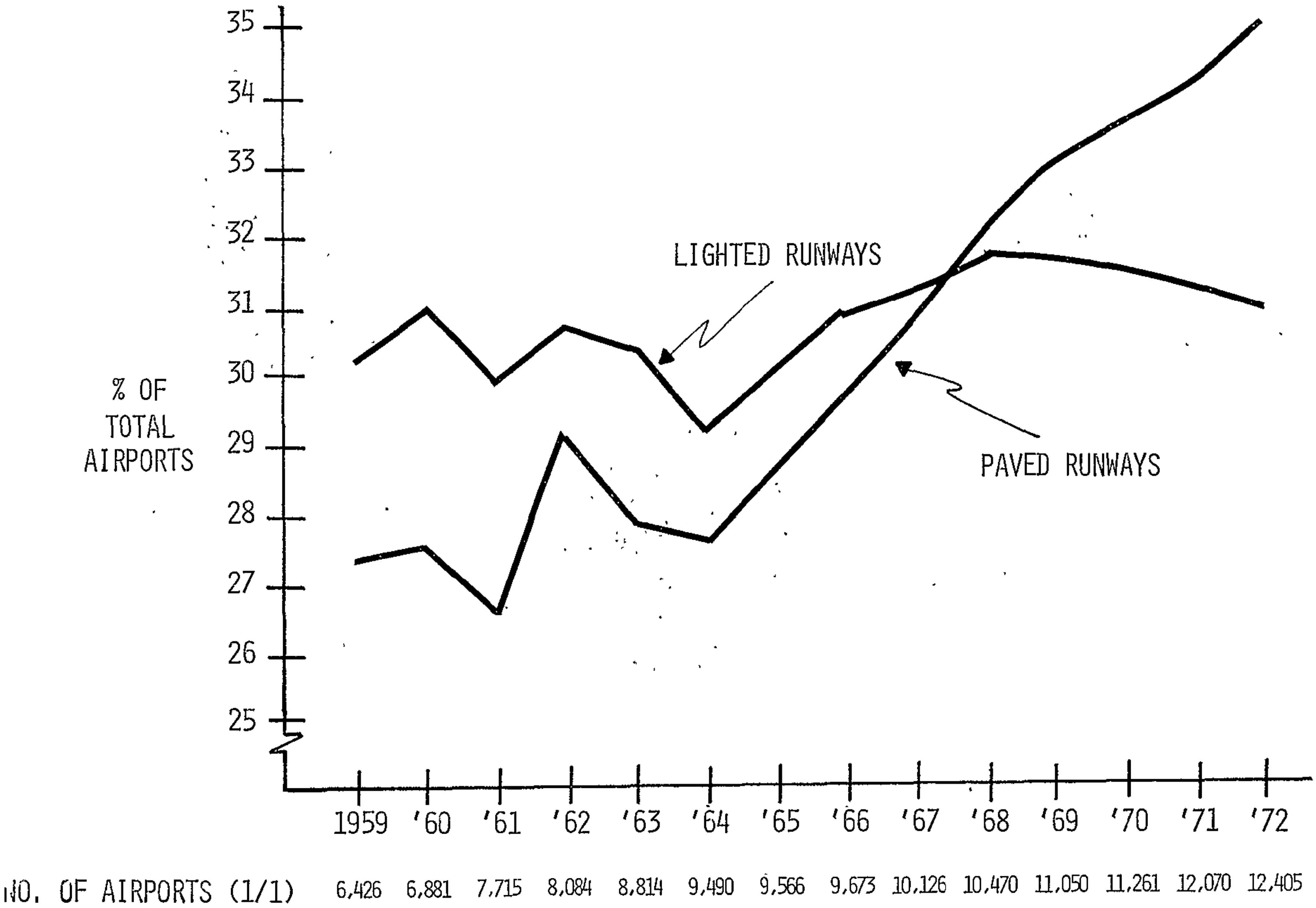
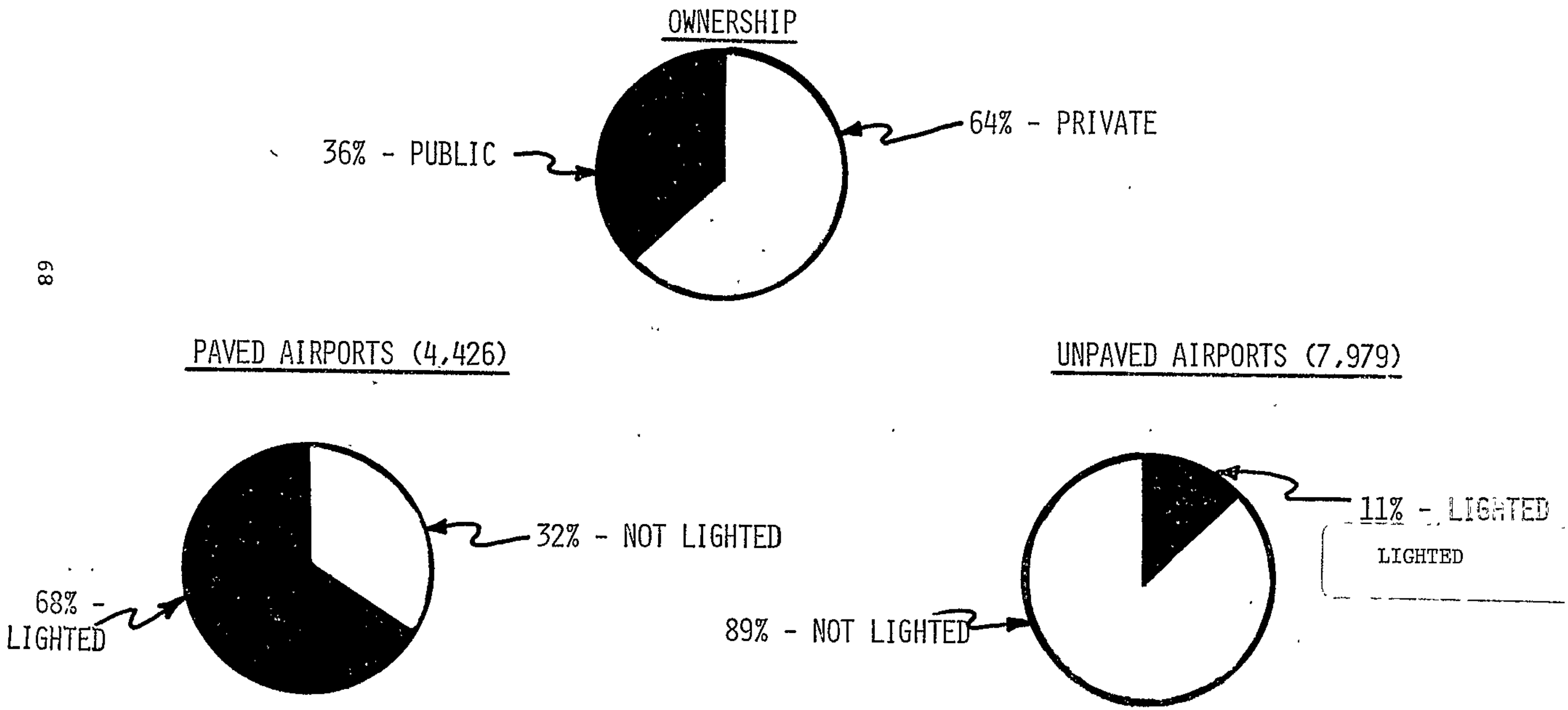


FIGURE III-14

U.S. AIRPORT PROFILE - 1973



TOTAL AIRPORTS = 12,405

SOURCE: FAA

FIGURE III-15

PUBLIC AIRPORTS AND BASED AIRCRAFT IN THE NEW YORK METROPOLITAN AREA (N.Y., N.J., CONN.) 1945-1972

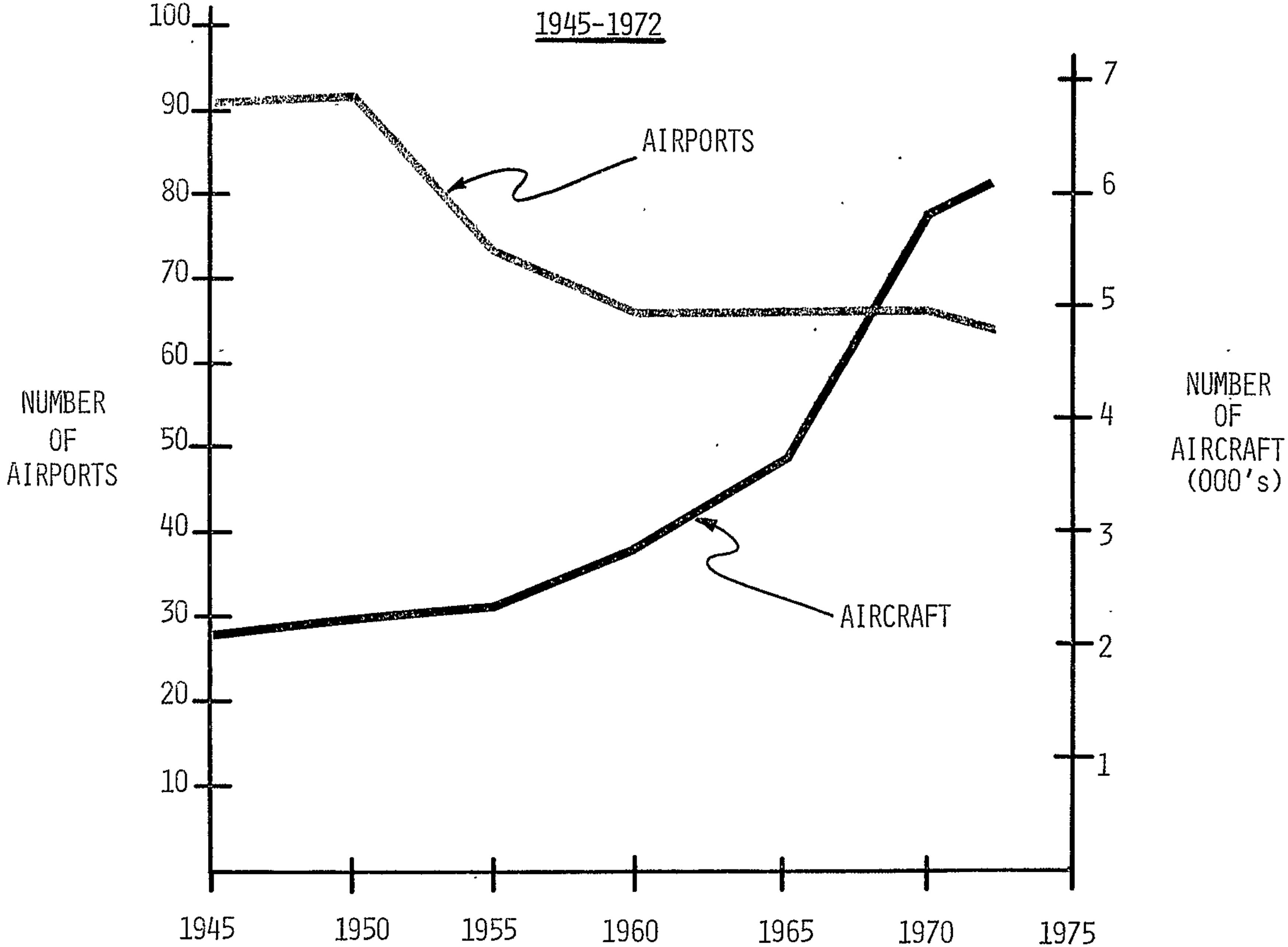


FIGURE III-16

AIRPORTS AND BASED AIRCRAFT IN SELECTED MAJOR SMSA's

SMSA	1957		1961		1972		1982*	
	AIRPORTS	A/C	AIRPORTS	A/C	AIRPORTS	A/C	AIRPORTS	A/C
LOS ANGELES/LONG BEACH	10	2,343	9	1,932	16	4,781	30	8,258
ANAHEIM-SANTA ANA-GARDEN GROVE	1	364	2	587	4	1,336	6	2,060
SAN FRANCISCO-OAKLAND	7	680	6	1,092	11	2,272	13	4,757
MIAMI-FT. LAUDERDALE-HOLLYWOOD	3	147	3	733	7	2,061	8	4,097
ATLANTA	5	354	6	501	8	1,276	8	2,567
CHICAGO	8	443	9	549	20	2,548	26	5,540
WASHINGTON, D.C.	3	205	3	193	5	427	7	1,122
BALTIMORE	2	50	2	109	3	289	8	1,275
ST. LOUIS	3	119	5	374	13	1,063	17	2,239
BOSTON	3	219	4	353	5	636	5	970
DETROIT	2	226	4	563	13	2,039	15	3,852
NEW YORK-NEWARK-PATERSON-CLIFTON-PASSAIC	12	676	15	1,227	25	2,647	30	5,512
PHILADELPHIA	10	252	11	437	17	1,151	21	2,695
HOUSTON	4	90	4	410	10	1,197	13	2,748
CLEVELAND	4	137	4	171	6	726	6	1,409
TOTAL	77	6,305	87	9,231	163	2,449	213	49,365

*FAA FORECAST

D. THE NATIONAL AVIATION SYSTEM

The operational characteristics of the avionics systems carried in today's aircraft must conform to the requirements of the National Aviation System and the ATC environment. This is specifically the case in the functional areas of communication and navigation and is indirectly true for other types of equipment. Therefore, in order to determine the nature of the avionics that aircraft will carry during the 1980's, it is necessary to make an assessment of the shape of the National Airspace System at that time and changes that are forthcoming in the regulatory environment that will have an impact on general aviation.

The National Aviation System "generations" shown in Figure III-17 summarize the evolution of the ATC system from 1936 to beyond 1985. At present, the system is at the beginning of the third generation. The implementation emphasis is on expanded automation and centralized flow control. Installation of conventional instrument landing systems is planned to continue through 1978. During the early 1980's, the planned emphasis is on conflict prediction and resolution, the Discrete Address Beacon System and automated data link, microwave landing system installation and general use of area navigation.

The primary navigation system in use today and during the next 10-15 years is the VORTAC system. Figure III-18 shows the VORTAC system configuration for 1971 and as planned for 1982. It can be seen that all basic VOR stations will be converted either by adding TACAN, DME or by DVOR conversion. The total number of VOR locations is planned to increase to 1,022. Insofar as airborne avionics is concerned, the most important system modification in this respect is the change from 100 kHz to 50 kHz channel spacing. However, this change has been in progress for some years, and avionics manufacturers have all made the necessary modifications.

Figure III-19 illustrates the proposed En Route Automation Program which is currently in its second phase. The final phase, implementing advanced automated functions, including ATC Data Link and Intermittent Positive Control, is planned

FIGURE III-17

NATIONAL AVIATION SYSTEM "GENERATIONS"

GENERATION	TIME PERIOD	KEY FEATURES
FIRST	1936-1960	• MANUAL STRIP PRINTING • ANC CONTROL 10 MINS.-1000' ALTITUDE-10 MILES • AIR GROUND COMM.-FSS RELAY • LOW FREQ. AND VOR NAVIGATION
SECOND	1960-1970	• LIMITED PRINTING OF STRIPS • RADAR CONTROL • INTRODUCTION OF ATCRBS • VORTAC NAVIGATION
THIRD	1970-1978	• NAS AND ARTS AUTOMATION • GREATER USE OF ATCRBS • CENTRALIZED FLOW CONTROL • VHF/UHF ILS
UPGRADED THIRD	1978-1985	• INCREASED AUTOMATION { CONFLICT PREDICTION, CONFLICT RESOLUTION } • DISCRETE ADDRESS BEACON-AUTO DATA LINK • MICROWAVE ILS • AREA NAVIGATION
ADVANCED	POST 1985 PROPOSALS	• AUTOMATED AIR TRAFFIC CONTROL, MANUAL OVERRIDE • SATELLITE SURVEILLANCE COMMUNICATIONS • NEW SYSTEM ORGANIZATION { TWO DOMESTIC CENTERS, TWO OCEANIC CENTERS } • WORLDWIDE NAV SYSTEM

FIGURE III-18

VORTAC SYSTEM CONFIGURATION - 1971 AND 1982

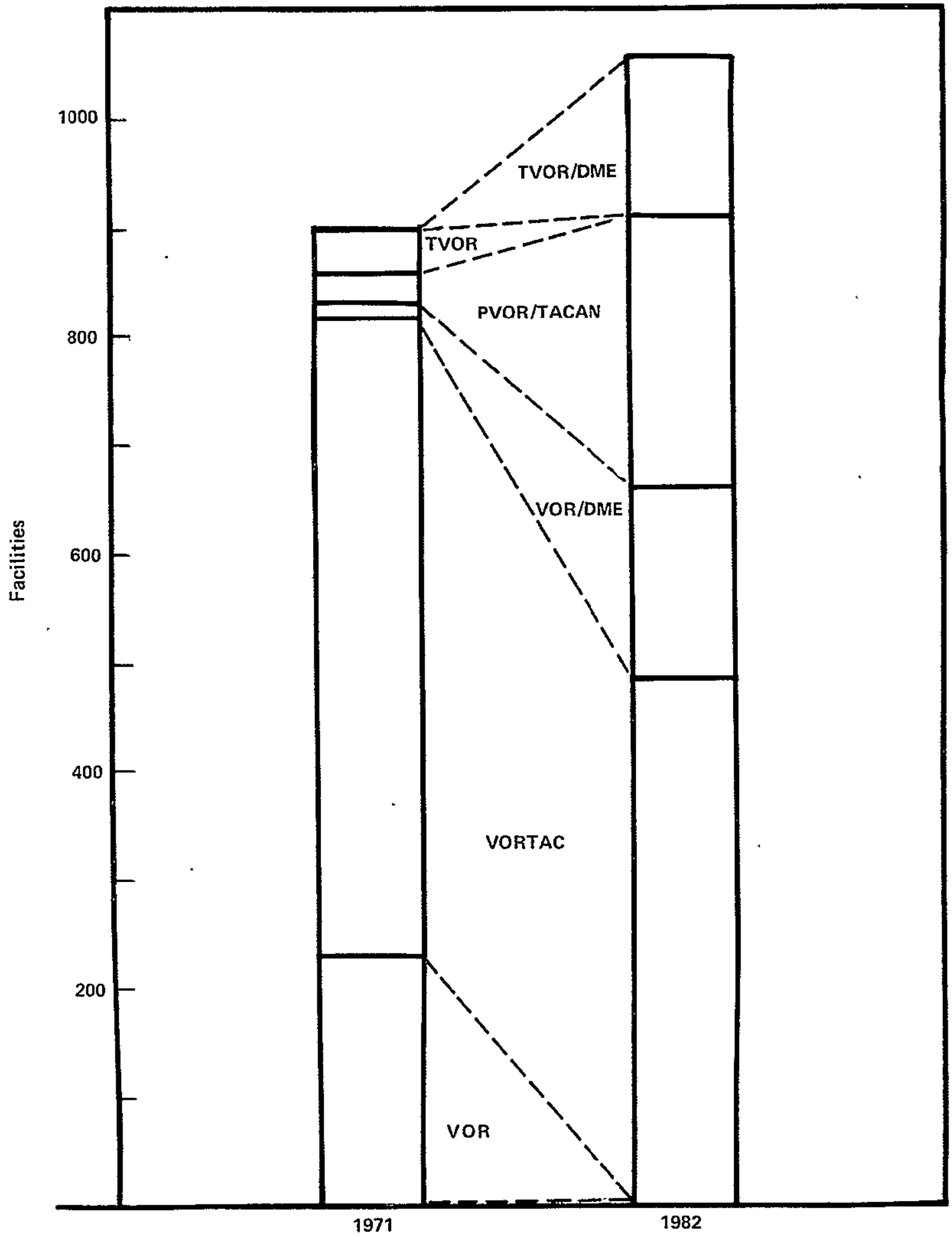
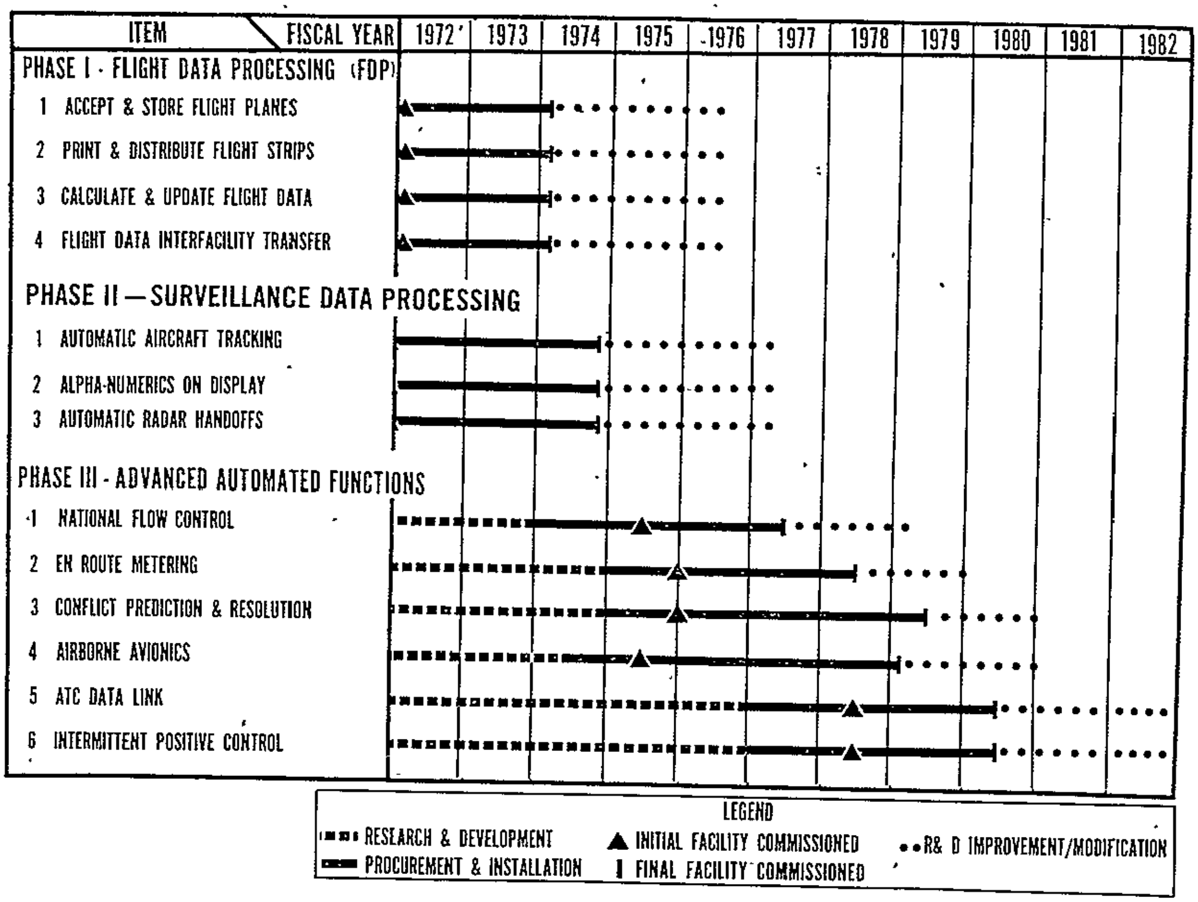


FIGURE III-19

PROPOSED EN ROUTE AUTOMATION PROGRAM



to be completed by 1982. The development program schedule for the Discrete Address Beacon System, a vital part of the En Route Automation Program, can be seen in Figure III-20. According to the plan, system implementation will begin towards the end of this decade and continue through the first few years of the Eighties. This could bring about a major change in the airborne avionics requirements for air-ground communications, although these requirements are not yet specified.

Figures III-21 and III-22 show the present airspace allocation and the planned allocation in 1982. The major change is the requirement for aircraft above 12,500 feet and in Terminal Control Areas to be equipped with transponders having altitude reporting capability. This requirement, however, is not in the future; it is here now. Therefore, by 1982, it can be assumed that most of the aircraft will be adequately equipped. The 63 Terminal Control Areas are shown in Figure III-23. The 9 Group I TCA's are as follows:

- Atlanta
- Chicago
- Washington National
- New York
- Los Angeles
- San Francisco
- Boston
- Miami
- Dallas

The 12 Group II TCA's are:

- Philadelphia
- Denver
- St. Louis
- Pittsburgh
- Detroit
- Cleveland
- Houston
- Minneapolis
- New Orleans
- Seattle
- Las Vegas
- Kansas City

FIGURE III-20

DISCRETE ADDRESS BEACON SYSTEM DEVELOPMENT PROGRAM

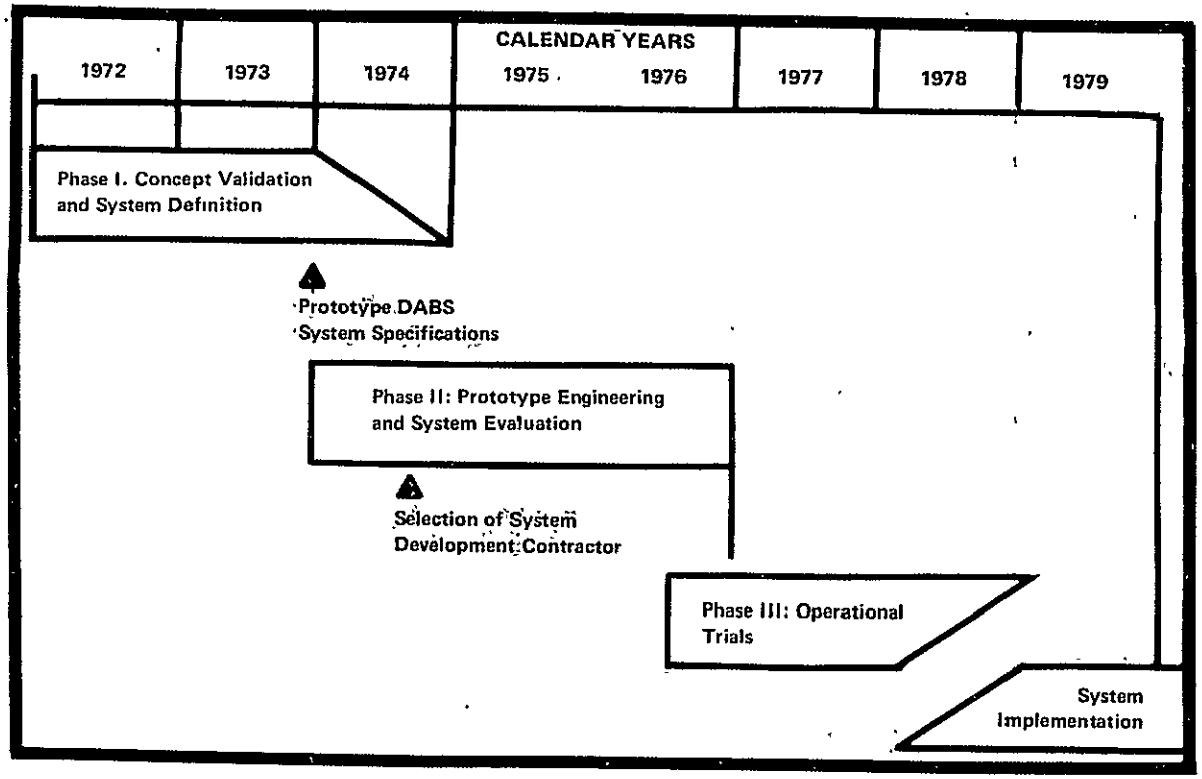


FIGURE III-21

FAA AIRSPACE ALLOCATION - 1972

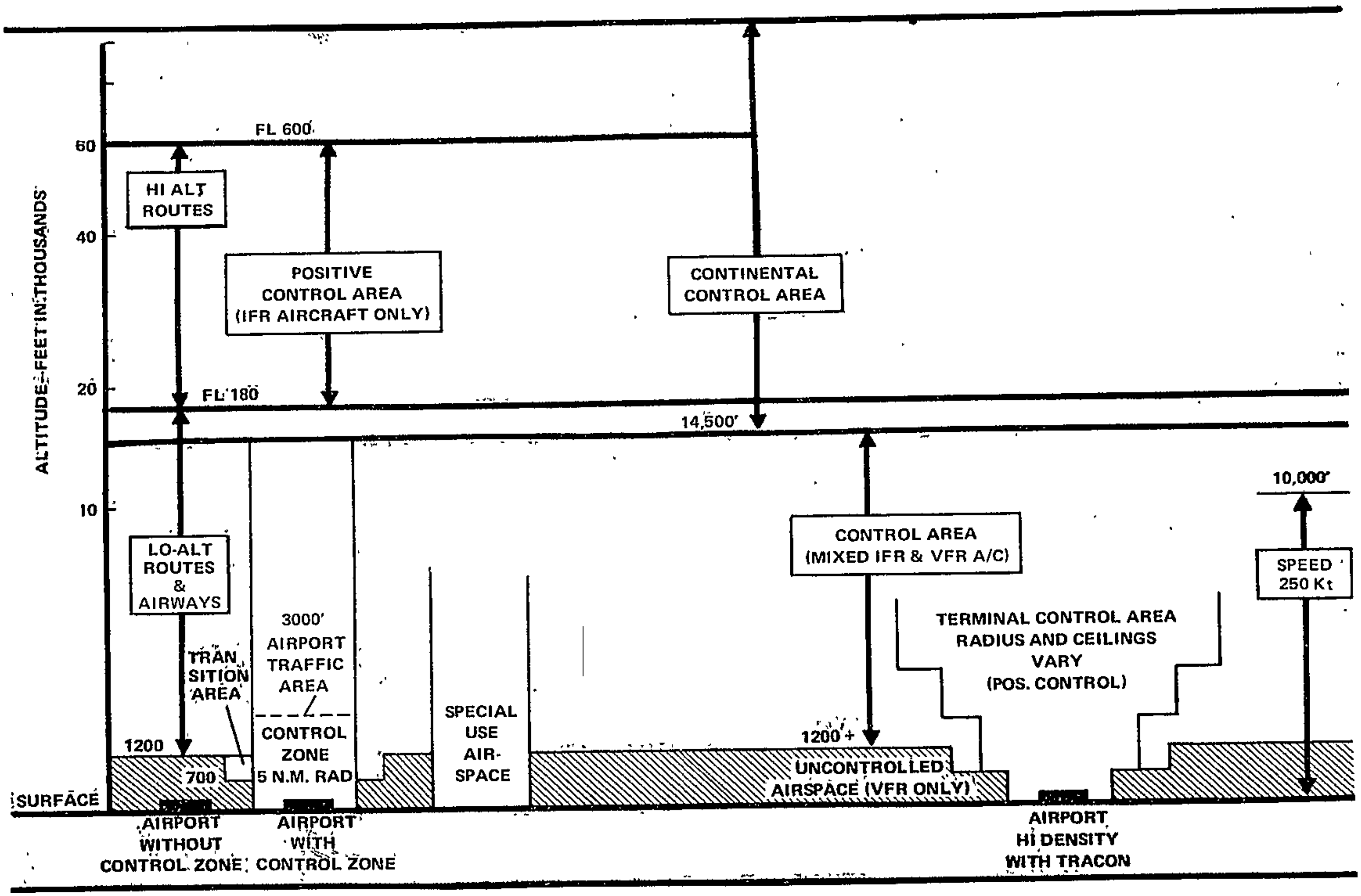


FIGURE III-22

FAA AIRSPACE ALLOCATION - 1982

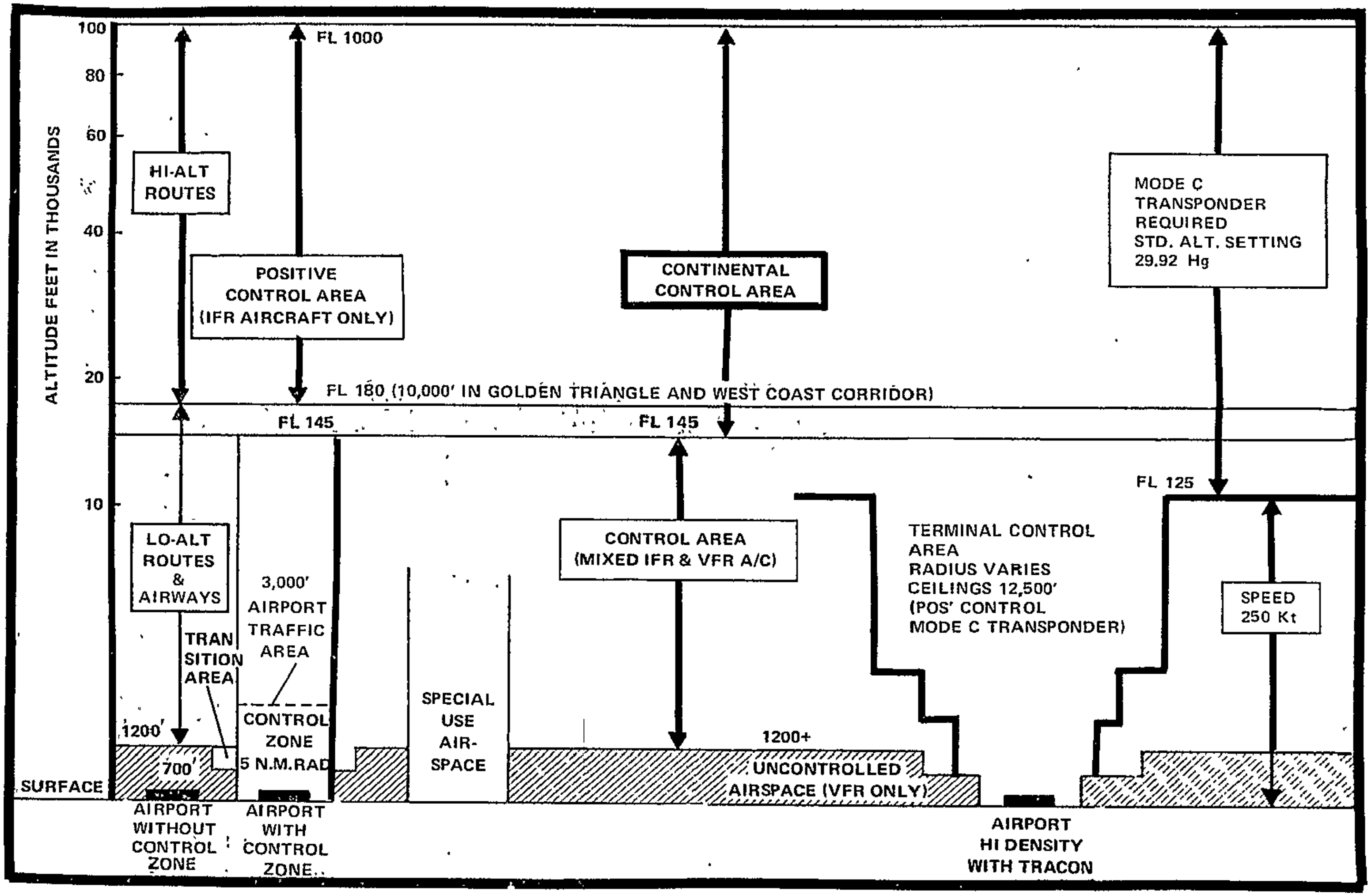
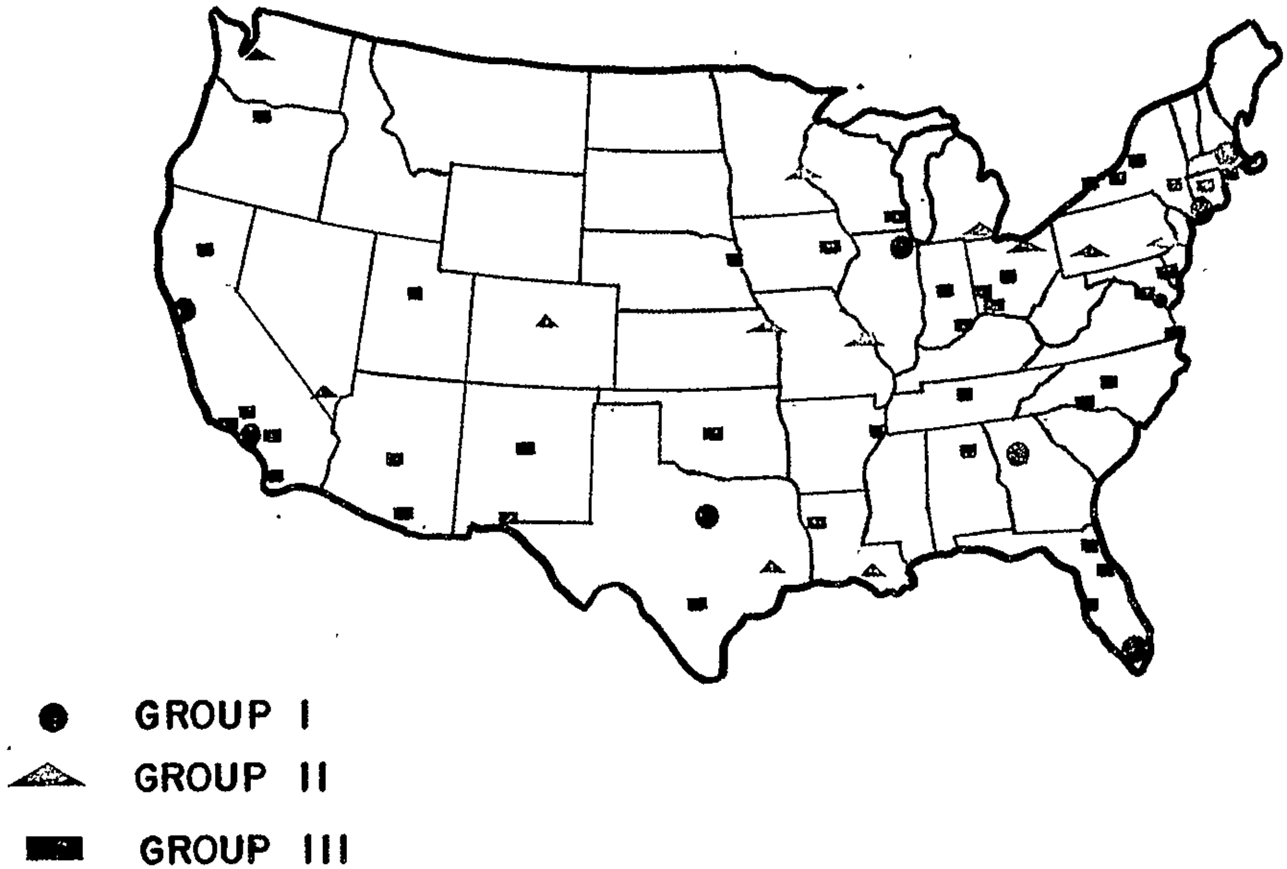


FIGURE III-23

TERMINAL CONTROL AREAS (TCA's)



The Group III TCA's are shown below:

- Albany
- Albuquerque
- Baltimore
- Birmingham
- Buffalo
- Burbank
- Charlotte
- Cincinnati
- Columbus, Ohio
- Dayton
- Des Moines
- El Paso
- Hartford
- Honolulu
- Indianapolis
- Jacksonville
- Louisville
- Memphis
- Milwaukee
- Nashville
- Norfolk
- Oklahoma City
- Omaha
- Orlando
- Portland, Ore.
- Phoenix
- Providence
- Raleigh-Durham
- Ontario, Calif.
- Rochester, N. Y.
- Sacramento
- Salt Lake City
- San Antonio
- San Diego
- San Juan
- Santa Ana/Long Beach
- Shreveport
- Syracuse
- Tampa
- Tucson
- Tulsa
- Washington-Dulles

A summary of the changes in major FAA ground facilities and equipment can be seen in Figure III-24. It is apparent that the changes which potentially will have the greatest impact on general aviation avionics are DABS, Collision Avoidance Systems, and microwave ILS. The planned increased equipment for approach and landing procesures is also considerable, as shown in Figure III-25, and it is of note that by 1982, 1,230 R/NAV approaches will be approved. The primary changes in pilot requirements and in airborne flight and navigation equipment (Figures III-26 and III-27) are centered in the bi-annual pilot proficiency checks, mandatory IFR ratings with commercial licenses, and the altitude reporting transponder in TCA's and above 12,500 feet.

FIGURE III-24

MAJOR FACILITIES AND EQUIPMENT SUMMARY

FACILITY	PRESENT SYSTEM - 1972	FUTURE SYSTEM - 1982	
		IN PLAN 1973-1982	TOTAL 1982
EN ROUTE CONTROL AND SERVICES:			
AIR ROUTE TRAFFIC CONTROL CENTERS	27	-2	25
SECTORS	770	314	1,084
NAS STAGE A	0	20	20
AIR ROUTE SURVEILLANCE RADAR	95	25	120
DISCRETE ADDRESS BEACON SYSTEMS	0	112	112
ELECTRONIC VOICE SWITCHING SYSTEMS	0	22	22
CAS GROUND STATIONS	0	55	55
EN ROUTE NAVIGATION AIDS:			
VORTAC SYSTEM:			
VOR	867	38	905
TACAN/DME AT VOR	722	111	833
DVOR/PVOR CONVERSION	35	316	351
TVOR	55	78	133
L/MF NAVAIDS	315	-4	311
TERMINAL AREA CONTROL AND SERVICES:			
AIRPORT TRAFFIC CONTROL TOWERS	394	98	492
AIRPORT SURVEILLANCE RADAR	176	92	268
DISCRETE ADDRESS BEACON SYSTEMS	0	106	106
ARTS III	64	0	64
AIRPORT SURFACE DETECTION EQUIPMENT	8	15	23
FLIGHT SERVICES:			
FLIGHT SERVICE STATIONS	356	539	895
AIR/GROUND FACILITIES	505	157	662
DIRECTION FINDERS	184	70	254
EN ROUTE WEATHER ADVISORY SERVICE	4	40	44
LANDING AIDS:			
CONVENTIONAL ILS	501	156	657
MICROWAVE ILS	0	603	603
V/STOL ILS	0	75	75
DME AT ILS	16	100	116

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FIGURE III-25

APPROACH AND LANDING PROCEDURES

1972 VS. 1982

1972		1982	
LOCALIZER	28	LOCALIZER	370
LDA	3	LDA	40
CAT I ILS	264	CAT I ILS	460
CAT II ILS	19	CAT II ILS	200
CAT IIIA ILS	1	CAT III ILS	70
VOR	1,200	VOR	1,630
VOR/DME	284	VOR/DME	400
NDB/LFR	1,080	NDB	1,200
RNAV	125	RNAV	1,230
DF	261	DF	240
PAR/ASR	382	PAR/ASR	270
TOTAL	3,647	TOTAL	6,110

FIGURE III-26

PILOT REQUIREMENTS - 1972 VS. 1982

TYPES OF AIRSPACE	FLIGHT CONDITION	PILOT REQUIREMENTS 1972	PILOT REQUIREMENTS 1982
UNCONTROLLED	VFR (DAY)	CURRENT PILOT CERTIFICATE: 1. STUDENT 2. PRIVATE 3. COMMERCIAL 4. ATR APPROPRIATE RATING: 1. SINGLE ENG. 2. MULTI ENG. 3. LAND 4. SEA 5. INSTRUCTOR 6. INSTRUMENT 7. HELICOPTER 8. GLIDER CURRENT MEDICAL: 1ST, 2ND (FAR 61.3)	SAME AS 1972
UNCONTROLLED	VFR (NIGHT)	SAME AS VFR (DAY)	SAME AS 1972
UNCONTROLLED	IFR	SAME AS VFR PLUS: PILOT CERTIFICATE: PRIVATE OR HIGHER WITH 200 HOURS RATING: INSTRUMENT	SAME AS 1972
CONTROLLED (NON-POSITIVE)	VFR	SAME AS UNCONTROLLED VFR PLUS: PILOT CERTIFICATE: PRIVATE OR HIGHER	SAME AS 1972 PLUS: ANNUAL PILOT PROFICIENCY CHECK
CONTROLLED (NON-POSITIVE)	IFR	SAME AS UNCONTROLLED IFR PLUS: FCC RADIO-TELEPHONE RATING	SAME AS 1972 PLUS: ANNUAL PILOT PROFICIENCY CHECK
POSITIVE CONTROL	VFR	NOT AUTHORIZED	NOT AUTHORIZED
	IFR	SAME AS CONTROLLED NON-POSITIVE IFR	SAME AS 1972 PLUS: ANNUAL PILOT PROFICIENCY CHECK

FIGURE III-27

AIRBORNE EQUIPMENT REQUIREMENTS - 1972 VS. 1982

TYPES OF AIRSPACE	FLIGHT CONDITION	AIRBORNE FLIGHT AND NAVIGATION EQUIPMENT REQUIREMENTS	
		1972	1982
UNCONTROLLED	VFR (DAY)	1. AIRSPEED 2. ALTIMETER 3. COMPASS 4. TACHOMETER 5. OIL TEMPERATURE 6. MANIFOLD PRESSURE 7. FUEL GAUGE 8. LANDING GEAR 9. BELTS (FAR 91.33)	SAME AS 1972
UNCONTROLLED	VFR (NIGHT)	ALL ABOVE PLUS: 1. POSITION LIGHTS 2. ANTI-COLLISION LIGHT 3. LANDING LIGHT (IF FOR HIRE) 4. ELECTRICAL SOURCE	SAME AS 1972
UNCONTROLLED	IFR	SAME AS VFR PLUS: 1. TWO-WAY RADIO 2. NAVIGATION SYSTEM 3. GYRO TURN/BANK 4. SENSITIVE ALTIMETER ADJUSTABLE FOR BAROMETER PRESSURE 5. CLOCK WITH SWEEP SECOND HAND 6. ARTIFICIAL HORIZON 7. DIRECTIONAL GYRO OR EQUIVALENT 8. GENERATOR	SAME AS 1972
CONTROLLED (NON-POSITIVE)	VFR	SAME AS UNCONTROLLED VFR	SAME AS 1972 PLUS TRANSPONDER
CONTROLLED (NON-POSITIVE)	IFR	SAME AS UNCONTROLLED IFR	SAME AS 1972 PLUS TRANSPONDER
POSITIVE CONTROL	VFR	NOT AUTHORIZED	NOT AUTHORIZED
	IFR	SAME AS UNCONTROLLED IFR PLUS: 1. DME 2. TRANSPONDER 3. VOR (IN TCA's)	SAME AS 1972

IV. IDENTIFICATION AND ASSESSMENT OF MAJOR INDUSTRY CONSTRAINTS TO GROWTH

In Chapter II, the development and growth of general aviation was described, and it was seen that it is an industry subject to considerable fluctuation. The total fleet has maintained an overall pattern of growth but, at the same time, it was seen that the actual growth never attained the forecast expectations. DSC believes that a basic realization must take place to properly evaluate the general aviation industry: General aviation is not a mass production industry. This is illustrated by the fact that during the five-year period 1969-1973, the industry underwent a severe period of decline and rapid growth. Between 1969 and 1970, new aircraft deliveries declined by 41%, and three years later, between 1972 and 1973, increased by almost 40%.

The external forces bearing on the general aviation industry, as shown in Figure IV-1 are:

- Technological forces
- Economic forces
- Social forces
- Political forces

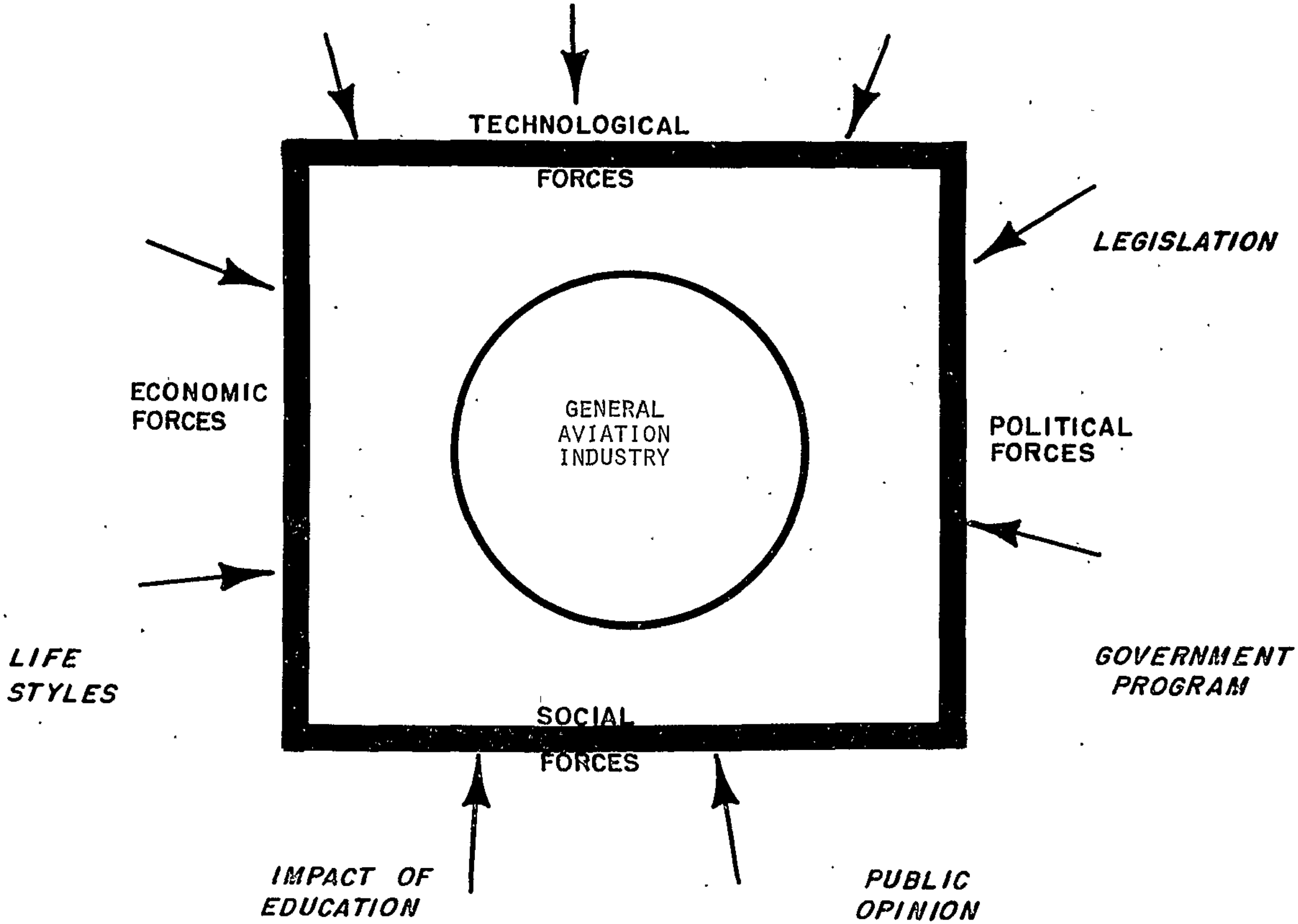
A. TECHNOLOGY

The products used in general aviation are not specifically designed for their use. In most cases, the research and development of products used in general aviation has been carried out for the military aircraft or for air carriers for a cost which is prohibitive to the bulk of general aviation. The R&D efforts of the general aviation industry are generally oriented towards the re-engineering of these products for application in light aircraft.

At the same time, it must be remembered that the total general aviation production volume is relatively small in comparison to other industries. Nevertheless, general aviation electronics is a highly competitive business. The cost of developing new products or making modifications to existing products, and associated costs such as market development and service, have to be absorbed by low production volumes.

FIGURE IV-1

EXTERNAL FORCES



For avionics, development funds are used just to keep abreast of competition by incorporating new technology and/or to meet new regulatory requirements.

B. ECONOMIC INFLUENCES

The economic factors bearing on general aviation were described when discussing forecasting in Chapter II. It was seen by the violent fluctuations in aircraft deliveries that the industry is extremely sensitive to money supply and the cost of money.

The economic growth for the remainder of this decade appears somewhat uncertain. It is likely that the fundamental change in the distribution of national resources to deal with pressing domestic and social problems will continue. Figure IV-2 shows the increase in general aviation aircraft manufacturers' net billing price as compared to the increase in the consumer price index. Figure IV-3 shows the consumer price index compared to the price of specific sample aircraft. In a price increase case study of the Beechcraft Bonanza (Figure IV-4), it can be seen that since the aircraft's introduction 25 years ago, the base retail price has increased by more than 350% and the equipped retail price by more than 500%. By comparison, general aviation aircraft performance, with the exception of the introduction of turbojet aircraft, has not increased appreciably since World War II (see Figure IV-5). For a highly discretionary industry like general aviation, the rising cost of flying is not favorable.

C. SOCIAL FACTORS

The process of social change in a society as large and heterogeneous as the United States is extremely varied and complex. Some of the current forces are not new and will probably continue to evolve far beyond the time frame of this study. Factors such as increased affluence and rising education levels have been a feature on the American scene for most of this century. Perhaps most important for the general aviation industry among the elements comprising the social outlook for the Seventies and the early Eighties are the factors of increasing desire for individualism and changing attitudes toward work and leisure. Society is

C-2

FIGURE IV-2

PRICE INDEXES

1960 = 100

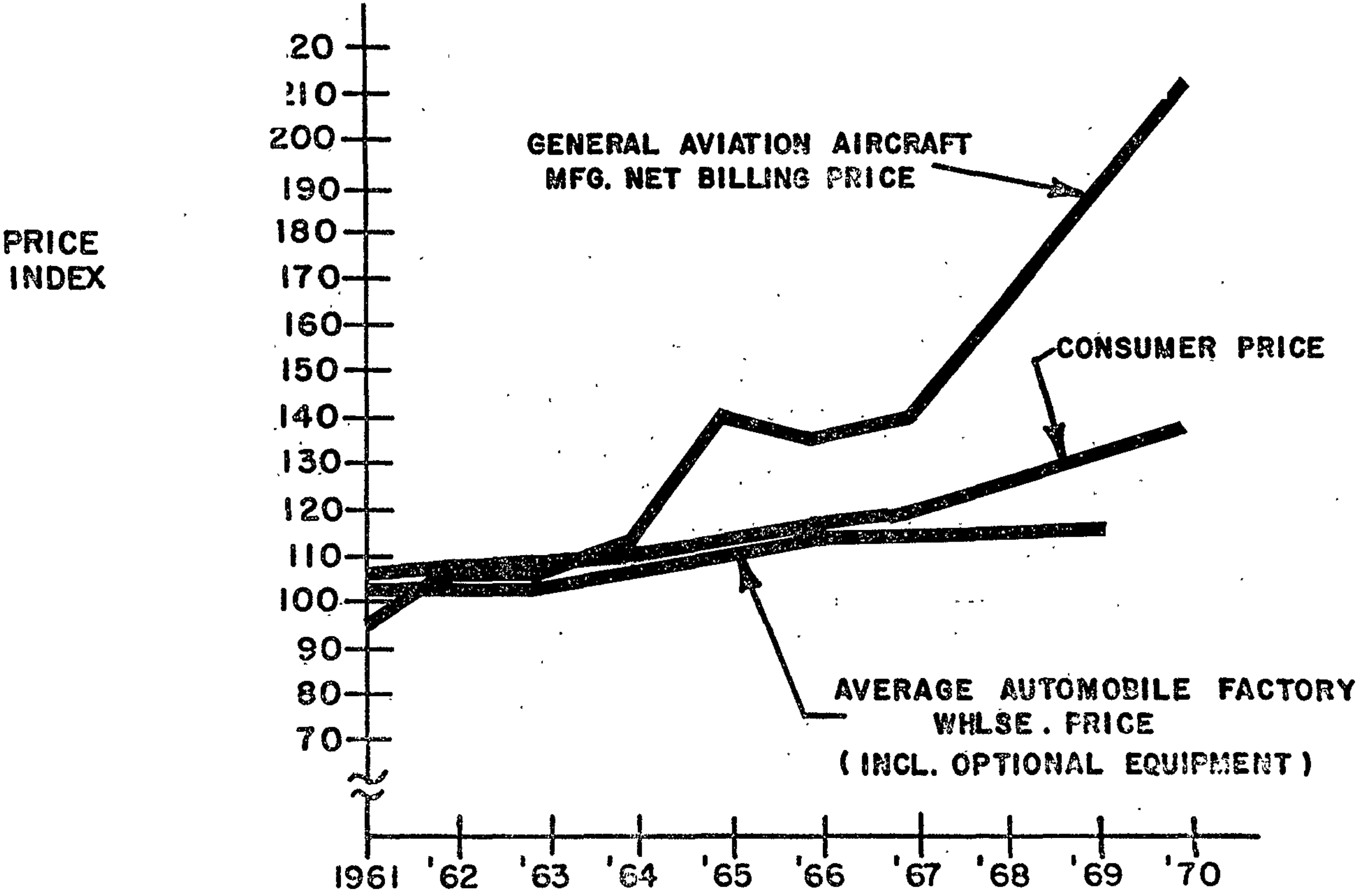


FIGURE IV-3

PRICE INDEXES

GENERAL AVIATION AIRCRAFT

1961 = 100

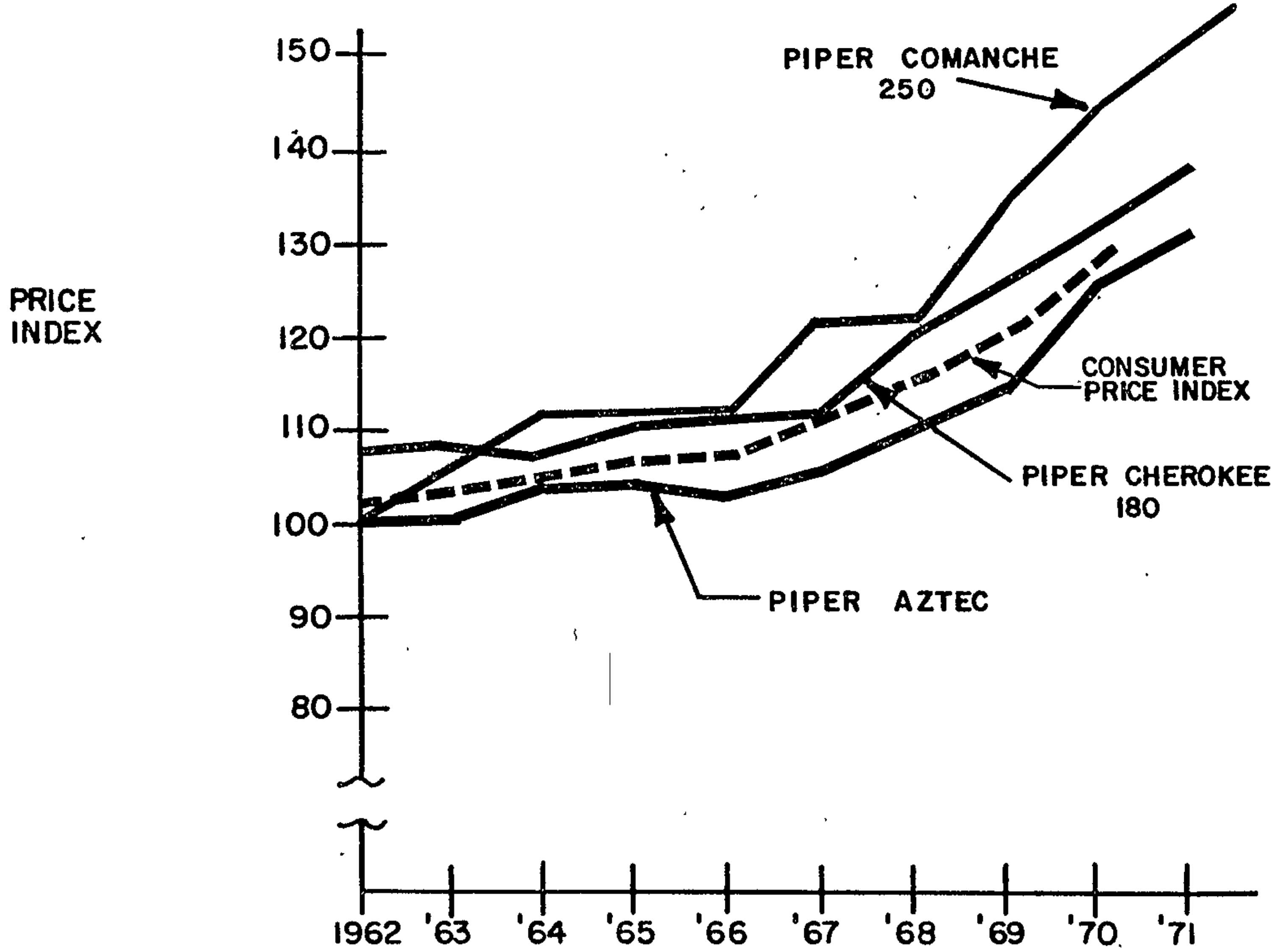
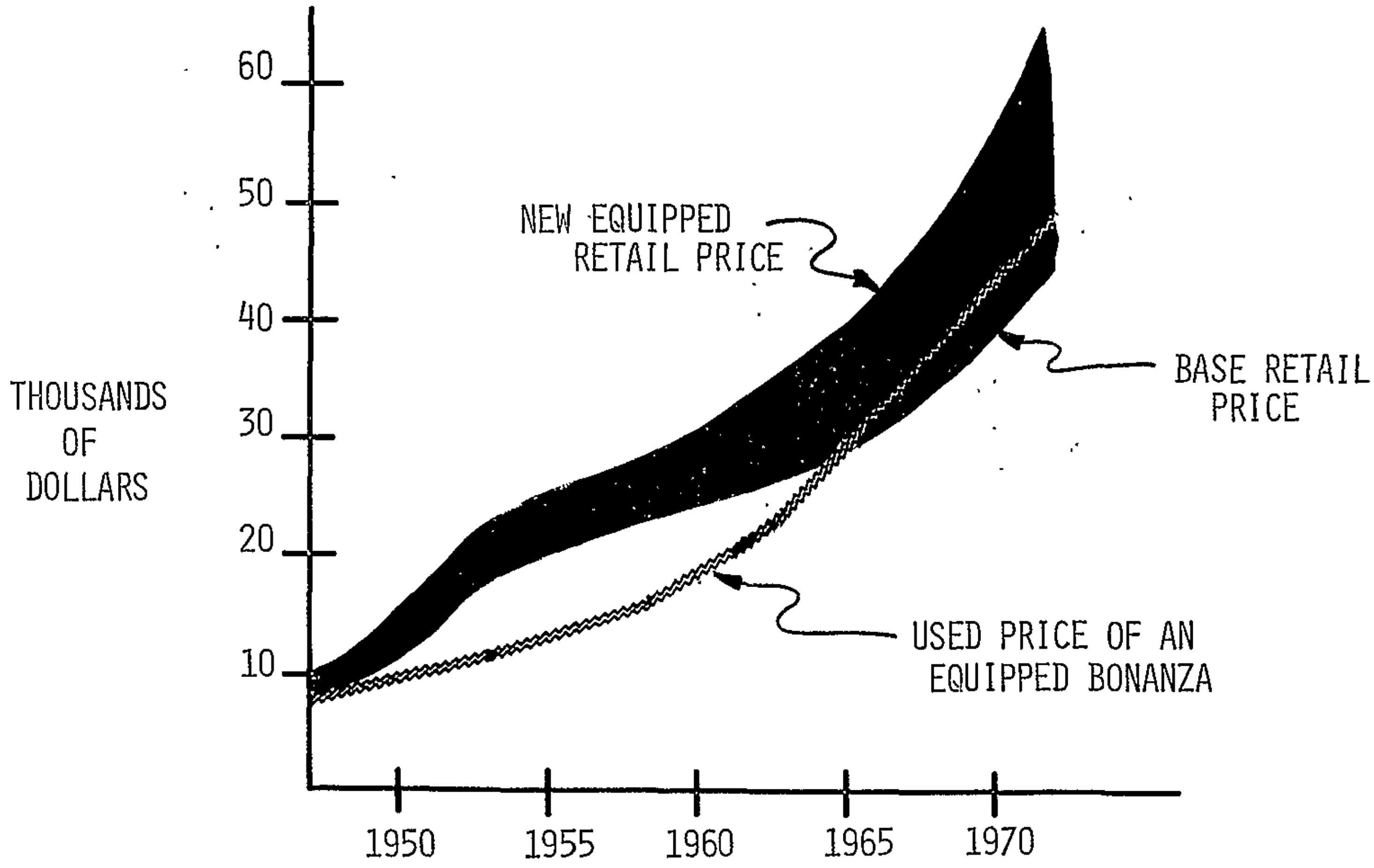


FIGURE IV-4

PRICE INCREASE CASE STUDY

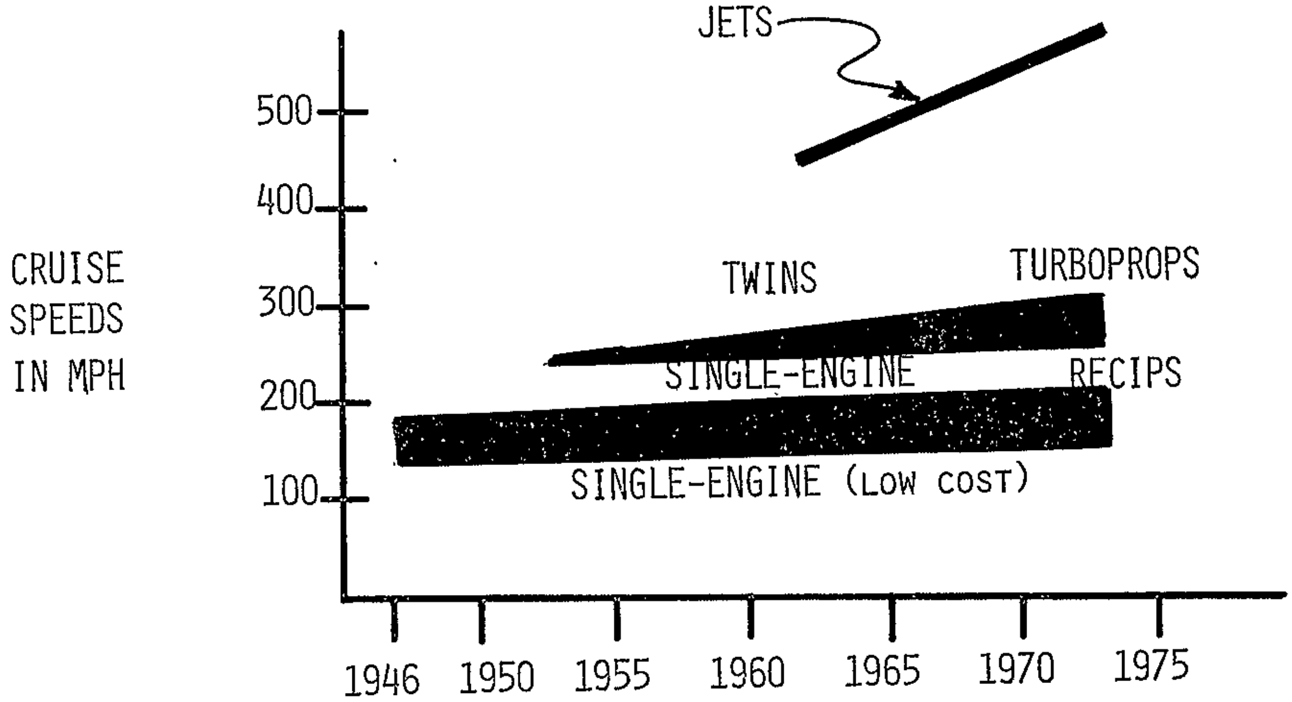
BEECHCRAFT BONANZA



SOURCE: AIR PROGRESS MAGAZINE

FIGURE IV-5

GENERAL AVIATION AIRCRAFT PERFORMANCE



SOURCE: AIR PROGRESS MAGAZINE

changing its views towards some of the established values, although the new values have not yet been identified clearly. People are having increasing opportunities to participate in activities outside the work environment, and in order to creatively use this time, they are looking for avenues of self-expression. The increased leisure time will come from shorter work weeks and more holidays. Moreover, people no longer consider vacations a novelty but rather are making more demands in this regard.

As society seeks avenues of individualism and mobility and as air travel becomes more commonplace, it would appear that the social outlook for general aviation is favorable, provided that it does not conflict with the increased concern for the environment and assuming economic problems do not overshadow social development.

D. POLITICAL FACTORS

Without question, government influence has become increasingly apparent in everyday life, and the political outlook during the next ten years appears to contain the following prospects:

- Increasing governmental regulations of social activities
- Increasing involvement of state and local government in the areas of regulatory activities and social problems
- Increased involvement in the transportation industry and the transportation system by the federal government

The outlook for general aviation in terms of the political factors during the next ten years indicates that the industry must develop a strong political position in the national transportation system to be sure that its interests are protected. A good example of how general aviation can suffer unless the industry presents a strong position occurred recently during the peak of the energy crisis when fuel allocations were established which were not favorable to general aviation.

Unless the general aviation industry presents a unified voice in public affairs and establishes a strong role in the national transportation system, it is likely that its future growth could become severely compromised.

E. GENERAL

The combination of the above forces will, to a very great extent, determine the future development of the general aviation industry. There are, however, factors within the industry which carry considerable influence and which the industry must face directly.

Although the safety record of general aviation has improved over the years, accidents always receive a considerable amount of public attention. The basic fear of flying, therefore, remains a fundamental problem.

To realize its growth potential, the general aviation industry must continue its efforts to make flying safer and easier. This would be achieved by continuing to provide better training methods and improved equipment while maintaining a cost level that is acceptable to a wider segment of the population, and through more efficient planning, attempt to anticipate customer needs rather than reacting primarily to government regulation.

V. IDENTIFICATION OF GENERAL AVIATION AVIONICS TRENDS

The most far-reaching development in electronics during the past 15 years was the introduction of the transistor and widespread use of solid state electronics. First introduced in civil aviation in 1958, it was not until the early Seventies that VHF transceivers became all solid state. A derivation of this technology during the past few years is the trend towards a greater degree of functional integration and the introduction of airborne computers. The increased use of solid state technology has led to improved packaging and decreased weight of avionics systems. The impact analysis in Chapter VII goes into this aspect in greater detail. It is also significant to note that despite the addition of more features, miniaturization and increased reliability, avionics prices in recent years have remained stable.

For the purposes of this analysis, we will discuss the technological changes and trends for each of the functional areas covered in this study, i.e., communications, navigation, instrumentation, flight controls, and displays.

A. COMMUNICATIONS

1. VHF Communications

The basic voice communications mode is VHF communications which has developed from the 90-channel vacuum tube radio sets of the 1950's to fully transistorized, digitally controlled 720-channel radios including, in some cases, automatic squelch and circuitry self-test features. The requirement for 720-channel capability is not expected to come into force until some time after 1977, and there is considerable debate within the industry at present regarding to what extent the full 720-channel capability is needed in the low altitude en-route and terminal airspace structure.

However, as the prices for 360- and 720-channel communications radios are essentially the same, it can be expected that most new aircraft owners and other purchasers of new equipment will opt for the 720-channel models. With more than 85% of the general aviation fleet currently equipped with VHF communications capability and as the amount of controlled airspace increases, it becomes essential to be so equipped, and it is unlikely that any significant number of aircraft will be without it by 1980.

2. HF Radio and UHF Telephone

Other types of voice communications carried in general aviation aircraft are HF radio and UHF telephone. The former is used primarily by aircraft flying long distances over water or operating in remote areas. The currently available HF transceivers have amplitude modulation and single sideband capability and are all solid state. Because of the special requirements for use and the need to subscribe to the ARINC network, it is estimated that no more than 4% of the general aviation fleet is HF-equipped, and it is not expected that this proportion will increase.

With the expansion in ground station coverage, it is likely that the number of UHF telephones in general aviation will increase gradually during the next few years. At present, it is estimated that between 2% and 3% are equipped. However, it is not an essential piece of avionics equipment and will probably not become widely used in the fleet.

3. Transponders

The ATC transponder is mandatory for aircraft operating in controlled areas. Introduced as mandatory equipment in 1967 for operation in positive control areas, it is estimated that over 65% of the general aviation fleet is now thus equipped. The transponders available today are all solid state and digitally controlled. Many of the newer models also have pushbutton code selection.

4. Altitude Reporting

Automatic altitude reporting is an FAA requirement which will begin phasing into operation with Group I TCA's after January, 1975, Group II TCA's after January 1, 1975, and above 12,500 feet installed after July 1, 1975. This is a new function in avionics, and we will probably see new technology in this area during the next few years. At the end of 1973, it was estimated that approximately 4% of the general aviation fleet was equipped with automatic altitude reporting capability and, by 1980, it is expected that this proportion will increase to over 60%.

5. Emergency Locator Transmitters

By July 1, 1974, the entire general aviation fleet, with the exception of some trainers, agricultural aircraft and turbojets, will be equipped with emergency locator transmitters. At the end of 1973, it is estimated that approximately 60% of the aircraft were equipped with ELT's.

6. Proximity Warning Indicators

A number of proximity warning indicators are now available in the marketplace—one of them using a development funded through a NASA program. A very small percentage of the fleet carry a PWI as yet and unless it becomes mandatory, it is not expected to gain widespread use rapidly.

7. Other Communications Functions

The remaining communications functions such as satellite communications, data link, and collision avoidance systems are currently at varying stages of planning and development. Satellite communications is a politically sensitive issue with the international airlines taking opposing positions. It is expected that ICAO will reach a decision in 1976; however, no significant impact on general aviation is expected to result during the time frame covered in this study.

The specifications of the DABS version of data link are currently being developed by the FAA, and the development schedule was described in Chapter III. The planned introduction of DABS is for the early 1980's, and it is very possible that a major portion of the communications between aircraft and the ATC will take place eventually using this medium.

Airborne CAS is not likely to reach implementation during the period covered in this study. A number of systems have been developed for testing by the FAA. Eventually, it is expected that the collision avoidance function may be handled by DABS/IPS (Intermittent Positive Control).

B. NAVIGATION

1. Automatic Direction Finders

The automatic radio direction finder (ADF) is the oldest surviving piece of navigation avionics, and it remains very popular. At the present time, approximately 55% of the general aviation fleet is equipped with ADF. Most of the ADF's currently available provide digital tuning, and the manufacturers are increasingly featuring equipment compatibility with HSI and RMI systems. The presentation of the ADF is also changing with the trend towards the integration of the HSI and ADF displays. It is anticipated that approximately 60% of the fleet will be ADF-equipped by the end of this decade.

2. VHF Navigation Receivers

The trend towards functional integration is most apparent in VHF navigation receivers which constitute the primary electronic navigation aid in aviation. At the beginning of 1973, it was estimated that more than 82% of the general aviation fleet carried at least one VHF navigation receiver, and approximately 30% were equipped with dual systems. The units available today are all transistorized, are digitally-controlled, provide R/NAV outputs, and have circuitry self-test features. There is also a trend towards including glideslope and marker-beacon receivers in the basic package, and these two functions are disappearing from the market as separate avionics.

3. Distance Measuring Equipment

Until recently, distance measuring equipment (DME) was not considered an essential piece of avionics, except for aircraft operating in the positive control area above 18,000 fleet. There was, nevertheless, a moderate demand for the DME as can be judged by the fact that approximately 20% of the general aviation fleet is thus equipped. For aircraft using area navigation, the DME has become a requirement. In the DME's currently available, digital displays have been replacing the needle indicators.

4. Radar Altimeters

Radar altimeters, originally a military development, were introduced into civil aviation during the latter half of the 1960's as an approach and landing aid under poor visibility conditions. In general aviation, their use is essentially limited to higher performance aircraft that operate in all weather conditions. The products currently available are too expensive for general aviation aircraft owners. At present, approximately 5% of the general aviation fleet is equipped with radar/radio altimeters, and unless there is a considerable price reduction, it is not likely that this percentage will increase substantially during the rest of this decade. There is, however, a trend toward radio altimeters integrated with flight director system.

5. Area Navigation

With the introduction of the airborne computer at relatively low cost, during the past few years area navigation has been considered as the most significant new development in general aviation avionics systems. The range of systems available is from a single waypoint computer listed for under $2,000 to a highly sophisticated system with almost unlimited waypoint storage capability, providing latitude and longitude, aircraft track angle, time to waypoint, cross-track deviation, automatically tuning navigation receivers, accepting inertial and Doppler data, etc., for more than $100,000. Many of the systems currently available offer V/NAV (R/NAV including waypoint altitude) as an option and during the next few years, T/NAV (R/NAV or V/NAV including waypoint ETA) will also be a widely available option. The trend appears to be towards a totally integrated navigation system. R/NAV procedures have become accepted both by the users and the ATC system, and it may become mandatory during the next ten years to be equipped with R/NAV capability in the high altitude route structure and possibly also in the high density terminal areas.

Cost is the single greatest obstacle to widespread use of R/NAV across the spectrum of general aviation and unless the cost of the total system including VOR, DME, navigation computer and displays is reduced, R/NAV will remain out of reach for a large portion of the general aviation fleet. The present potential is limited to the 20% of the fleet that is DME-equipped, and estimates of current installations indicate that no more than 2% of general aviation aircraft today have area navigation capability.

6. Omega Navigation

The newest development in long-range airborne navigation is the use of Omega and VLF systems. Manufacturers claim to offer navigational capability at least equal to INS and at a reduced cost. The U.S. Navy, which will operate the Omega ground stations, indicates that all eight stations will be operational by mid-1975. The current coverage extends over all of North America and some of South America, Europe, West Africa and Northeast Asia. The manufacturers presently claim to have resolved most of the problems associated with the changing atmospheric patterns. Normal accuracies are within one to two miles, and the systems are finding use in specialized applications. The systems currently installed in corporate aircraft are almost all associated with other long-range navigation systems such as inertial or Doppler, providing the required redundancy with a considerable cost reduction over dual INS.

Although Omega and VLF systems are being evaluated by the FAA, the program is not of high priority, and it is unlikely that the systems will receive approval for basic IFR navigation within the national airspace system in the near term. In the long term, i.e., beyond 1985, it is possible that Omega and differential Omega will provide the required accuracy and flexibility and will become an accepted standard of navigation. Current systems are available for $15,000 and up and are effectively out of reach of over 90% of the general aviation fleet.

7. Other Navigation Systems

The use of hyperbolic, Doppler, and inertial navigation systems in general aviation is currently limited to a small percentage of the corporate fleet. The systems are used essentially for long distance navigation out of the range of VHF ground stations; thus, there is no requirement for this class of equipment in most general aviation aircraft. It is estimated that less than 0.5% of the total fleet is equipped with any of these systems.

Because there will continue to be a requirement for some aircraft to have a self-contained navigation system, inertial navigation will continue to be a viable product in the market during the next decade. Research and development is being carried out in various areas to reduce the cost of INS but even if these are successful, the cost will remain very high (probably above $50,000).

C. INSTRUMENTATION

Instrumentation product areas defined for this study are currently only carried in high performance aircraft.

EQUIPMENT	% OF FLEET EQUIPPED
Dual Independent Altitude, Attitude, etc.	4.8%
Air Data Systems	0.2%
Recorders	0.4%
Engine Monitors	1.7%
Weather Radar	4.5%

None of the above systems are installed in the single-engine piston fleet. A dual independent instrument panel is found primarily in aircraft operating with a pilot and co-pilot and, therefore, is not required in the majority of general aviation aircraft. Some training aircraft are thus equipped, but this was not found to be a widespread practice.

Air data systems and recorders are also not considered essential to aircraft function and are generally carried in aircraft equipped with integrated flight control systems. These are usually only installed in top-of-the-line aircraft and are in a price range beyond the reach of most general aviation aircraft owners. It is not anticipated that they will gain widespread use by the mid-1980's.

Engine monitors other than the basic engine gauges have not yet been introduced in large quantities in general aviation. Development work is being carried out in this area and with the availability of computer chip technology, it is anticipated that a number of engine monitoring systems may become available during the next ten years. This is a feature that would be valuable in all categories of aircraft. Its cost will be an extremely important factor.

Airborne weather radar technology has undergone considerable change during the past few years. A number of low cost systems have been introduced and are now available to the light twin-engine aircraft operator. Development work has also been carried out in wing-mounted, phased array antenna arrangements to bring weather radar within the capability of single-engine aircraft. One manufacturer recently introduced a digital memory display (no sweep), and it can be expected that others will shortly follow suit. New developments are expected to multiply in this area in the near future, and it is very possible that more than 10% of the fleet will carry weather radar by 1985.

D. FLIGHT CONTROL

Of the flight control systems under consideration in this study, only three are currently carried in the general aviation fleet:

- Stability augmentation systems
- 2- and 3-axis autopilots
- Flight directors

Stability augmentation systems are defined as the basic stabilizing systems (e.g., wing levelers) as opposed to the more sophisticated autopilots. It is estimated that approximately 23% of the fleet is equipped with stability augmentation systems, primarily single-engine and light twin piston aircraft. The systems that are currently available are in the under $1,500 price range. The trend is toward complete modularity, so that a basic wing leveler can be developed into a sophisticated autopilot or even an integrated flight control system using the building-block concept. Two- and three-axis autopilots can be considered as standard equipment on high performance aircraft and are also found to a lesser extent in the lower fleet categories. It is estimated that approximately 18% of general aviation aircraft are equipped with this product.

In the sophisticated version, autopilots today are actually integrated flight control systems, including both flight directors and one or two computers. In this form, they can provide both R/NAV and V/NAV coupling, go-around mode, Category II monitoring, auto throttle and auto flare. The current systems range in price from $8,000 to over $50,000.

Flight directors were introduced into civil aviation during the early 1960's and, to date, it is estimated that only 5% of the general aviation fleet is equipped with them. At the beginning of this decade, there were only four products in this category, each with a price of over $3,000. Currently, there are over 16 different products available with prices starting at under $2,000.

There are currently three display types (crosspointer, combined-cue, and "bullseye") offered by the major U.S. manufacturers. Flight director displays will eventually be replaced by a CRT and a display generating computer. However, in the near term, these systems will be available at prices that are prohibitive for all but the most sophisticated turbojets in the fleet.

E. DISPLAYS

The displays carried in the general aviation fleet are almost exclusively of the electromechanical type whether the display in question is for situation information, command information or a combination of both. Over the years, manufacturers have experimented with various forms of displays, e.g., peripheral, head-up and map, but with little success or acceptance in general aviation. During the past few years, a few avionics products such as DME, radar altimeters, encoding altimeters, etc. have been equipped with digital displays to replace the conventional needle and dial, and digital displays are gaining general acceptance. Vertical tape indicators are also being introduced, particularly to display engine parameters. The trend in displays is towards greater integration using a CRT-type presentation. This trend towards integrated multi-function displays is in keeping with the general trend towards systems integration in avionics. However, a considerable amount of research and development remains to be performed in this area before the technology becomes available and acceptable to all classes of general aviation flying.

VI. ASSESSMENT OF PUBLIC BENEFITS

In DSC's analysis of the potential public benefits that could be derived from advances in general aviation avionics systems, it became quite apparent that the benefits would be more indirect than direct and, thus, difficult to quantify. In Chapter IV dealing with the major industry constraints to growth, it was seen that the two overriding factors were economics and the intrinsic fear of flying.

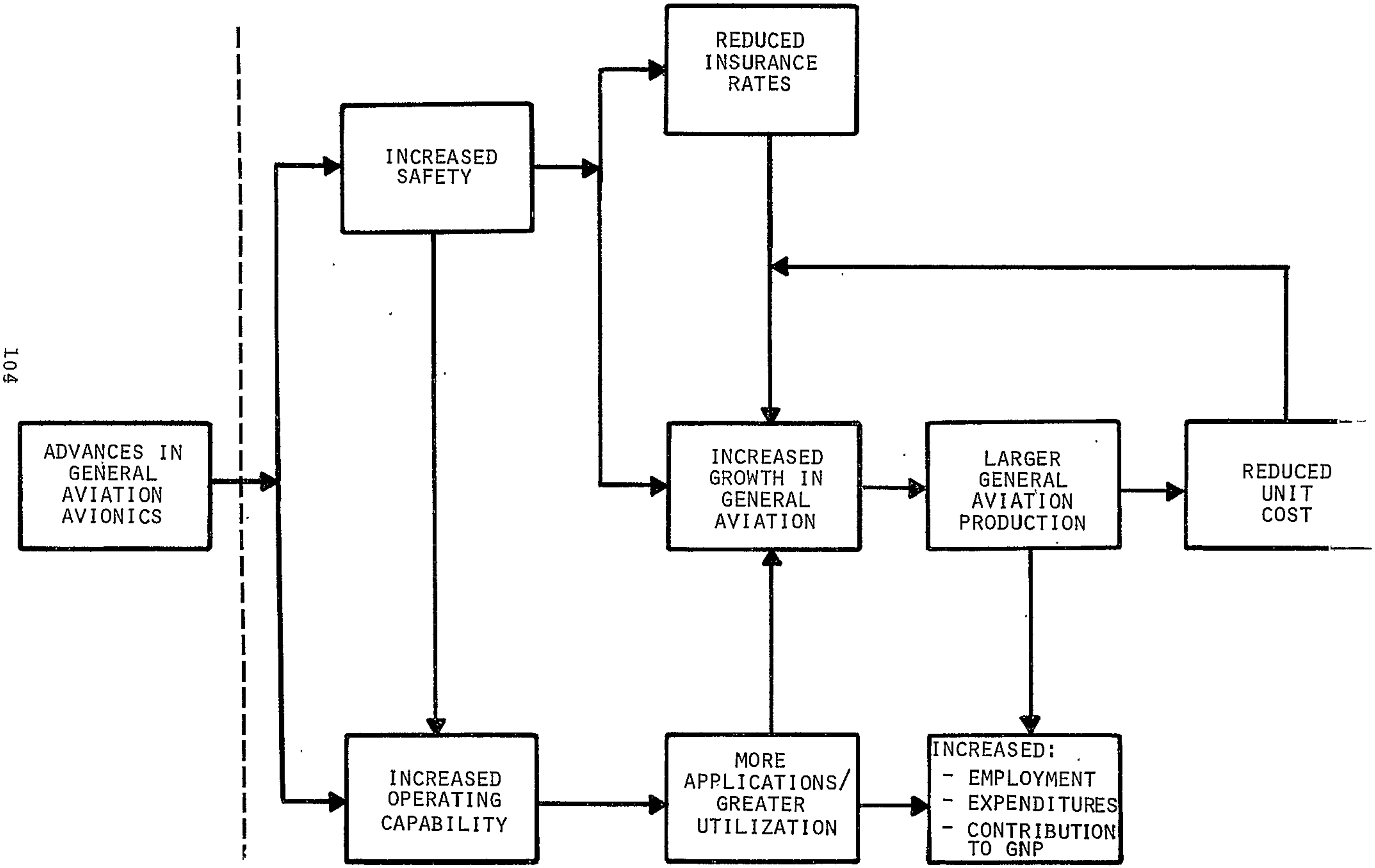
There is little doubt that flying is considered a costly activity by a large majority of the population and, if the cost of flying were to be reduced, particularly the initial cost as opposed to operating cost, it is probable that general aviation would grow in inverse proportion to the cost decrease. On the other hand (short of a technological revolution enabling a considerable reduction in aircraft and equipment costs at current volumes), production in general aviation is not now, and is not forecast to become within the next 10-15 years, of a large enough volume to lead to sufficiently reduced costs to encourage a more rapid growth. Moreover, the reduced cost of avionics, while certainly contributing to increased avionics use by the flying community, does not in itself contribute to the growth of general aviation.

A flow chart of the sequence of events that could lead to potential public benefits is shown in Figure VI-1. Basically, advances in general aviation avionics could contribute indirectly to increased safety and operating capability in general aviation. Insofar as the safety factor is concerned, NTSB statistics show that the major primary and secondary causes of general aviation accidents are attributable to pilot error, and only in extremely rare cases are accidents caused by instruments or avionics equipment. Even when examining the detailed causes and factors involved in the pilot error category, it is impossible to determine to what extent the avionics played a contributing role. For example, under the broad category of pilot error, the following detailed causes/factors were identified by the National Transportation Safety Board to have accounted for roughly 4% of the accidents in 1969:

- ° Continuation of VFR flight in adverse weather conditions
- ° Failure to obtain/maintain flying speed
- ° Improper level-off

FIGURE VI-1

ASSESSMENT OF BENEFITS



- Inadequate preflight preparation and/or planning
- Selection of unsuitable terrain
- Misjudgment of distance and speed
- Failure to maintain directional control

It is extremely difficult to determine the degree to which avionics might have contributed in these situations, or to evaluate how advanced avionics might have remedied these causes. However, it must be assumed that advanced and/or improved avionics would advise a pilot of potentially hazardous situations and assist him to recover from them. Thus, as shown in Figure VI-1, assuming advanced avionics does contribute to a greater degree of safety in general aviation, this would lead to an increased growth of the general aviation fleet. It would also lead to a reduction in aviation insurance which, in turn, would be conducive to increased operating capability of aircraft (e.g., under adverse weather conditions, difficult landing conditions, etc.). This would subsequently lead to greater utilization of the fleet and contribute to greater fleet growth. The benefits derived from this are obviously growth of the general aviation industry and production which, in turn, would provide increased employment and expenditures, contributing directly to the national economy.

Once a minimum level of safety were achieved, reducing the fear of flying, the growth of the general aviation industry would probably accelerate to production levels which would allow manufacturers to reduce unit cost. This would help to attract a larger portion of the public to private flying.

With safety being one of the key elements in general aviation, it is clear that any advances in avionics that can contribute to an improved safety record would be of considerable public benefit.

VII. AVIONICS PRICE SENSITIVITY AND IMPACT ANALYSIS

A. PRICE SENSITIVITY ANALYSIS

1. Methodology

An integral part of this study was to determine targeted prices for the avionics which would be recommended for NASA R&D activities. Recognizing that there is a wide variation in what would be considered an acceptable price based on user classification and aircraft type, DSC carried out a price sensitivity analysis of the general aviation industry. In undertaking this study, NASA fully appreciated that price for a piece of avionics for the corporate fleet would be considerably different than that marketed or sold to the pleasure aircraft segment. Since NASA has a strong desire to insure that avionics developments filter down throughout the general aviation population, price and/or cost targets were established as a primary area of concern and interest in this study.

Therefore, in the context of this program, DSC undertook a price sensitivity analysis which was aimed at determining:

- The future demand for existing avionics
- The funds available to purchase existing avionics and newly developed equipment
- The price range goals that must realistically be set for new avionics

The initial step in the methodology that was established to arrive at price sensitivity conclusions was to identify all of the pertinent variables in the avionics marketplace. A listing of the various demand factors is shown in Figure VII-1. These factors include the primary influences which either stimulate or depress the demand for a piece of avionics equipment.

Having identified these factors, attributing actual price sensitivity parameters to them did not prove to be a directly approachable goal. This was primarily due to the lack of reliable, valid industry data on avionics prices and demand patterns. Unlike general

FIGURE VII-1

AVIONICS DEMAND FACTORS

AIRCRAFT FLEET

- PRESENT FLEET - REPLACEMENTS, ADDITIONS
- NEW AIRCRAFT - FACTORY/FIELD INSTALLATIONS

CLASS OF AIRCRAFT

- PRESENT/FUTURE MIX OF AIRCRAFT

OPERATIONAL CONSTRAINTS

- FAA INFLUENCES/RULINGS
- ATC AND AIRPORT OPERATIONS

EQUIPMENT DESIGN

- AVAILABILITY OF SERVICES
- MAINTAINABILITY/RELIABILITY
- FAILURE CRITICALITY OF ITEM(S)
- INTERCHANGEABILITY (STANDARDIZATION) LEVEL

ADDED VALUE - BENEFIT

- FUNCTIONAL VALUE TO MARKET SERVED
- CAPABILITY/COST EVALUATION

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- REDUNDANCY/RELIABILITY

aviation aircraft, avionics are not a measured commodity of sales volume except at a very gross level. Therefore, it was necessary for DSC to develop an indirect approach to the sensitivity measurements.

Figure VII-2 illustrates the methodology that DSC utilized to address the issue of price sensitivity. The strength of this methodology lies in the use of factors that have readily available data bases and are interrelated. They include:

- Total aircraft costs and cost trends
- Avionics unit costs and cost trends
- Aircraft avionics complements
- Patterns of aircraft usage
- Types and numbers of aircraft which comprise the general aviation aircraft fleet

Since avionics represent a portion of the total aircraft package, DSC established information on aircraft sales which provided an excellent vehicle for projecting avionics demand factors. In our analysis, DSC found that the avionics market is closely tied to new aircraft deliveries. As illustrated in Figure VII-3, approximately 80% of total annual avionics sales in general aviation are installed in new aircraft; 50% of the total are factory-installed; and 30% are field installed. Furthermore, projecting to 1985, DSC has established that the relationship between avionics installations into new aircraft compared to retrofit sales is likely to remain relatively constant. However, DSC believes that due to increasing pressures by the airframe manufacturers, factory installations of avionics will increase as a proportion of total avionics installations in new aircraft.

The categories of avionics and aircraft analyzed in this price sensitivity study are shown in Figure VII-4. These breakdowns are consistent with general industry definitions and facilitate the use of available data. The data on aircraft and avionics costs were determined for the years 1965, 1968, 1971, and 1974 through research into general aviation trade journals and manufacturers' published price lists.

FIGURE VII-2

AVIONICS PRICE/SENSITIVITY MODEL

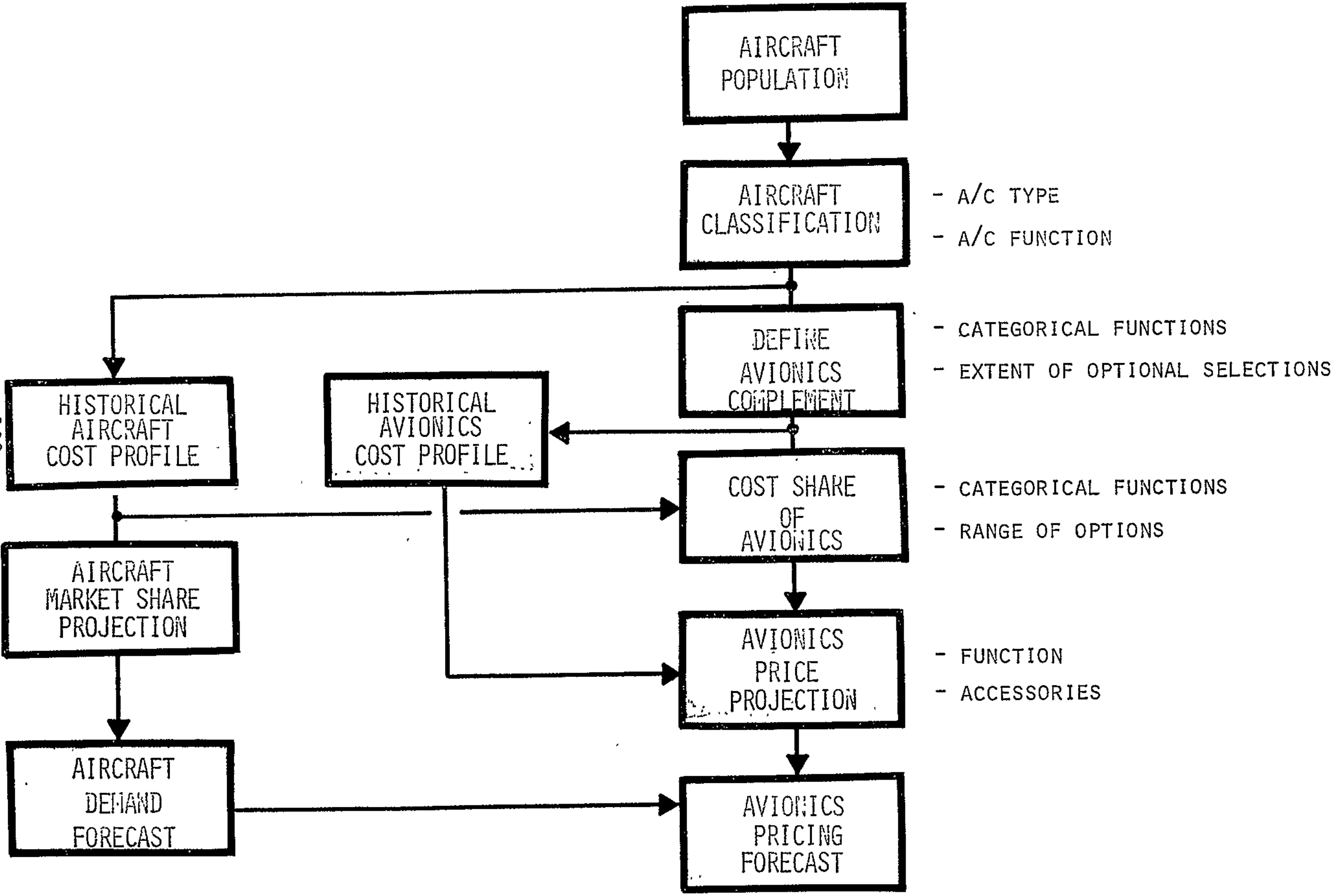

FIGURE VII-3

AVIONICS SALES

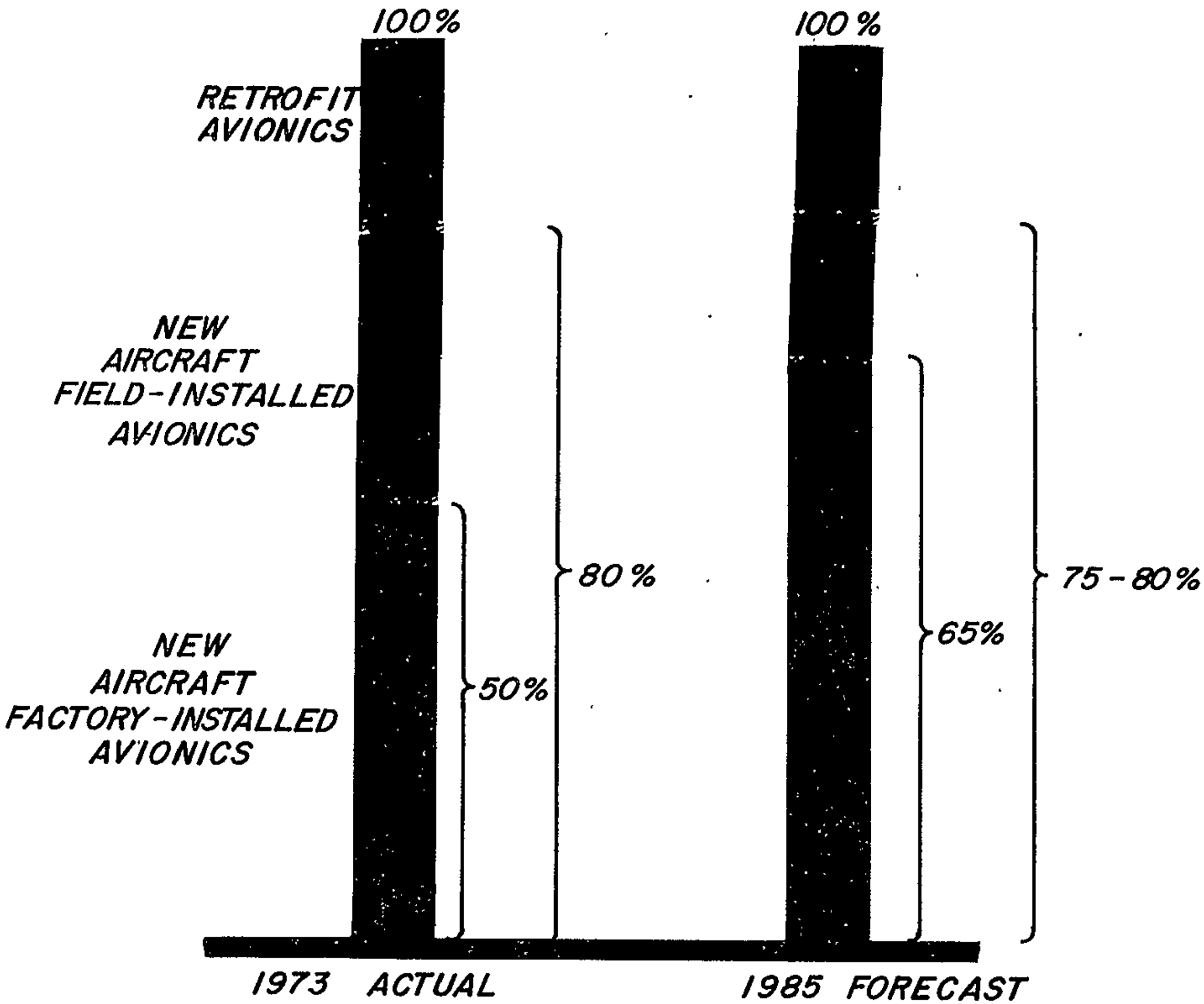

FIGURE VII-4

AIRCRAFT AND AVIONICS CATEGORIES

AIRCRAFT

• SINGLE-ENGINES	-	LIGHT (<2,500 LBS.)
	-	MEDIUM (2,500-3,000 LBS.)
	-	HEAVY (>3,000 LBS.)
• TWIN-ENGINES (PISTON)	-	LIGHT (<5,000 LBS.)
	-	MEDIUM (5,000-6,500 LBS.)
	-	HEAVY (>6,500 LBS.)
• TURBOPROPS - TWINS	-	ALL
• TURBOJETS - TWINS	-	ALL

AVIONICS

• NON-TSO	-	LIGHT/MEDIUM SINGLES
• TSO	-	HEAVY SINGLES/MEDIUM TWINS
• TSO-ARINC QUALIFIED ARINC QUALIFIED	-	MEDIUM/HEAVY TWINS
	-	TURBOJETS
	-	TURBOPROPS

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2. Aircraft Analysis

a. Aircraft Population

Figure VII-5 shows DSC's forecast of general aviation aircraft deliveries through 1985. Historical data is also shown in this figure.

Of additional interest are the dynamics within each class of aircraft as well as the change of fleet mix. From Figure VII-6, DSC has contrasted the percent of new aircraft in a category to that category as a percentage of the total fleet. This analysis shows that the most significant changes of mix of aircraft within class are occurring within the light singles and jet categories, as reflected by the percentage of the aircraft sector consisting of current model aircraft. However, while the light single sector of the fleet as a percentage of the total has remained constant, the jet share has been increasing by over 11% annually.

b. Aircraft Costs

Using the period 1965 to 1974 to develop aircraft price trends, DSC formed the basis for aircraft cost projections by category. Aircraft retail sales prices were related to actual sales records (units in each category) to establish a weighted average sales price (cost) for each aircraft type. Statistics employed covered approximately 50% of all aircraft sales with retail prices as reported by the General Aviation Manufacturers Association. The data is shown in Figure VII-7.

However, of more interpretative value are the graphical depictions for each class, illustrated in Figures VII-8 through VII-15. Importantly, the light singles and light twins have virtually a linear curve. The other single-engine aircraft classes and twin classes as well as turboprops indicate accelerating price changes; however, with only four major data points, no explicit conclusions are justified.

Turbojets provide a very interesting contrast. Having achieved major inroads into industry sales, this category of aircraft represents a volatile market segment, evidenced by recent average unit price reductions.

FIGURE VII-5

ACTUAL AND FORECASTED FLEET SALES (UNITS) 1967-1985*

AIRCRAFT CATEGORY		1967	1968	1969	1970	1971	1972	1973	1974 TO 1985
LIGHT SINGLE	NEW	7,359	7,684	6,129	3,318	3,703	4,476	6,341	107,536
	TOTAL	39,650	42,806	44,964	44,870	44,637	46,040	47,042	
MEDIUM-HEAVY SINGLE	NEW	4,195	3,712	3,887	2,581	2,583	3,440	4,450	80,542
	TOTAL	56,821	60,929	63,640	64,622	64,637	66,170	67,057	
LIGHT TWIN	NEW	489	329	424	241	209	498	522	10,631
MEDIUM-HEAVY TWIN	NEW	1,439	1,877	1,893	1,087	918	1,231	2,134	30,580
	TOTAL TWINS	14,041	15,966	17,252	17,558	16,835	18,360	19,176	
TURBOJET	NEW	95	96	125	67	52	127	228	3,882
	TOTAL	588	799	944	950	991	1,130	1,325	
TOTAL NEW ADDITIONS		13,577	13,698	12,457	7,292	7,466	9,774	13,675	233,171

*ACTUAL (1967-1973) FORECAST (1974-1985)

FIGURE VII-C

NEW AIRCRAFT AS A % OF AIRCRAFT CATEGORIES

AIRCRAFT CATEGORY	1967	1968	1969	1970	1971	1972	1973
LIGHT SINGLE	18.5% (35.0)	17.9% (35.5)	13.6% (35.4)	7.3% (35.0)	8.2% (35.0)	9.7% (34.9)	13.4% (34.9)
MEDIUM-HEAVY SINGLE	7.3 (51.1)	6.0 (50.5)	6.1 (50.1)	3.9 (50.4)	3.9 (50.4)	4.8 (50.2)	6.6 (49.8)
LIGHT TWIN } MEDIUM-HEAVY TWIN	13.7 (12.6)	13.8 (13.2)	13.4 (13.6)	7.5 (13.7)	5.4 (15.8)	8.9 (13.9)	13.8 (14.2)
TURBOJET	16.1 (.52)	12.0 (.66)	13.2 (.74)	7.0 (.74)	5.2 (.75)	10.9 (.85)	17.2 (.98)

( ) = CATEGORY AS A % OF TOTAL FLEET

FIGURE VII-7

AVERAGE AIRCRAFT COSTS - 1965-1974

AIRCRAFT CATEGORY	1965		1968		1971		1974	
	AVERAGE PRICE	RANGE (000's of $)	AVERAGE PRICE	RANGE (000's of $)	AVERAGE PRICE	RANGE (000's of $)	AVERAGE PRICE	RANGE (000's of $)
LIGHT SINGLES	12,648	10-15	14,396	11-17	16,631	13-20	18,075	14-26
MEDIUM SINGLES	17,787	14-23	18,416	15-22	20,998	20-24	24,316	21-27
HEAVY SINGLES	24,917	20-29	27,436	20-41	32,842	24-46	37,672	24-52
LIGHT TWINS	38,146	34-50	54,406	37-73	51,795	46-60	61,679	53-80
MEDIUM TWINS	60,703	55-80	79,486	60-114	89,464	68-145	120,013	73-178
HEAVY TWINS	122,244	94-200	152,209	100-193	158,689	110-197	179,956	114-230
TURBOPROPS	319,304	300-320	395,287	311-442	482,262	400-605	598,286	427-900
TURBOJETS	1,325,636	595-2,100	970,965	649-1,650	1,757,271	799-3,000	1,650,897	725-3,500

FIGURE VII-8

LIGHT SINGLE-ENGINE AIRCRAFT

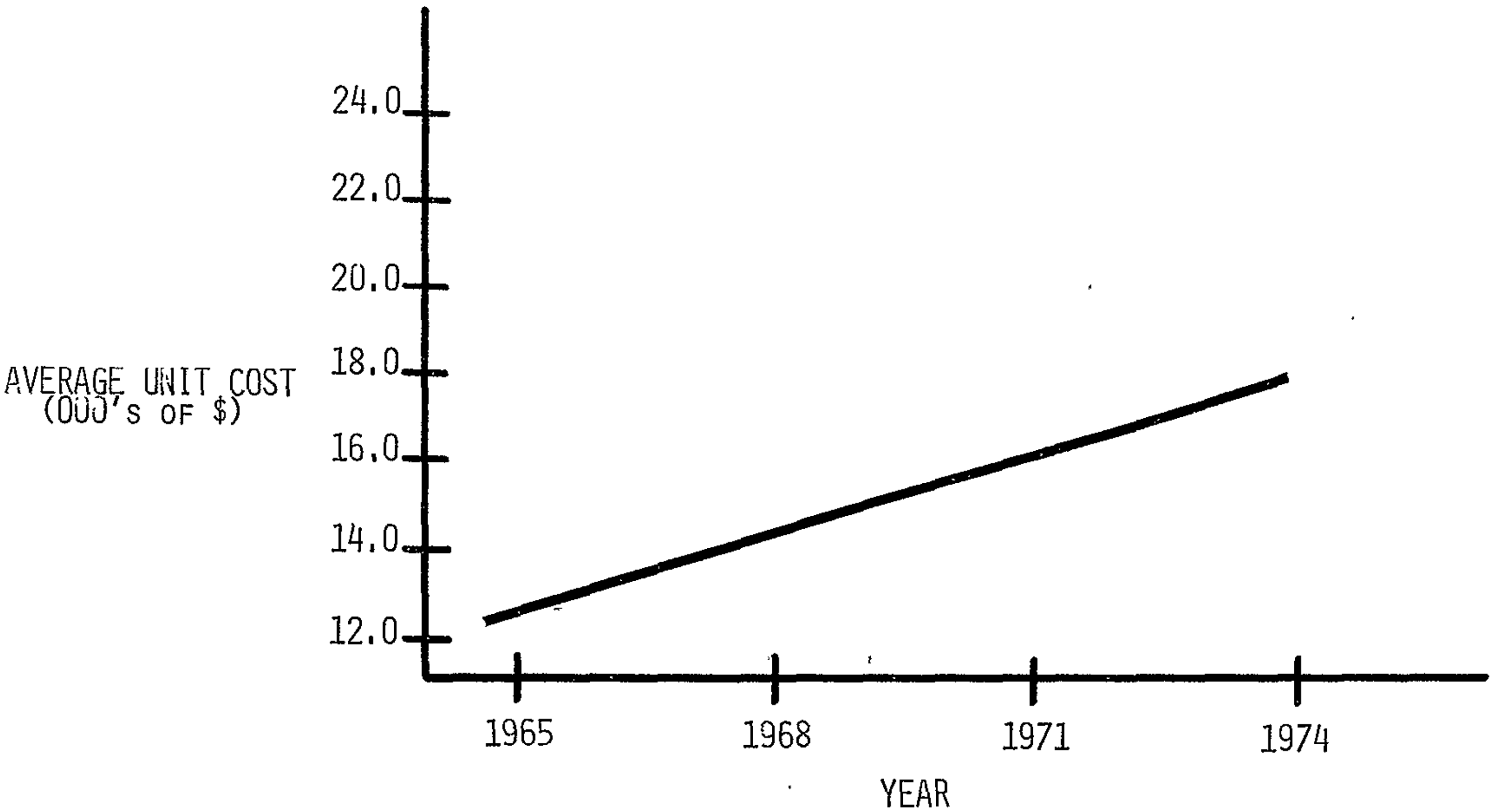


FIGURE VII-9

MEDIUM SINGLE-ENGINE AIRCRAFT

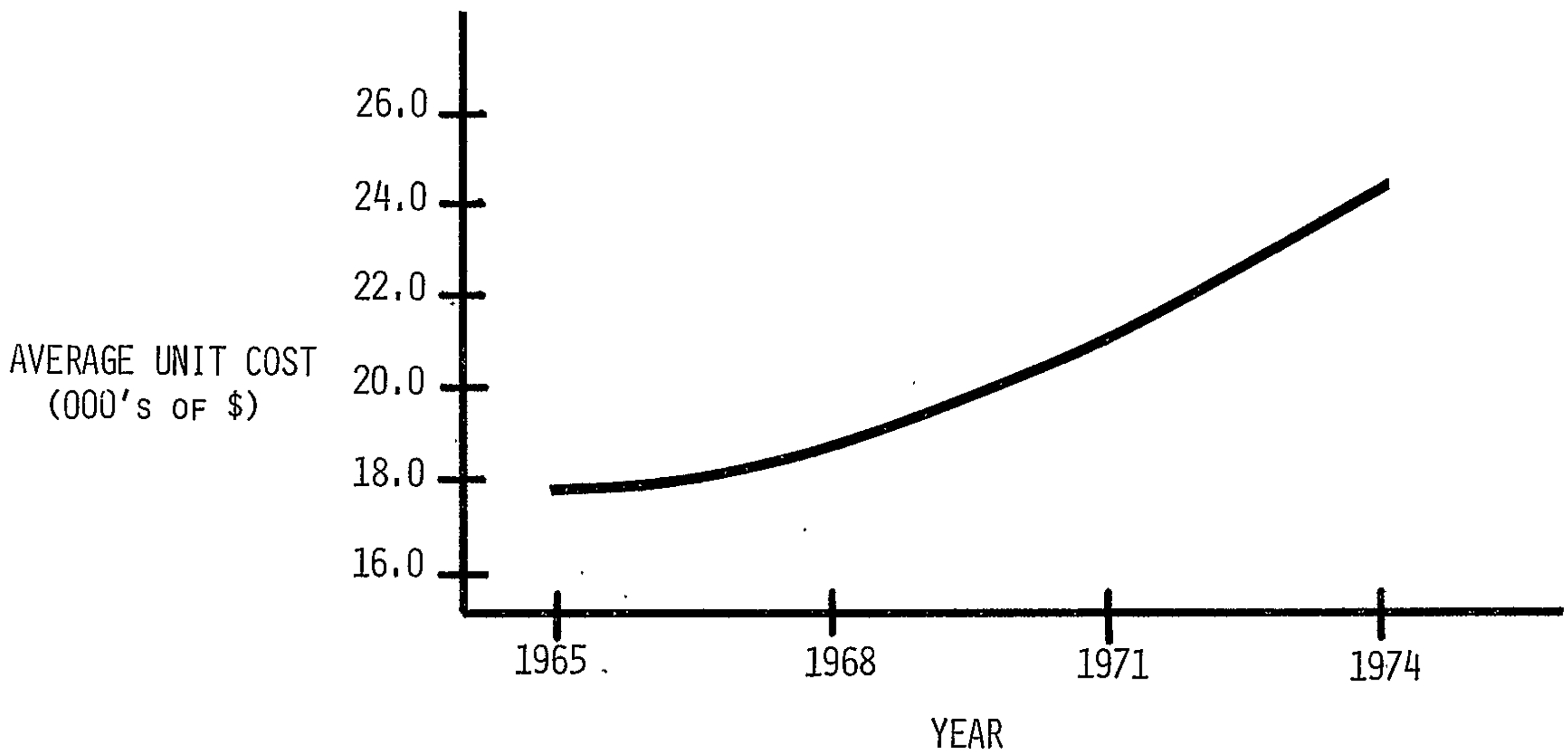


FIGURE VII-10

HEAVY SINGLE-ENGINE AIRCRAFT

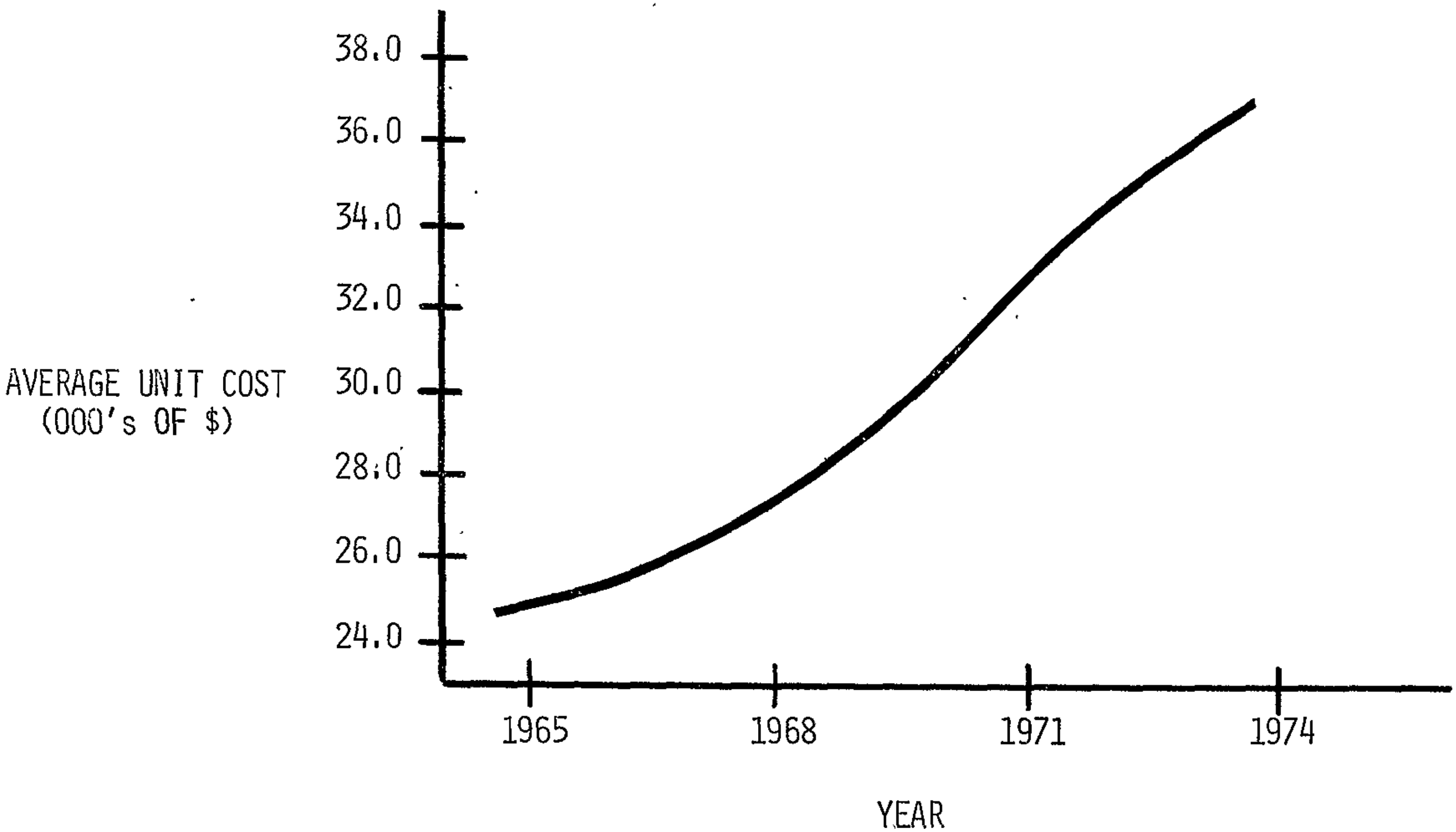


FIGURE VII-11

LIGHT TWIN-ENGINE AIRCRAFT

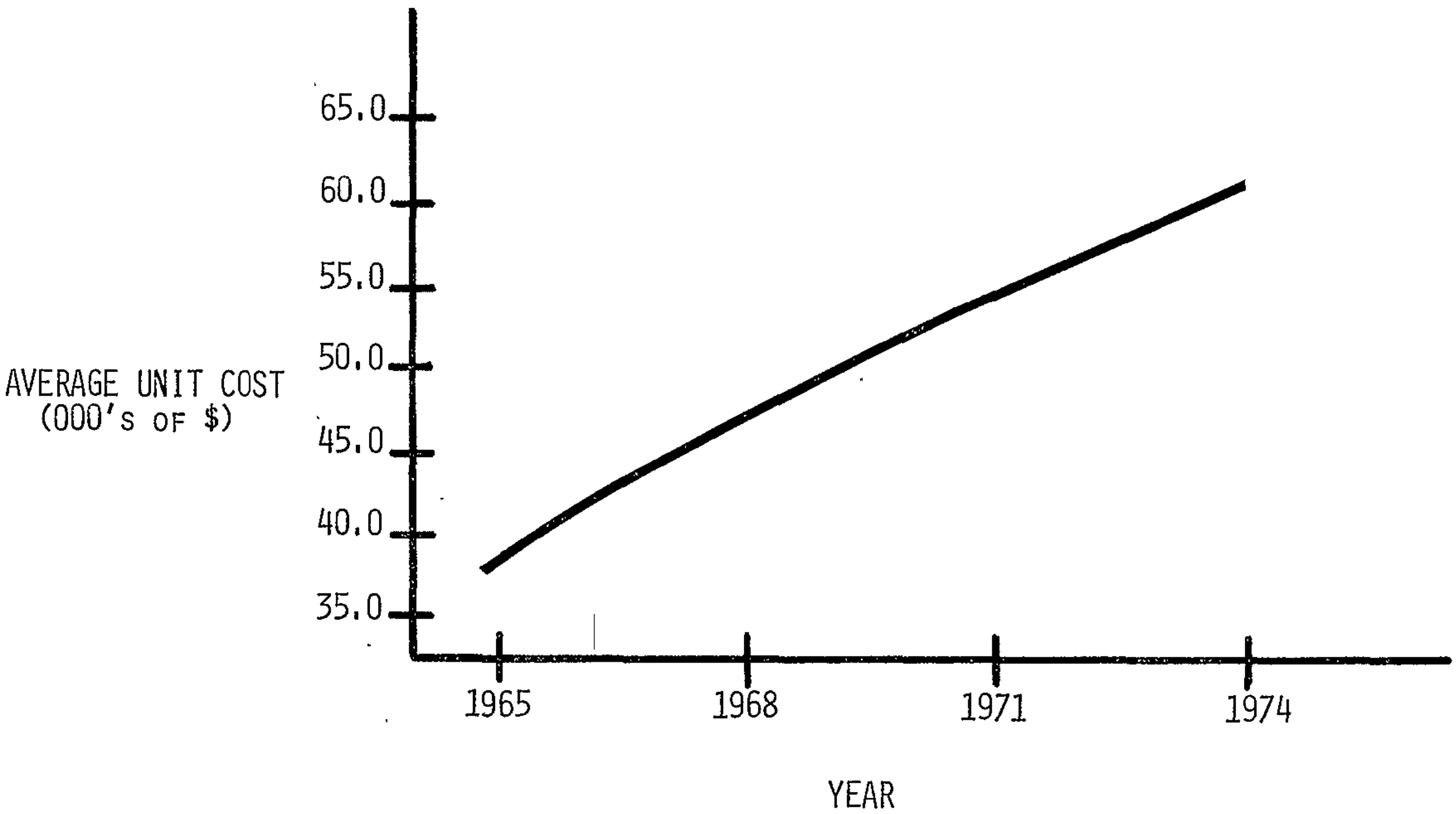


FIGURE VII-12

MEDIUM TWIN-ENGINE AIRCRAFT

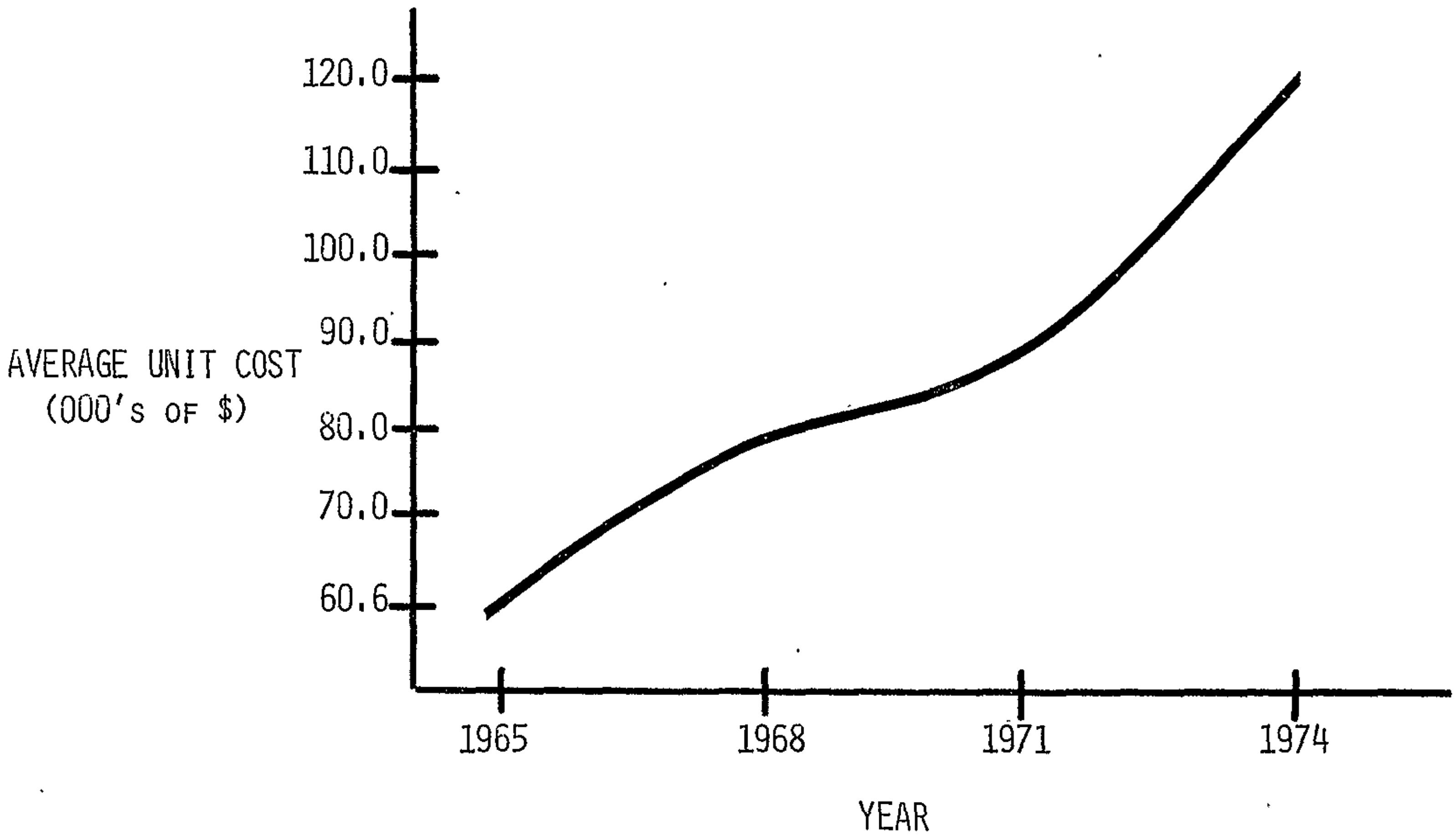


FIGURE VII-13

HEAVY TWIN-ENGINE AIRCRAFT

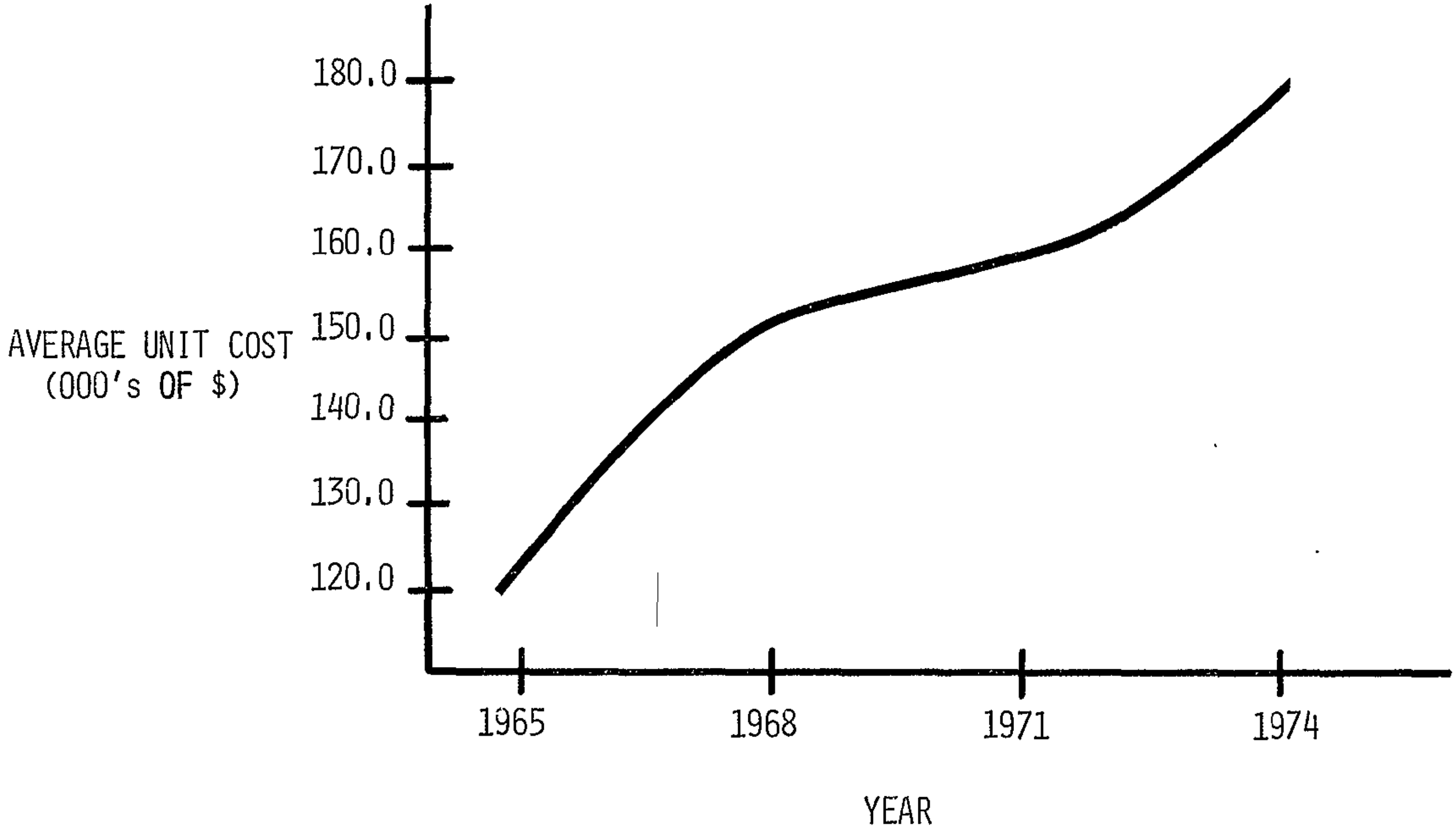


FIGURE VII-14

TURBOPROP AIRCRAFT

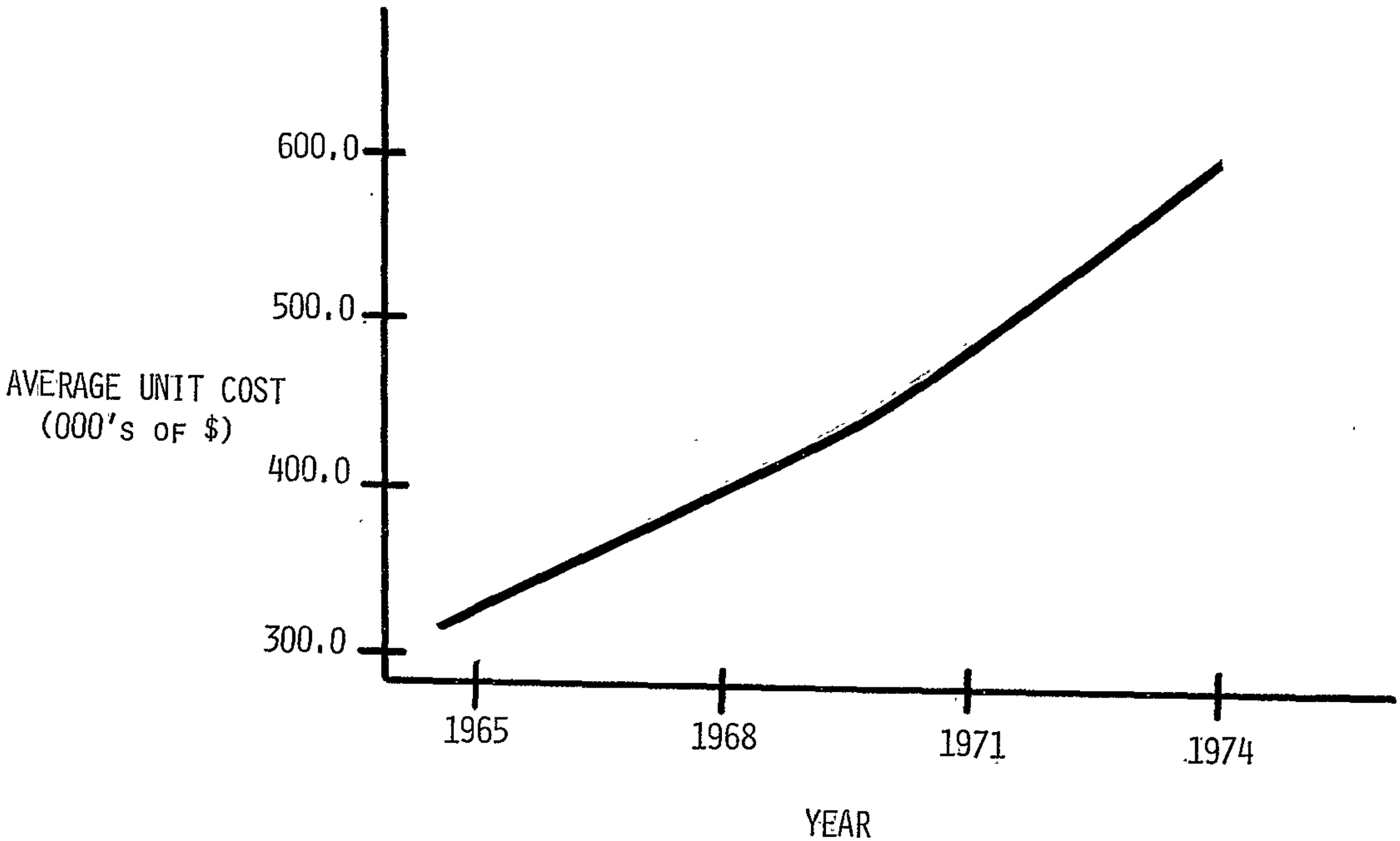
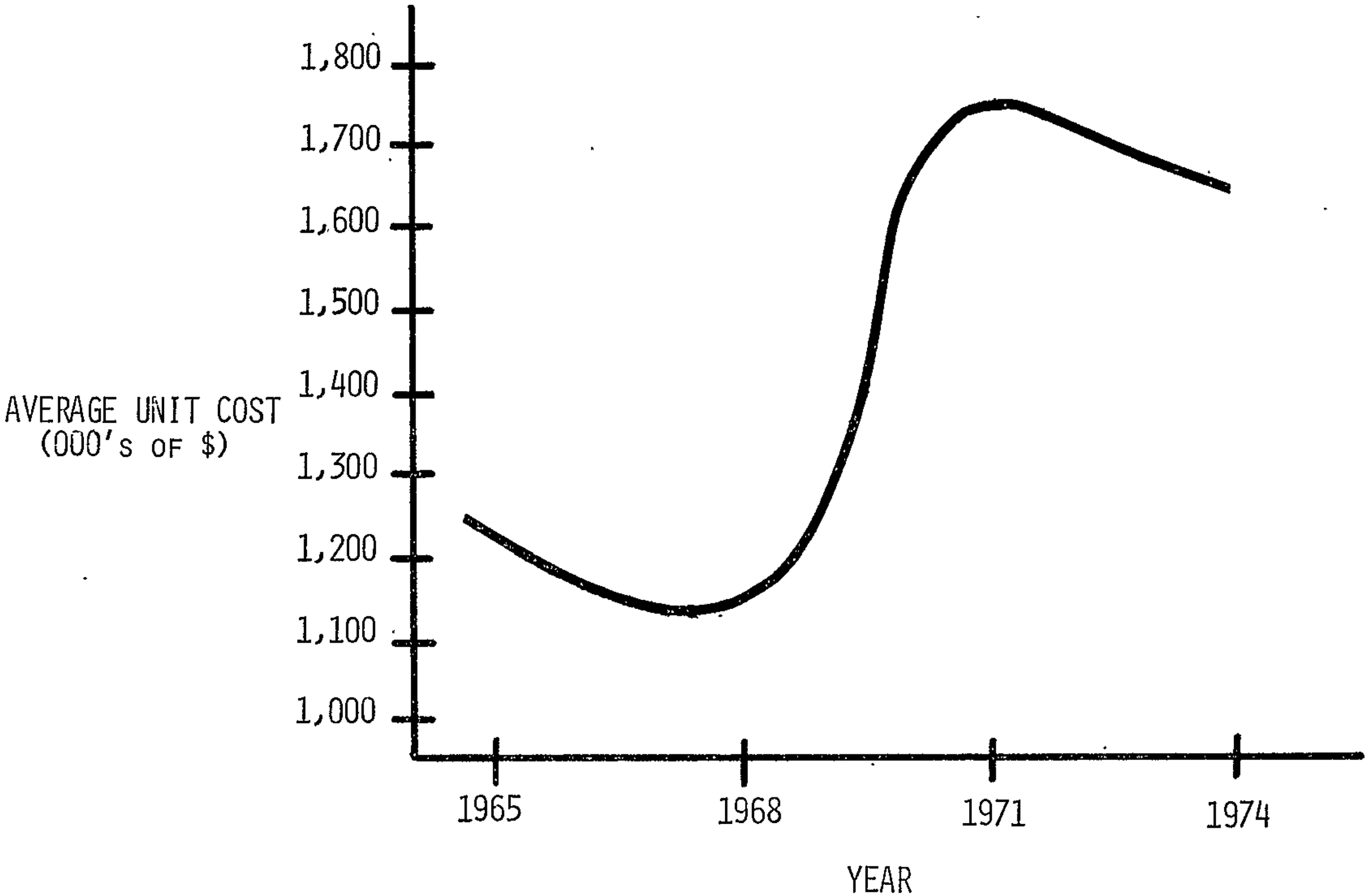


FIGURE VII-15

TURBOJET AIRCRAFT



Once the historical price trends of aircraft were quantitatively established, they were modified by more qualitative judgments of the present market status and anticipated product developments to arrive at projected cost trends. These judgments were based on interviews and discussions with the aircraft manufacturers as well as with other industry representatives to allow us to project into the future. These trends and the resultant cost projections by aircraft category are shown in Figure VII-16.

3. Avionics Complement and Cost Share

Figure VII-17 is a matrix of avionics distribution for 1972. As the matrix breaks down unit representation for the five categories of aircraft by percentage, total units in any class can be determined by multiplying the percentage figure by the total figure at the bottom of the column.

The data in Figure VII-18 forms the basis for the cost share analysis of avionics. Summing the total costs of factory-installed and field retrofit avionics and dividing this figure by the total aircraft delivered in the category yields the total cost of the avionics complement.

One problem with the use of this data is that approximately 40% of the avionics installed in the field go into used or older aircraft. This may result in an over-evaluation of the avionics package by up to 20%. However, no reliable industry figures exist on field avionics installations in the older aircraft to enable the elimination of the over-evaluation. Therefore, an analysis was made and it was determined that the maximum error attributable to this source would be a 3% high cost for the total equipped aircraft. It was decided to accept this higher source but to recognize that an error could exist.

Combining the average cost of avionics complement with the average aircraft cost, the avionics cost share was calculated for 1972. This data, by aircraft cost, is shown in Figure VII-19. It is significant that the avionics package contributes up to one-fifth of the total cost in the single-engine and heavy twin aircraft versus one-eighth in other categories of the fleet.

FIGURE VII-16

GENERAL AVIATION PRICE PROJECTIONS - FIXED WING AIRCRAFT

(000'S OF $)

AIRCRAFT TYPE	ANNUAL % INCREASE	AVERAGE UNIT COSTS 1975	1977	1979	1981	1983	1985
SINGLES							
• LIGHT	3.6	19.4	20.8	22.3	24.0	25.7	27.6
• MEDIUM	4.1	26.3	28.5	30.4	33.5	36.3	39.4
• HEAVY	4.7	41.3	45.2	49.6	54.4	59.6	65.3
TWINS							
• LIGHT	4.9	67.8	74.6	82.2	90.4	99.5	109.4
• MEDIUM	6.1	135.0	152.1	171.1	192.6	216.9	244.1
• HEAVY	2.4	188.6	197.8	207.3	217.4	228.0	239.0
TURBOPROPS	6.1	673.1	758.0	858.2	960.2	1,081.1	1,217.0
TURBOJETS	5.0	1,816.0	2,005.8	2,210.6	2,438.4	2,687.7	2,963.4

FIGURE VII-17

AVIONICS INSTALLATIONS IN GENERAL AVIATION AIRCRAFT

1972

(% OF AIRCRAFT SECTOR)

AIRCRAFT SECTOR	ANNUAL % OF AVIONICS EXPENDITURES	COMMUNICATION: VHF #1	VHF #2	HF	ATCRBS	AUTO. ALTITUDE REPORT.	ELT	UHF PHONE
LIGHT SINGLE	14%	27	1	-	20	-	27	-
MEDIUM-HEAVY SINGLE	9	56	57	13	62	9	42	-
LIGHT/MEDIUM TWIN	38 (with Heavy Twin)	15	37	69	15	32	29	54
HEAVY TWIN		1	2	5	1	18	1	-22
TURBOJET	39	1	3	13	2	41	1	24
	100%	100%	100%	100%	100%	100%	100%	100%
TOTAL UNITS (In Thousands)		116.1	44.6	5.4	72.1	2.2	18.8	1.8

AIRCRAFT SECTOR	NAVIGATION: ADF	VOR #1	VOR #2	DME	RADAR ALTIMETER	HYPERBOLIC (LORAN)	DOPPLER	INERTIAL	R/NAV	V/NAV	ILS	VLF
LIGHT SINGLE	16	26	1	2	-	-	-	-	-	-	1	-
MEDIUM-HEAVY SINGLE	57	56	57	56	5	-	-	-	8	-	55	-
LIGHT/MEDIUM TWIN	23	16	37	37	74	23	-	8	79	33	39	100
HEAVY TWIN	2	1	2	3	5	31	29	23	8	17	2	-
TURBOJET	2	1	3	2	16	46	71	69	5	50	2	-
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
TOTAL UNITS (In Thousands)	70.7	115.1	42.8	25.0	6.45	.13	.17	.26	1.2	.06	42.15	.02

AIRCRAFT SECTOR	INSTRUMENTATION: DUAL INDEP. ALT, ATT.	AIR DATA SYSTEM	RECORDERS	ENGINE MONITORS	WEATHER RADAR	FLIGHT CONTROL: STABILITY AUGMENTATION	AUTOPILOT	CMD AUGMENTATION FLIGHT DIRECTOR	DISPLAYS: ELECTRONIC & DIGITAL	PERIPHERAL	INTEGRATED	ELEC. SOURCE: 14 V DC	28 V DC	40 HZ AC
LIGHT SINGLE	-	-	-	-	-	11	4		-	-	-	30	-	-
MEDIUM-HEAVY SINGLE	-	-	-	-	-	78	56	3	2	-	16	64	3	3
LIGHT/MEDIUM TWIN	47	12	-	40	49	11	28	53	10	17	48	6	73	52
HEAVY TWIN	36	44	54	36	33	-	8	28	60	50	24	-	16	31
TURBOJET	17	44	46	24	18	-	4	16	28	33	12	-	8	14
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
TOTAL UNITS (In Thousands)	6.9	.8	.65	2.5	6.5	38.0	26.9	7.0	1.6	.3	9.38	106.65	16.76	7.91

FIGURE VII-17

AVIONICS INSTALLATIONS IN GENERAL AVIATION AIRCRAFT

1972

(% OF AIRCRAFT SECTOR)

ORIGINAL PAGE IS OF POOR QUALITY

AIRCRAFT SECTOR	ANNUAL % OF AVIONICS EXPENDI-TURES	COMMUNICATION							NAVIGATION											
		VHF #1	VHF #2	HF	ATCRBS	AUTO. ALTITUDE REPORT.	ELT	UHF PHONE	ADF	VOR #1	VOR #2	DME	RADAR ALTIMETER	HYPERBOLIC (LORAN)	DOPPLER	INERTIAL	R/NAV	V/NAV	ILS	VLF
LIGHT SINGLE	14%	27	1	-	20	-	27	-	16	26	1	2	-	-	-	-	-	-	1	-
MEDIUM-HEAVY SINGLE	9	56	57	13	62	9	42	-	67	66	67	66	5	-	-	-	8	-	55	-
LIGHT/MEDIUM TWIN	38	15	37	69	15	32	29	54	23	16	37	37	74	23	-	8	79	33	39	100
HEAVY TWIN		1	2	5	1	18	1	22	2	1	2	3	5	31	29	23	8	17	2	-
TURBOJET	39	1	3	13	2	41	1	24	2	1	3	2	16	46	71	69	5	50	2	-
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
TOTAL UNITS (In Thousands)		116.1	44.6	5.4	72.1	2.2	18.8	1.8	70.7	115.1	42.8	25.0	6.45	.13	.17	.26	1.2	.06	42.15	.02

AIRCRAFT SECTOR	INSTRUMENTATION					FLIGHT CONTROL			DISPLAYS			ELEC. SOURCE		
	DUAL INDEP. ALT, ATT.	AIR DATA SYSTEM	RECORDERS	ENGINE MONITORS	WEATHER RADAR	STABILITY AUGMENTATION	AUTOPILOT	CMD AUGMENTATION FLIGHT DIRECTOR	ELECTRONIC & DIGITAL	PERIPHERAL	INTEGRATED	14 V DC	28 V DC	40 HZ AC
LIGHT SINGLE	-	-	-	-	-	11	4		-	-	-	30	-	-
MEDIUM-HEAVY SINGLE	-	-	-	-	-	78	56	3	2	-	16	64	3	3
LIGHT/MEDIUM TWIN	47	12	-	40	49	11	28	53	10	17	48	6	73	52
HEAVY TWIN	36	44	54	36	33	-	8	28	60	50	24	-	16	31
TURBOJET	17	44	46	24	18	-	4	16	28	33	12	-	8	14
	100%	100%	100%	100%	100%	100%	100	100	100	100	100	100	[illegible]	[illegible]
TOTAL UNITS (In Thousands)	6.9	.8	.65	2.5	6.5	38.0	26.9	7.0	1.6	.3	9.38	106.65	16.76	7.91

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FIGURE VII-18

1972 AVIONICS COST ANALYSIS

TYPE OF AIRCRAFT	AVIONICS INSTALLED IN NEW AIRCRAFT (VALUE)	FIELD INSTALLED AVIONICS (VALUE)	TOTAL AVIONICS INSTALLATIONS (VALUE)	NUMBER OF AIRCRAFT DELIVERED	AVIONICS VALUE/ NEW AIRCRAFT
SINGLES	$20,018,786	$17,858,630	$37,877,415	7,916	$ 4,784
LIGHT	12,185,348	7,813,150	19,998,498	4,476	4,468
MEDIUM-HEAVY	7,833,438	10,045,479	17,878,917	3,440	5,197
TWINS	33,074,516	4,464,657	37,539,173	1,729	21,711
LIGHT	1,653,725	2,232,328	3,886,053	498	7,803
MEDIUM	13,891,296	1,116,164	15,007,460	886	16,938
HEAVY	9,591,609	446,465	10,038,074	224	44,812
TURBOPROPS	7,937,883	669,698	8,607,581	121	71,137
TURBOJETS	33,944,900	--	33,944,900	127	267,283
TOTAL	87,038,200	22,323,288	109,361,489	9,772	

FIGURE VII-19

DISTRIBUTION OF AVIONICS EXPENDITURES

1972

AIRCRAFT SEGMENT	AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT SEGMENT	AVERAGE AIRCRAFT COST	AVIONICS AS A % OF NEW AIRCRAFT COST
SINGLES			
LIGHT	$ 4,468	$ 16,992	20.8%
MEDIUM-HEAVY	5,197	22,622	18.7
TWINS			
LIGHT	7,803	55,089	12.4
MEDIUM	16,938	99,647	13.1
HEAVY	44,812	165,778	21.2
TURBOPROPS	71,137	520,937	12.0
TURBOJETS	267,283	1,721,813	13.3

4. Avionics Price Trends

In order to develop avionics price projections, the recent price history of the following equipment was plotted:

- VHF transceivers
  - NAV/COM
  - COM
- VHF receivers
  - NAV/COM
  - NAV
- HF communications
- ATC transponders
- Automatic direction finders (ADF)
- ILS glideslope
- Distance measuring equipment (DME)
- Autopilots
  - 1 and 2 axis
  - 3 axis
- Radar altimeters

Pricing analyses for avionics were divided into the categories shown previously in Figure VII-4. A ten-year in-depth pricing analysis of these avionics reveal the intrinsic relationships of equipment cost with aircraft demand (sales).

a. VHF Receivers and Transceivers

Four system types were studied, i.e., NAV/COM and COM transceivers, and NAV/COM and NAV receivers. As a thoroughly developed avionics package, these systems serve as a reference not only for analytical approach verification, but also as indicators of pricing behavior in a widely fluctuating aircraft sales market. As shown in Figures VII-20 through VII-23, the ten-year price profile is very stable with each of the three classes of equipment (non-TSO, TSO and TSO-ARINC) reliably tracking the market sales influences.

(1) Non-TSO Equipment

Sales of this category of equipment follow single and light twin aircraft market demand patterns. The gradual slope of each curve indicates the well-developed, intensive share of the aircraft market held by single-engine aircraft. Competition is intense and DSC expects no great fluctuation in pricing or sales of these products, barring a technological breakthrough.

Since these profiles are in current dollars, the application of constant dollar manipulations would show the classical pattern of a decreasing unit cost for this category of equipment over the ten-year span due to steady improvements in design and value engineering. This aspect, and the strong correlation of the derived data points (and curve) to both aircraft demand trends and price stability, verifies the integrity of the overall analytical approach.

(2) TSO Equipment

This equipment is mainly applicable to medium-heavy twins and similar high-performance aircraft. The curves for VHF avionics indicate a steady, strong demand for these systems despite a sharply curtailed aircraft sales picture since 1969. This would indicate a substantial retrofit market offsetting a decrease in OEM installations. As with the non-TSO'd equipment, real price profiles (inflation removed) would result in decreasing unit prices, as expected for these items.

FIGURE VII-20

AVIONICS: VHF TRANSCEIVERS - NAV/COM

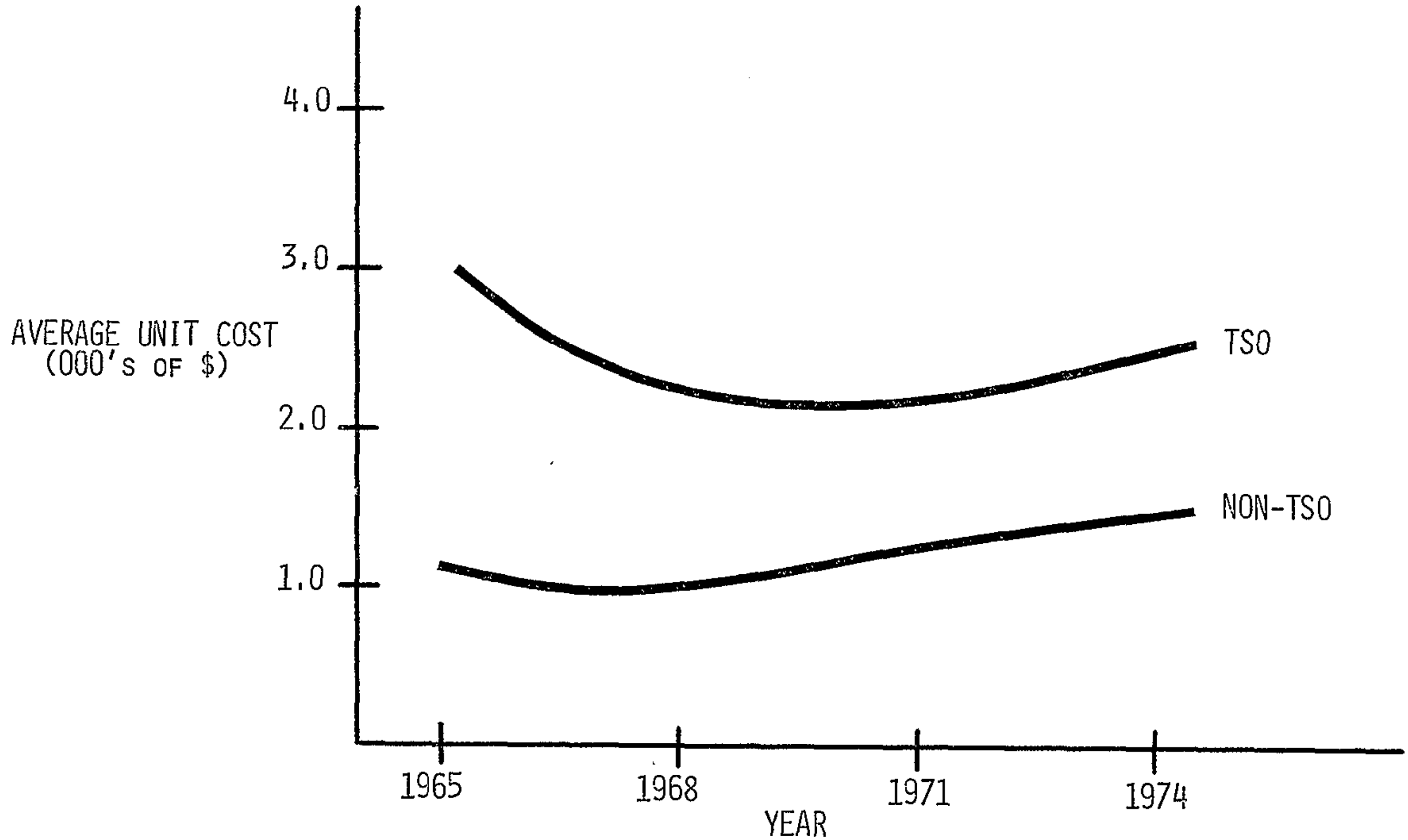


FIGURE VII-21

AVIONICS: VHF TRANSCEIVERS - COMMUNICATIONS ONLY

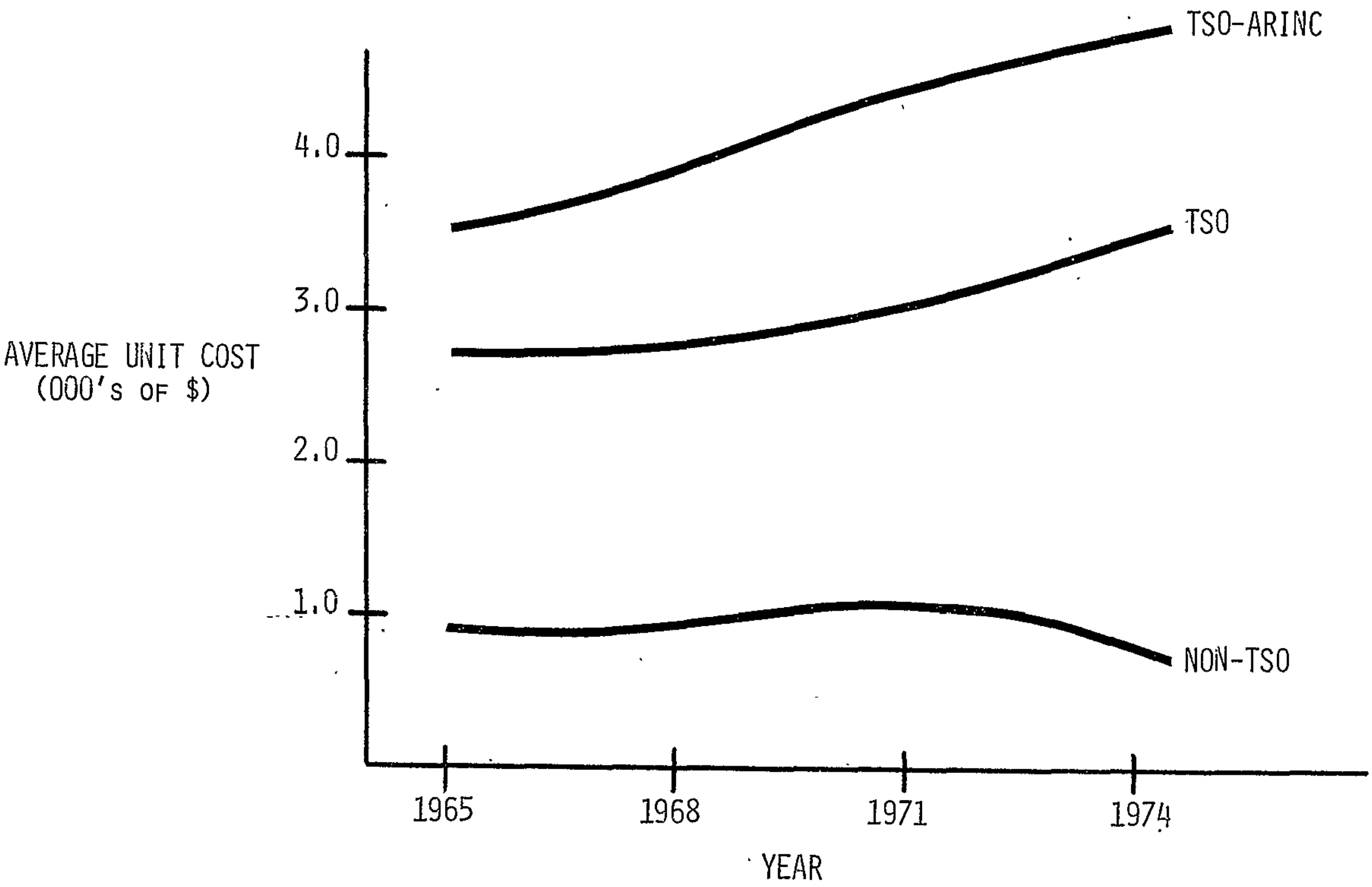


FIGURE VII-22

AVIONICS: VHF RECEIVERS - NAV/COM

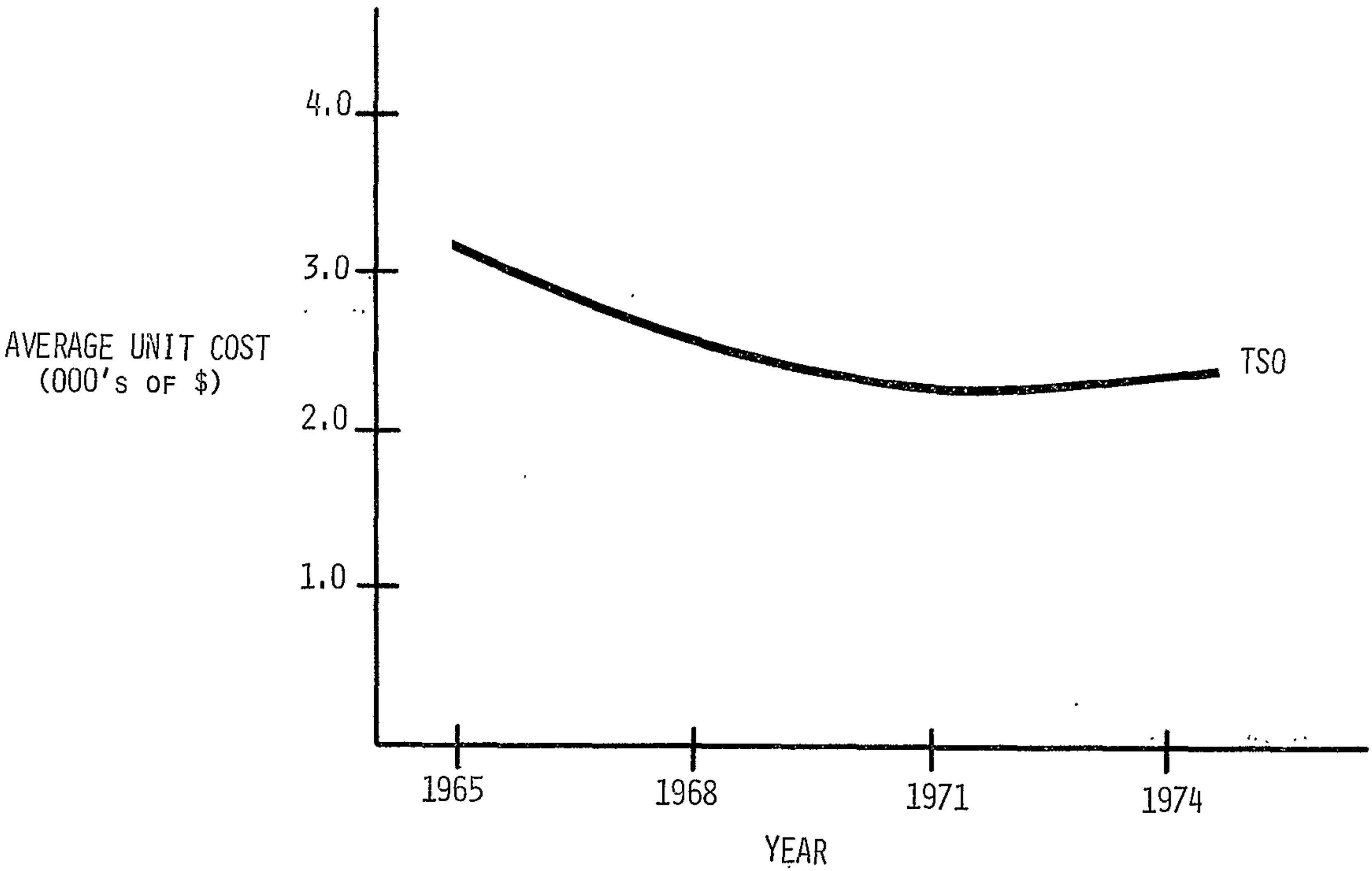
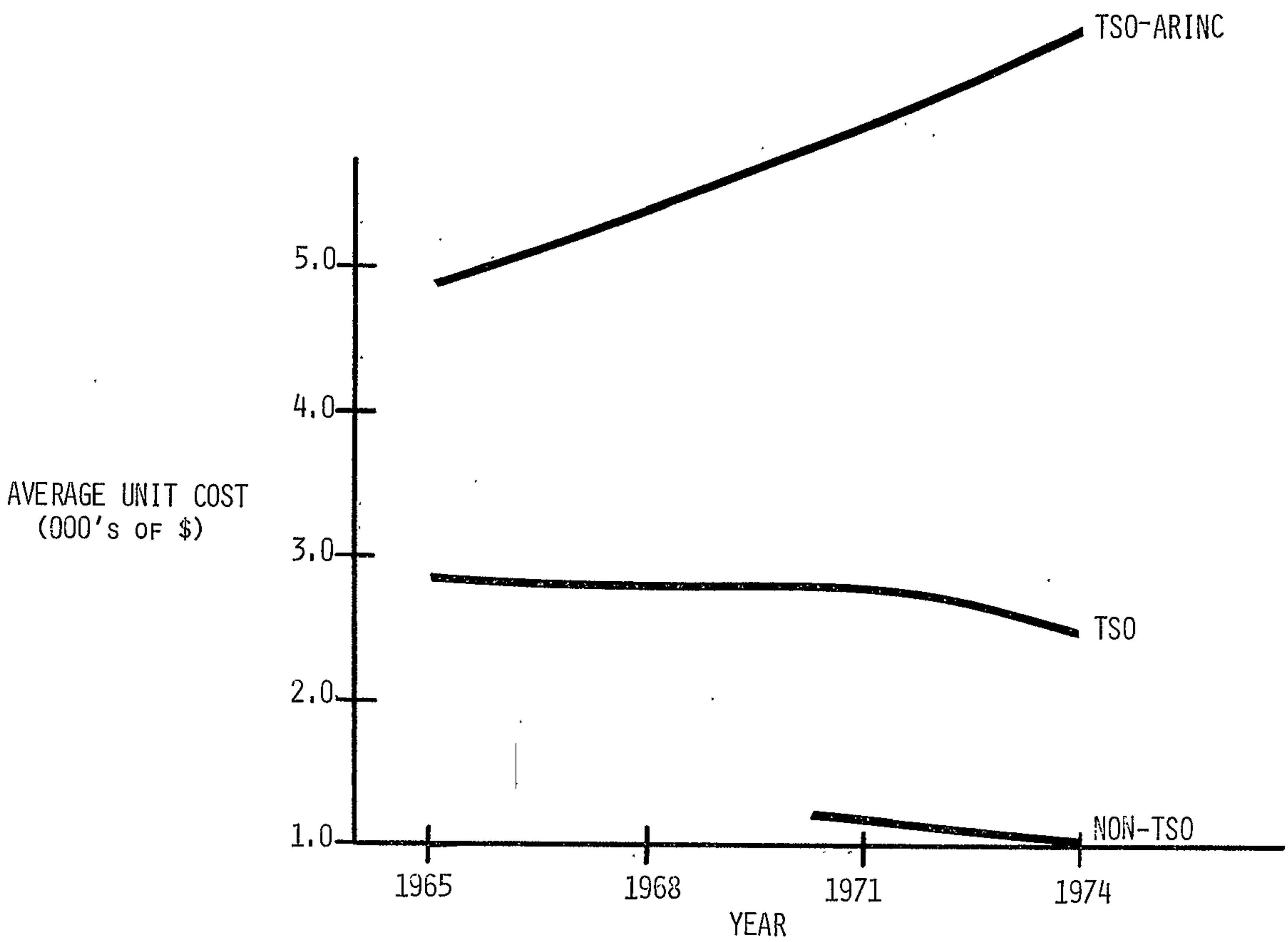


FIGURE VII-23

AVIONICS: VHF RECEIVERS - NAVIGATION ONLY



b. HF Communications

This equipment has experienced essentially the same patterns of sales and costs as the VHF NAV/COM transceivers, with prices and demand very stable (see Figure VII-24). In terms of constant dollars, the average unit price has been decreasing consistently. The primary market for HF communications lies in the combined category of heavy singles and light twins.

Estimated Market Distribution of Installed HF Communications (1/1/73)	
Heavy Singles	13%
Twins	63%
Turboprops	12%
Turbojets	12%

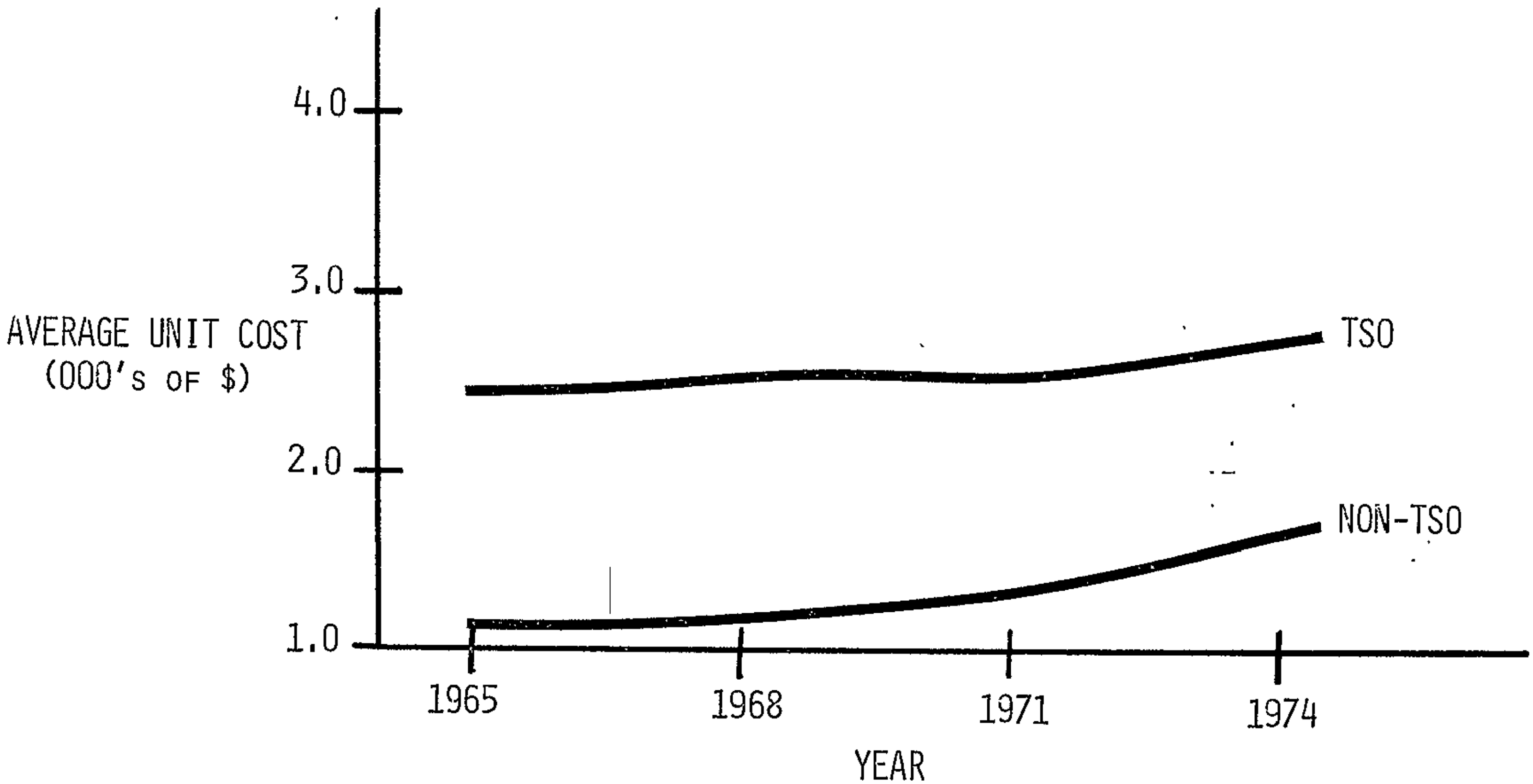
These figures support the trends in price variability in that the largest market components (i.e., singles and twins) expect product pricing policies to remain competitive.

c. ATC Transponders

Transponder installations have increased five-fold during the pricing analysis study period. These units and their pricing history represent the expected developmental impacts on price of a new product filling a major void (aircraft/ground control interface, in this case) in flight operations. Initial acceptance and employment by the heavier classes of aircraft has been followed by design breakthroughs and engineering improvements resulting in penetration to all markets. It can be seen

FIGURE VII-24

AVIONICS: HF COMMUNICATIONS



in Figure VII-25 that the non-TSO'd products have been dramatically reduced in price to reach the most price-sensitive markets, encouraging non-regressive approaches to legislating safety requirements to the entire aircraft fleet.

The TSO and TSO-ARINC unit prices track the aircraft sales record and reflect the demand increases for more costly market segments. There still seems to be a lagging competitive market in the higher priced lines. This, when coupled to the high sales volumes in heavy twins, turboprops and turbojets, results in higher average price increases during the early Seventies (shown in Figure VII-25). Market penetration of transponders is shown below:

Estimated Market Distribution of Installed ATC Transponders (1/1/73)	
Light Singles	19%
Medium-Heavy Singles	63%
Twins	14%
Turbojets and Turboprops	4%

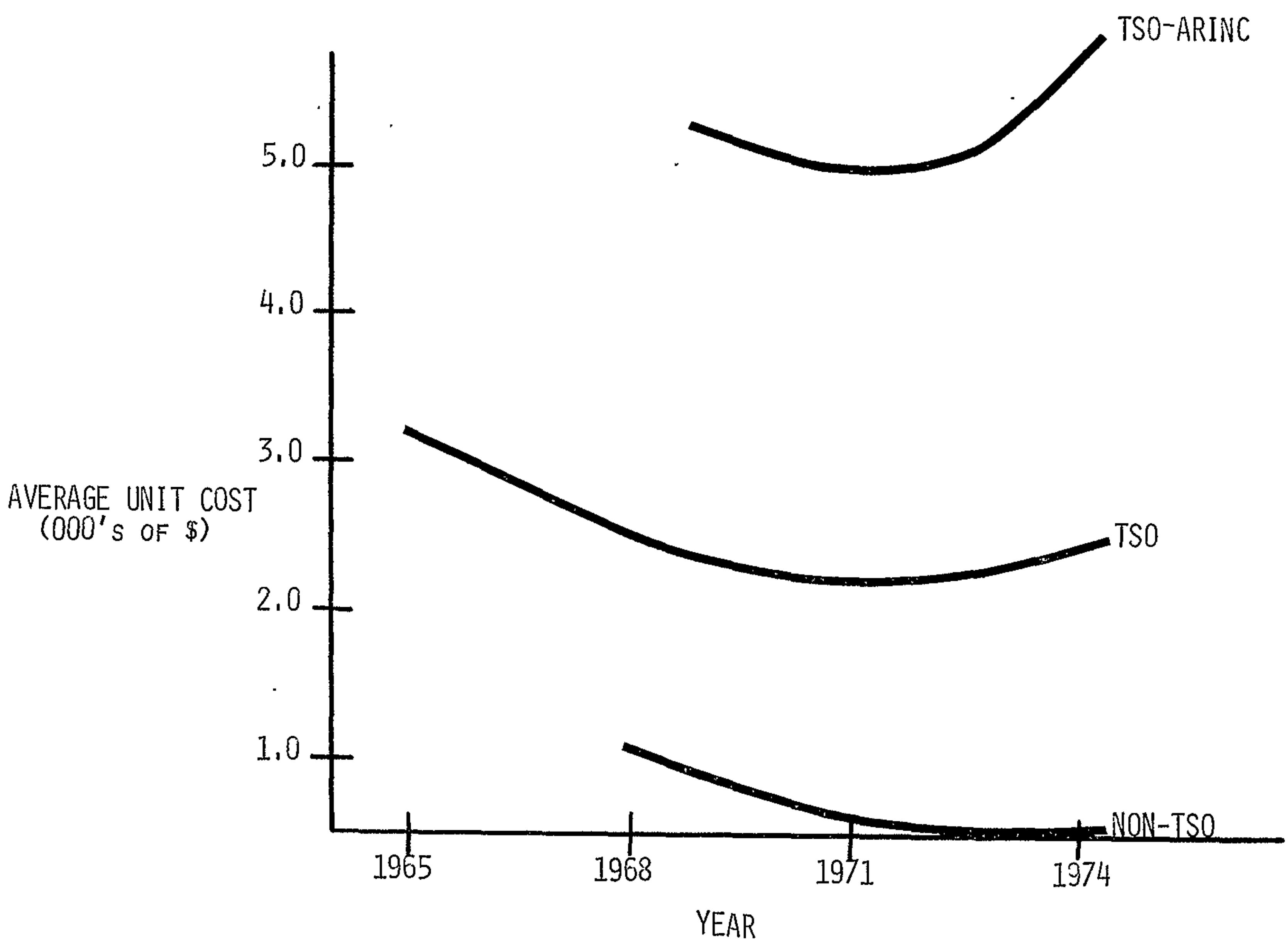
Major increases in sales to the single- and twin-engine aircraft are projected through the 70's, with further significant unit price reductions unlikely.

d. Automatic Direction Finders (ADF)

ADF unit prices for the NON-TSO and TSO qualified lines follow similar trends of other fully-developed avionics equipment, i.e., VHF transceivers. However, the TSO-ARINC pricing patterns support the

FIGURE VII-25

AVIONICS: ATC TRANSPONDERS



lack of competition theorem developed previously (see Figure VII-26). With prices held at attractive levels for TSO and non-TSO equipment over the ten-year analysis period, it might be postulated that all aircraft markets for this product may be saturated in terms of cost-benefit to pilots of smaller aircraft.

e. ILS Glideslope

As with the other avionics, this equipment has tracked aircraft sales, remaining competitively priced in the TSO and non-TSO'd lines. Due to the larger number of integrated packages becoming available, the separate units are likely to remain at current price levels (see Figure VII-27), and ultimately disappear as marker beacon receivers and glideslope are integrated into other packages, particularly VHF NAV units. With over 90% of all twins and 100% of the heavy aircraft already equipped, this integration, and inevitably the resulting price structure due to increased efficiency, further penetration into the singles market component (now at less than 25%) can be expected during the projection period (to 1985).

f. Distance Measuring Equipment (DME)

No major changes in the basic approaches for non-TSO'd hardware are reflected in Figure VII-28, while TSO prices are tending sharply upward due to the shift to remote mountings in mid-range priced aircraft. TSO-ARINC lines are reasonably stable, their initial designs having been fully developed by a number of firms capable of holding the price line to preserve their respective market shares.

g. Autopilots

In this category, 1- and 2-axis versions were reviewed along with 3-axis models. The latter configuration is limited, from a practical sense, to larger, high-priced aircraft where completely integrated flight control systems are the eventual goal, either through incremental additions to a modular system or an all-up system. As such, tracing the pricing of 3-axis systems is difficult; however, 1- and 2-axis systems were analyzed, as shown in

FIGURE VII-26

AVIONICS: ADF

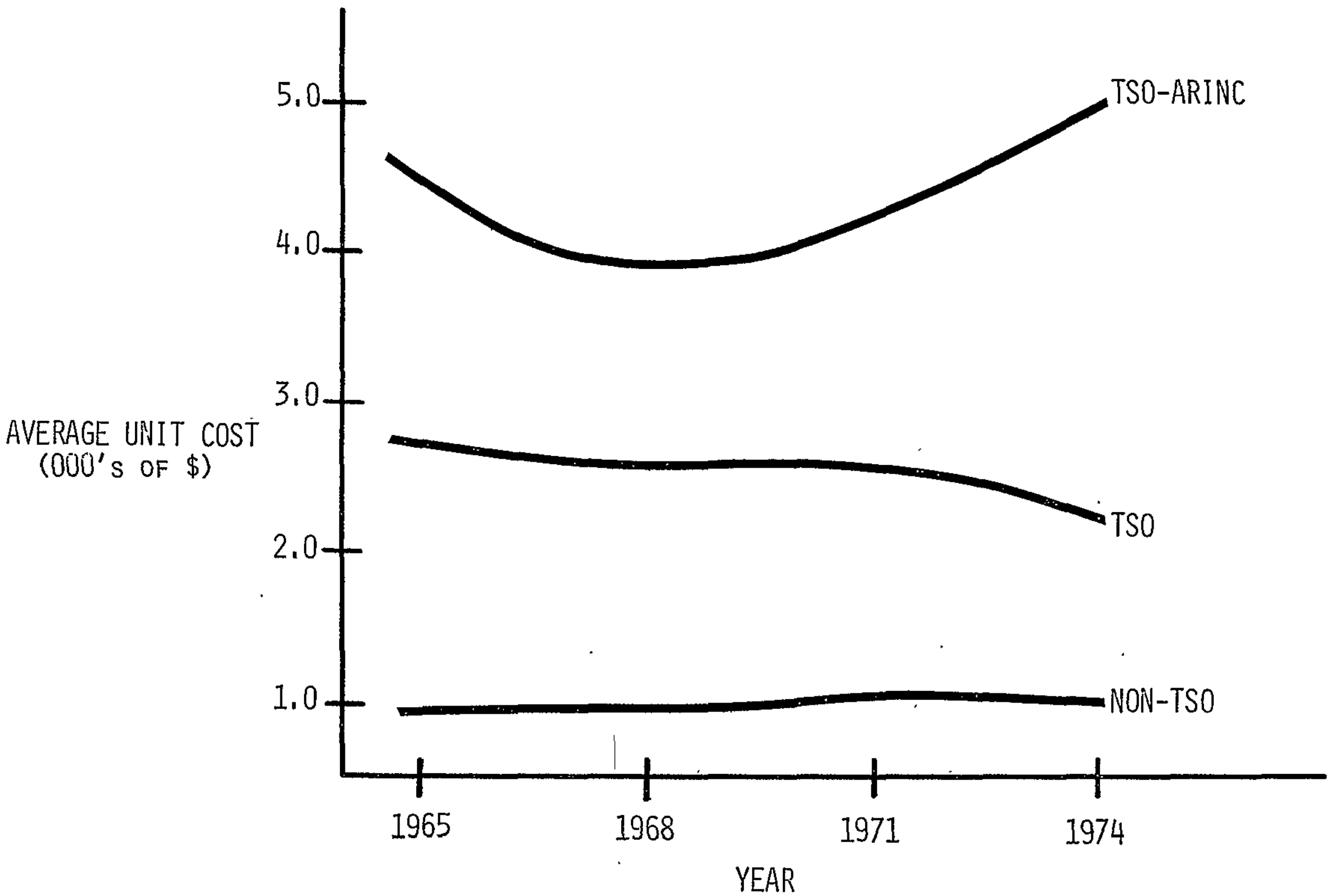


FIGURE VII-27

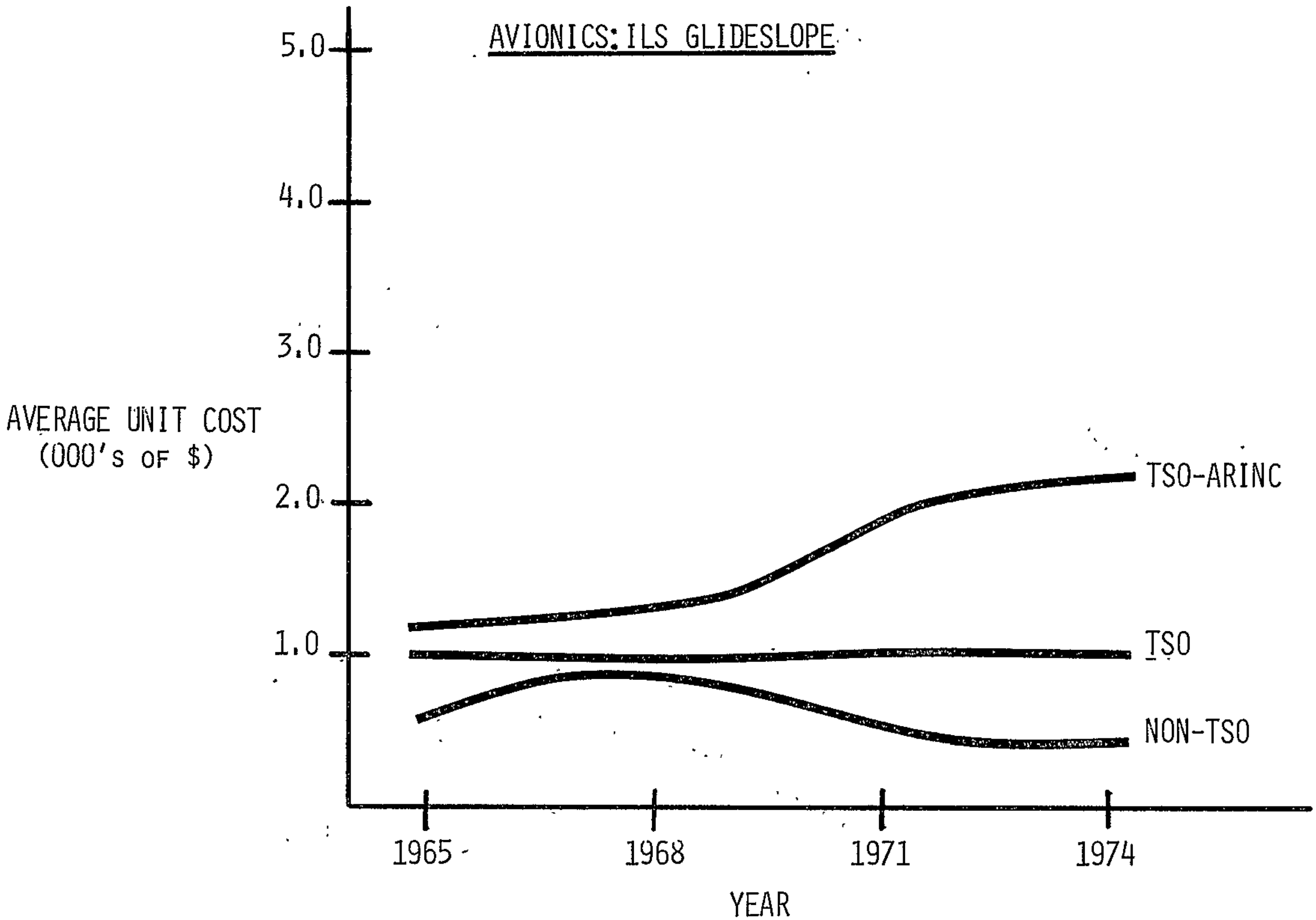


FIGURE VII-28

AVIONICS: DME

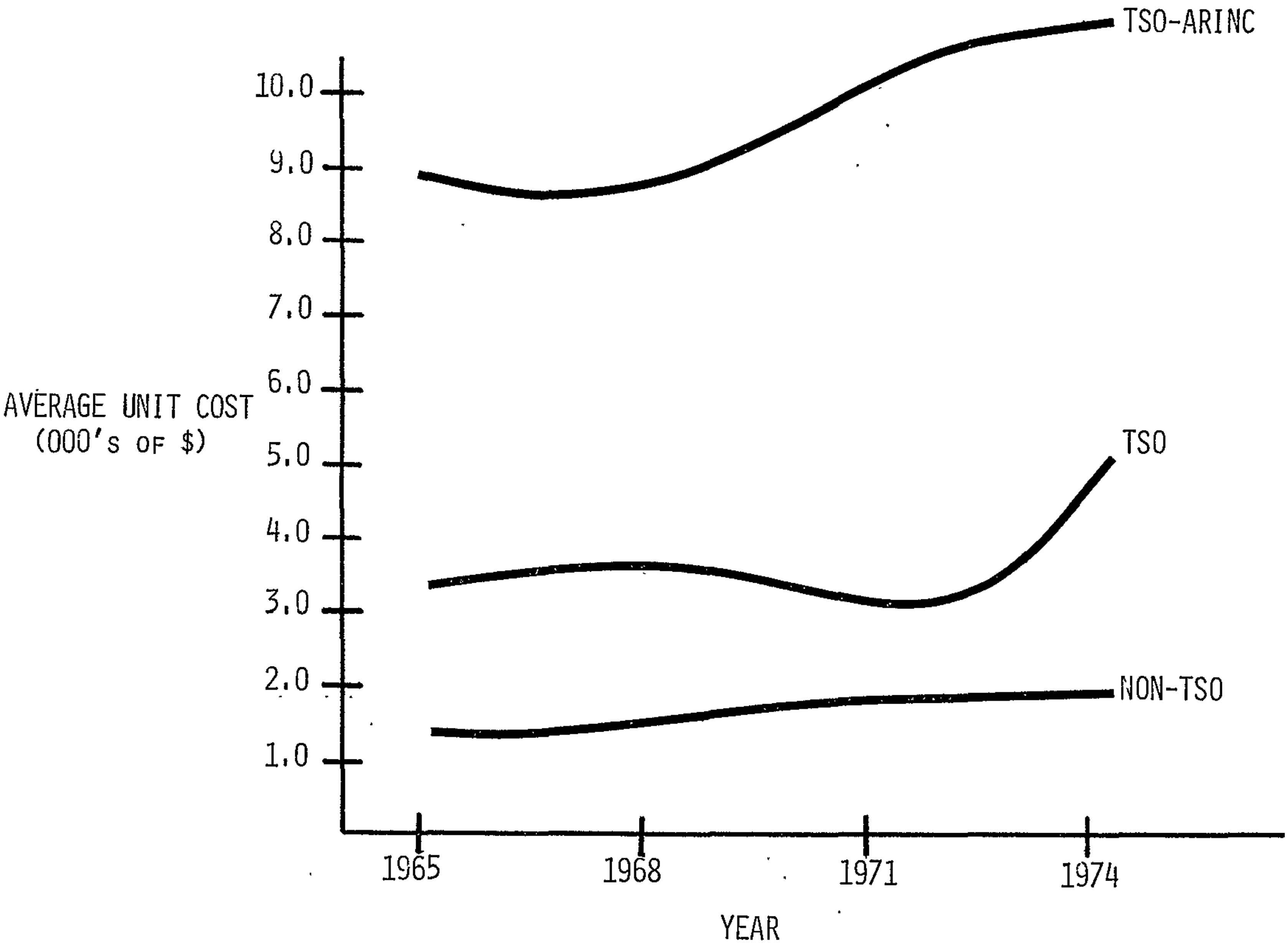


Figure VII-29. The trends indicate the effect of changing design approaches, most probably impacted by uncertainties in attracting lower-middle and middle-priced aircraft.

h. Radar Altimeters

These units are now undergoing significant redesign for inclusion in integrated systems. As such, the beginnings of higher efficiency in packaging and adaption to other electronics, particularly flight directors, are impacting both non-TSO and TSO-ARINC lines, as shown in Figure VII-30. Segregation of both these categories is seen to conflict due to the technology involved and the lack of significantly different alternatives needed to justify quality levels at separate price ranges. Remaining markets (singles, light twins) will be served by single-capability units priced at approximately $4,500.

5. Avionics Projections

Based on these historical trends, price projections were developed, and modified by the qualitative feedback from interviews with those in the industry. DSC forecasts of increases (or decreases) by equipment qualification and function are shown below:

ANNUAL ESTIMATED AVIONICS PRICE CHANGES 1974-1985 (%)

	Non-TSO	TSO	TSO-ARINC
By Equipment Qualification	+1.29	-0.39	+2.86
By Function			
• Navigation	+0.64	-0.75	+3.62
• Communication	-0.50	-0.64	+3.25
• Flight Control	+7.50	N/A	+0.95

FIGURE VII-29

AVIONICS: AUTOPILOT
1- AND 2-AXIS

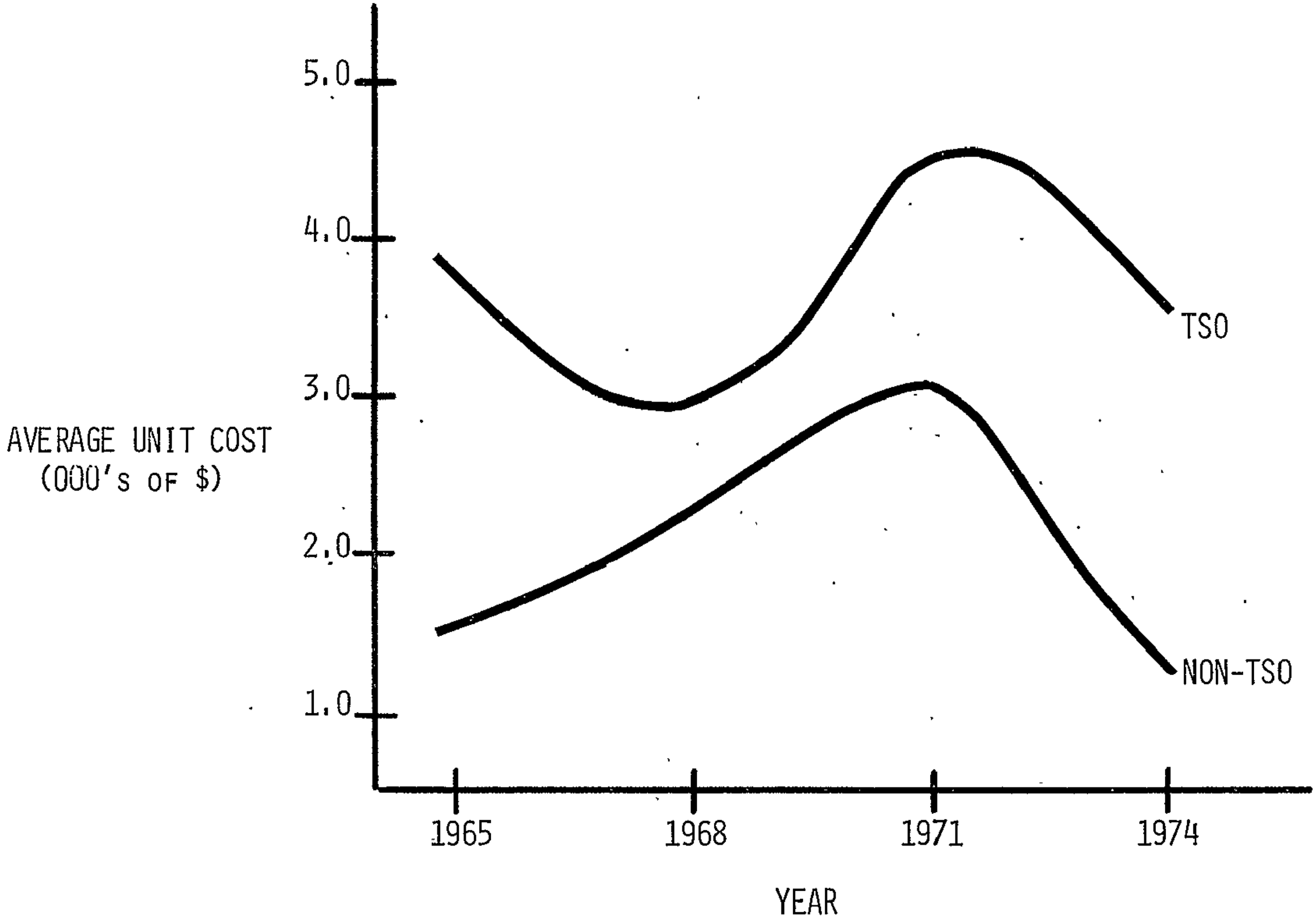
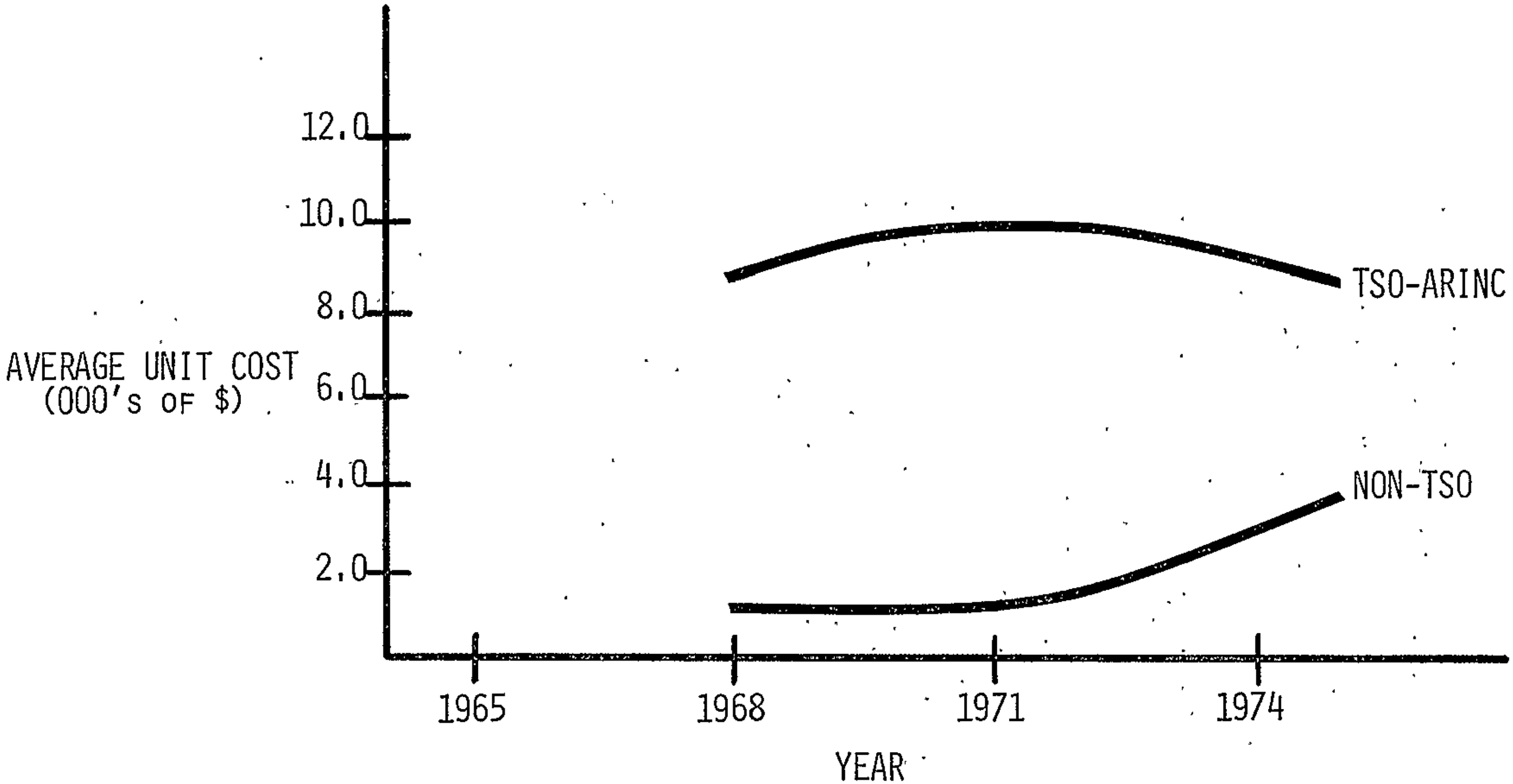


FIGURE VII-30

AVIONICS: RADAR/RADIO ALTIMETERS



The next step was to derive actual cost forecasts for the avionics complements for each class of aircraft. Figure VII-31 displays these results where a weighted percentage, according to the functional makeup of each aircraft's complement, has been applied to the base complement dollars as developed in Figure VII-18.

Finally, the demand for the various systems whose cost trends were analyzed in Section 4 of this chapter were projected to 1985. DSC apportioned the units by avionics complement to our forecast of fleet sales to develop Figure VII-17 shown previously. This data was combined and is shown in Figure VII-32, displaying projected equipment sales for 1985.

6. Avionics Expansion Funds

The final effort undertaken in this sensitivity analysis was to determine the funds available within each aircraft segment for expanded avionics capabilities, as well as for new equipment. This analysis allows us to establish the level of available funds for avionics in the fleet and the portion which can absorb new products and/or price increases. Two assumptions were made:

(1) The total equipped aircraft cost would be the dominant factor in future costs.

(2) Today's avionics cost share of aircraft total cost would remain constant.

The first assumption suggests that the total equipped aircraft costs will rise as a function of the growth percentages forecast presented in Figure VII-16. This is not an unrealistic assumption since the purchaser generally looks at the aircraft and avionics as a total package—the major portion being the aircraft which has the largest impact on price.

The second consideration assumes that the purchaser will continue to relate his expenditures for avionics to a percentage of the total aircraft value, as calculated in Figure VII-19. Therefore, any variation in available avionics funds due to differences in the rates of the avionics complement costs increase would be translated as available for additional avionics capability. It should be noted that this money

FIGURE VII-31

PROJECTED AVIONICS EXPENDITURES - 1975-1985

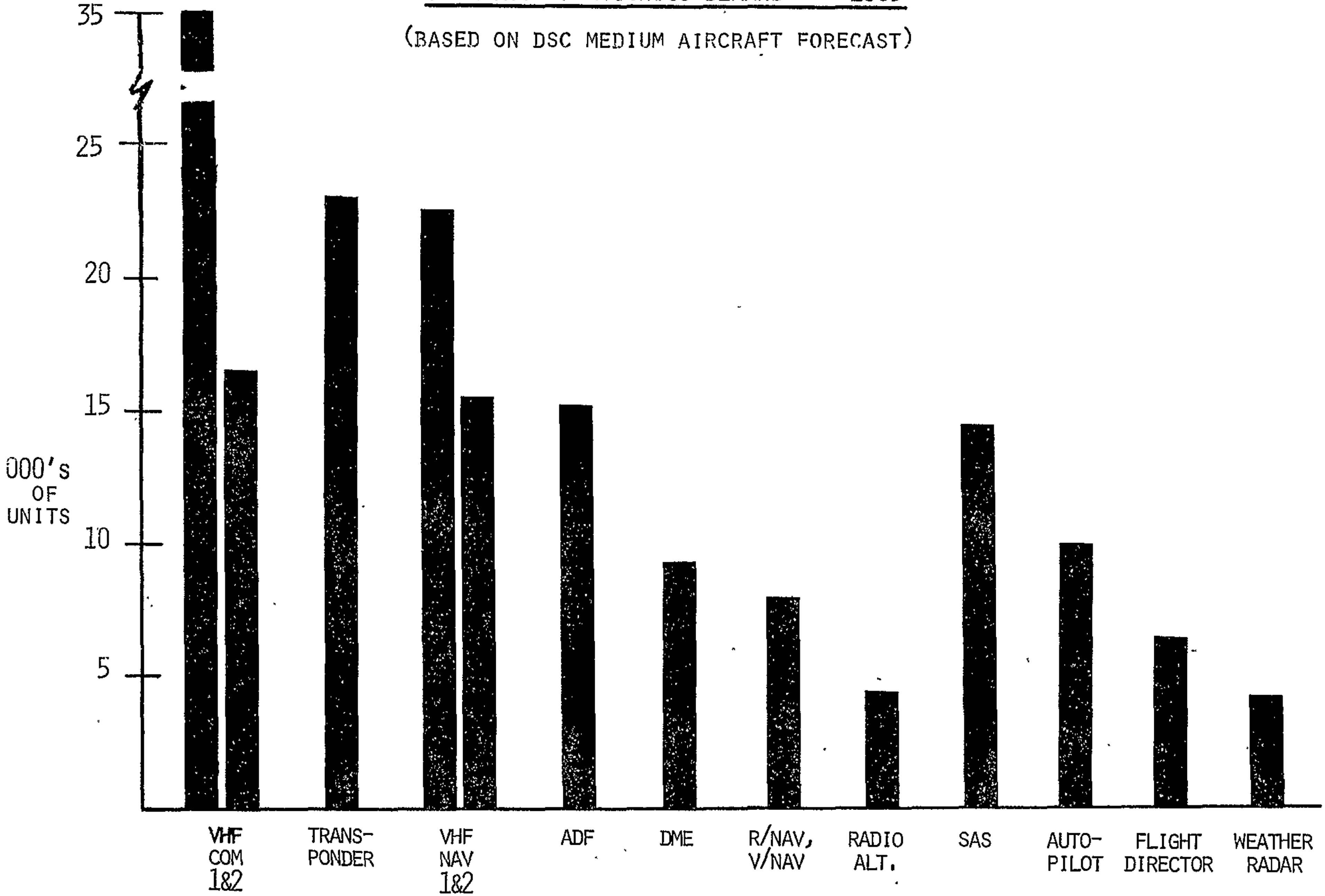
(000's OF $)

AIRCRAFT TYPE	AVIONICS $ IN 1972	1975	1977	1979	1981	1983	1985
SINGLES							
LIGHT	4.47	4.72	5.00	5.30	5.61	5.94	6.26
MEDIUM-HEAVY	5.20	5.42	5.75	6.08	6.44	6.82	7.18
TWINS							
LIGHT	7.80	7.94	8.08	8.23	8.37	8.53	8.68
MEDIUM	16.94	16.81	16.69	16.56	16.43	16.30	16.18
HEAVY	44.81	47.05	49.29	51.53	54.45	57.14	60.00
TURBOPROPS	71.14	75.26	79.60	84.23	89.06	94.26	99.73
TURBOJETS	267.28	182.79	299.09	316.46	334.64	354.15	374.73

FIGURE VII-32

FORECAST OF AVIONICS DEMAND - 1985

(BASED ON DSC MEDIUM AIRCRAFT FORECAST)



"would be available" but would only be spent on a discretionary basis by the individual purchaser who would evaluate that expenditure in terms of his demand factors (outlined in Figure VII-1). The specific estimates of funds available for avionics by aircraft class are shown in Figures VII-33 through VII-39.

A forecast of the price range for avionics by aircraft class in 1980 and 1985 can be seen in Figures VII-40 and VII-41. The overlaps at the low and high ends are indicated by the peaks and depressions occurring between each aircraft type. Turbojet and turboprop avionics prices are coincidental over the common range of values suggesting the high similarity or applicability of some avionics packages.

B. IMPACT ANALYSIS

The purpose of this portion of the DSC study was to determine what effects future avionics will have on the aircraft within the general aviation category. The potential effects have been subdivided into those of aircraft design and aircraft cost.

1. Aircraft Design

Aircraft design is primarily determined by such considerations as lift, thrust, weight, drag and handling characteristics, and the avionics complement will have an effect on the aircraft inasmuch as it affects one of these parameters.

To determine the effect of future avionics developments, the areas of weight, electrical power, airframe considerations and instrument panel layout were addressed. The top 15 items recommended for NASA's effort by DSC's panel of experts are qualitatively ranked for their impacts in Figure VII-42.

FIGURE VII-33

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE:
LIGHT SINGLES

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	24.1	25.8	27.6	29.6	31.6	33.9
% AVIONICS	19.5	19.3	19.2	18.9	18.7	18.4
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	0.31	0.38	0.47	0.56	0.66	0.81

FIGURE VII-34

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: MEDIUM-HEAVY SINGLES

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	39.2	42.6	47.0	50.3	54.7	59.5
% AVIONICS	13.8	13.4	12.9	12.8	12.4	12.0
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	2.07	2.25	2.72	2.96	3.44	3.98

FIGURE VII-35

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: LIGHT TWINS

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	75.7	82.7	90.4	98.8	108.0	118.1
% AVIONICS	10.4	9.7	9.1	8.4	7.8	7.3
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	1.51	2.23	2.98	3.95	4.96	6.02

FIGURE VII-36

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: MEDIUM TWINS

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	151.8	168.8	187.7	209.0	233.2	260.3
% AVIONICS	11.0	9.8	8.8	7.8	6.9	6.0
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	3.18	5.57	8.07	11.0	14.4	18.4

FIGURE VII-37

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: HEAVY TWINS

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	235.6	247.1	258.8	271.9	185.1	299.0
% AVIONICS	19.9	19.9	19.9	20.0	20.0	20.0
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	5.41	5.68	5.95	3.26	3.42	3.58

FIGURE VII-38

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: TURBOPROPS

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	748.3	837.6	942.4	1,049.2	1,175.3	1,316.7
% AVIONICS	10.0	9.5	8.9	8.4	8.0	7.5
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	14.9	20.9	29.2	37.7	47.0	59.2

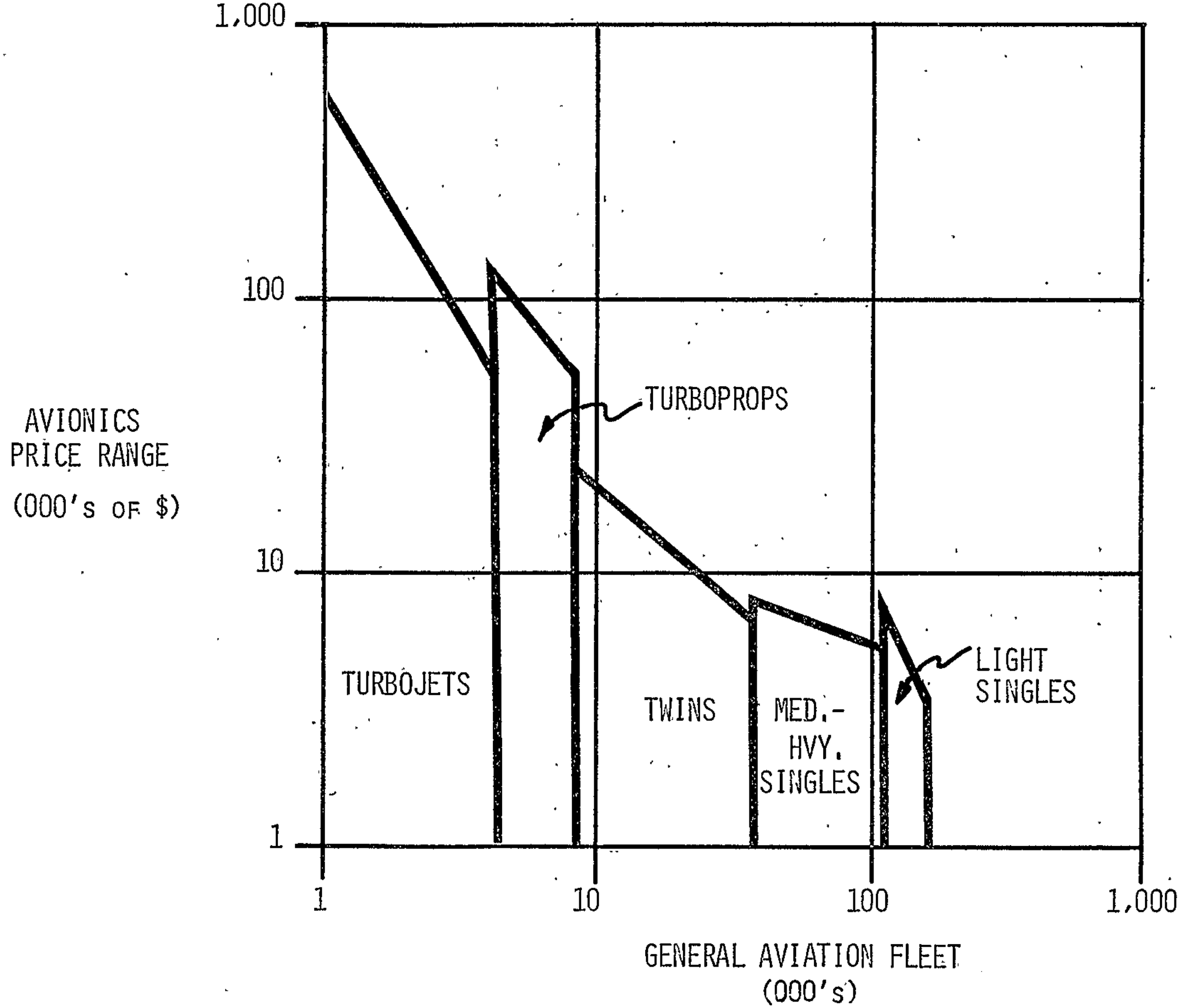
FIGURE VII-39

FORECAST AVERAGE AVIONICS EXPENDITURES BY AIRCRAFT TYPE: TURBOJETS

	1975	1977	1979	1981	1983	1985
TOTAL COSTS (000's OF $)	2,098.8	2,304.9	2,527.0	2,773.0	3,041.8	3,337.1
% AVIONICS	13.4	12.9	12.5	12.0	11.6	11.2
AVAILABLE FUNDS FOR NEW AVIONICS (% BASE YEAR - % PROJECTED YEAR) X TOTAL COST (000's OF $)	--	9.21	20.2	36.0	51.7	70.0

AVIONICS COST VS. AIRCRAFT TYPE - 1980

FIGURE VII-40



AVIONICS COST VS. AIRCRAFT TYPE - 1985

FIGURE VII-41

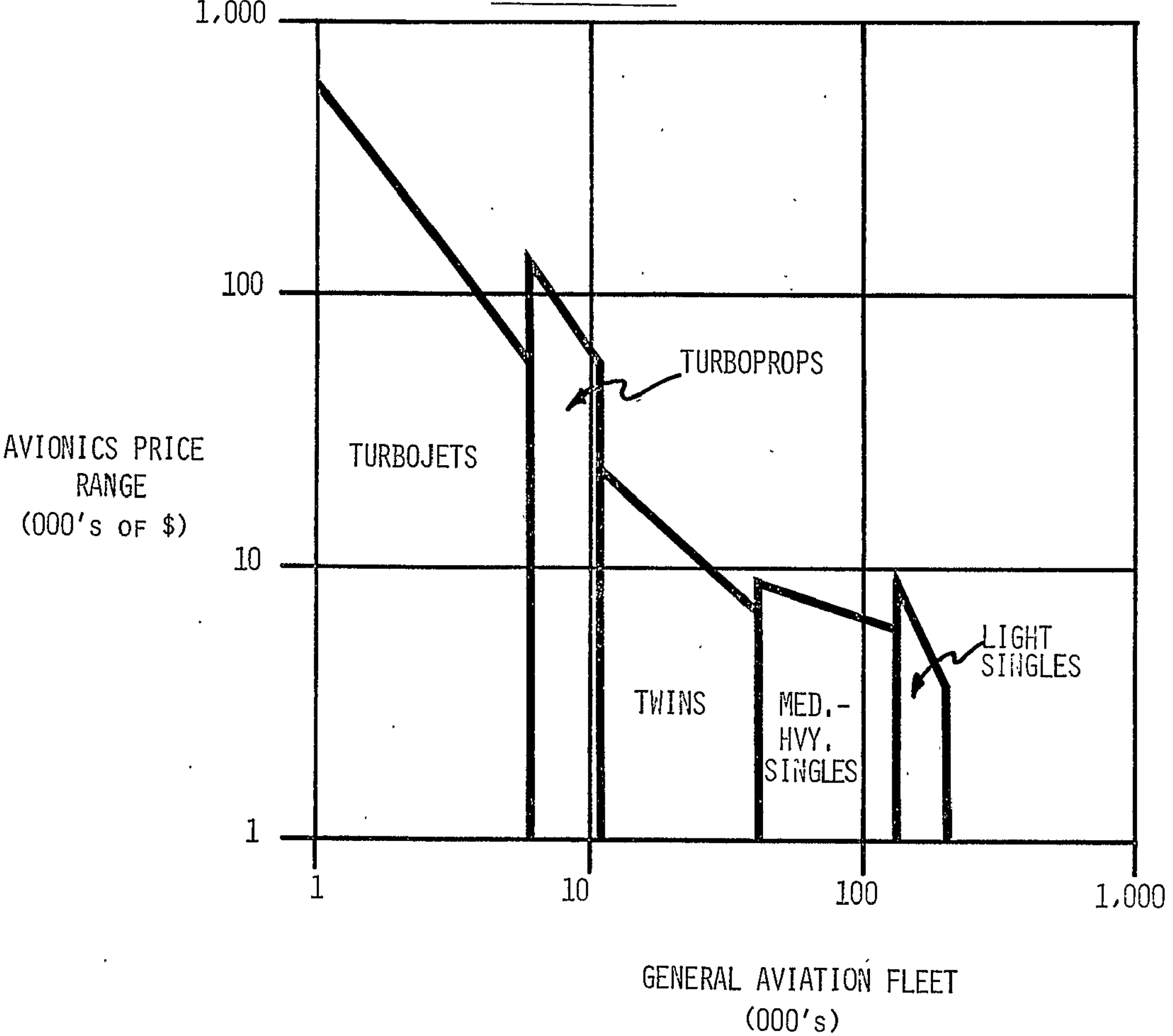


FIGURE VII-42

FORECAST OF EFFECT ON AIRCRAFT WITH THE ADDITION OF NEW AVIONICS

TYPE OF EQUIPMENT	AIRFRAME	WEIGHT	POWER CONSUMPTION	PANEL LAYOUT
INTEGRATED ELECTRONICS MULTI-FUNCTION DISPLAYS	N	D	D	S
RADAR ALTIMETER	C	I	I	N
ELECTRONIC DIGITAL DISPLAYS	N	D	D	S
ENGINE MONITORS	N	N	N	S
CLEAR AIR DETECTOR	N	I	I	C
MICROWAVE LANDING SYSTEM (NOT INCLUDING CONVENTIONAL ILS)	C	I	I	C
ELECTRONIC CRT DISPLAYS	N	I	I	S
PROXIMITY WARNING SYSTEM	N	I	I	C
VLF NAVIGATION	C	I	I	C
AUTOMATIC ALTITUDE REPORTING	C	I	I	N
COLLISION AVOIDANCE SYSTEM	C	I	I	C
WEATHER RADAR	C	I	I	S
V/NAV	C	I	I	S
T/NAV	C	I	I	S
AIR DATA SYSTEM	C	D	D	C

N = NO CHANGE
C = SOME CHANGE
S = SUBSTANTIAL CHANGE
I = INCREASE
D = DECREASE

a. <u>Weight</u>

As weight is a prime consideration in any aircraft, fuel, passengers, baggage, and avionics must be accommodated within the budget of "useful weight." The total fixed weight (aircraft and avionics) establishes the constraints within which the amount of fuel (therefore, distance) versus passengers and baggage is determined.

Figure VII-43 lists typical standard avionics weight totals for various aircraft categories and plots these as a percentage of useful weight. IFR capability consisting of basic navigation and communications equipment as specified by the FAA is included in all but the "Sport and Trainer" category, wherein the avionics equipment is limited to VHF communications and an ADF.

Two significant items can be derived from this information. First, the avionics takes up a minimal percentage of the available useful weight, due to the increasing use of solid-state devices in recent years. Whereas, in the past, a vacuum tube NAV/COM might have weighed 25 pounds, today the average one weighs only 5 pounds.

Secondly, the larger the plane, the smaller the fraction avionics represents as a part of the useful weight, even with increased capability. This allows for the addition of more advanced avionics such as weather radar or flight directors with minimal weight penalties (even though they may double the total avionics weight).

The broad range of available avionics is plotted according to weights, as shown in Figure VII-44. One noticeable feature is the tendency of equipment to lean towards the lower weight portion of its spectrum as a function of its market demand (i.e., cost), complexity and, to some degree, its maturity.

The NAV/COM transceiver, although relatively complex, has been reduced to the 2-20 pound range with 80% of the available products weighing less than 10 pounds. On the other hand, a newer, yet perhaps equally complex, item such as a flight director not only has fewer entries, but also a broader range of weights, i.e., 3 to 70 pounds.

COMPARISON OF AVIONICS WEIGHT VS. USEFUL WEIGHT FOR GENERAL AVIATION AIRCRAFT

FIGURE VII-43

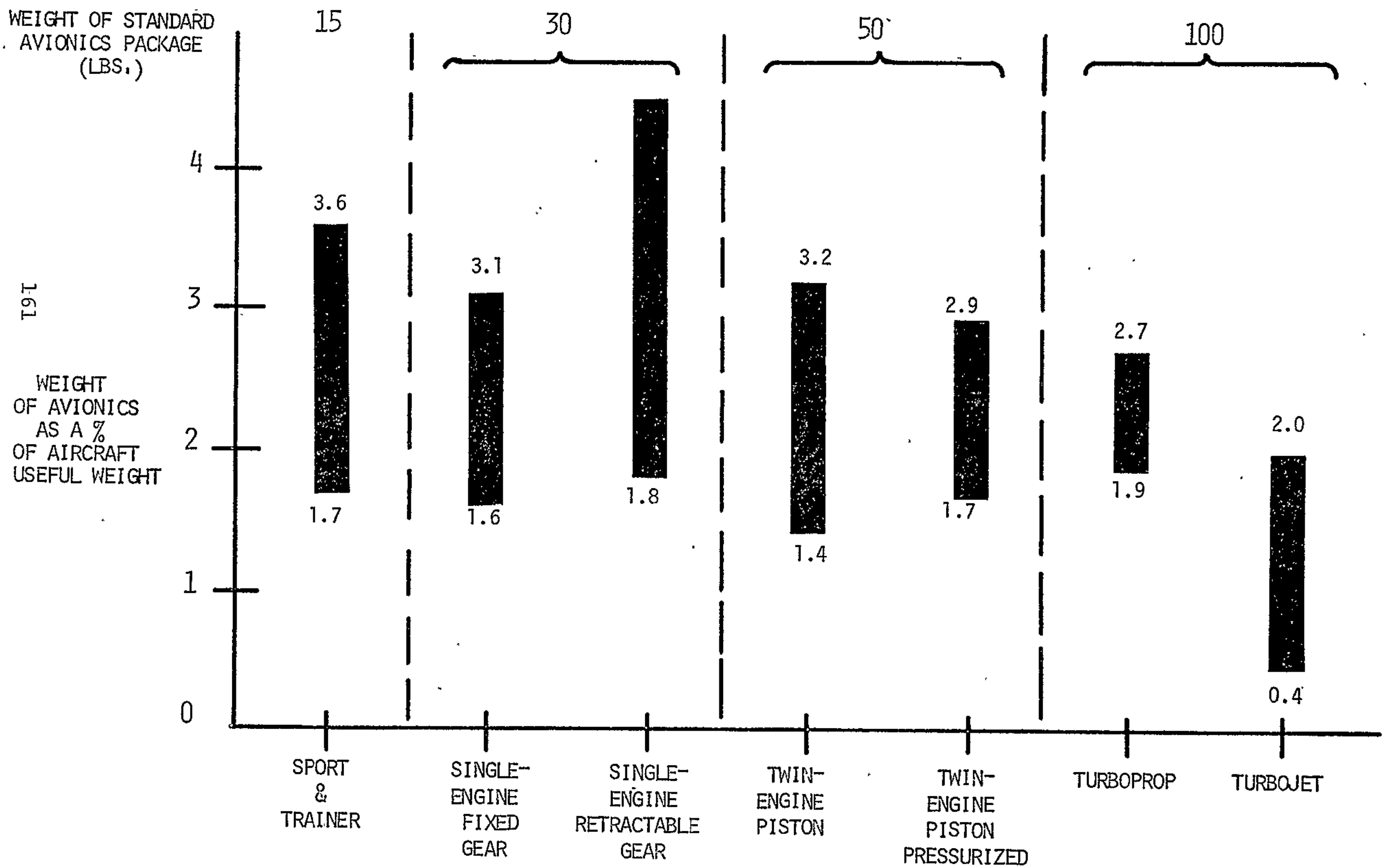


FIGURE VII-44

NUMBER OF AVIONICS ITEMS AVAILABLE CLASSIFIED BY WEIGHT RANGES

Weather Radar									1	1	2	1	1		2	2
DME						1	4	3	2	1						
Radar Altimeter			2				3	2	1	2						
Area Navigation			2		6	1	1	3		3		2				
ADF			1		2	8	6	1	2							
Flight Director		2	1			2				4	6	4		1		
Transponders		5	7	1	1	4		1	1							
Transceivers		8	12	9	10	14	2	7	5	1						
Encoding Altimeter	4	15	2	5	1			1								
OBS	8	12	4	1	2			2	2							
ELT	18	10	8	1												

1 2 3 4 5 6 8 10 15 20 30 40 50 60 80 100 200

Weight in Pounds

This is indicative of the developmental evolution that must occur to bring the weight of any piece of avionics toward its potential minimum. The rapidity of this evolution is greatly influenced by the price and demand experienced for a particular item in the market today. However, a research and development effort such as NASA's general aviation program could have a significant impact in bringing more advanced technology and concepts down to a weight range which could be accepted without significant weight penalty across the total spectrum of general aviation. Examples of these avionics are weather radar, flight directors, self-contained navigation systems, integrated flight control systems, etc.

b. Electrical Power

The recent replacement of tubes by solid-state components and the continued development of integrated circuits has reduced the need for electrical power. At the same time, the switch to alternators (facilitated by solid-state diodes) has increased the available current.

Today's single-engine aircraft is normally equipped with 60 amp capacity while, in the twin-engine aircraft categories, we find 100 amps per engine to be the case. This is due to the solid-state revolution where NAV/COM amperage needs are a nominal 5 versus 20 and more for its vacuum tube predecessors. The same is true of other avionics, with the result that adequate power puts no limitation on the addition of more equipment at this time.

c. Panel Layout

In new aircraft, panel variations are numerous and relatively easy to accomplish as long as there is sufficient space available. However, once the basic panel layout is established, additional avionics generally have to be located wherever there is space, and making modifications to an already existing layout is difficult.

Such innovations as an integrated electronic multi-function display for avionics and flight control parameters and an integrated engine monitor offer the opportunity for significant panel improvements and increased pilot efficiencies. This is due to the fact that additional avionics functions can be incorporated into the display in easy view of the pilot, without requiring a major panel redesign.

Due to the increasing amount of avionics, DSC has suggested that extensive human factors studies could greatly benefit instrument placement. Reference was made to the FAA effort that resulted in the "T" instrument arrangement now generally accepted throughout the industry. It is felt that a similar effort including the remaining avionics in its scope would be of great benefit. At present, when studies of this nature are carried out, they are by the individual airframe manufacturers and not in any coordinated manner benefitting the entire general aviation community.

Strides toward standardization in panel layout and data display could improve pilot effectiveness. In the past, human factor considerations have consisted mainly of the particular viewpoint held by the chief test pilot or owner of each individual airframe manufacturer, so that aside from the basic "T", instrument and avionics arrangement varies from manufacturer to manufacturer.

d. Aircraft Structure

No significant airframe structural modifications were foreseen as a result of avionics developments. The addition of an antenna for some new function (e.g., microwave landing system) would demand local structural strengthening; however, this would represent a very minor change. Such items could be accomplished within the present airframes without requiring major revisions.

The one exception to the above statement would be the incorporation of fly-by-wire. Such systems presently exist only in isolated test and research cases for the military sector. Adoption of this technology in general aviation could significantly affect aircraft design and cost. It is envisioned that the net effect would be a reduction in cost but much development effort remains, and it will be necessary to determine the extent of aerodynamics and structural change before such a statement can be fully substantiated.

2. Aircraft Cost

From the foregoing section, it can be seen that avionics generally have little physical impact on aircraft structure. Therefore, it is not anticipated that the basic aircraft cost will be affected by the evolution in avionics during the next ten years.

In DSC's interviews with pilots and FBO's, it was found that there is general satisfaction with the avionics manufacturers' efforts in introducing solid-state electronics in their products.

Weight of avionics is no longer a significant factor, and further weight reduction and integration is not considered to be a major target for much emphasis warranting any NASA R&D efforts. Rather, standardization and, particularly, improved reliability and maintainability are the areas that require research and wherein improvements would be most beneficial across the total spectrum of general aviation.

VIII. MARKET DEMAND FOR AVIONICS DURING THE EARLY 1980's

Market demand for avionics is influenced by three primary factors:

- Regulatory requirements
- New aircraft deliveries
- Avionics cost

In the preceding chapter, forecasts were made of future avionics expenditures based on analyses and estimations of avionics cost trends, forecasts of total aircraft expenditures, and future aircraft costs. In this chapter, Decision Sciences Corporation has generated forecasts of the unit demand for avionics based primarily on new aircraft deliveries and the regulatory environment as defined in the current National Aviation System Plan discussed in Chapter III.

Figure VIII-1 gives the estimated average ranges of avionics installations in new aircraft during the early 1980's by class of aircraft and for the major avionics categories. All new aircraft will be equipped with at least one VHF transceiver, and aircraft other than light singles will be equipped with two transceivers. This is also the case for the ATC transponder unless, with the advent of the Discrete Address Beacon System (DABS), it becomes mandatory equipment for all aircraft. It is also anticipated that VOR/DME will continue to be the primary navigation system in the United States and, subsequently, it is forecast that a major portion of new aircraft will be delivered with VHF navigation receivers. Dual installation levels are forecast to be approximately 60-65% in medium/heavy singles, 75-85% in light twins, and 100% in the higher performance aircraft. Only a small percentage of the light singles are expected to have dual installations.

Automatic direction finders will continue to have a relatively high degree of acceptance throughout the fleet. The forecast estimates of installations are 35-45% in light singles, 55-65% in medium/heavy singles, and 75-80%, 90-95% and 95% in light twins, medium/heavy twins, and turbojets, respectively.

In the remaining classes of avionics equipment, it is considered that the degree of pilot sophistication and aircraft use will be major determining factors and, therefore, the installation

FIGURE VIII-1

ESTIMATED RANGE OF AVIONICS INSTALLED IN NEW AIRCRAFT

1980-1985 TIME FRAME

TYPE OF EQUIPMENT	(% OF AIRCRAFT EQUIPPED) LIGHT SINGLES	MEDIUM-HEAVY SINGLES	LIGHT TWINS	MEDIUM-HEAVY TWINS	TURBOJETS
VHF COM 1	100%	100%	100%	100%	100%
VHF COM 2	5-7%	60-65%	80-85%	100%	100%
TRANSPONDER*	40-45%	75-80%	90%	100%	100%
VHF NAV 1	70-80%	100%	100%	100%	100%
VHF NAV 2	5%	60-65%	75-85%	100%	100%
ADF	35-45%	55-65%	75-80%	90-95%	95%
DME	3-5%	45-50%	55-60%	90-95%	100%
R/NAV, V/NAV	3-5%	45-50%	55-60%	90-95%	100%
RADAR ALTIMETER	2-3%	5-8%	10-15%	65-70%	100%
STABILITY AUGMENTATION	70-75%	45-55%	20-25%	--	--
AUTOPILOT	2-4%	30-35%	60-65%	85-90%	100%
FLIGHT DIRECTOR	2-4%	9-12%	35-45%	75-80%	100%
WEATHER RADAR	< 1%	4-6%	35-40%	50-60%	100%

*IT IS ASSUMED THAT THE DABS TRANSPONDER WILL NOT BE REQUIRED IN ALL AIRCRAFT.

rates are expected to be substantially lower in the smaller aircraft categories. Turbojets and heavy twin-engine aircraft are currently equipped with full complements of avionics and will continue to be fully equipped in the future.

In the other categories, the trend is expected to be towards expanded avionics complements, although the figure shows that light single-engine aircraft will generally continue to carry only limited navigation and communications equipment. Nevertheless, a few of the new light singles will receive DME, R/NAV, radar altimeters and flight directors. Based on the assumption that a low-cost weather radar for single-engine aircraft will be introduced during the next 2-3 years, it can be anticipated that a limited number of these will find their way into light singles. It is also expected that an increased number of these aircraft will be equipped with basic stability augmentation systems with the intention of eventually expanding them into complete autopilots.

A major change in the avionics complements carried in medium/heavy singles will be the greatly increased utilization of DME and R/NAV and V/NAV. It is anticipated that this will lead to an increased number of autopilot systems and flight directors being installed in this class of aircraft. Weather radar will also be a new feature in medium/heavy singles, assuming that the technology becomes available at the right price.

In Chapter II, it was seen that there is a great similarity in the avionics complements carried in heavy singles and light twin aircraft. In the avionics forecast, this continues to be the case during the early Eighties.

Based on the forecast of new aircraft deliveries shown in Chapter II and the rate of avionics installations in new aircraft between 1980 and 1985, forecasts have been prepared of the avionics demand in 1980 and in 1985. Figure VIII-2 shows the demand forecast for 1980 and Figure VIII-3 for 1985. In establishing these estimates, aircraft and avionics for export have been taken into account. At the present time, aircraft exports average approximately 25% of the annual production. Complete avionics export data is not available, and it is assumed for the purposes of this study that the amount exported is equivalent to the amount of avionics that would be carried in the exported aircraft if they were equipped for U.S. use (this then covers avionics which are sold on the retrofit market).

FIGURE VIII-2

FORECAST OF AVIONICS DEMAND - 1980
(BASED ON DSC MEDIUM AIRCRAFT FORECAST)

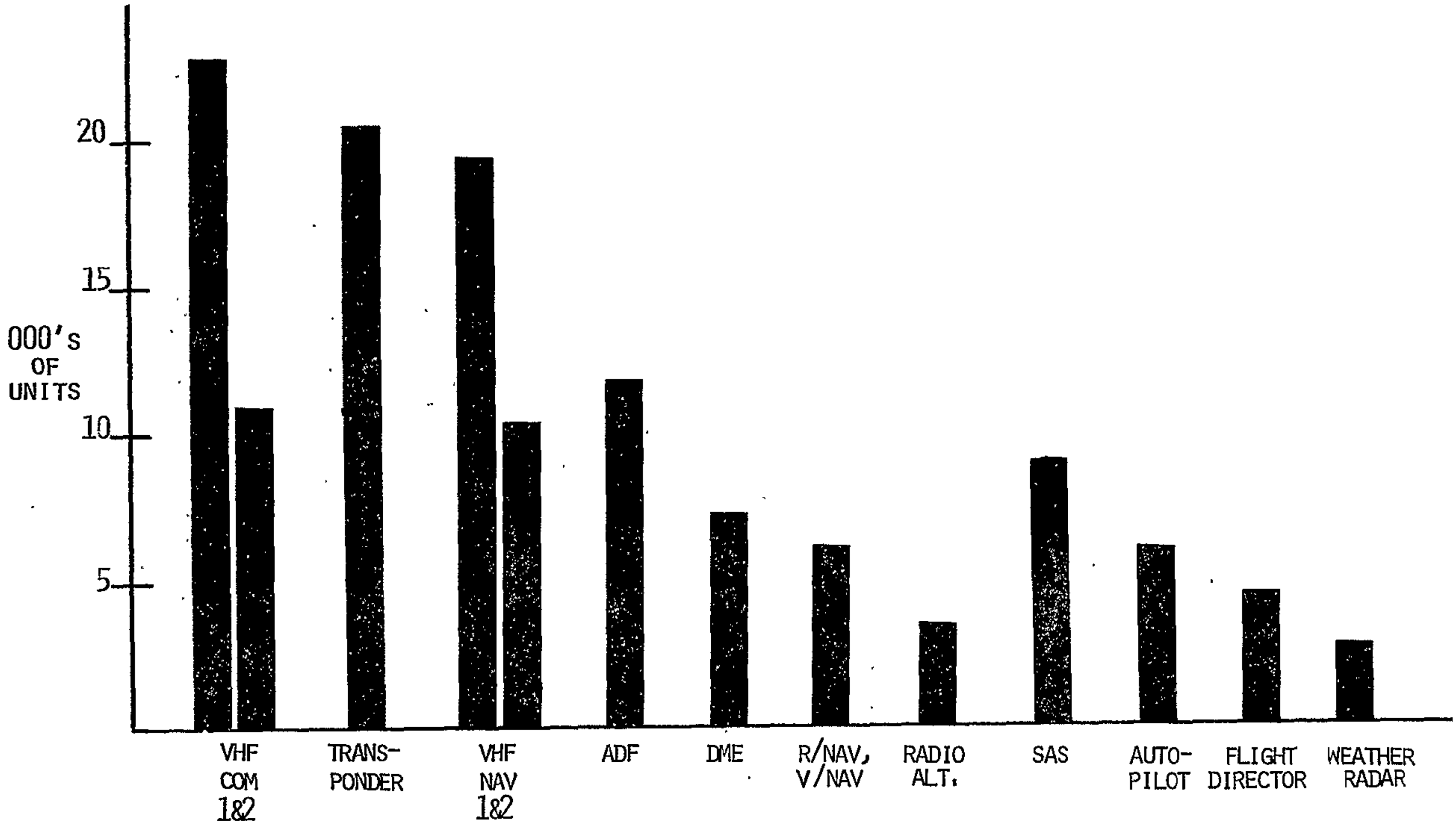
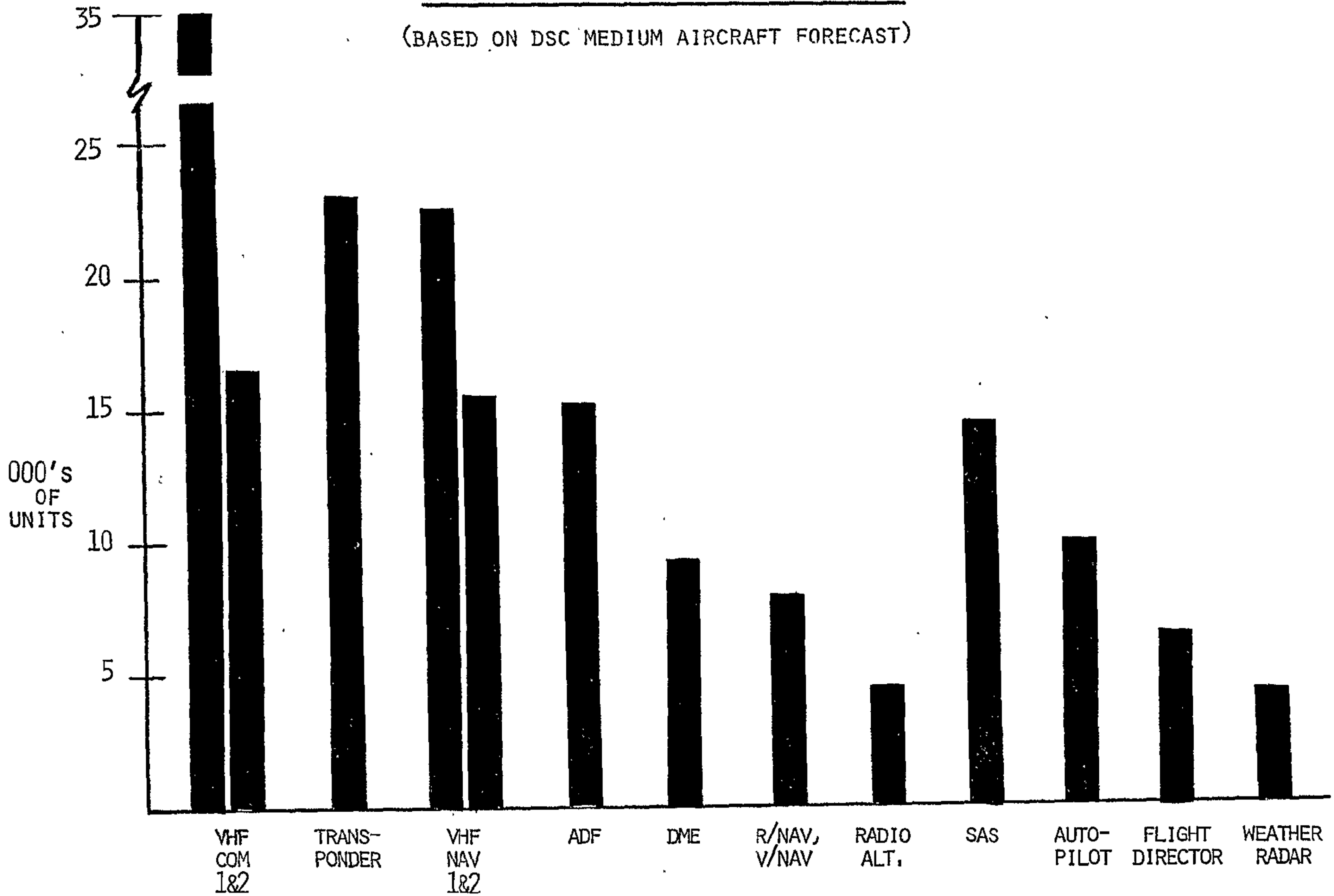


FIGURE VII-32

FORECAST OF AVIONICS DEMAND - 1985

(BASED ON DSC MEDIUM AIRCRAFT FORECAST)



Retrofit avionics was also taken into consideration in proportions varying from 25% to 50% of the amounts put in new aircraft, according to the type of avionics involved. The basic calculation was made for 1980 and was then extrapolated to provide the 1985 forecast. It is anticipated that by this time period, modular and integrated navigation and flight control systems will be available in the market; however, in the forecasts, each function is considered a separate unit. For example, in the case of a complete integrated R/NAV system, the forecast shows this as a VHF navigation receiver, DME, and an R/NAV computer and display.

IX. PROGRAM RECOMMENDATIONS

A. GENERAL

One of the primary objectives of this study was to determine areas wherein research and development by NASA would be most beneficial to the general aviation community. The general outline of the methodology used in this study for forecasting the technological requirements is shown in Figure IX-1. It involved extensive secondary research to assess the present state-of-the-art in avionics and to determine the developments and trends which are likely to influence avionics in the 1980's. Interviews were carried out with avionics manufacturers, the Federal Aviation Administration, industry organizations, and aviation publications as well as with independent industry experts -

- To obtain opinions of the current trends and developments in general aviation avionics, and to gauge reactions to the new equipment and technologies that are appearing on the market

- and to solicit ideas of the potential areas where new or advanced technology in avionics could be most beneficial to general aviation

In addition to our secondary research and in-person interviews, Decision Sciences Corporation used as a primary forecasting vehicle the Delphi technique.

Delphi technological forecasting is based on the use of a committee of experts in a single area who pool their knowledge about that area and prepare an intuitive forecast of future developments. The Delphi technique tends to produce results superior to those of conventional face-to-face committees since it is characterized by anonymous controlled feedback and statistical response. DSC utilized the Delphi approach in this program by bringing together an advisory market and technological forecasting group comprised of representatives of aircraft manufacturers, avionics manufacturers, and major service organizations directly involved in the field of general aviation. The Delphi methodology used is shown in Figure IX-2.

The role of the advisory panel was to:

FIGURE IX-1

TECHNOLOGICAL REQUIREMENTS FORECASTING METHODOLOGY

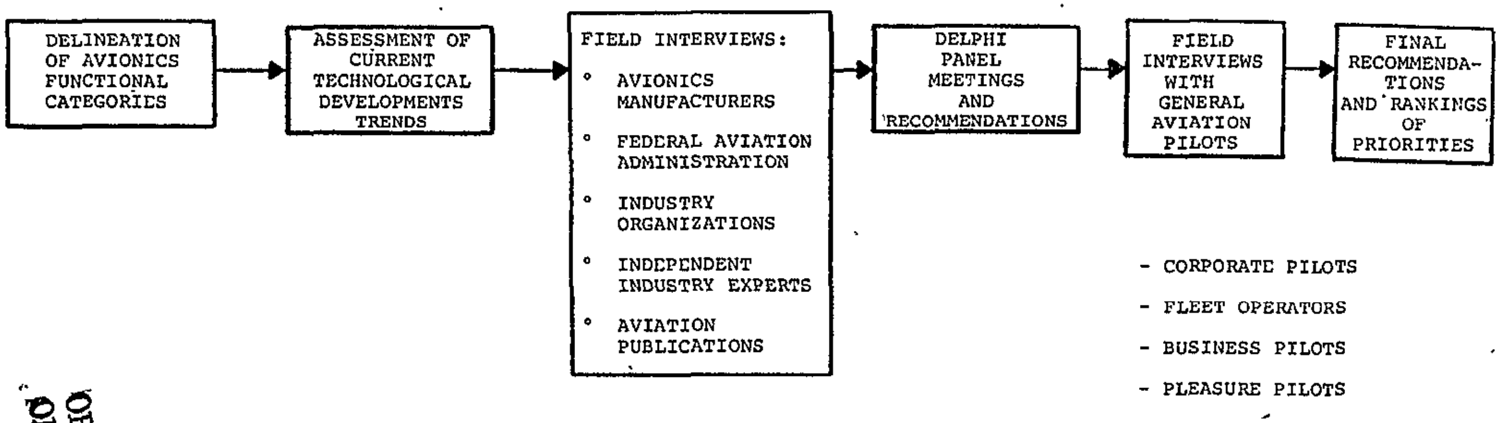
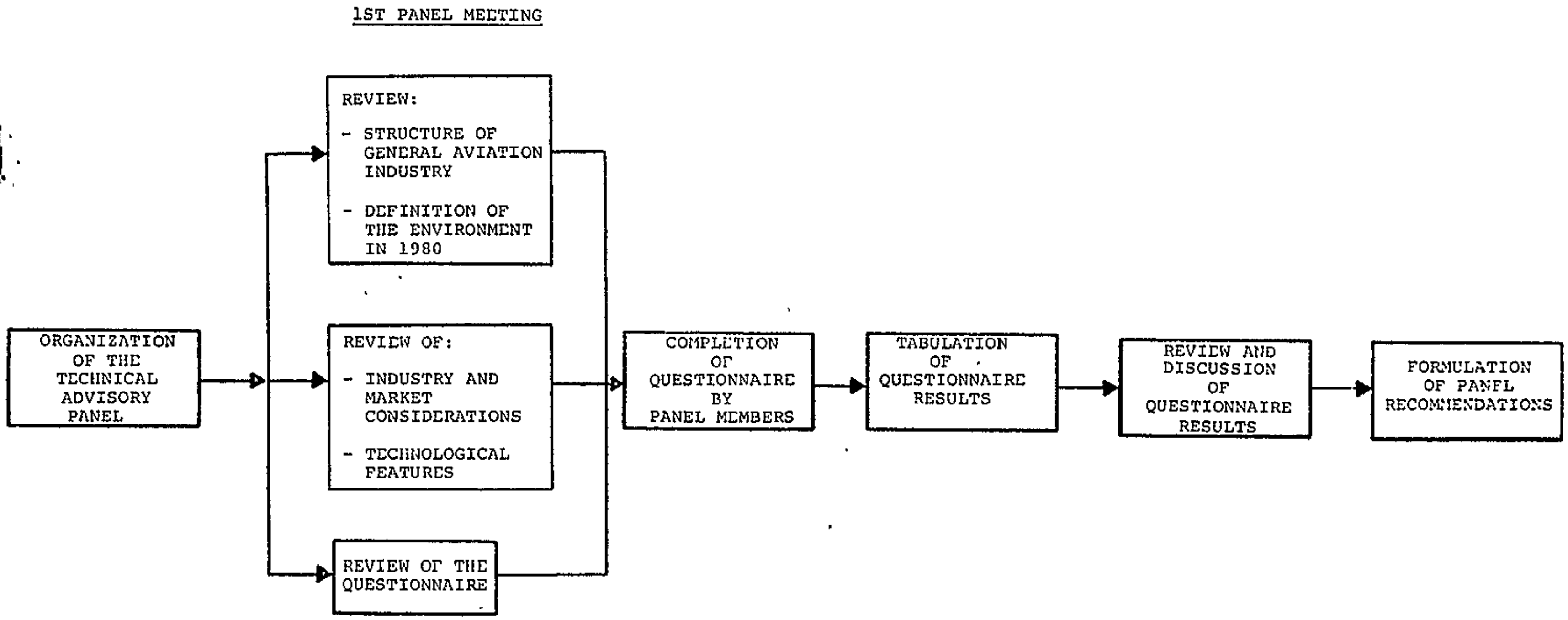


FIGURE IX-2

DELPHI METHODOLOGY



- Provide a critical assessment of DSC's evaluation of the general aviation market and the environment in which it will be operating in the 1980's

- Provide insights and views from a total industry perspective of the general aviation requirements for avionics in the 1980's

- Assist in identifying and delineating the constraints in the industry which could limit the introduction of new technology in general aviation

- Provide panel recommendations to direct NASA's avionics R&D activities into areas that would be of most benefit to general aviation

The advisory panel schedule consisted of an initial meeting to establish the industry definition, framework for and preliminary identification of areas of investigation. At this meeting, the questionnaire, which was to be completed by each panel member before the second meeting, was reviewed. The questionnaire consisted of two basic questions which were applied to the following five functional areas:

- Communications
- Navigation
- Flight control
- Instrumentation
- Displays

These functional areas were, in turn, subdivided into the following five aircraft categories:

- Single-engine piston - 1-3 place
- Single-engine piston - 4+ place
- Multi-engine piston
- Turboprop
- Turbojet

The primary questions which the advisory panel was asked to address were:

- A long-range outlook of the future technological requirements for general aviation avionics relating to the developments which could occur in the 1980-1985 time frame

- An assessment of acceptable R&D design goals and features for the equipment identified for the various aircraft classes

The second meeting of the panel was held to review and evaluate the survey results and to reach a consensus on the recommendations that would be made to NASA for R&D funding.

A number of considerations was discussed at the meeting in the formulation of the ultimate recommendations. They were:

- <u>Aviation Environment</u>

  General agreement was reached as to the shape of the environment during the next 10 years. The regulatory environment was defined as that presented in the FAA National Aviation System Plan. The size of the general aviation fleet in 1985 was assumed to be that forecast by the DSC forecasting model. Airport availability for general aviation was assumed to be at a level in 1985 comparable to today's, and aircraft performance, speed, altitude, and range were also anticipated to remain approximately the same

- <u>Safety</u>

  It was agreed that this would continue to be of primary concern and would constitute a dominant factor in general aviation technological development

- <u>Pilot Workload and Limitations of Panel Space</u>

  It was agreed that reduction in pilot workload is a desirable goal in avionics development, particularly in view of the fact that there is an increasing number of regulations and procedures, as well as increasing amounts of equipment adding to the complexity of flying. The panel, furthermore, took into account that by 1985, it is forecast that 44% of pilots will be IFR-rated

The advisory panel was invited to comment and give their views of present cockpit procedures, limitations of panel space, and current panel layout

° Present Capabilities of the General Aviation Industry

This consideration was deemed of primary importance in the formulation of recommendations for NASA. The panel recognized the considerable capabilities and resources at NASA's disposal, and the potential benefits a well-planned general aviation program could provide to the general aviation community. At the same time, the panel felt it important that there should not be a duplicate effort on NASA's part of the current development effort being carried out within the general aviation industry. In its recommendations, therefore, the panel took into consideration the technology currently available in the general aviation industry, and also the current technological trends which will impact upon avionics by 1980, e.g., trends towards system integration

An additional factor which was taken into consideration was the current level of technical capability of avionics dealers to service avionics equipment and an evaluation of equipment service requirements in 1980

The panel was also asked to take into account technical considerations such as:

° Equipment reliability and maintainability

° Requirement for built-in test equipment

° Opinions concerning design goals such as range, accuracy, sensitivity, etc. that an R&D program should target for.

- Targeted costs that would make the avionics available to the general aviation fleet

- Various options on input mode, fail mode, sensor output, redundance and failure detection

- Suggestions that would provide guidance to the planned R&D effort

The recommendations of the panel were, in turn, discussed in interviews with general aviation pilots to obtain users' views and opinions of where improvements and technological advances might be most useful. It was found during these interviews that pilots generally appear to be satisfied with the technological sophistication of avionics equipment available today. Their major areas of concern expressed in the interviews are:

- Reliability

- Maintainability

- Cost

Regarding the specific areas recommended by the industry panel, the pilots attitudes were generally positive, although their interests are primarily directed more towards their immediate needs and concerns than towards the requirements they might have in the 1980's.

B. RANKING OF PRIORITIES OF NASA R&D FUNDING AND PRODUCT REQUIREMENTS

1. Ranking of Priorities. The following is a discussion of DSC's evaluation of the priorities that should be established by NASA in its R&D activities for general aviation avionics. It is based on DSC's forecasts of market need and desirability, coupled with our panel's opinions and interviews with pilots, aircraft owners, and other industry representatives. Ranking of priorities is shown in Figure IX-3.

   The rankings were established by interviewing aircraft owners and other knowledgeable industry representatives, asking them to weight each product considering each of the three points cited below:

PRELIMINARY RANKING OF PRIORITIES FOR NASA R&D
(Within Each Functional Category)

	FUNCTIONS	AIRCRAFT CATEGORY				
		SINGLE-ENGINE 1-3 PLACE	SINGLE-ENGINE 4+ PLACE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET
COMMUNICATIONS	SATELLITE COMMUNICATIONS	5	5	4	5	3
	AUTOMATIC ALTITUDE REPORTING	3	3	3	-	-
	DATALINK	4	4	4	4	4
	CAS	2	1	1	2	1
	PWI	1	2	2	1	2
	UHF TELEPHONE	6	6	5	3	5
NAVIGATION	DME	3	3	1	-	-
	RADAR ALTIMETER	11	9	3	-	-
	HYPERBOLIC	10	8	8	4	4
	DOPPLER	7	10	-	8	8
	INERTIAL	7	10	-	7	6
	RNAV	4	6	4	2	3
	VNAV	5	4	5	3	2
	TNAV	9	4	6	5	5
	ILS GLIDE SLOPE	2	2	-	-	-
	MLS	1	1	2	1	1
	VLF	6	7	7	6	7
INSTRUMENTATION	DUAL INDEPENDENT ALT, ATT, ETC	4	1	-	-	-
	AIR DATA SYSTEMS	-	-	4	3	2
	RECORDERS	-	5	-	4	4
	ENGINE MONITORS	1	2	2	2	3
	WEATHER RADAR	3	3	3	-	-
	CAT DETECTOR	2	4	1	1	1
FLIGHT CONTROL	FLIGHT DIRECTOR	1	1	1	-	-
	AUTO THROTTLE	-	-	3	4	4
	INDEPENDENT LANDING MONITOR	-	-	2	2	2
	AUTOMATIC LANDING SYSTEM	-	-	-	3	3
	FLY-BY-WIRE	-	-	-	1	1
DISPLAYS	ELECTRONIC - DIGITAL	2	2	2	-	-
	ELECTRONIC - CRT	-	-	3	1	1
	PERIPHERAL	-	-	-	3	4
	HEAD-UP	-	-	-	2	3
	MAP - DIRECT/PROJECTED	-	-	-	4	2
	INTEGRATED (RMI, HSI, FLT. DIR)	1	1	1	-	-

1) Desirability

2) Present industry capability, and

3) Target date for market acceptance.

The recommended rankings are shown in Figures IX-4 through IX-9. Overall summary rankings are shown in Figures IX-10 through IX-12.

In evaluating the five major functional areas, DSC recommends that NASA R&D efforts are most urgently required in the area of displays (see Figure IX-4). The panel arrangement using the "T" layout constitutes the basic framework for avionics and instrumentation organization in general aviation aircraft. This layout, however, was devised almost 15 years ago by the FAA under considerably different circumstances and considerations. Avionics and instruments have proliferated considerably since then. No coordinated industry study has been undertaken in this area.

In the opinion of DSC, NASA is in a unique position to undertake the necessary human factors and related studies to optimize the organization of avionics and instrumentation in the cockpit. Furthermore, it would require an independent agency like NASA to carry out the study to make recommendations on panel design acceptable to all of general aviation.

DSC's ranking order of priority of the major functional areas for R&D funding is as follows:

- Displays
- Navigation and instrumentation
- Flight controls
- Communications

a. Displays

Within the general functional area of displays, the order of priority for R&D funding by specific type of display is shown in Figure IX-5. It is recommended that NASA direct its efforts specifically towards the development of integrated electronic multifunction displays. Basically, CRT-type display

FIGURE IX-4

RANKING OF PRIORITY FOR
NASA R&D FUNDING

CATEGORY OF AVIONICS EQUIPMENT	RANK
COMMUNICATIONS	5
NAVIGATION	$\boxed{2}$
INSTRUMENTATION	$\boxed{2}$
FLIGHT CONTROL	4
DISPLAYS	1

FIGURE IX-5

RANKING OF PRIORITY FOR NASA R&D FUNDING FOR DISPLAYS

TYPE OF DISPLAY	RANK
ELECTRONIC - DIGITAL	$\boxed{2}$
ELECTRONIC - CRT	3
PERIPHERAL	6
HEAD-UP	4
MAP - DIRECT OR PROJECTED	5
INTEGRATED ELECTRONIC MULTI-FUNCTION DISPLAY	1

could be utilized and although the work has been carried out in the area, it is felt that a considerable amount of research is necessary to resolve some fundamental problems that remain relating to reliability, redundance, and cost before this type of a display system becomes a viable product in the general aviation industry.

Digital and CRT displays are ranked second and third, but in DSC's opinion, the top three overlap. Therefore, if NASA were to develop an acceptable integrated electronic multi-function display for general aviation, the other requirements would be satisfied also.

b) Navigation

In the navigation function, there are two general recommendations:

The development of an integrated navigation system which would accept a variety of inputs on a plug-in module basis, e.g., VOR/DME and/or Omega and/or VLF and/or inertial, etc

The development of a low-cost ($5,000-$10,000) self-contained navigation system. Derivations of INS were considered, but it was unknown to what extent the cost of these could be reduced to a level acceptable to general aviation

Specific areas of recommendation are:

A radar altimeter incorporating both downward and forward looking features for approaches and landings as well as terrain clearance

Microwave landing systems/receivers which could lead to many more general aviation airfields being equipped with an ILS system (Although MLS was highly placed on the list of recommendations by the advisory panel and by industry experts during our field interviews, it was ultimately excluded from DSC's recommendations for NASA R&D as it is already a heavily funded development program area).

VLF and Omega navigation - It is felt that although considerable research is ongoing in this area, much development effort remains to be carried out before the accuracy, reliability and cost make it a viable product across the spectrum of general aviation

The ranking of navigation priorities is shown in Figure IX-6.

Because of the current FAA MLS program in which NASA is participating, any separate development effort by NASA would necessarily be constrained. Therefore, DSC does not consider MLS an area towards which NASA R&D funds should be directed at this time. However, once MLS receiver specifications are finalized, this decision should be reviewed. Thus, the alternate priority of VNAV/TNAV/RNAV is recommended to NASA.* The basic concept and technology of area navigation and variations thereof have been developed over the past 8-10 years, but the cost of a total system places it out of reach of the majority of the general aviation community. Further development effort will be required to alleviate this constraint.

c) Instrumentation

The primary area for NASA R&D efforts in the area of instrumentation (see Figure IX-7) is the development of engine monitoring systems. This is considered to be an area that is generally overlooked and wherein little research has been done during the past few years. The development of an engine monitoring system would necessitate research into sensor technology, as well as the development of data matrices against which the sensed information could be compared to establish whether there was any departure from normal.

It is suggested that studies be conducted in engine vibration harmonics. The harmonic profile is stored in a read only memory and high and low frequency departures are flagged. The development of an engine monitoring system could contribute significantly to easing pilot workload, insofar as it would not be necessary for the pilot to continuously monitor such parameters as manifold pressure, oil pressure, oil temperature, electrical system, etc. If a system monitored engine parameters, the pilot would be able to concentrate entirely on flying the aircraft. In the event of any unusual situation arising, the pilot would be notified and the relevant parameters would be displayed to enable him to make a decision regarding the appropriate action to take.

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* Note: TNAV is defined in this study as Time Constrained Area Variation, wherein ETAs for each waypoint are input to the system.

C-3

FIGURE IX-6

RANKING OF PRIORITY FOR NASA R&D FUNDING IN NAVIGATION

TYPE OF NAVIGATION	RANK
DME	7
RADAR ALTIMETER	1
HYPERBOLIC (OMÉGA, LORAN)	8
DOPPLER	11
INERTIAL NAVIGATION	9
R-NAV (2D)	6
VNAV (3D)	4
TNAV (4D)	5
ILS - GLIDESLOPE	10
MLS	2
VLF (U.S. NAVY, COMMUNICATIONS STATIONS AND OMEGA)	3

FIGURE IX-7

RANKING OF PRIORITY FOR NASA R&D FUNDING IN INSTRUMENTATION

TYPE OF INSTRUMENTATION	RANK
DUAL INDEPENDENT ALTITUDE, ATTITUDE, ETC.	5
AIR DATA SYSTEMS	4
RECORDERS	6
ENGINE MONITORING SYSTEM	1
WEATHER RADAR (WITH ILM MODULE FEATURE)	3
CLEAR-AIR-TURBULENCE (CAT) DETECTOR (INCLUDING WAKE VORTEX DETECTION)	$\boxed{2}$

Within the same general functional category, clear-air turbulence (CAT) detectors including wake vortex detection are considered to be a priority item for NASA R&D. The recommendation is made not only for CAT detectors in the conventional sense for use at high altitude, but also to include other forms of clear air turbulence which could impact on all categories of aircraft.

Another product area with potential for general aviation is weather radar featuring an independent landing monitor (ILM) modular add-on. Avionics manufacturers have carried out considerable development in weather radar technology and it is expected that within the next 2-3 years, weather radar will become available for installation in single-engine aircraft.

Over the years, a number of manufacturers have experimented with various types of independent landing monitors with very little success. A system offering a weather display mode and an ILM mode as an optional feature would be of greater benefit to general aviation than two independent systems. Moreover, it would offer potential cost savings by making use of common components and space saving which has become a critical element. Because of the potential increased safety that the ILM concept offers, it is considered to be of highest priority for research and development in the flight control category (see Figure IX-8). The other priority products in this group are:

- Flight directors
- Auto throttle

Although it only received a very low ranking in the list of priorities, the following special note should be made regarding fly-by-wire systems:

- Insofar as technological requirements for general aviation avionics during the early 1980's are concerned, fly-by-wire systems have yet to prove their potential application in civil and general aviation aircraft. However, the real benefit of this technology would lie in improvements in aircraft design and cost; therefore, R&D in this area should be pursued outside the scope of the program under consideration in this study

FIGURE IX-8

RANKING OF PRIORITY FOR
NASA R&D FUNDING IN FLIGHT CONTROLS

TYPE OF FLIGHT CONTROLS	RANK
FLIGHT DIRECTOR	$\boxed{2}$
AUTOTHROTTLE	3
INDEPENDENT LANDING MONITOR	1
AUTOMATIC LANDING SYSTEM	4
FLY-BY-WIRE	5

(d) Communications

The last functional category under consideration was airborne communications (Figure IX-9). Because of the general concern for increased safety and the specific concern of the danger of mid-air collisions, research is recommended for both proximity warning indicators (PWI) and collision avoidance systems (CAS). In DSC's opinion, however, due to the sensitive political status of CAS, this should not be pursued as a viable R&D alternative until the non-technical issues are resolved. The Advisory Panel and the number of pilots interviewed expressed the opinion that automatic altitude sensing and encoding equipment currently available could be significantly improved upon. It is recommended as an area where NASA R&D could make a significant contribution by developing avionics that would eliminate discrepancies in altitude measurement.

Taking into consideration the ranking of each general functional category and the ranking within each category of the specific products, DSC has established an overall ranking shown in Figures IX-10 through IX-12.

C. EQUIPMENT REQUIREMENTS

Having established the priority areas of funding, DSC studied the desired sophistication of the various systems and equipment that could be made available to general aviation through accelerated technology advances. However, in general aviation, the degree of sophistication is not so much a question of the technology that should be incorporated, but very much a function of the cost of the equipment. This point was greatly emphasized in our interviews with pilots, manufacturers, and industry representatives.

In regard to the functional specifications and accuracies of the equipment, the trend in general aviation avionics during the past few years has been increasingly towards TSO'd equipment. It is felt that any new equipment that is developed should meet the minimum performance and quality control standards defined by the Technical Standard Orders. Further performance standards that should be targeted for in new equipment are in the Minimum Operational Characteristics developed by the Radio Technical Commission for Aeronautics and in ARINC Equipment Characteristics. A matrix of the desirable features that should be incorporated in new general aviation avionics

FIGURE IX-9

RANKING OF PRIORITY FOR NASA R&D FUNDING IN COMMUNICATIONS

TYPE OF COMMUNICATIONS	RANK
SATELLITE COMMUNICATIONS	5
AUTOMATIC ALTITUDE REPORTING (INCL. ALTITUDE MEASUREMENT AND ENCODING)	$\boxed{2}$
DATALINK	4
COLLISION AVOIDANCE SYSTEM (CAS)	3
PROXIMITY WARNING INDICATOR (PWI)	1
UHF TELEPHONE	6

FIGURE IX-10

GENERAL RANKING OF PRIORITY FOR NASA R&D FUNDING

- 10 HIGHEST RANKED -

EQUIPMENT	RANK
INTEGRATED ELECTRONIC MULTIFUNCTION DISPLAYS	1
RADAR ALTIMETER	2
ENGINE MONITORING SYSTEM (EXCL. EGT)	3
CLEAR AIR TURBULENCE DETECTOR (INCLUDING WAKE VORTEX)	4
MICROWAVE LANDING SYSTEM (MLS)	5
PROXIMITY WARNING SYSTEM (PWI)	6
VLF NAVIGATION (OTHER THAN LORAN, OMEGA)	7
AUTOMATIC ALTITUDE REPORTING	8
COLLISION AVOIDANCE SYSTEM (CAS)	9
WEATHER RADAR (WITH ILM MODULE)	10

FIGURE IX-11

GENERAL RANKING OF PRIORITY FOR NASA R&D FUNDING

- 10 LOWEST RANKED -

EQUIPMENT	RANK
DOPPLER NAVIGATION	32
UHF TELEPHONE	31
PERIPHERAL DISPLAYS	30
RECORDERS	29
FLY-BY-WIRE*	28
MAP DISPLAYS	27
ILS GLIDESLOPE	26
HEAD-UP DISPLAYS	25
SATELLITE COMMUNICATION	24
AUTOMATIC LANDING SYSTEM	23

*Despite the low ranking, DSC is aware of current NASA/USAF programs in this area and believes this technology could lead to improvement in aircraft design and cost.

FIGURE IX-12

GENERAL RANKING OF PRIORITY
FOR NASA R&D FUNDING

- OTHER EQUIPMENT -

EQUIPMENT	RANK
V-NAV (3-D) (VOR/DME BASED)	11
T-NAV (4-D) (VOR/DME BASED)	12
AIR DATA SYSTEMS	13
INDEPENDENT LANDING MONITOR (ILM)	14
FLIGHT DIRECTORS	15
R-NAV (2-D) (VOR/DME BASED)	16
DME	17
HYPERBOLIC (LORAN, OMEGA)	18
AUTO THROTTLE	19
INERTIAL NAVIGATION	20
DATALINK	21
DUAL INDEPENDENT ALTITUDE, ATTITUDE, ETC. INSTRUMENTS	22

systems is shown in Figure IX-13.

1. Built-in Test Equipment

Built-in test equipment is a desirable feature to have, but it is felt that the cost increment would not be justifiable in single-engine and light twin piston aircraft. During the course of the interviews conducted with pilots, their main concern was not for new navigation, communications or flight control systems, but rather for equipment that was more reliable and easier to maintain. A major complaint was that it was always so difficult to determine the cause of equipment failure, and that too frequently, the same piece of equipment had to be serviced two or three times before being satisfactorily repaired. It was suggested that automatic ground testing equipment be developed to resolve this problem. This type of equipment is being used by the air carriers and in the U.S. Air Force, but at a price that is prohibitive in general aviation. The need, therefore, is to develop automatic ground testing equipment at a price that would enable its use in general aviation avionics service.

2. Failure Detection and Warning Systems

Failure detection and warning systems are of prime importance in avionics equipment. Reliable and efficient in-line monitoring is considered the most effective method of failure detection, but the method that is used is not as significant as the fact that there must be some kind of accurate failure detection and warning system.

3. Redundancy and Fail Mode

Redundancy is another feature that is almost mandatory in general aviation avionics systems. The means by which this is achieved depends primarily on the cost that can be supported by the aircraft owner/operator. The recommendations on redundancy and fail mode are also shown in Figure IX-13.

D. OVERALL RECOMMENDATIONS, TARGETED PRICES, AND RELIABILITY GOALS

The final ranking of priority for areas of funding for NASA R&D in general aviation avionics and the mean target prices that the program should aim for are shown in Figure IX-14. The figures in parentheses indicate the ranges of target prices that are proposed. The equipment and systems shown

FIGURE IX-13

DESIRABLE FEATURES IN 1980's AVIONICS FOR R&D FUNDING

FEATURE	USER AIRCRAFT CATEGORY				
	S.E. PISTON 1-3 PLACE	S.E. PISTON 4+ PLACE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET
BUILT-IN TEST EQUIPMENT	NO - DEVELOP BETTER GROUND TESTING EQUIPMENT	NO - DEVELOP BETTER GROUND TESTING EQUIPMENT	YES	YES	YES
FAILURE DETECTION AND WARNING SYSTEMS	YES	YES	YES	YES	YES
REDUNDANCY, ACTIVE OR STANDBY	STANDBY	STANDBY	STANDBY/ACTIVE	ACTIVE	ACTIVE
FAIL MODE, OPERATIONAL OR PASSIVE	PASSIVE	PASSIVE	PASSIVE/ OPERATIONAL	OPERATIONAL	OPERATIONAL

in this figure exclude the products currently being developed in other major funded programs, e.g., microwave landing systems, and areas of duplication, e.g., CRT displays. No target prices are given for radar altimeters and automatic altitude sensing and reporting equipment for the high performance aircraft categories as this equipment is considered to be available to these aircraft today. It is also considered that air data systems in 1-3 place single engine piston aircraft are not a high priority area for specific research and development efforts.

As reliability is of critical concern to avionics users, it is considered very important that reliability goals should be established for the products recommended for NASA R&D. In this case, the common measure of reliability is hours MTBF (mean time between failure) and the reliability goals for the 10 recommended avionics products are shown in Figure IX-15.

FIGURE IX-14

FINAL RANKING OF PRIORITY FOR NASA R&D FUNDING

AND TARGET PRICES FOR GENERAL AVIATION ACCEPTANCE

(Excluding Products Related to Current Major Funded Programs and Areas of Duplication)

EQUIPMENT	AIRCRAFT CATEGORIES				
	SINGLE-ENG. PISTON 1-3 PLACE	SINGLE-ENG. PISTON 4+ PLACE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET
INTEGRATED MULTI-FUNCTION DISPLAYS	$600 (250-1,500)	$750 (500-1,500)	$2,000 (1,000-5,000)	$4,000 (3,000-7,000)	$5,000 (3,000-15,000)
RADAR ALTIMETER	$400 (250-500)	$500 (250-1,000)	$1,300 (500-1,500)		
ENGINE MONITORING SYSTEM	$400 (300-2,500)	$500 (300-5,000)	$800 (500-5,000)	$2,000 (700-5,000)	$2,500 (2,000-5,000)
CLEAR AIR TURBULENCE DETECTOR	$200 (150-1,000)	$400 (150-2,000)	$750 (600-5,000)	$2,000 (1,000-5,000)	$5,000 (1,000-8,000)
PROXIMITY WARNING INDICATOR	$500 (250-1,000)	$500 (250-1,500)	$1,000 (250-3,000)	$2,000 (750-5,000)	$2,500 (750-5,000)
VLF AND/OR OMEGA NAVIGATION	$1,250 (500-2,000)	$1,500 (500-2,500)	$3,500 (2,500-8,000)	$8,000 (5,000-10,000)	$15,000 (5,000-25,000)
AUTOMATIC ALTITUDE SENSING AND REPORTING	$500 (250-1,000)	$500 (250-1,000)	$750 (500-1,500)		
WEATHER RADAR (INCLUDING ILM MODULE)	$1,500 (1,000-5,000)	$3,500 (2,500-10,000)	$5,000 (2,500-10,000)	$6,500 (5,000-15,000)	$ 7,500 (5,000-15,000)
RNAV/VNAV/TNAV	$500/$750/ $1,000	$1,200/$1,500/ $2,000	$1,750/$2,500/ $3,500	$3,000/$6,000/ $8,000	$3,000/$6,000/ $8,000
AIR DATA SYSTEM		$500 (200-800)	$1,500 (1,000-5,000)	$2,500 (1,000-3,000)	$3,500 (2,000-10,000)

FIGURE IX-15

RELIABILITY GOALS FOR THE

10 HIGHEST RANKED AVIONICS PRODUCTS

(MTBF)
In Hours

EQUIPMENT	AIRCRAFT CATEGORIES				
	SINGLE-ENG. PISTON 1-3 PLACE	SINGLE-ENG. PISTON 4+ PLACE	MULTI-ENGINE PISTON	TURBOPROP	TURBOJET
INTEGRATED MULTI-FUNCTION DISPLAYS	2,000 (1,000-5,000)	2,000 (1,000-5,000)	2,000 (1,000-5,000)	2,500 (500-5,000)	2,500 (500-5,000)
RADAR ALTIMETER	1,500 (1,000-5,000)	1,500 (1,000-5,000)	1,500 (1,000-5,000)		
ENGINE MONITORING SYSTEM	2,000 (1,000-5,000)	2,000 (1,000-5,000)	2,000 (1,000-5,000)	2,500 (1,500-5,000)	2,500 (1,500-5,000)
CLEAR AIR TURBULENCE DETECTOR	2,000 (1,000-3,000)	2,000 (1,000-3,000)	2,500 (1,000-5,000)	3,000 (1,000-5,000)	3,000 (1,000-5,000)
PROXIMITY WARNING INDICATOR	1,000 (500-3,000)	1,500 (500-5,000)	1,500 (500-5,000)	2,000 (1,000-5,000)	2,500 (1,000-10,000)
VLF AND/OR OMEGA NAVIGATION	1,500 (1,000-2,000)	1,500 (1,000-2,000)	1,500 (1,000-2,000)	1,500 (500-3,000)	1,500 (500-3,000)
AUTOMATIC ALTITUDE SENSING AND REPORTING	1,000 (500-3,000)	1,000 (500-5,000)	2,000 (500-5,000)		
WEATHER RADAR (INCLUDING ILM MODULE)	1,500 (500-2,000)	1,500 (500-2,000)	1,500 (500-2,000)	2,000 (1,000-5,000)	3,500 (2,000-5,000)
RNAV/VNAV/TNAV	2,000 (500-5,000)	2,000 (500-5,000)	2,000 (500-5,000)	2,000 (500-5,000)	2,000 (500-5,000)
AIR DATA SYSTEM		1,500 (500-2,000)	2,000 (1,000-5,000)	2,000 (1,000-5,000)	3,500 (2,000-5,000)

APPENDIX

DESCRIPTION OF SELECTED DSC GENERAL AVIATION PROJECTS

1. Forecast Model of General Aviation Aircraft Production and Fleet Size

In the Fall of 1970, Decision Sciences Corporation conducted an in-depth study of the general aviation industry which had, as its prime objective, the identification and measurement of the size and structure of the general aviation market during the time frame 1971-1980. In this strategic base study, DSC conducted an exhaustive analysis and investigation of general aviation via personal interviews, analysis of secondary material, and quantitative analytical techniques to establish a framework for a sophisticated structuring by aircraft user types and to forecast future fleet size and growth by type of aircraft.

As a result of this effort, we were able to develop an in-depth measurement of the size and growth of each of the various segments of the market for the time frame 1971-1980, and identify the sectors' requirements and expenditures for aviation products and services.

In order to accomplish this program, it was necessary to develop and implement a sophisticated, comprehensive model which could be used as a predictive tool to forecast the future size and rate of growth of the general aviation industry. This model, shown in schematic form in Figure 2, establishes a base trend line as the initial basis from which to measure the integral rate of change or value of general aviation shipments. In addition, the model calculates the effect of various classes of environmental factors on the size and growth of the general aviation fleet. Included in this analysis of environmental factors are:

- Cost Factors Exclusive of Inflation - These factors comprise such elements as the effect of regulations which require greater training for pilots, on-board equipment and aircraft, increases of costs to maintain aircraft, and other peripheral costs.

- Facilities Available - These factors include not only airports, but also airports of different kinds and varied capabilities. Also included are navigation and communication facilities.

- Airmen and Demographic Data - These factors deal with the number of students entering into training programs, the number of students graduating from these programs,

FIGURE 1

DECISION SCIENCES CORPORATION

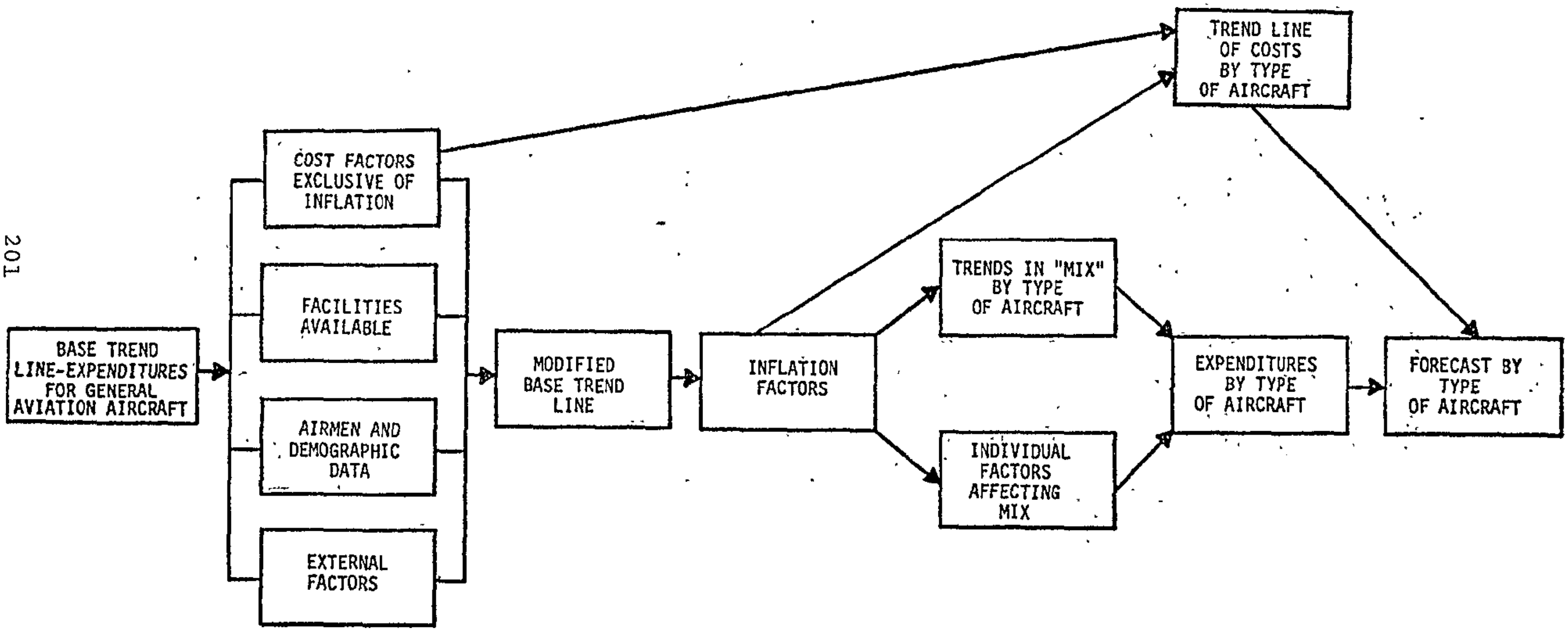
GENERAL AVIATION STUDY PROFILES

PROJECT	GENERAL AVIATION STUDY AREAS				
	DEFINITION OF PRODUCT MARKETS	FORECAST OF FUTURE GEN'L AVIATION AVIONICS MKT.	PRODUCT PRICE-DEMAND SENSITIVITY ANALYSIS	GEN'L AVIATION PROBLEM AREAS AND GROWTH CONSTRAINTS	FORECAST OF TECHNOLOGICAL ADVANCES
FORECAST MODEL OF GENERAL AVIATION AIRCRAFT PRODUCTION AND FLEET SIZE		X	X	X	X
OPPORTUNITIES FOR COMMUNICATION AND NAVIGATON EQUIPMENT IN GENERAL AVIATION AIRCRAFT	X	X	X	X	X
NEW NAVIGATION PRODUCT STUDY FOR GENERAL AVIATION AIRCRAFT AND COMMERCIAL AIRCRAFT	X		X	X	X
AFTER-SALES SERVICE SUPPORT ACTIVITIES REQUIRED FOR GENERAL AVIATION AVIONICS				X	X
PROSPECTS FOR ELECTRONIC EQUIPMENT SALES INTO THE GENERAL AVIATION INDUSTRY	X	X		X	X
NAVIGATION AND COMMUNICATION REQUIREMENTS FOR SMALL SINGLE-ENGINE AIRCRAFT	X		X	X	X
GENERAL AVIONICS DISTRIBUTION STUDY		X	X	X	
OPPORTUNITIES FOR ILM IN GENERAL AVIATION	X	X	X	X	X
GENERAL AVIATION AVIONICS FORECASTING MODEL	X	X	X	X	X
ANALYSIS OF GENERAL AVIATION CUSTOMER BUYING PATTERNS	X		X		
AIRPORT DEVELOPMENT FINANCIAL MODEL			X	X	X
AVIONICS REQUIREMENTS IN STOL AND V/STOL AIRCRAFT	X	X	X		X
GENERAL AVIATION MARKET SEGMENTATION STUDY		X	X	X	
ATTITUDE STUDY OF AVIONICS DEALERS		X		X	
IMAGE STUDY OF GENERAL AVIATION AVIONICS MANUFACTURERS	X			X	
AIRBORNE AVIONICS IN CIVIL AVIATION IN SOUTHEAST ASIA	X				X
GROUND AVIONICS REQUIREMENTS IN INDONESIA		X			X
OPPORTUNITIES FOR TECHNICAL SERVICES IN SOUTHEAST ASIA	X				X
APPLICATION OF LARGE-SCREEN DISPLAYS FOR AIR TRAFFIC CONTROL	X			X	X
AIR TRAFFIC CONTROL AND AIRPORT CARGO AND PASSENGER SYSTEMS	X			X	X

200

FIGURE 2

DSC GENERAL AVIATION AIRCRAFT FORECAST MODEL



the number of licensed pilots, and the level of training of pilots. Also included are factors relating to growth in certain segments of the population.

° External Factors - These factors include the effect of activity by airlines on the general aviation industry.

In summary, Decision Sciences Corporation has developed a unique analytical tool which has proven to be extremely accurate in measuring the size and rate of growth of general aviation fleet by discrete aircraft user segments including:

° Aircraft type, i.e.

  - Light single-engine aircraft
  - Medium single-engine aircraft
  - Heavy single-engine aircraft
  - Light twin-engine aircraft
  - Medium twin-engine aircraft
  - Heavy twin-engine aircraft
  - Jets

° Class of aircraft owner/operator, i.e.,

  - Strictly pleasure
  - Leisure travel
  - Pleasure/business
  - Business
  - Corporate executives

2. Opportunities for Communication and Navigation Equipment in General Aviation Aircraft

DSC carried out a comprehensive definition and delineation of the needs and requirements of general aviation aircraft for navigation and communication equipment during the 1970's. A detailed estimation of market size and growth rates; competitive activities; customer needs and requirements; customer attitudes toward competitive avionics firms; state-of-the-art; estimated market share; and marketing and distribution alternatives necessary for success were included as part of this study effort.

3. New Navigation Product Study for General Aviation Aircraft and Commercial Aircraft

For a major electronics firm, DSC carried out a comprehensive market study of a new navigation product-concept this organization had in its planning stage. This product contained a number of very unique characteristics and was a major breakthrough in product development in the navigation field. To accomplish this assignment, Decision Sciences clearly identified the sectors of the market with the highest potential for this product, evaluated product design alternatives, and recommended appropriate strategic and tactical marketing actions to successfully penetrate the market.

4. After-Sales Service Support Activities Required for General Aviation Avionics

Under contract to one of the largest electronics manufacturers of general aviation avionics in the United States, Decision Sciences Corporation carried out a major study of an optimum after-sales service support network required to adequately service its customers and provide maximum interface with ground service operators. This study involved an investigation into the technology and methods of operation relating to avionics service activities, and focused in on the entire spectrum of emerging requirements to support fixed-base operations and avionics dealerships. Included in this study was a comprehensive state-of-the-art survey of existing and emerging product test equipment, data flow and interface between the avionics dealer, the customer, and the electronics manufacturer.

5. Prospects for Electronic Equipment Sales into the General Aviation Industry During the Time Frame 1973-1985

DSC recently completed a large-scale investigation of the market for electronic equipment (ground and airborne) in the general aviation industry during the '70's and '80's. This study provided comprehensive insights to allow a major electronics manufacturer to gain an in-depth understanding of the obstacles, opportunities, and competitive environment which are faced in this industry. In addition, DSC provided a detailed delineation of specific product needs and requirements which must be provided to the market in the next five years by market sector. Product needs were defined according to logical decision-oriented customer groupings, leading to recommendations dealing with:

- Product features and option requirements in order of importance to customers
- Competitive share-of-market estimates
- Competitive product characteristics including strengths and weaknesses
- Competitive pricing and marketing strategies
- Estimated sales and profit potentials

6. Navigation and Communication Requirements for Small Single-Engine Aircraft

DSC carried out a comprehensive identification of the marketing opportunities and product needs of small single-engine aircraft. This program provided a clear delineation of product and market opportunities available in this area, and a comprehensive appraisal of the competitive environment. It included a forecast of the size and growth of the market during this time frame, and an identification and breakdown of product needs and requirements. In this program, we completed a comprehensive appraisal of the environment to provide a detailed identification of:

- Competition and its products
- Equipment needs which are not currently being satisfactorily met
- Industry technological developments and marketing trends
- Market size potential and share-of-market estimates
- Federal regulatory climate

7. General Avionics Distribution Study

This study investigated the current distribution channels for avionics and general aviation equipment servicing the general aviation fleet. The client was provided with a clear delineation of the present and emerging needs of the pilot population regarding avionics and a projection of the technological change that will be required by federal regulatory agencies in regard to both airborne and ground equipment in the 1970's. Additionally, the client, a major avionics manufacturer, was provided with a distribution system best suited to maximize its marketing efforts and increase profits. This study not only developed a logistics and distribution plan, but also recommended alternatives for meeting current and future problems.

8. Opportunities for Independent Landing Monitors in General Aviation

DSC conducted this product evaluation study in which a relatively new technology was analyzed to assess its applicability to general aviation. The study evaluated the product, assessed potential competition (both technological and product competition), identified opportunities and constraints for market penetration, and developed a strategic business plan to determine financial feasibility and market potential. Demand curves were developed to establish levels of unit sales for different product configurations at various prices.

9. General Aviation Forecasting Model

As part of a multi-client study, Decision Sciences Corporation developed a general aviation forecasting model that projected not only aircraft and avionics demand for three-, five-, and 10-year periods into the future, but also provided detailed projections with respect to:

- OEM avionics installations
- Retrofit avionics installations
- Aircraft distribution avionics installations
- Aircraft dealer avionics installations

These estimates were developed in terms of both dollar expenditures and unit sales. Projections were made for major classifications of avionics including NAV/COM, ADF, DME, transponder, and autopilot systems.

Industry activity, i.e., entry and exit of avionics firms, dollar sales for both aircraft and avionics, pilot buying patterns, economic indices, technological state-of-the-art, and the regulatory environment were all variables in the model which has proved to be extremely accurate.

10. Analysis of General Aviation Customer Buying Patterns

DSC carried out a study analyzing the general aviation avionics buying patterns of pilots. Pilot customers were surveyed utilizing a variety of marketing research approaches including mail and telephone surveys and consumer preference panels. Avionics preferences and needs were determined for aircraft owners of single-engine, twin-engine, and jet general aviation aircraft. General aviation avionics expenditures were assessed by customer segments that included executive transportation, pleasure flying, business flying, commuter airlines, and airframe dealers.

Profiles were developed for the various segments identifying current and emerging requirements for general aviation avionics. Also evaluated in this study were the buying influences of aircraft owners for particular avionics. These influences included such factors as avionics dealer influence, cost of the product, product availability and convenience of purchase, brand knowledge, product reliability and product reputation.

15. Opportunities for Technical Services in Southeast Asia

Part of a study completed by Decision Sciences Corporation for a major U. S. company was related to the requirements for technical operations and maintenance services for both ground and airborne avionics equipment in Southeast Asia. The study contained an assessment of the potential market and strategic and tactical considerations and recommendations for market entry based on the nature of the requirements, the sources of availability of funds to fulfill these requirements, and on an evaluation of the competitive environment in the various countries.

16. Study of the Opportunities for a New Design of a General Aviation Aircraft

DSC carried out a study for a general aviation aircraft manufacturer to determine the marketing opportunities for a newly designed aircraft. This involved a radical innovation in aircraft design and performance characteristics. In order to effectively develop answers to this issue, DSC conducted in-depth personal interviews with aircraft owners and operators, as well as with aircraft dealers throughout the country.

17. Analysis of the General Aviation Requirements for the 1980's

The primary objective of this project was to provide a framework and structure to support NASA in planning for its avionics research and development efforts. Thus, the chief aim of this program was to identify areas where substantial contributions could be made toward the design and operation of avionics for future U. S. general aviation aircraft. To support this general goal, the following subordinate objectives were met:

- Developed a complete definition of the present general aviation market and provided forecasts of future markets for general aviation systems through the period 1985
- Estimated the future demand for avionics equipment as a function of cost and the effect of demand on cost/price for given types of avionics equipment and products
- Identified emerging requirements due to new aircraft, regulations, and a generally changing aviation environment
- Identified major problem areas and constraints to growth to general aviation and related them to avionics systems and equipment
- Identified potential technological advances in avionics systems
- Forecasted the probable impact from this study including the economic, social, and general benefits to be derived

18. Decision Sciences Corporation General Aviation Avionics Data Base

Decision Sciences Corporation has assembled a comprehensive data base in the general aviation avionics market. This data base includes results of over three man-years of both secondary and primary data collection involving interviews with every major manufacturer of general aviation aircraft and general aviation avionics, and includes the results of comprehensive mail surveys and direct personal interviewing efforts with over 4,000 U.S. pilots and 1,500 fixed base operators and 500 avionics dealers. The DSC general aviation avionics data base is summarized in Figure 3.

FIGURE 3

DSC GENERAL AVIATION AVIONICS DATA BASE

DATA	FORMAT	TIME PERIOD	SOURCE
GENERAL AVIATION AIRCRAFT DELIVERIES	ANNUAL DELIVERIES, BY A/C CLASS, BY USER CATEGORY	1971-1985	DSC AIRCRAFT FORECASTING MODEL
GENERAL AVIATION AVIONICS EXPENDITURES	ANNUAL EXPENDITURES FOR AVIONICS, BY EQUIPMENT CLASS, FOR OEM AND RETROFIT	1971-1985	DSC AVIONICS FORECASTING MODEL
GENERAL AVIATION AIRCRAFT FLEET SIZE	TOTAL FLEET SIZE, BY CLASS OF A/C	1971-1985	DSC GENERAL AVIATION AIRCRAFT FORECAST MODEL
GENERAL AVIATION AIRCRAFT FLEET COMPOSITION	BY TYPE AIRCRAFT, BY USER CLASS	1972-1975	DSC SURVEY DATA (2,000 PILOTS; 1,500 AIRFRAME DEALERS)
AVIONICS DEALER ATTITUDES AND OPINIONS	ATTITUDES TOWARD EQUIPMENT AND MANUFACTURERS	1972-1973	DSC SURVEY DATA (500 DEALERS)
AIRCRAFT OWNER BUYING HABITS AND PATTERNS	BY USER CATEGORY AND AIRCRAFT TYPE	1973	DSC SURVEY DATA (2,500 PILOTS)
AIRCRAFT OWNER ATTITUDES TOWARD AVIONICS AND SERVICE	USER CATEGORY AND AIRCRAFT TYPE	1973	DSC SURVEY DATA (2,500 PILOTS)
IMPACT OF ENVIRONMENTAL FORCES ON GENERAL AVIATION AIRCRAFT AND AVIONICS	TECHNOLOGICAL, POLITICAL, ECONOMIC, SOCIAL	1973-1978	DSC ENVIRONMENTAL STUDIES
AVIONICS PRODUCT AND SYSTEMS INSTALLATION DATA	AVIONICS FUNCTIONS BY CLASS OF AIRCRAFT AND USER CATEGORY	1973	DSC SURVEY DATA (2,000 PILOTS; 1,500 AIRFRAME DEALERS)
PRODUCT DESIGN AND FEATURES STUDIES, SALES ESTIMATES AND PRICE/DEMAND ELASTICITY ANALYSIS	DISTANCE MEASURING EQUIPMENT VHF NAV/COM ADF TRANSPONDERS AUTOPILOTS AUDIO PANELS SINGLE SIDEBAND RADIOS AREA NAVIGATION VLF NAVIGATION WEATHER RADAR PERSPECTIVE RADAR LOW FREQUENCY BEACONS DATA LINK COMMUNICATIONS COLLISION AVOIDANCE SYSTEMS SATELLITE COMMUNICATIONS MLS SYSTEMS INTERIM MLS SYSTEMS PRECISION VOR VISUAL ILS WEIGHT & BALANCE MONITORS SAFE-FLIGHT EVALUATOR INTEGRATED NAV AIR-TO-GROUND TELEPHONES POWER & SPEED CONTROL DEVICES	1971-1978	DSC SURVEY DATA (BASED ON INTERVIEWS WITH OVER 2,000 PILOTS, 1,500 AIRFRAME DEALERS, AND 500 AVIONICS DEALERS)

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