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ABSTRACT
The results of a study to evaluate the potential life-cycle costs and cost savings that could be realized by applying the Digital Avionics Information System (DAIS) concept to future avionic systems were presented. The tasks evaluated included selection of program elements for costing, selection of DAIS installation potential, definition of a life-cycle-cost model, data collection and execution of the model. The results of the analysis indicated that the DAIS approach to avionics integration provided the potential for significant savings. The cost benefits that could be derived from the various DAIS-concept elements for the different life-cycle phases were described. Several tables of data, a bibliography, and a glossary of terms are appended. (Author/HB)

AFHRL-TR-75-34

AIR FORCE HUMAN RESOURCES LABORATORY

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DIGITAL AVIONICS INFORMATION SYSTEM PRELIMINARY LIFE-CYCLE-COST ANALYSIS

By

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

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A mathematical model was developed and exercised to evaluate the life-cycle costs of avionics developed according to the Digital Avionics Information System (DAIS) approach. The objective was to provide an initial estimate, based on available data, of the costs and cost savings associated with the DAIS concept. A comparative analysis was performed to estimate the relative costs of the avionics of four different aircraft types for both conventional and DAIS configurations. The results of this analysis were intended only to provide a perspective of the relative costs of DAIS and conventional avionics systems; they do not necessarily represent the true costs that may be encountered in an operational environment.

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The depth and accuracy of the estimates made in this report are necessarily restricted by the available data and the limited scope of the study. The DAIS costs are preliminary estimates or projections supplied by the DAIS Program Office at the Air Force Avionics Laboratory (AFAL). The data for the conventional avionics were extracted from many sources, including the Increase Reliability of Operational System (IROS) data system. Therefore, interpretation of the analyses contained in this report should be restricted to an assessment of the relative cost of the avionics integration approaches that have been addressed.

Because of limitations on the availability of data, only a qualitative assessment of the effects of applying the DAIS concept could be made for the cost categories of research and development, installation, support equipment, training equipment, and technical documentation.

SUMMARY

This report presents the results of a study to evaluate the potential life-cycle costs and cost savings that could be realized by applying the Digital Avionics Information System (DAIS) concept to future avionic systems. The tasks included selection of program elements for costing, selection of DAIS installation potential, definition of a life-cycle-cost model, data collection, and execution of the model.

Modern military avionics have become increasingly complex and sophisticated, and the costs of procuring and maintaining these systems have risen significantly. Avionic systems have traditionally been procured as autonomous units, with little commonality between different aircraft types. Each new aircraft procurement has resulted in a proliferation of unique systems, resulting in high avionics support costs throughout the life of the aircraft. The Digital Avionics Information System (DAIS) concept is intended to reverse the adverse cost-growth characteristic and provide maximum commonality and flexibility between aircraft avionic systems.

Cost pressures from increased system complexity, higher maintenance expenditures, and general economic inflation have mandated that the full life-cycle cost of an avionic system, from research and development through disposal, be examined before the system is chosen to be integrated into a weapon system. New avionic systems must meet current mission requirements, yet provide the growth capability and flexibility to absorb new technology and to respond to changing missions and operational requirements without the need for a costly major redesign. The DAIS concept is intended to meet these needs by providing the following:

- The ability to meet new mission requirements, primarily by means of software rather than hardware changes
- Increased mission reliability through the use of redundancy and fault-tolerant systems
- The flexibility of adding or changing sensors without rewiring the aircraft
- Commonality between aircraft types, with a reduction in logistic requirements
- Maximum use of modular design in both hardware and software

The results of the analysis described in this report indicate that the DAIS approach to avionics integration provides the potential for significant savings. Because of limitations on the availability of data, only a qualitative assessment of the effects of applying the DAIS concept could be made for the cost categories of Research, Development, Test, and Evaluation (RDT&E), installation, support equipment, training equipment, and technical documentation. The cost benefits that could be derived from the various DAIS-concept elements for the different life-cycle phases are described as follows:

- *Research, Development, Test, and Evaluation (RDT&E).* After an initial avionics development program, the only RDT&E funds that would be required for incorporation of DAIS into additional aircraft would be for the avionic sensor functions unique for those aircraft. These savings may be offset in part by software expenditures.
- *Acquisition.* The commonality between aircraft types as offered by the DAIS approach will permit commitments to large production lots. This will reduce the unit acquisition price through economies of scale. The avionics acquisition cost depends on the effects of procurement factors such as production-lot size, competition, learning-curve adjustments, and procurement philosophy (including application of warranties, form-fit-function specifications, or design-to-cost goals).
- *Installation.* The utilization of a time-division multiplexed data bus should result in significant cost and weight savings in the wiring of the avionic system. In addition, modifications to or additions of subsystems can be accomplished without rewiring the aircraft, resulting in further cost savings and airframe versatility.
- *Spares.* A module-removal maintenance concept greatly reduces the cost of base and pipeline spares from that associated with the removal of "black boxes" (Line Replaceable Units).
- *On-Equipment Maintenance.* The projected built-in-test capabilities of the DAIS system will reduce the costs associated with on-equipment maintenance by reducing the man-hours required for troubleshooting the system for corrective or preventive maintenance.
- *Off-Equipment Maintenance.* A disposable-module maintenance philosophy, coupled with a comprehensive built-in-test capability, will minimize the maintenance man-hours for off-equipment maintenance.
- *Support Equipment.* The costs associated with the acquisition and operation of the support equipment required to maintain a system of avionics should be reduced for a DAIS-configured aircraft because of the comprehensive built-in-test capabilities of the system. This cost advantage would increase with the number of aircraft types in which DAIS was incorporated because the quantity of support equipments required would be reduced. The actual requirements for support equipment depend on the maintenance

philosophy, but a minimization of different module types will minimize support-equipment requirements for either the module-removal or black-box-removal approach.

- *Training.* Application of the DAIS concept to aircraft avionics should reduce the costs of personnel training because of the benefits arising from the avionics commonality between aircraft. The training function could be centralized to a large extent since the basic avionic system would be the same for all aircraft types.

- *Technical Documentation.* Incorporation of DAIS avionics into a mix of aircraft would offer a significant benefit relative to the cost of developing technical documentation. After manuals for the first aircraft have been developed, the avionics commonality between aircraft would reduce the requirement for development of new technical material to those functional units unique to a weapon system.

The fundamental concept of avionics commonality could provide substantial cost reductions throughout the Air Force by centralizing both direct and indirect support of operational units. Uniformity of avionics hardware would permit minimizing the number of maintenance, supply, technical support, and management facilities required to support the aircraft, and all phases of system support would be streamlined.

It should be noted that the DAIS approach incorporates several architectural and maintenance concepts and that many of the cost benefits described above could be realized without implementing the full DAIS package. Therefore, any cost savings that DAIS offers over the conventional approach to avionics integration will be limited to those cost categories for which DAIS offers unique capabilities.

The data presented in this report indicate that the DAIS avionics may have a higher acquisition cost than currently operational systems ($750,190 per aircraft vs. $575,983 for a Close Air Support configuration). However, the DAIS avionics have a lower total life-cycle cost because of improved reliability and maintainability ($858,795 per aircraft vs. $1,153,984 for a Close Air Support configuration). These figures are based on the current Air Force maintenance philosophy of black-box removal at the flight-line level. The DAIS logistic support costs could be further reduced by adopting a flight-line module-removal maintenance philosophy.

An examination of life-cycle costs for a mix of Close Air Support, Transport, Fighter, and Bomber aircraft showed a total potential life-cycle cost saving of $1.2 billion through incorporation of the DAIS concept. A best-case analysis was performed for the Close Air Support configuration to establish a lower bound for the analysis. This analysis, presented in Section 2.5.5, was based on best-case values of cost and reliability for DAIS and conventional avionics. The results indicated that, on the basis of the costs examined, the DAIS concept offers no apparent cost advantage.

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CHAPTER ONE

INTRODUCTION

This is the final report on Task SG01, performed by ARINC Research under Contract F09603-74-A-0844 with the U.S. Air Force Human Resources Laboratory. The period of performance was 15 November 1974 through 31 May 1975.

1.1 BACKGROUND

Modern military avionic systems have become increasingly complex and sophisticated, and the costs of procuring and maintaining them have risen significantly. Avionic systems have traditionally been procured as autonomous units, with little degree of commonality between different aircraft types. Each new aircraft procurement has resulted in a proliferation of unique systems, resulting in high support costs throughout the life cycle of the aircraft. The Digital Avionics Information System (DAIS) concept is intended to reverse this adverse cost-growth characteristic and provide maximum commonality and flexibility between aircraft avionic systems.

The DAIS approach to avionics will draw heavily on recent advances in information-system technology. The software package will integrate the avionic elements into a functional system and provide the flexibility to add new subsystems without rewiring the aircraft. The DAIS avionics will consist of four principal elements:

1. A set of sensors to provide avionic parameters
2. An information data bus that distributes signals between system elements in a common format, using time-division multiplexing
3. An information-processing system that performs data processing and storage
4. An information presentation and control system whose functions can be tailored to fit specific mission requirements

A conventional avionics configuration is shown in Figure 1-1. The subsystems indicated are typical of a Close Air Support aircraft. The primary characteristic of interest of the conventional avionics suite

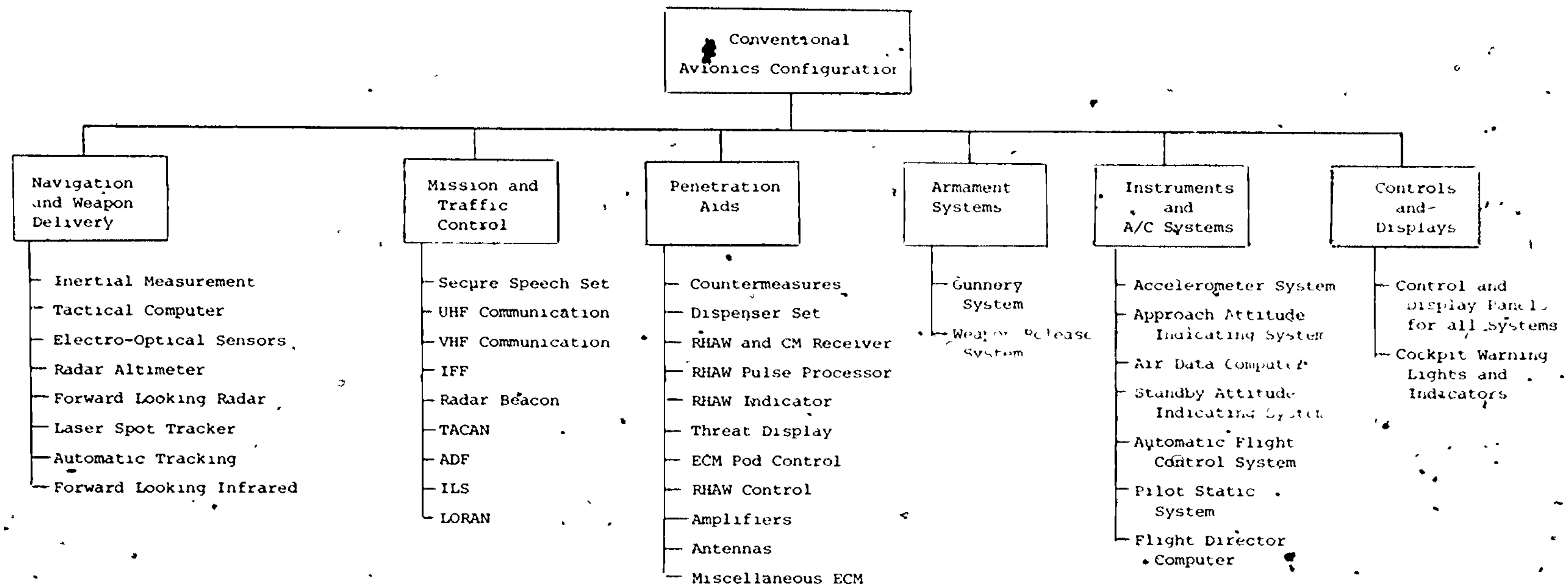

Figure 1-1. Conventional Avionics Configuration

is the independence of each of the equipments. There is only a small degree of information exchange between subsystems, and there is a significant amount of functional redundancy. Computers, controls, and displays are dedicated to one subsystem; and interconnection between Line Replaceable Units (LRUs) requires the use of relatively complex and bulky cabling.

A DAIS avionics configuration is shown in Figure 1-2. The basic contrast between DAIS and conventional avionics integration is the partitioning of the DAIS avionics suite into functionally related subsystems. Information flow over the multiplexed data bus is controlled by the processors and the bus controller units. The avionic sensors provide basic parametric data, which are processed and displayed under the control of the system software. The displays and controls are partitioned into dedicated and time-shared units as dictated by mission requirements.

The DAIS concept offers the potential for significant cost savings by providing a centralized program to take advantage of available state-of-the-art technology. Cost pressures from increased system complexity, higher maintenance cost, and general economic inflation have mandated that the full life-cycle cost of an avionic system, from research and development through disposal, be examined before it is chosen to be integrated into a weapon system. New avionic systems must meet current mission requirements, yet provide the growth capability and flexibility to absorb new technology and respond to changing missions and operational requirements without a costly major redesign. The DAIS concept is intended to meet these requirements by providing the following:

- The ability to meet new mission requirements primarily by means of software rather than hardware changes
- Increased mission reliability through the use of redundancy and fault-tolerant systems
- The flexibility of adding or changing sensors without rewiring the aircraft
- Commonality between aircraft types, with a reduction in logistic requirements
- Maximum use of modular design in both hardware and software

The purpose of the study reported on herein was to develop and exercise a mathematical model to evaluate the life-cycle costs of the DAIS approach to avionics. The objective was to provide an initial estimate, based on available data, of the potential costs and cost savings associated with the DAIS concept. A comparative analysis was performed to estimate the relative costs of the avionics of four different aircraft types for both conventional and DAIS configurations.

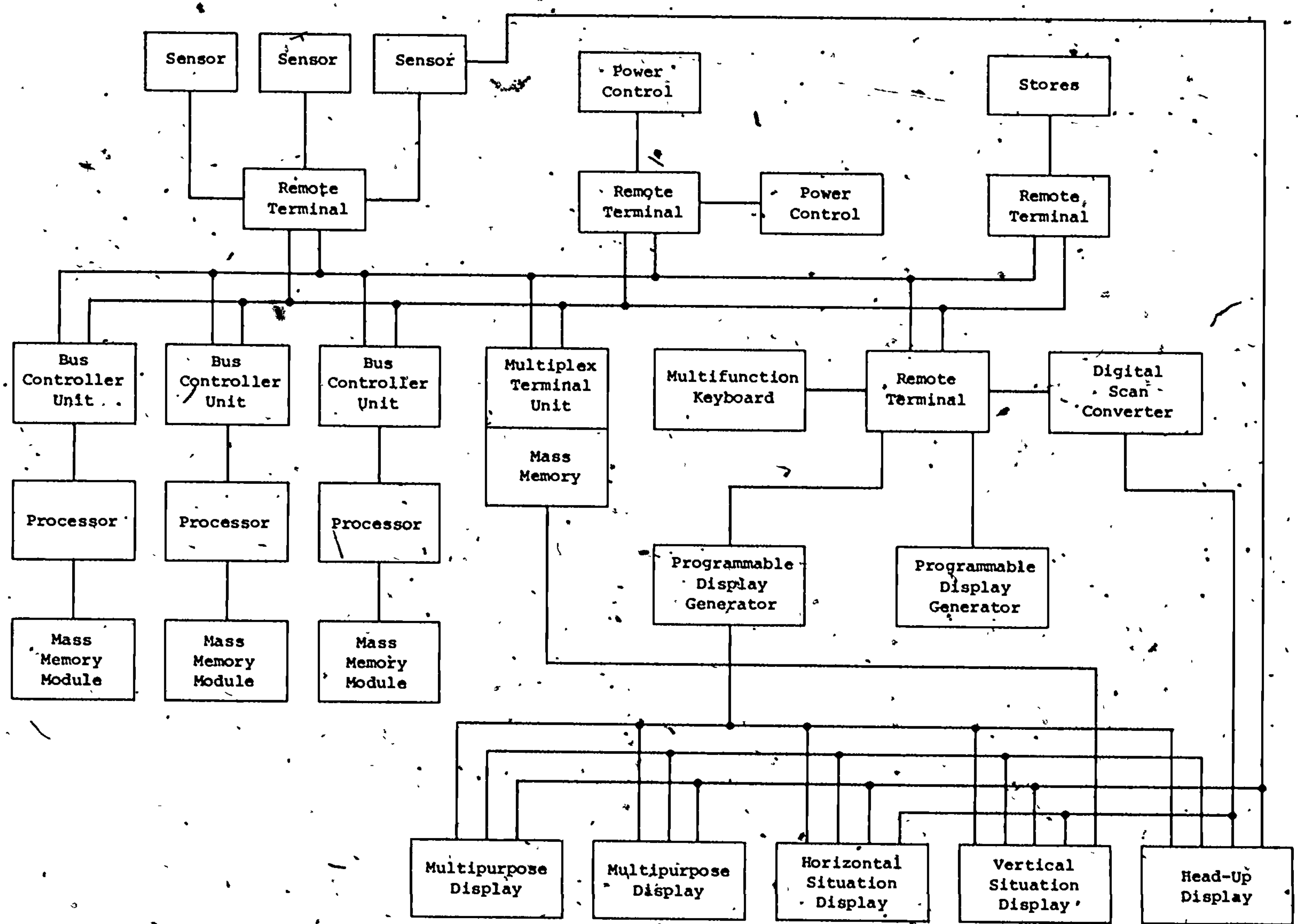

Figure 1-2. DAIS AVIONICS CONFIGURATION

1.2 TECHNICAL APPROACH

In order to evaluate the potential impact of the application of the DAIS concept to the life-cycle cost of a system of avionics, a mathematical model was developed that would utilize reliability, maintainability, and operational data to provide a means of analyzing the costs associated with the procurement and maintenance of these avionics. The scope of the study was limited to communication, Identify Friend or Foe (IFF), navigation, bombing navigation, and search radar systems, and their associated displays and controls, to provide a baseline for comparing the costs of several different aircraft configurations. The following paragraphs outline the specific approach used to define the full scope and depth of the analysis.

1.2.1 Selection of Program Elements for Costing

The initial step in the effort was to define the elements to be considered in the DAIS life-cycle-cost estimate. Where possible, these cost elements were included in a mathematical model to assess the quantitative impact of each on the total system cost. The following cost categories were addressed quantitatively:

- Acquisition
- Initial and replacement spares
- On-equipment maintenance
- Off-equipment maintenance
- Personnel training
- Management data

Because of limitations on the availability of data, only a qualitative assessment of the effects of applying the DAIS concept to avionic systems could be made for the following cost categories:

- Research, Development, Test, and Evaluation (RDT&E)
- Installation
- Support equipment
- Training equipment
- Technical documentation

1.2.2 Selection of DAIS Installation Potential

The cost that will be incurred by the application of the DAIS concept to avionic systems depends on the degree of incorporation of DAIS into various aircraft types. The specific configuration of DAIS avionic systems, in terms of the number and types of functions performed, will vary in accordance with the aircraft installation. Therefore, several general types of aircraft were considered in order to evaluate the full life-cycle-cost implications. The avionics of aircraft currently active in the Air Force inventory were chosen as a baseline for a comparative analysis between the costs associated with conventional avionics and those associated with the incorporation of the DAIS concept into these aircraft. The following types and quantities of aircraft were considered in the analysis:

Type	Quantity
Close Air Support	500
Transport	300
Fighter	1000
Bomber	500

1.2.3 Definition of the Life-Cycle-Cost Model

The model chosen to evaluate the DAIS concept is a deterministic model encompassing the most significant categories of life-cycle cost. The data elements required for this model consisted of acquisition, reliability, maintenance, and support parameters that defined the experience of a system in its operational environment. The general form of the model, which is an adaptation of the Air Force Logistics Command life-cycle-cost model, is shown in Appendix A.

1.2.4 Collection of Cost-Parameter Data

A compilation of the data sources used in this study is presented in Appendix B. The reliability, maintainability, and cost parameters required for the model were collected from various Air Force and Department of Defense sources. The primary source of base-level data for the conventional avionics was the Increase Reliability of Operational Systems (IROS) reports. Depot-level data for these avionics were extracted from the "DoD Cost and Production Report". The cost data for evaluation of the DAIS concept were provided by the DAIS Program Office at the Air Force Avionics Laboratory.

CHAPTER TWO

ANALYSIS OF DAIS COSTS

The life-cycle costs associated with the DAIS approach to avionics integration were examined by using data estimates provided by the Air Force Avionics Laboratory, the Air Force Human Resources Laboratory, and the Air Force Logistics Command. These costs were then compared with estimated life-cycle costs for conventional avionics by using data from the IROS data system. A Close Air Support avionics configuration was examined in depth, and the analysis was then extended to consider a mix of aircraft types.

2.1 BASELINE COSTS OF LABORATORY HOT-BENCH

The costs associated with the DAIS laboratory mock-up were examined to provide a baseline for estimating costs of incorporating DAIS avionics into operational aircraft. The available information is based on preliminary estimates and may be subject to some variations as dictated by program requirements. System elements that will be integrated into a Close Air Support (CAS) avionic hot-bench are shown in Table 2-1.* Other hot-bench requirements which are essential for evaluating the concept but may or may not be indicative of CAS requirements are shown in Appendix D.

2.2 SOFTWARE COSTS

A major ingredient in the DAIS approach to avionics is the dependence of the system on the software package. Software will make the difference between a collection of equipments on the one hand and an integrated system on the other. It is expected that the proposed architecture for DAIS will overcome many of the problems traditionally associated with system software. An integrated development plan will reduce overall software costs while increasing program reliability.

An advantage of the DAIS software package will be the extensive fault-detection capability offered by the Central Integrated Test System (CITS). This system will provide fully automated functional testing from preflight

*Data for this table were supplied by AFAL/AAD.

Table 2-1. HARDWARE FOR DAIS CLOSE AIR SUPPORT HOT-BENCH				
Equipment	Total Development Quantity	Estimated Unit Cost ($ Thousands)	Estimated Number for CAS System	CAS Prototype Cost ($ Thousands)
Computer with 32K Memory	7	65	4	260
Remote Terminals	23	35	15	525
Bus Controller	6	10	4	40
Video Switch/ Refresh Memory	2	100	1	100
Scan Converter	2	100	1	100
Programmable Display Generator*	3	250 200	2	400
Multi-Function Keyboard	2	20	1	20
Multi-Function Control Panel	3	4.3	2	8.6
Vertical Situation Display	2	20	1	20
3 Multi-Purpose Displays and Horizontal Situation Displays	2 sets	40	1 set	40
Head-Up Display	2	25	1	25
Hand Controller	2	10	1	10
Dedicated Control and Display Group	2	20	1	20
Total Cost of Unique DAIS Prototype Hardware ($ Thousands)				1,568.6

*One at $250,000 and two at $200,000.

through postflight, utilizing information furnished by the various system elements. The DAIS/CITS provides the potential for decreasing system costs by the following means:

- Reducing amount and complexity of flight-line Aeronautical Ground Equipment (AGE)
- Reducing system/subsystem testing time
- Reducing test-personnel skill requirements
- Reducing logistic support effort
- Increasing aircraft availability, thereby reducing number of aircraft required to maintain a given force requirement

Estimates of the costs of DAIS Mission software for a Close Air Support configuration are shown in Table 2-2. These estimates are based on current projections of CAS programming requirements and assume the utilization of a higher-order language (such as JOVIAL J73). The use of a higher-order language will result in easier maintenance of software, more flexibility, more reliability in the coding, and shorter development time.

Table 2-2. SUMMARY OF DAIS CLOSE AIR SUPPORT SOFTWARE*

Software Function	Number of Instructions and Data Words	Cost
Executive	8,000	$ 411,600
Navigation	5,93[illegible]	108,512
Weapon Delivery	6,534	111,552
ECM**	534	11,591
Control/Display Management	3,663	103,425
Flight Control	496	12,482
Management	7,838	190,359
Communications	991	23,114
Subroutines	3,174	63,436
Totals	37,169	$1,036,071
Average Cost per Instruction = $28		

*Data source 7, Appendix B.
**Although ECM hardware was not included in this study, this portion of the mission software was included as an integral part of the software package.

System software has historically proven to be expensive and often unreliable. For example, software costs per instruction approximating $75 for development and $4000 for maintenance were cited by Jacques S. Gansler, Deputy Assistant Secretary of Defense for Installations and Logistics (Materiel Acquisition) in a recent speech to the American Institute of Aeronautics and Astronautics. In consequence, this area involves the greatest risk with regard to incorporation of the DAIS concept into future avionic systems. The acquisition and maintenance of software has equaled or exceeded hardware costs in some avionic programs. The data supplied by AFAL/AAD show the projected cost of the DAIS Mission software to be relatively small when amortized over a number of aircraft. However, in view of past experience, the DAIS software costs should be closely monitored to ensure that other potential cost benefits offered by DAIS are not canceled by increases in software acquisition or maintenance costs.

Table 2-2 indicates the relative magnitude of DAIS software costs. These costs are considered part of the total development cost and are not included in the quantitative cost comparisons presented in Section 2.5.

2.3 EFFECTS OF LOT SIZE ON ACQUISITION COST

It is generally recognized that as the production-lot size of a purchase increases, the economies of scale will dictate that the unit price decrease. A simple model can be used to evaluate the effects of lot size;

$$C_p = A(P/P^*)^a$$

where

- C_p = price per unit of production lot
- A = unit price based on a known reference production lot
- P^* = a reference production-lot size
- P = production-lot size under consideration
- a = negative constant

This model is limited to evaluation of the effect of lot size on unit price. The nonrecurring costs (those associated with amortized research and development, production planning, and production test equipment) are not accounted for; but these costs are usually amortized over the first production quantity or paid for by funds not associated with acquisition.

To determine the value of the exponent $\underline{a}$, an assessment must be made of the impact of a given increase in lot size. For purposes of this study, we will assume that a twofold increase in lot size ($P = 2P^*$) will result in a 10-percent decrease in the unit price of the equipments. The derivation of the value of $\underline{a}$ then follows:

$$0.90 = (P/P^*)^a$$

$$0.90 = (2.0)^a$$

$$a = \frac{\ln 0.90}{\ln 2.00}$$

$$a = -0.1520$$

The economies of scale as calculated by the model described above are defined by production-lot-size curves. Thus a 10-percent reduction in cost for a twofold increase in production-lot size is defined as a 90-percent production curve (P.C.). The effects of lot size are shown in Figure 2-1. The points along these curves yield the cost of the last unit for a given lot size. The average cost per unit is given by the expression:

$$\text{Average unit cost} = \frac{A(P/P^*)^a}{a + 1}$$

2.4 ADAPTATION OF THE LIFE-CYCLE-COST MODEL FOR DAIS

The logistic support portion of the life-cycle-cost model described in Appendix A was adapted to correspond to the parameters available for evaluation of DAIS costs and to permit analysis of the effects of different maintenance concepts on the life-cycle cost. The model given below has the flexibility to evaluate combinations of three distinct maintenance scenarios: black-box (LRU) removal, repairable-module removal, and throwaway-module removal.

C_1 = Initial and replacement spares cost

$$C_1 = \left[AD + \sqrt{2.3}\ AD\right]\left[(LRR)(UC_L) + (1 - LRR)(1 - TM)\ RMC\right] + \left[\frac{(TFFH)(COND)}{MFTBMA_S}\right]\left[(LRR)(UC_L) + (1 - LRR)(1 - TM)(RMC)\right]$$

C_2 = On-equipment maintenance costs

$$C_2 = \left[BLR\right]\left[\frac{(TFFH)(IMH + RMH)}{MFTBMA_S}\right]$$

C_3 = Off-equipment maintenance costs

$$C_3 = \left[\frac{(TFFH)(LRR)}{MFTBMA_S}\right]\Big\{RTS\left[(BMC) + (BMH)(BLR)\right] + NRTS\left[(DMC) + (DMH)(DLR)\right]\Big\} + \left[\frac{(TFFH)(1 - LRR)(1 - TM)}{MFTBMA_S}\right]\Big\{RTS\left[(BMC)(RMC) + (BMH)(BLR)\right] + NRTS\left[(DMC)(RMC) + (DMH)(DLR)\right]\Big\} + \left[\frac{(TFFH)(1 - LRR)(TM)(TMC)}{MFTBMA_S}\right]$$

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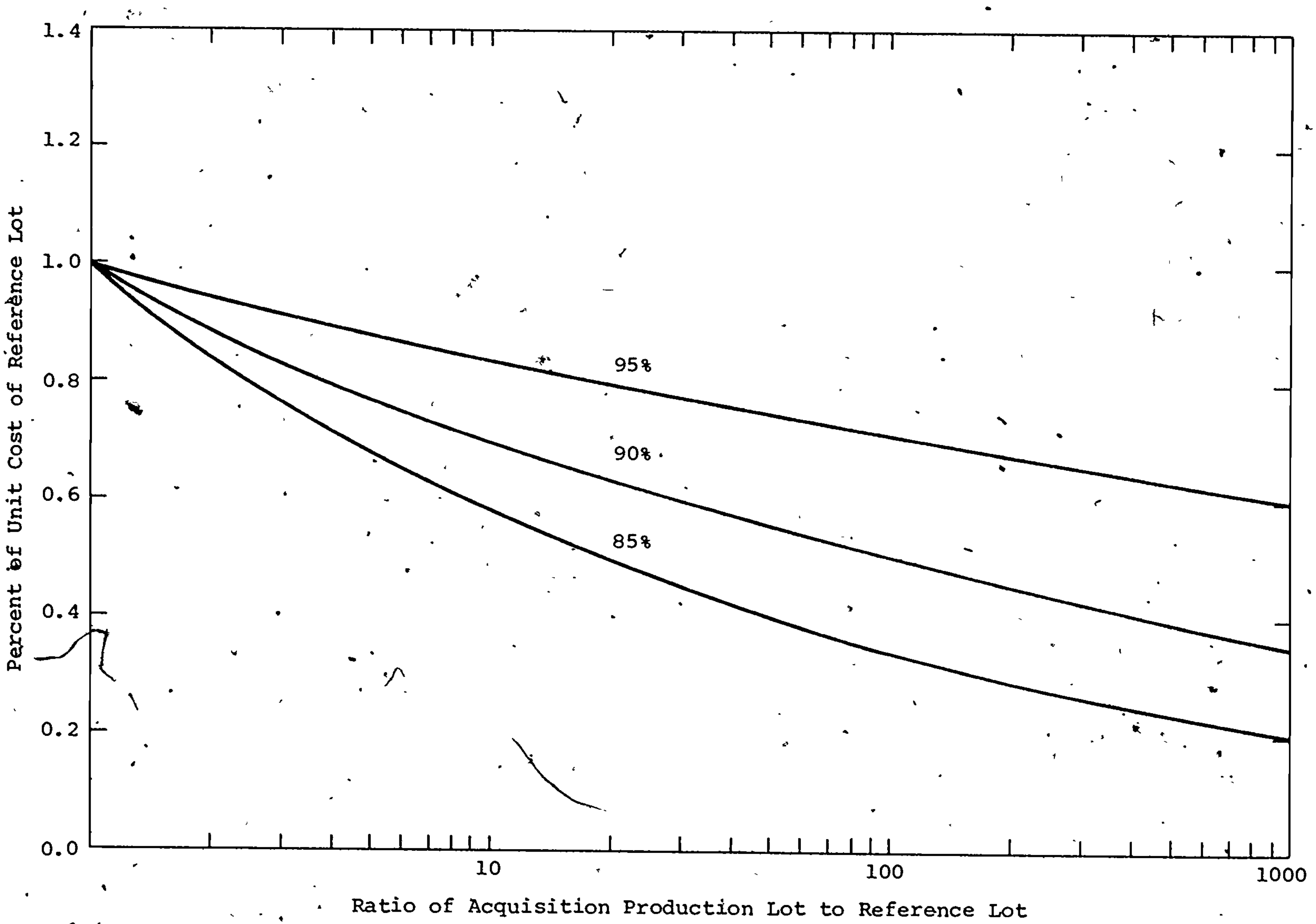

Figure 2-1. EFFECTS OF LOT SIZE AND PRODUCTION CURVE ON ACQUISITION PRICE

C_5 = Cost of personnel training

$$C_5 = (TCB)\left[1 + (PIUP - 1)(TRB)\right]\left\{\left[\frac{TFFH}{(PIUP)(MFTBMA_S)}\right]\right.$$

$$\left.\left[\frac{(IMH + RMH) + (LRR + [1 - TM]\ [1 - LRR])\ (RTS)(BMH)}{PMB}\right]\right\}$$

$$+ (TCD)\left[1 + (PIUP - 1)(TRD)\right]\left\{\left[\frac{TFFH}{(PIUP)(MFTBMA_S)}\right]\right.$$

$$\left.\left[\frac{(LRR + [1 - TM][1 - LRR])\ (NRTS)(DMH)}{PMD}\right]\right\}$$

C_6 = Cost of management and technical data

$$C_6 = \left[\frac{(TFFH)(BLR)}{MFTBMA_S}\right]\left[(MRO) + (LRR + [1 - TM][1 - LRR])(MRF + SR + TR)\right.$$

$$\left. + (1 - LRR)(TM)(SR)\right]$$

where

LRR = fraction of total maintenance actions that result in removal of a Line Replaceable Unit (black box)

UC_L = average cost of an LRU

AD = average demand on the pipeline for spares

$$= \left[\frac{PFFH}{MFTBMA_S}\right]\left[BRCT\ (RTS) + DRCT\ (NRTS)\right].$$

UC_s = unit cost of the system

$MFTBMA_S$ = system mean flight time between maintenance actions

TM = fraction of total number of modules that are designated as throwaways

TMC = unit cost of a throwaway module

RMC = unit cost of a repairable module

Other terms are as defined in Appendix F

The equation for initial spares cost is based on a normal approximation to the Poisson distribution and computes a spares sufficiency level of approximately 93.5 percent. The total quantity of spares calculated by this equation will satisfy the average demand and provide for a safety stock.*

Selection of values for the parameters delineated above permits evaluating the effects of different maintenance concepts and system and module costs on life-cycle cost. Module cost can be traded off against support cost to determine the economic feasibility of a discard-upon-failure maintenance philosophy or of conventional module or LRU repair.

The equation for the cost of personnel training is evaluated by calculating first the quantity inside the braces {}. This quantity represents the number of personnel required for maintenance based on the expected number of maintenance actions and the projected productivity. The quantity represented by those parameters for the base-level portion of the equation must be an integral multiple of the number of operational bases. The corresponding term for the depot-level portion of the equation need only be rounded to the next higher integer value before the calculation continues.

Four cost categories are included in the model described in Appendix A that are not represented here because of the lack of data:

- Support-equipment costs
- Training-equipment costs
- On-equipment costs for scheduled maintenance
- Technical documentation costs

2.5 EVALUATION OF DAIS AVIONICS LIFE-CYCLE COST FOR A CLOSE AIR SUPPORT CONFIGURATION

2.5.1 Research, Development, Test, and Evaluation (RDT&E) Cost

The RDT&E cost for the application of DAIS to a Close Air Support configuration of avionics could not be quantitatively evaluated because of the lack of data.

2.5.2 Acquisition Cost

From the baseline data of Table 2-1, the acquisition cost for the DAIS CAS avionics was estimated for three production-lot adjustments. These calculated costs are shown in Table 2-3. The production-lot adjustments are based on a production quantity of 500 aircraft installations. The costs

*In order to calculate actual spares quantities for initial pipeline sparing, the equation for initial spares would have to be applied to each module and LRU type separately. However, the average demand based on the total number of maintenance actions provides a useful quantity for estimating spares cost.

Table 2-3. DAIS CLOSE AIR SUPPORT AVIONICS

Equipment	Quantity per Aircraft	Total Cost per Aircraft, 95% P.C.*	Total Cost per Aircraft, 90% P.C.	Total Cost per Aircraft, 85% P.C.
Remote Terminals	15	$ 369,454	$ 256,880	$176,524
Computer	4	184,766	129,802	90,175
Bus Controller Unit	4	28,103	19,505	13,381
Video Switch/Refresh Memory	1	71,770	50,947	35,787
Scan Converter	1	71,770	50,947	35,787
Programmable Display Generator	2	281,031	195,069	133,807
Multi-Function Keyboard	1	14,354	10,190	7,157
Multi-Function Control Panel	2	6,042	4,193	2,876
Vertical Situation Display	1	14,354	10,190	7,157
Multi-Purpose and Horizontal Situation Displays	1	28,707	20,379	14,314
Head-Up Display	1	17,943	12,737	8,947
Hand Controller	1	7,177	5,094	3,579
Dedicated Control and Display Group	1	14,354	10,190	7,157
Sensors				
Radar Beacon	1	5,302	5,302	5,302
Forward-Looking Radar	1	63,440	63,440	63,440
Doppler Radar	1	26,190	26,190	26,190
Radar Altimeter	1	2,050	2,050	2,050
VHF Radio	1	5,455	5,455	5,455
UHF Radio	1	4,036	4,036	4,036
TACAN	1	6,029	6,029	6,029
Instrument Landing System	1	11,703	11,703	11,703
Inertial Measurement Unit	1	67,771	67,771	67,771
LORAN	1	35,000	35,000	35,000
IFF	1	2,467	2,467	2,467
Automatic Direction Finder	1	1,504	1,504	1,504
Total Avionics Cost per Aircraft (Including Remote Terminals)		$1,340,772	$1,007,070	$767,598
Total Avionics Cost per Aircraft (Excluding Remote Terminals)		$ 971,318	$ 750,190	$591,071

*P.C. = Production Curve. Costs are estimated on the basis of Table 2-1 data, assuming 500 production aircraft. The cost of the sensors is based on IROS data, assuming production-lot quantities. All cost data contained in this report are in current dollars. No adjustments were made for inflation.

associated with the sensors were extracted from data source 5. It was assumed that the cost of each basic functional unit of each aircraft system (receiver-transmitter, inertial measurement unit, etc.) would remain the same, but that computational, control, and display functions and their associated costs would be repartitioned in the integrated system.

It was necessary to consider two distinct cases for these avionics because of the nature of the laboratory hot-bench installation. The remote terminals in the laboratory system will serve as interfaces between the sensors and the multiplexing system. However, an aircraft installation could not accommodate the physical size of these units. The function performed by the remote terminals may be integrated into the sensor units or eliminated by future digital sensor designs. Therefore, the estimated system cost for the avionics is broken into two categories, as shown at the bottom of Table 2-3.

Figure 2-2 compares the cost of both of these categories: DAIS with remote terminals and DAIS without remote terminals. The cost of a current conventional avionic system is $575,983, as computed from the data in Appendix C.

2.5.3 Installation Cost

The use of a Time Division Multiplex (TDM) bus in DAIS-configured aircraft will greatly reduce the amount of wiring for the avionics, thereby significantly reducing the installation cost for these equipments. The interconnecting cabling for the DAIS avionics will consist of a shielded, twisted-pair cable. The small size and light weight of this cable will permit the use of multiple redundant cables to ensure maximum aircraft survivability and mission reliability. No data were available for a quantitative comparison of the cost of this approach to conventional intersystem cabling, but the cost reduction afforded by the TDM cabling should be proportional to the decrease in the quantity and complexity of the cables and connectors required.

2.5.4 Logistic Support Cost

The model described in Section 2.4 was used to evaluate the logistic support cost of the avionics of a DAIS-configured Close Air Support aircraft. Three distinct cases were considered in the analysis; two of these cases addressed module removal at the flight-line level of maintenance, and the third addressed removal of black boxes.

- Case I - Throwaway-Module Concept
  - Five percent of all maintenance actions result in removal of a black box (LRR = 0.05); other maintenance actions involve module removal.
  - Seventy-five percent of all removed modules are throwaways (TM = 0.75).

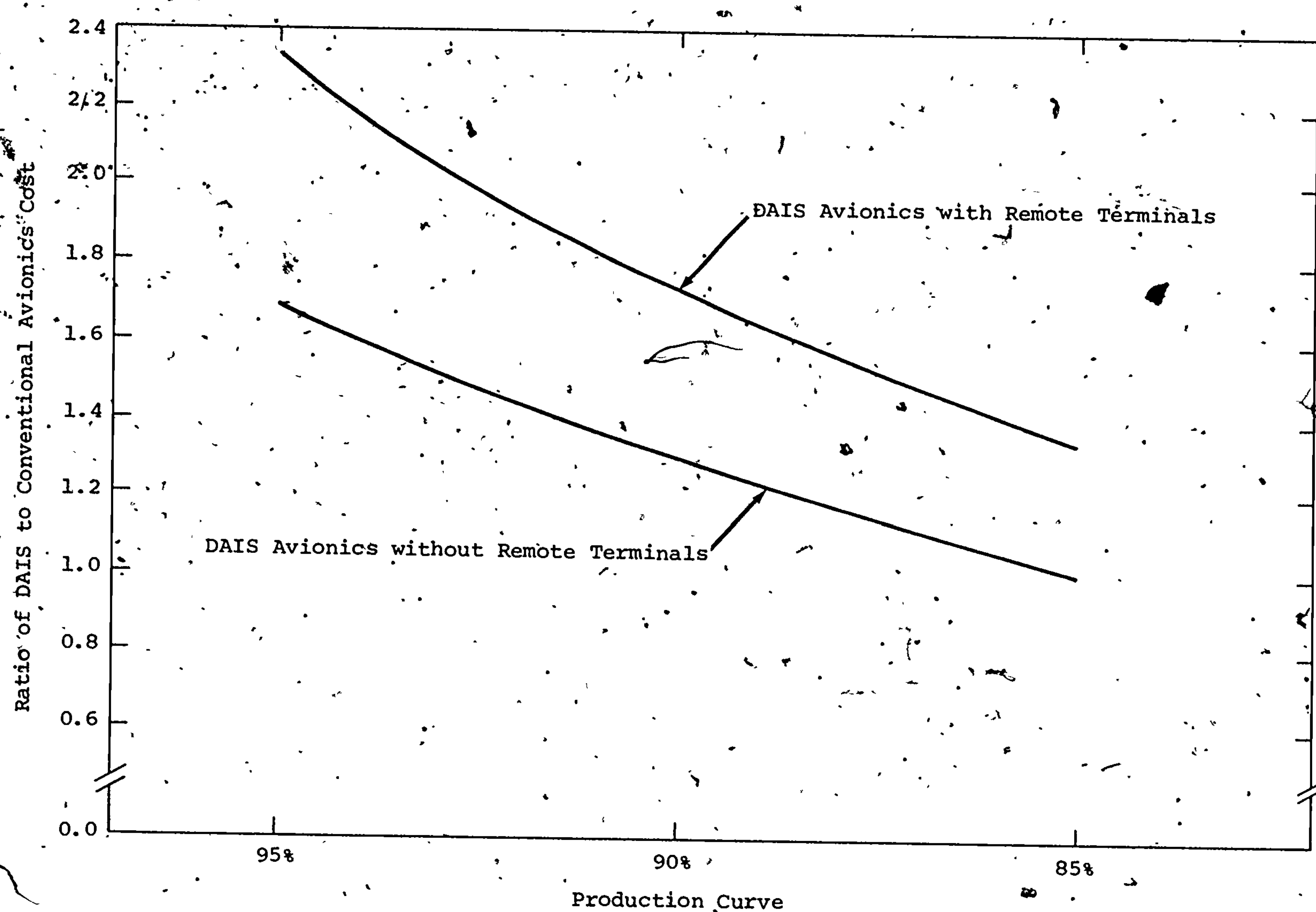

Figure 2-2. COMPARISON OF DAIS AND CONVENTIONAL CAS AVIONICS ACQUISITION COSTS FOR VARYING PRODUCTION-CURVE ADJUSTMENTS

- Average cost of a throwaway module is $50 (TMC = $50).
- Average cost of a repairable module is $500 (RMC = $500).
- Other data elements are as given in Table 2-4.

• Case II - Throwaway-Module Concept

- All data elements are the same as in Case I except that TMC is $100 and RMC is $1000.

• Case III - Black-Box-Removal Concept (This represents the current Air Force maintenance policy.)

- All maintenance actions result in removal of black box (LRR = 1.00, TM = 0.00).
- Base material cost is $100 per maintenance action (BMC = $100).
- Depot material cost is $50 per maintenance action (DMC = $50).
- Other data elements are as given in Table 2-4.

2.5.5 Total Life-Cycle Cost

Table 2-5 shows the results of an analysis of the LRU removal concept for the conventional and DAIS Close Air Support configurations based on the cost parameters in Table 2-4. This analysis assumes 500 aircraft each operating an average of 20 hours per month for a 15-year life cycle. The acquisition costs for the conventional avionics are based on Appendix C (Table C-2). The DAIS acquisition costs are based on Table 2-3, assuming no remote terminals and a 90-percent production curve, for a total production of 2300 systems.

In order to establish a lower bound on the magnitude of the cost figures resulting from the life-cycle-cost analysis, a best-case analysis was performed for both conventional and DAIS CAS configurations. The data for the best-case conventional suite of avionics was established by selecting independent best-case values of acquisition cost and reliability for a typical mix of Close Air Support avionics. The best-case conventional avionics are shown in Appendix C (Table C-7), and the best-case DAIS avionics are shown in Appendix D (Table D-2). It should be noted that the particular mix of avionics shown has not been integrated into an aircraft system, but each subsystem was chosen to represent known best-case values of acquisition cost and reliability. The system mean flight time between maintenance actions ($MFTBMA_S$) for the best-case conventional avionics is 7.78 hours; the DAIS $MFTBMA_S$ is estimated at 10 hours. This projected increase in reliability for the DAIS avionics is based on a potential reduction in hardware in a DAIS-configured system. The results of this baseline best-case analysis are shown in Table 2-6.

The analyses discussed above are based on the current Air Force maintenance philosophy of black-box removal at the flight-line level (DAIS Case III). State-of-the-art design and packaging practices have made the concept of module removal at the flight line technically feasible. A life-cycle-cost analysis

Table 2-4. COST PARAMETERS		
Parameter	Conventional Configuration	DAIS Case III
UC_S	$575,983	$750,190
UC_L	$7,000	$9,100
$MFTBMA_S$	See Table C-2	10 hours
RTS	0.76 (See Table C-2)	0.94
NRTS	0.23 (See Table C-2)	0.05
COND	0.01 (See Table C-2)	0.01
IMH & RMH	See Table C-2	1.00 hour
BMH	See Table C-2	5.00 hours
DMH	See Table C-2	24.0 hours
PIUP	15 years	Same
BRCT	0.33 month	Same
DRCT	2.00 months	Same
PFFH	10,000 hours	Same
TFFH	1,800,000 hours	Same
BLR	$11.70	Same
DLR	$12.44	Same
BMC	$100	Same
DMC	$50	Same
TCB	$950	Same
TCD	$1600	Same
TRB	0.33	Same
TRD	0.15	Same
PMB	1,680 hours	Same
PMD	1,788 hours	Same
MRO	0.08 hour	Same
MRF	0.24 hour	Same
SR	0.24 hour	Same
TR	0.16 hour	Same
M	25	Same

Table 2-5. COMPARISON OF DAIS AND CONVENTIONAL CLOSE AIR SUPPORT COSTS (500 AIRCRAFT FOR 15 YEARS)

Cost Category	Costs	
	Conventional	DAIS Case III
Initial and Replacement Spares	$107,215,713	$ 20,392,334
On-Equipment Maintenance	26,903,588	2,106,000
Off-Equipment Maintenance	147,392,868	29,955,240
Personnel Training	1,506,060	311,590
Management and Technical Data	5,982,258	1,537,380
Total Logistic Support	289,000,487	54,302,544
Acquisition	287,991,500	375,095,000
Totals	$576,991,987	$429,397,544

Note: Data in this table are based on 500 aircraft operating for 15 years.

Table 2-6. BEST-CASE CAS ANALYSIS (500 AIRCRAFT FOR 15 YEARS)

Cost Category	Costs	
	Best-Case Conventional	Best-Case DAIS
Initial and Replacement Spares	$ 12,940,642	$ 15,910,502
On-Equipment Maintenance	5,413,882	2,106,000
Off-Equipment Maintenance	38,502,879	29,955,240
Personnel Training	321,510	311,590
Management and Technical Data	1,948,997	1,537,380
Total Logistic Support	59,127,910	49,820,712
Acquisition	185,132,500	290,332,000
Totals	$244,260,410	$340,152,712
Input Parameters		
UC_S	$370,265	$580,664
UC_L	$ 4,500	$ 7,000
$MFTBMA_S$	7.78 hours	10.00 hours
RTS	0.94	0.94
NRTS	0.05	0.05
COND	0.01	0.01
IMH & RMH	2.00 hours	1.00 hour
BMH	5.00 hours	5.00 hours
DMH	24.00 hours	24.00 hours

Note: Data in this table are based on 500 aircraft operating 20 hours per month for a 15-year life cycle.

for a module-removal concept (Cases I and II in Section 2.5.5) was performed to evaluate the economic feasibility of this approach. The results of the analysis are given in Table 2-7 and Figure 2-3. These data show that the total life-cycle cost is lower for this maintenance concept, primarily due to the lower cost of the pipeline spares.

Table 2-7. EFFECT OF MAINTENANCE CONCEPT ON DAIS LIFE-CYCLE COST (500 AIRCRAFT FOR 15 YEARS)

Cost Category	Case I Costs	Case II Costs	Case III Costs
Initial and Replacement Spares	$ 1,285,725	$ 1,551,834	$ 20,392,334
On-Equipment Maintenance	2,106,000	2,106,000	2,106,000
Off-Equipment Maintenance	15,019,547	22,405,082	29,955,240
Personnel Training	148,355	148,355	311,590
Management Data	937,170	937,170	1,537,380
Total Logistic Support (subtotal)	19,496,797	27,148,441	54,302,544
Acquisition	375,095,000	375,095,000	375,095,000
Totals	$394,591,797	$402,243,441	$429,397,544

2.6 EVALUATION OF DAIS COSTS FOR A MIX OF FUTURE AIRCRAFT

The analysis of the life-cycle costs of DAIS and conventional avionics was extended to cover a mix of Close Air Support, Transport, Fighter, and Bomber aircraft.* Adjustment factors were used to correlate the calculated logistic support cost of the conventional CAS avionics to that of the avionics of the other aircraft. These factors are ratios of the logistic support cost as computed in the IROS reports for each aircraft type. When viewed on a per-aircraft-per-year basis, these ratios provide a normalized baseline that accounts for variations in flying schedule, number of deployment locations, and other operational parameters. These factors were applied to the calculated logistic support cost of the conventional CAS avionics to project the costs to the avionics of the other aircraft types.

The logistic support costs for the DAIS avionics were estimated by applying a ratio to the calculated DAIS Close Air Support logistic support cost. This ratio combined the effects of the number of distinct sensors in each aircraft type and the relative numbers of each type.

*The aircraft chosen to represent these types are the A-7D, C-141A, F-4D, and B-52G, respectively.

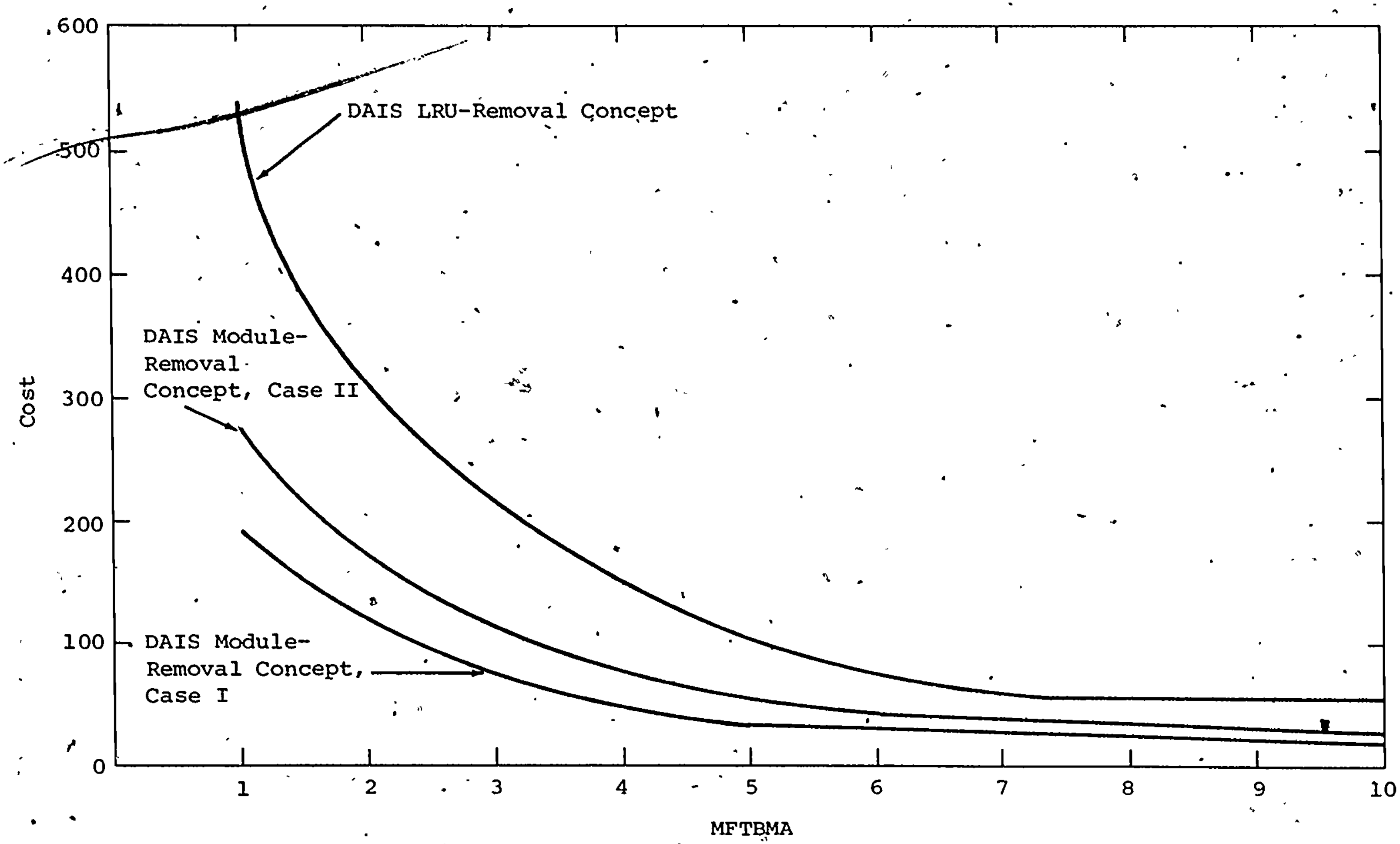

Figure 2-3. EFFECT OF SYSTEM MFTBMA ON LOGISTIC SUPPORT COST

The conventional avionics acquisition costs were estimated by applying the production-lot equation from Section 2.3 to the data in Table 2-1 (using the 90-percent production curve for 2300 total aircraft) and adding the costs of the sensors for each aircraft type.

The results of this analysis are shown in Table 2-8. No adjustments for discounting or inflation were made for any of the data in Table 2-8, which will affect the absolute value of these results, particularly for multi-year procurements.

The evaluation of life-cycle costs presented in Table 2-5 and Table 2-8 was based on estimates of costs of prototype hardware for the DAIS hot-bench and projections of support costs and repair times. The results of this analysis were then compared with the known costs of conventionally designed and procured systems. This approach could result in some misinterpretation concerning the areas of life-cycle cost in which the DAIS approach to avionics integration offers the most significant benefits. Since a considerable number of the major areas of savings from DAIS cannot be quantified at this time, the following qualitative analysis is provided.

2.6.1 Research and Development

If a system of DAIS avionics is incorporated into a mix of aircraft types, there should be a reduction in the total cost of research and development for the avionics of those aircraft. Following the investment for the initial avionics development, the only funds required for incorporating the DAIS suite of avionics into additional aircraft would be for sensor functions unique to those aircraft and the attendant software (programming) changes. However, as stated earlier, software and software documentation have historically been very expensive, and it is possible that any savings in hardware R&D expenditures could be neutralized by excessive software costs. Careful evaluation and monitoring of the costs of the total development effort (hardware and software) are necessary to ensure that the potential cost benefit offered by DAIS is realized.

2.6.2 Installation

The use of time-division multiplexing in a system of avionics should result in significant cost savings in the installation and modification of that system. Reductions in weight, cabling complexity, and modification requirements offer the potential for savings throughout the life of an aircraft.

2.6.3 Acquisition

The DAIS avionics hardware will incorporate state-of-the-art technology in terms of components, circuit techniques, and packaging. Alternative approaches to the design and procurement of avionic systems will also take advantage of these advances, and there is no basis for predicting an acquisition-cost differential between DAIS and other approaches on technological grounds. Hardware commonality across a mix of aircraft types, a central concept in the DAIS scheme, does offer the potential for greater

Table 2-8. EVALUATION OF COSTS ACROSS A MIX OF AIRCRAFT (15-YEAR LCC ESTIMATE)

Cost Category	Close Air Support Cost (500 Aircraft)		Transport Cost (300 Aircraft)		Fighter Cost (1000 Aircraft)		Bomber Cost (500 Aircraft)	
	Conventional	DAIS Case III	Conventional	DAIS Case III	Conventional	DAIS Case III	Conventional	DAIS Case III
Logistic Support	$289,000,487	$ 54,302,544	$345,066,582	$ 51,587,417	$566,440,955	$ 81,453,816	$664,701,120	$ 58,827,756
Acquisition	287,991,500	375,095,000	129,014,700	183,095,700	347,449,000	512,313,000	173,997,000	245,500,000
Total Cost	$576,991,987	$429,397,544	$474,081,282	$234,683,117	$913,889,955	$593,766,816	$838,698,120	$304,327,756
Cost per Aircraft	$ 1,153,984	$ 858,795	$ 1,580,271	$ 782,277	$ 913,890	$ 593,767	$ 1,677,396	$ 608,656
Total Across Mix:	Conventional = $2,803,661,344; DAIS = $1,562,175,233							

economies of scale through larger production-lot commitments. Applying the production-lot equation given in Section 2.3 to a mix of 500 Close Air Support, 300 Transport, 1,000 Fighter, and 500 Bomber aircraft reveals that a total purchase of 2,300 aircraft systems as a single production lot results in approximately a 20-percent decrease in unit acquisition cost for the DAIS core elements below that for a lot size of only 500 systems.

2.6.4 Logistic Support Cost

Calculations of logistic support cost require inputs of many operational, reliability, and maintainability parameters. Actual values of these parameters are established through field experience with a system and are influenced by a variety of factors, including hardware complexity, software versatility, technical documentation, training, support equipment, and other operational and environmental effects.

The primary factor in determining the logistic support cost of any system is the reliability exhibited by that system in an operational environment. The number of maintenance actions required to maintain an aircraft in a ready status determines the required number of spares, maintenance personnel, support equipment, and other support-related assets and activities. System reliability is measured by calculating mean flight time between maintenance actions (MFTBMA). Figure 2-3 shows the effect of MFTBMA on logistic support cost. Procurement decisions can be heavily influenced by a knowledge of whether the life-cycle cost of a system will be affected primarily by acquisition or by support costs.

The cost of spares constitutes one of the most significant categories of logistic support cost. For a given technological base and level of reliability, the cost of spares is most heavily influenced by the level of sparing and the range of applicability of a given set of spares. As shown in Figure 2-3, a black-box-removal maintenance concept results in a higher life-cycle cost than a module-removal concept because of the much higher cost of base and depot pipeline spares. This cost category dominates the total life-cycle cost at low reliability levels. The degree of commonality across a mix of aircraft types determines the number, and therefore the cost, of different spare units required to satisfy a specified level of spares sufficiency. The high degree of avionics commonality across aircraft types projected for the incorporation of DAIS into future aircraft should result in a significant reduction in spares cost because of the net reduction in required safety stock for the supply pipelines.

The areas of training, documentation, and support equipment would also benefit from commonality across many aircraft, but these cost categories are believed to represent only a fraction of the total life-cycle cost.

CHAPTER THREE

QUALITATIVE EVALUATION OF POTENTIAL DAIS COST BENEFITS

Examination of the sources listed in Appendix E reveals that there are several areas in which the DAIS approach offers significant cost and other benefits, but these benefits are difficult to assess quantitatively. Some of these areas are discussed in this chapter.

3.1 REDUCED VULNERABILITY TO JAMMING

A significant advantage of the digital data link, which uses time division of signals, is that its vulnerability to jamming is much smaller than that of systems using frequency division. In addition, the incorporation of electro-optical techniques of multiplexing will reduce susceptibility to pulse interference.

3.2 INCREASED MISSION RELIABILITY

It is expected that the DAIS software package will provide the flexibility to permit the design of fault tolerance into future digital avionic systems. A system will thus continue to perform even if one or more circuits fail because the function(s) performed by the failed circuit will be transferred to other sections of the system. This concept is possible in a digital system because of the ability of the software to control data flow through the system.

3.3 INCREASED SURVIVABILITY

The simplicity and light weight of the multiplexed data lines of the DAIS avionics will provide a sufficient advantage over current hard-wiring techniques to permit the use of multiple wiring runs. These redundant connections will be dispersed throughout the aircraft, decreasing the probability that battle damage to the wiring will disable the aircraft.

3.4 EASE OF LABORATORY EVALUATION

The DAIS concept provides the capability to evaluate new equipments and techniques in the laboratory at relatively low cost. A digital system provides the flexibility to demonstrate newly developed hardware or software at a cost potentially far below the current level of RDT&E expenditures. Avionics parameters can easily be simulated in such a system, and the impact of new sensors, displays, or other hardware can be evaluated even before they have been fully developed. This capability could be a fundamental tool in reversing the accelerating cost-growth characteristic of the current methods of designing and testing new systems.

3.5 EASE OF INTEGRATING NEW TECHNOLOGY

Further development of DAIS does not require the development of any new technologies. The concept draws from R&D programs currently being proven in advanced weapon systems. This does not mean that the DAIS approach freezes technology, but rather that it exploits the benefits that can be obtained with present state-of-the-art techniques. However, the modular characteristics of DAIS avionics should permit the incorporation of advancements in either hardware or software into the system at a relatively low cost. Basic research in information and systems science is rapidly expanding, and new electronic devices (such as bubble memories, fiber optics, low-power gates, etc.) appear almost weekly. Any new avionic systems must be designed to absorb these technological advances without the requirement for a major redesign. This is a fundamental element in the DAIS approach to avionic systems.

3.6 REDUCTION OF INVENTORIES

One of the major problems in maintaining a high readiness posture is the enormous size of the logistic network caused by the proliferation of module types. Each new system entering the inventory can add hundreds of unique modules to the supply system. The restricted availability of funds dictates that there will never be sufficient quantities of spares of all module types on hand to ensure that all requisitions can be filled. The reduction of the number of module types in a DAIS system and the degree of commonality between aircraft will reduce the costs of the logistic system.

3.7 MATERIAL AND MANAGEMENT CENTRALIZATION

The prospect of a high degree of commonality between aircraft avionic systems as offered by DAIS presents the potential for significantly streamlining all phases of system support. Uniformity of hardware would minimize the number of maintenance, supply, technical support, and management facilities and personnel required.

Centralization of aircraft support based on standardization of avionics should have a major impact on improving the procurement-to-support cost ratio.

CHAPTER FOUR

CONCLUSIONS

There are several general observations or conclusions that may be drawn from the data and discussions included in this report. These are discussed in the following subsections.

4.1 RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

The DAIS approach to avionics development provides the potential for a significant cost benefit in the area of RDT&E. After the investment for the initial avionics development, the only R&D funds that would be required for incorporating DAIS into additional aircraft types would be for the sensor functions unique to those aircraft and the associated software.

4.2 ACQUISITION

The acquisition cost of the DAIS avionics will depend on the effects of production-lot size, competition, and other procurement decisions. The degree of commonality between aircraft types offered by incorporation of the DAIS approach will permit the realization of economies of scale through large production-lot commitments.

Realization of the potential cost benefits offered by DAIS will depend to some extent on the degree of success in controlling the reliability and costs of the mission software.

4.3 INSTALLATION

The utilization of time-division multiplexing in a DAIS system of avionics will result in significant installation-cost savings. In addition, modifications to or additions of subsystems can be made without rewiring the aircraft, resulting in further cost savings and airframe versatility.

4.4 OPERATION AND MAINTENANCE

The projected built-in-test capabilities of the DAIS system should reduce the costs associated with on-equipment maintenance by lowering the man-hours required for troubleshooting the system for corrective or preventive maintenance.

The calculation of off-equipment maintenance costs is very sensitive to base-level material cost. For this reason, it is difficult to assess the full impact of the DAIS concept for this cost category. However, the partitioning of avionics into relatively small, low-cost modules (as in the disposable-module concept) provides the potential for labor and material cost savings if the DAIS built-in-test capabilities are realized.

The disposable-module concept provides the potential for significant logistic-support-cost savings, primarily from the savings in base and depot pipeline spares.

The governing factor in computing the logistic support cost of any system is the reliability exhibited by that system in its operational environment. The number of maintenance actions required to maintain the aircraft in a ready status determines the number of spares, maintenance personnel, support equipment, and other support-related assets and activities that increase the total cost of a system far beyond its acquisition cost. Therefore, improvements in the reliability of the avionics package will have a major impact on decreasing the logistic support cost of the aircraft.

4.5 SUPPORT EQUIPMENT

The costs associated with the acquisition and operation of the support equipment required to maintain a system of avionics would be reduced for a DAIS-configured aircraft because of the comprehensive built-in-test capabilities of the system. This cost advantage would increase with the number of aircraft types in which DAIS was incorporated because there would be a net reduction in the number of sets of support equipment required. The requirements for support equipment depend on the maintenance philosophy, but a minimization of different module types will minimize support-equipment requirements for either the module-removal or black-box-removal approach.

4.6 TRAINING

Application of the DAIS concept to aircraft avionics should reduce the costs of personnel training because of the benefits arising from the commonality between aircraft. The training function could be centralized to a large extent since the basic avionic system would be the same for all aircraft types and fewer equipments would be needed for technical training. In addition, only one central training curriculum would be needed to cover all aircraft types, with special material required only for those sensor functions unique to a given weapon system. A throwaway-module maintenance philosophy would eliminate the requirement for in-depth training below the module level, shortening courses and reducing training costs.

4.7 DOCUMENTATION

Incorporation of DAIS avionics into a mix of aircraft should offer a significant benefit relative to the cost of developing technical documentation. After manuals for the first aircraft have been developed, the commonality between aircraft would reduce the requirements for development of new technical material to the functional units that are unique to a weapon system.

4.8 GENERAL CONCLUSIONS

The fundamental concept of avionics commonality between aircraft could result in substantial cost reductions across the entire Air Force via centralization of both direct and indirect support of operational units. Uniformity of avionics hardware would permit minimization of the number of maintenance, supply, technical support, and management facilities required to support the aircraft; and all phases of system support would be streamlined.

The DAIS approach incorporates several architectural and maintenance concepts, and the various cost benefits described in this report could be realized without implementing the full DAIS package. Therefore, in a comparison of DAIS with state-of-the-art conventional avionics, the true cost savings achievable with DAIS are limited to those cost categories for which DAIS offers unique capabilities.

APPENDIX A

GENERAL FORM OF LIFE-CYCLE-COST MODEL

1. RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDT&E) COSTS

RDT&E expenditures are often the most difficult of all life-cycle-cost categories on which to obtain information. These funds are usually divided among several organizations; and reconstruction of the actual sources, recipients, and amounts expended can be a very time-consuming effort, with no guarantee that all costs have been accounted for. Therefore, the costs associated with RDT&E must be extracted from reports and budget documents of the organizations that control these funds.

2. ACQUISITION COSTS

System acquisition costs are a summation of the costs of the individual Line Replaceable Units (LRUs) for the quantity of aircraft under consideration, which can be stated as

$$C_A = \sum (\text{LRU unit costs}) (\text{Quantity per aircraft}) (\text{Number of aircraft})$$

$$C_A = \sum_{i=1}^{N} (UC_i) (QPA_i) (AC)$$

where

UC_i = unit cost of the i^{th} LRU

QPA_i = quantity per aircraft of the i^{th} LRU

AC = number of aircraft

N = total number of LRUs

i = index of each LRU within the aircraft

3. INSTALLATION COSTS

The installation costs include the wiring and labor required to install a system in the aircraft. These may be included in the cost of the airframe or may be accounted for in costs of retrofit, Engineering Change Proposals, or other modifications. Where data are available, the installation costs can be delineated as

$$C_I = \sum \text{(Unit installation cost) (Quantity per aircraft) (Number of aircraft)}$$

$$C_I = \sum_{i=1}^{N} (IC_i)\ (QPA_i)\ (AC)$$

where

IC_i = installation cost of the i^{th} LRU

Other terms are as previously defined

4. INITIAL AND REPLACEMENT SPARES COST

The initial and replacement spares cost encompasses the procurement of (1) the initial modules and complete units intended to serve as spares to be used in on-equipment maintenance (nonrecurring), and (2) the additional spare modules or units to replace those lost to the system through condemnation (recurring). The model computes the cost of the initial spares on the basis of the expected number of failures under peak-force operation conditions and the associated pipeline delays. The cost of replacement spares is determined from the total number of expected failures during the life cycle and the fraction of failures resulting in condemnations, as shown in the following equations:

$$C_1 = \sum \text{(LRU unit costs)} \times \{\text{Number of units for base and depot pipeline}\} + \sum \text{(LRU unit costs)} \times \{\text{Number of units condemned over life cycle}\}$$

$$C_1 = \sum_{i=1}^{N} (UC_i)\left(AD + \sqrt{2.3 \times AD}\right) + \sum_{i=1}^{N} (UC_i) \left\{\frac{(QPA_i)\ (1\text{-}RIP_i)\ (COND_i)\ (TFFH)}{MFTBMA}\right\}$$

where

$$AD = \text{Average demand} = \left[\frac{(PFFH)\ (QPA_i)}{MFTBMA_i}\right] \left[(BRCT_i)\ (RTS_i) + (DRCT_i)\ (NRTS_i)\right]$$

RIP_i = fraction of maintenance actions for the i^{th} LRU for which the LRU can be repaired in place

PFFH = peak force flying hours per month

$MFTBMA_i$ = mean flight time between maintenance actions for the i^{th} LRU

$BRCT_i$ = average base repair time in months for the i^{th} LRU

RTS_i = fraction of removals for the i^{th} LRU repaired at the base

$DRCT_i$ = average depot-repair response time in months for the i^{th} LRU

$NRTS_i$ = fraction of removals of the i^{th} LRU that result in depot repair

$COND_i$ = fraction of removals of the i^{th} LRU that result in condemnation

TFFH = total force flying hours over life cycle

Other terms are as previously defined

5. ON-EQUIPMENT MAINTENANCE COSTS

The on-equipment maintenance costs represent the recurring labor costs associated with performing all of the in-place and remove-and-replace maintenance actions during the equipment life cycle. They are obtained by the following equation:

$C_2 = \sum$ [Base labor rate] [Number of maintenance actions over life cycle] [Average man-hours per maintenance action] + [Base labor rate] [Man-hours for scheduled maintenance]

$$C_2 = \sum_{i=1}^{N} \left[BLR\right] \left[\frac{(TFFH)\ (QPA_i)}{MFTBMA_i}\right] \left[(IMH_i) + (RMH_i)\right] + \left[BLR\right] \left[\frac{(TFFH)\ (SMH)}{SMI}\right]$$

where

BLR = base labor rate

IMH_i = average time in man-hours to perform corrective maintenance in place for the i^{th} LRU

RMH_i = average time in man-hours to remove and replace the i^{th} LRU for subsequent repair

SMH = average time in man-hours to perform scheduled maintenance

SMI = scheduled maintenance interval in flying hours

Other terms are as previously defined

6. OFF-EQUIPMENT MAINTENANCE COSTS

The off-equipment maintenance costs represent the recurring labor and material costs associated with performing repair on the system at the base and depot levels. These costs are determined from the number of maintenance actions during the life of the equipment repaired at the base and depot levels, and the labor and material costs associated with each action, as shown in the following equation:

$$C_3 = \sum [\text{Number of maintenance actions over life cycle}] \times \{[\text{Base labor and material cost per maintenance action}] + [\text{Depot labor and material cost per maintenance action}]\}$$

$$C_3 = \sum_{i=1}^{N} \left[\frac{(TFFH)\ (QPA_i)\ (1-RIP_i)}{MFTBMA_i}\right] \left\{ RTS_i \left[(BMC_i) + (BMH_i)\ (BLR)\right] + NRTS_i \left[(DMC_i) + (DMH_i)\ (DLR)\right] \right\}$$

where

BMC_i = base material cost per maintenance action

BMH_i = average man-hours expended at the base to diagnose and repair the i^{th} LRU

DMC_i = depot material cost per depot maintenance action

DMH_i = average man-hours expended at the depot to diagnose and repair the i^{th} LRU

DLR = depot labor rate

Other terms are as previously defined

7. SUPPORT EQUIPMENT COSTS

The support equipment costs include the acquisition (nonrecurring) and operational (recurring) costs of the Aeronautical Ground Equipment (AGE) used to maintain the equipment at the base and depot levels. Both hardware and software costs are represented by this cost category. The following equation is used:

$$C_4 = \sum \left\{ \left[\text{Acquisition and operate costs of base level AGE}\right] + \left[\text{Acquisition and operating costs of depot level AGE}\right] \right\} + \left(\text{Cost of flight-line AGE} + \text{Cost of AGE software}\right)$$

$$C_4 = \sum_{j=1}^{K} \left\{ \left[CAB_j + (PIUP)\ (COB_j)\right] + \left[CAD_j + (PIUP)\ (COD_j)\right] \right\} + (FLA) + (CS)$$

where

CAB_j = cost of j^{th} piece of base level AGE

PIUP = operational service life of the system in years

COB_j = annual operating and maintenance cost of j^{th} piece of base-level AGE

CAD_j = cost of j^{th} piece of depot-level AGE

COD_j = annual operating and maintenance cost of j^{th} piece of depot-level AGE

FLA = cost of flight-line AGE for the aircraft

CS = cost of software associated with AGE

j = index of each piece of AGE

K = total number of AGE items

8. COST OF PERSONNEL TRAINING AND TECHNICAL EQUIPMENT

This cost element includes the specialized training for system maintenance personnel at the base and depot levels (nonrecurring), plus the additional training required at these levels because of personnel turnover (recurring). The training requirements are established by determining the number of base and depot-level personnel required annually to support the system, on the basis of the number of failures and the man-hours per failure to complete the repairs. Also included in this category is the nonrecurring cost of the special equipment (vans, simulators, etc.) required for maintenance or operator training. The following equation is used:

$$C_5 = \Big\{[\text{Cost of training per man at base level}]\ [\text{Total number of base personnel trained over life cycle}]\Big\}$$

$$+\Big\{[\text{Cost of training per man at depot level}]\ [\text{Total number of depot personnel trained over life cycle}]\Big\}$$

$$+\Big\{[\text{Cost of peculiar training equipment}]\Big\}$$

$$C_5 = (TCB)\ [1+ (PIUP)\ (TRB)] \left\{ \sum_{i=1}^{N} \frac{(TFFH)\ (QPA_i)}{(PIUP)\ (MFTBMA_i)} \left[\frac{(IMH_i + RMH_i) + (1-RIP_i)\ (RTS_i)\ (BMH_i)}{PMB}\right]\right\}$$

$$+ (TCD)\ [1 + (PIUP-1)\ (TRD)] \left\{ \sum_{i=1}^{N} \frac{(TFFH)\ (QPA_i)}{(PIUP)\ (MFTBMA_i)} \left[\frac{(1-RIP_i)\ (NRTS_i)\ (DMH_i)}{PMD}\right]\right\} + \Big\{TE\Big\}$$

where

TCB = cost of training per man at base level

TRB = annual turnover rate for base personnel

PMB = direct productive man-hours/man/year at base level

TCD = cost of training per man at depot level

TRD = annual turnover rate for depot personnel

PMD = direct productive man-hours/man/year at depot level

TE = cost of peculiar training equipment, including vans, simulators, laboratory equipment, recorders, etc.

Other terms are as previously defined

9. COST OF MANAGEMENT AND TECHNICAL DATA

The costs associated with the labor times required in filling out the various management-data-system forms for each maintenance action (recurring) and the cost of acquiring the original base and depot-level technical documentation (nonrecurring) comprise this cost element. The management-data costs are determined by the number of actions during the system life and the time per action needed to complete the various forms required for the data system. The following equation is used:

$$C_6 = \{\text{Cost of unscheduled maintenance record-keeping}\} + \{\text{Cost of scheduled maintenance record-keeping}\} + \{\text{Cost of technical documentation}\}$$

$$C_6 = \left\{\sum_{i=1}^{N} \frac{(TFFH)\ (QPA_i)\ (BLR)}{MFTBMA_i} \left[(MRO) + (1-RIP_i)\ (MRF + SR + TR)\right]\right\} + \left\{\frac{(TFFH)\ (BLR)}{SMI}\left[(MRO) + (0.1)\ (SR) + (0.1)\ TR\right]\right\} + \left\{(TD)\ (J+H)\right\}$$

where

MRO = average man-hours per maintenance action for completing on-equipment maintenance records

MFR = average man-hours per maintenance action for completing off-equipment maintenance records

SR = average man-hours per maintenance action for completing supply transaction records

TR = average man-hours per maintenance action for completing transportation forms

TD = cost per original page of technical documentation

J = number of pages of base and intermediate-level TOs

H = number of pages of depot-level TOs

Other terms are as previously defined

APPENDIX B

DATA SOURCES

1. Message from AFLC WPAFB, 161500Z, October 1974.
2. AFLC Life Cycle Cost Model description.
3. IROS report, File Number K051.PN3L, dated 1 November 1974.
4. IROS report, File Number K051.PN7L, dated 1 November 1974.
5. IROS report, File Number K051.PN8L, dated 1 November 1974.
6. *DoD Cost and Production Report*, File Number H036BHAAR, dated 17 October 1974.
7. AFAL/AAD.

APPENDIX C

DATA FOR CONVENTIONAL AVIONICS

Table C-1. CONVENTIONAL CAS COST PARAMETERS

Parameter	Value	Source*
PFFH	10,000 hours per month	500 A/C x 20 hours per month
TFFH	1,800,000 hours	PFFH x 12 months per year x 15 years
BRCT	0.33 months	2
DRCT	2 months	2
BLR	$11.70	1
DLR	$12.44	1
PIUP	15 years	AFLC/AQA
TCB	$950	AFHRL/ASR
TCD	$1600	AFHRL/ASR
TRB	0.33	2
TRD	0.15	2
PMB	1680 hours	2
PMD	1788 hours	2
MRO	0.08 hours	2
MRF	0.24 hours	2
SR	0.25 hours	2
M	25	Judgment

*See Appendix B for numbered data sources.

TABLE C-2

CONVENTIONAL CLOSE AIR SUPPORT OPERATIONAL DATA[1]

Nomenclature	QPA_i	UC_i	$MFTBMA_i$	$1\text{-}RIP_i$	RTS_i	$NRTS_i$	$COND_i$	IMH_i & RMH_i	BMH_i	BMC_i^2	DMC_i^2	DMH_i
FM-622A VHF Communication Set	1	$ 7,503	59.28	0.64	0.90	0.05	0.05	1.70	5.34	$100	$50	6.50
AN/ARC-51BX UHF Communication	1	5,706	22.78	0.56	0.94	0.05	0.01	1.41	5.32			2.41
AN/ARA-50 Automatic Direction Finder	1	4,726	73.19	0.22	0.88	0.12	0.00	1.33	5.68			3.65
AN/APX-72 IFF Transponder	1	3,219	46.93	0.34	0.84	0.15	0.01	1.56	2.70			23.12
Horizontal Situation Indicator	1	3,040	37.34	0.36	0.33	0.66	0.01	2.63	2.44			24.57
AN/ARN-52 TACAN Set	1	6,735	28.28	0.75	0.92	0.08	0.00	1.82	4.59			3.89
AN/ARN-58A Instrument Landing System	1	15,852	54.79	0.22	0.88	0.12	0.00	1.67	2.08			31.19
AN/ARN-92 LORAN Set	1	99,730	115.48	0.56	0.91	0.07	0.02	2.06	7.04			47.37
AN/APN-141 Radar Altimeter	1	6,290	26.50	0.60	0.74	0.25	0.01	0.94	1.83			31.16
AN/APN-154 Radar Beacon	1	6,166	158.39	0.65	0.89	0.11	0.00	2.01	2.30			114.43
AN/APQ-126 Forward Looking Radar	1	119,351	15.45	0.88	0.84	0.15	0.01	2.22	5.15			-
AN/ASN-91 Tactical Computer	1	100,932	49.45	0.16	0.87	0.13	0.00	2.83	4.95			-
Air Data Computer System	1	13,242	29.09	0.69	0.83	0.17	0.00	2.33	4.32			57.70
AN/APN-190(V) Doppler Radar	1	39,189	23.68	0.96	0.70	0.29	0.01	2.00	4.84			-
AN/AVQ-7 Head-up Display	1	50,148	13.66	0.73	0.71	0.29	0.00	1.89	5.68			-
AN/ASN-90(V) Inertial Measurement Unit	1	72,143	8.00	0.47	0.63	0.37	0.00	2.96	6.00			52.39
AN/ASN-99 Projected Map Display	1	22,011	58.26	0.49	0.75	0.25	0.00	1.77	3.07			-

1 All data from sources 4 and 5 except as noted
2 Estimated

Table C-3. CONVENTIONAL CLOSE AIR SUPPORT AVIONICS

Nomenclature	Unit Cost	QPA	Annual Logistic Support Cost per Aircraft*
FM-622A VHF Communication Set	$ 7,503	1	$ 321
AN/ARC-51BX UHF Communication Set	5,706	1	613
AN/ARA-50 Direction Finder Group	4,726	1	79
AN/APX-72 IFF/Transponder Set	3,219	1	181
Horizontal Situation Indicator	3,040	1	530
AN/ARN-52 TACAN Set	6,735	1	628
AN/ARN-58A Instrument Landing System	15,852	1	97
AN/ARN-92 LORAN Set	99,730	1	438
AN/APN-141 Radar Altimeter	6,290	1	427
AN/APN-154 Beacon Radar	6,166	1	44
AN/APQ-126 Forward Looking Radar	119,351	1	2,877
AN/ASN-91 Tactical Computer Set	100,932	1	888
Air Data Computer System	13,242	1	827
AN/APN-190(V) Doppler Radar	39,189	1	1,193
AN/AVQ-7 Head-Up Display	50,148	1	2,165
AN/ASN-90(V) Inertial Measurement Unit	72,143	1	4,006
AN/ASN-99 Projected Map Display	22,011	1	293

Total avionics cost per aircraft = $575,983

Total annual logistic support cost per aircraft = $15,607

*From data source 3.

Table C-4. CONVENTIONAL TRANSPORT AVIONICS

Nomenclature	Unit Cost	QPA	Annual Logistic Support Cost per Aircraft*
HF-102 HF Communications	$ 35,768	2	$ 2,067
618M-1C VHF Communications	10,151	2	45
807A VHF Communications	3,837	2	1,038
AN/ARC-90 UHF Communications	30,399	2	4,010
AN/ARQ-23 UFH Communications	3,087	1	19
AN/APX-64 IFF Transponder	9,635	1	225
DFA-73A Receiver, ADF	2,396	1	995
51Z-3 Marker Beacon Set	808	1	74
AN/ARN-21 TACAN System	5,929	1	3,174
806A/51R6 VHF Navigation	4,084	1	784
800B/51V-4 Glideslope System	2,550	1	209
AN/APN-59B Search Radar	37,354	1	6,241
AN/APN-157 LORAN Set	36,601	1	1,654
AN/APN-147 Doppler Radar Set	32,795	1	3,201
AN/ASN-35 Doppler Computer	16,034	1	1,265
AN/ASN-24 Doppler Computer	102,965	1	5,206
AN/APN-150 Radar Altimeter	15,501	1	974

Total avionics cost per aircraft = $430,049

Total annual logistic support cost per aircraft = $31,181

*From data source 3.

Table C-5. CONVENTIONAL FIGHTER AVIONICS			
Nomenclature	Unit Cost	QPA	Annual Logistic Support Cost per Aircraft*
AN/ASN-46A Navigation System	$ 28,058	1	$ 1,334
AN/ASN-36 Inertial Navigation System	82,073	1	6,466
AN/ARN-92(V) LORAN Set	99,730	1	438
Miscellaneous Installed LORAN Equipment	22,848	1	76
AN/ASQ-19 Integrated Electronic Control	23,866	1	2,104
AN/APX-76 Interrogator Set	12,546	1	1,094
AN/APN-155 Radar Altimeter	5,983	1	464
SST-181X Radar Transponder Assembly	2,846	1	28
AN/AJB-7/A Altitude Reference Bombing Computer	26,218	1	2,295
Standby Altitude Indicator Set	2,025	1	156
AN/ASQ-91 Computer System	41,256	1	829

Total avionics cost per aircraft = $347,449

Total annual logistic support cost per aircraft = $15,284

*From data source 3.

Table C-6. CONVENTIONAL BOMBER AVIONICS

Nomenclature	Unit Cost	QPA	Annual Logistic Support Cost per Aircraft*
AN/ARC-65 HF Communication Set	$ 17,382	1	$ 93
AN/ARC-58 HF Communication Set	11,788	1	1,141
AN/ARC-34 UHF Communication Set	5,102	2	1,855
AN/APX-25 IFF System	4,000	1	7
AN/APX-64 IFF System	9,635	1	446
Navigation Instruments	17,869	1	2,520
AN/APN-69 Radar Beacon	4,757	1	489
AN/APN-150 Radar Altimeter	6,969	1	889
AN/ASQ-38 Bombing-Navigation System	172,416	1	17,694
AN/APN-89/108 Doppler Radar	19,489	1	1,868
MD-1 Astrocompass	58,605	1	6,218
Compass System	14,880	1	2,750

Total avionics cost per aircraft = $347,994

Total annual logistic support cost per aircraft = $35,970

*From data source 3.

Table C-7. BEST-CASE CONVENTIONAL CAS DATA

Nomenclature	Unit Cost	MFTBMA (Hours)	Remarks
VHF Communications, FM-622	$ 7,503	59.28	See Table C-2
UHF Communications, AN/ARC-164	6,000	600	Estimated
Automatic Direction Finder, AN/ARA-50	4,726	73.19	See Table C-2
IFF Transponder, AN/APX-72	3,219	46.93	See Table C-2
Horizontal Situation Indicator	3,040	200	Best case of cost and MFTBMA
TACAN, ARN-XXX	12,000	200	Estimated
Instrument Landing System, AN/ARN-58A	15,852	54.79	See Table C-2
Radar Altimeter, AN/APN-194	4,900	700	Estimated
Forward Looking Radar	119,351	90	Best case of cost and MFTBMA
Tactical Computer	36,130	1100	Estimated
Air Data Computer	13,242	157	Best case of cost and MFTBMA
Head-Up Display	50,148	155	Best case of cost and MFTBMA
Inertial Measurement Unit	72,143	300	Best case of cost and MFTBMA
Projected Map Display AN/ASN-99	22,011	50.26	See Table C-2
Total	$370,265	7.78	

NOTE: The unit costs and MFTBMA for those equipments not included in Table C-2 are related to equipments from various aircraft. The cost and reliability values may not apply to the same equipment, but they are independent best-case values.

APPENDIX D

DAIS COST DATA

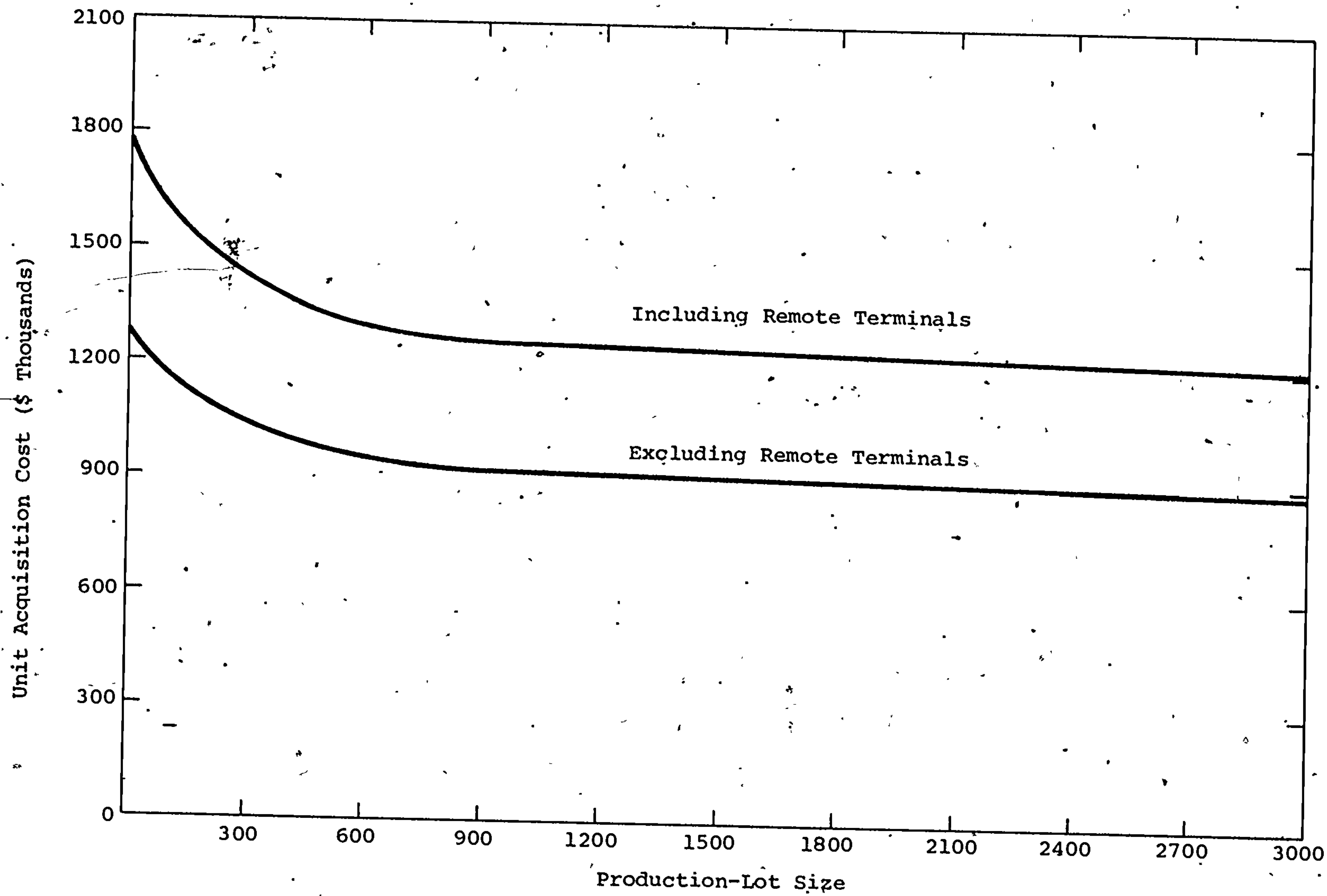

Figure D-1. CLOSE AIR SUPPORT UNIT ACQUISITION COST VS. LOT SIZE, 95% PRODUCTION CURVE

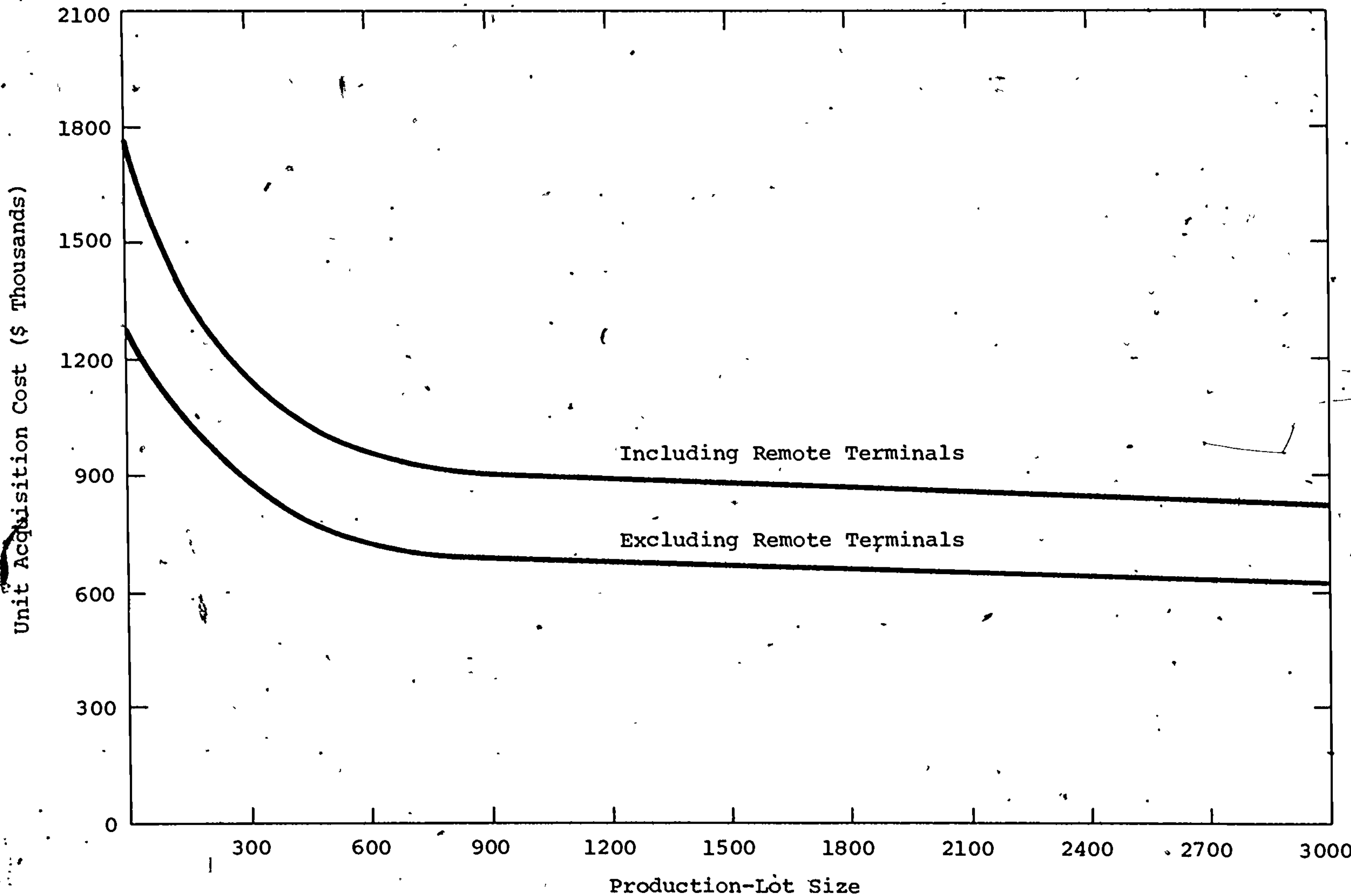

Figure D-2. CLOSE AIR SUPPORT UNIT ACQUISITION COST VS. LOT SIZE, 90% PRODUCTION CURVE

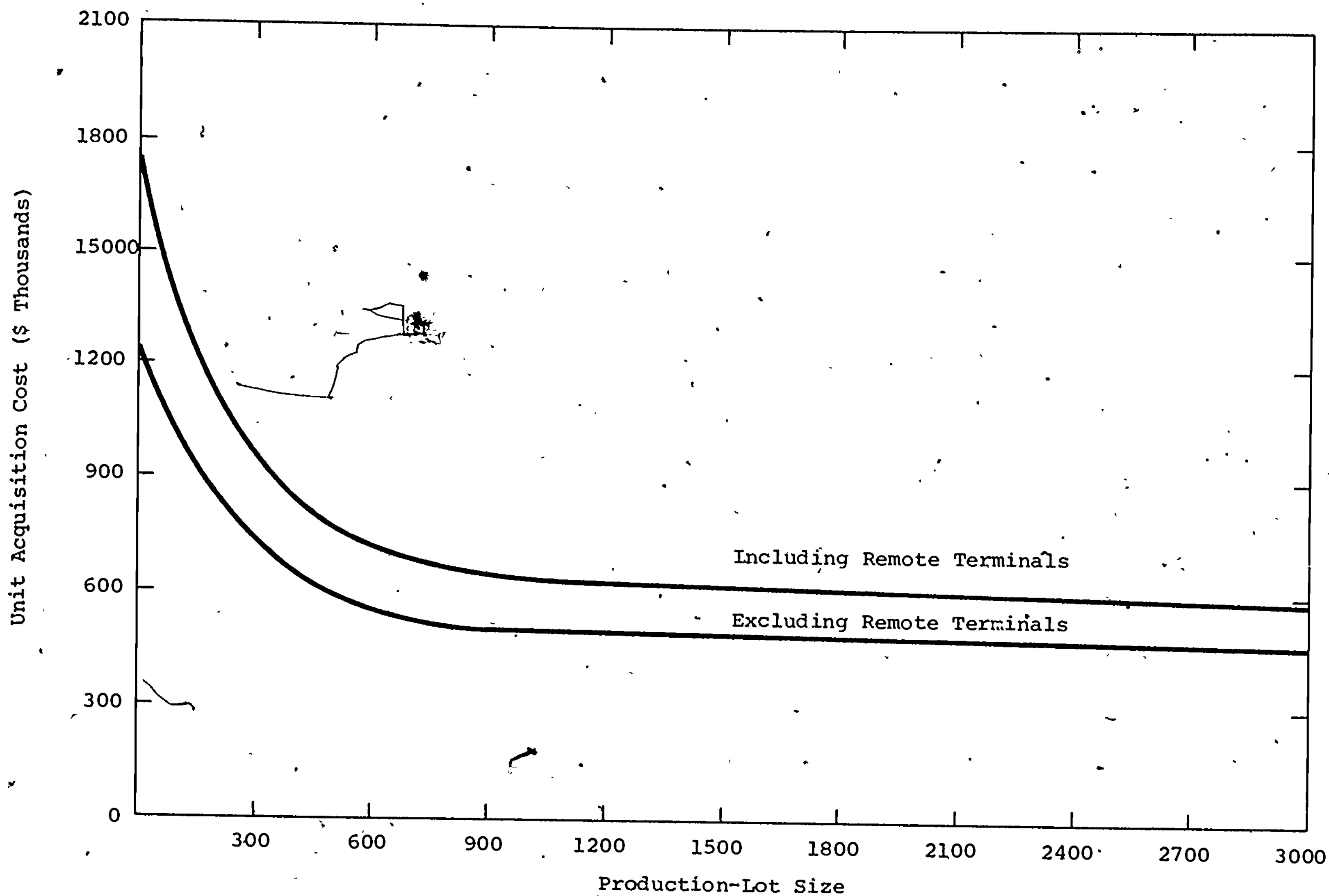

Figure D-3. CLOSE AIR SUPPORT UNIT ACQUISITION COST VS. LOT SIZE, 85% PRODUCTION CURVE

Table D-1. GENERAL DAIS HOT-BENCH REQUIREMENTS			
Item	Total Development Quantity	Estimated Unit Cost	Remarks
Computer Maintenance Panel	4	$ 8,000	Hot-Bench maintenance only
Training for Computer Engineers	-	4,000	
Computer Documentation	-	50,000	
Test Equipment for Multiplexer	1	250,000	Depot type
Multiplexer Documentation	-	50,000	
Software for Programmable Display Generator	1	50,000	Same for CAS system
Test Equipment for Cockpit Hardware	1	100,000	Depot type
Documentation for Cockpit Mockup	-	25,000	

Table D-2. DAIS BEST-CASE DATA

Equipment	Unit Cost
DAIS Core Elements	$411,741
VHF Communications	5,455
UHF Communications	4,244
Automatic Direction Finder	1,504
IFF Transponder	2,467
TACAN	10,742
Instrument Landing System	11,703
Radar Altimeter	1,597
Forward Looking Radar	63,440
Inertial Measurement Unit	67,771
Total	580,664

NOTE: The unit costs for the DAIS core elements are the same as in Table 2-3, 90% P.C.. For the sensors that are different from those listed in Table 2-3, a cost estimate was made on the basis of relative cost of the sensor to the total system for the best-case systems shown in Table C-7.

APPENDIX E

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APPENDIX F

GLOSSARY OF TERMS

AC	Number of aircraft
AGE	Aerospace Ground Equipment
BLR	Base labor rate
BMC_i	Base material cost per base maintenance action
BMH_i	Average man-hours expended at the base to diagnose and repair the i^{th} LRU
CAB_j	Cost of j^{th} piece of base-level AGE
CAD_j	Cost of j^{th} piece of depot-level AGE
CAS	Close Air Support
CITS	Central Integrated Test System
COB_j	Annual operating and maintenance cost of j^{th} piece of base-level AGE
$COND_i$	Fraction of removals of the i^{th} LRU that result in condemnation
CS	Cost of software associated with AGE
DAIS	Digital Avionics Information System
DLR	Depot labor rate
DMC_i	Depot material cost per depot maintenance action
DMH_i	Average man-hours expended at the depot to diagnose and repair the i^{th} LRU
$DRCT_i$	Average depot repair response time in months for the i^{th} LRU
ECM	Electronic countermeasures (equipment)
FLA	Cost of flight-line AGE for the aircraft
H	Number of pages of depot-level TOs

i	Index of each LRU within the aircraft
IC_i	Installation cost of the i^{th} LRU
IFF	Identification, Friend or Foe (equipment)
IMH_i	Average time in man-hours to perform corrective maintenance in place for the i^{th} LRU
j	Index of each piece of AGE
J	Number of pages of base and intermediate-level TOs
K	Total number of AGE items
LORAN	Long Range Navigation (equipment)
LRR	Fraction of total maintenance actions that result in removal of Line Replaceable Unit (black box)
LRU	Line Replaceable Unit
M	Number of operating locations
$MFTBMA_i$	Mean flight time between maintenance actions for the i^{th} LRU
$MFTBMA_S$	Mean flight time between maintenance actions for the entire system
MRF	Average man-hours per maintenance action for completing off-equipment maintenance records
MRO	Average man-hours per maintenance action for completing on-equipment maintenance records
N	Total number of LRUs
$NRTS_i$	Fraction of removals of the i^{th} LRU returned to the depot for repair
P.C.	Production Curve
PFFH	Peak force flying hours per month
PIUP	Operational service life of the system in years
PMB	Direct productive man-hours/man/year at base level
PMD	Direct productive man-hours/man/year at depot level
QPA_i	Quantity per assembly of the i^{th} LRU
RDT&E	Research, Development, Test, and Evaluation
RIP_i	Fraction of maintenance actions for the i^{th} LRU for which the LRU can be repaired in place

RMC	Unit cost of a repairable module
RMH_i	Average time in man-hours to remove and replace the i^{th} LRU for subsequent repair
RTS_i	Fraction of removals for the i^{th} LRU repaired at the base
SMH	Average time in man-hours to perform scheduled maintenance
SMI	Scheduled maintenance interval in flying hours
SR	Average man-hours per maintenance action for completing supply transaction records
TACAN	Tactical Air Navigation
TCB	Cost of training per man at base level
TCD	Cost of training per man at depot level
TD	Cost per original page of technical documentation
TDM	Time Division Multiplex
TE	Cost of training equipment
TFFH	Total force flying hours over life cycle
TM	Fraction of total number of modules that are designated as throwaways
TMC	Unit cost of a throwaway module
TR	Average man-hours per maintenance action for completing transportation forms
TRB	Annual turnover rate for base personnel
TRD	Annual turnover rate for depot personnel
UC_i	Unit cost of the i^{th} LRU
UC_s	Unit cost of an entire system
UHF	Ultra high frequency
VHF	Very high frequency

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