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DSC

DECISION SCIENCES CORPORATION

N75-16554

EXECUTIVE SUMMARY

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

by

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A. OBJECTIVES OF THE STUDY

In the context of NASA's role in general aviation technology to improve the safety of all flight operations, and to recognize and provide the growing technological needs and requirements, Decision Sciences Corporation was awarded a contract by NASA to undertake a comprehensive study and analysis of the technological requirements and potential demand for general aviation avionics systems for operation in the 1980's.

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.

B. ORGANIZATION OF THE FINAL REPORT

The final report of this study is organized into two volumes, i.e.

Executive Summary
Final Report

This volume presents a summary of the study project.

The final report contains a description of the seven tasks accomplished by DSC and our recommendations under Contract #NAS2-7888. Chapter I is the introductory chapter including the project objectives and a description of the methodology used in carrying out the project. 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. 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.

C. STRUCTURE AND FORECAST OF THE GENERAL AVIATION MARKET

1. Forecast of the General Aviation Fleet

To forecast the avionics requirements in general aviation during the 1980's, it was necessary to examine the present structure of the general aviation fleet. Therefore, general aviation was 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

Chapter I of the report examines in detail the various segments of the general aviation market and estimates the current level of avionics equipment and expenditures by segment.

In order to forecast the size of the general aviation fleet in 1985, DSC utilized our forecasting model, which 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 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 term, 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 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 forecast of aircraft provided by DSC's model and shown in Figure I was added to the existing general aviation fleet after taking into account exports, imports and attrition, resulting in the fleet forecast shown in Figure II. Thus, it is expected that 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.

The DSC forecast of fleet distribution by type of aircraft are shown in Figure III. It is significant that the share of single-engine piston aircraft is declining 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 I

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

GENERAL AVIATION FLEET - DSC FORECAST

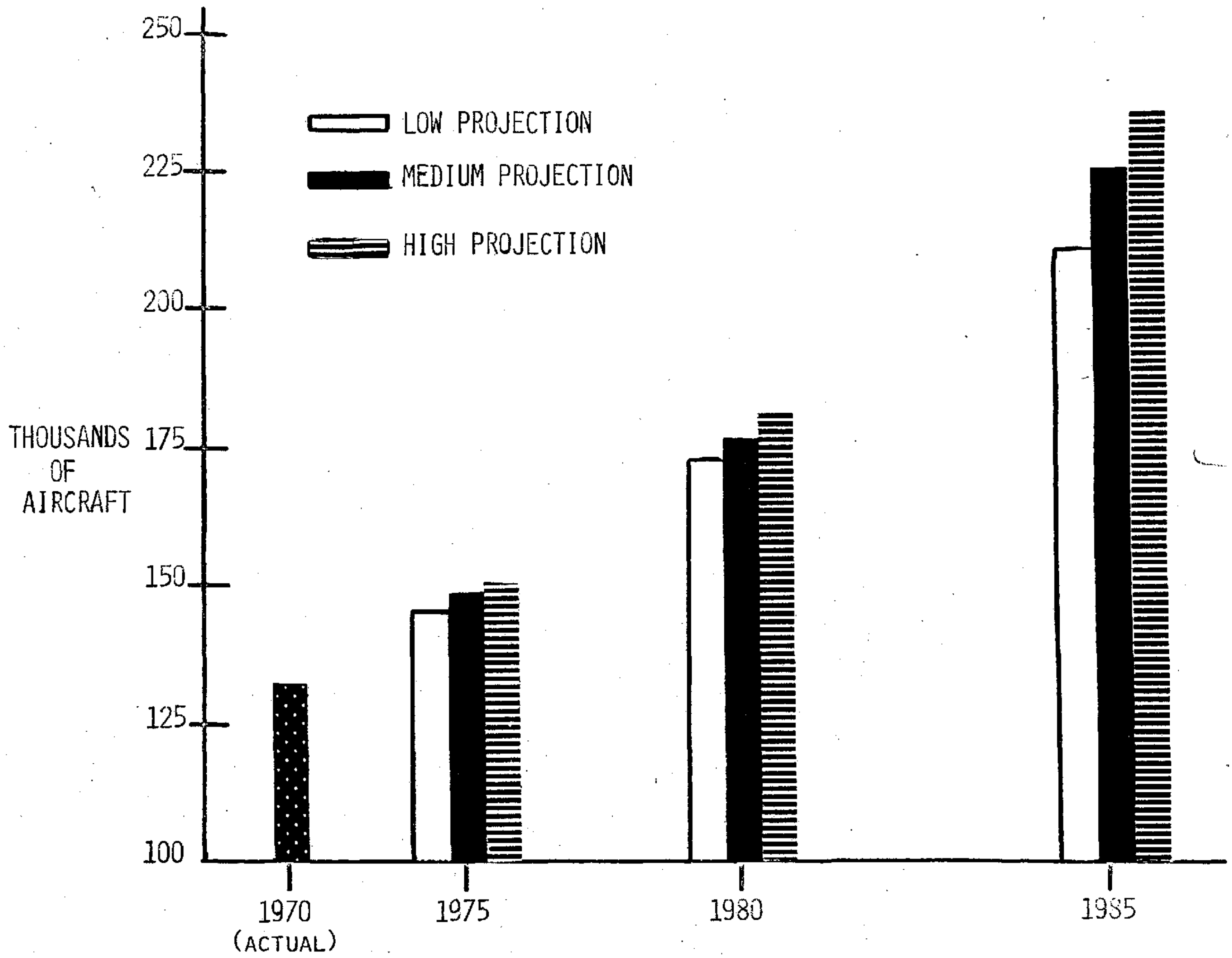


FIGURE III

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

2. Airmen

It was mentioned that an important factor in long-term forecasting was the number of airmen certificates. The statistics and the forecasts of airmen certificates used in this study were provided by the FAA. 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.

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. Between 1962 and 1972 IFR-rated pilots have increased by approximately 150% to a total of more than 190,000. During the next ten years, the number of instrument-rated pilots as a percentage of total non-student pilots is expected to reach 44% in 1985, for a total of more than 370,000 as shown in Figure IV. It is a reasonable assumption that the demand for avionics will increase as a result of the increase in instrument-rated pilots.

Within this context it can be noted that 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.

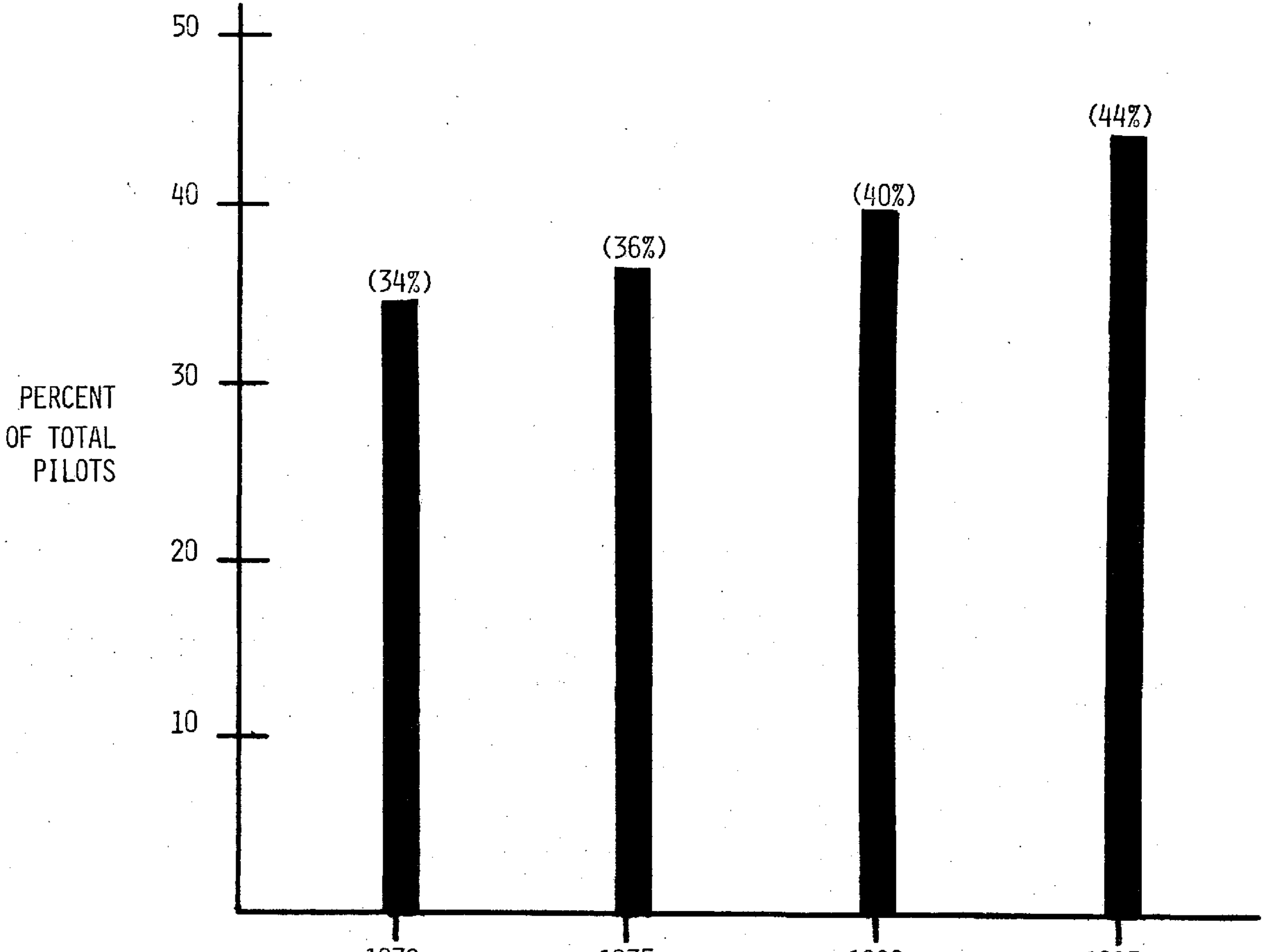
Thus, there has been not only an increase in the size of the general aviation fleet and in the amount of flying, but also a change in the nature of the activity of general aviation. The increase in the number of IFR-rated pilots was noted, and it appears that this is resulting in an increased sophistication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

3. 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

FIGURE IV

INSTRUMENT-RATED PILOTS AS A PERCENTAGE OF TOTAL PILOTS



SOURCE: FAA

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 was 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 V summarize the evolution of the ATC system fron 1936 to beyong 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 changes in pilot requirements and in airborne flight and navigation equipment 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.

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.

D. AVIONICS PRICE SENSITIVITY ANALYSIS AND DEMAND FORECAST

1. Avionics Price Sensitivity Analysis

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 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 realisticably be set for new avionics

FIGURE V

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

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 including the primary influences which either stimulate or depress the demand for avionics equipment.

Having identified these factors, attributing actual price sensitivity parameters to them did not prove to be a directly approachable goal due to the lack of reliable, valid industry data on avionics prices and demand patterns. Unlike general 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, and which would use factors that have readily available and interrelated data bases. They included:

- 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 avaition aircraft fleet

In our analysis, DSC found that the avionics market is closely tied to new aircraft deliveries. 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 results of the analysis enabled DSC to derive the actual cost forecasts shown in Figure VI for the avionics complements for each class of aircraft.

This sensitivity analysis also determined the funds available within each aircraft segment for expanded avionics capabilities, as well as for new equipment, and enabled us to establish

FIGURE VI

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

the level of available funds for avionics in the fleet and the portion which would be able to 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 of the value of new aircraft deliveries. 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. 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 "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. The specific estimates of funds available for avionics by aircraft class are shown in Figure VII through XIII.

In summary, the price sensitivity analysis established that the investment in avionics is generally a function of aircraft cost, although avionics costs are independent of aircraft costs and are not increasing at the same rate as aircraft costs. Furthermore the sensitivity to equipment price changes and/or new avionics requirements is inversely proportional to aircraft value, even though it is noteworthy that lighter aircraft tend to carry more avionics as a percentage of the value of the aircraft.

Finally, it was found that FAA regulatory actions have dramatic impact on rates of avionics installation and override issues of price sensitivity.

FIGURE VII

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 VIII

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 IX

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 X

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 XI

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 XII

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 XIII

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

2. Demand Forecast

Having established that market demand for avionics is influenced by three primary factors:

- Regulatory requirements
- New aircraft deliveries
- Avionics cost

and having established forecasts of future avionics expenditures, DSC also generated forecasts of the unit demand for avionics equipment for 1980 and 1985. Figure XIV shows 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) and Intermittent Positive Control (IPC), 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 protion of new aircraft will ~~be~~ be delivered with VHF navigation receivers.

Automatic direction finders will continue to have a relatively high degree of acceptance throughout the fleet.

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 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. Based on the forecast of new aircraft deliveries shown earlier and the rate of avionics installations in new aircraft between 1980 and 1985, the forecasts prepared of the avionics demand in 1980 and in 1985 can be seen in Figure XV and Figure XVI.

E. PROGRAM RECOMMENDATIONS

One of the objectives of this study was to determine areas wherein research and development by NASA would be most beneficial to the general aviation community. This 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 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 priorities that should be established by NASA in its R&D activities for general aviation avionics 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.

Having evaluated the current technological state-of-the-art in the five major functional areas, DSC recommends that NASA R&D efforts are most urgently required in the area of displays. 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. Although 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

FIGURE XIV

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.

FIGURE XV

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

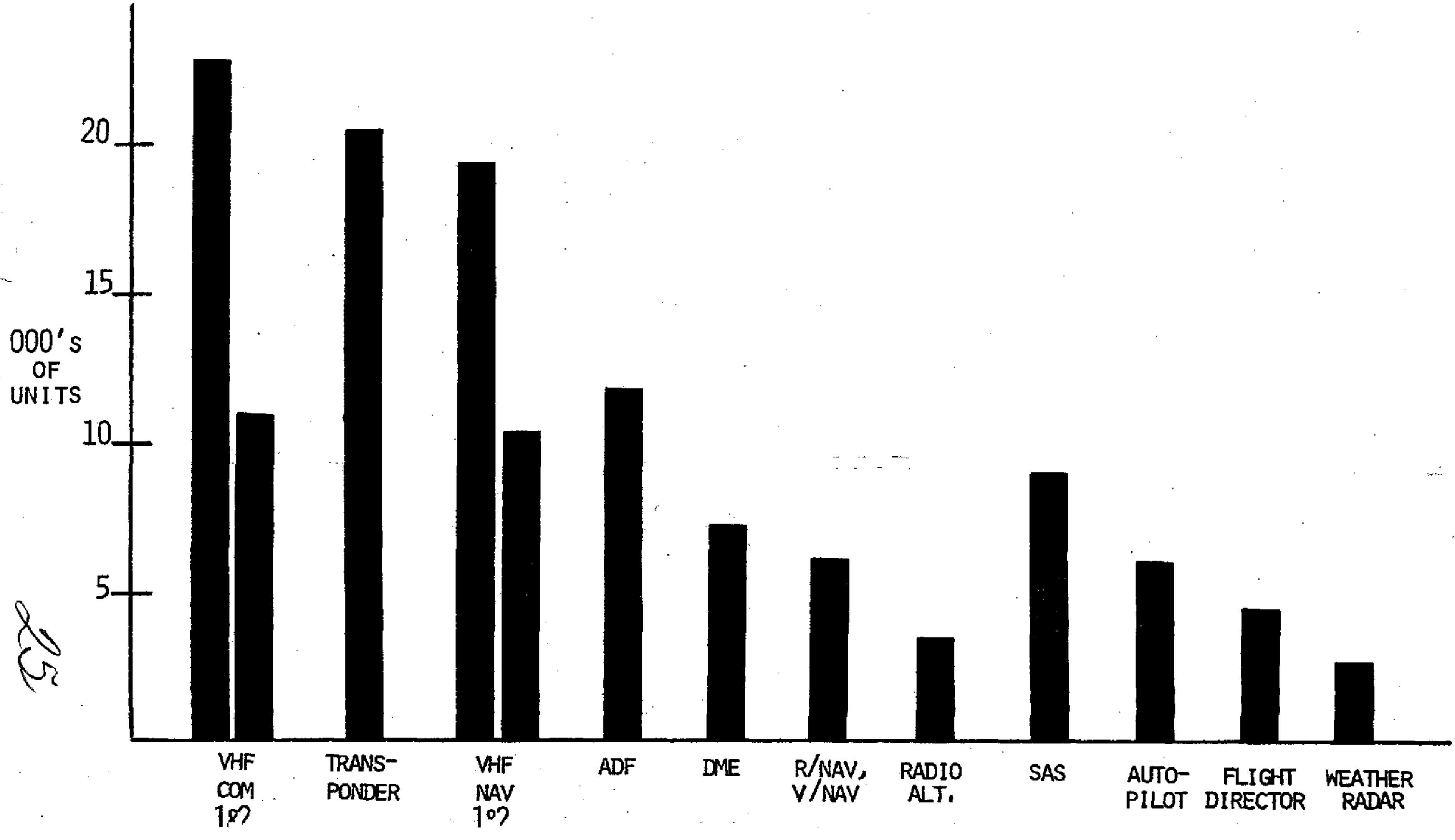


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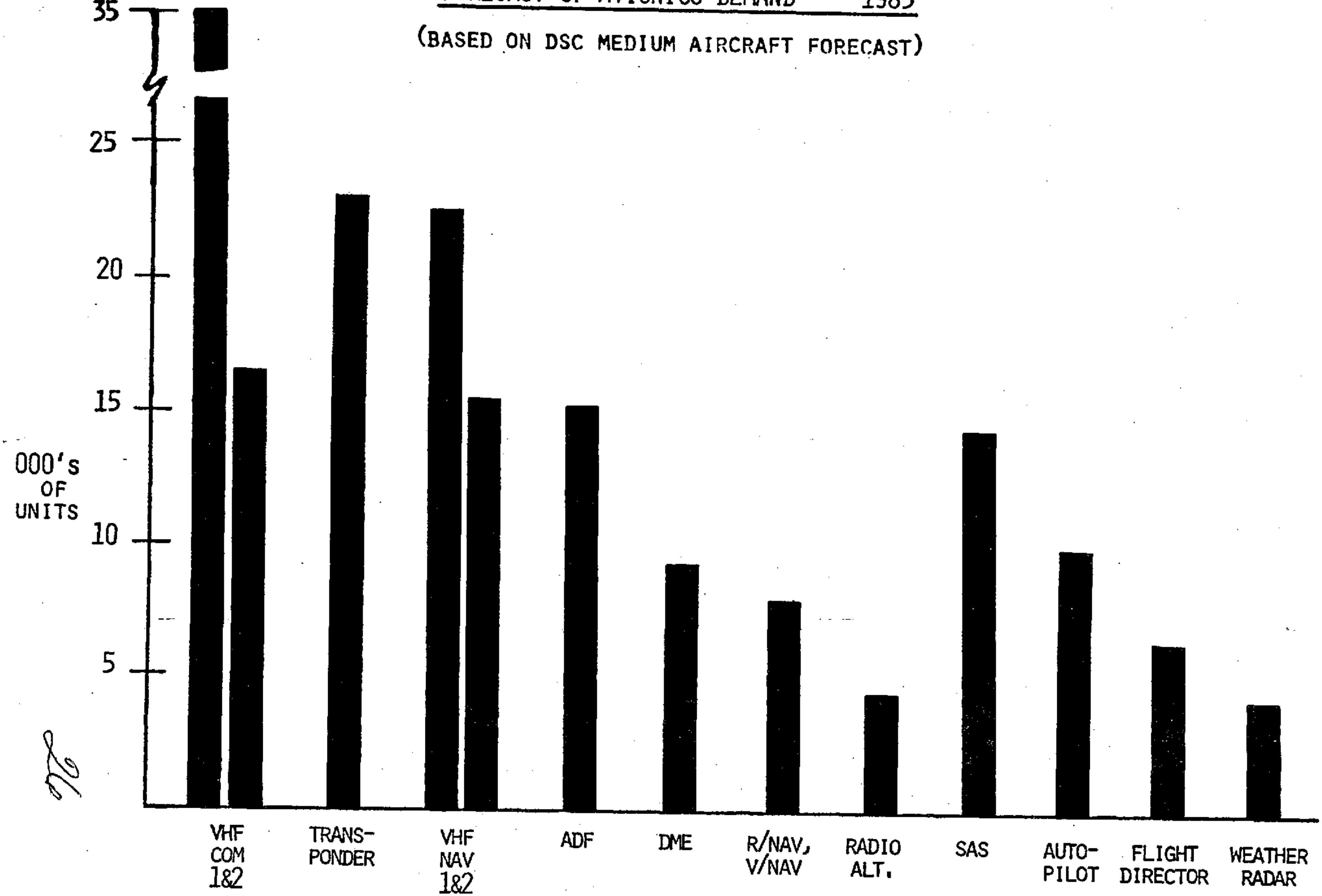
FIGURE XVI

FORECAST OF AVIONICS DEMAND - 1985

(BASED ON DSC MEDIUM AIRCRAFT FORECAST)



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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 shown in Figure XVII.

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 systems is shown in Figure XVIII.

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.

FIGURE XVII

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

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.

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 XVIII.

OVERALL RECOMMENDATION, TARGETED PRICES, AND RELIABILITY GOALS

There are two general recommendations not related to specific equipment:

- 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.

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 XIX. The figures in parentheses indicate the ranges of target prices that are proposed. The equipment and systems shown 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.

FIGURE XVIII

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

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FIGURE XIX

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)

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 XX.

FIGURE XX

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 MONITOR-ING 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 ALTI-TUDE 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)