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COST ANALYSIS OF THE AIRBORNE PORTION OF THE DISCRETE ADDRESS BEACON SYSTEM INTERMITTENT POSITIVE CONTROL (DABS/IPC) CONCEPT

FINAL REPORT

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December 1975

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16. Abstract

This report presents the results of the cost and reliability evaluations developed for discrete and LSI versions of the airborne portion of the DABS/IPC concept. To provide a basis for assessing the economic impact of DABS on the various aviation communities, separate cost evaluations have been developed for general aviation, commerical aviation, and the military.

This report presents the expected cost of ownership to the individual aircraft owner and the cumulative life-cycle cost to the user communities, based on the developed data.

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While space does not permit listing the names of all those who contributed to the study, we are pleased to acknowledge our indebtedness to the following persons for their assistance: Dr. J. D. Welch and P. H. Robeck, of Lincoln Laboratory, and W. G. Shear and J. Whalen, of Bendix Avionics Division.

SUMMARY

ARINC Research Corporation is under contract to the Federal Aviation Administration (Contract DOT-FA74WA-3506) to provide assistance in the development and evaluation of cost factors that will affect the FAA policy regarding Collision Avoidance Systems (CAS) as a national standard. The Discrete Address Beacon Systems (DABS) with its inherent Intermittent Positive Control (IPC) capability represents one method of ensuring safe aircraft separations, and this report examines the costs of the avionics required by the DABS/IPC system.

The cost of DABS/IPC avionics are developed for a discrete-component version similar to the existing prototype equipment and for an LSI version that is more indicative of future design techniques. To provide a basis for assessing the economic impact of DABS on the various aviation communities, separate cost evaluations have also been developed for general aviation, commercial aviation, and the military.

The classes of equipment studied have been limited to the Type I transponder and display equipment intended for the commercial air carriers and other high-performance aircraft, the Type II transponder and display intended for the general-aviation aircraft, and a modification of the APX-72 transponder for the military aircraft. The designs developed herein for evaluation purposes were based on the operational concept of DABS/IPC developed by Lincoln Laboratory for the Federal Aviation Administration.

To evaluate the costs associated with implementing the DABS concept and to permit comparison with other CAS studies, it was assumed that DABS implementation would begin in 1978. The number of DABS/IPC units to be installed each year was estimated and DABS/IPC life-cycle costs were developed from 1978 through 1988. The costs to be borne by the commercial carrier, military, and general-aviation user communties were evaluated separately. The cost analyses required the development of detailed cost and reliability data peculiar to the DABS/IPC system and the development of DABS/IPC impelmentation cost factors that apply equally to either ACAS or DABS/IPC concepts. System costs based on these data were evaluated with the aid of an economic analysis model.

The cost and reliability data describing the system concepts provided the basis for the economic evaluation of the system. These data were critical to the overall success of the study and were therefore developed with extreme care. The data development was based on designs provided by Lincoln Laboratory for

test and evaluation of the DABS/IPC concept and on designs developed by ARINC Research utilizing large scale integration of logic functions in an attempt to reduce system costs and improve system reliability. Both designs were developed reflecting production quality equipment intended for start of production in 1978.

Factors such as aircraft installation costs, equipment distribution costs, and the number of aircraft installing DABS/IPC on a year-by-year basis were assumed to apply equally to either ACAS or DABS/IPC concepts. They were developed so that the total cost of DABS implementation could be determined.

The individual aircraft costs and the combined user community costs of DABS implementation were developed using the independently derived system cost and reliability data. A summary of the DABS Cost Analysis is presented in Tables S-1 through S-3. Table S-1 identifies the costs of equipment required by the various users. The values shown are the expected manufacturers costs without mark-up for distribution. Table S-2 presents the costs per aircraft and life-cycle costs to each user community at the three annual inflation rates assumed in the study. Distribution costs have been included in the data presented. Table S-3 summarizes the total expenditure required to implement the airborne portion of DABS/IPC at the three annual inflation rates.

TABLE S-1. DABS/IPC COST OF EQUIPMENT*

System Component	Discrete-Component Version			LSI Version		
	Type I	Type II	Military	Type I	Type II	Military
Principal DABS Electronics	$6178	$493 (641)**	-	$4860	$616 (764)	-
Modification Kit	-	-	$2260	-	-	$ 941
IPC Indicator	2099	506	2099	1066	Included in Electronics	1066
Antenna	63	13	63	63	13	63
Control	516	-	300	516	-	300
ATC Display***	1527	-	-	1527	-	-

*Prices shown are original equipment manufacturers (OEM) costs, without mark-up for distribution.

**The values in parentheses represent the cost of equipment when altitude encoding is included.

***Optional equipment, not required.

The report also presents a review of the effects of variations in key [illegible]ameters (e.g., system failure rates) and key assumptions (e.g., quantities of equipment to be installed on each aircraft) in a sensitivity section. This is followed by a detailed review of the costs of providing built-in altitude-encoding capability in the Type II units. This built-in altitude-encoding capability would be required by the large majority of general aviation aircraft that are not equipped with encoding altimeters.

TABLE S-2. SUMMARY OF DABS/IPC COST ANALYSES

Cost Category	Commercial Aviation		Military Aviation		General Aviation [1]	
	Discrete Version ($)	LSI Version ($)	Discrete Version ($)	LSI Version ($)	Discrete Version ($)	LSI Version ($)
Cost of acquiring and installing DABS in a single aircraft (zero percent inflation)	15181.	11797.	12251.	8866.	1755. (2005)	1077. (1313)
Anticipated 11-year life-cycle cost for a single aircraft (zero percent inflation)	20051.	15989.	13884.	10270.	1865. (2125)	1176. (1434)
Total life-cycle cost for the entire user community (zero percent inflation)	67.6M	53.5M	246.0M	185.2M	606.8M (655.4M)	403.5M (452.1M)
Total life-cycle cost for the entire user community (six percent inflation)	95.3M	75.3M	359.9M	270.6M	929.4M (996.2M)	619.2M (687.0M)
Total life-cycle cost for the entire user community (ten percent inflation)	114.2M	90.0M	440.4M	325.4M	1216.4M (1305.2M)	809.6M (899.8M)

NOTES:
1. The individual aircraft data presented apply to the low performance aircraft which is the major category of general aviation aircraft.
2. The user community life-cycle costs include the combination of high and low performance aircraft.
3. The values in parenthesis represent the cost of DABS/IPC when altitude encoding is including in the General Aviation community.

TABLE S-3. TOTAL COST OF DABS/IPC IMPLEMENTATION

Inflation Rate	Discrete Version*	LSI Version*
Total Life-Cycle Cost for the entire community. (Zero Percent Inflation Rate)	$ 920.4M (969.0M)	$ 642.2M (690.8M)
Total Life-Cycle Cost for the entire community. (Six Percent Inflation Rate)	1384.6M (1451.4M)	965.1M (1032.9M)
Total Life-Cycle Cost for the entire community. (Ten Percent Inflation Rate)	1771.0M (1859.8M)	1225.0M (1315.2M)

*The values in parentheses represent the total cost of implementing DABS/IPC including altitude encoding in the entire general-aviation community.

The result presented in this report provide important data needed in FAA planning regarding future ATC systems, but the study was limited to avionics considerations only and will have to be augmented by cost predictions for the ground equipment costs associated with the DABS concept.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Federal Aviation Administration (FAA) has been engaged in an intensive evaluation of both air-derived and ground-derived Collision Avoidance System (CAS) concepts. These efforts will culminate in a recommendation to the Congress, by the end of 1975, on which of these concepts, if any, would be suitable for adoption as a national standard for collision avoidance. The most promising ground-derived concept under consideration is the Discrete Address Beacon System (DABS) with Intermittent Positive Control (IPC). Both the ground-derived and air-derived collision-avoidance system concepts have been subjected to exhaustive technical examination to ensure that the approaches are technically sound and feasible. Flight-test programs are being conducted with prototype hardware to demonstrate the capability of alternate versions of each concept. These flight tests have shown, thus far, that all of the systems are capable of providing aircraft collision-avoidance protection.

However, recommendation of a national policy for CAS cannot be based solely on technical factors but must also take into consideration the economic aspects of each alternative. Therefore, the FAA initiated this economic analysis to provide the necessary additional cost data essential to a policy decision on the CAS concepts. The work is being performed by ARINC Research Corporation under FAA Contract DOT-FA74WA-3506. This report presents the results of the analysis of the ground-derived CAS concept in terms of expected cost of ownership to an individual aircraft owner and total life-cycle costs (LCC) to the entire using community, i.e., commercial aviation, general aviation, and military aviation. This report does not address the costs associated with modifications to existing ATC ground facilities or expansion of the ATC facilities which might be required to support the Discrete Address Beacon System/Intermittent Positive Control (DABS/IPC) concept of CAS.

1.2 CONTRACT OBJECTIVES

The primary objective of the contract effort is to develop and evaluate detailed cost data on the ATC DABS transponders and the IPC display as defined by the FAA Engineering Requirements (ERs) prepared by Lincoln Laboratory.

The costs associated with the acquisition, installation, operation, and support of the proposed equipments have been addressed in this study and have been combined to establish the total cost of ownership to both the individual operator and the entire aviation community. Separate cost data have been developed for general aviation, the military, and commerical air carriers.

1.3 SCOPE

To provide fair and expeditious cost evaluations, the contract has required establishing a set of uniform rules that can be used in the evaluation of any collision-avoidance system. ARINC Research participation in the air-derived collision-avoidance system studies has resulted in the formulation of the necessary assumptions concerning such items as time frame of implementation, the aircraft retrofit requirements, and maintenance scenarios. These assumptions have been approved by the FAA and the manufacturers of the air-derived CAS system. These assumptions have been documented and adapted to the DABS/IPC evaluation and are presented as the Uniform Ground Rules for the Evaluation of DABS/IPC. A copy of the latest revision of the rules in included as Appendix A to this report.

It does not appear practical to start implementation of the DABS/IPC concept before the mid-1980's,with retrofit dictated by an individual or corporate desire to provide collision-avoidance protection to the equipped aircraft. However, the avionics equipment could be designed and marketed by 1978 and, for purposes of this analysis the DABS/IPC implementation has been scheduled to begin in 1978. This will permit the DABS/IPC analysis to be comparable with the other CAS analyses. Therefore, cost of implementation and life-cycle costs of ownership have been computed for each user community for the period 1978-1988; FAA supplied aircraft population data and mutually agreed upon aircraft retrofit schedules were used in these computations. The assumption of an 11-year impelmentation and life-cycle cost period for DABS/IPC provides a uniform basis for comparing the costs with air-derived CAS implementation.

The equipments defined by the FAA ERs were used by ARINC Research and selected general-aviation manufacturers as the basis for assessments of the unit costs and reliabilities.

1.4 REPORT ORGANIZATION

This report has been prepared in much the same way as the cost analysis [illegible] the air-derived CAS concepts to permit ready comparison of acquisition, installation, and life-cycle costs between the various collision-avoidance [illegible]s.

The report consists of eight chapters, describing the technical approach, data acquisition, analyses conducted, and results and conclusions obtained. The appendixes present supporting detailed data and results.

Chapter Two describes the overall approach to developing the economic evaluations, the assumptions and constraints employed, and the modeling methology used in obtaining the desired cost-of-implementation and cost-of-ownership values.

Chapter Three describes the development of the cost, reliability, maintainability, and design data for the commercial-aviation, general-aviation, and military-aviation equipment. It also describes the development of the data on costs and reliability that can be expected to result from maximum large-scale integration (LSI) of the logic required for DABS/IPC.

The cost of implementing the DABS/IPC concept requires the development of certain data that are common to all concepts. These data include installation costs, aircraft population statistics, and equipment configurations reflecting the practices and trends of the specific user communities that would ultimately be participants in a national collision-avoidance system. These common data are presented in Chapter Four.

In Chapter Five, the development and exercise of the economic analysis model are presented. The model is exercised for both the discrete-component and LSI configuration. Acquisition, installation, and maintenance support costs of the equipment and user populations are evaluated and summarized for the individual aircraft and for the total user communities. These costs are also combined to provide total life-cycle costs for the defined 11-year period.

In anticipation of potential differences of opinion over some of the assumptions and parameter values used in the model exerciese, a number of additional evaluations were developed in which certain input parameters and assumptions were varied in order to determine the sensitivity of the projected life-cycle cost to these parameters. The results of these special cases are presented in Chapter Six.

Chapter Seven presents a refinement in the overall DABS/IPC cost analysis to include the cost of providing altitude encoding data to all aircarft. Without a mandatory requirement, only the commercial aircraft, the military aircraft, and a portion of the general aviation fleet are likely to be equipped with altitude encoding equipment. Therefore, as a separate refinement in the overall cost analysis, ARINC Research has incorporated a modiifed, built-in altitude-encoding version of the Type II DABS/IPC for use in general aviation aircraft that lack an altitude-encoding system.

Chapter Eight summarizes the results of the investigation and presents specific conclusions derived from the economic analyses performed.

CHAPTER TWO

APPROACH

The evaluation of the cost of the DABS/IPC concept was intentionally developed in a manner that parallels the evaluation of airborne CAS* to provide easy comparison between the concepts in the costs of acquisition, installation, and logistic support. Where possible, identical scenarios were employed, e.g., time of implementation and aircraft statistics, to assure that economic benefits associated with the concepts would be readily comparable.

The development of detailed and accurate cost analyses for avionic equipment that currently exist only in prototype form can pose a number of formidable problems, including the following:

- Conversion of Engineering Requirements to Production Configuration of Equipment. The system concepts are in various stages of evaluation and employ existing technology levels. Evaluation criteria that take into account these limitations are needed to ensure that the study results will provide an evaluation of production-quality equipments.

- Anticipation of the Needs of the Aviation Community. The costs of any new equipment are controlled by the demand for the product. The demand for DABS/IPC transponders must be identified over a given time frame to permit estimation of production quantities and to justify development of the microelectronics necessary for cost-effective manufacture of these transponders. Therefore, it has been necessary in the study to limit the implementation schedule to a time frame that is realistic for the introduction of new avionics. The time frame has also been selected to be comparable to life-cycle-cost studies of alternate collision-avoidance concepts.

- Development of the Necessary Additional Data Required for a Comprehensive Cost Analysis. Although the development of data (such as aircraft fleet sizes) that apply equally to any CAS concept is of the lowest criticality in a comparative cost evaluation, it is extremely important to the accurate development of total implementation costs.

* Cost Analysis of Airborne Collision Avoidance (CAS) Concept, prepared for Department of Transportation, FAA, Office of Systems Engineering Management. FAA-EM-76-1, December 1975.

The general approach followed by ARINC Research Corporation in resolving these problems and obtaining the economic evaluations of the DABS/IPC concept is illustrated in Figure 2-1. The basic criteria for the evaluation were established through the adaptation of a set of Uniform Ground Rules for analysis of the air-derived collision-avoidance systems.

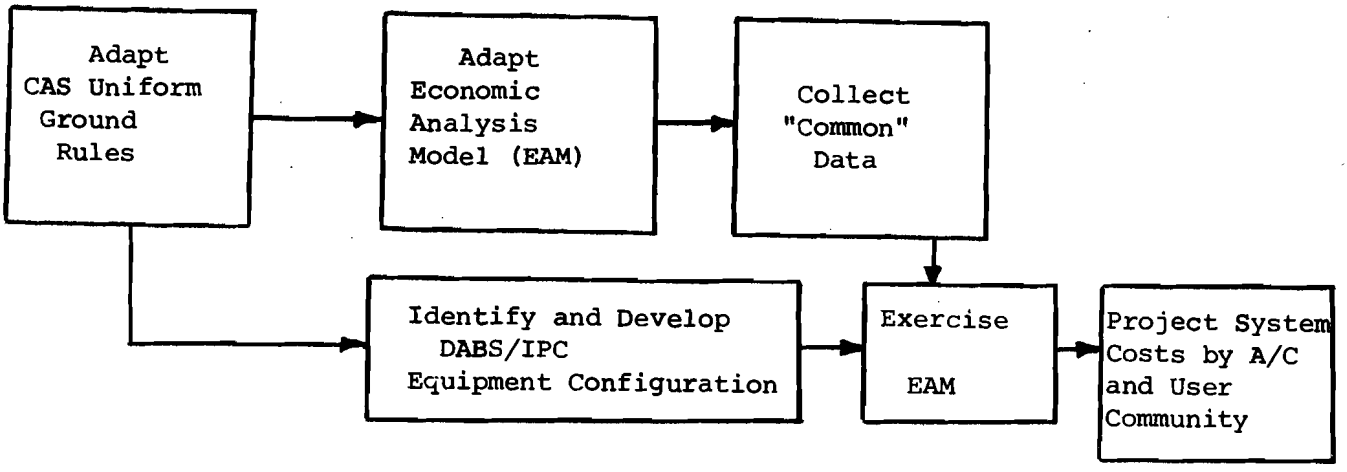

Figure 2-1. DABS/IPC ECONOMIC ANALYSIS APPROACH

An existing ARINC Research economic analysis model was adapted to evaluate the DABS/IPC implementation scenario. Parallel data-collection efforts were then initiated to obtain the common and system-peculiar input data needed to exercise the model. The common data, such as aircraft populations, installation costs, maintenance scenarios, etc., were developed or obtained from the FAA and from representative commercial, general, and military aviation users. The specific system data were developed from FAA ERs and from consultation with staff members of Lincoln Laboratory, developers of the DABS concept. These latter inputs provided the basis for the initial exercises of the economic analysis model (EAM). The definition of the DABS/IPC concept resulted in an equipment specification that was used as a basis for unit cost and reliability assessments by ARINC Research and a selected general-aviation equipment manufacturer. In addition, the model was exercised for several key parameter-variation cases in order to investigate the sensitivity of the results obtained to the input data and to the assumptions employed in the analysis. The outputs of each model exercise were the resultant acquisition, installation, support, and total costs, on a per-aircraft and total user-community basis, for each year and on a cumulative basis over the 1978-1988 period (an eleven year period).

The remaining sections of this chapter give details of how these steps were accomplished and how the key problems enumerated above were addressed; they also present the important assumptions that provide the basis for the entire study.

2.1 SYSTEM CONCEPT

The Discrete Address Beacon System (DABS)* is a cooperative surveillance and communications system for air traffic control. It employs ground-based interrogators and airborne transponders. Data-Link communications are accommodated integrally with the surveillance interrogations and replies. DABS has been designed as an evolutionary replacement for the current Air Traffic Control Radar Beacon System (ATCRBS) to provide surveillance and communications capability required for air traffic control in the 1980s and 1990s. DABS uses the same frequencies for interrogation and replies as ATCRBS. Interrogations are transmitted by differential phase-shift keying (DPSK) at a 4-mbps rate, and replies are transmitted by binary pulse-position modulation (PPM) at a 1-mbps rate.

The communications link provides an exchange of data that allows the ground equipment to perform intermittent positive control (IPC) functions, such as automatic proximity warning indication (PWI) and conflict resolution, for DABS/IPC-equipped aircraft.

The DABS transponder must reply to both ATCRBS and DABS interrogations, and it provides an interface with a variety of data-link message display and input devices.

Chapter Three of this study describes the development of the DABS transponder, IPC display, and the cost and reliabilities associated with the equipment.

2.2 REQUIRED AVIONIC EQUIPMENT

This study is limited to an evaluation of the cost and reliability of the airborne equipment required to provide the DABS/IPC functions associated with collision avoidance. The additional costs associated with data readout devices such as the ALEC (altitude echo) and ATC Message Display are treated as special cases in Chapter Six of the study.

The equipment considered consists of one of several DABS transponders (suitable for each class of user), control unit, antennas, IPC indicator, and miscellaneous hardware required for proper installation and operation in an airborne environment. The transponders have the operational characteristics defined by FAA documents ER-240-27 and ER-240-28, and the IPC display conforms to requirements defined by FAA document ER-240-30a. Equipment design allows for expected technological advances through the start of implementation in 1978 and utilizes proven existing transponder concepts where economically advantageous.

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*DABS: A System Description, Report No. FAA-RD-74-189

2.3 EQUIPMENT PRODUCTION

The expected quantities of production affect the cost of any avionic equipment. In order to maintain comparability to the airborne CAS, the total production quantity for a single manufacturer was limited to 3000 units of the commercial-carrier equipment and 10,000 units of the general-aviation equipment. These quantities were chosen in accordance with the normal industry experience with new avionic equipment, in which the production by any one manufacturer is limited to approximately one-third the total quantity required by commercial carriers.

It was assumed that implementation would begin in 1978 and would be completed in four years for commercial carriers and eight years for general and military aviation. These implementation periods, chosen after consultation with industry leaders, are consistent with the past experience of the aviation industry in introducing new equipment.

The proposed ARINC Research approach to defining equipment costs, installation costs, maintenance philosophies, and operating scenarios is contained in the Uniform Ground Rules. The latest version of the Rules, adapted to the DABS/IPC evaluation, is included as Appendix A to this report.

2.4 DEVELOPMENT OF THE ECONOMIC ANALYSIS MODEL (EAM)

The specific means of assessing the projected costs associated with the DABS/IPC concept was to refine and exercise a computer-based cost model developed for the evaluation of the airborne CAS. This model determines the annual and cumulative costs associated with a system and user category and tabulates those costs on a per-aircraft and a total user community basis. The model was developed by tailoring an existing ARINC Research cost model to the specific characteristics of the collision-avoidance concepts and the three categories of users (commercial, military, and general aviation).

The input data to the EAM consist of two types: data that are unique to a particular concept being evaluated and data that are common to any avionic equipment installed. The specific requirements for each type of data were defined concurrently with the development of the model, and a data-collection effort (described in the next two sections) was initiated.

Upon completion of the data-collection effort, the model was exercised for each user community. These exercises were conducted on both the discrete-component and LSI data sets. In addition, the EAM was exercised to determine the sensitivity of the results to variations in key parameters (e.g., MTBF) or assumptions (e.g., amortization).

2.5 SYSTEM DATA ELEMENTS

On the basis of the data requirements specified during the model development, detailed cost and system-performance data were developed. These data included physical characteristics, costs, reliabilities, and maintainabilities down to the smallest replaceable assemblies. Chapter Three describes the specific data developed during this effort.

2.6 COMMON DATA ELEMENTS

The data common to any avionics implementation (i.e., either air-derived CAS or DABS/IPC) consist of four basic types: (1) installation costs, (2) aircraft-fleet size projections, (3) aircraft equipment configurations, and (4) user-community operation and support parameters (e.g., average flying hours per month, labor rates, and pipeline times). Chapter Four describes the specific approach to developing these data and presents the data obtained.

Estimates for installing equipment on commercial air carriers were derived from experiences by two carriers in installing transponders in different types of aircraft. The general-aviation installation costs were developed through a questionnaire survey of general-aviation certified radio repair shops. The shops were asked to estimate the costs of installing a unit in single- and twin-engine aircraft. These estimates were based on quotes for installing a system similar to the DABS transponder in complexity and functions -- a modern general-aviation DME. Military-aircraft installation costs were developed by installation agencies of each of the three branches of the military for the airborne CAS equipment, and adapted to the DABS/IPC concept by ARINC Research.

Aircraft-fleet size projections for the commercial, military, and general-aviation communities were obtained directly from the U. S. Department of Transportation, FAA, Office of Aviation Policy, Aviation Forecast Branch for the period 1975-1985. These data were linearly extrapolated through 1988 to complete the coverage of the time period of interest.

The specific technical parameters considered for each category of user were based on the recommendations of FAA and Lincoln Laboratory personnel and on ARINC Research's knowledge of typical aviation practices.

Estimates of the common data elements that were peculiar to the individual user communities were developed from contacts with representative users within each category, consultation with the FAA, and ARINC Research personnel's prior knowledge gained from similar studies of these aviation user environments.

2.7 APPROACH SUMMARY

The preceding sections have provided an overview of the technical approach used in the study, outlined the capabilities of the Economic Analysis Model, described its use, and identified the general types and sources of data to be used in the evaluation. The succeeding chapters of this report describe in detail the data obtained, the characteristics of the EAM, and the specific results of the study.

CHAPTER THREE

DABS/EQUIPMENT COST AND RELIABILITY DEVELOPMENT

The equipment cost and reliability data developed in this chapter provide the basis for an economic analysis of the DABS/IPC concept and an economic comparison of a discrete-components system with an LSI version. Careful development of these data was an essential step in the overall economic analysis of the airborne portion of the DABS/IPC concept.

The development procedure used was to identify the required equipment, (the DABS transponder and the IPC display); establish the most probable mode of data transmission; and configure the production versions of the equipment for the various classes of users to establish production costs and system reliabilities.

ARINC Research conducted the analysis of the commercial-aviation, and general-aviation versions of the DABS/IPC concepts, and obtained the assistance of a general-aviation manufacturer to provide an additional analysis of the general-aviation version of the system. The assistance provided by the general-aviation manufacturer resulted in a redesign of the commercial-aviation system's logic.

In order to provide accurate data on costs and reliabilities, it was necessary to develop detailed equipment design data. Therefore, this chapter presents the background on the DABS system, the data and electrical characteristics of the proposed DABS transponders based on the design developed by Lincoln Laboratory, and LSI version of the DABS transponders developed by ARINC Research. Cost and reliability data are developed for the commercial-aviation Type I and general-aviation Type II transponders and displays, and additional cost and reliability data are developed for an LSI version of the Type I and Type II systems in an attempt to reduce the unit costs and improve system reliabilities. Finally, the peculiar needs of military aviation are addressed and a modification package designed which will allow the military to be active participants in the DABS concept without losing the existing tactical capabilities inherent in military transponders. The data developed in this chapter will provide a base for the economic analysis of the DABS/IPC concept.

3.1 DESIGN FEATURES OF THE DABS/IPC TRANSPONDER

The Air Traffic Control (ATC) Transponder was developed to provide ATC controllers aircraft identification and positioning information when

used in conjunction with the primary surveillance radar and secondary radar systems. Certified air carriers, military, and many general-aviation aircraft are equipped with a version of the ATCRBS transponders. The growth in the aviation community has resulted in a traffic load on the secondary radars that causes garbling of the transponder data when received messages are overlapped. This condition is expected to increase as more aircraft are transponder-equipped and the total aviation population increases, as predicted by the U.S. Department of Transportation, FAA, Office of Aviation Policy, Aviation Forecast Branch.

The development of the Discrete Address Beacon System was undertaken to provide the enhanced surveillance and communications capability required for air traffic control in the 1980s and 1990s. The capability of DABS to address and interrogate each aircraft discretely eliminates the channel interference currently experienced by ATCRBS. The communications capability (Datalink) inherent in the DABS concept provides the necessary transfer of IPC and PWI data from the ground equipment to each aircraft.

Introduction of the DABS transponder must be evolutionary, requiring operation in a mixed environment of DABS and ATCRBS equipment. Therefore, the design considered in this study reflects equipment capable of responding to normal ATCRBS interrogations, in addition to the discrete DABS functions, as defined in Reference 1.*

3.1.1 Transponder Data Characteristics

Several data transfer modes have been recommended and are being evaluated by Lincoln Laboratory. Sufficient evaluation has been performed such that Lincoln Laboratory can recommend the Differential Phase Shift Keying (DPSK) modulation technique at a 4-mbps rate for the ground-to-aircraft (Uplink) data link, and the Pulse Position Modulation (PPM) technique at a 1-mbps rate for the aircraft-to-ground (Downlink) data link for purposes of this analysis. The DABS transponder must include conventional ATCRBS Mode A and C capability, as defined in Reference 2, plus full DABS capability. The DABS modes handled by the transponder will include ALL-CALL and SURVEILLANCE as well as single-segment uplink (Comm-A) and downlink (Comm-B) communications transmissions. The extended-length uplink (Comm-C) and downlink (Comm-D) communications transmissions are not being considered in this economic evaluation.

The provisional signal formats considered in the equipment definition are identified in Reference 3.

3.1.2 Transponder Electrical Characteristics

The equipment considered in this study meets the general requirements of the Department of Transportation, FAA-ER-240-27, FAA-ER-240-28, and FAA-ER-240-30a (References 4,5, and 6). However, the ERs reflect equipment intended for test and evaluation of concepts. Therefore, certain latitude

*References are offered at the end of Chapter Eight.

has been exercised in interpreting the ER specifications. With the concurrence of the engineering staff of Lincoln Laboratory, all specifications considered unique to a test and evaluation program were omitted from the equipment considered and certain electrical parameters were changed to reflect available components in the transponder design. Every change was evaluated to ensure that the resultant equipment would operate satisfactorily in the planned DABS environment. Table 3-1 identifies the characteristic parameters of the equipment evaluated in the study for both the commercial aviation (Type I) and general-aviation (Type II) DABS transponders. The parameters of the military APX-72 system remain unchanged except for the modulation and demodulation techniques associated with the DABS modification; these will be the PPM and DPSK techniques, respectively.

The slight variations in operational parameters between the study and ER specifications, (e.g., Output Power, and Sensitivity) are a result of comparing existing components to the theoretical requirements of the ER's. The power output of the Type II unit has been specified at 355 watts to allow for cable losses between the unit and antenna. A radiated power of 150 watts is sufficient for proper operation of the DABS concept, according to Lincoln Laboratory engineering. The cable run in an average general-aviation aircraft is sufficiently short to insure the required radiated power with exisitng transmitters.

TABLE 3-1. DABS TRANSPONDER CHARACTERISTICS

Characteristics	Type I		Type II	
	Study	FAA ER-240-28	Study	FAA ER-240-27
Transmitter:				
Output Power	57 $\pm^{3}_{0}$ dBm	57 ± 3 dBm	54 ± 1 dBm	55.5 + 3 dBm
Modulation	PPM	PPM NRZ-PAM	PPM	PPM NRZ-PAM
Frequency	1090 ± 3 mHz	1090 mHz	1090 ± 3 mHz	1090 mHz
Duty Cycle	0.5%	0.5%	0.5%	0.5%
Receiver:				
Sensitivity	-76 dBm	-74 dBm	-74 dBm	-72.5 dBm
Dynamic Range	50 dB	50 dB	50 dB	50 dB
Frequency	1030 ± 0.2 mHz	1030 ± 0.1 mHz	1030 mHz	1030 ± 0.1 mHz
Stability	Crystal Controlled	(Not Specified)	Crystal Controlled	(Not Specified)
Demodulator	DPSK	DPSK	DPSK	DPSK
Power Requirements:	115V ± 10% 300-1000 Hz	115 VAC 400 Hz	14 ± 3VDC	13.75 VDC
Capability:	Mode A, Mode C ATCRBS; DABS	Mode A, Mode C ATCRBS; DABS	Mode A, Mode C ATCRBS; DABS	Mode A, Mode C ATCRBS; DABS
Temperature Range:	-54°C to +71°C operation	-54°C to +55°C operation	-15°C to +55°C operation	-15°C to +55°C operation
TSO Compliance	C74c	C74c	C74c	C74c

3.2 TRANSPONDER-COST DEVELOPMENT BASED ON DISCRETE COMPONENTS

The equipment cost development presented in this section represents the adaptation of module components that are used in the manufacture and assembly of ATCRBS transponders and meet the requirements of the DABS concepts. Existing components were chosen for the following reasons:

(1) The direct adaptability to the electrical requirements specified for DABS transponders
(2) Cost-effectiveness in the use of components that have already been subjected to the learning-curve effect of new equipment development

The equipment chosen as a base for development of the DABS transponder was that which exhibited the most promising potential for operating satisfactorily in the DABS environment during transponder tests performed by Lincoln Laboratory (Reference 7). The latest model ATCRBS transponder from each of two manufacturers was used for both the Type II (general aviation) and Type I (commercial aviation) cost and reliability development. Circuit modifications or expansions were made, and additional circuits (e.g., the DPSK demodulator and the DABS logic) were incorporated to provide the required operational design. The resultant design identified the component parts (by part number) in the quantities required to estimate system procurement costs, assembly labor costs, and reliabilities. Component parts costs and reliability estimates are presented in Appendix B.

The general-aviation version of the system was further subjected to cost and reliability evaluations by Bendix Aviation, an independent general-aviation manufacturer. It has been assumed that in the event of system implementation, the majority of the units required by general aviation would be manufactured by the general-aviation manufacturers. The results of the independent evaluation of the Type II DABS/IPC design are presented in Section 3.6.6.

3.2.1 Development of DABS Type I Transponder Costs

The equipment required by all the certified air carriers and most of the high-performance general-aviation aircraft was designed to meet the expected specifications of ARINC characteristics and the environmental requirements of the Radio Technical Commission for Aeronautics, Document No. DO-160, as applicable to air-carrier transponders.

Tables 3-2 to 3-5 are based on the expectation that two different manufacturers would produce the units; (Cases I and II, respectively incorporating the same variations in equipment design as presently exist in their respective ATCRBS transponders. Tables 3-2 to 3-5 identify the major modules required for assembly for the Type I transponder, summarize the parts by function for each module and give the total cost of material by component type for each module. The material costs shown represent the true costs of the components based on present advertised costs, with allowances made for the volume purchasing common to corporations involved in transponder manufacturing.

TABLE 3-2. DABS TYPE I TRANSPONDER (DISCRETE LOGIC) PARTS BREAKDOWN (CASE I)

MODULE / PARTS(ea)	TRANSMITTER		RF FRONT END*		IF AMP.*		VIDEO PROC.		CONTROL MATRIX		MONITOR		PWR.SUPPLY		DIGITAL LOGIC		CHASSIS	
	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
LSI's	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IC's	-	-	-	-	1	4.00	12	29.85	2	4.10	22	61.10	-	-	127	715.60	-	-
TRANSISTORS	2	13.85	5	4.30	12	5.01	19	15.62	29	13.92	12	6.00	10	7.89	-	-	-	-
DIODES	3	1.41	2	2.00	3	1.04	24	9.02	184	36.66	13	2.04	22	12.60	-	-	-	-
RESISTORS	11	.33	28	2.64	51	2.37	67	5.97	122	4.38	41	3.15	26	2.46	-	-	-	-
CAPACITORS	7	1.00	36	6.00	75	12.22	32	4.07	7	1.26	15	1.92	17	2.80	-	-	-	-
CRYSTALS	-	-	2	4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
POTENTIOMETERS	-	-	2	6.00	4	12.00	6	18.00	-	-	2	6.00	3	9.00	-	-	-	-
INDUCTORS	2	.30	11	1.85	26	1.30	-	-	-	-	1	.05	-	-	-	-	-	-
TRANSFORMERS	1	.65	-	-	-	-	-	-	-	-	-	-	1	11.00	-	-	-	-
POWER AMPLIFIERS	1	111.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PRINTED CIRCUITS	1	5.00	2	6.00	1	10.00	1	5.00	1	5.00	1	5.00	1	5.00	2	20.00	-	-
MISC.ELECT.	20	131.97	7	185.14	4	5.41	3	1.17	3	6.80	-	-	4	2.24	-	-	-	-
MISC.HARDWARE	-	-	1	12.00	1	2.60	Lot	5.00	2	.90	1	1.50	Lot	2.00	-	-	Lot	98.00
MATERIAL COST	265.70		229.93		55.95		93.70		73.02		86.76		54.99		735.60		98.00	

* Two (2) each required

TABLE 3-3. DABS TYPE I TRANSPONDER (DISCRETE LOGIC) PARTS BREAKDOWN (CASE II)

MODULE	TRANSMITTER		MODULATOR		RF FRONT END*		IF AMP*		VIDEO PROC.		MONITOR		PWR SUPPLY		DIGITAL LOGIC		CHASSIS	
PARTS(ea)	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
LSIs	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
ICs	-	-	11	44.59	-	-	3	12.00	12	58.45	24	88.14	2	8.00	127	715.60		
Transistors	-	-	11	7.02	4	1.84	7	3.69	8	11.33	16	18.53	6	3.39				
Diodes	-	-	51	30.40	8	6.99	4	1.62	66	30.31	16	5.27	13	7.32				
Resistors	-	-	100	3.00	22	.66	37	1.11	97	2.91	51	1.53	35	1.05				
Capacitors	-	-	24	1.59	41	8.35	50	5.64	23	2.19	23	2.32	15	1.79				
Crystals	-	-	1	2.00	2	4.00	-	-	-	-	-	-	-	-				
Potentiometers	-	-	1	.95	-	-	3	2.85	6	5.70	4	3.80	1	.95				
Inductors	-	-	2	2.36	8	.40	15	.75	-	-	-	-	1	1.05				
Transformers	-	-	1	.65	-	-	-	-	-	-	-	-	1	8.00				
Power Ampli.	1	111.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Printed Circuits	-	-	1	5.00	3	6.00	1	5.00	1	5.00	1	5.00	-	-	2	20.00		
Misc. Elect.	1	44.28	-	-	6	199.07	4	13.84	-	-	-	-	-	-	-	-		
Misc. Hardware	-	-	-	-	-	-	Lot	4.66	-	-	-	-	Lot	8.23	-	-	9	99.82
Material Cost	155.47		97.56		227.84		51.16		104.89		124.59		39.78		735.60		99.82	

* Two (2) Each Required.

TABLE 3-4. DABS TYPE I TRANSPONDER COST DEVELOPMENT (CASE I)

Cost \ Module	Transmitter ($)	Receiver ($) *	IF Amp ($) *	Video Processor ($)	Control Matrix ($)	Monitor ($)	Power Supply ($)	Digital Logic ($)	Chassis ($)	Final Assembly ($)	** Total Unit Cost ($)
Material	265.70	229.93	55.95	93.70	73.02	86.76	54.99	735.60	98.00	--	1979.53
Handling @25% material	66.43	57.48	13.99	23.43	18.26	21.69	13.75	183.90	24.50	--	494.90
Labor @$11 / hour	28.73	54.30	21.30	41.10	60.92	32.12	22.47	59.36	52.13	41.53	489.56
Burden @135% of Labor	38.79	73.30	28.76	55.48	82.24	43.36	30.34	80.13	70.37	56.06	660.89
Inspection @5% Labor and Burden	3.38	6.38	2.50	4.83	7.16	3.77	2.64	6.97	6.13	4.88	57.52
Subtotal	403.03	421.39	122.50	218.54	241.60	187.70	124.19	1065.96	251.13	102.47	3,682.40
Engineering and Quality Control @25%	100.76	105.35	30.63	54.64	60.40	46.93	31.05	266.49	62.78	25.62	920.63
FACTORY COST	503.79	526.74	153.13	273.18	302.00	234.63	155.24	1332.45	313.91	128.09	4,603.03
General and Administrative @20%	100.76	105.35	30.63	54.64	60.40	46.93	31.05	266.49	62.78	25.62	920.63
TOTAL COST	604.55	632.09	183.76	327.82	362.40	281.56	186.29	1598.94	376 69	153.71	5,523.66
PROFIT @15%	90.68	94.81	27.56	49.17	54.36	42.24	27.94	239.84	56.50	23.06	828.53
SELLING PRICE	695.23	726.90	211.32	376.99	416.76	323.80	214.23	1838.78	433.20	176.76	6,352.19

NOTE: *Two (2) each required.

**Total Unit Cost includes cost of two (2) Receivers and two (2) IF Amplifiers with the required comparator circuitry to provide diversity operation.

TABLE 3-5. DABS TYPE I TRANSPONDER COST DEVELOPMENT (CASE II)

COST \ MODULE	TRANSMITTER ($)	MODULATOR ($)	RF FRONT END ($)*	IF AMP. ($)*	VIDEO PROC ($)	MONITOR ($)	PWR SUPPLY ($)	DIGITAL LOGIC ($)	CHASSIS ($)	FINAL ASSEMBLY ($)	TOTAL UNIT COST ($)**
Material	155.47	97.56	227.84	51.16	104.89	124.59	39.78	735.60	99.82	-	1,915.71
Handling @ 25% Material	38.87	24.39	56.96	12.79	26.22	31.15	9.95	183.90	24.96	-	478.94
Labor @ $11/Hour	6.05	39.05	37.65	43.67	35.16	27.10	18.61	59.36	50.59	41.69	440.25
Burden @ 135% Labor	8.17	52.72	50.83	58.95	47.47	36.59	25.12	80.13	68.30	56.28	594.34
Inspection and Burden @ 5% Labor	.71	4.59	4.42	5.13	4.13	3.18	2.19	6.97	5.94	4.90	51.71
Subtotal	209.27	218.31	377.70	171.70	217.87	222.61	95.65	1,065.96	249.61	102.87	3,480.95
Engineering and Quality Control @ 25%	52.32	54.58	94.43	42.93	44.47	55.65	23.91	266.49	62.40	25.72	870.26
Factory Cost	261.59	272.89	472.13	214.63	272.34	278.26	119.56	1,332.45	312.01	128.59	4,351.21
General and Administrative @ 20%	52.32	54.58	94.43	42.93	54.17	55.65	23.91	266.49	62.40	25.72	870.26
Total Cost	313.91	327.47	566.56	257.56	326.81	333.91	143.47	1,598.94	374.41	154.31	5,221.47
Profit @ 15%	47.09	49.12	84.98	38.63	49.02	50.09	21.52	239.84	56.16	23.15	783.21
Selling Price	361.00	376.59	651.54	296.19	375.83	384.00	164.99	1,838.78	430.57	177.46	6,004.68

* Two (2) each required.

** Total unit cost includes cost of two (2) receivers and two (2) IF amplifiers with the required comparator circuitry to provide diversity operation.

The transmitter module includes the power amplifier (cavity oscillator), high-voltage power supply, modulator, logic-controlled hybrid switching, and the circulators. The switching is required to direct the transmitter output to the antenna system in sight of the ground DABS site.

Two receivers are required to provide diversity operation. Each receiver consists of a duplexer, pre-selector, mixer, local oscillator, and self-test unit. Each receiver is permanently committed to one of the antennas, providing true diversity.

The diversity operation requirement is extended through the IF amplifier, resulting in two identical and redundant IF chassis per receiver. One of the IF modules contains the signal-level comparator and switching networks, while the other houses the DPSK demodulator. The material-cost differences between the comparator and demodulator were sufficiently small to permit module-cost development based on either unit.

The video processor, control matrix, monitor, and power supply provide the normal operation and surveillance of the equipment. Provisions are made for automatic built-in test and external bench testing of the transponder.

The digital-logic module incorporates the design provided by Lincoln Laboratory and used in their DABS flight-evaluation program. The logic responds to the DABS and ATCRBS interrogations and other modes identified in Section 3.1.1.

The factory cost for each module was developed by applying cost factors for material-handling, labor and burden, inspection, and engineering. The direct cost of manufacture is identified in Tables 3-4 and 3-5 as the Factory Cost. A 20 percent general and administrative cost and a 15 percent profit were added to the factory costs of the system to establish the estimated minimum selling price of the modules or system. This selling price would be the acquisition cost borne by a commercial air carrier, the military, or an avionics distributor that resells these systems to the small percentage of general-aviation users requiring a Type I Unit.

The costs developed for the Type I DABS transponder vary between the two cases presented. The variations stem from material costs for components in the transmitter and RF stages of the two systems. The cost development is based on components and practices used by two leading commercial-aviation equipment manufacturers and are consistent with the cost variations in the advertised selling prices of ATCRBS transponders of these manufacturers. The equipment costs used in the study represent an average of the costs developed for the two cases presented.

3.2.2 Development of DABS Type II Transponder Cost

The general-aviation version of the DABS transponder was subjected to a pricing evaluation similar to that used for the Type I unit. Tables 3-6 and 3-7 identify the major modules required for assembly of the Type II transponder if manufactured by two different general-aviation manufacturers. The packaging of these units is unrestricted, conforming to the practice in the general-aviation community, and the environmental requirements reflect the less stringent specifications of document DO-160, as applicable to the general-aviation class of equipment.

The Type II transponder does not require diversity operation. The modules presented in Tables 3-6 and 3-7 consist of the transmitter, (a cavity oscillator), modulator, high-voltage power supplies, RF front end, logarithmic IF receiver, DPSK demodulator, and logic circuitry required to provide DABS and ATCRBS operation. The logic has been divided, by function, into the Digital Logic used in the system developed by Lincoln Laboratory and the Analog Logic required for use in ATCRBS operations, such as Reply Rate Limiting and Identification Control.

The material costs of Tables 3-6 and 3-7 were averaged and the resultant costs used in Table 3-8 in the development of system costs. Labor estimates were also averaged in determining the cost of system assembly, packaging, testing, and burn-in. This averaging technique is appropriate for the Type II systems because of the similarity in components used in manufacturing general-aviation products and the limited control and monitoring required of GA avionics. The direct cost of manufactures of a module and the system is identified in Table 3-8 as the Factory Cost. A 67 percent burden, general and administrative, and profit were added to the factory cost to establish the estimated minimum selling price. This selling price would be the acquisition cost borne by the military or by an avionics distributor who resells these systems to the general-aviation users. The advertised list price of the transponder would include a 100 percent distribution mark-up, and this is shown for the system cost in Table 3-8.

3.2.3 IPC Display Cost Development

The aircraft position and tactical command indicator used in the DABS/IPC concept is a self-contained unit, designed for mounting in the instrument panel of an aircraft. The indicator display consists of 36 lights arranged in groups of three, representing a twelve-hour clock, providing the pilot with information on the direction of other nearby aircraft. An additional eight lights, represented by arrows and Xs provide the pilot with tactical commands for horizontal or vertical escape maneuvers when the aircraft is on a collision course with any other nearby aircraft. Pilot-actuated switches are provided on the general-aviation version of the display for acknowledgement and test functions. The commercial-carrier and military versions of the system have the pilot-actuated devices on the control panel. Figure 3-1 on page 3-14 presents a typical command indicator used in the study.

TABLE 3-6. DABS TYPE II TRANSPONDER PARTS BREAKDOWN (CASE 1)

Module / Parts (ea)	Transmitter		Receiver		Power Supply		Analog Logic		Digital Logic		Chassis	
	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
LSI's	-	-	-	-	-	-	-	-	-	-	-	-
IC's	-	-	3	3.33	2	3.00	7	3.23	127	94.46	-	-
Transistors	3	1.70	9	4.94	4	2.66	6	2.60	-	-	1	.40
Diodes	5	1.40	4	1.86	5	1.83	8	1.77	-	-	1	.35
Resistors	10	.28	55	1.65	14	.42	18	.54	-	-	15	.45
Capacitors	12	1.56	65	6.92	4	.60	9	1.05	-	-	5	.45
Crystals	-	-			-	-	-	-	-	-	-	-
Potentiometers	1	.29	3	.87	1	.29	-	-	-	-	-	-
Inductors	3	1.29	24	2.13	-	-	-	-	-	-	5	.30
Transformers	1	50	4	3.00	-	-	-	-	-	-	-	-
Power Amps	1	21.00	-	-	-	-	-	-	-	-	-	-
Printed Circuits	1	3.00	1	3.00	1	3.00	1	3.00	1	16.-	1	3.00
Misc. Elect.	-	-	3	9.24	-	-	-	-	-	-	4	1.80
Misc. Hardware	-	-	LOT	1.50	-	-	-	-	1	3.00	LOT	34.48
Material Cost	31.02		39.94		11.80		12.19		107.46		41.23	

TABLE 3-7. DABS TYPE II TRANSPONDER PARTS BREAKDOWN (CASE 2)

Module / Parts (ea)	Transmitter		Receiver		Power Supply		Analog Logic		Digital Logic		Chassis	
	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
LSIs	-	-	-	-	-	-	-	-	-	-	-	-
ICs	-	-	3	3.33	2	3.00	7	3.23	127	94.46	-	-
Transistors	4	1.35	8	3.57	6	2.06	6	2.60	-	-	4	.48
Diodes	2	.24	4	1.72	8	3.53	8	1.77	-	-	1	.12
Resistors	13	.39	43	1.29	23	.75	18	.54	-	-	10	.30
Capacitors	5	.25	46	4.10	25	2.15	9	1.05	-	-	7	.55
Crystals	-	-			-	-	-	-	-	-	-	-
Potentiometers	1	.29	3	.87	2	.64	-	-	-	-	-	-
Inductors	-	-	15	1.77	2	.12	-	-	-	-	2	.12
Transformers	-	-	1	.75	1	.50	-	-	-	-	-	-
Power Amps	1	21.	-	-	-	-	-	-	-	-	-	-
Printed Circuits	1	10.	1	3.00	-	-	1	3.00	1	10.	-	-
Misc. Elect.	1	1.50	2	7.74	-	-	-	-	-	-	-	-
Misc. Hardware	-	-	LOT	3.00	-	-	-	-	1	3.00	LOT	38.94
Material Cost	35.02		32.64		12.75		12.19		107.46		40.51	

TABLE 3-8. DABS TYPE II TRANSPONDER COST DEVELOPMENT

Cost \ Module	Transmitter (Dollars)	Receiver (Dollars)	Power Supply (Dollars)	Analog Logic (Dollars)	Digital Logic (Dollars)	Chassis (Dollars)	Final Assembly and Test (Dollars)	Total
Average Material	33.02	36.29	12.28	12.19	107.46	40.87	--	242.11
Average Labor @$2.75	4.16	12.08	3.22	5.97	10.26	8.22	9.35	53.26
Direct Factory Cost	37.18	48.37	15.50	18.16	117.72	49.09	9.35	295.37
Mark-Up for O.H., G&A, Profit @67%	24.91	32.41	10.39	12.17	78.87	32.89	6.26	197.90
Manufacturers Sale Price	62.09	80.78	25.89	30.33	196.59	81.98	15.61	493.27
Distribution Cost @100%								493.27
List Price								986.54

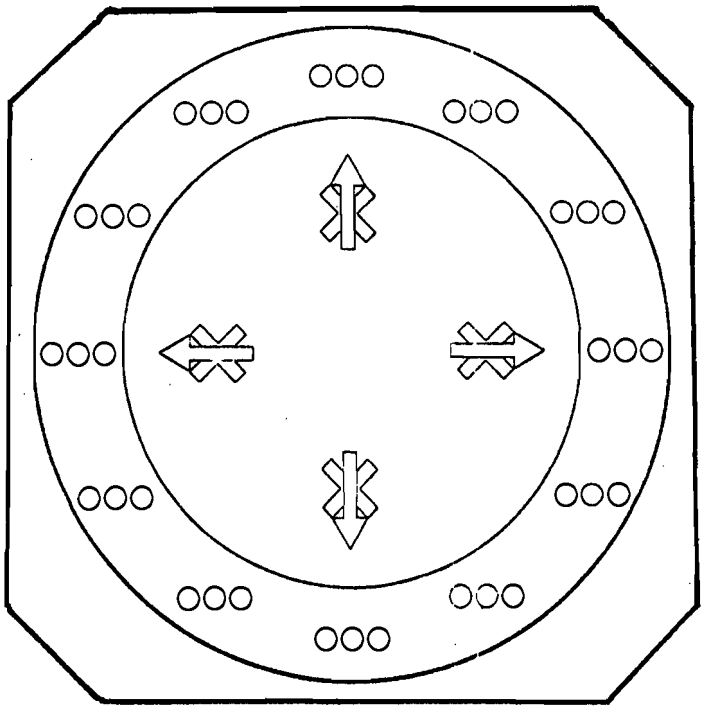


Figure 3-1. TYPE I IPC COMMAND INDICATOR

Table 3-9 identifies the display components, by function, required to assemble the indicator for the two major classes of users. The material costs represent the costs of the components based on present advertised costs, with allowances made for volume purchasing. The major difference in material costs between the commercial-aviation and general-aviation versions of the display stems from the cost difference associated with the temperature rating of components required by each user class.

Tables 3-10 and 3-11 present the cost development of the displays for each category of manufacture, reflecting the same practices of mark-ups and profit discussed earlier for transponder-cost development.

3.2.4 DABS Control Unit

The cost and reliability of the Type I system control unit were not developed. The existing ATCRBS control unit will be replaced by units incorporating the specific requirements of DABS, e.g., pilot-actuated data devices, aircraft identification codes (other than for Mode A), etc., but the overall cost of the unit is expected to remain at the same level as present units. Therefore, the study reflects the minimum cost of existing control units and the reliability of these units as documented in FARADA for similar devices.

TABLE 3-9. IPC/PWI DISPLAY PARTS BREAKDOWN

Parts (ea) \ Unit	Commercial Aviation Version		General Aviation Version	
	Quantity	Cost	Quantity	Cost
LSIs	--	--	--	--
ICs	100	513.98	100	164.50
Transistors	12	2.16	12	2.16
Diodes	--	--	--	--
Resistors	76	2.28	76	2.28
Capacitors	23	2.45	23	2.15
Potentiometers	1	3.00	1	1.18
Inductors/Chokes	1	1.05	1	.55
Printed Circuits	6	30.00	6	18.00
Miscellaneous Electrical	50	51.93	50	51.93
Miscellaneous Hardware	LOT	29.00	LOT	17.50
Material Cost	$ 635.85		$ 260.25	

TABLE 3-10. IPC DISPLAY COST DEVELOPMENT (GENERAL AVIATION DISCRETE COMPONENT VERSION)

Factor	Cost
Material	$260.25
Labor @ $2.75/Hour	42.46
Direct Cost	302.71
Mark-Up for Overhead Burden and Profit @ 67%	202.82
Factory Selling Price	505.53
Distributor Mark-Up @ 100%	505.53
List Price	1011.06

TABLE 3-11. IPC DISPLAY COST DEVELOPMENT (COMMERCIAL AVIATION DISCRETE COMPONENT VERSION)

Factor	Cost
Material	$635.85
Material Handling @ 25%	158.96
Labor @ $11.00/Hour	170.94
Burden @ 135% of Labor	230.77
Inspection @ 5% Labor and Burden	20.09
Subtotal	1216.61
Engineering and Quality Control @ 25%	304.15
Factory Cost	1520.77
General and Administrative @ 20%	304.15
Total Direct Cost	1824.92
Profit @15%	273.74
Selling Price	2098.65

3.2.5 DABS ATC Data-Link Display Cost Development

The DABS concept is designed to provide data exchange between an aircraft and ground control, in addition to normal transponder operations and the collision-avoidance capability evaluated in this study. In order to identify the probable life-cycle costs associated with the airborne portion of DABS, attention must be given to the equipments that will probably be included as part of the DABS/IPC implementation. This section identifies and develops the cost of a display device capable of providing a pilot with ATC information in the form of heading, airspeed, altitude echo, and 16-character ASCII displays. The development of production-version costs and reliabilities has been limited to the commercial air carriers, the most probable users of this type of equipment, with a recommendation that only one display be provided for each commercial-carrier aircraft. Figure 3-2 presents a probable ATC display configuration evaluated in the study.

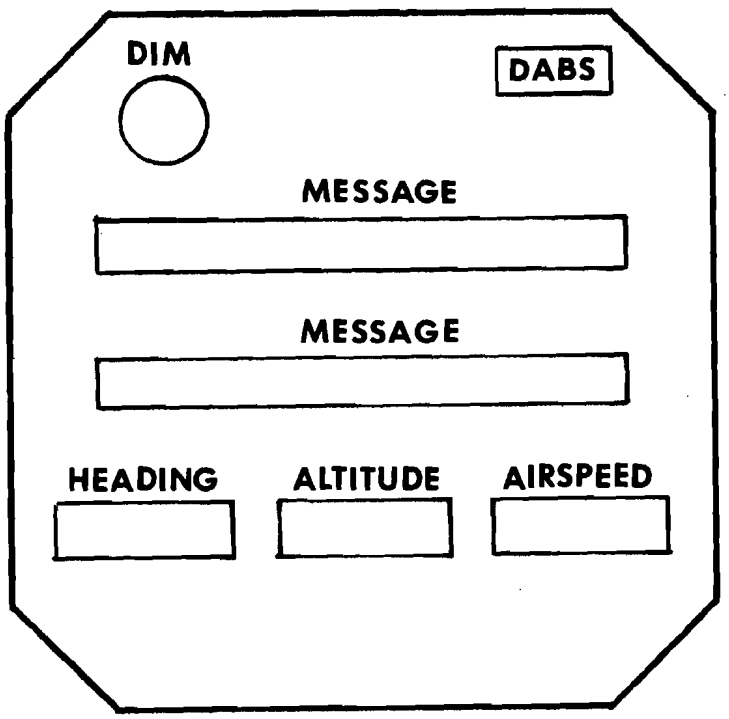


Figure 3-2. ATC DATA-LINK DISPLAY

Table 3-12 develops the cost of an ATC Display on the basis of the design information contained in Reference 1. The design assumes data transfer between the DABS transponder and the ATC display by way of the Standard Message (SM) bus, and is compatible with the Type I transponder developed in this chapter. LSI technology has not been applied to this display because of the expected limited production and utilization. However, mandatory requirements for the addition of an ATC display for all aircraft would justify LSI development and reduce the acquisition costs.

TABLE 3-12. ATC MESSAGE DISPLAY COST DEVELOPMENT

FACTOR	COST
MATERIAL	$ 521.98
MATERIAL HANDLING @ 25%	130.50
LABOR @ $11.00/HOUR	94.33
BURDEN @ 135% OF LABOR	127.34
INSPECTION @ 5% LABOR & BURDEN	11.00
SUB TOTAL	885.22
ENGINEERING AND QUALITY CONTROL @ 25%	221.31
FACTORY COST	1106.53
GENERAL & ADMINSTRATIVE @ 20%	221.31
TOTAL DIRECT COST	1327.83
PROFIT @ 15%	199.17
SELLING PRICE	1527.01

(See Appendix B for parts breakdown)

3.3 DABS/IPC SYSTEM RELIABILITY AND MAINTAINABILITY

The reliability of each of the systems was reviewed and evaluated. The detailed parts lists developed for cost evaluation permitted application of the MIL-217* reliability-prediction technique in the determination of system or module MTBF by component failure rate. However, since a detailed circuit analysis was not practical, a uniform approach to system reliability was chosen for both systems (Types I and II) to ensure a comparable basis for analysis.

When the MIL-217 reliability-prediction technique is used, it is necessary to make assumptions regarding key system operating parameters. For example, the operating ambient was chosen at 40°C. The stress ratios for components was assumed to be 0.5. Junction temperatures used were those listed in D.A.T.A. Reference Standards for Industry, as applicable to the semiconductor class. Critical transistors, e.g., modulators, were evaluated to establish the normalized junction temperature (T_n), and failure rates were derived from curves and data tables of MIL-217. The K-factor for airborne application was used.

*Military Standardization Handbook, Reliability Stress and Failure Rate Data for Electronic Equipment, MIL-HDBK-217B, 20 September 1974.

TABLE 3-13. DABS/IPC COST AND RELIABILITY DATA (DISCRETE DATA)

Unit	MTBF (Hours)	Mean Time To Isolate A Failure (Hours)	MTTR (Hours)	Expected Average Material Repair Cost Per (Dollars)
DABS TYPE I TRANSPONDER SYSTEM WITH IPC DISPLAY				
Display	7136	1.0	2.0	7.85
Antenna	50000			
Control	10000			51.60
Transponder	1178	1.0		
Transmitter	3507		1.0	30.12
Receiver	19797		1.2	17.74
IF Amplifier	16963		1.0	.62
Video Processor	13994		1.0	.88
Control Matrix	8752		1.0	.39
Monitor	25823		1.0	1.03
Power Supply	23144		1.2	1.13
Digital Logic	16800		2.0	7.23
Chassis	57777		0.5	8.82
DABS TYPE II TRANSPONDER SYSTEM WITH IPC DISPLAY				
Display	7136	1.0	2.0	6.52
Antenna	50000			
Transponder	2552	1.0		
Transmitter	4582		1.0	18.82
Receiver	19384		1.0	.55
Power Supply	50408		1.0	.45
Logic Analog	63613		0.5	.33
Logic Digital	16800		2.0	.95
Chassis	37068		0.5	1.76

Additional failure-rate data used in the evaluation were obtained from the TRI-Service and NASA FARADA* data. These failure rates are computed on the basis of actual experience in given environments.

*Failure Rate Data (FARADA), Fleet Missile Systems Analysis and Evaluation Group Annex, Naval Weapons Station, Seal Beach, Corona, California.

The reliability evaluations of the systems considered all electronic components in the circuits of the systems. A failure of any component was treated as causing a failure of the system.

The average maintenance times to isolate a failure to a module level, or to repair a failed module, were determined by comparison with data available on similar components. The estimates reflect the assumption that the production version of the DABS/IPC concept will be assembled with readily accessible plug-in modules, as is common with existing high-quality ATCRBS transponders.

The average material cost per repair action was developed by determining the contribution of any component to the module's reliability based on component cost and expected failure rate.

The detailed development of these data is presented in Appendix B to this Report.

The resultant data, as evaluated by ARINC Research, are presented in Table 3-13 for both classes of equipment -- the high-performance Type I system for air carriers and the limited-packaging Type II system for the majority of the general-aviation community. These data provide the basis for the cost of ownership and life-cycle costs evaluated in Chapter Five of this report.

3.4 TRANSPONDER COST DEVELOPMENT BASED ON THE INTRODUCTION OF LARGE SCALE INTEGRATION (LSI)

The greatest difference between the existing ATCRBS transponders and the airborne DABS/IPC systems is in the increased data-handling requirements of DABS/IPC. The logic required to process and display or respond to ground transmissions currently requires more than 100 integrated circuits for the transponder logic and an equal amount for the IPC display. The cost associated with the logic modules for the Type I DABS transponder represents approximately a 400-percent increase over the logic currently used in a high-quality ATCRBS transponder. The increase in logic cost for the Type II DABS transponder is even higher, approaching 600-percent. In addition, the general-aviation version of DABS/IPC must be packaged in separate units for the transponder and display because of the space requirements for mounting the many discrete logic chips.

Present capabilities of the microelectronic manufacturers indicate the feasibility of custom-designing logic chips (LSIs) to perform the functions required by the DABS/IPC logic sections. The only practical limitations to custom design are the maximum sizes of the chip (currently limited to 40-pin configurations) and the cost of the chip, which must reflect the high development costs experienced by the microelectronics manufacturers.

ARINC Research has reviewed the functional block diagrams of the required logic developed by Lincoln Laboratory and has sectionalized the logic, by function, into an average of seven chips for the DABS Transponder and five chips for the IPC display. Table 3-14 identifies each of the LSIs by function for each unit of the DABS/IPC system. A detailed review of the proposed LSI logic indicates that the average density of each chip will be 400 logic functions, with the highest density at 818 logic functions. This density is well within the present design capability of the microelectronics manufacturers. Some discrete components will still be required, e.g., lamp drivers or line drivers and receivers, where high power outputs or line-to-TTL compatibility are required. A block diagram of the IPC display logic is presented in Figure 3-3. The simplified logic diagrams are presented in Appendix C.

The Bendix Aviation Corporation, in reviewing the logic required for the DABS transponder operations, has proposed the use of a single LSI chip with nominal discrete components to perform all the required logic operations. Bendix Aviation possesses the design and development capability for LSIs and has the only LSI'd ATCRBS transponder on the market (also using a single LSI chip). The recommendation by Bendix Aviation, a potential manufacturer of the DABS transponder, has been followed in this study because of the obvious cost reduction in component costs. The simplified schematic diagram of the DABS transponder logic is presented in Figure 3-4. The average cost of each chip has been determined to be $20 for the general-aviation version and $35 for the higher temperature requirements of the air-carrier version of DABS/IPC. The costs reflect the advertised prices of similar components, e.g., ROMS, RAMS, processors, all with densities comparable to those projected for DABS/IPC logic and in system-production quantities used in the study. The development costs are assumed to be amortized in the large production quantities predicted for DABS/IPC implementation.

3.4.1 DABS Type I Cost Development - LSI Version

The introduction of LSI technology to the manufacture of the Type I transponder will affect only the digital logic module of the proposed configuration presented in Section 3.2. The number of components and their associated cost will be reduced, with the resultant material cost and assembly labor data changed to reflect the lower costs. Tables 3-15 and 3-16 identify the two Type I transponders cost development with LSI'd logic and present the expected minimum selling price of each transponder. Comparison with Tables 3-4 and 3-5 shows a decrease of 17.5 percent in the minimum selling price of the transponder when LSI technology is utilized.

The use of LSI technology has also been extended to the manufacture of the IPC display indicator. The benefits will be realized in the reduction of the material costs, assembly labor, and packaging (smaller volume required to house the integrated logic). Table 3-17 identifies the costs associated with unit production. Comparison with the display presented in Table 3-11 shows a decrease of 45 percent in the minimum selling price of the display when LSIs are used.

TABLE 3-14. LSI PARTITIONING

LSI Number	Description	Transponder Type I	Transponder Type II
1	Mode Control, SLS, Reset Circuits	x	x
2	ATCRBS Clock	x	x
3	DPSK Decoder, Processor, Mode Decode	x	x
4	Timing Circuits	x	x
5	Preamble, Altitude, and Address Generators, A/C Reply Regulator	x	x
6	Control, Logic and Check Circuits Modulator Control	x	x
7	Lockout Timing and Logic Circuits	x	x
8	Data Input, Processor/ Decoder/Encoder	x	-
9	PWI Logic (1 thru 18)	x	x
10	PWI Logic (19 thru 36)	x	x
11	IPC Display Logic	x	x
12	Clock Timing/Distribution	x	-

Note: Items 8-12 are in the IPC display for the Type I system and part of the transponder for the Type II system.

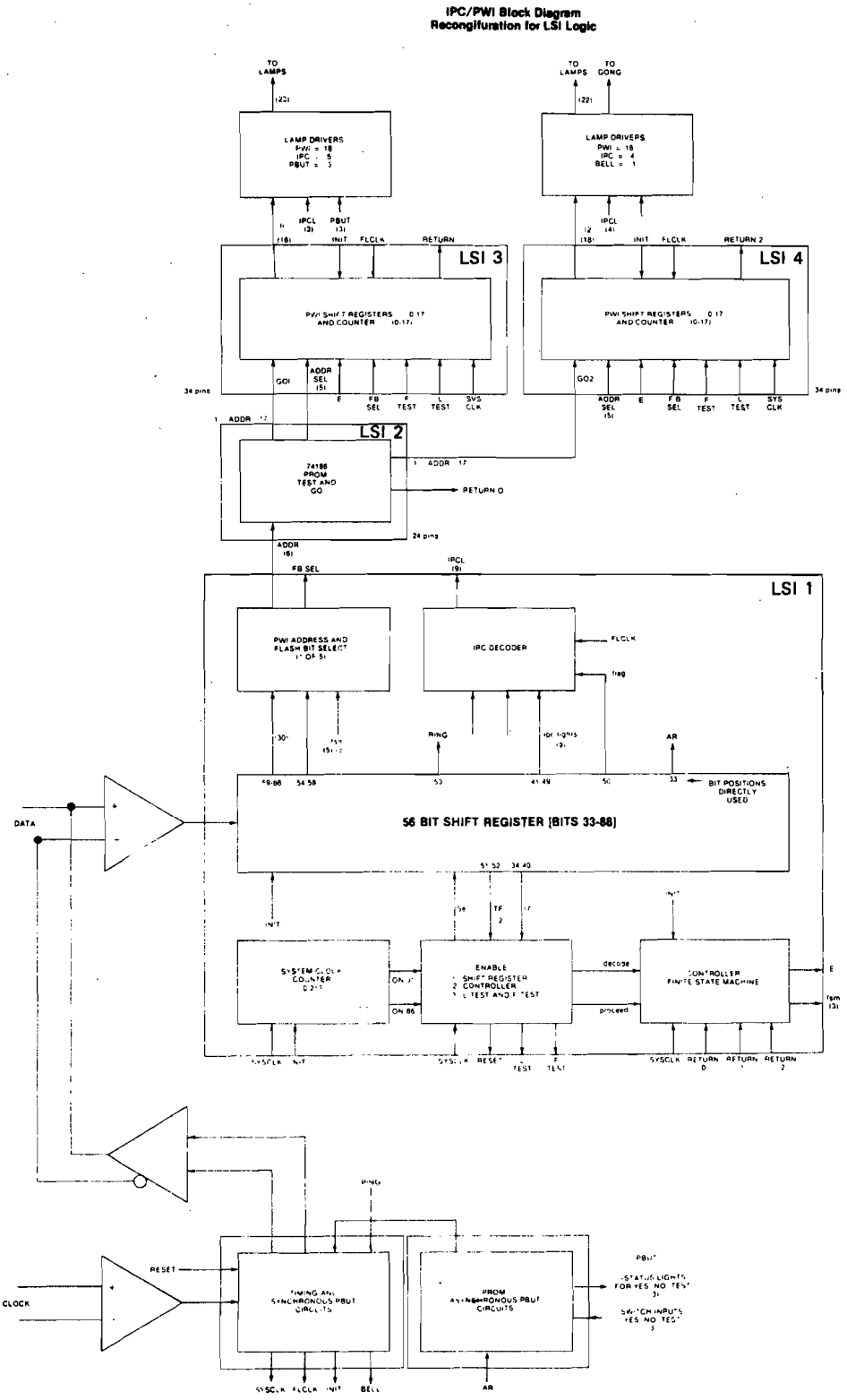
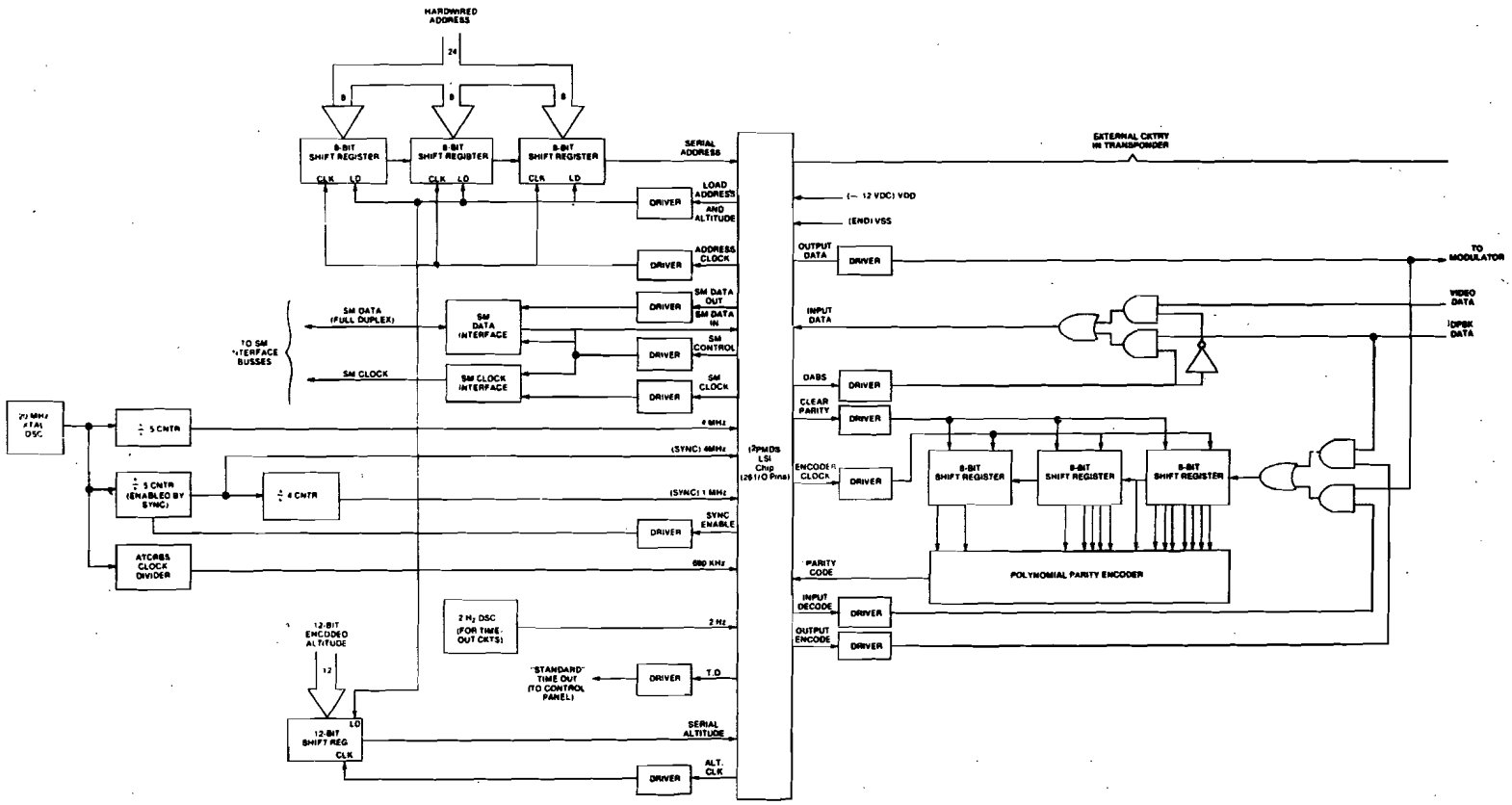


Figure 3-3. IPC DISPLAY LOGIC FUNCTIONAL BLOCK DIAGRAM



DABS TRANSPONDER PROCESSOR

Figure 3-4. DABS TRANSPONDER LOGIC BLOCK DIAGRAM (TENTATIVE APPROACH)

TABLE 3-15. DABS TYPE I TRANSPONDER COST DEVELOPMENT - CASE I (LSI VERSION)

Cost \ Module	Transmitter ($)	Receiver ($)*	IF Amp ($)*	Video Processor ($)	Control Matrix ($)	Monitor ($)	Power Supply ($)	Digital Logic ($)	Chassis ($)	Final Assembly ($)	TOTAL** UNIT COST
Material	265.70	229.93	55.95	93.70	73.02	86.76	54.99	196.48	98.00	--	1,440.41
Handling @25% MTL	66.43	57.48	13.99	23.43	18.26	21.69	13.75	49.12	24.50	--	360.12
Labor @$11. per hour	28.73	54.30	21.30	41.10	60.92	32.12	22.47	22.62	52.13	41.53	452.82
Burden @135% of labor	38.79	73.30	28.76	55.48	82.24	43.36	30.34	30.53	70.37	56.06	611.29
Inspection @5% Labor and Burden	3.38	6.38	2.50	4.83	7.16	3.77	2.64	2.66	6.13	4.88	53.21
Subtotal	403.03	421.39	122.50	218.54	241.60	187.70	124.19	301.41	251.13	102.47	2,917.85
Engineering and Quality Control @25%	100.76	105.35	30.63	54.64	60.40	46.93	31.05	78.35	62.78	25.62	729.49
FACTORY COST	503.79	526.74	153.13	273.18	302.00	234.63	155.24	376.76	313.91	128.09	3,647.34
General and Administrative @20%	100.76	105.35	30.63	54.64	60.40	46.93	31.05	75.35	62.78	25.62	729.49
TOTAL COST	604.55	632.09	183.76	327.82	362.40	281.56	186.29	452.11	376.69	153.71	4,376.83
PROFIT @15%	90.68	94.81	27.56	49.17	54.36	42.24	27.94	67.82	56.50	23.06	656.51
SELLING PRICE	695.23	726.90	211.32	376.99	416.76	323.80	214.23	519.93	433.20	176.76	5,033.34

NOTE: *Two (2) each required.

**Total Unit Cost includes cost of two (2) receivers and two (2) IF Amplifiers with the required comparator circuitry to provide diversity operations.

TABLE 3-16. DABS TYPE I TRANSPONDER COST DEVELOPMENT - CASE II (LSI VERSION)

COST \ MODULE	TRANSMITTER ($)	MODULATOR ($)	RF FRONT END ($)*	IF AMP. ($)*	VIDEO PROC ($)	MONITOR ($)	PWR SUPPLY ($)	DIGITAL LOGIC ($)	CHASSIS ($)	FINAL ASSEMBLY ($)	TOTAL UNIT COST ($)**
Material	155.47	97.56	227.84	51.16	104.89	124.59	39.78	196.48	99.82	-	1,376.59
Handling @ 25% Material	38.87	24.39	56.96	12.79	26.22	31.15	9.95	49.12	24.96	-	344.16
Labor @ $11/Hour	6.05	39.05	37.65	43.67	35.16	27.10	18.61	22.62	50.59	41.69	403.51
Burden @ 135% Labor	8.17	52.72	50.83	58.95	47.47	36.59	25.12	30.53	68.30	56.28	544.74
Inspection and Burden @ 5% Labor	.71	4.59	4.42	5.13	4.13	3.18	2.19	2.66	5.94	4.90	47.40
Subtotal	209.27	218.31	377.70	171.70	217.87	222.61	95.65	301.41	249.61	102.87	2,716.40
Engineering and Quality Control @ 25%	52.32	54.58	94.43	42.93	44.47	55.65	23.91	78.35	62.40	25.72	682.12
Factory Cost	261.59	272.89	472.13	214.63	272.34	278.26	119.56	376.76	312.01	128.59	3,395.52
General and Administrative @ 20%	52.32	54.58	94.43	42.93	54.17	55.65	23.91	75.35	62.40	25.72	682.12
Total Cost	313.91	327.47	566.56	257.56	326.81	333.91	143.47	452.11	374.41	154.31	4,074.64
Profit @ 15%	47.09	49.12	84.98	38.63	49.02	50.09	21.52	67.82	56.16	23.15	611.19
Selling Price	361.00	376.59	651.54	296.19	375.83	384.00	164.99	519.93	430.57	177.46	4,685.83

* Two (2) each required.

** Total unit cost includes cost of two (2) receivers and two (2) IF amplifiers with the required comparator circuitry to provide diversity operation.

TABLE 3-17. IPC DISPLAY COST DEVELOPMENT (COMMERCIAL AVIATION LSI VERSION)

Factor	Cost
Material	$ 305.48
Material Handling at 25%	76.37
Labor at $11.00/Hour	95.58
Burden at 135% of Labor	129.03
Inspection at 5% Labor and Burden	11.23
Subtotal	617.69
Engineering and Quality Control at 25%	154.42
Factory Cost	772.12
General and Administrative at 20%	154.42
Total Direct Cost	926.54
Profit at 15%	138.98
Selling Price	1065.52

3.4.2 DABS Type II Transponder/Display Cost Development (LSI Version)

The use of LSI technology will have the greatest effect on the general-aviation equipment because it will allow system packaging in a single box configuration, sized to fit into the equipment console of the average general-aviation aircraft. Single-box packaging will permit elimination of the IPC power supply, line driver logic and inter-box connectors and fabrication of the separate chassis and face plates. The logic required to perform the DABS and IPC functions would be contained in six LSI chips, common to the air-carrier version, as shown in Table 3-14, but mounted on a single printed circuit board.

The remainder of the transponder modules would be the same as those developed in Section 3.2, but repackaged to suit the combined configuration of DABS and IPC as shown in Figure 3-5. Table 3-18 presents the cost development of the combined, LSI version of the transponder and display. The expected selling price of the single-configuration transponder would be 26 percent lower than that of the equipment developed in Section 3.2 with discrete logic components.

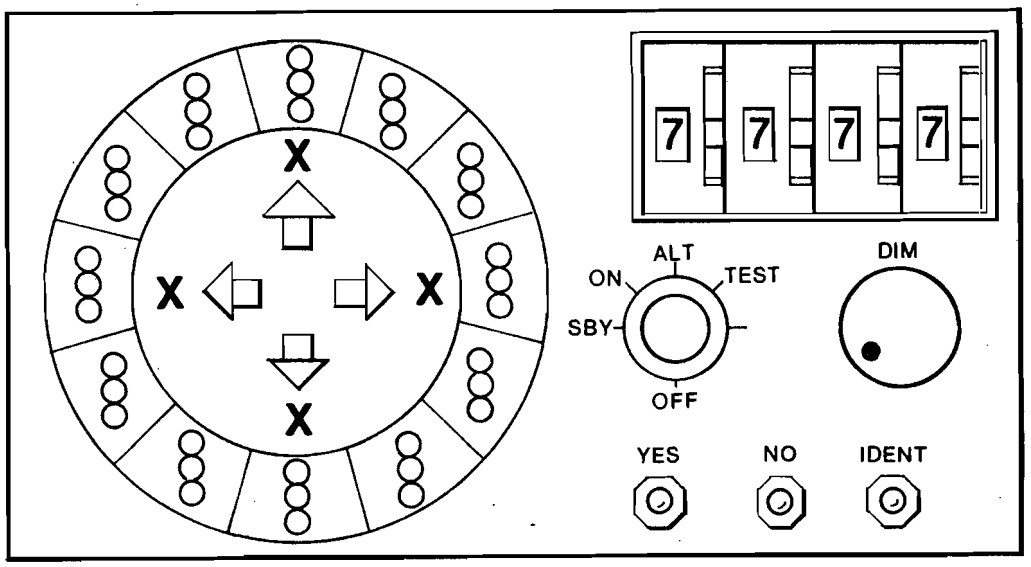


FIGURE 3-5. DABS/IPC COMBINED CONFIGURATION TYPE II TRANSPONDER

TABLE 3-18. DABS TYPE II TRANSPONDER WITH DISPLAY COST DEVELOPMENT (LSI VERSION)

COST \ MODULE	TRANSMITTER (DOLLARS)	RECEIVER (DOLLARS)	POWER SUPPLY (DOLLARS)	ANALOG LOGIC (DOLLARS)	DIGITAL LOGIC (DOLLARS)	CHASSIS (DOLLARS)	FINAL ASSEMBLY AND TEST (DOLLARS)	TOTAL (DOLLARS)
AVERAGE MATERIAL	33.02	36.29	12.28	12.19	164.68	60.34	--	318.80
AVERAGE LABOR @ 2.75/HOUR	4.16	12.08	3.22	5.97	6.79	8.78	9.32	50.32
DIRECT FACTORY COST	37.18	48.37	15.50	18.16	171.47	69.12	9.32	369.12
MARK-UP FOR O.H, G&A, PROFIT @ 67%	24.91	32.41	10.39	12.17	114.88	46.31	6.25	247.32
MANUFACTURERS SALE PRICE	62.09	80.78	25.89	30.33	286.35	115.43	15.57	616.44
DISTRIBUTION COST @ 100%								616.44
LIST PRICE								1232.88

NOTE: The cost of the IPC Display is included in the Logic and Chassis Modules.

3.4.3 Reliability and Maintainability of the LSI Versions

The introduction of LSIs has reduced the number of components required in the logic sections of the equipments and affected the reliability of the modules and systems. Data have been developed by using techniques similar to those presented in Section 3.3 for the new configurations. Table 3-19 presents the cost and reliability data for the LSI versions of the air-carrier and general-aviation equipment, with the expected changes in system and logic-module reliabilities and the re-evaluated average material cost per repair action.

The development of system reliabilities for the LSI version was based on the recommendations of MIL-217B, which were adhered to for most of the electronic components comprising the transponder and IPC display. However, the recommended reliability prediction for monolithic large scale integration contained in MIL-217B appears to be in contradiction with the current practice in the microelectronics community. MIL-217B implies that a finite practical reliability limit of 1000 gates should be applied to any LSI design if reliability considerations are critical. According to the proposed prediction formulations:

$$\lambda_P = \pi_L \pi_Q \left(0.9187\pi_T e^{0.005G} + 0.013\pi_E e^{0.004G}\right) \qquad \text{(EQ. 3-1)}$$

where G = number of gates, an LSI design with a density of 1000 gates can be expected to average 4.7 failures per million hours of operation. If the density is doubled (to 2000 gates), the reliability of the device decreases to 430 failures per million hours of operation (an increase in failures of two orders of magnitude).

The progress made in LSI development in recent years has shown a steady trend towards more complex (high density) chips at higher reliabilities and lower costs. LSIs have been developed for commercial applications with chip densities well in excess of 1000 gates (e.g. scientific calculators, digital wrist watches), which exhibit very high reliabilities. ARINC Research believes that the technological improvement by 1978, the projected start of system implementation, in the design and manufacture of LSIs will result in highly reliable components whose failure rate can best be predicted by the equation from MIL-217B which treats the gate density as a linear function.

$$\lambda_P = \pi_L \pi_Q \left(.0012\ \pi_T (G)^{0.67} + .00389\ \pi_E (G)^{0.35}\right) \qquad \text{(EQ. 3-2)}$$

The effect of strict adherence to the prediction techniques of MIL-217B is presented as a sensitivity analysis in Chapter Six.

TABLE 3-19. DABS/IPC COST AND RELIABILITY AND MAINTENANCE DATA (LSI VERSION)

Unit	MTBF (Hours)	Mean Time To Isolate A Failure (Hours)	MTTR (Hours)	Expected Material Cost Per Repair (Dollars)
DABS TYPE I TRANSPONDER SYSTEM WITH IPC DISPLAY				
Display	15649	1.0	2.0	14.14
Antenna	50000			--
Control	10000			51.60
Transponder	1243	1.0		--
Transmitter	3507		1.0	30.12
Receiver	19797		1.2	17.74
IF Amplifier	16963		1.0	.62
Video Processor	13994		1.0	.88
Control Matrix	8752		1.0	.39
Monitor	25823		1.0	1.03
Power Supply	23144		1.2	1.13
Digital Logic	65215		1.0	17.47
Chassis	57777		0.5	8.82
DABS TYPE II TRANSPONDER SYSTEM WITH IPC DISPLAY				
Antenna	50000			
Transponder	2269	1.0		
Transmitter	4582		1.0	18.82
Receiver	19384		1.0	.55
Power Supply	50408		1.0	.45
Logic Analog	63616		0.5	.33
Logic Digital	9944		1.5	15.57
Chassis	28684		0.5	7.82

3.5 REVIEW OF THE TYPE II DABS TRANSPONDER COST AND RELIABILITY BY A GENERAL AVIATION MANUFACTURER

The cost and reliability data on the general-aviation transponders developed by ARINC Research in the preceding sections was subjected to an independent evaluation by Bendix Aviation, manufacturers of general-aviation equipment, and participants in FAA sponsored studies on DABS and Synchro-DABS. The purpose of the additional review was to obtain concurrence with the developed data and identify production techniques or design modifications which would result in a more cost-effective system.

The Bendix engineering staff, working with ARINC Research engineers on the design features of the DABS and IPC systems found agreement on the data developed and presented in this chapter. An important result of the joint efforts has been the introduction by Bendix of a logic design requiring only one LSI chip for the Type II transponder, and a reduction in the number of LSIs for the IPC display. The results were introduced into the study and are reflected in the data developed. Figure 3-6 presents the concurrence by Bendix Aviation with the cost data on the Type II transponder.

3.6 MILITARY TRANSPONDER MODIFICATION DEVELOPMENT

The Type I and Type II transponders developed for the commercial-aviation and general-aviation users are not appropriate for the military community. The military requires a system which provides identification of friend or foe (IFF) MARK XII capabilities in addition to the DABS or ATCRBS interrogations. The military has developed a system, the APX-72, as part of the AIMS* standardization program and retrofitted a majority of the military aircraft with this system. For purposes of this study, it is assumed that all military aircraft are equipped with this system. The introduction of the Type I or Type II DABS transponder into this community would require each military aircraft to carry two sets of transponders (one for DABS and one for IFF) duplicating many of the required interrogation capabilities. ARINC Research believes that the military would not accept the additional space and weight requirements for redundant equipment, but would enter a development program to retain the tactical requirements of the APX-72 and integrate the DABS concept into the AIMS equipment.

In recent studies on the DABS system (Reference 8), the manufacturer of the APX-72 indicated the feasibility of modifying the unit at military depots to include the DABS capability. The present study is concerned with the cost of implementing DABS/IPC by replacing the existing ATCRBS transponders with equipment designed for the DABS concept. The integration of multiple systems, such as AIMS, prevents direct replacement of only one function without identifying the cost associated with the other functions required by

*AIMS - Air Traffic Control Radar Beacon System, Identification Friend or Foe, Mark XII System.

Bendix

Avionics Division

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ARINC Research Corporation
A Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

Attention: Mr. S. H. Kowalski

August 13, 1975

Subject: Cost Development of DABS/IPC Transponder

Dear Stan:

We have reviewed your work sheets defining the DABS/IPC cost development.

Your approach appears reasonable, and we concur with the cost factors and the resultant bottom line pricing.

We understand that engineering/factory tooling amortization will be handled separately in the interest of uniformity.

Very truly yours,

Wayne G. Shear

/nt

Figure 3-6. GENERAL AVIATION MANUFACTURER'S CONCURRENCE WITH DEVELOPED DATA

the system (e.g., IFF). The approach used in this study follows the recommendations of the APX-72 manufacturer in modifying the transponder to include the DABS functions while retaining the remainder of the system.

Review of the APX-72 transponder shows that modifications will be required to the logic cards in the circuit board cage assembly, rewiring of the assembly, addition of the DPSK Demodulator, and replacement of the external control and power connector. The circuit board cage assembly consists of seven plug-in printed circuit cards performing the functions indicated:

A-1 Processor
A-2 Decoder, Transponder
A-3 Mode 4 Subassembly
A-4 Encoder Clock
A-5 Encoder Control
A-6 Encoder Gating
DL-1 Delay line

Space is also available for the addition of one more card. Figure 3-7 shows the APX-72 and the digital section affected by the proposed modification.

The cards affected by the introduction of DABS would be A-2, A-4, A-5, and A-6. The remaining cards are associated with other functions and should not be affected.

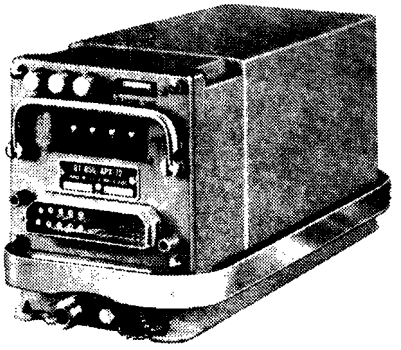
There are various methods available for the modification. Cards could be provided to the depots, requiring extensive rewiring of the transponder by depot personnel. The following sections identify the method proposed by ARINC Research, which is considered the most likely to result in a successful modification.

Both the discrete and LSI versions of the logic required for DABS operation are developed to identify the probable costs associated with system introduction based on production quantities and length of the retrofit period.

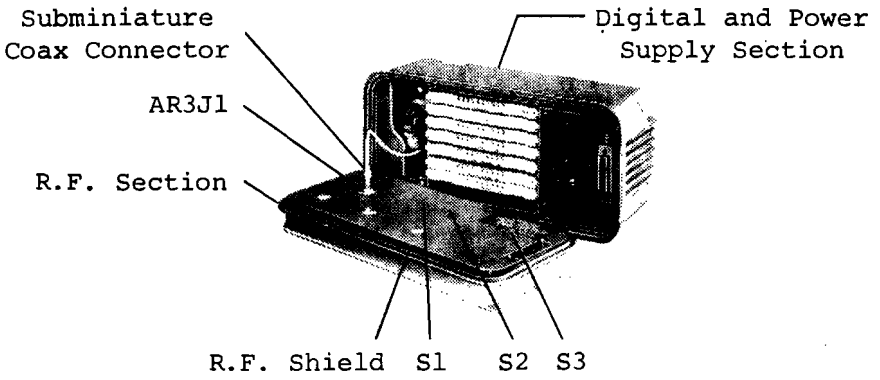
As with the type I units for commercial aviation, it has been assumed that the new control units required by the military will be identical in cost and reliability to those presently used.

3.6.1 Discrete Logic Version Modification

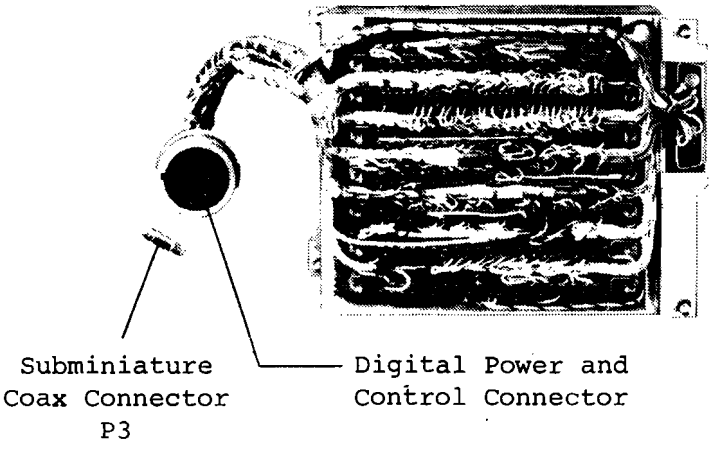
The logic required by the APX-72 system to respond to DABS/ATCRBS interrogations is identical to that developed for the commercial carrier (Type I) system. The number of discrete logic components requires packaging on multiple printed circuit cards configured for the APX-72 circuit board cage assembly. The components comprising the DPSK Demodulator can be incorporated on one of the logic cards. The replacement of cards A-2, A-4, and A-6, together with installation of a new card in the blank space available in the cage assembly, should provide adequate space for the entire logic required by DABS.



COMPLETE ASSEMBLY



DISASSEMBLY



CIRCUITBOARD CAGE ASSEMBLY

Figure 3-7. RECEIVER-TRANSMITTER, RADIO RT-859/APX-72

The Encoder Control card, A-5, would have to be redesigned to perform the functions of the ATCRBS operations (e.g., Automatic Overload Control, Reply Rate Limiting, etc.). The logic identified as "Analog Logic" for the Type II DABS transponder would provide adequate logic circuitry to accomplish this requirement. However, the components would have to be upgraded to the temperature requirements of the military.

The rewiring of the circuit board cage assembly by the manufacturer of the modification kit will increase the probability of a properly operating unit and reduce the extensive workload at the depot level.

Table 3-20 shows the cost of the modification kit that would be required by all APX-72-equipped aircraft. The kit would contain a new cage assembly, five new cards, external connector, and instructions for field modification. The new cards represent the cost of the Type I DABS logic and a Type II Analog logic (upgraded).

3.6.2 LSI Version Modification

The cost advantages recognized by the commercial-aviation and general-aviation communities in the use of LSI components for the DABS logic circuitry will also be realized by the military in the modification of the APX-72. The concept of providing a pre-packaged cage assembly, without the A-1, A-3, and DL-1 cards, is again proposed for the LSI version, but the entire logic required for DABS can be located on one card, reducing the number of cards and associated wiring of the cage. Table 3-21 shows the cost of the LSI version of the modification kit. The DABS logic cost is identical to the cost developed for the Type I (LSI) version. The remainder of the kit is assumed to be identical to the discrete version.

3.6.3 Military System Development

The modification kits developed in the preceding sections identify the variations between the commercial aviation and military aviation requirements for DABS implementation. Additionally, in order to maintain the existing AIMS program with minimum modifications, the retrofit of military aircraft would not include diversity operation or additional message displays.

The requirement for an IPC display would be the same as for the commercial aviation community, and the display developed for the Type I system would be suitable for the military. Both the discrete and LSI versions of IPC display are appropriate to the military community.

3.6.4 Military System Reliability

The addition of the DABS/IPC system to the AIMS transponder changes the overall reliability of the transponder. However, since this study is concerned only with the implementation of DABS/IPC, reliability data pertinent to the modification are considered and developed. Table 3-22 presents the calculated reliability of the modification with separate data for the DABS Logic, Analog Logic, and IPC Display. The reliability of the LSI version is also presented. The system reliability applicable to the introduction of DABS is 4582 hours for the discrete version and 10219 hours for the LSI version. The last column of the table identifies the expected average material cost per repair action computed in the same way as for the commercial carrier Type I transponder. These data will provide the basis for computation of the logistic support costs associated with the introduction of DABS.

TABLE 3-20. COST OF MODIFICATION KIT FOR THE APX-72 (DISCRETE)

Factor	Cost
DABS Logic	$1,838.78
Analog Logic	173.46
Cage Assembly (Including wiring)	170.00
External Connector	47.60
Assembly and Test @ $11/hour plus 135% Burden	29.70
Total Cost	$2,259.54

TABLE 3-21. MODIFICATION KIT FOR THE APX-72 (LSI)

Factor	Cost
DABS Logic	$519.93
Analog Logic	173.46
Cage Assembly (Including Wiring)	170.00
External Connector	47.60
Assembly and Test @ $11/hour plus 135% Burden	29.70
Total Cost	$940.69

TABLE 3-22. MILITARY MODIFICATION COST AND RELIABILITY DATA

Unit	MTBF (Hours)	Mean Time to Isolated Failure (Hours)	MTTR (Hours)	Expected Material Cost/Repair (Dollars)
Discrete Version				
Display	7136	1.0	2.0	7.85
Control	10000			30.00
Transponder	12797	1.0		
DABS Logic	16800		2.0	7.23
Analog Logic	53714		.5	.80
LSI Version				
Display	15649	1.0	2.0	14.14
Control	10000	.5	.5	30.00
Transponder	29454	1.0		
DABS Logic	65215		1.0	17.47
Analog Logic	53714		.5	.80

CHAPTER FOUR

DABS/IPC INSTALLATION DATA

This chapter addresses the development of those data items which are treated in the economic analysis as being common to any CAS concept. The data items discussed include the specific aircraft equipment configurations for each user category, the estimated installation costs of transponders and displays for each user category, distribution costs, and the aircraft population projections within each user category. In addition to the common data elements cited in this chapter, there are many other data items that are common to the type of system but peculiar to the specific user category (e.g., labor rates, pipeline times, training cost). These additional data items are defined in Appendix E, together with the values for these items used for the analyses. These latter values were established through contact with representative user organizations, ARINC Research prior experience, and consultation with the FAA and the personnel at Lincoln Laboratory. The developed values were included as a part of the Uniform Ground Rules established at the beginning of the study.

4.1 COST OF DABS/IPC-RELATED ELECTRONICS COMPONENTS

The equipments studied have been limited to the airborne elements of the DABS/IPC system. The classes of equipment are separated into those intended for the commercial air carriers (Type I) and other high-performance aircraft that require and justify the maximum-capability system meeting ARINC characteristics, and the less expensive (Type II), unrestricted packaging intended for the general-aviation aircraft.

Chapter Three developed the cost of both versions of electronic equipment and display based on the practice of most avionics manufacturers. Emphasis was placed on the manufacturing costs of the "black-box" and display electronics without development of the costs of antennas or control panels, necessary for the DABS/IPC operation. This section identifies these additional costs and summarizes the equipment necessary for the DABS/IPC system.

4.1.1 Antennas

The DABS/IPC system operates on the same frequencies as the present ATCRBS and requires the identical antennas as presently installed on all ATCRBS equipped aircraft. The antennas can be either of the blade or flush mounted type for the high-performance aircraft, and the less expensive quarter-wave length stub for the low-performance aircraft. The presently advertised selling price of $63 for a Collins 237Z-1 or equivalent blade antenna has been accepted and used in the study, as well as the $13 retail price of the stub antenna.

4.1.2 Control Panel

Each air carrier and military ATCRBS-equipped aircraft requires a control unit to provide mode and code selector switches for the transponders. The general-aviation transponders have the controls built into the electronics box, but the high performance equipment requires separate packaging because of the remote location of the transponder. The DABS Type I transponder will require the same mode and code selector switches and the additional pilot-actuated push-button for replies to DABS or IPC interrogations. An aircraft peculiar DABS identification code may also be built into the control unit. The overall size of the DABS control unit is expected to remain the same, replacing the existing ATCRBS control panel. The cost of the new unit is expected to remain at the same price, although the unit will be slightly more complex, because of the larger projected production quantities required to retrofit the existing fleet of aircraft. An investigation of the selling prices of existing control units from avionics manufacturers has shown that the average cost to commercial carriers or distributors is $516. Similarly the control units cost the military $300. These costs have been used in the study in determining the cost of implementation of DABS/IPC.

4.1.3 Summary of Electronics Costs

The elements comprising a DABS/IPC system for each concept evaluated in this study are presented in Table 4.1 Both the discrete logic and LSI-logic version costs are shown for easy comparison. The principal electronics and indicator costs are the suggested OEM (factory selling) prices without allowances for distribution costs. The effect of distribution is identified in the following section.

TABLE 4-1. DABS/IPC EQUIPMENT COST

	DISCRETE VERSION	LSI VERSION
HIGH-PERFORMANCE TYPE I DABS/IPC		
DABS Electronics*	$6178	$4860
IPC Indicator*	2099	1066
Antenna	63	63
Control Unit	516	516
ATC Display*	1527	1527
LIMITED-PERFORMANCE TYPE II DABS/IPC		
DABS Electronics*	493	616
IPC Indicator*	506	(Included in Electronics)
Antenna	13	13
MILITARY MODIFICATION FOR DABS/IPC		
DABS Mod Kit*	2260	941
IPC Indicator*	2099	1066
Antenna	63	63
Control Unit	300	300

*Manufacturer's expected OEM prices without mark-up for distribution.

4.2 DISTRIBUTION COST

In Chapter Three emphasis was placed on the identification of the factory selling price for the DABS/IPC equipment; as a result, no allowance was made for the distribution cost associated with marketing the units to the general public. It is expected that the commercial airlines and the military will be able to obtain DABS/IPC equipments directly from the manufacturers, but the general-aviation community will have to pay additional money to avionics distributors as a part of the acquisition cost of the units. To account for this added expense, the industry accepted practice of a 30 percent mark-up (verified by four avionics manufacturers) of the Type I DABS/IPC equipment and a 100 percent mark-up of the Type II DABS/IPC equipment has been applied to the general aviation avionics. However, many distributors of the Type II avionics who are not engage in equipment

installations advertise discounts nationally on new, factory warranted equipment. The advertised discounts vary depending on demand and availability but are generally between 10 and 30 percent. A 20 percent discount of the list price has been applied to the Type II equipment evaluated in this study, reflecting the mean of the advertised discounting practice in the general-aviation community when a unit is purchased without installation. These values are considered to be representative of the distribution costs found in the general-aviation community and are based on data obtained from avionics manufacturers. Table 4-2 presents the expected cost of equipment to the general-aviation community when distribution costs are included.

TABLE 4-2. EXPECTED SELLING PRICE OF ELECTRONICS (GENERAL AVIATION)

	DISCRE VERSION	LSI VERSION
HIGH-PERFORMANCE TYPE I DABS/IPC		
DABS Electronics*	$ 8031	$ 6318
IPC Indicator*	2729	1386
Antenna	63	63
Control Unit	516	516
LIMITED-PERFORMANCE TYPE II DABS/IPC		
DABS Electronics**	789	986 (Included in Electronics)
IPC Indicator**	809	
Antenna	13	13

*Includes 30% mark-up
**Includes 100% mark-up followed by a 20% discount

Distribution costs were also considered as a logistic-support cost factor associated with the replacement of modules or component parts. The distribution costs of the individual replacement parts were computed at the same percentage mark-up as identified for the system acquisition.

4.3 AIRCRAFT CONFIGURATIONS

The complement of equipment to be installed by each of the users depends on individual needs, the probable flight profiles, the reliabilities required to provide suitable aircraft availability (especially for the air carriers), and the anticipated or required flight crews for special classes of aircraft.

This section identifies the probable DABS/IPC aircraft configurations for each class of user based on existing practices in the aviation community concerning flight critical avionic equipment.

4.3.1 Commercial Aviation

The present practice by the majority of air carriers of a single ATCRBS transponder system utilization is assumed to be applicable to the DABS/IPC implementation. Therefore, all certified commercial air carriers are assumed to require the following complements of collision-avoidance avionics:

- 1 Set of DABS electronics (Type I)
- 2 Antennas (top and bottom) (one existing)
- 2 IPC indicators (pilot and co-pilot)
- 1 Set of controls and switching equipment

The electronics will be located in the normal avionics bay of the aircraft. The indicators will be installed in a prominent location on the instrument panel, replacing, as necessary, existing less critical indicators, which will be relocated. The variations in instrument-panel configurations among the airlines prevent identifying the indicators that are likely to be relocated. A single set of DABS electronics has been assumed for commercial carriers to be consistent with the installation decisions generally made for similar avionics such as ATCRBS transponders. It is recognized that some air carriers utilize with dual installations, and the economic impact of such a decision is addressed in Chapter Six.

4.3.2 Military Aviation

It is assumed that the military will participate in a national DABS/IPC program to the same extent it currently participates in the ATCRBS program. The military is expected to employ the minimum of required equipment consistent with the level of performance and number of pilot positions. Therefore, the following configuration was considered in the study for all military aircraft currently equipped with the APX-72 system:

- 1 Set of DABS electronics (Mod to APX-72)
- 2 IPC indicators (1 for single seat aircraft)
- 1 Set of control equipment
- no new antenna

The single set of electronics was selected to agree with the existing configuration of a single APX-72 system (or similar) currently installed on all military aircraft. Aircraft now wired for the APX-72 but not equipped with the system (e.g., Army aircraft) were assumed in this study to have the equipment, and only the modification costs were considered as applicable to the DABS implementation.

4.3.3 General Aviation

The private aircraft owner is usually cost-conscious, carrying the minimum avionics required consistent with flight regulations and safety. Therefore, it has been assumed in this study that almost all (95 percent) private aircraft owners will prefer to install the least expensive DABS/IPC. The assumed installation consists of either a single set of electronics with built-in IPC indicators (LSI version of Type II) or a DABS Type II transponder electronics with a separate IPC indicator. In either configuration, the electronics will be installed in the flight console of the aircraft, and for the separate indicator case, the display will be located in the pilot's instrument panel. The existing ATCRBS antenna will be reused by the system.

The remaining five percent of the general-aviation aircraft are assumed to be in the high-performance class, requiring the DABS Type I equipment. This study considers the minimum required equipment and assumes a single system for each of the general-aviation users. The equipment will be installed either in the avionics bays of the large airframes or at remote locations peculiar to the particular aircraft type. A single indicator will be required, replacing an indicator at the pilot's position. The replaced unit will be relocated to a less prominent position. The minimum equipment required by each of the high-performance aircraft will consist of the following:

- 1 Set of electronics (Type I)
- 1 IPC indicator (pilot only)
- 2 Antennas (top and bottom) (one existing)
- 1 Set of controls

The particular needs of some larger general-aviation aircraft (e.g., cargo or executive jets) requiring additional indicators can be satisfied at additional expense to the owners, but these are not considered in this study in determining the implementation costs of DABS/IPC.

4.4 INSTALLATION COSTS

The cost of equipment installation considered in this study falls into two categories: (1) retrofit of the existing fleet, and (2) implementation in new aircraft. Installation costs have been developed for each of the various user categories and general classes of aircraft, i.e., the high-performance aircraft capable of speeds greater than 250 knots, and the

low-performance aircraft with speeds lower than 250 knots. For purposes of the analysis and consistent with the CAS report, it was assumed that the installation costs in new commercial carrier and general aviation aircraft were 60 percent of the estimated retrofit installation cost. The installation costs for new military aircraft are discussed in Section 4.4.2. The costs developed reflect the equipment configurations identified for each user community in Section 4.3.

4.4.1 Commercial-Aviation Installation Costs

The similarity between airborne CAS and DABS/IPC in equipment configurations and quantities of components allows use of the costs developed for CAS in the commercial-carrier aircraft. Allowances have been made for the existence of an ATCRBS antenna, but all other installation parameters, e.g., aircraft cabling, shelf fabrications, etc, are considered new. The proposed Type I transponders will be larger than existing ATCRBS transponders, requiring new locations in the electronics bays. The additional data transfers between transponders and display/control will require access to all cabling between these units, and this accounts for the majority of the on-aircraft cabling costs.

The development of CAS installation-cost estimates for the commercial carriers was based on the experience gained by United Airlines and Piedmont Airlines in their test and evaluation exercise with the McDonnell Douglas EROS system. These airlines retrofitted a B-727 and B-737, respectively, with collision-avoidance equipment, and, although the equipment was not identical to the proposed production versions, the concepts were sufficiently similar to utilize the data on labor, materials, engineering, and space availability. Considerations were given to the prototype installations, and the results presented have the concurrence of the airline individuals involved in the retrofit program.

The installation costs presented are the expected average costs per aircraft with single system implementation. The large new aircraft have adequate space to accomodate the system. Some of the smaller commercial aircraft, e.g., the F-227 operated by Piedmont, have no space left in the electronics bay and will require expansion of the present areas. At the same time, some aircraft have been produced with provisions for the installation of CAS (e.g., plates that are intended to be removed and replaced with a CAS antenna but that can be utilized for DABS). Therefore, the costs shown have been assumed to be representative of costs for any of the commercial aircraft.

The cost breakdown for system retrofit in the commercial-aviation case is as follows:

Installation Factor	Time Required	Cost
Shelf Fabrication and Installation	48 hours	$ 1,067.
Antenna Installation	6 hours	133
IPC Indicator Installation	4 hours	89
Existing Indicator Relocation	4 hours	89
Control Unit Installation	24 hours	45.
On-Aircraft Cabling	100 hours	2,222
Engineering (300 hours ÷ Fleet Size)	3 hours	67
Material (Lot)	--	516.
Totals	167 hours	$ 4,227.

The installation of the ATC Display developed in Chapter Three is treated as a special case, probable for the commercial aviation but not mandatory for the successful operation of DABS/IPC. Therefore, the cost of installing the ATC Display is presented separately and evaluated as a sensitivity parameter in Chapter Six.

The cost of installation of the ATC Display in a commercial-aviation aircraft is:

Installation Factor	Time Required	Cost
ATC Display Installation	4 hours	$ 89
On-Aircraft Cabling	36 hours	800
Material		100
Totals	40 hours	$989

4.4.2 Military-Aviation Installation Costs

In developing the installation cost estimate for the military aviation community, the existence of the AIMS system on all military aircraft has been assumed. The cost factors that the military will have to contend with are those associated with the removal of the electronic package from the aircraft, shipment to a modification depot, modification of the equipment, shipment to the installing activity, and reinstallation in the airframe. Additional costs for the IPC indicator installation, relocation of existing indicators, and replacement of the existing control unit increase the scope of the modification to a level comparable to the installation of a new system. Each branch of the military, by direction of the Department of Defense (DOD), has developed installation costs for each type of aircraft in the inventory for the implementation of the airborne Collision Avoidance System (CAS). Many of the costs were based on experience with the installations of the AIMS systems because of the similarity in equipment sizes, locations, and complexities. The adaptation of these military-developed installation

data to the DABS/IPC implementation is appropriate because of the similarity to CAS in effort required to install indicators and controls, receive the airframe between the electronics and indicators and controls, and the additional labor required to modify the APX-72 for DABS/IPC operation. The modification of the APX-72 is expected to require the equivalent labor as the installation of a new box in an aircraft. Therefore, the military-developed installation data for CAS have been used in this study.

Installation costs for the military aircraft have been based on data provided by the Department of Defense (DoD) and represent the weighted average of the cost associated with each type of aircraft installation. These costs are governed by the types and numbers of aircraft in the military community. Each of the military branches was directed by DoD to develop costs associated with the implementation of CAS in existing and new aircraft scheduled to remain in the military inventory beyond 1985. The data prepared by the installation facilities of each branch of the services reflect the costs to retrofit the existing fleet, by aircraft type, and the costs to add a system to new aircraft during production. The cost categories considered by the installation facilities included: (1) the acquisition of the electronics, antennas, indicators, and control; (2) the labor hours converted to dollars for installation on the aircraft; (3) the materials (Group A) required to support the installation; and (4) the non-recurring logistic support costs. The latter included:

- Engineering - design of the installation, EMI/ECM testing, prototype testing on each type of airframe, and continuing support engineering during the eight year retrofit period.
- Initial Spares - introduction of spare parts into inventory.
- Technical Data - including system technical orders (TOs) and aircraft manual modifications.
- Test Equipment - special or peculiar support test equipment required to maintain a system.
- Training - the cost of training personnel at each installation and maintenance facility to repair and operate the system.
- Reprocurement - the cost of manufacturing drawings and system details required to permit reprocurement of an identical system from different manufacturers.

The treatment of each element within the non-recurring category varies between the services and reflects the operating procedures of each branch of service. For example, spares provisioning varies from a percentage of the acquisition cost to provisioning based on the number of repair facilities. The scenario for computing training costs vary from personnel training at depot facilities (NAVY) to training at intermediate facilities with no depot

training (ARMY) to personnel training at a rate of one man per each aircraft in the inventory (AIR FORCE). The non-recurring costs, other than engineering, provided by the DOD have been carefully reviewed to insure that each category is properly included and evaluated by the Economic Analysis Model used in this study. However, the specific costs presented have not been averaged and included in the installation costs presented in this section. The impact of non-recurring costs on a per-aircraft and fleet basis is evaluated and presented in Chapter Five.

The cost breakdown for system implementation in the military community is as follows:

Installation Factor	Per Aircraft Retrofit	Per Aircraft New
Material Acquisition (Group A)	$1453	$ 840
Installation (Labor)	3538	6357
Engineering (Design and Test)	502	180
Total	$5493	$7377

The installation costs presented are the weighted average of the data provided for the entire military community. Where some cost factors, such as labor, may be much higher for the tactical fighter aircraft, the same costs would be much lower for the twin-engine, piston-powered aircraft or the average ARMY helicopter aircraft.

It should be noted that different organizations within the military prepared the installation cost estimates for the new and retrofit aircraft.

4.4.3 General Aviation

The installation costs for the high-performance general-aviation aircraft have been developed from the experience of Piedmont Airlines (Piedmont engages in the maintenance and retrofit of avionic equipment for corporate aircraft). The resultant costs have been weighted to reflect the various classes and configurations anticipated in the high-performance general-aviation aircraft.

The following data identify the estimated costs to install the DABS/IPC system in a high-performance general-aviation aicraft:

Installation Factor	Time Required	Cost
DABS Type I Installation	24 hours	$ 430
Antennas Installation	6 hours	107
IPC Indicator Installation	2 hours	36
Existing Indicator Relocation	2 hours	36
Cabling	40 hours	716
Material (Lot)		529
Totals	74 hours	$1,854

The installation costs for the single-engine and light twin-engine aircraft were developed through a survey of the maintenance facilities supporting the general-aviation community. All FAA-certified repair facilities were requested to provide an estimate on the installation of a NARCO DME-190. The DME-190 was chosen as being similiar in size and complexity to the proposed DABS Type II transponders requiring similar cabling, antenna, and power. The questionnaire further requested a breakdown in hours of the effort required for unit installation, antenna installation, cabling, average material cost, and installation and repair labor rates. The replies received reflect more than 25 percent of the repair facilities and are considered representative of the entire general aviation community.

The following data are the results of the survey. The installation costs are the average of the information received and reflect the variety of airframes encountered by the responding facilities. A engineering adjustment has been used on the cabling manhours to allow for the existing ATCRBS transponder cabling and for connecting the encoding altimeter assumed to be a part of the existing aircraft avionics. The variation in installation costs between the separate transponder and indicator and the LSI version that results in a single package are identified. There are no significant variations in on-aircraft cabling or transponder installation costs. However, the installation of the IPC indicator, and the probable relocation of existing displays, results in the differences presented in the following data on costs to install the system in general-aviation aircraft:

Installation Factor Integral Display	Time Required	Cost
Removal of Existing ATCRBS Transponder	1.00 hrs.	$ 16.
Type II Electronic Installation	3.00 hrs.	49.
Cabling	1.00 hrs.	16.
Material (Lot)	--	10.
Totals	5.00 hrs.	$ 91.
Separate Display		
IPC Indicator	2.00 hrs.	$ 33.
Relocation of Existing Display	2.00 hrs.	33.
Increase	4.00 hrs.	$ 66.
Total for Separate Configuration	9.00 hrs.	$ 157.

The cost of antenna installation has been omitted on the premise that the majority of the general-aviation aircraft are already equipped with ATCRBS transponders and the existing antenna will be reusable. For aircraft that require the entire installation, the increased cost is offset, in establishing population averages, by elimination of the cost in removing existing equipment and the reduction of unit installation cost because of space availability.

4.4.4 Summary of Installation Costs

Table 4-3 presents a summary of the installation costs developed in this section and used in the life-cycle cost evaluation of Chapter Five. The data for new aircraft installations are those provided by the military and the expected ratio of the retrofit costs for Commercial and General Aviation.

TABLE 4-3. SUMMARY OF INSTALLATION COSTS (PER AIRCRAFT)

	Commercial Aviation	Military Aviation	General Aviation
Retrofit Installations			
High Performance	$4227.	$5493.	$1854. 91.
Limited Performance	0.	5493.	157.*
New Aircraft Installations			
High Performance	2536.	7377.	1112. 55.
Limited Performance	0.	7377.	94.*

* Cost of Installing Separate Electronics and Indicator.

4.5 AIRCRAFT SCENARIOS

System implementation has been chosen to begin in 1978 to provide the required comparison with airborne CAS. The three-year period allowed before the start of DABS implementation would be required to pass the necessary legislation, develop the necessary regulations, start installation and retrofit of the ground facilities, complete the development of the airborne avionics, and begin the production process.

The retrofit period for the entire avaiation community has been assumed for purposes of this study to be eight years. The installation program has been assumed to affect only those aircraft not scheduled for retirement during the retrofit period. For all user categories, the number of retrofits has been assumed to be linear, with all existing aircraft being equipped with DABS/IPC by the end of 1985. All new aircraft delivered in 1978 and in later years would have the DABS/IPC implemented as part of the original required avionic equipment.

All aircraft registered in the continental United States, except experimental aircraft, gliders, balloons, and nonmilitary rotorcraft, have been assumed to require the installation of DABS/IPC. In reality, many other types of aircraft may not be required to operate collision-avoidance equipment, but their inclusion or omission from the assumed GA population should not affect the decision regarding which of the CAS concepts is most attractive to general aviation from a cost point of view.

The aircraft-fleet population projections used in this study have been based on available information developed in 1974 by the U.S. Department of Transportation, FAA, Office of Aviation Policy, Aviation Forecast Branch.

4.5.1 Commercial Aviation

It is assumed that the air carriers' retrofit period will be four years and that all aircraft not scheduled for retirement within the first four years will be retrofitted with the Type I version of DABS/IPC. Table 4-4 identifies the projected fleet of commercial-carrier equipment, with planned expansions and retirements that were used in the analysis.

TABLE 4-4. COMMERCIAL-CARRIER AIRCRAFT STATISTICS

Year	Existing	New	Retirements	Total
1978	2,848	133	50	2,931
1979	2,931	157	69	3,019
1980	3,019	142	67	3,094
1981	3,094	180	102	3,172
1982	3,172	149	78	3,243
1983	3,243	142	69	3,316
1984	3,316	130	63	3,383
1985	3,383	119	53	3,449
1986	3,449	65	0	3,514
1987	3,514	64	0	3,578
1988	3,578	65	0	3,643
Totals		1,346	551	

4.5.2 Military Aviation

The Military-aviation community considered by this study includes all U.S. based military aircraft operated by the active Armed Forces, the Reserves, and the National Guard.

The retrofit period for the military was assumed to be linear over the entire eight years. As for the commercial category, any aircraft scheduled for retirement during the retrofit period was not considered in the cost analysis. All new aircraft scheduled for delivery in 1978 or later were assumed to have DABS/IPC incorporated in the basic avionics at the factory. Table 4-5 identifies the assumed fleet of military aircraft considered in this study. All jet and turbine aircraft are assumed to fall in the high-performance category, while all piston and helicopter aircraft are assumed to fall in the low-performance category.

TABLE 4-5. CONUS MILITARY AIRCRAFT STATISTICS

JET AND TURBINE				PISTON			HELICOPTER			
(High Performance)				(Low Performance)			(Low Performance)			
Year	Existing	New	Ret	Existing	New	Ret	Existing	New	Ret	TOTAL
1978	10882	143	53	1542	0	154	7553	13	18	19908
1979	10972	84	4	1388	0	170	7548	61	5	19874
1980	11052	117	5	1218	0	102	7604	52	1	19935
1981	11164	204	35	1116	0	65	7655	118	3	20154
1982	11333	32	1	1051	0	5	7770	72	0	20252
1983	11364	15	11	1046	0	0	7842	0	0	20256
1984	11368	0	0	1046	0	0	7842	0	0	20256
1985	11368	0	0	1046	0	0	7842	0	0	20256
1986	11368	0	0	1046	0	0	7842	0	0	20256
1987	11368	0	0	1046	0	0	7842	0	0	20256
1988	11368	0	0	1046	0	0	7842	0	0	20256
TOTALS		595	109		0	496		316	27	

4.5.3 General Aviation

The largest and fastest-growing element of the aviation community is general aviation. The population extends from the large, pure-jet cargo fleets, through executive and corporate aircraft, to the air-taxis and the privately owned pleasure aircraft. The sizes and types of aircraft are as numerous as the variety of uses to which they are subjected. The latest FAA statistics for 1974 list more than 150,000 registered aircraft in the general-aviation community. The general-aviation community has also been divided into high- and low-performance categories. For purposes of this study, and on the basis of sampled data on new aircraft production, 10 percent of the multi-engine aircraft were assumed to be in the high-performance category. All single-engine aircraft were assumed to be the low-performance category, and all turbine aircraft were assumed to be in the high-performance category. An eight-year linear retrofit of general-aviation aircraft has been assumed for the analysis.

Table 4-6 presents the projected general-aviation population data on the existing and predicted expansion of the community by engine configuration, for the period considered in the life-cycle of the study. The eight year retrofit program identified the quantities of both types of DABS/IPC equipment that will be required to satisfy the needs of the community and represents the 5 percent Type I and 95 percent Type II DABS/IPC deployment dictated by performance.

TABLE 4-6. GENERAL-AVIATION AIRCRAFT STATISTICS

Year	Single-Engine		Multi-Engine		Turbine		Total New	Grand Total
	Existing	New	Existing	New	Existing	New		
1978	140,300	4,200	22,600	1,100	4,900	400	5,700	173,500
1979	144,500	4,000	23,700	1,200	5,300	600	5,800	179,300
1980	148,500	4,100	24,900	1,100	5,900	500	5,700	185,000
1981	152,600	5,100	26,000	1,200	6,400	400	6,700	191,700
1982	157,700	4,900	27,200	1,200	6,800	600	6,700	198,400
1983	162,600	4,800	28,400	1,300	7,400	600	6,700	205,100
1984	167,400	4,500	29,700	1,600	8,000	700	6,800	211,900
1985	171,900	5,500	31,300	800	8,700	300	6,600	218,500
1986	177,400	5,500	32,100	800	9,000	300	6,600	225,100
1987	182,900	5,500	32,900	800	9,300	300	6,600	231,700
1988	188,400	5,500	33,700	800	9,600	300	6,600	238,300
Totals		53,600		11,900		5,000	70,500	

CHAPTER FIVE

INDIVIDUAL AIRCRAFT AND FLEET COSTS FOR DABS/IPC IMPLEMENTATION

The costs of implementing the Discrete Address Beacon System/Intermittent Positive Control concept for the various users of the national airspace are presented in this chapter. The economic analyses are based on the data developed in Chapters Three and Four and are performed with the assistance of an economic cost model. Implementation-cost data are shown on an individual-aircraft and total-fleet basis for two sets of data: the discrete logic version of DABS/IPC, resulting in separate Transponder and display components; and the LSI version of DABS/IPC, resulting in single packaging for general aviation and reduced size of display for commercial aviation.

5.1 COST MODEL

ARINC Research Corpoation's economic analysis model* (EAM) has been adapted to evaluate the economic impact of proposed collision-avoidance systems and to provide a basis for cost comparison among the several competing CAS concepts currently under development.

The model evaluates the economic impact and provides a basis for cost comparison in three different user environments: Commercial Aviation, General Aviation, and Military Aviation. Further, within each user category and system, the model considers three levels of CAS: Type I (commercial aviation) capability, Type II (general aviation) capability, and Military modification to the APX-72 capability. The distribution of these three CAS levels within a specific user category is specified by the input data to the model.

The model has been programmed in FORTRAN for use with a computer time-sharing system. It computes the expected annual and cumulative acquisition, installation, and logistic support costs for each concept/user combination desired. The program is flexible so that data changes can be readily implemented, sensitivity evaluations performed, or additional data outputs obtained.

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* Developed for cost analysis of a Proposed Defense Navigation Satellite System Receiver, prepared by ARINC Research Corporation for USAF Space and Missile Systems Organization under Contract F09603-73-A-0933-TB01.

The program features and mathematical formulation of the EAM are documented in Appendix D to this report.

5.2 ADDITIONAL INPUTS REQUIRED BY THE MODEL

The data developed by ARINC Research on costs and reliabilities, together with the statistical data developed in Chapter Four, constitute only a portion of the data required to compare systems or establish the cost of implementation.

Many parameters contributing to the evaluation of the systems and life-cycle costs are dictated by the user communities. For example, the average hours flown by a user vary from 17.3 hours per month for the general-aviation equipment to 238 hours per month for the air-carrier equipment. These data were developed, as were other parameters required by the model, through contact with the user community (e.g., United and Piedmont Airlines, AOPA*, and ATA**), research work completed through other contracts within ARINC Research, and information furnished by the FAA.

A complete listing of the parameters influencing the evaluation is presented in tabulated format in Appendix E to this report. All the parameters considered influential in evaluating the relative costs and reliabilities of the systems have been programmed into the cost model.

5.3 RESULTS OF APPLYING THE ECONOMIC ANALYSIS MODEL

The ARINC Research EAM computes annual and cumulative acquisition, installation, and logistic support costs for each concept/user combination desired. The model was programmed to print out data for three additional years beyond the assumed retrofit period of 1978 through 1985 to evaluate the effects of new aircraft production without retrofit, and of maintenance and logistics costs after fleet implementation.

This section presents the results derived from the model on the basis of the parametric inputs provided for both the discrete logic and the LSI logic data. The results are presented on a per-aircraft basis to identify separately the costs of acquisition, installation, nonrecurring logistics recurring logistics, and, finally, the 11-year life-cycle costs expected by an aircraft owner in any of the user categories are presented. These costs data are presented in Section 5.3.1.

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* Aircraft Owners and Pilots Association (AOPA)

** Air Transport Association (ATA)

The life-cycle costs of system implementation are presented on a year-by-year basis for each user community's total fleet of aircraft. To make the data easy to interpret, Section 5.3.2 presents the life-cycle costs based on the discrete logic data and the LSI logic data in graphical format.

5.3.1 Cost of Ownership per Aircraft

The cost of ownership of a DABS/IPC collison-avoidance system on a per-aircraft basis consists of the initial acquisition and installation costs for equipment configurations developed in Chapter Four, a proportion of the nonrecurring logistic support costs (determined by averaging over the entire user population in the 11-year life cycle), the recurring logistics costs attributed to an aircraft during the first year, and the cumulative life-cycle cost of aircraft maintenance during the 11 years. These costs can be combined to provide an evaluation of the systems based on both initial investment and reliability. One cost factor (amortization of manufacturer initial costs) was omitted from the cost analyses presented in this chapter because of the uncertainties regarding the effect that the competitive market would have on these costs. However, the possible effects of amortization are considered in Chapter Six.

The logistic support costs are divided into two categories; the non-recurring costs associated with introduction of a new system, and the recurring costs experienced from normal corrective maintenance of the system. The cost categories are:

- On-aircraft maintenance
- Off-aircraft maintenance
- Spare parts
- Inventory management
- Support equipment
- Training
- Technical data and failure documentation
- Facilities

All categories contribute to the recurring logistics costs and all but on-and off-aircraft maintenance contribute to the non-recurring logistics cost. For example, spare parts would normally be purchased by a user and

introduced into the inventory system. This would result in costs associated with the spares and the costs of inventory set-up, both considered as non-recurring. Upon failure of a unit, spares would be used up and replacement spares reordered, encountering a recurring cost of parts and documentation. The EAM computes these types of cost parameters based on the probability of failures.

The logistic support costs for the general-aviation community are limited to the recurring costs of maintenance, i.e., on- and off-aircraft maintenance costs consisting of labor and materials to repair a failed unit. The individual general-aviation owner is not expected to provision either spare parts or test equipment and, consequently, does not directly incur the management or facility costs associated with provisioning. These costs are reflected in the general-aviation cumulative life-cycle costs, however, since the EAM reflects all cost categories.

5.3.1.1 Commercial Aviation

Table 5-1 compares the costs of system implementation on a per-aircraft basis for the two DABS/IPC versions. The table shows the acquisition, installation, and estimated portions of the nonrecurring and recurring logistic costs in 1975 dollars, to be incurred for DABS/IPC equipment installed in 1978. The life-cycle cost represents the total cost associated with DABS installations made in 1978 and maintained through 1988. The exact relationship between the first-year-of-ownership costs and the life-cycle costs is complex and is based on the economic analysis model. However, the life-cycle cost is essentially the first-year cost, plus the cumulative recurring logistic cost without inflation.

The data for the discrete version present the costs expected if present practices of manufacturing airborne transponders are followed. Limited production quantities of the DABS/IPC equipment would dictate the use of developed and available discrete logic components, which are required to process the digital data used in communications between the aircraft and ground control. The life-cycle cost data presented for this category will apply if the implementation of DABS/IPC is either limited to commercial air carriers, or extended over periods that are economically impractical for LSI development because of the increased per unit cost caused by amortization over a smaller production quantity.

The LSI-version data present the expected cost of acquisition, logistics, installation, first-year-of-ownership, and life-cycle costs in the commercial air carrier category. Except for the installation costs, which should be identical to those of the discrete version, each cost parameter is lower than for the comparable discrete version. This is attributed to the reduction in the number of logic components, the higher reliability of LSI logic components, and the lower cost of the logic components when the size of the user community is large enough to amortize the development costs without a severe cost penalty.

TABLE 5-1. COST OF OWNERSHIP, COMMERCIAL AVIATION
(Per Aircraft - Retrofit)
(Zero Percent Inflation Rate)

Cost \ System	Discrete Version (Dollars)	LSI Version (Dollars)
Acquisition*	10954	7570
Installation	4227	4227
Nonrecurring Logistic	272	212
Recurring Logistic (1st Year)	478	358
1st Year of Ownership	15931	12367
Life-Cycle Cost	20051	15989

* DABS Transponder (1) Antenna (1), IPC Indicator (2), Control (1).

5.3.1.2 Military Aviation

Table 5-2 presents the cost of ownership and life-cycle cost per aircraft for the military fleet. The aquisition cost reflects the cost of the modification package, display and control unit, which will be required by all military aircraft. The cost associated with modification of the APX-72, performed at military depots, is included in the installation cost. The logistic support costs reflect the expected expenditures for the modification only, and not the logistic support of the entire APX-72. Cost of special test equipment required to support the DABS system is included in the non-recurring logistic cost factor. Data are presented for both the discrete and LSI versions of the modification. The life-cycle cost identifies the expected expenditure per aircraft which was retrofitted in 1978. The LSI version assumes an eight year retrofit of the military community justifying the development costs of LSIs. All data are presented in 1975 dollars.

TABLE 5-2. COST OF OWNERSHIP, MILITARY AVIATION
(Per Aircraft - Retrofit)
(Zero Percent Inflation Rate)

Cost \ System	Discrete Version (Dollars)	LSI Version (Dollars)
Acquisition*	6758	3373
Installation	5493	5493
Nonrecurring Logistic	77	35
Recurring Logistic (1st Year)	397	380
First Year of Ownership	12725	9281
Life-Cycle Cost	13884	10270

* DABS Modification (1), IPC Indicator (2), Control (1)

The costs associated with the LSI version of the DABS/IPC are presented and the maximum advantage realized for this is in the initial acquisition cost of the system. The relatively low value of the expected flight hours for the military aviation results in only a nominal cost reduction in logistic support when the LSI version of the equipment is used.

5.3.1.3 General Aviation

The data in Table 5-3 identify the cost of ownership and the anticipated life-cycle costs for the DABS/IPC concept for high-performance general-aviation aircraft. The acquisition costs include the distribution costs expected in a competitive market for the full-capability (Type I) DABS/IPC. Nonrecurring costs (e.g., spares inventory) are not identified, since they are considered inappropriate for the private general-aviation owner. The low recurring logistics costs for each system are based on a limited flight-hours-per-month average. For some classes of the high-performance GA community -- e.g., corporate or cargo jet aircraft - these costs will increase considerably. However, the typical aircraft owner equipped with a Type I DABS/IPC is expected to experience the indicated maintenance costs on the average.

TABLE 5-3. COST OF OWNERSHIP, GENERAL AVIATION (High Performance) (Per Aircraft - Retrofit) (Zero Percent Inflation Rate)

Cost \ System	Discrete Version (Dollars)	LSI Version (Dollars)
Acquisition	11339	8283
Installation	1854	1854
Recurring Logistics (1st Year)	21	18
1st Year of Ownership	13216	10155
Life-Cycle Cost	13430	10339

* DABS Transponder (1), Antenna (1), IPC Indicator (1), Control (1).

Table 5-4 reflects the anticipated costs of ownership for the majority of the general-aviation community (i.e. the owners of limited-performance aircraft). Analysis of the data developed favors the LSI version of the DABS/IPC on the basis of lower acquisition, installation, and logistic support costs. However, these costs reflect manufacturing quantities that justify the high development costs of LSIs. If, as in the case of commercial air carriers, the implementation period is extended beyond the life cycle assumed in this study, the development costs involved in the limited production of units would be proportionately higher and reflect in the acquisition cost of the equipment. The maintenance per aircraft is low but reasonable because of the 17.3-hour average flight time per month.

TABLE 5-4. COST OF OWNERSHIP, GENERAL AVIATION
(Low Performance) (Per Aircraft - Retrofit)
(Zero Percent Inflation Rate)

Cost \ System	Discrete Version (Dollars)	LSI Version (Dollars)
Acquisition	1598*	986**
Installation	157	91
Recurring Logistics (1st Year)	10	9
1st Year of Ownership	1765	1086
Life-Cycle Cost	1865	1176

* DABS Transponder (1), Antenna (0), IPC Indicator (1).

** DABS Transponder with Built-In Indicator (1), Antenna (0).

Note: Most GA aircraft have transponders, and the transponder antenna can be used by the DABS

5.3.2 Life-Cycle Fleet Costs

The per-aircraft costs identified in the preceding section are important to the general-aircraft owner and the small-fleet commercial carriers. However, the commercial air carriers and the military support large fleets of aircraft and are more concerned with the cumulative costs of system implementation which include the total costs of acquisition, installation, and recurring and nonrecurring logistics than they are with the proportional costs per aircraft.

The total general-aviation expenditures, as well as the cumulative totals, are presented to identify the cost of a DABS/IPC implementation for the entire aviation community.

The cost-model outputs based on the data developed are shown in Figures 5-1 through 5-9. The graphs reflect the impact of inflation, assumed to increase at zero, six, and ten percent per year, for the entire life-cycle of the study. The zero-percent case permits comparison of costs with any other life-cycle study of comparable length, regardless of the start of implementation, providing that the base costs are presented in 1975 dollars. The six-percent case reflects the present rate of inflation and is assumed to be

the probable inflation rate for the duration of the life cycle. The ten-percent case is presented as a worst-case limit for the life-cycle costs. All graphs are suitably identified as to the rate of inflation used in determining life-cycle costs in the user community.

5.3.2.1 Commercial-Aviation Costs

Figures 5-1 through 5-3 represent the expenditures required to implement each of the systems in the air-carrier community. The effect of system retrofit in the first four years of implementation is evidently controlled by the acquisition cost of the system. The logistic support costs required to maintain the systems are higher for the discrete-logic version of the equipment than for the LSI version. The expected higher reliabilities associated with LSI components compared with the cumulative failures of the numerous discrete-logic components are sufficient to offset the higher replacement costs of LSIs and result in an overall reduction of logistic costs for the LSI version of equipment. The lower initial acquisition costs of the LSI version of the transponder and display, together with the lower logistic support costs, result in substantial life-cycle cost reductions over the discrete-logic versions, regardless of the inflation rate during the life-cycle. The effects of LSI development costs on commercial aviation are evaluated as a sensitivity parameter in Chapter Six.

5.3.2.2 Military-Aviation Costs

Figures 5-4 through 5-6 present the expenditures required to implement the systems in the military community. The data reflect the cost of acquisition of the modification package, modification of the APX-72, the IPC display installation, and retrofit of the military aircraft, and life-cycle cost of logistic support of the DABS/IPC portion of the modified APX-72 system. Costs associated with the RF portion or other functions of the APX-72 are not included in the evaluation.

The life-cycle costs in the military community reflect the cost advantage of LSI utilization both for acquisition and maintenance of the equipment. However, the high reliability predicted for the modified portion of the APX-72 is evident in the low maintenance cost of either version of the logic proposed.

This study presents results on only the CONUS-based military aircraft as defined in Chapter Four. However, it is recognized that a large number of military aircraft are based overseas and are subject to periodic rotation through the U. S. and the National Air Space. It has been assumed that the military would not operate DABS/IPC units in aircraft stationed at overseas bases, but that these aircraft would be modified for a DABS/IPC installation when they were restationed in the U. S. Unfortunately, ARINC Research was unable to determine the number of aircraft that would fall into this category. Therefore, the following formula is recommended to establish the added installation costs to be borne by the military when the required number of additional aircraft installations is determined:

$$\text{Added Cost} = \sum_{i=1}^{8} \left[\left(\frac{N_1}{8} \right) \left(I_f + E_f \right) (1+\alpha)^{i-1} \right. \qquad \text{(EQ. 5-1)}$$

where N_{1_i} = a total number of military aircraft stationed overseas in the ith year

I_f = installation cost in 1978 -- \$5,493*

E_f = cost of IPC indicator and control -- \$2,099* (Discrete) \$1,066* (LSI)

i = year of retrofit, 1 through 8

α = inflation rate

*All costs are shown in 1975 dollars and should be inflated before being used in Equation 5-1.

5.3.2.3 General Aviation Costs

Figures 5-7 through 5-9 illustrate the total cumulative life-cycle costs incurred by the general-aviation community in implementing either of the DABS concepts. The primary costs associated with DABS implementation in general-aviation are system acquisition and installation, with acquisition costs being the predominant reason for the cost difference among the two versions. The high reliabilities of the equipments and the low average aircraft utilization (e.g. approximately 200 hours per year) combine to result in maintenance costs that are less than six percent of the total life-cycle costs for each of the concepts.

5.3.2.4 Total Aviation Community

Figures 5-10 through 5-12 present the cost of system implementation for both versions of equipment in the entire aviation community for the 11-year life cycle. The required expenditure for acquisition, installation, and maintenance costs varies from \$642.2 million for the LSI system to \$920.4 million for the discrete-logic system when zero-percent inflation is applied. The comparative expenditures for each system are presented in Table 5-5, which identifies the major categories comprising the life-cycle costs.

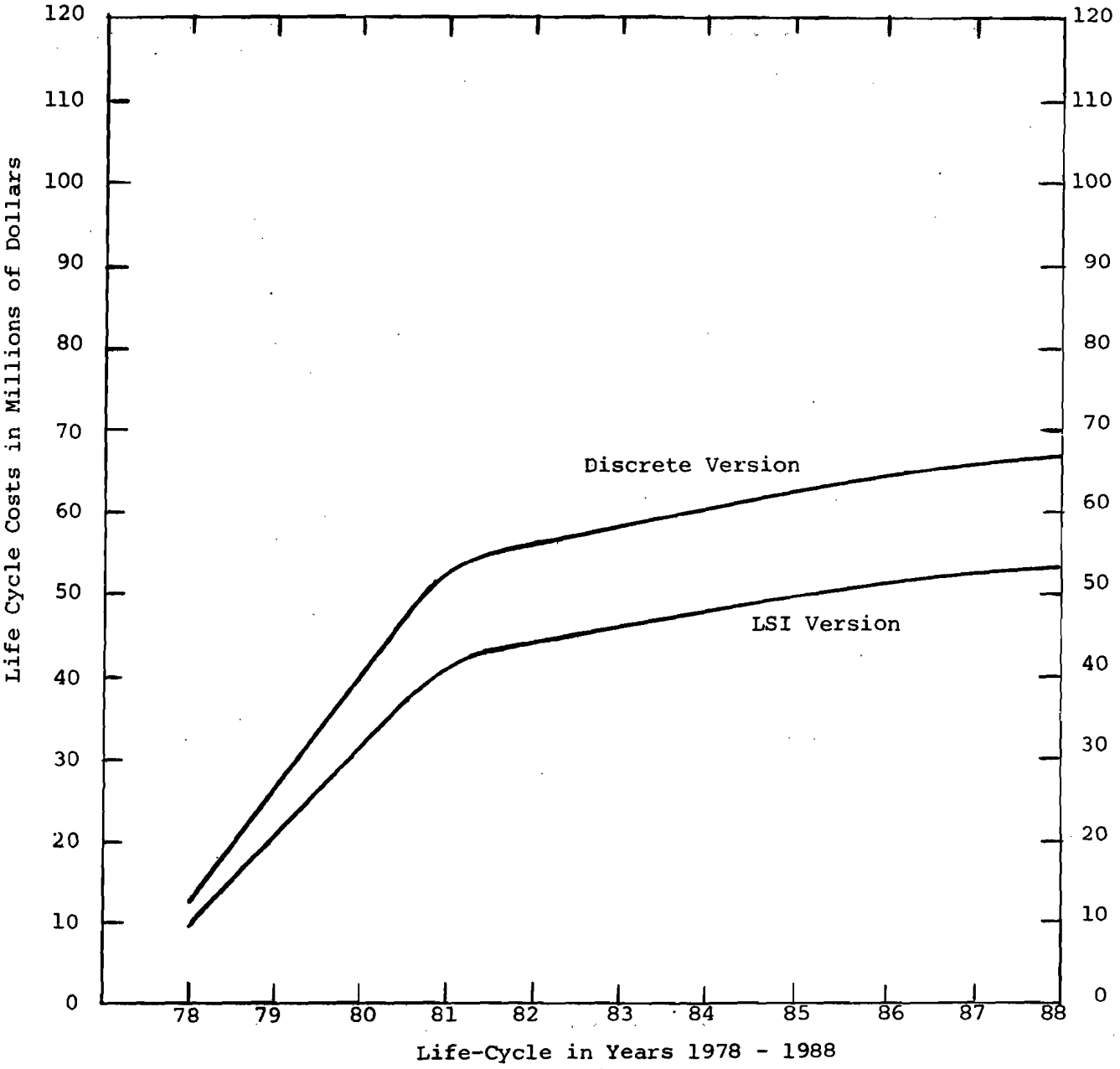

Figure 5-1. Cumulative DABS/IPC Cost (Commercial Aviation) (Zero Percent Inflation Rate)

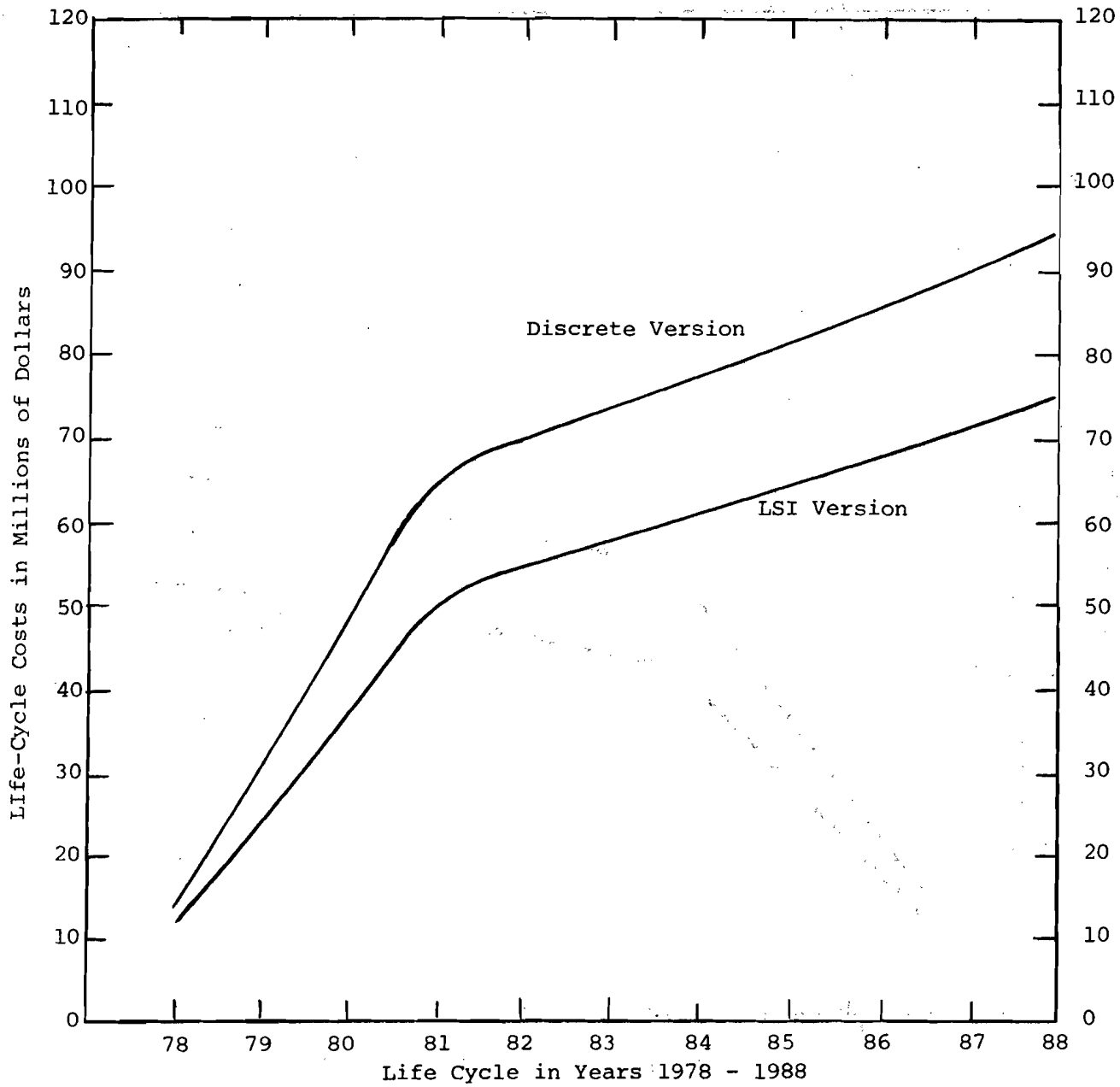

Figure 5-2. Cumulative DABS/IPC Cost (Commercial Aviation) (Six Percent Inflation Rate)

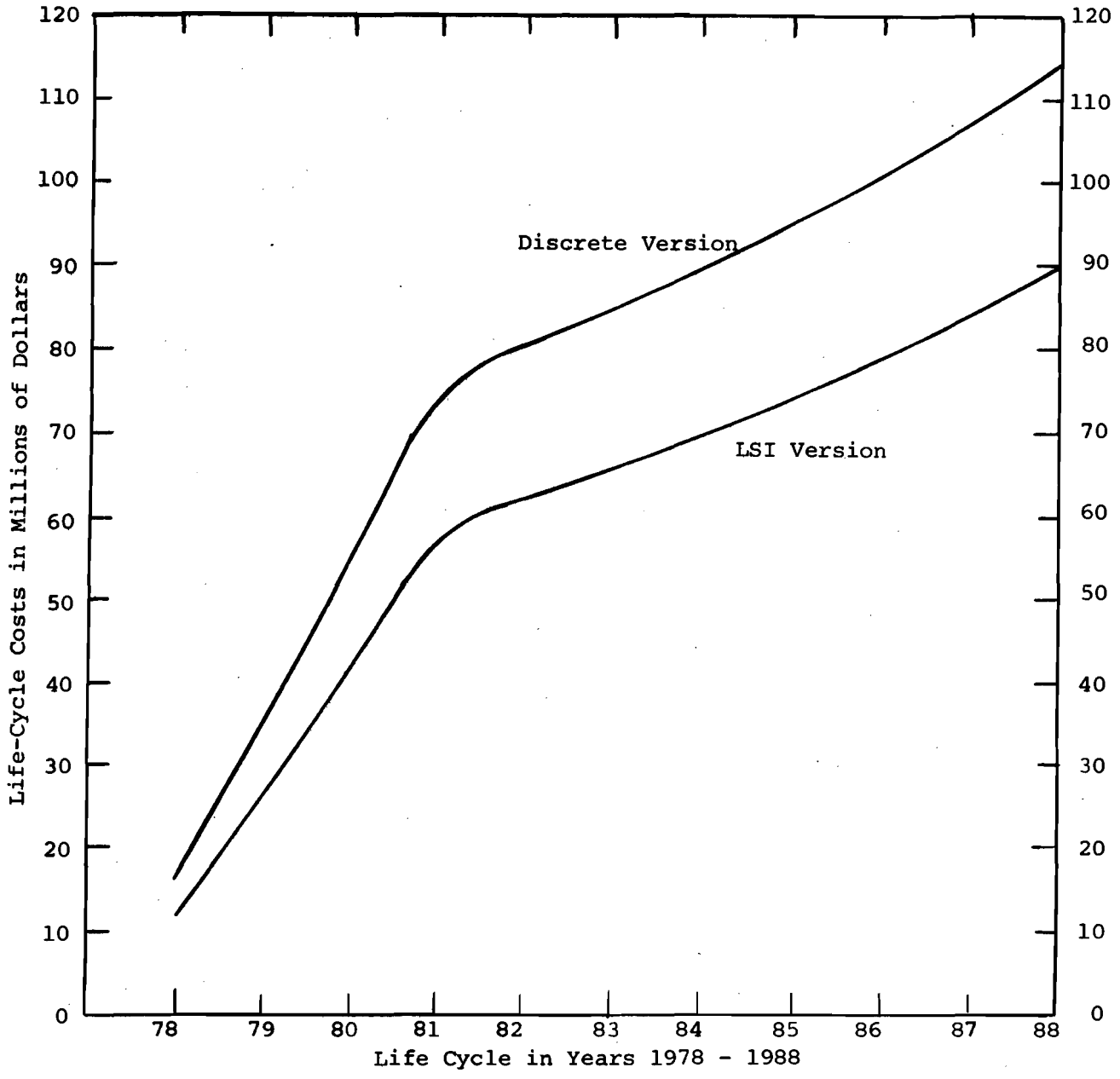

Figure 5-3. Cumulative DABS/IPC Cost (Commercial Aviation) (Ten Percent Inflation Rate)

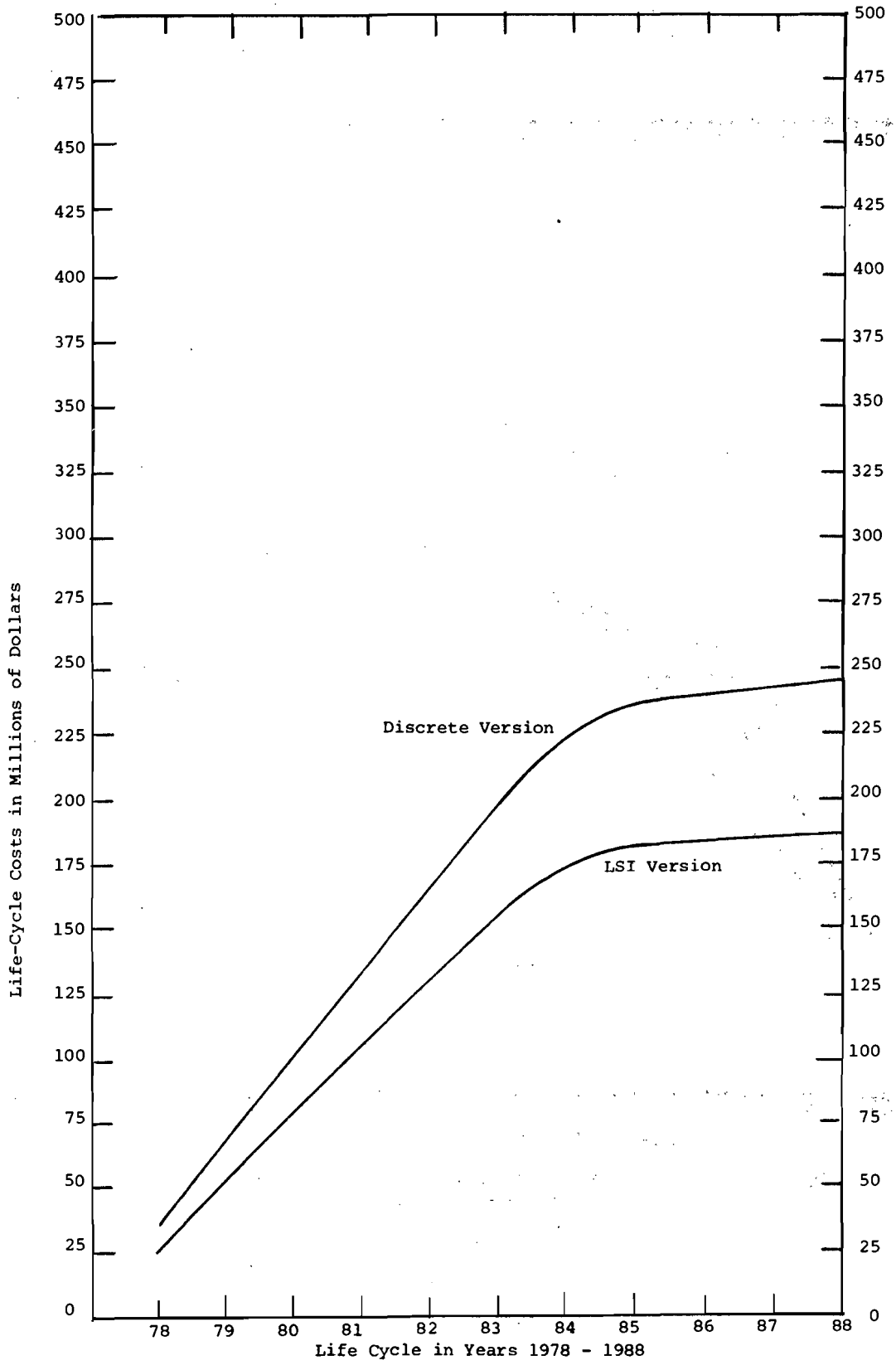

Figure 5-4. CUMULATIVE DABS COST (MILITARY AVIATION)
(ZERO PERCENT INFLATION RATE)

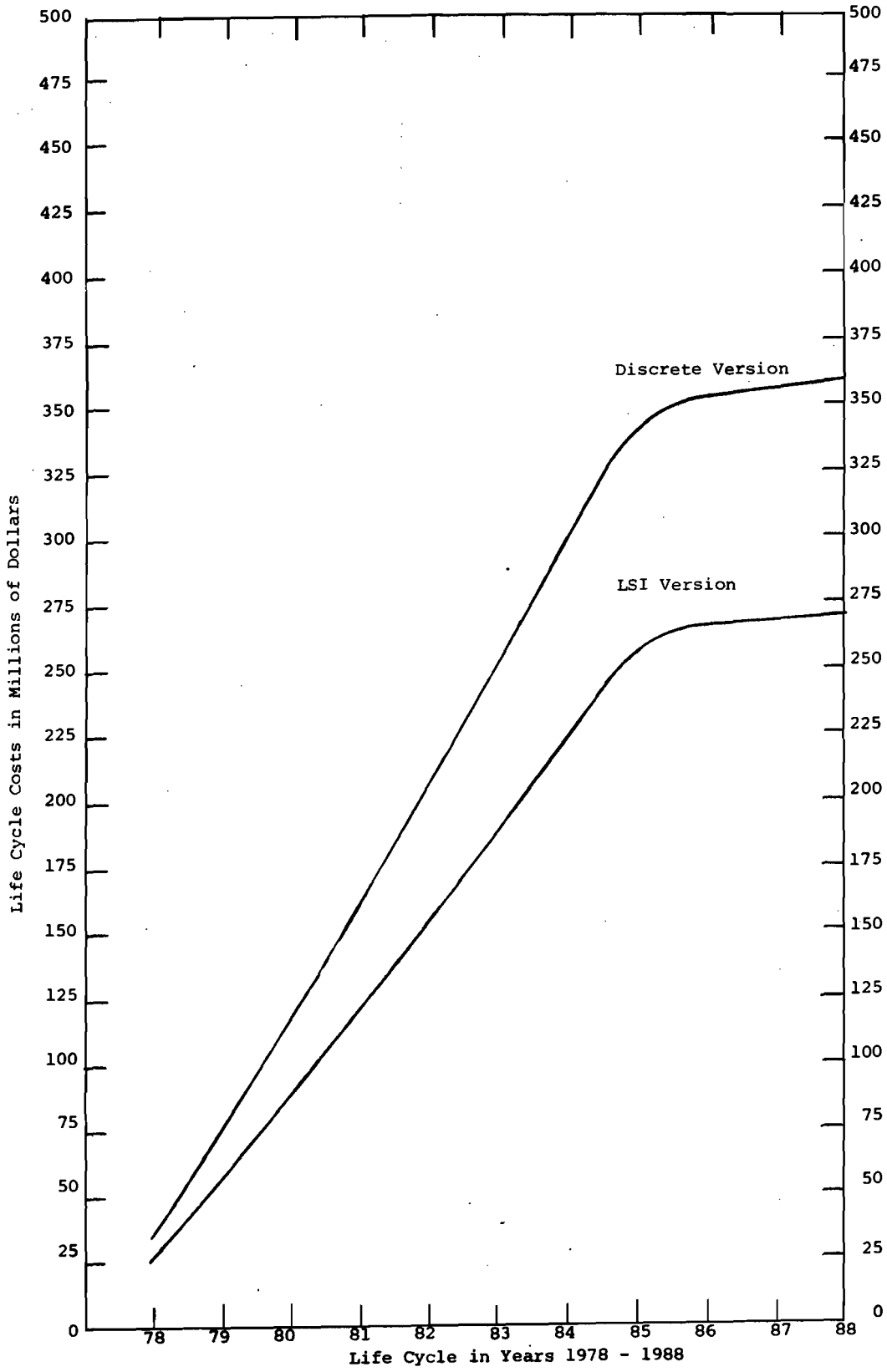

Figure 5-5. CUMULATIVE DABS COST (MILITARY AVIATION)
(SIX PERCENT INFLATION RATE)

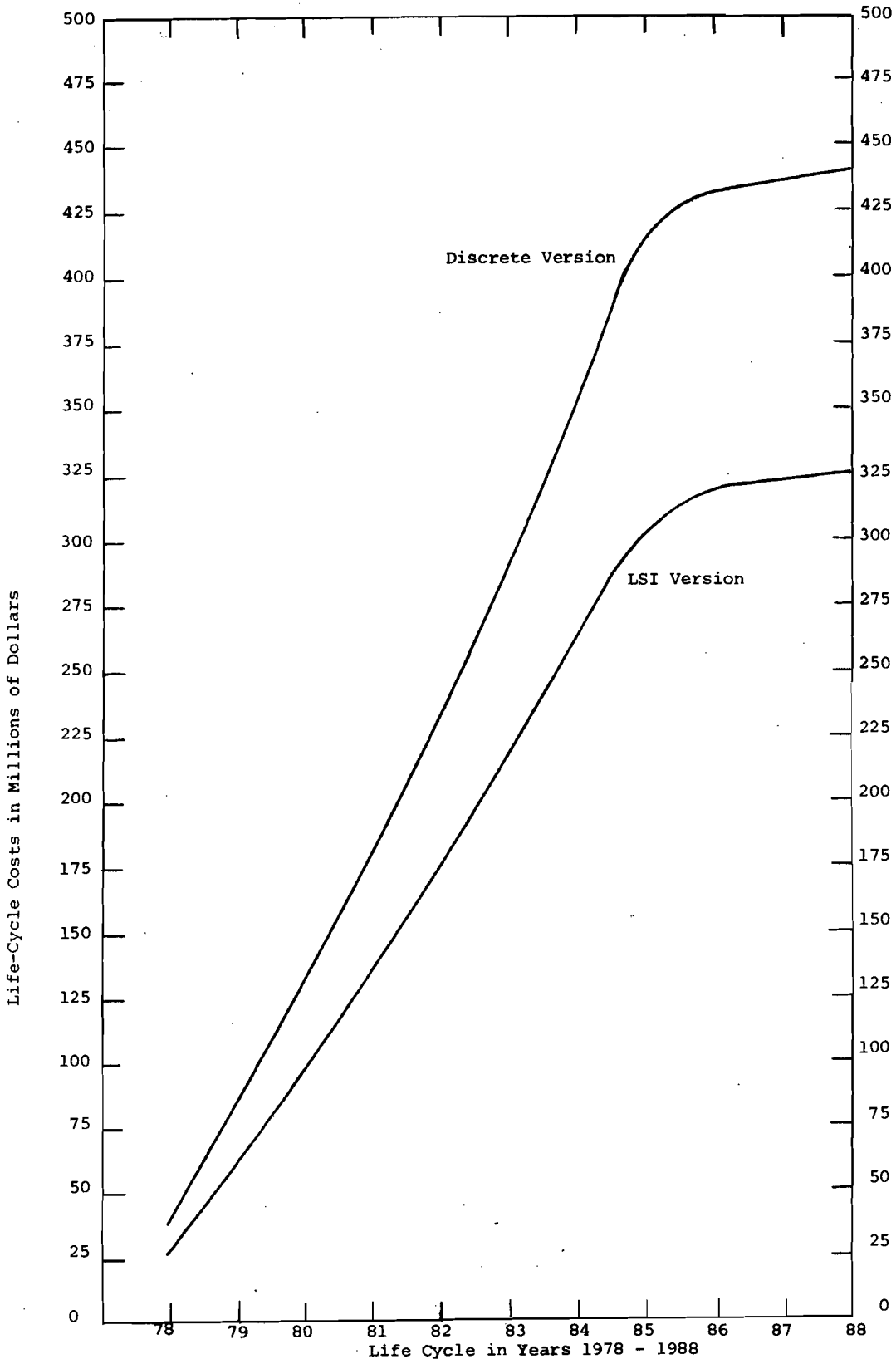

Figure 5-6. CUMULATIVE DABS COST (MILITARY AVIATION)
(TEN PERCENT INFLATION RATE)

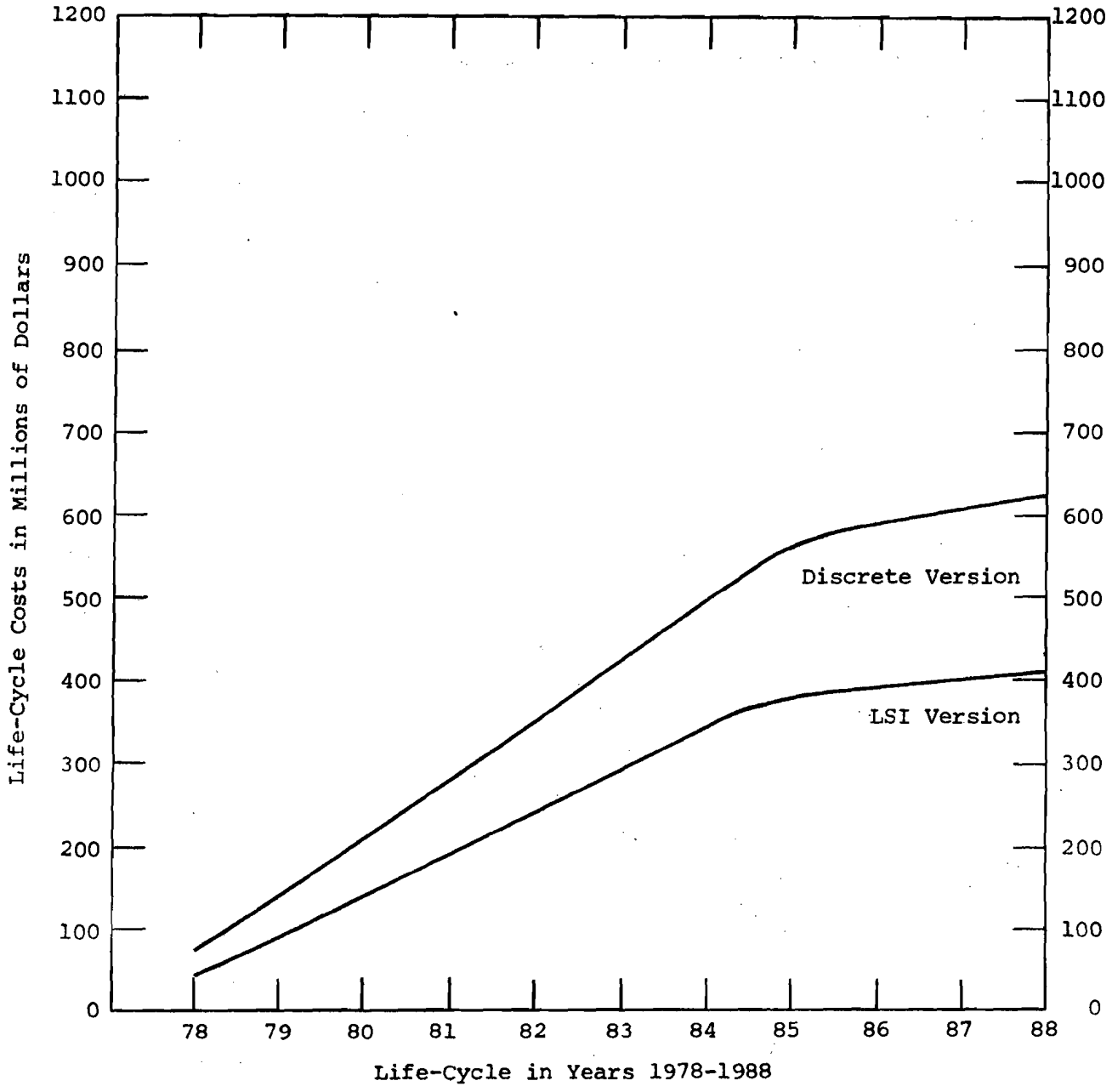

Figure 5-7. CUMULATIVE DABS COST (GENERAL AVIATION)
(ZERO PERCENT INFLATION RATE)

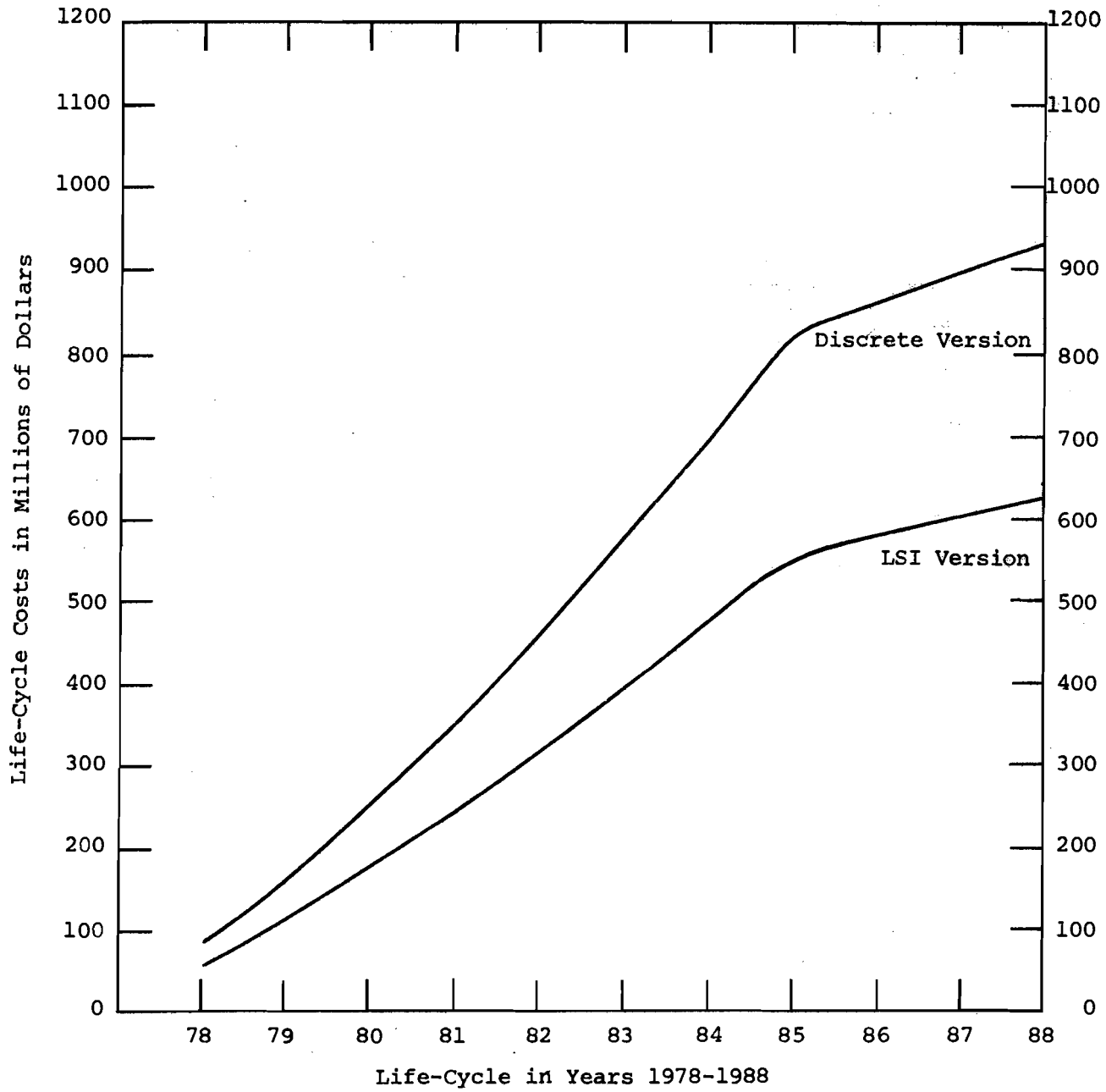

Figure 5-8. CUMULATIVE DABS COST (GENERAL AVIATION)
(SIX PERCENT INFLATION RATE)

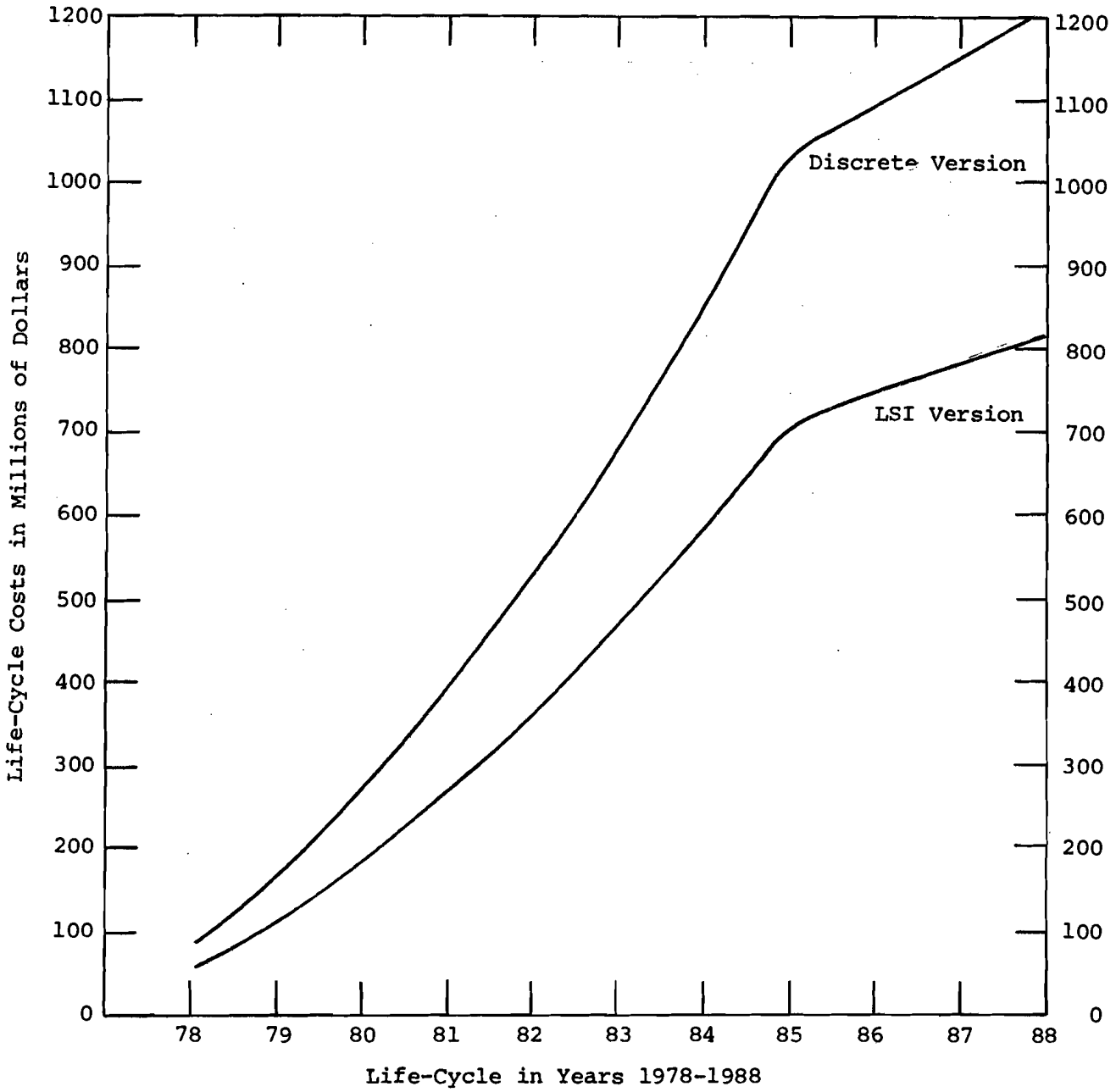

Figure 5-9. CUMULATIVE DABS COST (GENERAL AVIATION)
(TEN PERCENT INFLATION RATE)

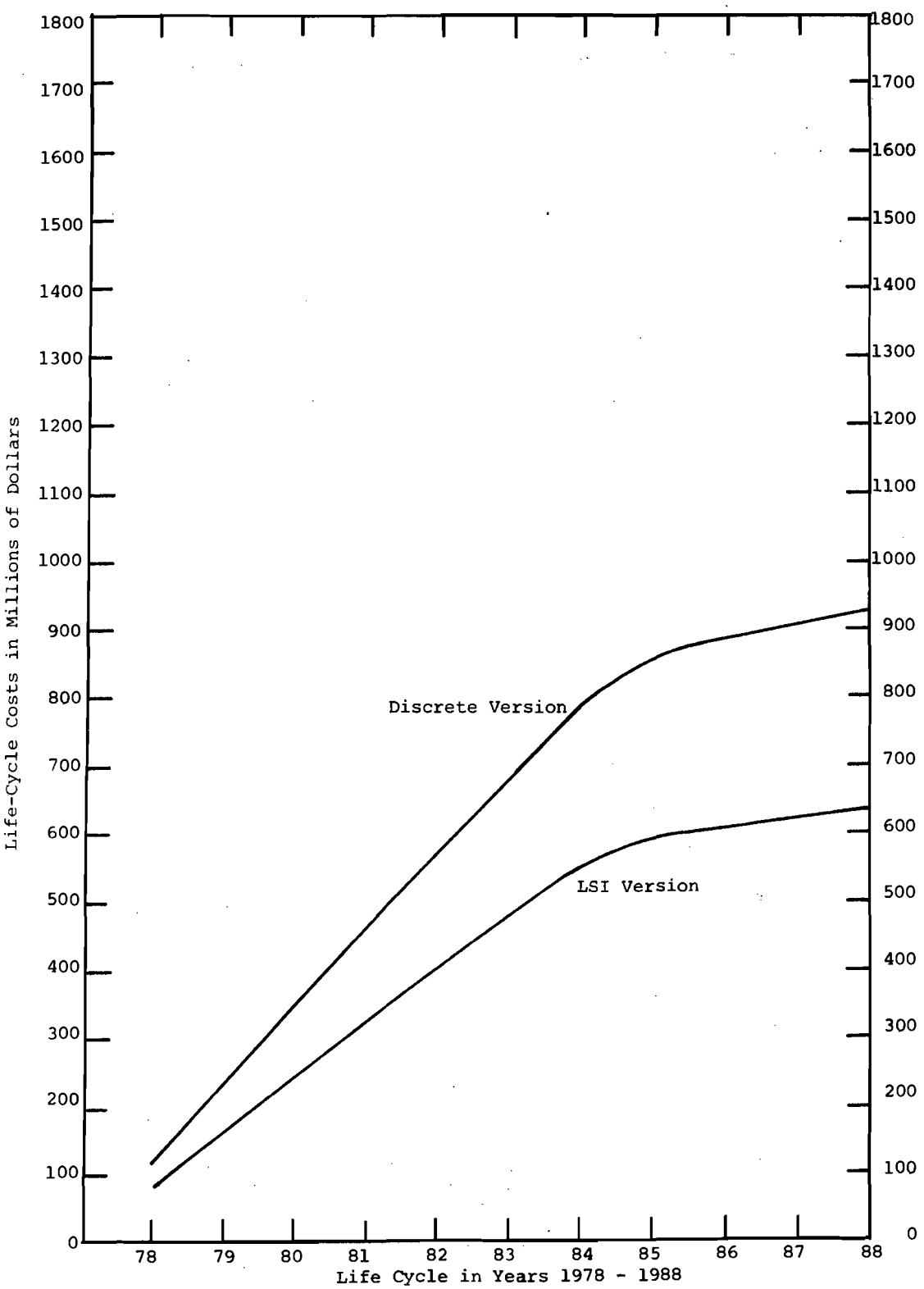

Figure 5-10. CUMULATIVE DABS COST (TOTAL AVIATION COMMUNITY) (ZERO PERCENT INFLATION RATE)

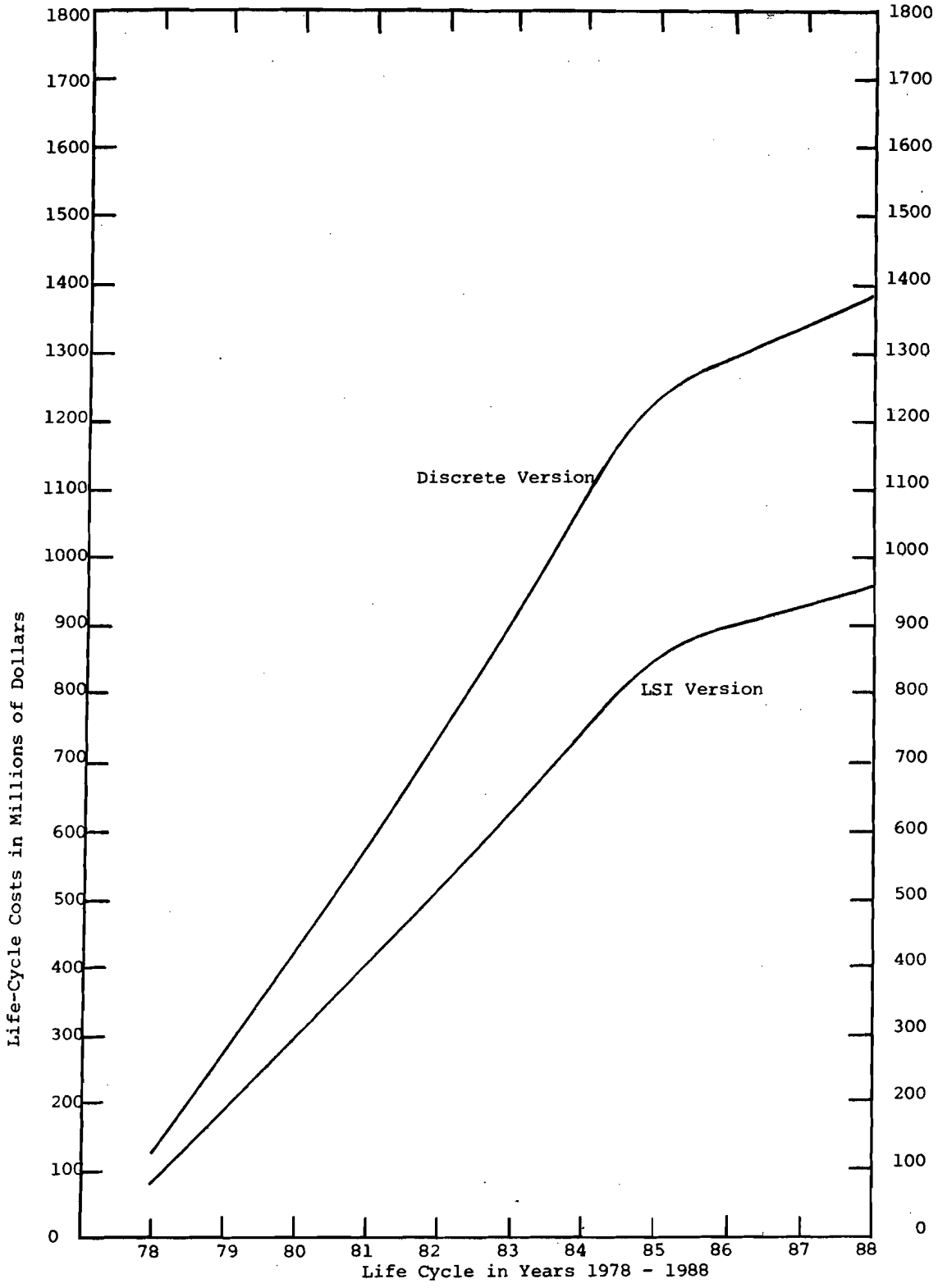

Figure 5-11. CUMULATIVE DABS COST (TOTAL AVIATION COMMUNITY) (SIX PERCENT INFLATION RATE)

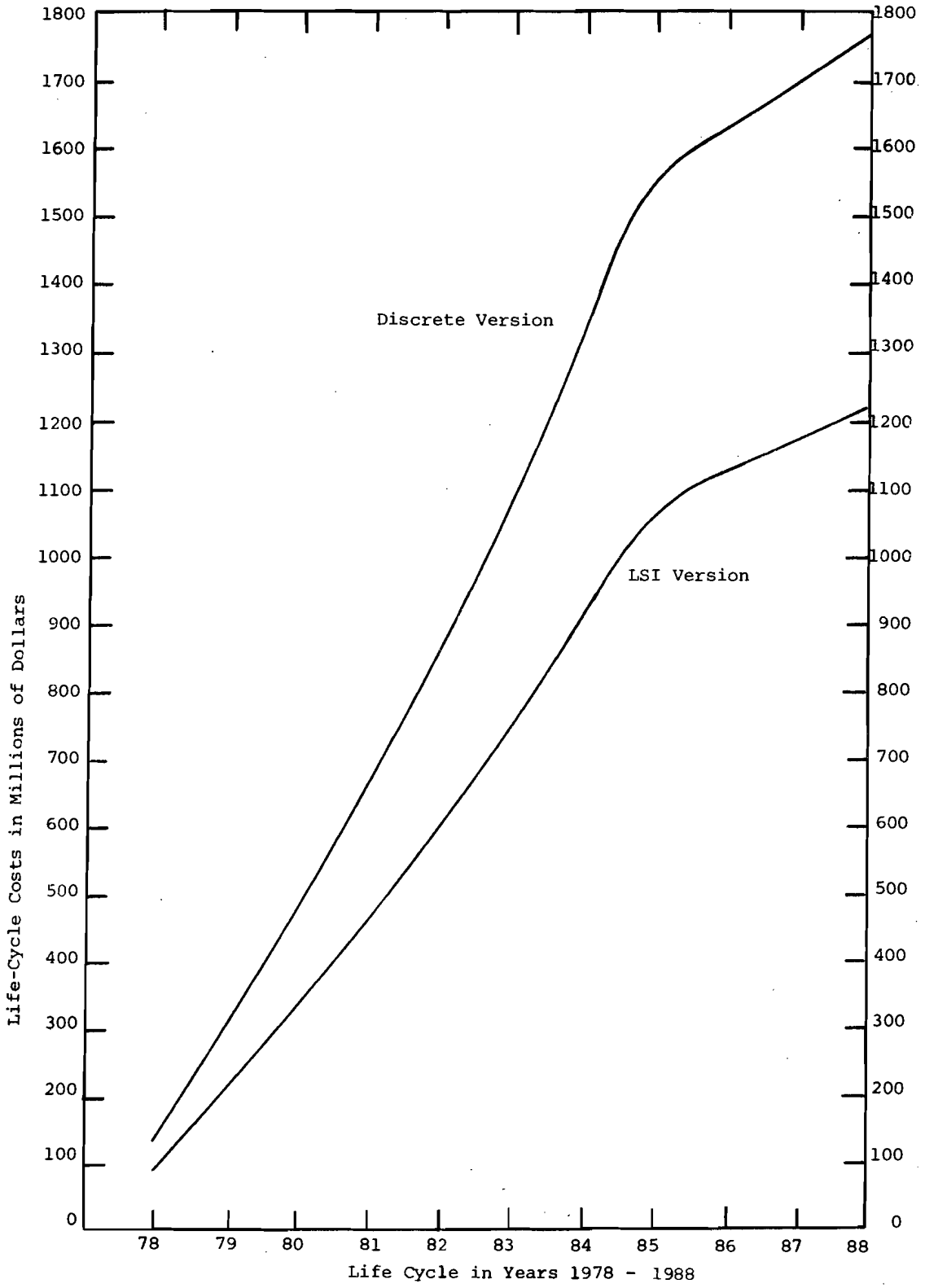

Figure 5-12. CUMULATIVE DABS COST (TOTAL AVIATION COMMUNITY) (TEN PERCENT INFLATION RATE)

TABLE 5-5. LIFE-CYCLE COSTS FOR TOTAL AVIATION COMMUNITY
(In Millions of Dollars)
(Zero Percent Inflation Rate)

System	Acquisition Cost	Installation Cost	Total Logistic	Total
Discrete	682.3	177.3	60.8	920.4
LSI	426.6	164.1	51.5	642.2

CHAPTER SIX

SENSITIVITY OF THE DABS COST ANALYSES TO PARAMETER VARIATIONS AND ALTERNATIVE ASSUMPTIONS

In the development of data in Chapters Three and Four for the cost analyses of the DABS system concepts, assumptions had to be made regarding operational scenarios and system parameters. While a major effort was made to achieve data accuracy, it was considered advisable to review the cost analyses for their sensitivity to parameter variations and alternative scenarios.

The cases considered in this review were as follows:

- The sensitivity of life-cycle costs to variations in system MTBFs
- The sensitivity of life-cycle costs to variations in LSI logic reliability
- The effect of including amortization costs in the analyses
- The effect of including ATC Message Display equipment in the commercial air carrier category
- The effect of providing redundant electronics in the commercial air carrier community

The reasons for conducting these additional analyses and the results of the analyses are presented in the following sections.

6.1 SENSITIVITY OF LIFE-CYCLE COST TO MTBF VARIATIONS

In an economic analysis of any system, the mean time between failures (MTBF) is usually difficult to predict accurately, and it has a major impact on the life-cycle cost. Therefore, the effect of MTBF variations on DABS life-cycle costs was evaluated. Figures 6-1 through 6-3 illustrate the effect of variations in the developed system MTBFs on the life-cycle costs predicted for the commercial, military, and general-aviation fleets, respectively. The figures indicate the system MTBFs developed in Chapter Three and present the life-cycle costs for wide MTBF variations about these values. A comparison is also presented for the discrete and LSI versions of the DABS/IPC equipment. The zero-percent inflation rate was chosen to permit comparison with other life cycles, regardless of implementation dates, on the basis of 1975 dollar costs.

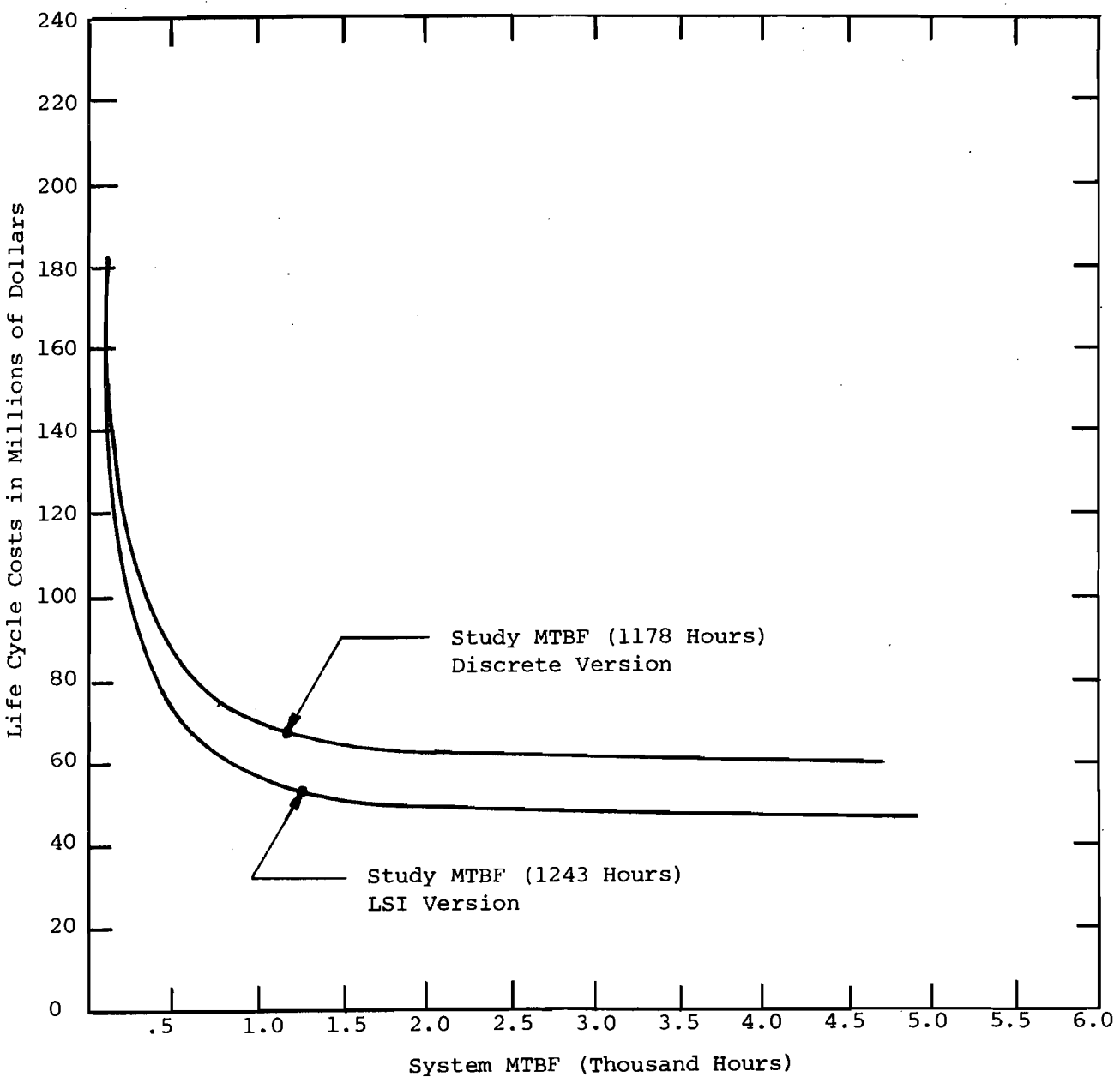

Figure 6-1. Life Cycle Costs as a Function of DABS and IPC Electronics MTBF (Commercial Aviation) (Zero Percent Inflation Rate)

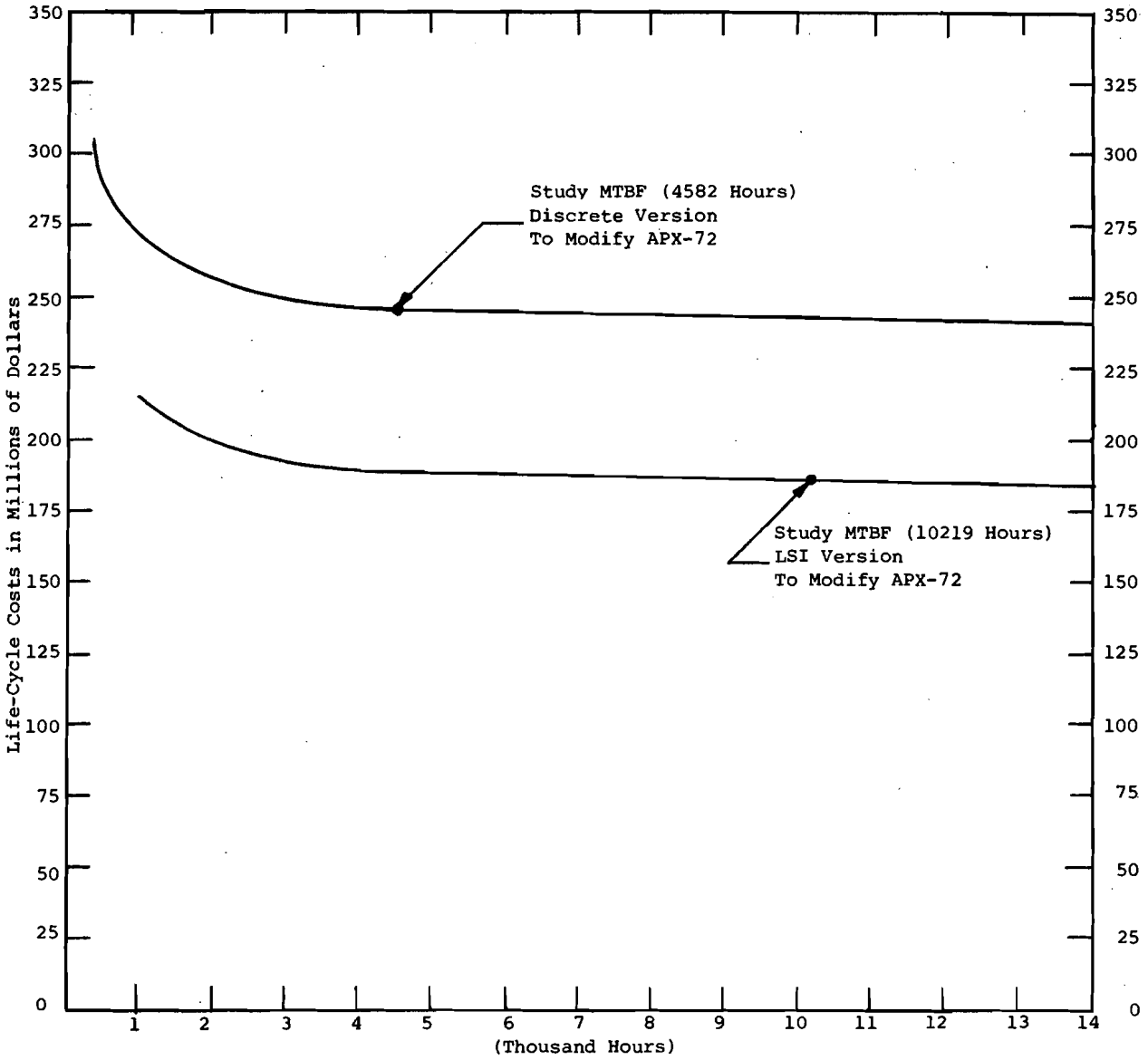

Figure 6-2. LIFE-CYCLE COSTS AS A FUNCTION OF DABS AND IPC ELECTRONICS MTBF (MILITARY AVIATION) (ZERO PERCENT INFLATION RATE)

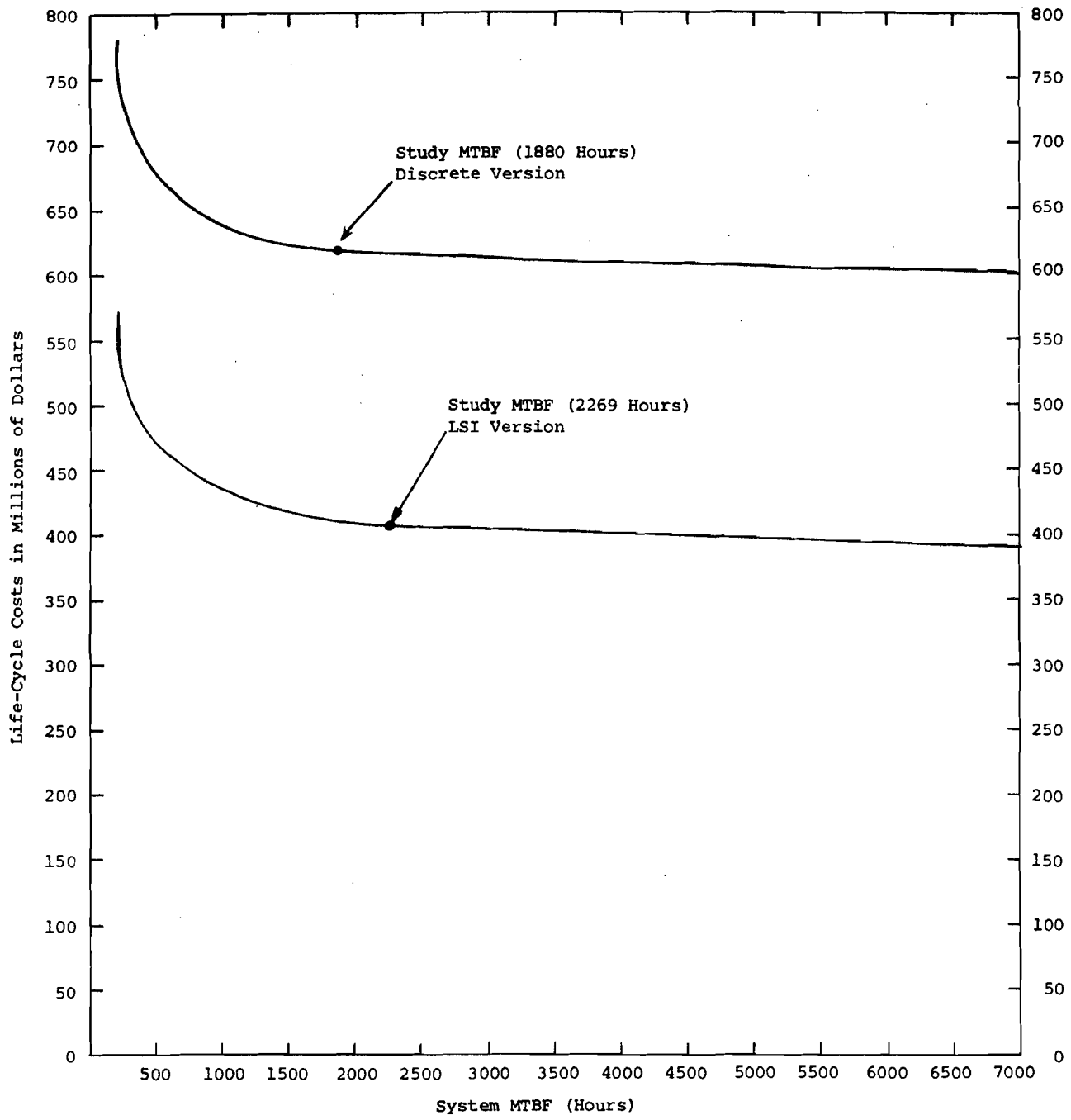

Figure 6-3. LIFE-CYCLE COSTS AS A FUNCTION OF DABS AND IPC ELECTRONICS MTBF (GENERAL AVIATION) (ZERO PERCENT INFLATION RATE)

Figure 6-1 indicates that the commercial air carrier life cycle cost estimates can be affected by errors in the prediction of the system MTBF. For both the discrete and LSI versions, the life cycle costs are in the knee of the cost versus MTBF curves.

Figures 6-2 and 6-3 indicate that the military aviation and general aviation life cycle cost estimates are not very sensitive to variations in the predicted system MTBF's. This is true for both the discrete and the LSI versions of the systems required by the military and general aviation. The MTBF's for the general aviation community represent a weighted average of 5 percent commercial and 95 percent general aviation type DABS installations.

In considering total aviation community costs for implementing DABS, the total cost estimates are only slightly affected by MTBF variations occurring in any of the systems. The only significant variations would occur with the commercial aviation systems, but these costs are only a small portion of the total costs.

Figures 6-1, 6-2 and 6-3 also provide a basis for comparing the discrete and LSI cost versions to identify if there are any MTBF variations that would make the discrete systems less costly than the LSI systems. It is apparent that it would require major variations in the LSI system MTBF predictions to make the discrete systems more attractive than the LSI systems. However, the direct application of the MIL-217B reliability prediction technique could create major changes in the reliability of the LSI systems, and this issue is considered in the following Section.

6.2 THE SENSITIVITY OF LIFE-CYCLE COST TO VARIATIONS IN LSI LOGIC RELIABILITY

The reliability prediction technique of MIL-217B for the LSI logic was questioned in section 3.4.3. The reliability analysis applied in Chapter Three reflected the experience of ARINC Research in LSI reliability. However, to provide consistency in the reliability prediction technique used in the study, this sensitivity analysis is performed with LSI failure rates based totally on the recommendations of MIL-217B.

Cost data for the discrete revision of the DABS/IPC are those developed in Chapter Three. The failure rates of the LSI logic used in this sensi-ivity analysis are 433 and 4339 failures per million hours of operation for Type I and Type II, respectively, as opposed to 6.6 and 76.7 failures per million hours used in the initial analysis for Type I and Type II, respectively. Figure 6-4 presents the life-cycle costs for the commercial air carriers as a function of system MTBF for the 11-year life cycle.

Figure 6-5 presents the comparable data for the military community. In both of these cases the relative costs between the discrete-component and LSI versions are little affected by a strict adherence to the MIL-217B predection methods for LSI reliability.

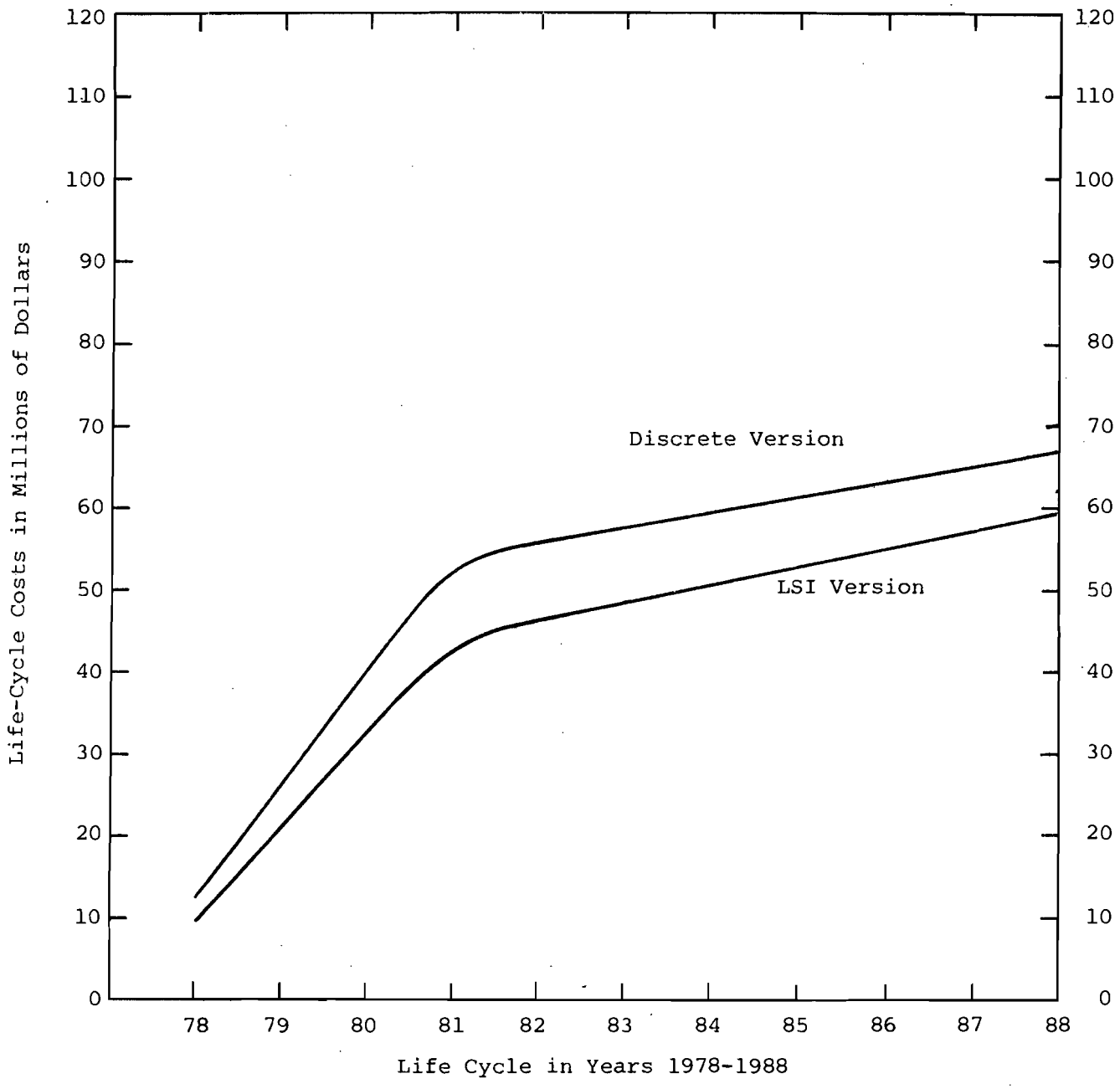

Figure 6-4. CUMULATIVE DABS COST AS A FUNCTION OF LSI RELIABILITY (COMMERCIAL AVIATION, ZERO-PERCENT INFLATION RATE)

Figure 6-5 presents the comparable data for the military community.

Figure 6-6 presents the analysis results for the general-aviation community. The results show that the LSI version is still less expensive over the life cycle of the study, but the trend of the life-cycle cost, if extrapolated beyond the 1988 period, indicates that logistic support would be significantly more costly for the LSI version than for the discrete version. These results are not supported by ARINC Research experience with LSI reliabilities. The data presented in Chapter Five show the probable relationship between the discrete and LSI versions of equipment in any user community.

6.3 THE EFFECT OF INCLUDING AMORTIZATION OF MANUFACTURERS' START-UP COSTS

The costs associated with production start-up, tooling, engineering, and development of LSI logic are normally included in a manufacturer's selling price. However, in the review of possible ways to evaluate these amortization costs, it was recongized that a competitive market with multiple manufacturers, would probably modify and reduce the normally expected amortization costs. Therefore, amortization costs were eliminated from the cost analysis in Chapter Five. Nevertheless, it was desirable to re-evaluate the life-cycle costs with the effect of amortization included in order to determine if any of the cost evaluations would be altered.

The production start-up, tooling, and engineering costs used in this study are based on costs proposed by manufacturers producing similar avionic equipment in comparable quantities. The cost of LSI development was based on ARINC Research experience in other studies and information provided by Bendix Aviation, a corporation with LSI development capability and experience. Table 6-1 identifies the costs to be amortized with the discrete version and the LSI version of the DABS/IPC equipment. In accordance with the provisions of the Uniform Ground Rules used for the evaluation, all amortization costs are applied to production within the first two years of system implementation.

TABLE 6-1. AMORTIZATION COSTS

System Type	Discrete Versions Costs (Dollars)	LSI Version Costs (Dollars)
Total to be Amortized	773,000	1,223,000
Type I System	473,000	585,500
Type II System	300,000	487,500
Military Modification	0	150,000
Per Aircraft -		
Type I	315	390
Type II	120	195
MIL MOD	0	30

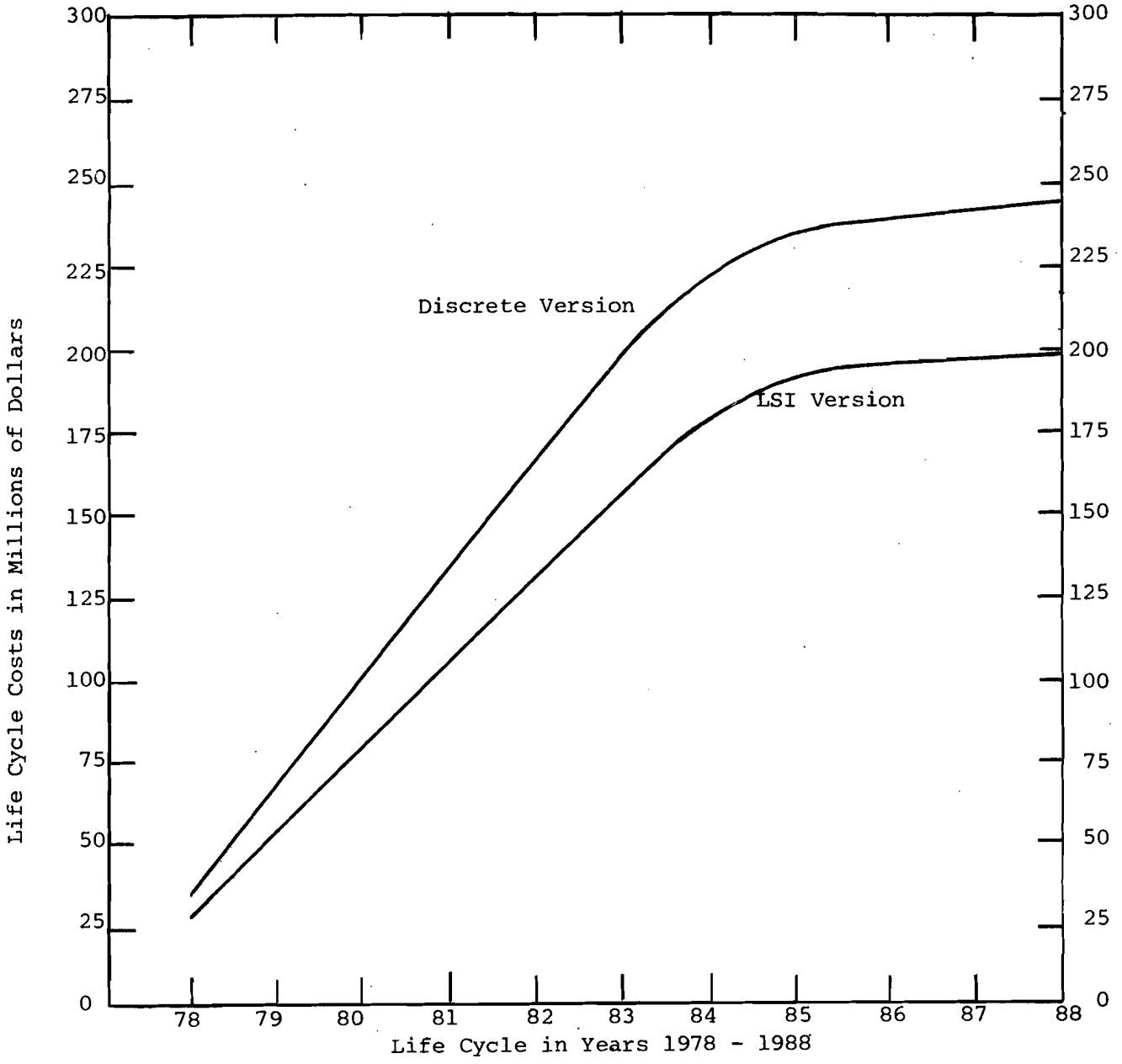

Figure 6-5. CUMULATIVE DABS COST AS A FUNCTION OF LSI RELIABILITY (MILITARY AVIATION) (ZERO PERCENT INFLATION RATE)

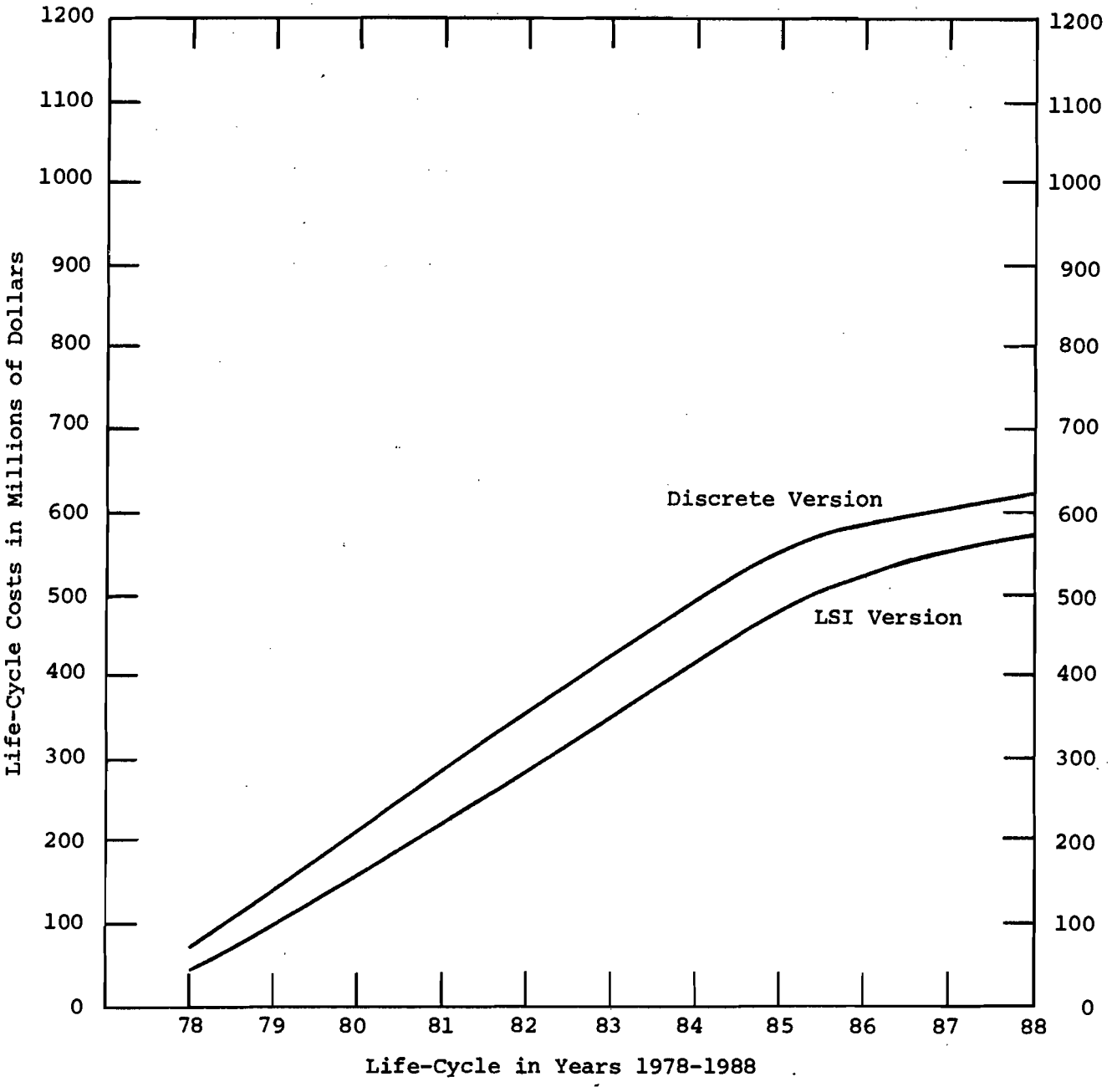

Figure 6-6. CUMULATIVE DABS COST AS A FUNCTION OF LSI RELIABILITY (GENERAL AVIATION) (ZERO PERCENT INFLATION RATE)

The amortization costs have been converted into per-aircraft costs based on limited production quantities of 1500 Type I units and 2500 Type II units that would be subject to amortization by any one manufacturer during the first two years of the DABS installation program. In the case of the military the amortization costs for the development of the modification package would be limited to LSI development costs since all manufactured components are already in production. The military amortizations costs were applied to 5138 aircraft, the expected number to be modified with DABS during the first two years of implementation. The resultant increased cost per unit was applied to all systems manufactured and installed during the first two years of system implementation under the assumptions that there would be multiple manufacturers and any manufacturer engaged in the production of a system would be subject to similar startup costs. The expected cost of DABS /IPC equipment where amortization is included is shown in Table 6-2. The resulting total costs to be amortized by the multiple manufacturers during the first two years of production became $7.9 million for the discrete version, and $12.4 million for the LSI version of DABS/IPC.

TABLE 6-2. DABS/IPC EQUIPMENT COST, INCLUDING AMORTIZATION

	DISCRETE VERSION	LSI VERSION
HIGH-PERFORMANCE TYPE I DABS/IPC		
DABS Electronics*	$6378	$4875
IPC Indicator*	2214	1126
Antenna	63	63
Control Unit	516	516
LIMITED-PERFORMANCE TYPE II DABS/IPC		
DABS Electronics*	568	811
IPC Indicator*	551	(included in electronics)
Antenna	13	13
MILITARY MODIFICATION FOR DABS/IPC		
DABS Mod Kit*	2260	946
IPC Indicator*	2214	1091
Antenna	63	63
Control Unit	300	300

*Manufacturer's Expected OEM Prices without mark-up for Distribution.

Figures 6-7 through 6-10 present the life-cycle costs of each system with amortization costs included.

Figure 6-10 presents the total aviation community life-cycle costs, including amortization. The actual effect of including amortization costs in the economic analyses can be seen by a close comparison of Figures 5-10 and 6-10. Although amortization costs are greater for the LSI systems, Figure 6-10 indicates that the LSI concept remains the lowest-cost alternative when amortization costs are included in the overall cost analysis.

6.4 THE EFFECT OF INCLUDING AN ATC MESSAGE DISPLAY IN THE COMMERCIAL AIR CARRIERS

In Chapter Three data were developed on the cost and reliability of a display which would provide ATC messages to aircraft by utilizing the Standard Message (SM) data link of the DABS Transponders. The display was not included in the life-cycle study since it is not mandatory for proper operation of the DABS system. However, the designed capability of the DABS system provides a data link which would provide a pilot with useful information as defined in section 3.2.5.

The installation of the ATC Display has been limited in this study to commercial aviation because of the acquisition cost of the unit. However, all the transponders developed in this study have the inherent capability for data transfer to any aircraft equipped with the ATC display.

The costs for installing the ATC Display in the commercial air carrier, together with the acquisition and logistic support costs are presented in Table 6-3.

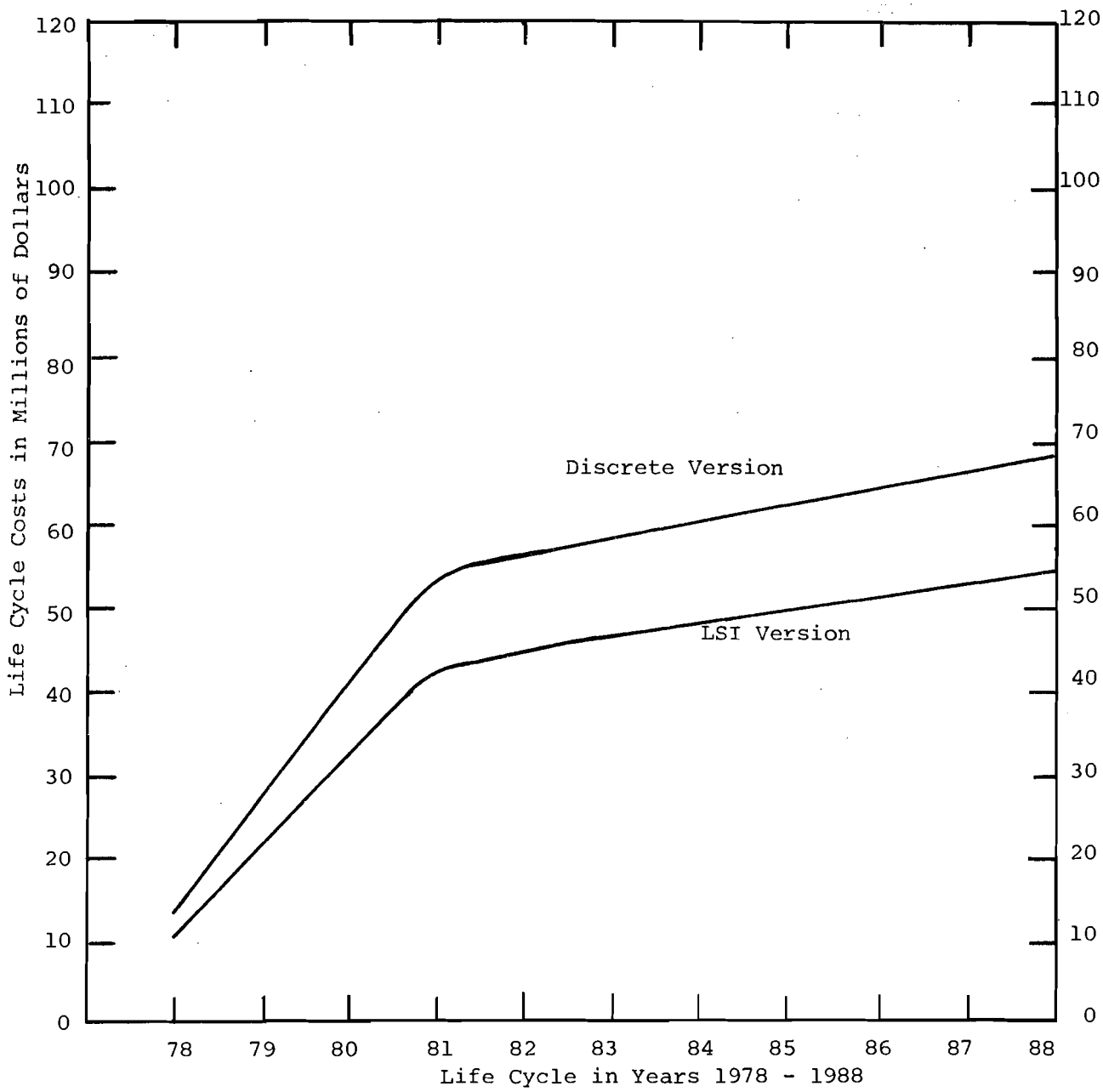

Figure 6-7. CUMULATIVE DABS COST INCLUDING AMORTIZATION (COMMERCIAL AVIATION) (ZERO PERCENT INFLATION RATE)

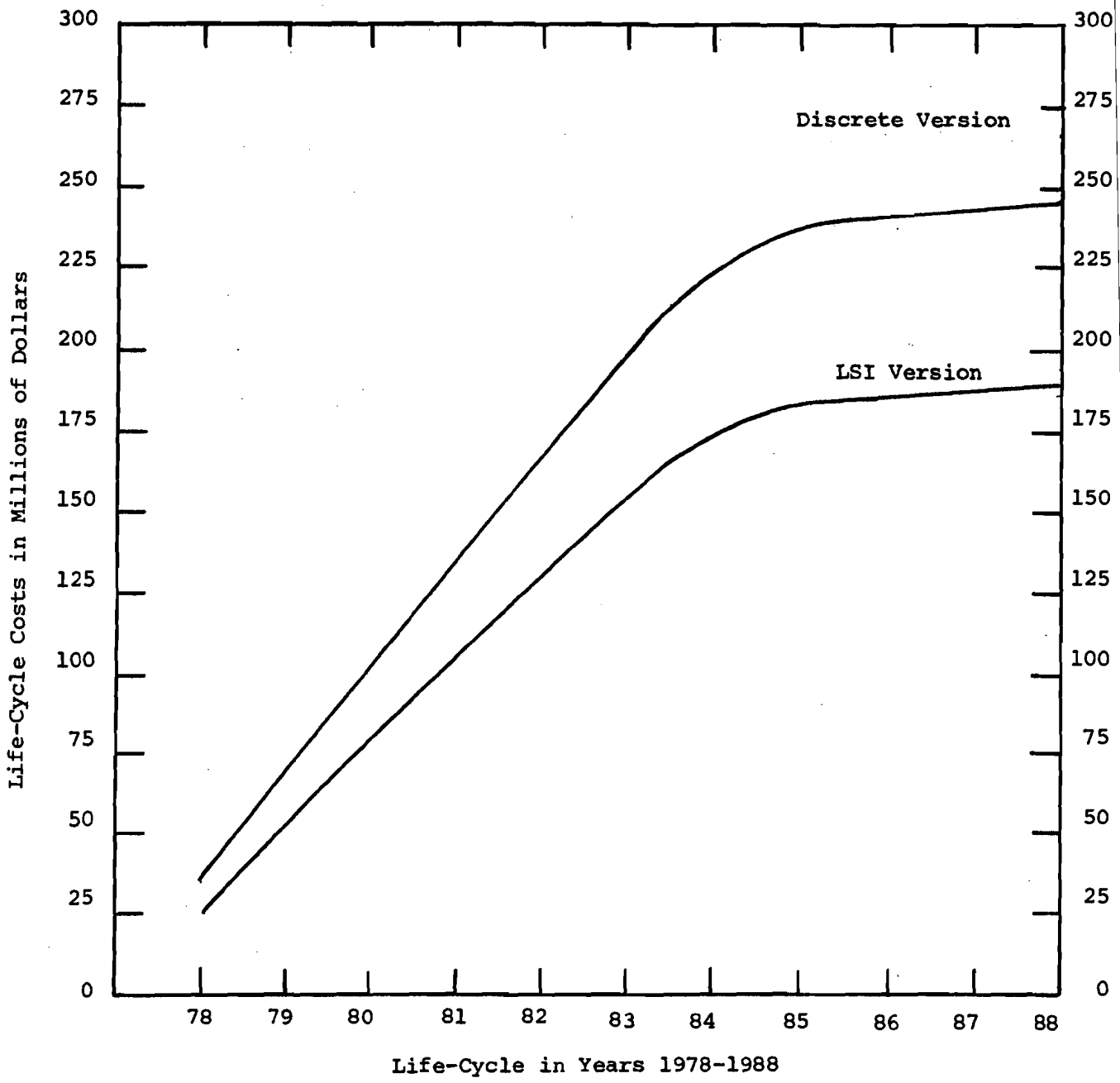

Figure 6-8. CUMULATIVE DABS COST INCLUDING AMORTIZATION (MILITARY AVIATION) (ZERO PERCENT INFLATION RATE)

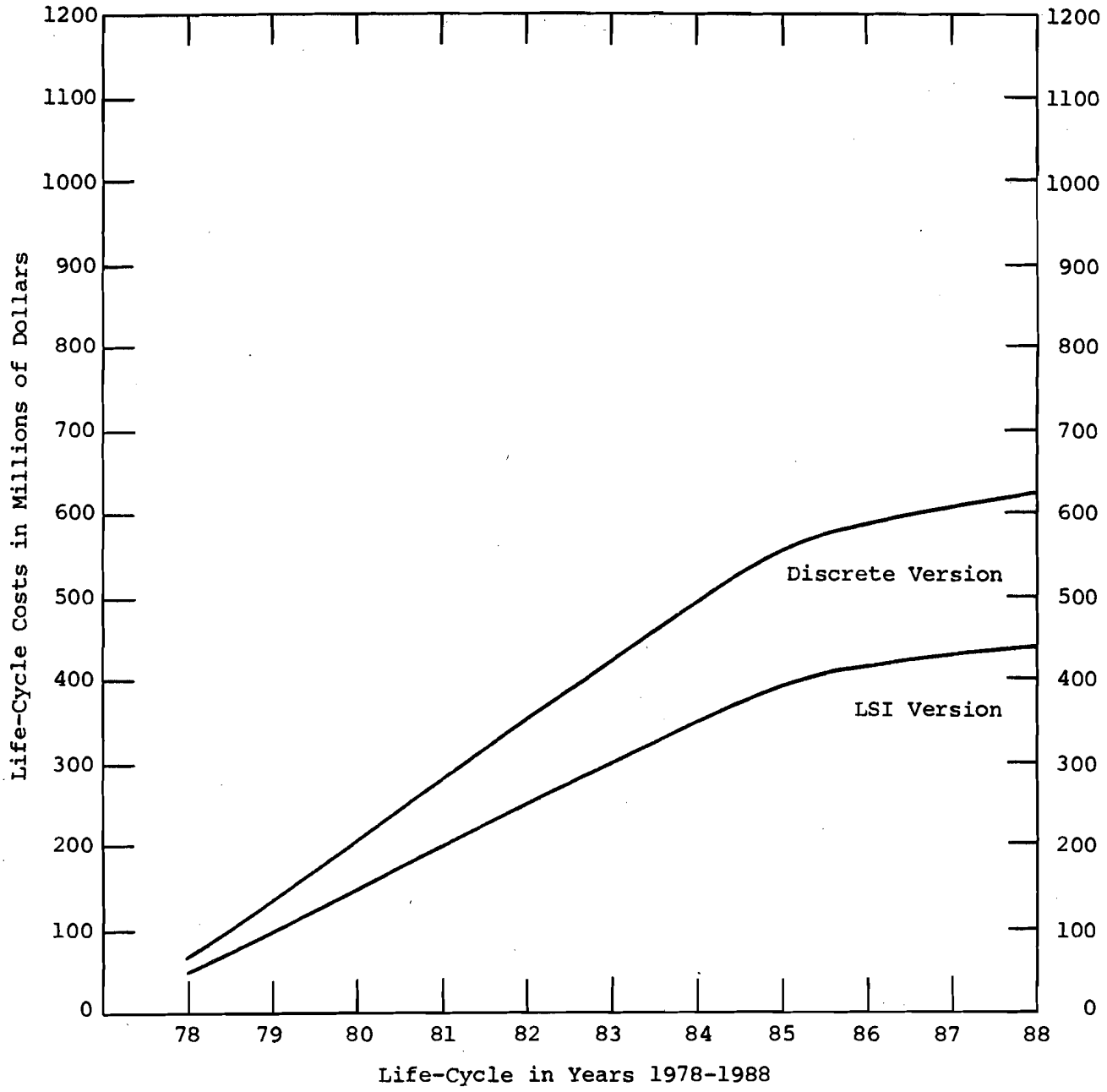

Figure 6-9. CUMULATIVE DABS COST INCLUDING AMORTIZATION (GENERAL AVIATION) (ZERO PERCENT INFLATION RATE)

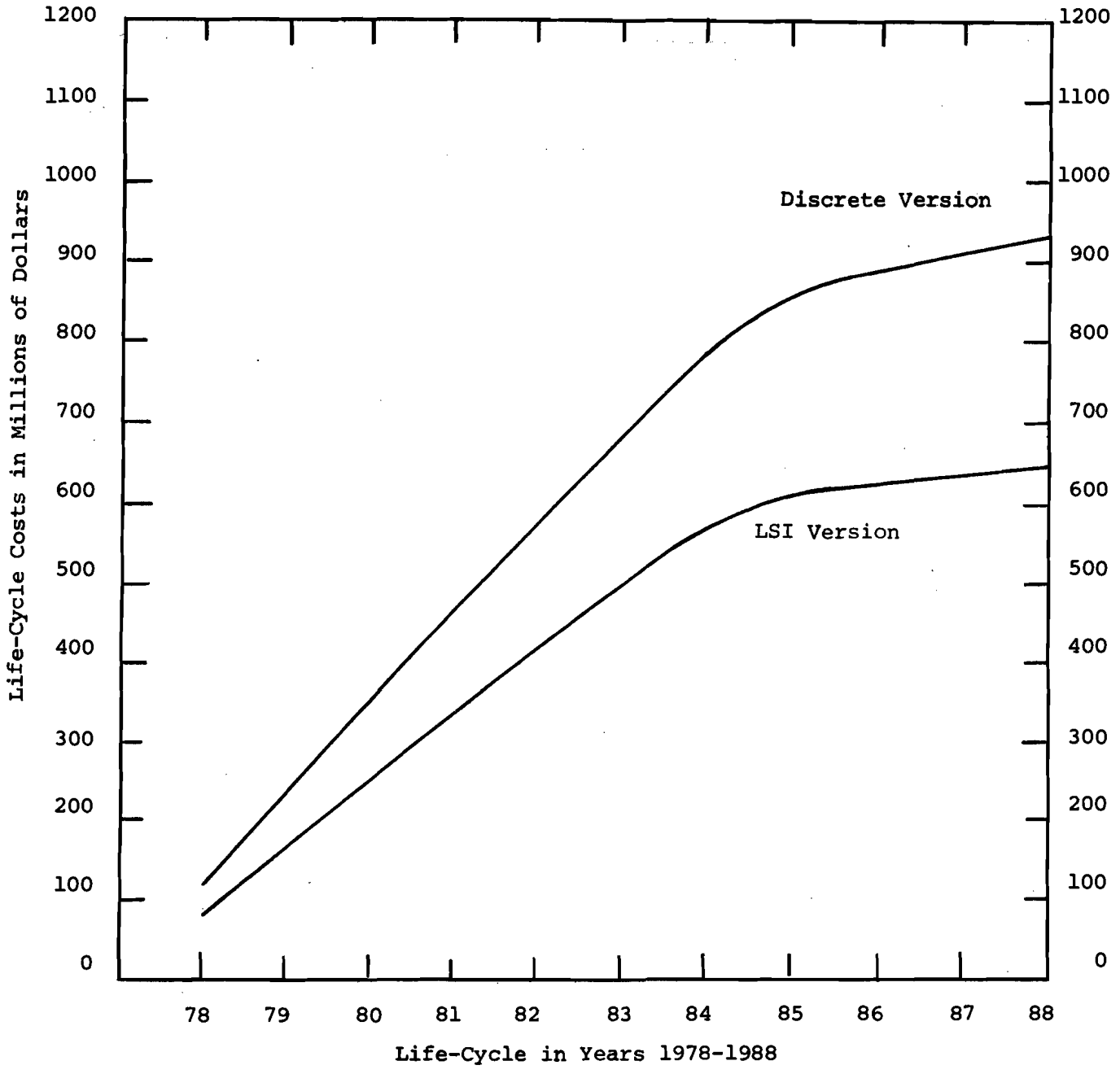

Figure 6-10. CUMULATIVE DABS COST INCLUDING AMORTIZATION (TOTAL AVIATION COMMUNITY) (ZERO PERCENT INFLATION RATE)

TABLE 6-3. COMMERCIAL AVIATION ATC DISPLAY
(Per Aircraft)
(Zero Percent Inflation Rate)

Cost Category	Amount (Dollars)
Acquisition	1527
Installation	989
Nonrecurring Logistic	8
Recurring Logistics	16
First Year of Ownership	2541
Life Cycle Cost	2707

Figure 6-11 presents the life-cycle costs of introducing the ATC message display into the commercial-aviation community. The data have been presented for the costs associated with the display only and the total DABS/IPC system life cycle costs, including the display. The graph identified as the "LSI Version" includes the LSI transponder, LSI IPC display and a discrete logic ATC display as developed in Chapter Three. The life-cycle cost to the commercial-aviation community for the ATC display would be $18.8 million if each aircraft was equipped and the cumulative life-cycle cost of DABS with an ATC display for this community would result in an expenditure of $86.4 million for the discrete version and $72.3 million for the LSI version of the system.

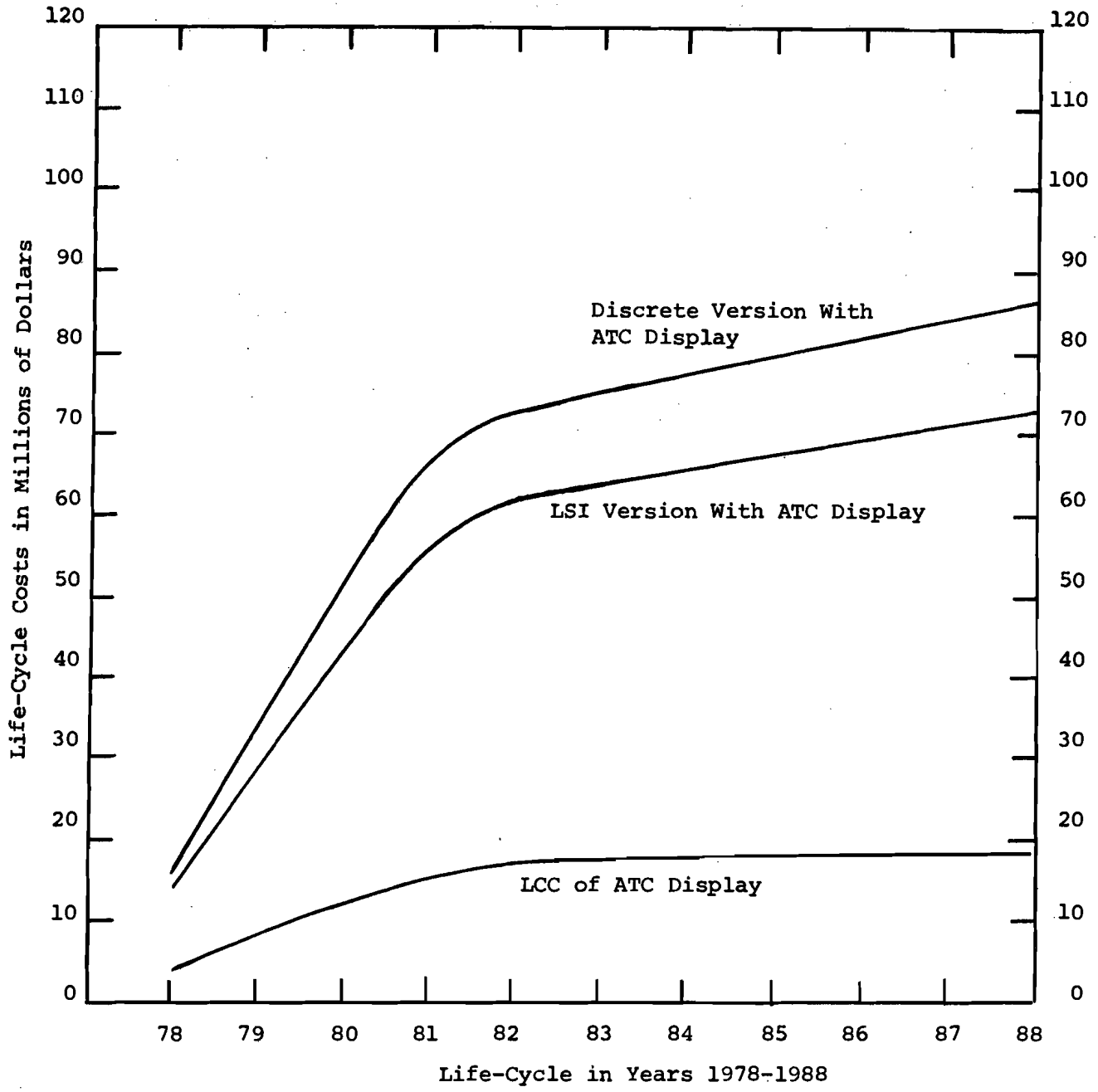

Figure 6-11. CUMULATIVE DABS COST WITH ATC DISPLAY (COMMERCIAL AVIATION) (ZERO PERCENT INFLATION RATE)

6.5 THE EFFECT OF PROVIDING REDUNDANT ELECTRONICS IN THE COMMERCIAL CARRIER COMMUNITY

In Chapter Five data were developed on the cost of ownership and life-cycle costs to the commercial-carrier community for implementation of a single DABS/IPC system in each airframe. The results present the expected cost to this community based on the minimum equipment required for the successful implementation and operation of the DABS concept. However, historically the commercial carriers have followed the practice of achieving high operational availability through system redundancy. This section presents the results of an evaluation of the DABS/IPC concept when redundant equipment is implemented in each air carrier aircraft.

The equipment required by a certified commerical carrier to provide system redundancy consists of the following components:

- 2 sets of DABS electronics (Type I)
- 2 antennas (top and bottom) (one existing)
- 2 IPC indicators (pilot and co-pilot)
- 2 sets of controls and switching equipment

The additional DABS electronics will be located in the normal avionics bay of the aircraft. The indicators and antennas required for a single system will be switched to operate with either of the redundant electronics.

The installation costs associated with dual system implementation will increase over those presented in section 4.4.1 by the following:

Installation Factor	Time Required	Cost
Shelf fabrication and installation	48 hours	1067.
Control Unit Installation	2 hours	45.
On-Aircraft Cabling	20 hours	444.
Material		541.
Totals	70 hours	2097.

The estimated costs to install assume that the implementation of a dual system would be accomplished at one time, rather than by addition of a second system. The total cost of a dual system implementation in an existing aircraft would be $6323.

Table 6-4 compares the costs of the dual system implementation on a per-aircraft basis for both the discrete and LSI versions of DABS/IPC. The increased cost reflects the additional acquisition and installation required for dual systems, and a lower proportion of the non-recurring costs since the initial costs can be distributed over a greater number of units. The recurring

logistics costs increase because the EAM assumes that the redundant, or stand-by, unit in each aircraft is in the "on" or "hot-standby" condition.

TABLE 6-4. COST OF OWNERSHIP, COMMERCIAL AVIATION
(Per Aircraft-Retrofit)
(Zero Percent Inflation Rate)

Cost \ System	Discrete Version (Dollars)	LSI Version (Dollars)
Acquisition*	17649	12947
Installation	6323	6323
Nonrecurring Logistic	493	390
Recurring Logistic (1st Year)	739	666
1st Year of Ownership	25204	20326
Life-Cycle Cost	32639	27035

* DABS Transponder (2) Antenna (1), IPC Indicator (2), Control (2).

Figures 6-12 through 6-14 identify the total annual cost and cummulative life-cycle cost of implementing a redundant configuration of two DABS/IPC versions in the air carrier community. The graphs reflect the impact of inflation, assumed to increase at zero, six, and ten percent per year for the entire eleven-year life cycle of the study.

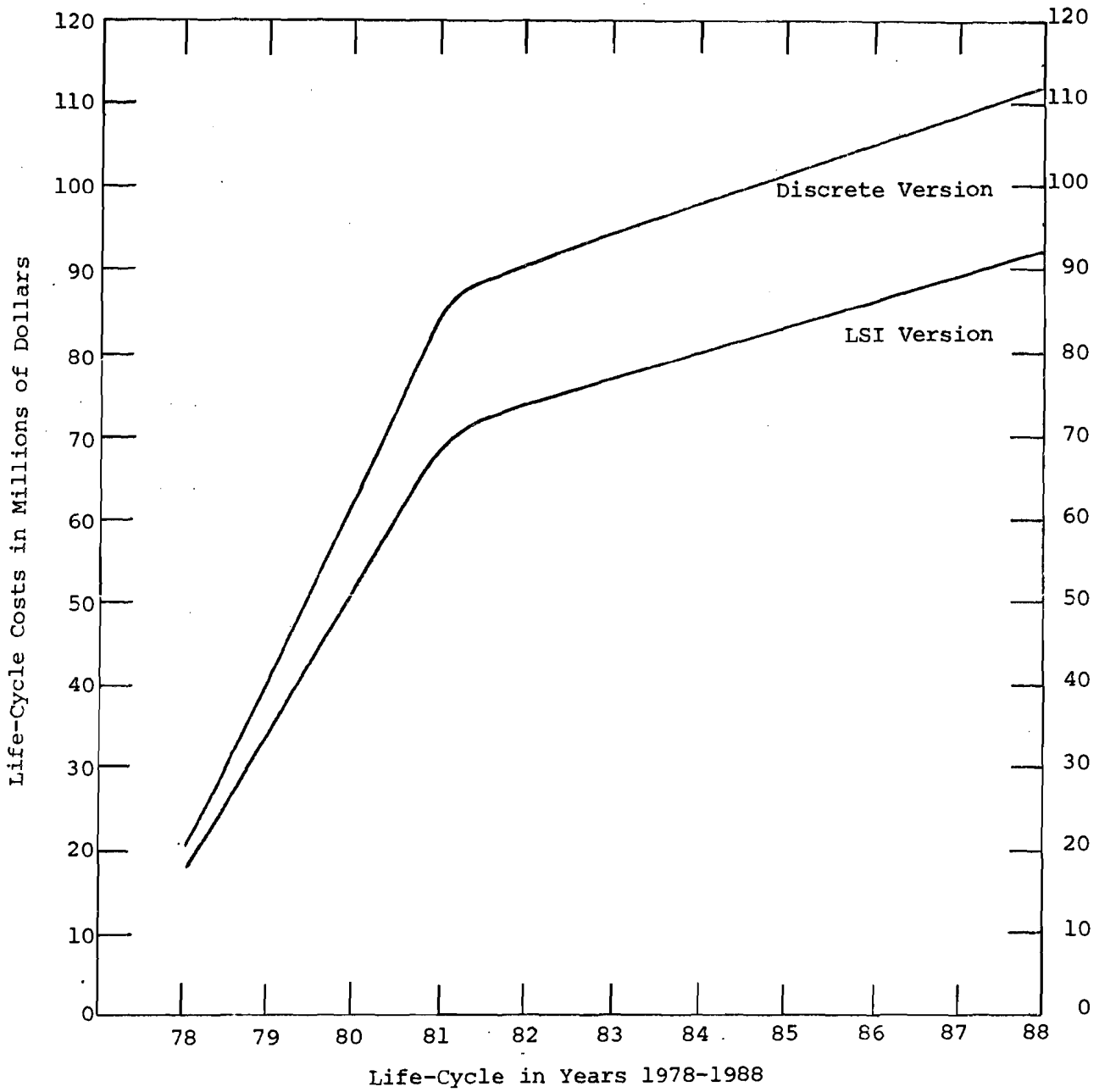

Figure 6-12. CUMULATIVE DUAL DABS/IPC COST (COMMERCIAL AVIATION) (ZERO PERCENT INFLATION RATE)

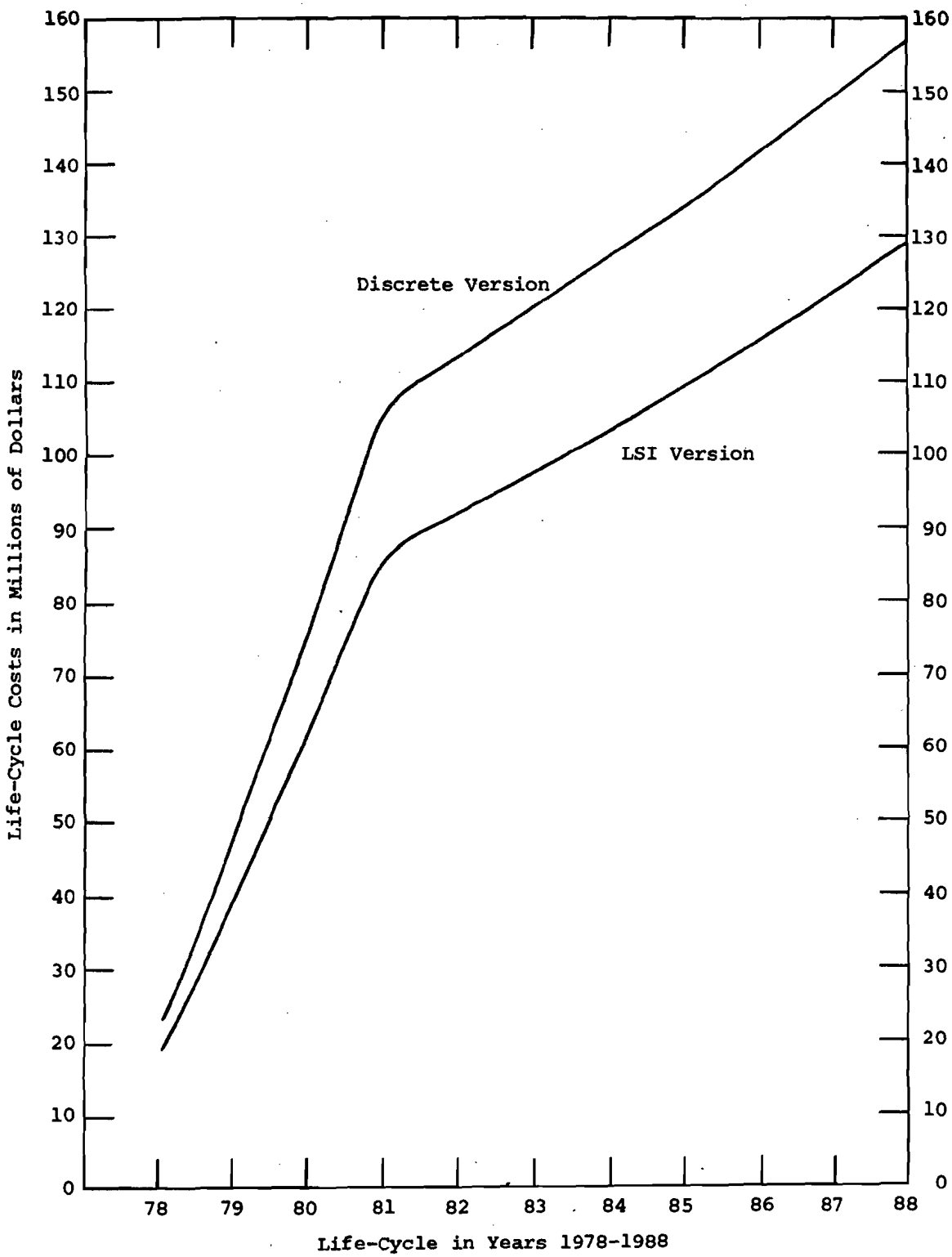

Figure 6-13. CUMULATIVE DUAL DABS/IPC COST (COMMERCIAL AVIATION)

(SIX PERCENT INFLATION RATE)

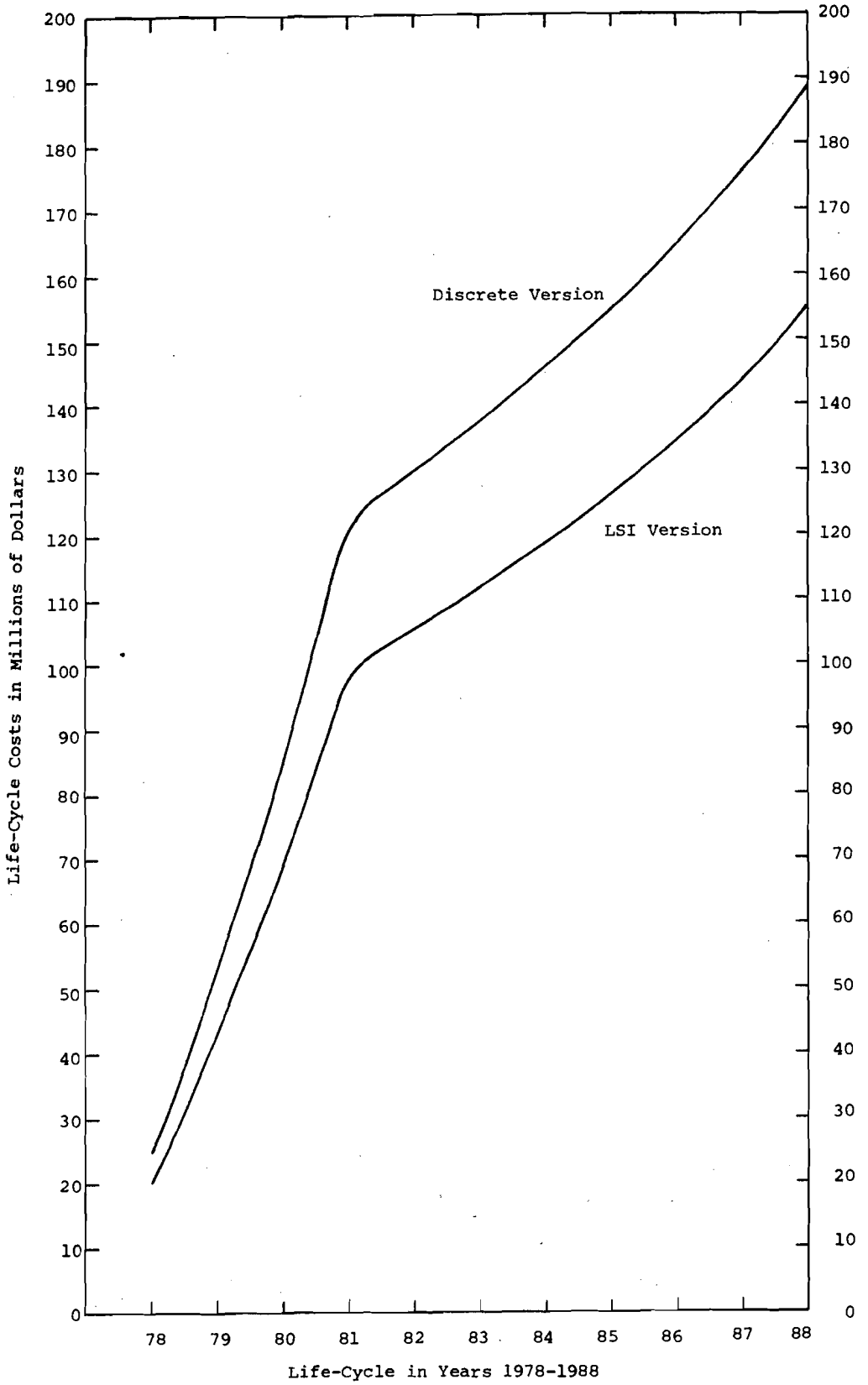

Figure 6-14. CUMULATIVE DUAL DABS/IPC COST (COMMERCIAL AVIATION) (TEN PERCENT INFLATION RATE)

CHAPTER SEVEN

THE COST OF ALTITUDE ENCODERS FOR THE GENERAL-AVIATION COMMUNITY

The preceeding chapters of this study were concerned with the development of system acquisition costs and implementation costs of the airborne portion of the DABS/IPC concept. In order to ascertain costs peculiar to the DABS/IPC system the study concentrated on equipment directly attributable to the concept. However, the satisfactory operation of DABS/IPC requires accurate altitude information, normally provided by encoding altimeters. All commercial air carriers and the majority of the military aircraft have this information available from the various encoding altimeters installed in the aircraft. The small portion of the military which does not presently have encoding altimeters has an active program for equipment installation which will provide the required information by the time DABS/IPC is implemented. The general-aviation community, however, has only a small percentage of its aircraft equipped with encoding altimeters. This chapter develops the costs associated with acquisition of equipment suitable for altitude encoding and presents the cost of ownership and life-cycle costs to the general-aviation community of the DABS/IPC concept when all required avionics are included.

7.1 ALTITUDE ENCODING

All aircraft are equipped with altitude indicating devices which operate from barometric pressure or electronic pulse information. This information is displayed to the pilot by a mechanical indicator and provides the required readout for a safe flight. In 1960 the FAA started a program which was to lead to the present automatic altitude reporting using the ATCRBS system. In order to provide this automatic reporting, the altitude information in each aircraft had to be converted into digital data for transmission by the ATCRBS transponders. This was accomplished by the addition of an altitude encoder device. An altitude-reporting transponder system is now required to operate in portions of the airspace, but since the general-aviation pilot has no requirement to enter these areas, he has not equipped his aircraft with an encoding altimeter. Recently the general-aviation manufacturers have developed inexpensive blind encoders which provide the existing pressure altimeter systems with the necessary digital code for use in automatic altitude-reporting transponders. The encoders are advertised at list prices under $600 and are available from several leading manufacturers.

This chapter evaluates the economic benefits of one of the available designs, the NARCO AR-500 Altitude Reporter, which would provide the "GREY" code required by DABS/IPC and other avionics, and which could be incorporated into the DABS electronics.

7.2 NARCO BLIND ENCODER

NARCO Avionics has developed an "Altitude Reporter", the NARCO AR-500, which converts the barometric pressure used by the aircraft altimeter to the "GREY" code required by transponders through the use of a sealed aneroid capsule which operates a transducer. The transducer information is converted into the correct altitude code electronically.

ARINC Research has reviewed the published data on the AR-500 and has evaluated the use of the pressure sensor and electronics in the DABS design under the assumption that the general-aviation manufacturers would attempt to develop a single-package DABS/IPC containing the necessary avionics. Price-competative blind encoders of other manufacturers would be similarly applicable to the DABS/IPC concept.

7.3 NARCO ENCODER COST DEVELOPMENT

The NARCO encoder uses standard, commercially available components. Table 7-1 identifies the components required to assemble the encoder module and the expected costs of components based on large quantity purchasing common to most avionics manufacturers. Again, it is assumed that the encoder module could be incorporated into the proposed DABS/IPC concept, thereby utilizing the available power supplies and timing systems inherent in each DABS transponder.

The manufacturing and assembly times required for each encoder module are shown in Appendix B. The total time required is estimated at 4.45 hours per encoder module, with an additional 1.0 hours for calibration and testing. The expected cost of the encoder module for the DABS concept is:

Material Cost	73.39
Labor: 5:45 hours @ $2.75/hour	14.99
Direct Cost	88.38
Manufacturer's Burden, Overhead and Profit @ 67%	59.21
Factory Selling Price	147.59
List Price	295.18

TABLE 7-1. NARCO ENCODER PARTS BREAKDOWN

PARTS	ENCODER MODULE	
	QTY	COST (Dollars)
SENSOR	1	35.00
IC	15	9.03
TRANSISTORS	13	4.09
DIODES	1	.37
RESISTORS	48	5.69
CAPACITORS	11	1.45
POTENTIOMETERS	5	4.75
PRINTED CIRCUITS	1	5.00
MISC. ELECTRICAL	3	1.56
MISC. HARDWARE	Lot	6.45
TOTALS		73.39

This list price reflects the cost of a module without a power supply, timing systems, and aircraft packaging (all of which are already available in the DABS electronics). Therefore the list price is considerably lower than the presently advertised AR-500 "Altitude Reporter".

7.4 APPLICATION OF ENCODERS TO THE DABS CONCEPT

The expected cost of encoder modules developed in this chapter shows that the most economical approach to providing altitude information to the DABS system is by incorporating the encoders into the DABS electronics. The addition of a blind encoder to the DABS concept should be possible without an increase in case size and with only a nominal increase in weight. Table 7-2 presents the expected selling price of both Type II versions of DABS/IPC with built-in altitude encoders, based on the costs developed in Chapters Three and Seven. The prices shown include the expected distribution costs as developed in Chapter Four.

TABLE 7-2. PER AIRCRAFT COST (IN DOLLARS) OF EQUIPMENT INCLUDING ALTITUDE ENCODERS (GENERAL AVIATION-LOW PERFORMANCE)

SYSTEM / COST*	TYPE II DABS/IPC WITH ALTITUDE ENCODERS	
	DISCRETE VERSION (DOLLARS)	LSI VERSION (DOLLARS)
ELECTRONICS (DABS)	1025	1222
INDICATOR (IPC)	809	**
ANTENNA	13	13
TOTAL	1847	1235

*Costs shown include mark-up for distribution.
**Included in Electronics

7.5 ENCODER RELIABILITY AND MAINTAINABILITY

The reliability of the encoder module was evaluated using similar techniques to those presented in Chapter Three. Failure rate data of common components were derived from FARADA and the curves and data tables of MIL-217A. The reliability of the aneroid capsule and transducer, the "sensor" used in the NARCO encoder, was assumed to be the same as for a solid-state sensor. These data were used with the FARADA data to establish the encoder module reliability and are documented in Appendix B to this study. The predicted reliability for the encoder module to be used in the DABS designs is estimated at 19461 hours.

Maintainability of the encoder module has been estimated at two hours per repair action. The estimate was based on the probability of failure of the sensor, the highest failure rate item in the module, and the test and calibration time required when the sensor is replaced.

7.6 COST OF OWNERSHIP AND LIFE-CYCLE COSTS

The cost, reliability, and maintainability data developed in this chapter were combined with the developed DABS/IPC cost and reliability data of Chapter Three and applied to the Economic Analysis Model to determine cost of ownership and life-cycle costs in the general-aviation community. The DABS/IPC implementation data developed in Chapter Four apply to the DABS/IPC units with altitude encoding. The DABS with built-in altitude encoding will require a static pressure line connection in lieu of an electrical connection to a separate encoding altimeter. It is assumed that the costs for these two types of installation are identical.

Table 7-3 presents the cost of ownership and the anticipated life-cycle costs for the general aviation limited performance aircraft for each DABS/IPC version with the required altitude encoding. The costs are shown in 1975 dollars, for equipment installed in 1978. The acquisition costs are those developed in Chapter Three with the addition of the altitude encoding as developed in this chapter and include the distribution costs developed in Chapter Four. The first year of ownership shows the expected cost for implementation and maintenance to the private aircraft owner, and the life-cycle cost identifies the expected cost of the system installed and operated for eleven years.

TABLE 7-3. COST OF OWNERSHIP, GENERAL AVIATION, INCLUDING ALTITUDE ENCODING (PER AIRCRAFT-RETROFIT) (ZERO PERCENT INFLATION RATE)

COST \ SYSTEM	DISCRETE VERSION (DOLLARS)	LSI VERSION (DOLLARS)
ACQUISITION	1834	1222
INSTALLATION	157	91
RECURRING LOGISTICS	11	11
1st YEAR OF OWNERSHIP	2002	1324
LIFE-CYCLE COST	2112	1434

*Costs shown include mark-up for distribution.

Figures 7-1 through 7-3 present the life-cycle costs to the entire general-aviation community for implementing the DABS/IPC concept with altitude encoding. Of the total general-aviation fleet, the high performance aircraft (5% percent) are assumed to have encoding altimeters. Of the low performance aircraft, ten percent are assumed to have encoding altimeters. The remaining 85 percent of the population will require the DABS equipment with built-in altitude encoders. The figures reflect this division of capability and present the life-cycle costs at the three annual inflation rates used in the study. The results show that the addition of altitude encoding capability to the DABS/IPC concept will increase GA life-cycle costs by 48 million dollars at a zero percent inflation rate.

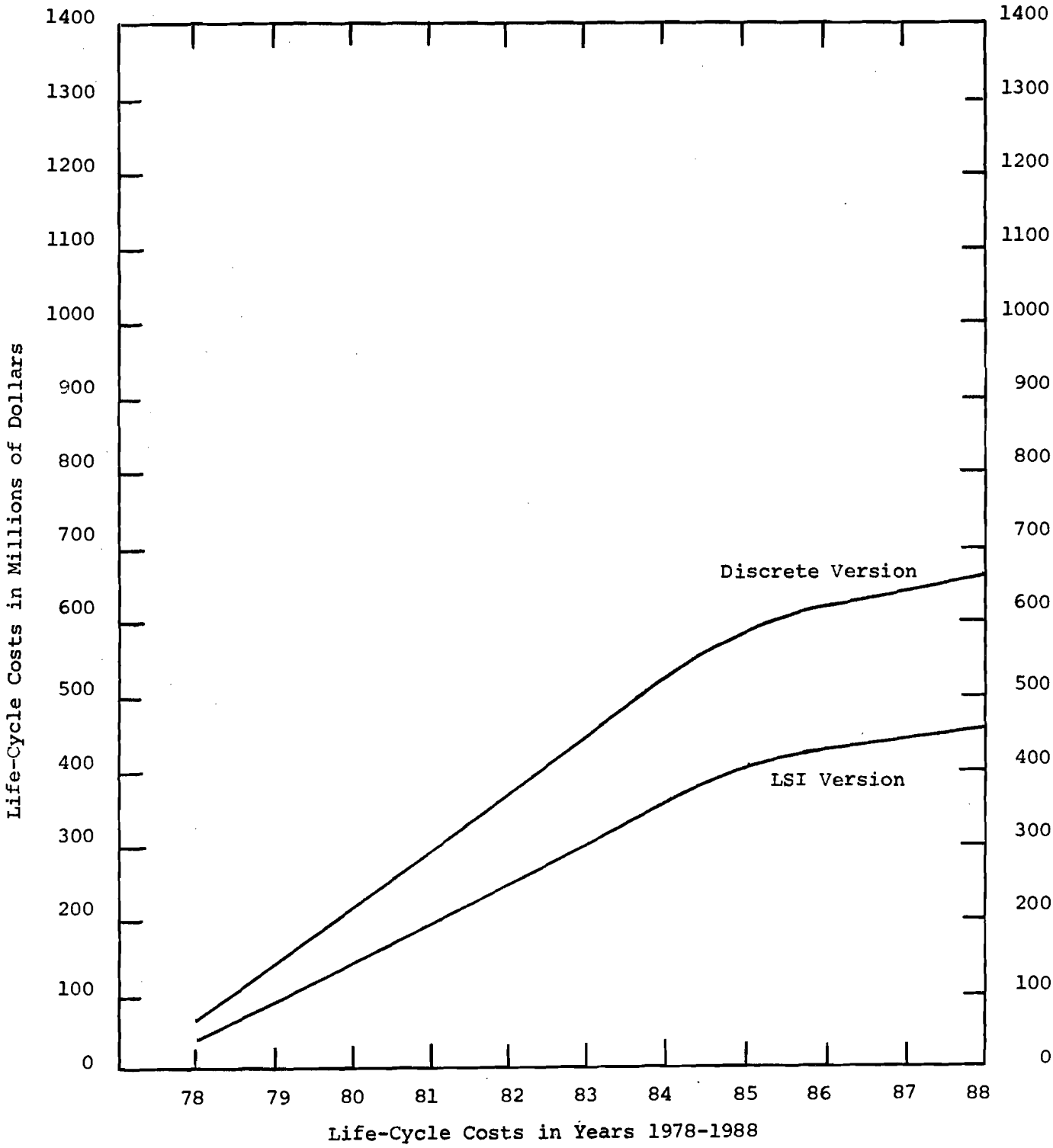

Figure 7-1. CUMULATIVE DABS/IPC COST INCLUDING ALTITUDE ENCODERS (GENERAL AVIATION) (ZERO PERCENT INFLATION RATE)

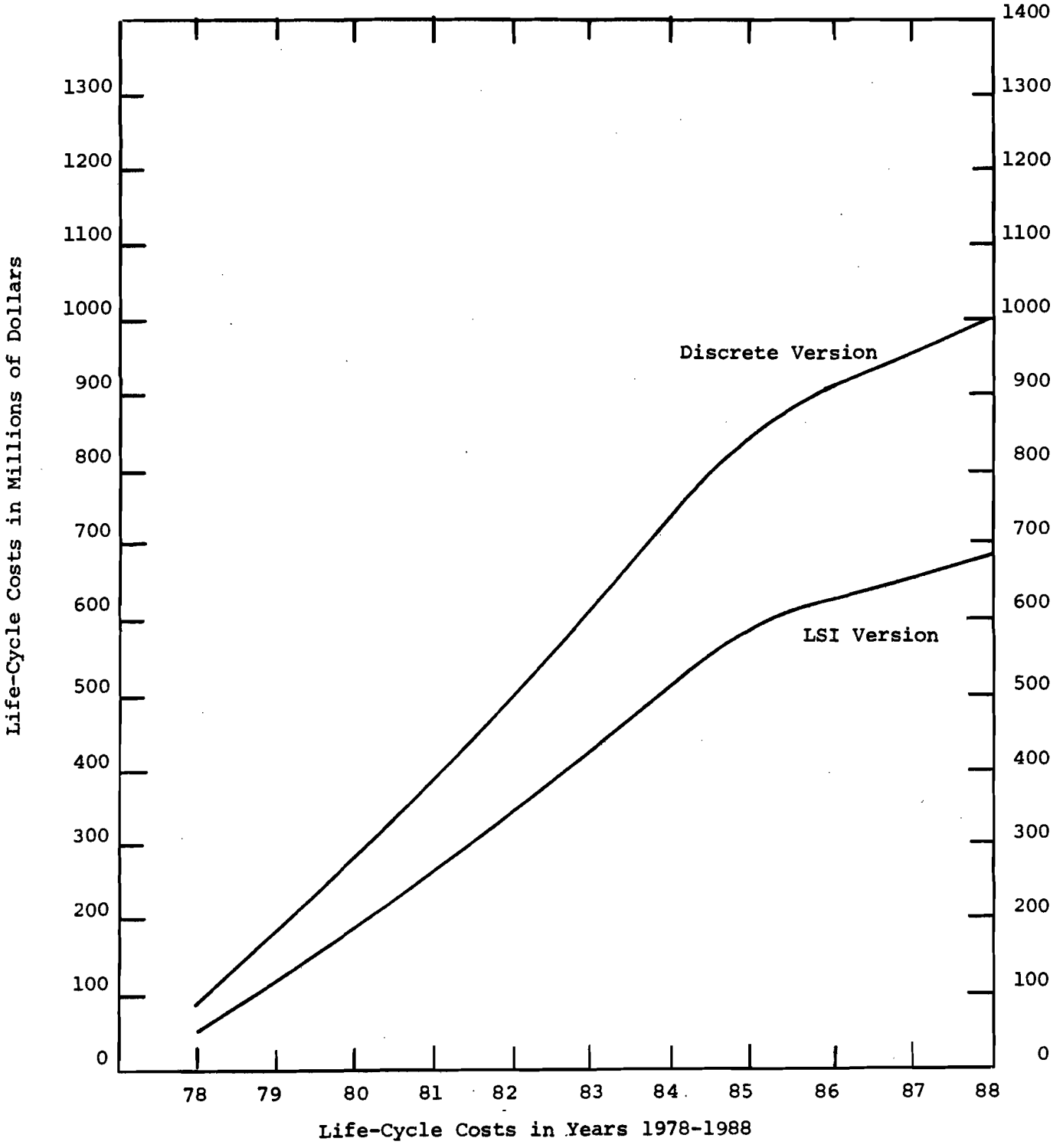

Figure 7-2. CUMULATIVE DABS/IPC COST INCLUDING ALTITUDE ENCODERS (GENERAL AVIATION) (SIX PERCENT INFLATION RATE)

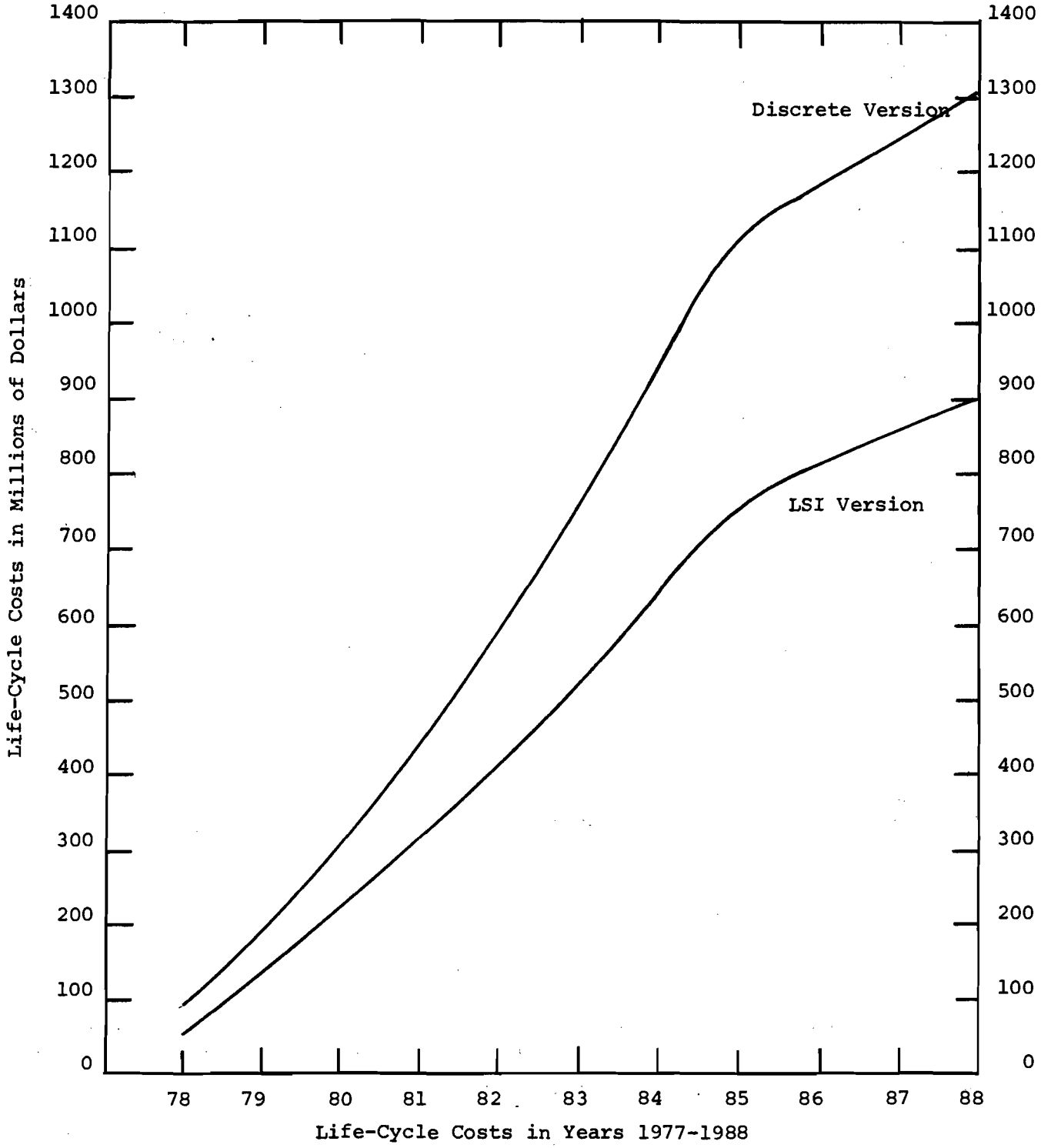

Figure 7-3. CUMULATIVE DABS/IPC COST INCLUDING ALTITUDE ENCODERS (GENERAL AVIATION) (TEN PERCENT INFLATION RATE)

CHAPTER EIGHT

RESULTS AND CONCLUSIONS OF THE DABS/IPC COST ANALYSIS

The development of the airborne equipment required for DABS/IPC implementation has resulted in three distinct models designed to meet the needs of each of the three user communities -- commercial aviation, general aviation, and the military. In addition, data were developed for both discrete and LSI versions of each model to evaluate the life-cycle costs associated with each version and establish the lowest costs to the users while maintaining the full capability inherent to the DABS concept.

8.1 REVIEW OF THE DABS/IPC COST ANALYSIS

The primary results of the DABS/IPC cost analyses are summarized in Table 8-1 on an individual-aircraft basis and for the entire user communities.

The individual aircraft costs are likely to be the most important costs to general aviation, while the total user community life-cycle costs will be most important to the commercial and military aviation interests concerned with the overall costs of implementing DABS. Life-cycle costs developed for each user category are also presented at an annual inflation rate of 6 and 10 percent to identify the probable and maximum anticipated expenditures in the introduction of DABS.

Key elements in the DABS cost analyses reported herein have been the cost and reliability data developed by ARINC Research based on the conceptual DABS design of Lincoln Laboratories, but adapted to the production configurations of equipment proposed for production start in 1978. The adaptation of existing, well proven components of the ATCRBS transponders to the DABS transponder design has reduced the normal start-up costs associated with new equipment development and has allowed the development of cost and reliability data based on known costs and established failure rates. The resultant data have a sufficient historical base to permit a high degree of confidence in the economic evaluations of the DABS concept.

TABLE 8-1. SUMMARY OF DABS/IPC COST ANALYSES

Cost Category	Commercial Aviation		Military Aviation		General Aviation[1,2]	
	Discrete Version ($)	LSI Version ($)	Discrete Version ($)	LSI Version ($)	Discrete Version ($)	LSI Version ($)
Cost of acquiring and installing DABS in a single aircraft (zero percent inflation)	15,181	11,797	12,251	8,866	1,755 (2,005)	1,077 (1,313)
Anticipated 11-year life-cycle cost for a single aircraft (zero percent inflation	20,051	15,989	13,884	10,270	1,865 (2,125)	1,176 (1,434)
Total life-cycle cost for the entire user community (zero percent inflation)	67.6M	53.5M	246.0M	185.2M	606.8M (655.4M)	403.5M (452.1M)
Total life-cycle cost for the entire user community (six percent inflation)	95.3M	75.3M	359.9M	270.6M	929.4M (996.2M)	619.2M (687.0M)
Total life-cycle cost for the entire user community (ten percent inflation)	114.2M	90.0M	440.4M	325.4M	1,216.4M (1,305.2M)	833.1M (899.8M)

NOTES: 1. The individual aircraft data presented apply to the low performance aircraft which is the major category of general aviation aircraft. The user community life-cycle costs include the combination of high and low performance aircraft.

2. The values in parenthesis represent the cost of DABS/IPC when altitude encoding is included in the General Aviation Community.

In addition to the cost and reliability data developed by ARINC Research, an independent analysis of the general-aviation equipment was performed by Bendix Aviation, a manufacturer of general-aviation products. The general agreement between Bendix and ARINC Research on the cost of the equipment and LSI partitioning of the DABS logic provides strong substantiation of the costs presented in Table 8-1.

8.2. DISCUSSION OF THE SENSITIVITY ANALYSES

Major variations in the reliability data were considered to determine if there were any conditions that would cause a significant change in the estimated life cycle costs. It was shown that the total aviation community costs are virtually unaffected by variations in the predicted system MTBF's. However, it was noted that the commercial aviation community costs are affected by MTBF variations while the military and general aviation community costs are relatively unaffected.

A further conclusion of the sensitivity analyses was that for any reasonable variation in the DABS reliability, including strict adherence to MIL-217B prediction techniques, there was no change in the relative advantage of the LSI version. Even when amortization costs, including LSI development cost for the LSI version, were added to the life-cycle costs, the LSI version still maintained a substantial advantage over the discrete logic version of DABS based on amortization of LSI development costs over a sufficiently large production quantity of equipment.

The addition of an ATC message display was treated as a special case since it is not mandatory for the successful operation of DABS/IPC. It was shown that the addition of the ATC message display could result in a 30 percent increase in costs to the commercial aviation community.

The addition of a second set of electronics at time of DABS/IPC implementation in the commercial-carrier community will increase the cumulative life-cycle costs in proportion to the acquisition cost of the second system. The increase in costs will be 64.8% percent for the discrete version and 71.6% percent for the LSI version of the system.

8.3. DISCUSSION OF THE ALTITUDE ENCODERS FOR GENERAL-AVIATION

The availability of altitude encoding equipment has been investigated and cost-effective alternatives developed. Although blind encoders are presently available at prices acceptable to the general-aviation community, a more cost effective solution would be to design the altitude encoding capability into the Type II DABS/IPC concept.

8.4 RELATION OF THE DABS COST ANALYSES TO THE IMPLEMENTATION OF A NATIONAL DABS SYSTEM

This study has been concerned with the economic evaluation of the airborne portion of the DABS concept; it has not addressed other key issues that will most likely affect the development and implementation of a national DABS system. For example, the operability of the system or human-engineering evaluation of the IPC display have not been considered or evaluated. A change in the data presentation of the IPC display, e.g., elimination of or large reduction in the PWI display, could have a major economic impact on the costs presented in this study.

In addition, the analyses and conclusions reported herein have been based on the assumption that all aircraft will be required to install and operate DABS equipment. However, if there is a significant change from this policy, wherein only a portion of the total aviation community will have to be DABS-equipped, or the time of implementation is extended well beyond the eight year retrofit period, then the costs of the DABS/IPC components will increase, being controlled by the production quantities required to meet the new demand for equipment.

Two additional assumptions made in this study are reiterated; (1) the cost of the DABS ground stations were not evaluated in this study and (2), the 1978 start of implementation is based on the earliest availability of avionics, and not the expected introduction of the DABS system into the operation of ATC.

LIST OF REFERENCES

1. DABS: A System Description, Report No. FAA-RD-74-189.

2. DOT Order 1010.51A US National Standard for the IFF Mark X (SIF) Air Traffic FFIC Control Radar Beacon System Characteristics.

3. Provisional Signal Formats for DABS, Report No. FAA-RD-74-62.

4. Type A DABS Transponder
   FAA-ER-240-27, 1 November 1974

5. Type B DABS Transponder
   FAA-ER-240-28, 1 November 1974

6. IPC/PWI Display
   FAA-ER-240-30a, 18 November 1975

7. Final Report DABS/ATCRBS Transponder Bench Testing Program, FAA-RD-73-160

8. Synchronized Discrete Address Beacon System, (Synchro-DABS), FAA-EM-73-1, January 1973.

APPENDIX A

UNIFORM GROUND RULES

REVISION 2

RECOMMENDED UNIFORM GROUND RULES

FOR
THE EVALUATION OF LIFE CYCLE COSTS AND SYSTEMS RELIABILITY OF DISCRETE ADDRESS BEACON SYSTEM/INTERMITTENT POSITIVE CONTROL

Prepared for
Federal Aviation Administration
Office of Systems Engineering Management
AEM-200
Under Contract DOT-FA74WA-3506

24 July 1974
Revised 9 August 1974
Revised 8 April 1975

Prepared By
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A Subsidiary of Aeronautical Radio Incorporated
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Annapolis, Maryland 21401

STUDY OF LIFE CYCLE COSTS OF AIRBORNE EQUIPMENT FOR DABS/IPC

A critical factor in the selection of an airborne Collision Avoidance System (CAS) is the costs of the systems, which must be borne by the government and the aviation community. The purpose of this study is to make that factor available by determining the potential costs of each of the CAS concepts.

The study will be conducted in two phases, each of approximately two months' duration. In the first phase, a set of ground rules acceptable to the concerned parties will be drawn up, the primary effort of data collection from the developers of the concepts will be accomplished. In the second phase data voids will be identified and filled, supplementary data will be obtained from additional sources and life cycle costs will be analyzed in detail.

In order to accomplish the study fairly, it will be necessary to have a set of ground rules for the conduct of the study. The ground rules are predicated on their being multiple manufacturers, producing compatible but not necessarily identical designs, using a common level of technology, and experiencing a level of reliability that is a function of the technology used and the design complexity imposed by the system concept. Certain other assumptions are made as shown by the attached list of ground rules.

GROUND RULES FOR THE DABS/IPC LIFE CYCLE COST STUDY

1.1 CLASSES OF EQUIPMENTS

The classes of equipments to be studied will be limited to the airborne avionics identified in FAA-ER-240-28, intended for commercial air carriers and other high performance aircraft, and a general aviation version intended for the lower performance aircraft. Consideration shall be given to the military AIMS program in identifying modifications to existing transponders or new replacement equipment which will permit military participation in the DABS/IPC operation.

1.2 TECHNOLOGY LEVELS OF THE PRODUCTION DESIGNS

Due tc the size of the market, should DABS/IPC be made a national standard, the production quantities will be large enough to make the use of LSI designs the most economical. Therefore, it is assumed that the production designs will make maximum use of LSI circuitry, with MSI circuits, ICs and discrete components used where they are most appropriate.

1.3 QUALITY LEVEL OF COMPONENTS

Present commercial practice in selection of avionics components will be used for both classes of DABS/IPC equipments. For military aircraft it is assumed that commercial equipments will be used, except for those military aircraft which provide a hostile environment for the equipment, i.e., an unpressurized avionics compartment. For the latter, specially designed equipment will be evaluated.

1.4 QUANTITIES PRODUCED PER MANUFACTURER

It is assumed that there will be multiple manufacturers of each class of equipment and that each manufacturer will produce sufficient quantities to complete the production learning curve (assumed to be 85 percent) and to amortize start up costs. It is assumed that each manufacturer of Commercial Aviation (CA) systems will produce at least 3,000 units and each manufacturer of the General Aviation (GA) systems will produce at least 10,000 units.

1.5 TIME SPAN UNDER CONSIDERATION

The time span considered under the study will be from 1978 as the start of deployment to 1988 as the end of the period for determination of life cycle costs. Full deployment for commercial air carriers is assumed to be approximately four years (1978-1981) and for military aircraft and general aviation aircraft, is assumed to be approximately eight years (1978-1985). These time spans for full deployment were selected as a basis for the study and are not intended as a representation of FAA intent or policy.

1.6 COMPUTATION OF EQUIPMENT COSTS TO THE USERS

Potential manufacturers of each class of equipment will be consulted in order to develop estimates of the equipment costs to the users. The estimated costs will include the effects of inflation and learning. The annual rate of inflation will be six percent. Learning curve factors and quantities will be averaged from the values used by the consulted manufacturers. Start up costs will be amortized over the first two years' production. The assumed production rates, quantities and number of manufacturers will be consistent with other assumptions stated elsewhere in the ground rules on target dates, rates of deployment and number of installations.

1.7 INSTALLATION COSTS

Aircraft will be categorized as air carrier, military and general aviation and installation costs will be developed for each category for the appropriate type DABS/IPC for that category of aircraft. Separate installation costs will be developed for production line installation in new aircraft and for retrofit installation in existing aircraft. Installation cost estimates will be validated by comparing them against installation costs of comparable equipments such as DME and transponders.

1.8 MAINTENANCE

It is assumed that air carriers and the military will apply present maintenance practices to the DABS/IPC equipment. The designs of the general aviation equipments will be examined for maintenance requirements to determine the distribution of service facilities that will be likely to add DABS/IPC equipment maintenance to their present capabilities. The expansion of the availability of general aviation service facilities will be commensurate with the cumulative installations of the DABS/IPC equipments.

1.9 OPERATING SCENARIOS

Descriptions will be developed of typical operations of the various classes of aircraft to obtain estimates of peak and average monthly operating hours and of other factors required for life cycle cost estimating.

1.10 EQUIPMENT DESCRIPTION

The airborne equipment that will be the subject of this study consists of the following main components; (1) the principal electronics, i.e., transmitter, receiver, BIT and logic circuitry, (2) pilot's maneuver indicator, (3) control panel and (4) antenna(s), antenna cabling and antenna switch. Any other displays such as for range and altitude of an intruder are considered to be optional. They will be costed separately unless the system designers consider them to be an essential part of the system.

1.11 NUMBERS OF AIRCRAFT

The numbers of aircraft installations involved will be based on FAA information on the number of existing aircraft and projections of increases. A straight line installation rate is assumed for retrofit of aircraft existing in the start year of 1978. Subsequent to the start date, all new aircraft are assumed to have DABS/IPC equipment installed during manufacture.

LIFE CYCLE COST MODEL

2.1 COST MODEL DESCRIPTION

A common cost model which is applicable to all three categories of aircraft being considered within the study, i.e., military, commercial, and general aviation, is planned for the study. Individual cost elements which may differ among the categories will be handled through specification of the input parameter values. For example, the times required to fill out forms for the maintenance management systems of the military represent a cost-producing element which one would not expect to incur in the GA category. Hence, in the GA evaluation, these and other similar input paramters would be zeroed out.

The cost model will compute for the DABS.IPC concept in each category on an annual and cumulative basis beginning with the year 1978 and extending through at least 1988, the following major cost elements: acquisition cost, installation cost, and logistic support cost. These costs will be displayed on a total category fleet basis and on a per aircraft basis. In addition, the logistic support costs will be broken down into eight constituent elements and displayed in terms of their non-recurring, annual recurring and total values. These cost elements are:

- Initial and replacement spares
- On-aircraft maintenance
- Off-aircraft maintenance
- Inventory and supply management
- Test equipment
- Training
- Data management and technical documentation
- Facilities

2.2 COST MODEL INPUTS

Evaluation of the cost model will require specification of numerous data items. Where such data elements are unknown or estimated with uncertainty, the model will be evaluated over the range of possible values of the element in order to ascertain the sensitivity of the projected cost to its value and to identify the expected range of results. For example, in computing the cost of spares, a key element is the expected pipeline delay.

If this quantity is unknown for a given category, but is expected to be somewhere between two weeks to two months, then the model would be evaluated over this range. The following discusses some of the principal inputs and assumptions considered within the model.

2.2.1 It is assumed that the number of aircraft in each category is known for each year in the interval 1978 - 1988. The retrofit schedule will be approximately with a straight line between the retrofit initiation and completion dates.

2.2.2 The unit acquisition costs will include on a parameterized basis, the effects of learning and inflation. Similarly, the installation and logistic support costs (where applicable) will include the effects of inflation.

2.2.3 Weighted cost estimates will be used for the initial and retrofit installation costs in each category of aircraft.

2.2.4 On-aircraft maintenance is assumed to be limited to remove and replace actions.

2.2.5 Off-aircraft maintenance costs will include labor, material and shipping costs, with the latter corresponding to the expected percentage of the removals where repair cannot be completed at a base location.

2.2.6 For costing purposes, all maintenance actions are treated as failures with the MTBFs being adjusted to MTBRs as discussed in the definitions (paragraph 3.2) and the material costs similarly adjusted to allow for the expected percentage of repair actions having "no trouble found" results.

2.2.7 Test equipment and training costs will be attributed only to those factors directly attributable to the DABS/IPC system, i.e., general support equipment costs will not be factored into the cost element.

2.2.8 The number of repair sites for the military systems is assumed constant over the time interval. However, the number of CA and GA repair sites is assumed to increase with time according to a model input specified distribution to be developed.

2.3 DATA SOURCES

As noted earlier, there are a large number of cost and performance data element inputs to the cost model. Many of these, as also previously discussed, can only be bounded at this time, and their sensitivity determined accordingly. As many as possible of the elements will be initially established through discussions with the three producers and through contact with a limited number of users in each category. These data elements will be refined as applicable as the study progresses. For example, initial estimates of the MTBF and MTTR of the systems will be determined. Then, as better and more complete design information becomes available, so that R and M predictions can be made, these estimates will be updated. Similarly, cost estimates will be updated as additional potential producers and users are contacted and initial sensitivity exercises are completed.

DEFINITION OF TERMS

Mean Time Between Failure (MTBF) is the expected operating time between verified failures of the equipment.

Mean Time Between Removals (MTBR) is the expected operating time between suspected failures of the equipment. It is assumed that MTBR = k MTBF, where k is a factor less than one which is to be established for each category of users during the study.

Mean Time To Repair (MTTR) is the expected time required to verify a failure, isolate its cause and perform the necessary repair actions.

Mean Maintenance Man Hours (MMMH) is the expected man hours required to complete a maintenance action. For purposes of the cost model, it is assumed that MMMH = MTTR, i.e., a single maintenance man will be performing the repair action. It is also assumed for the purposes of the cost model that the MMMH will be the same for a verified failure as for a "no trouble found" situation. This latter assumption may require reducing the predicted MTTR in accordance with the expected percentage of "no trouble found" occurrences.

Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions.*

Mean Down Time (MDT) is the expected time during which the item is not in condition to perform its intended function. This time includes expected administrative and logistic delays as well as active repair times.

Maintainability is a characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.*

* MIL-STD-721-B

Availability is a measure of the degree to which an item is in the operable and commitable state at the start of the mission, when the mission is called for at an unknown (random) point in time.*

Intrinsic Availability is defined as the ratio of the MTBF to the sum of the MTBF and MTTR.

Operability is defined to be the capability of the participating systems to continue proper operation in the event of failure or improper operation of any of the airborne or ground units.

Critical Failures are defined to be failures that adversely affect the operability of the overall system. A failure that merely removes the failed system from participation is a non-critical failure. A failure in one airborne or ground unit that causes improper operation of one or more other units in the overall system is a critical failure.

Learning Curve is defined, for purposes of this study, by the following expression:

$$LC = A(R + P/2)^b$$

A = Price of first production unit

R = Cumulative number of units produced in past

P = Production lot size under consideration

b = Ln q/Ln 2, slope of the learning curve

q = Constant percentage of decrease = .85

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* MIL-STD-721-B

SUMMARY TABLE OF DABS/IPC STUDY GROUNDRULE ASSUMPTIONS

Item	Paragraph	Assumptions
1	1.1	There will be two classes of DABS/IPC (commercial air carrier and general aviation). A third class, (for the military) will be evaluated if requried.
2	1.2	Maximum use of LSI technology will be made in the designs
3	1.3	Commercial quality components will be used
4	1.4	Learning and inflation factors will be applied to the costs. Learning curve at 85% and inflation at an annual rate of 6 percent.
5	1.4	Manufacturers of CA systems will produce at least 3000 units
6	1.4	Manufacturers of GA systems will produce at least 10,000 units
7	1.5	The deployment of units will begin in 1978 with full deployment of commercial users reached in four years and military and general aviation users in eight years. Retrofit for all users will be linear
8	1.6	Start up costs will be amortized over the first two years production
9	1.8	Existing military and commercial maintenance philosophy and procedures will be followed
10	1.10	Equipment consists of the principal electronics, pilot's indication control panel, antenna, antenna cabling and antenna switch
11	1.11	Aircraft numbers in each user category will be based on FAA estimates for the time period of interest
12	2.1	A common cost model will be used for all three user categories
13	2.1	The cost model will compute annual and cumulative values in each major cost element for each user category
14	2.1	Elements of the logistic support costs will also be divided into non-recurring and recurring costs

15	2.2.1	A linear retrofit schedule is assumed
16	2.2.4	On-aircraft maintenance is limited to remove and replace actions
17	2.2.6	All maintenance actions are treated, for costing purposes, as failures with the MTBFs being adjusted to MTBRs (MTBR) = k (MTBF), k 1
18	2.2.7	Only training and test equipment peculiar to CAS will be costed
19	2.2.8	The number of repair sites for the military users is assumed constant with time, whereas the number of commercial and general aviation sites is assumed to be time dependent
20	3.4	A single maintenance man will be used per repair action (MMHR = MTTR)

APPENDIX B

DEVELOPMENT OF COST AND RELIABILITY DATA FOR TRANSPONDERS AND DISPLAYS

SYSTEM DABS - Type I CASE I SHEET 1 OF 14

SUB-ASSEMBLY Transmitter

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Osc.	1	111.19	111.19		25	250.	250.	7250.*
Thermistor	2	.15	.30		10	1.35	2.7	.405
2N3723	1	7.10	7.10		6	1.266	1.266	8.989
2N4897	1	6.75	6.75		6	1.266	1.266	8.546
1N3070	3	.47	1.41		15	.155	.465	.219
IF Transformer	1	.65	.65		25	.475	.475	.309
Coils	2	.15	.30		10	.069	.138	.021
Resistor FC	11	.03	.33		55	.013	.143	.004
CAP - Tant.	5	.18	.90		25	.629	3.145	.566
CAP - Disc	2	.05	.10		10	.291	.582	.029
F. T. Term.	16	.01	.16		64			
PC Board	1	5.00	5.00		10			
H. V. Module	1	44.28	44.28		250	20.	20.	885.6
Circulator	1	87.23	87.23		150	5.	5.	436.15
Board Process				485				
Cut and Swage				160				
TOTALS			265.70	645 X 2	661 X 2		285.18	$\frac{8590.8}{285.18} = 30.12$

* Based on Tube Cost of $29.00

SYSTEM DABS - Type I CASE I SHEET 2 OF 14

SUB-ASSEMBLY Receiver

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Preselector	1	12.50	12.50		50	1.18	1.18	14.75
Diplexer	1	110.43	110.43		100	5.00	5.00	552.15
Mixer	1	60.15	60.15		5	5.00	5.00	300.75
2N918	2	.46	.92		12	1.266	2.532	.582
2N3866	2	1.50	3.00		12	3.749	7.498	11.247
2N2369	1	.38	.38		6	1.266	1.266	.481
FD 1766	2	1.00	2.00		10	.155	.31	.31
Crystal	2	2.00	4.00		12	.266	.452	.904
Potentometer	2	3.00	6.00		30	.664	1.328	3.984
Coil, Adj.	2	.70	1.40		20	.475	.95	.666
Coil	9	.05	.45		54	.069	.621	.031
Thermistor	4	.39	1.56		20	1.35	5.4	2.106
Caps - Variable	4	1.10	4.40		60	1.58	6.32	6.952
Caps - Disc	32	.05	1.60		160	.291	9.312	.466
Resistor - FC	13	.03	.39		65	.013	.169	.005
Resistor - Film	15	.15	2.25		75	.046	.69	.104
FT Terminals	Lot	.50	.50		100			
PC Board	2	3.00	6.00		30			
Chassis w/conn	1	12.00	12.00	388	154			
Board Process				970				
Cut & Swage				333				
TOTALS			229.93	1691 X 1.8	975 X 2		50.512	$\frac{896.069}{50.512} = 17.74$

SYSTEM DABS - Type I CASE I SHEET 3 OF 14

SUB-ASSEMBLY IF Amplifier

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
S16835	6	.47	2.82		36	1.266	7.596	3.570
2N2907A	1	.40	.40		6	2.124	2.124	.85
2N2222	2	.40	.80		12	1.266	2.532	1.013
FH 1100	3	.33	.99		18	.155	.465	.153
HP 2800	1	.50	.50		6	.155	.155	.078
1N 755A	1	.41	.41		5	.4	.4	.164
1N 4454	1	.13	.13		5	.155	.155	.020
M760	1	4.00	4.00		8	.715	.715	2.860
Saw Filter	1	4.24	4.24		8	1.18	1.18	5.003
Potentiometer	4	3.00	12.00		60	.664	2.656	7.968
CAP - Adj.	6	1.10	6.60		90	1.58	9.48	10.428
CAP - Tant	19	.18	3.42		95	.629	11.951	2.151
DAP - Disc	44	.05	2.20		220	.291	12.804	.640
Thermistor	3	.39	1.17		15	1.35	4.05	1.580
Coil	26	.05	1.30		130	.069	1.794	.090
Resistor - FC	44	.03	1.32		220	.013	.572	.017
Resistor - Film	7	.15	1.05		35	.046	.322	.048
Conn - UG146	1	2.60	2.60		80			
PC Board	1	10.00	10.00		50			
Board Process				485				
C & S				333				
TOTALS			55.95	818	1099 X 1		58.951	$\frac{36.633}{58.951} = .62$

SYSTEM DABS - Type I CASE I SHEET 4 OF 14

SUB-ASSEMBLY Video Processor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MA 710	1	4.00	4.00		8	.715	.715	2.86
SG 41	2	2.05	4.10		16	.06	.12	.246
SG 81	2	3.20	6.40		16	.715	1.43	4.576
SG 141	5	2.25	11.25		40	.12	.60	1.350
SG 191	1	2.05	2.05		8	.09	.09	.185
SF 101	1	2.05	2.05		8	.715	.715	1.466
2N2222	1	.40	.40		6	1.266	1.266	.506
2N2905	1	6.00	6.00		6	2.124	2.124	12.744
2N2369	5	.40	2.00		30	1.266	6.33	2.532
2N2907A	5	.40	2.00		30	2.124	10.62	4.248
2N956	6	.74	4.44		36	1.266	2.596	5.621
2N3823	1	.78	.78		6	11.904	11.904	9.285
1N3070	2	.47	.94		10	.155	.31	.146
1N5711	6	.35	2.10		30	.155	.93	.326
1N457A	11	.35	3.85		55	.155	1.705	.597
HPA2800	4	.50	2.00		20	.155	.62	.31
1N4454	1	.13	.13		5	.155	.155	.02
Potentiometer	6	3.00	18.00		90	.664	3.985	11.952
Thermistor	3	.39	1.17		15	1.35	4.05	1.58
CAP - T/E	19	.18	3.42		95	.55	10.45	1.881
CAP - Disc	13	.05	.65		65	.291	3.783	.189
Resistor - Film	33	.15	4.95		165	.046	1.518	.228
TOTALS								

SYSTEM DABS - Type I CASE I SHEET 5 OF 14

SUB-ASSEMBLY Video Processor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Resistor - FC	34	.03	1.02		170	.013	.442	.013
Misc. Hardware	Lot	5.00	5.00		100			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			93.70	818 X 2	1050 X 2		71.457	$\frac{62.860}{71.457} = .88$

SYSTEM DABS - Type I CASE I SHEET 6 OF 14

SUB-ASSEMBLY Control Matrix

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD 8050	23	.50	11.50		184	2.532	58.236	29.118
2N956	2	.41	.82		12	1.266	2.532	1.038
2N2907A	4	.40	1.60		24	2.124	8.496	3.398
1N4454	136	.13	17.68		680	.155	21.08	2.740
1N758A	43	.41	17.63		215	.4	17.2	7.052
1N457A	2	.35	.70		10	.155	.31	.109
1N754A	1	.41	.41		5	.4	.4	.164
1N4002	2	.12	.24		10	.155	.31	.037
54L30T	2	2.05	4.10		16	.03	.06	.123
Cap - T/E	7	.18	.126		35	.55	3.85	.693
Resistor - FC	116	.03	3.48		580	.013	1.508	.045
Resistor - Film	6	.15	.90		30	.046	.276	.041
BHGD21-65176	2	2.50	5.00		30			
MS24515-682	1	1.80	1.80		50			
PB Switch	2	.45	.90		50			
PC Board	1	5.00	5.00		20			
Board Process				485				
C & S				333				
TOTALS			73.02	818 X 2	1951 X 2		114.258	$\frac{44.558}{114.258} = .39$

SYSTEM DABS - Type I CASE I SHEET 7 OF 14

SUB-ASSEMBLY Monitor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54L00	4	2.05	8.20		32	.12	.48	.984
54L10	4	2.05	8.20		32	.09	.36	.738
54L20	3	2.05	6.15		24	.06	.18	.405
54L30	1	2.05	2.05		8	.03	.03	.062
54L72	1	3.15	3.15		8	.715	.715	2.252
54L73	3	5.20	15.60		24	.715	2.145	11.154
SG141	2	2.25	4.50		16	.12	.24	.540
SG81	1	3.20	3.20		8	.715	.715	2.288
SG191	1	2.05	2.05		8	.09	.09	.185
SD8050	2	.50	1.00		16	2.532	5.064	2.532
MA710	2	4.00	8.00		16	.715	1.43	5.72
2N2907A	3	.40	1.20		18	2.124	6.372	2.549
2N2646	3	.67	2.01		18	1.266	3.798	2.545
2N887	2	.50	1.00		12	1.58	3.16	1.580
2N2369	1	.38	.38		6	1.266	1.266	.481
2N956	1	.41	.41		6	1.266	1.266	.519
1N746A	1	.49	.49		5	.4	.4	.196
1N4002	1	.12	.12		5	.155	1.705	.019
1N4454	11	.13	1.43		55	.155	1.705	.222
Potentiometer	2	3.00	6.00		30	.664	1.328	3.984
Coil	1	.05	.05		5	.069	.069	.003
Cap - T/E	9	.18	1.62		45	.55	4.95	.891
TOTALS								

SYSTEM DABS - Type I

SHEET 8 OF 14

SUB-ASSEMBLY Monitor

Case I

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cap - Disc	6	.05	.30		30	.291	1.746	.087
Resistor - Film	16	.15	2.40		80	.046	.736	.110
Resistor - FC	25	.03	.75		125	.013	.325	.010
Connector	1	1.50	1.50		25			
PC Board	1	5.00	5.00	818	20			
TOTALS			86.76	818x2	2102x2		38.725	$\frac{40.055}{38.725} = 1.03$

SYSTEM DABS - Type I

SHEET 9 OF 14

SUB-ASSEMBLY Power Supply

Case I

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N2905A	2	.61	1.22		12	2.498	4.996	3.048
2N3054	1	.82	.82		6	3.749	3.749	3.074
2N1613	4	.60	2.40		24	1.266	5.064	3.038
2N3740	2	1.20	2.40		12	2.498	4.996	5.995
2N3055	1	1.05	1.05		6	3.749	3.749	3.939
1N4002	9	.12	1.08		45	.155	1.395	.167
1N4740	1	.38	.38		5	.4	.4	.152
1N4736A	2	.41	.82		10	.4	.8	.328
1N4734A	2	.41	.82		10	.4	.8	.328
1N4719	2	.35	.70		10	.358	.716	.251
1N754	2	.60	1.20		10	.4	.8	.480
1N4562B	1	5.65	5.65		5	.4	.4	2.260
1N4735A	1	1.40	1.40		5	.4	.4	.560
1N4005	1	.42	.42		5	.361	.361	.152
1N4454	1	.13	.13		5	.155	.155	.020
Transformer	1	11.00	11.00		615	1.5	1.5	16.50
3jX37B	2	.75	.75		50	.651	1.302	.977
Potentiometer	3	3.00	9.00		45	.664	1.992	5.976
Cap - T/E	15	.18	2.70		75	.55	8.25	1.485
Cap - Disc	2	.05	.10		10	.291	.582	.029
Resistor - Film	14	.15	2.10		70	.046	.644	.097
Resistor - FC	12	.03	.36		60	.013	.156	.005
TOTALS								

SYSTEM DABS - Type I

SUB-ASSEMBLY Power Supply

Case I

SHEET 10 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Fuse	2	.37	.74		20			
PC Board	1	5.00	5.00		10			
Misc. Hardware	Lot	2.00	2.00		100			
Board Process				485				
C & S				333				
TOTALS				818	1225x1		43.207	$\frac{48.857}{43.207} = 1.13$

SYSTEM DABS - Type I CASE I SHEET 11 OF 14

SUB-ASSEMBLY Digital Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
NE 555	3	.50	1.50		24	.715	2.145	1.073
20 mHZ Osc.	1	4.00	4.00		8	.715	.715	2.86
9615	1	19.20	19.20		8	.715	.715	13.728
9614	1	15.20	15.20		8	.715	.715	10.868
5400	12	2.05	24.60		96	.12	1.44	2.952
5402	5	2.25	11.25		40	.12	.6	1.35
5404	10	2.55	25.50		80	.035	.35	.893
5408	4	2.65	10.60		32	.12	.48	1.272
5410	3	2.05	6.15		24	.09	.27	.554
5411	3	2.65	7.95		24	.09	.27	.716
5420	1	2.05	2.05		8	.24	.24	.492
5425	1	2.95	2.95		8	.24	.24	.708
5430	1	2.05	2.05		8	.24	.24	.492
5432	3	2.90	8.70		24	.12	.36	1.044
5427	4	2.95	11.80		32	.09	.36	1.062
5437	1	3.15	3.15		8	.715	.715	2.252
5442	1	12.10	12.10		8	.715	.715	8.652
5450	10	2.05	20.50		80	.715	7.15	14.658
5453	1	2.05	2.05		8	.715	.715	1.466
5474	3	4.20	12.60		24	.07	.21	.882
5486	1	2.75	2.75		8	.12	.12	.330
5495	2	7.70	15.40		16	.715	1.43	11.011
TOTALS								

SYSTEM DABS - Type I CASE I SHEET 12 OF 14

SUB-ASSEMBLY Digital Logic (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54107	13	5.20	67.60		104	.715	9.295	48.334
54111	2	3.60	7.20		16	.715	1.43	5.148
54123	1	6.46	6.46		8	.715	.715	4.619
54161	9	9.61	86.49		72	.715	6.435	61.840
54164	17	10.10	171.70		136	.715	12.155	122.766
54165	11	10.10	111.10		88	.715	7.865	79.437
54180	2	20.00	40.00		16	.715	1.43	28.6
PC Board	2	10.00	20.00		46			
Board Process				970				
Cut & Swage				666				
TOTALS			735.60	1636 X 2	1062 X 2		59.52	$\frac{429.195}{59.52} = 7.21$

SYSTEM DABS - Type I

SHEET 13 OF 14

SUB-ASSEMBLY Chassis

Case I

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cable Assy	1				1000.			
Conn, Plug	2	2.50	5.00		50.	1.342	2.684	6.710
Chassis Assy	1							
Front Panel	1							
RF Cables	Lot	13.00	13.00	1365	684.			
RF Conn.	5	(1.25)				1.128	5.64	7.050
Misc. Hardware	Lot							
Conn. ARINC	2	40.00	80.00		1000.	1.342	2.684	107.360
PC Conn.					500			
Wiring	Lot					6.3	6.3	
TOTALS			98.00	1365.	3234.		17.308	$\frac{121.120}{17.308} = 7.00$

SYSTEM DABS - Type I

SHEET 14 OF 14

SUB-ASSEMBLY Final Assembly

Case I

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transmitter	1				60			
Receiver	2				50			
IF Amplifier	2				50			
Video Proc.	1				50			
Control Matrix	1				50			
Monitor					75			
Power Supply	1				190			
Digital Logic	1				100			
Chassis	1				150			
Func. Test					2000			
Burn-In					1000			
TOTALS					3775			

SYSTEM DABS - Type I

SUB-ASSEMBLY Transmitter

CASE II

SHEET 1 OF 15

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Osc.	1	111.19	111.19		25	250.	250.	7250.*
High Voltage		44.28	44.28		250		(11.321)	501.
Transformer	1					8.998	8.998	
5000V Diode	2					.361	.722	
Cap. Tant.	2					.629	1.2581	
Cap. Disc	1					.291	.291	
Resistor	4					.013	.052	
TOTALS			155.47		275 X 2		261.321	$\frac{7751}{261.32} = 29.66$

* Cost of tube $29.00

SYSTEM DABS - Type I CASE II SHEET 2 OF 15

SUB-ASSEMBLY Modular (Including Control)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
IC 9601	1	6.75	6.75		8	.715	.715	4.826
IC 5400	1	2.05	2.05		8	.12	.12	.246
IC 74L30	2	.72	1.44		16	.03	.06	.043
IC CA3045	6	4.00	24.00		48	.715	4.29	17.16
IC 5493	1	10.35	10.35		8	.715	.715	7.4
2N708	4	.28	1.12		24	1.266	5.064	1.418
2N2368	2	.30	.60		12	1.266	2.532	.76
2N2608	1	1.70	1.70		6	11.904	11.904	20.237
2N2897	1	.55	.55		6	1.266	1.266	.696
2N3250	1	.44	.44		6	2.124	2.124	.935
2N3440	1	.90	.90		6	1.266	1.266	1.139
2N3584	1	1.71	1.71		6	1.266	1.266	2.165
1N661	2	.46	.92		10	.155	.31	.143
1N645	28	.80	22.40		140	.155	4.34	3.472
1N753A	2	.41	.82		10	.4	.8	.328
1N758	13	.37	4.81		65	.4	5.2	1.924
1N914	5	.12	.60		25	.155	.775	.093
1N978B	1	.85	.85		5	.4	.4	.34
IF Transformer	1	.65	.65		25	.475	.475	.309
Potentiometer	1	.95	.95		15	.664	.664	.631
Coil - Adj.	1	2.31	2.31		25	.475	.475	1.097
Coil	1	.05	.05		5	.069	.069	.003
TOTALS								

SYSTEM DABS - Type I

SHEET 3 OF 15

SUB-ASSEMBLY Modulator (Cont'd)

Case II

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Capacitor - Tant	3	.18	.54		15	.55	1.65	.297
Capacitor - Disc	21	.05	1.05		105	.291	6.111	.306
Crystal	1	2.00	2.00		6	.226	.226	.452
Resistor	100	.03	3.00		500	.013	1.3	.039
PC Board	1	5.00	5.00		25			
Board Process				485				
Cut & Swage				160				
TOTALS			97.56	645X2	1130X2		54.117	$\frac{66.459}{54.117} = 1.23$

SYSTEM DABS - Type 1 CASE II SHEET 4 OF 15

SUB-ASSEMBLY RF Front End

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
BP Filter	1	14.	14.		50	1.18	1.18	16.52
Circulator	1	87.40	87.40		150	5.00	5.00	437.
LP Filter	1	6.	6.		50	11.844	11.844	71.064
Preselector	1	12.50	12.50		50	1.18	1.18	14.75
Stripline Assy.	1	75.97	75.97		500			
2N918	4	.46	1.84		24	1.266	5.064	2.329
HP 2800	2	.50	1.00		10	.155	.31	.155
HP 2817	1	3.91	3.91		5	.155	.155	.606
1N746A	1	.48	.48		5	.4	.4	.192
FDH - 600	4	.40	1.60		20	.155	.62	.248
Crystal	2	2.00	4.00		30	.226	.452	.904
Cap - Adj.	6	1.10	6.60		90	1.58	9.48	10.428
Cap - Disc	16	.05	.80		80	.291	4.656	.233
Cap - FT	19	.05	.95		95	.291	5.529	.276
Thermistor	1	3.20	3.20		5	1.35	1.35	4.32
Coil	8	.05	.40		40	.069	.552	.028
Resistor	22	.03	.66		110	.013	.286	.009
PC Board	3	2.00	6.00		75			
Board Process				485				
Cut & Swage				150				
TOTALS			227.84	635	1394 X 2		48.213	$\frac{559.}{48.213} = 11.60$

SYSTEM DABS - Type I CASE II SHEET 5 OF 15

SUB-ASSEMBLY IF Amp.

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N918	2	.46	.92		12	1.266	2.532	1.165
2N2897	1	.55	.55		6	1.266	1.266	.696
2N3250	3	.44	1.32		18	2.124	6.372	2.804
2N3478	1	.90	.90		6	1.266	1.266	1.139
MC 1590	2	4.00	8.00		16	.715	1.43	5.72
1N914	1	.12	.12		5	.155	.155	.019
HP 2800	3	.50	1.50		15	.155	.465	.233
Thermistor	3	3.20	9.60		15	1.35	4.05	12.96
Potentiometer	3	.95	2.85		45	.664	1.992	1.892
Cap - ADj.	2	1.10	2.20		30	1.58	3.16	3.476
Cap - T/E	8	.18	1.44		40	.55	4.4	.792
Cap - Disc	15	.05	.75		75	.291	4.365	.218
Cap - FT	19	.05	.95		95	.291	5.529	.276
Coil	9	.05	.45		45	.069	.621	.031
Resistor	33	.03	.99		165	.013	.429	.013
PC Board	1	5.00	5.00		25			
Chassis	1	2.00	2.00	250	125			
Connector	1	.71	.71		15			
Connector - BNC	1	.45	.45		25			
Hardware	Lot	1.50	1.50		150			
Board Process				485				
Cut & Swage				333				
TOTALS								

SYSTEM DABS - Type I CASE II SHEET 6 OF 15

SUB-ASSEMBLY IF Amp. (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Saw Filter	1	4.24	4.24		8	1.18	1.18	5.003
M760	1	4.00	4.00		8	.715	.715	2.86
Coils	6	.05	.30		30	.069	.414	.021
Resistor	4	.03	.12		20	.013	.052	.002
Cap - Disc	6	.05	.30		30	.291	1.746	.087
TOTALS			51.16	1068 X 1.8	1024 X 2		42.139	$\frac{39.407}{42.139} = .94$

SYSTEM DABS - Type I

SHEET 7 OF 15

SUB-ASSEMBLY Power Supply

CASE II

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N2270	1	.55	.55		6	1.266	1.266	.696
2N2897	2	.55	1.10		12	1.266	2.532	1.393
TIP 31	1	.52	.52		6	3.749	3.749	1.949
TIP 32	1	.57	.57		6	2.498	2.498	1.424
TIP 41	1	.65	.65		6	3.749	3.749	2.437
IC MC1741C	2	4.00	8.00		16	.715	1.43	5.720
1N645	4	.80	3.20		20	.155	.62	.496
1N752	2	.37	.74		10	.4	.8	.296
1N964B	2	.41	.82		10	.4	.8	.328
20A1	2	.18	.36		10	.155	.31	.056
Transformer	1	8.00	8.00		615	1.5	1.5	12.0
Potentiometer	1	.95	.95		15	.664	.664	.631
Choke	1	1.05	1.05		25	2.12	2.12	2.226
Cap - T/E	8	.18	1.44		40	.55	4.4	.792
Cap - Disc	7	.05	.35		25	.291	2.037	.102
Resistor	35	.03	1.05		175	.013	.455	.014
FT Term	100	.01	1.00		200			
Ant. Turnball	1	4.00	4.00		150			
Term. Board	1	1.50	1.50	150	150			
Connector	1	1.73	1.73		15			
F.W. Rectifier	1	1.30	1.30		10	.62	.62	.806
1N4005	2	.45	.90		10	.155	.31	.14
TOTALS			39.78	150	1542.		29.86	$\frac{31.506}{29.86} = 1.06$

SYSTEM DABS - Type I

SHEET 8 OF 15

SUB-ASSEMBLY Video Processor

Case II

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CA3045	5	4.00	20.00		40	.715	3.575	14.3
52710	1	4.76	4.76		8	.715	.715	3.403
5472	1	3.15	3.15		8	.715	.715	2.252
MC1741	1	4.00	4.00		8	.715	.715	2.860
MFE3001	1	7.35	7.35		8	11.904	11.904	87.494
74L20	1	.72	.72		8	.06	.06	.043
74L30	1	.72	.72		8	.03	.03	.022
2N708	1	.28	.28		6	1.266	1.266	.354
9601	1	6.75	6.75		8	.715	.715	4.826
2N2222A	3	.40	1.20		18	1.266	3.798	1.519
2N2323A	1	1.65	1.65		6	.465	.465	.767
2N2897	1	.55	.55		6	1.266	1.266	.696
2N3250	1	.55	.55		6	2.124	2.124	1.168
2N3497	1	7.10	7.10		6	2.124	2.124	15.08
1N645	22	.80	17.60		110	.155	3.41	2.728
1N753A	1	.41	.41		5	.4	.4	.164
1N758A	23	.37	8.51		115	.4	9.2	3.404
1N914	16	.12	1.92		80	.155	2.48	.298
1N971A	1	.37	.37		5	.4	.4	.148
HP2800	3	.50	1.50		15	.155	.465	.233
Potentiometer	6	.95	5.70		90	.664	3.984	3.785
Caps - T/E	8	.18	1.44		40	.55	4.4	.792
TOTALS								

SYSTEM DABS - Type I CASE II SHEET 9 OF 15

SUB-ASSEMBLY Video Processor (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CAPS - Disc	15	.05	.75		75	.291	4.365	.218
Resistors	97	.03	2.91		485	.013	1.261	.038
PC Board	1	5.00	5.00		25			
Board Process				485				
Cut & Swage				333				
TOTALS			104.89	818	1189 X 2		59.837	$\frac{146.592}{59.837} = 2.45$

SYSTEM DABS - Type I

CASE II

SHEET 10 OF 15

SUB-ASSEMBLY Monitor

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5400	11	2.05	22.55		88	.12	1.32	2.706
5404	2	2.55	5.10		16	.035	.07	.179
5410	1	2.05	2.05		8	.09	.09	.185
5430	1	2.05	2.05		8	.24	.24	.492
5474	1	4.20	4.20		8	.07	.07	.294
5493	1	10.35	10.35		8	.715	.715	7.4
5496	2	10.80	21.60		16	.715	1.43	15.444
9601	2	6.75	13.50		16	.715	1.43	9.653
52709	1	2.54	2.54		8	.715	.715	1.816
52710	1	2.10	2.10		8	.715	.715	1.502
52720	1	2.10	2.10		8	.715	.715	1.502
2N3390	2	.91	1.82		12	1.266	2.532	2.304
2N708	2	.28	.56		12	1.266	2.532	.709
2N2323	3	1.65	4.95		18	.465	1.395	2.302
2N2608	1	1.70	1.70		6	11.904	11.904	20.237
2N2897	3	.55	1.65		18	1.266	3.798	2.089
2N3250	2	.55	1.10		12	2.124	4.248	2.336
2N3980	3	2.25	6.75		18	1.266	3.798	8.548
1N645	4	.80	3.20		20	.155	.62	.496
1N753	1	.37	.37		5	.4	.4	.148
1N914	10	.12	1.20		50	.155	1.55	.186
HP2800	1	.50	.50		5	.155	.155	.078
TOTALS								

SYSTEM DABS - Type I CASE II SHEET 11 OF 15

SUB-ASSEMBLY Monitor (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Potentiometer	4	.95	3.80		60	.664	2.656	2.523
CAP - T/E	9	.18	1.62		45	.55	4.95	.891
CAP - Disc	14	.05	.70		70	.291	4.074	.204
Resistors	51	.03	1.53		255	.013	.663	.020
DC Board	1	5.00	5.00		25			
Board Process				485				
Cut & Swage				333				
TOTALS			124.59	818	823 X 2		52.785	$\frac{84.242}{52.785} = 1.60$

SYSTEM DABS - Type I CASE II SHEET 12 OF 15

SUB-ASSEMBLY Digital Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
NE 555	3	.50	1.50		24	.715	2.145	1.073
20 mHZ Osc.	1	4.00	4.00		8	.715	.715	2.86
9615	1	19.20	19.20		8	.715	.715	13.728
9614	1	15.20	15.20		8	.715	.715	10.868
5400	12	2.05	24.60		96	.12	1.44	2.952
5402	5	2.25	11.25		40	.12	.6	1.35
5404	10	2.55	25.50		80	.035	.35	.893
5408	4	2.65	10.60		32	.12	.48	1.272
5410	3	2.05	6.15		24	.09	.27	.554
5411	3	2.65	7.95		24	.09	.27	.716
5420	1	2.05	2.05		8	.24	.24	.492
5425	1	2.95	2.95		8	.24	.24	.708
5430	1	2.05	2.05		8	.24	.24	.492
5432	3	2.90	8.70		24	.12	.36	1.044
5427	4	2.95	11.80		32	.09	.36	1.062
5437	1	3.15	3.15		8	.715	.715	2.252
5442	1	12.10	12.10		8	.715	.715	8.65[illegible]
5450	10	2.05	20.50		80	.715	7.15	14.658
5453	1	2.05	2.05		8	.715	.715	1.466
5474	3	4.20	12.60		24	.07	.21	.882
5486	1	2.75	2.75		8	.12	.12	.330
5495	2	7.70	15.40		16	.715	1.43	11.011
TOTALS								

SYSTEM DABS - Type I CASE II SHEET 13 OF 15

SUB-ASSEMBLY Digital Logic (Cont'd)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54107	13	5.20	67.60		104	.715	9.295	48.334
54111	2	3.60	7.20		16	.715	1.43	5.148
54123	1	6.46	6.46		8	.715	.715	4.619
54161	9	9.61	86.49		72	.715	6.435	61.840
54164	17	10.10	171.70		136	.715	12.155	122.766
54165	11	10.10	111.10		88	.715	7.865	79.437
54180	2	20.00	40.00		16	.715	1.43	28.6
PC Board	2	10.00	20.00		46			
Board Process				970				
Cut & Swage				666				
TOTALS			735.60	1636 X 2	1062 X 2		59.52	$\frac{429.135}{59.52} = 7.21$

SYSTEM DABS - Type I CASE II SHEET 14 OF 15

SUB-ASSEMBLY Chassis

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Chassis	1	13.00	13.00	1365	684			
Connectors	2	40.00	80.00		1000	1.342	2.684	107.36
PC Conn.	4	1.18	4.72		500	1.342	5.368	6.334
RF Conn.	2	1.05	2.10		50	1.128	4.512	4.738
Cable Assy.					1000	6.3	6.3	0
TOTALS			99.82	1365	3234		21.12	$\frac{118.432}{21.12} = 5.61$

SYSTEM DABS - Type I CASE II SHEET 15 OF 15

SUB-ASSEMBLY Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Transmitter	1				60			
Modulator	1				15			
RF Front End	2				100			
IF Amp	2				50			
Power Supply	1				190			
Video Proc.					50			
Monitor	1				75			
Digital Logic	1				100			
Chassis	1				150			
Functional Test					2000			
Burn-In					1000			
TOTALS					3790			

SYSTEM DABS - Type II

SUB-ASSEMBLY Transmitter

CASE I

SHEET 1 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Oscillator	1	21.	21.		250	200.	200.	4200.
Resistor	1	.10	.10		5	.03	.03	.003
2N2222	1	.40	.40		6	1.266	1.266	.506
IN4153	2	.30	.60		10	.155	.31	.093
IN4735	1	.30	.30		5	.4	.4	.12
GP RECT. - HV	2	.25	.50		10	.358	.716	.179
Transformer	1	.50	.50		315	2.309	2.309	1.155
Transistors	2	.65	1.30		12	2.498	4.996	3.247
Potentiometer	1	.29	.29		15	.664	.664	.193
Coil - 100mh	3	.43	1.29		18	.069	.207	.089
CAP - Mylar	3	.16	.48		15	.55	1.65	.264
CAP - Disc	9	.12	1.08		45	.291	2.619	.314
Resistors	9	.02	0.18		45	.013	.117	.002
PC Board	1	3.00	3.00	793	25			
TOTALS			31.02	793	776		215.284	$\frac{4206.}{215.3} = 19.54$

SYSTEM DABS - Type II

SUB-ASSEMBLY Receiver

CASE I

SHEET 2 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LP Filter	1	1.50	1.50		250	11.844	11.844	17.766
BP Filter	1	3.50	3.50		250	1.18	1.18	4.13
Tuned CKT	1	.75	.75		25	.475	.475	.356
Coils	23	.06	1.38		138	.069	1.587	.095
CAP - M/T	28	.15	4.20		140	.55	15.4	2.310
CAP - Disc	36	.05	1.80		180	.291	10.476	.524
CAP - VAR	1	.92	.92		15	1.58	1.58	1.454
IF Trans.	4	.75	3.00		160	.475	1.9	1.425
Resistor FC	55	.03	1.65		275	.013	.715	.021
Potentiometer	3	.29	.87		45	.664	1.992	.578
Crystal	1	1.50	1.50		15	.226	.226	.339
IN4153	1	.30	.30		5	.155	.155	.047
IN4154	1	.25	.25		5	.155	.155	.039
FD777	1	.98	.98		5	.155	.155	.152
FH1100	1	.33	.33		5	.155	.155	.051
2N3646	1	.65	.65		6	1.266	1.266	.823
2N5086	2	.45	.90		12	2.124	4.248	1.912
SKA4580	4	.65	2.60		24	1.266	5.064	3.292
2N2222A	1	.40	.40		6	1.266	1.266	.506
MPS6515	1	.39	.39		6	1.266	1.266	.494
M760	1	1.50	1.50		8	.715	.715	1.073
LM319N	1	1.50	1.50		8	.715	.715	1.073
TOTALS								

SYSTEM DABS - Type II

SUB-ASSEMBLY Receiver (cont'd)

CASE I

SHEET 3 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
7408	1	.33	.33		8	.12	.12	.040
SAW Filter	1	4.24	4.24		10	1.18	1.18	5.003
PC Board	1	3.00	3.00	793	25			
Chassis	1	1.50	1.50	20	25			
TOTALS			39.94	813 X 2	1651 X 2		63.835	$\frac{43.503}{63.835} = .68$

SYSTEM DABS - Type II

SUB-ASSEMBLY Power Supply

CASE I

SHEET 4 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2F0305	1	1.50	1.50		8	.715	.715	1.073
IF0301	1	1.50	1.50		8	.715	.715	1.073
IN4153	2	.30	.60		10	.155	.31	.093
IN5224B	1	.41	.41		5	.4	.4	.164
MJE 1100	1	.75	.75		6	1.266	1.266	.950
MJE 1090	1	.75	.75		6	2.124	2.124	1.593
2N2222A	1	.40	.40		6	1.266	1.266	.506
IN5229B	2	.41	.82		10	.4	.8	.328
2N3251A	1	.76	.76		6	2.124	2.124	1.614
Potentiometer	1	.29	.29		15	.664	.664	.193
CAP - T/M	4	.15	.60		20	.55	2.2	.330
Resistor FC	14	.03	.42		70	.013	.182	.005
PC Board	1	3.00	3.00	793	25			
TOTALS			11.80	793 X 1.4	195 X 1.4		12.766	$\frac{6.972}{12.766} = .55$

SYSTEM DABS - Type II

CASE I

SHEET 5 OF 9

SUB-ASSEMBLY Analog Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N5305	1	.50	.50		6	1.266	1.266	.633
2N2222A	4	.40	1.60		24	1.266	5.064	2.026
2N2102A	1	.50	.50		6	1.266	1.266	.633
IN4154	4	.13	.52		20	.155	.62	.081
IN4153	3	.30	.90		15	.155	.465	.140
IN3666	1	.35	.35		5	1.717	1.717	.601
SN7404	3	.38	1.14		24	.035	.105	.040
SN7420	1	.30	.30		8	.03	.03	.009
SN74121	1	.63	.63		8	.715	.715	.450
SN7402	1	.30	.30		8	.03	.03	.009
7406A	1	.86	.86		8	.035	.035	.030
CAP - M/T	6	.15	.90		30	.55	3.3	.495
CAP - Disc	3	.05	.15		15	.291	.873	.044
Resistor FC	18	.03	.54		90	.013	.234	.007
PC Board	1	3.00	3.00	793	25			
TOTALS			12.19	793 X 2	292 X 2		15.72	$\frac{5.197}{15.72} = .33$

SYSTEM DABS - Type II CASE I SHEET 6 OF 9

SUB-ASSEMBLY Digital Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
NE 555	3	.50	1.50		24	.715	2.145	1.073
Osc Chip-20mH	1	1.00	1.00		8	.715	.715	.715
DM 8820	1	3.00	3.00		8	.715	.715	2.145
DM 8831	1	3.00	3.00		8	.715	.715	2.145
7400	12	.30	3.60		96	.12	1.44	.432
7402	5	.30	1.50		40	.12	.6	.18
7404	10	.38	3.80		80	.035	.35	.133
7408	4	.33	1.32		32	.12	.48	.158
7410	3	.30	.90		24	.09	.27	.081
7411	3	.33	.99		24	.09	.27	.089
7420	1	.30	.30		8	.24	.24	.072
7425	1	.45	.45		8	.24	.24	.108
7430	1	.30	.30		8	.24	.24	.072
7432	3	.44	1.32		24	.12	.36	.158
7427	4	.45	1.80		32	.09	.36	.162
7437	1	.63	.63		8	.715	.715	.450
7442	1	.89	.89		8	.715	.715	.636
7450	10	.30	3.00		80	.715	7.15	2.145
7453	1	.30	.30		8	.715	.715	.215
7474	3	.48	1.44		24	.07	.21	.101
7486	1	.50	.50		8	.12	.12	.060
7495	2	.97	1.94		16	.715	1.42	1.387
TOTALS								

SYSTEM DABS - Type II

SUB-ASSEMBLY Digital Logic (cont'd)

CASE I

SHEET 7 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74107	13	.48	6.24		104	.715	9.295	4.462
74111	2	1.15	2.30		16	.715	1.43	1.645
74123	1	1.14	1.14		8	.715	.715	.815
74161	9	1.08	9.72		72	.715	6.435	6.950
74164	17	1.35	22.95		136	.715	12.155	16.409
74165	11	1.35	14.85		88	.715	7.865	10.618
74180	2	1.89	3.78		16	.715	1.43	2.703
PC Board	1	10.00	10.00	793	25			
Connector	1	3.00	3.00		15			
TOTALS			107.46	793 X 2	1056 X 2		59.52	$\frac{56.319}{59.52} = .95$

SYSTEM DABS - Type II

SUB-ASSEMBLY Chassis

CASE I

SHEET 8 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Squawk Res.	13	.03	.39		130	.013	.169	.005
CAP - M/T	2	.15	.30		10	.55	1.1	.165
CAP Disc	3	.05	.15		15	.291	.873	.044
Coil	5	.06	.30		30	.069	.345	.021
Resistor FC	2	.03	.06		10	.013	.026	.001
GP Diode	1	.35	.35		5	.155	.155	.054
2N2222A	1	.40	.40		6	1.266	1.266	.506
Thermistor	1	.55	.55		12	1.35	1.35	.743
V3 301 Lamp	1	.75	.75		12			
Fuse & Holder	2	.25	.50		20			
Control Sw.	1	.91	.91		50	4.419	4.419	4.021
Ident. Sw.	4	2.50	10.00		200	4.419	17.676	44.190
Coax. Conn.	1	.49	.49		15			
Conn. Pwr	1	.66	.66		50			
Conn. IPC	1	1.12	1.12		50			
Chassis	Set	16.80	16.80	689	174			
RF PC Board	1	3.00	3.00		50			
Front Panel	1	4.50	4.50	74	22			
TOTALS			41.23	763	851 X 2		27.379	$\frac{49.750}{27.379} = 1.82$

SYSTEM DABS - Type II CASE I SHEET 9 OF 9

SUB-ASSEMBLY Final Assembly

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
PC Boards	5				50			
Power Supply	1				40			
Receiver	1				50			
Transmitter	1				60			
Wiring					200			
Functional Test					2000			
Burn - In					1000			
TOTALS								

SYSTEM DABS - Type II

SUB-ASSEMBLY Transmitter

CASE II

SHEET 1 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cavity Osc.	1	21.00	21.00		250	200.	200.	4200.
2N2405	1	.87	.87		6	1.266	1.266	1.101
2N5134	1	.12	.12		6	1.266	1.266	.152
2N3638	1	.16	.16		6	2.124	2.124	.34
2N4916	1	.20	.20		6	2.124	2.124	.425
Diode - GP	2	.12	.24		10	.155	.31	.037
Potentiometer	1	.29	.29		15	.664	.644	.193
CAP - Disc	5	.05	.25		25	.291	1.455	.073
LP Filter	1	1.50	1.50		250	11.844	11.844	17.766
Resistor	13	.03	.39		65	.013	.169	.005
PC Board	1	10.00	10.00	793	25			
TOTALS			35.02	793 X 2	664 X 2		221.222	$\frac{4220.}{221.} = 19.08$

SYSTEM DABS - Type II

SUB-ASSEMBLY Receiver

CASE I

SHEET 2 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
RCA 40243	4	.47	1.88		24	1.266	5.064	2.380
F1100	1	.22	.22		5	.155	.155	.034
CD 6585	1	.22	.22		5	.155	.155	.034
2N5086	2	.45	.90		12	2.124	4.248	1.912
MPS 6515	1	.39	.39		6	1.266	1.266	.494
2N2222A	1	.40	.40		6	1.266	1.266	.506
FD 777	1	.98	.98		5	.155	.155	.152
IN4153	1	.30	.30		5	.155	.155	.047
M760	1	1.50	1.50		8	.715	.715	1.073
LM319N		1.50	1.50		8	.715	.715	1.073
7408	1	.33	.33		8	.715	.715	.236
Saw Filter	1	4.24	4.24		10	1.18	1.18	5.003
Crystal	1	1.50	1.50		15	.226	.226	.339
Preselector	1	3.50	3.50		250			
Trans-Slug Tuned	1	.75	.75		40	.475	.475	.356
Potentiometer	3	.29	.87		45	.664	1.992	.578
Coil-Tuned	3	.35	1.05		60	.475	1.425	.499
Coils	12	.06	.72		60	.069	.828	.050
CAPS - T/E	18	.15	2.70		90	.55	9.900	1.485
CAP Disc	28	.05	1.40		140	.291	8.148	.407
Resistor FC	43	.03	1.29		215	.013	.559	.017
PC Board	1	3.00	3.00	793	25			
TOTALS								

SYSTEM DABS - Type II

SUB-ASSEMBLY Receiver (Cont'd)

CASE II

SHEET 3 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
Cover, Top	1							
Cover, Bottom	1	1.50	1.50	50	25			
Shield	1							
Hardware	Set	1.50	1.50		50			
TOTALS			32.64	813 X 2	1117 X 2		39.342	$\frac{16.675}{39.342} = .42$

SYSTEM DABS - Type II

SUB-ASSEMBLY Power Supply

CASE II

SHEET 4 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N5494	1	.12	.12		6	1.266	1.266	.152
2N5138	1	.12	.12		6	2.124	2.124	.255
2N5172	2	.12	.24		12	1.266	2.532	.304
SD445	2	.79	1.58		12	2.124	4.248	3.356
2F0305	1	1.50	1.50		8	.715	.715	1.073
1F0301	1	1.50	1.50		8	.715	.715	1.073
IN4153	2	.30	.60		10	.155	.31	.093
IN5224B	1	.41	.41		5	.4	.4	.164
IN751	1	.45	.45		5	.4	.4	.18
Diode - GP	1	.12	.12		5	.155	.155	.019
Diode - 500V	1	.59	.59		5	.358	.358	.211
Diode - 2000V	2	.68	1.36		10	.358	.716	.487
Potentiometer	1	.35	.35		15	.664	.664	.232
Potentiometer	1	.29	.29		15	.664	.664	.193
Transformer	1	.50	.50		315	1.5	1.5	.75
CAP - T/E	6	.15	.90		30	.55	3.3	.495
CAP - Disc	16	.05	.80		80	.291	4.656	.233
CAP - Mylar	3	.15	.45		15	.55	1.65	.248
Resistor - 3W	2	.06	.12		10	.013	.026	.002
Resistor - FC	21	.03	.63		105	.013	.273	.008
Coils	2	.06	.12		10	.069	.138	.008
TOTALS			12.75		687 X 1.4		26.91	$\frac{9.536}{26.91} = .35$

SYSTEM DABS - Type II

CASE II

SHEET 5 OF 9

SUB-ASSEMBLY Analog Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N5305	1	.50	.50		6	1.266	1.266	.633
2N2222A	4	.40	1.60		24	1.266	5.064	2.026
2N2102A	1	.50	.50		6	1.266	1.266	.633
IN4154	4	.13	.52		20	.155	.62	.081
IN4153	3	.30	.90		15	.155	.465	.140
IN3666	1	.35	.35		5	1.717	1.717	.601
SN7404	3	.38	1.14		24	.035	.105	.040
SN7420	1	.30	.30		8	.03	.03	.009
SN74121	1	.63	.63		8	.715	.715	.450
SN7402	1	.30	.30		8	.03	.03	.009
7406A	1	.86	.86		8	.035	.035	.030
CAP - M/T	6	.15	.90		30	.55	3.3	.495
CAP - Disc	3	.05	.15		15	.291	.873	.044
Resistor FC	18	.03	.54		90	.013	.234	.007
PC Board	1	3.00	3.00	793	25			
TOTALS			12.19	793 X 2	292 X 2		15.72	$\frac{5.197}{15.72} = .33$

SYSTEM DABS - Type II CASE II SHEET 6 OF 9

SUB-ASSEMBLY Digital Logic

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
NE 555	3	.50	1.50		24	.715	2.145	1.073
Osc Chip-20mH	1	1.00	1.00		8	.715	.715	.715
DM 8820	1	3.00	3.00		8	.715	.715	2.145
DM 8831	1	3.00	3.00		8	.715	.715	2.145
7400	12	.30	3.60		96	.12	1.44	.432
7402	5	.30	1.50		40	.12	.6	.18
7404	10	.38	3.80		80	.035	.35	.133
7408	4	.33	1.32		32	.12	.48	.158
7410	3	.30	.90		24	.09	.27	.081
7411	3	.33	.99		24	.09	.27	.089
7420	1	.30	.30		8	.24	.24	.072
7425	1	.45	.45		8	.24	.24	.108
7430	1	.30	.30		8	.24	.24	.072
7432	3	.44	1.32		24	.12	.36	.158
7427	4	.45	1.80		32	.09	.36	.162
7437	1	.63	.63		8	.715	.715	.450
7442	1	.89	.89		8	.715	.715	.636
7450	10	.30	3.00		80	.715	7.15	2.145
7453	1	.30	.30		8	.715	.715	.215
7474	3	.48	1.44		24	.07	.21	.101
7486	1	.50	.50		8	.12	.12	.060
7495	2	.97	1.94		16	.715	1.42	1.387
TOTALS								

SYSTEM DABS - Type II

SUB-ASSEMBLY Digital Logic (cont'd)

CASE II

SHEET 7 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
74107	13	.48	6.24		104	.715	9.295	4.462
74111	2	1.15	2.30		16	.715	1.43	1.645
74123	1	1.14	1.14		8	.715	.715	.815
74161	9	1.08	9.72		72	.715	6.435	6.950
74164	17	1.35	22.95		136	.715	12.155	16.409
74165	11	1.35	14.85		88	.715	7.865	10.618
74180	2	1.89	3.78		16	.715	1.43	2.703
PC Board	1	10.00	10.00	793	25			
Connector	1	3.00	3.00		15			
TOTALS			107.46	793 X 2	1056 X 2		59.52	$\frac{56.319}{59.52} = .95$

SYSTEM DABS - Type II

SUB-ASSEMBLY Chassis (Incl. Test Osc.)

CASE II

SHEET 8 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N5139	1	.12	.12		6	2.124	2.124	.255
2N5128	1	.12	.12		6	1.266	1.266	.152
2N4870	1	.12	.12		6	1.266	1.266	.152
2N5134	1	.12	.12		6	1.266	1.266	.152
Diode - GP	1	.12	.12		5	.155	.155	.019
CAP - T/E	2	.15	.30		10	.55	1.1	.165
CAP - Disc	5	.05	.25		25	.291	1.455	.073
Coil	2	.06	.12		12	.069	.138	.008
Resistor - FC	10	.03	.30		50	.013	.13	.004
Chassis w/cover	Set	21.30	21.30	689	196			
Selector PC	1	2.00	2.00		485			
Ident. Sw.	4	2.50	10.00		200	4.419	17.676	44.190
Control Sw.	1	.91	.91		50			
Dimmer	1	.35	.35		25			
Hardware	Lot	1.50	1.50		200			
BNC Conn.	1	.49	.49		15			
PC Conn.	1	1.12	1.12		50			
IPC Conn.	1	1.12	1.12		50			
TOTALS			40.51	689	1412 X 2		26.576	$\frac{45.169}{26.576} = 1.70$

SYSTEM DABS - Type II

SUB-ASSEMBLY Final Assembly

CASE II

SHEET 9 OF 9

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
PC Boards	3				50			
Power Supply	1				40			
Receiver	1				50			
Transmitter	1				60			
Wiring					200			
Functional Test					2000			
Burn-In					1000			
TOTALS					3400			

SYSTEM IPC Display - Type I SHEET 1 OF 2

SUB-ASSEMBLY

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
DM 7820	1	7.00	7.00		8	.715	.715	5.005
DM 76L70	20	10.10	202.00		160	.715	14.30	144.43
NE 555	2	.50	1.00		16	.715	1.43	.715
5404	2	2.55	5.10		16	.035	.07	.179
5416	9	4.25	38.25		72	.035	.315	1.339
5439	12	2.05	24.60		96	.12	1.44	2.952
5440	1	2.35	2.35		8	.06	.06	.141
5486	1	2.75	2.75		8	.12	.12	.33
54L00	9	2.05	18.45		72	.12	1.08	2.214
54L04	6	2.55	15.30		48	.035	.21	.536
54L02	7	2.25	15.75		56	.12	.84	1.89
54L10	9	2.05	18.45		72	.09	.81	1.661
54L20	3	2.05	6.15		24	.06	.18	.369
54L30	1	2.05	2.05		8	.03	.03	.062
54L85	4	7.48	29.92		40	.715	2.86	21.393
54L93	3	10.35	31.05		24	.715	2.145	22.201
54L193	2	7.48	14.96		20	.715	1.43	10.696
93L28	3	11.95	35.85		30	.715	2.145	25.633
96L02	5	8.60	43.00		50	.715	3.575	30.745
2N3638A	12	.18	2.16		72	2.124	25.488	4.588
Potentiometer	1	3.00	3.00		15	.664	.664	1.992
Choke - 5A	1	1.05	1.05		15	2.12	2.12	2.226
TOTALS								

SYSTEM IPC Dispaly - Type I

SHEET 2 OF 2

SUB-ASSEMBLY

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CAPS - T/D	10	.18	1.80		50	.55	5.5	.99
CAPS - DISC	13	.05	.65		65	.291	3.783	.189
Power Supply	1	40.00	40.00		100	20.00	20.00	800.00
Resistors	76	.03	2.28		380	.013	.988	.03
LED	44	.22	9.68		220	.155	6.82	1.5
Lamps	2	.15	.30		30	8.664	17.328	2.599
P.B. w/Lamps	3	.65	1.95		45	11.849	23.698	15.404
P.C. Board	6	5.00	30.00		90			
Face Plate	1	2.00	2.00	325	25			
Chassis	1	5.00	5.00	550	150			
Cover	1	1.00	1.00	100	75			
Conn. MS	1	15.00	15.00		200			
Conn. Stripline	4	1.50	6.00		500			
Board Process	6			3410				
Assembly					500			
Test					1000			
Burn-In					1000			
TOTALS			635.85	4385x1.1	536x2		140.144	$\frac{1102}{140-14} = 7.86$

SYSTEM IPC Display - Type II

SHEET 1 OF 2

SUB-ASSEMBLY

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
DM 8820	1	3.95	3.95		8	.715	.715	2.824
DM 86L70	20	2.30	46.00		160	.715	14.30	32.890
NE 555	2	.50	1.00		16	.715	1.43	.715
7404	2	.62	1.24		16	.035	.07	.043
7416	9	1.80	16.20		72	.035	.315	.567
7439	12	1.05	12.60		96	.12	1.44	1.512
7440	1	.50	.50		8	.06	.06	.03
7486	1	.72	.72		8	.12	.12	.086
74L00	9	.50	4.50		72	.12	1.08	.540
74L04	6	.62	3.72		48	.035	.21	.13
74L02	7	.50	3.50		56	.12	.84	.42
74L10	9	.50	4.50		72	.09	.81	.405
74L20	3	.50	1.50		24	.06	.18	.09
74L30	1	.50	.50		8	.03	.03	.015
74L85	4	2.19	8.76		40	.715	2.86	6.263
74L93	3	1.12	3.36		24	.715	2.145	2.402
74L193	2	2.60	5.20		20	.715	1.43	3.718
93L28	3	6.00	18.00		30	.715	2.145	12.87
96L02	5	5.75	28.75		50	.715	3.575	20.556
2N3638A	12	.18	2.16		72	2.124	25.488	4.588
Potentiometer	1	1.18	1.18		15	.664	.664	.784
Choke -5A	1	.55	.55		15	2.12	2.12	1.166
TOTALS								

SYSTEM IPC Display - Type II

SHEET 2 OF 2

SUB-ASSEMBLY _____

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CAP - T/E	10	.15	1.50		50	.55	5.5	.825
CAP - Disc	13	.05	.65		65	.291	3.783	.189
Power Supply	1	40.00	40.00		100	20.0	20.0	800.00
Resistor FC	76	.03	2.28		380	.013	.988	.03
LED	44	.22	9.68		220	.155	6.82	1.5
Lamps	2	.15	.30		30	8.664	17.328	2.599
PB w/Lamp	3	.65	1.95		45	11.849	23.698	15.404
PC Board	6	3.00	18.00		90			
Face Plate	1	1.50	1.50	325	25			
Chasis	1	5.00	5.00	550	150			
Cover	1	1.00	1.00	100	75			
Conn - Pwr	1	2.00	2.00		25			
Conn - IPC	1	2.00	2.00		125			
Conn - Stripline	4	1.50	6.00		500			
Board Process				2410				
Assembly					500			
Test					1000			
Burn - In					1000			
TOTALS			260.25	3385 X 1.4	5310 X 2		140.144	$\frac{913.163}{140.144} = \$6.52$

SYSTEM IPC Display - Type I - LSI Version SHEET 1 OF 1

SUB-ASSEMBLY _____

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LSI	5	35.00	175.00		100	.383	1.915	67.025
5416	8	4.25	34.00		64	.715	5.72	24.31
DM7820	1	7.00	7.00		8	.715	.715	5.005
LED	44	.22	9.68		220	.155	6.82	1.500
Lamps	2	.15	.30		30	8.664	17.328	2.599
Choke	1	1.05	1.05		15	2.12	2.12	2.226
Cap - T/E	10	.18	1.80		50	.55	5.5	.99
Cap - Disc	13	.05	.65		65	.291	3.783	.189
Power Supply	1	40.00	40.00		100	20.00	20.00	800.00
PC Board	2	5.00	10.00		50			
Face Plate	1	2.00	2.00	325	25			
Chassis	1	5.00	5.00	450	150			
Cover	1	1.00	1.00	100	75			
Conn-MS	1	15.00	15.00		200			
Conn-Strip	2	1.50	3.00		250			
Board Process				1303				
Assembly					300			
Test					1000			
Burn-In					1000			
TOTALS			305.48	2178 X 1.1	3702 X 1.7		63.901	$\frac{903.845}{63.901} = 14.14$

SYSTEM DABS - Type I - LSI

SUB-ASSEMBLY Digital Logic

SHEET 1 OF 1

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LSI - Custom	1	35.	35.00		20	4.703	4.703	164.605
54164	3	10.10	30.30		24	.715	2.145	21.665
54165	4	10.10	40.40		32	.715	2.860	28.886
54161	3	9.61	28.83		24	.715	2.145	20.613
5404	1	2.55	2.55		8	.035	.035	.089
5408	1	2.65	2.65		8	.12	.12	.318
5432	1	2.90	2.90		8	.12	.12	.348
5417	1	4.25	4.25		8	.12	.12	.510
DM7820	1	19.20	19.20		8	.715	.715	13.728
DM7831	1	15.20	15.20		8	.715	.715	10.868
5494	1	7.70	7.70		8	.715	.715	5.506
NE555	1	.50	.50		8	.715	.715	.358
20mHz Crystal	1	2.00	2.00		6	.226	.226	.452
PC Board	1	5.00	5.00		25			
Board Process				485				
Cut & Swage				333				
Conn.	1				15			
					1000			
TOTALS			196.48	818X2	210X2		15.334	$\frac{267.946}{15.334} = 17.47$

SYSTEM DABS - Type II - LSI

SUB-ASSEMBLY Digital Logic

SHEET 1 OF 2

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LSI - DABS	1	20.	20.		20	47.026	47.026	940.52
LSI - IPC	5	20.	100.		100	5.92	29.6	592.00
7404	1	.38	.38		8	.035	.035	.013
7408	1	.33	.33		8	.12	.12	.040
7416	8	1.80	14.40		64	.715	5.72	10.296
7417	1	1.80	1.80		8	.714	.715	1.287
7432	1	.44	.44		8	.12	.12	.053
7494	1	.97	.97		8	.715	.715	.694
74161	3	1.08	3.24		24	.715	2.145	2.317
74164	3	1.35	4.05		24	.715	2.145	2.896
74165	4	1.35	5.40		32	.715	2.86	3.861
74180	3	1.89	5.67		24	.715	2.145	4.054
NE555	1	.50	.50		8	.715	.715	.358
20 MHz Crystal	1	1.50	1.509		15	1.50	1.50	2.250
PC Board	1	3.00	3.00	793	25			
Connector	1	2.00	2.00		15			
Misc. Comp	Lot	1.00	1.00		50	5.00	5.00	5.00
TOTALS			164.68	793 X 2	441 X 2		100.561	$\frac{1565.637}{100.561} = 15.57$

SYSTEM DABS - Type II - LSI CASE SHEET 2 OF 2

SUB-ASSEMBLY Chassis

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SQ. Resistors	13	.03	.39		130	.013	.169	.005
Cap - M/T	2	.15	.30		10	.55	1.1	.165
Cap - Disc	3	.05	.15		15	.291	.873	.044
Coils	5	.06	.30		30	.069	.345	.021
Diode - GP	1	.35	.35		5	.155	.155	.054
Resistor FC	2	.03	.06		10	.013	.026	.001
2N2222A	1	.40	.40		6	1.266	1.266	.504
Thermistor	1	.55	.55		12	1.35	1.35	.743
Ind. Lamp	2	175	1.50		24			
Fuse & Holder	1	.25	.25		10			
Control Sw.	1	.91	.91		50	4.419	4.419	4.021
Ident. Sw,	1	15.00	15.00		200	17.676	17.676	265.140
Conn. Ant.	1	.49	.49		15			
Conn. Pwr.	1	.66	.66		50			
Chassis	1	16.80	16.80	689	174			
RF PC Card	1	3.00	3.00		50			
Front Panel	1	9.00	9.00	250	100			
LED	44	.22	9.68		220	.155	6.82	1.500
Dimmer	1	.55	.55		15	.644	.664	.365
TOTALS			60.34	939	1126 X 2		34.863	$\frac{272.565}{34.863} = 7.82$

SYSTEM NARCO

SUB-ASSEMBLY ENCODER MODULE

SHEET 1 OF 1

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
RESISTOR - PREC.	11	.25	2.75		55	.013	.143	.036
RESISTOR - POT	5	.95	4.75		75	.664	3.32	3.154
RESISTOR -TEMP. COMP	1	1.50	1.50		5	1.35	1.35	2.025
THERMISTOR	1	.56	.56		5	1.35	1.35	.756
CONTROL CONNECTOR	1	.75	.75		8	1.35	1.35	1.013
THERMAL CUT-OFF	1	.25	.25		15			
PC BOARD	1	5.00	5.00	818	25			
CONNECTOR	1	1.00	1.00		15			
FUNCTIONAL CONN.	1	.45	.45		5			
MISC. HARDWARE	LOT	1.50	1.50		25			
18 COND. CABLE	1	2.50	2.50		1042.			
ALIGNMENT & TEST					1000.			
6 CONDUCTOR CABLE W. PLUG	1	1.00	1.00		250.			
TOTALS			73.39	818	3088x1.5		51.385	$\frac{597.575}{51.385} = 11.24$

SYSTEM DABS

SHEET 1 OF 1

SUB-ASSEMBLY ATC MESSAGE DISPLAY

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
54143	25	12.00	300.00		250	.715	17.875	214.5
54186	1	20.58	20.58		10	.715	.715	14.715
54164	9	10.10	90.90		72	.715	6.435	64.994
DM7820	1	7.00	7.00		8	.715	.715	5.005
Timing Circuits	1	15.00	15.00		50	2.860	2.860	42.900
Power Supply	1	40.00	40.00		100	20.000	20.000	800.
Face Plate	1	2.00	2.00	325	25	-	-	
Chassis	1	5.00	5.00	300	100	-	-	
Cover	1	1.00	1.00	100	75	-	-	
Connector-MS	1	15.00	15.00		200	-	-	
Stripline	2	1.50	3.00		250	-	-	
P C Board	2	5.00	10.00	970	50	-	-	
C&S				500		-	-	
Assembly					250	-	-	
Test					500	-	-	
Born-In					1000	-	-	
Led (7 Seg)	25	.50	12.50		250	.155	3.875	1.938
TOTALS			521.98	2195	3190		52.479	$\frac{1144.052}{52.479} = 21.80$

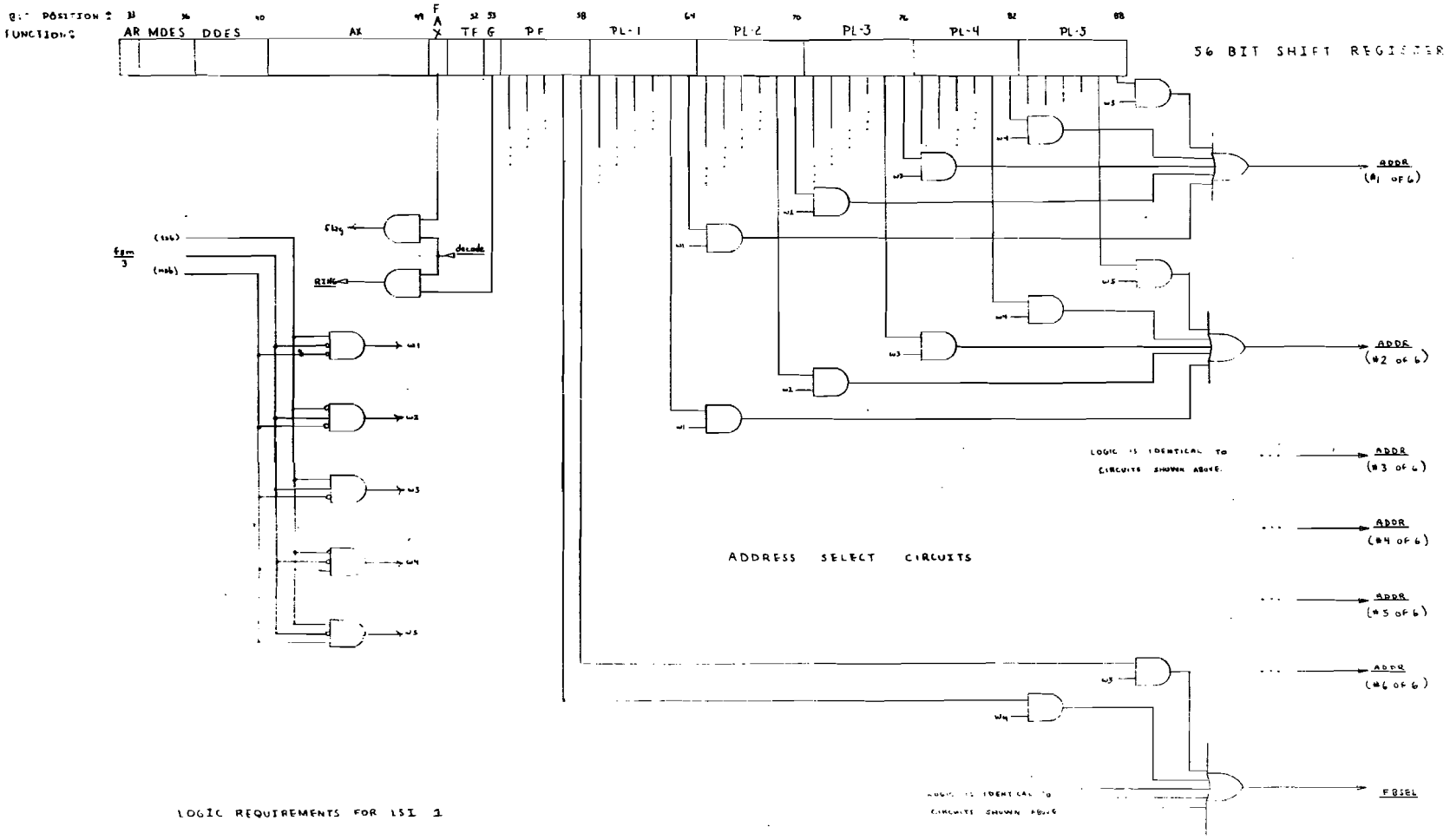
APPENDIX C

IPC DISPLAY

SIMPLIFIED LOGIC DIAGRAM

IPC/PWI DISPLAY
LSI-1 CIRCUIT SCHEMATIC (PART A)

6/29/75 DAA



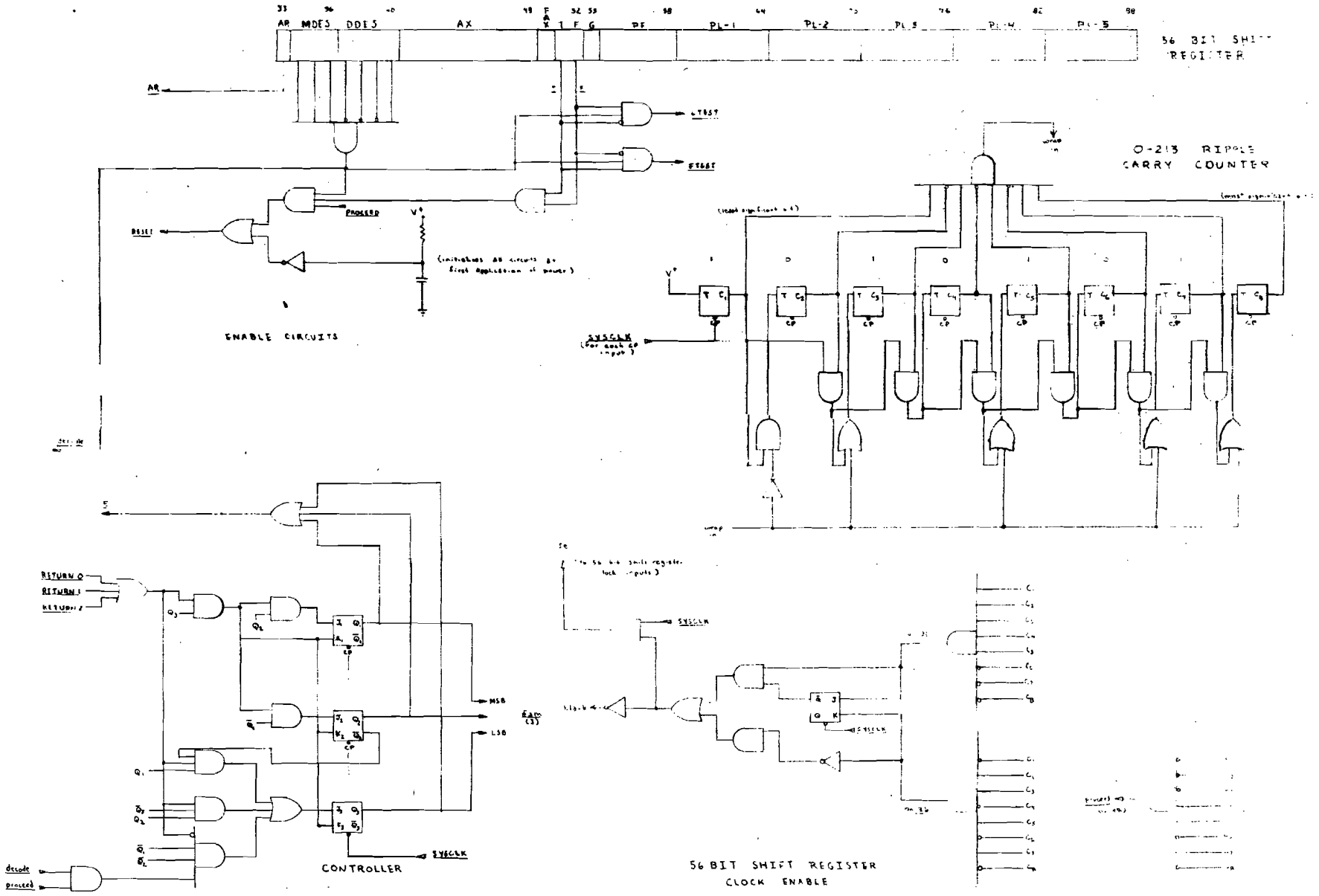
LOGIC REQUIREMENTS FOR LSI 1

FUNCTION	# GATES
56 BIT MASTER/SLAVE SHIFT REGISTER WITH CLEAR D-REGT	360
PWI ADDRESS AND FLASH BIT SELECT	41
SYSTEM CLOCK 0-213 COUNTER	43
SHIFT REGISTER ENABLE AND CONTROLLER ENABLE	26
CONTROLLER	43
IPC DECODER CIRCUIT	54
	817 TOTAL GATES

NOTE UNDERLINED NAMES REFER TO INPUTS AND OUTPUTS FOUND IN THE IPC/PWI BLOCK DIAGRAM.

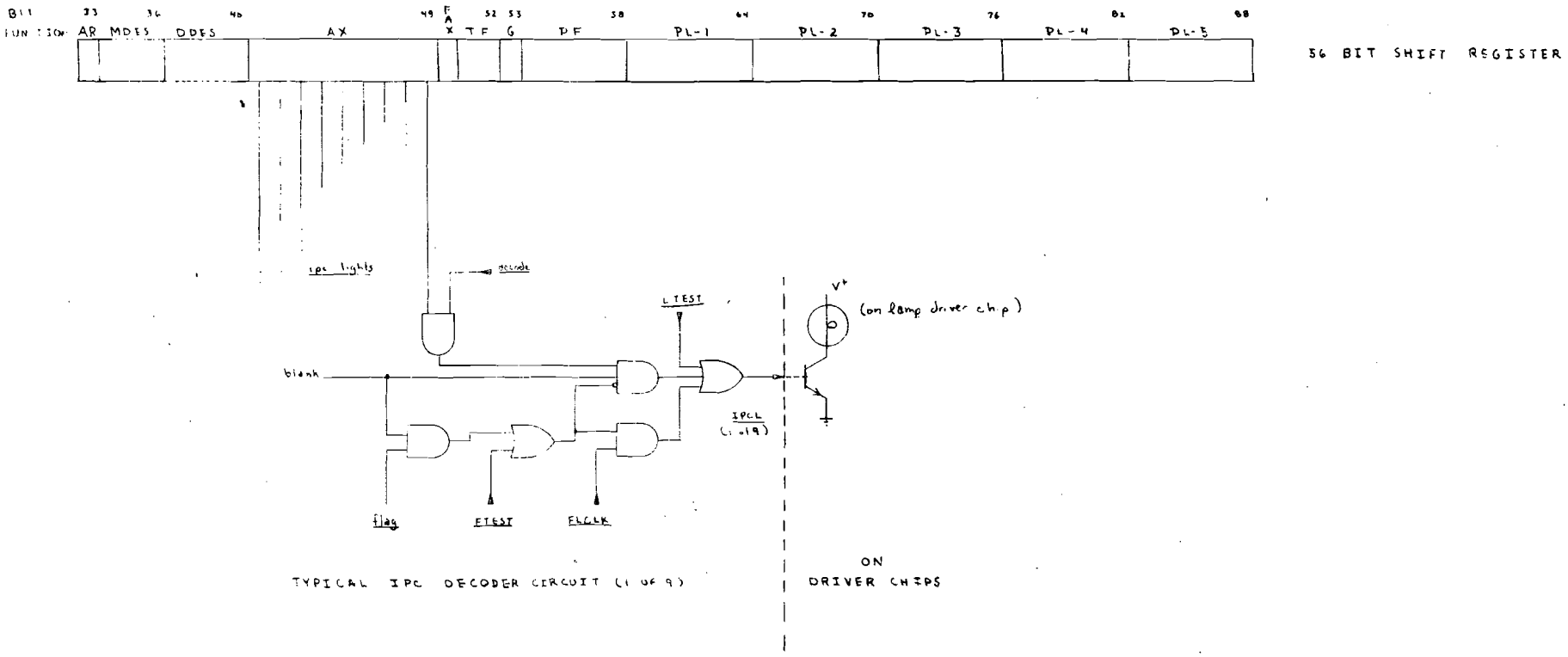
IPC/PWI DISPLAY
LSI-1 CIRCUIT SCHEMATIC (PART B)

6/29/75 DAK



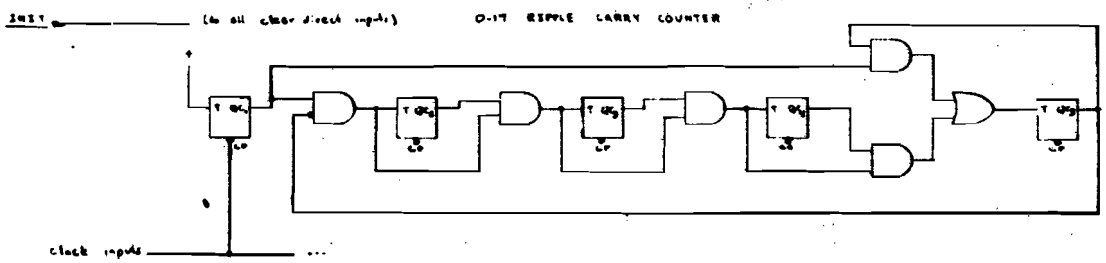
IPC/PWI DISPLAY
LSI-1 CIRCUIT SCHEMATIC (PART C)

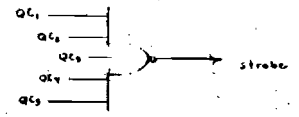
7/7/75

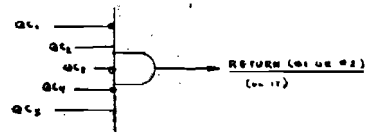


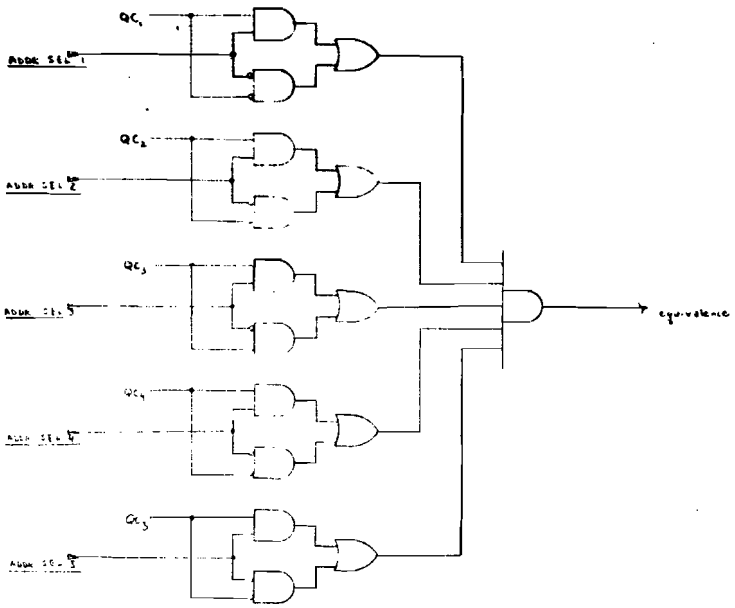
IPC/PWI DISPLAY
LSI-3/LSI-4 CIRCUIT SCHEMATIC (PART A)

7/7/75 DAL







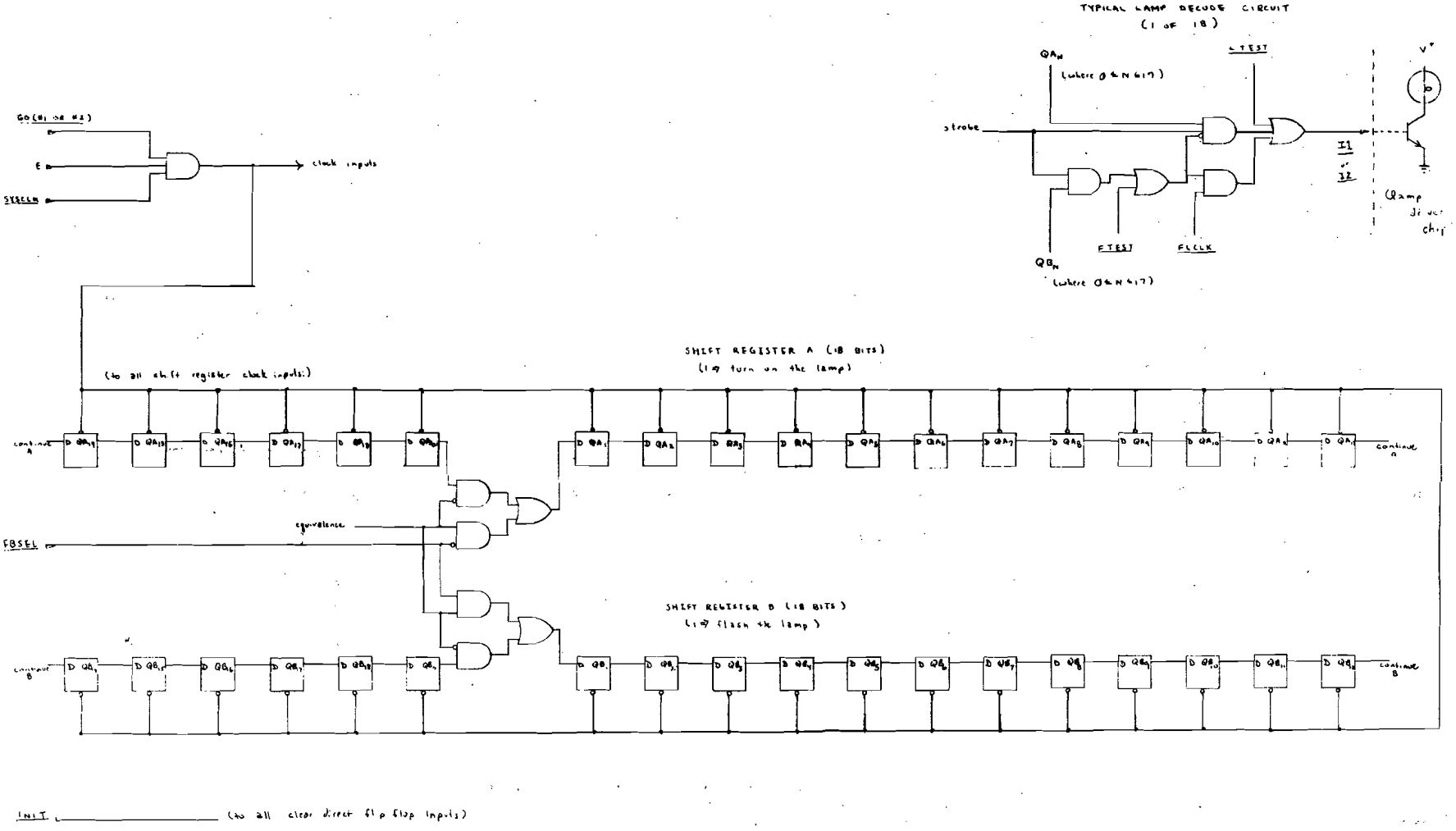


LOGIC REQUIREMENTS FOR LSI-3 OR LSI-4

D-17 RIPPLE CARRY COUNTER	56
EQUIVALENCE AND RETURN CIRCUITS	17
LAMP MEMORY CIRCUITS	367
LAMP DECODE CIRCUITS	115
	555 TOTAL GATES

IPC/PWI DISPLAY
LSI-3/LSI-4 CIRCUIT SCHEMATIC (PART B)

7/7/75 DAd



APPENDIX D

LIFE CYCLE COST MODEL

CONTENTS

1. Mathematical Formulation of the Cost Model

2. CAS Life Cycle Cost Model Parameter Summary

3. Typical Data File for "Test" CAS

4. Typical User File for "Use" Category

5. Life Cycle Cost Model Program

REVISION No. 1

LIFE CYCLE COST MODEL FOR THE EVALUATION OF LIFE CYCLE COSTS, SYSTEM OPERABILITY AND RELIABILITY OF ALTERNATIVE COLLISION AVOIDANCE SYSTEMS

Prepared For

FEDERAL AVIATION ADMINISTRATION
OFFICE OF SYSTEMS ENGINEERING MANAGEMENT

AEM-200
UNDER CONTRACT DOT-FA 74WA-3506

3 September 1974
Revised 16 October 1974

Prepared By

The Telecommunications Program
of
ARINC Research Corporation
a Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

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1.	GENERAL DESCRIPTION	1
2.	PROGRAM FEATURES	1
3.	MODEL FORMULATION	2
4.	SAMPLE RESULTS	15

1. GENERAL DESCRIPTION

ARINC Research Corporation's life cycle cost model (LCCM) has been adapted to evaluate the economic impact of proposed collision avoidance systems (CAS) and to provide a basis for cost comparisons among the several competing CAS concepts currently under development. The specific concepts being evaluated within the current ARINC Research study are:

(1) AVOIDS (Minneapolis-Honeywell)
(2) EROS (McDonnell-Douglas)
(3) SECANT (RCA)

The model evaluates each of these concepts in three different user environments: Commercial Aviation, General Aviation, and Military Aviation. Further, within each user category and concept combination evaluation, the model considers (as appropriate) three levels of CAS: a full or commercial aviation capability, a limited or general aviation capability, and a remitter capability. The distribution of these three levels within a specific user category is specified by the input data to the model.

The model itself is an expected value model which has been programmed in FORTRAN for evaluation using the Control Data KRONOS 2.1 Time Sharing System. The model computes the expected acquisition, installation and logistic support costs by year and cumulative for each concept/user combination desired. The program is designed for flexibility so that data changes can be readily implemented, sensitivity evaluations can be performed, or additional data outputs can be obtained.

2. PROGRAM FEATURES

The CAS LCCM implementation consists of a common main program, called CASCOST, and six input data files called AVOIDS, EROS, SECANT, COM, GEN, and MIL. (Differences due to the specific user categories are handled through appropriate modification of the data files.) At the beginning of the program's exercise, the system and user file names are specified from the teletype terminal keyboard. The program then calls the designated files and reads them to obtain the specific data parameters used in the evaluation.

In addition to calling the user and system files, the inflation rate and the type of evaluation to be performed (i.e., whether for full only, limited only, remitter only, or the composite of all three) are also specified as inputs from the teletype terminal keyboard.

The specific outputs of the model are as follows:

(1) The total acquisition cost for the designated user category and system by year and cumulative.

(2) The total installation cost for the designated user category and system by year and cumulative.

(3) The total non-recurring logistic support cost for the designated user category and system by year.

(4) The total recurring logistic support cost for the designated user category and system by year.

(5) The total logistic support cost for the designated user category and system by year and cumulative.

(6) The total cost for the designated user category and system by year and cumulative.

(7) The cost per aircraft for the designated user category and system by year (e.g., the cumulative total cost in year I divided by the number of CAS equipped user aircraft in year I.)

(8) The ratio of average cumulative total logistic support cost to cumulative acquisition cost in percent for the designated user category and system by year (e.g., 100 times the cumulative total logistic support cost in year I divided by I times the cumulative acquisition cost in year I.)

(9) The detailed cost element breakdowns of the non-recurring, recurring and total logistic support costs for the designated user and system by year.

(10) The cost per aircraft per year to the aircraft owner and the corresponding average annual logistic support to acquisition cost ratio (General Aviation case only).

3. MODEL FORMULATION

The following describes the mathematical formulation of the CAS LCCM which has been implemented into the program CASCOST. The parameter definitions used in the model are presented in Attachment A and correspond to those previously submitted to the FAA.* As noted earlier, the model computes on a yearly and cumulative basis the acquisition, installation, logistic support costs, and their totals for a given CAS system concept and user category combination in the time period 1978-1988. Inflation factors are applied to all of the cost categories over the time period of interest.

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* Submitted in conjunction with the revision of the "Recommended Uniform Ground Rules for the Evaluation of Life-Cycle Costs, Systems Operability and Reliability of Alternative Collision Avoidance Systems"prepared for the FAA by ARINC Research on 9 August 1974.

3.1 Acquisition Costs

The acquisition costs are determined by the number of CAS systems purchased for a given user category each year, the average unit cost of the systems during the year (reflecting learning and amortization factors), and the effects of inflation. The acquisition costs for the i'th year are given by:

$$
\begin{aligned}
ACOS_i &= \Big[F(FUCOS + AFCOS) + L(LUCOS + ALCOS) \\
&\quad + E(EUCOS + AECOS)\Big] \; (1 + XINF)^{i-1}; \; i \leq 2 \\
&= \Big[F(FUCOS + L(LUCOS) + E(EUCOS)\Big] \; (1 + XINF)^{i-1}; \; i > 2 \qquad (1)
\end{aligned}
$$

where:

$$F = Q(Q1) \; (IRAC_i + NNAC_i) \qquad (2)$$

$$L = Q(1-Q1) \; (1-FREM) \; (IRAC_i + NNAC_i) \qquad (3)$$

$$E = Q(1-Q1) \; (FREM) \; (IRAC_i + NNAC_i) \qquad (4)$$

$IRAC_i$ = the number of aircraft retrofitted in year i

$NNAC_i$ = the number of new aircraft in year i

All other variables are as identified in Attachment A.

The cumulative acquisition cost is simply:

$$TCOSA_i = \sum_{j=1}^{i} ACOS_j \qquad (5)$$

3.2 Installation Costs

The installation cost in the i'th year is determined simply by the number of CAS units installed in new aircraft or retrofited into existing aircraft that year times the appropriate per unit installation rate and modified by the inflation factor. The resultant installation cost is given by:

$$ICOS_i = Q \Big[Q1\ (IRAC_i \cdot RICOS + NNAC_i \cdot FICOS) + (1-Q1)\ (1-FREM)\ (IRAC_i \cdot LRCOS + NNAC_i \cdot LICOS) + (1-Q1)\ (FREM)\ (IRAC_i \cdot ERCOS + NNAC_i \cdot EICOS) \Big]\ (1 + XINF)^{i-1} \qquad (6)$$

The cumulative installation cost is simply:

$$TOCI_i = \sum_{j=1}^{i} ICOS_j \qquad (7)$$

3.2 Logistic Support Cost

The logistic support cost is considered to be composed of the sum of eight cost elements, each having a non-recurring and recurring cost component. Hence, the logistic support cost in the i'th year and the cumulative logistic support cost to that year are given by:

$$LCOS_i = \sum_{j=1}^{8} \Big[NRCOS_{i,j} + RLCOS_{i,j} \Big] \qquad (8)$$

$$TCOSL_i = \sum_{j=1}^{i} LCOS_j \tag{9}$$

The following paragraphs present the methodology for determining the individual cost elements and their components.

3.3.1 Initial and Replacement Spares

This cost element consists of the expenses associated with the procurement of the spares inventory. The nonrecurring component is the expenditure in the i'th year to purchase the additional spares required to satisfy the demand with a given level of spares sufficiency. In determining the nonrecurring costs, there are several assumptions and constraints which should be noted:

(1) A minimum of one spare at each base is assumed for the principal electronics, pilot's maneuver indicator, and control panel for each level of CAS capability.

(2) A minimum of one spare of each type of principal electronics module is assumed for each depot.

(3) No spares are assumed for the complete antenna systems.

The recurring spares cost represents the cost of purchasing additional spares to replace those which are lost to the logistic system through condemnation actions. Inflation factors are applied to both components. The resultant components are given by:

$$
\begin{aligned}
NRCOS_{i,1} = \Bigg\{ & \sum_{j=1}^{NFMOD} \Bigg[\frac{(PFOH)(Q)(Q1)}{FMTBF_j} \Big[DRCT(1-RTS_j) + BRCT(RTS_j) \Big] \\
& + SUF \sqrt{\frac{(PFOH)(Q)(Q1)}{FMTBF_j} \Big[DRCT(1-RTS_j) + BRCT(RTS_j) \Big]} - TSPRF_j \Bigg] FUC_j \\
& + \sum_{j=1}^{NFMOD} \Bigg[\frac{(PFOH)(Q)(1-Q1)(1-FREM)}{LMTBF_j} \Big[DRCT(1-RTS_j) + BRCT(RTS_j) \Big] \\
& + SUF \sqrt{\frac{(PFOH)(Q)(1-Q1)(1-FREM)}{LMTBF_j} \Big[DRCT(1-RTS_j) + BRCT(RTS_j) \Big]} \\
& - TSPRL_j \Bigg] LUC_j + \sum_{j=1}^{NEMOD} \Bigg[\frac{(PFOH)(Q)(1-Q1)(FREM)}{EMTBF_j} \Big[DRCT(1-RTS_j) \\
& + BRCT(RTS_j) \Big] + SUF \sqrt{\frac{(PHOH)(Q)(1-Q1)(FREM)}{EMTBF_j}} \\
& \sqrt{\Big[DRCT(1-RTS_j) + BRCT(RTS_j) \Big]} - TSPRE_j \Bigg] EUC_j \Bigg\} (1+XINF)^{i-1} \qquad (10)
\end{aligned}
$$

$$RLCOS_{i,1} = (TFOH)(Q)\left\{ Q1 \sum_{j=1}^{NFMOD} \frac{(FUC_j)(COND_j)}{(FMTBF_j)} \right.$$

$$+ (1-Q1)(1-FREM) \sum_{j=1}^{NLMOD} \frac{(LUC_j)(COND_j)}{(LMTBF_j)}$$

$$\left. + (1-Q1)(FREM) \sum_{j=1}^{NEMOD} \frac{(EUC_j)(COND_j)}{(EMTBF_j)} \right\} (1+XINF)^{i-1} \qquad (11)$$

where:

$$PFOH = (PHR)(NAC_i - (IT-i)/IT) \; ; \; i \leq IT$$

$$= (PHR)(NAC_i) \; ; \; i > IT \qquad (12)$$

$$TFOH = 12(AHR)(NAC_i - (IT-i)/IT) \; ; \; i \leq IT$$

$$= 12(AHR)(NAC_i) \; ; \; i > IT \qquad (13)$$

$$NFMOD = NMODF + 4$$

$$NLMOD = NMODL + 4$$

$$NEMOD = NMODE + 4$$

$TSPRF_j$, $TSPRL_j$ and $TSPRE_j$ represent the total number of the j'th type of spares purchased prior to the year i.

3.3.2 On-Aircraft Maintenance

This cost element represents the expected expenditure in performing on-aircraft corrective maintenance. This element contains only a recurring cost component, i.e., $NRCOS_{i,2} = 0$, and represents the labor cost associated with remove and replace actions. It is assumed that no individual principal electronics modules will be removed and replaced on an on-aircraft basis. The cost element is given by:

$$RLCOS_{i,2} = (TFOH)(Q)(BLR)\left\{\sum_{j=1}^{4} \frac{(Q1)(FRMH_j)}{(FMTBF_j)} + \frac{(1-Q1)(1-FREM)(LRMH_j)}{(LMTBF_j)} + \frac{(1-Q1)(FREM)(ERMH_j)}{(EMTBF_j)}\right\}(1+XINF)^{i-1} \tag{14}$$

3.3.3 Off-Aircraft Maintenance

The expected labor, materiel, and shipping costs associated with performing corrective maintenance at base and depot locations are represented by this cost element. Like the preceeding element, this element is a recurring cost only, i.e. $NRCOS_{i,3} = 0$. The element is given by: (the factor 1.125 shown in the equation represents the additional weight due to packaging for shipment.)

$$
\begin{aligned}
RLCOS_{i,3} = (TFOH)(Q) \Bigg\{ & Q1 \sum_{j=1}^{NFMOD} \Big[(FDMH_j)\big[(RTS_j)(BLR) + (1-RTS_j)(DLR)\big] \\
& + FDMC_j + 1.125\ (SHC)(FWT_j)\big[2(1-RTS_j)(1-FCOND_j) + FCOND_j\big]\Big] / (FMTBF_j) \\
& + (1-Q1)(1-FREM) \sum_{j=1}^{NLMOD} \Big[(LDMH_j)\big[(RTS_j)(BLR) + (1-RTS_j)(DLR)\big] \\
& + LDMC_j + 1.125\ (SHC)(LWT_j)\big[2(1-RTS_j)(1-LCOND_j) + LCOND_j\big]\Big] / LMTBF_j) \\
& + (1-Q1)(FREM) \sum_{j=1}^{NEMOD} \Big[(EDMH_j)\big[(RTS_j)(BLR) + (1-RTS_j)(DLR)\big] \\
& + EDMC_j + 1.125\ (SHC)(EWT_j)\big[2(1-RTS_j)(1-ECOND_j) \\
& + ECOND_j\big]\Big] / (EMTBF_j) \Bigg\} (1 + XINF)^{i-1} \qquad (15)
\end{aligned}
$$

3.3.4 Inventory Entry and Supply Management

This cost element represents the management cost associated with introducing and maintaining new coded supply items into the user inventory and the management cost of maintaining a supply inventory for all of the coded items for the system that are stocked at the repair sites. The first year's inventory entry cost is treated as a nonrecurring cost and is then treated as part of the recurring cost in subsequent years. The supply management cost is treated as a recurring cost throughout. The resultant components are given by:

$$NRCOS_{i,4} = (IAC)\left[(PPF)(PPFB) + (PPL)(PPLB) + (PPE)(PPEB)\right] \; ; \quad i = 1$$

$$= 0 \; ; \quad i > 1 \tag{16}$$

$$RLCOS_{i,4} = SA\left[4\,(PPFB+PPLB+PPEB)(NBAS_i) + \left[(TPF)(PPFB) + (TPL)(PPLB) + (TPE)(PPEB)\right](NDEP_i)\right] \; ; \quad i = 1$$

$$= \left\{(IAC)\left[(PPF)(PPFB) + (PPL)(PPLB) + (PPE)(PPEB)\right] + SA\left[4(PPFB+PPLB+PPEB)(NBAS_i) + \left[(TPF)(PPFB) + (TPL)(PPLB) + (TPE)(PPEB)\right](NDEP_i)\right]\right\}(1+XINF)^{i-1} \; ; \quad i > 1 \tag{17}$$

where:

$$PPFB = 0; \quad Q1 = 0$$

$$= 1; \quad Q1 \neq 0$$

$$PPLB = 0; \quad Q1 = 1 \text{ or } FREM = 1$$

$$= 1; \quad Q1 \neq 1 \text{ and } FREM \neq 1$$

$$PPEB = 0; \quad Q1 = 1 \text{ or } FREM = 0$$

$$= 1; \quad Q1 \neq 1 \text{ and } FREM \neq 0$$

3.3.5 Special Support Equipment

This cost element includes the nonrecurring cost of purchasing special test equipment ($NRCOS_{i,5}$) and the recurring cost of operating the test equipment ($RLCOS_{i,5}$). It is assumed in the model that the test equipment will be unique to the principal electronics and will only be operated at depot level facilities. It is further assumed that there will be a minimum of one such unit at each depot facility. The nonrecurring and recurring costs of special support equipment in the i'th year, assuming NSUPF, NSUPL, and NSUPE units of support equipment have been purchased prior to year i, are given by:

$$NRCOS_{i,5} = \left\{ \left[\frac{(PFOH)(Q)(Q1)(FDMH_1)(DUR)}{(FMTBF_1)(ATE)(DAA)} - NSUPF \right] (CADF) \right.$$

$$+ \left[\frac{(PFOH)(Q)(1-Q1)(1-FREM)(LDMH_1)(DUR)}{(LMTBF_1)(ATE)(DAA)} - NSUPL \right] (CADL)$$

$$\left. + \left[\frac{(PFOH)(Q)(1-Q1)(FREM)(EDMH_1)(DUR)}{(EMTBF_1)\ (ATE)\ (DAA)} - NSUPE \right] (CADE) \right\}$$

$$(1+XINF)^{i-1} \tag{18}$$

$$RLCOS_{i,5} = \frac{(PFOH)(Q)(DUR)}{(ATE)(DAA)} \left[\frac{(Q1)(FDMH_1)(CODF)}{(FMTBF_1)} + \frac{(1-Q1)(1-FREM)(LDMH_1)(CODL)}{(LMTBF_1)} + \frac{(1-Q1)(FREM)(EDMH_1)(CODE)}{(EMTBF_1)} \right] (1+XINF)^{i-1} \quad (19)$$

3.3.6 Training

The training cost consists of the specialized maintenance training to meet the expected corrective maintenance demands ($NRCOS_{i,6}$) and the recurrent cost of additional specialized training resulting from turnover of personnel ($RLCOS_{i,6}$). It is assumed that training requirements are associated with only the principal electronics and are common to all three levels of systems. It is further assumed that this training cost is only incurred for depot level personnel and that a minimum of one person per depot will receive training. The training costs in the i'th year are then, assuming NPERS have been trained prior to year i:

$$NRCOS_{i,6} = \left\{ \frac{(TFOH)(Q)}{(PMD)} \left[(Q1) \sum_{\substack{j=1 \\ j\neq 2,3,4}}^{NFMOD} \frac{(FDMH_j)}{(FMTBF_j)} + (1-Q1)(1-FREM) \sum_{\substack{j=1 \\ j\neq 2,3,4}}^{NLMOD} \frac{(LDMH_j)}{(LMTBF_j)} + (1-Q1)(FREM) \sum_{\substack{j=1 \\ j\neq 2,3,4}}^{NEMOD} \frac{(EDMH_j)}{(EMTBF_j)} \right] - NPERS \right\} (TCD)(1+XINF)^{i-1} \quad (20)$$

$$RLCOS_{i,6} = \frac{(TFOH)(Q)(TRD)(TCD)}{(PMD)} \left[(Q1) \sum_{\substack{j=1 \\ j \neq 2,3,4}}^{NFMOD} \frac{(FDMH_j)}{(FMTBF_j)} \right.$$

$$+ (1-Q1)(1-FREM) \sum_{\substack{j=1 \\ j \neq 2,3,4}}^{NLMOD} \frac{(LDMH_j)}{(LMTBF_j)}$$

$$\left. + (1-Q1)(FREM) \sum_{\substack{j=1 \\ j \neq 2,3,4}}^{NEMOD} \frac{(EDMH_j)}{(EMTBF_j)} \right] (1+XINF)^{i-1} \; ; \quad i > 1$$

$$= 0; \quad i = 1 \tag{21}$$

3.3.7 Data Management and Technical Documentation

This cost element consists of the recurring costs arising from the labor time involved in filling out the necessary forms associated with each maintenance action ($RLCOS_{i,7}$) and the nonrecurring cost ($NRCOS_{i,7}$) associated with the preparation of base and depot level documentation. These are given by:

$$NRCOS_{i,7} = TD \left[(NBDF+NDDF)(PPFB) + (NBDL+NDDL)(PPLB) + (NBDE+NDDE) \right.$$

$$\left. (PPEB) \right] \; ; \quad i = 1$$

$$= 0; \quad i > 1 \tag{22}$$

$$RLCOS_{i,7} = (TFOH)(Q)(BLR)\left\{\sum_{j=1}^{4}\left[\frac{(Q1)(OR+FR+SR+(1-RTS_j)TR)}{(FMTBF_j)} + \frac{(1-Q1)(1-FREM)(OR+FR+SR+(1-RTS_j)TR)}{(LMTBF_j)} + \frac{(1-Q1)(FREM)(OR+FR+SR+(1-RTS_j)TR)}{(EMTBF_j)}\right]\right\}(1+XINF)^{i-1} \quad (23)$$

3.3.8 Facilities

The facilities costs are considered to consist of the recurring operating costs of the repair facilities (e.g., space rent, electricity, general tools, telephone, etc.) It is assumed that no new support facilities will be needed for the system and hence no nonrecurring costs will be required, i.e., $NRCOS_{i,8} = 0$. The recurring cost is then given by:

$$RLCOS_{i,8} = \left[(FIB)(NBAS_i) + (FID)(NDEP_i)\right](1+XINF)^{i-1} \quad (24)$$

4. SAMPLE RESULTS

In order to demonstrate the application of the model and its resultant outputs, the program was exercised for a sample system (File Name TEST) and a sample user (File Name USE). Attachments B through D present the data files used for this exercise as well as the listing of CASCOST. The resultant output obtained from the program exercise is presented below.

TYPICAL LIFE CYCLE COST PROFILE PRINTOUT

"TEST" CAS IN A "USE" CATEGORY

RUN,MA=77777

74/08/26. 16.19.33.
PROGRAM CASCOST

-------CAS LIFE CYCLE COST EVALUATION-------
SYSTEM ? TEST
USER ? USE

YEAR	ACQ COST	CUM COST	INST COST	CUM COST
1978	1733774	1733774	4176458	4176458
1979	1299975	3033749	4427045	8603503
1980	1175809	4209558	4692668	13296172
1981	1150699	5360257	4974228	18270400
1982	1149493	6509750	5272682	23543082
1983	1162231	7671981	5588043	29132125
1984	1184509	8856490	5924385	35056510
1985	1214064	10070554	6279849	41336359
1986	181342	10251896	551392	41887751
1987	191430	10443326	584475	42472226
1988	202095	10645421	619544	43091770

YEAR	NREC LCOST	REC LCOST	TOT LCOST	CUM LCOST
1978	242500	437312	679812	679812
1979	151580	645993	797573	1477386
1980	161209	871105	1032313	2509699
1981	180230	1120913	1301143	3810842
1982	185048	1397856	1582903	5393745
1983	196318	1703364	1899682	7293427
1984	217530	2041171	2258701	9552128
1985	230882	2433387	2664270	12216398
1986	30682	2616385	2647067	14863464
1987	35775	2812582	2848357	17711821
1988	35459	3022904	3058362	20770183

YEAR	CAS COST	CUM COST	PER A/C	ANNUAL LCOS/ACOS
1978	6590044	6590044	9243	39.21
1979	6524594	13114638	9203	24.35
1980	6900791	20015428	9362	19.37
1981	7426071	27441499	9629	17.77
1982	8005078	35446577	9949	16.57
1983	8650955	44097533	10315	15.84
1984	9367595	53465128	10719	15.41
1985	10158183	63623310	11162	15.16
1986	3379800	67003111	11552	16.11
1987	3624262	70627373	11971	16.96
1988	3880001	74507374	12418	17.74

DØ YØU WANT LØGISTIC SUPPØRT CØSTS BREAKDØWN BY YEAR?
TYPE YES ØR NØ ? YES

YEAR	ELEMENT	NREC LCØST	REC LCØST	TØT LCØST
1978				
	SPARES	173475	17963	191438
	ØNMAINT	0	9103	9103
	ØFFMAINT	0	125673	125673
	INVMGT	5775	11700	17475
	SUPPØRT	15250	241	15491
	TRAINING	3200	0	3200
	TECHDATA	44800	12633	57433
	FACILITIES	0	260000	260000
1979				
	SPARES	148188	38056	186244
	ØNMAINT	0	19284	19284
	ØFFMAINT	0	266239	266239
	INVMGT	0	18523	18523
	SUPPØRT	0	511	511
	TRAINING	3392	1018	4410
	TECHDATA	0	26763	26763
	FACILITIES	0	275600	275600
1980				
	SPARES	159411	60523	219933
	ØNMAINT	0	30668	30668
	ØFFMAINT	0	423419	423419
	INVMGT	0	19635	19635
	SUPPØRT	0	812	812
	TRAINING	1798	1348	3146
	TECHDATA	0	42563	42563
	FACILITIES	0	292136	292136
1981				
	SPARES	170464	85519	255983
	ØNMAINT	0	43335	43335
	ØFFMAINT	0	598293	598293
	INVMGT	0	20813	20813
	SUPPØRT	5955	1148	7103
	TRAINING	3811	2001	5812
	TECHDATA	0	60141	60141
	FACILITIES	0	309664	309664
1982				
	SPARES	181008	113328	294336
	ØNMAINT	0	57426	57426
	ØFFMAINT	0	792849	792849
	INVMGT	0	22062	22062
	SUPPØRT	0	1521	1521
	TRAINING	4040	2727	6767
	TECHDATA	0	79698	79698
	FACILITIES	0	328244	328244
1983				
	SPARES	194177	144133	338310
	ØNMAINT	0	73036	73036
	ØFFMAINT	0	1008363	1008363
	INVMGT	0	23385	23385
	SUPPØRT	0	1934	1934
	TRAINING	2141	3212	5353
	TECHDATA	0	101362	101362
	FACILITIES	0	347939	347939

```
1984
    SPARES          205898      178262      384160
    ØNMAINT              0       90330       90330
    ØFFMAINT             0     1247134     1247134
    INVMGT               0       24789       24789
    SUPPØRT           7093        2392        9485
    TRAINING          4539        4085        8625
    TECHDATA             0      125363      125363
    FACILITIES           0      368815      368815
1985
    SPARES          218177      215930      434107
    ØNMAINT              0      109418      109418
    ØFFMAINT             0     1510662     1510662
    INVMGT               0       33042       33042
    SUPPØRT           7894        1449        9343
    TRAINING          4812        5052        9864
    TECHDATA             0      151854      151854
    FACILITIES           0      405980      405980
1986
    SPARES           30682      232902      263583
    ØNMAINT              0      118018      118018
    ØFFMAINT             0     1629395     1629395
    INVMGT               0       35025       35025
    SUPPØRT              0        1563        1563
    TRAINING             0        5355        5355
    TECHDATA             0      163789      163789
    FACILITIES           0      430339      430339
1987
    SPARES           35775      251132      286907
    ØNMAINT              0      127256      127256
    ØFFMAINT             0     1756937     1756937
    INVMGT               0       37126       37126
    SUPPØRT              0        1685        1685
    TRAINING             0        5677        5677
    TECHDATA             0      176610      176610
    FACILITIES           0      456159      456159
1988
    SPARES           35459      270712      306171
    ØNMAINT              0      137177      137177
    ØFFMAINT             0     1893919     1893919
    INVMGT               0       39354       39354
    SUPPØRT              0        1816        1816
    TRAINING             0        6017        6017
    TECHDATA             0      190379      190379
    FACILITIES           0      483529      483529
DØ YØU WANT TØ RUN ANØTHER CASE (TYPE YES ØR NØ) ? NØ
   STØP
```

ATTACHMENT B

TYPICAL DATA FILE FOR "TEST"CAS

```
 74/03/26. 16.12.27.
PRØGRAM    TEST

10 TEST DATA FILE
20 FUCØS 10000. LUCØS 5000. EUCØS 3000.
30 AFCØS 50000. ALCØS 25000. AECØS 10000.
40 NMØDF 4 NANTF 2
50 LECTRØNICS FUC 300. FMTBF 1000. FWT 25.
60 FRMH .25 FDMH .5 FDMC 0. FCØND .001
70 INDICATØR FUC 250. FMTBF 3000. FWT 3.
80 FRMH .5 FDMH 2. FDMC 25. FCØND .01
90 CØNTRØL FUC 50. FMTBF 10000. FWT 1.
100 FRMH .25 FDMH .75 FDMC 5. FCØND .01
110 ANTENNA FUC 0. FMTBF 50000. FWT 0.
120 FRMH 2. FDMH 0. FDMC 50. FCØND 0.
130 XMTTR FUC 200. FMTBF 4000. FWT 0.
140 FRMH 0. FDMH 2. FDMC 50. FCØND .1
150 RCVR FUC 200 FMTBF 4000. FWT 0.
160 FRMH 0. FDMH 2. FDMC 25. FCØND .1
170 LØGIC FUC 200. FMTBF 4000. FWT 0.
180 FRMH 0. FDMH 3. FDMC 75. FCØND .1
190 BIT FUC 200 FMTBF 4000. FWT 0.
200 FRMH 0. FDMH 1. FDMC 20. FCØND .1
300 NMØDL 4 NANTL 2
310 LECTRØNICS FUC 500. LMTBF 500. LWT 15.
320 LRMH .25 LDMH .5 LDMC 0. LCØND .001
330 INDICATØR LUC 50. LMTBF 1000. LWT 2.
340 LRMH 1. LDMH 2. LDMC 10. LCØND .01
350 CØNTRØL LUC 50. LMTBF 10000. LWT .5
360 LRMH .5 LDMH .75 LDMC 5. LCØND .01
370 ANTENNA LUC 0. LMTBF 50000. LWT 0.
380 LRMH 2. LDMH 0. LDMC 50. LCØND 0.
390 XMTTR LUC 125. LMTBF 2000. LWT 0.
400 LRMH 0. LDMH 2. LDMC 50. LCØND .1
410 RCVR LUC 125. LMTBF 2000. LWT 0.
420 LRMH 0. LDMH 1.5 LDMC 30. LCØND .1
430 LØGIC LUC 125. LMTBF 2000. LWT 0.
440 LRMH 0. LDMH 3. LDMC 50. LCØND .1
450 BIT LUC 125. LMTBF 2000. LWT 0.
460 LRMH 0. LDMH 1. LDMC 20. LCØND .1
```

```
600 VMØDE 2 NANTE 1
610 LECTRØNICS EUC 175. EMTBF 1000. EWT 5.
620 ERMH .25 EDMH .5 EDMC 0. ECØND .001
630 INDICATØR EUC 0. EMTBF 10.E10 EWT 0.
640 ERMH 0. EDMH 0. EDMC 0. ECØND 0.
650 CØNTRØL EUC 25. EMTBF 10000. EWT .5
660 ERMH .75 EDMH 1. EDMC 2. ECØND .01
670 ANTENNA EUC 0. EMTBF 50000. EWT 0.
680 ERMH 2. EDMH 0. EDMC 25. ECØND 0.
690 XMITTER EUC 100. EMTBF 2000. EWT 3.
700 ERMH 0. EDMH 2. EDMC 30. ECØND .1
710 RCVR EUC 75. EMTBF 2000. EWT 2.
720 ERMH 0. EDMH 2. EDMC 20. ECØND .1
800 CADF 10000. CADL 5000. CADE 250.
810 CØDF 1000. CØDL 500. CØDE 25.
820 PPF 25. PPL 25. PPE 5.
830 TPF 150. TPL 125. TPE 100.
840 VBDF 50. VBDL 25. VBDE 5.
850 VDDF 100. VDDL 75. VDDE 25.
```

ATTACHMENT C

TYPICAL USER FILE FOR "USE" CATEGORY

```
 74/08/26. 16.17.21.
PRØGRAM   USE

10 USE DATA FILE
20 FICØS 5000. LICØS 2500. EICØS 1000.
30 RICØS 8000. LRCØS 5000. ERCØS 2000.
40 1978 NAC 5000 NBAS 50 NDEP 1
50 1979 NAC 5100 NBAS 50 NDEP 1
60 1980 NAC 5200 NBAS 50 NDEP 1
70 1981 NAC 5300 NBAS 50 NDEP 1
80 1982 NAC 5400 NBAS 50 NDEP 1
90 1983 NAC 5500 NBAS 50 NDEP 1
100 1984 NAC 5600 NBAS 50 NDEP 1
110 1985 NAC 5700 NBAS 50 NDEP 2
120 1986 NAC 5800 NBAS 50 NDEP 2
130 1987 NAC 5900 NBAS 50 NDEP 2
140 1988 NAC 6000 NBAS 50 NDEP 2
150 NRAC 4900 IT 8 Q 1.1 Q1 .3 PQTY 5000.
160 ATE .9
170 DRCT 2.
180 BRCT .33
190 AHR 80.
200 PHR 100.
210 SUF 0.
220 BLR 10.
230 SHC .33
240 DLR 15.
250 RTSE 0.
260 RTSI 1.
270 RTSC 1.
280 RTSA 1.
290 IAC 105.
300 DUR .95
310 SA 12.
320 DAA 160.
330 TCB 1600.
340 TCD 1600.
350 PMB 1680.
360 PMD 1788.
370 ØR .08
380 FR .24
390 SR .25
400 TR .16
410 TRB .33
420 TRD .15
425 TD 160.
430 FIB 5000.
440 FID 10000.
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ATTACHMENT D

LIFE CYCLE COST MODEL PROGRAM

CAS COST

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LNH
10 PRØGRAM CASCØST (INPUT,ØUTPUT,TAPE2,TAPE3)
20 DIMENSIØN NYR(12),NAC(12),NBAS(12),NDEP(12),ACØS(12),ICØS(12)
30 DIMENSIØN FUC(25),FMTBF(25),FWT(25),FRMH(25),FDMH(25),FDMC(25),
31+FCØND(25),LUC(25),EUC(25),TSPRF(25),TSPRL(25),TSPRF(25)
40 DIMENSIØN LMTBF(25),EMTBF(25),LWT(25),EWT(25),LRMH(25),ERMH(25),
41+LDMH(25),EDMH(25),LDMC(25),EDMC(25),LCØND(25),ECØND(25),AF(10),
42+AL(10),AE(10),AR(35),NRCØS(11,8),RLCØS(11,8),NLCØS(12),RTS(4)
50 REAL LUCØS,LICØS,LRCØS,LA,ICØS,LUC,LMTBF,LWT,LRMH,LDMH,LDMC
60 REAL LCØND,IAC,NRCØS,LCØS,L1,L2
61 REAL NBDF,NBDL,NBDE,NDDF,NDDL,NDDE
62 DIMENSIØN TNRCØS(12),TRLCØS(12),TLLCØS(12)
63 DIMENSIØN CRFT(12)
70 53 PRINT,*-------CAS LIFE CYCLE CØST EVALUATIØN-------*
80 PRINT,* SYSTEM*,
90 READ, SFILE
100 PRINT,* USER*,
110 READ, UFILE
120 CALL GET (5HTAPE2,SFILE,0,0)
130 CALL GET (5HTAPE3,UFILE,0,0)
140 READ (2,) L,L,L,L
150 READ (2,) L,L,FUCØS,L,LUCØS,L,EUCØS
160 READ (2,) L,L,AFCØS,L,ALCØS,L,AECØS
170 READ (3,) L,L,L,L
180 READ (3,) L,L,FICØS,L,LICØS,L,EICØS
190 READ (3,) L,L,RICØS,L,LRCØS,L,ERCØS
200 READ (3,) (L,NYR(I),L,NAC(I),L,NBAS(I),L,NDEP(I),I=1,11)
210 DATA FREM /.1/,XLRN/.85/,XINF/.06/
220 READ (3,) L,L,NRAC,L,IT,L,Q,L,Q1,L,POTY
230 IRAC=NRAC/IT
240 PRINT,* YEAR     ACQ CØST     CUM CØST    INST CØST     CUM CØST*
250 TCØSA=TCØSI=TCØSL=NNACT=TCØSR=TCØSN=0
260 B=ALØG(XLRN)/ALØG(2.0)
270 F1=L1=E1=0
280 EQUIVALENCE (FUCØS,FA),(LUCØS,LA),(FUCØS,EA)
290 AMØRF=AFCØS/2.$AMØRL=ALCØS/2.
300 AMØRE=AECØS/2.
310 DØ 1 I=1,11
320 ACØS(I)=ICØS(I)=0
330 NNAC=NAC(I)-NNACT-NRAC
335 CRFT(I)=NAC(I)-NRAC*(IT-I)/IT
336 IF(I.GT.IT)CRFT(I)=NAC(I)
337 IF(I.GT.IT)IRAC=0
340 F=INT(Q*Q1*(IRAC+NNAC))+1
350 L=INT(Q*(1-Q1)*(1-FREM)*(IRAC+NNAC))+1
360 E=INT(Q*(1-Q1)*FREM*(IRAC+NNAC))+1
```

```
370 F2=F1+F
380 L2=L1+L
390 E2=E1+E
400 IF(F1.GT.PØTY) GØTØ 2
410 IF(F2.GT.PØTY) GØTØ 3
420 XDUM=FA*(F2**(B+1)-F1**(B+1))/(F*(B+1))
430 GØTØ 4
440 3 XDUM=FA*((PØTY**(B+1)-F1**(B+1))/(B+1)+(F2-PØTY)*(PØTY**B))/F
450 GØTØ 4
460 2 XDUM=FA*(PØTY**B)
470 4 IF(I.GT.2) GØTØ 5
480 XDUM=XDUM+AMØRF/F
490 5 ACØS(I)=ACØS(I)+F*XDUM
500 IF(L1.GT.PØTY) GØTØ 6
510 IF(L2.GT.PØTY) GØTØ 7
520 XDUM=LA*(L2**(B+1)-L1**(B+1))/(L*(B+1))
530 GØTØ 8
540 7 XDUM=LA*((PØTY**(B+1)-L1**(B+1))/(B+1)+(L2-PØTY)*(PØTY**B))/L
550 GØTØ 8
560 6 XDUM=LA*(PØTY**B)
570 8 IF(I.GT.2) GØTØ 9
580 XDUM=XDUM+AMØRL/L
590 9 ACØS(I)=ACØS(I)+L*XDUM
600 IF(E1.GT.PØTY) GØTØ 10
610 IF(E2.GT.PØTY) GØTØ 11
620 XDUM=EA*(E2**(B+1)-E1**(B+1))/(E*(B+1))
630 GØTØ 12
640 11 XDUM=EA*((PØTY**(B+1)-E1**(B+1))/(B+1)+(E2-PØTY)*(PØTY**B))/E
650 GØTØ 12
660 10 XDUM=EA*(PØTY**B)
670 12 IF(I.GT.2) GØTØ 13
680 XDUM=XDUM+AMØRE/E
690 13 ACØS(I)=(ACØS(I)+F*XDUM)*((1+XINF)**(I-1))
700 TCØSA=TCØSA+ACØS(I)
710 IF(I.LE.IT)GØTØ 14
720 IRAC=0
730 14 ICØS(I)=Q*(Q1*(IRAC*RICØS+NNAC*FICØS)+(1-Q1)*(1-FREM)*(IRAC*
731+LRCØS+NNAC*LICØS)+(1-Q1)*FREM*(IRAC*ERCØS+NNAC*EICØS))*((
732+1+XINF)**(I-1))
740 TCØSI=TCØSI+ICØS(I)
750 PRINT 901, NYR(I),ACØS(I),TCØSA,ICØS(I),TCØSI
760 901 FØRMAT (I5,4F12.0)
770 F1=F2
780 L1=L2
790 E1=E2
800 1 NNACT=NNACT+NNAC
810 READ (2,) L,L,NMØDF,L,NANTF
820 NFMØD=NMØDF+4
830 DØ 15 I=1,NFMØD
840 READ (2,) L,L,L,FUC(I),L,FMTBF(I),L,FWT(I)
850 READ (2,) L,L,FRMH(I),L,FDMH(I),L,FDMC(I),L,FCØND(I)
851 15 CØNTINUE
860 READ (2,) L,L,NMØDL,L,NANTL
870 NLMØD=NMØDL+4
880 DØ 16 I=1,NLMØD
890 READ (2,) L,L,L,LUC(I),L,LMTBF(I),L,LWT(I)
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```
900 16 READ (2,) L,L,LRMH(I),L,LDMH(I),L,LDMC(I),L,LCOND(I)
910 READ (2,) L,L,NMODE,L,NANTE
920 NEMOD=NMODE+4
930 DO 17 I=1,NEMOD
940 READ (2,) L,L,L,EUC(I),L,EMTBF(I),L,EWT(I)
950 17 READ (2,) L,L,ERMH(I),L,EDMH(I),L,EDMC(I),L,ECOND(I)
960 READ (2,)(L,L,AF(I),L,AL(I),L,AE(I),I=1,6)
980 EQUIVALENCE (AF(1),CADF),(AL(1),CADL),(AE(1),CADE),(AF(2),CODF),(
981+AL(2),CODL),(AE(2),CODE),(AF(3),PPF),(AL(3),PPL),(AE(3),PPE),(AF(4),
982+TPF),(AL(4),TPL),(AE(4),TPE),(AF(5),NBDF),(AL(5),NBDL),(AE(5),
983+NBDE),(AF(6),NDDF),(AL(6),NDDL),(AE(6),NDDE)
990 READ (3,)(L,L,AR(I),I=1,30)
1000 EQUIVALENCE (AR(1),ATE),(AR(2),DRCT),(AR(3),BRCT),(AR(4),AHR),(
1001+AR(5),PHR),(AR(6),SUF),(AR(7),BLR),(AR(8),SHC),(AR(9),DLR),(AR(
1002+10),RTS(1)),(AR(11),RTS(2)),(AR(12),RTS(3)),(AR(13),RTS(4)),(AR
1003+(14),IAC),(AR(15),DUR),(AR(16),SA),(AR(17),DAA),(AR(18),TCB),(
1004+AR(19),TCD),(AR(20),PMB),(AR(21),PMD),(AR(22),OR),(AR(23),FR),
1005+(AR(24),SR),(AR(25),TR),(AR(26),TRB),(AR(27),TRD),(AR(28),TD),
1006+(AR(29),FIB),(AR(30),FID)
1009 PRINT,*  *
1010 PRINT,* YEAR  NREC LCOST   REC LCOST   TOT LCOST   CUM LCOST*
1015 NSUPF=NSUPL=NSUPE=NPERS=0
1020 FMTBF(4)=FMTBF(4)/NANTF
1021 FAILF=FAILL=FAILE=0.
1022 DO 46 K=2,4
1023 FAILF=FAILF+1/FMTBF(K)
1024 FAILL=FAILL+1/LMTBF(K)
1025 46 FAILE=FAILE+1/EMTBF(K)
1030 LMTBF(4)=LMTBF(4)/NANTL
1040 EMTBF(4)=EMTBF(4)/NANTE
1042 DO 21 K=1,25
1044 21 TSPRF(K)=TSPRL(K)=TSPRE(K)=0
1050 DO 18 I=1,11
1060 MINSPB=NBAS(I)
1070 MINSPD=NDEP(I)
1072 TNRCOS(I)=TRLCOS(I)=0
1080 IF(UFILE.EQ.34GEN)RTS(I)=FLOAT(NDEP(I))/FLOAT(NBAS(I))
1090 PFOH=PHR*CRFT(I)
1100 TFOH=12*AHR*CRFT(I)
1110 DO 19 J=1,8
1120 19 NRCOS(I,J)=RLCOS(I,J)=0
1130 DO 20 K=1,4
1140 NDUM=PFOH*Q*Q1*(DRCT*(1-RTS(K))+BRCT*RTS(K))/EMTBF(K)+SUF*
1141+SQRT(PFOH*Q*Q1*(DRCT*(1-RTS(K))+BRCT*RTS(K))/EMTBF(K))
1150 IF(NDUM.LT.MINSPB) NDUM=MINSPB
1155 IF(Q1.EQ.0.)NDUM=0
1160 NSPRF=NDUM-TSPRF(K)
1170 TSPRF(K)=NDUM
1180 NDUM=PFOH*Q*(1-Q1)*(1-FREM)*(DRCT*(1-RTS(K))+BRCT*RTS(K))/LMTBF(K)
1181++SUF*SQRT(PFOH*Q*(1-Q1)*(1-FREM)*(DRCT*(1-RTS(K))+BRCT*RTS(K))
1182+/LMTBF(K))
1190 IF(NDUM.LT.MINSPB) NDUM=MINSPB
1195 IF((Q1.EQ.1.).OR.(FREM.EQ.1.))NDUM=0
```

```
1200 NSPRL=NDUM-TSPRL(K)
1210 TSPRL(K)=NDUM
1220 NDUM=PFØH*Q*(1-Q1)*FREM*(DRCT*(1-RTS(K))+BRCT*RTS(K))/EMTBF(K)+
1221+SUF*SQRT(PFØH*Q*(1-Q1)*FREM*(DRCT*(1-RTS(K))+BRCT*RTS(K))/EMTBF(K))
1230 IF(NDUM.LT.MINSPB) NDUM=MINSPB
1235 IF((Q1.EQ.1.).ØR.(FREM.EQ.0.))NDUM=0
1240 NSPRE=NDUM-TSPRE(K)
1250 TSPRE(K)=NDUM
1260 NRCØS(I,1)=NRCØS(I,1)+NSPRF*FUC(K)+NSPRL*LUC(K)+NSPRE*EUC(K)
1270 XDUM=TFØH*Q*(Q1*FUC(K)*FCØND(K)/EMTBF(K)+(1-Q1)*LUC(K)*LCØND(K)
1271+*(1-FREM)/LMTBF(K)+(1-Q1)*FREM*EUC(K)*ECØND(K)/EMTBF(K))
1280 20 RLCØS(I,1)=RLCØS(I,1)+XDUM
1290 DØ 22 K=5,NFMØD
1300 NDUM=PFØH*Q*Q1*BRCT/EMTBF(K)+SUF*SQRT(PFØH*Q*Q1*BRCT/EMTBF(K))
1310 IF(NDUM.LT.MINSPD)NDUM=MINSPD
1315 IF(Q1.EQ.0.)NDUM=0
1320 NSPRF=NDUM-TSPRF(K)
1330 TSPRF(K)=NDUM
1340 XDUM=TFØH*Q*Q1*FUC(K)*FCØND(K)/EMTBF(K)
1350 NRCØS(I,1)=NRCØS(I,1)+NSPRF*FUC(K)
1360 22 RLCØS(I,1)=RLCØS(I,1)+XDUM
1370 DØ 23 K=5,NLMØD
1380 NDUM=PFØH*Q*(1-Q1)*(1-FREM)*BRCT/LMTBF(K)+SUF*SQRT(PFØH*Q*(1-
1381+Q1)*(1-FREM)*BRCT/LMTBF(K))
1390 IF(NDUM.LT.MINSPD)NDUM=MINSPD
1395 IF((Q1.EQ.1.).ØR.(FREM.EQ.1.))NDUM=0
1400 NSPRL=NDUM-TSPRL(K)
1410 TSPRL(K)=NDUM
1420 XDUM=TFØH*Q*(1-Q1)*(1-FREM)*LUC(K)*LCØND(K)/LMTBF(K)
1430 NRCØS(I,1)=NRCØS(I,1)+NSPRL*LUC(K)
1440 23 RLCØS(I,1)=RLCØS(I,1)+XDUM
1450 DØ 24 K=5,NEMØD
1460 NDUM=PFØH*Q*(1-Q1)*FREM*BRCT/EMTBF(K)+SUF*SQRT(PFØH*Q*(1-Q1)*
1461+FREM*BRCT/EMTBF(K))
1470 IF(NDUM.LT.MINSPD)NDUM=MINSPD
1475 IF((Q1.EQ.1.).ØR.(FREM.EQ.0.))NDUM=0
1480 NSPRE=NDUM-TSPRE(K)
1490 TSPRE(K)=NDUM
1500 XDUM=TFØH*Q*(1-Q1)*FREM*EUC(K)*ECØND(K)/EMTBF(K)
1510 NRCØS(I,1)=NRCØS(I,1)+NSPRE*EUC(K)
1520 24 RLCØS(I,1)=RLCØS(I,1)+XDUM
1530 NRCØS(I,1)=NRCØS(I,1)*((1+XINF)**(I-1))
1540 RLCØS(I,1)=RLCØS(I,1)*((1+XINF)**(I-1))
1550 DIMENSIØN LNAME(8)
1560 DATA (LNAME(I),I=1,8)/6HSPARES,7HØNMAINT,8HØFFMAINT,6HINVMGT,
1561+7HSUPPØRT,8HTRAINING,8HTECHDATA,10HFACILITIES/
1570 DØ 25 K=1,4
1580 XDUM=TFØH*Q*(Q1*FRMH(K)/EMTBF(K)+(1-Q1)*(1-FREM)*LRMH(K)/
1581+LMTBF(K)+(1-Q1)*FREM*ERMH(K)/EMTBF(K))*RLR
1590 25 RLCØS(I,2)=RLCØS(I,2)+XDUM
```

```
1600 RLCØS(I,2)=RLCØS(I,2)*((1+XINF)**(I-1))
1610 DØ 26 K=1,NEMØD
1620 IF(K.GT.4)GØTØ 27
1630 XDUM=TFØH*Q*Q1*(EDMH(K)*(RTS(K)*BLR+(1-RTS(K))*DLR)+EDMC(K)+
1631+1.125*SHC*EWT(K)*(2*(1-RTS(K))*(1-ECØND(K))+ECØND(K)))/
1632+EMTBF(K)
1640 GØTØ 26
1650 27 XDUM=TFØH*Q*Q1*(EDMH(K)*DLR+EDMC(K))/EMTBF(K)
1660 26 RLCØS(I,3)=RLCØS(I,3)+XDUM
1670 DØ 28 K=1,NLMØD
1680 IF(K.GT.4)GØTØ 29
1690 XDUM=TFØH*Q*(1-Q1)*(1-FREM)*(LDMH(K)*(RTS(K)*BLR+(1-RTS(K))*
1691+DLR)+LDMC(K)+1.125*SHC*LWT(K)*(2*(1-RTS(K))*(1-LCØND(K))+
1692+LCØND(K)))/LMTBF(K)
1700 GØTØ 28
1710 29 XDUM=TFØH*Q*(1-Q1)*(1-FREM)*(LDMH(K)*DLR+LDMC(K))/LMTBF(K)
1720 28 RLCØS(I,3)=RLCØS(I,3)+XDUM
1730 DØ 30 K=1,NEMØD
1740 IF(K.GT.4)GØTØ 31
1750 XDUM=TFØH*Q*(1-Q1)*FREM*(EDMH(K)*(RTS(K)*BLR+(1-RTS(K))*
1751+DLR)+EDMC(K)+1.125*SHC*EWT(K)*(2*(1-RTS(K))*(1-ECØND(K))+
1752+ECØND(K)))/EMTBF(K)
1760 GØTØ 30
1770 31 XDUM=TFØH*Q*(1-Q1)*FREM*(EDMH(K)*DLR+EDMC(K))/EMTBF(K)
1780 30 RLCØS(I,3)=RLCØS(I,3)+XDUM
1790 RLCØS(I,3)=RLCØS(I,3)*((1+XINF)**(I-1))
1800 PPEB=PPLB=PPEB=1.
1810 IF(FREM.EQ.0.)32,33
1820 32 PPE=TPE=PPEB=0.
1830 33 IF(FREM.EQ.1.)34,35
1840 34 PPL=TPL=PPLB=0.
1850 35 IF(Q1.EQ.0.)36,37
1860 36 PPF=TPF=PPFB=0.
1870 37 IF(Q1.EQ.1.)38,39
1880 38 PPL=TPL=PPLB=PPE=TPE=PPEB=0.
1890 39 IF(I.GT.1)40,41
1900 40 NRCØS(I,4)=0.
1910 RLCØS(I,4)=IAC*(PPF*PPFB+PPL*PPLB+PPE*PPEB)+SA*(4*(PPFB+PPLB+
1911+PPEB)*NBAS(I)+(TPF*PPFB+TPL*PPLB+TPE*PPEB)*NDEP(I))
1920 GØTØ 42
1930 41 NRCØS(I,4)=IAC*(PPF*PPFB+PPL*PPLB+PPE*PPEB)
1940 RLCØS(I,4)=SA*(4*(PPFB+PPLB+PPEB)*NBAS(I)+(TPF*PPFB+TPL*PPLB+
1941+TPE*PPEB)*NDEP(I))
1950 42 RLCØS(I,4)=RLCØS(I,4)*((1+XINF)**(I-1))
1960 XDUM=PFØH*Q*Q1*DUR*EDMH(1)/(EMTBF(1)*ATE*DAA*NDEP(I))
1970 NDUM=INT(XDUM)+1
1980 IF(NDUM.LT.NDEP(I))NDUM=NDEP(I)
1985 IF(Q1.EQ.0.)NDUM=0
1990 NNDUM=NDUM-NSUPF
```

```
2000 NSUPF=NDUM
2010 NRCØS(I,5)=NNDUM*CADF
2020 RLCØS(I,5)=XDUM*CØDF
2030 XDUM=PFØH*Q*(1-Q1)*(1-FREM)*DUR*LDMH(1)/(LMTBF(1)*ATF*DAA*NDEP(I))
2040 NDUM=INT(XDUM)+1
2050 IF(NDUM.LT.NDEP(I)) NDUM=NDEP(I)
2055 IF((Q1.EQ.1.).ØR.(FREM.EQ.1.))NDUM=0
2060 NNDUM=NDUM-NSUPL
2070 NSUPL=NDUM
2080 NRCØS(I,5)=NRCØS(I,5)+NNDUM*CADL
2090 RLCØS(I,5)=RLCØS(I,5)+XDUM*CØDL
2100 XDUM=PFØH*Q*(1-Q1)*FREM*DUR*EDMH(1)/(EMTBF(1)*ATF*DAA*NDEP(I))
2110 NDUM=INT(XDUM)+1
2120 IF(NDUM.LT.NDEP(I))NDUM=NDEP(I)
2125 IF((Q1.EQ.1.).ØR.(FREM.EQ.0.))NDUM=0
2130 NNDUM=NDUM-NSUPE
2140 NSUPE=NDUM
2150 NRCØS(I,5)=(NRCØS(I,5)+NNDUM*CADE)*((1+XINF)**(I-1))
2160 RLCØS(I,5)=(RLCØS(I,5)+XDUM*CØDE)*((1+XINF)**(I-1))
2170 XDUM=0
2180 DØ 43 K=1,NEMØD
2190 IF((K.GT.1).AND.(K.LT.5))GØTØ 43
2200 XDUM=XDUM+TFØH*Q*Q1*EDMH(K)/(EMTBF(K)*PMD)
2210 43 CØNTINUE
2220 DØ 44 K=1,NLMØD
2230 IF((K.GT.1).AND.(K.LT.5))GØTØ 44
2240 XDUM=XDUM+TFØH*Q*(1-Q1)*(1-FREM)*LDMH(K)/(LMTBF(K)*PMD)
2250 44 CØNTINUE
2260 DØ 45 K=1,NEMØD
2270 IF((K.GT.1).AND.(K.LT.5))GØTØ 45
2280 XDUM=XDUM+TFØH*Q*(1-Q1)*FREM*EDMH(K)/(EMTBF(K)*PMD)
2290 45 CØNTINUE
2300 NDUM=INT(XDUM)+1
2305 IF(NDUM.LT.NDEP(I))NDUM=NDEP(I)
2310 NNDUM=NDUM-NPERS
2315 RLCØS(I,6)=NDUM*TRD*TCD*((1+XINF)**(I-1))
2320 NPERS=NDUM
2325 IF(I.EQ.1)RLCØS(I,6)=0.
2330 NRCØS(I,6)=NNDUM*TCD*((1+XINF)**(I-1))
2340 XDUM=(ØR+FR+SR)*(Q1*FAILF+(1-Q1)*(1-FREM)*FAILL+(1-Q1)*
2341+FREM*FAILE)
2350 XDUM=(XDUM+(ØR+FR+SR+(1-RTS(1))*TR)*(Q1/EMTBF(1)+(1-Q1)*(1-
2351+FREM)/LMTBF(1)+(1-Q1)*FREM/EMTBF(1)))*TFØH*Q*BLR
2360 RLCØS(I,7)=XDUM*((1+XINF)**(I-1))
2370 NRCØS(I,7)=TD*(NBDF*PPFB+NBDL*PPLB+NBDE*PPEB+NDDF*PPFB+NDDL*PPLB
2371++NDDE*PPEB)
2380 IF(I.GT.1)NRCØS(I,7)=0.
2390 RLCØS(I,8)=(FIB*NBAS(I)+FID*NDEP(I))*((1+XINF)**(I-1))
```

```
2400 DØ 47 J=1,8
2410 TNRCØS(I)=TNRCØS(I)+NRCØS(I,J)
2420 47 TRLCØS(I)=TRLCØS(I)+RLCØS(I,J)
2430 TLLCØS(I)=TNRCØS(I)+TRLCØS(I)
2440 TCØSL=TCØSL+TLLCØS(I)
2450 18 PRINT 901, NYR(I),TNRCØS(I),TRLCØS(I),TLLCØS(I),TCØSL
2470 CLCC=TCØSA=TCØSL=0
2475 PRINT,*  *
2480 PRINT,* YEAR   CAS CØST   CUM CØST     PER A/C   ANNUAL LCØS/ACØS*
2490 DØ 48 I=1,11
2500 TLCC=TLLCØS(I)+ACØS(I)+ICØS(I)
2503 TCØSA=TCØSA+ACØS(I)
2504 TCØSL=TCØSL+TLLCØS(I)
2505 XXX=100*TCØSL/(I*TCØSA)
2510 CLCC=CLCC+TLCC
2515 XX=CLCC/CRFT(I)
2520 48 PRINT 902,NYR(I),TLCC,CLCC,XX,XXX
2525 PRINT,*  *
2530 902 FØRMAT (I5,3F12.0,F16.2)
2540 PRINT,* DØ YØU WANT LØGISTIC SUPPØRT CØSTS BREAKDØWN BY YEAR?*
2545 PRINT,* TYPE YES ØR NØ*,
2550 READ,AA
2560 IF(AA.NE.3HYES)GØTØ 50
2570 PRINT,* YEAR   ELEMENT  NREC LCØST   RFC LCØST   TØT LCØST*
2580 DØ 51 I=1,11
2590 PRINT 903,NYR(I)
2600 903 FØRMAT (I5)
2610 DØ 52 J=1,8
2620 XX=NRCØS(I,J)+RLCØS(I,J)
2630 52 PRINT 904,LNAME(J),NRCØS(I,J),RLCØS(I,J),XX
2640 904 FØRMAT (A15,3F12.0)
2650 51 CØNTINUE
2660 50 PRINT,* DØ YØU WANT TØ RUN ANØTHER CASE (TYPE YES ØR NØ)*,
2670 READ,AA
2680 IF(AA.NE.3HYES)GØTØ 9999
2690 REWIND 2
2700 REWIND 3
2710 GØTØ 53
2720 9999 STØP
2730 END

BYE
```

APPENDIX E

COMMON PARAMETERS AFFECTING LIFE-CYCLE COSTS

DABS LIFE CYCLE COST MLDEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	COMMERCIAL CARRIER	MILITARY	GENERAL AVIATION
1	SFILE	System File Name Input	DABS DABSL	DABS DABSL	DABS DABSL
2	UFILE	User File Name Input	COM	MIL	GEN
3	FICOS	Installation cost in new A/C of Type I Transponder	2536	N/A	1112
4	RICOS	Retrofit cost of Type I Transponder	4227	N/A	1854
5	LICOS	Installation cost in new A/C of Type II Transponder	N/A	N/A	Discrete 94 LSI 55
6	LRCOS	Retrofit cost of Type II Transponder	N/A	N/A	Discrete 157 LSI 91
7	EICOS	Installation cost in new A/C of Military Modification	N/A	7377	N/A
8	ERCOS	Retrofit cost of Military Modification	N/A	5493	N/A
9	NYR (I)	Year I	1978	1978	1978
10	NAC (I)	Number of A/C in each user category in Year I	2693	19,501	173,500
11	NBAS (I)	Number of bases in each user category in Year I	15	166	146
12	NDEP (I)	Number of depots in each user category in Year I	3	8	5
13	FREM	Fraction of Military A/C with Modification	N/A	1	N/A
14	NRAC	Number of A/C in each user category to be retrofitted	2560	19,345	167,800
15	XLRN	Learning curve parameter			
16	XINF	Inflation parameter	0,.06, .1	0, .06, .1	0, .06, .1

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	commercial CARRIER	MILITARY	GENERAL AVIATION
17	IT	Retrofit completion period	4	8	8
18	Q	Average number of DABS units per A/C in each user category	1	1	1
19	Q1	Fraction of A/C in each user category with Type I Transponder	1	N/A	0.05
20	NMODF	Number of modules in Type I Transponder principal electronics	10	N/A	10
21	NMODL	Number of modules in Type II Transponder principal electronics	N/A	N/A	6
22	NMODE	Number of modules in Military MOD principal electronics	N/A	2	N/A
23	NANTF	Number of antennas in Type I Transponder Configuration	2	N/A	2
24	NANTL	Number of antennas in Type II Transponder configuration	N/A	N/A	1
25	NANTE	Number of antennas in Military Modification configuration	N/A	1	N/A
26	FUC(4)	Initial selling price of Type I capability antenna system (1)	$63	$63	$63

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE		COMMERCIAL CARRIER	MILITARY	GENERAL AVIATION
27	LUC (4)	Initial selling price of Type II capability antenna system (1)	N/A	$13	$13
28	EUC (4)	Initail selling price of military mod antenna system (1)	N/A	N/A	N/A
29	FMTBF (4)	MTBF of Type I capability antenna system (1)	50,000 hours	50,000 hours	50,000 hours
30	LMTBF (4)	MTBF of Type II Capability antenna system (1)	N/A	50,000 hours	50,000 hours
31	EMTBF	MTBF of military mod antenna system (1)	N/A	N/A	N/A
32	FRMH (1)	Average time to remove and replace Type I capability principal electronics	.25 hours	.25 hours	.25 hours
33	LRMH (1)	Average time to remove and replace Type II capability principal electronics	.5 hours	.5 hours	.5 hours
34	FRMH (2)	Average time to remove and replace Type I IPC Display	.5 hours	.5 hours	.5 hours

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	COMMERCIAL CARRIER	MILITARY	GENREAL AVIATION
35	FRMH (4)	Average time for on A/C repair of Type I capability antenna system	2 hours	2 hours	2 hours
36	LRMH (4)	Average time for on A/C repair of Type II capability antenna system	.25 hours	.25 hours	.25 hours
37	FCOND (1)	Fraction of Type I capability principal electronics failures resulting in condemnations	.001	N/A	.001
38	LCOND (1)	Fraction of Type II capability principal electronics failures resulting in condemnations	N/A	N/A	.001
39	ECOND (1)	Fraction of military mod capability principal electronics failures resulting in condemnations	N/A	.001	N/A
40	FCOND (2)	Fraction of Type I capability IPC Display indicator failures resulting in condemnations	.01	.01	.01
41	FCOND (4)	Fraction of Type I capability antenna system failures resulting in condemnations	1	N/A	1
42	LCOND (4)	Fraction of Type II capability antenna system failures resulting in condemnations	N/A	N/A	1
43	ECOND (4)	Fraction of military mod capability antenna system failures resulting in condemnations	N/A	N/A	N/A

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	COMMERCIAL CARRIER	MILITARY	GENERAL AVIATION
44	CODF	Annual operating cost rate of special support equipment for Type I capability	$1058	$1058	$1058
45	CODL	Annual operating cost rate of special support equipment for Type II capability	N/A	$ 529	$ 529
46	CODE	Annual operating cost rate of special support equipment for military mod capability	N/A	$529	N/A
47	FIBF	Base facilities costs for Type I	N/A	$ 529	N/A
48	FIBL	Base facilities costs for MIL MOD DABS	N/A	$ 529	N/A
49	FIDF	Depot facilities costs for Type I	$529	N/A	N/A
50	FIDL	Depot facilities costs for MIL MOD DABS	N/A	$100,000	N/A
51	ATE	Support equipment availability figure for each user category	1	0.9	1
52	DRCT	Average depot level response time (pipeline) for each user category	0.1 months	2.0 months	.25 months
53	BRCT	Average base level response time (pipeline) for each user category	0.1 months	0.33 months	0.1 months
54	AHR	Average flight hours per month for each user category	238 hours	80 hours	17.3 hours
55	PHR	Peak flight hours per month for each user category	298 hours	100 hours	20 hours
56	SUF	Spares sufficiency factor (standard deviations from mean)	0	1.65	0
57	BLR	Base labor rate for each user category	22.29	13.00	16.28
58	SHC	Shipping costs per lb. for each user category	.35	.35	.35
59	DLR	Depot labor rate for each user category	22.29	15.80	17.90

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	COMMERCIAL CARRIER	MILITARY	GENERAL AVIATION
60	RTS	Fraction of maintenance actions repaired at base level for each user category	Electronics = 0 Indicator = 1 Antenna = 1	Electronics = 0 Indicator = 1 Antenna = 1	Electronics = 0.2 Indicator = 1 Antenna = 1
61	IAC	Cost of introducing and maintaining each new inventory coded item for user category	$16	$990.	N/A
62	DUR	Support equipment utilization factor for each user category	3	3	3
63	SA	Annual supply management cost for each inventory coded item for each user category	$6.35	$12.72	N/A
64	DAA	Support equipment time available per month for each user category	160 hours	160 hours	160 hours
65	TCB	Cost per man of base level training for each user category	N/A	N/A	N/A
66	TCD	Cost per man of depot level training for each user category	$1695	$8000.	N/A
67	PMB	Direct base productive manhours per man year for each user category	N/A	N/A	N/A
68	PMD	Direct depot productive manhours per man year for each user category	1788 hours	1456 hours	1788 hours
69	ØR	Average time to complete on A/C maintenance records for each user category	0.08 hours	0.25 hours	0.08 hours
70	FR	Average time to complete off A/C maintenance records for each user category	0.24 hours	0.5 hours	0.24 hours
71	SR	Average time to complete supply transaction records for each user category	0.25 hours	0.5 hours	0.25 hours
72	TR	Average time to complete transportation forms for each user category	0.16 hours	0.5 hours	0.16 hours

DABS LIFE CYCLE COST MODEL PARAMETER SUMMARY - COMMON DATA

ITEM	VARIABLE	DESCRIPTION	COMMERCIAL CARRIER	MILITARY	GENERAL AVIATION
73	TRB	Average annual turnover rate at base for each user category	N/A	.2	N/A
74	TRD	Average annual turnover rate at depot for each user category	0.05	0.06	N/A
75	TD	Cost per page of original technical documentation for each user category	N/A	$170	N/A