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CONCEPT FORMULATION STUDY FOR AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEMS (AIDAPS). VOLUME II. AIDAPS DESIGN AND TRADE STUDIES

Northrop Corporation

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CONCEPT FORMULATION STUDY FOR AUTOMATIC INSPECTION, DIAGNOSTIC AND PROGNOSTIC SYSTEMS (AIDAPS)

FINAL REPORT - VOLUME II

SEPTEMBER 1972

U.S. ARMY AVIATION SYSTEMS COMMAND
ST. LOUIS, MISSOURI

CONTRACT DAAJ01-71-C-0583(P3L)

PREPARED BY

NORTHROP CORP, ELECTRONICS DIVISION

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AVIATION SYSTEMS COMMAND

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CONCEPT FORMULATION STUDY FOR AUTOMATIC INSPECTION, DIAGNOSTIC, AND PROGNOSTIC SYSTEM (AIDAPS)

FINAL REPORT

VOLUME II - AIDAPS DESIGN AND TRADE STUDIES

PART 1

PREPARED FOR

U.S. ARMY AVIATION SYSTEMS COMMAND
ST. LOUIS, MISSOURI

UNDER CONTRACT:
DAAJ01-71-C-0503 (P3L)

APPROVED BY

A. R. Vogel

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SYSTEMS STATUS MONITORING GROUP

Northrop Corporation Electronics Division NORTHROP

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SECTION I

XVIII

1.0 INTRODUCTION

1.1 OBJECTIVE

The objective of this study is to determine the most cost effective approach to the Army requirement for an Automatic Inspection Diagnostic and Prognostic System (AIDAPS). The system must automatically diagnose mechanical malfunctions, warn of impending mechanical failures, and eliminate unnecessary inspections or part removals. It must also permit the change of aircraft components on an on-condition basis instead of a time change basis. The ultimate goals of the program are to reduce aircraft life cycle ownership costs, increase aircraft availability and improve aircraft safety.

To realize the above objective and goals, the achievement of the following subordinate objectives is required:

a) Determine the feasibility of system development, and identify risk areas with an indication of required research.

b) Define acceptable systems for current aircraft.

c) Define acceptable systems for future aircraft.

d) Recommend a program for engineering development.

1.2 SCOPE

This report is concerned with automatic inspection, diagnostic and prognostic equipment. In the past decade, many maintenance systems have been developed for the purpose of aiding maintenance actions. Some of these have been manual systems, some have been designed purely for test or trouble-shooting purposes, and others were developed to satisfy specific maintenance functions. The scope of AIDAP System capabilities is more extensive than these previous systems in that it must automatically perform inspection, diagnosis and prognosis on a complete aircraft. Specific AIDAPS applications are examined for the AH-1, CH-47, CH-54, OH-6, OH-58, OV-1, UH-1, U-21, UTTAS and HLH aircraft.

1.3 REPORT ORGANIZATION

The recommended AIDAP System, which was selected after analysis of a number of candidate systems, is described in Section 2.0 of this report along with a brief summary of the findings which led to the recommendation. Since the configuration of this recommended system evolved during the course of the study, the system savings, costs, weights and sizes do not agree precisely with those attributable to differently configured systems which were considered earlier in the study. However, these differences do not affect the study results in any significant manner.

Section 3.0 describes the Army environment as it impacts on AIDAPS design and usage. Section 4.0 contains a review of the technologies and state of the art associated with aircraft inspection, test and maintenance data collecting systems. Utilizing the requirements described in Section 3.0, and the technologies discussed in Section 4.0, a series of AIDAPS configurations were developed for analysis. The evolution of these AIDAP systems is described in Section 5.0. The operational characteristics, potential use, and constraints of the candidate AIDAP systems appear in Section 6.0.

Section 7.0 describes the background information required to accomplish the cost effectiveness evaluation of the systems, and Section 8.0 shows the tradeoffs accomplished. Section 9.0 describes the effects of the recommended AIDAP System on the operations and costs of the applicable Army aircraft.

Because of limitations on the availability of data, it was necessary to evaluate the applicability of AIDAPS to armament and avionics in a manner different from the methods used in Section 8.0. It was also necessary to separately evaluate the elimination of GSE due to AIDAPS. The results of these analyses appear in Section 10.0.

Section 11.0 contains the design criteria necessary for an ideal AIDAPS installation on the future HLH, UTTAS and AH-56A aircraft.

SECTION 2

2-1.1

2.0 SUMMARY

The results of this study indicate that a modular universal AIDAP system can be developed utilizing only a normal engineering development program. No scientific or basic research is required. The cost for developing and producing such a system and for operating the system for a period of 10 years on the AH-1, UH-1, CH-54, CH-47, and OV-1 aircraft is approximately $120,000,000. The resulting savings in aircraft maintenance, logistics accidents, and the benefits of increased aircraft effectiveness over a 10 year time period total approximately $515,000,000, thereby providing a net savings of approximately $395,000,000. This is approximately 19 percent of the total maintenance and support costs for these aircraft. Approximately 50 percent of these savings are due to increased aircraft effectiveness. The savings in maintenance and logistic costs alone are equal to approximately 9 percent of the total maintenance and support costs for the aircraft.

Further, the AIDAP system can be incorporated into the HLH and UTTAS aircraft for a life cycle cost of approximately $65,000,000 and achieve a gross 10 year savings of approximately $980,000,000, for a net savings of approximately $915,000,000. These figures are based on the procurement of 2356 UTTAS aircraft at a cost of $1,400,000 each and 43 HLH aircraft at a cost of $9,000,000 each. The estimated savings due to AIDAPS are proportional to both the quantity and the cost of the aircraft. To put this in perspective, the maintenance, support and accident costs for the future aircraft for a period of 10 years is estimated at $5 to $10 billion.

Although the modular universal system described in this report represents the best technical device based on present day technologies, it is recognized that procurement of AIDAP systems will probably be specific to certain aircraft types. In addition, availability of procurement funds and manufacturing capabilities, as well as program administration requirements, will necessitate procurement over an extended period of time. During this time period, operating experience will be gained with the early production systems. This experience may allow design improvements to be incorporated in AIDAPS for aircraft types equipped at later dates. Hence, development and programming practices may dictate systems which are not truly universal. Nonetheless, the modular universal system design philosophy should prevail and the differences between systems should be small. Although some changes in the predicted cost and savings will certainly occur, the conclusions derived in this study will remain valid. For representative procurement programs, see Volume III.

Figures 2-1 through 2-4 show the physical characteristics of the selected system. The inputs to the system are from existing or planned sensor units installed in the airframe or on maintenance significant components. The Central Electronics Unit (CEU) accepts these data and performs the appropriate data processing for inspection, diagnosis of malfunctions, and prognosis of impending malfunctions. An aircraft status light indicates the presence of an existing or impending malfunction. A similar light indicates the status of the AIDAPS. On the more complex aircraft, a Remote Data Acquisition Unit (RDAU) acquires data from remote sensors and converts the data to digital form for transmission to the CEU. Air safety data resulting from the CEU computations are transmitted to the existing audio, voice or visual warning devices. Maintenance information is stored in a data storage module for subsequent transfer to a hardcopy printer located on the ground. Air-safety and maintenance information are normally transmitted from the CEU to the displays only during the presence of an unsafe condition, a malfunction, or an impending malfunction. However, prognostic information is maintained on a current basis so that at any time the data recording module can be removed and the prognostic information displayed.

The study results are based on the most cost effective AIDAP system which can be achieved using present day technologies. To determine the configuration of this system, these procedures were followed:

a) The Army aircraft maintenance and support environment, present and planned, was reviewed to determine the Army requirements for such a system.

b) The state of the art was reviewed to establish a set of candidate systems utilizing the latest technologies and meeting the military requirements.

c) The precise maintenance actions which could be accomplished, simplified or eliminated by an AIDAPS were identified from The Army Maintenance Management System (TAMMS) data, and crash message summaries were reviewd to determine which accidents could be eliminated or alleviated.

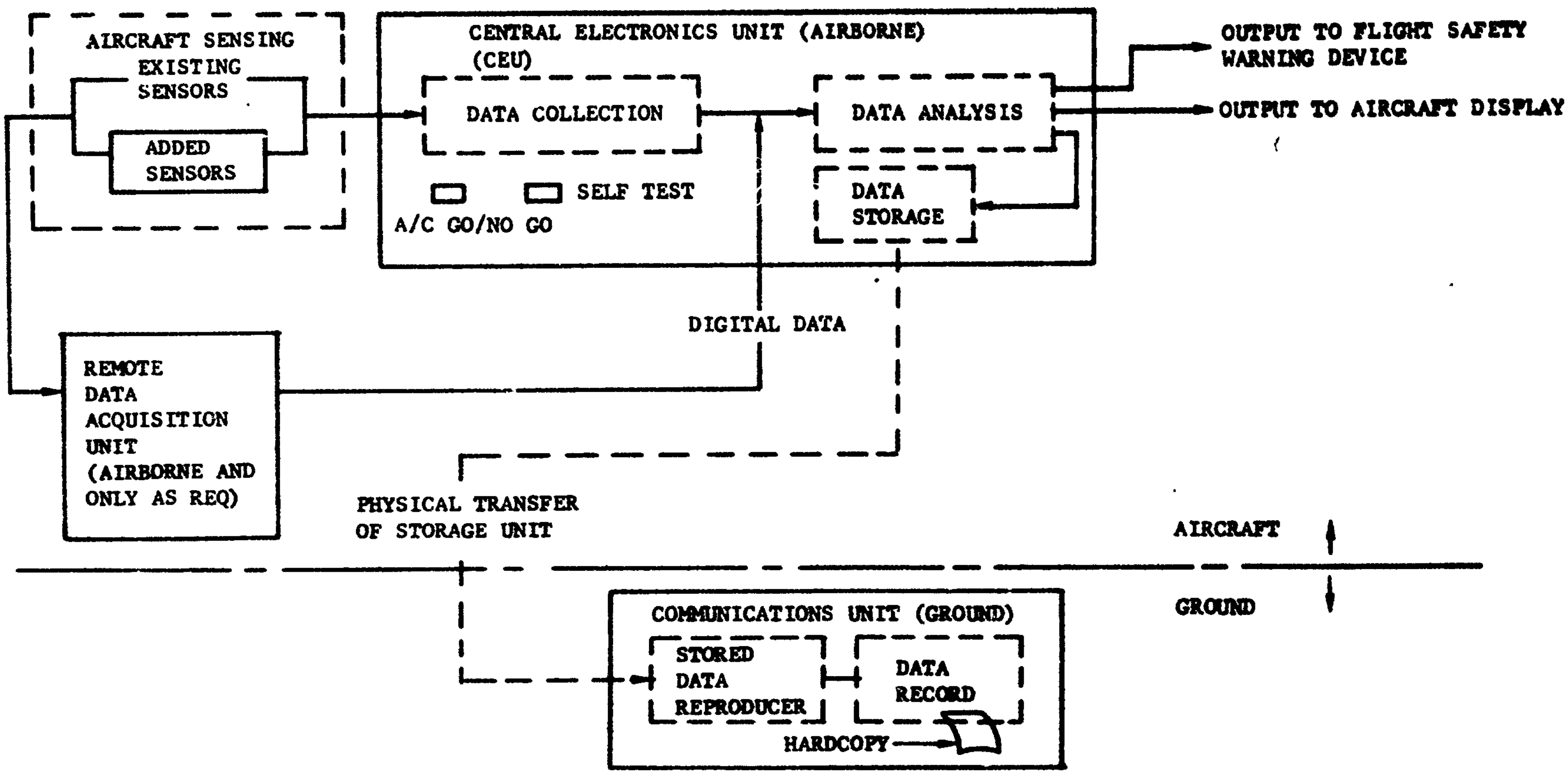
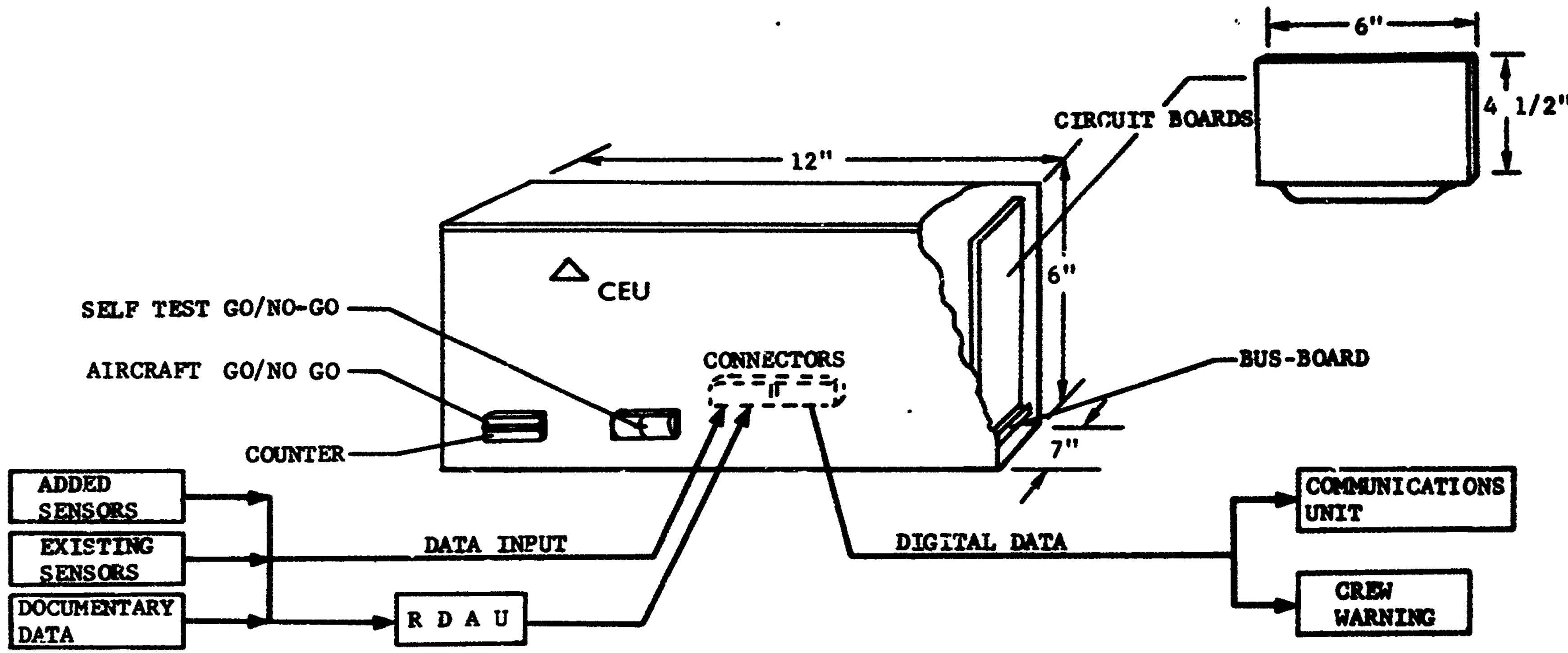


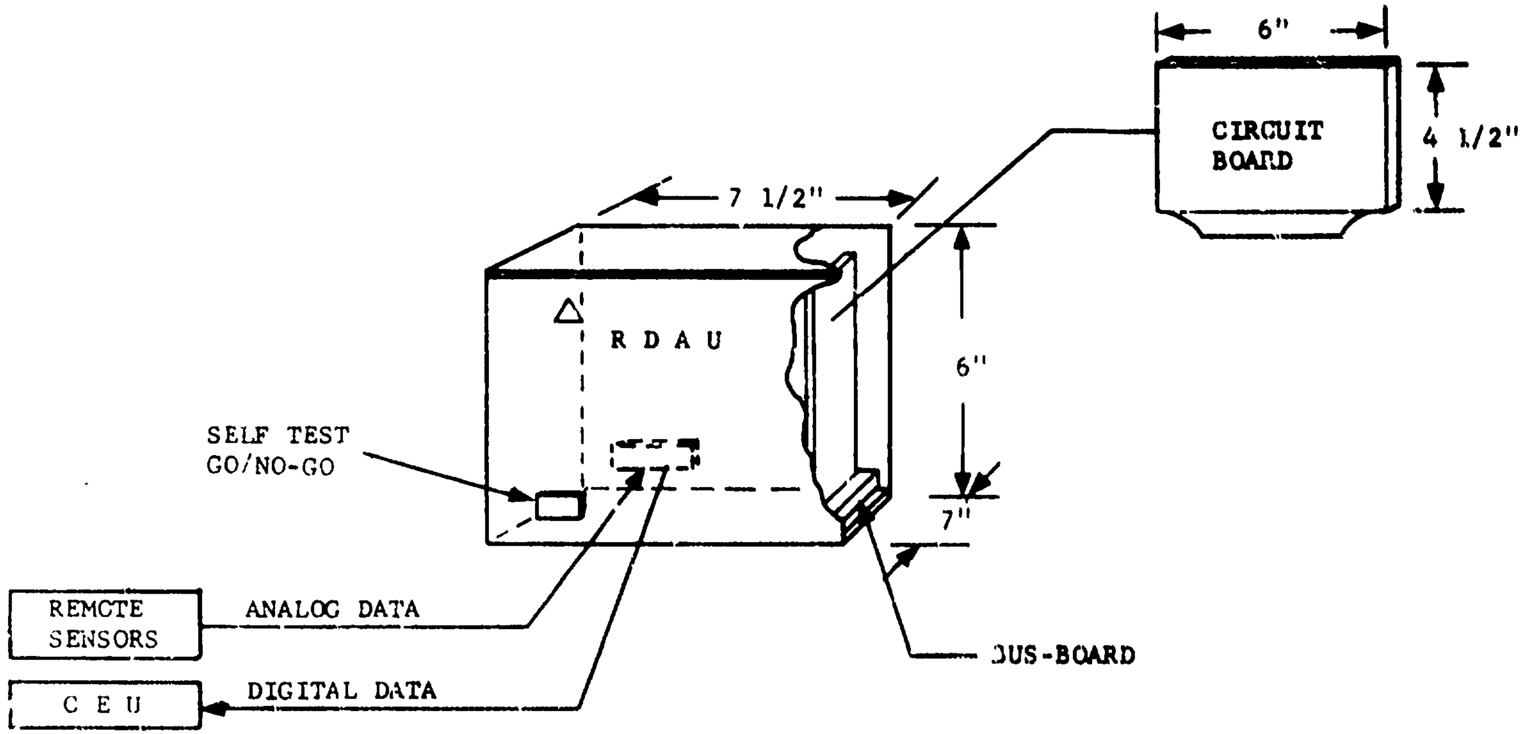
FIGURE 2-1 AIDAPS EQUIPMENT CONFIGURATION
(UNIVERSAL HYBRID)



△

WT	≈9.0 LBS
PWR	≈30 WATTS AT 28 VDC
VOL	≈0.29 FT^3
COST	≈$10.4K

FIGURE 2-2 AIDAPS CENTRAL ELECTRONICS UNIT (CEU)



△ WT ≈6 LBS
PWR ≈20 WATTS AT 28 VDC
VOL ≈0.14 FT^3
COST ≈$6.5K

FIGURE 2-3 AIDAPS REMOTE DATA ACQUISITION UNIT (RDAU)

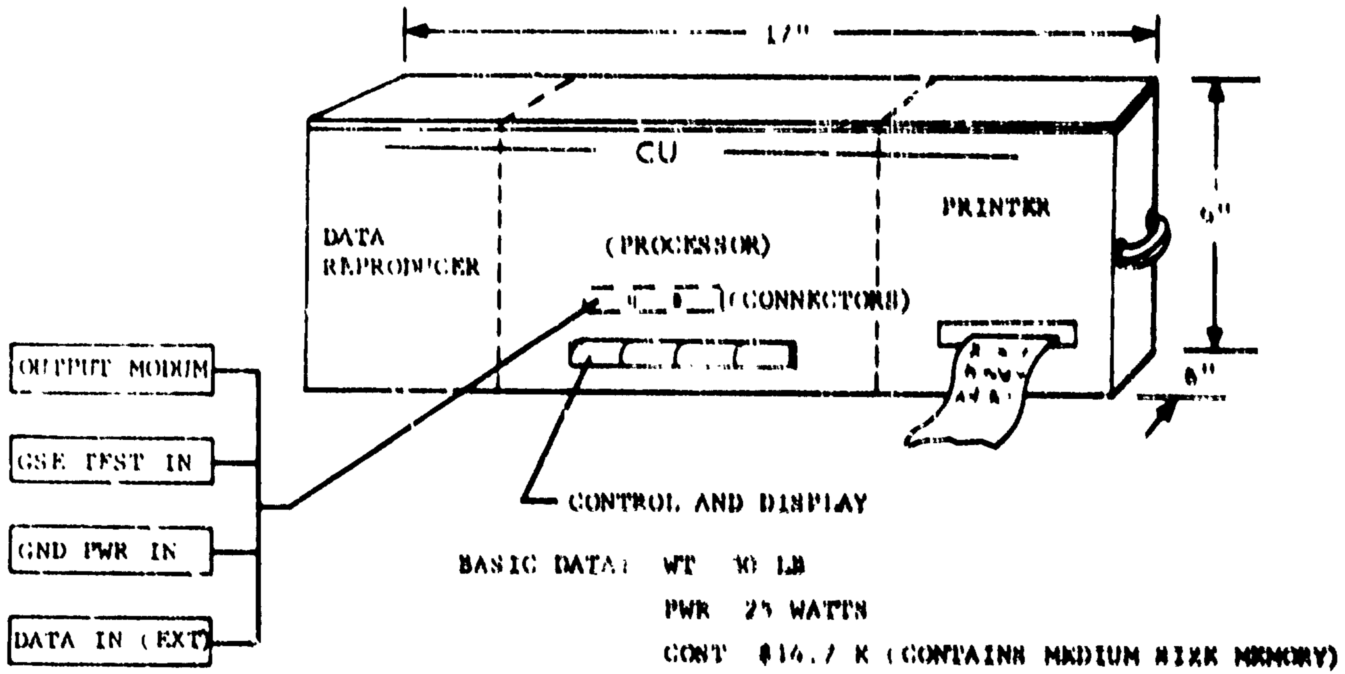


FIGURE 2-4 AIDAPS GROUND 'COMMUNICATION UNIT' (CU) HARDWARE DESCRIPTION (BASIC)

d) A cost effectiveness analysis was performed on each of these candidate AIDAP systems to select the most cost effective system.

e) The effects of the selected AIDAPS upon aircraft maintenance and support were determined.

The results of these procedures are discussed in the following paragraphs.

2.1 ARMY REQUIREMENTS

A review of the Army maintenance environment established the validity of the basic requirements for an AIDAP system as stated in the Qualitative Material Requirement (QMR) entitled "Automatic Inspection Diagnostic and Prognostic System For Army Aircraft," which received Department of Army approval in October 1967. However, subsequent advances in technology have allowed more cost effective configurations, with superior performance to those which might be deduced from the QMR, to be examined.

The Army aircraft maintenance environment is perhaps more severe today than when the original QMR was written. Increasingly complicated weapons and other mission equipment are being added to the basic airframes, and new aircraft are planned for procurement which are more sophisticated than the types being replaced. Meanwhile, available spare part supplies are being depleted, and the skill level of available maintenance personnel is not likely to improve. Few, if any, significant advances have been made in the maintenance equipment which the field soldier must use for these aircraft.

Today's field army is equipped with the most highly developed technical weapons which an advanced industrial society can provide. It is becoming increasingly apparent that if these field armies are to remain effective, some industrial technologies must be applied to easing their maintenance and logistic burden. This study has been directed toward this end. It examines the application of AIDAPS to 10 Army aircraft types. The objective has been to determine the system which is most effective in reducing aircraft maintenance, logistic requirements, accidents and aborts, and which can be procured and operated at minimum cost.

The 10 aircraft types considered in the study are shown in Table 2-1 along with their design and operational characteristics which are significant study inputs. The characteristics of these aircraft cover a wide spectrum. Their empty weights range from approximately 1,000 lbs. to an estimated 30,000 lbs.; payloads range from 600 to 45,000 lbs. and costs from $56,000 to $9,000,000. The peacetime utilization of the aircraft ranges from 15 to 40 flying hours per month. The amount of maintenance required (maintenance index) ranges from 5.76 to 32.46 man-hours per flying hour and the abort rate and accident rates also show large variations. The maintenance indices, abort rates, and accident rates show a general increase with aircraft empty weight, and to some extent with cost. The accident rate also includes the effects of operational usage, with the attack and observation helicopters showing high values. The last column contains the Weighted Sensor Count (WSC) as defined in Para. 5.4.2. This factor is a measure of aircraft AIDAPS parameter complexity.

2.2 AIDAPS ALTERNATIVES

AIDAP systems designed for aircraft with a wide range of performance characteristics can be expected to have a significant range of design characteristics. Therefore, in the initial phase of this study, unique AIDAP systems were defined. Unique AIDAP systems are defined as those developed for a specific aircraft type.

2.2.1 DESIGN CONSIDERATIONS

As a first step in system definition, design decisions were made concerning hardware approaches applicable to all systems. Appendix B discusses these elements in detail. These decisions are:

- Digital systems will be used including data storage and transfer.
- Existing sensors will be used to the maximum practical extent.
- Added sensors will be similar to existing sensors except where state-of-the-art advances are significant.
- Documentary data will be accommodated.
- Solid state multiplexing will be used.
- Existing aircraft displays for flight safety will be used; i.e., warning lights or voice warning.

TABLE 2-1 ARMY AIRCRAFT CHARACTERISTICS

Aircraft	Approx. Empty Weight	Representative Payload (Lbs.)	Cost	Fly Hrs. Per Month*	Maint. Index	Abort Rate Per 100,000 FH	Accident Rate Per 100,000 FH	Complexity Factor (WSC)
AH-1	5,545	1,933	365,254	30	8.85	196	24.3	357
CH-47	19,723	6,945	1,145,500	20	32.46	233	12.3	646
CH-54	19,234	11,5[illegible]2	1,800,000	15	31.32	399	21.0	544
OH-6	1,158	600	56,262	30	5.74	108	36.2	217
OH-58	1,200E	600	90,208	30	5.74E	102	26.4	217
OV-1	10,011	1,930	1,058,540	35	10.60	98	10.9	431
UH-1	4,736	1,800	266,578	30	8.04	76	15.3	308
U-21	5,401	2,000	246,337	40	7.67	70	13.4	374
HLH	30,000E	45,000E	9,000,000E	15	31.7E	281E	15.5E	881
UTTAS	7,400E	2,640E	1,400,000E	30	10.8E	105E	19.4E	694

E = Estimate
* = Peacetime

- Maintenance displays will be hardcopy alphanumeric.
- Data compression will be used.
- Telemetry will not be used.

2.2.2 AIDAPS CANDIDATE CONFIGURATIONS

A set of four candidate system configurations were analysed for each aircraft. Each system configuration was subject to considerable evolution during the study. Section 5.0 contains a history of this evolution. However, the generic configuration types remained constant. The four configuration types are:

a) Airborne: In this configuration, all data sensing, collecting, analysis and display are accomplished by units permanently installed in the aircraft. The units sample and analyze the data at a sufficiently high rate so that data sampling can be considered as continuous. All diagnostic and prognostic data analysis are accomplished on board. Air safety messages are immediately transmitted to the aircrew through the existing warning system. One of the important air safety messages is a warning derived from the automatic weight and balance computations. Simultaneously, a more detailed printout is provided which the aircrew may examine at their option. Malfunctions not involving flight safety are printed as they occur, and an aircraft status light is lit indicating the presence of a malfunction. The printout is available to the aircrew at their option but is also delivered to ground maintenance personnel after landing. In addition, after engine coast-down following every flight, a complete prognostic printout is provided.

b) Hybrid I: This system configuration is functionally the same as the airborne system except that a recording device and a ground printer are used. An airborne display is provided for air safety. During flight, data is recorded on a recording module. Once each day the recording module is removed and played back in a ground processing unit which provides the long term prognostic information to be used for scheduling of on condition replacements. An aircraft status light is provided. If, during the flight day, the status light illuminates, the recording module is removed and read out for diagnostic data.

c) Hybrid II: This system performs no data analysis in the air. The only data processing accomplished in the air is that required for data recording. Hence, no air safety data aircraft status light nor any airborne display is provided to the aircrew. After each flight, a magnetic tape is removed and played back for aircraft status and diagnostic information. The flight tapes are recycled daily to provide a prognostic printout. No airborne warning capability exists with this system and no weight and balance calculations can be made.

d) Ground Based: In this system, only the sensors are permanently mounted in the aircraft. Once a day, a data acquisition unit is brought aboard the aircraft and connected to the sensor cabling. The data acquisition unit transmits the data down a digital transmission wire to the ground processor which accomplishes the diagnostic and prognostic analysis and prints the results. Engines are run up to the highest power rating that can be safely achieved. A hovering condition is desirable for helicopters. Five minutes of data recording is accomplished.

Using the four generic configurations as a basis, the following three design approaches to AIDAPS applicability were developed and analyzed:

a) Unique AIDAPS designs applicable to individual aircraft types.

b) Systems designed to be common to groups of aircraft.

c) Modular universal systems.

The total number of systems configurations is shown in Table 2-2.

Table 2-3 shows the weights of the airborne portion of each AIDAPS system and the hardware procurement costs per aircraft for each system. The airborne weights include the sensors and cabling. The costs are for hardware procurement alone. They are adjusted for quantity produced but do not include design, development, test and evaluation (DDT&E).

2.3 AIDAPS CONFIGURATION SELECTION

2.3.1 AIDAPS CONFIGURATION COST EFFECTIVENESS

Table 2-4 shows the life cycle costs per aircraft for all systems considered in the study. The major factor affecting the per aircraft procurement

TABLE 2-2 CANDIDATE AIDAPS CONFIGURATIONS

AIRCRAFT	UNIQUE AIDAPS	GROUPED AIDAPS	UNIVERSAL AIDAPS
AH-1	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
CH-47	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid I	Basic Airborne (+) Basic Hybrid I (+)
Ch-54	Airborne Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid I	Basic Airborne (+) Basic Hybrid I (+)
OH-6	Airborne, Hybrid I Hybrid II, Ground	Group I Airborne Group I Hybrid I	Basic Airborne Basic Hybrid I
OH-58	Airborne, Hybrid I Hybrid II, Ground	Group I Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
OV-1	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
UH-1	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
U-21	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
HLH	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid I	Basic Airborne (+) Basic Hybrid I (+)
UTTAS	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid I	Basic Airborne (+) Basic Hybrid I (+)

+ = addition of an RDAU

TABLE 2-3 AIDAPS WEIGHTS AND PROCUREMENT COSTS

SYSTEM	OH-6	OH-58	UH-1	AH-1	U-21	OV-1	CH-47	CH-54	UTTAS	HLH
AIRBORNE - UNIQUE										
PROCUREMENT (K$/AIRCRAFT)	21.8	15.8	15.0	19.6	26.4	22.5	26.3	34.6	20.6	37.7
AIRBORNE WT. (lbs)	31.7	31.7	33.8	33.8	35.8	36.1	50.8	50.8	50.8	50.8
HYBRID I - UNIQUE										
PROCUREMENT (K$/AIRCRAFT)	16.0	11.6	11.2	14.6	19.8	16.6	21.1	27.7	16.6	30.2
AIRBORNE WT. (lbs)	21.7	27.7	29.8	29.8	31.8	32.1	46.8	46.8	46.8	46.8
HYBRID II - UNIQUE										
PROCUREMENT (K$/AIRCRAFT)	14.1	10.2	9.9	12.9	17.7	14.7	19.4	25.5	15.2	27.7
AIRBORNE WT (lbs)	23.7	23.7	29.8	29.8	27.8	28.1	42.8	42.8	42.8	42.8
GROUND - UNIQUE										
PROCUREMENT (K$/AIRCRAFT)	8.9	6.5	6.2	8.1	11.0	9.9	10.8	14.2	8.5	15.5
AIRBORNE WT. (lbs)	13.8	13.8	15.6	15.6	17.4	18.6	25.8	29.8	25.8	25.8
AIRBORNE - GROUPED										
PROCUREMENT (K$/AIRCRAFT)	16.8	16.8	17.4	17.4	16.7	16.1	23.5	23.6	23.3	24.9
AIRBORNE WT. (lbs)	31.0	31.0	37.2	37.6	31.1	32.3	55.3	54.4	52.3	60.3

TABLE 2-3 (Concluded)

SYSTEM	OH-6	OH-58	UH-1	AH-1	U-21	OV-1	CH-47	CH-54	UTTAS	HLH
HYBRID I - GROUPED										
PROCUREMENT (K$/AIRCRAFT)	12.0	12.0	12.5	12.5	11.9	11.2	18.2	18.2	17.9	19.6
AIRBORNE WT. (lbs)	27.0	27.0	32.9	33.4	26.8	28.1	51.1	50.2	48.0	56.1
AIRBORNE - UNIVERSAL										
PROCUREMENT (K$/AIRCRAFT)	15.3	15.3	16.0	16.0	15.4	14.8	19.6	19.6	19.4	20.4
AIRBORNE WT. (lbs)	32.0	32.0	37.2	37.6	31.1	32.3	55.1	54.2	52.0	59.8
HYBRID I - UNIVERSAL										
PROCUREMENT (K$/AIRCRAFT)	10.9	10.9	11.5	11.5	10.9	10.4	15.0	15.0	14.8	[illegible]
AIRBORNE WT. (lbs)	27.7	27.7	32.9	33.4	26.8	28.1	50.8	49.9	47.8	55.6

TABLE 2-4 AIDAPS COST SUMMARY

DOLLARS (IN THOUSANDS) PER AIRCRAFT

	UNIQUE SYSTEMS				UNIVERSAL SYSTEMS		GROUPED SYSTEMS	
	A/B	HYB I	HYB II	GRD	A/B	HYB I	A/B	HYB I
OH-6 (234 AIRCRAFT)								
DDT&E	14.1	14.5	14.5	12.4	3.0	3.4	7.7	8.1
INVESTMENT	28.6	22.6	20.5	15.0	22.2	17.1	23.5	18.4
OPERATIONS	5.6	5.6	5.6	12.0	4.3	4.7	4.3	4.7
TOTAL	48.3	42.7	40.6	39.4	29.5	25.2	35.5	31.2
OH-58 (1906 AIRCRAFT)								
DDT&E	1.7	1.8	1.8	1.5	0.4	0.4	0.9	1.0
INVESTMENT	22.1	17.6	16.1	12.2	22.1	16.9	23.2	17.8
OPERATIONS	3.7	3.8	4.1	10.4	2.7	2.8	2.7	2.8
TOTAL	27.5	23.2	22.0	24.1	25.2	20.1	26.8	21.6
UH-1 (3568 AIRCRAFT)								
DDT&E	1.1	1.1	1.1	1.0	0.2	0.2	0.3	0.4
INVESTMENT	21.5	17.4	16.0	11.9	24.0	19.1	25.1	19.8
OPERATIONS	3.7	3.7	3.9	7.3	3.1	3.1	3.1	3.1
TOTAL	26.3	22.2	21.0	20.2	27.3	22.4	28.5	23.3
U-21 (104 AIRCRAFT)								
DDT&E	46.2	49.0	47.1	40.4	6.7	7.7	11.5	12.5
INVESTMENT	34.6	27.9	26.0	18.3	24.0	19.2	25.0	19.2
OPERATIONS	8.7	8.7	8.7	16.3	7.7	6.7	7.7	6.7
TOTAL	89.5	85.6	81.8	75.0	38.4	33.6	44.2	38.4
AH-1 (584 AIRCRAFT)								
DDT&E	6.5	6.8	6.7	5.8	1.2	1.4	2.0	2.2
INVESTMENT	26.4	21.1	19.2	13.9	23.6	18.8	24.8	19.5
OPERATIONS	4.6	4.6	4.8	6.3	3.8	3.8	3.8	3.8
TOTAL	37.5	32.5	30.7	26.0	28.6	24.0	30.6	25.5

TABLE 2-4 AIDAPS COST SUMMARY
(Concluded)

DOLLARS (IN THOUSANDS) PER AIRCRAFT

	UNIQUE SYSTEMS				UNIVERSAL SYSTEMS		GROUPED SYSTEMS	
	A/B	HYB I	HYB II	GRD	A/B	HYB I	A/B	HYB I
UTTAS (2356 AIRCRAFT)								
DDT&E	2.6	2.7	2.7	2.3	0.3	0.3	0.7	0.8
INVESTMENT	26.1	22.0	20.5	14.2	26.4	21.6	30.2	24.7
OPERATIONS	4.4	4.7	5.2	16.3	4.4	4.7	4.4	4.8
TOTAL	33.1	29.4	28.4	32.8	31.2	26.6	35.3	30.3
OV-1 (231 AIRCRAFT)								
DDT&E	21.6	22.9	22.5	19.0	3.0	3.5	5.2	5.6
INVESTMENT	30.7	24.2	22.1	16.9	22.5	17.7	23.8	18.2
OPERATIONS	5.6	5.6	6.1	9.5	4.3	4.3	4.3	4.3
TOTAL	57.9	52.7	50.7	45.4	29.8	25.5	33.3	28.1
CH-54 (75 AIRCRAFT)								
DDT&E	81.3	86.7	84.0	72.0	10.7	10.7	22.7	24.0
INVESTMENT	45.3	37.3	36.0	22.7	29.3	25.3	33.3	28.0
OPERATIONS	9.3	9.3	9.3	12.0	8.0	8.0	8.0	8.0
TOTAL	135.9	133.3	129.3	106.7	48.0	44.0	64.0	60.0
CH-47 (459 AIRCRAFT)								
DDT&E	13.3	14.2	13.7	11.8	1.7	1.7	3.7	3.9
INVESTMENT	35.3	29.8	27.9	18.5	30.5	25.5	34.2	28.5
OPERATIONS	4.1	4.4	4.6	8.7	4.1	4.1	4.1	4.1
TOTAL	52.7	48.4	46.2	39.0	36.3	31.3	42.0	36.5
HLH (43 AIRCRAFT)								
DDT&E	141.9	151.2	146.5	125.6	18.6	18.6	39.5	41.9
INVESTMENT	46.5	37.2	34.9	23.3	30.2	25.6	34.9	27.9
OPERATIONS	14.0	14.0	14.0	16.3	14.0	14.0	14.0	14.0
TOTAL	202.4	202.4	195.4	165.4	62.8	58.2	88.4	83.8

and DDT&E costs is the procurement quantity. Prorating the DDT&E cost for the unique systems over a small number of aircraft results in large DDT&E charges per aircraft. In addition, large quantity procurement benefits are not realized.

The investment costs includes procurement of the equipment, sensors, wiring, installation support equipment, and the initial training of personnel. The costs of the unique system AIDAPS is highest for the Airborne System and reduces through Hybrid I, Hybrid II with the Ground System being the least expensive. The reasons for these variances in costs are the assumed higher cost of providing a complete airborne system per aircraft, and the capability of the ground portion of the hybrid and ground systems to service several aircraft. Only one ground portion of the hybrid systems is required per 15 aircraft and only one AIDAP Ground System is required per five aircraft.

Figures 2-5a and b show the net savings per aircraft for each aircraft type and AIDAP system. The aircraft are arranged in order of increasing complexity. Total savings include savings in maintenance and support personnel, accidents, logistics, overhaul costs and improvements in aircraft effectiveness. Additional savings are possible in the maintenance of armament and avionics systems, but lack of maintenance data precluded these savings from being estimated on the same basis. The net savings are the total savings less AIDAPS life cyle cost.

The net savings increase with increasing aircraft cost, weight, and complexity. However, the variations in AIDAPS DDT&E and procurement costs per aircraft due to the variations in the number of aircraft of each type causes the net savings for the unique systems to violate this pattern.

In the case of the lighter weight aircraft, the net savings are actually negative for the unique systems. Even the universal and grouped systems do not produce sufficient net savings for the OH-6, OH-58, and U-21 to justify procurement of an AIDAPS for these aircraft.

The modular Universal Hybrid I System shows the greatest net savings in all cases except for the HLH where the modular Universal Airborne AIDAPS shows a slight advantage. The preference for the Universal Hybrid I System is due to its lower procurement cost. If equipment for the Universal Airborne System can

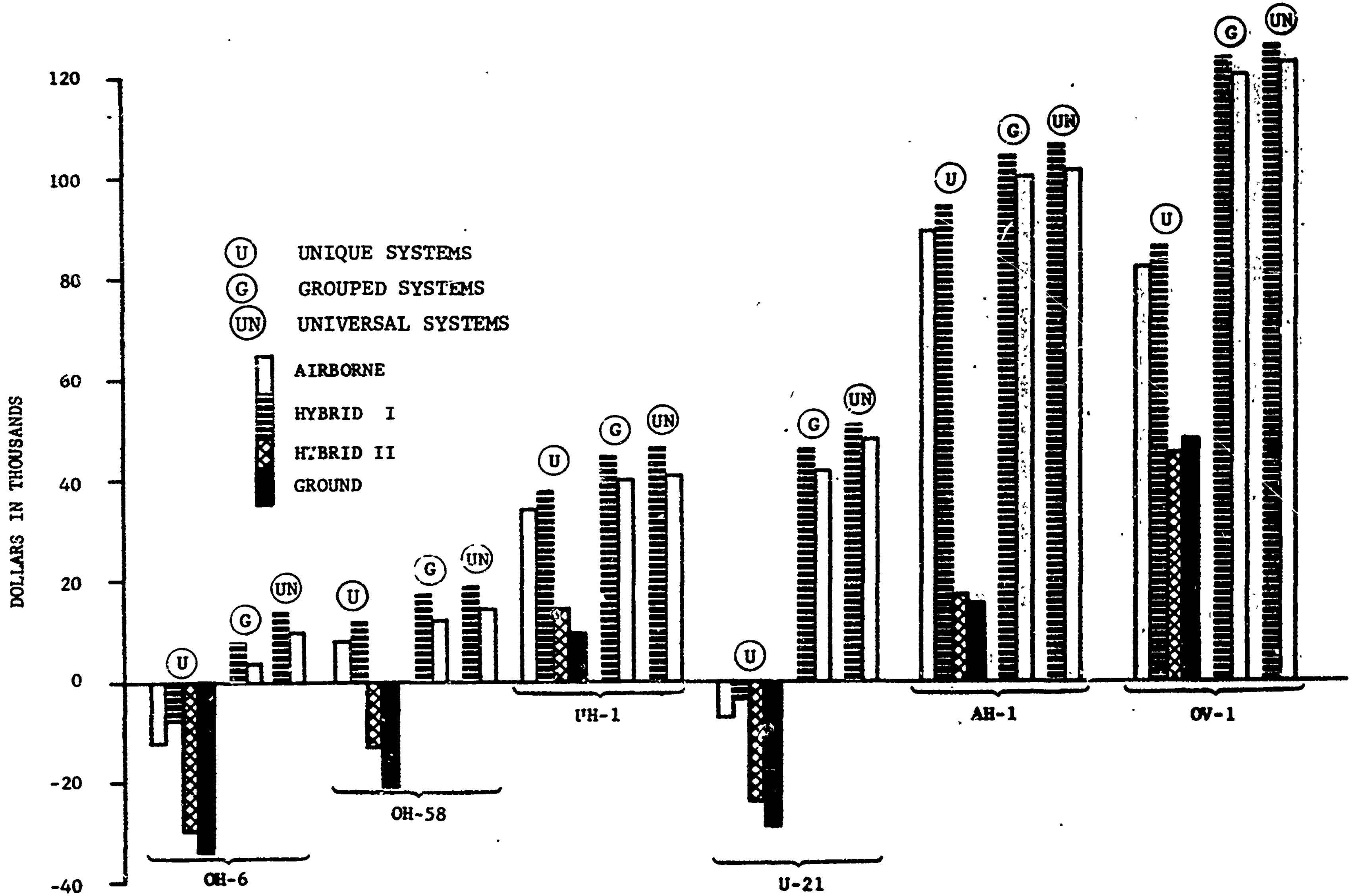


FIGURE 2-5a SYSTEM NET SAVINGS PER AIRCRAFT
(10 YEARS OPERATION)
(Expected Conditions)

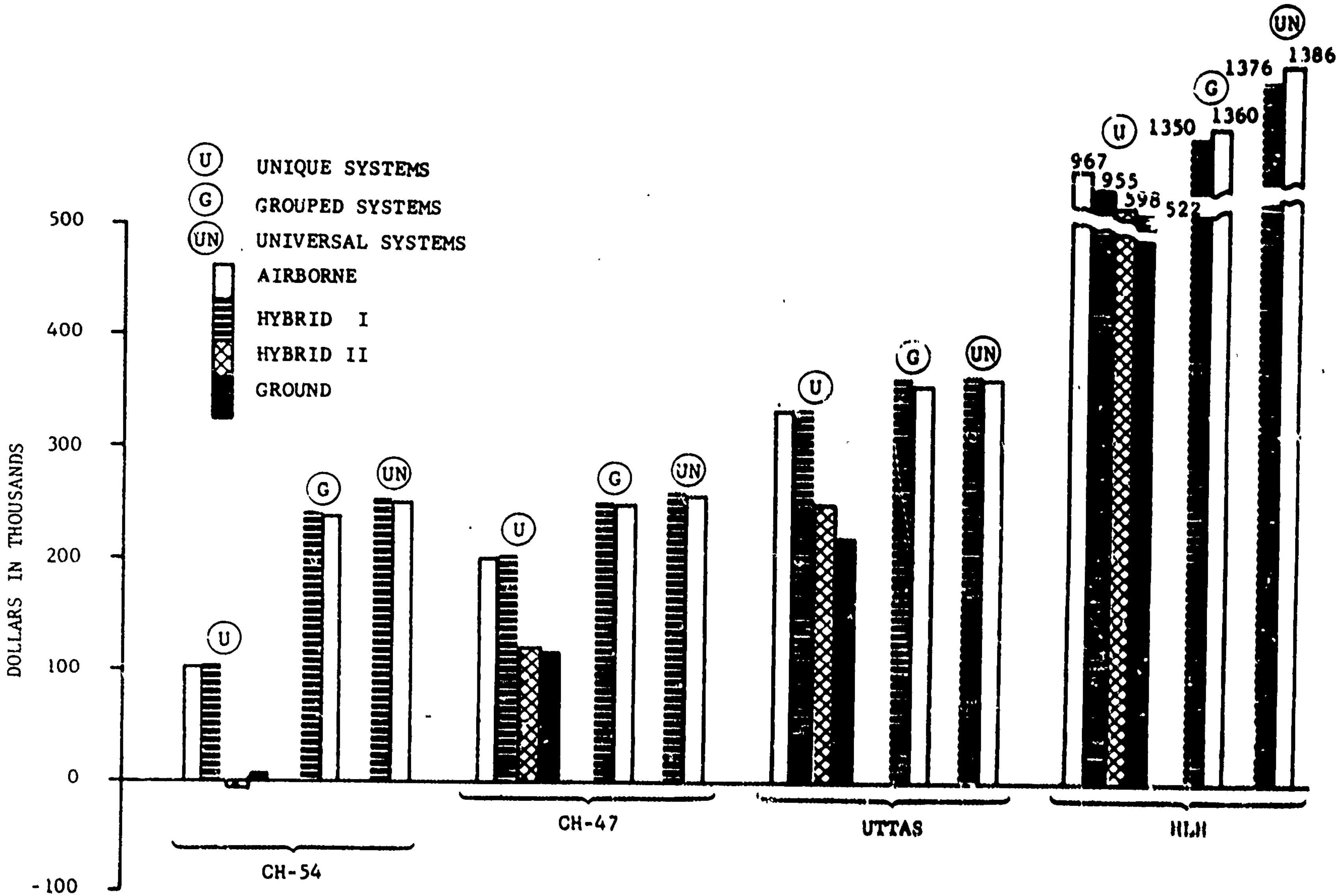


FIGURE 2-5b SYSTEM NET SAVINGS PER AIRCRAFT
(10 YEARS OPERATION)
(Expected Conditions)

be procured which meets the appropriate cost, weight, volume, reliability and other design constraints, the airborne system is preferred.

2.3.2 Operational Preferences

The AIDAPS configurations differ in performance and operational characteristics. Table 2-5 shows the more important characteristics affecting aircraft operations.

These characteristics impose severe operational constraints on the Ground System and the Hybrid II System. The Ground System requires a special aircraft ground run-up to be effective. This run-up will create light, noise and/or dust signatures which are undesirable during combat operations. The hybrid and airborne systems require no such run-ups and therefore avoid such signatures. The Hybrid II System requires ground processing equipment to achieve any benefits. This greatly reduces its effectiveness during dispersed operations.

Under dispersed operations, the Ground System must be transported to the aircraft for any inspection or diagnostic action. For long term prognostics, each Ground System can only be used on five specific aircraft. With the Hybrid II System, only the data tape need be transported. Inspection and diagnostic capability can be obtained from any ground portion of a system dedicated to an aircraft type. For long term prognostics, however, the tape must be transported to the ground portion of a system dedicated to a particular aircraft. One ground portion is dedicated to 15 aircraft. Inspections and diagnosis can be performed by the Hybrid I and Airborne systems at any location without transportation of any tapes. The Airborne system can also perform long term prognostics at any location.

The above constraints demand that the time required for diagnosis and prognosis is greatly increased for the Hybrid II System and the Ground System unless the ground portion of these systems is dispersed with the aircraft. This dispersal requires substantial additional logistics effort as well as an increase in the required number of ground portions. The requirement for transportation of equipment will either reduce the aircraft mobility and dispersibility or, if the ground portions and/or tapes are not transported, will reduce the AIDAPS effectiveness during dispersed operations. It is precisely at these times, especially during combat, when the AIDAPS is most needed.

TABLE 2-5 AIDAPS OPERATIONAL CHARACTERISTICS

Characteristic	Airborne	Hybrid I	Hybrid II	Ground
Time required for: Inspections Diagnosis	 3 min. 3 min.	 6 min. 3 min.	 7 min. 7 min.	 30 min. 30 min.
Time aircraft required during inspections	None	None	None	22 min.
Air Warning	Yes	Yes	No	No
Dispersibility	Equally effective anywhere	Diagnostics anywhere with portable display unit. Long term prognosis only at home base.	Diagnostics only at base equipped with ground portion. Long term prognostics only at home base.	Diagnostics only at base equipped with ground portion. Long term prognostics only at home base.

In addition, on-condition maintenance does not seem to be practicable with the Ground and Hybrid II systems because of their low test accuracy due to the small data samples available to them, and to their lack of air warning. If on-condition maintenance is attempted with these systems, a sizable fraction of the airborne failures which are now avoided by time removals will then occur in the air. However, the net number of failures is somewhat reduced for these systems. See paragraph 7.2.6.4. Since time removal requirements generally apply to components which present a flight safety hazard, the risk of accidents may substantially increase for very low test accuracies. This is particularly true for those components exhibiting low failure rates and high time removal rates.

Weight and balance calculations (see paragraph 7.2.4) are also not feasible with these systems because of the interference with normal operations. It does not seem reasonable to require a special inspection by these systems prior to each flight, and after the aircraft is loaded, merely to check weight and balance.

Because of the operational disadvantages inherent in the Ground and Hybrid II systems, there is a strong operational preference for the Airborne and Hybrid I systems with the Airborne system slightly superior. Because of this preference, and because of the low cost effectiveness of the unique Hybrid II system and the Ground system, these configurations were not included in the analysis of grouped and universal systems.

2.3.3 Selected System Cost Effectiveness

The strong cost effective and operational preferences for the modular Universal Airborne and Hybrid I systems dictate that one of these systems be chosen as the preferred system. The slight operational advantage of the Airborne System and the slight cost effective advantage of the Hybrid I system are not of sufficient magnitude to justify a choice.

Figure 2-6 shows the savings in maintenance personnel per aircraft that can be achieved by the selected system. The differences in manpower savings between aircraft of similar types such as OH-6, OH-58 and the AH-1 and UH-1 are due to differences in inspection procedures. In addition no credit for weight and balance calculations could be taken with the AH-1 installations.

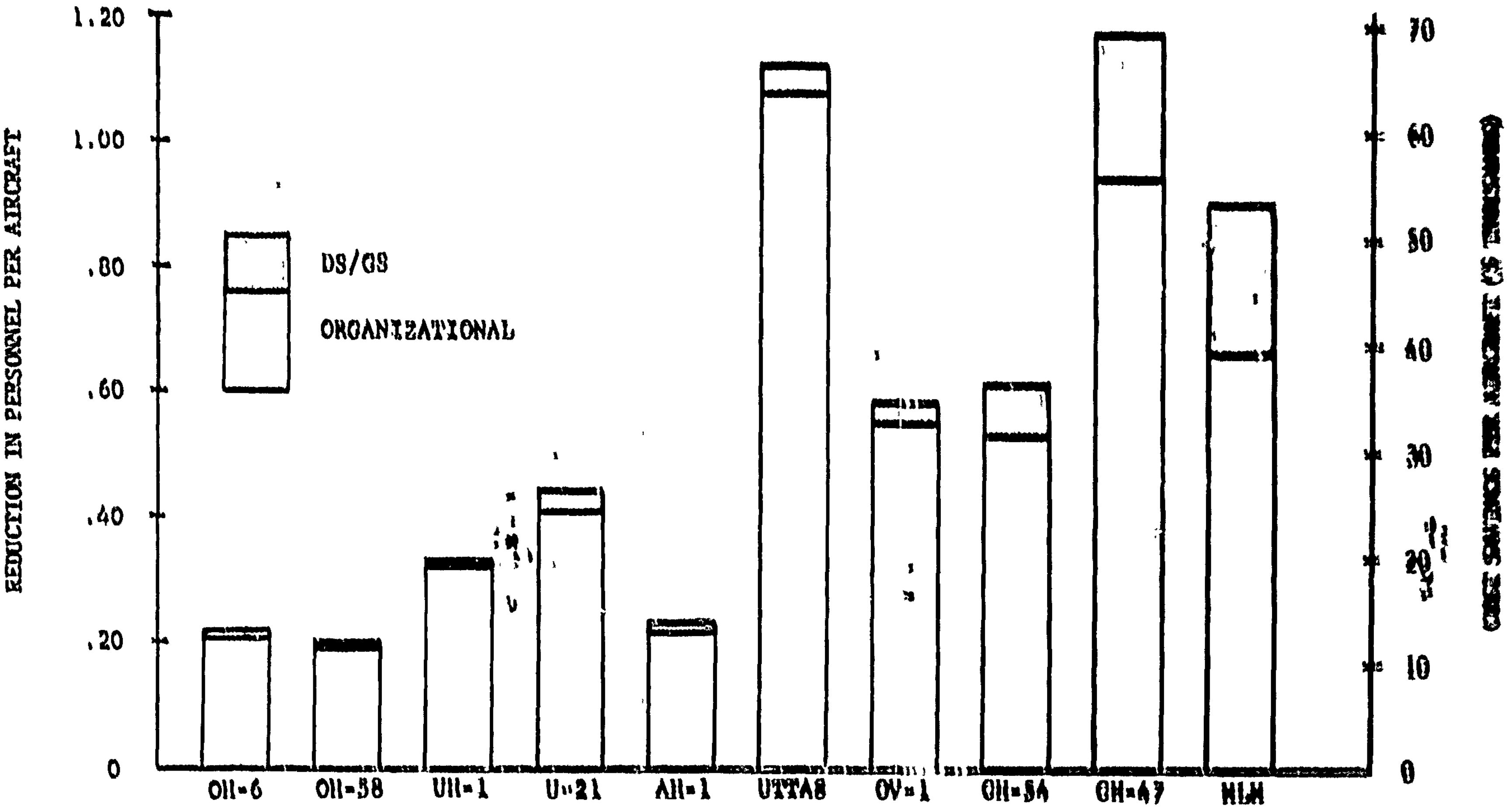


FIGURE 2-6 PERSONNEL SAVINGS PER AIRCRAFT
HYBRID I - UNIVERSAL EXPECTED CONDITION
(10 YEARS OPERATION)

The high value achieved for the UTTAS is due to the relatively high complexity of this aircraft. In this and subsequent figures, savings due to monitoring avionics and armament equipment are not included.

Figure 2-7 shows the savings in logistics. These savings are due to the reduction in unwarranted removals and time removals. The reduced number of removals creates a reduction in demand for spares. This allows a one-time reduction in spares inventory. In addition, packaging, shipping and bench check costs are reduced and the elimination of time removals reduces the number of overhauls required.

Figure 2-8 shows the accident savings per aircraft. These savings are directly proportional to aircraft cost. The high accident rate of the AH-1 accounts for the large accident savings for this aircraft. Although changes now in effect may reduce the accident rate of this aircraft, the savings in accidents as well as maintenance and logistics will still be substantial. Similarly, the low accident rates for engines and transmissions for the OV-1 account for the resulting savings in accidents on this aircraft.

Figure 2-9 shows the increase in aircraft effectiveness. The measure of effectiveness is the payload which can be reliably transported per day. The increase in effectiveness is primarily due to the increase in aircraft availability due to decreased aircraft downtime. The decrease in aircraft abort rates also affects this measure. The payload penalty due to AIDAPS weight has been subtracted.

Figure 2-10 shows the total savings, procurement costs and net savings on a per aircraft basis. Figure 2-11 gives the same information on a total fleet basis. Table 2-6 shows the savings accrued through monitoring the avionics systems with AIDAPS.

Since an AIDAPS is considered a cost savings device, one of the prime considerations in a procurement decision is the time required to recover the initial expenditures. Figure 2-12 shows the time required to recover the initial expenditures for DDT&E and procurement of the systems in relation to the date production is initiated and ended. As a ground rule for the study, a break-even period of under three years is considered desirable. Due to the long development period of the future aircraft, their break-even point occurs before procurement is completed.

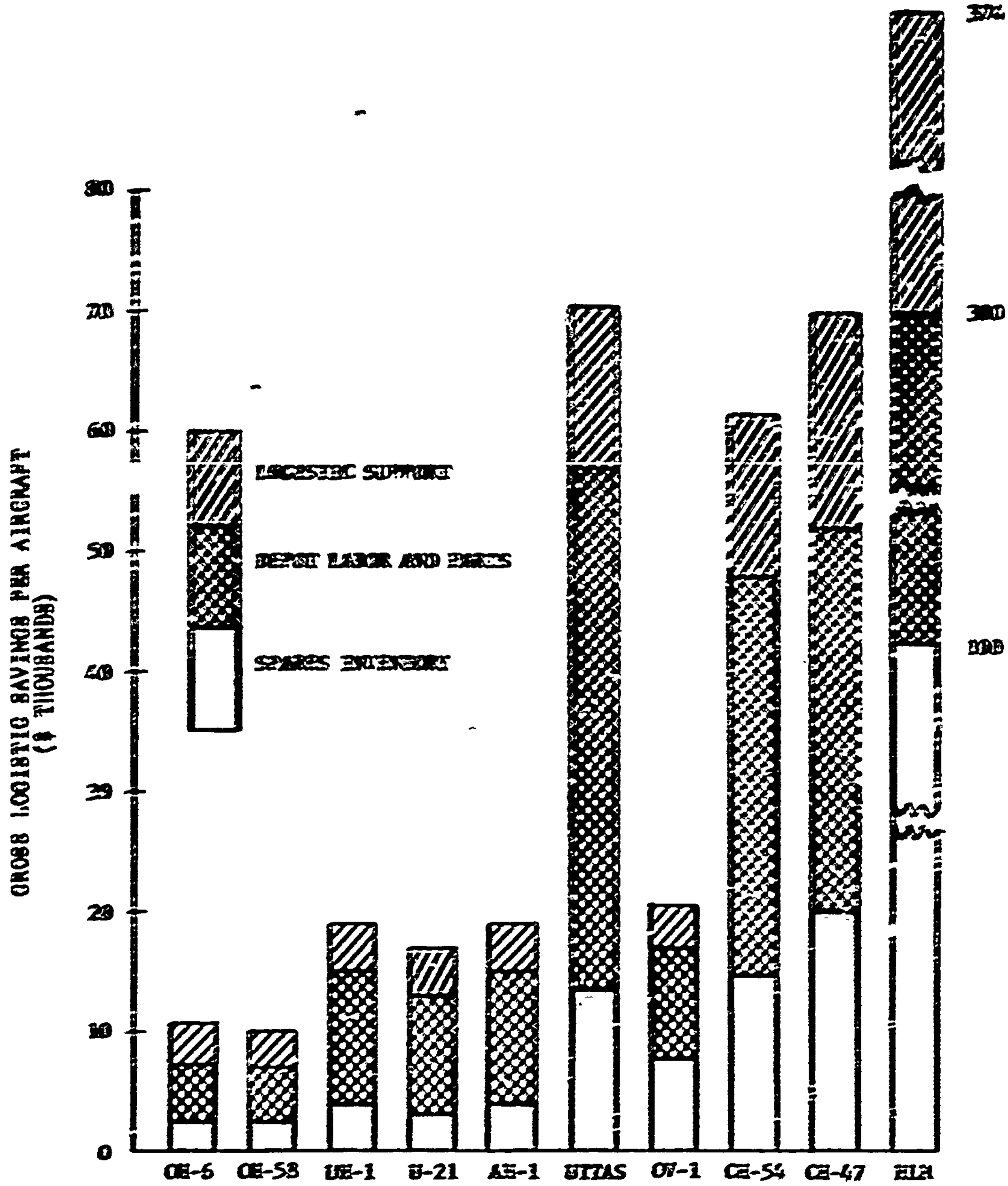


FIGURE 2-7 LOGISTIC SAVINGS PER AIRCRAFT

HYBRID I - UNIVERSAL EXPECTED CONDITION

(10 YEARS OPERATION)

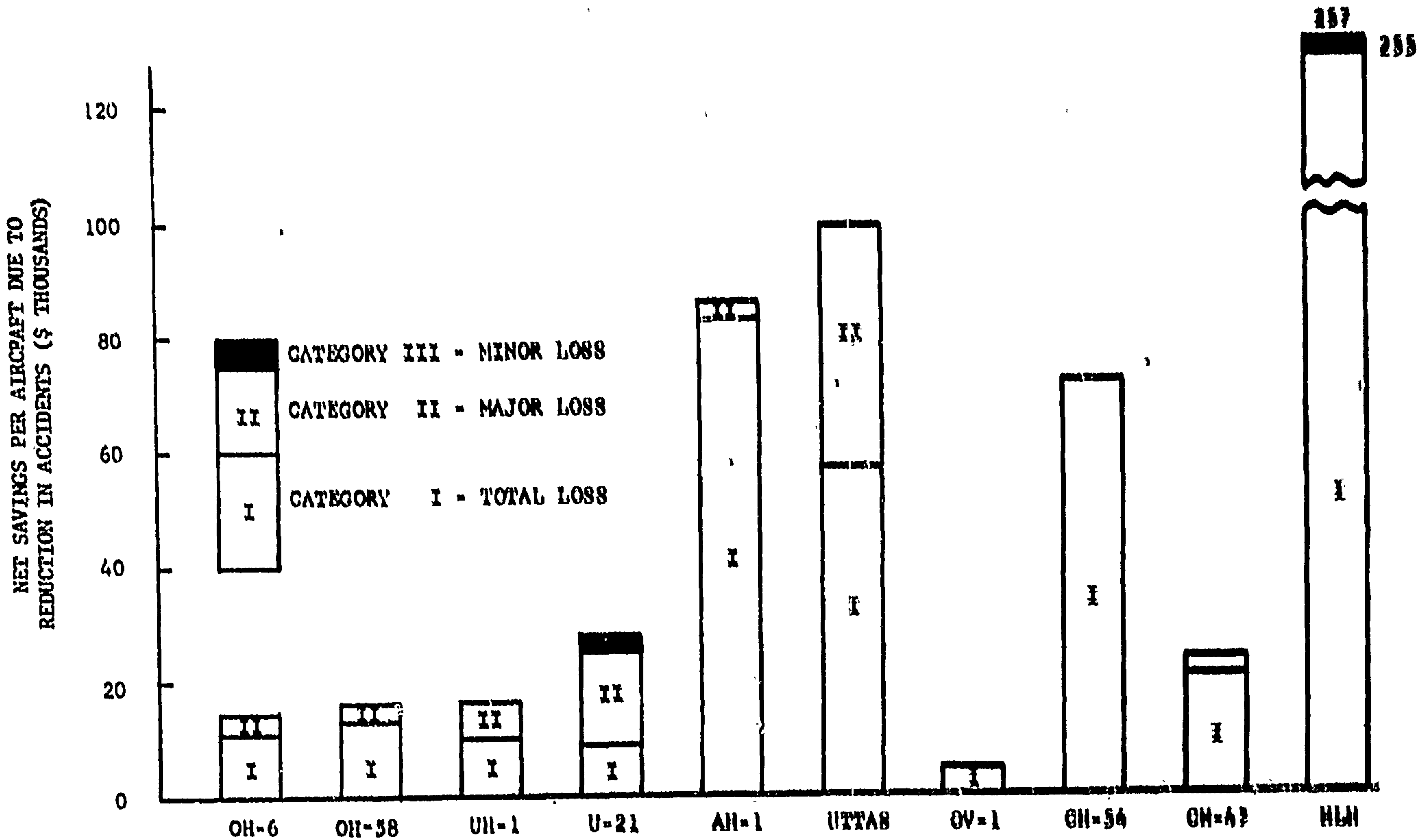


FIGURE 2-8 ACCIDENT SAVINGS PER AIRCRAFT
HYBRID I - UNIVERSAL EXPECTED CONDITION
(10 YEARS OPERATION)

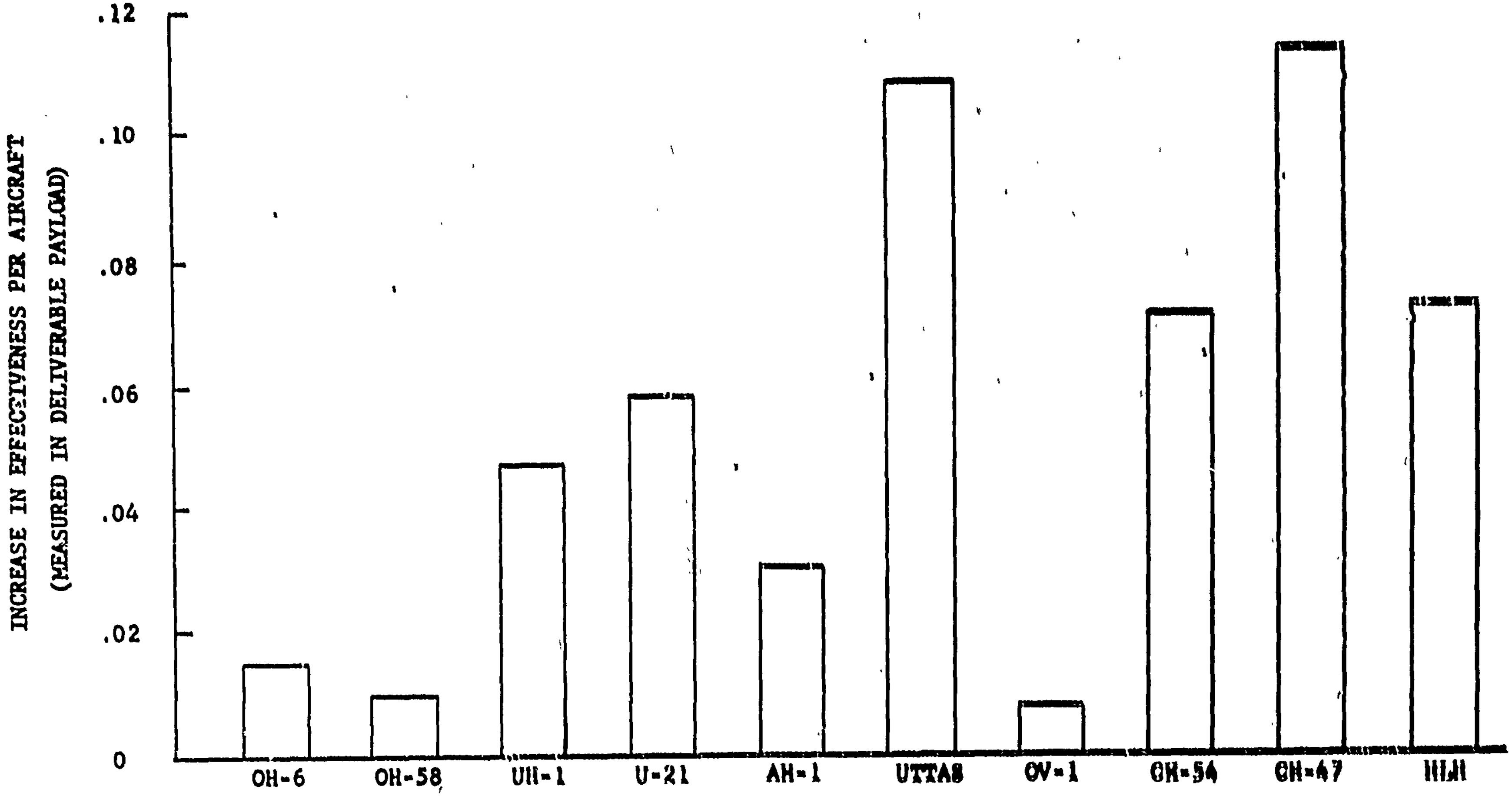


FIGURE 2-9 INCREASE IN EFFECTIVENESS PER AIRCRAFT
HYBRID I - UNIVERSAL EXPECTED CONDITION
(10 YEARS OPERATION)

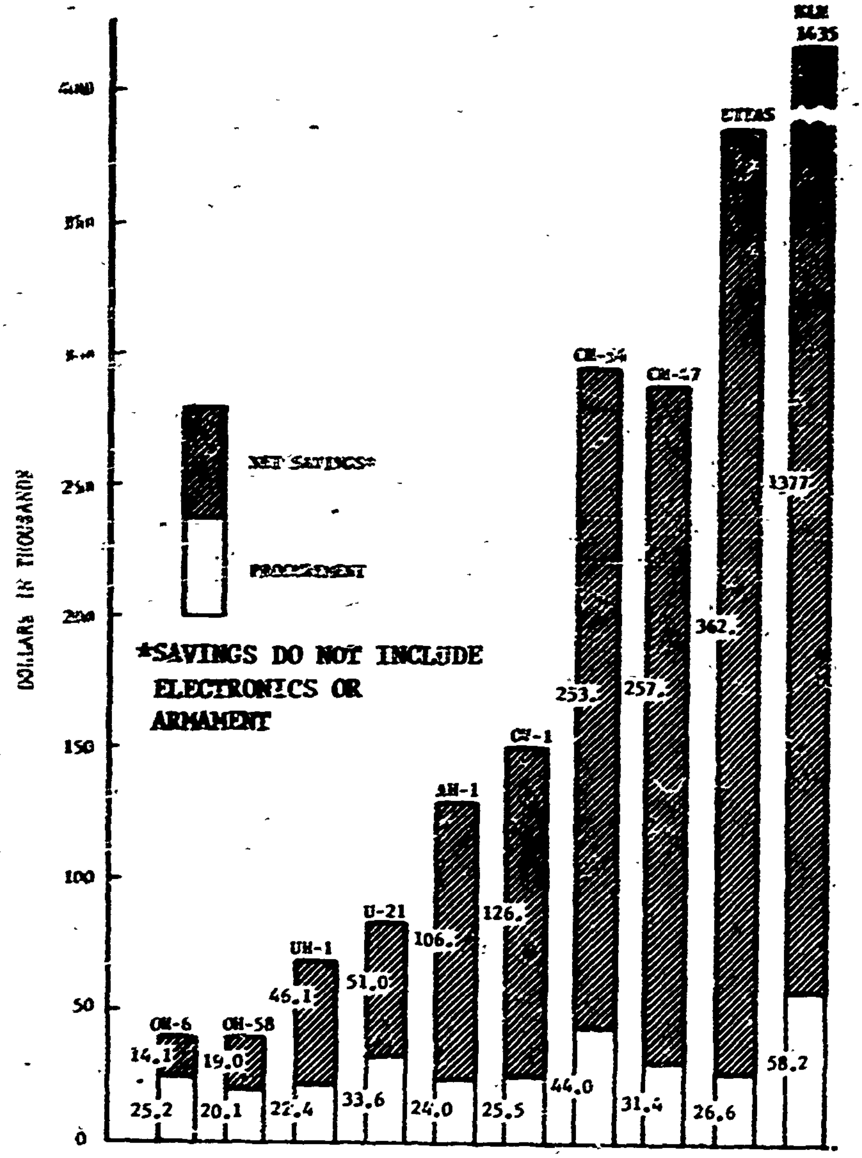
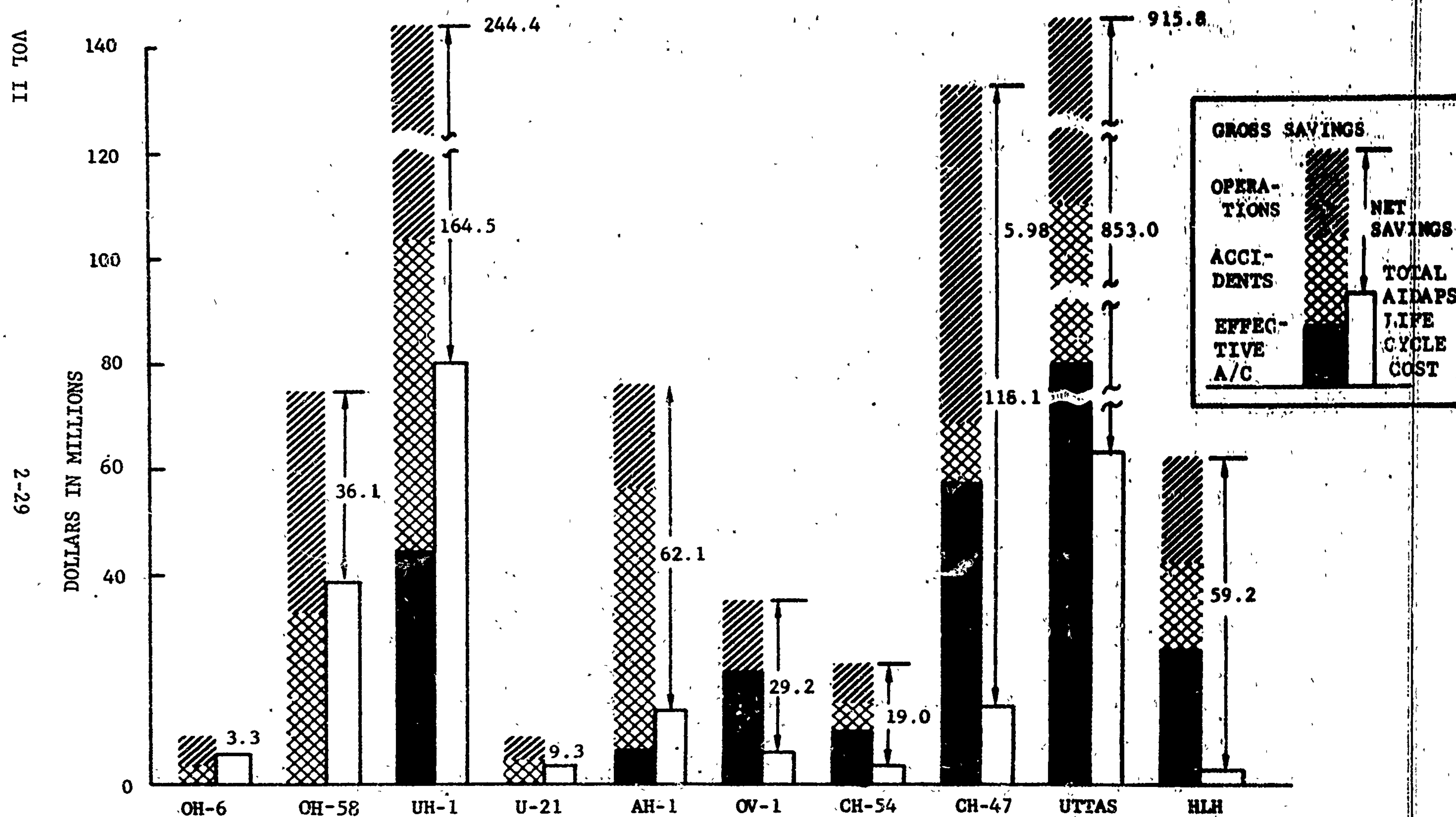


FIGURE 2-10 SYSTEMS PROCUREMENT COSTS AND NET SAVINGS PER AIRCRAFT
HYBRID I - UNIVERSAL EXPECTED CONDITION (10 YEARS OPERATION)



GROSS SAVINGS DO NOT INCLUDE SAVINGS IN ELECTRONICS OR ARMAMENT

FIGURE 2-11 SYSTEM GROSS SAVINGS, TOTAL PROCUREMENT AND NET SAVINGS
HYBRID I - UNIVERSAL EXPECTED CONDITION
(10 YEARS OPERATION)

TABLE 2-6 NET SAVINGS ACCRUED FROM MONITORING AVIONICS SYSTEMS BY AIDAPS

AIRCRAFT	NET SAVINGS	
	PER AIRCRAFT (THOUSANDS OF DOLLARS)	TOTAL FLEET (MILLIONS OF DOLLARS)
OH-6	.183	.043
OH-58	.182	.347
UH-1	.182	.652
AH-1	.183	.107
U-21	.221	.023
OV-1	9.030	2.086
CH-47	1.790	.822
CH-54	1.053	.079
UTTAS	2.207	5.201
HLH	1.581	.068

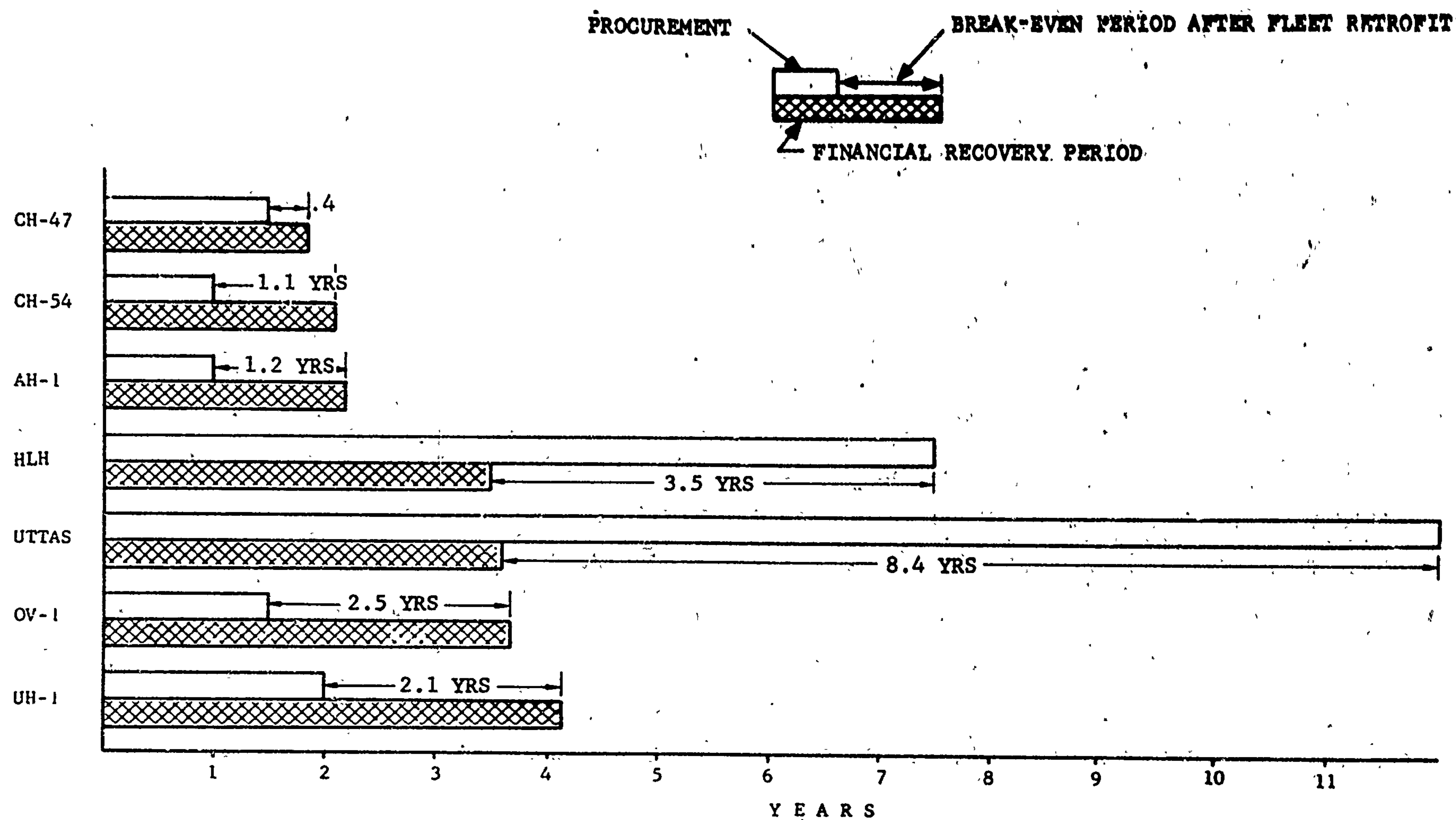


FIGURE 2-12 TIME REQUIRED FOR AIDAPS PROCUREMENT COSTS TO BE RECOVERED
HYBRID I - UNIVERSAL SYSTEMS

Figure 2-13 shows the costs and savings resulting from the recommended AIDAPS programs. The OH-6, OH-58 and U-21 aircraft are excluded from this program because the net savings achieved for these aircraft are small and the time required to recover the initial investment is generally more than 5 years.

The recommended program achieves significant cost savings and improves the effectiveness of the Army aircraft. The improvements in aircraft availability and the reduction in aircraft support requirements in wartime are even greater than the expected benefits shown in this summary. These savings are real in the sense that the study has preserved a direct relationship between the maintenance tasks eliminated by the AIDAPS as reflected in the TAMMS data, the cost benefits claimed, and the capabilities of the AIDAP system designs. Although the data upon which this study is based are subject to some variations, it is apparent that modern technology can produce an AIDAP system which will result in large savings in peacetime, will ease the maintenance and logistics burdens on the field soldier and supporting elements in wartime, and will enhance the safety and operational capability of the air vehicles.

2.4 CONCLUSIONS AND RECOMMENDATIONS

The feasibility of an Automatic Inspection Diagnostic and Prognostic System is well demonstrated by the existence of a number of commercial and/or military systems each of which demonstrates one or more of the required characteristics within the weight, volume and cost limitations imposed by Army aircraft.

Advances in light weight and low cost computer circuitry and recording and printing components have occurred which make the design and development of an adequate AIDAPS for the Army a feasible engineering effort. The only unusual developmental effort required is the gathering of component performance data required for long term prognostics. This can be easily accomplished during the developmental program.

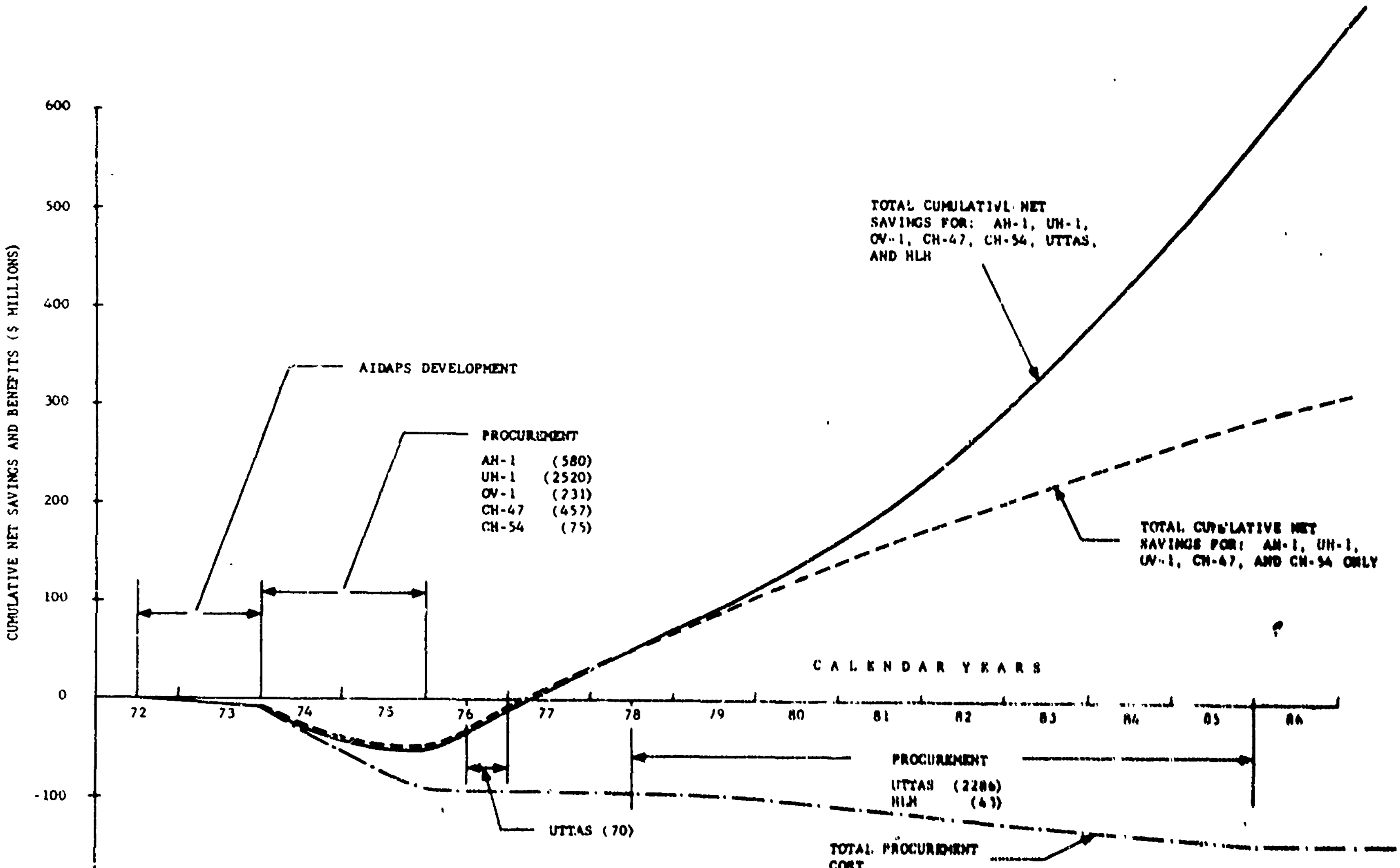


FIGURE 2-13 HYBRID I AIDAPS SYSTEM

TIME PHASED PROGRAM

COST SAVINGS AND BENEFITS

(UNIVERSAL SYSTEM - EXPECTED CONDITION)

A highly cost effective AIDAP system can be developed for the UH-1/AH-1 aircraft over a developmental period of 18 months at a cost of approximately $4.2 million. Procurement of sufficient quantities of equipment to outfit the entire UH-1H/AH-1 fleet can be accomplished over a period of approximately two years at a total investment cost of approximately $77 million, including training of personnel and spare parts (see Volume III).

The addition of $2.4 million for adaptation costs and approximately $18 million for procurement will equip the CH-47, CH-54 and OV-1 fleets. Equipping of these fleets can be easily completed by the end of fiscal year 1976.

An additional $1.8 million for adaptation and approximately $52 million for procurement will equip the HLH and UTTAS aircraft. The AIDAPS procurement program for these aircraft can be concurrent with the aircraft procurement program.

As a result of equipping the AH-1 and UH-1 Fleets, approximately $25 million will initially be saved annually in aircraft maintenance, logistics, accidents and increased aircraft availability and reliability. A total net savings of $180 million can be expected within approximately ten years after completion of procurement. If AIDAP systems are procured for the CH-47, CH-54, and OV-1 aircraft, an additional $166 million in net savings over a period of ten years can be expected.

The net savings achievable on the HLH and UTTAS during ten years of operation are approximately $60 million and $850 million, respectively.

Although AIDAP systems for the OH-6, OH-58 and U-21 are cost effective, the ratios of net savings and benefits to development and procurement costs are less than two to one and the time required to achieve a net return is significantly longer than three years. For these reasons, an immediate developmental program for AIDAP systems for these aircraft does not seem desirable. However, the experience gained in the development and use of AIDAPS on other aircraft may allow a more effective system to be conceived at some future date.

2.4.1 RECOMMENDATIONS

The following recommendations are made:

a) A program to develop an AIDAP system for the UH-1H and AH-1 aircraft should be initiated immediately.

b) AIDAP development and procurement programs for the OV-1, CH-47, and CH-54 should also be initiated at an early date.

c) AIDAPS development programs for the HLH and UTTAS aircraft should be initiated and scheduled on a basis consistent with the development of these aircraft.

d) AIDAPS programs for the OH-6, OH-58 and U-21 should not be initiated at the present time. However, the requirements for AIDAP systems for these aircraft should be reviewed when operational experience is gained with AIDAPS on other aircraft.

e) The following experimental programs should be pursued to enhance AIDAPS capabilities in specific technological capabilities:

1) Airborne oil deterioration sensors

2) CEPSTRUM analysis of vibration data

3) Optical correlators

4) Adaptive vibration analysis

5) High frequency vibration analysis

6) Acoustic emission monitoring of structurally loaded aircraft components.

f) Upon introduction of AIDAPS into the Army inventory, data retrieved from the AIDAPS operational use should be made available to the managers of Army Logistics improvement programs as well as experimental and developmental AIDAPS programs.

AIDAPS equipment is a rapidly advancing technology. Automatic inspection, diagnosis and prognosis systems which will greatly reduce the Army's maintenance and logistics problems, help prevent accidents, and improve the availability of aircraft to the using organizations can be designed and produced immediately. The initiation of a program to develop such equipment will not only provide these benefits, but will also provide basic experience which will facilitate further advances in AIDAPS technology.

SECTION 3

3-1.1

3.0 ARMY ENVIRONMENT

Proper military equipment design is necessarily based on satisfying the operational requirements of the using organizations. Since the AIDAP system does not perform a tactical function, but is procured to improve the mission capability of associated aircraft, the AIDAPS configuration must be compatible with the normal aircraft operational, maintenance and logistics environment, and with Army policies and procedures.

3.1 ARMY AIRCRAFT

The aircraft selected by the Army for inclusion in the study are:

AH-1	OV-1
CH-47	UH-1
CH-54	U-21
OH-6	HLH
OH-58	UTTAS

A description of these aircraft is contained in Appendix A. They range in complexity from single engine, light observation helicopters, to multi-engined helicopters and winged aircraft. Although a certain functional commonality exists between the aircraft systems, the range of complexity is large. Indicative of this complexity is the number of sensors currently installed. Table 3-1 shows the number of sensors for each system on current aircraft and an estimate of the number which will be provided on future aircraft. The number of sensors is important to an AIDAP system since they represent potential signal sources.

3.2 ARMY AIRCRAFT OPERATIONAL ENVIRONMENT

Army aircraft combat operations are unique in that the aircraft must be located and employed alongside the field soldier. An AIDAP system must provide reliable assistance to the soldiers operating, maintaining, and supporting the aircraft. It must accompany the aircraft during deployment on a worldwide basis. Facilities within this environment will range from an Airmobile Maintenance Shop parked in the sand, mud, or snow alongside a forward airstrip, to hard surface or hangar facilities in rear or secure areas.

TABLE 3-1 AIRCRAFT SYSTEM EXISTING SENSORS

SYSTEM	FUNCTIONAL GROUP	OH-6	OH-58	OV-1	CH-47	CH-54	UH-1	U-21	AH-1	UTTAS	HLH (TWIN ROTOR) 3 ENGINE
AIRFRAME	01	0	0	0	0	0	0	0	0	0	0
ALIGHTING GEAR	02	0	0	3	0	0	0	3	0	0	0
ENGINE	03	8	8	16	16	24	10	14	10	32	48
ROTOR/TRANSMISSION	04	5	5	0	15	6	5	0	5	16	19
PROPELLER	05	0	0	2	0	0	0	2	0	0	0
HYDRAULIC	06	0	0	2	3	3	2	0	3	2	3
PNEUMATIC	07	0	0	0	0	0	0	0	0	0	0
INSTRUMENTS	08	0	0	0	0	0	0	0	0	0	0
ELECTRICAL	09	3	3	9	7	8	2	8	2	8	8
FUEL	10	0	0	1	0	0	5	4	5	0	0
FLT. CONTROL	11	0	0	0	5	1	0	0	5	5	0
UTILITY	12	0	0	0	0	0	0	0	4	0	0
CARGO HANDLING	17	0	0	0	0	0	0	0	0	0	0
APU	18	0	0	0	1	2	0	0	0	4	4
AVIONICS	19	4	4	18	7	10	4	10	4	7	13
MISC		1	1	2	2	2	1	2	1	2	3
ARMAMENT	30	0	0	0	0	0	0	0	0	0	0
TOTAL NUMBER OF SENSORS		21	21	53	56	56	29	43	39	75	98

The AIDAPS equipment must be a passive element as far as aircraft operation is concerned. It should require little or no attention from the pilot or aircrew during normal operations and yet be capable of providing air safety information on a timely basis. It also must not significantly degrade the payload, or range nor impose any constraints on the aircraft missions. Thus the major requirements imposed on the AIDAP-system by aircraft operational considerations are that it must be automatic, light weight, reliable, accurate and capable of functioning within the environmental extremes imposed by Army aircraft operations.

3.3 ARMY AIRCRAFT MAINTENANCE ENVIRONMENT

The objectives of the AIDAP system include the reduction in the required maintenance tasks and skills associated with all levels of Army maintenance. The focal point for these objectives must be the organizational level since this is the point at which all maintenance requirements begin. Within the existing environment, the required maintenance reporting forms have an impact upon the AIDAPS data printout. A brief discussion of these factors follows. For a full discussion, see Appendix B.

3.3.1 CATEGORIES OF MAINTENANCE WITHIN THE ARMY

Categories of maintenance are used as a means of designating the scope of maintenance to be performed by units and activities at various command levels within the Department of the Army. The responsibility for the performance of maintenance within a given category is assigned to a unit or activity in accordance with its primary mission, its degree of mobility, and the intended availability of personnel, skills, and material resources. These categories, briefly defined, are as follows:

a) Organizational Maintenance (ORG) - This category of maintenance is the responsibility of the unit commander in maintaining the operational readiness of equipment under his control. It includes preventive maintenance, services and those organizational level functions authorized in the -20 technical manuals. Authorized maintenance functions at the organizational level include inspection, service, adjustment, alignment, calibration, replacement and repair. Most on aircraft maintenance is accomplished at this level.

b) Direct Support Maintenance (DS) - Direct support maintenance is assigned to and performed by designated TOE and TDA maintenance activities in direct support of using organizations. The repair of end items or unserviceable assemblies is performed in support of using units on a return-to-user basis.

c) General Support Maintenance (GS) - This category of maintenance normally is assigned to and performed by designated TOE and TDA maintenance units or activities in support of individual Army area supply requirements. General support maintenance represents the principal maintenance capability available to the Field Army Commander for overhauling his materiel assets. When required, general support maintenance may provide support on a return-to-user basis for equipment whose repair is beyond the capability of direct support units.

d) Depot Maintenance - This category of maintenance is the responsibility of, and is performed at, organic Army facilities including the Floating Aircraft Maintenance Facilities, facilities of other DOD elements, and commercial contractor facilities. Depot maintenance augments depot stocks of serviceable material and supports organizational, direct, and general support maintenance activities by use of more extensive shop facilities and equipment, and personnel of higher technical skill than are available at lower categories of maintenance. Actions in this category normally consist of the following: inspection and test; repair; modification; alternation; modernization; conversion; calibration; overhaul; renovation (for ammo only); reclamation and rebuild of parts, assemblies, subassemblies, components, baisc or end items; and the emergency manufacture of non-available parts for immediate consumption.

3.3.2 FORMS AND RECORDS FOR ARMY MAINTENANCE

The AIDAPS printout must interface properly with the standard forms and records maintained by the Army. These forms and records are specified in TM 38-750, The Army Maintenance Management System (TAMMS). An index of TAMMS record and report forms is presented in Table 3-2.

3.3.3 MAINTENANCE DATA

Aircraft maintenance data was derived from two primary sources. The source for general aircraft data was FM 101-20. Detailed maintenance data was derived from

TABLE 3-2 INDEX OF TAMMS RECORD AND REPORT FORMS

Form No.	Title
	OPERATIONAL
DA Form 2400	Equipment Utilization Record
DA Form 2401	Organizational Control Record for Equipment
	MAINTENANCE
DA Form 2402	Exchange Tag
DA Form 314	Preventive Maintenance Schedule and Record
DA Form 2404	Equipment Inspection and Maintenance Worksheet
DA Form 2405	Maintenance Request Register
DA Form 2406	Materiel Readiness Report
DA Form 2407	Maintenance Request
DA Form 2407-1	Maintenance Request Continuation Sheet
DA Form 2410	Component Removal and Repair/Overhaul Record
DA Form 2410-1	Component Removal, Installation, Movement and Condition Record (Trans Report)
DA Form 2418	Backlog Status and Workload Accounting Card
	HISTORICAL (Log)
DA Form 2408	Equipment Log Assembly (Records)
DA Form 2408-1	Equipment Daily or Monthly Log
DA Form 2408-4	Weapon Record Data
DA Form 2408-5	Equipment Modification Record
DA Form 2408-7	Equipment Transfer Report
DA Form 2408-8	Equipment Acceptance and Registration Record
DA Form 2408-10	Equipment Component Register
DA Form 2408-12	Army Aviator's Flight Record
DA Form 2408-13	Aircraft Inspection and Maintenance Record
DA Form 2408-14	Uncorrected Fault Record
DA Form 2408-15	Historical Record for Aircraft
DA Form 2408-16	Aircraft Component Historical Record
DA Form 2408-17	Aircraft Inventory Record

TABLE 3-2 INDEX OF TAMMS RECORD AND REPORT FORMS (Concluded)

Form No.	Title
	HISTORICAL (Log) (Continued)
DA Form 2408-18	Equipment Inspection List
DA Form 2408-19	Aircraft Engine Turbine Wheel Historical Record
DA Form 2409	Equipment Maintenance Log (Consolidated)
	AMMUNITION
DA Form 2415	Ammunition Condition Report
	CALIBRATION
DA Form 2416	Calibration Data Card
DA Form 2417	Unserviceable or Limited Use Tag
DA Label 80	US Army Calibration System

TAMMS data and appears in Appendix E, Books 1, 2, 3, and 4. Table 3-3 shows the maintenance manhours required per flying hour for each of the aircraft considered in the study. For some aircraft these manhour estimates have been adjusted for differences between models. The manhour estimates for the UTTAS and HLH are based on comparisons with similar aircraft systems in existing aircraft. Data labeled with an E represents estimates. Table 3-4 shows the inspection requirements for each aircraft.

3.4 ARMY LOGISTICS

As a result of increasing cost of logistic support for the Army, as well as the increasing immobility of field operation due to dependance upon logistic support, the Department of the Army has initiated a program called Logistics Offensive Program (LOP). The stated objective of this program is to provide "Optimum material readiness with minimum maintenance burden near the forward edge of battle." The major elements within the program are the establishment of Maintenance Assistance Inspection Teams (MAIT), the Selective Item Maintenance System (SIMS), and the Component Direct Exchange (DX) program. A long range objective for the LOP program is the Maintenance Support Positive program (MS+) which is aimed at modularization of all Army equipment, and the Standard Army Maintenance Reporting and Management Subsystems (SAMRSMS).

The objectives of these programs are as follows:

Maintenance Assistance Inspection Teams (MAIT)

- Reduction of faulty-diagnosed components
- Assistance in repair management of repairables

Selective Item Maintenance System (SIMS)

- Information for TAMMS/MAC changes
- Control and Status Information on Components
- Reduction in spare parts levels

Component Direct Exchange Program (DX)

- Efficient and timely handling of repairables
- Facilitate remove and replace functions
- Standardize exchange procedures

TABLE 3-3 ARMY AIRCRAFT MAINTENANCE MAN-HOUR REQUIREMENTS

AIRCRAFT	ORG	DS	GS	TOTAL
AH-1	4.05	2.62	2.18	8.85
CH-47	11.3	12.31	8.85	32.46
CH-54	17.81	7.85	5.66	31.32
OH-6	2.25	2.81	0.67	5.74
OH-58	2.25	2.81	0.67	5.74
OV-1	5.5	3.0	2.10	10.60
U-21	4.19	2.34	1.51	8.04
UH-1	3.25	2.41	2.02	7.67
HLH	14.7E	10.5E	6.5E	31.7E
UTTAS	5.3E	3.0E	2.5E	10.8E

TABLE 3-4 ARMY AIRCRAFT INSPECTION MAN-HOUR REQUIREMENTS

AIRCRAFT	MAINT INDEX	INSPECTION MAN-HOURS		
		DAILY	INTERMEDIATE	PERIODIC
AH-1	8.85	1.5E	5.0E	85E
CH-47	32.46	6.9	61.4	204.9
CH-54	31.32	7.0	32.0	160.0
OH-6	5.74	0.8	--	27.0
OH-58	5.74	1.0E	--	25.0E
OV-1	10.6	1.6	7.4	146.6
UH-1	7.67	1.5	5.6	80.4
U-21	8.04	1.9	5.0E	85E
HLH	31.7E	12.0E	116.0E	232.0E
UTTAS	10.8E	1.8E	7.0E	96.0E

Component Direct Exchange Program (DX) (Continued)

- Improve material readiness
- Control of total assets
- Realistic stockage levels

Standard Army Maintenance Reporting and Management System (SAMRMS)

- Standardized maintenance system
  - Management
  - Reporting
- CS_3 compatibility

Maintenance Support Positive (MS+)

- Modular design of all components
- Remove and replace functions at the FEBA
- Reduction in faulty diagnosed components
- Reduction in spare parts, tools and GSE at the FEBA
- Reduction in skill levels at the FEBA
- Direct exchange support
- Repair and overhaul in rear areas
- Increased unit mobility and mission readiness

3.5 ARMY AIRCRAFT ACCIDENTS

Crash Facts Messages (CFMs) are used to report aborts and accidents. These reports classify airborne events as incidents, precautionary landings, forced landings, minor accidents, major accidents and total loss accidents. For the purpose of this analysis, incidents, precautionary landings, and forced landings are called aborts. The crash message summaries identify the aircraft type model and series, indicate the accident category and accident cause and give brief engineering comments as well as other data. Table 3-5 shows the abort and accident rates segregated by aircraft, and type of event. Since an insufficient data base existed for the OH-58, these data were combined with OH-6 data and the composite date used for the OH-58. Although very small data bases existed for the certain other aircraft, these data were not combined because of the differences in configuration and operational use. These data were derived from crash message summary data provided by USAABAR. The data covered a one year period of operations.

TABLE 3-5 AIRCRAFT ACCIDENT AND ABORT RATES PER 100,000 FLIGHT HOURS

AIRCRAFT	TOTAL HOURS FLOWN (12 MONTHS)	SITUATION RATES			
		ABORT RATE	MINOR ACCIDENT RATE	MAJOR ACCIDENT RATE	TOTAL LOSS RATE
OH-6	306,471	107.68	0.0	21.54	14.68
OH-58	252,352	101.63	.42	15.84	10.13
UH-1	2,188,238	75.82	.82	7.04	7.45
CH-47	202,979	233.40	.49	4.43	7.39
CH-54	14,272	398.54	7.01	0.0	14.01
AH-1	328,897	195.57	.61	12.46	11.25
OV-1	73,709	97.65	2.71	1.36	6.78
U-21	75,726	70.14	1.32	9.24	2.80
UTTAS	-	104.73E	1.15E	10.25E	8.00E
HLH	-	280.71E	.59E	5.56E	9.30E

Table 3-6 gives the accident and abort rates per 100,000 flying hours for each aircraft functional group or cause. The data for the UTTAS and HLH are estimates. These estimates were computed using the situation rates associated with the UH-1H and CH-47C, respectively. The situation rates for Engine, Rotor and Transmission, and Flight Control systems were factored based on the configuration of the two aircraft. The remaining system situation rates were used directly as presented for the UH-1H and CH-47C.

3.6 AIDAPS REQUIREMENTS

The basic Army document defining AIDAPS requirements is a Qualitative Materiel Requirement (QMR) entitled "Automatic Inspection, Diagnostic and Prognostic System for Army Aircraft" which received Department of Army approval in October 1967. Subsequently, advanced in test and checkout technologies, including the development of new sensing, recording, and printing devices, as well as advanced in data processing techniques, have significantly improved the position of industry to accomplish the basic QMR requirements.

The existence of special Army programs such as the Logistics Offensive Program (Program LOP), the analysis of Army maintenance data, and interviews with Army field personnel clearly show that maintenance and support of modern aircraft presents one of the most troublesome aspects of deploying a modern field army. This is particularly true when the field army is deployed within a combat environment at a long distance from its industrial base.

Aircraft maintenance and logistics problems originate at the aircraft. Today's Army aircraft represent some of the most mechanically complicated devices in operation. These aircraft must exist and function within the environment experienced by the combat soldier and yet maintain an operational readiness and effectiveness compatible with simple military weapons. To accomplish these objectives, maintenance and logistic support personnel must be equipped with the most advanced, efficient and reliable maintenance devices that can be provided.

The following three capabilities of Army aircraft AIDAPS equipment are paramount to accomplishing such objectives.

TABLE 3-6 AIRCRAFT FUNCTIONAL GROUP ACCIDENT AND ABORT RATES (PER 100,000 FLIGHT HOURS)

AIRCRAFT/EVENT	AIRFRAME 01	ALIGHTING GEAR 02	ENGINE 03	ROTORS & TRANSMISSION 04	HYDRAULIC 06	INSTRUMENTS 08	ELECTRICAL 09	FUEL 10	FLT CONTROLS 11	UTILITY 12	PILOT ERROR 59	MAINT. ERROR 69	STRUCK OBJECT 89	UNKNOWN 99		TOTAL
OH-6A																
ABORT RATE			25.16	33.21	2.01		9.06	2.01	4.03		3.02	1.01	28.18			107.68
MINOR ACCIDENT																--
MAJOR ACCIDENT			7.18	1.60				.80	3.19		2.39		6.38			21.54
TOTAL LOSS			7.34	1.84									5.51			14.68
OH-58																
ABORT RATE	.05	.16	20.55	42.39	5.23	.05	5.02	1.30	2.93		2.44	.97	19.58	.96		101.63
MINOR ACCIDENT			.13	.07							.09		.13			.42
MAJOR ACCIDENT			5.90	1.26	.08			.44	1.97		1.19		4.62	.38		15.84
TOTAL LOSS			4.05	1.11					.14		.68		3.74	.41		10.13
UH-1H																
ABORT RATE	.19	.56	24.27	11.20	14.57	.19	.37	.75	2.61		2.79	1.49	15.13	1.68		75.82
MINOR ACCIDENT			.33								.16		.33			.82
MAJOR ACCIDENT			3.05	.59	.12				.35		.59		1.76	.59		7.04
TOTAL LOSS			.44	.44					.44		2.19		2.63	1.31		7.45
CH-47C																
ABORT RATE	.47	1.42	71.07	40.95	37.71	.47	4.36	2.65	8.15		8.24	4.17	49.00	4.26		233.40
MINOR ACCIDENT			.16	.09							.08		.16			.49
MAJOR ACCIDENT			1.84	.36	.06			.03	.30		.39		1.14	.30		4.43
TOTAL LOSS			1.00	.52					.36		1.80		2.64	1.08		7.39

TABLE 3-6 (Continued)

AIRCRAFT/EVENT	AIRFRAME 01	ALIGHTING GEAR 02	ENGINE 03	ROTORS & TRANSMISSION 04	HYDRAULIC 06	INSTRUMENTS 08	ELECTRICAL 09	FUEL 10	FLT CONTROLS 11	UTILITY 12	PILOT ERROR 59	MAINT. ERROR 69	STRUCK OBJECT 89	UNKNOWN 99	TOTAL
CH-54															
ABORT RATE	.81	2.43	21.35	69.92	64.38	.81	7.45	4.53	13.92		14.08	7.12	83.66	7.28	396.54
MINOR ACCIDENT			2.32	1.22							1.16		2.32		7.01
MAJOR ACCIDENT															--
TOTAL LOSS			1.90	.99					.68		3.40		5.00	2.04	14.01
AH-1															
ABORT RATE	1.17	2.35	67.86	25.62	45.57		3.52	3.52	17.21	1.17	1.17	2.35	19.75	3.52	195.57
MINOR ACCIDENT			.31										.31		.61
MAJOR ACCIDENT				1.12				2.24			2.24		6.85		12.46
TOTAL LOSS			11.25												11.25
OV-1															
ABORT RATE	.25	.74	37.64	21.99	19.79	.25	2.43	1.42	4.33		4.37	2.20		2.23	97.65
MINOR ACCIDENT			1.49	.47							.75				2.71
MAJOR ACCIDENT		.02	.76	.15	.02			.01	.12		.16			.10	1.36
TOTAL LOSS			1.45	.75					.51		2.55			1.53	6.78
U-21															
ABORT RATE	.18	.53	27.04	15.79	14.21	.18	1.75	1.02	3.11		3.14	1.58		1.60	70.14
MINOR ACCIDENT			.73	.23							.36				1.32
MAJOR ACCIDENT		.17	5.17	1.02	.17			.08	.85		1.10			.68	9.24
TOTAL LOSS			.60	.31					.21		1.05			[illegible]	[illegible]

TABLE 3-6 (Concluded)

AIRCRAFT/EVENT	AIRFRAME 01	ALIGHTING GEAR 02	ENGINE 03	ROTORS & TRANSMISSION 04	HYDRAULIC 06	INSTRUMENTS 08	ELECTRICAL 09	FUEL 10	FLT CONTROLS 11	PILOT ERROR 59	MAINT. ERROR 69	STRUCK OBJECT (MISC) 89	UNKNOWN 99		TOTAL
UTTAS															
ABORT RATE	.19	1.42	48.54	15.00	14.57	.19	.37	.75	2.61	2.79	1.49	15.13	1.68		104.73
MINOR ACCIDENT			.66							.16		.33			1.15
MAJOR ACCIDENT			5.10	1.74	.12				.35	.59		1.76	.59		10.25
TOTAL LOSS			.66	.65					.55	2.20		2.63	1.31		8.00
HLH															
ABORT RATE	.47	1.42	106.60	49.14	37.71	.47	4.36	2.65	12.22	8.24	4.17	49.00	4.26		280.71
MINOR ACCIDENT			.24	.11						.08		.16			.59
MAJOR ACCIDENT			2.76	.43	.06			.03	.45	.39		1.14	.30		5.56
TOTAL LOSS			1.50	.78					.54	1.80		2.64	2.04		9.30

a) To provide a fast and accurate inspection capability which assures that an aircraft is safe and mission worthy. The inspection must consume a minimum of the maintenance personnel's time.

b) To provide a fast and accurate diagnostic capability which will allow the aircraft to achieve a mission ready status in a minimum time with a minimum expenditure of manhours. The system must have sufficient diagnostic accuracy to prevent functional components from being entered into the logistic pipeline with all its attendant costs and time for packaging, transportation and bench test.

c) To provide a prognostic capability which will allow components to be utilized for the full period of their functional capability (on-condition maintenance) without degrading the flight safety or mission worthiness of the air vehicle. This capability reduces packaging and transportation costs, the quantity of material required in the logistics pipeline, and repair and overhaul costs.

To provide these capabilities, the AIDAP system must possess the following additional attributes:

a) Be capable of worldwide deployment

b) Be capable of functioning within the environmental extremes experienced by deployed troops and aircraft

c) Be capable of operation and maintenance by skill levels presently possessed by Army personnel

d) Possess the functional capabilities and measurement accuracies required to diagnose existing and prognosticate impending malfunctions

e) Be highly reliable

f) Require low maintenance

g) Be easily deployed and dispersed with the related aircraft

h) Possess self test capability

i) Be modularized and repairable at the organizational level by remove and replace actions

j) Provide printout in English and/or decimal numerics

k) Be compatible with the CS_3 computer system and standard Army TAMMS forms.

Further, the system must be capable of performing its inspection, diagnostic and prognostic functions on certain components to be selected on a cost effective basis from the airframe, propulsion, rotor and transmission, propeller, fuel, oil, electrical, flight control, hydraulics, armament and avionics functional groups.

SECTION 4

4-1.1

4.0 AIDAP SYSTEM FEASIBILITY

Over the past decade, a variety of air and ground based automatic test equipment has been designed to aid in aircraft maintenance. The experience gained in the design and use of this equipment provides the background data for this study. For an automatic inspection, diagnosis and prognosis system to be feasible, two criteria must be met: a) the information processing technology necessary to accomplish these functions must be available; and b) the basic circuitry and hardware components must be available.

4.1 AIDAPS FUNCTIONAL FEASIBILITY

The technology for aircraft data monitoring systems has made significant advances in the past decade. This has resulted primarily from NASA and DoD aerospace program requirements for compact, lightweight, low power, and highly reliable systems and components. The successful application of these systems clearly demonstrates the functional feasibility of automatic inspection, diagnosis and prognosis (AIDAP) systems for Army aircraft. AIDAPS, as applied herein, is an automatic inspection and maintenance tool for Army aircraft systems and subsystems. It is a broad-based monitoring and analysis system which aids in determining the operational status of components and subsystems on Army aircraft. The general capabilities of the AIDAP systems considered in this study are:

a) <u>Inspection</u> - Inspection is defined as the act of determining the physical or operational status of components or systems. AIDAPS will perform preflight, inflight and post-flight inspection to the highest practical degree as an aid in determining the safe or unsafe status of the aircraft. It is not intended that the implementation of an AIDAPS will eliminate the necessity of all visual inspection procedures.

b) <u>Diagnosis</u> - Diagnosis is defined as the act of isolating the cause of an existing adverse condition. Detection of an adverse condition does not necessarily give adequate information as to the cause of the condition. For example, an indication of engine overtemperature could be caused by an instrumentation failure, a procedural error, or an engine problem. Maintenance action cannot be efficiently initiated until the precise component causing the adverse condition has been isolated. AIDAPS will perform automatic diagnostic analysis of detected adverse conditions in order to clarify the operational status of the aircraft and will isolate the cause of the condition to the Line Replaceable Unit (LRU) level wherever practical.

c) Prognosis - Prognosis is defined as the act of predicting a future event; in this case, an impending failure. The justification for developing an effective means of prognosis is that it will enable efficient preventive maintenance based on actual condition rather than elapsed time. With this definition, there is no requirement on how far in advance the prediction must be made. However, in order to permit planning of maintenance activities, AIDAPS preferably should be able to predict an impending flight failure prior to take-off.

To provide these capabilities, the AIDAP systems must accomplish the following functions:

a) Parameter Sensing - Parameter sensing from a systems point of view concerns the evaluation of the contribution and effectiveness of each parameter being monitored, and the cost of monitoring that parameter. System costs include the cost of signal conditioning and the analyses necessary to utilize any given parameter. Contributions to effectiveness are directly related to the amount of status information contained in a parameter.

b) Data Collection - Data collection includes conditioning of raw sensor signals to a standard digital form and presenting these signals for analyses. This function may or may not include the recording of data depending on the location of the analyses function.

Extensive effort has been expended in previous studies of this type in an effort to determine an optimum sampling rate. The optimum sampling rate is dependent on the response rate of each individual parameter, the general operational mode, and the analyses technique being utilized. The optimum sampling rate is therefore variable.

Since signal conditioning techniques are available for all types of sensor outputs, the decisions required at the systems level include "remote vs. centralized," and "airborne vs. ground." The basic criteria for these decisions are weight and cost, and are, therefore, dependent on the number of parameters monitored and the selection of sensor locations.

c) <u>Analysis</u> - It is the intent of this section to establish the type of analysis capability required by AIDAPS rather than to evaluate the feasibility of various numerical analysis techniques which have possible AIDAPS applications. AIDAPS will have three basic capabilities -- inspection, diagnosis, and prognosis, each of which requires a unique analysis capability.

Inspection and diagnostics are both concerned with evaluating the present status of the system under test, and therefore have a considerable amount of overlap in the type of analysis required. The inspection function is implemented to detect any adverse condition. The analysis involved in this function includes detecting if a parameter exceeds some predetermined limit value or deviates more than a predetermined amount from an expected value. Upon detection of an adverse condition, the diagnostic function is initiated to further identify and isolate the condition. In general, there are more causes for failure than there are indications of failure. The diagnostic function then becomes a more detailed inspection or a logical deduction capability since diagnosis can also involve pattern recognition of a combination of parametric deviations from a normal operational model.

The prognosis function is concerned with the prediction of the occurrence of an adverse condition prior to its existence. The prediction of a given impending failure can be based only on detecting a tendency or trend in operating characteristics toward a condition which would be diagnosed as a failure if the trend continues. Prognostic analysis, therefore, requires a trend detection and extrapolation capability and also requires that failure modes exhibit a degradation trend which is detectable. It is also concerned with detecting the wear, depletion or degradation of a part or substance which could lead to a functional failure if not corrected.

In general, prognosis can be viewed as long term or short range. Theoretically, it could be separated into any number of time differentiable periods. However, the selection of two time domains illustrates a basic difference of philosophy inherent in discussing prognosis. Short term prognosis is best defined as the prediction, with reasonable certaintly that the next aircraft mission or two will be completed without a major component or material failure. This encompasses a time period of 1-10 flight hours. In the case of long-term trending, where the prediction is oriented to time periods of 100 or more hours, the risk and the approach to accomplishing both can be different even though they both involve trend detection and extrapolation capability. In the general discussions that follow, an AIDAPS is assumed to have the capability to perform all prognosis required.

d) Information Display - The output of AIDAPS is information to aid operation and maintenance decision making. For optimum effectiveness, AIDAPS must provide the required information to the point of decision making in a timely fashion. This information can be either system data or results of analysis. It can take any form ranging from instantaneous in-flight safety warnings (lights or voice warning) to a post-flight printout (hard copy) of data which shows degraded performance of some aircraft system. The accompanying prognosis may indicate that the degraded system will require repair before the next flight or within the next 25 operating hours. The pilot has no need while in-flight for the latter type of data.

4.1.1 AIDAPS PROGRAMS ANALYZED

A number of efforts have been funded by DoD to evaluate and/or demonstrate the feasibility of automatic maintenance concepts. In summarizing these efforts, emphasis is placed on the evolution from earlier concepts, to present requirements for inspection, diagnosis, and prognosis as well as an evaluation of their effectiveness and identification of their contribution to the state of the art.

4.1.1.1 Automatic Light Aircraft Readiness Monitor (ALARM)

Project ALARM was organized, developed and tested by the York Division of the Bendix Corporation during 1961 and 1962 for the U. S. Army Transportation Research Command, Fort Eustis, Virginia (TRECOM Tech. Report 63-10). It was a feasibility study of a light aircraft monitor at first and second echelons of maintenance. It evaluated the automation of preflight and post-flight inspection procedures and the inflight monitoring of critical safety-of-flight items.

The contractor applied his system to a UH-1 helicopter in a series of functional, operational, ground, and flight tests. It was determined that automatic electrical inspection was feasible for engine, transmission and gearbox oil level, temperature, and chip detection. Engine overspeed detection and oil flow and vibration monitoring were also deemed feasible. Temperature and vibration measurements were felt to be possible sources of warning for impending failure when monitored automatically. However, no criteria were established as to how the temperature and vibration data would be used in the prognosis mode.

4.1.1.2 Portable Aircraft Condition Evaluator Recorder (PACER)

Project PACER was to be organized, developed and tested by the York Division of Bendix Corporation as a parallel effort compatible with project ALARM. Whereas the ALARM system was a go/no-go indicator, PACER was a comparator. PACER was contracted by the U. S. Army Command located at Fort Eustis during approximately the same period that it was developing and testing the ALARM system. PACER used the same sensor system as ALARM. Vibration signatures, pressure, flow and temperature were parameters of particular interest. In the case of PACER, as in the case of ALARM, the U. S. Army Transportation Research Command, Aeronautical Systems and Equipment Group, concluded that normal operating levels of vibration, pressures, and temperatures must be established. They indicated, again, particular interest in establishing normal operation go/no-go limits as a first step toward deriving an electronic maintenance inspection and diagnostic system. They also recommended that rather than follow-on fabrication of the PACER system, further studies be made using the ALARM system, modified to read out levels of vibration, temperature, and pressure.

Thus, the PACER system was never tested. It did, however, provide an opportunity to study the aircraft evaluation requirements and design a hardware/software system to meet them. The system designed was a ground based unit. The design was constrained to monitor functions which exhibit deterioration or wearout failures. In that approach, trend prediction was to be the focal point of the data analysis. The threshold devices which indicated go/no-go were excluded because of reliance on the ALARM system.

The PACER system would have compared sensor signals with preestablished values. These values would have represented either measurement boundaries beyond which a failure would be indicated, or no-go conditions indicating, when exceeded, the need for immediate corrective action. These signals were compared with the last prior measurement to ascertain if conditions were altered. Finally, PACER was to be usable only at ground maintenance stations and it required that a vehicle ground "run up" be made.

4.1.1.3 Engine Analyzer System (EASY)

An August 1967 report (Number 68-3176), prepared for the Systems Engineering Group, Aeronautical Systems Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, describes this system. It was the result of a 12-month 1966-1967 test program which was conducted by AIResearch of the Garrett Corporation. In project EASY, airborne and ground equipment were combined to automatically collect and process engine performance and stress data. The process output indicated whether F-105F and F-4C aircraft engines were capable of functioning properly in their next mission usage. The EASY program was also used to diagnose a faulty engine and predict maintenance requirements. Thus, the EASY program incorporated the inspection, diagnosis and prognosis concepts of AIDAPS.

The test program evaluated engine monitoring concepts. A ground-based computer system was used to evaluate data collected in flight. During each aircraft post-flight period, the EASY computer/indicator (C/I) was inspected for displayed go/no-go indications of aircraft faults. Pilot comments were correlated with this information, and if both indicated engine problems, maintenance corrective action was made. In cases of limited information or pilot-C/I disagreement, the entire inflight magnetic tape data record was analyzed. If no pilot or C/I indications occurred, only weekly data record analyses were made.

Project EASY successfully accomplished three objectives: (1) inflight engine performance data acquisition, (2) detection of inflight limit exceedences warranting immediate maintenance action, and (3) ground based computer prediction of timely maintenance requirements by use of a trending technique. It was also determined that on-board monitoring equipment could be reduced in weight and volume, making the airborne application more practical. The EASY program demonstrated the potential of On - Condition maintenance, but identified a need for controlled tests to properly establish maintenance requirements. These requirements are used in determining diagnostic logic, field implementation, and logistics requirements compatible with the EASY application.

4.1.1.4 MAIDS Mark III

This computer controlled automatic inspection and diagnostic syst : was tested during the period September 1966 through January 1968. The MAIDS design and fabrication were performed by the U. S. Army Fire Control Development and Engineering Laboratories, Frankford Arsenal, Philadelphia, Pennsylvania, (Report Number T68-6-2). The equipment was installed and used by the U. S. Army maintenance shop at Fort Bragg. The purpose of these efforts was to provide for the U. S. Army Tank-Automotive Command, Warren, Michigan, a determination of the practicality of utilizing ground based test equipment in troop units thus providing maintenance support capability and the technical training and/or technical experience which the maintenance personnel required.

The MAIDS Mark III program consisted of both manual/visual checks, as well as automatic diagnosis based on dynamic tests. Its automatic documentation of the diagnosis and parts required at the conclusion of each test provided a basis for estimating future parts requirements in the course of scheduling vehicle maintenance. The program achieved a high diagnostic accuracy (approximately 96%).

This program provided confirmation of the feasibility of ground based computer aided maintenance monitoring equipment. Although the system was specifically designed for supporting automative material, the methods and concepts are compatible with ground support of aircraft. The overall MAIDS approach established the validity of a malfunction analysis baseline for developing a diagnostic test program using "truth tables" to correlate each known malfunction with a likely cause. It also demonstrated the feasibility of the building block technique of programming.

4.1.1.5 Aircraft Integrated Data System (ACIDS)

The ACIDS is the product of a systems engineering study by the Parks College of Aeronautical Technology, prepared for the U. S. Army Aviation Materiel Command, St. Louis, Missouri, dated June, 1968 (Report Number 68-1). It encompassed an analysis of the state of the art of equipment and systems which will automatically collect and process data for selected dynamic components of the UH-1D helicopter system. This comprehensive study correlated data collected from 6 commercial aircraft users, the U. S. Air Force Military Airlift Command, 5 aircraft component manufacturers, 7 automated data acquisition systems, the research of 3 Air Force activities and a state university, and the Federal Aviation Agency, the U. S. Army Aviation Materiel Laboratories, the U. S. Naval Air Test Center, and the U. S. Army Technicians School, Fort Eustis, Virginia.

The planned system would record the history of performance and condition of respective dynamic components, make deterministic predictions of the operational life of the components so measured and provide a capability for detection and diagnosis of malfunctions. The system would also generate data usable in predicting parts removal requirements, future parts and spacing needs, and fleet analysis.

This study identified the severe weight penalty imposed on airborne equipment for the UH-1D application. The study, therefore, identified those systems for which the added weight and dollar cost of automatic monitoring would not exceed the estimated maintenance savings. The engine (and its subsystems), transmission and gear boxes (42° and 90°) were established as practical ACIDS monitoring targets. The study also emphasized that only "necessary" parameters be monitored.

4.1.1.6 Aircraft Integrated Data System (AIDS) for Bomber Aircraft

This AIDS study was conducted for the USAF Aeronautical Systems Division by AIResearch of the Garrett Corporation and reported in comprehensive documentation dated July 22, 1970 (Report Number 69-5410-2). The effort comprised three phases: initial study and development; fabrication and ground test; and aircraft installation, flight test, and final specification revision.

The objective of the effort was to develop AIDS concepts that would improve operational effectiveness and maintenance efficiency of strategic bomber-type aircraft. The major work elements employed are, however, compatible with the AIDAPS light aircraft effort:

a) Analyze missions and identify aircraft applications.

b) Analyze subsystems - line replaceable units (LRU's) parameters to be monitored and types of monitoring (trend analysis and failure prediction, fault isolation and performance inspection), and ascertain quality of existing operational and maintenance data.

c) Analyze data processing and handling requirements - airborne versus ground hardware and software, displays, equipment state of the art.

Other elements included concept definitions, test program definition, use area visits, and integration of the monitoring system program with other aircraft data functions, such as battle damage detection, crash data recording, structural integrity recording, voice recording, aircraft checklist automation, mission analysis, and reconstruction.

The summary of this program indicated AIDS would promote increased aircraft availability, reduce mission costs, increase mission effectiveness, improve accident analysis capability, improve mission analysis capability, and increase aircraft safety.

4.1.1.7 MELPAR Instrumentation System

This program was conducted for the U. S. Army Aviation Material Laboratories, Fort Eustis, Virginia. The results of this program were reported in USAAVLABS Technical Report 70-46 by MELPAR - division of American-Standard Company, Falls Church, Virginia.

The objective of this program was to accumulate sufficient vibration and temperature data to establish baseline operating levels and to determine maximum limits for use in the development of an automatic diagnostic and inspection system for the UH-1 series helicopter.

Samples of data were taken from 12 instrumented helicopters at controlled times by three automatic self-calibrating data collection systems. Each of the three data collection systems consisted of two major packages. One package was a 14-channel magnetic tape recorder with wide-band FM electronics and operating at 60 inches per second. The other package contained 14 signal conditioning circuits, DC to DC power supplies, and a digital data control system and clock that controlled the period between data collections, the duration of data collection, and a completely automatic calibration system. The relevant data were processed by a trailer mounted, ground based, high-speed digital computer.

Maintenance records on the instrumented helicopters were reviewed, summarized, and correlated with measured changes in temperature and acceleration level during the same time period.

The summary of this program indicated that ground run-up vibration data appeared to be of a different character and less reliable than in-flight data for assessment of helicopter condition. Hover tests out of ground effect and of limited scope, did not appear to provide augmented sensitivity to worn components. Large differences existed in the normal operating temperatures between the various aircraft. As a result, subtle increases in temperature could not easily be interpreted as impending malfunctions by a single limit system. It was thus concluded that individual maximum operating temperature limits for helicopters, rather than composite operating temperature limits, should be established. It was therefore recommended that subsequent program efforts be expanded in establishing the relationship between measured accelerations (and temperatures) on UH-1D helicopters and their requirements for maintenance. This program has demonstrated the basic efficacy of monitoring vibration and temperatures.

4.1.1.8 UH-1 Test Bed Program

The U. S. Army Aviation Systems Command is currently evaluating Automatic Inspection, Diagnostic and Prognostic Systems supplied by two independent contractors. The objective of this program is to demonstrate the capability of off-the-shelf hardware to detect UH-1H helicopter malfunctions, isolate faulty components, and, by the use of trending techniques, predict the life remaining in serviceable components. The Test Bed AIDAP systems are being applied to selected UH-1H subsystems. Components and subsystems monitored by the AIDAPS include the engine, transmission, drive train, hydraulic flight control, electrical system, and fuel systems.

This program is an extension of previous limited scope Army AIDAPS programs and will provide an expanded data base. The Test Bed Systems were initially operated in a controlled test cell environment at the U. S. Army Aeronautical Depot Maintenance Center (ARADMAC) in order to establish baseline signature data. In addition, substandard and discrepant parts, such as bearings, were installed in the various major components under test and abnormal signature data obtained. This effort provided normal vs. abnormal aircraft subsystem signature ranges and defined the parameter limits for the failure modes simulated. These data needs were identified by the previous ALARM and PACER Army programs.

The Test Bed Systems have also been evaluated in normal Army operation through flight test at ARADMAC involving approximately 322 flight hours. The AIDAP systems were evaluated as to their capability in detecting, isolating, and predicting component malfunction. Aircraft were flown with normal, discrepant and maladjusted components during the flight test phase.

4.1.2 AIDAP SYSTEM EXAMPLES

Table 4-1 presents examples of prototype and production maintenance data systems. These systems exhibit a wide variation in equipment configurations and functional capabilities. These variations stem from different requirements due to aircraft size and applicable maintenance level as well as design philosophy. The configuration of these equipments may be categorized in five types as follows:

a) Type I System (Ground Based) - No added hardware onboard the aircraft. This system type performs all signal conditioning, data collection, analysis and display with the use of ground based equipment. Data collection can be accomplished by means of a quick-disconnect umbilical with systems operated over a restricted range. Analyses can either be performed at the flight line or in the maintenance shop.

b) Type II System (Hybrid) - Onboard signal conditioning and data collection. This system allows for the collection of functional data during normal operation of the aircraft. Data collection can be by the use of an airborne recording device or by continuous data link to a maintenance base. Varying degrees of onboard data compression can be incorporated into this system but no analysis of aircraft condition is performed onboard the aircraft.

c) Type III System (Hybrid) - Onboard flight safety inspection. The onboard portion of this system contains enough analysis capability to detect failure modes that affect the safety of the aircraft. The airborne system also collects the data necessary for further ground analysis of the aircraft condition. Most data analyses and presentations are on the ground.

TABLE 4-1 AIDAP SYSTEM APPROACHES

INFORMATION REFERENCE	PROGRAM	HARDWARE STATUS	SYSTEM ID *	SYSTEM TYPE	STATE-OF-THE-ART: DATA COLLECTION			DATA ANALYSIS			DATA DISPLAY FORMAT	SF LEVEL/ COMMENTS
					MONITOR	CONDITIONING	RECORD	INSPECTION	DIAGNOSTIC	PROGNOSTIC		
INDUSTRY REPORT	AIDAP TEST AND UH-1D	OFF-THE-SHELF & PROTOTYPE	HRS (C)	IV	BROAD VARIABLE RANGE OF SYSTEMS & PARAMETERS	A/D CONVER. MULTIPLEXING DATA COMPARISON COMPRESSION INSP/MAINT. DATA CODING	REAL TIME PRESENTATION MAG. TAPE DATA STORAGE	◐ (LRU) LIMIT DETECT. SELF TEST FAIL-SAFE MULTIPLE THRESHOLD DISCRIMINATION	◐ LIMIT/FAULT TREND LOGIC DATA CROSS CORRELATION	◐ TREND DATA ANALYSIS SIGNATURE DATA PERFORMANCE CALCULATIONS	LIGHTS COUNTERS HARD COPY DATA PRINTOUT VOICE (OPTION)	① ORGANIZATIONAL 20[illegible]
SYMPOSIUM REPORT	N/OJ-121B	PROTOTYPE	EPMS (D)	IV	LIMITED SYSTEMS & PARAMETERS	A/D CONVER. MULTIPLEXING COMPRESSION DATA COMPARISON	REAL TIME PRESENTATION COMMAND DATA	◐ (LRU) LIMIT DETECTION & COMMAND MESSAGES	◐ DATA COMPARISON	● FAULT TRENDS ANALYSIS	LIGHTS HARD COPY DATA PRINTOUT	② DEPOT DATA REVIEW 182
COMMERCIAL PUB.	COMMERCIAL AIRLINES (OPEN)	PRODUCTION	EDM (E)	II	LIMITED RANGE OF SYSTEMS & PARAMETERS	COMPRESSION A/D CONVER. MULTIPLEXING	TELEMETER CONTINUOUS SYSTEM DATA DOWN-LINK ONLY	● (LRU) LIMIT DETECTION	● PERFORMANCE INDICES	● FAILURE PREDICTION TREND DATA ANALYSIS	NONE	② DEPOT DATA REDUCTION & ANALYSIS 166

① PORTABLE
② STATIONARY
③ MOBILE VAN
● REQ'S G/B DATA REDUCTION
◐ AIRBORNE AUTOMATIC DATA REDUCTION

TABLE 4-1 (Continued)

INFORMATION REFERENCE	PROGRAM	HARDWARE STATUS	SYSTEM ID #	SYSTEM TYPE	STATE-OF-THE-ART: DATA COLLECTION			STATE-OF-THE-ART: DATA ANALYSIS			DATA DISPLAY FORMAT	GSE LEVEL/ COMMENTS
					MONITOR	CONDITIONING	RECORD	INSPECTION	DIAGNOSTIC	PROGNOSTIC		
INDUSTRY BROCHURE	COMMERCIAL AIRLINES (OPER)	PRODUCTION	DADS (F)	II	FIXED RANGE OF SYSTEMS & PARAMETERS	COMPRESSION A/D CONVER. MULTIPLEXING	TELEMETER CONTINUOUS SYSTEM DATA UP-DATA LINK INTELLIGENCE	● (LRU) SINGLE THRESHOLD LIMIT DETECTION	● FAILURE DIAGNOSTICS LIMIT TRENDS	● NONE	HARD-COPY MESSAGE	② DEPOT DATA REDUCTION & ANALYSIS 1-0
INDUSTRY REPORT	C-5A	PROTOTYPE	MADAR (G)	V	BROAD VARIABLE RANGE OF SYSTEMS & PARAMETERS	COMPRESSION A/D CONVER. MULTIPLEXING	TELEMETER CAPABILITIES ANALOG/ DIGITAL MAG. TAPE RECORDING ELAPSED TIME DATA	◐ (LRU) MULTIPLE THRESHOLD LIMIT DETECTION SELECTED PERFORMANCE DATA MAINT. ACTION	◐ OPER. & MAINT. DIAGNOSTIC MESSAGES SIGNATURE DATA CROSS CORRELATION	◐ RANDOM ACCESS COMPUTER FOR REAL TIME TREND DATA ANALYSIS FAILURE PREDICTION	OSCILLOSCOPE DATA TRACES STATUS INDICATORS COUNTERS HARD-COPY DATA PRINTOUT	② DEPOT ADDITIONAL LONG-TERM DATA TREND ANALYSIS 234
INDUSTRY REPORT	OPERATIONAL CH-54 CH-47 OV-1	PRODUCTION	VMS (H)	III	LIMITED RANGE OF SYSTEMS & PARAMETERS	DC ANALOG LEVEL GATING	VOICE MESSAGE CREW VOICE	◐ (SYS) LIMIT EXCEEDANCE	NONE FLIGHT SAFETY ONLY	NONE	VOICE	① ORGANIZATIONAL 103

① PORTABLE
② STATIONARY
③ MOBILE VAN
● REQ'S G/B DATA REDUCTION
◐ AIRBORNE AUTOMATIC DATA REDUCTION

TABLE 4-1 (Concluded)

INFORMATION REFERENCE	PROGRAM	HARDWARE STATUS	SYSTEM ID #	SYSTEM TYPE	STATE-OF-THE-ART: DATA COLLECTION: MONITOR	DATA COLLECTION: CONDITIONING	DATA COLLECTION: RECORD	DATA ANALYSIS: INSPECTION	DATA ANALYSIS: DIAGNOSTIC	DATA ANALYSIS: PROGNOSTIC	DATA DISPLAY FORMAT	USE LEVEL/ COMMENTS
INDUSTRY REPORT	OPERATIONAL CH-54 CH-47 OV-1	PRODUCTION	APSS (I)	III	LIMITED RANGE OF SYSTEMS & PARAMETERS	DC ANALOG LEVEL GATING	VOICE MESSAGE CREW VOICE MAG. TAPE STORAGE	◐ (SYS) MULTIPLE LIMIT EXCEEDANCE	NONE	NONE	LIGHTS COUNTERS VOICE	① ORGANIZATIONAL 122
INDUSTRY REPORT	OPERATIONAL F-104G	PROTOTYPE	ISRS (J)	IV	FIXED RANGE OF SYSTEMS AND PARAMETERS	COMPRESSION A/D CONVER. MULTIPLEXING SCALING INSP/MAINT. DATA CODING	CREW VOICE VOICE MESSAGE LIMIT/FAULT EVENT & CONTINUOUS DATA MAG TAPE STORAGE	◐ (LRU) MULTI-LIMIT DETECTION SELF-TEST FAIL-SAFE	◐ CROSS CORRELATION FAULT TREND MAINT. EVENTS	● LONG TERM TREND DATA ANALYSIS PERFORMANCE PREDICTION	LIGHTS ELAPSED TIME COUNTERS VOICE	① ORGANIZATIONAL 196
INDUSTRY REPORT	(VARIABLE CONFIG.) ARCMA FAMILY OF TACTICAL MISSILES	PRODUCTION	DATICO (K)	I	BROAD VARIABLE RANGE OF SYSTEMS & PARAMETERS	SCALING A/D CONVER. MULTIPLEXING LOGIC GATING FREQ. DISCRIMINATION FILTERING	INTERROGATION TEST DATA COUNT & DELTA TIME MEAS'S ANALOG/ DIGITAL DATA TELEMETRY RF DATA (PAM/FM) MAG TAPE STORAGE MANUAL/AUTO COMMAND	LRU GO/NO-GO TAPE CONTROLLED SYS. STIMULI TEST. PERFORMANCE LEVEL MEAS'S ELAPSED TIME BETWEEN DISCRETE EVENTS STD'S CHECK OF SYSTEM ACCURACIES SYS'S CONTROL LOOP TESTING	MULTIPLE THREHSOLD LIMIT DETECTION SELF TEST & REPAIR LOGIC ANALYSIS (COMPUTER) AUTO TEST INITIATION	AUTO TREND ANALYSIS HISTORICAL DATA BASE PERFORMANCE PREDICTION FAILURE PREDICTION	LIGHTS DIGITAL MULTIMETER LINE PRINTER TYPE-WRITER PUNCHED TAPE AUDIBLE ALARM	③ ORGANIZATIONAL 234

① PORTABLE
② STATIONARY
③ MOBILE VAN
● REQ'S G/B DATA REDUCTION
◐ AIRBORNE AUTOMATIC DATA REDUCTION

d) Type IV System (Hybrid) - On board inspection, diagnostic, and limited prognostic capability. All analyses pertaining to the present functional condition of the aircraft are performed on board the aircraft during normal operation. The results of this analysis can be displayed to the flight crew or to maintenance personnel on board the aircraft or at the flight line. This system records only the data which are required for ground-based prognostic analyses.

e) Type V System (Airborne) - No operational ground-based equipment. A complete "stand alone" AIDAPS capability is contained on board each aircraft. All AIDAPS information pertaining to present and future functional conditions of the aircraft is available in real time during normal operation.

The ability of any type of system to perform a desired set of functions is dependent upon the level of applied technology. This technology, however, primarily affects the size and weight of the equipment. For instance, at least six of the systems shown in Table 4-1 (types C,D,E,G,J & K) possess inspection diagnostic and prognostic capabilities. Of these six systems, five are airborne configurations. However, only two, C and J, are small enough for application to Army aircraft.

It can be concluded from the programs and technologies described in this section that the technical capability to perform automated inspection, diagnosis and prognosis is not only feasible, but has been demonstrated. However, the selection of the optimum system size, design philosophy and characteristics requires considerable attention. This is particularly true because advances in high density computer logic and memory devices within the past five years, as well as reliable, light weight printers, permit a much higher degree of airborne system capability on single aircraft than was previously achievable.

4.1.3 DATA ANALYSIS TECHNIQUES

The systems discussed above have demonstrated significant inspection and diagnostic capabilities on all monitored systems; however, for most systems, AIDAPS prognostic capability has been limited to a few components. Significant advances in prognosis theory and analysis techniques have resulted from several programs. These techniques show considerable promise to extend the prognostic capability to most or all of the monitored components. These techniques include:

Cepstrum Analysis	Threshold Detection and Time Integration
Adaptive Vibration Analysis	Fourier Spectral Density Transforms
High Frequency Vibration Analysis	Fast Fourier Spectral Analysis
Optical Correlation	Trend Analysis
Waveform Correlations	Density Plots
	Spectrometric Oil Analysis

A description of these and other techniques is contained in Appendix A. Four of these techniques will be discussed here.

4.1.3.1 Threshold Detection and Time Integration

Threshold detection, illustrated in Figure 4-1, is probably the simplest and oldest form of diagnosis. Basically stated, a decision is made whenever a signal rises above or below a predetermined reference level. For some parameters, the signal may not be recoverable. In such cases, a permanent degradation of some component may be indicated. In cases where the signal is recoverable, a degree of prognostic capability may be achievable by a simple count of the number of times the threshold is exceeded, or the duration of the exceedance. A more satisfactory method is to perform time integrations of the exceedance. A similar result can be accomplished by using multiple thresholds. However, the availability of low volume, low-cost computational circuitry allows accurate numerical integration to be accomplished at little increase in equip ment cost and no decrease in reliability.

4.1.3.2 Fourier Spectral Density Transform

One of the most powerful techniques for analyzing complex pseudoperiodic signals is the Fourier spectral density transform. Essentially, the method relies upon the fact that any analog signal (time dependent) is composed of a series of frequencies of various amplitudes all added together. The Fourier

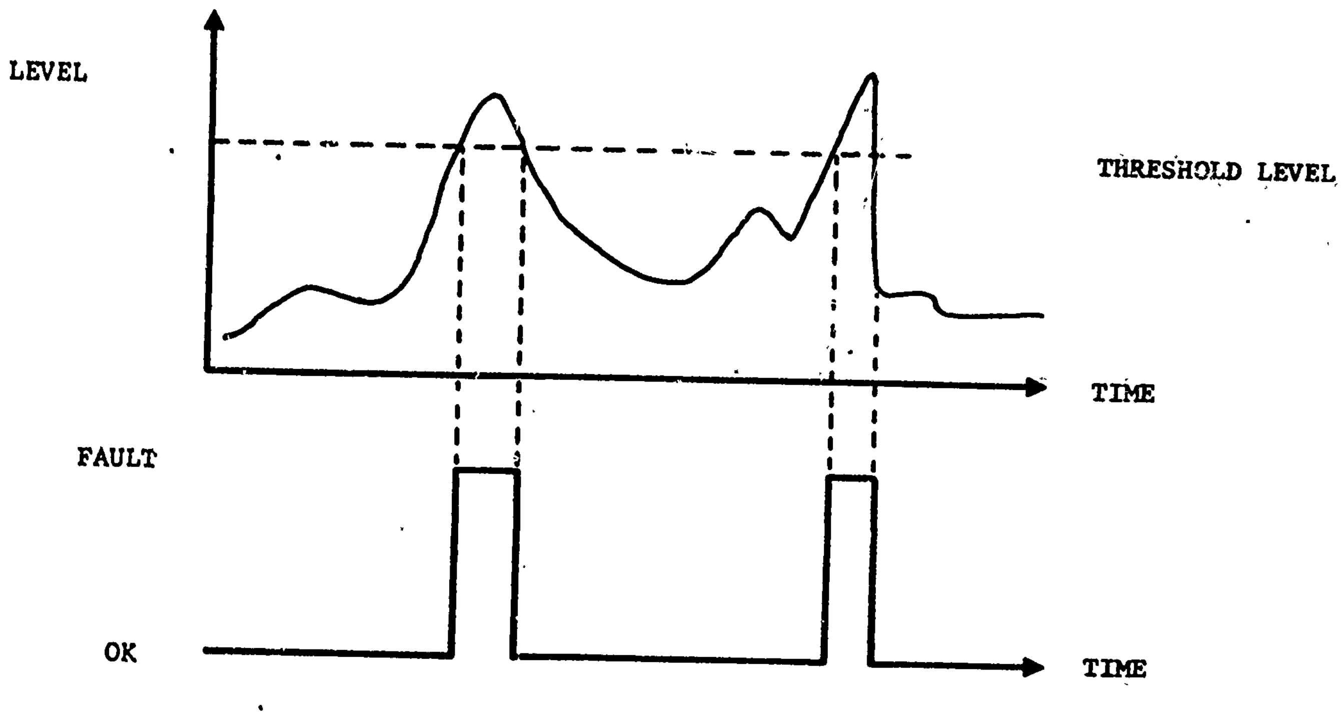


FIGURE 4-1 EXAMPLE OF THRESHOLD DETECTION

spectral density transform is the amplitude of the various frequencies that make up the analog signal. One method for finding the spectral density transform is illustrated in Figure 4-2.

The signal for which the transform is to be taken is recorded upon an endless-loop tape recorder. The playback of this signal is fed into a mixer along with a high frequency sine wave from a voltage controlled oscillator (VCO). The heterodyned output is fed through a high frequency narrowband filter. As the VCO sweeps across its frequency range, the recorded signal is scanned across the band pass filter. The process is much like tuning in a radio station. The amplitude of the tuned frequency is detected and outputted.

The object behind taking the transform is that rotating machinery tends to concentrate its vibrations in certain frequency bands related to the mechanical construction of the machine. By observing the generation of new frequencies and the shifting of previous amplitudes, much can be inferred as to the operation of the machine.

4.1.3.3 Fast Fourier Spectral Density Plots by Frequency Dilation

The state-of-the-art in high speed MOS shift registers will soon make 10 MHz, 1500 bit registers an economical reality. This makes it possible to perform a Fourier Spectral Density Transform over a frequency range of 100 to 10 kHz, with a resolution of less than 30 Hz, every 50 ms. The technique is called Frequency Dilation.

Figure 4-3 illustrates the procedure in block diagram form. The input signal, f(t), is low pass filtered to remove frequencies higher than those of interest. This filtered signal is converted from its analog form by a 9-bit analog to digital converter into a series of 9-bit digital words. These words are entered into a 1500-bit circulating shift register via buffer storage and transfer gates. The data circulates within the shift register at 500 times the highest frequency of the input signal. The effect of this high speed circulation is much like playing a tape recorded message back at high speed.

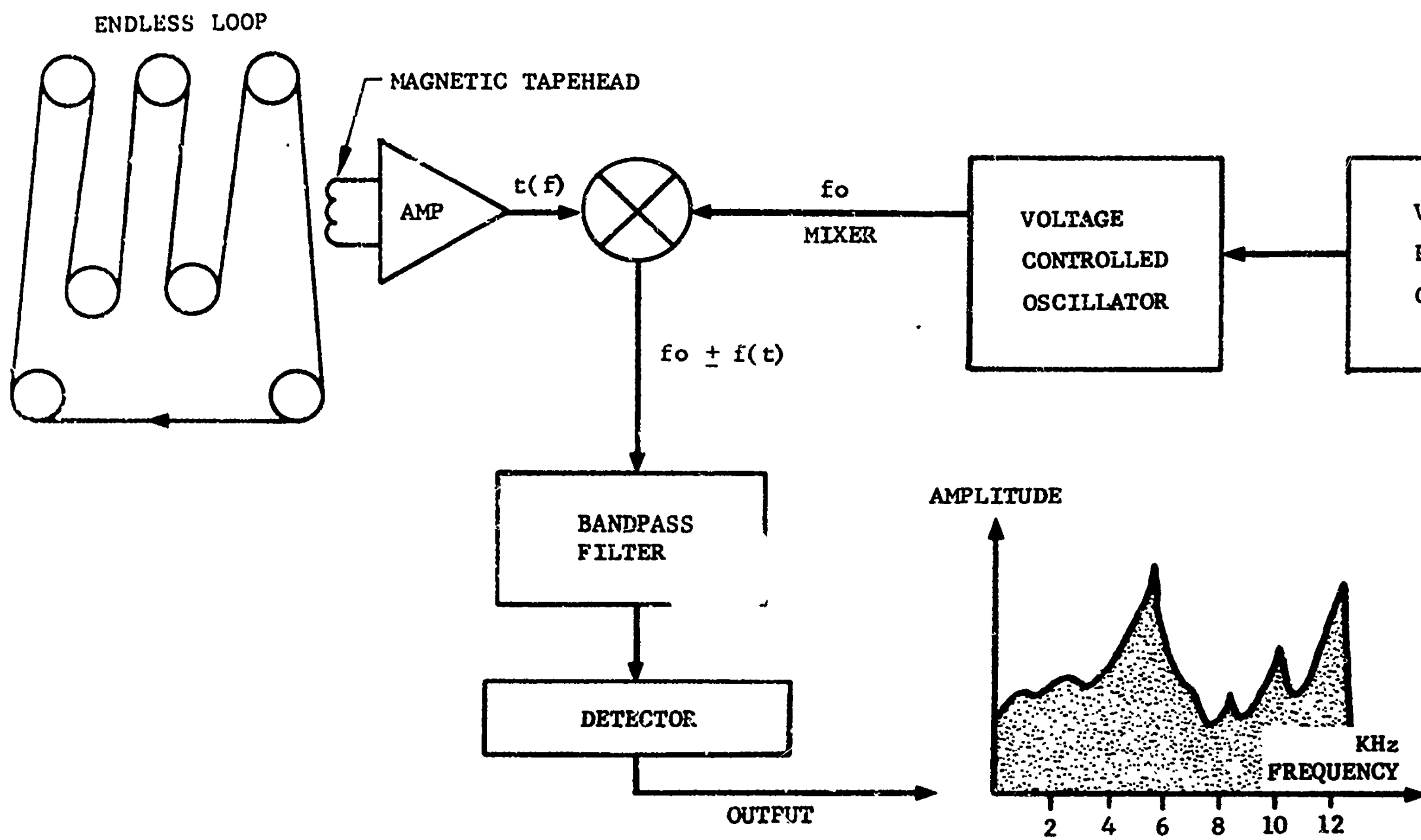


FIGURE 4-2 BLOCK DIAGRAM OF FOURIER SPECTRAL DENSITY TRANSFORM

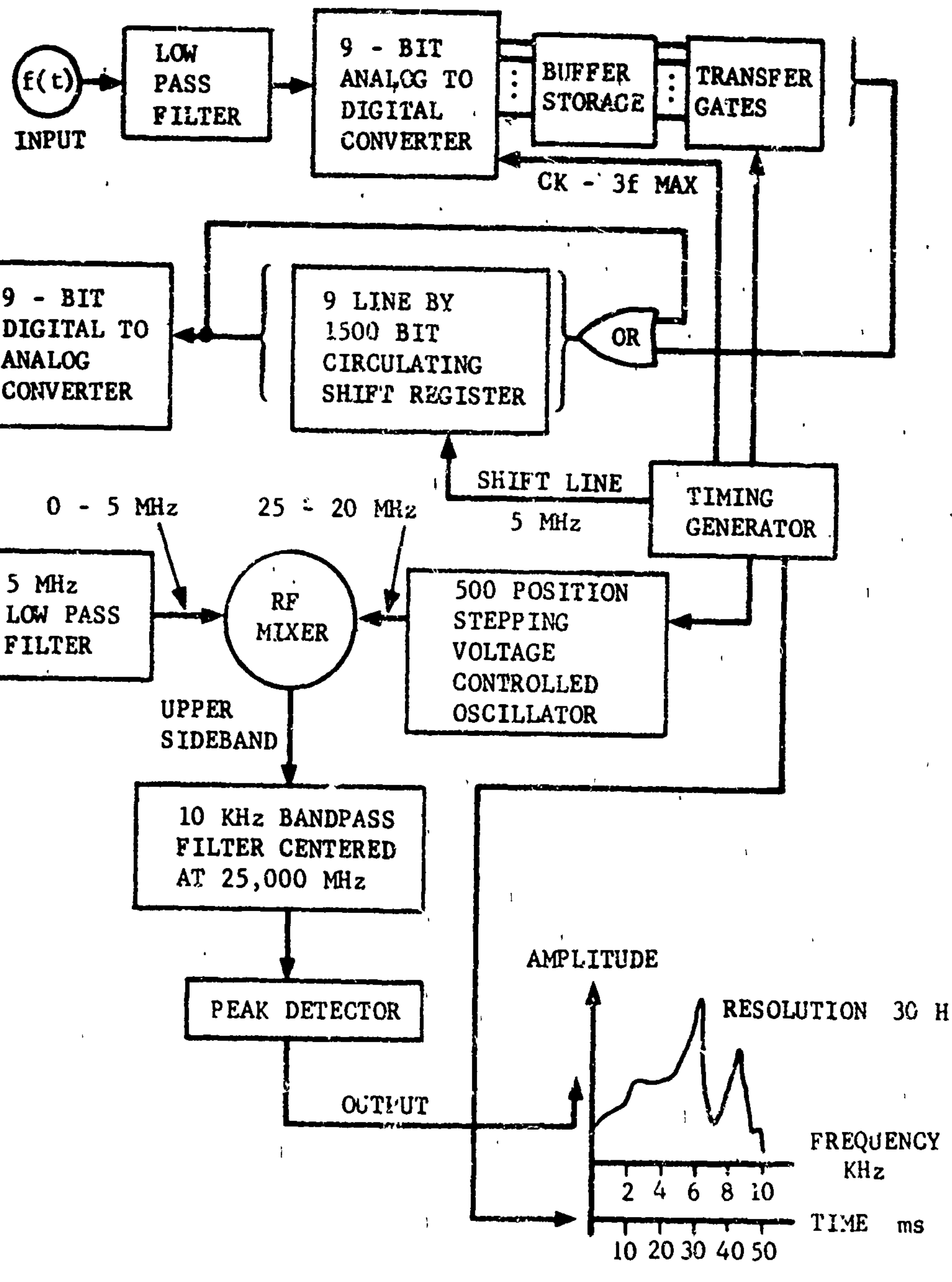


FIGURE 4-3 BLOCK DIAGRAM OF SPECTRAL DENSITY PLOTS BY FREQUENCY DILATION

The output of the register is converted from its digital form back into analog form. The frequency components of this analog signal are 500 times the corresponding frequency of the input signal.

After low pass filtering to remove spurious frequencies above 5 MHz, the frequency dilated signal is heterodyned by the output of a voltage controlled oscillator into the pass band of a 10 kHz crystal filter. As the VCO sweeps from 25 to 20 MHz, the frequency dilated signal is swept across the crystal filter. The output of the filter is rectified, thus producing the spectral density plot. Since the crystal filter has a bandwidth of 10 kHz, the resulting resolution of the spectral components is 10 kHz divided by 500 (the "speed-up" factor) or 20 Hz. But, because of the filter characteristics this really amounts to 32 Hz.

Without the aid of frequency dilation, this plot would require almost 35 minutes to perform. Another advantage of this approach is that particular frequency bands may easily be gated off by means of analog gates timed with the frequency axis of the spectral density transform (Figure 4-3).

The great speed of this technique for spectral density generation is very much in line with multiplexing input transducers and output filter bands. This technique is extremely versatile and with MOS technology it should become increasingly popular as a means of performing spectral density plots.

4.1.3.4 Trend Analysis Model

This well known model is used to predict component failure. The prediction is based upon the analysis of accumulated data about one or more component parameters, and the relationship of the data to previously established values which indicate adverse or faulty conditions. On the basis of appropriate mathematical methods, a curve is fitted to the sampled data. These methods include least-mean-squares curve fitting and/or curve smoothing mathematics. Some form of error minimizing technique could also be applied (for example, regression analysis). Once a curve is established describing the sampled data, a projection is made. This extension of the curve shows the time when an adverse condition or failure is expected to occur. Figure 4-4 illustrates two examples of trend analysis.

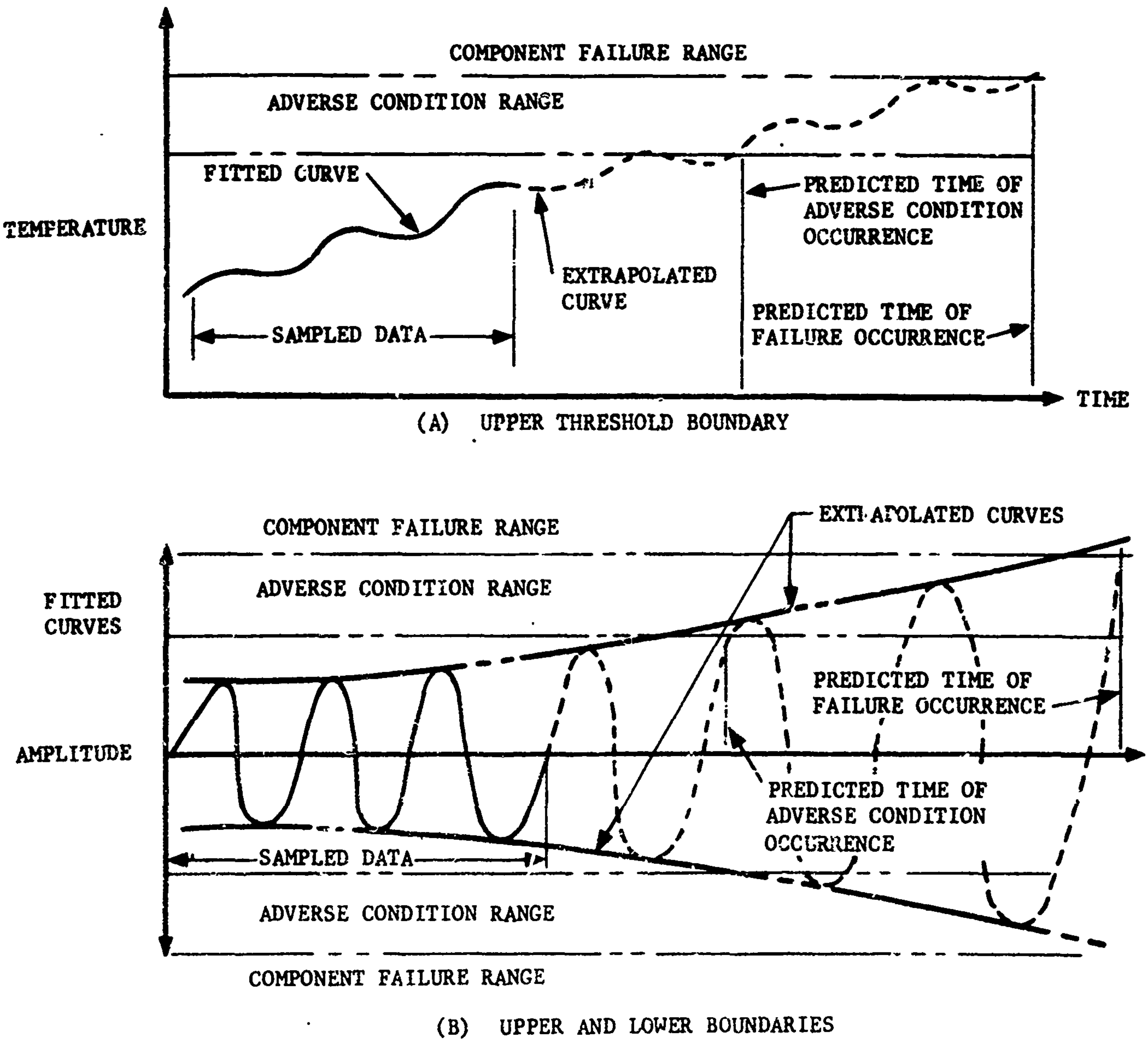


FIGURE 4-4 TREND ANALYSIS EXAMPLES

While it is not likely that a single data processing technique can be used to prognosticate failure for all components, a sufficient number of techniques exist to apply the prognostic capability to a large number of aircraft subsystems and components so that AIDAP systems objectives can be met.

4.2 HARDWARE AVAILABILITY

There have been many advances in the electronics and allied arts in the last five years which will have a direct impact on AIDAPS design. The general trend has been toward increased performance at lower costs and higher reliability along with smaller sizes and lighter weights. Specifically, the following developments have attracted the most interest. It is to be noted that some of the items which are discussed were developed before 1966 but have not become economically feasible until recently.

4.2.1 LARGE SCALE INTEGRATED ARRAYS (LSI)

Processing techniques have been improved such that the yield on arrays of several thousand gates is sufficient to reduce costs to the order of tens of dollars per unit. The advantages are in the small size (less than one square inch, including leads), the high reliability (external connections are reduced to an absolute minimum), and the low fabrication costs (the unit can be inserted and fixed in place, soldered, welded, etc., automatically in a few seconds). The following LSI are of particular interest to AIDAPS:

a) All the arithmetic, logic, and control functions of a full capability digital computer on a single "chip." The addition of memory is all that is necessary to complete the computer.

b) Complete, programmable, digital filters in a single unit. A method of producing subminiature filters with great freedom in the selection of time-constants, number of poles and frequency characteristics.

c) Special arrays such as non-mechanical storage disc simulators, digital autocorrelation functions and special purpose computers can be economically designed using one of several commerical Computer Aided Design (CAD) methods. Starting with logical expressions, a functional block diagram or truth tables, and using a series of preprogrammed "standard cells" (gates, registers, inverters, etc.), a computer designs the chip and controls a precision plotter in the preparation of a rubylith master. The computer also designs a test program and, after the chips have been fabricated, tests them in all the possible logical combinations. Such applications of CAD now cost only a few hundred dollars and the units which are produced usually are under fifty dollars in lots of one hundred.

4.2.2 INTEGRATED FUNCTIONALLY DEDICATED CIRCUITS

Extensive use of some circuits has permitted this integration as low-cost, monolithic, single chip units. Some of these are:

a) Operational Amplifiers

b) Precision Comparators

c) Analog-to-digital and digital-to-analog converters

d) Phase-locked loops

e) High efficiency power supplies

f) Monolithic Digital Multipliers

4.2.3 NEW TECHNOLOGICAL DEVELOPMENTS

Several new technological developments which may have direct application to AIDAPS have become practical in the last five years. Among these are the opto-electronics, tri-state logic, and thermal printing methods and equipments.

4.2.4 NEW MEMORY DEVICES AND TECHNIQUES

Memory, in several forms and functions, is necessary to AIDAPS. There have been improvements in conventional memory methods such as magnetic cores and tape. There are, however, several newer methods or devices which will allow significant performance improvements, greatly reduced equipment sizes, or both. Some of these are:

a) Large scale solid-state Random Access Memories (RAM) units are currently available with capacities of 4K bits per chip. A 4K word memory would require 14 chips for a 14-bit word and would occupy an area on an etched circuit board of 2.5 inches by 2.5 inches.

b) Large scale solid-state Read Only Memories (ROM) Units are currently available with capacities of up to 8K bits. Some units have the data stored during fabrication and others are field programmable. They find use as look-up tables in code conversions, in arithmetic operations, in display control, in microprogramming and in process control. All of these functions may be useful to AIDAPS. For example, the airborne AIDAPS can be tailored to an individual aircraft by a single, plug-in ROM.

c) Amorphous Read Mostly Memories, a new device, has a potential for a very low cost, non-destructive-readout, electrically alterable, memory of small size and with a high unit capacity. The amorphous material allows relatively large chip areas with high yields.

d) Stored Charge Erasable Read Only Memories. These are high density, low-cost, logically written units which can be bulk-erased by x-rays or ultra violet light.

e) Magnetic Domain Shift Memories. These are the "bubble" memories which are usually configured in long shift registers. The information contained in the registers is non-volatile but can only be serially accessed. Densities of the order of one million bits per square inch and shift rates of 1 MHz have been achieved. By using a series of "short lines", access times of a millisecond or less can be attained. The structures are only a few thousandths of an inch thick and many can be stacked. If 0.05 inch were allowed per layer, a one-inch cube would have a capacity of 20 million bits.

4.2.5 SENSORS

Table 4-2 presents a survey of the sensors currently available. The table is ordered by sensor type with columns indicating different means of measurement. A comparison of this table with the anticipated parameters to be measured clearly indicates that sensors are available to meet most AIDAPS requirements for all Army aircraft. Sensors which have characteristics exceeding the ranges shown in the table can be obtained. Particularly difficult parameter measurements on future aircraft may dictate the use of these extended range sensors.

TABLE 4-2 SENSORS AVAILABLE

TYPICAL PRESSURE SENSOR CHARACTERISTICS

Type	Strain Gage	Variable Reluctance	Piezoelectric	Capacitance	Potentiometric	Pressure Switc[illegible]
Meas Range	0 to 1000 psia	0 to 1000 psia	0 to 1000 psi Dynamic	[illegible] 1000 psia	0 to 1000 psia	0 to 1000 psi[illegible]
Media	Gas, liquids	Gas, liquids	Gas, liquids	[illegible] liquids	Gas, liquids	Gas, liquids
Sensitivity (at rated excitation)	0.005 to 100 mV/psi	0.040 to 470 mV/psi	0.5 to 80 p coul/psi	[illegible] 500 V/psi	1:1	
Threshold	Infinitesimal	0.01 to 0.10%	0.0001 to 0.001 psi	0.01 to 0.2%	0.01 to 0.3%	
Excitation	2 to 28V DC sometimes ac	5 to 115V @ 3 to 10 Kc Hz	Self-generating	8 to 100 KHz	1 to 50V ac or dc	
Output (FS)	20 to 60 mV (to 5V)	16 to 250 mV AC, 5V dc	To 12,500 p coul	0 to 5V d[illegible]	1 to 50V ac or dc	
Power Dissipation	0.2	0.3 to 1.0 watt	None	1 watt	0.06 to 1.0 watt	
Output Impedance	50 to 5000 ohms (commonly 350 ohms)	300 to 1200 [illegible]	10^{10} to 10^{17} ohms in parallel with 5 to 800 pf	10 ohm to 1000 ohm from demodulator	50 to 10,000 ohms	
Freq of Range Measureand	0 to 20 KHz	0 to 8 KHz	0.2 to 100,000 Hz	0 to 50 KHz	20 to 200 Hz	
Price Range	\$100 to \$500	\$100 to \$600	\$100 to \$500	\$100 to \$900	\$50 to \$1000	
Static Error Band	±0.[illegible] to ±0.5% FS	0.1 to 1.0%	Not applicable	0.05 to 1.0%	±0.5 to ±5.0%	
Repeatability	±0.05 to ±0.15% FS	0.05 to 0.25%	0.1 to 0.5%	0.01 to 0.10%	±0.05 to ±1.0%	
Overrange	1.5 to 10 times FS	1.5 to 3 times FS	1.5 to 3 times FS	1.2 to 10 times FS	1.2 to 10 times FS	
Time Constant	0.01 to 5.0 msec	0.1 to 5.3 msec	3 µsec to 5 msec	5 to 25 msec	6 to 50 msec	
Stability	0.2 to 1.0% for 2 yr	0.05 to 0.5%/yr	1%/yr	Good	±0.08 to ±0.6%/yr	
Cycling Life	10^6 cycles	10^6 cycles	Infinite	10^5 to 10^6 cycles	10^4 to 10^6 cycles	
Dimensions	0.06" x 0.12" to 2" x 3"	0.6" x 1.75" to 1.5" x 3"	0.3" x 0.25" to 0.6" x 10"	0.75" x 1.5"	1" x 1" to 2" x 4"	
Weight	0.2 to 18 oz.	1 oz to 1.5 lb	0.2 to 10 oz	1.5 to 13 oz	2.2 to 15 oz	
Accel. Sensitivity Max. Temp	0.01 to 0.3% FS/g	0.001 to 0.05%/g	0.01 psi/g	0.05%/g	0.05%/g (1% Vib. error)	
Thermal Drift	0.01% FS/°F Typ	0.01%/°F	0.01%/°F	0.01%/°F [illegible]	0.025%/ F	
Ruggedness	Excellent	Good	Excellent	Good	Fair	
Contamination Susceptibility	Good					
Readout (digital)	Analog	Analog or digital	Analog	Analog, var	Analog	Go no-go
Signal Cond. Required	Amplification	Excitation, demodulation, amplification	Charge amplif[illegible]	Excitation, demodulation, amplification	None	None
Used on any MIL Equip.	Yes	Yes				
Other						

TABLE 4-2 SENSORS AVAILABLE (Continued)

TEMPERATURE SENSORS

Type	Resistance	Thermistor	Optical and Infrared	Acoustic	Heat Flux Sensors*****
Temp. Range	0 to 2000°F	0-200 to 0-900°F	200 to 6500°F	to 12,500°F	0-5 to 0-300 BTU/ft^2-sec
Media	gas, liq, solid	gas, liq, solid	gas, liquid, solid	gas, liquid, solid	gas, liquid
Output (FS)	2 to 4 times nominal resistance*	7 to 100 resistance ratio***	0 to 0.5 volt	--	0 to 10 millivolts
Output Impedance**	50 to 2000 ohms	0.5 K to 22 K ohms	--	--	50 to 5000 ohms
Price Range	$3 to $100 each	$0.30 to $15.00	$750 to $5,000	$1,000 to $2,000	$50 to $300
Accuracy	0.05 to 1.0%	0.3%	±10°F	1%	0.5%
Time Constant	50 msec to 1 sec	1 to 100 sec****	50 to 500 msec	usec	--
Stability	2 years	--	good	good	fair
Cycling Life	---	---	---	---	---
Ruggedness	good	good	good	excellent	fair
Contamination Susceptibility	fair	good	good	good	fair to poor
Signal Cond Reqd	Bridge, amplification	none	none	none	amplifier

*outputs to 5V with built-in electronics

**at 60°F

*** $\frac{R @ 25°C}{R @ 125°C}$

**** in air

*****requires cooling water; sensors limited to 450°F case temperatures

TABLE 4-2 SENSORS AVAILABLE (Continued)

VIBRATION SENSORS - ACCELEROMETERS

TYPE	PIEZOELECTRIC	STRAIN GAGE	SERVO*	INDUCTIVE** & CAPACITIVE**	POTENTIOMETER	INDUCTIVE***	ANGULAR (All Types****)
Meas. Range*	0 - 100 g	0 - 100 g	0 - 100 g	0 - 100 g	0 - 100g	0 - 100 g	0-10 to 0-100,000 [illegible]
Sensitivity	0.1 to 500 pC/g	0.04 to 20 mV/g	0.01 to 50 V/g	0.001 to 10 V/g	0.005 to 25 V/g	0.0001 to 1 V/g	0.1 to 10 V/rad/s^2
Threshold	0.001 g	0.00001 to 0.01 g	10^{-4} to 10^{-6} g	10^{-7} g	0.5 to 10%	0.01%	0.0005 to 0.01%
Excitation	self generating	5 to 10V AC or DC	±15 or 28 VDC or 800 to 100 KHz	±15 to ±30, 28 VDC	0 to 50V AC or DC	[illegible] V	±15 VDC or self-generating
Output (FS)	2.5 to 10 V	20 to 500 mV (5 V**)	5 to 10 V or ±5 to ± 7.5 V DC	±5 to ±15 VDC	Equals excitation	1 MHz	±5 V
Power Dissipation	none (28V, 10 ma**)	0.05 to 0.2W(0.8W**)	1 to 2 W	5 to 200 mW	0.5 W	--	0 to 5 W
Output Impedance	10^9 ohms (50 ohms**)	120 to 1400 ohms (50**)	50 ohms to 5 K ohms	1 to 20 ohms	1K to 10K ohms	2 K ohms	200 to 5 K ohms
Freq. Range (Output)	0.3 to 30,000 Hz	0 - 2 KHz	0-60 to 0-400 Hz	0-200 to 0-1000 Hz	0-8 to 0-140 Hz	0-100 to 0-3000 KHz	0-12 to 0-200 KHz
Price Range	$70 to $500	$80 to $500	$400 to $1000	$300 to $600	$90 to $350		$300 to $500
Static Error Band	2 to 3%	0.25 to 2.0%	0.00015 to 0.3%	0.1 to 0.2%	±0.8 to ± 3.5%	±0.5%	0.25 to 1.0%
Repeatability	0.2 to 2%	0.1 to 2.0%	0.00005 to 0.02%	0.01%	±0.5 to ±0.75%	±0.05%	0.05 to 1.0%
Overrange	2 to 5 times FS	2 to 20 times FS	1.1 to 5 times FS	100g Max	1.1 to 6 times FS	500 g	110%
Time Constant	5 to 10 µsec	--	2 to 10^{-4} sec.	--	5 to 10 msec	--	--
Stability	0.2 to 1%/year	0.2%/yr	.02%/yr	.05%/yr	.25%	±0.05%/8 hr	--
Cycling Life	10^{10}cycles to infinite	10^6 to infinite	10^6 to 10^7 cycles	rated infinite	10^6 cycles	1 yr	10^7 cycles
Dimensions	0.9"x0.2" to 1"x1.6"	1.1"x0.6" to 1.6"x2"	1"x1" to 1.2"x2"	1.25"x1.25" to 1.7"x1"	0.75"x1" to 1.6"x2"	0.68"x1"	1.25"x2" to 5"x5"
Weight	1.0 to 350 gm	1 to 6 oz	2 to 4 oz	2 to 3.4 oz	1 to 10 oz	1.6 oz	3 oz to 8 lb
Max Temp	200 to 500°F	150 to 250°F	200°F	200°F	200°F	350°F	--
Thermal Drift	5 to 10% (pyroelec.)	.002 to .12%/°F	.005 to .01%/°F	.01%/°F	.001 to 1.5%/°F	.002%/°F	0.001 to 0.2%/°F
Ruggedness	excellent	good to excellent	good	good	fair	good	unknown
Contamination Susceptibility	excellent	excellent	fair	fair	fair	fair	unknown
Readout (Digital)	analog	analog	analog	analog	analog	analog	analog
Signal Cond. Req'd	charge amp	amplifier	none	none	none	excitation, demod. & amp	none
Used on Mil Equip.	yes	yes	yes	yes	yes	yes	unknown
Other							

*Selected Range
**With built-in electronics
***Kaman Sciences KA-1100
****Servo and Electromagnetic

TABLE 4-2 SENSORS AVAILABLE (Continued)

VIBRATION SENSORS - DISPLACEMENT SENSORS

TYPE	CAPACITANCE	INDUCTIVE	LVDT	STRAIN GAGE	ANGULAR***
Meas Range*	0 - 0.5 in	0 - 0.5 in	0 - 0.5 in	0 - 0.5 in	0 to ±20'
Sensitivity	4 - 500 V/in	0.01 to 2000 V/in	3.5 to 720 V/in	0.2 V/on	0.2 to 200 mV/'
Threshold	10^{-9} to 10^{-5} in	10^{-8} to 10^{-6} in	10^{-8} to 10^{-3} in	10^{-9} to 10^{-7} in	infinitesimal to 1' of arc
Excitation	28V DC**	0.[illegible] to 100 KHz	AC, 14 to 28 VDC**	2 to 10VDC or AC	AC or DC****
Output (FS)	1 to 5 VDC**	0.1 to 5 V	5 to 32 VDC**	30 to 150 mV	20 mV to 50V
Power Dissipation	0.05 to 0.5W	0.05 to 0.65W	0.05 to 1.0W	30 to 300 mW	.03 to 2W
Output Z	10 to 1000 ohms	0.4 K to 10 K ohms	10 to 7500 ohms	350 to 500 ohms	350 ohms to inductive****
Freq. range of meas.	--	0 - 1 K to 0 - 160 KHz	0 - 10 KHz	50 Hz	10 to 10,000 Hz
Price Range***	$200 - $500	$200 to $600	$10 to 350***	$100 to $500	$30 to $300
Static Error Band	0.1 to 1.0%	0.5%	0.005 to 1.0%	0.25 to 1%	0.1 to 2.0%
Repeatability	0.02 to 0.1%	0.05 to 0.5%	0.001 to 0.1%	0.02 to 0.157	0.02 to 1%
Overrange	150% to infinite	none to infinite	105% to 150%	150%	1.75 to 2.4 times FS
Time Constant	0.08 to 1.0 msec	5 to 300 µsec	0.1 to 20 msec	--	-
Stability	0.001 to 0.1%/hr	0.05%/8 hr	3 to 10 yr, 0.05%/8 hr	0.05 to 0.1%/8 hr	0.5%/yr
Cycling Life	--	10^7 to infinite	10^6 to infinite	10^6 cycles	10^6 to 10^7 cycles
Dimensions	0.06"x1.5" to 0.75"x1"	0.04"x0.4" to 1.5"x1.5"	0.4"x1" to 2.6"x2.3"	0.75"x1"	1"x1" to 2.9"x1.3"
Weight	2 - 3 oz	2 to 10 oz	0.05 to 8 oz	2 oz to 4 oz	2 oz to 1 lb
Acceleration Sensor	--	good	very good	good	good
Max. Temp.	160° to 225°F	200 to 350°F	160 to 275°F	130 to 160°F	155°F
Thermal Drift	0.01 to 0.03%/°F	0.02%/°F	0.007 to 0.2%/°F	0.005 to 0.005%/°F	0.0005 to 0.[illegible]/°F
Ruggedness	poor to fair	good	good	good	good
Contamination Susceptibility	poor	good	good	good	fair to good
Readout (digital)	analog	analog	analog	analog	analog
Sig. Cond. Req'd	excitation, demod, amp	excitation, demod, amp	built-in or need excitation & demod.	amp	****
Used on Mil equip.	yes	yes	yes	yes	yes
Other					

* Selected Range
**With built-in electronics
***Price is generally proportional to stroke length
****Types: Inductive, Strain Gage, Differential Transformer, Electromagnetic and Potentiometric

TABLE 4-2 SENSORS AVAILABLE (Continued)

FLOW SENSORS

TYPE	TURBINE	THERMAL	STRAIN GAGE	FUEL*
Meas. Range	0-0.001 to 0-100 ft^3/min	0-0.1 to 0-500 lb/min	0.1 to 2000 gpm	50 to 5000 lb/hr
Media	Liquids, gasses	gasses, some liquids	liquids, gasses	Aircraft liquid fuels
Sensitivity	--	0.05 to 400 V/lb/min	20 mV/psi	--
Threshold	--	0.001 to 0.1%	0.1%	1%
Excitation	usually none	110VAC, 5-28VDC	5 to 10VAC, DC	26V, 400 Hz
Output (FS)	20 mV to 3V or Var. freq. pulse train	0.5 to 10V	20 to 40 mV	28V
Power Dissipation	none	2 to 10 mW	0.2 W	0.35 W
Output Impedance	1K to 10K ohms	1 to 200 ohms	120, 350 ohms	--
Meas. Freq. Range	--	--	40 to 1000 Hz	--
Price Range	\$200 to \$700	\$350 to \$1500	\$350 to \$650	\$400 to \$600
Static Error Band	0.5 to 2%	0.5 to 1.0%	0.3 to 0.5%	1%
Repeatability	0.25%	0.05 to 1.0%	0.1 to 0.25%	1%
Overrange	1.5 to 2 times FS	2 times FS to infinite	2 to 5 times FS	10 times FS
Time Const.	3 to 6 msec	0.5 msec to 5 sec	1 msec	0.1 sec
Stability	> 1 yr	1 yr	3 mo	5 yr
Cycling Life	10^3 to 10^4 hr	> 10^6 cycles	10^6 cycles	10^4 hr
Dimensions	1"x2.25" to very large	1"x2" to 4"x1"	--	2"x3"x5"
Weight	8 oz to 2 lb	0.75 to 4 lb	3 to 12 oz	2.5 lb
Accel. Sens.	good	--	poor	good
Max. Temp.	to 1000°F	200°F	650°F	--
Thermal drift	--	--	--	--
Ruggedness	good	--	poor	good
Contamination Susceptibility	fair	--	fair	good
Readout (digital)	analog or var. freq.	analog	analog	synchro
Signal Cond. Rad.	Freq. to analog/digital	none	amplifier	--
Used on Mil Equip	Yes	--	--	Yes

TABLE 4-2 SENSORS AVAILABLE (Continued)

LEAK DETECTORS

TYPE	HALOGEN GAS HEATED DIODE	SONIC LEAK DETECTOR	CHEMICAL LEAK DETECTOR	OIL LEAK DETECTOR
Leak Sensitivity	10^{-6} to 10^{-9} atm. cc/sec	10^{-3} atm. cc/sec Can sense air leak thru hole .0005" dia. @ 80 mm Hg. pressure.	Poor - will not give size of leak, only location.	Gross leaks
Applicability	Fair - requires high voltage. Heated element cannot be used in presense of flammable vapor.	Good - portable	Good - can be readily located in difficult leak potential areas.	Good - wrap-on tape which turns red with oil.
Cost	\$500 to \$5000	\$300	\$10.00 to \$100	\$10.00 (Est.)
Weight (Est.)	15 lbs.	5 to 10 lbs.	1 to 5 lbs.	1 lb.
Ruggedness	Fair	Good	Excellent	Excellent
Readout	Analog	Analog	--	Go-no-go

TABLE 4-2 SENSORS AVAILABLE (Continued)

LEVEL SENSORS

TYPE	CAPACITANCE	ULTRASONIC **	RESISTIVE PROBE ***
Meas. Range	0 to 10 feet	0 to 200 feet	0 to 4 feet
Media	Liquids	Liquids	Liquids
Sensitivity	Typ 7 pf/ft	-	mV/in.
Threshold	0.005 to 0.2 inch		0.1 psi
Excitation	20 Kc; 100V *	Ultrasonic	AC or DC
Output (FS)	0-0.1 to 0-10 VDC	0-1 to 0-50 KV	0 to 1 V
Power Dissipation	None	1 to 5.0 W	0 to 1 W
Output Z	High, 225 Ohms *	High	1 to 50 Ohms
Meas. Frequency Range	--	--	--
Price Range	$300 to $600	$100 to $500	$500 to $800
Static Error Band	0.1 to 3%	--	1%
Repeatability	0.1 to 1%	--	0.5%
Overrange	None	--	--
Time Constant	0.15 to 100 msec	--	--
Stability	0.5/5 year	0.001%	--
Cycling Life	10^6 to infinity	--	--
Dimensions	2" diameter	Custom	--
Weight	1/4 lb/ft to 10 lb.	--	--
Accel. Sens.	Good	--	--
Maximum temperature	3000°F	--	--
Thermal Drift	--	--	--
Ruggedness	Good	--	--
Contamination Susceptibility	Good	--	--
Readout (Digital)	Analog	--	--
Signal Cond. Required	Excitation, Demodulation	--	--
Used on MIL equipment	Yes	--	--

* With Built-In Electronics

** Federal R & D

***Continental Sensing LS-50

TABLE 4-2 SENSORS AVAILABLE (Continued)

REVOLUTION COUNTERS

TYPE	DC TACHOMETER	AC TACHOMETER
Range Output	0 to 3600 RPM 0 to 45V per 1000 RPM	0 to 3600 RPM .68 to 24.5V per 1000 RPM (Gradient)
Linearity	0.1%	
Brush Life	100,000 hours at 3600 RPM	
Price	$25.00	$50.00
Size	1-1/8" diameter Temp. compensated output voltage at 25°C within .01% degree when operated within range of -20°C to +75°C.	8 to 24
Frequency Range		60 or 400 Hz configuration
Generator Input		26 or 115V
Generator Power		2.2 VRMS to .600 VRMS
Generator Output		Unit is two phase instrument but when operated with one phase excited, the induction generator produces an output voltage proportional to the shaft speed and a frequency identical to the supply.
Availability	Servo-Tek, Hawthorne, N. J.	Rotating Components, Bayshore, N.Y.

TABLE 4.2 SENSORS AVAILABLE (Continued)

ACOUSTIC SENSORS

TYPE	PIEZOELECTRIC	VARIABLE RELUCTANCE	CAPACITANCE
Meas. Range	85 to 160 dB*	100 to 160 dB*	17 to 150 dB
Sensitivity	-104 dB**	--	1.6 to 5 mV/μ bar
Excitation	Self excited	AC	200 V, 2.5 ma
Output (FS)	100 mV to 300 mV	1 V	10 μV to 10V
Power Dissipation	--	--	5 watts
Output Impedance	***	15 to 2000 ohms	High***
Freq. Range of Measurement	0.1 kHz to 300 kHz	0 to 10 kHz	20 Hz to 25 kHz
Price Range	$300 to $600	$40 to $600	$200 to $600
Freq. Response Error Band	± 3 dB	±1 to 10 dB	± 1 to ± 2 dB
Repeatability	0.1 to 0.2 dB	0.01 to 10%	--
Overrange	≈ 200 dB	--	165 to 175 dB
Time Constant	1 to 8 μsec	50 μsec	--
Stability	0.1 to 1.0 dB/yr	0.05 dB/8 hr	0.3 dB/yr
Cycling Life	--	1 yr	1 yr
Dimensions	0.6"x0.8" to 1.3"x2.5"	0.80"x0.47" to 1"x 1.8"	0.5"x1" to 0.5"x5"
Weight	0.4 to 12 oz	0.3 to 4 oz	3 oz to 1.5 lb***
Accel. Sensitivity	good	fair	good
Max. Temp.	250°F to 500°F	165 to 1000°F	150°F
Thermal Drift	0.002 dB/°F	± 0.003 dB/°F	0.006 dB/°F
Ruggedness	excellent	good	fair
Contamination Susceptibility	excellent	good	good
Readout (digital)	analog	analog	analog
Signal Cond. Required	amplifier	amplifier or none	power supply/amplifier
Used on Mil Equip.	Yes	Yes	Yes
Other			

*Selected Range
**Re 1V/μ bar
***As low as 200 ohms with built-in electronics

TABLE 4-2 SENSORS AVAILABLE (Continued)

FORCE/TORQUE SENSORS

STRAIN GAGES

Type	Foil	Wire	Semiconductor	Weldable	Flame Sprayable
Range (Max)	2% to 5%*	2% to 3%*	0.3%	1%	0.5%
Gage Factor	2.0 to 2.2	1.7 to 3.5	75 to 175	2 to 3.5	2 to 4
Active length/ width	.03"/.03" to .70"/.26"	.06"/.06" to 2.5"/.11"	.03"/ to .25"/	.25"/.19" to .5"/.12"	.12"/.06" to .5"/.25"
Excitation	Constant Voltage	Constant Voltage	Constant Voltage or Constant Current	Constant Voltage	Constant Voltage
Max. Temp.	850°F	780°F	600°F	1200°F	1800°F
Resistance	120, 350 ohms	60,120,300,350, 500,1000 ohms	60 ohms to 10 K ohms	120 ohms	120,350,500 ohms
Price**	$8.50 to $63.00	$7.25 to $125	$60 to $150	$60 to $73	$35 to $60

*5% corresponds to 50,000 microinch/inch

**Prices per package of 4 or 5

Most of the sensors shown in Table 4-2 are not significantly different from those aboard aircraft in the immediate post World War II era. Notable exceptions are the development of solid state sensors as well as the use of solid state devices for amplification, signal conversion and signal conditioning. Solid state sensors generally have improved accuracy and reliability and reduced weight and size. More recently, significant effort has been expended to reduce their cost.

The survey of the sensor technology indicates that generally sensors are available to meet the accuracy required forthe AIDAP system applications. As an example, a study has been conducted to examine the sensor accuracy requirements for a typical Army aircraft. The engine parameters considered were the engine fuel flow, shaft horsepower, exhaust gas temperature, compressor pressure ratio, engine core and power turbine speeds, and engine inlet air conditions. The sensitivity analysis of the sensor accuracies for engine condition indicators (fuel flow, compressor pressure ratio, shaft horsepower, and exhaust gas temperature) as a function of corrected engine core speed show that the desired accuracy requirements for the parameters are the following:

- Fuel flow rate within ± 1% of F.S
- Engine core and power turbine speed within ± 0.5% of F.S.
- Shaft horsepower within ± 1% of F.S.
- Exhaust gas temperature within ± 1% of F.S.
- Compressor discharge pressure within ± 1% of F.S.
- Engine inlet air temperature and pressurewithin ± 1% of F.S.

There are available sensors which will meet these accuracy requirements with the exception of shaft horsepower. Shaft horsepower is determined from the measured values of the power turbine speed and torque pressure. Both engine core and power turbine speeds can be accurately measured. However, the uncertainty of the torque pressure data is approximately 5% of F.S. Since shaft horsepower is computed from power turbine speed and torque pressure, the accuracy of the shaft horsepower value will be greater than 5%. Therefore, the development of a new sensor is recommended to improve the accuracy of the shaft horsepower measurement, if this parameter is required for a particular AIDAPS application.

Another sensor that could benefit from additional development funds is the engine fuel flow transmitter. Industry survey indicates that there are many sensors available which measure fuel volumetric flow for the engine size of the Army aircrafts, but none are adequate for measuring fuel mass flow rate. In order to convert the volumetric flow rate to mass flow rate, the fuel density and its variation as a function of fuel temperature must be known in addition to the fuel temperature when the volumetric flow data was recorded. These uncertainties can be avoided by utilizing a fuel flow sensor which provides fuel mass flow rate. There are several fuel mass flow meters available for larger engines used on the commercial and other government aircrafts. Development of similar flow meters is recommended for the smaller engine sizes of some Army aircrafts for the AIDAPS applications.

A number of new types of sensors have been developed, or are being developed, which may contribute significantly to an AIDAPS system. These include acoustic emission transducers, variable reluctance displacement transducers, leakage detectors, metal fatigue sensors, oil analysis sensors and chip detectors (See Appendix A, Section 5.)

The assessment of the sensor requirements for AIDAPS reveals the general availability of transducer elements to support present day requirements. The objective in all cases is to provide sensors which will measure the required parameters and present an electrical output compatible with the overall AIDAP system requirements. In all cases, this goal is attainable. Anticipated sensor improvements will increase sensor accuracy and provide refinements in AIDAPS functions.

4.3 RECOMMENDED PROGRAMS

Although present day equipment and technology are sufficient to meet the basic AIDAP system requirements, certain developmental or proposed developmental programs could significantly enhance AIDAPS capabilities. The following programs have been selected for particular emphasis.

a) Airborne Oil Deterioration Sensor
b) Cepstrum Analysis of Vibration Data
c) Optical Correlator
d) Adaptive Vibration Analysis
e) High Frequency Vibration Analysis
f) Acoustic Emission Monitoring of Structurally Loaded Aircraft Components

4.4 FEASIBILITY SUMMARY

As a result of the advancement of aircraft maintenance data monitoring equipment and other pertinent technologies, all the technological capabilities exist which are required to design an AIDAP system. These technologies include the sensing, data processing, computing, data storage, data recording and data printing hardware required to design a system, as well as the data analyses techniques required for diagnosis and prognosis. The large reductions in weight and volume of data processing equipment allows incorporation into airborne equipment a great many functions which previously could only be accommodated on the ground. As a result of the survey of these current AIDAP requirements, technology, programs and equipments, the following conclusions can be drawn:

a) The development of an AIDAPS meeting the requirements detailed in the Department of the Army QMR entitled "Automatic Inspection, Diagnostic and Prognostic System for Army Aircraft" requires only an engineering effort.

b) Advances in sensing, computing and recording technologies allow further refinement of the AIDAPS equipment configuration beyond that which might be envisioned from the QMR.

c) Although diagnostic and prognostic capabilities are technically feasible for most present aircraft components, the cost/effectiveness of applying these technologies to those components, which are not troublesome from a maintenance and logistic standpoint, must be analyzed.

d) Certain technological developments are worth pursuing as potential contributions to improved AIDAPS capabilities.

e) The requirement that the sensors have a mean time between failure (MTBF) rate equal to or exceeding the mean time between overhaul (MTBO) or MTBF of the component being monitored can now be attained. In order to meet a suitable MTBF for the entire AIDAPS, and to provide a suitable diagnostic and prognostic capability, the sensors should preferably have an MTBF which is considerably greater than (preferably twice) the MTBO or MTBF of the monitored components. Such sensor reliabilities are well within current state of the art for most of the sensor types required.

SECTION 5

5-11

5.0 AIDAP SYSTEM CONFIGURATION APPROACHES

The objective of this section is to define practical system approaches to the selection of hardware systems for cost effectiveness analysis. Only a summary of the details of system selection is presented here. For a full discussion see Appendix B, Sections 2.0 and 3.0.

5.1 AIDAPS FUNCTIONS

To define the possible system design alternatives, the AIDAPS capabilities are divided into four functional blocks; sensing, collection, analysis and display/record. These functional divisions are basic to any AIDAP system. In this logical division each functional block performs a separate and distinct operation related to the overall objective of AIDAPS.

5.1.1 SENSING

The function of sensing is defined herein as the act of detecting an electrical or physical unit of measure; i.e., parameter, by means of a device referred to as a sensor or transducer. For the purposes of this study signal conditioners are categorized under the function of collection and/or acquisition.

The sensing function includes all wiring from the sensors to the collection interface and any additional transducers which must be added to monitor parameters not presently instrumented.

5.1.2 COLLECTION

Data collection includes the acquisition of the analog or discrete signals from the sensors; all multiplexing prior to, and subsequent to, signal conditioning; analog to digital conversion; primary editing; and digital data formating necessary to arrange the data in the best form for analysis.

5.1.3 ANALYSIS

Analysis refers to operations performed on the data to obtain useful information. This includes secondary level data editing and compression, threshold detection, parameter cross correlation, trend analysis, signature comparisons, and the control of data transmission, which are necessary to achieve the objectives of fault detection, fault isolation, and fault prediction.

Processing will include the means to determine if monitoring conditions are valid relative to the determination of maintenance items. As an example, the conditions of fuel demand by the engine must be known for the determination of satisfactory fuel flow rate.

Consideration must be given to techniques which allow for spurious or short term "invalid" inputs from signal conditioning. These spurious inputs can be caused by sensor transients or external electrical influences and should not indicate maintenance items. Methods of confirmation or time dependence should be evaluated in relation to the elimination of incorrect or superfluous data.

5.1.4 DISPLAY/RECORD

Display is defined as the presentation of the information resulting from AIDAPS implementation to the Army maintenance or flight personnel, i.e., the link between man and machine.

Display techniques and components utilized for presentation must be optimized in relation to their ability to meet presentation requirements and their suitability in adopting outputs from processing circuits. Existing aircraft display equipments relevant to inflight safety will be utilized in lieu of additional display equipments.

Presentation of maintenance items should be as simple as possible and compatible with the maintenance concept.

Information to be displayed or analyzed on the ground must be recorded so that ground display is possible with airborne data acquisition.

5.2 AIRBORNE/GROUND BASED/HYBRID CONFIGURATIONS

The Automatic Inspection, Diagnosis and Prognosis System (AIDAPS) is designed to monitor, analyze, isolate, display, record, report and present information relative to the aircraft and its systems, to the aircrew and/or the ground crew, as appropriate. Numerous mechanizations of AIDAPS may be configured to satisfy these requirements.

There are three basic types of systems; airborne, ground based, and a combination of both, herein referred to as hybrid. Essentially, each type involves equipment in either the aircraft or on the ground, configured and proportioned as implied in the name. Each type of system has certain inherent advantages and disadvantages. The relative merits and applicability of each approach are evaluated for all 10 Army aircraft both individually and collectively.

Evaluation criteria for these three basic systems, airborne, ground based, and hybrid, for future aircraft, UTTAS and HLH, could be somewhat different than for existing aircraft. Cabling, baseline sensors, and BITE could be established in the original aircraft design, however, the "independent considerations" apply regardless of aircraft type. The tradeoffs involved are compounded by the Army's wide range of aircraft type, model and series comprised of fixed wing and helicopters.

The fundamental disparity between the airborne and ground based concepts is the question of the capability of a ground-based system to adequately diagnose an air vehicle condition and prognose impending failures when it is on the ground, in contrast to an airborne system which can continuously monitor the vehicle in all modes of flight. Since the ground-based data collection systems assume an umbilical cable to couple the aircraft to a ground-based console, it is apparent that fixed-wing versus helicopter operation would present a different set of constraints. Within the limits of flight safety, it can be assumed that the helicopter can operate in a hover mode in addition to normal ground operation, whereas fixed-wing aircraft is limited to only an engine runup on the ground. The basic advantage of the ground-based system, with its need to have only sensors on board the aircraft, is that the signal conditioning and processing equipment can be shared by several aircraft and therefore overall equipment costs and airborne weight can be reduced. There are other aspects of the ground-based versus the airborne data collection systems which will be presented subsequently in this report.

The four basic functional blocks are considered with respect to an airborne, ground or hybrid application because each of the functions could be accomplished in the air or on the ground.

There are numerous variations of these fundamental approaches. To be objective, the criteria for selection must consider only what is required to perform the function in the most reliable, useful and cost-effective manner consistent with the aircraft mission and related operational constraints.

5.2.1 AIRBORNE DEFINITION

An airborne system has all the elements located in and flown as part of the aircraft. An airborne system has many more possible configurations than a ground system due to the ability to perform both data analysis and data presentation functions in the air. Some onboard analysis systems compare the conditioned data with known signature values or curves. The data is displayed only when it exceeds specified values. Other systems record all data for subsequent ground analysis and display.

The principal advantage of an airborne acquisition system over a ground-based system is its ability to monitor the aircraft in all modes of operation. Intermittent or transient problems which are not necessarily repeated in a ground runup and hover, can be detected and identified. Another advantage is the potential to increase real-time inflight safety by alerting the pilot to an adverse condition which is not readily identifiable via the cockpit instruments.

The obvious disadvantages are the decrease in aircraft payload, and the increase in the cost of providing one AIDAPS for each aircraft as opposed to a ground system which can be used to service several aircraft.

a) <u>Airborne Sensing</u> - Sensing will be considered airborne if the sensors are permanently installed in the aircraft.

b) <u>Airborne Collection</u> - Collection will be considered airborne when the hardware is an integral part of the aircraft and is flown on the aircraft during all normal flight operations.

c) <u>Airborne Analysis</u> - Analysis will be considered airborne if performed in real time while the aircraft is in flight and the hardware is installed in the aircraft during all flight modes.

d) <u>Airborne Display</u> - The display equipment must be flown with the aircraft during all modes of flight to be considered airborne. A display which is connected directly to the aircraft after it has landed, then removed prior to normal flight, will not be considered airborne display.

5.2.2 HYBRID DEFINITION

With a hybrid system, some of its functions are performed in the air and some on the ground. The sensors are considered an integral part of the aircraft. Many variations of a hybrid system are possible. One alternative is inflight data collection, ground analysis, and ground display. There are many versions that perform some onboard analysis and some ground analysis. Once the data has been analyzed, either in the air or on the ground, it is then displayed. The display can be in flight, on the ground, or combinations of each. The displays can take the form of lights, flags, analog traces, numerical printout, code printout, CRT displays, voice warning messages, or combinations thereof. If any part of the data is to be presented on the ground, some form of data storage is required. This data storage can be accomplished by various types of recorders. Examples of hybrid systems are shown in Table 5.1 to illustrate two possible hybrid system configurations.

TABLE 5-1 EXAMPLES OF HYBRID SYSTEMS

SYSTEM	AIRBORNE EQUIPMENT	GROUND EQUIPMENT
A	Sensors: (1) Existing (2) New Signal Conditioning Recording	Data Transfer Analysis Display
B	Sensors: (1) Existing (2) New Signal Conditioning Partial Analysis Recording Partial Display	Data Transfer Partial Analysis Display

System Type A is categorized as a flight data system in which all data is acquired, conditioned and recorded in flight for complete computerized data analysis on the ground. This is a recording system rather than an analytical system. In essence, it approximates the traditional mechanizations that have been used for several decades for flight test programs. Extensive analysis on the ground is required to separate the pertinent information from the mass of data collected. Any extended delay in maintenance data due to analysis following landing is incompatible with the QMR and practical applications.

System Type B recognizes the limitations of Type A above and performs partial airborne computation with subsequent ground computation. System Type B is superior to Type A, with respect to providing some data that can be displayed during flight. The system also has more airborne complexity than Type A. Type B involves data acquisition, recording and in-flight computation for the specific aircraft. Because the computation is done in the air, inflight real time display is feasible. This concept has the dual capability of presenting inflight critical information in real time and pertinent information after landing in minimal time with ground recovery equipment. The data recovery equipment permits review of the information on the flight line by maintenance personnel.

5.2.3 GROUND-BASED DEFINITIONS

A ground-based system has none of its components except sensors permanently installed in the aircraft. Any component temporarily installed to gather data, and then removed before normal flight operations, is considered as ground based.

5.3 AIDAPS HARDWARE DESIGN ALTERNATIVES

In addition to the basic configuration choices, a number of design philosophies or techniques must be considered. Table 5.2 summarizes the possible design alternatives, indicates the selection made for further analysis, and briefly indicates the reason for the choice. For a full discussion of design considerations, see Sections 2.0 and 3.0 of Appendix B.

TABLE 5-2 DESIGN ALTERNATIVES AND SELECTION

FUNCTION	DESIGN CHARACTERISTIC	ALTERNATIVES	SELECTION	REASON
SENSING	LOCATION	AIRBORNE HYBRID GROUND	AIRBORNE	OTHER SENSING ARRANGEMENTS ARE INCOMPATIBLE WITH AIRCRAFT TURNAROUND REQUIREMENTS AND REQUIRE EXCESSIVE MANPOWER AND SKILLS
	SENSOR TYPES	EXISTING ON AIRCRAFT COMMON TYPES NEW	EXISTING AND NEW	EXISTING SENSORS REQUIRE NO AIRCRAFT MODIFICATION. IN MOST CASES THEY ARE ADEQUATE. NEW SENSORS MUST BE USED WHERE NO SENSOR EXISTS ON CURRENT AIRCRAFT. THESE NEW SENSORS SHOULD TAKE ADVANTAGE OF THE LATEST STATE OF ART BUT SHOULD BE OF COMMON TYPES.
	TYPE	DIGITAL ANALOG	PRIMARILY DIGITAL	LESS EXPENSIVE, MUCH MORE RELIABLE, LESS INTERFERENCE, LESS WIRING. IN THE CASE OF VIBRATION DATA, SOME ANALOG PROCESSING MAY BE NECESSARY.
DATA COLLECTION	SAMPLING	CONTINUOUS SELECTIVE • AUTOMATIC • AIR CREW OPTION	BOTH	CONTINUOUS IS PREFERRED. THE SAMPLING RATE IS SUCH THAT IT AMOUNTS TO CONTINUOUS MONITORING FOR ALL PRACTICAL PURPOSES WHERE AIRBORNE DATA ANALYSIS IS INVOLVED. WHERE GROUND DATA ANALYSIS IS INVOLVED, SELECTIVE SAMPLING MUST BE USED BECAUSE OF THE LONG TIMES REQUIRED FOR DATA TRANSMITTAL. WHEN SELECTIVE SAMPLING IS USED, IT IS AUTOMATIC IN CERTAIN PORTIONS OF THE FLIGHT PROFILE, BUT ALSO HAS AN AIRCREW OPTION.
	SIGNAL CONDITIONING	TIME-SHARED INDIVIDUAL	TIME-SHARED	LESS EXPENSIVE AND LESS WEIGHT. HOWEVER, VIBRATION DATA MAY REQUIRE INDIVIDUAL PROCESSING.

TABLE 5-2 DESIGN ALTERNATIVES AND SELECTION (Continued)

FUNCTION	DESIGN CHARACTERISTIC	ALTERNATIVES	SELECTION	REASON
DATA COLLECTION (CONT.)	DATA TRANSMISSION	TELEMETERING MAGNETIC RECORD DIGITAL TRANS-MISSION WIRE	MAGNETIC RECORD AND DIGITAL TRANS-MISSION WIRE	TELEMETERING IS TOO EXPENSIVE, WEIGHTS TOO MUCH AND REQUIRES TOO MANY CHANNELS TO HANDLE MANY AIRCRAFT. MAGNETIC RECORD IS FASTEST FOR HYBRID SYSTEMS AND DIGITAL TRANSMISSION IS MOST PRACTICAL FOR GROUND SYSTEMS.
DATA ANALYSIS	TYPE	SIMPLE EXCEED-ANCE LIMITS MULTIPLE EXCEEDANCE LIMITS SPECTRAL ANALYSIS	ALL	TYPE OF DATA ANALYSIS IS DETERMINED BY THE NATURE OF THE PARAMETER AND COMPONENTS BEING MEASURED.
	TEMPORAL FACILITY	REAL TIME RECORDED	BOTH	DEPENDS ON TYPE OF SYSTEM AND USE OF INFOR-MATION. AIRBORNE ANALYSIS DISPLAYS SAFETY OF FLIGHT INFORMATION TO PILOT. DIAGNOSTIC INFORMATION IS ALSO IMMEDIATELY AVAILABLE. LONG TERM PROGNOSTICS CAN BE DELAYED.
	METHOD	DIGITAL ANALOG	DIGITAL	LESS EXPENSIVE, MORE RELIABLE, MORE ACCURATE
	DATA COMPRESSION	INFLIGHT POST-FLIGHT	BOTH	INFLIGHT IS DESIRABLE BUT CAN BE ACCOM-PLISHED ONLY WITH AIRBORNE ANALYSIS
	LOGIC	DEDICATED FORTRAN COBAL, ETC.	DEDICATED	SIMPLICITY. INTERNAL COMPATIBILITY WITH OTHER COMPUTERS IS NOT REQUIRED.
	COMPUTER TECHNIQUE	DEDICATED GENERAL PURPOSE CS_3	DEDICATED	MUCH SIMPLER AND LESS EXPENSIVE THAN GENERAL PURPOSE. CS_3 IS NOT AVAILABLE ON A TIMELY BASIS FOR DIAGNOSIS AND PROGNOSIS. PRINTOUT COMPATIBILITY WITH CS_3 IS ACHIEV-ABLE THROUGH TAMMS.

TABLE 5-2 DESIGN ALTERNATIVES AND SELECTION (Continued)

FUNCTION	DESIGN CHARACTERISTIC	ALTERNATIVES	SELECTION	REASON
DATA ANALYSIS (CONT)	LOCATION	AIRBORNE HYBRID GROUND	ALL	REQUIRED FOR COST EFFECTIVENESS ANALYSIS WHICH DETERMINE THE OPTIMUM SYSTEM.
DISPLAY	TYPE	VOICE WARNING LIGHTS PRINTED	ALL	DEPENDS ON EQUIPMENT ON AIRCRAFT. SAFETY OF FLIGHT DATA SHOULD BE DISPLAYED BY VOICE WARNING OR WARNING LIGHTS. MAINTENANCE PRINT-OUT SHOULD BE PRINTED IN ENGLISH. WARNING LIGHT SHOULD INDICATE PRESENCE OF MALFUNCTION.
	LOCATION	AIRBORNE HYBRID GROUND	ALL	REQUIRED FOR COST EFFECTIVENESS ANALYSIS WHICH PROVIDES THE RECOMMENDED SYSTEM.

The hardware design characteristics applicable to all systems are as follows:

- Digital systems will be used including digital data transmission and recording.
- Maximum use of existing sensors will be made.
- New sensors will be of similar types as existing sensors, except where improved performance is required and possible.
- Documentary data will be accommodated wherever practical.
- Solid-state multiplexing will be used.
- Existing aircraft flight safety displays will be used.
- Ground display will be a printer.
- Data compression will be used.
- Telemetry will not be used.

5.4 SYSTEM CONFIGURATION APPROACHES

The remaining system design alternatives apply to the location (i.e., ground, hybrid and airborne of each AIDAPS functional capability) and the degree of complexity (i.e., simple, medium and complex). The degrees of complexity are defined for each functional capability as follows:

- Sensing

  Simple - less than 40 parameters monitored

  Medium - between 40 and 80 parameters

  Complex - more than 80 parameters

- Collection

  Simple - analog

  Medium - time shared analog to digital conversion

  Complex - analog to digital conversion with data compression and process control

- **Analysis**

  Simple - comparison to fixed preset limits

  Medium - comparison to fixed preset limits and comparison to interrelated limits and logical situations with a digital output

  Complex - complete medium capability plus trend analysis and recognition of failure signatures.

The possible system configurations consist of all the combinations of four functional capabilities with three locations and three levels of complexity for each. This allows $3^2 = 9$ combinations of location and complexities for each functional capability. Since there are four functional capabilities for each aircraft, there are 9^4 or 6561 different possible combinations to be analyzed for each aircraft.

5.4.1 LOGICAL CONSTRAINTS

The number of possible combinations to be analyzed for each aircraft can be greatly reduced by operational, design and logic constraints. These are:

a) Sensing must be on aircraft (airborne). Hybrid or ground sensing is costly and requires excessive time.

b) Data collection should not be hybrid since the data acquisition circuitry is small and lightweight and the same circuitry can be shared by many parameters.

c) The analysis function must be ground based if data collection is ground based.

d) The display and record function should be airborne or hybrid, if airborne analysis is used. Safety of flight information is only of value if it is displayed to the aircrew on a timely basis.

e) The display and record function can only be ground based if analysis is ground based.

Application of these constraints reduces the number of alternatives to 1539.

5.4.2 SOPHISTICATION CONSTRAINTS

5.4.2.1 Sensor Complexity

The degree of sophistication required by sensor and data collection depends upon the aircraft complexity and the system concepts developed. From the standpoint of AIDAPS, one major measurement of this complexity is the number of sensors and type of sensors which must be monitored. Sensors of different types require differences in data processing and analysis. Therefore, it is necessary to derive a measure which is related to both the number of sensors and the data processing complexity. For this study, a weighted sensor count was derived for each aircraft. The definition of the weighted sensor count is shown on Table 5-3. This table also shows the ratio of weighted sensor count for existing sensors to the weighted sensor count of added sensors. This ratio is shown for the UH-1 engines (61/53) as well as the balance of the aircraft (57/59).

Table 5-4 shows a comparison of many factors associated with aircraft complexity. From this table initial aircraft groupings were made. Each group contains those aircraft which are sufficiently similar to warrant similar AIDAP system applications. Although the AIDAP systems are similar in many respects, they are still capable of processing varying numbers of sensors for the types of aircraft within the groups. These preliminary groups are shown in Table 5-5 and are used to define the cost effectiveness for unique systems. Unique AIDAP systems are defined as those which are designed for application to a specific aircraft type.

TABLE 5-3 DERIVATION OF WEIGHTED SENSOR COUNT (WSC)

PARAMETERS	ASSIGNED WEIGHT
DISCRETE	1
SIMPLE V OR I ANALOG	4
CHARGE AMPLIFIER	5
BRIDGE AMPLIFIER	6
LINEAR DIFF. TRANSFORMER	8
TACHOMETER	10
SYNCHRO	12

<u>USE OF WSC TO PROJECT A/C AIDAPS COMPLEXITY</u>

WSC FOR EXISTING ENGINE PARAMETERS x $\left(1 + \frac{61}{53}\right)$ = PROJECTED WSC_E

WSC FOR PARAMETERS OF BALANCE OF A/C x $\left(1 + \frac{57}{59}\right)$ = PROJECTED WSC_S

SUM EQUALS WSC FOR A/C

TABLE 5-4 AIRCRAFT COMPARISON

AIDAPS Considerations	OH-6	OH-58	OV-1	U-21	UH-1	AH-1	CH-47	CH-54	UTTAS	HLH
Weight (Typical) (pounds)	2,400	2,645	11,715	9,650	6,600	6,600	38,000	42,000	*	*
Cost (dollars)	56,262	90,208	1,058,540	240,337	266,568	365,256	1,145,500	1,800,000	1,400,000	9,000,000
Parameters (WSC)	217	217	431	374	308	337	666	566	696	881
Primary Mission	C CC	C CC	CC CS	CSS	C CC	C	CS CSS	CS CSS	C CC	CS CSS
Percent of Aircraft in Inventory	20.1	9.3	2.3	1.4	53.4	5.7	6.9	0.9	*	*
Utilization(1) (hours per month)	60	60	75	75	70	70	55	50	*	*
MMH/FH	5.74	5.74	10.60	8.06	7.67	8.85	32.45	31.33	10.8E	371.7E
Fixed Wing (FW) Vs Rotary Wing (RW)	RW	RW	FW	FW	RW	RW	RW	RW	RW	RW
Number of Engines	1	1	2	2	1	1	2	2	2	2*
Number of Flight Crew	1	1	2	2	2	2	3	3	3	6
Attrition Factors*	0.0041	0.0041	0.0012	0.0009	0.0030	0.0030	0.0005	0.0005	*	*

*PEACETIME ATTRITION FACTOR = MONTHLY LOSS RATE/EXISTING FLEET SIZE

(1) WORLD WIDE AVERAGE

E = ESTIMATE

TABLE 5-5 INITIAL AIRCRAFT GROUPS

GROUP	AIRCRAFT	GROUP	AIRCRAFT
I	OH-6 OH-58	IV	OV-1
II	UH-1 AH-1	V	CH-47 CH-54 HLH UTTAS
III	U-21		

5.4.2.2 Data Collection Complexity

Complex data collection is used in all cases to reduce costs and bring the data storage and presentation requirements within feasible ranges.

5.4.2.3 Analysis Complexity

Complex data analysis is required to accomplish most diagnosis and prognosis.

5.4.2.4 Display/Record

Simple displays are inadequate for providing permanent data records and storage. These records are required to support observation and interpretation of diagnostic and prognostic information. Complex displays are extremely costly and lack operational portability and mobility. The medium level display using hardcopy printed records in numeric or English language is the best compromise.

The combination of the location and sophistication constraints results in four basic system configurations for cost effectiveness analysis. These systems are:

Airborne - with complex data collection and analysis and medium displays

Hybrid I - with complex airborne data collection and analysis, airborne display of flight safety information and a medium complexity ground display of maintenance data.

Hybrid II - with complex airborne data collection at selected intervals and complex ground based data analysis and medium display.

Ground - with complex data collection, analysis and medium display, all ground based.

The sensing complexity for all four systems is simple, medium or complex depending on requirements of the aircraft on which the unique system is installed.

5.5 HARDWARE DESCRIPTION

The remainder of this section describes the evolution of the hardware configurations from the unique systems, through the group and universal systems. The hardware units are shown for each system.

5.5.1 CANDIDATE AIDAP SYSTEMS (UNIQUE)

This section shows the unique AIDAP systems which are candidates for the cost effectiveness analysis. A detailed discussion of system characteristics appears in Appendix B.

A modular hardware concept was selected for each of the four AIDAPS configurations. The modular approach permits the adaptability of the basic data acquisition and processing units to a variety of AIDAP system application requirements. Reasonable expansion of conditioning and processing capabilities may be introduced without any change to a modular envelope and without significant change in weight. Solid state MOS integrated digital circuit devices are applied to the greatest degree possible to minimize power requirements, modular weight and cost. As previously noted, the hardware configuration is based on a constant AIDAP functional base. Likewise the internal configurations of the modular units are essentially controlled by this same base. A reduction of this base can be readily accomplished by eliminating a specific modular element and, as necessary, incorporating a desired functional replacement within a remaining unit. This can be done without affecting the aircraft/AIDAPS peripheral interface design.

Figure 5-1 shows a block diagram applicable to all unique systems. The sensor outputs are fed to electronic processing units for analog to digital conversion. Documentary data consisting of certain data entered, such as aircraft number and certain part numbers, date, etc., which are entered automatically, or manually by the ground or aircrews. The sensor data is continuously monitored. In the Airborne or Hybrid I systems, flight safety data is transmitted to the aural and/or light displays. In the hybrid systems, data is transmitted to the ground data analysis and printer unit by means of a magnetic tape. For the Ground System, data transmission

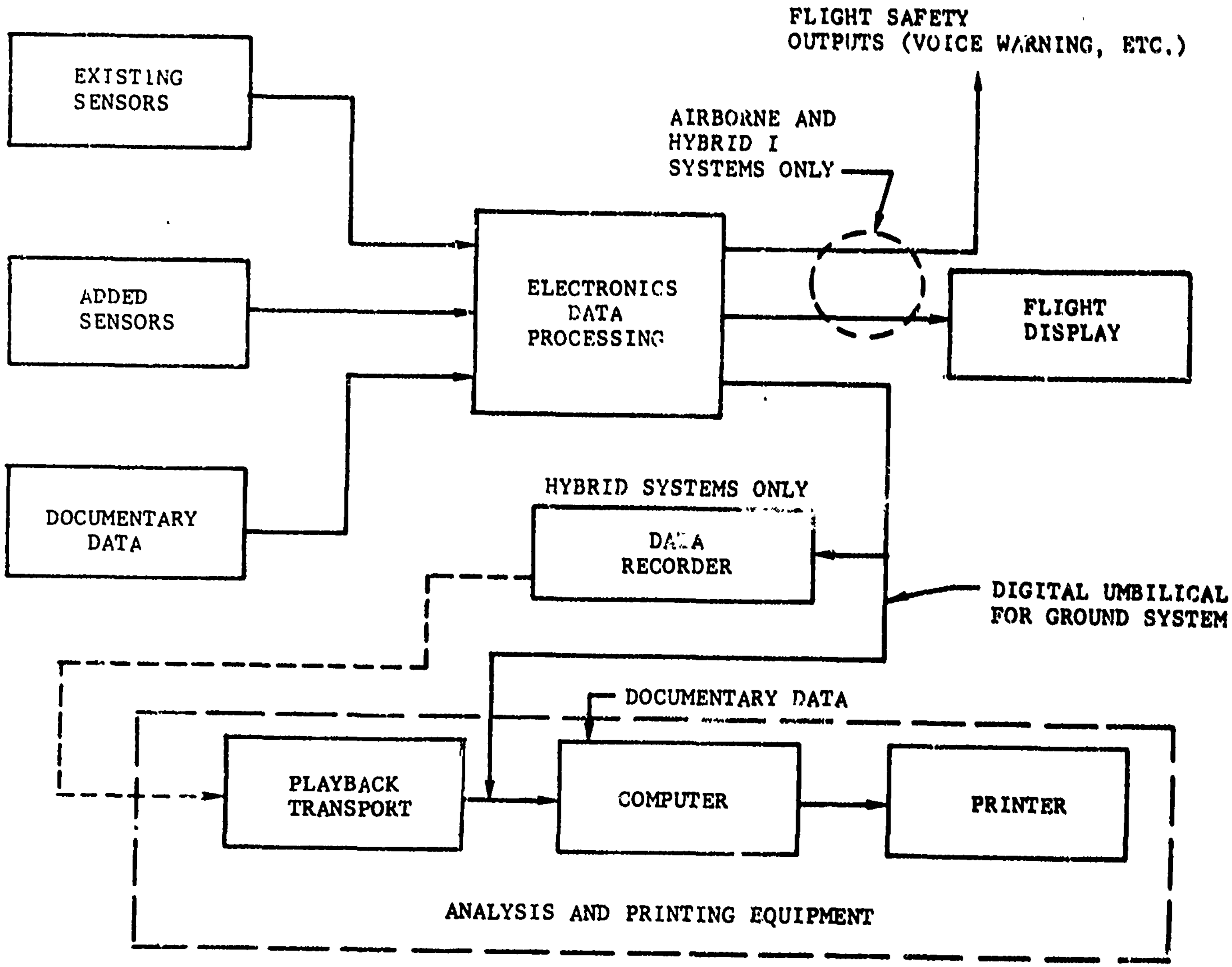


FIGURE 5-1 AIDAPS HARDWARE BLOCK DIAGRAM

is accomplished by means of a digital umbilical transmission wire. The data is analyzed for diagnostic and prognostic indications and printed out in English language on a paper tape.

5.5.1.1 Airborne Configuration

Figure 5-2 shows the equipment physical configuration for an airborne system.

The Flight Data Entry Panel (FDEP) provides the following functions:

- Manual/Automatic insertion of aircraft "Documentary Data" (DOCD)
- Power and operational mode control of a voice warning unit.
- Primary power control of an airborne digital processor, when applied to the AIDAP system.

The Voice Warning Unit (VWU) is utilized to enhance aircraft and crew inflight safety. The unit performs the following functions:

- Accepts conditioned and processed sensor analog data from selected flight critical aircraft parameters in a direct mode via digital data from a central electronics unit.
- Provides control logic for selection of prerecorded voice warning messages. Outputs voice messages to the pilot headset, and to an inflight magnetic tape recorder for data storage.

The Airborne Data Processor (ADP) performs the real time prognosis.

The Central Electronics Unit (CEU) is the basic data acquisition and processing module for the system. It is essentially a general purpose computer similar to the CEU for the Hybrid I system. All diagnostic interchanges are performed by the CEU. It serves the following purposes:

- Accepts sensor analog data from selected aircraft parameters in a direct mode, and digital data from a remote data acquisition unit.
- Provides aircraft interface circuit isolation.
- Performs signal noise filtering, operational process control, multiplexing, conditioning, analog-to-digital signal conversion, data compression, computational analysis, and record process control.

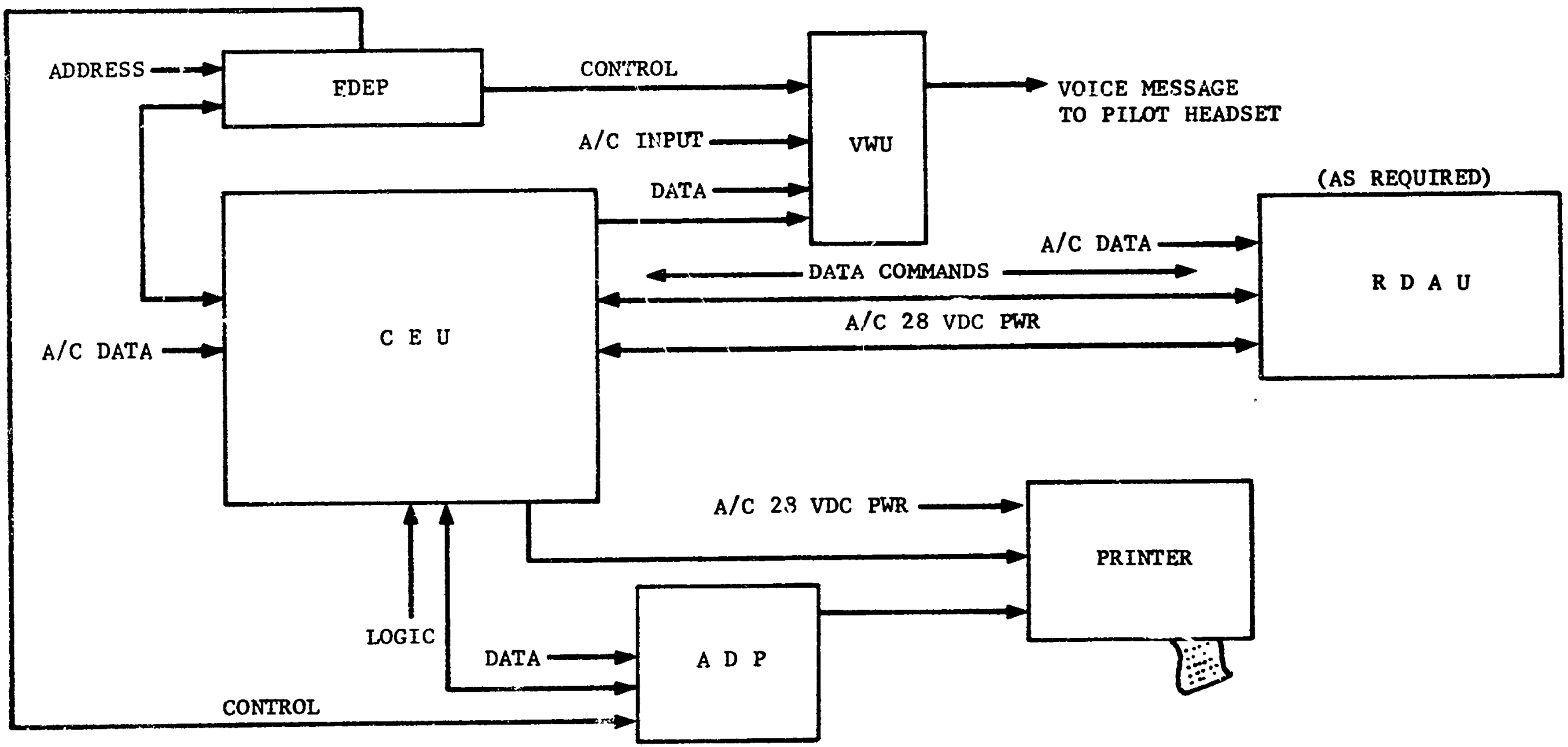


FIGURE 5-2 AIDAPS EQUIPMENT CONFIGURATION (AIRBORNE)

- Provides appropriate displays for visual monitoring of selected aircraft ~~subsystems and AIDAP~~ system operational status, i.e., go/no-go.
- Outputs timing and operational logic data to the VWU, to the remote data acquisition unit, and to an inflight recorder unit.
- Outputs inspection and diagnostic digital data to the inflight recorder unit for data storage, and to an airborne digital processor when applied in the AIDAPS pure airborne configuration.

The Remote Data Acquisition Unit (RDAU) is primarily used to permit the adaptability of the basic CEU to aircraft types of significantly different complexities. This configuration approach also reduces the harness wire weight normally required between remote sensing areas and a centrally located data conditioning and processing unit. The functional purpose(s) of the unit are as follows:

- Accepts sensor analog data from selected aircraft parameters; provides aircraft interface circuit isolation; performs signal noise filtering, signal multiplexing, and analog-to-digital signal conversion.
- Outputs digital data to the CEU for subsequent processing functions as previously described.

Primary power to the RDAU and the CEU is locally provided by aircraft 28 vdc power. Power regulation is integral with each of the units.

5.5.1.2 Hybrid Configurations

Figure 5-3 depicts a hybrid allocation of AIDAP system hardware. The hardware elements for the Hybrid I configuration have the same functions as the airborne units except for the substitution of a magnetic tape recorder for the ADP. The ADP functions are performed by the ground processor equipment. For the Hybrid II system, the CEU has been omitted and control of the recorder is incorporated into the RDAU. The ground processor equipment incorporates the remaining CEU and ADP functions for trending computations and long term prognosis. Fault isolation logic for automatic inspection and diagnosis is accomplished within the airborne CEU.

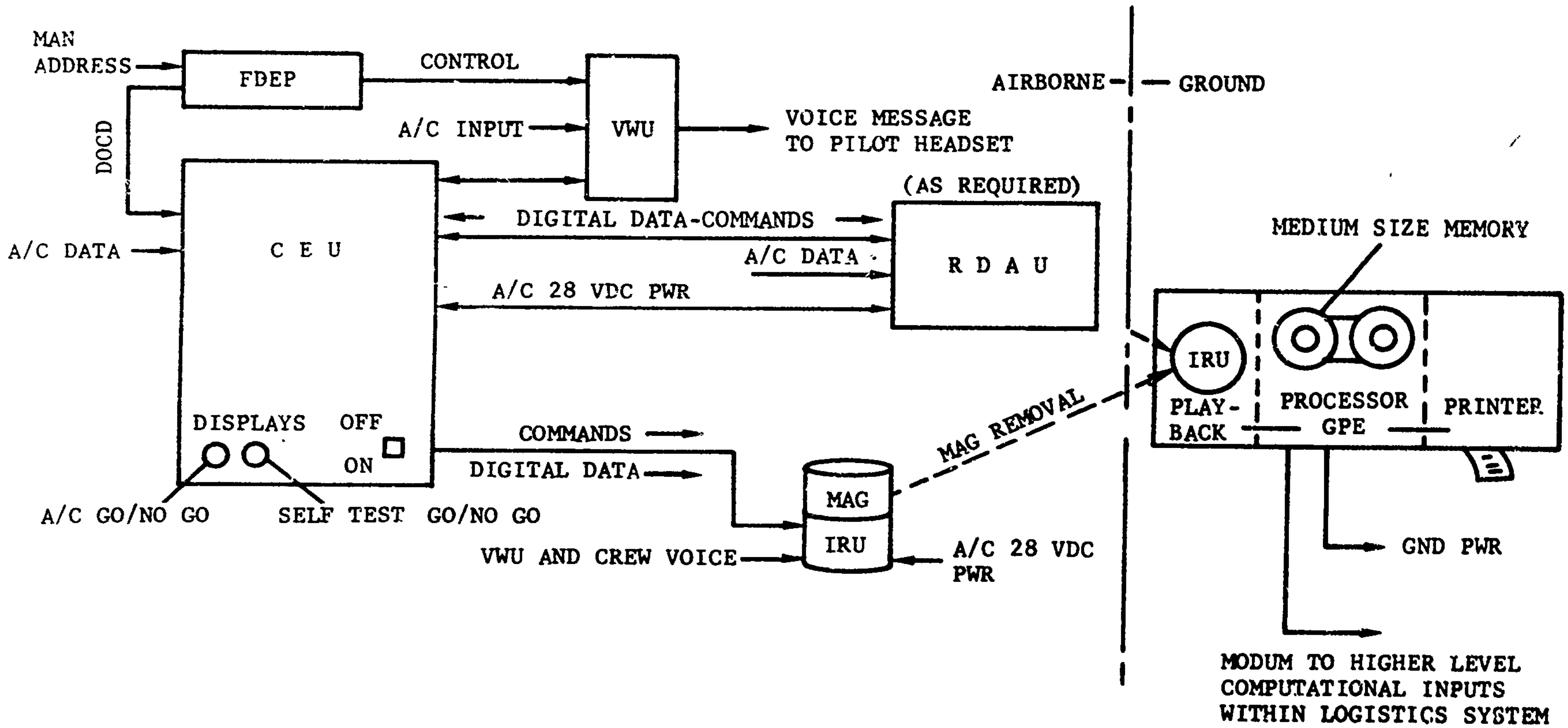


FIGURE 5-3 AIDAPS EQUIPMENT CONFIGURATION (HYBRID)

The Inflight Recorder Unit (IRU) is utilized for inflight data storage. It is an incremental speed, four track cartridge type magnetic tape recorder. The tape motion is automatically controlled by the CEU or RDAU output data logic. The data tracks consist of

- One Audio channel
- Two digital data channels
- One time data channel

The IRU is a split case design which permits quick removal of the tape cartridge. The cartridge is conveyed to the ground processing equipment for data reconstruction and readout. The unit accepts the following data inputs:

- Digital data from the CEU
- Voice data from the VWU and/or the crew.

The Ground Processing Equipment is utilized for flight line data reconstruction and data printout. It is a ground portable or mobile unit. It consists of modular segments identified as:

- Magnetic tape reproducer
- Data processor with a medium size magnetic tape memory
- Non-impact hardcopy data printer

The GPE accepts data in the following configurations:

- Magnetic tape cartridge from A/C recorder
- Aircraft data via a remote data acquisition unit and hardware umbilical
- System checkout and test data from ground test support equipment.

The GPE has the following capabilities:

- Reprogrammable general purpose computer
- Long term data storage
- Computes data trends
- Outputs data to higher maintenance levels when logistic interface capability permits such.

5.5.1.3 Ground Configuration

Figure 5-4 depicts a ground based allocation of AIDAP system hardware. The RDAU is the same basic package described for the hybrid configuration. It is sized such that it can be used as a ground based data acquisition unit. Multiple units are employed as required. The RDAU is temporarily installed in the aircraft and interfaces with the ground umbilical cable. It accepts sensor analog data from selected aircraft parameters and performs operations as previously described. Digital data is transmitted via the hardwire umbilical cable to the GPE for data compression; computational processing for inspection, diagnostic and prognostic data; record process control; and hardcopy data printout. The GPE processor provides timing and control logic for system operation.

5.5.1.4 Hardware Elements

Figures 5-5 through 5-12 illustrate the hardware elements which are used in the unique AIDAP systems. The cost data is based on a buy of approximately 500 units. The cost and weight data vary for each aircraft type. See Section 7.3 for the precise cost and weight data for each AIDAPS type and aircraft application.

5.5.2 CANDIDATE AIDAP SYSTEMS (GROUP)

As a result of the unique system cost effectiveness tradeoffs, the Hybrid II and Ground Based systems were eliminated from further consideration and the Hybrid I and Airborne systems were redesigned to be applicable to a group of aircraft. Since it became apparent the original aircraft grouping was inadequate, the aircraft were organized into three groups. Thus there are three Group AIDAP designs of each generic type.

System	Aircraft Application	Aircraft Group
Airborne & Hybrid	OH-6, OH-58	I
Airborne & Hybrid	AH-1, UH-1, U-21, OV-1	II
Airborne & Hybrid	CH-47, CH-54, HLH, UTTAS	III

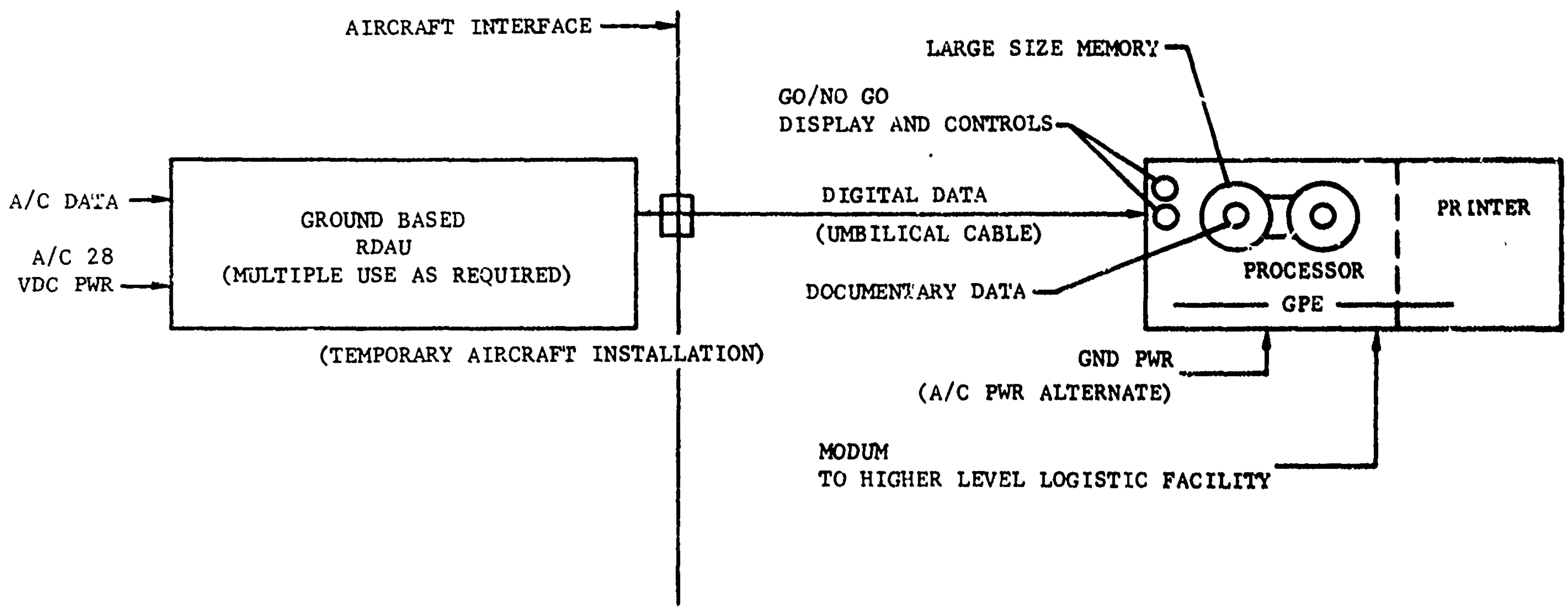
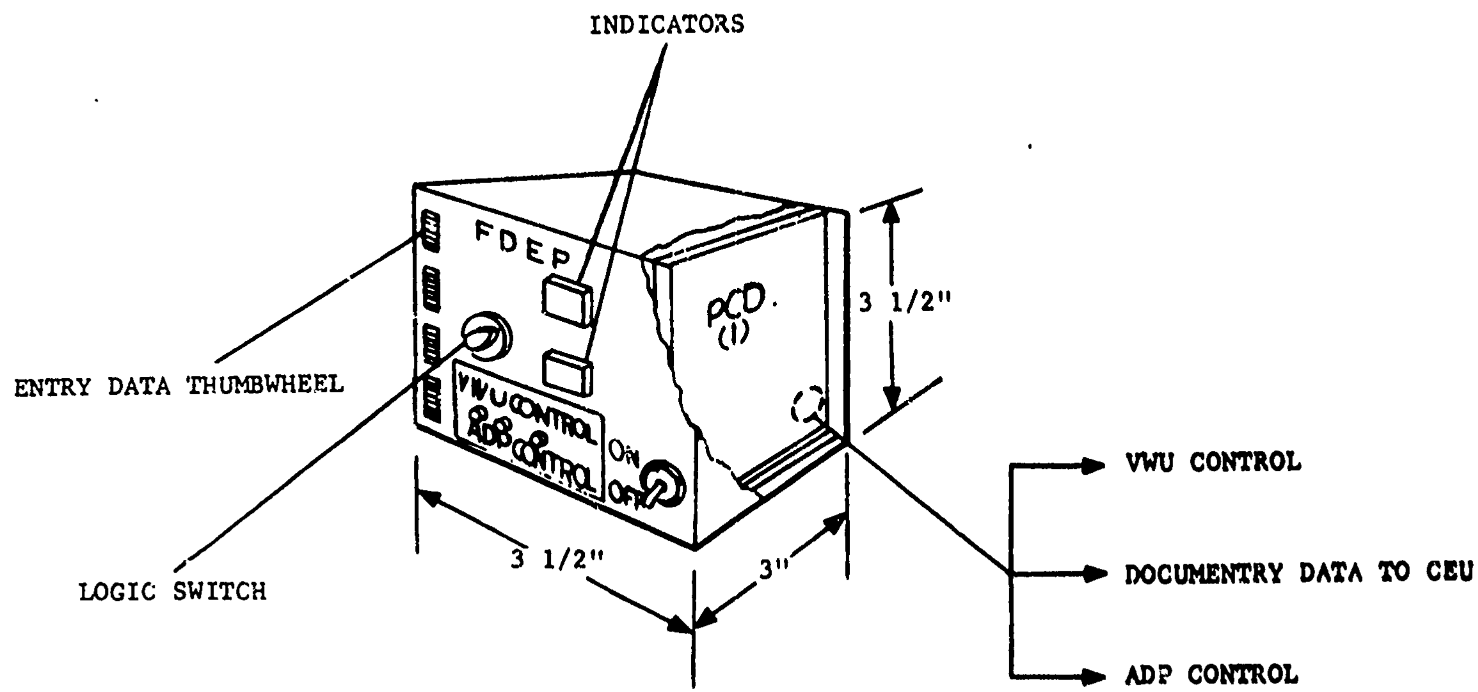


FIGURE 5-4 AIDAPS EQUIPMENT CONFIGURATION (GROUND BASED)

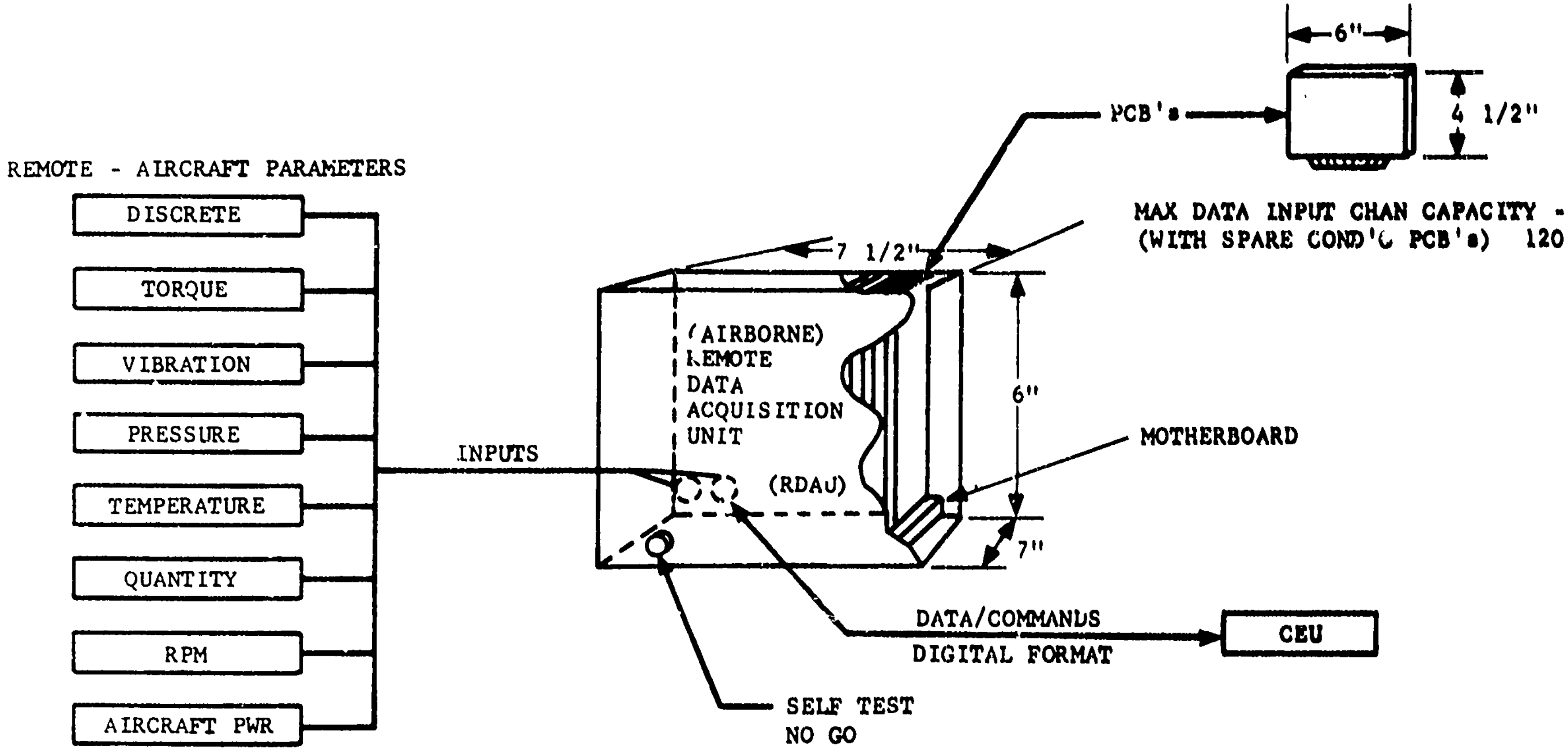


<u>FLIGHT DATA ENTRY PANEL (FDEP) DATA:</u>

WT.- - - -8 OZ

COST- - -≈$0.2K

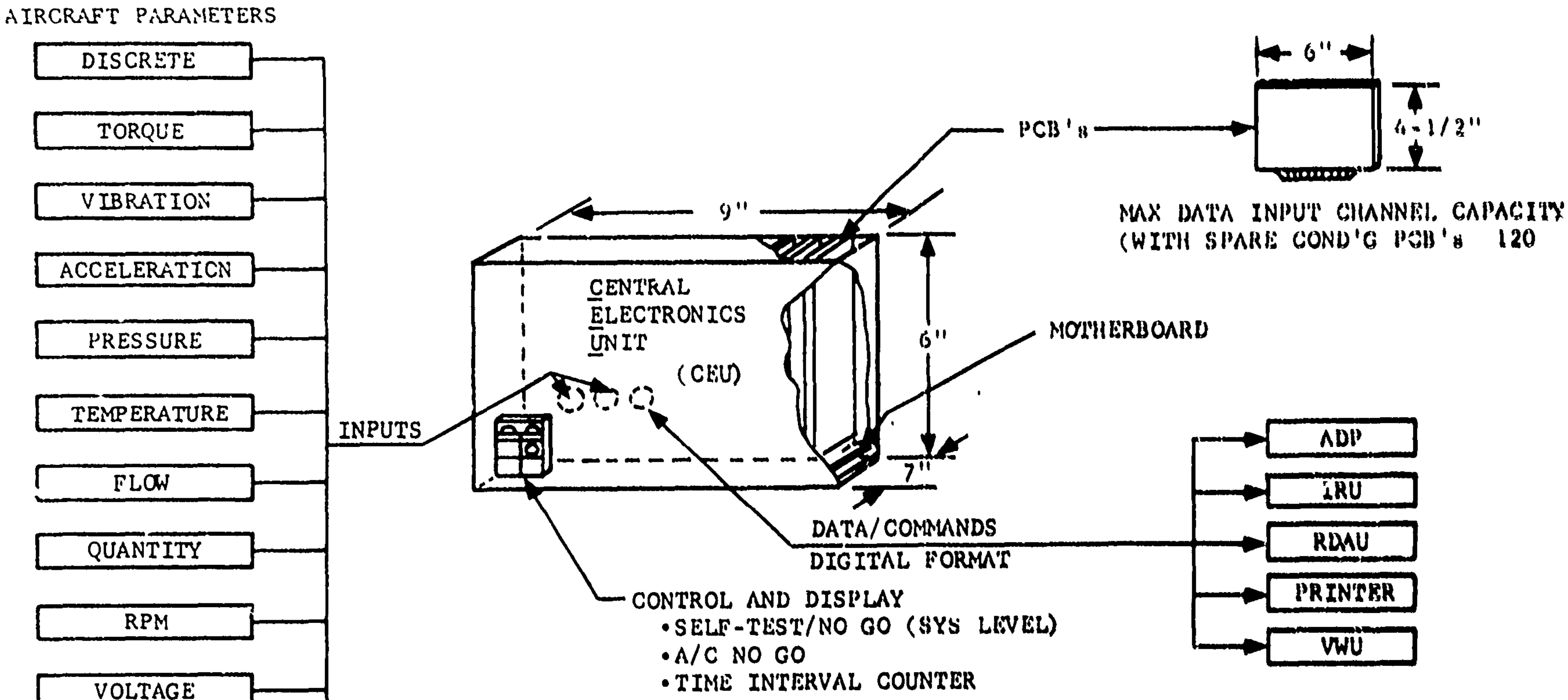
FIGURE 5-5 AIDAPS FLIGHT DATA ENTRY (FDEP) HARDWARE DESCRIPTION



PCB CONFIG PHYSICAL DATA:		(BASIC)*
LEVEL 1 MULTIPLEX	2	WT......8 LBS
CONDITIONING	5	PWR...25 WATTS AT 28 VDC
LEVEL 2 MULTIPLEX	1	VOL.....0.12 FT^3
A/D CONV./PROCESSOR	1	COST DATA:
PWR REG	1/2	≈$6.0K
MOTHERBOARD	1	WITH CHASSIS AND CONNECTORS
• ISOLATION		
• BUSING LOGIC		

NOTE:
*VARIES WHEN APPLIED AS A G/B UNIT

FIGURE 5-6 AIDAPS REMOTE DATA ACQUISITION UNIT (RDAU) HARDWARE DESCRIPTION (BASIC)

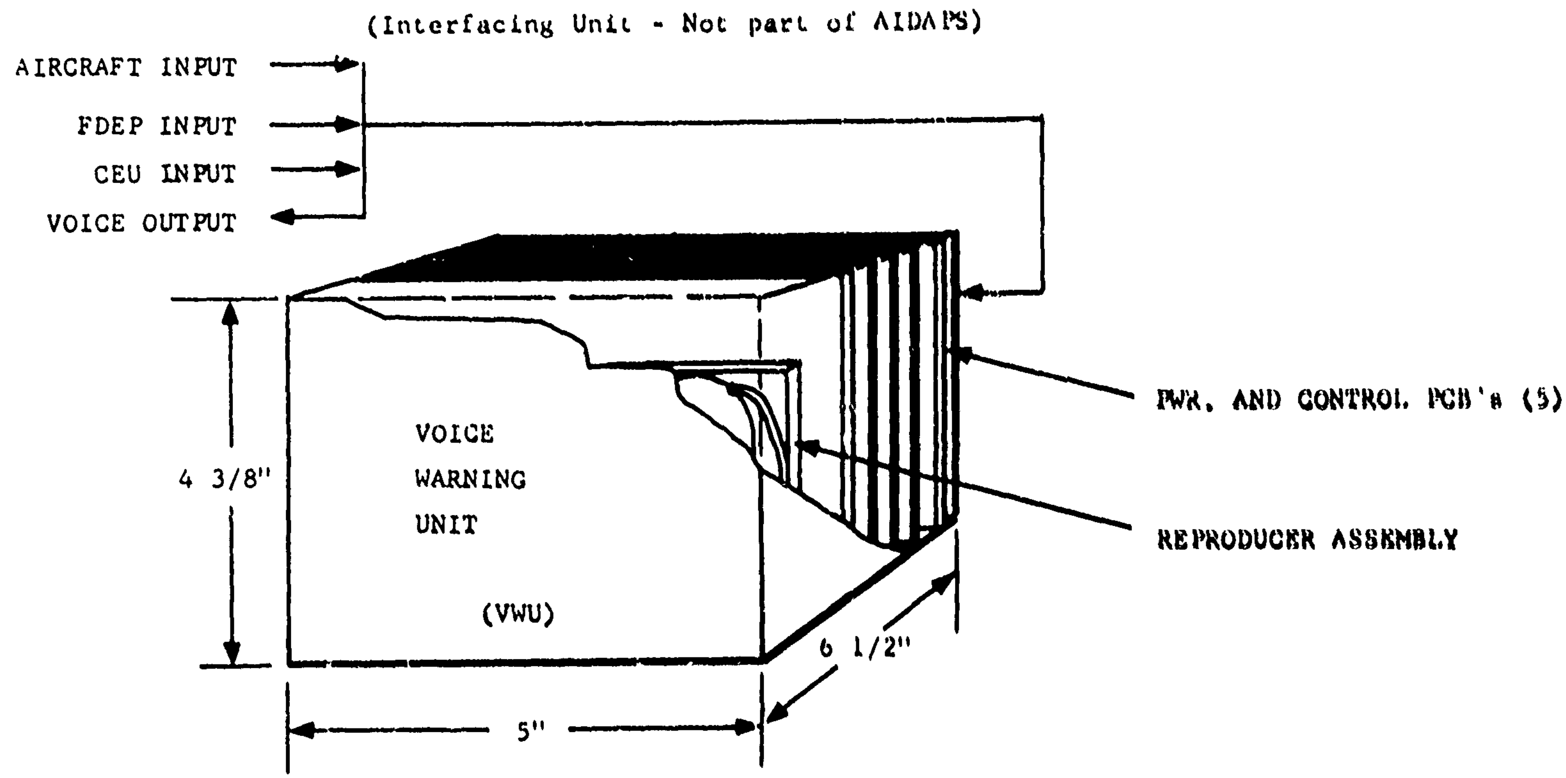


PCB CONFIG PHYSICAL DATA:		(BASIC)*
LEVEL 1 MULTIPLEX	2	WT...9.0 LB
CONDITIONING	5	PWR...30 WATTS AT 28 VDC
LEVEL 2 MULTIPLEX	1	
A/D CONVTR/PROCESSOR	2	VOL...0.22 FT^3
COMPUTATION LOGIC	2	**COST DATA**
MEMORY	1	≈$8.4K WITH CHASSIS AND CONNECTORS
PWR REG AND RECORD CONT	1	
MOTHERBOARD	1	
•ISOLATION		
•BUSING LOGIC		

NOTES:
*APPLICABLE TO AIDAPS A/B AND HYBRID I

VALUES VARY WHEN APPLIED TO AIDAPS HYBRID II

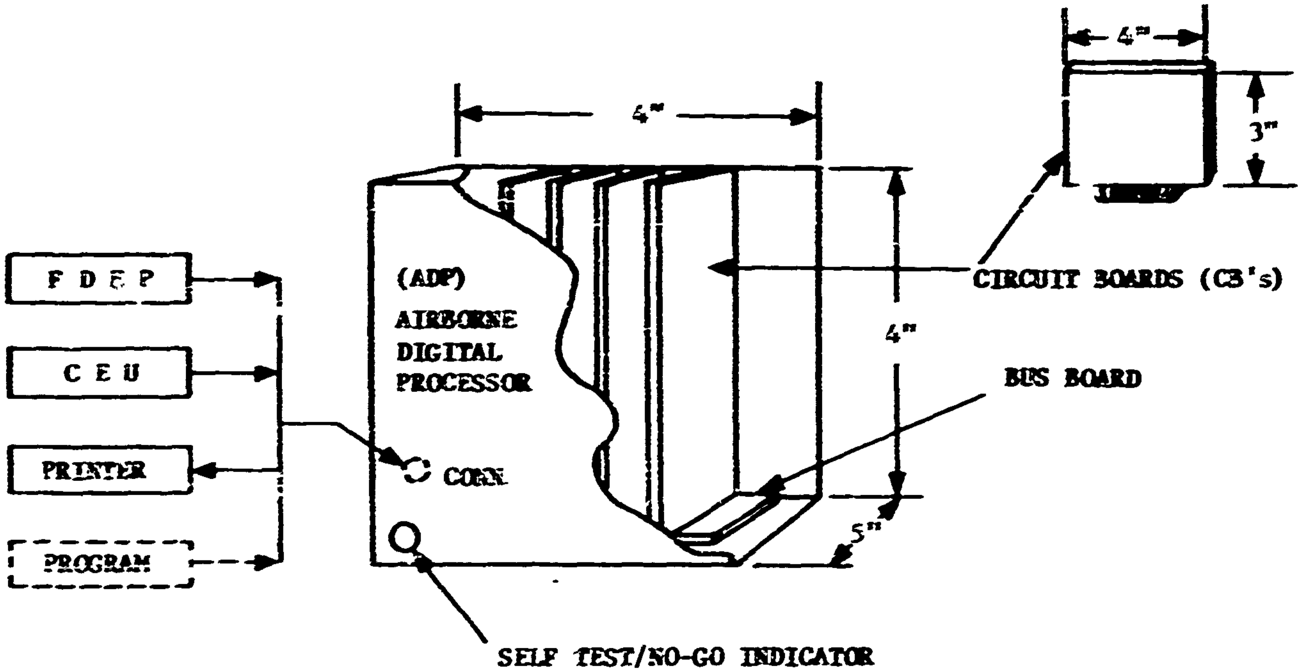
FIGURE 5-7 AIDAPS CENTRAL ELECTRONICS UNIT (CEU) HARDWARE DESCRIPTION (BASIC)



VWU DATA:

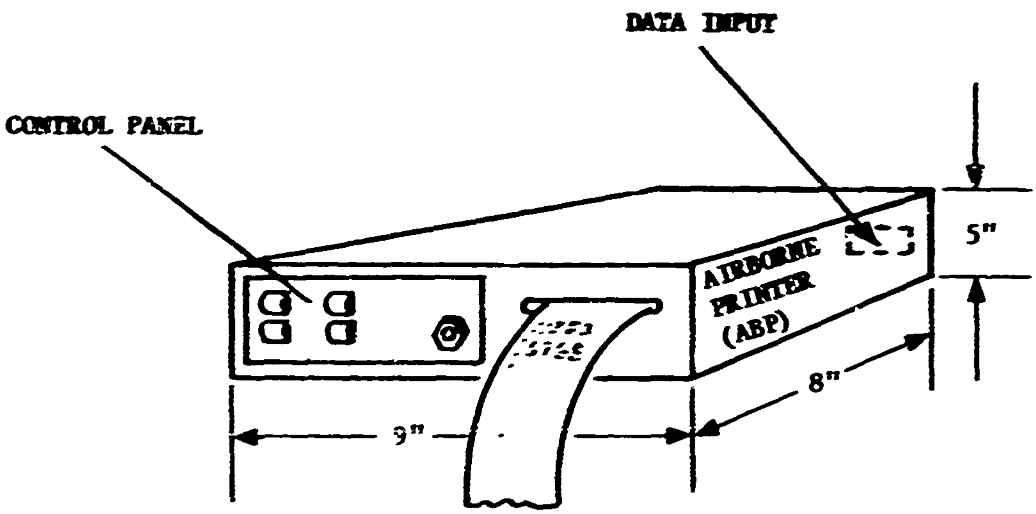
WEIGHT	= 4.5 LBS.	
COST	= $5.0 K	
INPUT PWR. REQUIREMENTS		15 WATTS AT 28 VDC

FIGURE 5-8 VOICE WARNING UNIT (VWU) HARDWARE DESCRIPTION



CB CONFIG PHYSICAL DATA:		(BASIC)	
INPUT/OUTPUT (I/O)	1	WT	2.5 LBS
PROCESSOR	1	PWR	20 WATTS AT 28 VDC
MAGNETIC MEMORY	1	VOL	0.046 FT^3
ROM AND RAM	1	COST DATA:	
SPARES	2	≈$2.0K WITH CHASSIS AND CONNECTOR	
BUS BOARD	1		

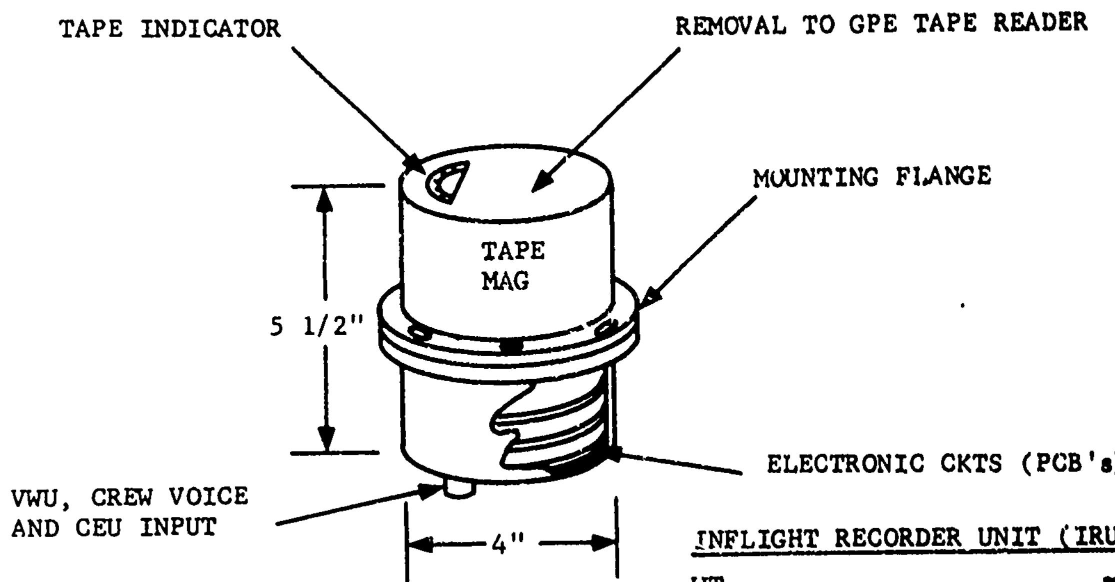
FIGURE 5-9 AIDAPS AIRBORNE DIGITAL PROCESSOR (ADP) HARDWARE DESCRIPTION



PRINTER DATA:

NON-IMPACT TYPE -	
WT	≈5 LBS
COST	≈$6K
PRINT RATE	30 CPS, 300 WORDS/MIN
PAPER WIDTH	≈3 5/8"
PRINT MEDIUM	THERMAL
INPUT PWR REQ'MTS	10 WATTS AT 28 VDC

FIGURE 5-10 AIDAPS AIRBORNE PRINTER (ABP) HARDWARE DESCRIPTION

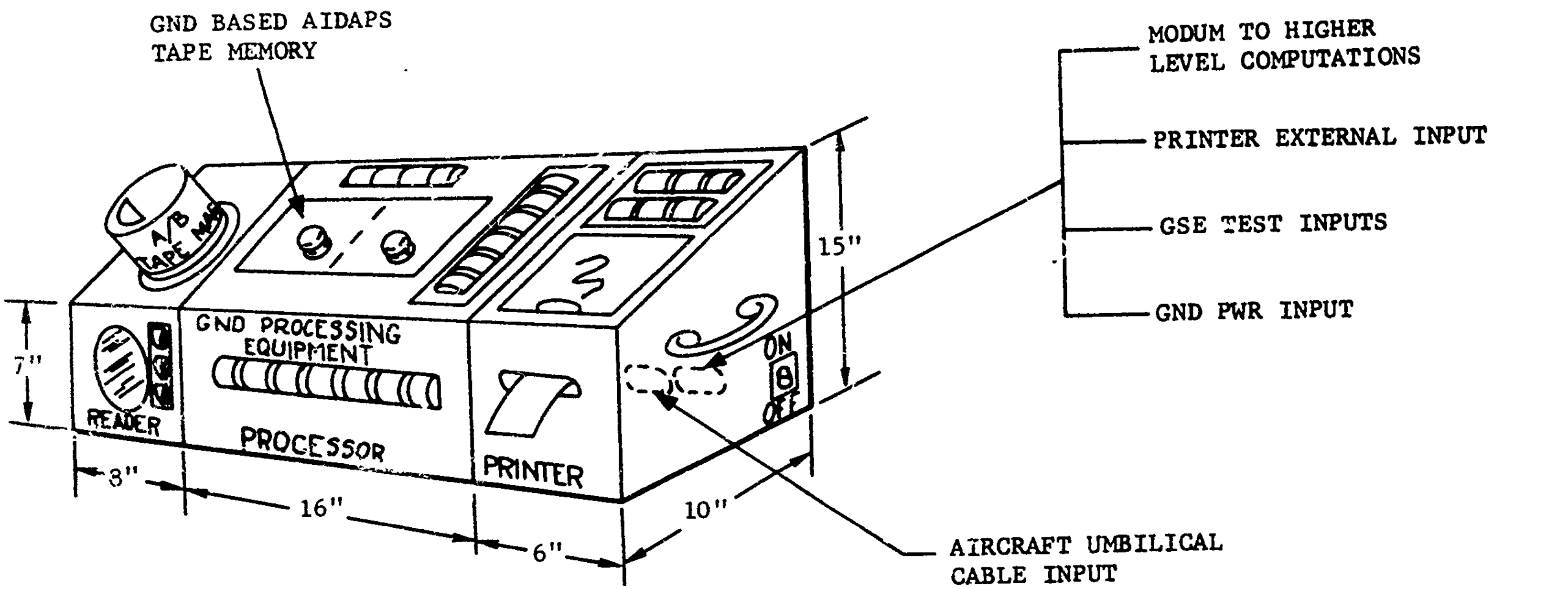


INFLIGHT RECORDER UNIT (IRU) DATA:

WT	≈3.5 LBS
COST	≈$2.0K
INPUT PWR REQUIREMENTS	15 WATT AT 28 VDC
4 TRACK	

- 1 AUDIO
- 1 TIME
- 2 DIGITAL

FIGURE 5-11 AIDAPS INFLIGHT RECORDER UNIT (IRU) HARDWARE DESCRIPTION



GPE DATA: (DEPENDENT ON AIDAP CONFIG APPLICATION)

AIDAP CONFIG	WT	COST	DELTA BETWEEN AIDAPS CONFIGURATION
HYBRID - A/B (A) S	33	$17.2K	ADDTIONAL DIGITAL PROCESSING AND MEDIUM SIZE MEMORY
HYBRID - A/B (A) M	30	$14.7K	BASIC
GROUND BASED	40	$25.0K	ADDED DIGITAL PROCESSING, SPECIAL COMPUTATIONAL ANALYSIS AND LARGE SIZE MEMORY. DELETED DATA REPRODUCER/READER

FIGURE 5-12 AIDAPS GROUND PROCESSING UNIT (GPU) HARDWARE DESCRIPTION

In addition, there were changes in the parameters monitored to achieve greater AIDAPS effectiveness.

The basic configurations as shown in Figures 5-5 through 5-12 did not change. However, system costs and weights did change as a result of this system redefinition. The changes resulted from sizing the CEU to accommodate the most complex aircraft of the group.

The major cost changes were due to prorating the DDT&E costs across more aircraft, and from reduction in procurement costs due to larger quantity production. These effects were most apparent for aircraft available in small numbers. For a comparison of system costs and weights see paragraph 7.3.

5.5.3 CANDIDATE AIDAP SYSTEMS (UNIVERSAL)

During the development of the Group systems, it became apparent that further cost reductions could be accomplished by designing modular Universal systems.

The CEU for the Universal systems was designed for the aircraft in Group II. The RDAU was designed to accommodate the aircraft in Group III. A Communications Unit (CU) serves as the data link between the CEU and the aircrew and maintenance personnel. In a completely airborne configuration it consists of an airborne printer with communications completed via the printed record. In a hybrid system the CU is composed of a magnetic memory unit (a tape recorder, bubble memory, or the equivalent) and a readout device and printer on the ground. The printed record completes the communications link.

Other combinations are possible. For example, the data may be stored in permanent memory in the CEU and a printer brought aboard the aircraft after every flight to printout the record. As an additional alternative, communications to the maintenance man could be via an alphanumeric display, either in the aircraft or ground based with information transferred by a magnetic memory unit.

The concept of the Universal system approach is that basic hardware elements will be designed and employed for various aircraft applications. The airborne equipment and applicable ground equipment will be reprogrammed using software prepared during the development program for its specific incorporation in different aircraft types or models. On occasion, however, as a universally designed CEU is employed in these other aircraft, portions of the signal conditioning section will be physically changed by removing selected circuit boards and replacing them with already designed circuit boards for the aircraft signal conditioning in question.

Illustrations of the modular Universal Hybrid I System are contained in Section 2.0, Figures 2-1 through 2-3. Figure 5-13 shows the modular Universal Airborne System. The units comprising this system are similar to those of the hybrid system except for the Communications Unit shown in Figure 5-14.

5.6 AIDAP SYSTEM CAPACITIES

One of the most important system characteristics affecting system size, weight and cost is the number of parameters required to be monitored. A relatively large number of parameters must be monitored for the inspections and the first few components. As shown in Figure 5-15, almost 50 parameters are required for the first 10 items (inspections and components) on the AH-1 aircraft. From the tenth to the twenty-fifth component, each additional component requires approximately one additional parameter. Beyond the twenty-fifth component, less than one parameter per component is required. This is due to the ability to correlate the signals of various parameters and logically diagnose the source of a failure. Indeed, the last few components are obtained free in the sense that the parameters required for monitoring these components are already monitored for other purposes. Figures 5-16 through 5-23 show the parameter count versus component count for the other aircraft. The components are ranked in order by maintenance indices. The components with the highest maintenance indices are shown first. Daily, intermediate, and periodic inspections are included, and since these have high maintenance indices, they usually are the first three components. Table 5-6 shows the sensor types, quantities, and weighted sensor count required for each aircraft.

The AIDAPS configurations established in this section represent a spectrum of design philosophies and system approaches optimized in respect to normal design tradeoffs. As noted below, the candidate AIDAPS configurations represent the best available choices to provide one or more of the basic AIDAPS requirements, or a compromise system of these requirements.

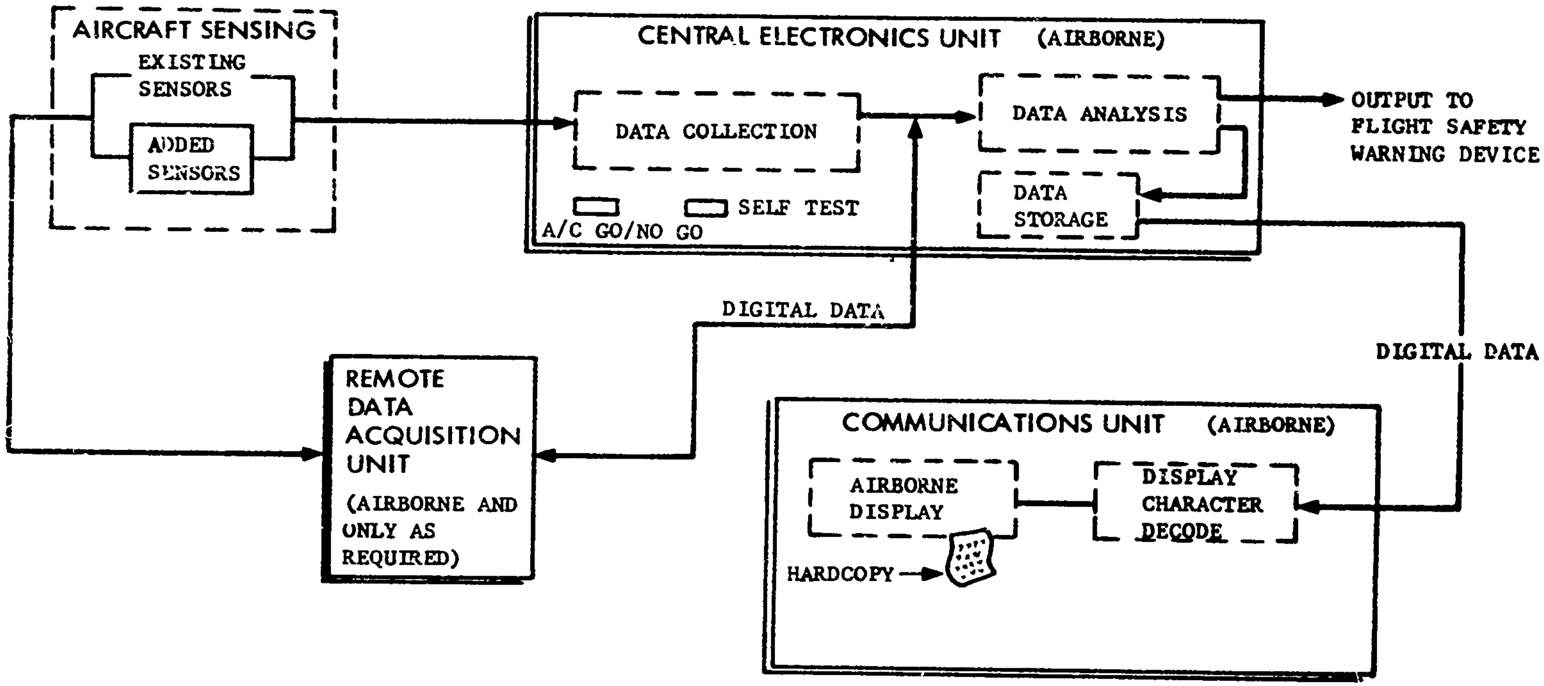
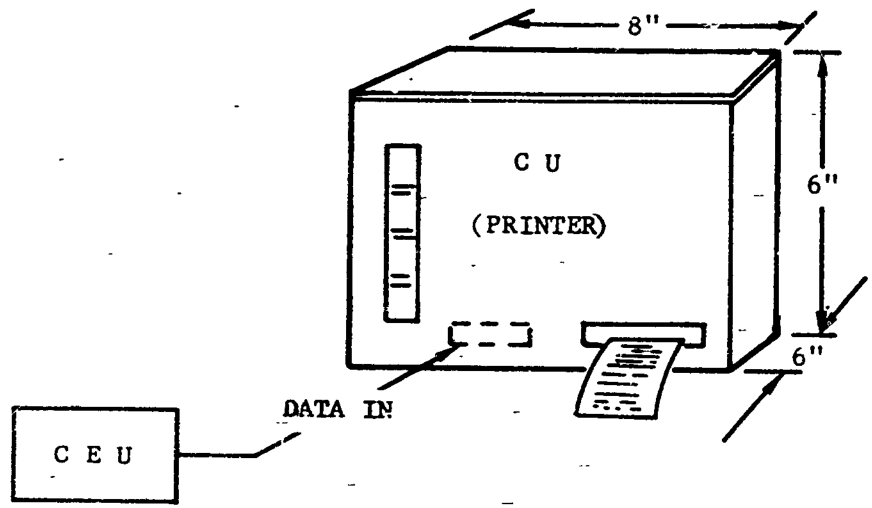


FIGURE 5-13 AIDAPS EQUIPMENT CONFIGURATION (UNIVERSAL AIRBORNE)



BASIC DATA:

WT	≈8 LBS
COST	≈$2.5K
PRINT RATE	≈30 LINES PER SEC.
PAPER WIDTH	≈3 5/8"
PWR	≈10 WATTS AT 28 VDC
VOL	≈0.16 FT^3

FIGURE 5-14 AIDAPS AIRBORNE COMMUNICATION UNIT (CU)

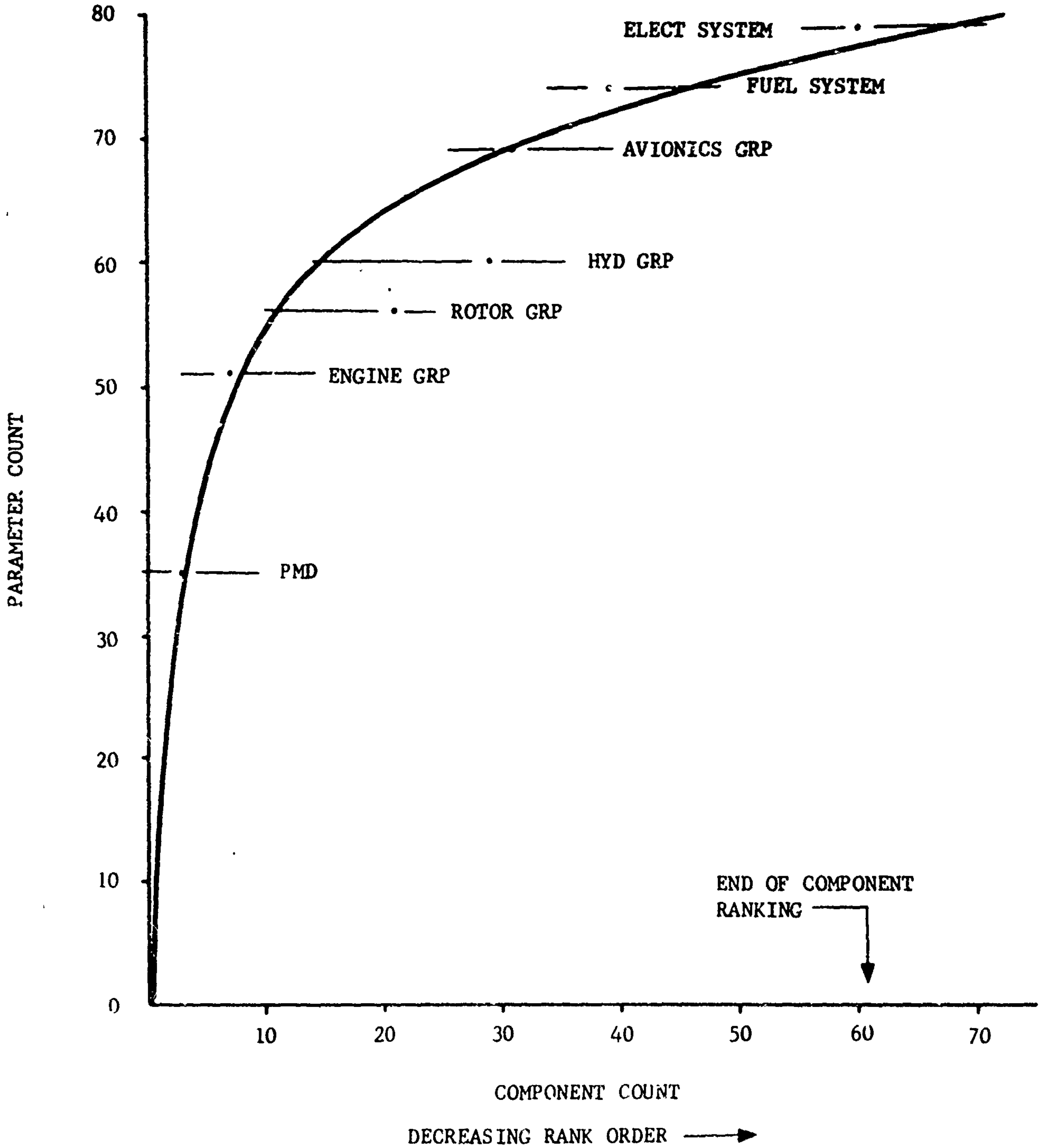


FIGURE 5-15 AH-1 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

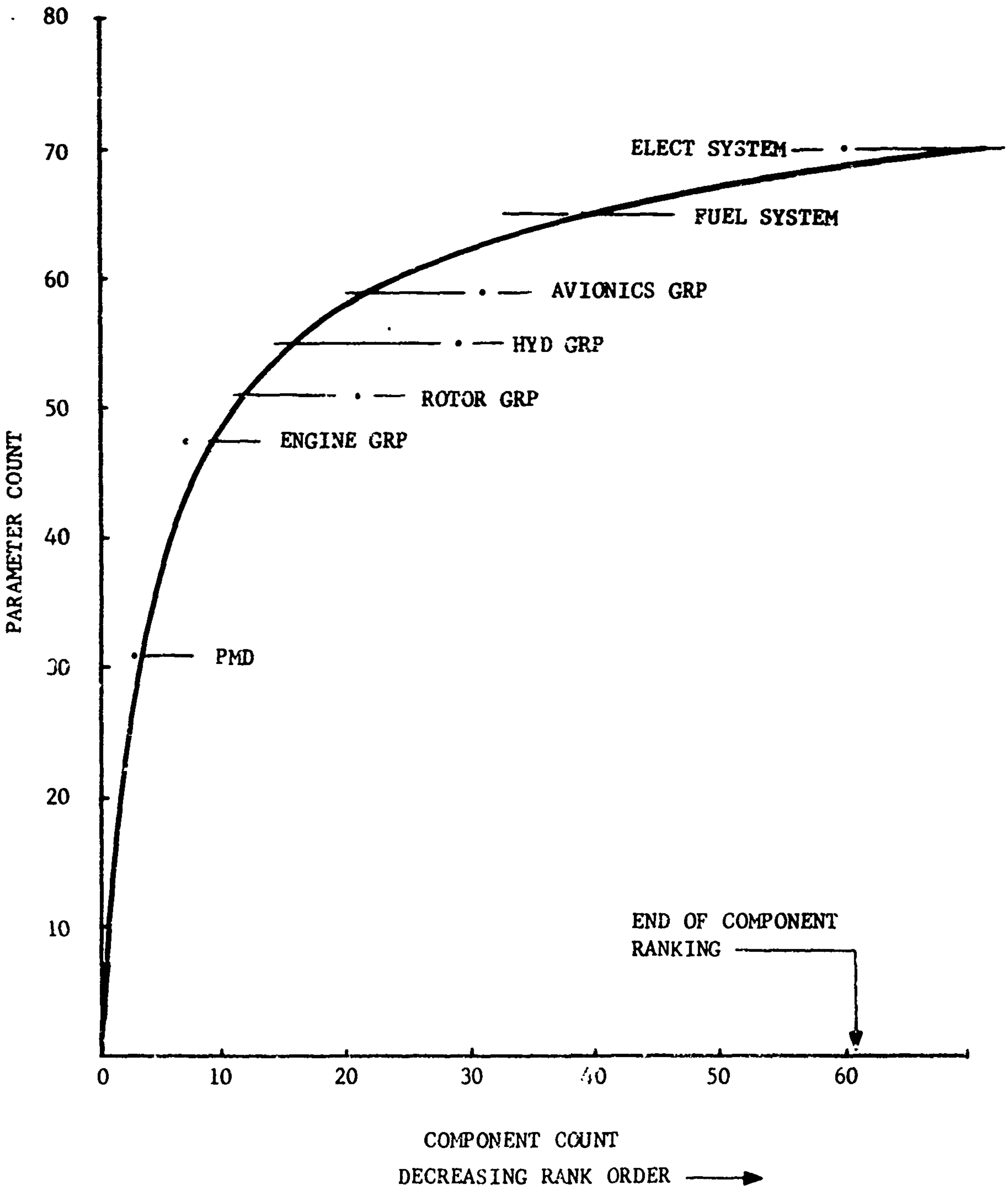


FIGURE 5-16 UH-1 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

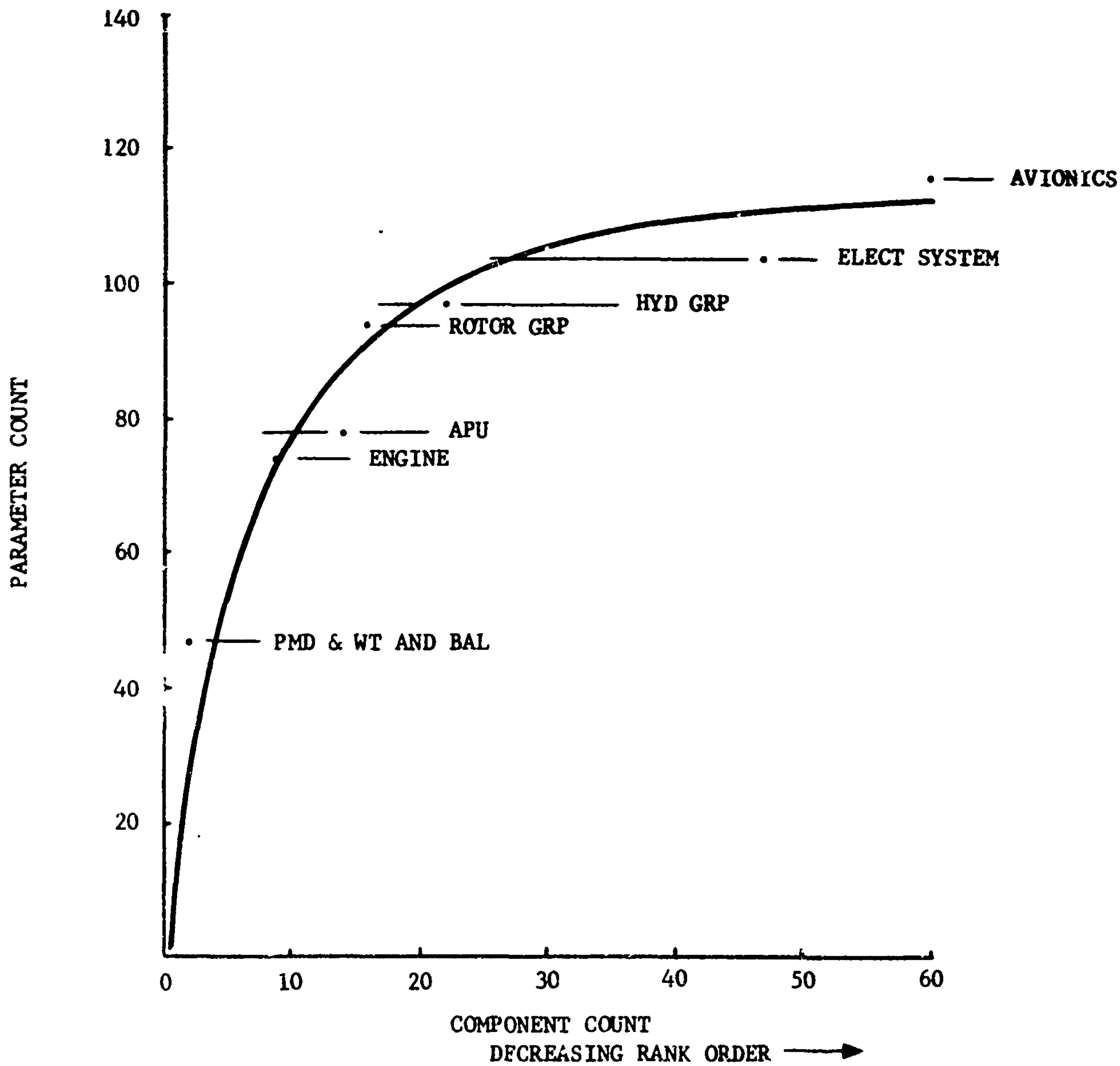


FIGURE 5-17 CH-47 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

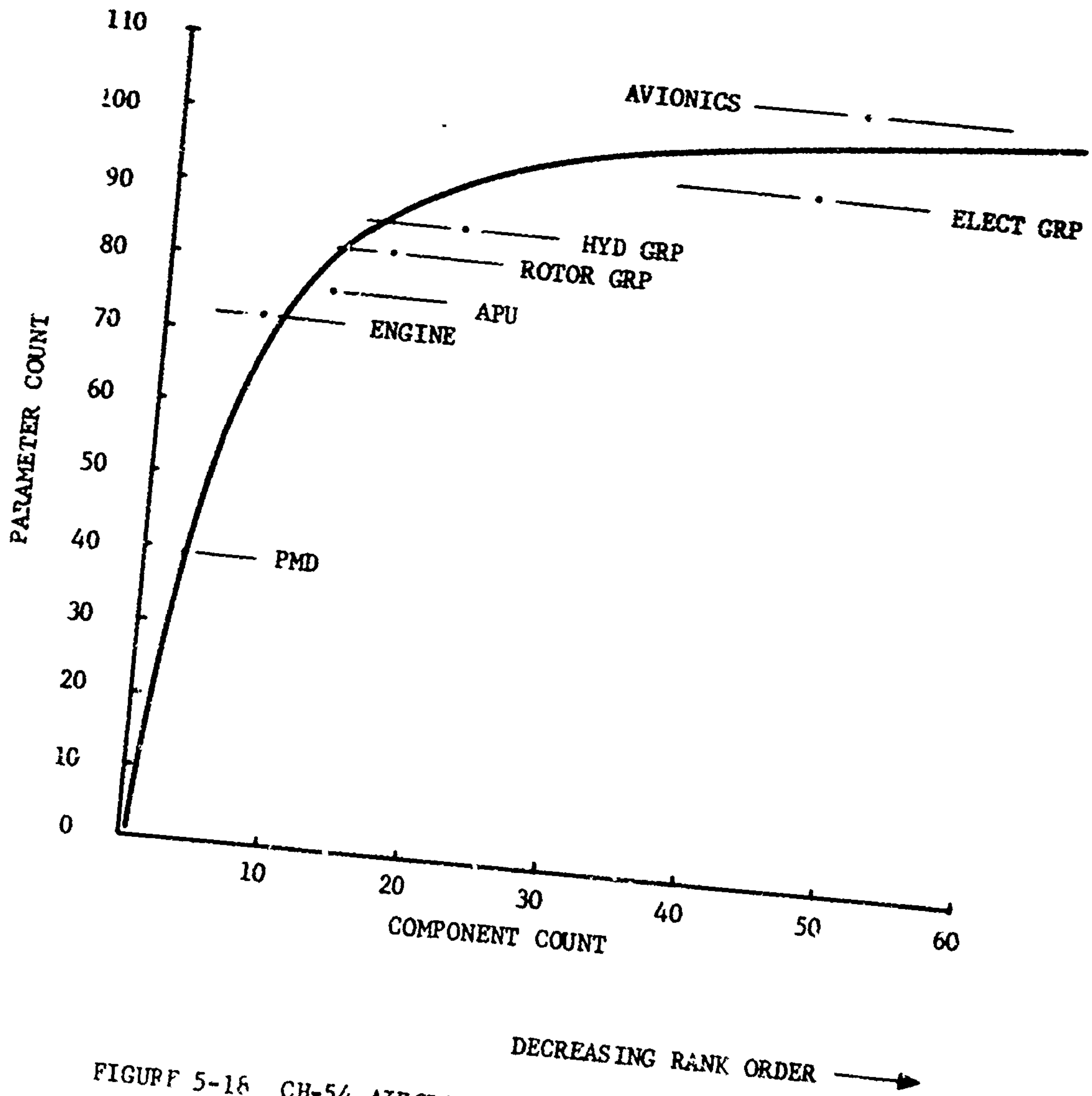


FIGURE 5-16 CH-54 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

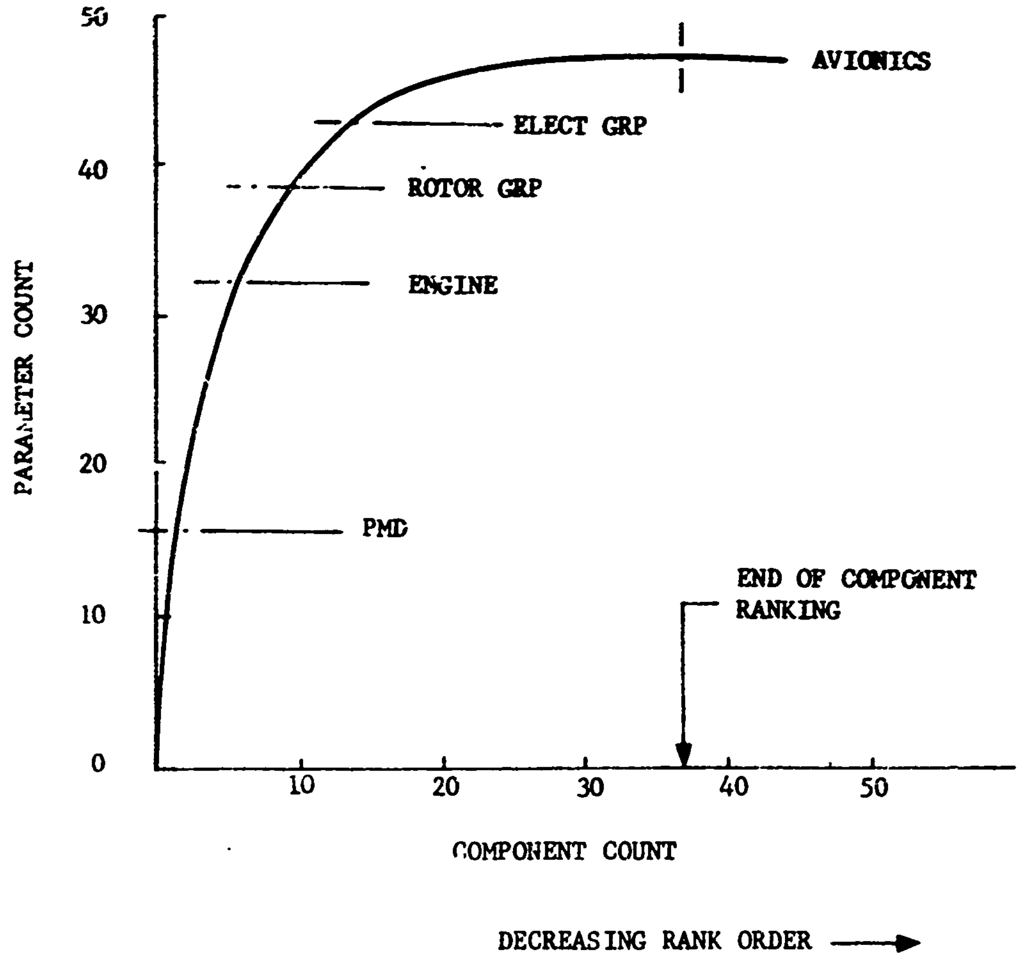


FIGURE 5-19 OH-6/OH-58 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

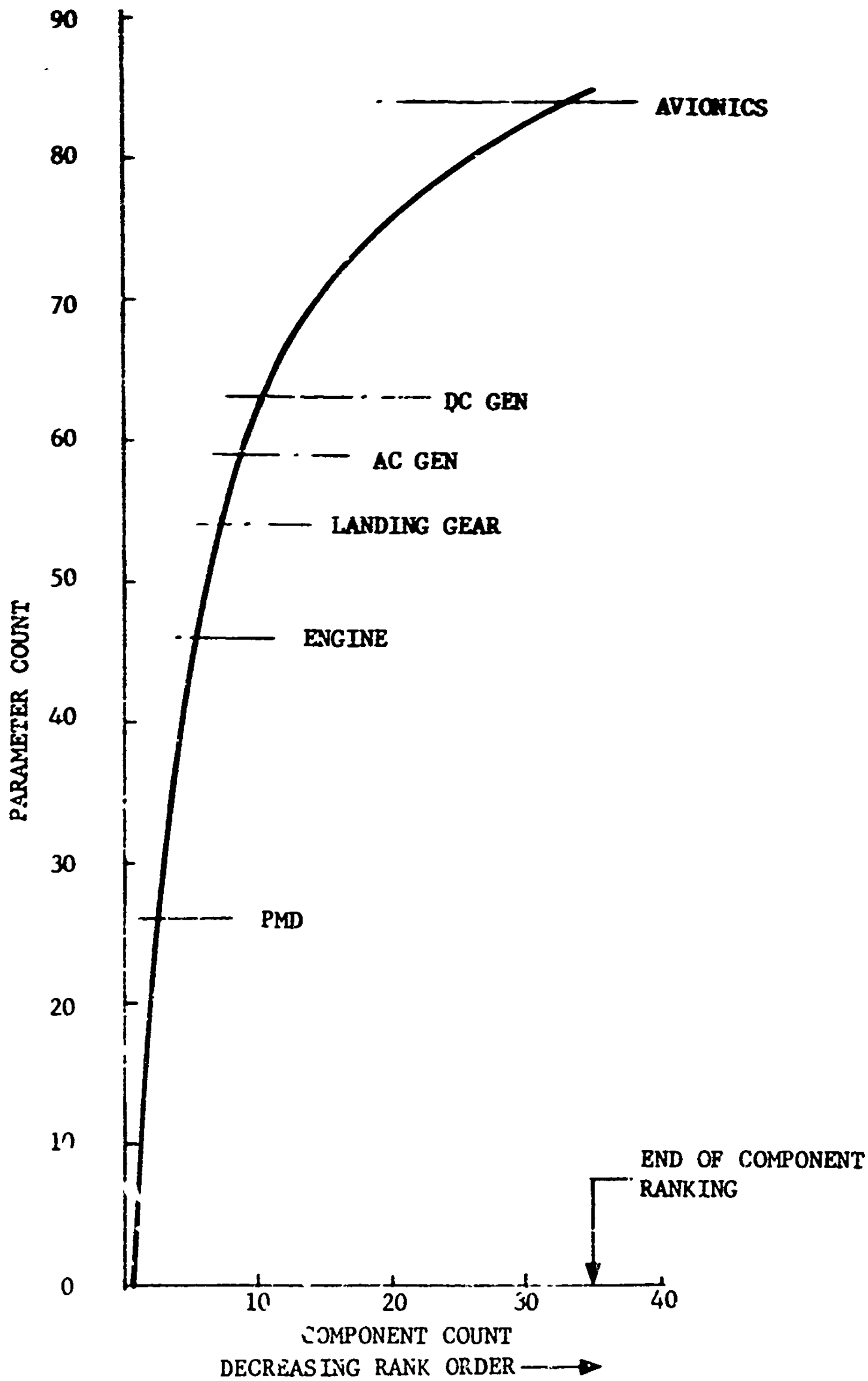


FIGURE 5-20 OV-1 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

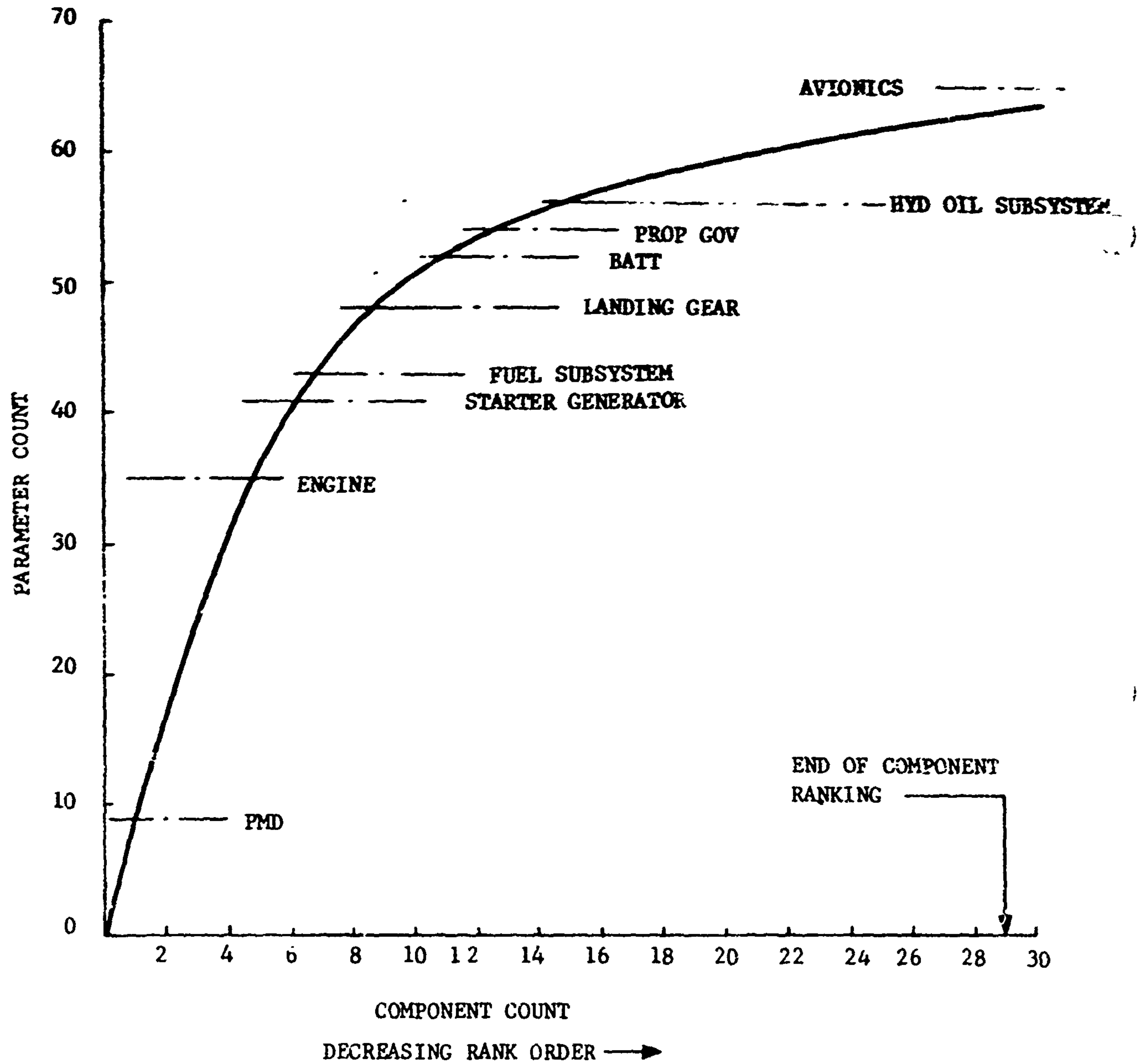


FIGURE 5-21 U-21 AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

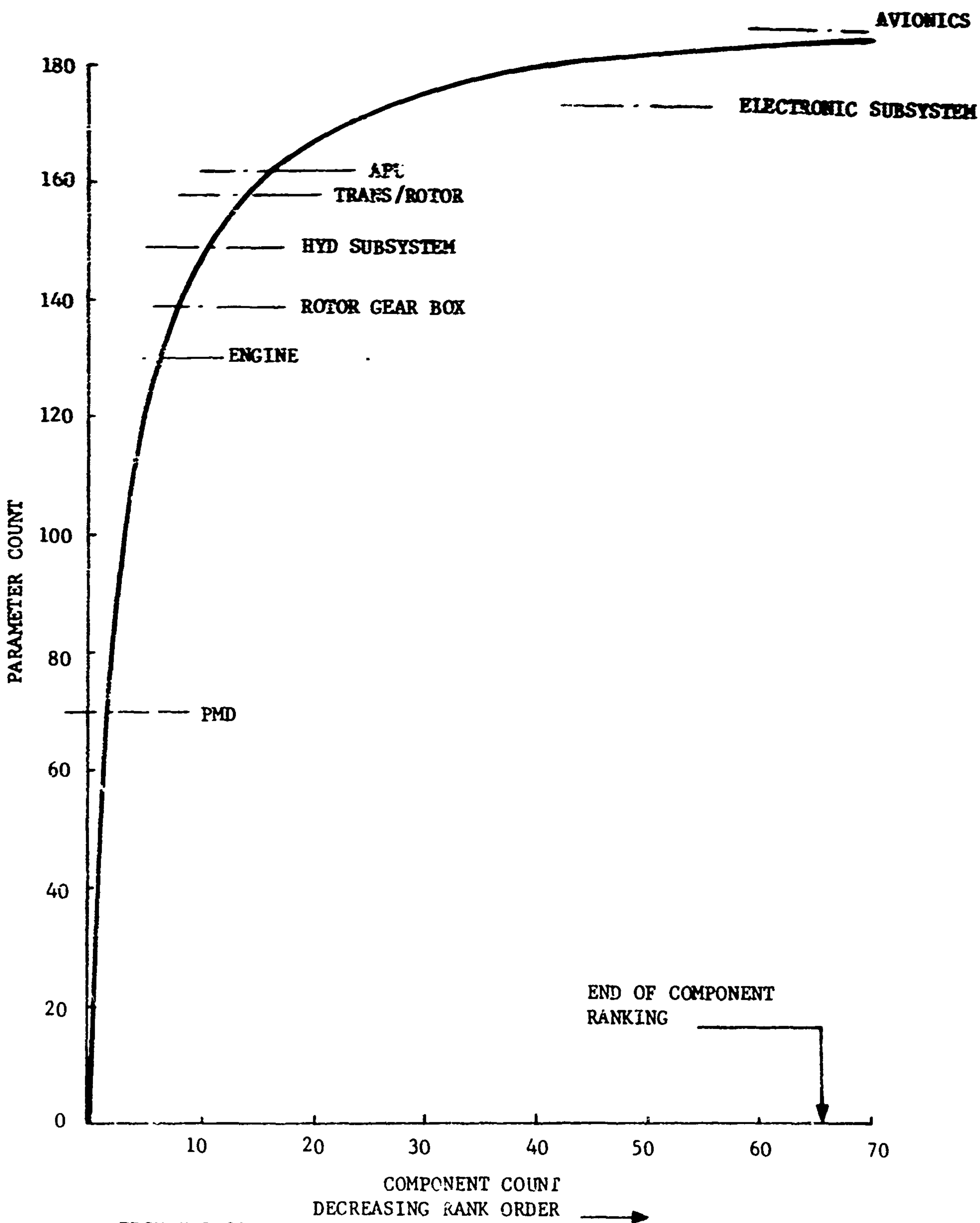


FIGURE 5-22 HLH AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

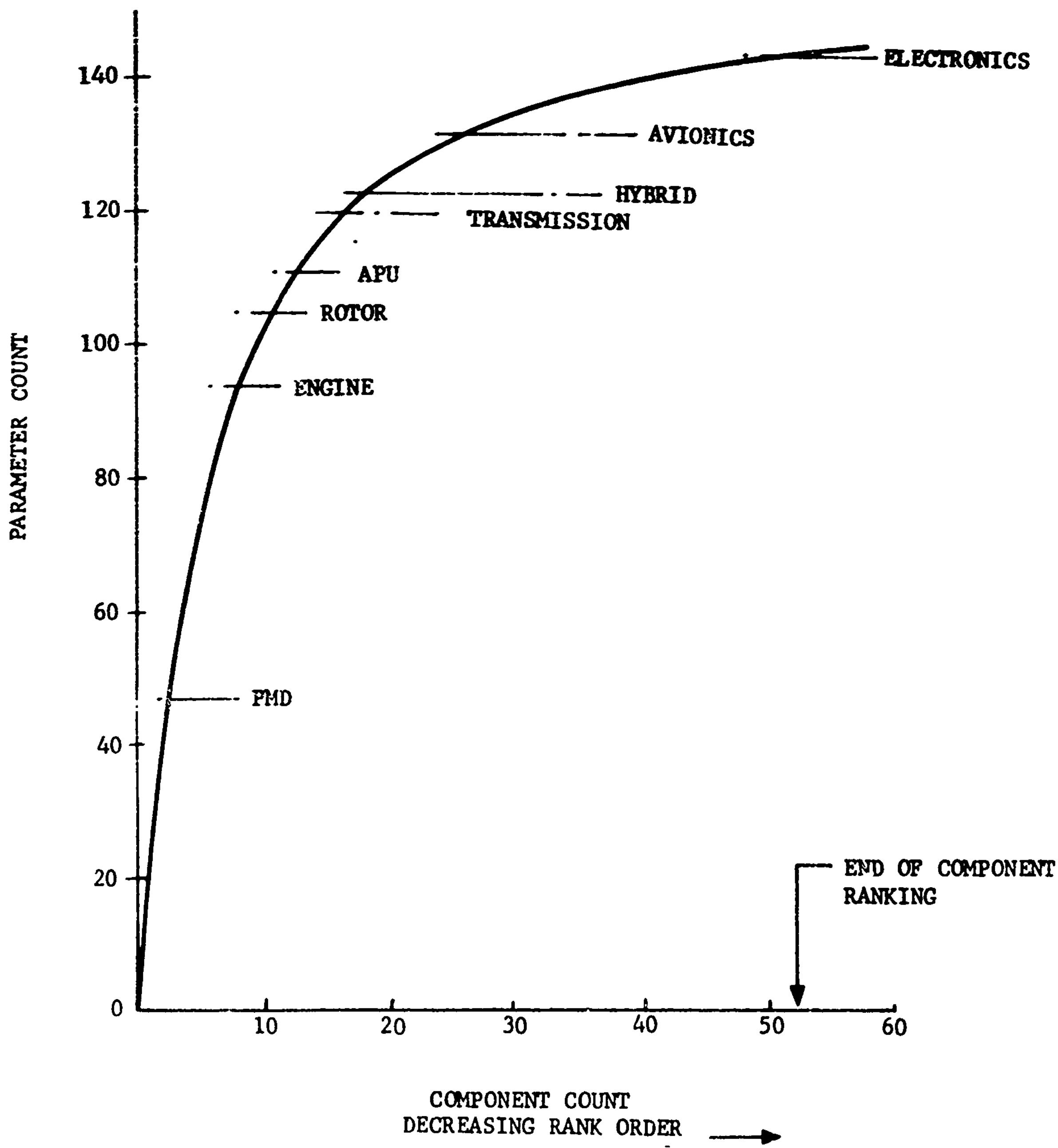


FIGURE 5-23 UTTAS AIRCRAFT COMPONENTS VS APPLIED PARAMETERS

TABLE 5-6 AIDAPS SIGNAL CONDITIONING SUMMARY PARAMETER COUNT AND WSC (WEIGHTED SENSOR COUNT)

		WEIGHT FACTOR	OH-6		OH-58		UH-1		AH-1		U-21		OV-1		CH-47		CH-54		UTTAS		ELM	
			COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC	COUNT	WSC
1	DISCRETE VOLTAGE (CHIP DETECTOR, EVENT, TEMPERATURE)	1	10	10	10	10	19	19	20	20	12	12	19	19	16	16	18	18	30	30	44	44
2.	PROPORTIONAL VOLTAGE (AC OR DC)	4	3	12	3	12	2	8	4	16	8	32	15	60	11	44	10	40	12	48	11	44
3.	S.G. (STRAIN GAGE) BRIDGE DIAPHRAGM (PRESSURE, LOAD)	4	7	28	7	28	11	44	12	48	7	28	9	36	20	80	21	84	23	92	27	108
4	RESISTANCE BULB (TEMPERATURE, QUANTITY)	4	2	8	2	8	3	12	3	12	3	12	4	16	8	32	4	16	8	32	10	40
5.	LINEAR POTENTIOMETER (DISPLACEMENT)	4	5	20	5	20	1	4	1	4	-	-	-	-	-	-	-	-	-	-	-	-
6	S.S. (SOLID STATE) LEAK DETECTOR (FLUID LEAKAGE)	4	5	20	5	20	10	40	13	52	9	36	10	40	10	40	13	52	17	68	23	92
7.	LOAD SHUNT (CURRENT)	4	1	4	1	4	2	8	2	8	1	4	-	-	-	-	-	-	2	8	3	12
8.	ENGINE COMPRESSOR EROSION MONITOR	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	3	12
9.	PIEZOELECTRIC ACCELEROMETER (VIBRATION)	5	5	25	5	25	9	45	9	45	2	10	2	10	10	50	8	40	10	50	13	65
10.	ENGINE PRESSURE RATIO (EPR) SENSOR	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	12	-	-	-	-
11	THERMOCOUPLE (TEMPERATURE)	6	1	6	1	6	1	6	1	6	2	12	2	12	5	30	5	30	5	30	7	42
12.	CAPACITANCE PROBE (FLUID QUANTITY)	6	-		-	-	1	6	1	6	2	12	3	18	8	48	4	24	8	48	10	60
13	PROXIMITY DETECTOR	8	1	8	1	8	1	8	1	8	-	-	-	-	-	-	-	-	-	-	-	-
14	LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT-DISPLACEMENT)	8	-	-	-	-	1	8	1	8	-	-	2	16	4	32	2	16	7	56	9	72
15	TACH GENERATOR (SHAFT SPEED)	10	3	30	3	30	3	30	3	30	4	40	4	40	5	50	6	60	6	60	8	80
16	TURBINE FLOW METER (FLUID FLOW RATE)	10	1	10	1	10	1	10	1	10	2	20	2	20	2	20	2	20	2	20	3	30
17.	SYNCHRO (PRESSURE, QUANTITY)	12	3	36	3	36	5	60	7	84	13	156	12	144	17	204	11	132	10	120	12	144
18.	OPTICAL SENSOR (OIL CONTAMINATION)	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	24	3	36
	TOTAL SENSOR COUNT, ( ) = ADDED SENSORS		67,(26)		67,(21)		70,(41)		79,(40)		55,(22)		84,(31)		116,(60)		106,(50)		144,(69)		186,(88)	
	TOTAL WSC			217		217		308		357		374		431		646		544		694		881

Lightweight and low cost -- Ground Based System

Accuracy and operational suitability -- Airborne Unique System

Compromise of the above -- Hybrid I, Hybrid II, and all Group and Universal systems

The final selection of the recommended systems are made by cost effective new tradeoffs in section 7.0.

A note of design commonality is worth observing before leaving this subject. As discussed in Appendix B, the state of the art in electronic component technology is moving rapidly. Heretofore, it was only possible to design an AIDAPS using a very large general purpose airborne computer or to provide a small, almost hardwired special purpose computer to do the job. With the advancements made in the last two years, it is possible to obtain the versatility of a general purpose machine without accepting a weight penalty. This means that the configurations and physical characteristics of the AIDAPS presented in this study can be realized and will incorporate general computer technology that permits use of software to modify system logic, threhsolds and computations without physical changes to the hardware. Whether the equipment is airborne or ground-based, if significant computational capability is required in any portion of the hardware, standard processes will be employed. This will, of course, necessitate the development of software for each specific aircraft application. However, some engineering must be accomplished in all cases, whether to hard-wire a system or program it with software. Software costs are obviously the best approach for highly versatility equipment. The computer language employed is a function of the processor and the application and not critical to the advancement of the effort. Programs can be written to make an AIDAPS interface with almost any test language.

SECTION 6

6-1.1

6.0 AIDAPS OPERATIONAL CHARACTERISTICS

6.1 OPERATIONAL PLAN

The AIDAP configurations described in Section 5 are highly flexible designs capable of being deployed with the aircraft or the aircraft supporting organizations and operated by the air or ground crews. Each AIDAPS generic type, however, has inherent operating, deployment and/or mobility advantages and disadvantages which are discussed in this section.

6.1.1 AIRBORNE SYSTEM

6.1.1.1 Deployment

The Airborne System is a self-contained airborne equipment set which is deployed with the aircraft and maintains its full operational capability at all times and all locations. The AIDAPS Test Set for the Airborne System is airmobile, and is deployed with GS units. In the event there are no local GS units, it may be deployed to the DS level.

6.1.1.2 Employment

The Airborne AIDAP System (see Figure 6-1) requires no attention from the aircrew other than their option to insert the date. Failure to insert this date in no way degrades the system operation but no data correlation date will appear on the printout. When a condition affecting safety of flight occurs, warning is transmitted to the aircrew through the normal warning system. Whenever any malfunction occurs or is impending, the appropriate information is printed and can be examined by the aircrew and/or retained for the maintenance crew. Once during each flight, a complete prognostic printout of the status of the aircraft systems is accomplished.

After a flight, the ground crew checks the aircraft status light for indication of a malfunction. If one has occurred, the maintenance mechanic examines the data printout to diagnose the malfunction. The interpretation of this data will require approximately 3 minutes. The AIDAPS automatically isolates the malfunction to components or groups of components.

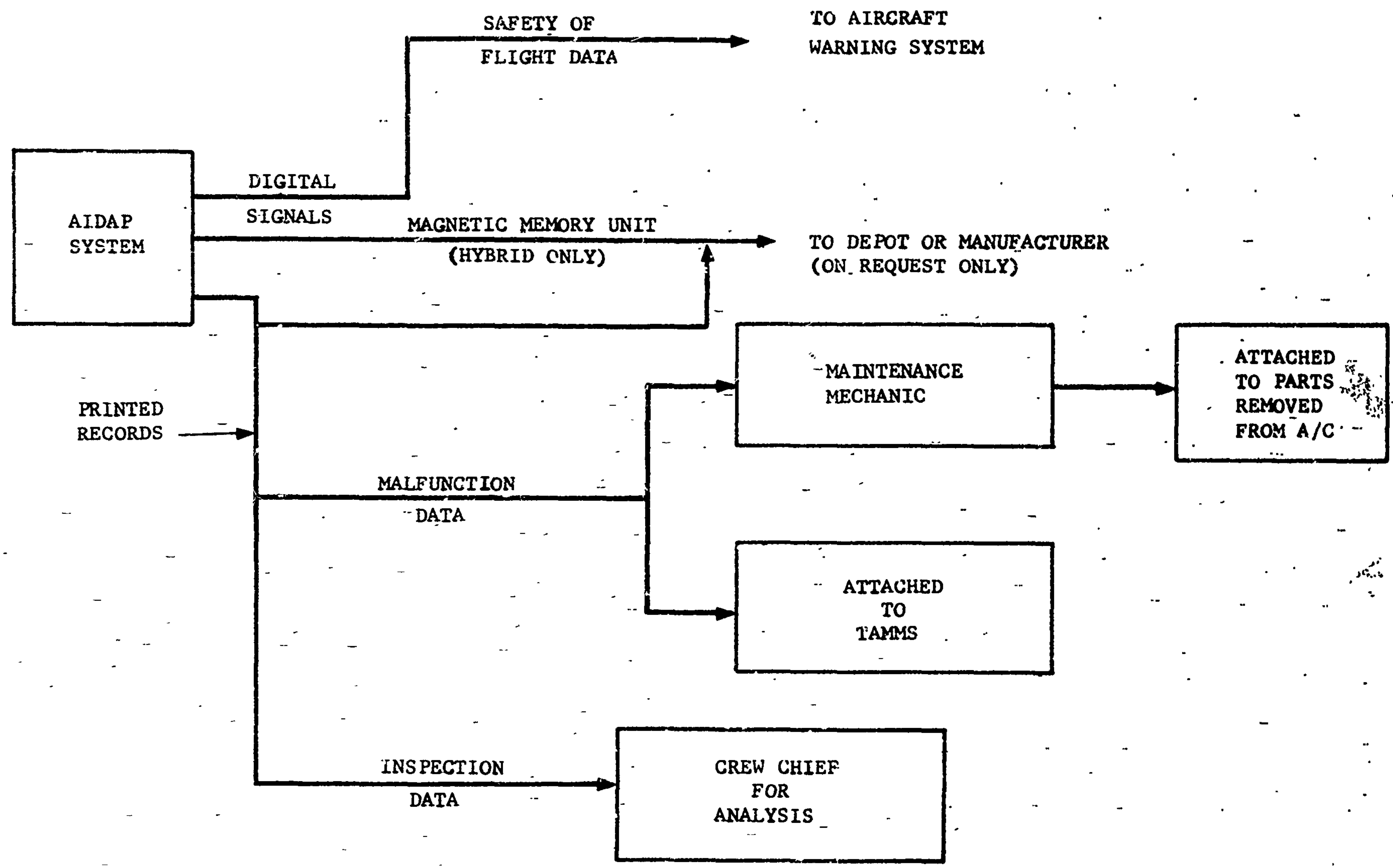


FIGURE 6-1 AIDAP SYSTEM DATA FLOW

Once each day the crew chiefs or maintenance officer examines the aircraft status printouts for indication of the health of each aircraft component monitored. This printout indicates the remaining time to on condition replacement of major components. These replacements can then be scheduled for subsequent days.

When a malfunction occurs, a copy of the AIDAPS diagnostic printout is attached to the appropriate TAMMS report. If a component is replaced, the original copy is attached to the repairable part.

6.1.1.3 Maintenance

The Airborne AIDAPS has an automatic built-in test capability. Hence no test equipment is required at the organizational level. When an AIDAPS malfunction is indicated, the indicated module is removed and replaced. This requires an average of less than 10 minutes. If the CEU has malfunctioned, the modular memory is removed and installed in the replacement CEU. In this manner, the memory required for diagnostics or prognostics is preserved.

The faulty components are transferred to the DS or GS unit which has the AIDAPS Test Set. One of these test sets will be required for approximately each 100 aircraft. This test set isolates the malfunction to a replaceable card or component which is shipped to the depot or factory for repair.

6.1.2 HYBRID I SYSTEM

6.1.2.1 Deployment

The airborne portion of the Hybrid I system is deployed with the aircraft. The ground portion is airmobile and portable and is deployed with the organizational units. One ground processing unit is required for approximately 15 aircraft. Deployment of the AIDAP System Test Set is the same as for the Airborne System.

6.1.2.2 Employment

The airborne employment of the Hybrid I System is identical to that of the Airborne AIDAPS with the exception that the maintenance data printout will not be available inflight.

After a flight, the maintenance personnel will examine the aircraft status light and/or digital display. The status light will be lit if a malfunction is detected. If the light is on, the memory unit is removed and transported to the ground unit and processed for diagnostic information. The printout indicates the component or group of components which have malfunctioned. Removing the memory unit, transporting it to the ground unit and processing the information requires approximately six minutes. The disposition of the printed records is identical to the airborne system. In the Hybrid systems the memory units can be made available to the depots or the contractors for special studies if this is desired.

Once each day, the memory unit is removed and processed for prognostic data. This allows the on condition removals to be scheduled.

6.1.2.3 Maintenance

Maintenance of the Hybrid I System is identical to the Airborne System.

6.1.3 HYBRID II SYSTEM

6.1.3.1 Deployment

The deployment of the Hybrid II System is identical to Hybrid I.

6.1.3.2 Employment

Airborne operation of the Hybrid II System is identical to Hybrid I except that no air safety nor diagnostic information can be supplied to the aircrew.

Ground operation of the Hybrid II System is similar to Hybrid I except that no aircraft status light is provided and the data memory unit must be processed after every flight. Processing time is increased to seven minutes.

6.1.4 GROUND SYSTEM

6.1.4.1 Deployment

For the Ground System, only the sensors and associated wiring are deployed with the aircraft. One ground processor must be provided for five aircraft. The ground processor may no longer be portable. Deployment of the AIDAPS Test Set is the same as for the Airborne System.

6.1.4.2 Employment

A special ground runup is required for the Ground System. Once each day, the Ground AIDAP System is moved to one of its aircraft (the ground systems must be dedicated to five specific aircraft for full diagnostic and prognostic capability). The Ground System is then connected to its power source and the RDAU is installed on the aircraft. A pilot is then required to bring a rotary wing aircraft to a three foot hover. Fixed wing aircraft can be brought to full throttle by a maintenance mechanic. Five minutes of maximum operation are required while the data is being sampled. An additional sample is made during coast down. Figure 6-2 shows estimated time lines for the ground run up. The top section of the figure indicates the time required for the ground crew, while the lower portion shows the time required for the aircraft.

The use of the data printouts are the same as for the Airborne System.

6.1.4.3 Maintenance

Maintenance of the Ground AIDAP system is identical to the Airborne System.

6.2 AIDAPS IMPACT ON ARMY AIRCRAFT MAINTENANCE CAPABILITIES

6.2.1 IMPACT ON ORG, DS, GS AND DEPOT MAINTENANCE

The envisioned impact of AIDAPS on organizational levels of maintenance includes possible MAC changes, reduction or elimination of inspections, quantity changes in allowances of spares, repair parts, special tools and GSE, and a reduction in TAMMS record keeping.

The positive identification of a malfunctioning component by AIDAPS will permit downgrading of MAC removal or replacement functions to the organizational

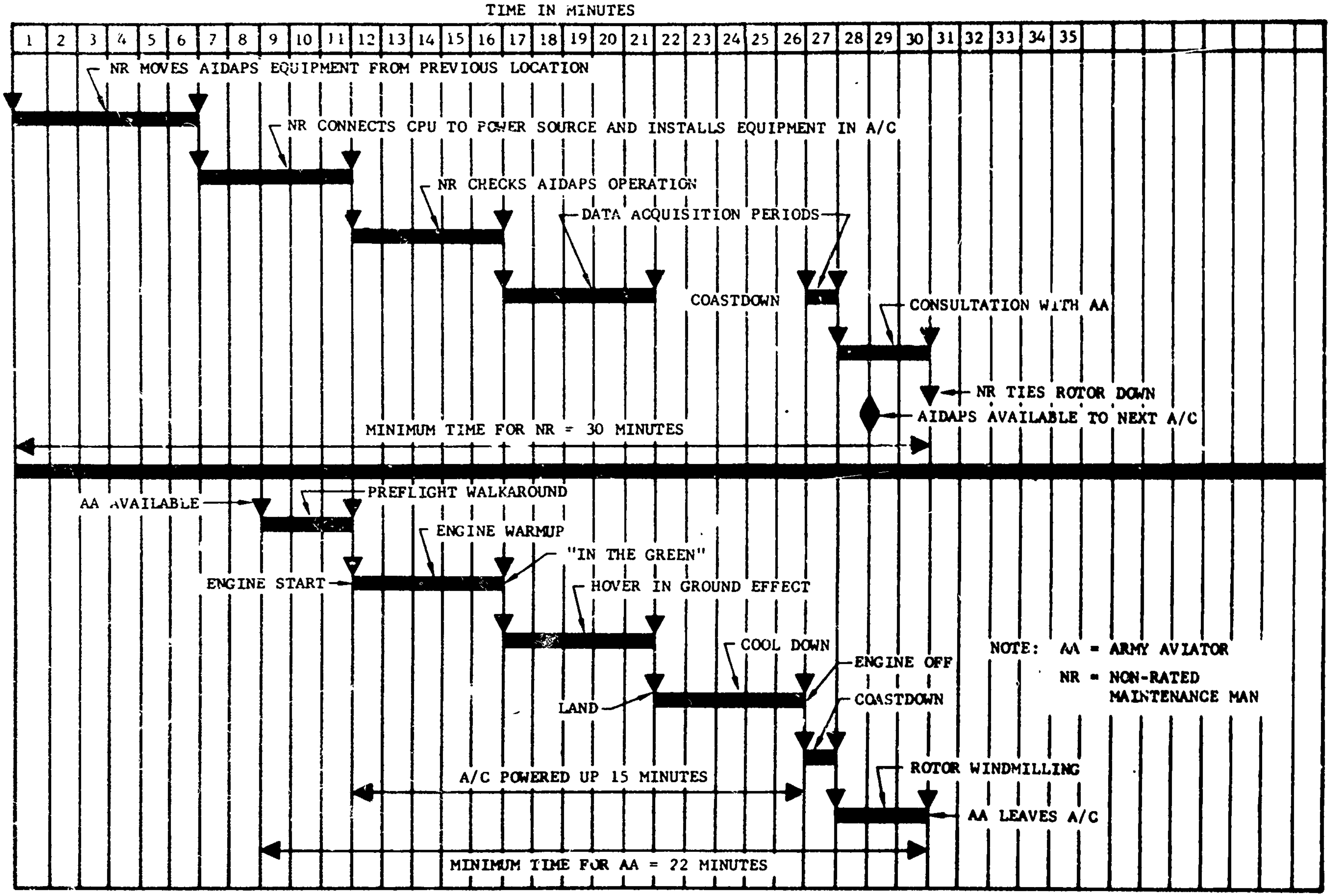


FIGURE 6-2 PROCESSING TIME REQUIRED BY A GROUND-BASED AIDAPS

level of maintenance consistent with skills, special took requirements, time and the tactical situation.

Current inspections including the PMD, PMI and PMP are designed to insure daily and hourly checks of aircraft and components. They are required mainly because of the "unknown" condition of aircraft subsystems. An AIDAPS will reduce these unknowns so that it may be possible to eliminate the PMI's (every 25 hours) and extend the 100 hour PMP. Table 6-1 shows the potential effects of AIDAPS upon Army maintenance procedures.

TABLE 6-1 EFFECTS OF AIDAPS ON MAINTENANCE PROCEDURES

A. Organizational Maintenance Level Detailed Functional Comparison*

Current System	Future System
1. Inspect	1. Inspect
a) Preventive Maintenance Daily (PMD)	a) Selected functions performed by AIDAPS
b) Preventive Maintenance Intermediate (PMI)	b) Reduced (major items performed by AIDAPS)
c) Preventive Maintenance Periodic (PMP)	c) Reduced (major items performed by AIDAPS)
d) Special Inspections	d) Selected functions performed by AIDAPS
e) Flight Tests (TBAVN 23-16)	e) Manual recordings by test pilot of A/C instrument values will be accomplished by AIDAPS
f) Standards of Serviceability (-20 Technical Manual)	f) No change except for large reduction in component replacement requirements since AIDAPS will permit "on condition" component replacement in lieu of flying hour or calendar criteria
g) Visual inspection of components for leaks, damage, missing items, etc. [Maintenance Allocation Chart (MAC)]	g) No change except as outlined above for PMD, PMI, PMP and Special Inspections
2. Test	2. Test
Maintenance Operational Checks (TBAVN 23-16 and MAC) for subsystems and component serviceability and/or failure.	AIDAPS will verify test flight results reported by aviator and ground checks by organizational level mechanic. AIDAPS will identify a failed LRU.
3. Service (MAC)	3. Service (MAC)
a) Engine and Related Systems	a) No change
b) Rotors and Transmission System	b) No change
c) Hydraulic System	c) No change
d) Electrical System	d) No change
e) Fuel System	e) No change
f) Armament System	f) No change

* Maintenance functions are those listed in the current study aircraft Maintenance Allocation Charts (MAC), and which may be influenced by an AIDAPS.

TABLE 6-1 (Continued)

A. Organizational Maintenance Level Detailed Functional Comparison (Continued)

Current System	Future System
4. Adjust (MAC)	4. Adjust (MAC)
a) Airframe	a) No change
b) Engine and Related Systems	b) MAC may be changed to permit additional large tolerance adjustments using AIDAPS.
c) Rotors and Transmission System	c) MAC may be changed to permit additional large tolerance adjustments using AIDAPS
d) Hydraulic System	d) MAC may be changed to permit additional large tolerance adjustments using AIDAPS
e) Aircraft Instruments	e) MAC may be changed to permit additional large tolerance adjustments using AIDAPS
f) Electrical System	f) MAC may be changed to permit additional large tolerance adjustments using AIDAPS
g) Fuel System	g) MAC may be changed to permit additional large tolerance adjustments using AIDAPS.
h) Flight Controls	h) MAC may be changed to permit additional large tolerance adjustments using AIDAPS
i) Armament System	i) No change
5. Align (MAC)	5. Align (MAC)
None	No change
6. Calibrate (MAC)	6. Calibrate (MAC)
a) Aircraft Instruments	No change
(1) Compass Swing	
(2) Altimeter	
7. Install (MAC)	7. Install (MAC)
N/A	N/A

TABLE 6-1 (Continued)

A. Organizational Maintenance Level Detailed Functional Comparison (Continued)

Current System	Future System
8. Replace (MAC) (Selected Components)	**8. Replace (MAC) (Selected Components)**
a) Airframe	a) No change with AIDAPS
b) Alighting Gear	b) Reduction in special inspections on AIDAPS monitored items, i.e., hard landing
c) Engine and Related Systems	c) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
d) Rotors and Transmission System	d) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
e) Hydraulic System	e) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
f) Aircraft Instruments	f) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
g) Electrical System	g) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
h) Fuel System	h) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
i) Flight Control System	i) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
j) Utility System	j) MAC can be changed to permit replacement of additional LRU's based on AIDAPS diagnosis. On condition maintenance replaces time changes.
9. Repair (MAC)	**9. Repair (MAC)**
All aircraft functional groups	Selected MAC functions can be downgraded to the organizational maintenance level based on AIDAPS diagnosis of cause of component malfunction

TABLE 6-1 (Continued)

A. Organizational Maintenance Level Detailed Functional Comparison (Continued)

Current System	Future System
10. Overhaul (MAC)	10. Overhaul (MAC)
N/A	N/A
11. Rebuild (MAC)	11. Rebuild (MAC)
N/A	N/A
12. Diagnosis	12. Diagnosis (MAC)*
N/A	Limited diagnosis not involving extensive analysis of printout data
13. Prognosis	13. Prognosis (MAC)**
N/A	Limited short term prognosis not involving extensive analysis of the data

* Diagnosis is a proposed new functional addition to MAC based on AIDAPS capability.

** Above comment on diagnosis applies to prognosis.

TABLE 6-1 (Continued)

B. Direct Support Maintenance Level Detailed Functional Comparison

Current System	Future System
1. Inspect	1. Inspect
a) Preventive Maintenance Periodic (PMP)	a) Selected DS functions performed by AIDAPS
b) Special Inspections	b) Selected DS functions performed by AIDAPS
c) Test Flights (TBAVN 23-16)	c) Manual recording of aircraft instrument values by test pilot will be accomplished by AIDAPS
d) Standards of Serviceability (-35 Technical Manual)	d) AIDAPS will permit "on condition" component replacement in lieu of flying hour or calendar period criteria
e) Visual Inspection of components for leaks, damage, missing items, etc.	e) No change except as outlined above for PMP and Special Inspections
2. Test	2. Test
Test equipment checkout of selected aircraft components except complete engines, gear boxes, main transmission(s), etc.	AIDAPS diagnostic capability will permit a reduction in initial test stand run requirements on repairable components
3. Service	3. Service
Function at DS level pertains to sophisticated aircraft components, i.e., filter assemblies on CH-47 aircraft	AIDAPS diagnostic/prognostic capability will permit elimination of selected servicing functions at the DS level
4. Adjust	4. Adjust
Close tolerance adjustments are authorized by Maintenance Allocation Chart on selected aircraft components (this function frequently requires special tools/test equipment)	No change except for a possible reduction in special equipment by use of AIDAPS diagnostic capability
5. Align	5. Align
Selected alignment functions not requiring a jig, primarily associated with rotor hub and blades assemblies	No change in basic functions. AIDAPS will assist in checking quality of work accomplished.

TABLE 6-1 (Continued)

B. Direct Support Maintenance Level Detail Functional Comparison (Continued)

Current System	Future System
6. Calibrate MAC authorizes limited calibration, i.e., fuel quantity indicator, exhaust temperature indicator. In addition, DS calibrates selected items of GSE and special tools.	6. Calibrate No change
7. Install Function assigned infrequently by MAC, i.e., armor plate bracketry on CH-47. No AIDAPS impact.	7. Install No change
8. Replace Predominant maintenance function authorized by MAC applicable to majority of aircraft subsystems and components less major structural items at the DS level.	8. Replace AIDAPS will reduce the number of replacement actions by diagnosis/prognosis of faulty components, "on condition" replacement, and reduction of faulty diagnosed removals which are found serviceable when tested at higher levels of maintenance.
9. Repair This function applied extensively to DS level on a component repair and return to user basis.	9. Repair AIDAPS will reduce quantity of components returned for repair by positive diagnosis of component condition.
10. Overhaul Function rarely authorized at the DS level. Exception is the heater fuel solenoid valve for the CH-47.	10. Overhaul AIDAPS usage in a fault isolation mode will permit selected items to be downgraded for overhaul from the GS to the DS level.
11. Rebuild Not applicable to the DS maintenance level.	11. Rebuild No change

TABLE 6-1 (Continued)

D. Direct Support Maintenance Level Detail Functional Comparison (Continued)

Current System	Future System
12. Diagnosis N/A	12. Diagnosis Diagnosis to include component fault isolation using a special MOS trained individual and AIDAPS
13. Prognosis N/A	13. Prognosis Prognosis based on trend analysis by a special MOS trained individual and AIDAPS

TABLE 6-1 (Continued)

C. General Support Ma- -tenance Level Detailed Functional Comparison

Current System	Future System
1. **Inspect** a) Special Inspections b) Test Flights (TBAVN 23-16) c) Standards of Serviceability (-35 Technical Manual)	1. **Inspect** a) Selected GS functions performed by AIDAPS. b) Manual recording of some aircraft instrument values will be accomplished by AIDAPS. c) AIDAPS will permit "on condition" component replacement in lieu of flying hours or calendar period criteria.
2. **Test** Test equipment checkout of selected aircraft components including complete engine assemblies but excluding gear boxes, main transmissions, etc. Example - fuel control unit on CH-47.	2. **Test** AIDAPS diagnostic capability will permit a reduction in initial test stand run requirements on reparable components.
3. **Service** Function at GS level pertains to more sophisticated aircraft components than of DS level, i.e., main fuel manifold filters for CH-47.	3. **Service** AIDAPS diagnostic/prognostic capability will permit elimination of selected servicing functions at the GS level.
4. **Adjust** The adjustment function at the GS level is mainly applicable to adjustment of sophisticated aircraft components using special test equipment.	4. **Adjust** AIDAPS will reduce the quantity of components returned to GS levels of maintenance by positive diagnosis of the component status at lower levels of maintenance.
5. **Align** The alignment function is applicable to components and aircraft repair (requiring a jig) at the GS level of maintenance.	5. **Align** No change
6. **Calibrate** The calibration function is applicable to aircraft components, organic and supported special equipment and GSE at the GS level of maintenance.	6. **Calibrate** No change

TABLE 6-1 (Continued)

C. General Support Maintenance Level Detailed Functional Comparison (Continued)

Current System	Future System
7. **Install** This function is rarely assigned to the GS maintenance level.	7. **Install** No change
8. **Replace** This function normally requires special tools/test equipment at the GS level, i.e., engine inlet housing replacement on the CH-47.	8. **Replace** No change
9. **Repair** This function normally requires high skill levels and special tools/test equipment/material at the GS level, i.e., repair of the engine turbine tail-pipe and inner cone on the CH-47.	9. **Repair** No change
10. **Overhaul** This function comprises the bulk of the GS workload and requires high skill levels, special tools and test equipment.	10. **Overhaul** AIDAPS usage in a fault isolation mode will permit selected items to be downgraded for overhaul from depot to the GS level.
11. **Rebuild** N/A to GS level	11. **Rebuild** No change
12. **Diagnosis** N/A	12. **Diagnosis*** Diagnosis to include wider range (vs. DS) of component fault isolation using AIDAPS
13. **Prognosis** N/A	13. **Prognosis** Prognosis of component failure by trend analysis by AIDAPS

* Diagnosis and prognosis are recommended additions to future MAC's based on AIDAPS capability.

TABLE 6-1 (Continued)

D. Depot Support Maintenance Level Detailed Functional Comparison

Current System	Future System
1. **Inspect** a) Overhaul and retirement schedule on major components is based on flying hour or calendar time criteria. b) Standards of Serviceability	1. **Inspect** a) AIDAPS will permit "on condition" replacement of major components. b) AIDAPS will permit determination of the actual condition of aircraft components thus eliminating arbitrary changeout of major components to meet standards of serviceability.
2. **Test** Test equipment checkout of all aircraft components returned for overhaul or rebuild plus test flights on overhauled/rebuilt aircraft.	2. **Test** AIDAPS identification of component failure will reduce test time of components received at the Depot.
3. **Service** This function is performed at the depot level subsequent to overhaul/rebuild actions.	3. **Service** No change
4. **Adjust** This function is performed at the depot level subsequent to overhaul/rebuild actions	4. **Adjust** No change
5. **Align** Major alignment functions are performed using jigs and special test equipment.	5. **Align** No change
6. **Calibrate** A full range of calibration functions are accomplished to include references to secondary standards.	6. **Calibrate** No change
7. **Install** This function is infrequently assigned by MAC.	7. **Install** No change

TABLE 6-1 (Concluded)

D. Depot Support Maintenance Level Detailed Functional Comparison (Concluded)

Current System	Future System
8. Replace This function at the depot level includes replacement of major structural portions of aircraft.	8. Replace No change
9. Repair Comment 8 above applies.	9. Repair No change
10. Overhaul Primary mission of Army depots is to restore items to a completely serviceable condition as prescribed by maintenance serviceability standards using the IROAN principle.	10. Overhaul No change
11. Rebuild The rebuild function is the second major mission of Army depots. Rebuild actions are normally applicable to critical flight safety aircraft components, i.e., rotor blades.	11. Rebuild No change
12. Diagnosis N/A	12. Diagnosis Diagnosis to facilitate overhaul/rebuild functions using AIDAPS
13. Prognosis N/A	13. Prognosis Prognosis of component failure by trend analysis by AIDAPS

6.2.2 IMPACT ON ARMY MAINTENANCE AND LOGISTIC PROGRAMS

The general purpose of an AIDAP System is to improve the maintainability and supportability of an aircraft. Since this objective is identical to the objectives of the Army programs organized under the Logistic Offensive Program (Section 3.0), the AIDAPS will enhance their overall achievement.

The employment of an AIDAPS will allow more accurate and more detailed information to be gathered. This data, when properly processed, can provide a realistic basis for the studies, actions and decisions involved in these Army programs. In addition, AIDAPS can provide basic information required for experimental and developmental programs for maintenance equipment.

Specifically, AIDAPS is a tool by which many of the objectives of the Army logistics programs can be accomplished. The contributions AIDAPS can make to these program objectives are listed in Table 6-2.

TABLE 6-2 POTENTIAL IMPACT OF AIDAPS
ON ARMY LOGISTIC PROGRAMS

Logistic Program	Impact
Maintenance Assistance Instruction Team (MAIT)	Improved workload allocation provided by data from the AIDAPS printout Positive diagnosis of malfunctions Enhanced repair capabilities at lower maintenance levels
Selective Item Management System (SIMS)	More accurate TAMMS data from AIDAPS printout Provides data usable for updating Maintenance Allocation Charts (MAC) More accurate component repair frequencies More accurate spare parts demand rates
Direct Exchange (DX)	Positive diagnosis of malfunctions Fault isolation below module level More accurate aircraft status reports More accurate stockage predictions Spare parts Fuel (from flight time)
Standard Army Maintenance Reporting and Management Subsystems (SAMRMS)	Better information for MAC updating More accurate TAMMS data and component usage data More accurate reporting of operating time More accurate CS_3 data More accurate aircraft status reports
Maintenance Support Positive (MS+)	Diagnostic/prognostic capability to modular level and below Positive diagnosis Reduced inspection and troubleshooting maintenance man-hour requirements Reduced unwarranted removals Reduced time change removals Reduced aircraft maintenance downtime

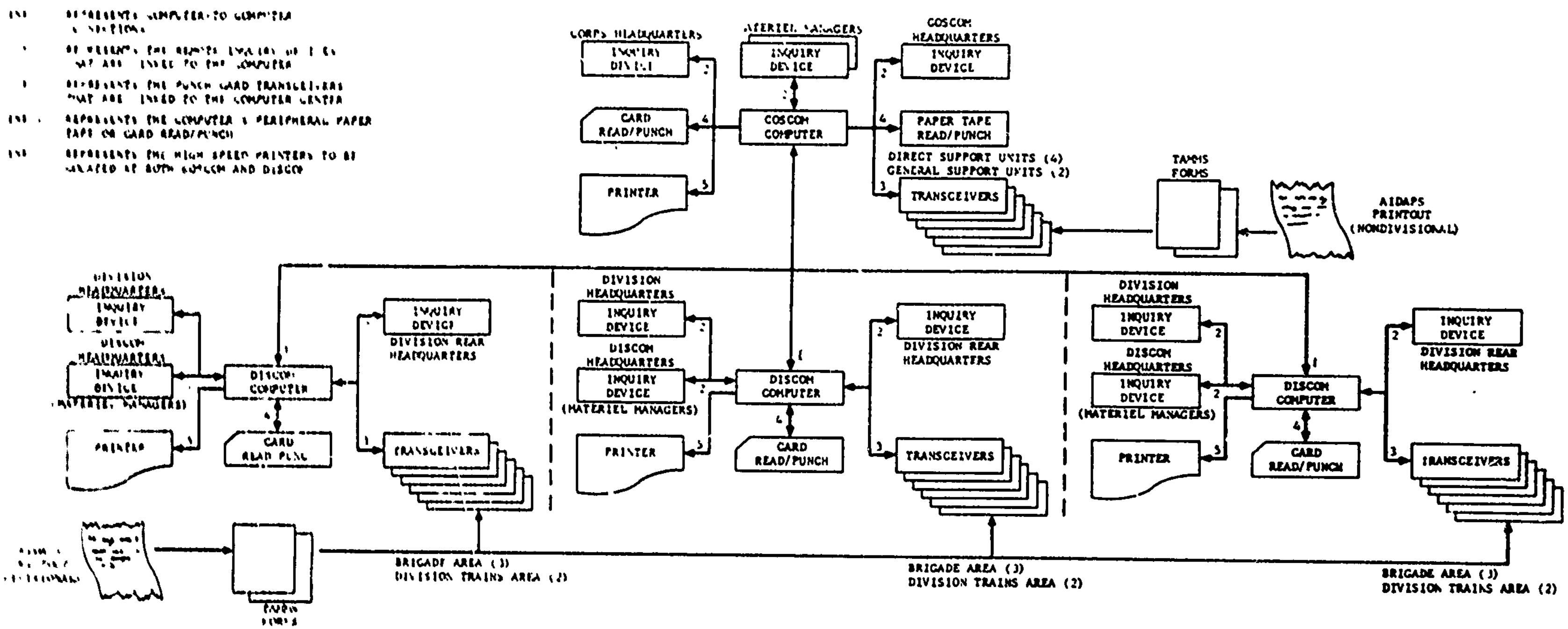


FIGURE 6-3 CS_3 SYSTEM COMMUNICATIONS INTERFACE FOR A THREE-DIVISION CORPS

6.4 AIDAP OPERATIONAL PREFERENCES

This discussion analyzes the major operational factors which affect AIDAP system selection. These factors include the ability to deploy and operate aircraft equipped with alternative AIDAP system candidates. The operational advantages and disadvantages of each AIDAP system are determined by its operational requirements. The major differences due to the operational requirements of the candidate AIDAP system are presented below:

a) The Ground System requires approximately thirty minutes to check out an aircraft.

b) Flight-rated personnel are required by the Ground AIDAPS to put the aircraft in hover. This is in addition to the need to have nonrated persons to operate the AIDAPS.

c) Safety considerations dictate that the aircraft not be raised beyond ground effect and convention limits the hover to about three feet. Under these conditions, since it is presumed the aircraft is not loaded, only about 50 percent of rated power could be drawn. Under such limited loading, there are many engine and transmission malfunctions or degradations which would not be revealed. Examples are malfunctions of the fuel control at rated power, the damage of the compressor, power turbine or nozzles due to previous foreign object damage, abuse, or wear (shown by high gas generator output temperature or abnormal fuel flow at approximately rated power), and wear in the power train. It is not reasonable to assume that an aircraft would be fully loaded before runup and test; i.e., with a reasonable doubt that the aircraft could be dispatched. This is particularly evident if the load consists of personnel.

d) The complete absence of horizontal motion conceals a series of malfunctions or maintenance requirements which involve the aerodynamic surfaces. Examples are low and medium frequency vibrations due to forward air speed over aerodynamic surfaces such as main rotors, stabilizers, tail rotors, etc.

e) If nonrated personnel run up the aircraft, only about 20 percent of rated power could be drawn (AR's prohibit the nonrated man from moving the collective from the down/locked position).

f) Further, if a limited number of AIDAPS are available; weight, balance and safe lift-off (W, B and SLO) can only be performed once per flight-day. This would be of little service in operations involving multiple flights, or those in which the task is to depart home base, land at another location, pick up a load, and deliver that load to a still different location.

The major advantage of the Ground System is its ability to be procured in less numbers than the number of aircraft it services. If one Ground System is procured for five aircraft, a total of 2.5 hours is required to process the AIDAPS daily inspection on all five aircraft. In addition, unscheduled aircraft maintenance during flying activities will require its use.

With the Hybrid II System, the daily inspections can be accomplished without additional aircraft operation. The tape cartridge is simply removed and replaced. The tape is then processed by the ground portion of this system providing accurate diagnostic and prognostic indications of the status of the aircraft. It is estimated that this operation will consume approximately seven minutes. The aircraft will not necessarily be out of service during this time since normal load and unload activities can continue. In addition, rated personnel are not required. The data gathered during the preceding flight provides a much better data base than can be acquired in a ground runup or short duration flight. Weight, balance and safe lift-off calculations cannot be performed with this system.

The Hybrid I System has substantially the same operational characteristics as Hybrid II, except that an onboard status light is provided to indicate the presence of a malfunction, and air safety data is provided to the aircraft warning system.

The Airborne System performs the equivalent of the Hybrid I daily inspections continuously in flight. A prognostic printout is provided at the end of each flight.

Both the Airborne and Hybrid I systems are capable of accomplishing weight and balance and safe lift-off calculations prior to takeoff. In addition, they possess the computational capability for providing safety of flight information to a warning system during flight.

A situation can occur such that the elapsed time for use of any of the systems might be approximately the same. If an aircraft has not been flown for long periods of time, this could result in a special request for a full report on vehicle health which requires a flight just to obtain the information. Under normal circumstances, however, the Airborne or Hybrid I systems would provide this data at liftoff/hover via voice warning to the crew if an incipient failure had occurred in the interim.

Table 6-4 presents a summary of the operational advantages and disadvantages of the alternative systems. The listed environmental factors include Army doctrinal considerations which enable equipment to "live with the troops" under worldwide environmental extremes throughout the conflict intensity spectrum identified under U.S. Army tasks. Further discussion of each item is presented in Table 6-4.

TABLE 6-4 OPERATIONAL COMPATIBILITY TRADEOFF

ARMY ENVIRONMENT FACTOR	AIDAP SYSTEM			
	AIRBORNE	HYBRID I	HYBRID II	GROUND
Deployment	One self-contained system on each aircraft	Airborne portion on each aircraft. One small, portable ground system required for 15 aircraft	Airborne portion on each aircraft. One ground system required for 15 aircraft	One ground system required for 5 aircraft
Employment Light, Noise & Dust Discipline	No additional signatures (Ground testing reduced)	No additional signatures (Ground testing reduced)	No additional signatures (Ground testing reduced)	Generates additional noise, dust & light due to hovering requirements during daily ground tests & troubleshooting
Employment Tactical Dispersion	Effective at all locations	Airborne portion has diagnostic capability. Ground portion can be remote from aircraft location (overnight round trip for tape cartridge) or persed with	Ground portions can be remote from A/C location. Not as effective as Hybrid I because it lacks airborne diagnostics	AIDAP system must be dispersed with aircraft. Most difficult of all to disperse, although possible
Base Dispersion	No affect on AIDAPS test time	Dispersion of aircraft may increase time required for troubleshooting but to small degree	Dispersion of aircraft increases time required for troubleshooting but to much lesser degree than ground based	Dispersion of aircraft increases time required for troubleshooting and inspections

TABLE 6-4 OPERATIONAL COMPATIBILITY TRADEOFF (Concluded)

ARMY ENVIRONMENT FACTOR	AIDAP SYSTEM			
	AIRBORNE	HYBRID I	HYBRID II	GROUND
Usage Serial Processing	No ground runup or hover tests required. No additional aircraft or pilot time is accrued.	No ground runup or hover tests required. No additional aircraft or pilot time is accrued.	No ground runup or hover tests required. No additional aircraft or pilot time is accrued.	Requires pilot to conduct daily hover test. Additional 15 minutes of aircraft operation required for each inspection and diagnostic activity.
Mobility	Good anywhere	Ground portion must be dedicated to 15 individual aircraft for prognostics only. Aircraft can use any ground units for inspections and most diagnosis. Airborne portion contains short term prognosis.	Ground portion must be dedicated to 15 individual aircraft. Air vehicle must land near its designated AIDAP system.	Ground system must be dedicated to 5 individual aircraft. Air vehicle must land near its designated AIDAP system.
Effectiveness	Greatest	Greatest	Reduced because of 1) Low sampling rates 2) Weight & balance instrumentation not practical	Reduced because of 1) Lower operating stresses on aircraft systems 2) Reduced monitoring time 3) Longer time required for tests & inspections 4) Weight & balance instrumentation not practical

6.4.1 DEPLOYMENT

The AIDAPS equipment must be capable of worldwide deployment. Further, the deployment of the AIDAPS equipped aircraft must be enhanced rather than degraded. All AIDAP systems are capable of this deployment, although costs and transportation requirements are somewhat greater for the ground systems because of their size and weight.

6.4.2 LIGHT, NOISE AND DUST DISCIPLINE

The requirements for concealment and dispersion are historical battlefield constraints. The most significant requirement influenced by AIDAPS is the requirement for light, noise and dust discipline. Most operational aircraft are committed to missions or standby status during the day. In addition, they may be committed to selected missions at night, such as battlefield illumination and surveillance, long-range patrol implants and extraction, etc. For this reason, it is desirable to conduct much maintenance during the twilight hours when it is particularly desirable to avoid noise, dust or light signatures. The Ground System requires a daily runup and/or hover for inspection purposes. This is avoided by the other three systems since the data recorded on the previous flight constitutes a better test than can be achieved by ground runups or short duration hovers. This is due to the larger data samples as well as the high system stresses encountered during wartime or peacetime missions. When a ground runup or hover is required, the generation of dust, noise and/or the exposure of light sources at night cannot be eliminated.

6.4.3 TACTICAL DISPERSION

Two modes of dispersion can be considered, one is tactical dispersion wherein the aircraft are deployed to alternate landing areas, the other is base dispersion wherein the aircraft are located on or near a single base which provides the logistic support.

When aircraft are dispersed for extended periods to alternate landing sites, the ground portions of appropriate AIDAPS must likewise be dispersed if it is to fulfill its mission. (Dispersements of a few days do not require the accompaniment of the ground based portion of the Hybrid I System.) In the case of a pure ground based system, the total complement of equipment must be transported. For the hybrid systems only a portion of the hardware needs dispersement. The ground portion of the AIDAPS hardware becomes easier to deploy for Hybrid II and Hybrid I due to the smaller size and weight of the equipment and its inherent increase in portability. The Hybrid I system has a very small, portable unit for display of the information and is the easiest of the three systems to deploy in the field. In addition, only one display per fifteen aircraft is required whereas a ground based system is required for every five aircraft.

For the hybrid systems, an alternative to deploying equipment is to transport the tape cartridges and thus maintain a high degree of effectiveness. The only degradation is the time associated with troubleshooting. Alternatively, the Airborne System maintains full effectiveness at any location. In addition, if a malfunction warning occurs during flight, the air warning provided by the Hybrid I and Airborne systems allows pilots to land at the nearest or most suitable maintenance facilities.

6.4.4 BASE DISPERSION

None of the AIDAP systems have any effect upon the requirement to disperse aircraft around a base for concealment or avoidance of concentrated target areas. However, such dispersal increases the time required to accomplish daily inspections or troubleshooting actions for all AIDAP systems except the airborne system. Dispersal doctrine will, however, be defined by the tactical situation.

6.4.5 USAGE

Although all AIDAP systems reduce the total maintenance requirements of an aircraft, the Ground System requires an additional 15 minutes of aircraft operating time per inspection or troubleshooting action. This is accompanied by the additional aircraft operating cost for this period of time. In addition, rated personnel are required for this test. This increases maintenance scheduling problems, especially under dispersed operating conditions.

6.4.6 MOBILITY

The helicopter has revolutionized battlefield mobility. Combat commanders can now move quickly over and around the battlefield. The ground frontages that an infantry unit can control have been expanded ten-fold. Inherent in tactical or air mobility is a requirement that logistic equipment possesses the same mobility as a tactical unit being supported. All AIDAP systems will enhance aircraft mobility by providing easier maintenance and by improving the ability of the aircraft to operate independently from its support base. However, only the Airborne AIDAP system inherently possesses the same mobility as the aircraft which it services.

The Hybrid I System is only slightly less mobile than the Airborne System as it requires the use of a portable ground display and storage device. The Hybrid II System equipment is larger and less portable. The Ground System, which is designed as normal aerospace ground equipment, is the least portable of the three.

As an alternative, the two hybrid systems can employ transportation of tape cartridges to any AIDAPS equipped field for diagnosis and prognosis. They must, however, be transported to the ground portion dedicated to the particular aircraft for full prognostic capability. The Ground AIDAP System is only as mobile as the aircraft support unit. Either a Ground AIDAPS must be transported to the aircraft or the aircraft must be flown to a Ground System if it is to be used at all. In addition, the prognostic capability as well as some diagnostic capability is only applicable on the five aircraft to which each Ground System is dedicated.

6.5 SUMMARY OF AIDAPS OPERATIONAL PREFERENCES

The ranking of operational desirability of the candidate AIDAP systems is as follows:

a) Airborne System

- Superior in all operational factors considered except deployment.

b) Hybrid I

- Equal to airborne system in usage, light, noise and dust discipline and effectiveness.
- Inferior to airborne system in tactical and base dispersion and mobility.
- Better than the airborne system in deployment.

c) Hybrid II

- Equal to Hybrid I in usage; light, noise and dust discipline, and deployment.
- Inferior to Hybrid I in tactical and base dispersion, mobility and effectiveness.

d) Ground System

- Inferior to all candidate systems in every respect.

SECTION 7

7-1.1

7.0 AIDAPS COST EFFECTIVENESS INPUTS

The assessment of the cost effectiveness of an AIDAP System requires the processing of large amounts of data related to maintenance actions as well as detailed costs. To accurately process this data, three models were developed as shown in Figure 7-1. The AIDAP System Procurement Cost Model develops the AIDAPS hardware development and procurement costs and certain cost factors such as AIDAPS maintenance index and spares requirements. The AIDAPS/Aircraft Maintenance Analysis Model computes the differences in resource requirements between an AIDAPS equipped aircraft and one without AIDAPS. The AIDAP System Cost Benefit Model computes the life cycle costs of the AIDAPS and the savings and benefits due to the reduced aircraft resource requirements. The sum of the cost savings plus the value of the effectiveness benefits less the AIDAPS life cycle cost equals the net benefits. The following discussion describes the basic cost effectiveness relationships used. For a complete model description, see Appendix C.

7.1 AIDAP SYSTEM COST EFFECTIVENESS RELATIONSHIPS

7.1.1 AIDAPS PROCUREMENT COSTS, COST FACTORS AND WEIGHTS

The AIDAPS Procurement Cost Model is used to develop cost factors which are dependent upon hardware characteristics and are used as inputs to the AIDAPS life cycle cost. These factors are divided into two groups, those which show significant variations for different AIDAPS and those which are relatively independent of AIDAPS configuration. These variable and constant cost factors are shown on Figure 7-2.

The configuration dependent cost factors were calculated for the following AIDAPS applications:

AIRCRAFT	UNIQUE AIDAPS	GROUPED AIDAPS	UNIVERSAL AIDAPS
AH-1	Airborne, Hybrid I, Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
CH-47	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid I	Basic Airborne + RDAU Basic Hybrid I + RDAU

AIRCRAFT	UNIQUE AIDAPS	GROUPED AIDAPS	UNIVERSAL AIDAPS
CH-54	Airborne, Hybrid I, Hybrid II, Ground	Group III Airborne Group III Hybrid	Basic Airborne + RDAU Basic Hybrid I + RDAU
OH-6	Airborne, Hybrid I Hybrid II, Ground	Group I Airborne Group I Hybrid I	Basic Airborne Basic Hybrid I
OH-58	Airborne, Hybrid I Hybrid II	Group I Airborne Group I Hybrid I	Basic Airborne Basic Hybrid I
OV-1	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
UH-1	Airborne, Hybrid I Hybrid II, Ground	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
U-21	Airborne, Hybrid I Hybrid II, Groun	Group II Airborne Group II Hybrid I	Basic Airborne Basic Hybrid I
HLH	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid	Basic Airborne + RDAU Basic Hybrid I + RDAU
UTTAS	Airborne, Hybrid I Hybrid II, Ground	Group III Airborne Group III Hybrid	Basic Airborne + RDAU Basic Hybrid I + RDAU

The cost factors for the above systems were computed from the following considerations:

DDTE	-	Comparison with similar programs, particularly the UH-1 Test Bed, and Army Flight Safety System program.
Sensors	-	Detailed list of sensors required plus manufacturers' quotes.
Installation	-	Detailed cost estimate of material and man-hours required using standard cost estimating procedures.
Hardware	-	Comparison with similar programs for similar equipment. Modified by complexity factors associated with each AIDAPS configuration and aircraft application.
Maintenance Index	-	Developed from design reliability figures of similar equipment degraded by field experience.

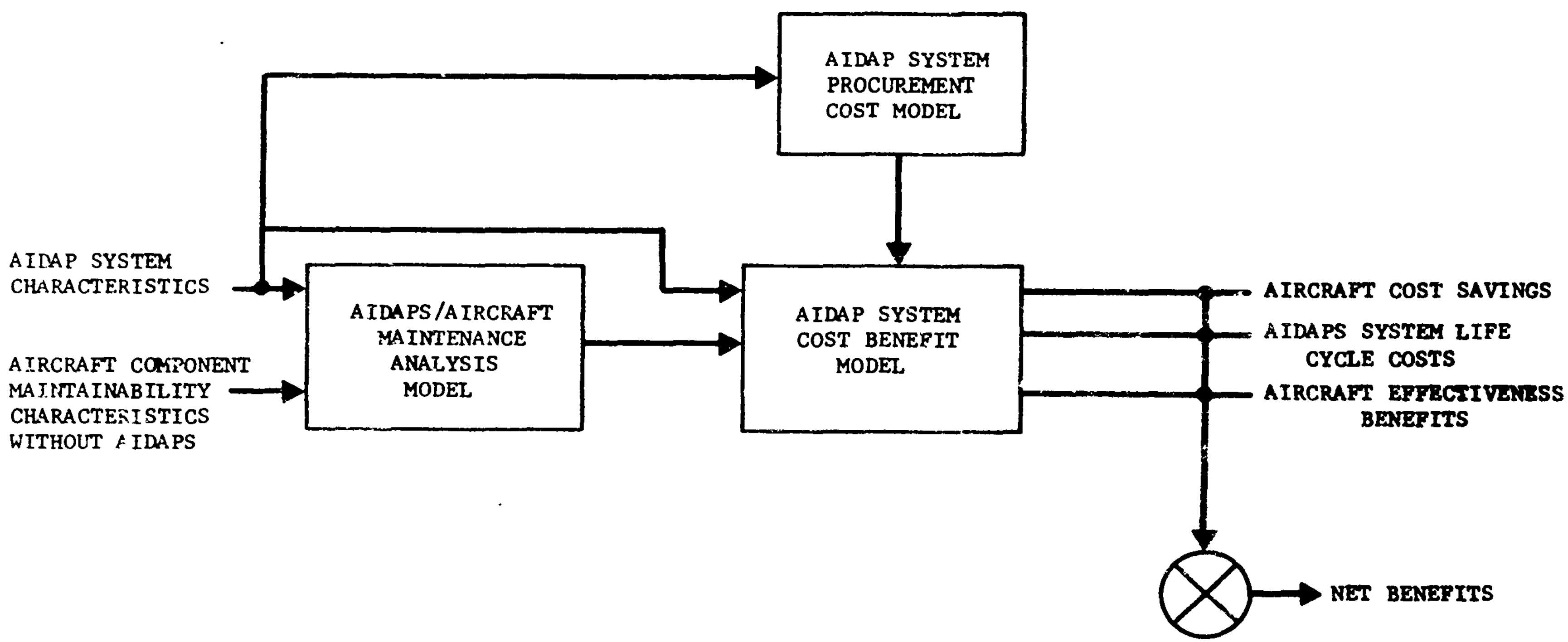


FIGURE 7-1 COST/EFFECTIVENESS MODELS BLOCK DIAGRAM

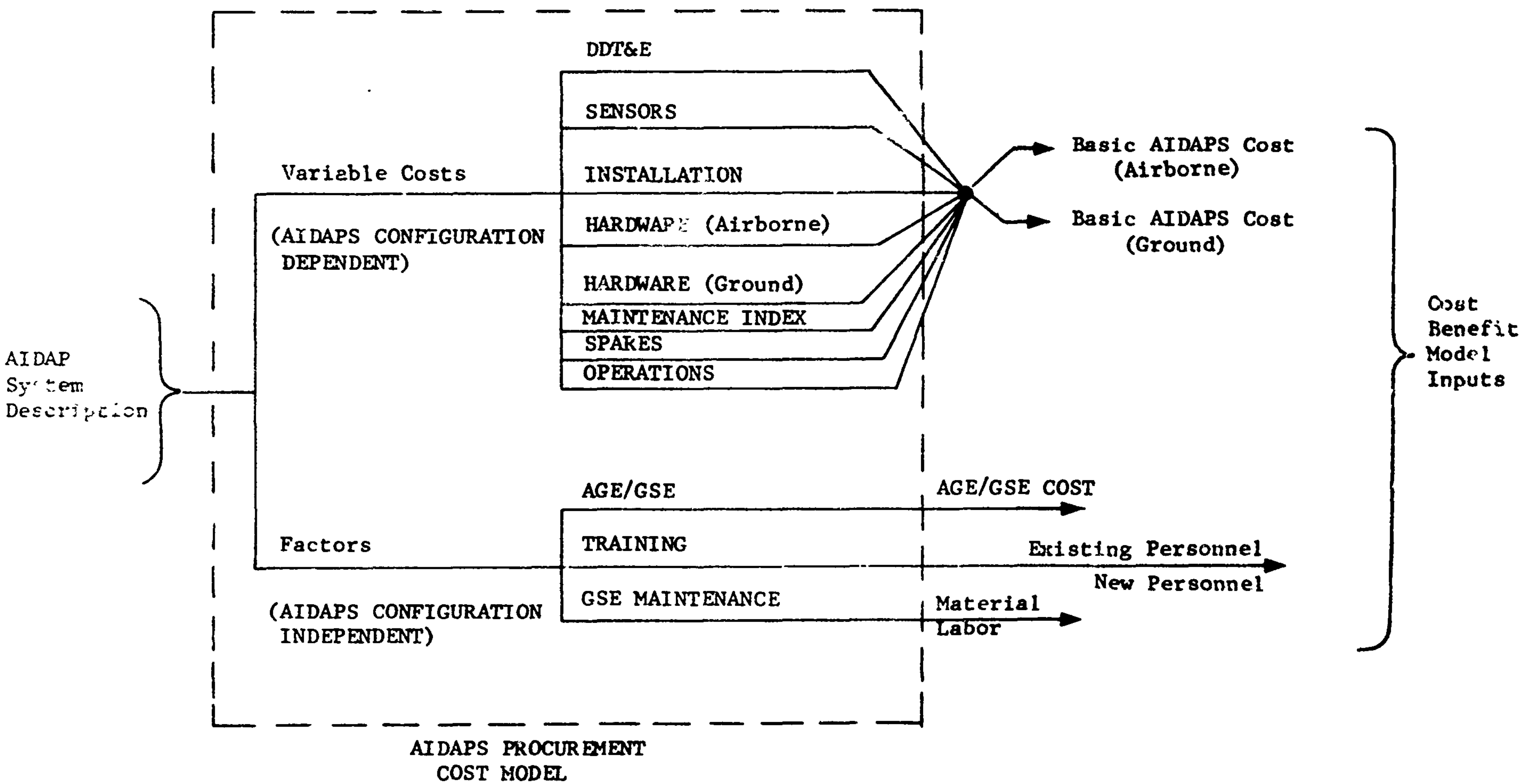


FIGURE 7-2 AIDAPS COST ELEMENT RELATIONSHIPS
(PROCUREMENT COST MODEL)

Spares - Based on maintenance and equipment condemnation rates, 120 days initial supply plus replenishment spares.

Operations - Based on maintenance index and consumables.

For the cost estimates of the AIDAP systems, see paragraph 7.3.

7.1.2 AIDAPS/AIRCRAFT MAINTENANCE ANALYSIS MODEL

This model has the following basic inputs for each maintenance task which is influenced by AIDAPS:

a) Frequency
b) Task duration (time)
c) Number of men required (crew size)
d) Frequency reduction due to AIDAPS
e) Time reduction due to AIDAPS
f) Reduction in number of men required due to AIDAPS

The means by which the maintenance tasks are selected are described in paragraph 7.2, and the input data for all aircraft are contained in Appendix C.

The formulas used for calculating the man-hour savings are shown in Figure 7-3. This figure also shows the particular maintenance parameter, frequency, time, and number of maintenance men which are affected by AIDAPS for each basic maintenance task. An AIDAPS set can reduce the frequency of unwarranted removals and scheduled removals. It is also possible that the frequency of daily, intermediate, and periodic inspections can be reduced. However, since the AIDAPS can only perform a part of these inspections, this study assumed that the only inspection items accomplished by AIDAPS would be eliminated, thus reducing the inspection time but not the frequency. The time required, as well as the number of men required for troubleshooting, also can be reduced. Only one man is required to read the AIDAPS printout, while frequently two or more men are required for conventional troubleshooting. This is particularly true when engine run-up is required.

AIDAPS FUNCTION	MAINTENANCE ACTION	MAINTENANCE PARAMETERS		
		FREQUENCY	TIME	NO. OF MEN
INSPECTION	INSP			
DIAGNOSIS	TROUBLE SHOOTING			
	UNWARRANTED REMOVALS			
PROGNOSIS	SCHEDULED REMOVALS			

AIRCRAFT WITHOUT AIDAPS

FREQ. x TIME x NO. OF MEN = MANHOURS WITHOUT AIDAPS

AIRCRAFT WITH AIDAPS

(FREQ.-DFREQ.)x(TIME - DTIME) x (NO. MEN-DMEN) = MANHOURS WITH AIDAPS EQUALS SAVINGS IN MANHOURS

FIGURE 7-3 MODEL LOGIC RESOURCE CALCULATIONS

In addition to maintenance man-hours, the following maintenance factors (resources) are also affected.

a) Aircraft downtime (availability)

b) Number of LRU's packaged and shipped to higher echelons for benchchecks

c) Number of LRU's packaged and shipped to depot for overhaul

d) Number of aircraft accidents

e) Number of mission aborts

The life cycle value of the reduction in the preceding maintenance factors are computed in the AIDAP System Cost/Benefit Model.

7.1.3 AIDAP SYSTEM COST/BENEFIT MODEL

This model accepts the inputs from the AIDAPS Procurement Cost Model and computes the AIDAPS life cycle cost. The cost elements computed are shown on Table 7-1. It also accepts the resource savings from the AIDAPS/Aircraft Maintenance Analysis Model and computes the aircraft life cycle savings using the same methodology, and same computer program as is used for the AIDAP system life cycle costs. The formulation of the cost elements is described in Appendix C. The cost items affected by the outputs of the AIDAPS/Aircraft Maintenance Analysis Model are shown below:

Resource Saving	Cost Item Affected
Maintenance Man-hours	Personnel Costs
Packaging & Shipping	Logistic Support Costs
Number of Overhauls	Depot Labor & Material
Number of Accidents	Accident Costs

In addition to the actual cost savings, certain aircraft effectiveness parameters are also influenced. These parameters are:

a) Aircraft downtime (availability)

b) Aircraft abort rates

c) Aircraft average payloads

TABLE 7-1 AIDAPS LIFE CYCLE COST ELEMENTS

I. DESIGN, DEVELOPMENT, TEST AND EVALUATION COST AIDAPS II INITIAL INVESTMENT COST AIDAPS AIDAPS SPARES AIRCRAFT/AIDAPS SUPPORT EQUIPMENT PERSONNEL INITIAL SUPPLIES OFFICER TRAINING ENLISTED MAN TRAINING OFFICER TRAVEL ENLISTED MAN TRAVEL OTHER INITIAL INVESTMENT	III. ANNUAL OPERATING COST AIRCRAFT/AIDAPS MAINTENANCE ORGANIZATIONAL (PARTS COSTS) DIRECT SUPPORT (PARTS COSTS) GENERAL SUPPORT (PARTS COSTS) DEPOT (PARTS AND LABOR COSTS) LOGISTIC SUPPORT AIRCRAFT ATTRITION PERSONNEL OFFICER PAY AND ALLOWANCE ENLISTED MAN PAY & ALLOWANCE OFFICER REPLACEMENT ENLISTED MAN REPLACEMENT OFFICER TRAVEL ENLISTED MAN TRAVEL OTHER

The net effect of improvement in these parameters is that they allow the aircraft to successfully deliver more pounds of payload per day. Therefore, the model computes the ratio of the deliverable pounds of payload per day of an aircraft equipped with AIDAPS, to the delivered payload per day of an aircraft without AIDAPS. This ratio is called the relative increase in aircraft effectiveness. The cargo delivery capability of a fleet of aircraft equipped with AIDAPS is increased over a non-AIDAPS-equipped fleet by the same ratio. Therefore, the increase in effectiveness achieved by adding AIDAPS to an aircraft fleet is equivalent to purchasing a quantity of aircraft which provides the same increase in payload delivery. The cost of these additional aircraft is used as the dollar value of the increased aircraft effectiveness. For aircraft which are not cargo carriers, the measure of effectiveness is pounds of armament delivered per day, or range covered per day (fuel).

The formulation of the relative effectiveness is:

$$E_R = \frac{A_{VA}}{A_{VO}} \times \left(\frac{1 - A_A}{1 - A_0}\right) \times \left(\frac{P_0 - R \cdot W_A}{P_0}\right)$$

A_{VA}	=	Aircraft Availability	A_{VO}	=	Aircraft Availability
A_A	=	Aircraft Abort Rate	A_0	=	Aircraft Abort Rate
R	=	Ratio of Missions Which Are Payload Limited to Total Missions	P_0	=	Average Payload
W_A	=	AIDAPS Airborne Weight			

The measure of aircraft reliability used is 1.0 minus the abort rate (per mission). The payload with AIDAPS is the normal payload minus the AIDAPS weight modified by the factor R. This factor is the ratio of the flights which are payload limited to the total number of flights. Not all flights are accomplished at maximum allowable payload. For this study, this ratio was assumed to be 0.5:1. In cases where this factor was significant (OH-6 and OH-58), R was varied from 0.0 to 1.0. Table 7.2 summarizes the model methodology for each AIDAPS capability.

7.2 AIDAPS EFFECTIVENESS

The basic worth of an AIDAPS is found in the elimination of specific maintenance tasks, reduction in man-hours required for specific maintenance tasks, and the reduction in specific air safety hazards. Therefore, the prime focus of this study must be on the detailed maintenance data available from TAMMS and on accident summaries. Particular emphasis is placed on ensuring that a one-for-one correspondence exists between the effects claimed in the AIDAPS effectiveness analysis, the savings and benefits claimed in the cost effectiveness analysis, and the final AIDAPS preliminary design and specification. This should assure that the AIDAPS eventually produced will, in fact, accomplish the intended actions and achieve the estimated savings.

The following paragraphs explain the procedures followed in the effectiveness analysis.

7.2.1 TAMMS MAINTENANCE DATA ANALYSIS

In order to establish the detailed maintenance characteristics for the aircraft being considered in the study, one year of raw TAMMS data in the form of IBM magnetic tapes were acquired on each type, model, and series (TMS) aircraft. These tapes were acquired from the Automatic Data Processing Office, Management Control Branch, AVSCOM; St. Louis, Missouri. These data reflected the maintenance actions reported on DA Forms 2408-3, 2407, and 2410. The following paragraphs describe how the data were processed into a format for use in the AIDAPS study concept. The computer printouts are contained in Appendix E Books 1, 2, 3 and 4.

7.2.1.1 Initial Data Processing

The raw data included all basic card formats associated with an individual maintenance record. In order to accumulate the maintenance data required, the "B" card from DA Form 2408-3, the "4" card from DA Form 2407 and certain

TABLE 7-2 SUMMARY EFFECTS OF AIDAPS ON AIRCRAFT MAINTENANCE OPERATIONS & COSTS

AIDAPS CAPABILITY	MAINTENANCE/ EFFECTIVENESS	COST/BENEFIT FACTOR
INSPECTION	AIRCRAFT INSPECTIONS	
	MAINTENANCE MANHOURS	PERSONNEL COST
	AIRCRAFT DOWN TIME	INCREASED A/C AVAILABILITY
DIAGNOSIS	TROUBLE SHOOTING	
	MAINTENANCE MANHOURS	PERSONNEL COST
	AIRCRAFT DOWN TIME	INCREASED A/C AVAILABILITY
	UNWARRANTED REMOVALS	
	MAINTENANCE MANHOURS	PERSONNEL COST
	BENCH CHECKS	PERSONNEL COST
	PACKAGING & SHIPPING	LOGISTIC COSTS
	AIRCRAFT DOWN TIME	INCREASED A/C AVAILABILITY
	COMPONENT HAZARD	A/C ATTRITION & ACCIDENT REPAIR
PROGNOSIS	SCHEDULED REMOVALS	
	MAINTENANCE MANHOURS	PERSONNEL
	AIRCRAFT DOWNTIME	A/C AVAILABILITY
	COMPONENT OVERHAULS	OVERHAUL COSTS
	PACKAGING & SHIPPING	LOGISTICS COSTS
	ABORT RATE	INCREASED EFFECTIVENESS
	COMPONENT ACCIDENT RATES	A/C ATTRITION AND ACCIDENT REPAIR

pertinent maintenance data from the 370 character DA Form 2410 were extracted from the raw TAMMS data. These data were transcribed into a standardized data format to allow compilation of the data on a common basis. In addition, all identically reported individual records were summarized to a single record with the reported units and man-hours summed to reduce the number of records to be processed.

In accordance with procedures outlined in TM 38-750, only certain maintenance activities associated with a specific identifiable component require identification of the component by its federal stock number (FSN) or its manufacturer's part number. However, in order to accumulate the total maintenance history against a particular component, all other maintenance activities require this component identification. Since the data were accumulated over an extensive period of time, a number of different Federal Stock Numbers (FSN) were used to identify a single component type because of product improvement, different manufacturers, etc. Also included in the data base were maintenance actions containing erroneous FSN's. To correct these three conditions, two procedures were used depending upon the number of data records received for a specific type, model, and series aircraft.

7.2.1.2 Records Without a Reported FSN

All data records, regardless of record count, not containing a FSN were punched onto standard IBM key punch cards. Using the nomenclature as a guide, these records were matched to data with FSN's and the appropriately identified FSN was manually added to these records. System codes were developed to allow accumulation of the reported maintenance data that could not be identified to a specified component. A miscellaneous service code was added for those records which could not be identified, even to a system level. This was accomplished in order to retain all reported maintenance labor performed on a particular type, model, series (TMS) aircraft.

7.2.1.3 Components With Several Reported FSN's

Maintenance records were punched onto standard IBM key punch cards for those components with maintenance records which were within the capability of of manual processing. The appropriate -35P's manuals (Direct Support, General Support and Depot parts) were consulted to acquire the most recently valid FSN being used. All other reported FSN's for the same component were then manually changed to this FSN to allow development of the total maintenance history for this component.

For TMS aircraft with a large amount of reported maintenance records, a single IBM card was punched with the reported FSN; the valid FSN was then manually added to this card. Correction of the reported FSN to the valid FSN was then accomplished through use of a conversion program written for the IBM 360 computer.

7.2.1.4 Records With Erroneous Reported FSN's

These records were punched either in their entirety, or as a conversion card depending on total record count. If the nomenclature could be identified to a valid FSN, this FSN was manually added to the card or cards. If the record could not be identified to a specific FSN, it was identified to the Federal Stock Class (FSC) as reported, or to the system code if identifiable to that level by the reported nomenclature.

7.2.1.5 DA Form 2410 Records

A number of records existed for a specific maintenance action, depending on the level of repair and the number of copies of the basic 2410 Form that may have been transmitted to the TAMMS data center. For this reason, the Form 2410 document control number was used to identify the occurrence of a maintenance activity. Pertinent data from each of the various records containing the same document control number were then transcribed to a single record. This procedure was accomplished through use of a computer program. A survey of these composite DA Form 2410 records revealed that man-hour requirements had not been included, and that action taken codes and/or malfunction codes were missing in different proportions from many of them. It was therefore necessary to transcribe these records onto IBM key punch cards for corrections and additions. The percentage of action taken code to the total number reported was determined. Each type of reported action taken code was then manually added to the remaining records in this same proportion. An estimate in man-hours for each action taken category was determined based on previous experience on like components, personal knowledge or similarity to other components with a known maintenance history. These man-hour values were also manually added to the punched cards. No attempt was made to add failure codes to the records without such codes, as there was no justifiably valid manner to make such corrections.

7.2.1.6 Depot Level Maintenance Requirements

To satisfy the basic maintenance data requirements of the AIDAPS study, it was necessary to extract depot level requirements from the total maintenance data base. This was accomplished by using the Directory of Authorized Support Organizations to identify specific depot codes. The maintenance data identified with these codes were extracted from the DA Form 2407 data. A similar procedure was used with the DA Form 2410 data; however, these data did not, in all cases, contain the organizations associated with the maintenance recorded. In these cases, the Maintenance Allocation Charts (MAC) were consulted to determine, by reported component, which maintenance activities involved depot participation. By using the action taken codes, depot level requirements were identified and manually coded on the key punch card. These depot cards were separately accumulated and removed from the basic maintenance data base to allow development of the maintenance requirements consistent with the maintenance levels identified in FM 101-20.

7.2.1.7 Man-Hour Per Flight Hour (MH/FH) Determination

With the maintenance data base for each TMS aircraft completed, the maintenance analysis computer program was exercised using the aircraft flight hours reported for the data time period. Initial results reflected MH/FH values lower than what should normally be expected. An aircraft serial number count indicated fewer aircraft than were reflected with the reported flight hours. As a result, a computer program was developed which extracted the flight hours associated with the basic DA Form 2408-3 records. This was accomplished by taking the first reported record and the last reported record for each aircraft and determining the individual aircraft cumulative flight hours.

In addition, a maintenance record count was made by aircraft serial number. The number of records reported and the total flight hours were compared for each aircraft. In those instances where the number of reported records indicated incomplete maintenance data, based on the reported flight hours for the same aircraft, the flight hours were ignored but the maintenance data was retained because the negligible bias to the data base did not justify the effort involved to extract the data. The adjusted flight hours were then summed for all legitimate aircraft serial numbers and used as the flight hour base for the maintenance data assembled. The resulting direct man-hours per flight hour obtained compared favorably with those published in FM 101-20.

7.2.2 UNSCHEDULED MAINTENANCE

An AIDAP system has the capability of inspecting an aircraft, either on the ground or in the air, of diagnosiing the status of the aircraft systems and components, and of predicting the remaining time to failure of systems and/or components (prognosis).

To determine the impact of these capabilities upon maintenance, a detailed analysis of maintenance data is necessary. This analysis is conducted in three major steps:

a) Candidate components for monitoring are selected from rank ordered component lists.

b) The detailed maintenance records are examined for maintenance actions which can be affected by AIDAPS and appropriate data transcribed to the work sheets.

c) The results of the examination are transferred from the work sheets to the computer input format sheets.

7.2.2.1 Candidate Components

Table 7-3 shows a portion of a listing of CH-54A components and general aircraft maintenance actions rank ordered by maintenance man-hours. Similar listings are available with the components rank ordered by maintenance frequency and job average. Job average is the average number of man-hours consumed per maintenance action.

TABLE 7-3 RANK ORDER LIST

CH-54A

MANHOURS PER 1000 FLT HOURS

1970 DATA

(ORG,36,AND 65)

RANK	WUC	TITLE	MAINT RATE	JOB AVERAGE	MH/1000FH
1	A 03100	PMD	371.49561	12.7	4715.57422
2	C 03400	PMP	18.72950	181.1	3391.49844
3	B 03300	PMC	50.50280	36.4	1890.52319
4	04 16150426277	MAIN ROTOR BLADE	55.63076	11.9	664.41102
5	03 20400042461	ENGINE	34.90822	17.7	617.91000
6	04 16151154750	TAIL ROTOR BLADE	49.00491	8.3	409.69991
7	04 16151790164	MAIN ROTOR HEAD ASSY	9.09400	40.7	369.82642
8	01 11100	AIRFRAME REPAIR	64.30957	5.2	332.42163
9	K 04500	MISC SERVICES	54.33600	5.6	304.52490
10	04 16150750395	SERVO	11.02076	25.7	283.20662
11	04 16150636065	MAIN GEAR BOX	14.44468	15.0	217.31210
12	I 04300	INITIAL INSPECTION	93.03493	2.0	188.35747
13	J 04400	FINAL INSPECTION	94.90691	1.5	138.02638
14	18 28390314775	APP ENGINE	2.24495	51.2	114.94746
15	D 03500	INSPECTION KIT	3.74492	29.5	110.63556
16	04 16150092371	ROTARY DAMPER ASSEMBLY	9.62979	10.8	103.78770
17	04 16150157142	CLUTCH	10.59277	9.2	97.75302
18	F 04100	TECH BULLETIN COMPLIANCE	14.33768	6.5	92.88966
19	04 16150024001	TAIL ROTOR GEAR BOX	4.27991	21.3	91.01212
20	01 11000	AIRFRAME	35.84421	2.4	87.73790
21	04 16150524364	TAIL ROTOR HEAD ASSY	4.49390	16.5	74.33122
22	E 04000	AIRCRAFT CLEANING	4.70790	15.5	72.99377
23	04 14000	TRANSMISSION/ROTOR SYS	4.92189	14.7	72.15916
24	01 15600569222	DOOR	27.07040	2.4	64.07016
25	17 16000200050	CARGO HOOK	12.19773	4.8	58.12108
26	10 15605569222	FUEL CELL	33.70425	1.6	54.16220
27	11 66158290443	AFCS SERVO CYLINDER	2.24695	24.1	54.09519
28	03 20401074675	TAIL PIPE ASSY	12.94671	3.8	49.32508
29	04 16159846034	DAMPER BEARING	7.38284	6.0	44.31859
30	17 16000195277	HOIST CABLE	4.17291	10.2	42.37106
31	17 15608410468	HOIST	3.53092	10.8	37.90416
32	01 57295283303	RIVET	74.79135	0.5	35.42690
33	17 16009368502	CARGO HOOK RING ASSY	9.84378	3.4	33.42606
34	09 59750742072	STRAPS	69.76245	0.5	32.58078
35	06 16507854497	PUMP HYD	3.67087	5.5	30.99416
36	11 47100	CABLE	6.84789	4.4	30.37659
37	03 29159283906	FUEL CONTROL	3.10293	9.5	29.52063
38	18 16151908544	APP CLUTCH ASSY	3.10293	9.0	28.02266
39	03 28409577064	ENGINE EXHAUST DUCT	4.17291	6.5	27.24150
40	04 16150879047	ROTOR BRAKE SEAL	3.53092	7.7	27.24159
41	18 23100	APP SYSTEM	4.60090	5.8	25.63170
42	06 16159046169	INTERMEDIATE GEAR BOX	3.95391	6.6	25.90831
43	03 29451150730	PARTICLE SEPARATOR	1.60496	16.2	25.94691
44	01 11110	NUT	28.08936	0.9	25.25145
45	04 16158519154	ROTOR BRAKE PACKAGE	7.38284	3.4	25.06953
46	17 16000785215	DECOUPLER	2.99593	8.3	24.71645
47	19 58269559172	ADF AN/ARN 83	5.45688	4.3	23.43246
48	10 29158024356	FUEL FILTER	23.86047	1.0	23.35757
49	03 29959145940	CABLE	11.55575	2.0	23.33617
50	03 29958940707	BIAS CABLE	1.60496	13.8	22.14850
51	09 61407532252	BATTERY	8.66081	2.4	20.66122
52	11 47000	FLIGHT CONTROL SYSTEM	3.20993	6.4	20.56493
53	04 16808341457	TAIL ROTOR CABLE	3.42392	5.6	19.13116
54	02 16208526600	STRUT MAIN	2.46095	7.7	19.04447
55	09 59351251005	CANNON PLUG	10.91376	1.7	19.04556
56	09 61495786606	WIRE	12.62572	1.4	18.29659
57	04 14100	ROTOR	3.10293	5.6	17.40851
58	06 45000	HYDRAULIC SYSTEM	6.84785	2.5	17.34430
59	18 64306010011	APP START SYSTEM	0.96298	17.5	16.85213
60	09 42100	WIRE	7.48983	2.2	16.78792
61	09 42000	ELECTRICAL SYSTEM	6.74085	2.5	16.54102
62	04 53308108505	O RING PACKING	3.20993	5.1	16.34923
63	04 16158354879	MAIN ROTOR TIP CAP	9.95078	1.6	16.30043
64	06 47308245269	COUPLING	1.60496	10.1	16.26364
65	02 16309935313	BRAKE LINING	10.43577	1.5	15.71795
66	04 16159830066	OIL PUMP	1.49797	10.2	15.27926
67	03 23000	POWERPLANT SYSTEM	5.13589	2.9	15.05455
68	04 16158515304	DRIVE SHAFT	4.17291	3.6	15.02246
69	01 11140	BOLTS	21.72052	0.7	15.01176
70	03 29451150725	EAPS	3.74492	3.9	14.49818
71	19 63000	AVIONICS SYSTEM	5.99187	2.4	14.27348
72	01 15600212730	WINDOW	3.53092	4.0	14.24138
73	03 28409104919	SHAFT	1.92596	7.4	14.23068
74	02 15608346522	STRUT NOSE	2.24695	6.0	13.41750
75	19 58210823927	UHF AN/ARC-51	3.95891	3.4	13.28910
76	01 15608426003	HORIZONTAL STABILIZER	2.24695	5.9	13.21420
77	03 28409171954	TURBINE ASSEMBLY	0.32099	40.1	12.87164
78	04 30308800478	OIL COOLER V-BELT	6.31286	2.0	12.58292
79	04 16158368578	DROOP RESTRAINER	4.38690	2.9	12.54012
80	06 45100	HOSE ASSY	12.19773	1.0	12.35823
81	03 53305857864	O RING PACKING	13.90969	0.9	12.09073
82	11 29958419555	COLLECTIVE PITCH	2.99593	4.0	11.99443
83	04 16159893752	ROTOR BRAKE SEAL	2.24695	5.1	11.44875
84	04 53309359259	PACKING	2.56794	4.4	11.38454
85	03 15600693395	CYLINDER	1.17657	9.5	11.12776

The candidate components are coded onto a computer input format sheet (see Table 7-4), along with their Federal Stock Number, and are assigned a J and K index which is used by the computer to identify each component. The J index is the functional group to which the component belongs, and the K index is arbitrarily assigned.

Table 7-5 shows an example of the detailed printout of the CH-54 engine maintenance data. It shows the maintenance rate per 1000 flying hours for each type of maintenance action, the man-hours expended per 1000 flying hours for each maintenance action, "INDEX", the average man-hours per action (job average) "AVG", and the percentage of total actions due to a particular type of malfunction. The actions which can be substantially eliminated by AIDAPS are circled, and those which can be reduced are marked with an X.

The primary benefits of AIDAPS are:

a) Reduction or elimination of "Unwarranted Removals" coded as "No Defect." These codes are found under Remove/Replace, A, L and R. "No Defect Removals" are considered unwarranted removals.

b) Elimination of Scheduled Removals "SR". Incorporation of "On Condition Maintenance" will eliminate the necessity of periodic removals for overhaul or inspections. "No Defect--Removed Time" and "No Defect Rmvd Scheduled" are considered scheduled removals.

c) Reduction of the incidence of airborne failures. Specifically, failure codes such as Flameout, Slow Acceleration, Surged, Internal Failure, Bearing Failure, Seized, Burned and Overheats, can be reduced by an estimated overall 10 percent. The sum of these codes under Code A is 0.128 and 10 percent thereof is .013. This is summed with the Unwarranted Removals.

d) The reduction or elimination of the "On Aircraft" tests and checks. These actions are listed under "Checked" and "Tested (J)" and the "Checked, Service (P)" subcodes thereunder. Additional diagnostic time can be found under the item "Checked, Serviceable (Code A)." This code is a shop code, so the job average is inserted into Table 7-7 under MHBC (bench check).

TABLE 7-4 AIRCRAFT DESCRIPTION NOMENCLATURE CARD

J	K	NOMENCLATURE	FED. STK NO.
02	2	BRAKE LINING	16309935313
02	3	NOSE STRUT	15608346522
02	4	WHEEL	16300874080
02	5	BRAKE ASSY	16309348410
02	6	MAIN LANDING WHEEL	16308778003
02	7	MAIN TIRE	26208346673
02	8	MAIN GEAR ASSY	16208256688
02	9	LINING	16300119085
02	10	WHEEL BRAKE CYLINDER	16208518911
03	1	ENGINE	28409042461
03	2	TAIL PIPE ASSY	28401074675
03	3	FUEL CONTROL	29159283906
03	4	ENGINE EXHAUST DUCT	28409577064
03	5	PARTICLE SEPARATOR	29451150730
03	6	POWER PLANT SYSTEM	23000
03	7	EAPS	29451150725
03	8	SHAFT	28409184919
03	9	LOAD CELL	66209974726
03	10	ENGINE ACCESS DRIVE	28402369728
03	11	ANTI ICING VALVE	29959929408
03	12	FLEX SHAFT	29959034505
03	13	IGNITER PLUG	29254744990
03	14	STARTER	29959070360

TABLE 7-5 DETAILED MAINTENANCE PRINTOUT

CH-54A
MANHOURS PER 1000 FLT HOURS
1970 DATA
(ORG,DS,AND GS)

28409842461
ENGINE

ACTION	RATE/1000	MH/MX	AVG	MALFUNCTIONS-PERCENT					
REMOVE/REPLACE	11.9037	240.4022	20.1						
REMOVE/REPLACE (A)	7.5968	202.4180	26.6	SR NO DEFECT-RMVD TIME	0.065	WORK EXCESSIVELY	UR 0.016	SEIZED	0.016
				NOT LISTED	0.016	NO DEFECT	[illegible]	CRACKED	0.177
				X FLAME-OUT	0.032	LEAKING	0.032	BROKEN	0.113
				INTERMITTENT	0.016	FOREIGN OBJECT DAMAG	0.065	BURNED	0.016
				SLOW ACCELERATION	0.016	~~B PLUS INCORRECT~~	~~0.020~~	NOISY	0.016
				MECHANICAL BINDING	0.016	INTERNAL FAILURE	0.065	OVERHEATS	0.048
				UR NO DEFECT-RMVD SCHED	0.016	BEARING FAILURE	0.016	OUT OF ADJUSTMENT	0.016
				X SURGED	0.016	VIBRATION EXCESSIVE	0.016	MISSING	0.016
				~~[illegible]~~	~~[illegible]~~	CHIPPED	0.016	NO DEFCT FACLTE MAIN	0.016
				X HOT START	UR 0.016				
REMOVE/REINSTALL(L)	4.1729	36.0047	8.6	NO DEFECT-RMVD SCHED	0.296	OIL LEAK	UR 0.037	NO DEFCT FACLTE MAIN	0.185
				WORK EXCESSIVELY	0.037	NO DEFECT	0.222	~~CAPACITANCE INCORREC~~	~~[illegible]~~
				BURST	0.037	OVERLUBRICATED	0.037	BROKEN	0.037
				ENG RMVD EXCESS MAIN	0.037	SCHEDULED MAINTENANC	0.037 UR		
REMOVE (R)	0.1070	1.9260	18.0	ENG RMVD EXCESS MAIN	1.000				
INSTALLED (S)	0.1070	0.0535	0.3	MISSING	1.000				
CHECKED	3.7449	105.6922	28.2						
TESTED (J)	TS 0.3210	1.0914	3.4	NO DEFECT	1.000				
CHECKED-SERVICE (P)	0.9730	10.3253	10.7	NO DEFECT	0.667	LEAKING	0.111	WITHIN SPCFD TOLERNC	0.111
				INCORRECT MODULATION	0.111				
CHECKED,NRTS (M)	0.1070	0.1070	1.0	LEAKING	1.000				
CHECKED,NOT REP. (N)	*								
SERVICEABLE (4)	TS [illegible]539	94.1686	40.0	NOT LISTED	0.182	NO DEFECT RMVD TRBSH	0.045	CANNIBALIZATION	0.409
				NO DEFECT	0.227	NO DEFCT FACLTE MAIN	0.136		
NRTS-NOT AUTHRZD(1)	*								
NRTS-LACK EQUIP(2)	*								
NRTS-LACK SKILLS(3)	*								
NRTS-LACK OF PART(4)	*								
NRTS-BACKLOG(5)	*								
NRTS-LACK OF DATA(6)	*								
NRTS-EXESS(7)	*								
NRTS-NOT USED(8)	*								
NRTS-CONDEMNED(9)	*								
UNKNOWN (X)	*								
REPAIR	15.8357	257.4041	16.3						
ADJUSTED (B)	7.8108	24.7913	3.2	IMPROPERLY-INSTALLED	0.045	LEAKING	0.045	ADJUSTMENT, IMPROPER	0.159
				RPM TOO LOW	0.023	NOT LISTED	0.045	OUT OF ADJUSTMENT	0.409
				LOOSE BOLT,NUT,SCREW	0.023	NOT LISTED	0.023	IMPROPERLY-MACHINED	0.023
				SURGED	0.023	LOOSE	0.045	WORK EXCESSIVELY	0.023
				CHAFED	0.023	DELAMINATED	0.068	TORQUE INCORRECT	0.023
REPAIRED (C)	5.0289	34.7314	6.9	CRACKED	0.250	FOREIGN OBJECT DAMAG	0.107	GROOVED	0.036
				BROKEN	0.107	CUT	0.036	NICKED	0.036
				BRITTLE	0.036	NO DEFECT	0.071	BRKN/MSSNG WIRE/KEY	0.036
				STRIPPED	0.036	NO DEFECT-RMVD TIME	0.036	OIL LEAK	0.036
				NO DEFECT-RMVD SCHED	0.036	SURGED	0.071	MISSING	0.036
				LEAKING	0.036				
CALIBRATED (D)	*								
REPAIRED(8)	2.4609	196.8757	80.0	BROKEN	0.087	NOT LISTED	0.174	X HOT START	0.087
				INTERNAL FAILURE	0.087	LEAKING	0.087	OIL CONSUMPTN EXESSV	0.043
				OIL LEAK	0.043	FOREIGN OBJECT DAMAG	0.043	X OVERSPEED	0.043
				VIBRATION EXCESSIVE	0.043	NOT LISTED	0.043	FAIL CAUSD OTHR COMP	0.043
				X SEIZED	0.043	X HEAT DAMAGE	0.043	NOT LISTED	0.043
				CHIPPED	0.043				
REBUILT(O)	*								
MISCELLANEOUS	0.5350	1.0058	1.9	NO DEFECT	0.750	NOT LISTED	0.250		
SERVICES	3.4239	14.4126	4.2						
SERVICES (E)	3.4239	14.4126	4.2	WRONG PART	0.042	NO DEFECT	0.250	BROKEN	0.083
				CORRODED	0.042	LEAKING	0.083	LOOSE	0.042
				CRACKED	0.042	POOR BINDING	0.042	DIRTY	0.042
				SCHEDULED MAINTENANC	0.083	SURGED	0.042	CRASH DAMAGE	0.042
				NOT LISTED	0.125	OUT OF ADJUSTMENT	0.042		
OVERHAULED	0.0	0.0	0.0						
OVERHAULED (C)	*								
COMPONENT TOTAL	34.9482	617.9109	17.7	NO DEFECT-RMVD TIME	0.020	WORK EXCESSIVELY	0.012	SEIZED	0.008
				NOT LISTED	0.008	NO DEFECT	0.149	CRACKED	0.076
				IMPROPERLY-INSTALLED	0.008	LEAKING	0.044	NO DEFECT-RMVD SCHED	0.040
				WRONG PART	0.004	BROKEN	0.060	FOREIGN OBJECT DAMAG	0.032
				CORRODED	0.004	GROOVED	0.004	LOOSE	0.012
				ADJUSTMENT, IMPROPER	0.028	MISSING	0.012	CUT	0.004
				OIL LEAK	0.012	NO DEFCT FACLTE MAIN	0.036	FLAME-OUT	0.008
				RPM TOO LOW	0.004	NOT LISTED	0.008	OUT OF ADJUSTMENT	0.080
				NICKED	0.004	LOOSE BOLT,NUT,SCREW	0.004	INTERMITTENT	0.004
				BURNED	0.004	POOR BINDING	0.004	BRITTLE	0.004
				SLOW ACCELERATION	0.004	B PLUS INCORRECT	0.004	NOT LISTED	0.004
				ENG RMVD EXCESS MAIN	0.008	BRKN/MSSNG WIRE/KEY	0.004	NOT LISTED	0.048
				NOISY	0.004	MECHANICAL BINDING	0.004	INTERNAL FAILURE	0.024
				STRIPPED	0.004	OVERHEATS	0.012	WITHIN SPCFD TOLERNC	0.004
				DIRTY	0.004	HOT START	0.012	OIL CONSUMPTN EXESSV	0.004
				BEARING FAILURE	0.004	IMPROPERLY-MACHINED	0.004	OVERSPEED	0.004
				NO DEFECT RMVD TRBSH	0.004	SURGED	0.020	CAPACITANCE INCORREC	0.004
				SCHEDULED MAINTENANC	0.012	VIBRATION EXCESSIVE	0.008	CANNIBALIZATION	0.036
				FAIL CAUSD OTHR COMP	0.004	CHAFED	0.004	INCORRECT MODULATION	0.004
				DELAMINATED	0.012	TORQUE INCORRECT	0.004	CRASH DAMAGE	0.004
				BURST	0.004	OVERLUBRICATED	0.004	HIGH VSWR	0.004
				CHIPPED	0.008	HEAT DAMAGE	0.004	NOT LISTED	0.004

31 % ADDED TO DIAG. TO ACCOUNT FOR INSPECTIONS

Additional maintenance which can be prevented (unwarranted removal) can be found in the repair activities, specifically, under the action "Repaired (B)." The items indicated by an "X" will be reduced by AIDAPS an estimated 10 percent.

No defect actions reported under miscellaneous and services are not included because they usually refer to general maintenance activities such as oiling, greasing, visual inspections, etc., upon which AIDAPS will have little or no effect.

Additional diagnostic time is consumed when an aircraft is transferred from one organization to another. These actions are usually coded "Incoming Inspections" and are not segregated by malfunctioning systems. For the CH-54A, approximately 3.1% of the total component caused maintenance actions are of this nature. Therefore, 3.1% of the total component maintenance rate can be attributed to diagnostic actions.

The remaining portion of the maintenance tasks are to be found on the computer listing for the depot for the same part--in this case, Table 7-6. This table indicates that 32.1% of the items sent to the depot were scheduled maintenance items which AIDAPS would reduce.

The items circled on the illustration of Table 7-5 and 7-6 are recorded on a work sheet (Table 7-7). One entry is made for each of the action codes and AIDAPS effect that is coded Scheduled Removal, Unwarranted Removal or Diagnostic. In addition, for each type of maintenance action, the maintenance rate is recorded in the column labeled "Maintenance Rate, MR," and the work average is recorded in column "MHRR" for unwarranted removals and scheduled removals, or column "MHTS" for diagnostic items. For example, the code for the maintenance action as reported in Table 7-5 is written in the first column. The indicators of the system and component, the name of the component, and the Federal Stock Number of the component are placed in columns 2 through 5, respectively. Column 6 contains an abbreviation of the type of maintennace action. Column 7 contains the maintenance rate for that maintenance action. Columns 8,9,10 and 11 contain the total percentages of the maintenance action which can be attributed to scheduled removals, unwarranted removals, diagnostic actions or inspections, respectively.

TABLE 7-6 DEPOT MAINTENANCE PRINTOUT

1979 DATA
(DEPOT)

2840904Z461
ENGINE

ACTION	RATE/1000	INDEX	AVG	MALFUNCTIONS-PERCENT					
REMOVE/REPLACE	0.0	0.0	0.0						
REMOVE/REPLACE (A)	*								
REMOVE/REINSTALL(L)	*								
REMOVE (R)	*								
INSTALLED (S)	*								
CHECKED	0.4280	15.4077	36.0						
TESTED (J)	*								
CHECKED,SERVICE (P)	*								
CHECKED,NRTS (R)	*								
CHECKED,NOT REP. (N)	*								
SERVICEABLE (4)	0.3210	12.8397	40.0	NOT LISTED	1.000				
NRTS-NOT AUTHRZD(1)	*								
NRTS-LACK EQUIP(2)	*								
NRTS-LACK SKILLS(3)	*								
NRTS-LACK OF PART(4)	*								
NRTS-BACKLOG(5)	*								
NRTS-LACK OF DATA(6)	*								
NRTS-EXESS(7)	*								
NRTS-NOT USED(8)	*								
NRTS-CONDEMNED(9)	0.1070	2.5679	24.0	NOT LISTED	1.000				
UNKNOWN (X)	*								
REPAIR	0.2140	17.1196	80.0						
ADJUSTED (B)	*								
REPAIRED (C)	*								
CALIBRATED (D)	*								
REPAIRED(B)	0.2140	17.1196	80.0	LEAKING	0.500	INTERNAL FAILURE	0.500		
REBUILT(D)	*								
MISCELLANEOUS	*								
SERVICES	0.0	0.0	0.0						
SERVICES (E)	*								
OVERHAULED	5.6705	907.3398	160.0						
OVERHAULED (C)	5.6705	907.3398	160.0	CRASH DAMAGE	0.038	NOT LISTED	0.245	OIL LEAK	0.019
				CRACKED	0.094	NO DEFECT-RMVD TIME	0.302	WORK EXCESSIVELY	0.038
				HOT START	0.019	LEAKING	0.019	CONTAMINATION	0.019
				FOREIGN OBJECT DAMAG	0.132	SCHEDULED MAINTENANC	0.019	BATTLE DAMAGE	0.019
				NO DEFCT FACLTE MAIN	0.038				
COMPONENT TOTAL	6.3129	939.8672	148.9	CRASH DAMAGE	0.034	NOT LISTED	0.288	OIL LEAK	0.017
				CRACKED	0.085	NO DEFECT-RMVD TIME	0.271	WORK EXCESSIVELY	0.034
				HOT START	0.017	LEAKING	0.034	CONTAMINATION	0.017
				FOREIGN OBJECT DAMAG	0.119	SCHEDULED MAINTENANC	0.017	INTERNAL FAILURE	0.017
				BATTLE DAMAGE	0.017	NO DEFCT FACLTE MAIN	0.034		

SR

SR

TABLE 7-7 AIDAPS EFFECTIVENESS WORK SHEET

AIDAPS/AIRCRAFT EFFECTIVENESS

MAINT. LEVEL	Jth	Kth	NAME/ PARAMETER	FSN	ITEM & CODE	MAINT RATE MR	SCH. REM SR	UNW REM UR	DIAG DI	INSP I	MR · SR	MR · UR	MR · DI	MR · I	MAC FUNC CODE	OVH INTERV	DEPOT % OVH	SENSOR TYPE	ON A/C	SCHED REMOV. RATIO	MANHOURS REQUIRED MHTS	MHRR	MHBC	MHOH	RATIONALE/COMMENTS
	3	1	ENGINE	28409042461									.210+			800	.180	REF. P/L		.158					*ADJUSTMENT FOR INCOMING INSPECTIONS
A					R/R	7.60	.081	.110			.615	.836			F							26.6 (3)			12.0 = REM & REP. RATE
L					R/RI	4.17	.296	.278			1.234	1.159			F							8.6 (3)			35.0 = TOTAL MAINT. RATE (ORG., DS & GS) 6.31 = TOTAL MAINT. RATE (DEPOT)
J					TEST	.32			1.0				.32		O/F						3.4 (2)				
F					CHECK	.963			1.0				.963		O/F						10.7 (2)				+DIAGNOSTIC TIME FROM 23000 (PROPULSION SYST.)
A					SERV	2.35			1.0				2.350		H								40.6		
B					REP	2.46	.017				.042 1.891		1.09*		F							80 (1)			
C	(DEPOT)				OVER-HAUL	5.67	.321				1.820				D									160	
											1.891	1.995	4.933								8.879 (2)	16.09 (2.98)	40.0 (1)	160 (1)	AVERAGES
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	COLUMN NUMBER

Columns 12 through 15 are filled in by multiplying the respective percentages in columns 8 through 11 by the maintenance rate in column 7. In column 12, actions reported from the depot level should be duplicated by remove and replace action at ORG, DS or GS. Therefore, the actions are not added and only the largest reported (in this case ORG, DS and GS) is considered ans used because it is assumed to be the most accurate. Column 16 contains the organizational code from the MAC charts. Column 17 contains the overhaul interval derived from Chapter 3 of the -20 manual. The entry in column 18 is obtained by dividing the total depot actions by the total maintenance actions. Columns 19 and 20 are the sensor types and their locations necessary for the monitoring of the component. In this case the list was too long, so the reader is referred to the AIDAPS parameter list for the engine. Column 21 contains the ratio of the total of column 12 to the total number of remove and replace actions.

Columns 22 and 23 have been previously discussed. Column 24 contains the man-hours required for bench check which is taken from the job average opposite the item marked "Serviceable(A)." Column 25 is obtained from the job average as recorded for overhauls on the depot printout on the same component, Table D. The totals on columns 22 through 25 are the average times and crew sizes weighted by the frequencies listed in columns 12 through 14. Once the work sheet is completed, the data is transferred onto computer input format sheets from which computer input cards are keypunched.

The maintenance data describing the aircraft maintenance without AIDAPS is listed on card types 4 and 5. As shown in Table 7-8, on card type 4, the first two columns contain the component index numbers. The third column contains the maintenance index which is used to place the cards in rank order. Columns 4, 5 and 6 refer to inspection are filled out only for inspection items. Column 4 contains inspection frequency; column 5 contains the inspection time; and column 6 contains the number of maintenance men required. Columns 7,8 and 9 contain the diagnostic data. Column 7 contains frequency as listed at the bottom of column 14 in Table 7-7. The entry in column 8 is determined from column 22 of Table 7-7 by dividing the troubleshooting man-hours by the crew size which appears in parentheses just below the man-hour figure. The crew size is then

TABLE 7-8 AIDAPS/AIRCRAFT DESCRIPTION CARDS

AIRCRAFT DESCRIPTION - CARD TYPE 4

COMP ID		MAINT INDEX	INSPECTIONS			DIAGNOSIS			UNWARRANTED REMOVAL			ACCIDENT POTENTIAL				A/C ID
			FREQ	TIME	CREW	FREQ	TIME	CREW	FREQ	TIME	CREW					
J	K		FIA	TIA	NC	FTSA	TTSA	NCTSA	FUR	TRR	NCRR	HZD 1	HZD 2	HZD 3		
4	1	332.2				.394	6.41	1.7	.80	9.3	1.0			.1779		AH-1
4	2	245.6				4.62	7.36	1.1	.81	7.7	2.0			.1388		AH-1
1	1	547.8	202.9	2.7	1.0											AH-1

AIRCRAFT DESCRIPTION - CARD TYPE 5

COMP ID		MAINT RATIO				BENCH MNHRS	ABORT RATE	COMP COST	OVERHAUL COST		A/C ID
J	K	ORG	DS	GS	DEPOT						
4	1	.449	.290	.241	.02	8.0	.0392	205.00	53.00		AH-1
4	2	.458	.296	.246		8.0	.0306	559.00	168.00		AH-1
1	1										AH-1

AIDAPS DESCRIPTION - CARD TYPE 2

COMP ID		INSPECTIONS			TROUBLE SHOOTING		UNWARRANTED REMOVAL FREQ	SCHEDULED REMOVAL FREQ	COMP HAZARD	COMPONENT ABORT FREQ	COMPONENT AIR FAILURE FREQ		A/C ID
		FREQ	TIME	CREW	TIME	CREW							
J	K	DFI	DDTI	DNC	DDTS	DNCTS	DFUR	DFSRA	DHZD	DAR	DF		
4	1				6.35	.7	.80	.121		.0127			AH-1
4	2				7.30	.1	.81	.645		.0099			AH-1
1	1		.54										AH-1

recorded in column 9. Column 10 is obtained from the total of column 13 of Table 7-7. Columns 11 and 12 are derived from column 23 of Table 7-7 in the same manner as discussed for columns 8 and 9. Columns 13, 14 and 15 are obtained from the Accident Analysis Study, (paragraph 7.2.5).

Aircraft description card 5 contains similar data. The first two columns contain the component identification indices. The maintenance ratio for column 6 is the first entry, and this is obtained from column 18 of the work sheet. Columns 3,4, and 5 are then filled in from ratios attributable to the aircraft as a whole. For the CH-54A, the third column is determined by multiplying .57 (ratio obtained from FM 101-20) by 1 minus the depot ratio. The fourth column is determined by multiplying .25 by 1 minus the depot ratio, and the fifth column is determined by multiplying .18 by 1 minus the depot ratio. Column 7 comes directly from column 24 of Table 7-7, and column 8 comes from the Accident Analysis Study. Column 9 contains the component cost as determined from the Federal Stock Catalogue, and column 10 contains the overhaul cost as determined from Reference 1 adjusted to 1971 prices and other sources.

The last card illustrated is the AIDAPS description card, Type 2, which gives the difference in maintenance requirements between an aircraft not equipped with AIDAPS and an aircraft equipped with AIDAPS. Columns 1 and 2 are once again the component identification indices. Columns 3, 4 and 5 contain the differences in inspection frequency, elapsed time or maintenance men requirements. Column 6 contains the difference in the time required for troubleshooting. The time required to troubleshoot with the AIDAP Airborne System is approximately three minutes; i.e., .05 hours, for reading the AIDAPS output tape (display) and determining appropriate corrective action. The average troubleshooting time without AIDAPS is 4.44 hours. This is determined by dividing MHTS (8.879) in column 22, Table 7-7 by the average crew size (2) in the same column. The difference is 4.39 hours. In addition, only one man is required for troubleshooting, while the normal average requirement is two. The difference, one man,

[1] Lt. Col. John E. Munnelly and Major Rolf S. Scovell, "An Analysis of Depot Maintenance Requirements and the Development of a Model to Estimate Fixed Depot Workload...", August 1966 AD806825.

is entered into column 7. Column 8 contains the difference in unwarranted removal rates. These are obtained directly from column 13 of Table 7-7. The computer model adjusts both this number and the troubleshooting frequency by the test accuracy for the AIDAP System involved. Column 9 contains the difference in scheduled removal frequency. This is obtained by using the ratio of scheduled removals to total removals as listed in column 21 of Table 7-7. This number is entered into the appropriate chart in the On Condition Maintenance Study (paragraph 7.2.4) to determine the difference in frequency of removals achieved by going from a time removal requirement to on condition maintenance. This difference is entered in column 9. Column 10 contains the difference in the component accident hazard expressed as a ratio. Column 11 contains the difference in component abort rate, and column 12 contains the difference in aircraft system accident frequency expressed as a ratio. For the development of this data, see paragraph 7.2.5.

7.2.3 PROCESSING OF INSPECTION DATA

In addition to the unscheduled maintenance, a large number of maintenance man-hours (MH) are expended in daily, intermediate, and periodic inspections. For example, the maintenance data analysis computer printouts for the UH-1H (reference Appendix E, Book 1) show that 552.65 MH/1,000 flight hours were devoted to the daily inspection, 257.33 MH/1,000 flight hours were devoted to the intermediate inspections, and 932.34 MH/1,000 flight hours were devoted to the periodic inspections, for a total of 1,742.32 MH/1,000 flight hours.

While many of the inspection tasks involve human visual observation and judgment, there are also many tasks which can be automated with the same AIDAPS hardware and techniques which are contemplated for the diagnostic and prognostic functions. In some instances, the automatic inspection could not be performed by the initially planned hardware; however, the addition of a simple transducer, such as a solid-state hydrocarbon leak detector, often provides the additional capability.

To quantize the effects of AIDAPS on this important aspect of maintenance, the following procedure was utilized.

a) The current inspection checklists for the daily, intermediate, and periodic were examined. The number of inspection items for each were compiled. For the UH-1H there were 65 items on the daily, 62 items on the intermediate, and 89 items on the periodic. From the printout data, it was found to require an average of 2.7 MH for each daily, 8.7 MH for each intermediate, and 99.2 MH for each periodic. Dividing the respective quantities, an average inspection item on the daily required 0.042 MH, an average inspection item on the intermediate required 0.14 MH, and an average inspection item on the periodic required 1.12 MH.

b) The checklists were then examined, item by item (see Table 7.9). If the task could be performed by planned (or easily added) instrumentation, an "x" was placed by the item. If only a fraction of the task could be automated, the estimated fraction was noted; i.e., x/2, x/3, etc. An example of such notation is shown in Table 7-9. Item 5.19 is marked x/4, since the task is performed only every second inspection and only about half of the task can be automated (checked for leaks). Item 6.4 is marked "x", since the oil level, leaks and chip detector will be instrumented. Similar rationale is applied to the examination and marking of each item.

c) The number of "x's" for each inspection was summed, including all fractions, to arrive at an equivalent number of manual items which could be eliminated by automatic inspections. This equivalent number is 22 for the daily inspection, 14 for the intermediate, and 28 for the periodic.

d) By multiplying the equivalent number of items by the average time required for an item, the time saved for each inspection is computed. Finally, multiplying the time saved for each inspection by the frequency of that

TABLE 7-9 CHECKLIST EXAMPLE

		CRITICAL INSPECTION ITEM						TAIL BOOM AREA CRITICAL INSPECTION ITEM	
5.17		FUEL CONTROL STRAINERS INSPECTED AND CLEANED, SERVO FILTER REPLACED.		5-367 5-372		6.1		TAIL BOOM EXTERIOR FOR EVIDENCE OF DAMAGE AND FOR SECURITY OF ELEVATORS AND TAIL SKID.	4-254 4-263 4-269 4-201
		CRITICAL INSPECTION ITEM						CRITICAL INSPECTION ITEM	
5.18		FUEL MANIFOLD INLET STRAINER (T53-L-9/-9A) OR BYPASS STRAINER IN MAIN FUEL LINE TO MANIFOLD (T53-L-11 SERIES) INSPECTED AND CLEANED.		5-181		6.2		TAIL BOOM ATTACH BOLTS VISUALLY FOR SECURITY, FITTINGS FOR CRACKS.	
		CRITICAL INSPECTION ITEM						CRITICAL INSPECTION ITEM	
x 4 5.19	2ND	POWER DRIVEN ROTARY (BOOSTER) PUMP, VISUALLY FOR LEAKS, DAMAGE, AND SECURITY.		5-194		x 6.3		TAIL ROTOR DRIVE SHAFT INSTALLATION FOR VISIBLE DAMAGE AND SECURITY OF SHAFTS, HANGERS, COUPLING CLAMPS AND COVERS. CHECK BEARINGS FOR SMOOTH OPERATION.	7-114 7-115 7-116 7-122
		CRITICAL INSPECTION ITEM						CRITICAL INSPECTION ITEM	
5.20		OIL FILTER, REMOVE ELEMENTS, INSPECT AND CLEAN. DETERMINE SOURCE OF CHIPS, IF ANY FOUND. REQUEST ASSISTANCE FROM DIRECT SUPPORT MAINTENANCE.		5-288 5-310		x 6.4		INTERMEDIATE (42°) GEARBOX FOR SECURITY, OIL LEVEL AND LEAKS. INSPECT AND CLEAN MAGNETIC PLUG. ON ELECTRICAL CHIP DETECTOR, CHECK CONTINUITY. CHECK BREATHER VENT CAP FOR CLOGGING.	7-130
		CRITICAL INSPECTION ITEM						CRITICAL INSPECTION ITEM	
x 5.21		FUEL REGULATOR HOSE ASSEMBLY INLET CONNECTIONS FOR LEAKS.				x 6.5		TAIL ROTOR (90°) GEARBOX FOR SECURITY, OIL LEVEL AND LEAKS INSPECT AND CLEAN MAGNETIC PLUG. ON ELECTRICAL CHIP DETECTOR, CHECK CONTINUITY.	7-139
		CRITICAL INSPECTION ITEM							
x 2 5.22		FUEL AND OIL HOSE ASSEMBLIES, VISUALLY FOR SECURITY, LEAKS, AND DAMAGE.							

	Ave. Time W/O AIDAPS	No. of Items W/O AIDAPS	Ave. Time Per Item	Equiv. # Elim.	Time Saved Per Insp.	Freq. of Insp.	MH/1000 FH Saved
PMD	2.7 hr.	65	0.042 hr.	22	0.92 hr.	204	187.0
PMI	8.7 hr.	62	0.140 hr.	14	1.96 hr.	29.5	57.8
PMP	99.2 hr.	89	1.116 hr.	28	31.2 hr.	9.4	293.5

TOTAL MH SAVING/1000 FH = 538.3

With regard to automatic inspections, it is important to note that the essentially continuous inspections which are performed by the hybird or airborne AIDAPS will yield information about the condition of a component or subsystem that is superior to the information which can be secured by a "cold aircraft" inspection or even a ground runup.

7.2.4 WEIGHT AND CENTER OF GRAVITY CALCULATIONS

During the course of the study, it was recognized that the computational capabilities of the AIDAP system could be used to accomplish the weight and balance calculations presently done by hand. AMRDL efforts in this area support consideration of this technique for AIDAPS. Personnel at the Army Flight Safety Center, Fort Rucker, Alabama, estimated that at least 50% of the accidents on liftoff were due to an unbalanced load or an attempt to lift off a load greater than that allowed by the ambient altitude-temperature conditions. Many of these accidents can be prevented by a timely warning of excessive weight or c.g. locations outside the acceptable limits. The Hybrid I and Airborne AIDAP systems can provide such warning if the alighting gear is appropriately instrumented. In addition, the time required to perform the calculations can be greatly shortened.

The number of accidents which could be eliminated were calculated in the accident study. Considerably less than 50% of the pilot caused actions could be eliminated. Many accidents due to weight and c.g. are coded as "rotor struck object" or similar notations. Since the number of such codings which were really weight and balance problems is unknown, only the accidents actually listed as weight and balance problems were used.

7.2.5 AIDAPS TEST ACCURACY

The differences in the monitoring actions of the various AIDAPS configurations result in different levels of effectiveness in the performance of automatic inspection, diagnosis and prognosis. The monitoring of a component varies from continuous sampling for the Airborne and Hybrid I system, through a six-second sample every three minutes for the Hybrid II, to a five-minute sample once a day for the Ground system. In order to quantify this effect, Northrop has introduced the concept of "test accuracy, TA" and defined it as "a measure of the probability that an AIDAPS will recognize that a malfunction or degradation exists if a malfunction or degradation actually does exist, and, conversely, will recognize that a malfunction or degradation does not exist when a malfunction or degradation does not actually exist." Further, it follows that 1-TA is either the probability that a malfunction or degradation will be indicated when no malfunction or degradation exists or the probability that a malfunction or degradation will not be correctly recognized when they do exist. The first condition may be called the "false alarm" probability, and the second condition may be called the "miss" probability. The TA then becomes the "detection" probability. These terms are shown graphically in Figure 7-4.

Test Accuracy is directly related to the data sampling schedule since deleterious events may occur during periods of nonobservation. If all events would leave permanent, AIDAPS-discernible traces, a malfunction or degradation would always be discovered upon the next sampling, irrespective of the time period. In such an instance, the test accuracy would be the accuracy of the instrumentation and the test accuracy would be the same for the Airborne, Hybrid I, Hybrid II and Ground Based systems. All events do not leave discernible traces, however, although they can be important to inspection and of even greater importance to diagnosis and prognosis.

The TA, the "confidence factor" is, therefore, composed of accuracy of instrumentation and the probability of missing an event which would leave no trace. In actual practice, the failure and degradation modes of each component to which AIDAPS is applied will be known, and a TA will have to be computed or measured so limits and decision levels can be established. However, as an

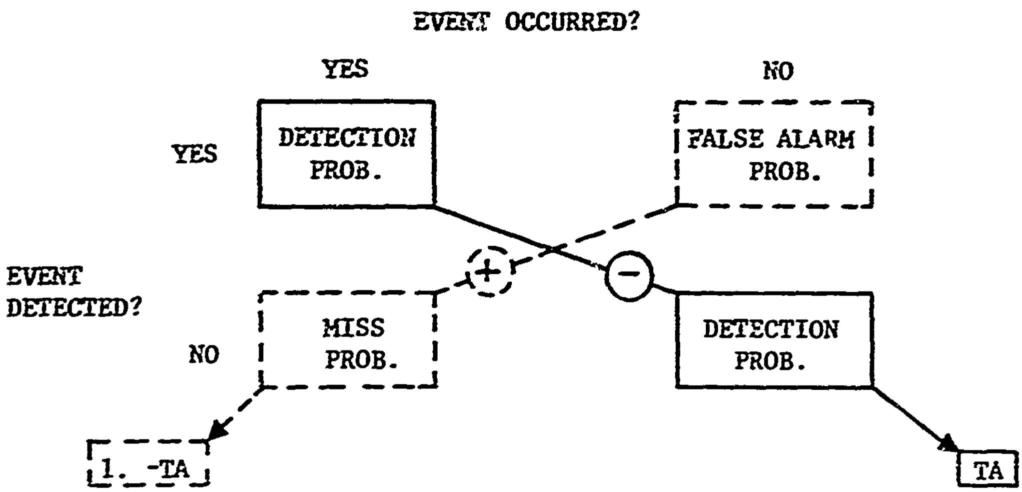


FIGURE 7-4 DEFINITION OF TEST ACCURACY

input to the cost effectiveness models of this study, a generalized Test Accuracy was necessary. In examination of the printout for each component, in the manner described in paragraph 7.2.2 and in subordinate paragraphs, the assumption of perfect performance in inspection, diagnosis and prognosis was initially assumed; i.e., on aircraft inspections, and scheduled and unwarranted removals would be eliminated for any component to which AIDAPS was applied. This ideal situation, in reality, would not exist and the actual performance would be degraded by some factor which reflects the uncertainty of the decisions, the Test Accuracy, TA.

The determination of TA for each component is beyond the scope of a concept formulation study. However, the method which is described in the following paragraphs was used to determine the necessary factor for the models.

7.2.5.1 Components of TA

The failure to detect a malfunction or degradation (1-TA) is a function of the systemic errors and errors due to the frequency of data acquisition. These are composed of the following:

7.2.5.1.1 Systemic Errors (with estimates of realizable accuracies) -

a) Transducer or sensor errors (±0.5 to ±1.0%)

b) Conversion error (±0.2%)

c) Aliasing errors (0.5%)

d) Computational errors (±1.8%)

The digital computation circuitry is essentially error free, but the computation of a quantity in which each of the factors have an error will result in a possible error in that quantity which is the RSS value of the errors of the factors. If the quantity is composed of five factors, each of which has a possible ±0.8% error, the computational error would be a possible $\pm\sqrt{3.2} = 1.8\%$.

The systemic error would then be the RSS of the error elements or approximately $\pm\sqrt{4.17} = \pm 2.1\%$. It can be seen that the computational error is the controlling factor. In order to approximate a "worst case" condition, the following computations assume a systemic error of 5%. (Section 4.2.5 discusses sensor and system accuracies.)

7.2.5.1.2 Frequency-of-Sampling Errors - Since the Airborne and Hybrid I configurations sample essentially continuously, there is little possibility that an event will be missed. However, the Hybrid II and the Ground configuration can experience considerable degradation of data due to missed events; i.e., events which leave no discernible trace. This is shown graphically in Figure 7-5 where the "A" type event results in a permanent condition which can be discovered at any subsequent time, and the "B" type event is the recoverable condition which leaves no trace. Because of the relatively short sampling periods of the Hybrid II and Ground systems, it can be shown that the probability of a Type B event being recognized by the Ground system is virtually zero, and only about one in nine forthe Hybrid II system. (It is assumed that a Type B failure would occur for a 15-20 second duration in flight before returning to normal.) That is, the miss probability is 100% for the Ground system and about 88% for the Hybrid II system.

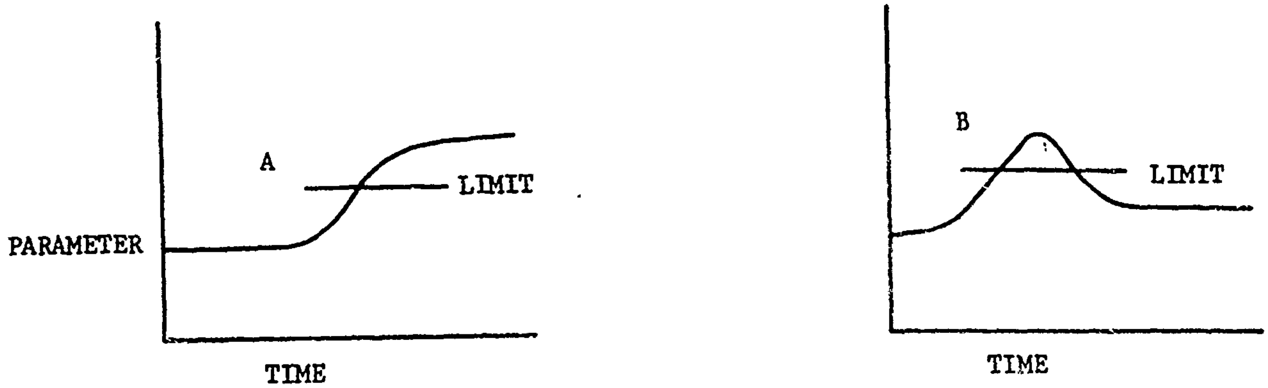


FIGURE 7-5 TYPES OF MALFUNCTIONS

7.2.5.2 Estimate of a Numerical Value for TA

In order to estimate a value for the possible degradation of the instrumentation data, the parameter list for the UH-1 was examined and for each parameter an estimate was made of the relative frequency of the Type "A" to the Type "B" occurrences. That is, assuming the parameter had experienced 100 meaningful excursions, how often would it leave a permanent trace (Type A) or leave no trace (Type B).

While the concern of AIDAPS is with the behavior of the components of the aircraft, test accuracy must be determined via the parameters. Decisions which are made about a component can only be based upon the observation of the associated parameters of that component with full knowledge of the degree of uncertainty in the observation; i.e., TA.

These estimates and a brief rationale for each estimate are given in Table 7-10. To illustrate, consider items 15 and 16. In the case of item 15, fuel flow may surge due to malfunctions of the fuel control or due to improper operation. It also may be less than normal due to reduced fuel pressure. Therefore, it was estimated that 50% of the excursions would be of Type "A" and 50% would be of Type "B". In the case of item 16, it was judged that reduced fuel pressure would usually be due to worn fuel pump parts and, therefore, would be 90% of Type "A" and only 10% of Type "B".

The "A's" and "B's" were summed and divided by the total number of parameters to determine average values for "A" and "B":

$$\frac{\Sigma A}{r} = \text{A average} = 42.9/63 = 68\%$$

$$\frac{\Sigma B}{r} = \text{B average} = 20.1/63 = 32\%$$

The estimation of the relative values of A and B for each parameter was performed completely independently by three engineering specialists who were all knowledgeable regarding AIDAPS and the UH-1. While there were some differences in the A/B value for some parameters, the average values for "A" and "B" were as follows:

Specialist I	A = 68%	B = 32%
Specialist II	A = 71%	B = 29%
Specialist III	A = 68%	B = 32%

Combining the instrumentation or systemic errors, the "miss probability" due to short sampling and the average of values "A" and "B" yields the following tabulation:

	Airborne	Hybrid I	Hybrid II	Ground
Errors due to "miss"	0	C	32 x 88% = 28.2	32 x 100% = 32
Systemic errors	5%	5%	5%	5%
Total Errors (1-TA)	5%	5%	33%	37%
Test Accuracy (TA)	95%	95%	67%	63%
Test Accuracy used for all costs/benefits evaluations	95%	95%	80%	75%

In the operation of the cost benefits models, TA values of 80% for the Hybrid II system and 75% for the Ground system were actually employed. Paragraph 8.3.4 discusses the sensitivity of the models to variation in TA for inspection, diagnosis and prognosis.

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT

ITEM	AIRCRAFT SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
1	01	Tail Boom Vibration	0.4	0.6	Vibs are a function of rotational and air speeds, loads, etc. Some may be due to looseness of structure or power train unbalance
2	02	Alighting Gear Load Left Mtg Pad Forward	0.6	0.4	
3	02	Alighting Gear Load Right Mtg Pad Forward	0.6	0.4	60% of hard landings or uneven set-downs where a limiting load has been exceeded will result in permanent deformation. 40% will leave no trace.
4	02	Alighting Gear Load Left Mtg Pad Aft	0.6	0.4	
5	02	Alighting Gear Load Right Mtg Pad Aft	0.6	0.4	
6	03	Exhaust Gas Temperature, EGT	0.2	0.8	Excessive EGT will usually leave no trace except possible discoloration of metal surfaces
7	03	Gas Producer Speed, N_1	0.1	0.9	Overspeeds, short of distruction, are corrected by automatic or manual means. Permanent bias may be due to governor malfunction and the like in some instances.
8	03	Compressor Discharge Pressure, CDP	0.8	0.2	Reduced CDP is usually due to permanent effects such as dirt and erosion. Transient changes may occur due to restrictions of inlet air or changes in N_1.
9	03	Outside Air Pressure, OAP	0.5	0.5	Errors may be due to transient effects such as icing or permanent offsets.
10	03	Outside Air Temperature, OAT	0.5	0.5	Errors may be of transient nature such as sun exposure or instrumentation malfunction.

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT (Continued)

ITEM	SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
11	03	Engine Oil Quantity	1.0	0.0	May be refilled but for any period between refills wholly Type A
13	03	Combustion Chamber Drain	1.0	0.0	No drainage when engine is running; some on shutdown
14	Misc.	Pitot Tube Heater Current	1.0	0.0	A "no current" condition would be due to an open circuit, open breaker, etc. Transient failures would be failure of the power source
15	03	Engine Fuel Flow	0.5	0.5	Approximately 50% of incorrect fuel flow will be due to miss-operation and 50% will be due to wear or damage
16	03	Engine Fuel Pressure	0.9	0.1	Reduced fuel pressure will generally be irreversible
17	03	Power Turbine Speed, N_2	0.2	0.8	Overspeeds, short of distruction, are corrected by automtic or manual means. Permanent bias may be due to governor malfunction and the like in some instances
18	03	Output Torque Pressure	0.5	0.5	Low torque pressure may be due to miss-adjustment or wear (Type A) and overpressure may be of a transient nature (Type B)
19	03	Bleed Band Position	0.2	0.8	Only if the band wave "stuck" in open or closed position would it be Type A
20	03	Inlet Guide Vane Position	0.2	0.8	Only if IGV were stuck in some position would it be Type A
21	03	Engine Compressor Vibration	0.8	0.2	Vibrations caused by compressor unbalance and FOD would be Type A. Some resonances could be a function of speed and power settings

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT (Continued)

ITEM	SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
22	03	Engine Fuel Leak Detector	1.0	0.0	A leak would not recover
23	03	Differential Air Pressure, Partial Separator	1.0	0.0	Clogged air filters would not recover
24	03	Differential Fuel Pressure Across Pump	0.5	0.5	Can be a transient effect or a longer term degradation due to wear
25	03	Differential Pressure Across Oil Filter	1.0	0.0	Dirty oil filter will not recover
26	03	Engine Oil Pressure	0.3	0.7	Subject to many transients, can be permanent degradation
27	03	Magnetic Chip Detector, Engine	1.0	0.0	Chips completing detection circuit will remain
28	03	Differential Pressure Switch Across Oil Filter	1.0	0.0	Blocked filter will not recover
29	03	Engine Oil Temperature	0.5	0.5	Increased oil temperature may be a secondary effect such as the failure of shaft seals or a transient such as increased power demands
30	04	Vibration of 42° Gear Box	0.6	0.4	Unbalances will be permanent but some vibrations will be a function of shaft and airspeeds
31	04	Magnetic Chip Detector, 42° Gear Box	1.0	0.0	As in Item 27
32	04	Vibration of 90° Gear Box	0.6	0.4	As in Item 30
33	04	Magnetic Chip Detector, 90° Gear Box	1.0	0.0	As in Item 27

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT (Continued)

ITEM	SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
34	04	Vibration of Main Transmission	0.5	0.5	As in Item 30, but Main Transmission vibrations are more a function of load, airspeed, attitude, altitude, etc.
35	04	Magnetic Chip Detector, Main Transmission	1.0	0.0	As in Item 27
36	04	Main Drive Shaft Runout	0.6	0.4	Some runout will only occur with large loads and at higher IAS
37	04	Main Transmission Oil Pressure	0.5	0.5	Approximately equal possibilities that a change will be of a transient nature
38	04	Differential Pressure Across Main Transmission Oil Filter	1.0	0.0	As in Item 28
39	04	Main Transmission Oil Temperature	0.3	0.7	Transmission oil temperature is primarily a function of Transmission loading
40	04	Main Transmission Vertical Displacement	0.4	0.6	A function of flight loads and condition of dampers and linkages
41	04	Oil Leak from 42° Gear Box	0.8	0.2	May be a function of A/C attitude and IAS. Can be result of worn seals
42	04	Oil Loak from 90° Gear Box	0.8	0.2	As in Item 41
43	04	Vibration of Main Rotor Assembly	0.6	0.4	Wear of linkages, deterioration of dampers, and out-of-track will be permanent. Some conditions will be a function of loads and IAS.
44	04	Oil Leak from Main Transmission	0.5	0.5	May be due to flight loads and A/C attitude as well as wear of seals

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT (Continued)

ITEM	SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
45	04	Main Rotor Speed	0.2	0.8	As in Item 17
46	06	Leakage from Power Cylinder #1	1.0	0.0	Such leakage will continue
47	06	Leakage from Power Cylinder #2	1.0	0.0	As in Item 46
48	06	Leakage from Power Cylinder #3	1.0	0.0	As in Item 46
49	06	Hydraulic 'Hammer'	0.0	1.0	Occurs with rapid and severe movements of controls under flight power
50	06	'Low' Hydraulic Pressure Switch	1.0	0.0	Low hydraulic pressure would be due primarily to malfunction of pumps or leakage and would not recover.
51	06	Position of Hydraulic Control Solenoid	1.0	0.0	An ON-OFF situation
52	09	Primary Essential Bus Voltage	0.5	0.5	May experience transients due to many flight-related causes
53	09	Position of Bus Control Relay	1.0	0.0	As in Item 51
54	09	Position of Inverter Bus Voltage Failure Relay	1.0	0.0	As in Item 51
55	09	Generator Load Current	0.5	0.5	May experience many transients
56	10	Fuel Leak in Aft Cell Area	1.0	0.0	As in Item 46

TABLE 7-10 ESTIMATES FOR THE DERIVATION OF THE TEST ACCURACY (TA) FOR THE UH-1 AIRCRAFT (Continued)

ITEM	SUBSYSTEM	PARAMETER	A	B	BRIEF RATIONALE FOR ESTIMATING A/B RATIOS
57	10	Fuel Leak in Forward Cell Area	1.0	0.0	As in Item 46
58	10	Right Fuel Boost Pump Pressure Switch	1.0	0.0	As in Item 51
59	10	Left Fuel Boost Pump Pressure Switch	1.0	0.0	As in Item 51
60	10	Main Fuel Filter Bypass Switch	1.0	0.0	As in Item 28
61	10	Engine Fuel Low Switch	0.3	0.7	May give false indication due to A/C attitude
62	10	Position of Starting Fuel Solenoid	1.0	0.0	As in Item 51
63	Misc	Engine Ground Strap Continuity	0.2	0.8	Other paths to ground may be intermittently established
			42.9	20.1	

7.2.6 ON CONDITION MAINTENANCE STUDY

The capability of monitoring devices such as AIDAPS may allow maintenance to be performed on an on condition basis rather than at specific flying hour intervals. While good diagnostic capability is sufficient to apply this approach, savings are considerably enhanced by a prognostic capability. The most significant contribution of on condition maintenance to the maintenance organization is the reduction in the number of time removals. This reduction in removals not only eliminates aircraft down time and organizational maintenance man-hours for removing and replacing components, but also eliminates the costly transportation of some equipments back to depots. It also reduces the attendant long shipping times and large number of spare items in the pipeline, as well as the cost of overhauls.

When a time change requirement is removed from a component, such as an engine, the component will continue to be operated until the monitoring equipment indicates that a malfunction is imminent. Thus, although time change requirements will be eliminated, on condition removals will rise slightly. This analysis seeks to provide a measure of the removal frequency (or mean time until removal) of those components which are at present removed on a time basis.

7.2.6.1 Methodology

A typical distribution of the time to removal of a time change is shown in Figure 7-6a. It is plotted on probability paper for convenience. When plotted on this paper, the distributions frequently display two separate slopes: one with a relatively constant slope extending over a large portion of the chart, and a second distribution of a relatively high slope representing the time removals. Occasionally, a third distribution appears near the origin and represents early failures

These graphs involve an underlying assumption that the frequency distributions are Gaussian. The Gaussian assumption was made because it characterizes processes involving aging or wearout phenomena. The assumption is made that the total distribution consists of two underlying Gaussian distributions, one characterizing the main failure modes of the equipment and the other characterizing the time removals. Under this assumption, the elimination of time removal requirement means that the distribution characterizing the main failure

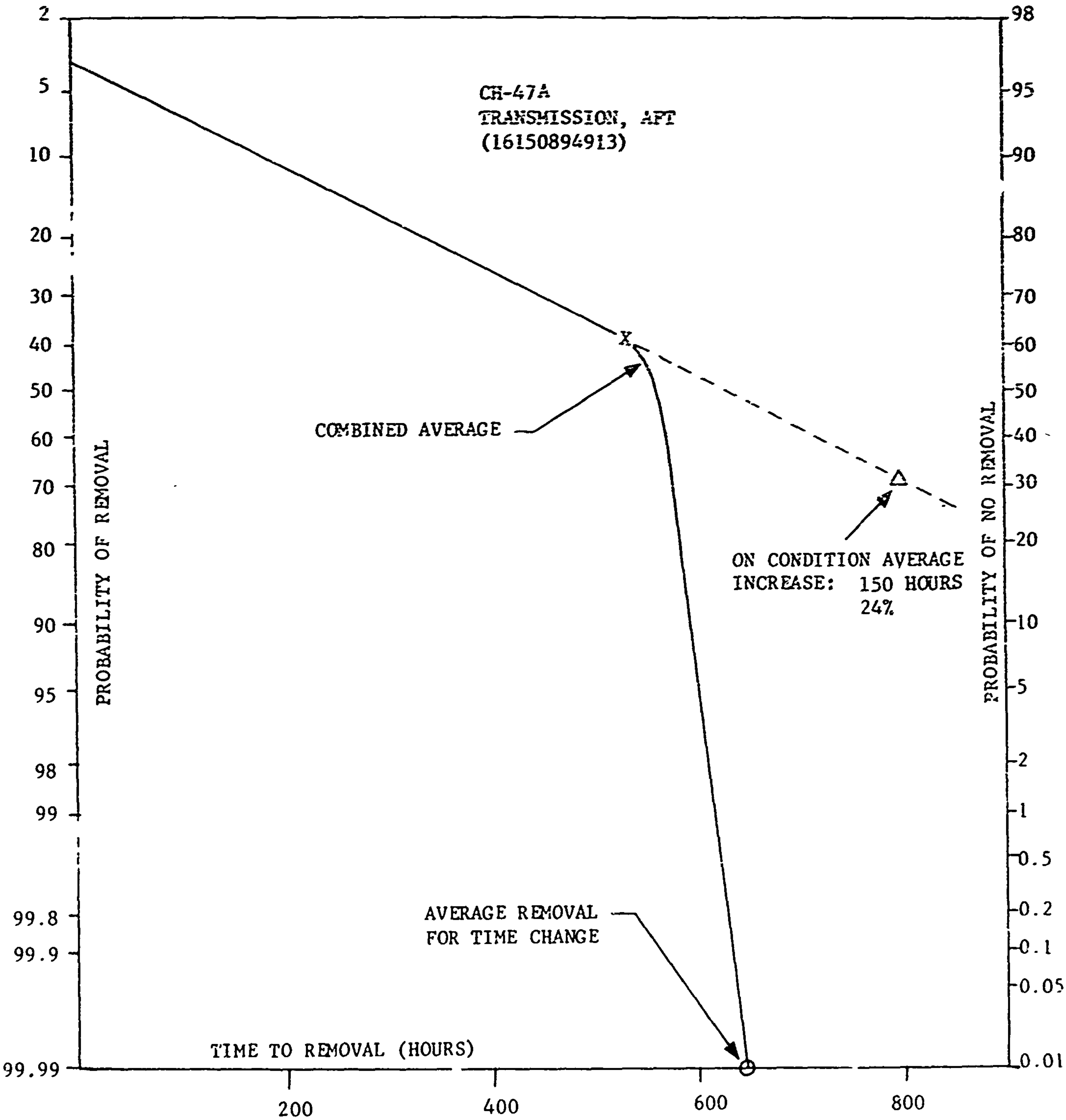
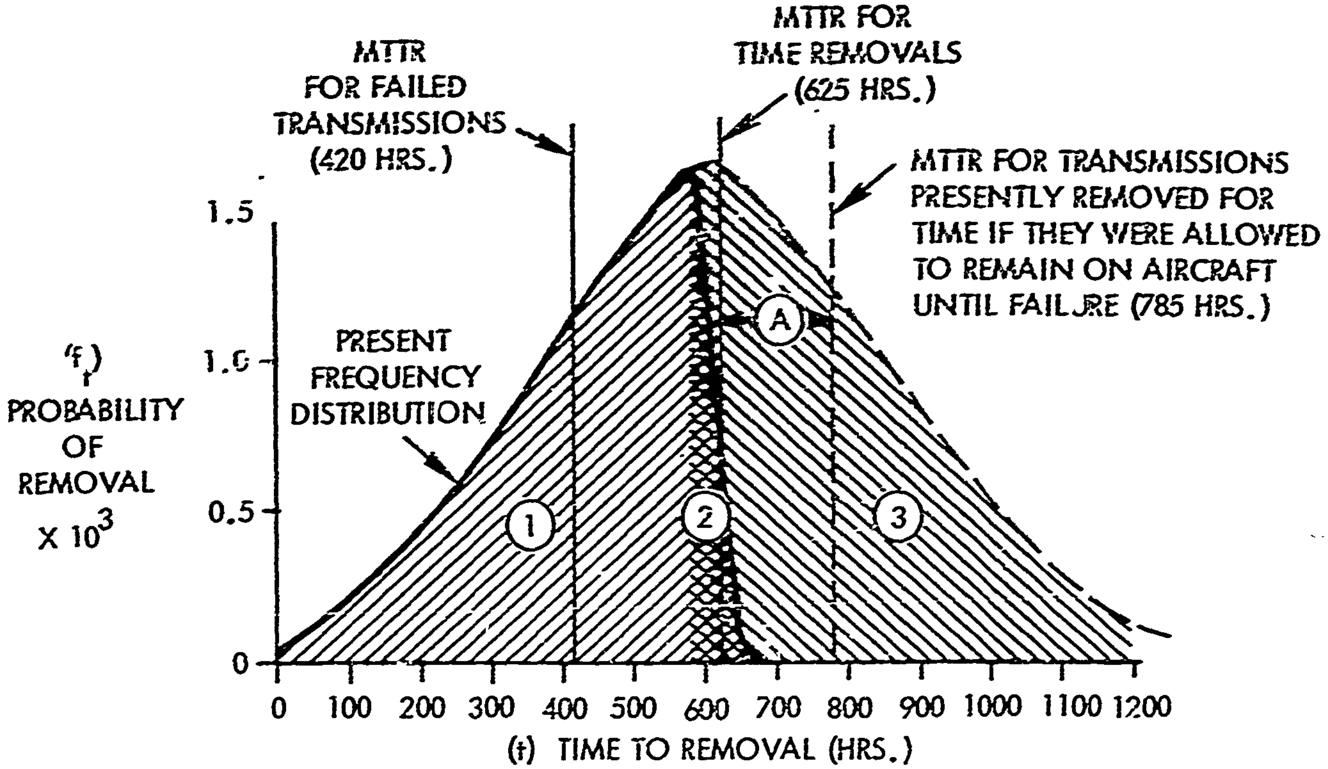


FIGURE 7-6a CUMULATIVE PROBABILITY OF REMOVAL

modes predominates. The expected extension of the time to removal would be the expected value obtained from the main failure distribution beyond the point where it is truncated by the time removal distribution. Since the assumed Gaussian distributions allow negative parameter values, these graphs do not adequately describe the early failure rates. However, these early failures are of no significance to this study.

As shown on figure 7-6a, approximately 46% of the removals are due to failures, and 54% are due to time removals. Transmissions removed because of failures showed an average mean time to removal of 420 hours, while components removed because of time had an average mean time between removals of 625 hours. The combined average life of both categories is 515 hours.

If on condition maintenance is allowed, no time removals will occur. Those transmissions presently removed because of time (between 585 and 650 hours) will be allowed to operate until they fail according to the usual failure modes. The distribution of the usual failure modes is characterized by the initial portion of the curve. However, this represents only 46% of the present total. An underlying assumption is made that the distribution of failures is Gaussian because this distribution characterizes processes involving aging or wearout phenomena. Figure 7-6b further illustrates the situation. The heavy dark line represents the present frequency distribution which, when integrated, yields the cumulative distribution shown in figure 7-6a. It should be noted that this figure is for illustrative purposes and is not entirely to scale. The two solid vertical lines show the MTTR for the failed transmissions and the transmissions removed because of time, respectively. If the transmissions presently removed because of time were allowed to operate until failure, they would fail according to the curve defining areas (2) and (3). The MTTR of this area, extending from 585 hours to infinity, is 785 hours. This means that the average time for removal for components presently removed because of time would be increased from 625 hours to approximately 785 hours--a difference of 160 hours. However, since the components would be removed when the AIDAPS indicated a failure was imminent, prior to actual failure, an increase of 150 hours or 24% was used for this component in this study.



(1) = CHARACTERISTIC AREA FOR TRANSMISSIONS PRESENTLY REMOVED DUE TO FAILURE

(2) = CHARACTERISTIC AREA FOR PRESENT TIME REMOVALS. (THIS AREA NOT TO SCALE.)

(2) & (3) = CHARACTERISTIC AREA FOR TRANSMISSIONS REMOVED DUE TO TIME IF THEY WERE ALLOWED TO REMAIN ON AIRCRAFT UNTIL FAILURE

(A) = INCREASE IN SERVICE LIFE DUE TO ON CONDITION MAINTENANCE IN LIEU OF TIME REMOVALS.

FIGURE 7-6b CH-47A AFT TRANSMISSION PROBABILITY OF REMOVAL DURING HOUR t.

7.2.6.2 Data Analysis

A selected sample of CH-47A components manifesting a relatively high percentage of time change removals were used in this analysis. The cumulative distribution of time to removals was obtained by ranking the data in order of increasing time to removals, and plotting this against the cumulative percent of removals.

Upon the elimination of the time removal requirement, the "on condition" removals will have a mean time to removal ($MTTR_{OC}$) greater than the mean time to removal for time changes ($MTTR_{TC}$). This new expected value can be obtained by integration of the distribution curve between proper limits. However, for this exercise, an estimated value was obtained and this is indicated in the graphs.

The difference between the on condition mean time to removal and the time change mean time to removal provides the essential data. A tabulated summary of these data is shown in Table 7-11.

7.2.6.3 Reduction in Frequency of Removal

The results of this analysis are summarized in the graphs in Figures 7-7 through 7-11. These graphs project the potential reduction in maintenance through use of AIDAPS and the on condition maintenance concept.

Figure 7-7 shows the percent increase in mean time to removal for time change as a function of the percent of removals due to time change. It should be noted that the "percent increase in mean time to removal for time change" represents the difference between the time change mean time to removal and the on condition mean time to removal ($MTTR_{TC}$ - $MTTR_{OC}$), expressed as a percentage of the mean time to removal for time change.

TABLE 7-11 ON CONDITION MAINTENANCE DATA SUMMARY

	$MTTR_{TC}$	$MTTR_{OC}$	% INCREASE MTTR	% DECREASE FREQUENCY	% REMOVALS DUE TO TIME CHANGE
	Transmission Components				
1.	320	395	23.5	19.0	59.0
2.	625	775	23.5	19.0	54.0
3.	760	850	11.7	10.5	37.0
4.	540	605	11.9	10.7	37.0
5.	560	660	17.6	15.0	51.0
6.	1050	1100	5.3	5.0	30.0
7.	1050	1165	11.1	10.0	43.0
	Swashplate Components				
8.	650	725	11.7	10.5	42.0
9.	635	780	22.7	18.5	50.0
10.	445	500	12.4	11.0	45.0
11.	545	625	14.3	12.5	50.0
12.	670	830	24.2	19.5	59.0
13.	615	715	16.3	14.0	54.0
	Shaft, Adapter Assembly Components				
14.	860	910	5.8	5.5	22.0
15.	1170	1300	11.1	10.0	33.0
16.	930	1180	26.9	21.2	46.0
17.	910	1090	19.7	16.5	40.0
18.	620	670	8.1	7.5	33.0
19.	1250	1430	14.3	12.5	43.0

$MTTR_{TC}$ = Mean Time to Removal (Time Change)

$MTTR_{OC}$ = Mean Time to Removal (On Condition)

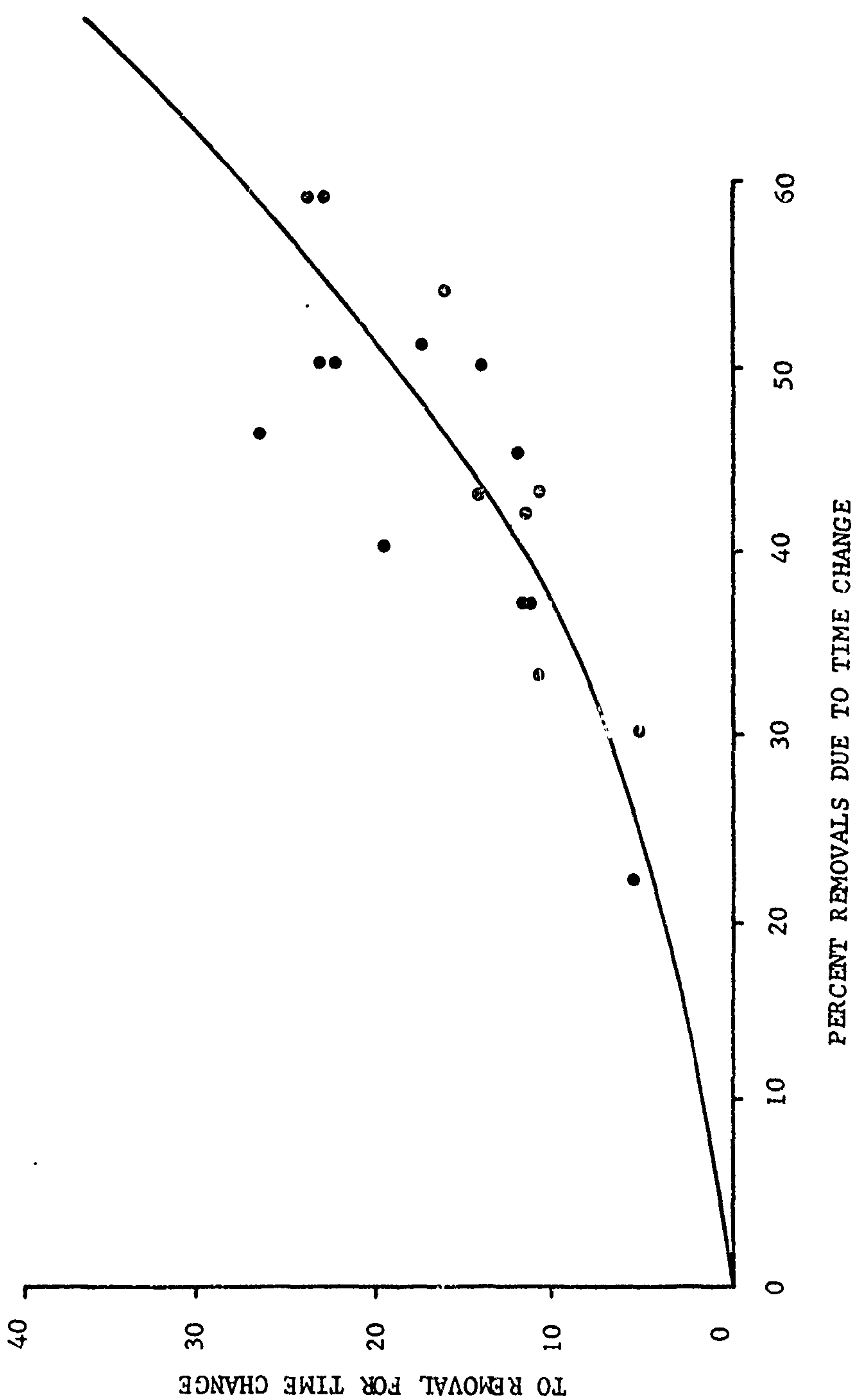


FIGURE 7-7 CH-47A INCREASE IN MEAN TIME TO REMOVAL DUE TO ON CONDITION MAINTENANCE INSTEAD OF TIME CHANGE REMOVALS (ALL COMPONENTS)

In Figure 7-8 the mean time to removal for each item was converted to a removal frequency (the reciprocal of the mean time to removal) and thus the percent decreases in frequency of time change removals is plotted as a function of the percent of removals due to time change. Figures 7-9 through 7-11 present similar graphs; however, the data has been separated into three component groupings.

7.2.6.4 The Possible Extent of "On Condition" Maintenance Using an AIDAPS With a Low Test Accuracy

Components removed on a time basis are usually those which have an impact on air safety. As an example of the effects of "on condition" maintenance on air safety, consider aft transmission no. 1615 045-9961 (Figure 7-6). This figure shows approximately 55% of removals are presently due to time changes and approximately 45% are due to malfunctions. The total expected number of removals (see Table 7-12) per 100,000 FH is 385 of which 212 were time removals and 173 were due to failures, presumably incurred during operations. CH-47 accident data reveals that these 173 operational failures can be expected to yield approximately 1.0 total loss accidents, .7 major accidents and .2 minor accidents per 100,000 flying hours. Applying an AIDAPS with a .6 test accuracy but retaining time removals will reduce the expected number of operating failures by 60% with an attendant reduction in expected number of accidents.

If on condition maintenance is allowed, the time removals will remain on the aircraft until a failure or indication of failure occurs. This reduces the total number of removals per 100,000 flying hours to 347; however, the number of operational failures increases to 139, or almost as high as without AIDAPS. The resulting increase in accidents will be much more costly than the savings due to the change to on condition maintenance. The next example illustrates that if the AIDAPS fails to achieve prognostic capability 0.4, i.e., if it fails to detect 40% or more of the impending malfunctions prior to the flight on which they would occur, the number of accidents with AIDAPS and on condition maintenance exceeds the number of accidents of an aircraft without AIDAPS.

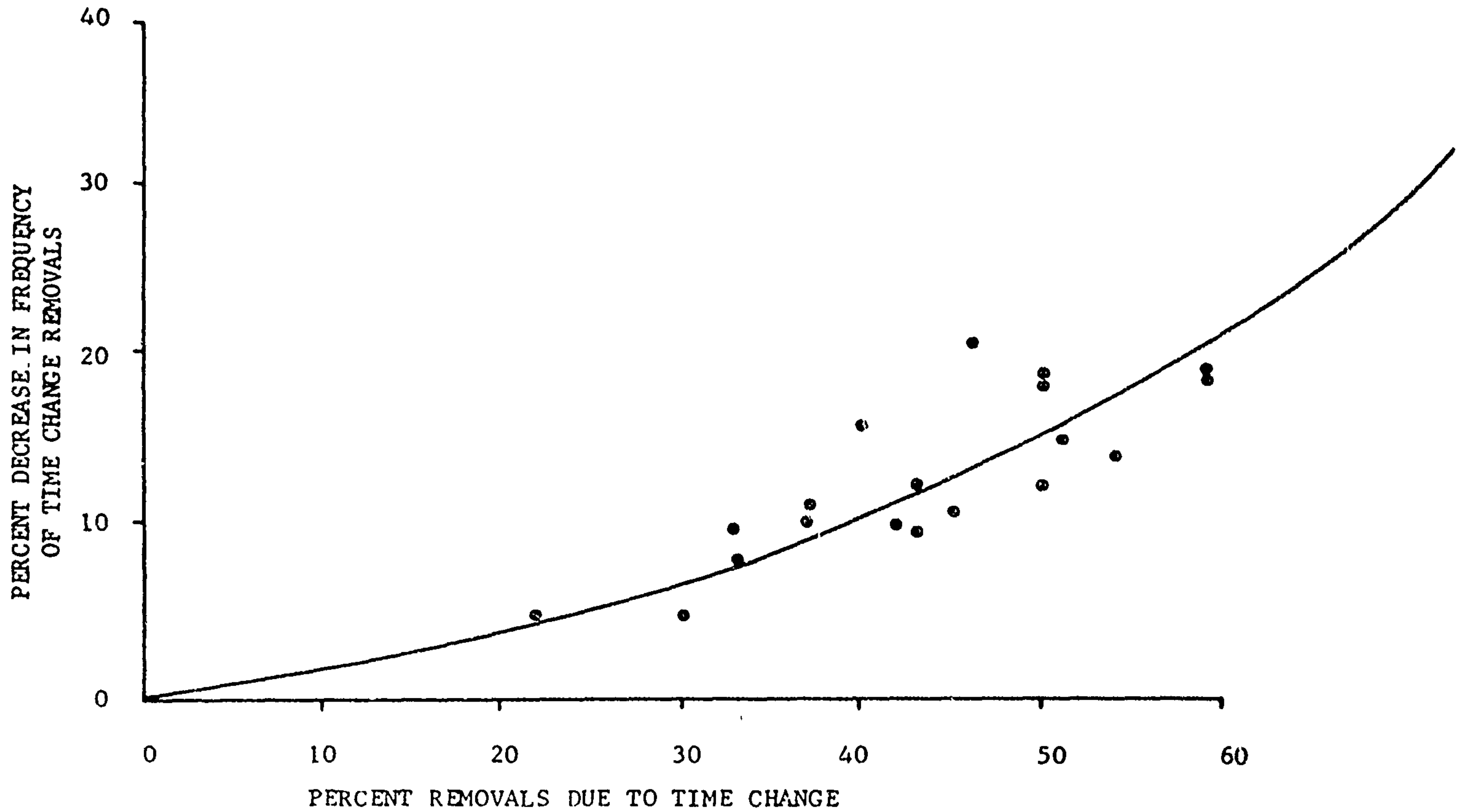


FIGURE 7-8 CH-47A REDUCTION IN REMOVAL FREQUENCY DUE TO ON CONDITION MAINTENANCE INSTEAD OF TIME CHANGE REMOVALS (ALL COMPONENTS)

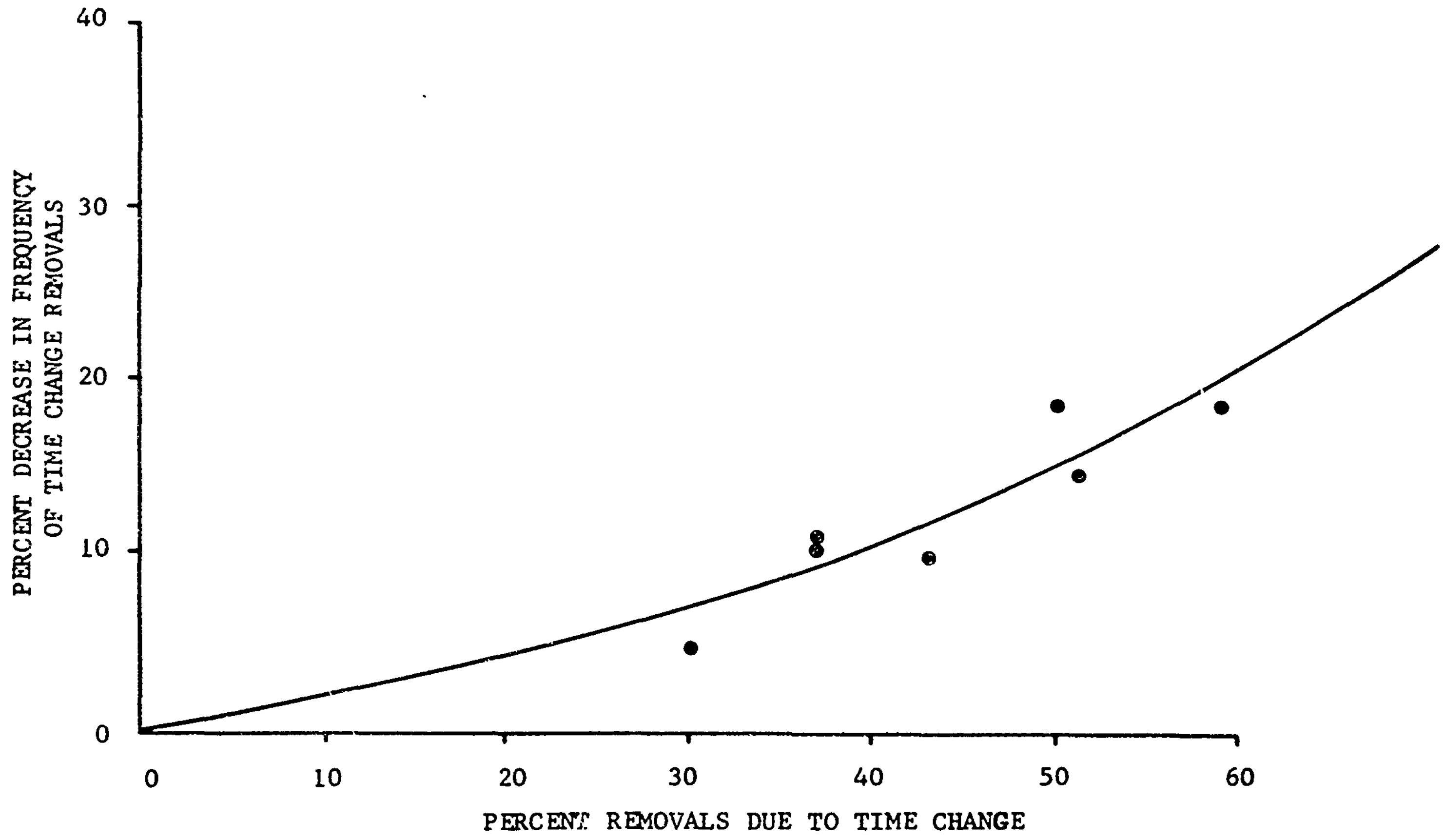


FIGURE 7-9 CH-47A REDUCTION IN REMOVAL FREQUENCY DUE TO ON CONDITION MAINTENANCE INSTEAD OF TIME CHANGE REMOVALS (TRANSMISSION PARTS)

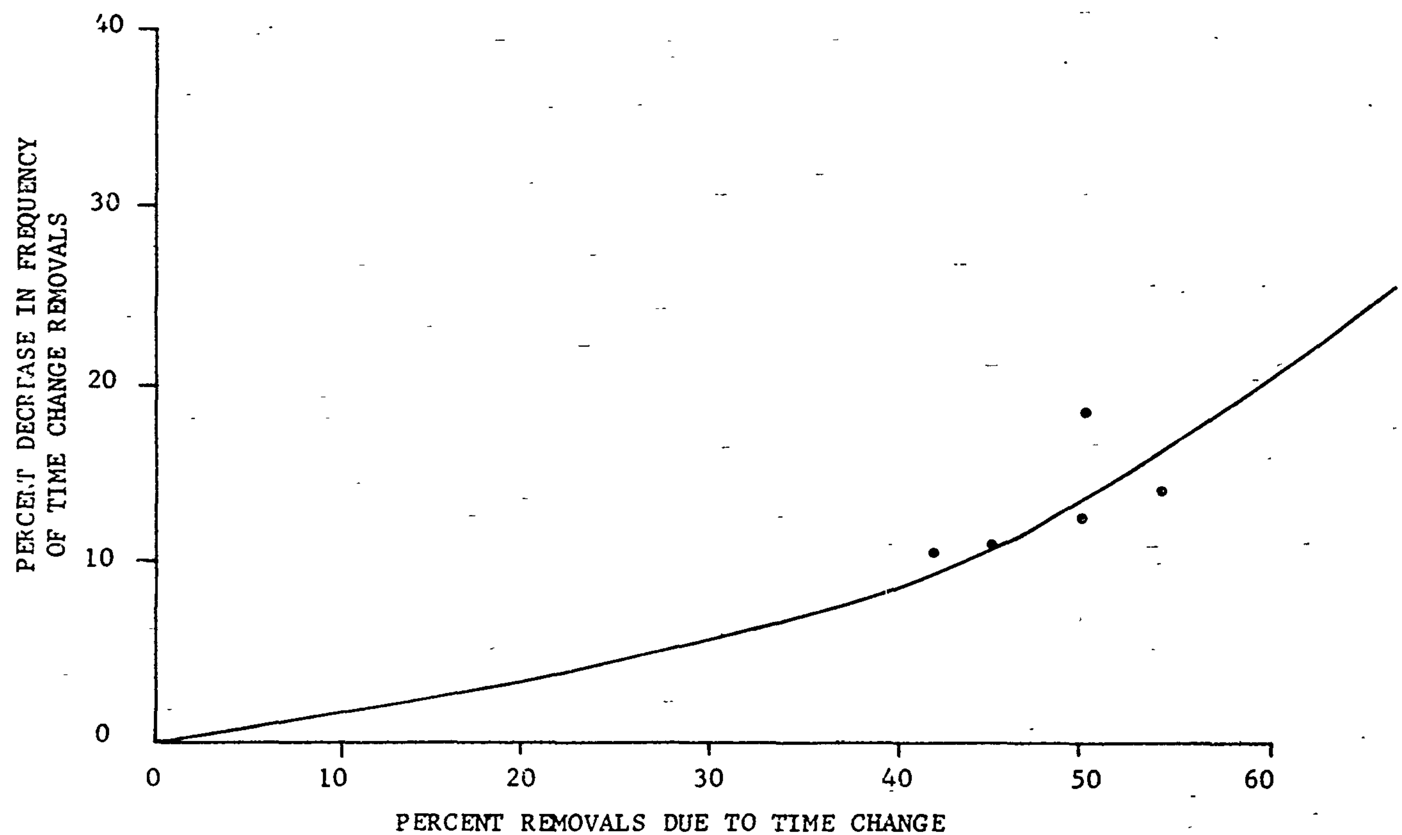


FIGURE 7-10 CH-47A REDUCTION IN REMOVAL FREQUENCY DUE TO ON CONDITION MAINTENANCE INSTEAD OF TIME CHANGE REMOVALS (SWASHPLATE PARTS)

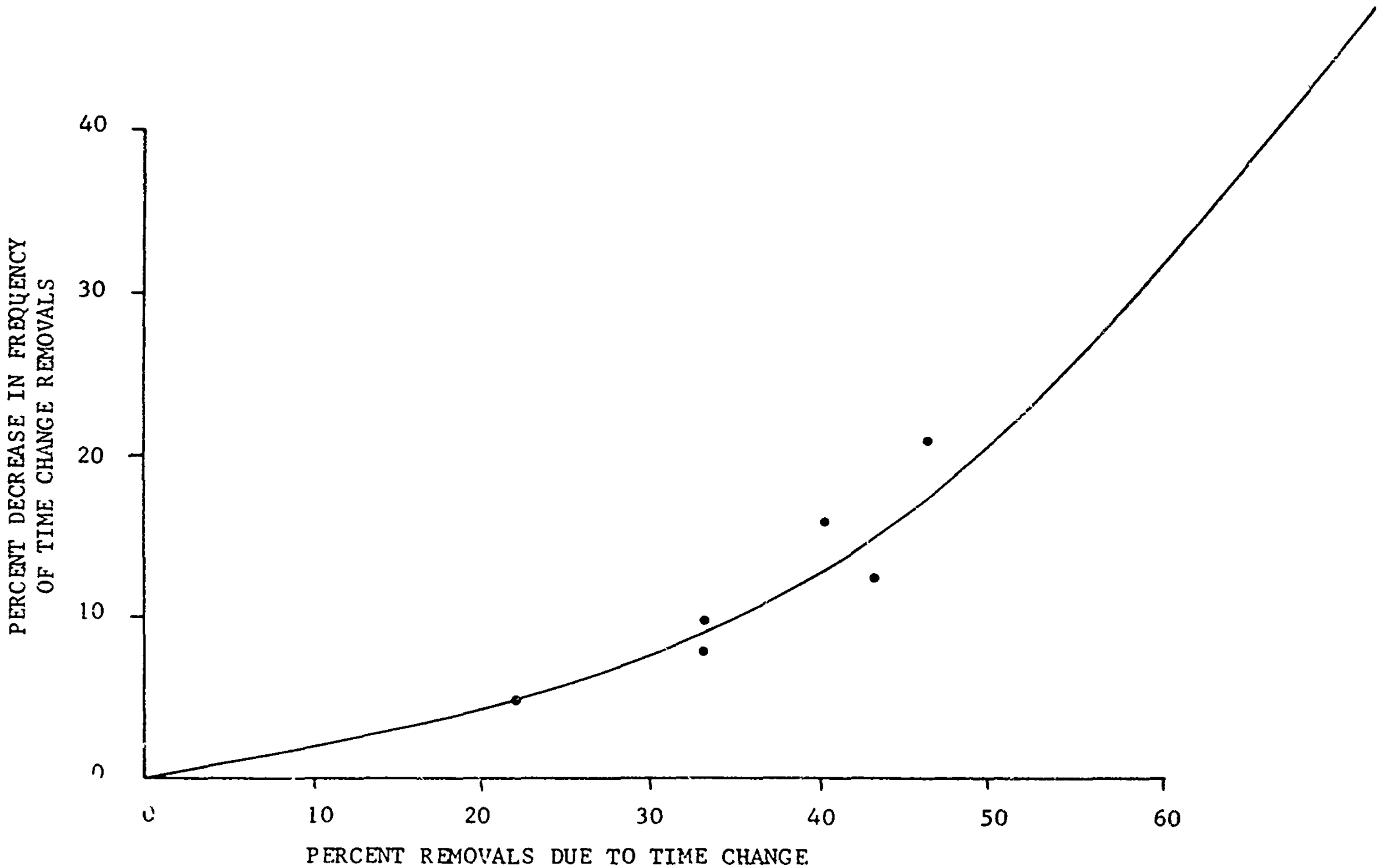


FIGURE 7-11 CH-47 REDUCTION IN REMOVAL FREQUENCY DUE TO ON CONDITION MAINTENANCE INSTEAD OF TIME CHANGE REMOVALS
(SHAFT ASSEMBLY PARTS)

TABLE 7-12 EFFECTS OF ON CONDITION MAINTENANCE ON AIR SAFETY
WITH AIDAPS SYSTEM OF VARIOUS TEST ACCURACIES
(TRANSMISSION 1615 045-9961)

CONDITION		PER 100,000 FLYING HOURS	OPERATING FAIL RATE PER FLYING HOUR	EXPECTED ACCIDENTS PER 100,000 FLYING HOURS TOTAL	MAJOR	MINOR
Present Without AIDAPS						
Time Removals		212				
Failures		173	173	.97	.67	.26
TOTAL		385	173	.97	.67	.26
AIDAPS With .6 Test Accuracy and Time Removal						
Time Removals		212				
Failures		173	69	.39	.27	.08
TOTAL		385	69	.39	.27	.08
AIDAPS With .6 Test Accuracy and On Cond. Maintenance						
On Condition	Former Time	174*	70	.39	.27	.08
	Former Failures	173	69	.39	.27	.08
TOTAL		347	139	.78	.54	.16
AIDAPS With .4 Test Accuracy and On Cond. Maintenance						
On Condition	Former Time	174*	104	.58	.40	.10
	Former Failures	173	104	.58	.40	.10
TOTAL		347	208	1.16	.80	.20
AIDAPS With .95 Test Accuracy and On Cond. Maintenance and Air Warning						
On Condition	Former Times	174*	9	N	N	N
	Former Failures	173	9	N	N	N
TOTAL		347	18	N	N	N

*Represents the expected operational failures due to the components presently removed on a time basis. Number of failures = 212 x (1.0 - .18). The factor .18 represents the reduction in removal frequency from Figure 7-9.

N = Negligible

If an AIDAPS with a high test accuracy is achieved the number of operational failures is greatly reduced. Further, since reliable airborne warning can be provided with these systems, the accident potential from this component will be reduced to substantially zero in this case.

Although it is apparent that on condition maintenance should not be allowed with AIDAPS of low test accuracy, there appears to be no definite value of test accuracy below which on condition maintenance is not feasible. However, for test accuracies above 80% and with airborne diagnosis, short term prognosis and warning, accidents due to failure of the heavily monitored components should be substantially eliminated. Therefore, the ability to go to on condition maintenance has been limited to those systems displaying the above characteristics. A detailed look at each time removal component is warranted to establish if specific components might be suitable for on condition maintenance with the Ground System. Obviously, those components which always exhibit a type A failure indication are candidates for on condition maintenance regardless of the type of AIDAPS system used.

Table 7-13 lists the parameters for the UH-1 which have a 100% "A" designation together with the components monitored. It is evident from the tabulated comments that only the following items can be maintained on an "on condition" basis by the Ground AIDAP System:

a) Engine Fuel Drain
b) Pitot Tube Heater
c) Main Rotor Assembly
d) Power Cylinders and Irreversible Valves
e) Hydraulic System
f) Electrical System
g) Fuel System

Only one of these, the Main Rotor Assembly, is listed in the Overhaul and Retirement Schedule (TM55-1520-210-20, page 3-37).

TABLE 7-13 PARAMETERS OF 100% "A" TYPE FAILURE INDICATIONS

ITEM	SUBSYSTEM	COMPONENT MONITORED	COMMENTS
12	03	Engine Oil Quantity	Rate of oil consumption can be an indication of engine condition - not sufficient alone for engine analysis.
13	03	Engine Fuel Drain	Indication of proper operation of fuel drain valve.
14	misc.	Pitot Tube Heater	Operation can be monitored.
19	03	Interstage Airbleed	Operation can be monitored; will operate during start and deceleration of engine.
23	03	Engine Air Partical Separator	ΔP across filters can be monitored for maintenance.
25	03	Engine Fuel Filter	ΔP across filters can be monitored for maintenance.
31	04	42° Gearbox, Chips	Discrete for flt, safety & main.
33	04	90° Gearbox, Chips	Discrete for flt. safety & main.
35	04	Main Gearbox, Chips	Discrete for flt. safety & main.
43	04	Main Rotor Assembly	Vibration monitoring will reveal wear or looseness in bearing, linkages, clamps, etc. Faults may become more evident at 60 to 100K airspeed.
46,47,48	06	Power Cylinders and Irreversible Valves	Can be monitored for primary failure mode of leakage.
50	06	Hydraulic Pressure	Probably due to hydraulic pump wear.
51	06	Hydraulic Control Solenoid.	Operation can be monitored.
53	09	Bus Control Relay	Operation can be monitored.
54	09	Inverter Bus Voltage	Operation can be monitored.
56	10	Aft Fuel Cell Leakage	Can be monitored.
57	10	Fwd Fuel Cell Leakage	Can be monitored.
58	10	Rt Fuel Boost Pump	Operation can be monitored.
59	10	Left Fuel Boost Pump	Operation can be monitored.
60	10	Main Fuel Filter	ΔP Switch
62	10	Starting Fuel Solenoid	Operation can be monitored.

Items (a) and (b) in Table 7-13 are primarily concerned with inspections. All of the other items exhibited scheduled removals on the UH-1 maintenance history printout. This indicates that at least some of the major components of the subsystems have removal schedules and, presumably, could be maintained on an on condition basis with Ground AIDAPS.

It must be emphasized that these subsystems represent only a minor portion of the aircraft. For example, the total maintenance index for the subsystems which are listed is 49 MH/1000 FH in contrast to the total for the UH-1 of 4322 MH/1000 FH. Man-hours required for scheduled removals are only a small fraction of this. The situation is similar for the Hybrid II System. Therefore, although it is evident that on condition maintenance is possible on some components with the Ground and Hybrid II AIDAP Systems, the benefits derived therefrom are negligible and have been omitted from this study.

7.2.6.5 Air Safety Analysis

More than 600 accident reports from the UH-1, OH-6 and AH-1 aircraft were analyzed with the objective of determining the ability of AIDAPS to: (a) detect impending failures of each accident causing system prior to flight or, (b) for those potential malfunctions not detected, providing sufficient warning to the pilot during flight to prevent an accident. The first capability eliminates aborts as well as accidents. The second capability reduces accidents only. The basic data examined consisted of printouts of classified USAABAR Crash Message Tape Records. A sample of the data evaluated as the first step in the analysis process is shown as Table 7-14a.

For the purposes of this accident analysis only, those aborts and accidents associated with a malfunctioning engine, transmission or other AIDAPS-monitored components, and those accidents associated with faulty weight and balance conditions, were considered. No credit was taken for accidents associated with pilot errors, collisions or components not suitable for monitoring by AIDAPS. When a component is monitored by AIDAPS, the prognostic capability will necessarily improve as the component nears the end of its life. It is easier to predict that a component will fail in the next 2 hours after 500 hours of history are available, than it is to predict a component will fail after 500 hours when only two hours of history are available. This is particularly true when specific parameters

TABLE 7-14a ACCIDENT DATA - SAMPLE

1	2	3	4	5	6
3	FORCED LANDING	LOSS OF RPM/LOW RPM	LOSS OF ROTOR RP-SOPPL FOL	04	P
3	FORCED LANDING	OTHER	SHORT SHAFT SNPD-ACHVRGN	04	P
3	FORCED LANDING	SUSPECT TAIL ROTOR FAILURE	TROTOR BRG DISINTEGRATED	04	P
3	FORCED LANDING	SUSPECT CON SYS FAILURE	SPRAG CLUTCH FAILURE	04	P
3	FORCED LANDING	SUSPECT CON SYS FAILURE	YAWED WITH TRVIB-CSE UNK	04	P
3	FORCED LANDING	SUSPECT HYD SYS FAILURE	HYD FAILURE IN LNDG	06	P
3	FORCED LANDING	SUSPECT HYD SYS FAILURE	SERVO ACTUATOR LINEBROKE	06	P
3	FORCED LANDING	WARNING LIGHT CAME ON	HYD LINE BRKN	06	P
3	FORCED LANDING	OTHER	2NUTSLEFTOFF CYCLICSTUDS	11	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	COMPRESSOR STALL	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	ENG FAILD AUTOROTATED	03	P
3	FORCED LANDING	FUEL EXHAUSTION	ENG FAIL-FUEL EXAUSTION	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	ENG FLD AT 3FT HVR-CSEUN	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	10FT HVR-ENG.FAIL	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	ENG FAIL -CSE UNK	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	LOUDNOISE-ENG FLD-CSEUNK	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	ENG FAIL - CAUSE UNK	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	PARTIAL ENG FAIL RECOVRD	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	FIRE&SMOKE FROM ENGINE	03	P
3	FORCED LANDING	SUSPECT ENGINE FAILURE	ENG FAIL T53L13A LE16363	03	P
3	FORCED LANDING	OTHER	OIL LINE FAILURE	03	P

1 SITUATION CODE
2 REPORTED SITUATION
3 CAUSE
4 REMARKS
5 SYSTEM CODE
6 AIRCRAFT CODE

such as vibration, compressor efficiency, temperature, etc. are used to predict the condition of components. This short-term prognostic accuracy allows those components which are near failure to be replaced after the flight in which the AIDAPS detected an impending failure. This prevents the failure from occurring on the next flight causing an abort or an accident. Presently, maintenance men cannot prevent these types of failures because they either do not monitor the pertinent parameters often enough or they do not monitor them at all (i.e., vibration).

Air warning provides an additional means for preventing accidents for failure modes which do not lend themselves to prognosis and as a safety feature for the AIDAPS prognostic capability. Many accidents are caused because a pilot does not realize the performance of some system is below normal. For instance, if he calls for full engine power during a landing, a degraded engine may not have sufficient power to recover or avoid an obstacle. An AIDAP system will provide notice of degradation prior to the time it would normally be observed by the pilot. In such cases, this airborne warning capability will help avoid the accident.

For accidents involving weight and balance, credit for accident prevention was taken only if the accident data showed that the weight and balance calculations were either wrong or never made. The AIDAPS can make these calculations much more rapidly and accurately than the present hand procedure, and, further, will make them at the initiation of every flight.

In the accident/abort study, each accident was studied to determine if AIDAPS could have prevented it, and, if so, which of the modes; i.e., detection of an impending malfunction or airborne warning, would have applied.

Accident data from three aircraft, UH-1H, OH-6A and the AH-1G were available and were analyzed separately. For each aircraft, the data were grouped by systems in order to observe any systematic trend in their contribution to accidents. It was observed that three systems--engine, transmission/rotor and hydraulic--contribute to the majority of the accidents, approximately 75% or more. Each accident report was examined individually, and a determination was made whether AIDAPS would have a major, a minor, or no effect upon the likelihood of the occurrence of the malfunction. A determination was also made as to the effect of AIDAPS upon the likelihood of the accident occurring given that a malfunction has occurred. This relates to the reduction in the hazard frequency.

A summary of the factors employed after the basic effectiveness decision had been made is shown below.

AIDAPS IMPACT	FREQUENCY	HAZARD
MAJOR IMPACT	.95	.50
MINOR IMPACT	.30	.20

ACCIDENT IMPROVEMENT FACTORS

The .95 is derived from the test accuracy value determined earlier providing that the application of an AIDAPS will have a major impact on determining as well as predicting the condition of a component. If the overall impact cannot be substantiated as well, but there is strong reason to suspect that the accident could have benefited from AIDAPS, a degraded value of .30 was employed.

Even if a component still fails in the air, it is possible to warn the pilot and avoid an accident or prevent the accident from becoming as serious as it would have been without the AIDAPS. These events are reflected in the hazard rate. The selected values for this factor were determined after a review of various Air Force tests performed to determine the effectiveness of voice warning.

Once the effect of AIDAPS has been assigned, the percent reduction can be computed. Accident reports of the first three categories--total loss, major accident and minor accident--were combined to obtain the percent reduction in the accident frequency and the percent reduction in the hazard frequency. The reduction in the frequency of aborts was obtained by analyzing accident reports of the remainng categories--incidents, forced landings and precautionary landings. By similar analysis, the AIDAPS effect on the likelihood of the occurrence of the malfunction was determined and the percent reduction in frequency was computed. A detailed discussion regarding the actual computations used in the models to determine savings resulting from improved accident characteristics is presented in Appendix C, sections 3.0 and 4.0.

Table 7-14b shows the results of this study. Sufficient accident data was not available on all aircraft to accomplish a detailed analysis. The composite data was used for the aircraft not listed on Table 7-14b. For the OH-58, the

TABLE 7-14b PERCENT REDUCTION IN ACCIDENT, ABORT & HAZARD FREQUENCIES

SYSTEM	AIRFRAME (01)	ALIGHTING GEAR (02)	ENGINE (03)	TRANSMISSION ROTOR (04)	HYDRAULIC (06)	INSTRUMENTS (08)	ELECTRICAL (09)	FUEL (10)	FLIGHT CONTROL (11)	PILOT ERROR (59)	TOTAL AIRCRAFT	TOTAL NUMBER OF OCCURRENCES
UH-1												
% Reduction in Accident Freq	0	0	39.5	20.0	30.0	0	0	0	0	19.0	30.0	52
% Reduction in Abort Freq	0	0	34.5	52.0	25.3	95.0	15.0	63.0	44.2	9.7	43.6	314
% Reduction in Hazard	0	0	23.5	10.0	20.0	0	0	0	0	0	15.6	-
OH-6												
% Reduction in Accident Freq	0	0	0	0	0	0	0	0	0	0	0	25
% Reduction in Abort Freq	0	0	54.4	20.9	30.0	0	53.0	0	31.3	0	36.2	78
% Reduction in Hazard	0	0	41.5	25.0	0	0	0	50.0	0	0	27.6	-
AH-1												
% Reduction in Accident Freq	0	0	16.7	0	0	0	0	0	0	0	10.7	14
% Reduction in Abort Freq	0	0	67.9	32.5	45.3	0	63.2	95.0	42.0	0	52.2	152
% Reduction in Hazard	0	0	40.0	0	0	0	0	50.0	0	0	32.8	-
COMPOSITE												
% Reduction in Accident Freq	0	0	25.7	10.9	30.0	0	0	0	0	11.2	18.8	91
% Reduction in Abort Freq	0	0	58.2	39.3	32.0	95.0	49.7	62.5	41.5	9.1	45.0	544
% Reduction in Hazard	0	0	30.7	14.5	20.0	0	0	50.0	0	0	21.6	-

data for the OH-6 were used. The items designated "% reduction in accident frequency" and "% reduction in abort frequency" indicates the detection of impending malfunctions prior to flight. The item called "% reduction in hazard" is the reduction in accidents due to airborne diagnosis and warning. The figures shown are for an AIDAPS System with a 95% test accuracy. Less accurate AIDAP Systems have a proportional degradation in accident prevention. For AIDAP Systems with no air warning capability, the percentage reduction in hazard is zero.

7.3 AIDAPS PROCUREMENT COSTS, COST FACTORS AND WEIGHTS

This section presents the outputs of the AIDAPS Procurement Cost Model. See Appendix C for the cost derivation. These outputs form the basis of the equipment dependent costs of the AIDAPS Life Cycle Cost/Benefit Model. Some equipment dependent cost factors vary with the AIDAPS configuration and some do not. Table 7-15 shows the cost factors which do not vary significantly with the AIDAPS configuration.

TABLE 7-15 AIDAPS INDEPENDENT COST FACTORS

Cost Item	Basic Cost	Cost Per Aircraft	Cost Per 1000 Flying Hrs.
Test Units	$50,200 per set	$502.00	N/A
Test Equip. Maint.	3% per year	$15.06/Yr.	$31.37
Training	$6,855 per student	N/A	N/A

7.3.1 UNIQUE AIDAP SYSTEM COSTS

Table 7-16 shows the basic hardware costs for the unique systems by aircraft groups. These costs are based on a buy of 500 and are in 1971 dollars. There may be slight differences in system cost between aircraft within a group. These cost differences are due to small changes in the number of sensors required and resulting differences in PC boards to handle additional parameters. However, these cost changes are negligible.

Table 7-17 shows the same cost items adjusted for learning curve effects due to the procurement quantities required to outfit a complete aircraft fleet.

Tables 7-18 through 7-20 show cost information computed by the AIDAPS Life Cycle Cost Model. It is presented here for purposes of continuity.

Table 7-18 shows the total DDT&E and procurement cost on a per aircraft basis. These costs include the hardware, aircraft modification and DDT&E costs prorated across all aircraft of a given type. Only one ground portion of the hybrid systems is required per 15 aircraft, and only one Ground AIDAPS is required for five aircraft. The high unit cost of the U-21, CH-54, and HLH systems is due primarily to the low number of AIDAPS required. The prorated DDTE costs make up a major portion of the total AIDAPS procurement price for these aircraft.

Table 7-19 shows the 10 year operating costs. The difference in cost for operating different AIDAP Systems on the same aircraft is primarily due to differences in the time required for aircraft inspections and diagnosis. The difference in operating costs for the same AIDAPS generic type applied to different aircraft is due primarily to spares provisioning costs which are dependent upon the system procurement cost. Differences in aircraft utilization and attendant differences in AIDAPS utilization are also important.

TABLE 7-16 AIDAPS HARDWARE COST BASED ON 500 SYSTEMS PROCURED (UNIQUE SYSTEMS)

AIRCRAFT GROUP	AIRCRAFT TYPE	AIDAPS HARDWARE COST (K DOLLARS)					
			HYBRID SYSTEM I		HYBRID SYSTEM II		
		AIRBORNE SYSTEM	AIRBORNE HARDWARE	GROUND HARDWARE	AIRBORNE HARDWARE	GROUND HARDWARE	GROUND SYSTEM
I	OH-6, OH-58	17.6	11.6	14.7	9.7	17.2	31.0
II	UH-1, AH-1	18.0	12.0	14.7	10.1	17.2	31.4
III	U-21	18.4	12.4	14.7	10.5	17.2	31.8
IV	OV-1	17.4	11.4	14.7	9.5	17.2	31.8
V	CH-47, CH-54, UTTAS, HLH	22.6	16.6	14.7	14.7	17.2	37.0

TABLE 7-17 AIDAPS HARDWARE COST BASED ON FLEET SIZE (EXCLUDING SENSORS) (UNIQUE SYSTEMS)

AIRCRAFT TYPE	NO. IN FLEET	AIDAPS HARDWARE COST (K DOLLARS)					
		AIRBORNE SYSTEM	HYBRID SYSTEM I		HYBRID SYSTEM II		GROUND SYSTEM (5 A/C)
			AIRBORNE	GROUND (15 A/C)	AIRBORNE	GROUND (15 A/C)	
OH-6	234	19.9	13.1	16.6	11.0	19.4	35.0
OH-58	1906	14.4	9.5	12.1	8.0	14.1	25.4
UH-1	3568	13.5	9.0	11.0	7.6	12.9	23.6
AH-1	584	17.6	11.8	14.4	9.9	16.9	30.8
U-21	104	23.5	15.9	18.8	13.4	22.0	40.7
OV-1	228	19.8	13.0	16.8	10.8	19.6	36.3
CH-47	451	23.1	16.9	15.0	15.0	17.5	37.7
CH-54	74	30.3	22.2	19.7	19.7	23.0	49.6
UTTAS	2356	18.1	13.3	11.8	11.8	13.8	29.6
HLH	43	33.0	24.2	21.5	21.5	25.1	54.0

TABLE 7-18 AIDAPS INITIAL INVESTMENT COST PER AIRCRAFT INCLUDING DDTE + PROCUREMENT + INSTALLATION (THOUSANDS OF DOLLARS)

AIRCRAFT	NO. IN FLEET	AIDAP SYSTEM K DOLLARS/AIRCRAFT			
		AIRBORNE	HYBRID I	HYBRID II	GROUND
OH-6	234	42.8	37.3	34.9	27.6
OH-58	1906	23.8	19.4	17.8	13.7
UH-1	3568	22.6	18.6	17.1	12.9
AH-1	584	33.0	28.0	26.0	19.5
U-21	104	81.2	76.5	73.0	59.3
OV-1	228	52.3	47.3	44.5	35.9
CH-47	451	48.6	43.9	41.7	30.5
CH-54	74	126.9	124.3	119.7	94.6
UTTAS	2356	28.5	24.7	23.1	16.5
HLH	43	189.1	189.4	182.9	147.7

TABLE 7-19 AIDAPS TOTAL OPERATING COST PER AIRCRAFT (10 YEARS) (THOUSANDS OF DOLLARS)

AIRCRAFT	NO. IN FLEET	AIDAP SYSTEM K DOLLARS / AIRCRAFT			
		AIRBORNE	HYBRID I	HYBRID II	GROUND
OH-6	234	5.4	5.5	5.8	12.1
OH-58	1906	3.7	3.8	4.1	10.4
UH-1	3568	3.8	3.7	3.9	5.0
AH-1	584	3.9	3.9	4.0	5.0
U-21	104	8.4	8.6	8.9	16.5
OV-1	228	5.9	5.9	6.1	9.7
CH-47	451	5.2	5.4	5.7	12.1
CH-54	74	9.2	9.3	9.5	12.7
UTTAS	2356	4.4	4.7	5.2	16.3
HLH	43	13.7	13.8	14.0	17.2

Table 7-20 shows the total life cycle costs for the generic AIDAP System types and aircraft applications. The life cycle costs generally increase as one progresses from the Ground System to the Airborne System. An exception is the HLH, for which the Hybrid I System shows the highest cost. This is due to the proration of DDT&E cost across the small number of systems required. The DDT&E cost is highest for the Hybrid I System.

Table 7-21 shows the airborne weights of the system including sensors, cabling and electronics. The weight shown for the Ground Based System consists entirely of sensors and wiring. It is equal to approximately one half the weight of the entire Airborne System.

Table 7-22 shows all the cost factors computed by the AIDAPS Procurement Cost Model.

7.3.2 GROUPED AIDAP SYSTEM COSTS

As a result of tradeoffs for the unique system, the Hybrid II and Ground-Based AIDAP Systems were eliminated from further consideration. The Airborne and Hybrid I systems were modified to be applicable to groups of aircraft based on refinements on the number of sensors to be monitored. These design changes produced only a minor effect upon basic (i.e., quantity = 500) systems costs. However, the quantity produced, as well as the prorating of DDT&E costs over larger numbers of aircraft, produced significant cost reductions for those aircraft types existing in small numbers. Table 7-23 shows the cost outputs of the AIDAPS procurement model for the Group AIDAP systems. For a definition of the aircraft/AIDAP system groups see paragraph 5.6.

TABLE 7-20 AIDAPS TOTAL LIFE CYCLE OWNERSHIP COST PER AIRCRAFT (THOUSANDS OF DOLLARS)

AIRCRAFT	NO. IN FLEET	OWNERSHIP COST $\frac{\text{K DOLLARS}}{\text{AIRCRAFT}}$			
		AIRBORNE	HYBRID I	HYBRID II	GROUND
OH-6	234	48.1	42.8	40.7	39.7
OH-58	1906	27.5	23.2	21.9	24.1
UH-1	3568	26.3	22.3	21.0	18.9
AH-1	584	36.8	31.8	29.9	24.5
U-21	104	89.6	85.1	81.9	75.8
OV-1	228	58.2	53.2	50.6	45.2
CH-47	451	53.8	49.2	47.3	42.3
CH-54	74	136.2	133.6	129.2	107.3
UTTAS	2356	33.1	29.5	28.3	32.8
HLH	43	202.8	203.1	196.8	164.9

TABLE 7-21 AIDAPS AIRBORNE WEIGHT (LBS)

AIRCRAFT GROUP	AIRCRAFT TYPE	AIRBORNE WEIGHT POUNDS/AIRCRAFT			
		AIRBORNE	HYBRID I	HYBRID II	GROUND
I	OH-6	31.7	27.7	23.7	13.8
	OH-58	31.7	27.7	23.7	13.8
II	UH-1	33.8	29.8	25.8	15.6
	AH-1	33.8	29.8	25.8	15.6
III	U-21	35.8	31.8	27.8	17.4
IV	OV-1	36.1	32.1	28.1	18.6
V	CH-47	50.8	46.8	42.8	25.8
	CH-54	50.8	46.8	42.8	25.8
	UTTAS	50.8	46.8	42.8	25.8
	HLH	50.8	46.8	42.8	25.8

TABLE 7-22 UNIQUE AIDAPS COST FACTORS

Aircraft	System	Maint. Index MMH/K FH	Procurement Cost K Dollars/Aircraft	Airborne Weight Lbs./Aircraft	Initial Spares Cost Percent of Procure. Cost	Replacement Spares Cost Dollars/K FH	Depot Maint. Cost Dollars/K FH	Depot Logistics Weight Lbs./K FH	GS Logistics Weight Lbs./K FH	Installation Cost K Dollars/Aircraft	DDT&E Cost Millions of Dollars
OH-6	Airborne	5.828	21.8	31.7	3.96	10.98	283.7	.583	5.44	4.38	3.28
	Hybrid I	5.152	16.0	27.7	4.88	16.12	250.5	.513	4.81	4.11	3.43
	Hybrid II	5.304	14.1	23.7	4.06	20.99	258.0	.530	4.95	4.11	3.36
	Ground	2.604	8.9	13.8	2.24	7.98	126.7	.261	.99	3.57	2.94
OH-58	Airborne	5.828	15.8	31.7	3.96	10.98	283.7	.583	5.44	4.00	3.28
	Hybrid I	5.152	11.6	27.7	4.88	16.12	250.5	.513	4.81	3.74	3.43
	Hybrid II	5.304	10.2	23.7	4.06	20.99	258.0	.530	4.95	3.74	3.36
	Ground	2.604	6.5	13.8	2.24	7.98	126.7	.261	.99	3.20	2.94
UH-1	Airborne	6.266	15.0	33.8	3.45	13.69	304.9	.627	5.85	4.33	3.81
	Hybrid I	5.612	11.2	29.8	4.23	18.82	273.2	.561	5.25	4.06	4.00
	Hybrid II	5.764	9.9	25.8	3.78	23.70	280.7	.577	5.39	4.06	3.91
	Ground	2.926	6.2	15.6	2.35	10.44	142.3	.282	1.11	3.53	3.39
AH-1	Airborne	6.266	19.6	33.8	3.45	13.69	304.9	.627	5.85	4.48	3.81
	Hybrid I	5.612	14.6	29.8	4.23	18.82	273.2	.561	5.25	4.20	4.00
	Hybrid II	5.764	12.9	25.8	3.78	23.70	280.7	.577	5.39	4.20	3.91
	Ground	2.926	8.1	15.6	2.35	10.44	142.3	.282	1.11	3.67	3.39
U-21	Airborne	6.706	26.4	35.8	5.73	16.17	326.6	.670	6.26	5.22	4.81
	Hybrid I	6.052	19.8	31.8	7.00	21.31	294.6	.605	5.65	4.80	5.06
	Hybrid II	6.204	17.7	27.8	6.07	26.19	302.1	.621	5.79	4.80	4.94
	Ground	3.268	11.0	17.4	4.42	12.70	158.9	.326	1.24	4.42	4.24
OV-1	Airborne	6.896	22.5	36.1	5.44	17.74	335.4	.689	6.43	5.05	5.02
	Hybrid I	6.242	16.6	32.1	6.77	22.87	303.8	.624	5.83	4.78	5.29
	Hybrid II	6.384	14.7	28.1	5.98	27.75	310.8	.634	5.95	4.78	5.16
	Ground	3.468	9.9	18.6	4.25	14.12	168.7	.347	1.32	4.24	4.42
CH-47	Airborne	9.376	26.3	50.8	4.43	32.82	455.9	.938	8.75	5.98	6.14
	Hybrid I	8.662	21.1	46.8	5.26	37.96	421.3	.865	8.08	5.70	6.48
	Hybrid II	8.874	19.4	42.8	4.81	42.84	432.0	.887	8.27	5.70	6.32
	Ground	4.784	10.8	25.8	4.29	26.78	232.6	.478	1.82	5.06	5.36
CH-54	Airborne	9.376	34.6	50.8	4.43	32.82	455.9	.938	8.75	7.10	6.14
	Hybrid I	8.662	27.7	46.8	5.26	37.96	421.3	.865	8.08	6.83	6.48
	Hybrid II	8.874	25.5	42.8	4.81	42.84	432.0	.887	8.27	6.83	6.32
	Ground	4.784	14.2	25.8	4.29	26.78	232.6	.478	1.82	6.19	5.36
UTTAS	Airborne	9.376	20.6	50.8	4.43	32.82	455.9	.938	8.75	2.92	6.14
	Hybrid I	8.662	16.6	46.8	5.26	37.96	421.3	.865	8.08	2.78	6.48
	Hybrid II	8.874	15.2	42.8	4.81	42.84	432.0	.887	8.27	2.78	6.32
	Ground	4.784	8.5	25.8	4.29	26.78	232.6	.478	1.82	2.46	5.36
HLH	Airborne	9.376	37.7	50.8	4.43	32.82	455.9	.938	8.75	5.20	6.14
	Hybrid I	8.662	30.2	46.8	5.26	37.96	421.3	.865	8.08	5.07	6.48
	Hybrid II	8.874	27.7	42.8	4.81	42.84	432.0	.887	8.27	5.07	6.32
	Ground	4.784	15.5	25.8	4.29	26.78	232.6	.478	1.82	4.75	5.36

TABLE 7-23 GROUP ADAPS DEPENDENT COST FACTORS

		MAINTENANCE INDEX (MMH/ K FH)	PROCUREMENT COST K DOLLARS /AIRCRAFT)	AIRBORNE WEIGHT (LBS/ AIRCRAFT)	INITIAL SPARES COST (OF PROCUREMENT COST)	REPLACEMENT SPARES COST DOLLARS /K FH)
OH-6	AIRBORNE	6.257	16.84	30.97	5.23	14.55
	HYBRID	5.482	11.96	26.97	6.25	18.32
OH-58	AIRBORNE	6.257	16.84	30.97	5.23	14.55
	HYBRID	5.482	11.96	26.97	6.25	18.32
UH-1	AIRBORNE	8.139	17.36	37.15	6.91	28.09
	HYBRID	7.286	12.49	32.90	8.51	31.85
AH-1	AIRBORNE	8.264	17.35	37.65	4.65	28.58
	HYBRID	7.410	12.48	33.40	5.74	32.34
U-21	AIRBORNE	6.335	16.74	31.10	7.05	14.33
	HYBRID	5.482	11.87	26.85	8.40	18.08
OV-1	AIRBORNE	6.489	16.10	32.34	6.66	15.46
	HYBRID	5.636	11.23	28.09	8.11	19.22
CH-47	AIRBORNE	10.899	23.54	55.31	9.20	58.79
	HYBRID	10.045	18.18	51.06	11.16	62.55
CH-54	AIRBORNE	10.413	23.59	54.43	4.43	55.36
	HYBRID	9.559	18.23	50.18	5.35	59.12
UTTAS	AIRBORNE	12.105	23.29	52.30	9.87	64.55
	HYBRID	11.251	17.94	48.05	12.05	68.31
HLH	AIRBORNE	13.868	24.91	60.34	6.35	102.27
	HYBRID	13.014	19.56	56.09	7.73	106.03

		DEPOT MAINTENANCE COST (DOLLARS /K FH)	DEPOT LOGISTICS WEIGHT (LBS/ K FH)	GSLOGISTICS WEIGHT (LBS/ K FH)	INSTALLATION COST (K DOLLARS /AIRCRAFT)	DDT&E COST MILLIONS OF DOLLARS)
OH-6	AIRBORNE	304.49	0.626	5.84	5.05	1.835
	HYBRID	266.77	0.548	5.12	4.69	1.920
OH-58	AIRBORNE	304.49	0.626	5.84	4.68	1.835
	HYBRID	266.77	0.548	5.12	4.32	1.920
UH-1	AIRBORNE	396.11	0.814	7.60	5.66	1.215
	HYBRID	354.57	0.729	6.80	5.30	1.280
AH-1	AIRBORNE	402.18	0.826	7.71	5.92	1.215
	HYBRID	360.64	0.741	6.92	5.56	1.280
U-21	AIRBORNE	308.31	0.634	5.91	6.01	1/215
	HYBRID	266.77	0.548	5.12	5.65	1.280
OV-1	AIRBORNE	315.82	0.649	6.06	5.61	1.215
	HYBRID	274.28	0.564	5.26	5.26	1.280
CH-47	AIRBORNE	530.42	1.090	10.17	7.29	1.678
	HYBRID	488.88	1.005	9.38	6.93	1.798
CH-54	AIRBORNE	506.74	1.041	9.72	8.13	1.678
	HYBRID	465.20	0.956	8.92	7.77	1.798
UTTAS	AIRBORNE	589.10	1.210	11.30	3.72	1.678
	HYBRID	547.56	1.125	10.50	3.54	1.798
HLH	AIRBORNE	674.39	1.387	12.94	6.54	1.678
	HYBRID	633.34	1.301	12.15	6.36	1.798

7.3.3 UNIVERSAL AIDAP SYSTEM COSTS

While generating the costs of the grouped AIDAP systems, it became apparent that additional cost savings can be achieved by creating universal modules at no sacrifice in AIDAPS effectiveness. This allowed a constant effectiveness, lowest cost tradeoff to be accomplished to establish the least cost universal system of two generic types, Airborne and Hybrid 1. (See Section 7.3). Table 7-24 presents the outputs of the AIDAPS Procurement Cost Model for the modular universal AIDAP systems.

7.4 AIRCRAFT OPERATIONAL & COST FACTORS

Although hypothetical combat scenarios were not necessary for this study, it was necessary to make some assumptions and estimates of the world wide Army environment in the post 1975 time era. Only a few of the assumptions have a strong impact on the study.

7.4.1 GENERAL ASSUMPTIONS

The general assumptions are:

a) Ten years of substantially peacetime operations.

b) Basic time frame is 1975 through 1985.

c) All costs in 1971 dollars except aircraft procurement and part procurement costs.

d) Aircraft procurement cost of existing aircraft are as listed in FM-101-20.

e) Part procurement costs as listed in the Federal Stock Catalogue.

f) Military Environment as defined in FM-101-20.

g) Army aircraft maintenance policies remain substantially unchanged except as influenced by AIDAPS.

The basic time frame was extended in certain cases where the AIDAPS or aircraft procurement schedule did not allow for 10 years of operation within the base period. This extension applied primarily to the HLH and UTTAS.

TABLE 7-24 UNIVERSAL AIDAPS DEPENDENT COST FACTORS

		MAINTENANCE INDEX (MMH/ K FH)	PROCUREMENT COST K DOLLARS /AIRCRAFT)	AIRBORNE WEIGHT (LBS/ AIRCRAFT)	INITIAL SPARES COST (OF PROCUREMENT COST)	REPLACEMENT SPARES COST DOLLARS /K FH)
OH-6	AIRBORNE	6.257	15.34	31.97	6.79	15.22
	HYBRID	5.482	10.86	27.72	7.92	10.79 18.79
OH-58	AIRBORNE	6.257	15.34	31.97	6.79	15.22
	HYBRID	5.482	10.86	27.72	7.92	18.79
UH-1	AIRBORNE	8.159	16.00	37.15	8.45	26.72
	HYBRID	7.236	11.51	32.90	10.16	32.30
AH-1	AIRBORNE	8.264	15.98	37.65	5.68	29.22
	HYBRID	7.410	11.50	33.40	6.84	32.79
U-21	AIRBORNE	6.335	15.42	31.10	8.96	14.96
	HYBRID	5.482	10.94	26.85	10.42	18.53
OV-1	AIRBORNE	6.489	14.83	32.34	8.41	16.09
	HYBRID	5.636	10.35	28.09	10.01	19.66
CH-47	AIRBORNE	10.899	19.60	55.06	11.35	59.04
	HYBRID	10.045	14.99	50.81	13.62	62.61
CH-54	AIRBORNE	10.413	19.64	54.18	5.46	55.60
	HYBRID	9.559	15.03	49.93	6.53	59.18
UTTAS	AIRBORNE	12.105	19.39	52.05	12.15	64.79
	HYBRID	11.251	14.78	47.80	14.71	68.37
HLH	AIRBORNE	13.868	20.39	59.84	7.89	102.51
	HYBRID	13.014	15.78	55.59	9.62	106.08

		DEPOT MAINTENANCE COST (DOLLARS /K FH)	DEPOT LOGISTICS WEIGHT (LBS/ K FH)	GSLOGISTICS WEIGHT (LBS/ K FH)	INSTALLATION COST (K DOLLARS /AIRCRAFT)	DDT&E COST MILLIONS OF DOLLARS)
OH-6	AIRBORNE	304.49	0.626	5.84	5.05	.733
	HYBRID	266.77	0.548	5.12	4.69	.775
OH-58	AIRBORNE	304.49	0.626	5.84	4.68	.733
	HYBRID	266.77	0.548	5.12	4.32	.775
UH-1	AIRBORNE	336.11	0.814	7.60	5.66	.733
	HYBRID	354.57	0.729	6.80	5.30	.775
AH-1	AIRBORNE	402.18	0.826	7.71	5.92	.733
	HYBRID	360.64	0.741	6.92	5.59	.775
U-21	AIRBORNE	308.31	0.634	5.91	6.01	.733
	HYBRID	266.77	0.548	5.12	5.65	.775
OV-1	AIRBORNE	315.82	0.649	6.06	5.61	.733
	HYBRID	274.28	0.564	5.26	5.26	.775
CH-47	AIRBORNE	530.42	1.090	10.17	7.29	.793
	HYBRID	488.88	1.005	9.38	6.93	.840
CH-54	AIRBORNE	506.74	1.041	9.72	8.13	.793
	HYBRID	465.20	0.956	8.92	7.77	.840
UTTAS	AIRBORNE	589.10	1.210	11.30	3.72	.793
	HYBRID	547.56	1.125	10.50	3.54	.840
HLH	AIRBORNE	674.89	1.387	12.94	6.54	.793
	HYBRID	633.34	1.301	12.15	6.36	.840

7.4.2 OPERATIONAL DATA

In order to assess the total impact of AIDAPS upon Army operations, it is necessary to estimate certain operational and logistic data. These data were projected to the 1975-85 time frame. The primary operational data inputs are:

a) Average aircraft utilization for each type
b) Number of aircraft in inventory for each aircraft type by fiscal year
c) Aircraft deployment (percent overseas and percent in CONUS)
d) Average number of missions per day for each aircraft type
e) Number of operational days per month
f) Representative mission payloads for each aircraft type
g) Aircraft abort rates for each aircraft type
h) Average aircraft availability for each aircraft type
i) Average aircraft accident rate for each aircraft type and for each class of accidents

Some of these inputs were subject to large deviations. For instance, present world wide aircraft utilization is over twice the value listed in FM-101-20 for peacetime operation for some aircraft. Hence, three estimates were made for each of the inputs which show significant deviations, and which have significant effects upon the study results. These estimates are labeled pessimistic, expected and optimistic. The pessimistic assumptions are those which are least favorable to AIDAPS. Expected assumptions are those which are our best estimate of the 1975-85 environment. The optimistic assumptions are those most favorable to AIDAPS. In certain cases an alternate pessimistic assumption or alternate optimistic assumption is listed. These are assumptions which have been made for sensitivity analysis of the specific parameters.

Data taken from FM-101-20 peacetime operations is considered pessimistic since these data, particularly aircraft utilization, are the most pessimistic available. These data were used to perform the tradeoffs for the unique systems since only the relative performance of the AIDAPS candidates is necessary so that more realistic cost and savings estimations could be made for the AIDAPS justification. The expected values are based on the assumption that no large scale war (Vietnam type) would occur, but that the normal exigencies such as occurred between the Korean War and Vietnam would continue.

Table 7-25 shows a summary of the operational factors and cost which are dependent upon aircraft type. These data are shown for the standard (pessimistic) conditions. On subsequent tables, three figures are shown for those data which ca [illegible]e accurately estimated. The estimates which were not available from off[illegible] sources or data are marked with an "E".

The following discussion lists the source and/or the methods used to develop each estimate.

7.4.2.1 Aircraft Costs

These data were derived from SB 700-20 for all aircraft except the HLH and the UTTAS. The costs of these aircraft were obtained from commercial publications.

7.4.2.2 Aircraft Utilization, Deployment, Missions and Inventory

Table 7-26 shows current Army aircraft deployment utilization and status from April 1969 through December 1970. Table 7-27 shows a projection of this data to the years 1975 to 1985 based upon the following assumptions:

a) End of Vietnam conflict will require reassessment/realignment of strategic deployment capability.

b) Combat forces redeployed from Vietnam will substantially be sent to Europe or other foreign countries (AH-1, CH-54).

c) Low density of CH-54's requires wide dispersion.

d) National Guard and reserve forces will be updated with CH-47A and UH-1A's.

e) Proficiency and training requirements will increase the percentage of OH-58's and OH-6's required in CONUS.

f) Distribution of HLH will be approximately the same as the CH-54 and distribution of the UTTAS will be approximately the same as the UH-1.

No differentiation is made between overseas and CONUS deployment for aircraft utilization and status since these factors are probably more sensitive to other variables and official estimates are being used. Three estimates are

TABLE 7-25 AIRCRAFT DATA (STANDARD PEACETIME CONDITIONS)

AIRCRAFT	$ COST	UTIL. (3)	AVERAGE PAYLOAD	MISSIONS PER OPERATIONAL DAY (2)	ACCIDENT RATES/100,000FH 1 TOTAL	2 MAJOR	3 MINOR	ABORT RATE/ 1,000 HR	PROB. MAINT.	AVE. MAINT. TIME
AH-1	365,254	30	1,993	0.99	11.25	12.46	.61	1.96	1.0	3.60
CH-47 (6)	1,145,500	20	6,945	0.693	7.39	4.43	.49	2.33	1.0	3.12
CH-54	1,800,000	15	11,522	0.50	14.01	0.0	7.01	3.99	1.0	2.40
OH-6	56,262	30	600 (4)	0.84	14.68	21.54	0.0	1.08	1.0	2.40
OH-58	90,208	30	600E	0.84	5.55	11.1	.79	.52E	1.0	4.80
OV-1C	1,058,540	35	1,930	1.46	6.78	1.36	2.71	.977	.864	3.12
UH-1	266,578	30	1,800	0.84	7.45	7.04	.82	.758	1.0	3.12
U-21	246,337	40	2,000	0.48	2.8	9.24	1.32	.701	1.0	2.40
HLH	9,000,000 (5)	15	45,000E	0.50	14.01	0.0	7.01	3.99	1.0	2.4
UTTAS	1,400,000 (1)	30	2,640E	0.84	7.45	7.04	.82	.758	1.0	3.12

(1) Armed Forces Journal, 7 June 1971, Page 21
(2) 24 flying days per month
(3) Data taken from FM 101-20, Peacetime TOE and Indirect Support (Worldwide)
(4) Viet Nam experience
(5) Defense Market Survey, Market Intelligence Report, October 1970
(6) Data averaged for A, B and C models

TABLE 7-26 CURRENT ARMY AIRCRAFT DISTRIBUTION, UTILIZATION AND STATUS

DATA	UH-1 (1)		AH-1		OH-6		OH-58		CH-47 (2)		CH-54	
CATEGORY	OS	US	OS	US	OS	US	OS	US	OS	US	OS	US
INVENTORY DISTRIBUTION %	76%	24%	81%	19%	72%	28%	77%	23%	79%	21%	75%	25%
FLIGHT HOURS PER VEH PER MO	58 Hrs	40 Hrs (4)	37 Hrs	25 Hrs	56 Hrs	40 Hrs (4)	45 Hrs	40 Hrs (4)	50 Hrs (4)	19 Hrs	37 Hrs	19 Hrs
OR	70%	71%	74%	72%	74%	69%	80%	83%	70%	67%	68%	66%
NORS	6%	11%	7%	9%	7%	19%	5%	7%	7%	18%	12%	21%
NORM	26%	18%	19%	19%	19%	12%	15%	10%	23%	15%	20%	13%
	U-21		OV-1 (3)									
INVENTORY DISTRIBUTION %	71%	29%	70%	30%								
FLIGHT HOURS PER VEH PER MO	66 Hrs	40 Hrs	38 Hrs	15 Hrs								
OR	76%	75%	78%	73%								
NORS	3%	7%	8%	9%								
NORM	21%	18%	14%	18%								

(1) UH-1 B, C, D, H Total Deployment; (2) CH-47A, B, C Total Deployment; (3) OV-1A, B, C Total Deployment
(4) Estimated

TABLE 7-27 PROJECTED ARMY AIRCRAFT DISTRIBUTION, UTILIZATION AND STATUS FOR POST 1975

DATA CATEGORY	UH-1	AH-1	OH-6	OH-58	CH-47
PERCENT OVERSEAS	76/60/60	90/80/80	72/60/60	77/60/60	74/50/50
FLIGHT HRS PER VEHICLE PER MO (1)	80/40/30	70/40/30	70/40/30	70/40/30	60/30/20
% OR	65/76/80	63/72/75	70/77/80	73/80/83	59/65/82
% NORS (2)	7%	10%	10%	7%	15%
% NORM	27/17/13	27/18/15	20/13/10	20/13/10	26/20/13
	CH-54	U-21	OV-1	HLH	UTTAS
INVENTORY DISTRIBUTION	90/75/75	71/60/60	70/60/60	90/75/75	76/60/60
FLIGHT HRS PER VEHICLE PER MO	50/25/15	75/50/40	70/40/35	69/25/15	69/40/30
% OR	57/69/76	66/79/82	58/70/72	59/68/75	67/76/80
% NORS	14%	5%	8%	15%	7%
% NORM	29/17/10	29/16/18	34/22/20	26/17/10	26/17/13

(1) Optimistic figure represents Wartime TOE, best (expected) estimate is average over a period of 10 years excluding major conflicts. Pessimistic estimate is an average of Peacetime TOE aircraft and Indirect Support aircraft.

(2) Operational Readiness and Downtimes, Aviation Training Base Aircraft.

presented for each variable to which the AIDAPS analysis is sensitive. Aircraft NORS rate does not affect the analysis. Aircraft NORM rate is dependent upon aircraft utilization and manning. It was assumed that Army manning policies would remain substantially the same (if AIDAPS is not available) so that the adjusted NORM rates only reflect the assumptions made on aircraft utilization. It is generally assumed that the amount of maintenance required, and thus downtime for maintenance, is a direct ratio to the amount of flying accomplished.

Aircraft utilization is the major variable for which optimistic, expected, and pessimistic type assumptions are made.

The predicted aircraft inventories were derived from FM-101-20 and a letter from DA staff stating Aircraft Inventory Projections dated 21 December 1970.

7.4.2.3 Payload

The installation of an AIDAP System aboard an aircraft involves only one performance penalty. This penalty is the increase in weight. Since this increase is small, its impact upon most aircraft operations is not severe; however, it must be evaluated to preserve an unbiased analysis.

The weight of the AIDAP System will affect operations only on those missions which call for a maximum payload capacity under the existing takeoff conditions. For these missions, there are a number of possible alternative effects. These are:

a) An equivalent weight of cargo may not be carried.
b) A longer takeoff run may be required.
c) Rotary wing aircraft may not be able to operate in the vertical takeoff mode.
d) An equivalent weight of fuel may not be carried.

In tactical operations aircraft are usually loaded to the maximum capacity allowed by the ambient weather conditions and takeoff space available. These operational effects can be considered as payload effects for cargo carrying aircraft. For [illegible] and reconnaissance missions, where cargo capacity is not of primary concern, the penalty can be taken as fuel which ultimately results in less loiter time or [illegible].

Table 7-28 shows the missions to be evaluated in this analysis. Three missions are shown for each aircraft. Wherever possible, these missions were taken from excerpts from FM -101-20, "Army Aviation Planning Manual." Each mission is described in terms of three characteristics: takeoff altitude, maximum payload, and an estimate of the percentage of missions which will utilize the maximum payload under combat conditions.

The primary mission for each aircraft is usually the basic mission listed in the referenced material. The mission labeled "optimistic" represents a selection of a typical mission which will be penalized very little by the AIDAPS weight. The pessimistic mission is one that is the most severely penalized mission of the missions listed in the reference material. It is the mission carrying the least payload. Usually this reduced payload is due to a takeoff restriction. The table lists this takeoff restriction in terms of a takeoff (pressure) altitude. Pressure altitude was selected due to the variables associated with computation of density altitude, and the fact that precise aircraft performance based on density altitude is not required. The only assumption the analysis actually makes is that the payload capacity is restricted to the value shown because of some combat, altitude or temperature condition.

Although the additional AIDAPS weight may cause degradation of some missions, it is not reasonable to assume that all missions are payload limited. For this reason, an assumption on the number of missions which are payload limited was made. This assumption was that 50% of the missions are payload limited. However, a sensitivity analysis was accomplished on the lighter aircraft for this parameter. The primary payload was used on the expected and pessimistic computer runs. The alternate pessimistic payload was used for payload sensitivity analysis.

7.4.2.4 Average Missions Per Day

Table 7-29 shows the average mission durations which were derived from the missions listed in FM-101-20. When the average daily flying hours derived from the monthly aircraft utilization is divided by these mission durations, the average number of missions per day is obtained. This is shown in Table 7-30.

TABLE 7-28 AVERAGE PAYLOADS

AIRCRAFT	PRIMARY MISSION T.O. ALT.	PRIMARY MISSION PAYLOAD	OPTIMISTIC T.O. ALT.	OPTIMISTIC PAYLOAD	ALTERNATE PESSIMISTIC T.O. ALT.	ALTERNATE PESSIMISTIC PAYLOAD	REMARKS
AH-1G	0-5000[1]	1933	0-5000	1943	10,000	270	1. BASIC
CH-47C	0-9900[1]	6925*	S.L.[2]	15,390*	0-13,850	5000*	1. BASIC I; 2. BASIC III;
CH-54A	0-5000[1]	11,522/0	S.L.[2]	20,000/0	10,000	7300/0	1. BASIC; 2. BASIC WITH 10,000' T.O. ALT.
OH-6A	0-5000[1]	600E	0-10,000	637[2]	0-10,000	400	1. BASIC; 2. ALTERNATE II
OH-58	0-5000E	600E	0-10,000E	650E	0-10,000E	400E	
OV-1C	--	1930		2194		1930	PAYLOAD = FUEL LOAD
UH-1H	0-4000E	1800E	0-1000	2400	0-8000	800	
U-21A	--	2000		3000		1901	
HLH		45,000E		60,000E		15,000E	
UTTAS		2600E		3600E		1500E	

*WEIGHTED AVERAGE FOR A, B, AND C MODELS

E = ESTIMATED

TABLE 7-29 AVERAGE MISSION DURATION

	EXPECTED AND PESSIMISTIC		OPTIMISTIC		ALTERNATIVE PESSIMISTIC	
	PAYLOAD	DURATION	PAYLOAD	DURATION	PAYLOAD	DURATION
AH-1	1,933	1.27	2,699	.87	270	2.6E
CH-47	6,445	1.2	15,390	.62	7,000	.80
CH-54	11,522	1.25	20,000	.45	7,300	1.97
OH-6	600	1.5	637	1.65	400	1.85
OH-58	600	1.5	650	1.65	400	1.85
OV-1	1,930	1.0	2,194	.98	1,930	.50
UH-1	1,800	1.5	2,400	1.40	800	1.51
U-21	2,010	3.5	3,000	2.3	190	2.2
HLH	45,000E	1.25E	60,000E	.45E	15,000E	1.2E
UTTAS	2,640E	1.5E	3,600E	1.4E	1,500E	1.5E

TABLE 7-30 MISSIONS PER DAY

	OPTIMISTIC			EXPECTED			PESSIMISTIC		
AIRCRAFT	FH PER DAY	AVERAGE MISSION DURATION	MISSIONS PER DAY	FH PER DAY	AVERAGE MISSION DURATION	MISSIONS PER DAY	FH PER DAY	AVERAGE MISSION DURATION	MISSIONS PER DAY
AH-1	2.92	.87	3.14	1.67	1.27	1.31	1.25	1.27	.985
CH-47	2.5	.62	4.04	1.25	1.2	1.04	.833	1.2	.693
CH-54	2.09	.45*	4.65	1.04	1.25	0.833	.625	1.25	.5
OH-6	2.92	1.65	1.77	1.67	1.5	1.11	1.25	1.5	.835
OH-58	2.92	1.65	1.77	1.67	1.5	1.11	1.25	1.5	.835
OV-1	2.92	.98	2.98	1.67	1.0	1.67	1.46	1.0	1.46
UH-1	3.33	1.5	2.38	1.67	1.5	1.11	1.25	1.5	.835
U-21	3.13	2.3	1.36	2.09	3.5	0.60	1.67	3.5	.477
HLH	2.09	.45	4.65	1.04	1.25	0.833	.625	1.25	.5
UTTAS	3.33	1.4	2.38	1.67	1.5	1.11	1.25	1.5	.835

*VIETNAM HANDBOOK

7.4.2.5 Estimation of Maintenance Parameters

In order to determine the effect of AIDAPS on aircraft availability, it is necessary to determine the aircraft Not Operationally Ready (NORM) rates. Basic NORM rates corresponding to peacetime TOE conditions are available from FM-101-20. It is necessary to vary these for utilizations different from peacetime TOE conditions. The amount of unscheduled maintenance, and the portion of periodic maintenance dependent upon flying time are functions of aircraft utilization. On a per flight basis, the average maintenance duration is a function of the probability that maintenance is performed, multiplied by the expected maintenance duration given that maintenance is required.

7.4.2.6 Probability of Maintenance and Average Maintenance Duration

The estimates of the aircraft probability of maintenance is divided into two parameters, the probability of unscheduled maintenance and the probability of scheduled maintenance. The probability of unscheduled maintenance is obtained from the system break rates are summed for all systems to obtain an aircraft break rate per flying hour. Multiplying by the average mission duration gives the break rate per mission. Under the assumption that the system breaks are independent, the following expression for the probability of unscheduled maintenance per mission (P_U) can be written:

$$P_U = 1.0 - \exp. - MT$$

where:

M = aircraft break rate per flying hour

T = average mission duration

Scheduled maintenance consists primarily of daily inspections which occur once per day on days on which flying is accomplished. Therefore if, on the average, less than one mission per day is accomplished, this probability can be assumed to be 1.0. When more than one mission per day is accomplished, the probability of scheduled maintenance (P_S) is:

$$P_S = 1.0/N_M$$

where N_M = the number of missions per day.

The total probability of maintenance (P_M) then becomes:

$$P_M = P_U + P_S - P_U P_S$$

The calculations shown above are based on a constant maintenance manpower. It is assumed that the amount of maintenance required is directly proportional to aircraft utilization. The repair times, downtimes and NORM rates for the HLH were derived to match the QMR requirements and are very low. However, since these values have only a minor effect on the results of the model, no adjustments to the QMR data were made.

Table 7-31 shows the maintenance parameters used in the study. The columns are identified as follows:

A/C = Aircraft type (input)

MR = Maintenance rate per flying hour as determined from TAMMS data (input)

MT = Average mission duration (input)

PU = Probability of unscheduled maintenance per mission

PS = Probability of scheduled maintenance per mission

DMD = Daily maintenance duration

TPM = Total probability of maintenance per mission

AMD = Average maintenance duration per mission

RT = Average time to perform unscheduled maintenance

DT = Average maintenance down time per day

NORM = Not operationally ready-maintenance rates (from FM-101-20 for the expected case only)

7.4.3 ADDITIONAL COST FACTORS

Additional cost factors necessary to estimate the costs and benefits of the AIDAP systems are shown in Tables 7-32 and 7-33. The symbols used in the AIDAPS Cost Benefit Model and their definition are also shown. These cost data were derived from the Army Force Planning Cost Handbook, Department of the Army,

TABLE 7-31 AIRCRAFT MAINTENANCE PARAMETERS (STANDARD CONDITIONS)

PROB OF MAINTENANCE (STANDARD MISSION)

A/C	MR	MT	PU	PS	DMD	TPM	AMD	RT	DT	NORM
AH-1	0.391	0.497	0.391	1.000	3.600	1.000	3.655	5.546	3.600	0.150
CH-47	1.067	1.230	0.722	1.000	3.120	1.000	4.502	1.457	3.120	0.130
CH-54	1.510	1.887	0.849	1.000	2.400	1.000	4.800	1.532	2.400	0.100
OH-6	0.535	0.802	0.552	1.000	2.400	1.000	2.874	3.750	2.400	0.100
OH-58	0.535	0.802	0.552	1.000	2.400	1.000	2.874	3.780	2.400	0.100
OV-1	0.839	0.839	0.568	0.685	4.800	0.894	3.806	3.869	4.800	0.250
UH-1	0.390	0.585	0.443	1.000	3.120	1.000	3.737	5.050	3.120	0.130
U-21	0.400	1.400	0.753	1.000	3.120	1.000	6.541	6.160	3.120	0.130
HLH	1.830	2.287	0.898	1.000	2.400	1.000	4.800	0.890	2.400	0.100
UTTAS	0.650	0.975	0.623	1.000	3.120	1.000	3.737	3.100	3.120	0.130

PROB OF MAINTENANCE (EXPECTED)

A/C	MR	MT	PU	PS	DMD	TPM	AMD	RT	DT	NORM
AH-1	0.391	0.497	0.391	0.763	4.800	0.856	4.281	5.516	4.325	0.180
CH-47	1.067	1.230	0.722	0.962	4.800	0.989	4.665	1.460	4.546	0.189
CH-54	1.510	1.887	0.849	1.000	4.080	1.000	4.916	1.530	3.983	0.155
OH-6	0.535	0.802	0.552	0.901	3.120	0.956	2.941	3.760	3.103	0.129
OH-58	0.535	0.802	0.552	0.901	3.120	0.950	2.941	3.750	3.103	0.129
OV-1	0.839	0.839	0.568	0.590	5.530	0.827	4.006	3.869	5.261	0.219
UH-1	0.391	0.585	0.444	0.961	4.020	0.945	3.890	5.050	3.837	0.166
U-21	0.400	1.404	0.753	1.003	3.840	1.000	6.400	6.160	3.925	0.164
HLH	1.830	2.287	0.898	1.000	4.080	1.000	4.898	0.890	3.998	0.167
UTTAS	0.650	0.975	0.623	0.901	4.080	0.963	3.813	3.110	3.953	0.165

PROB OF MAINTENANCE (OPTIMISTIC MISSION)

A/C	MR	MT	PU	PS	DMD	TPM	AMD	RT	DT	NORM
AH-1	0.391	0.340	0.288	0.318	8.400	0.515	5.195	5.410	6.480	0.270
CH-47	1.067	0.662	0.484	0.248	9.600	0.612	5.885	1.462	6.304	0.263
CH-54	1.510	0.679	0.493	0.215	7.000	0.602	2.822	1.530	7.008	0.292
OH-6	0.535	0.883	0.586	0.565	5.500	0.820	3.789	3.760	4.702	0.196
OH-58	0.535	0.883	0.586	0.565	5.500	0.320	3.789	3.760	4.702	0.196
OV-1	0.839	0.822	0.561	0.335	9.600	0.708	4.550	3.869	8.048	0.335
UH-1	0.391	0.547	0.422	0.420	8.150	0.665	5.153	5.050	6.587	0.274
U-21	0.400	0.920	0.661	0.735	6.700	0.895	5.507	6.160	6.939	0.289
HLH	1.830	0.823	0.561	0.215	11.000	0.655	3.609	0.890	6.322	0.263
UTTAS	0.650	0.910	0.597	0.420	7.200	0.767	3.946	3.110	6.222	0.259

TABLE 7-32 AIDAPS COST BENEFIT MODEL
DEFINITION OF TERMS AND COST FACTORS

Fixed Inputs

FEPS	=	Initial stocks and supplies ($/man). Includes cost of minor TOE equipment initial allowances, repair parts (prescribed list), station equipment, and organizational clothing and equipment. The average cost per man is $1,126.	
CFTF	=	Flight training cost per man as follows:	$
		Fixed Wing	30,842
		Rotary Wing (excl. CH-47 & CH-54)	40,967
		CH-47	81,122
		CH-54	75,845
COTF	=	Indirect commissioned and warrant officer training cost includes officer branch training and student leave and administrative time = $3,382 per man.	
CWTF	=	Maintenance commissioned and warrant officers (direct) training cost includes COTF ($3,382 per man) and maintenance training cost of $4,532 per man. The total training cost per man is $7,914.	
CMF	=	Maintenance enlisted man training cost includes:	
		Basic combat training	$ 953
		Advanced individual training	1,219
		Student leave and administrative time	163
		Aircraft repairman training	2,700
		Total	$5,035
CEI	=	Indirect enlisted man training cost is $2,335.	
CTO	=	Commissioned and warrant officer initial PCS deployment. The cost/man factors are as follows:	

TABLE 7-32 AIDAPS COST BENEFIT MODEL
DEFINITION OF TERMS AND COST FACTORS
(Continued)

		Within CONUS (operational travel)	$ 920
		CONUS to Europe	1,367
		CONUS to Pacific	1,115
		CONUS to Alaska	1,023
		CONUS to So. Command	1,065
CTE	=	Enlisted man PCS deployment cost/man factors are as follows:	
		Within CONUS (operational travel)	$ 229
		CONUS to Europe	454
		CONUS to Pacific (run)	368
		CONUS to Alaska	331
		CONUS to So. Command	343
CE	=	Other initial investment cost per man includes personnel procurement and processing and accession travel and initial clothing costs. The average cost per man is $415.	
CSMF	=	Support equipment maintenance factor (%) applied to the support equipment investment cost. Assumed percent factor = 3%.	
CRSE	=	Support equipment replacement (secondary items - includes repair parts) is estimated at an average of 7% of the support equipment investment cost.	
CR1	=	Conditional probability of pilot casualty due to Category 1 accident. USAF experience = 35%.	
CR2	=	Conditional probability of pilot casualty due to Category 2 accident. Assumed 1/2 of CR1 = 17.5%.	
CR3	=	Conditional probability of pilot casualty due to Category 3 accident = 0.	

TABLE 7-32 AIDAPS COST BENEFIT MODEL
DEFINITION OF TERMS AND COST FACTORS
(Continued)

COFPA/WOFPA = Flight officer pay and allowance includes flight pay and average military pay and allowance.

	Commissioned Officer (COFPA)	Warrant Officer (WOFPA)
Flight Pay	$2,144	$1,449
Average MPA (Worldwide)	11,183	11,183
Total	$13,327	$12,632

COPA/WOPA = Commissioned and warrant officer pay and allowance based on worldwide average MPA = $11,183 per man.

CEPA = Enlisted man pay and allowance based on worldwide average = $4,357 per man.

TOR = Annual replacement of personnel (turnover rates) is computed at 14.8% for officers and 26.5% for enlisted men.

CMO = Costs for procurement and processing and accession travel and initial clothing of replacements necessary to maintain the strength of the force unit at full TOE. Estimated at $415 per man.

CBO = Separation travel and payments. Costs charged to the force unit for personnel attrition from the active Army are computed at:

	Officer	Enlisted
Separation Payments	1,024	256
Separation Travel	471	100
Total	1,4[illegible]	356

Central supply activities	$191 per man
Medical activities	208 per man
Army-wide activities	10 per man
Total cost/man	$409 per man

TABLE 7-33 TRANSPORTATION COST FACTORS

Aircraft average costs per pound $75.00/lb. (Approximate average of AH-1 CH-47C, CH-54A, OH-6A, OH-58, OV-1C, UH-1H and U-21A.)

Preparation for shipping costs per pound (AFM 375-6):

	CONUS	Overseas
Packing Labor	$.1868	$.2331
Material	.0497	.0620
Total	$.2365	$.2951

Packaged to item weight ratios (AFM 375-6)

CONUS = 1.285 Overseas = 1.436

Shipping costs per pound (Round Trip)

	Per Packaged Weight		Per Item Weight	
	CONUS	Overseas	CONUS	Overseas
To DS	.006	.006	.008	.008
To GS (375-6)	.012	.012	.015	.015
To Depot	.118	.406	.152	.583

Total costs per pound item weight:

	CONUS			Overseas		
	DS	GS	Depot	DS	GS	Depot
Pack	.237	.237	.237	.295	.295	.295
Shipping	.008	.015	.152	.008	.015	.583
Total	.245	.252	.389	.303	.310	.878

Total shipping costs per dollar item value:

	CONUS	Overseas
Direct Support	.00327	.00404
General Support	.00336	.00413
Depot	.00519	.01170

November 1969, DOD Instruction 7220.23, 29 April 1970 "Standard Rates for Costing Military Personnel Services", and other sources. Table 7-32 defines the basic cost factors. Basic cost factors are those which are not dependent on the aircraft or AIDAPS types. The symbols used in the model are shown as well as the value of the factors.

Table 7-33 shows the manner in which logistic costs for preparation for shipping and shipping cost factors were derived. Wherever indicated, these data were derived from AFM 375-6.

SECTION 8

8-1.1

8.0 TRADEOFFS

This section contains the tradeoffs which were used to select the best AIDAP systems. The systems were selected on the basis of their overall cost effectiveness. However, to preserve visibility into the results of the study, the AIDAPS costs, savings and benefits are shown for maintenance personnel, logistics, aircraft effectiveness, and accidents for all major tradeoffs. Tradeoffs which are peculiar to a specific aircraft type are discussed under the aircraft heading. Tradeoffs which apply to all aircraft are discussed under a separate heading even though the data may have been derived for a specific aircraft.

One of the essential design requirements for a successful AIDAPS system is its capacity. Systems which monitor too many components are too heavy, too costly, and too complex to be cost effective on Army aircraft. Therefore, primary consideration must be given to components which are most troublesome, exhibit high inspection time, high fault isolation time, replacement time, are costly, contribute to secondary damage, require depot overhaul or critically affect flight safety. In performing the tradeoffs, the components are arranged in order of maintenance man-hour requirements because this is a composite measurement of most of the above maintenance characteristics. Therefore, most charts are presented with the components monitored as the abscissa. For a given aircraft, all components are ranked identically on every chart and run from the highest maintenance indices on the left, to the lowest maintenance indices on the right. Since inspections are treated as a component in the Army TAMMS data, and because it is logical to consider them as components from an instrumentation standpoint, the first few components on each chart usually represent inspections. The first component is the aircraft inspection performed daily by the AIDAPS as described in Section 6.1. This allows the first point of each graph to be considered as the total AIDAPS cost for the designated cost item.

The cost of the AIDAP systems is considered as a constant for each aircraft and AIDAPS type. The AIDAPS cost does not vary as a function of number of components monitored. The number of components to be monitored has been successively optimized during the course of the study. Initially, they were determined from the rank order component lists. As the benefits of monitoring each component became known, the cost of monitoring was compared with the savings and benefits of monitoring. Components with positive net savings and/or benefits were added and those with negative net savings and benefits were deleted.

8.1 UNIQUE AIDAP SYSTEMS

The following paragraphs describe the cost effectiveness of Unique AIDAP Systems which are uniquely designed and developed for individual aircraft. Since the differences between certain aircraft are small, the AIDAPS designs are applicable to groups as described in Section 5. However, the design differences which tailor an AIDAPS designed for a group to an individual aircraft within that group are insignificant from the standpoint of cost effectiveness.

8.1.1 TRADEOFF ASSUMPTIONS

The Unique AIDAP System tradeoffs were conducted under the "standard condition" assumptions. These assumptions refer to the peacetime environment as shown in FM101-20. Historically, the utilization rates achieved by aircraft are somewhat higher. Since aircraft utilization has the major impact on total cost/benefits, the savings shown in these graphs for the unique AIDAPS are somewhat low. For this reason, these conditions are also referred to as "pessimistic" conditions. In general, these assumptions have no effect upon the tradeoff decisions because the relative net savings of the candidate systems remain in the same proportion regardless of these input assumptions. Wherever an input assumption will affect the tradeoff decision, the effects of the assumption were examined.

8.1.1.1 Aircraft and AIDAPS Model Inputs

Table 8-1 shows the aircraft dependent input data and Table 8-2 shows the AIDAPS dependent data. For deviation of these data, see Section 7.4.2 for aircraft and Sections 4.0 and 5.0 for AIDAPS.

Higher test accuracies than were computed in Section 7.0 were used in these runs for the Hybrid II and Ground AIDAP systems. This was done to ensure that the uncertainty of a given parameter alone would not bias the results too heavily.

TABLE 8-1 AIRCRAFT OPERATIONAL INPUTS
(STANDARD CONDITIONS)

AIRCRAFT TYPE	AH-1	CH-47	CH-54	OH-6	OH-58	OV-1	UH-1	U-21	HLH	UTTAS
NO. OF COMPONENTS MONITORED	61	60	73	39	39	35	66	29	66	52
UTILIZATION (FLT HRS/MO.)	30	20	15	30	30	35	30	40	15	30
MISSION PAYLOAD LIMITS (LBS.)	1993	6945	11522	600	600	1930	1400	2000	45000	2640
ABORT RATE (PER 1000 FH)	1.96	2.33	3.99	1.08	.52	.977	.758	.701	3.99	.758
MAINTENANCE INDEX	8.85	32.46	31.32	5.74	5.74	10.91	7.67	8.04	34.0	7.67
MANPOWER PRODUCTIVITY (MH/MO.)	133.6	133.6	133.6	133.6	133.6	133.6	133.6	133.6	133.6	133.6
UNIT FLYAWAY COST ($)	365254	110000	180000	56272	90208	1058540	266578	246337	9000000	1400000
PERCENT OVERSEAS	80	50	75	60	60	60	60	60	75	60
*OPERATIONAL READINESS (%)	80	65	77	80	84	72	80	80	76	80
*PROBABILITY OF MAINT	1.0	0.84	1.0	1.0	1.0	0.879	1.0	1.0	1.0	1.0
*AVG. MAINTENANCE DURATION	2.40	2.53	2.16	2.40	2.16	2.82	3.12	3.60	2.16	3.12
*NO. OF MISSIONS PER DAY	0.70	1.6	1.0	0.79	0.70	1.0	1.0	0.50	0.50	0.90

*DEPENDENT ON UTILIZATION OR PAYLOAD

The time listed under processing time of Table 8-2 includes the total time to remove a tape cartridge and transport it to the ground-based printer (if required), process the tape, accomplish the necessary computations, and print and interpret the results.

TABLE 8-2 AIDAPS PERFORMANCE CHARACTERISTICS

AIDAP System	Processing Time	Test Accuracy	Weight Bal. & Safe Liftoff	Airborne Warning	On Condition Maintenance
Airborne	3 Min.	.95	Yes	Yes	Yes
Hybrid I	6 Min.	.95	Yes	Yes	Yes
Hybrid II	7 Min.	.80	No	No	No
Ground	30 Min.	.75	No	No	No

8.1.1.2 Effect of Input Operational Factors On Model Computations

The operational factors and the cost item they affect are:

FACTOR	COST EFFECTS
Aircraft utilization	All savings of AIDAPS operating costs
Aircraft fleet size	Total costs, benefits and savings
Average aircraft payloads	Increase in aircraft effectivensss
Aircraft cost	Accident savings & value of aircraft effectiveness
Aircraft deployment	Packing and shipping costs
Aircraft availability	Increase in aircraft effectivensss
Aircraft abort rates	Increase in aircraft effectivensss
Aircraft probability of maintenance	Increase in aircraft effectiveness

Aircraft utilization is overwhelmingly the most important operational factor, not only because it affects most cost items, but also because it is subject to the largest uncertainty. For example, the utilization of the UH-1 varies from 30 flying hours per month for peacetime TOE to almost 80 flying hours per month in Vietnam. All aircraft cost savings and AIDAPS operating costs are linearly proportional to utilization. Although aircraft effectiveness in not linearly proportional to utilization, it increases with increased utilization.

Aircraft fleet size affects all costs and benefits linearly. However, it is believed the estimates used are highly accurate and changes will not be significant. For the HLH, and UTTAS, however, the actual procurements may be considerably different from the planning estimates used.

Average aircraft payload only affects the benefits due to increased aircraft effectiveness. The change in aircraft effectiveness due to a difference in average payload can be found by the formula:

$$E_1 = E_o \times \frac{P_o - \frac{P_o}{P_1} RA_w}{P_o - RA_w}$$

where:

E_1 = The new relative effectiveness of the aircraft.

E_o = The computed relative effectiveness of the aircraft. This value is obtained from the graphs titled "Increase in Effective Number of Aircraft". It is equal to 1.0 plus the percent of total fleet expressed as a ratio.

P_1 = New payload

P_o = Original payload

R = Percentage of missions which are payload limited.

A_w = AIDAPS airborne weight

Typical values for R and A_w are .5 and 30 pounds respectively. Therefore, it can be seen that if P_o is 1,000 pounds or over, likely changes in the assessed maximum payload limit become insignificant. Therefore, this equation is only significant for aircraft having payloads less than 1,000 pounds; i.e., the OH-6 and OH-58.

The increase in the number of effective aircraft can be found:

$$NEA = (E_1 - 1.0)\, N_A$$

where N_A is the total number of aircraft in the fleet.

Accident savings are linearly proportional to aircraft cost. Packing and shipping costs are linearly proportional to aircraft deployment for small deviations; i.e., ± 20%.

The increase in aircraft effectivensss is nearly independent of any reasonable assumption as to aircraft availability, abort rates and probabilities of maintenance. Reasonable changes in these inputs produce an insignificant effect (less than 5%) on the overall net costs and benefits.

8.1.2 AIDAPS CONFIGURATION SELECTION

The following tradeoffs are arranged alphabetically according to aircraft type designation. Special tradeoffs examining the sensitivity to certain AIDAPS characteristics or to input data appear at the end of each tradeoff discussion.

8.1.2.1 AH-1 Tradeoffs

Figure 8-1 shows the net reduction in man-hours required per 1,000 flying hours achieved through the use of an AIDAPS as a function of the number of components monitored. The first component monitored represents the aircraft inspection performed by the AIDAP system so that the origin of each curve at component one represents the increase (negative savings) of manpower required to support the AIDAP system. Identification of the components monitored can be obtained from Appendix D. The number of maintenance men saved is shown as well as the personnel cost savings. The personnel cost savings include support and supervision personnel as well as maintenance personnel.

The differences in the personnel savings for the different AIDAPS are primarily due to differences in the time required to acquire, process, and interpret data and the differences in test accuracy.

Figure 8-2 shows the difference in logistics benefits. The differences in net cost savings are due primarily to the inability of the Ground System and Hybrid II to support on condition maintenance, and to differences in test accuracy. The origin of the curves on this graph and all subsequent graphs represents the penalty due to the AIDAPS without taking credit for any benefits.

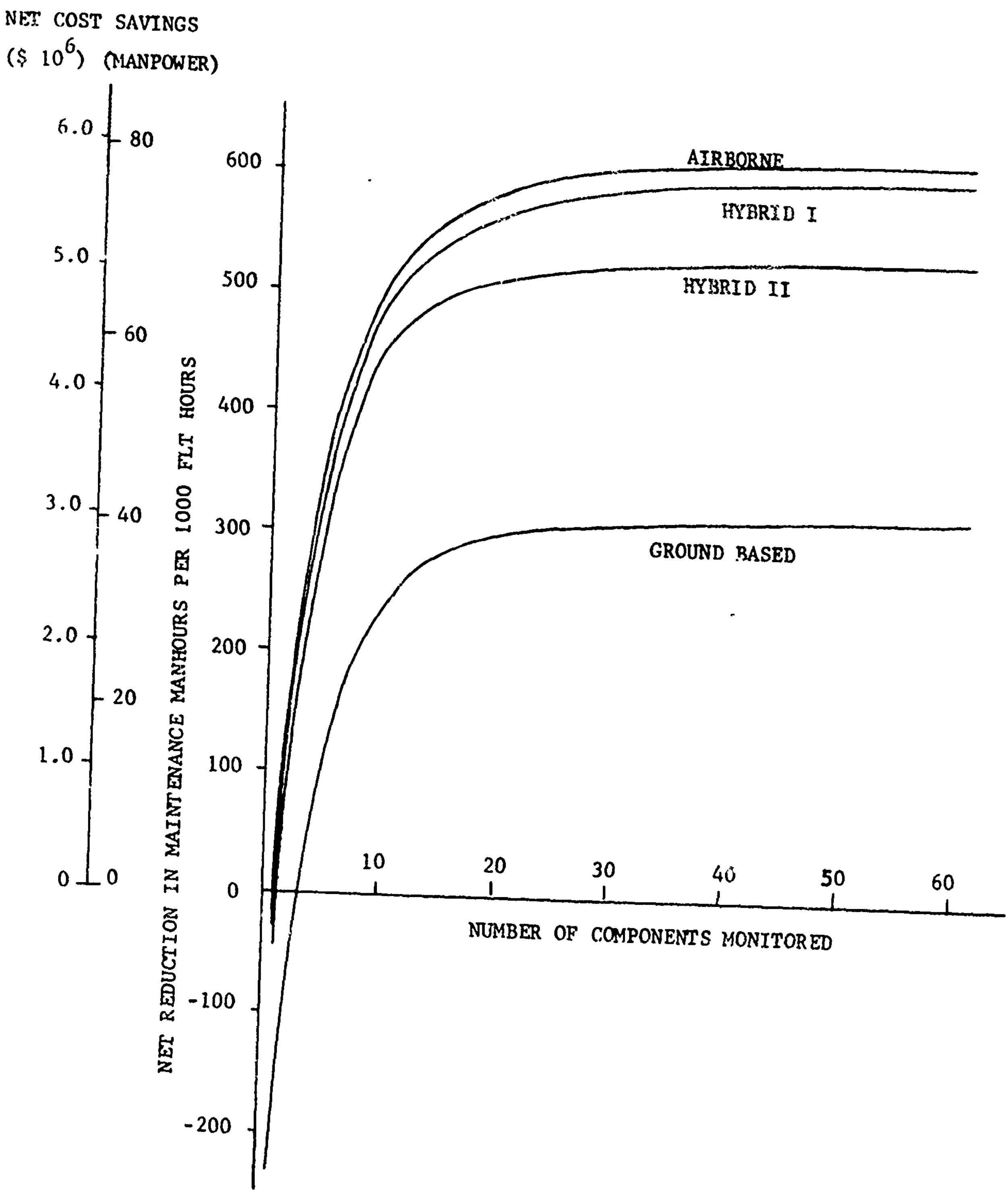


FIGURE 8-1 AH-1 PERSONNEL SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

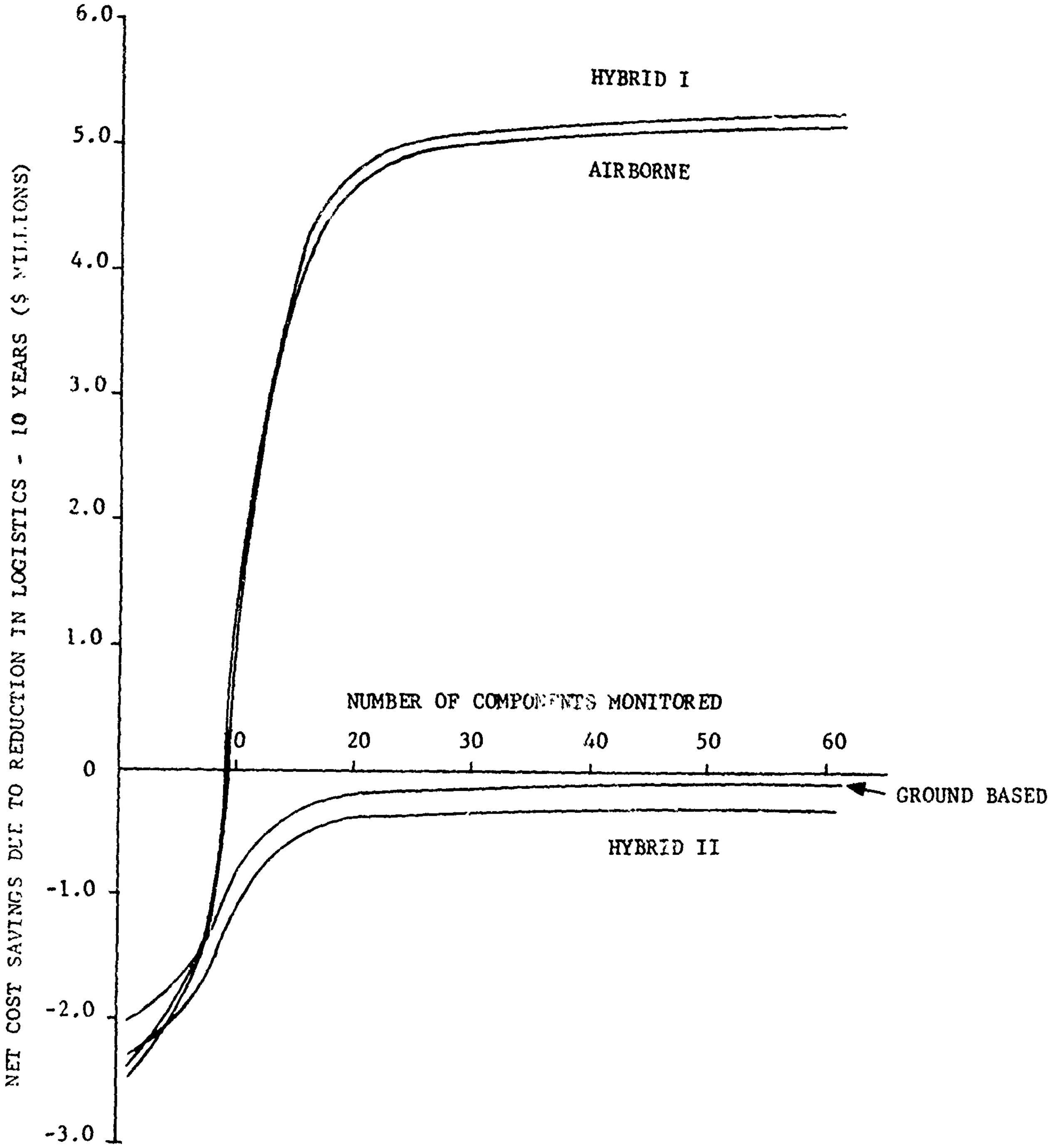


FIGURE 8-2 AH-1 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

Figure 8-3 shows the effect of an AIDAPS on aircraft accidents versus number of components monitored. The difference between the savings for different AIDAPS is due primarily to the inability of the Hybrid II and Ground AIDAPS to provide airborne warning and weight and balance calculations. Test accuracy is also important.

Figure 8-4 shows the increase in the effective number of aircraft versus the number of components monitored. The increase is due primarily to improved aircraft availability although reduced aborts also are an influence. The origin of the graph shows the reduction in aircraft effectiveness due to AIDAPS weight, and the effect of the special AIDAPS inspection on aircraft availability. The percent of total fleet scale represents an approximate reduction in the non-flyable maintenance float.

Figure 8-5 shows the total net savings. The difference between the net savings of the Ground System and Hybrid II System is not sufficient to justify a choice between these two systems. The Ground System is more cost effective than the Hybrid I due to its lower cost. The major competitors are the Hybrid I and the Airborne System. The reason the Complex Hybrid is more cost effective is due to its lower cost. The large difference between the cost effectiveness of the Hybrid I/Airborne pair and the Ground/Hybrid II pair is primarily due to differences in accident prevention; i.e., airborne warning and prognostic capability.

Figure 8-6 shows the relationship between expenditures and savings on a time phased basis. The total expenditures for development and procurement over a 30-month period are $16.3 million. Total savings and benefits from aircraft operations accrue initially, after the entire fleet is equipped, at a rate of approximately $5.6 million per year. This rate decreases slightly with time because of attrition and phaseout schedules. Approximately 2-1/2 years after the investment is complete, the investment has been recovered. The dotted line represents savings in actual dollars. The solid line represents total dollar savings plus the benefit derived from increased aircraft effectiveness

Under the assumption of decreasing fleet size, the cost savings shown in these figures are slightly different from the 10 year savings computed on a constant fleet size shown on previous charts. However, if the beginning of the operation period is considered to be at the end of the procurement phase, the differences are usually not large.

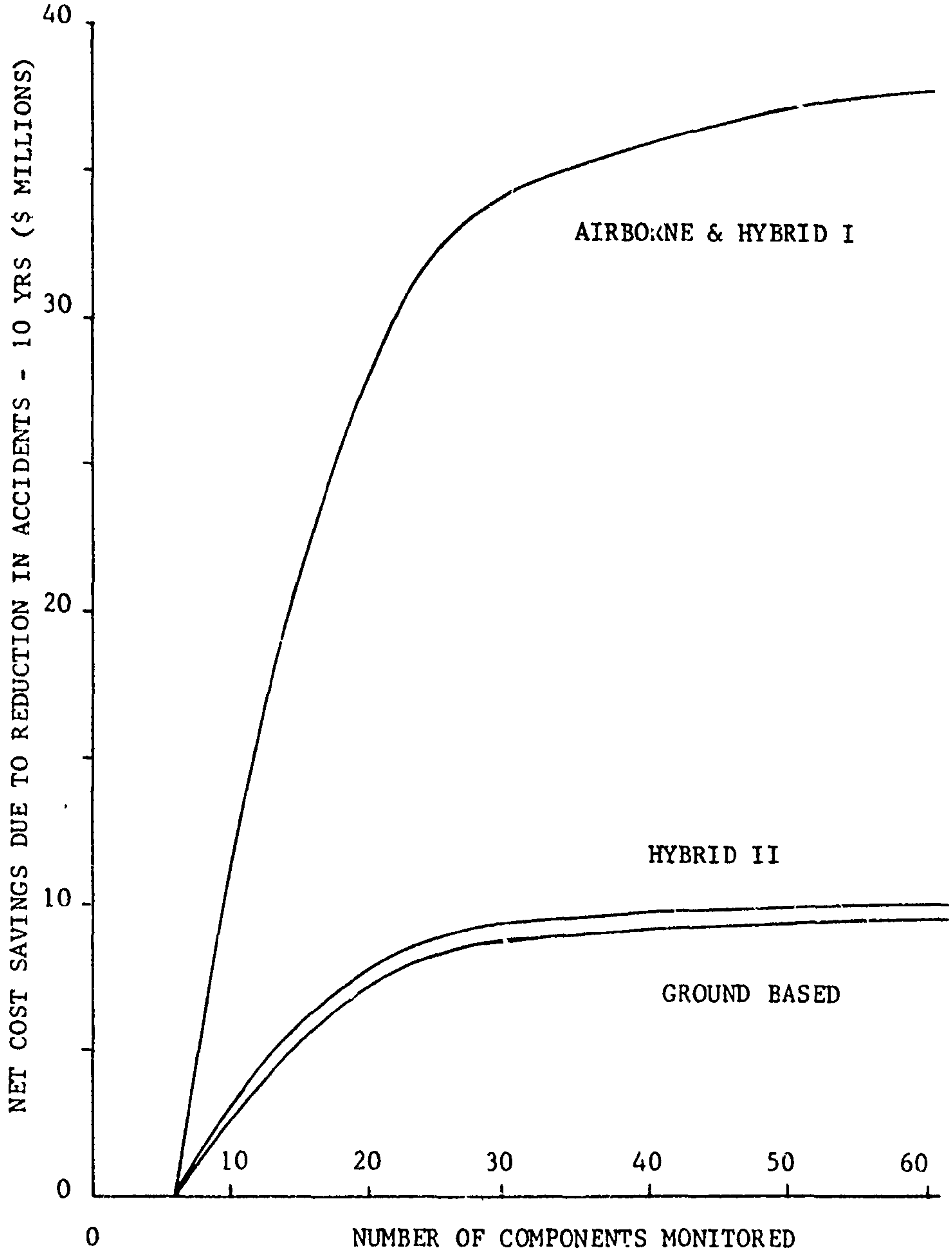


FIGURE 8-3 AH-1 ACCIDENT SAVINGS VS COMPONENTS MONITORED

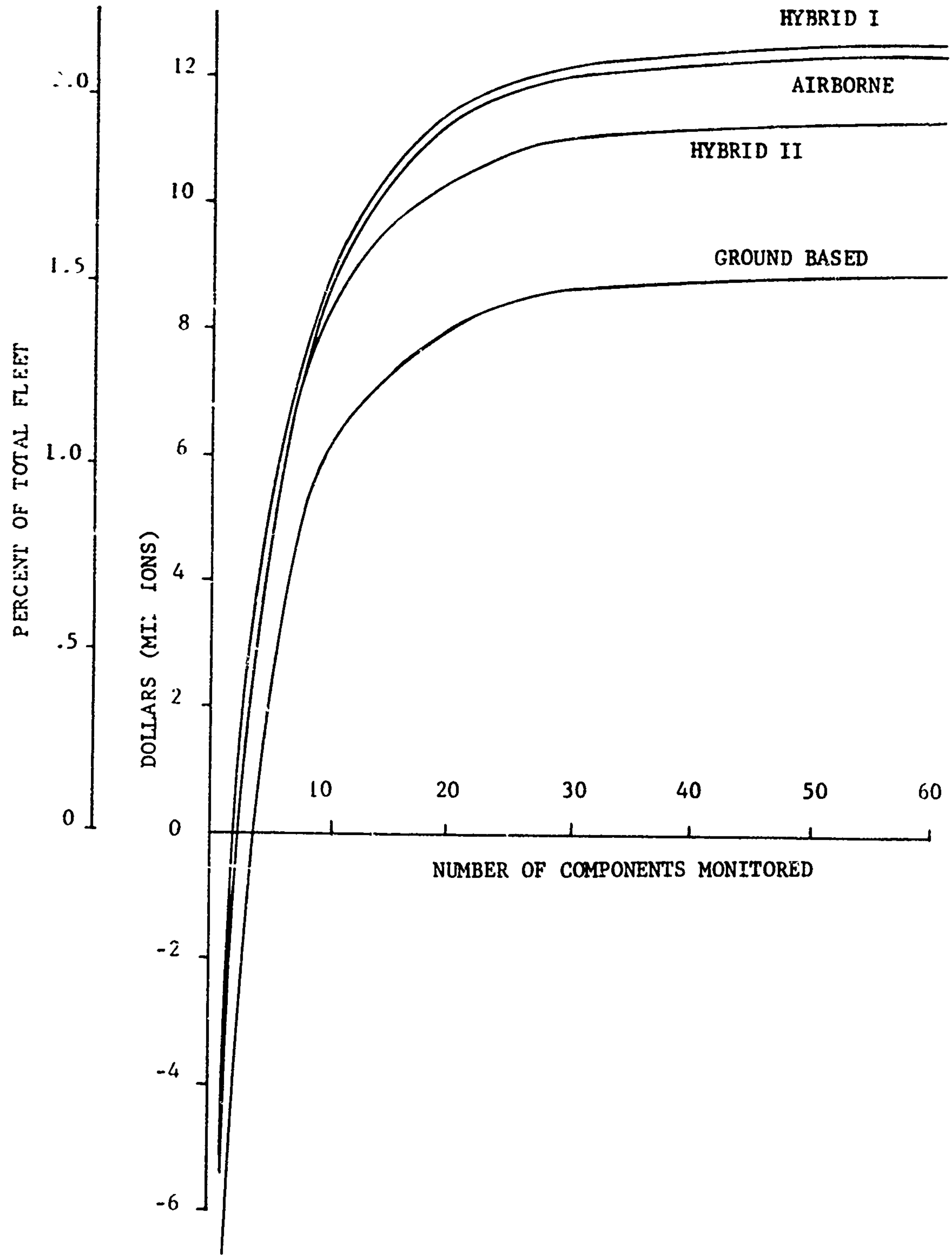


FIGURE 8-4 AH-1 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED

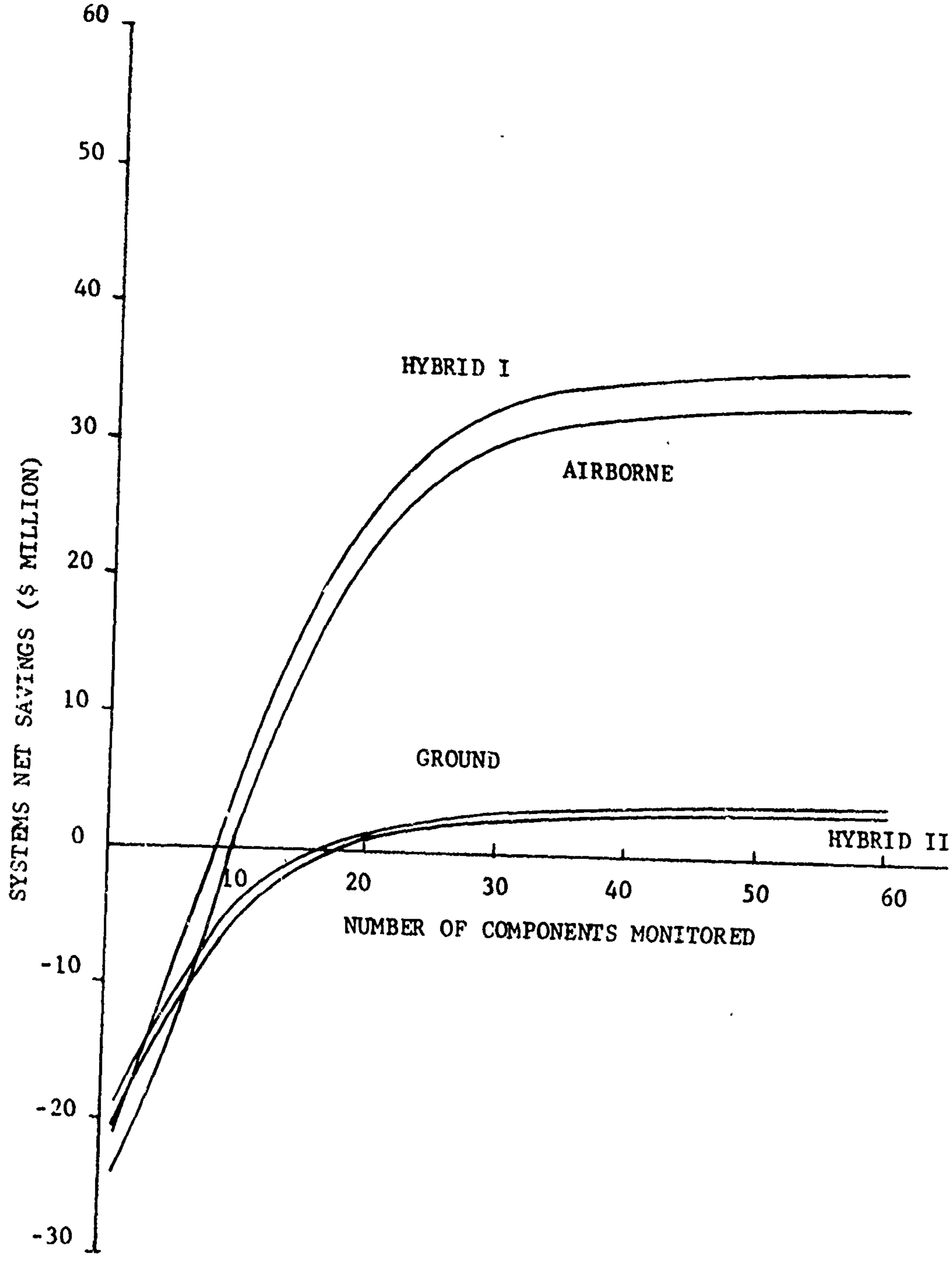


FIGURE 8-5 AH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

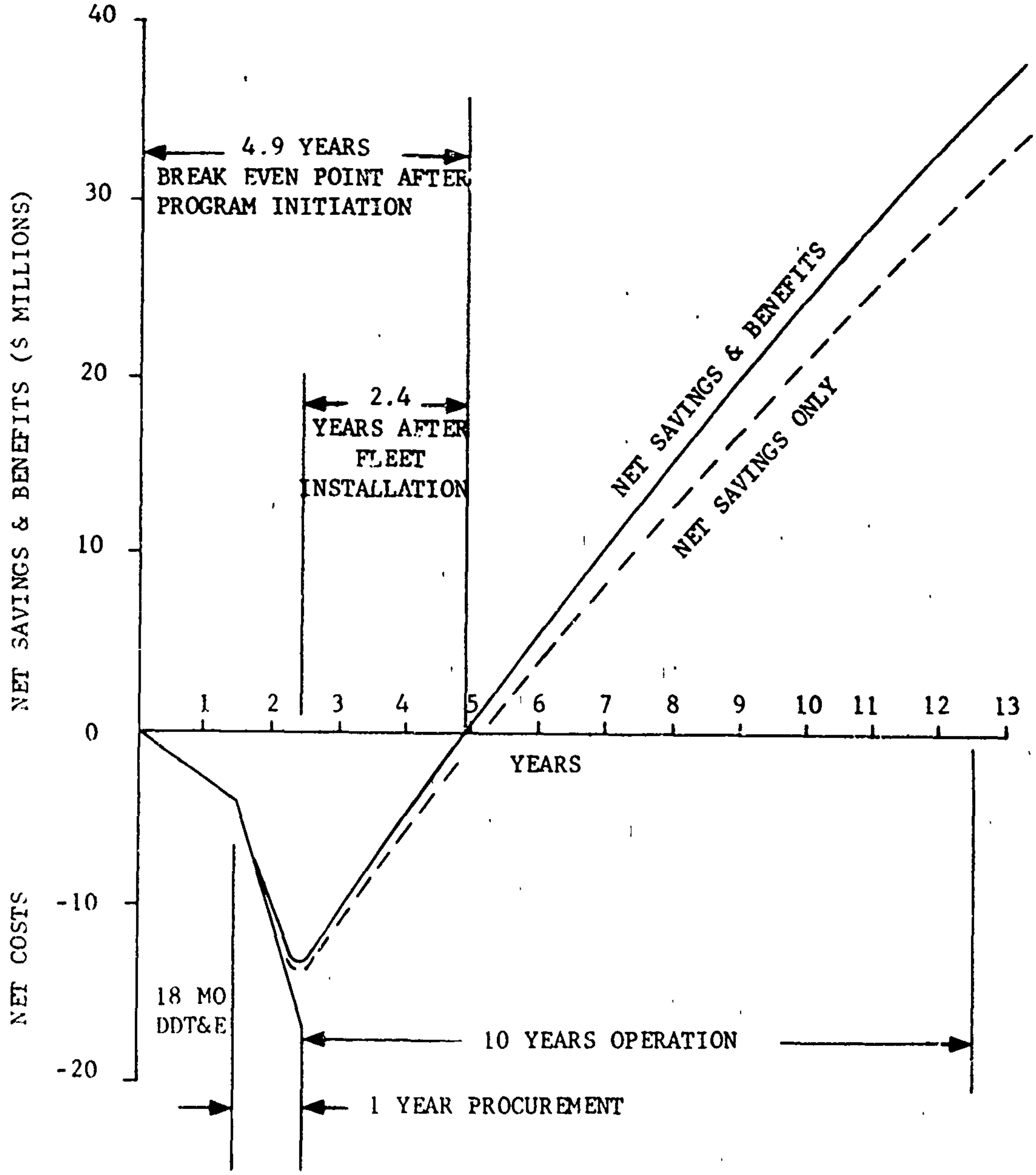


FIGURE 8-6 AH-1 HYBRID I UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM COST, SAVINGS & BENEFITS
(STANDARD CONDITIONS)

Figures 8-7 and 8-8 show the effects of a 20-hour aircraft utilization on net savings. The total 10-year net savings are reduced from $37 million to $17.5 million and the break-even point is increased from 2.4 years to 4.1 years.

Figure 8-9 shows the effect of varying aircraft utilization on system net savings. The standard estimate achieves a $37 million savings. The expected utilization based on periods of tension, but no Vietnam size conflict is 40 flying hours per month. This achieves a net savings of approximately $57 million. The combat environment (70 flying hours per month) yields a savings of nearly $140 million.

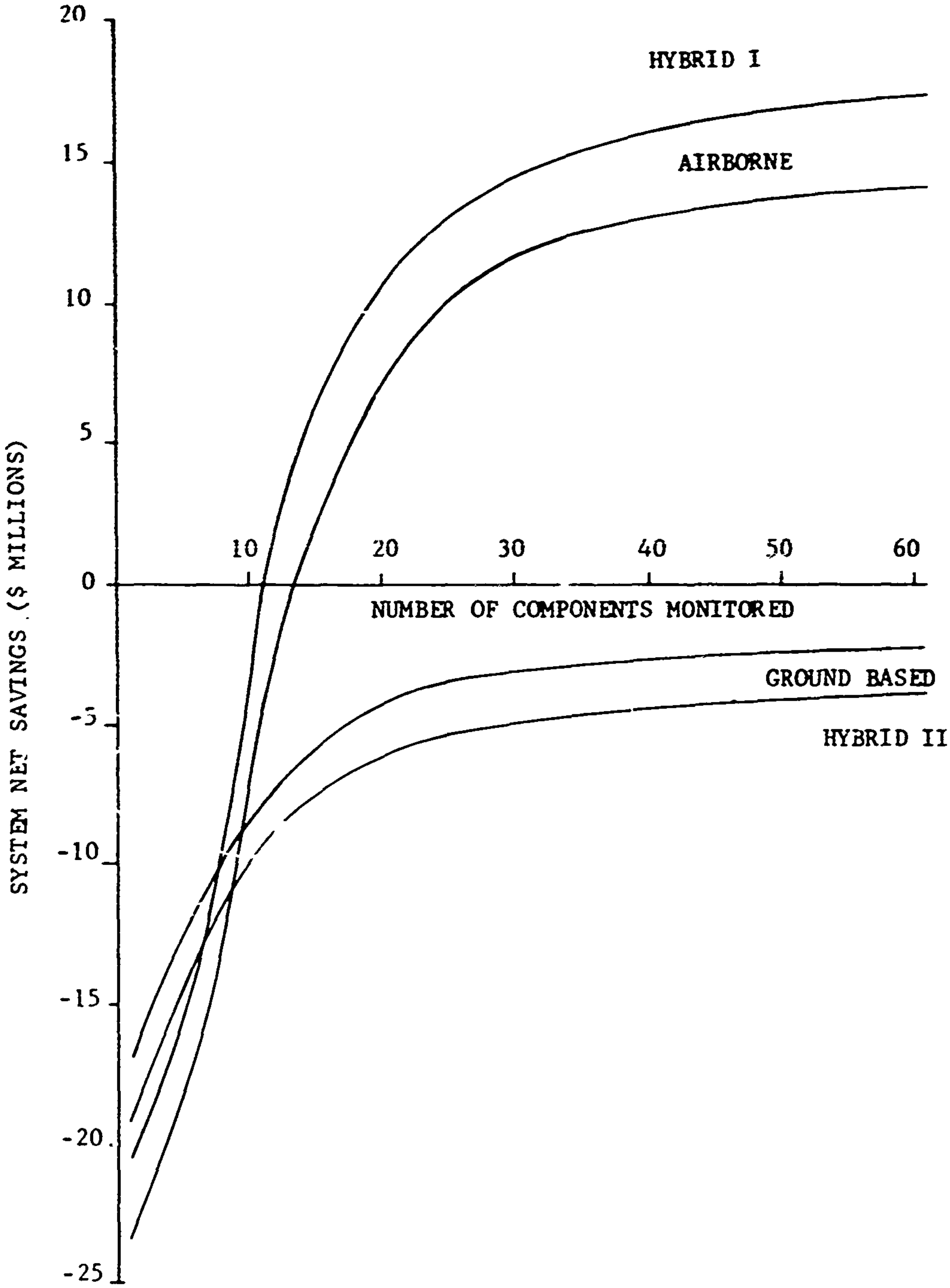


FIGURE 8-7 AH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED
AIRCRAFT UTILIZATION = 20 FLT HRS/MO

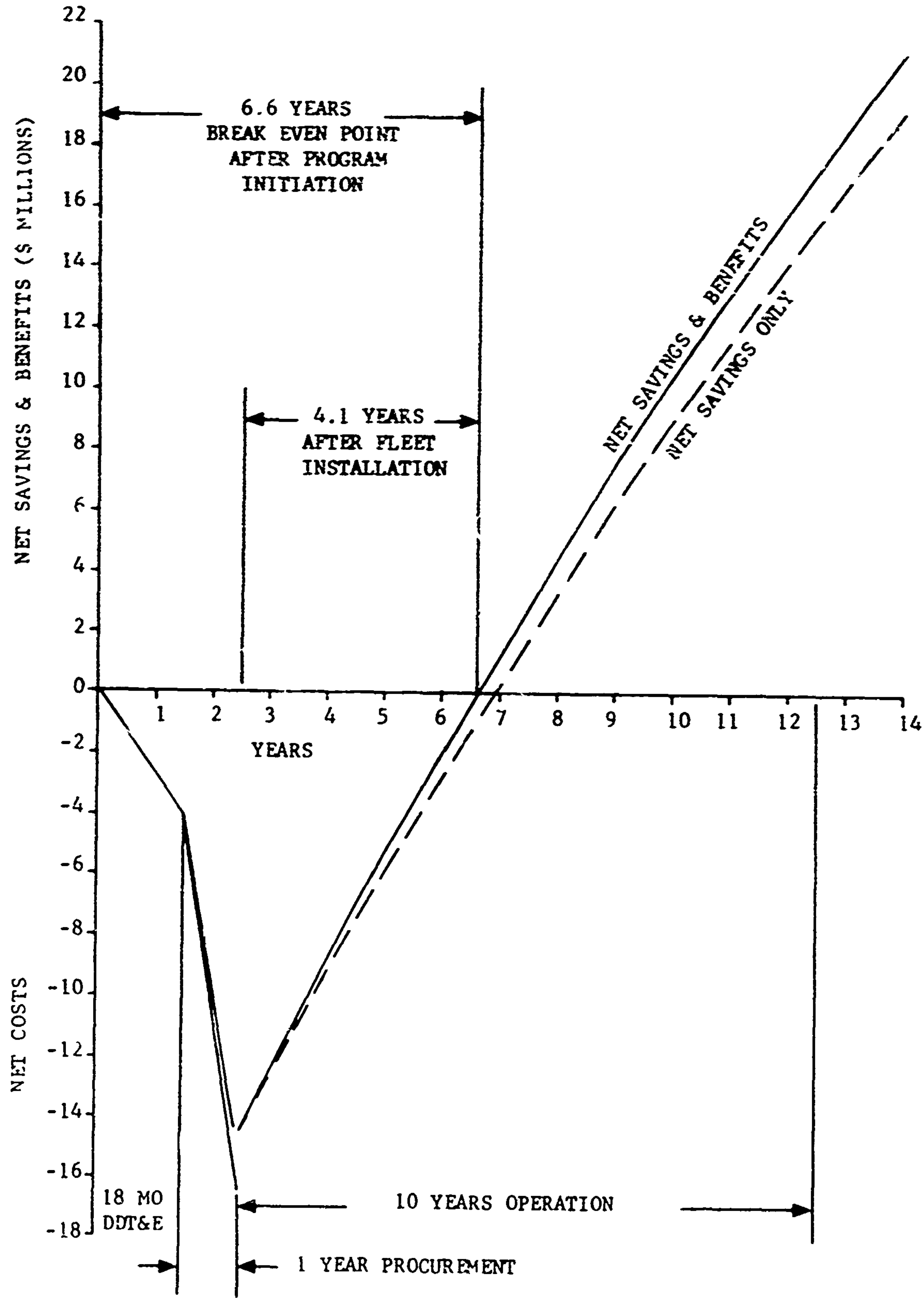


FIGURE 8-8 AH-1 HYBRID I UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM COST, SAVINGS & BENEFITS
(AIRCRAFT UTILIZATION = 20 FLT HRS/MO)

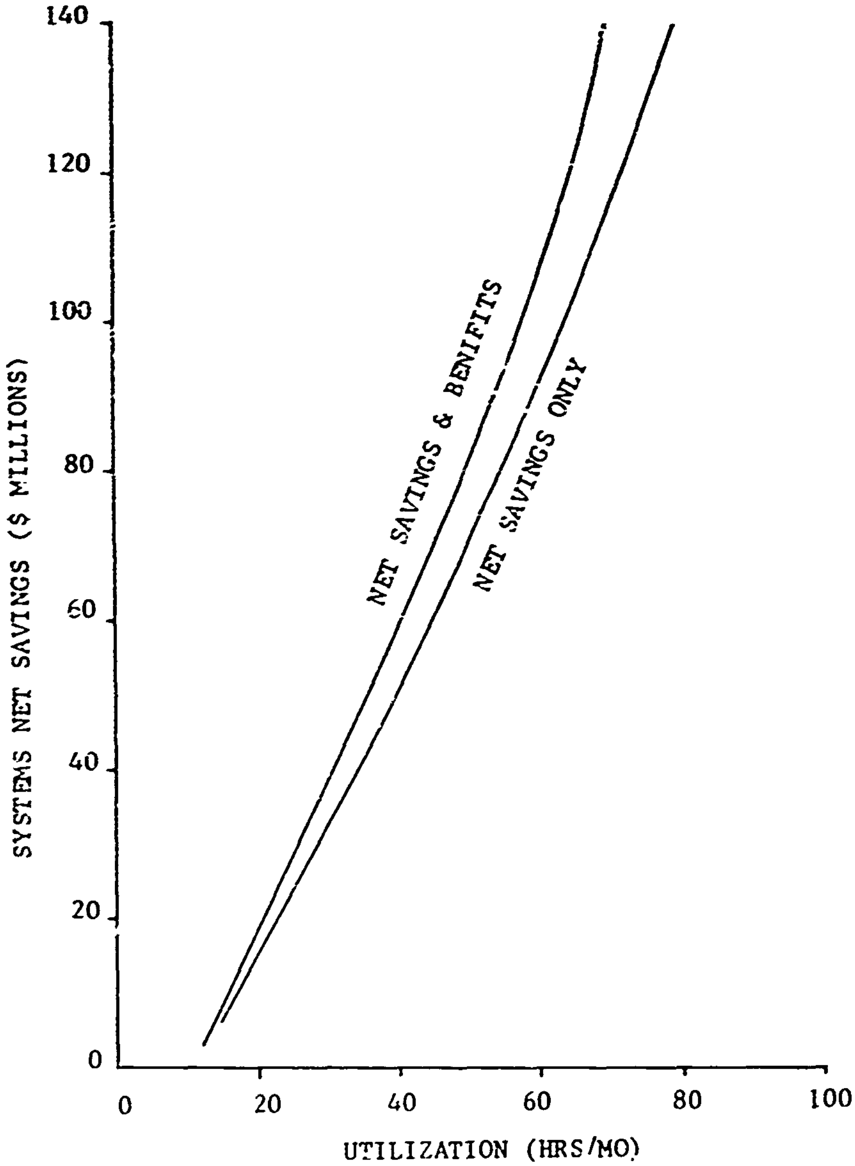


FIGURE 8-9 AH-1 HYBRID I - SYSTEM NET SAVINGS VS AIRCRAFT UTILIZATION (10 YEARS OPERATION)

8.1.2.2 CH-47 Tradeoffs

Figures 8-10 through 8-15 present the same type of data as was presented for the AH-1 and the same comments apply. See paragraph 8.1.2.1.

It should be noted that all AIDAP systems achieve greater effectiveness on this more complex aircraft and the cost effectiveness of the Airborne and Hybrid I systems is substantially equal. The break-even point under the standard conditions is 2.1 years (Figure 8-15)

Figure 8-16 and 8-17 show the effects of a 30 flying hour per month utilization.

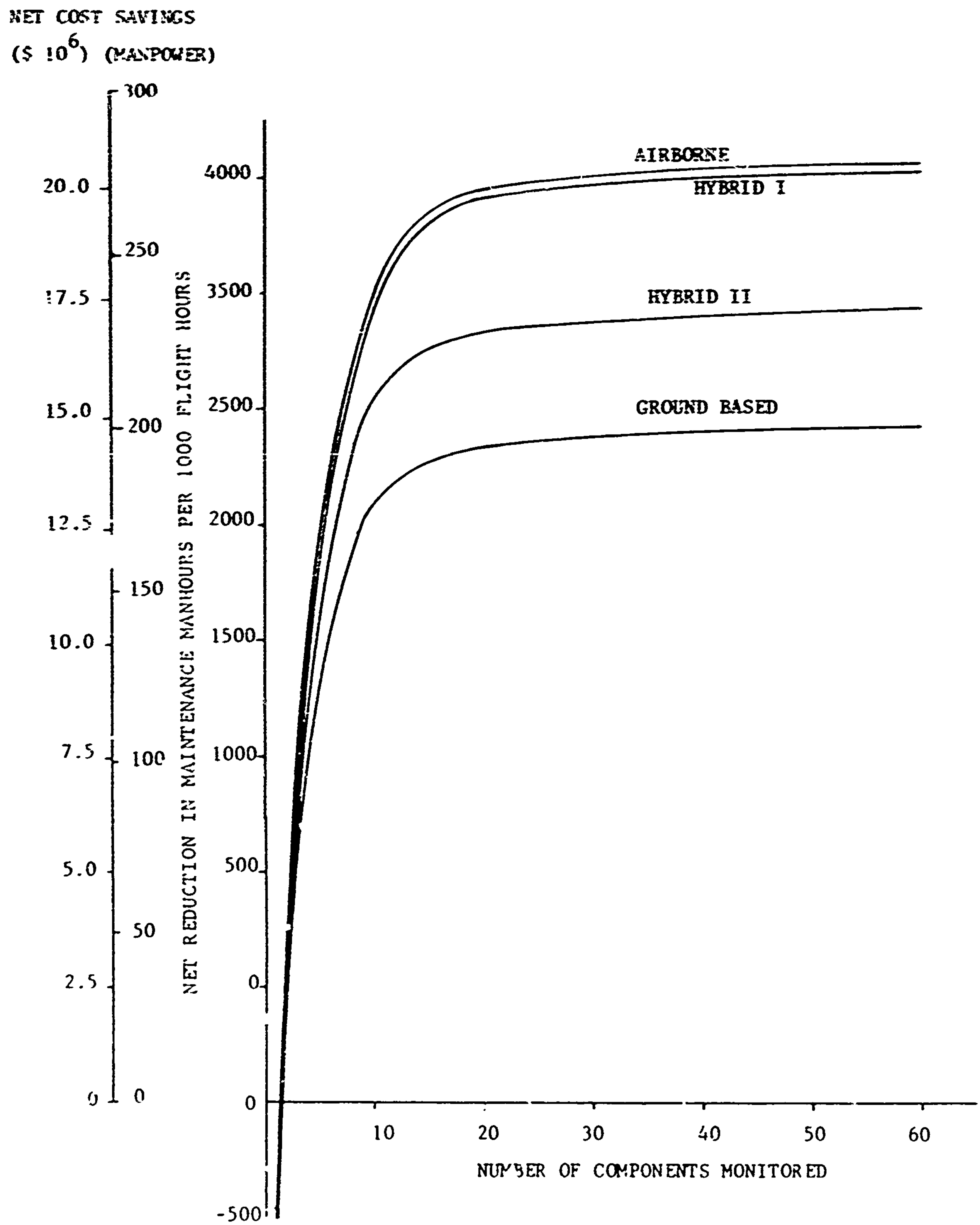


FIGURE 8-10 CH-47 PERSONNEL SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

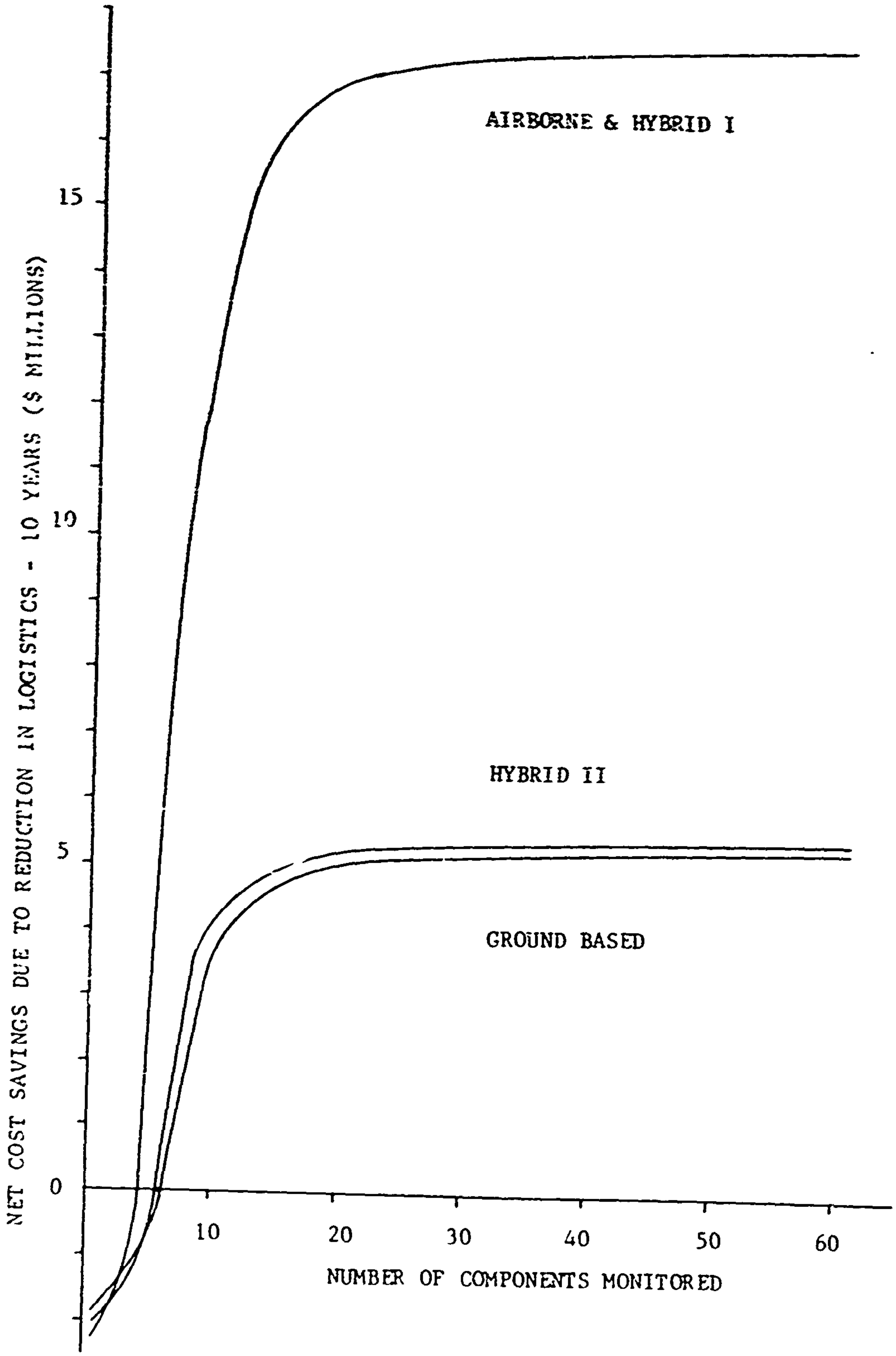


FIGURE 8-11 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITION)

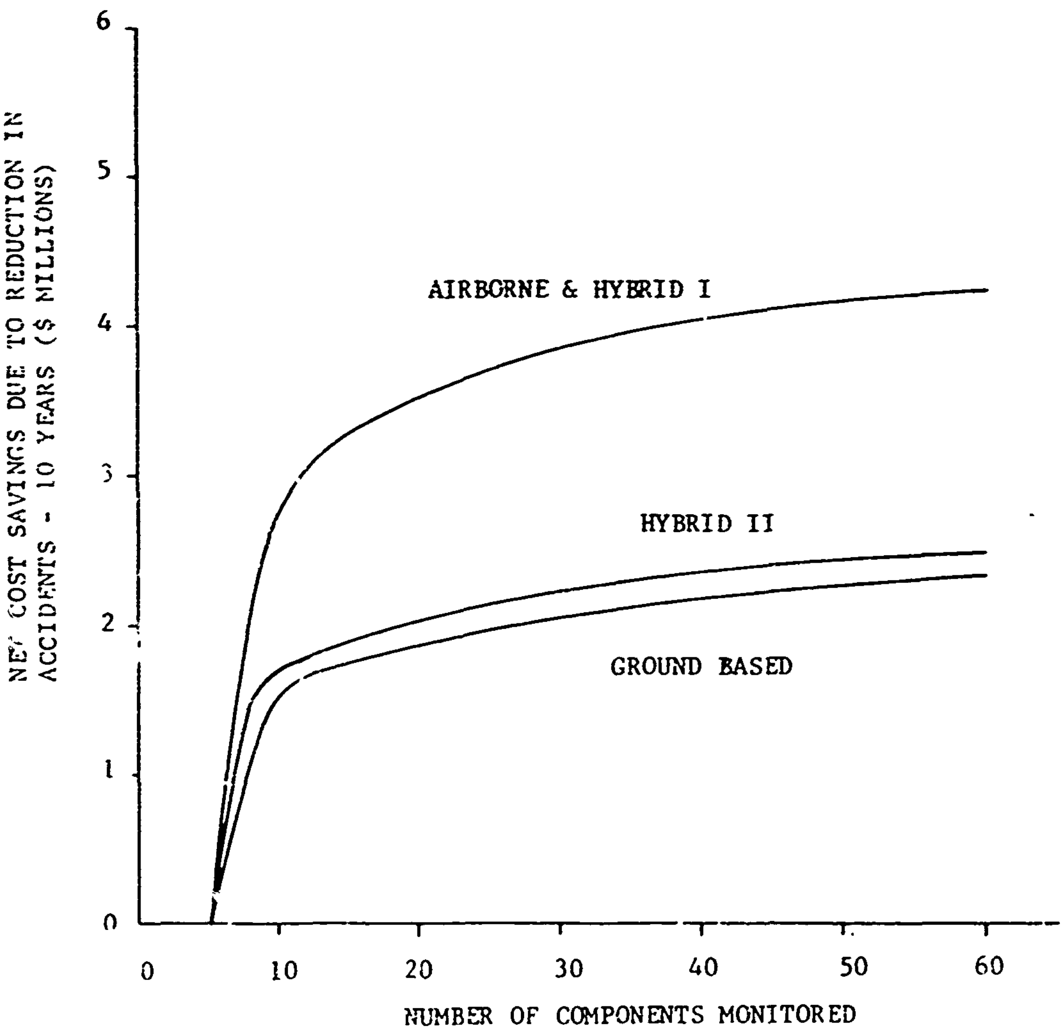


FIGURE 8-12 CH-47 ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

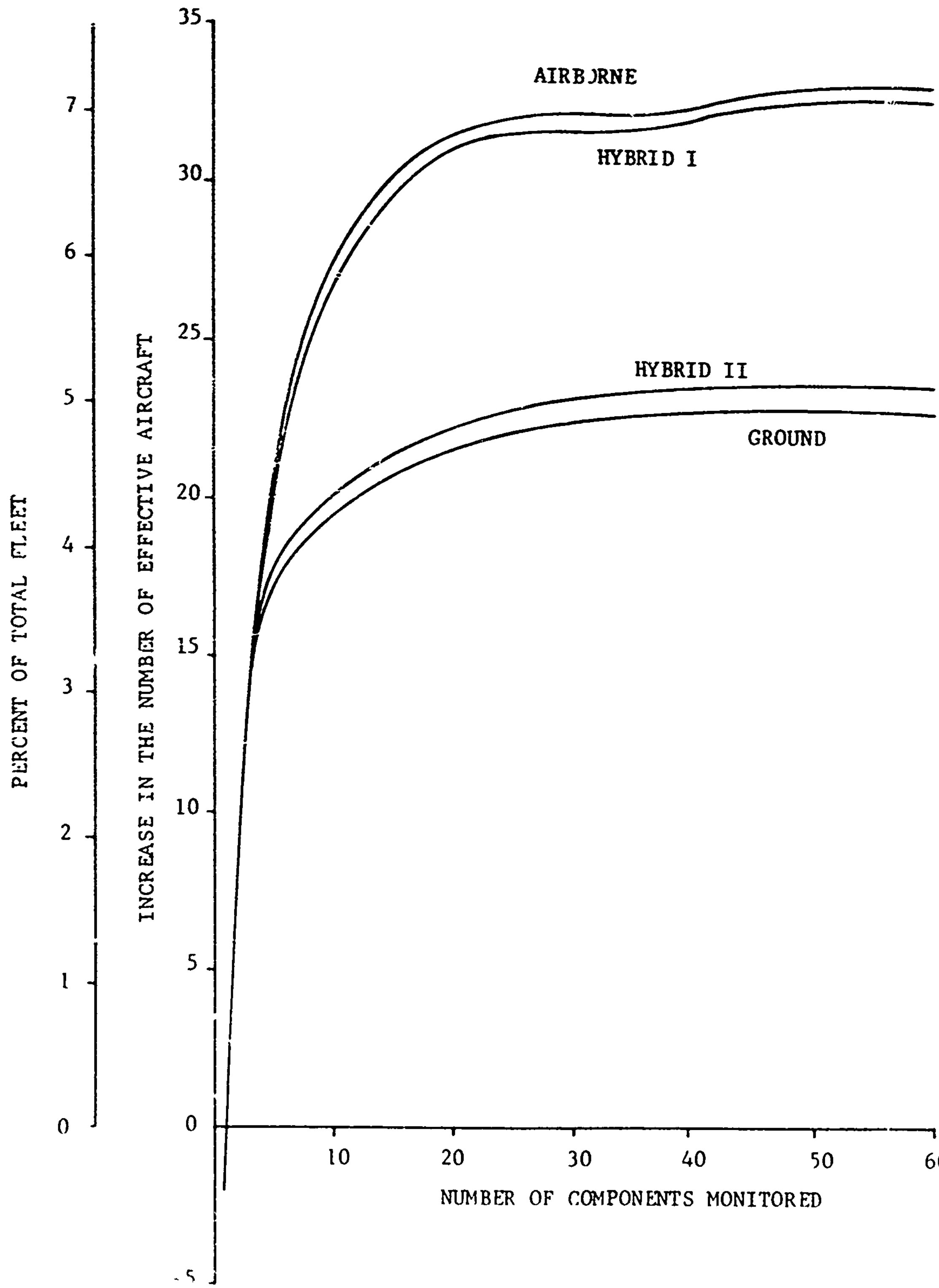


FIGURE 8-1 CH-47 EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

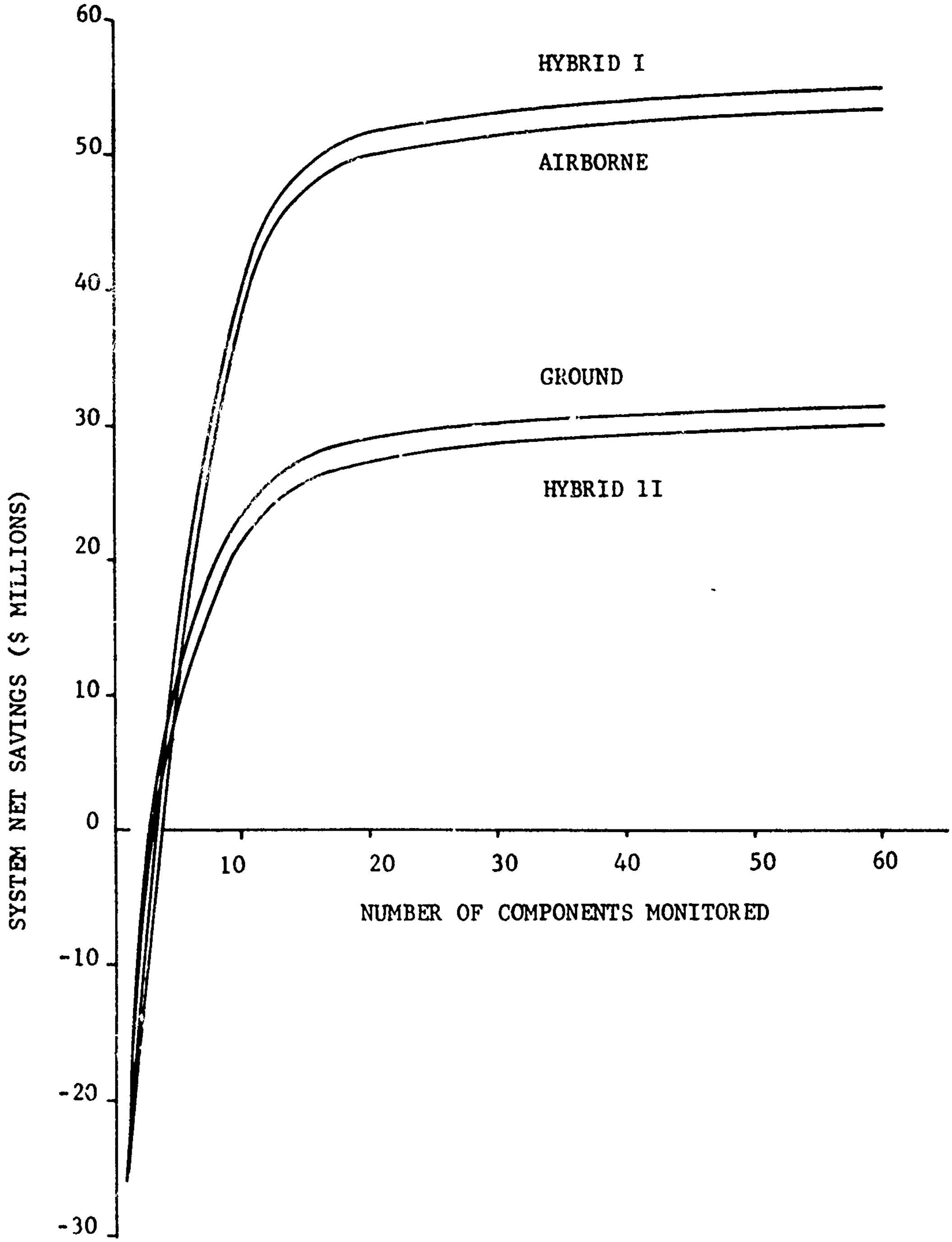


FIGURE 8-14 CH-47 SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

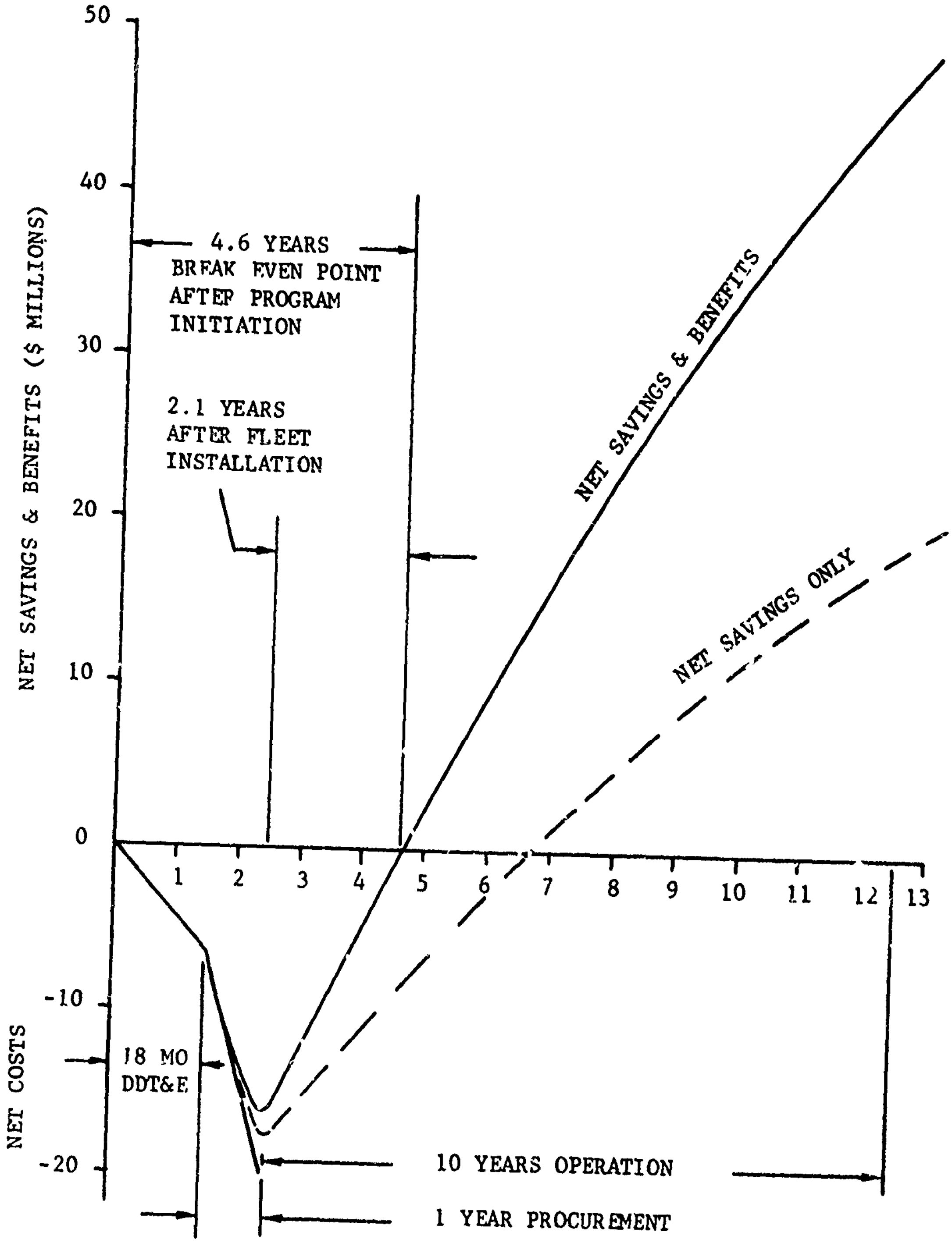


FIGURE 8-15 CH-47 HYBRID I UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM COST, SAVINGS & BENEFITS (STANDARD CONDITIONS)

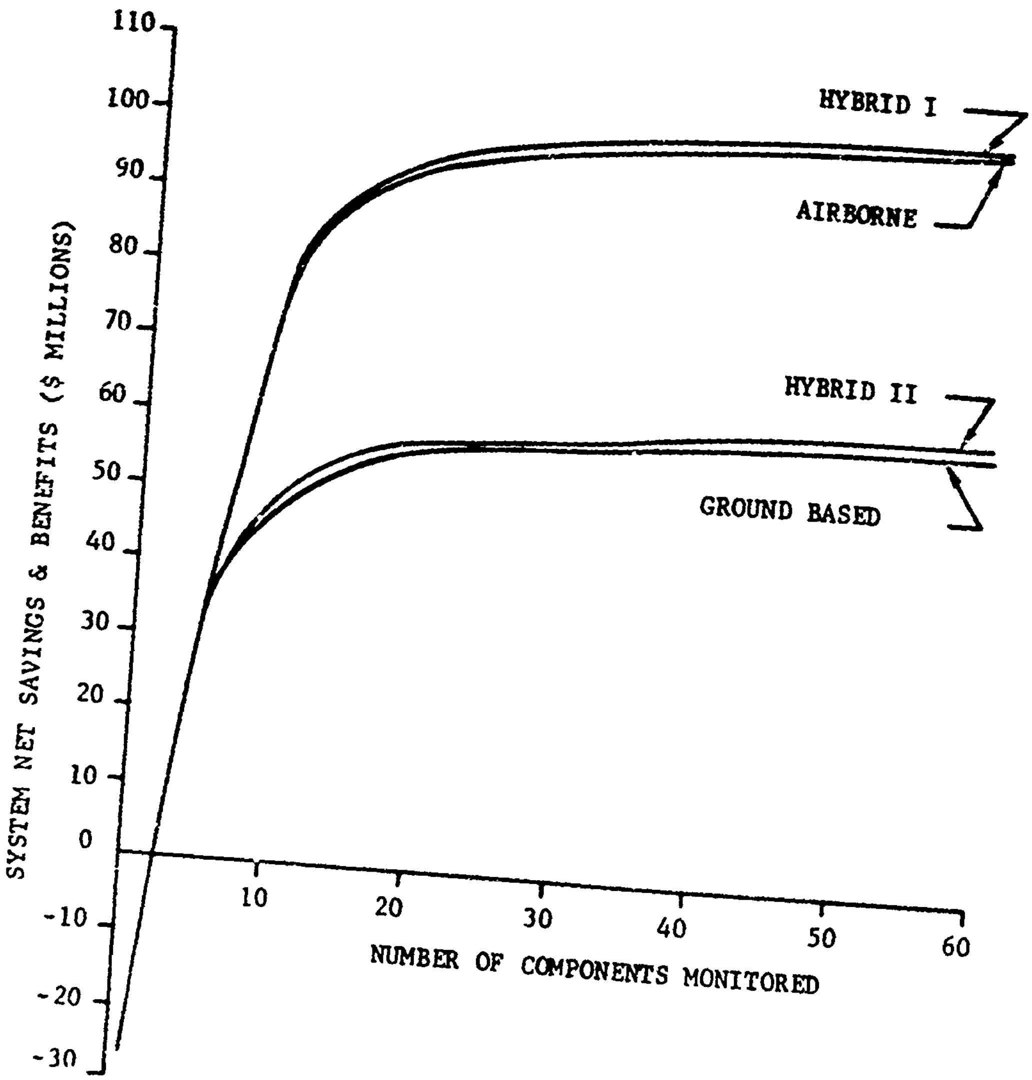


FIGURE 8-16 CH-47 SYSTEM NET SAVINGS & BENEFITS MONITORED
(AIRCRAFT UTILIZATION = 30 FLT HRS/MO)

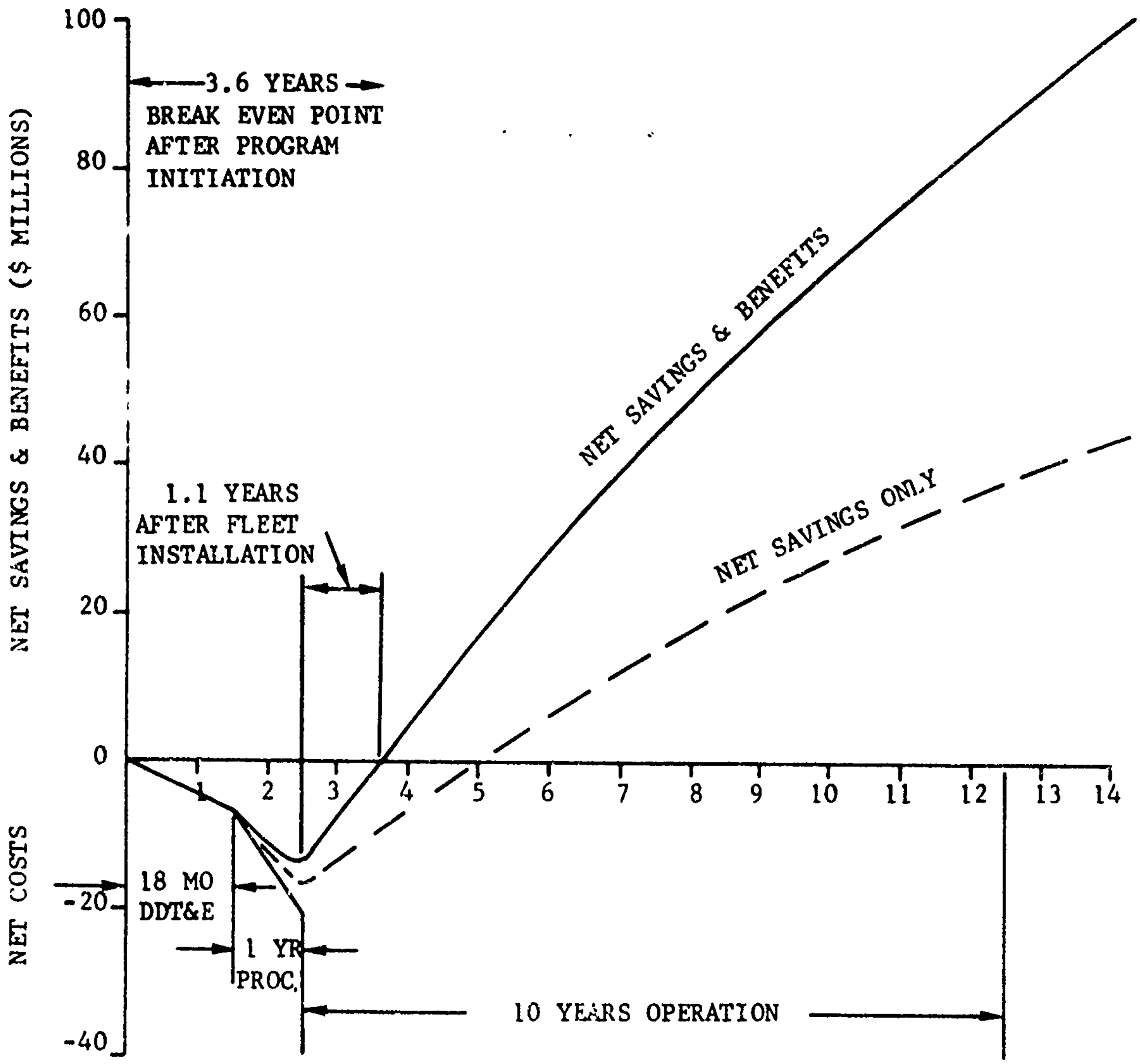


FIGURE 8-17 CH-47 HYBRID I UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM SAVINGS & BENEFITS (AIRCRAFT ULTILIZATION = 30 FLT HRS/MO)

8.1.2.3 <u>CH-54 Tradeoffs</u>

Figures 8-18 through 8-28 show the effects of applying the Unique AIDAP System candidates to the CH-54 fleet. Figures 8-18 through 8-21 indicate that there are significant savings in manpower, logistics, and accident as well as a significant increase in the aircraft effectiveness. However, Figure 8-22 shows that the net savings after subtracting AIDAPS development, investment and operating costs, are very small for the Airborne and Hybrid I systems and are negative (net loss) for the Hybrid II and Ground Systems. Further, Figure 8-23 indicates the break-even point is almost nine years after the investment funds are expended. The reason for the low net benefits is the low number of aircraft in the CH-54 fleet and the resulting high cost of prorating the DDT&E cost for a unique AIDAPS across this small fleet. The AIDAPS developmental cost is approximately $6.5 million for the Hybrid II system. If this is distributed across 75 aircraft, the result is almost $90,000 per aircraft. Obviously, an AIDAP system designed and developed uniquely for the CH-54 is not an economically viable program. Figures 8-24 through 8-28 show the sensitivity of cost savings and benefits for the CH-54 as a function of aircraft utilization. For net savings to be achieved, the aircraft utilization must be approximately 10 flying hours per month or more.

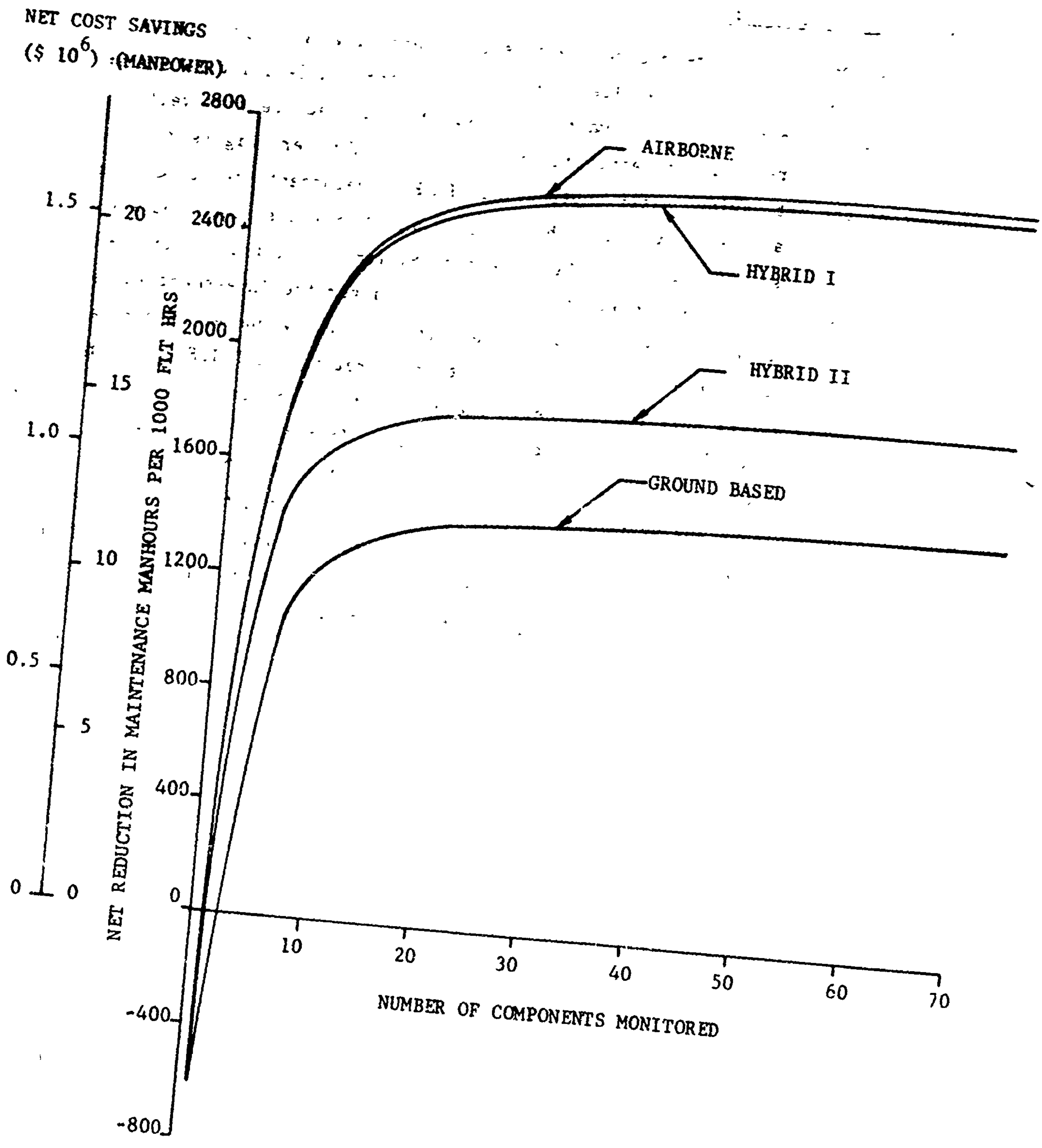


FIGURE 8-18 CH-54 PERSONNEL SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

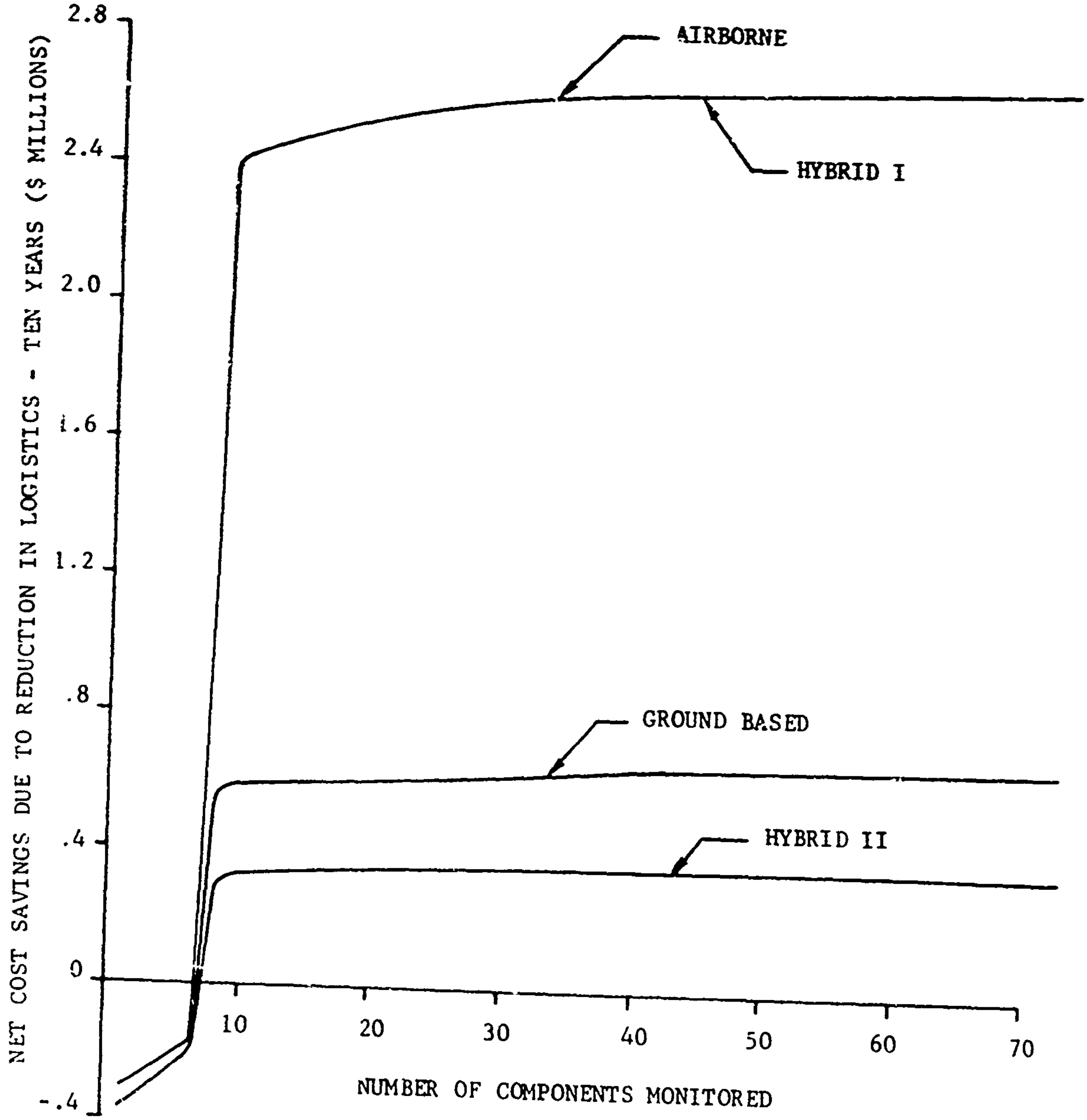


FIGURE 8-19 CH-54 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

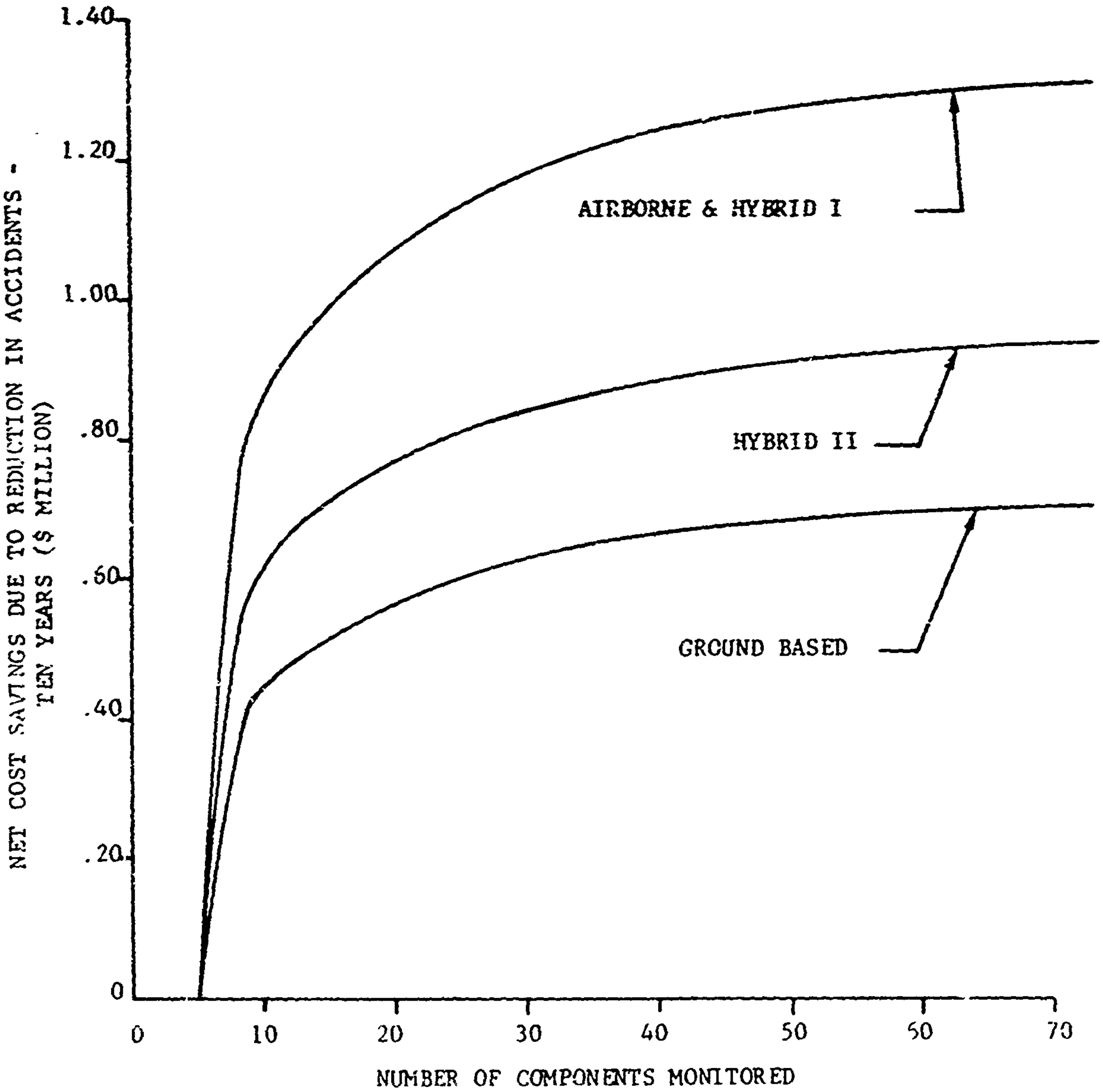


FIGURE 8-20 CH-54 ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

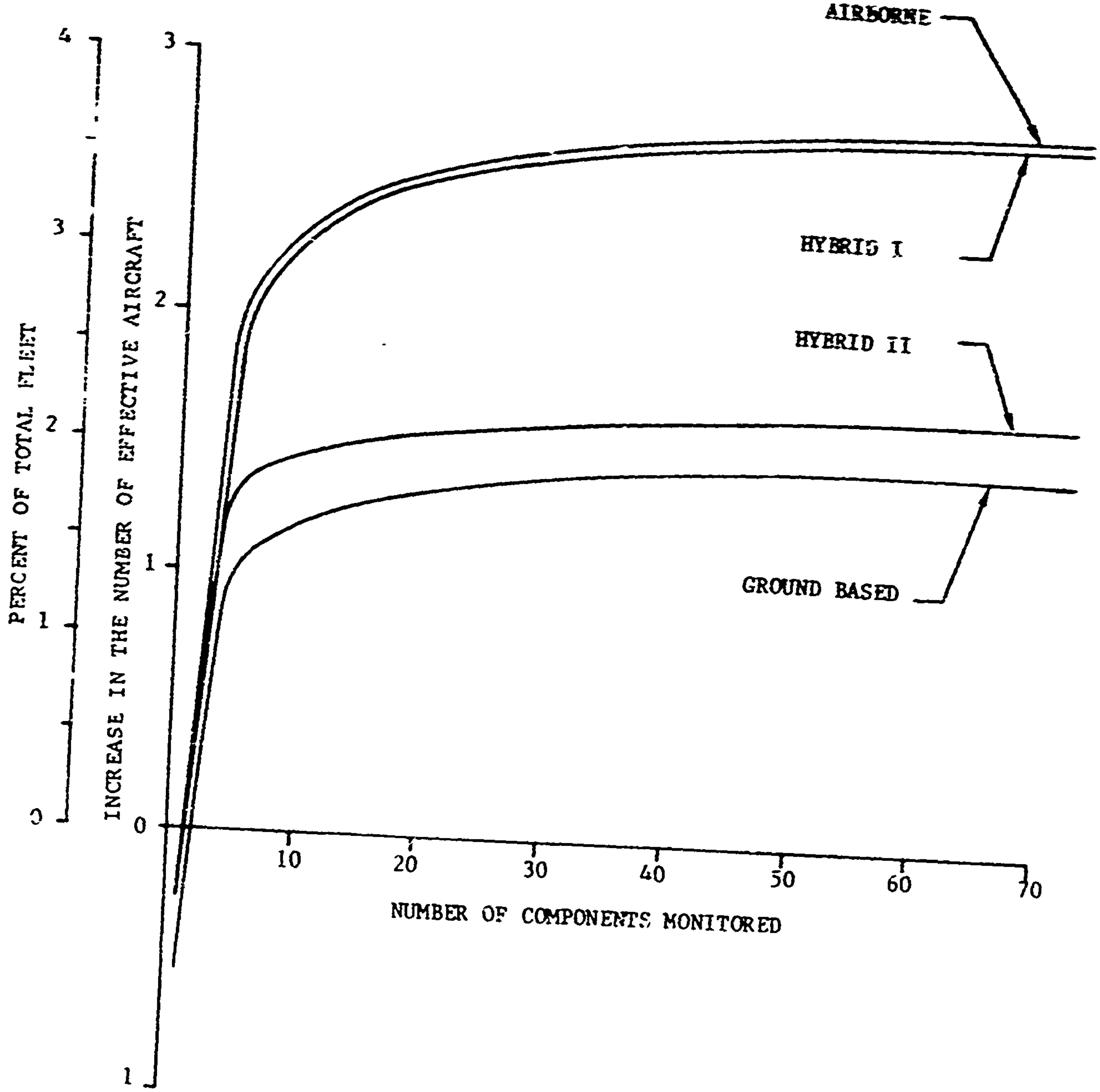


FIGURE 8-21 CH-54 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

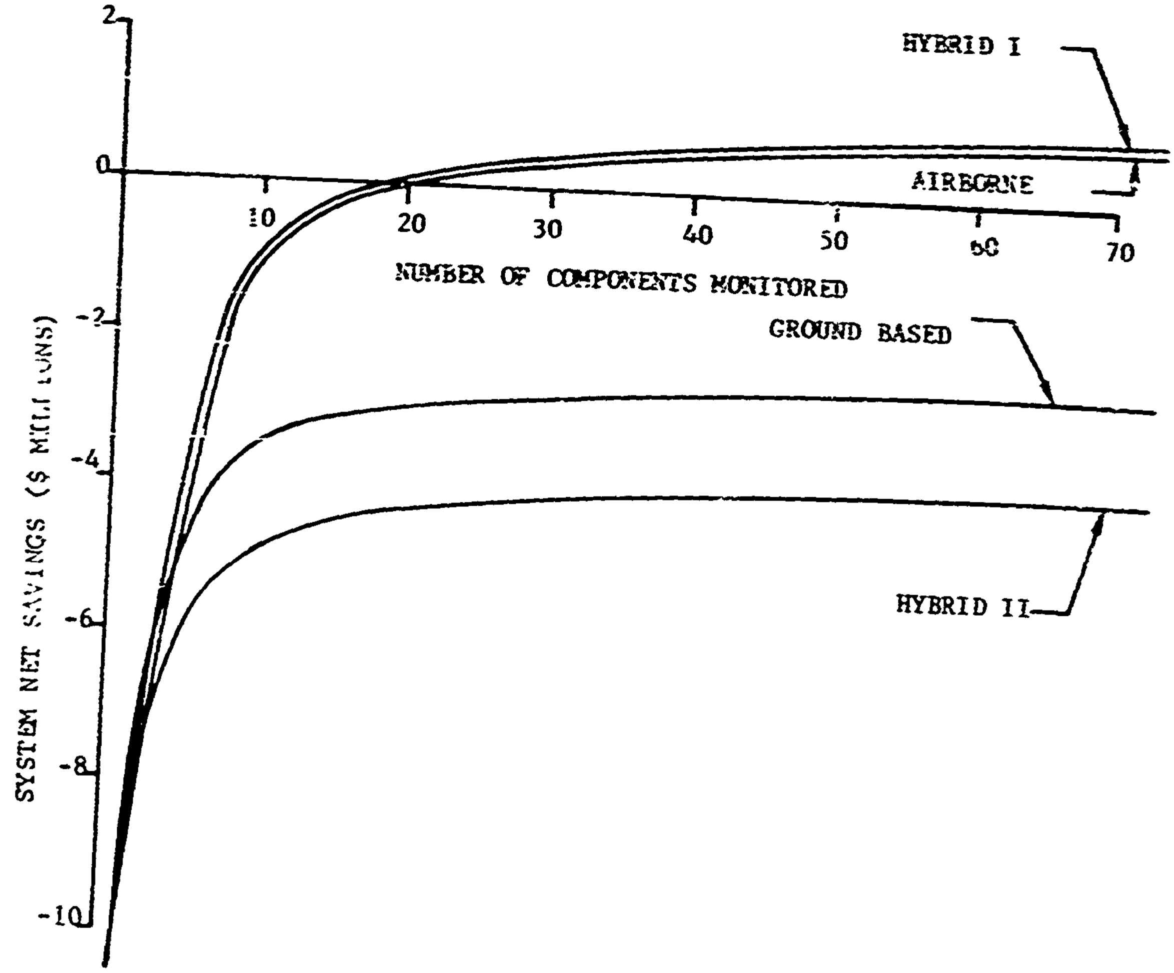


FIGURE 8-22 CH-54 SYSTEMS NET SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

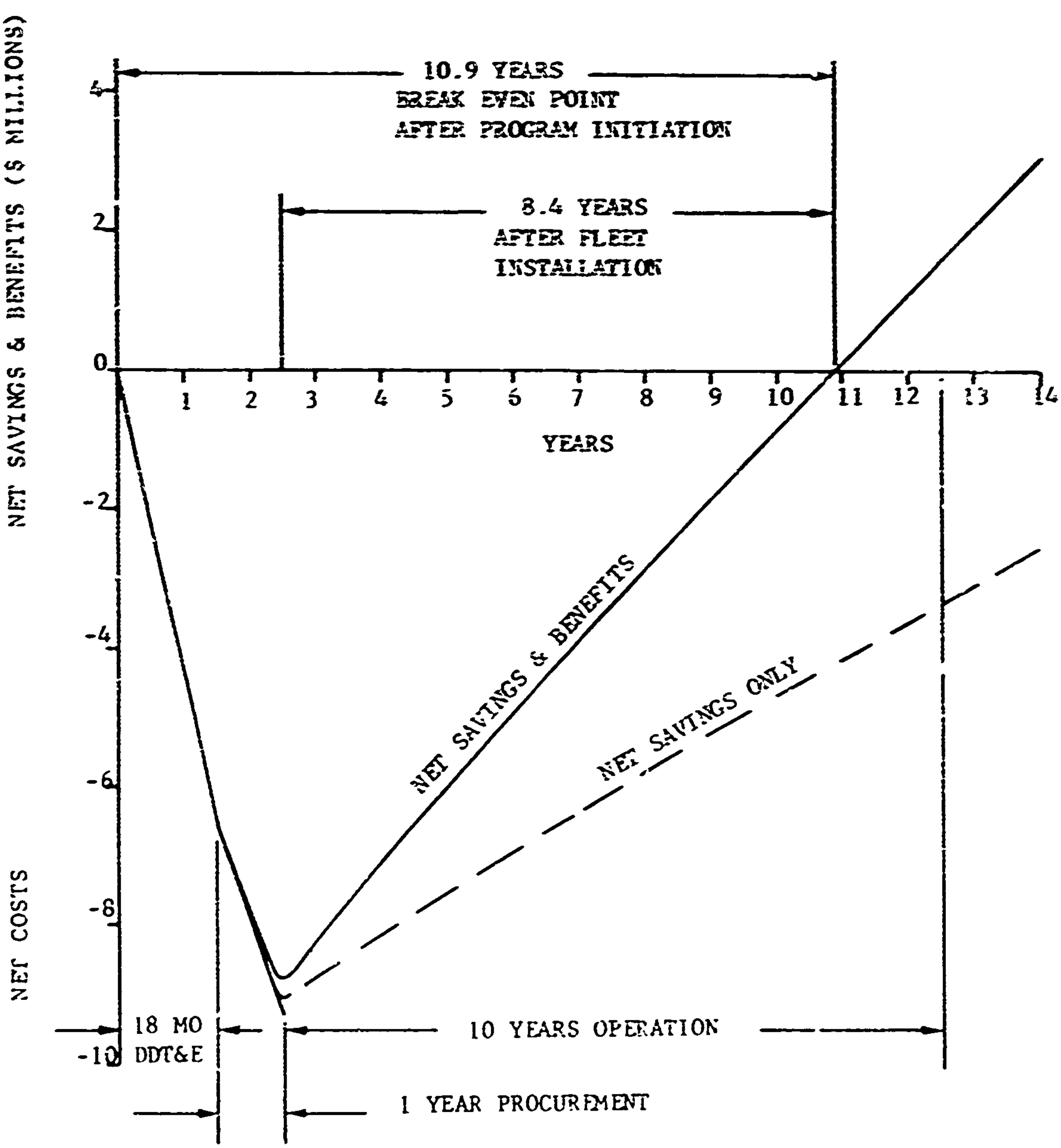


FIGURE 8-23 CH-54 HYBRID I UNIQUE AIDAP SYSTEM -
TIME PHASED PROGRAM COST, SAVINGS & BENEFITS
(STANDARD CONDITIONS)

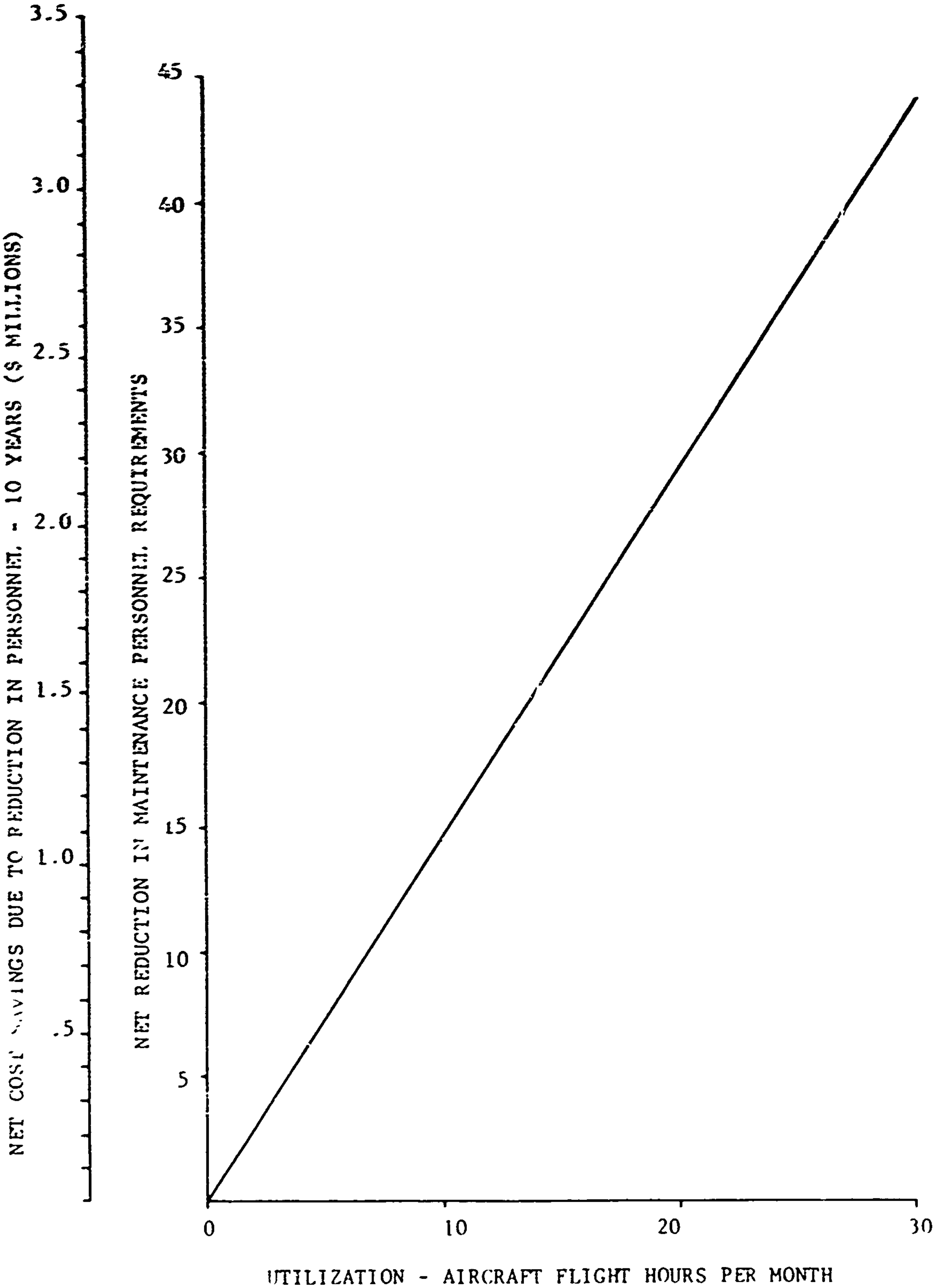


FIGURE 8-24 CH-54 HYBRID I PERSONNEL SAVINGS VS AIRCRAFT UTILIZATION

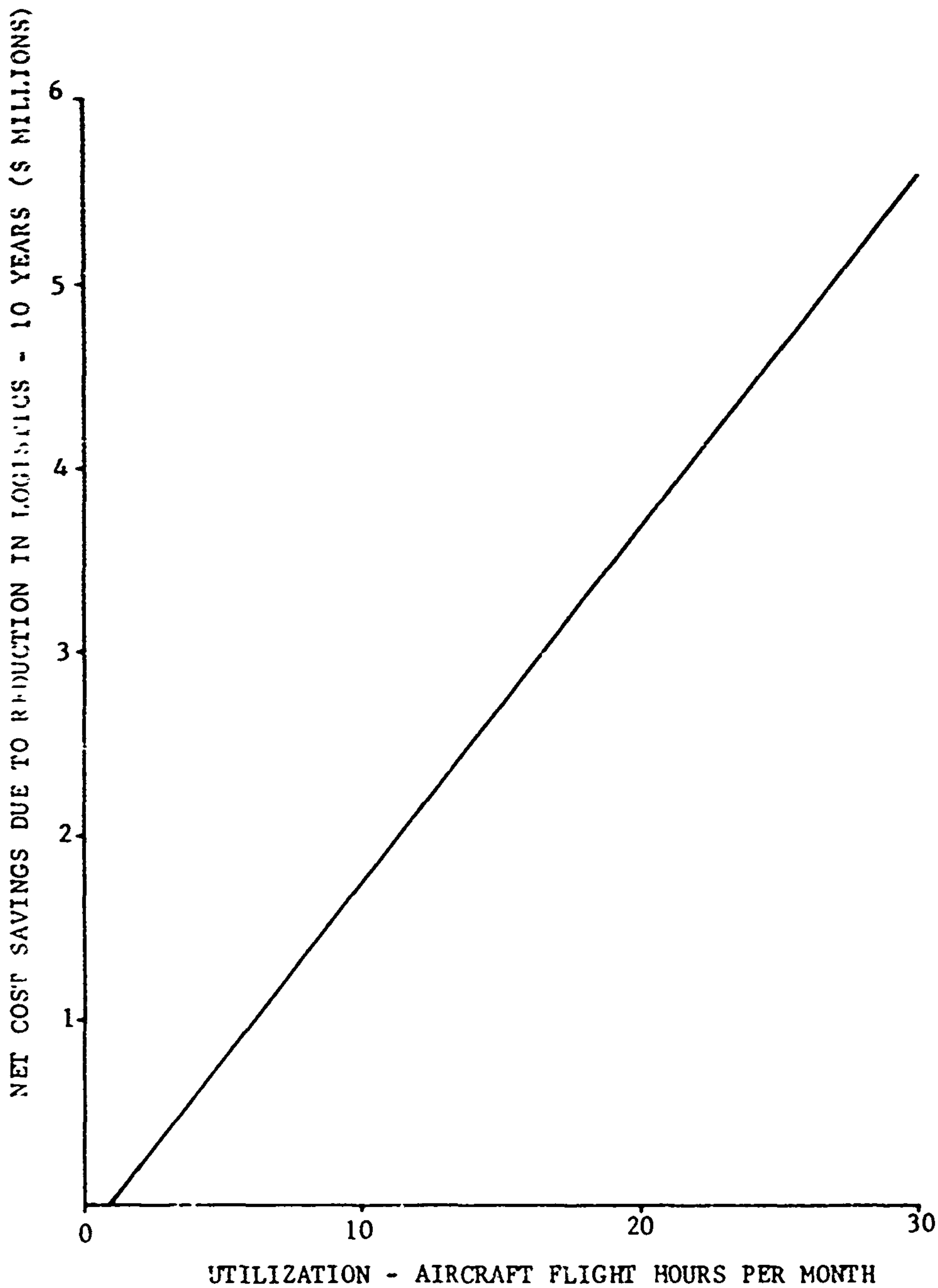


FIGURE 8-25 CH-54 HYBRID I LOGISTICS SAVINGS VS AIRCRAFT UTILIZATION

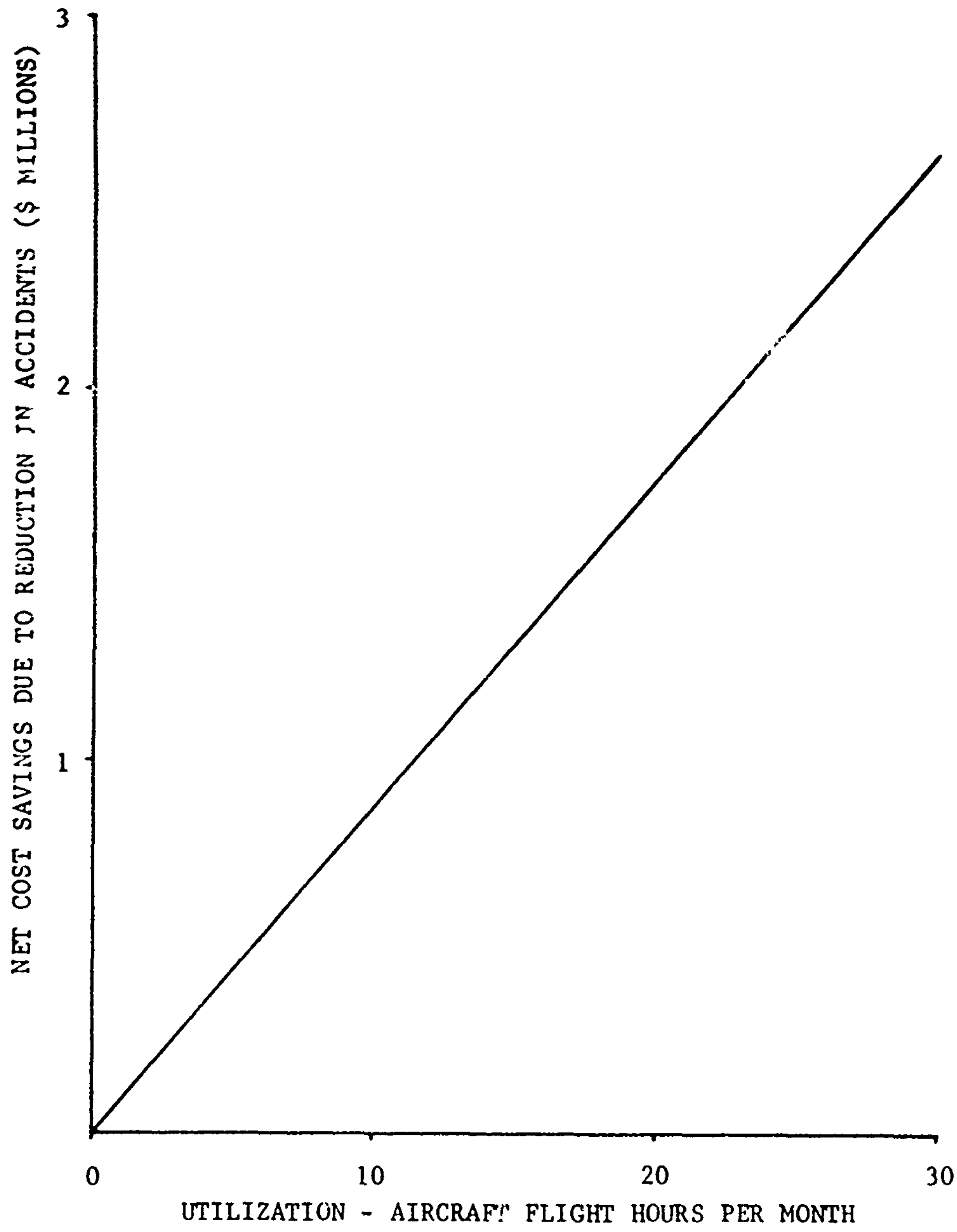


FIGURE 8-26 CH-54 HYBRID I ACCIDENT SAVINGS VS AIRCRAFT UTILIZATION

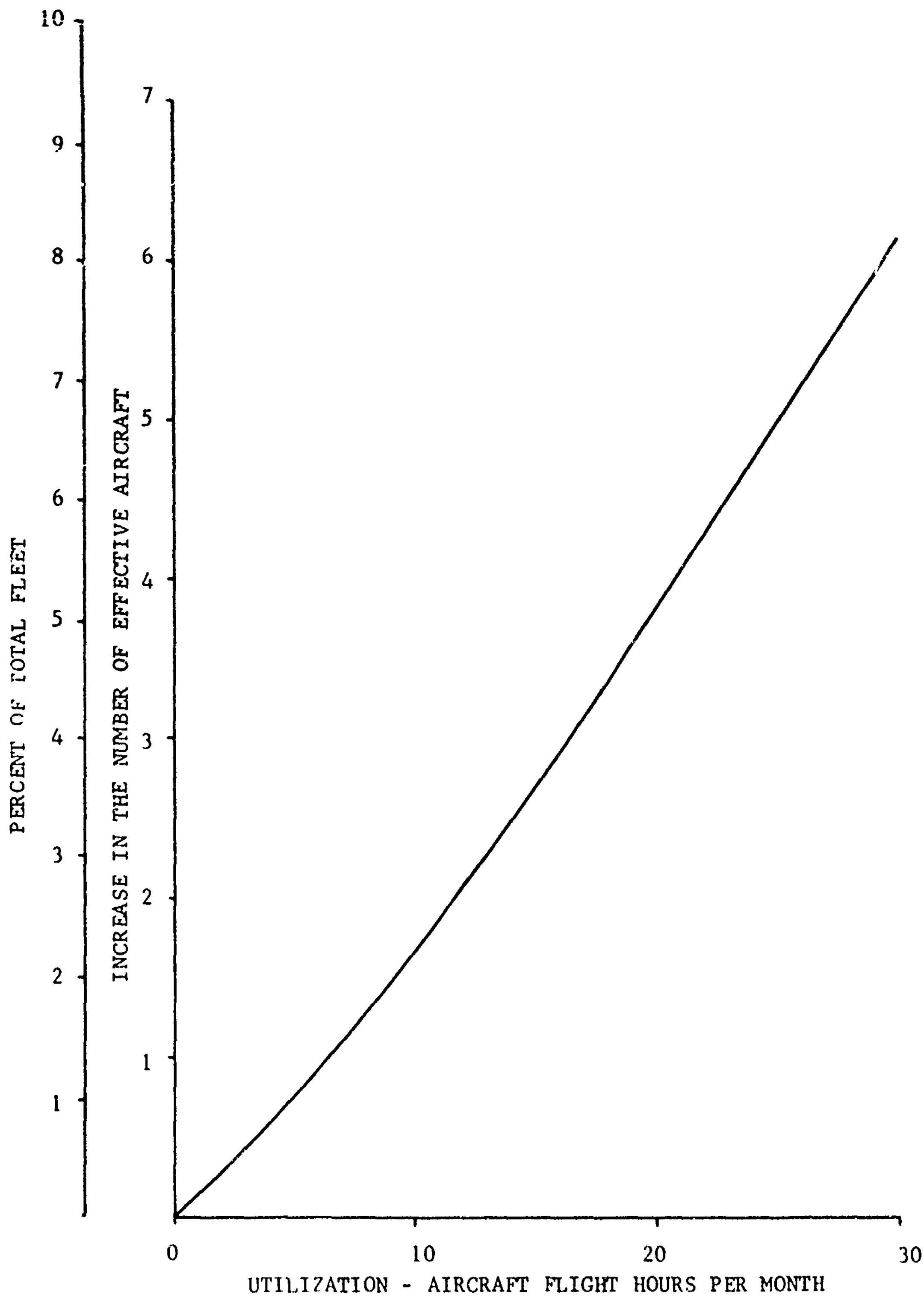


FIGURE 8-27 CH-54 HYBRID I INCREASE IN EFFECTIVE AIRCRAFT VS AIRCRAFT UTILIZATION

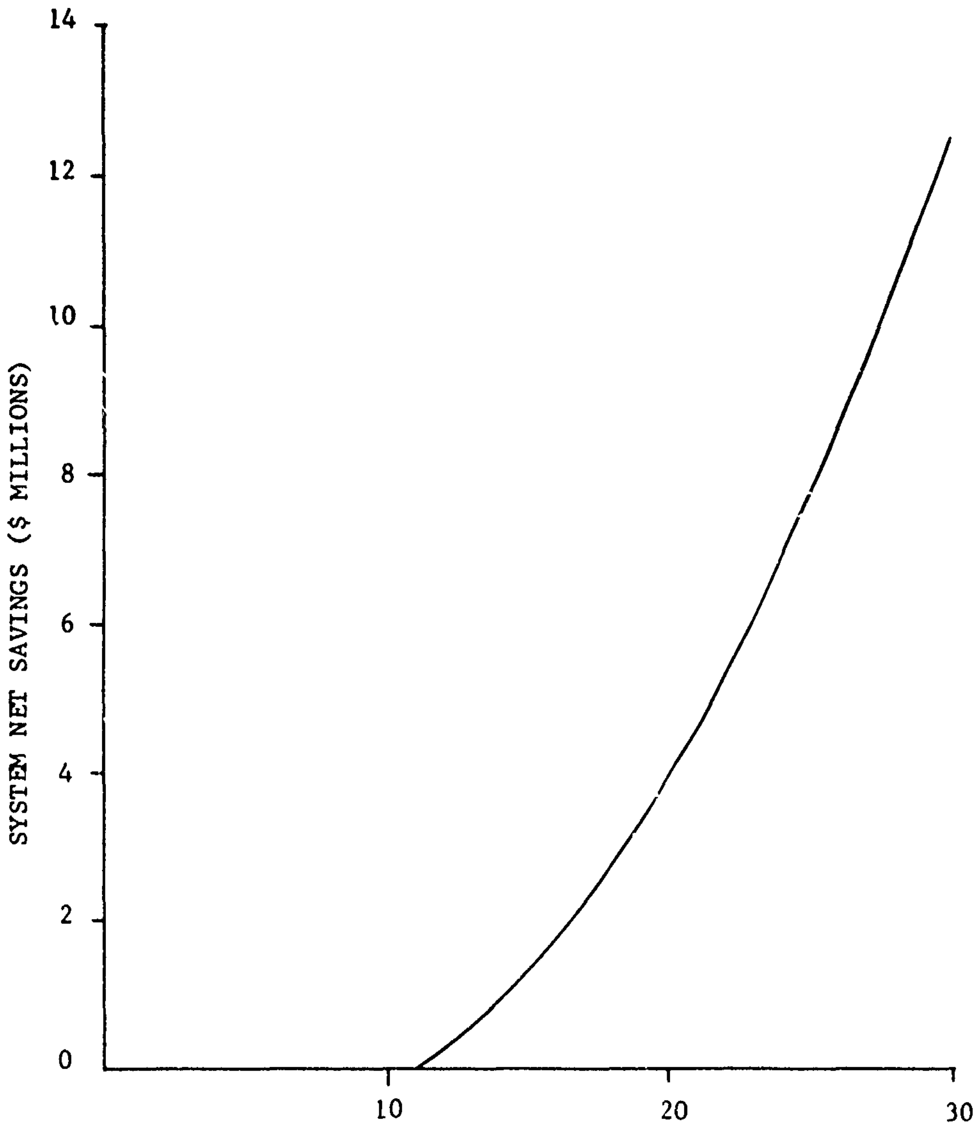


FIGURE 8-28 CH-54 HYBRID I SYSTEM NET SAVING VS AIRCRAFT UTILIZATION

8.1.2.4 OH-6 Tradeoffs

Figures 8-29 through 8-33 show the results of applying the candidate AIDAP systems to the OH-6 aircraft. Since this is a lightweight, simple, and relatively inexpensive aircraft, the savings achieved per aircraft are smaller than for the heavier more complex aircraft. For instance, Figure 8-29 shows that the savings in manpower achieved by the ground system never quite equal the additional manpower required for operation and maintenance of the AIDAP Ground System. Figure 8-30 shows that neither the Ground nor the Hybrid II AIDAPS achieve savings in logistic costs sufficient to equal the logistics costs of supporting these AIDAP systems. However, the Hybrid I and Airborne systems do achieve some logistics savings. Likewise, neither the Ground System nor the Hybrid II systems achieve accident savings. This is due to their lack of an airwarning capability.

Figure 8-32 shows that the increase in aircraft effectiveness barely compensates for the additional weight installed in the aircraft. Hence, the net savings as shown on Figure 8-33 never achieve a positive value. Although the application of a non-unique system may reduce the AIDAPS development and procurement cost sufficiently to achieve slightly positive savings, it is apparent that these savings will probably not be sufficient to justify procurement of a device which would justify the automatic inspection and prognisis generic classification. Figures 8-31 and 8-32 indicate that an extremely simple, lightweight device, dedicated primarily to reducing accidents, but capable of inspection and diagnosis for a very few components may be cost effective. Consideration of such a non-automatic and non-prognostic device is beyond the scope of this study.

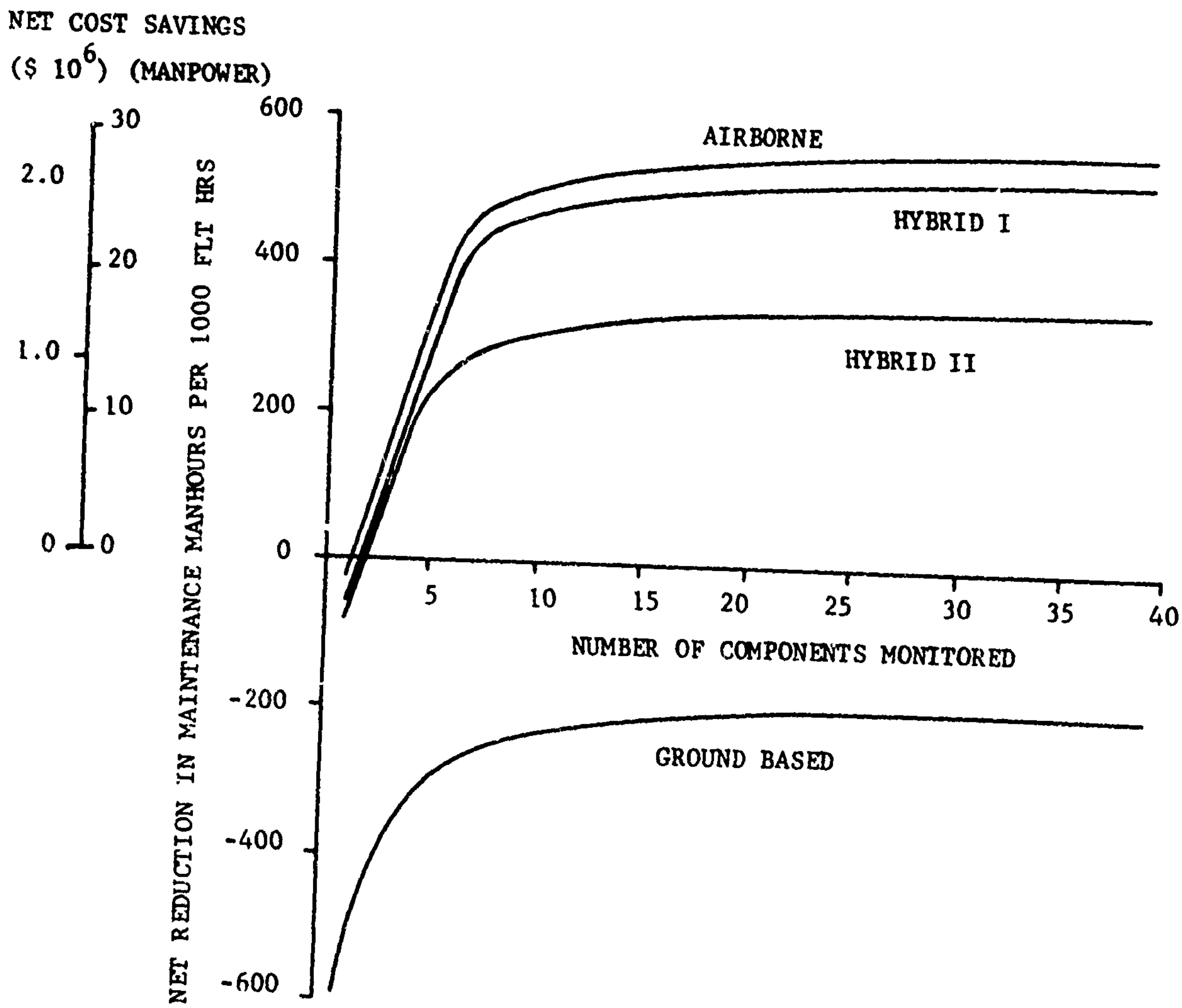


FIGURE 8-29 OH-6 PERSONNEL SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

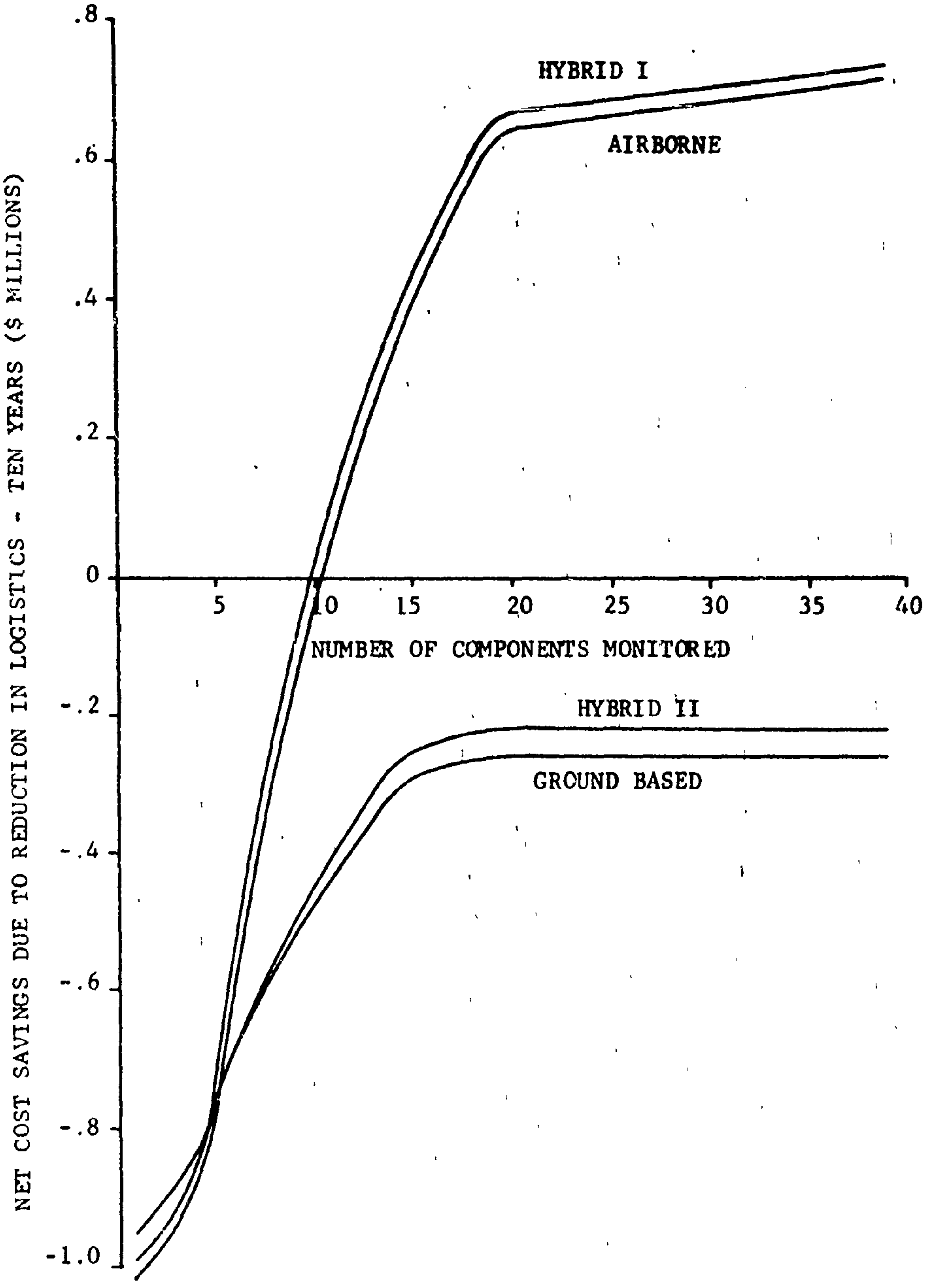


FIGURE 8-30 OH-6 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

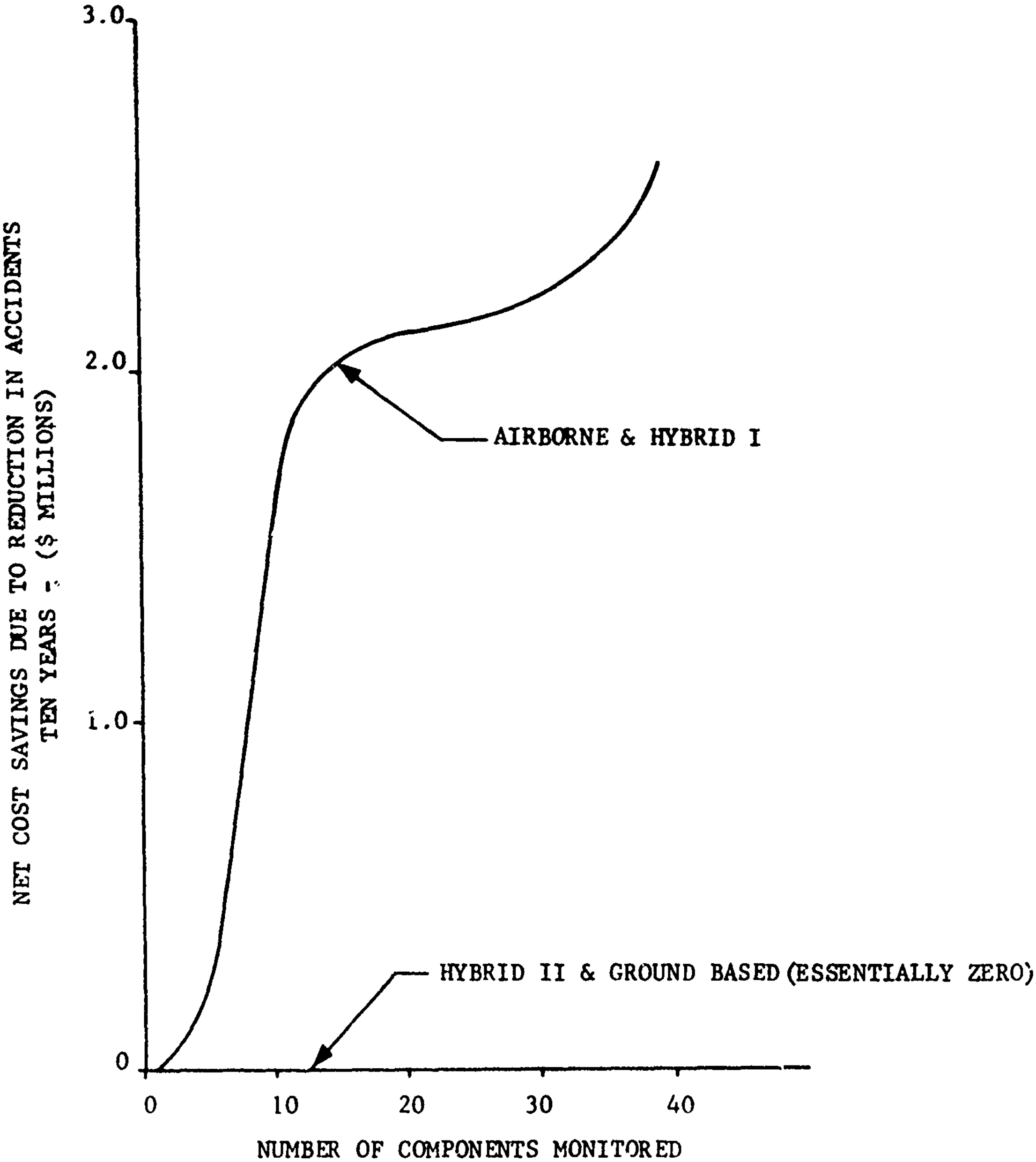


FIGURE 8-31 OH-6 ACCIDENT SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

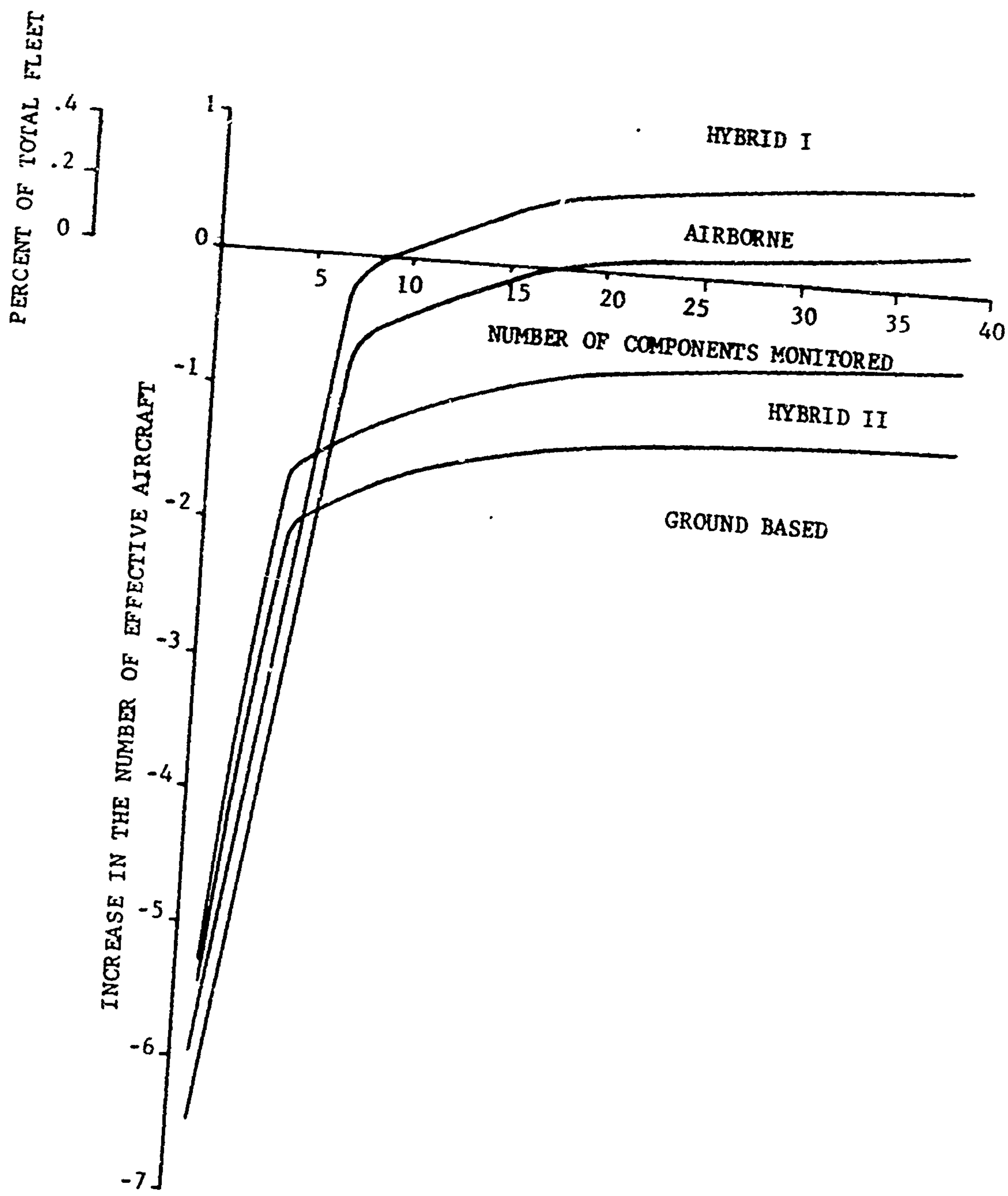


FIGURE 8-32 OH-6 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

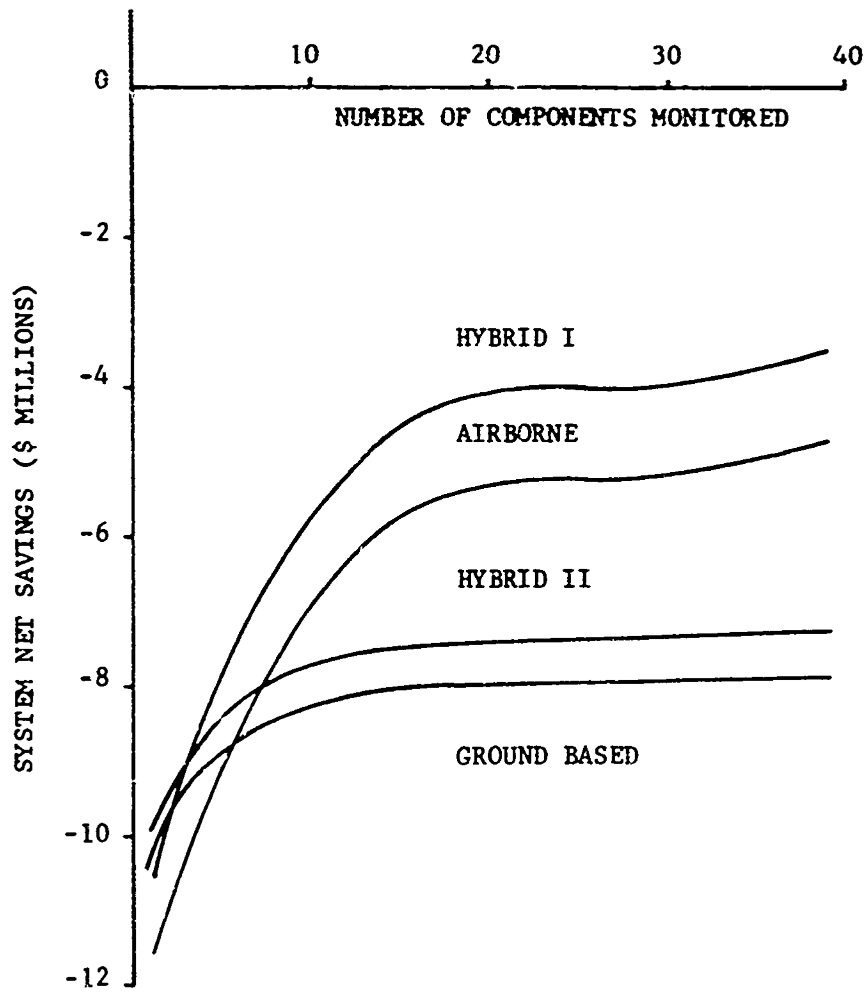


FIGURE 8-33 OH-6 SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

8.1.2.5 OH-58 Tradeoffs

Figures 8-34 through 8-39 show the results of the tradeoffs for the OH-58 aircraft. In general, the discussion of the curves for the OH-6 applies to the curves for the OH-58. Figure 8-36 shows a large upswing between the 30th and 40th components. This is due to the inclusion of a number of components that are not troublesome from the maintenance standpoint, but have high accident potentials. Such components have a significant impact on air safety.

Figure 8-38 shows that net savings are accrued for the OH-58 as contrasted to a net deficit for the OH-6. This is due to the reduced DDT&E and procurement costs on a per aircraft basis because of the large number of OH-58 aircraft in the inventory. Figure 8-39 shows the expenditures, savings and benefits on a time basis.

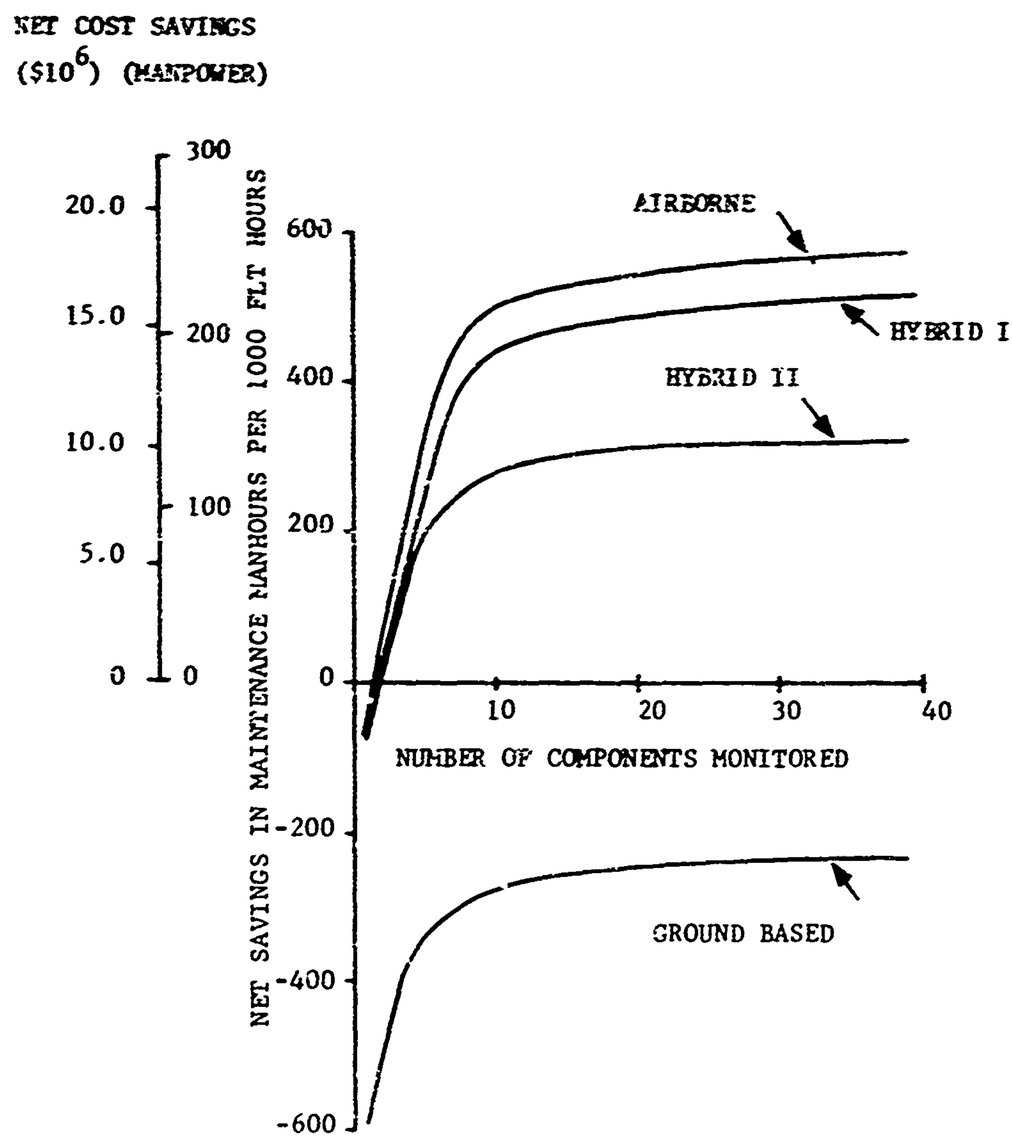


FIGURE 8-34 OH-58 PERSONNEL SAVINGS
VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

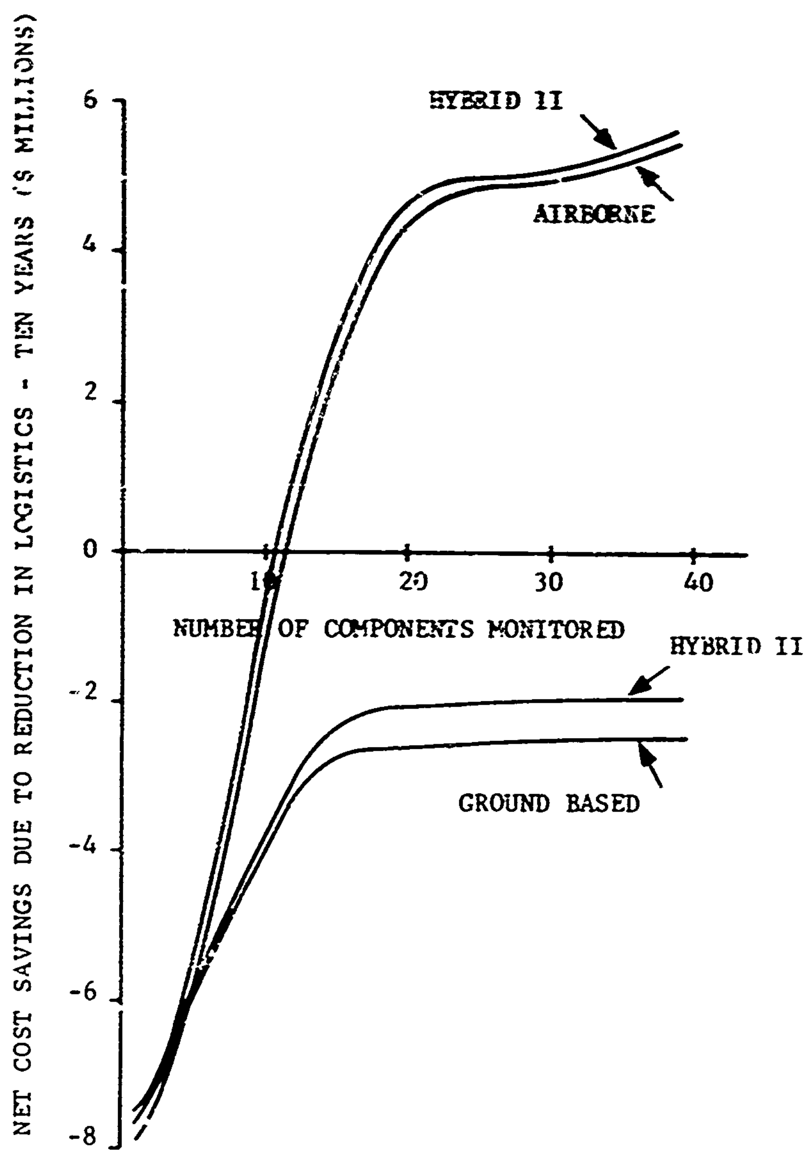


FIGURE 8-35 OH-58 LOGISTICS SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

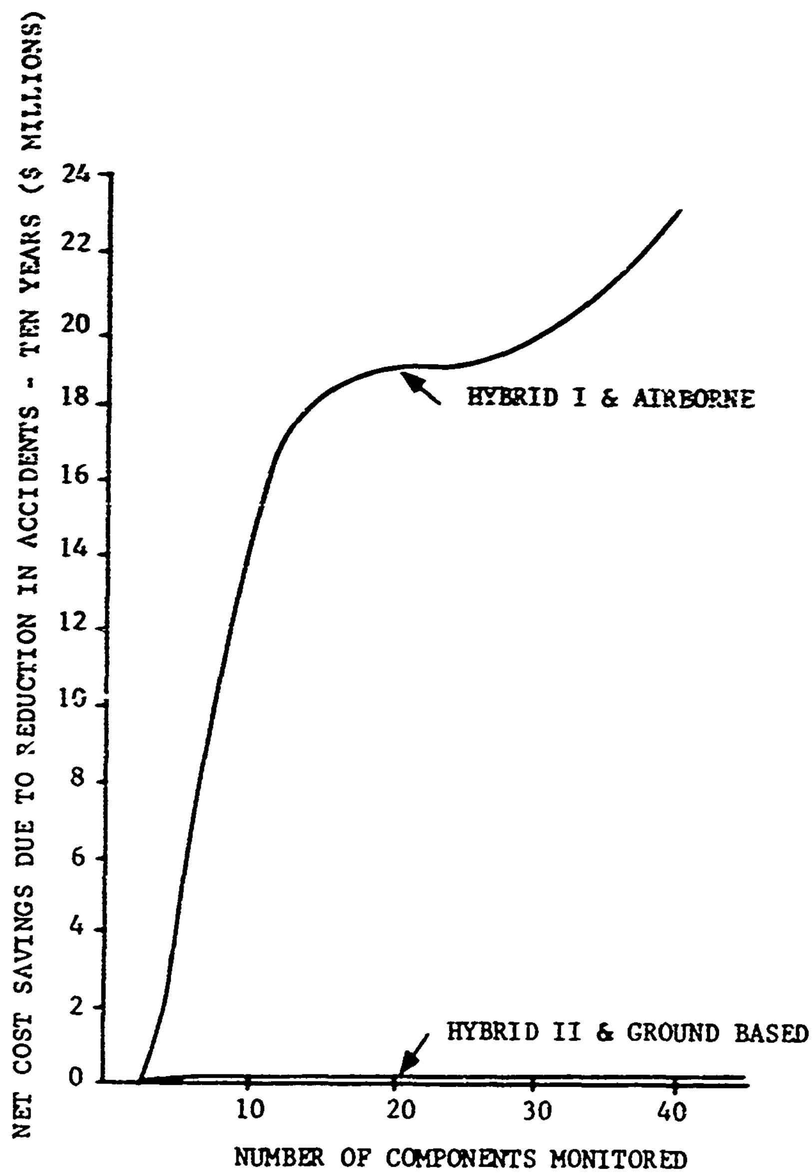


FIGURE 8-36 OH-58 ACCIDENT SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

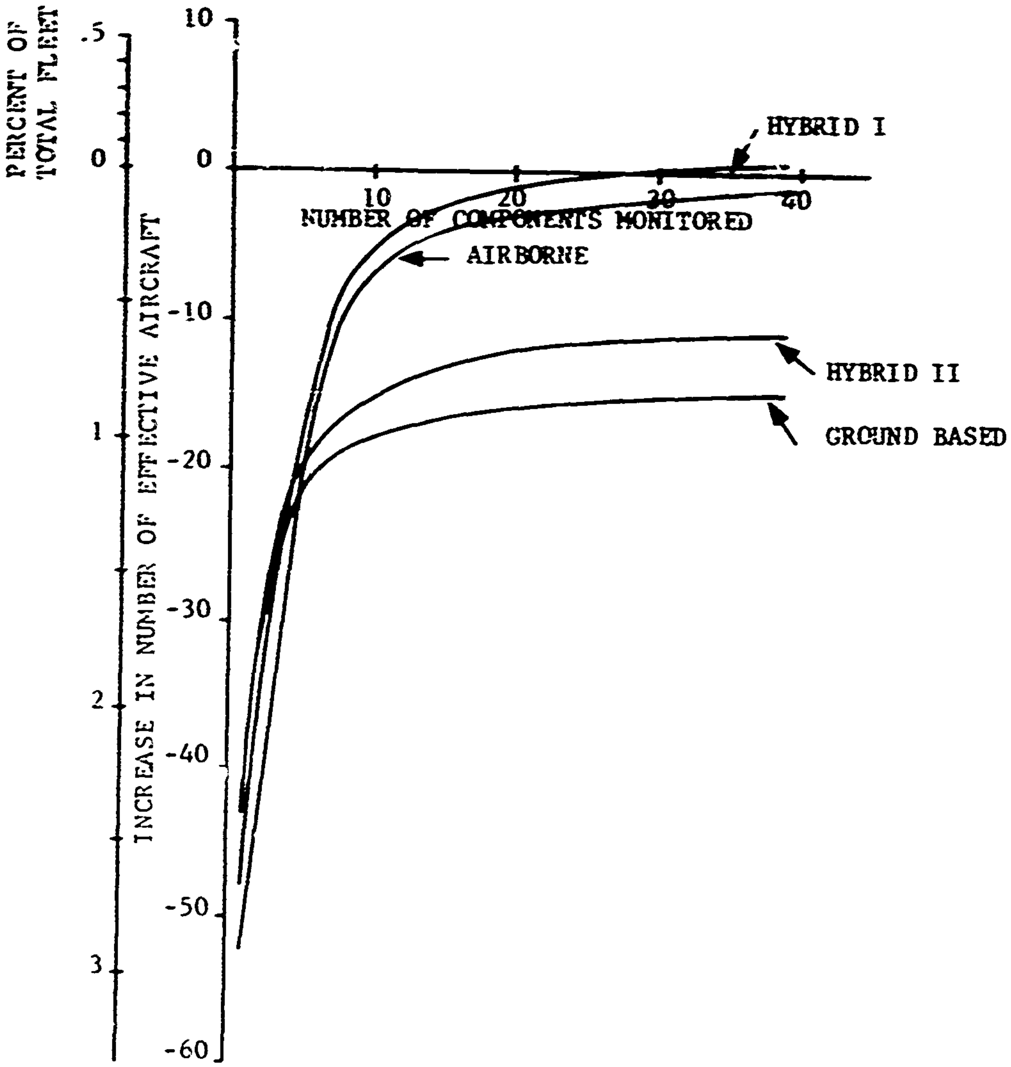


FIGURE 8-37 OH-58 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED

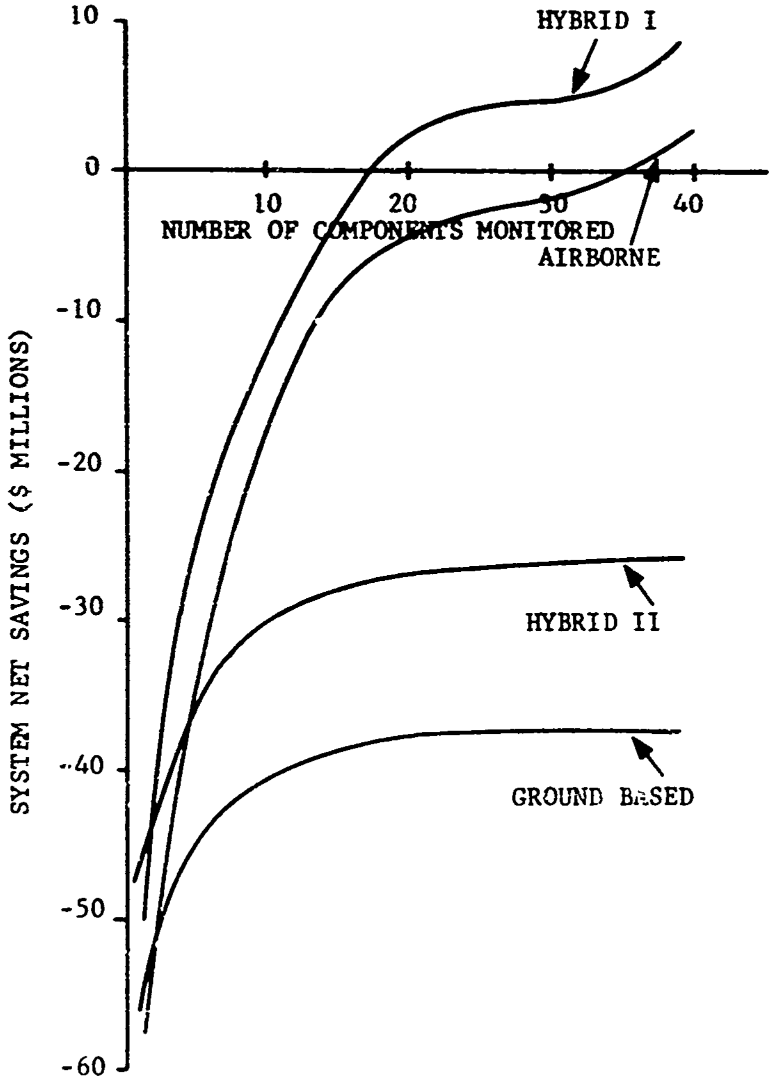


FIGURE 8-38 OH-58 SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

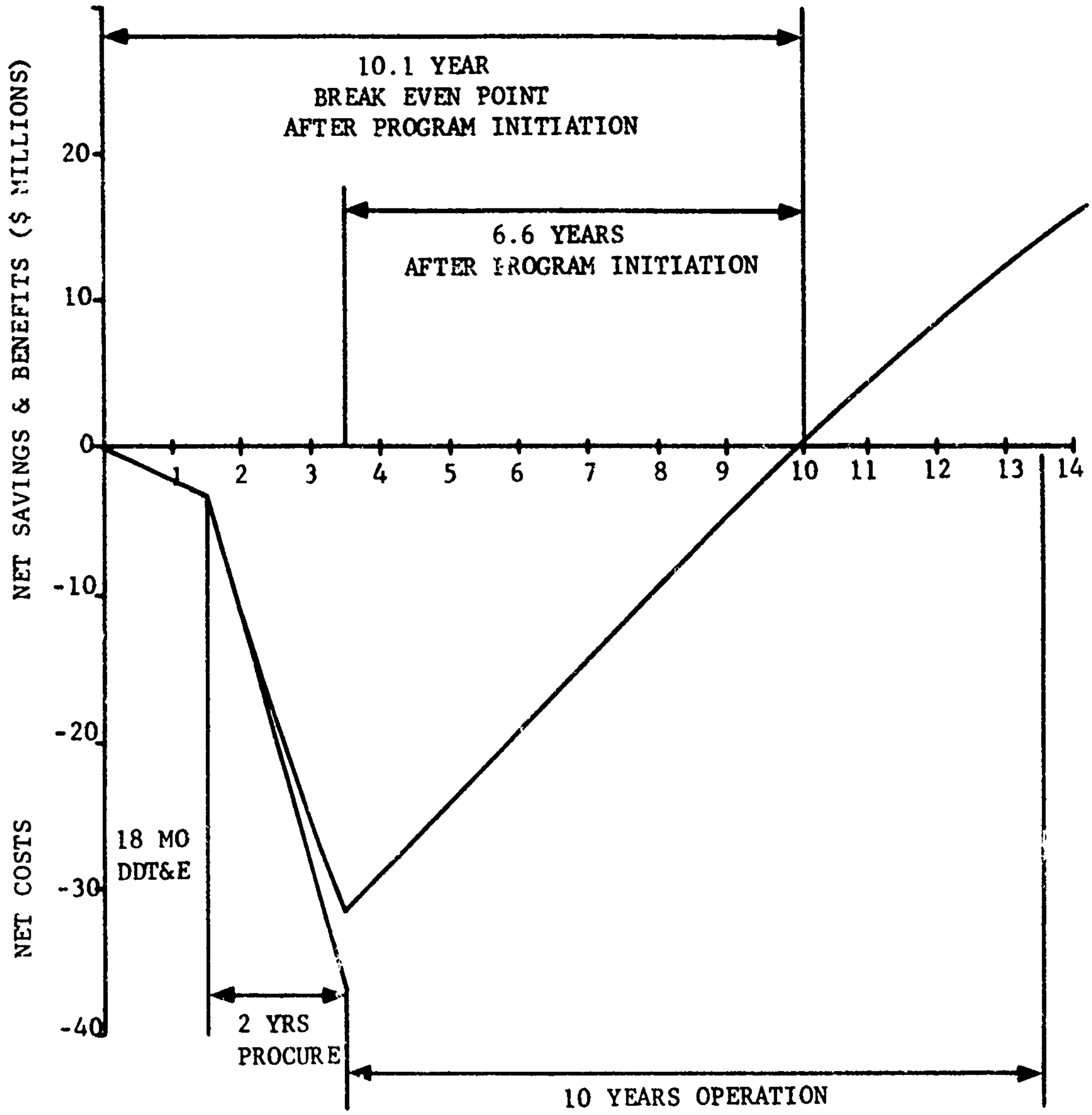


FIGURE 8-39 OH-58 HYBRID I UNIQUE AIDAPS SYSTEM -
TIME PHASED PROGRAM COST SAVINGS & BENEFITS

8.1.2.5 OV-1 Tradeoffs

Figures 8-40 through 8-45 show the results of the computer runs for the OV-1 aircraft. Application of AIDAPS to this aircraft produces significant savings resulting in a break-even point only 3.4 years after the system is procured. See Figure 8-45. Much of the savings for this aircraft is due to the ability of the AIDAPS to reduce downtime, and the high value of that downtime due to the high cost of the aircraft (see Figure 8-43).

It should be pointed out that the ground and Hybrid I systems may achieve higher engine test accuracies on fixed wing aircraft than on helicopters. On fixed wing aircraft, it is possible to run the engine at higher power settings than is possible for partially loaded helicopters during ground run-up. However, it is unlikely that the test accuracy for these systems could be significantly higher than .75 and .80, respectively. Therefore, these values are used for the OV-1. Additionally, since this aircraft is not subject to the hazards of excessive loads and imbalance that is peculiar to helicopters, no weight and balance benefits were allowed for any AIDAPS system on this aircraft. Even on fixed wing aircraft, the Ground and Hybrid I systems require long times for removing and processing the maintenance data and lack airborne warning capability. Figure 8-44 contains a dotted curve showing the results which could be achieved by an idealized, ground-based AIDAPS if it could attain the same test accuracy as an airborne system (.95) and if full benefits of on condition maintenance are included. The following table shows a comparison of the idealized Ground system with the Airborne for the OV-1.

Savings/Cost Category	Airborne	Idealized Ground
Personnel	6.8	5.6
Logistics	4.0	4.0
Other Maintenance & Operations	0.7	0.7
Accidents	0.9	0.5
Effective Aircraft	16.1	11.5
Total Savings	28.5	223.
Life Cycle Costs	13.4	10.5
Net Savings	15.1	11.8

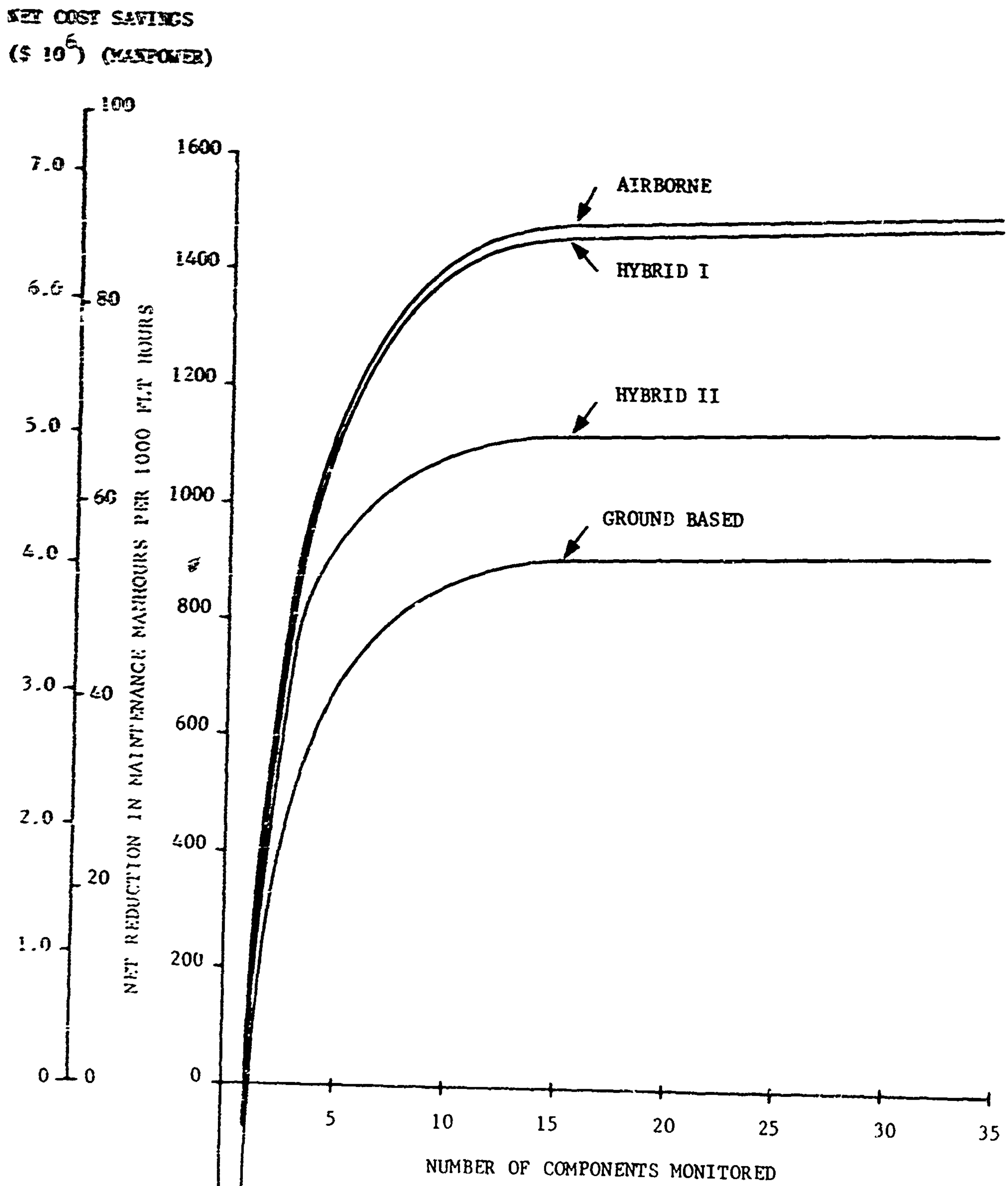


FIGURE 8-40 OV-1 PERSONNEL SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

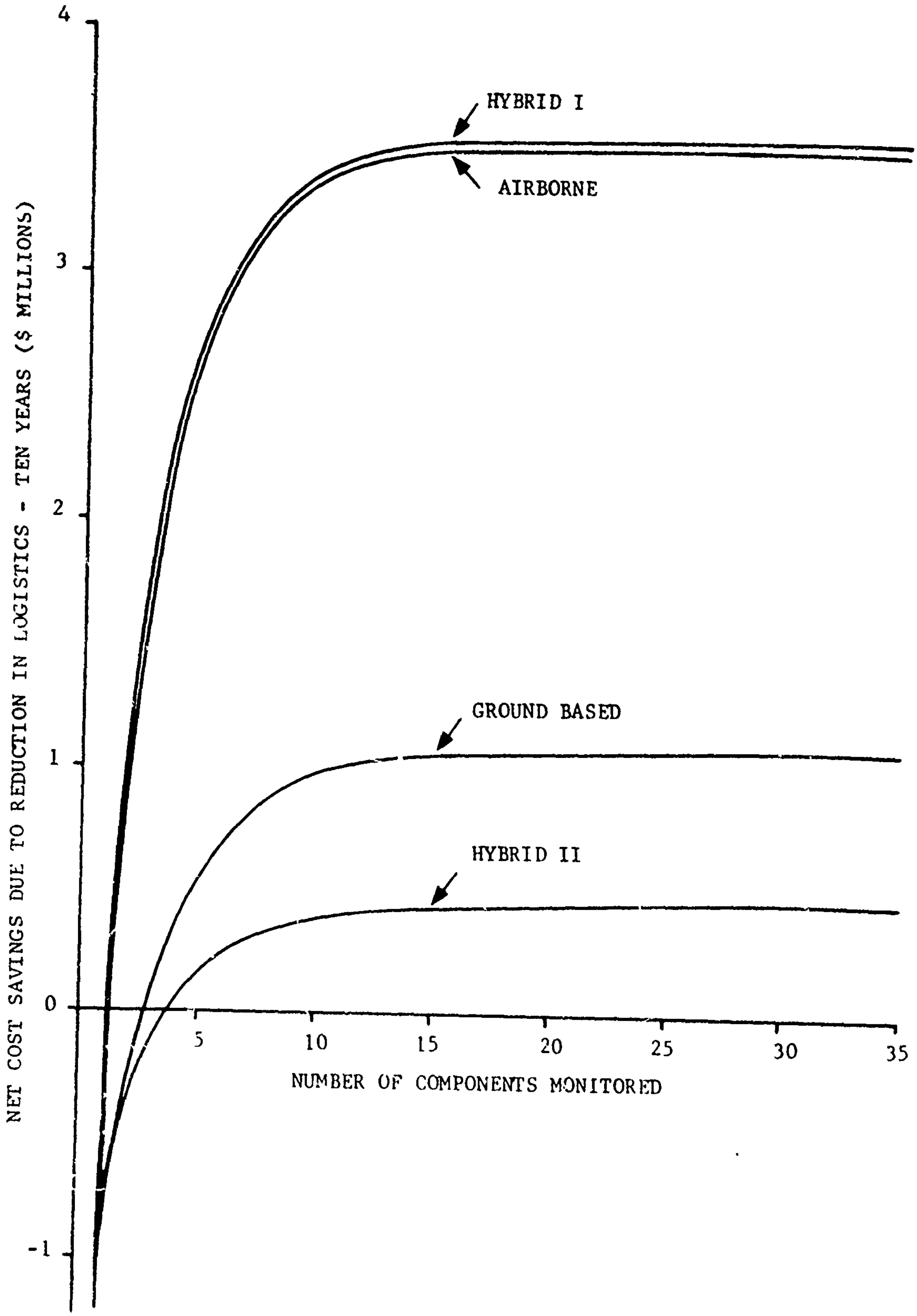


FIGURE 8-41 OV-1 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

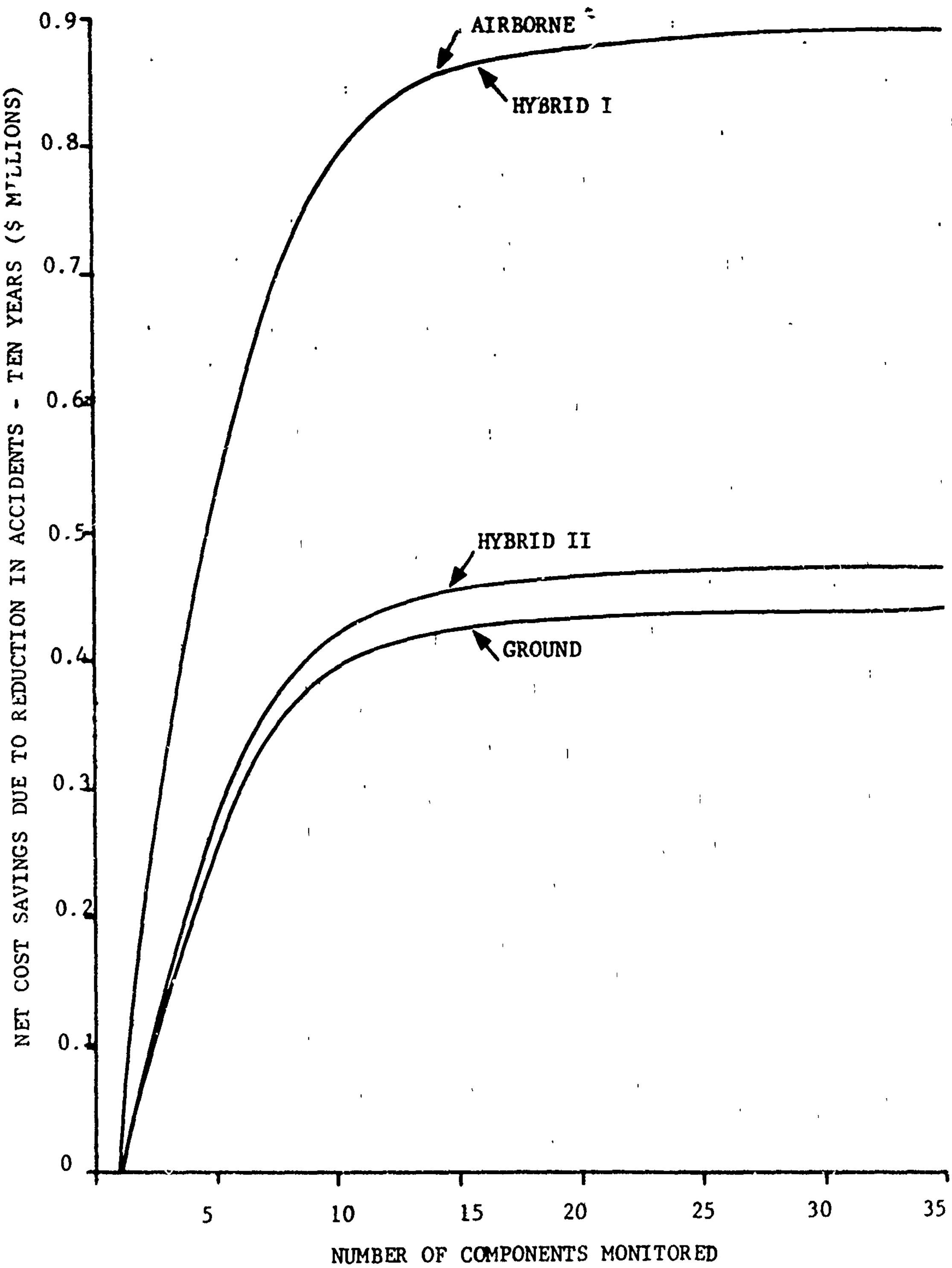


FIGURE 8-42 OV-1 ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

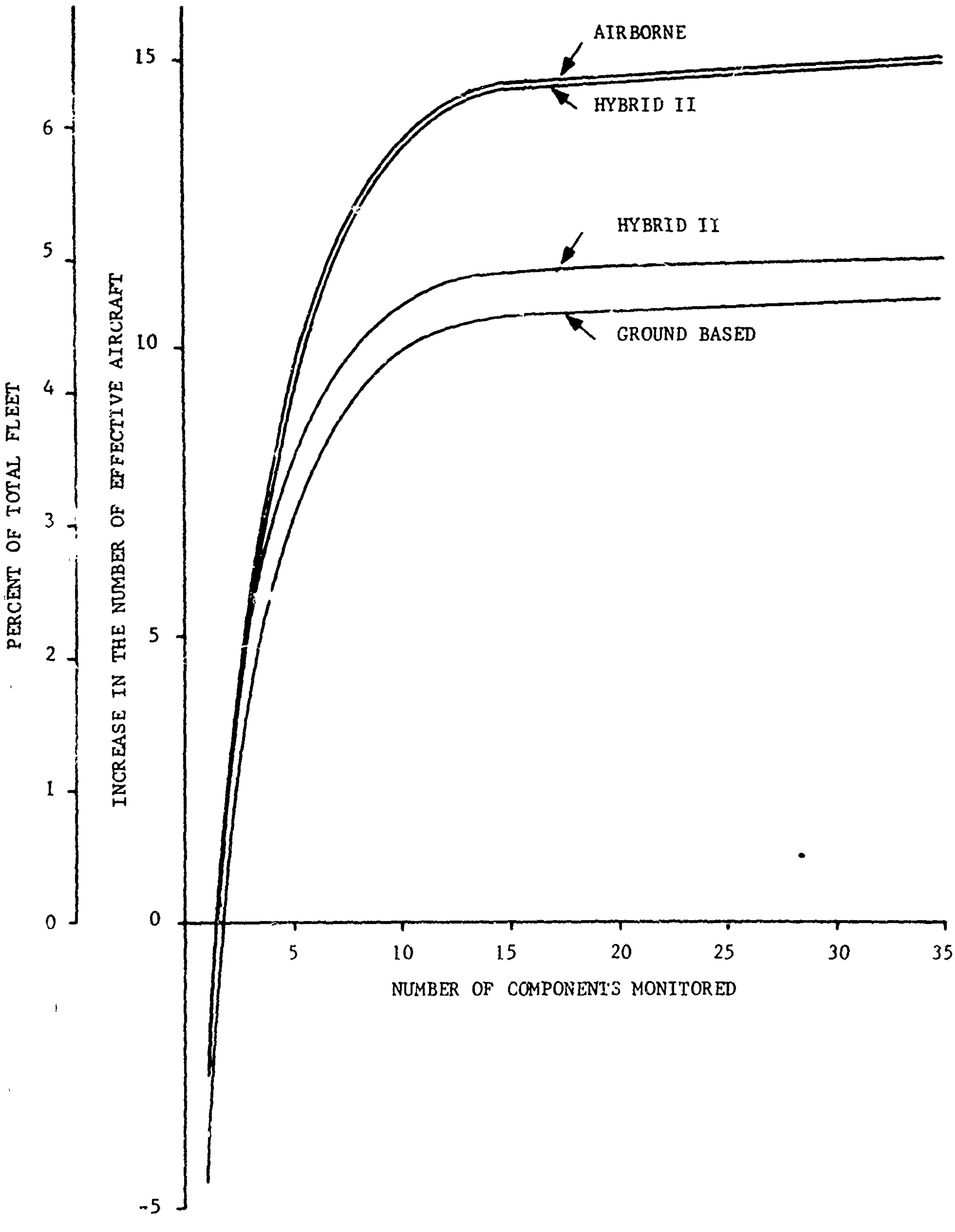


FIGURE 8-43 OV-1 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

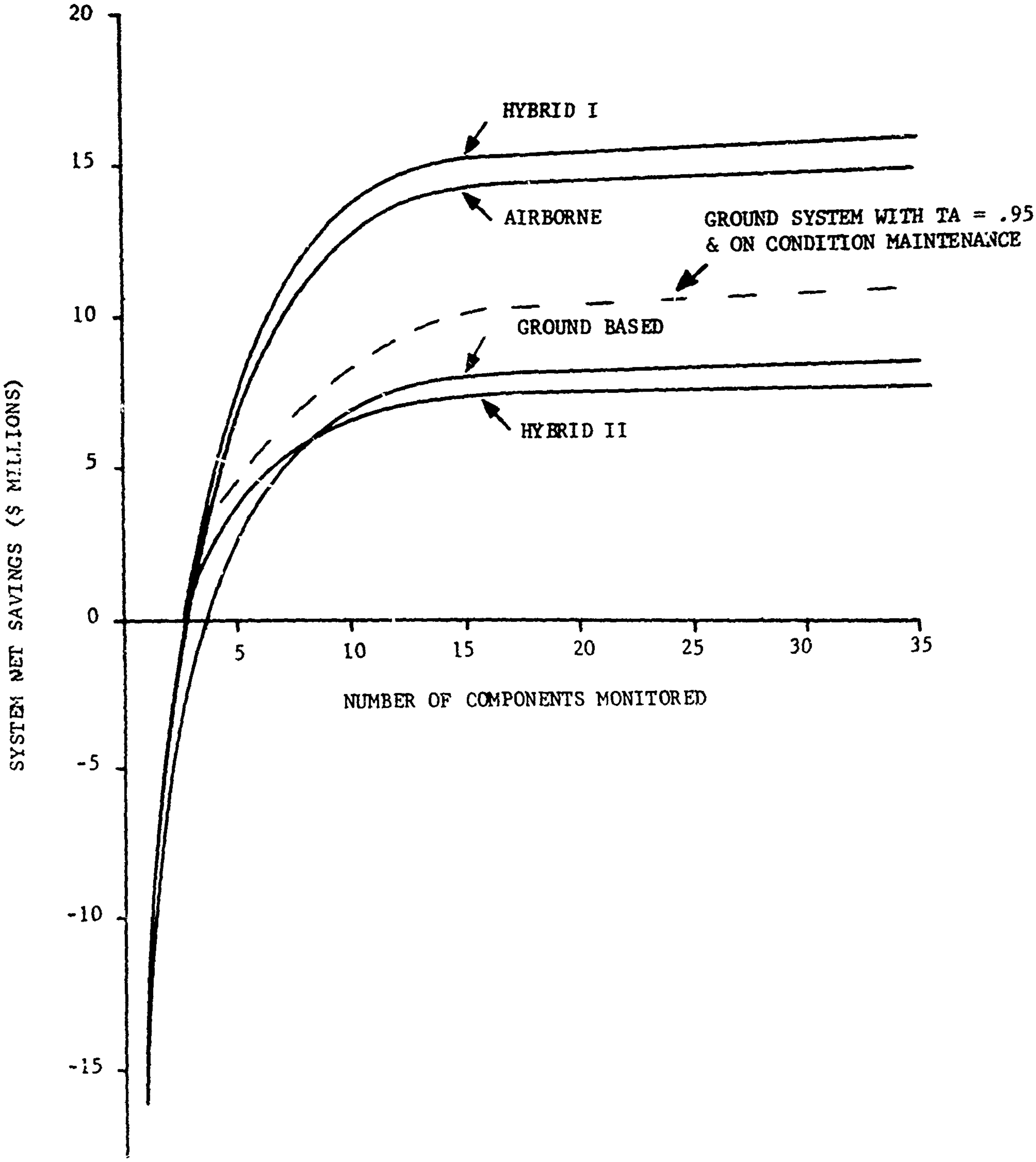


FIGURE 8-44 OV-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

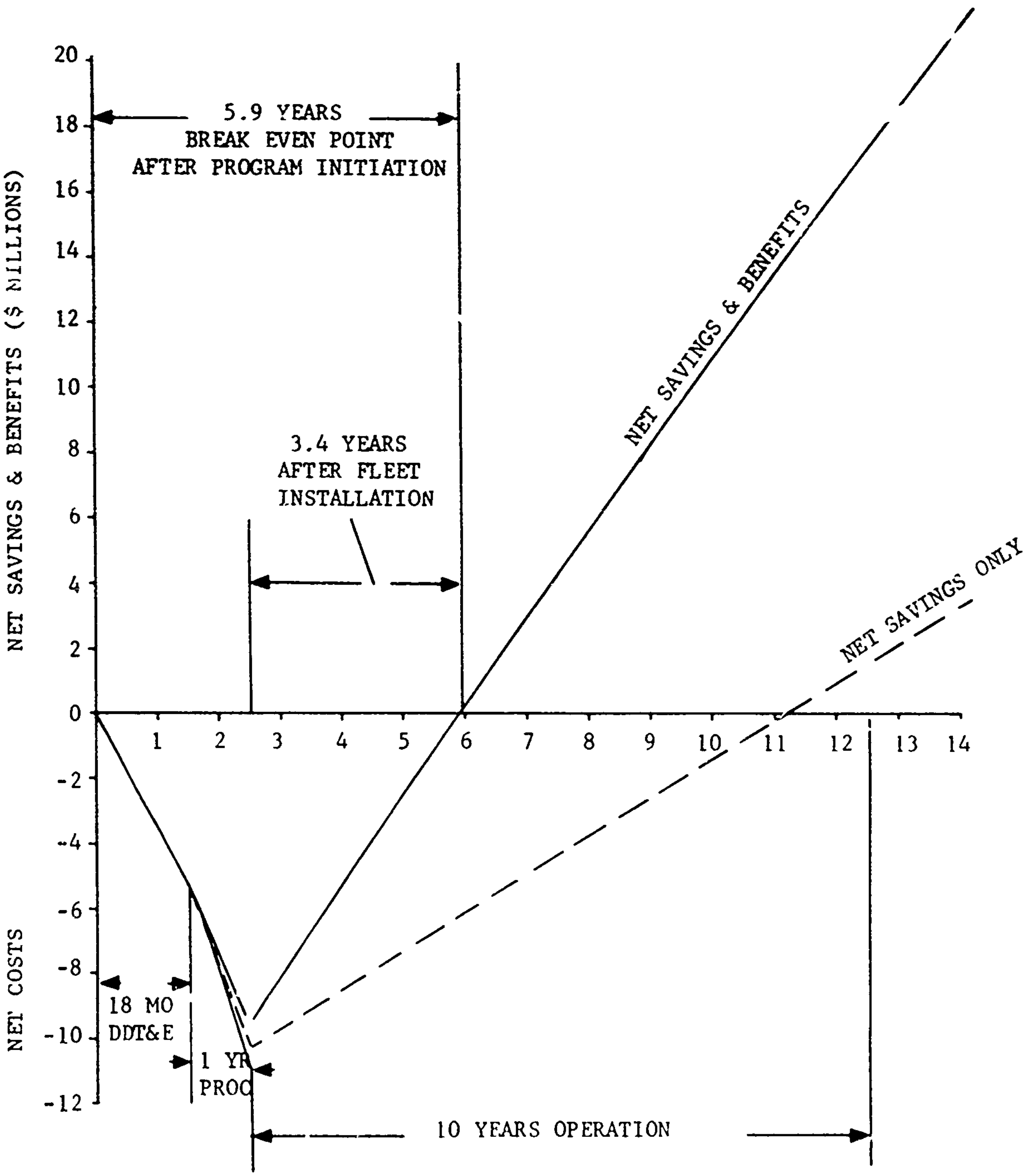


FIGURE 8-45 CV-1 HYBRID I UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM COST SAVINGS & BENEFITS

8.1.2.7 UH-1 Tradeoffs

Figures 8-46 through 8-53 show the results of the UH-1 system trade studies. All AIDAP systems achieve significant savings in maintenance man-hours, accidents and net savings as well as increased aircraft effectiveness for this aircraft. The logistics savings achieved by the Ground and Hybrid II systems, however, do not quite equal the logistics costs for these two systems. (See Figure 8-47). This is due to the low test accuracies and inability to achieve adequate on condition maintenance with these two systems. The Ground System achieves higher aircraft effectiveness than the Hybrid II System (Figure 8-48). This is due to the lighter weight of the airborne portion of the ground systems. The savings in aircraft downtime and improved abort rates are substantially equal for these two systems on this aircraft.

Although significant savings are achieved even under the standard conditions, much greater savings can be expected. (See Figure 8-51). The standard values are taken from the peacetime TOE. The optimistic values are wartime TOE. The expected values are our estimates of the average which might be experienced over the '75 to '85 time period, assuming the Vietnam war has ended, but that other less intense situations do occur.

A change in aircraft utilization causes a linear change in all AIDAPS operating costs, savings, and benefits, except for the increase in aircraft effectiveness. Figure 8-52 shows the variation in the increased aircraft effectiveness as a function of utilization.

Figure 8-53 shows the payoff in net savings and benefits as a function of time after program initiation. Even under the most pessimistic assumptions, a break-even point is achieved approximately three years after the procurement funds are expended. Under the most optimistic assumptions, the payoff occurs almost coincident with the end of the procurement program.

While not entirely obvious at this point, an observation of importance that can be seen here is that the cost savings for the UH-1 is similar to the AH-1 on a per aircraft basis. An exception, however, is the fact that accident savings for the AH-1 is dramatically higher than for the UH-1. Based on the reduced TAMMS data, this is primarily due to AH-1 engine problems that were experienced during the time span examined. Total dollar savings is, of course, much higher for the UH-1 due to the large fleet size.

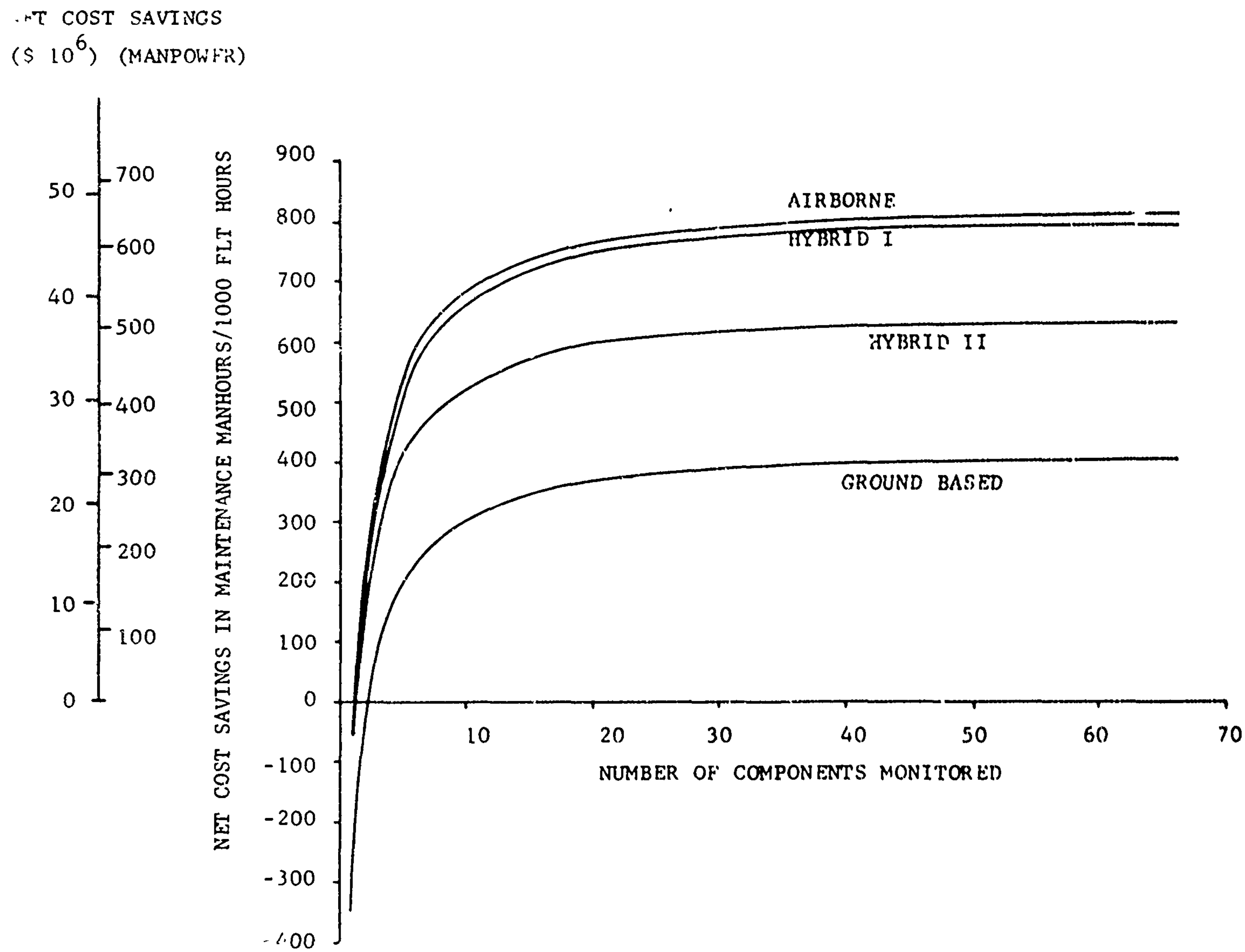


FIGURE 8-46 UH-1 PERSONNEL SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

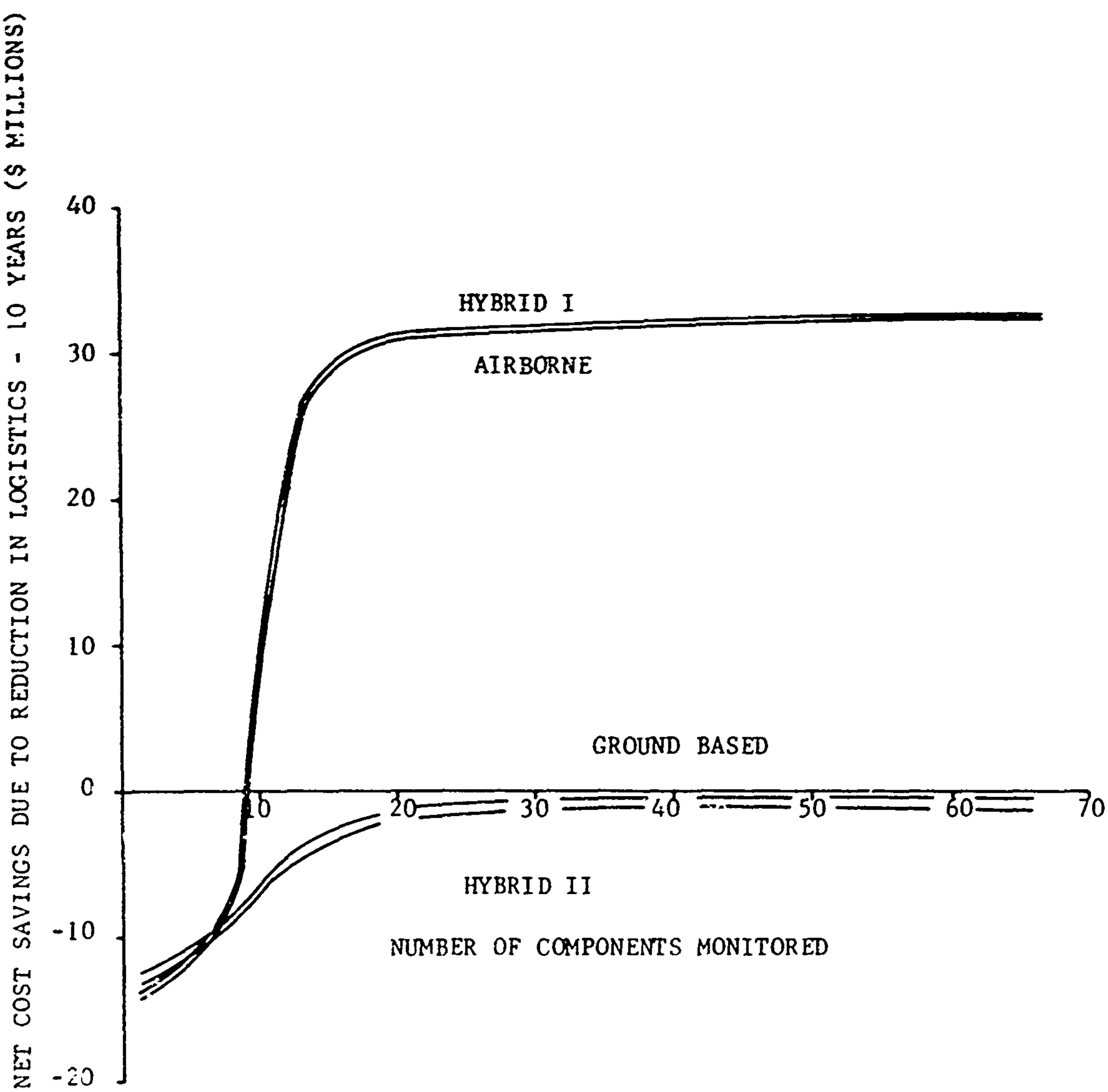


FIGURE 8-47 UH-1 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

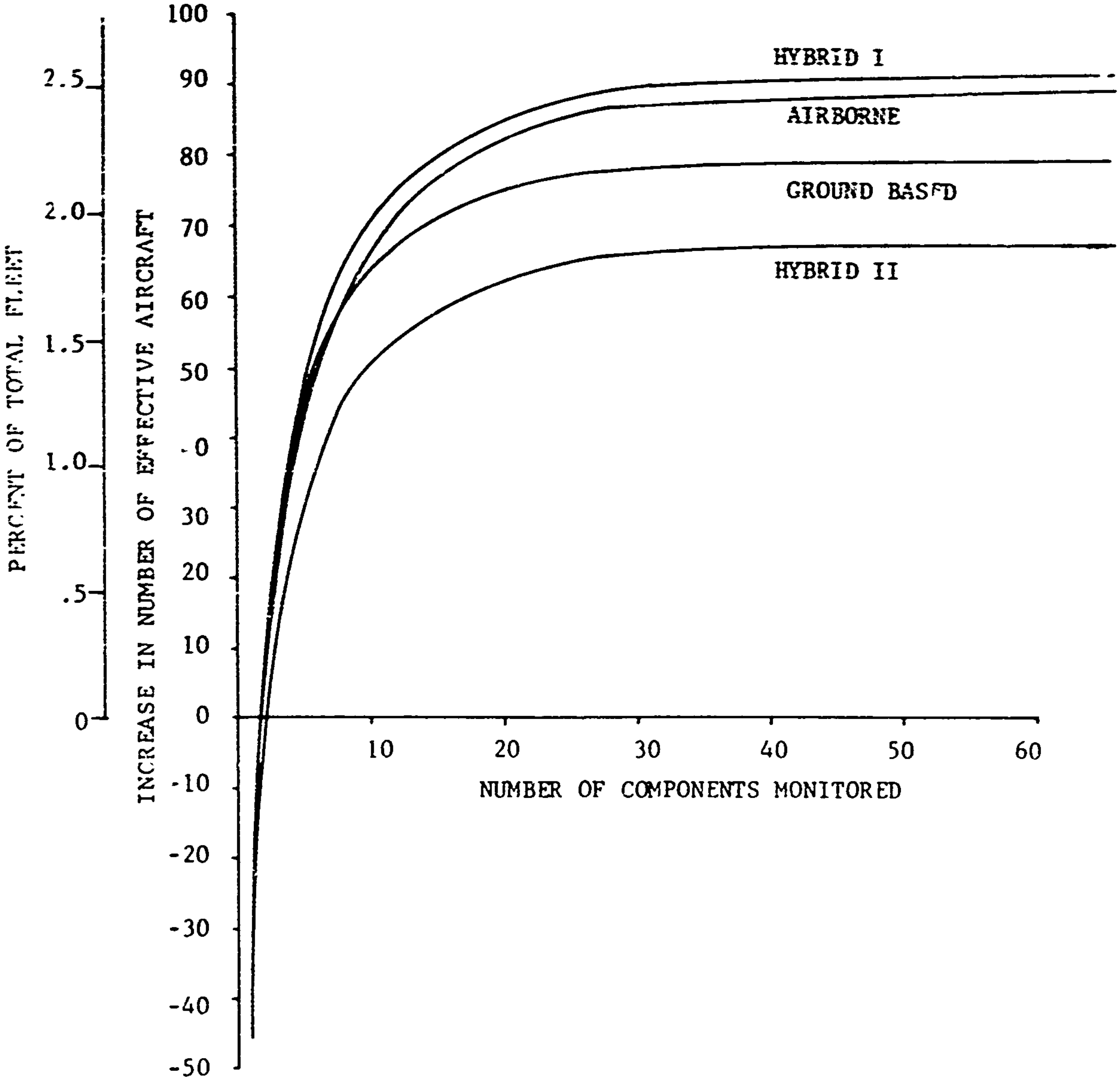


FIGURE 8-48 UH-1 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

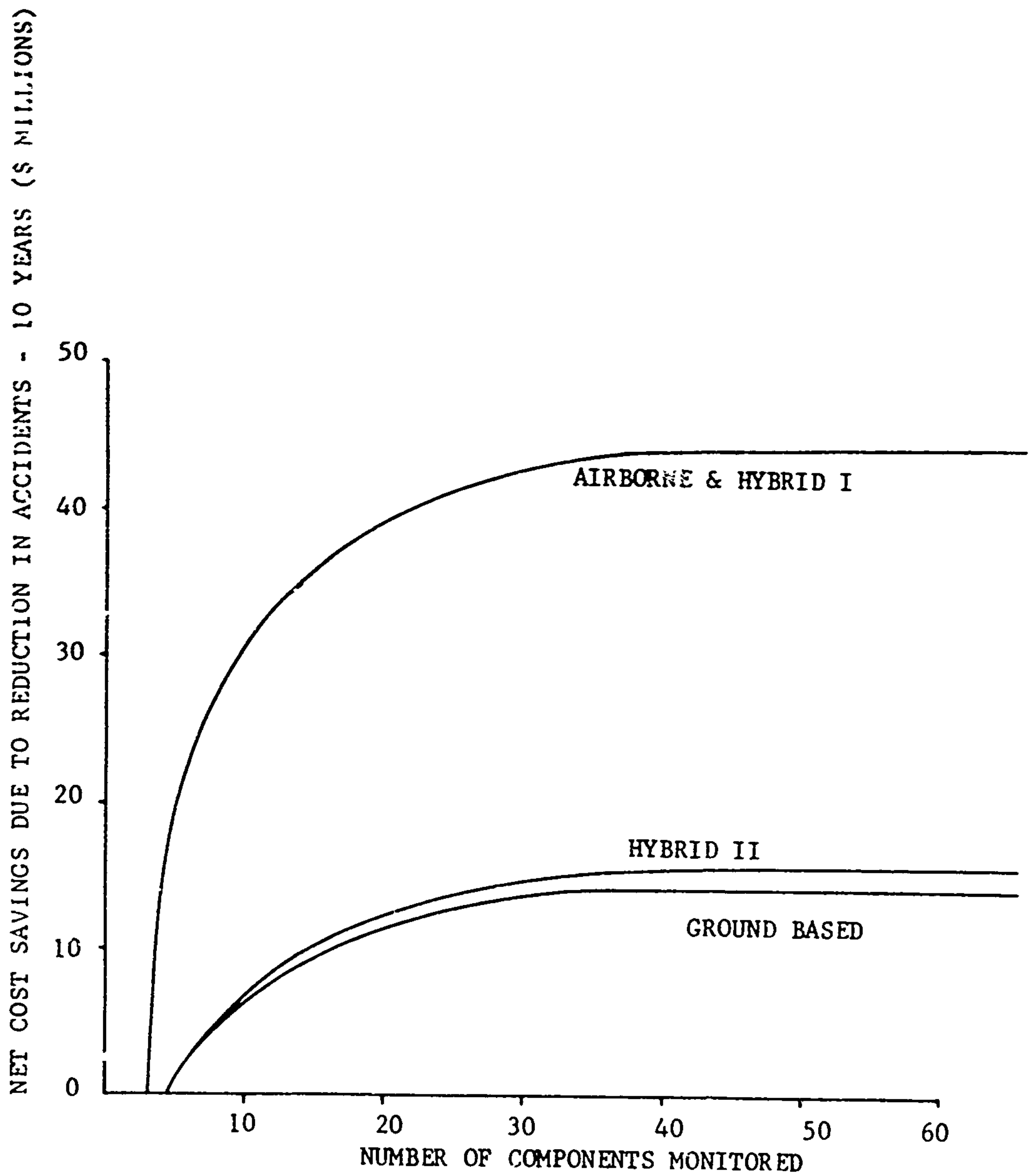


FIGURE 8-49 UH-1 ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

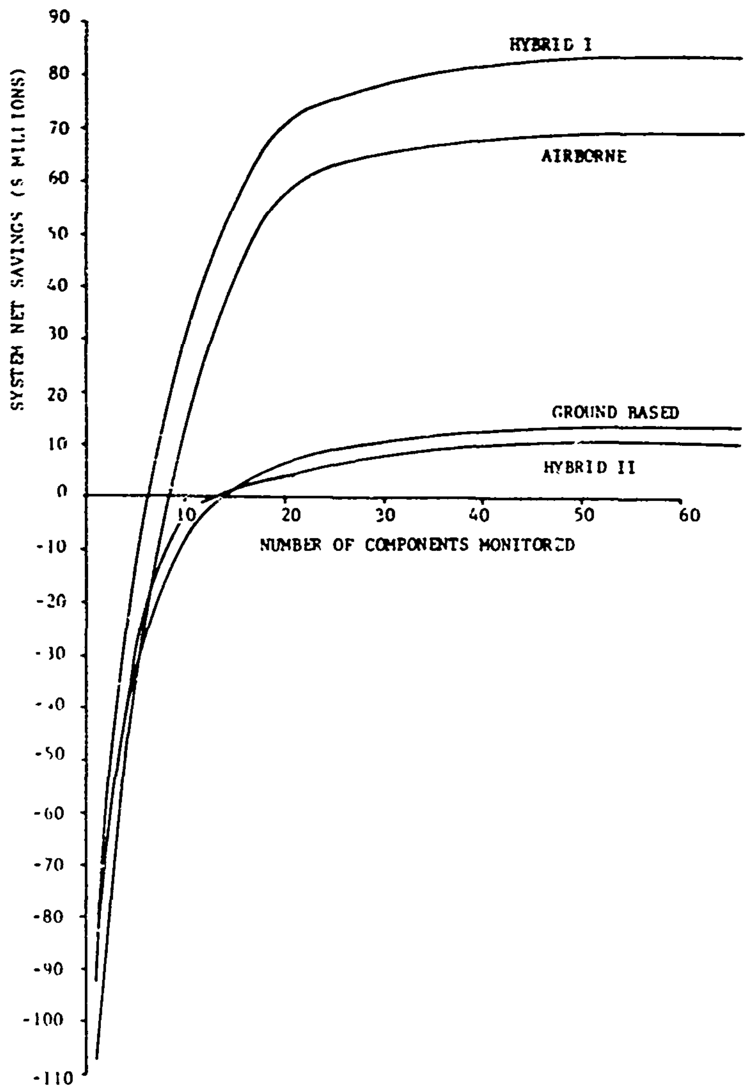


FIGURE 8-50 UH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

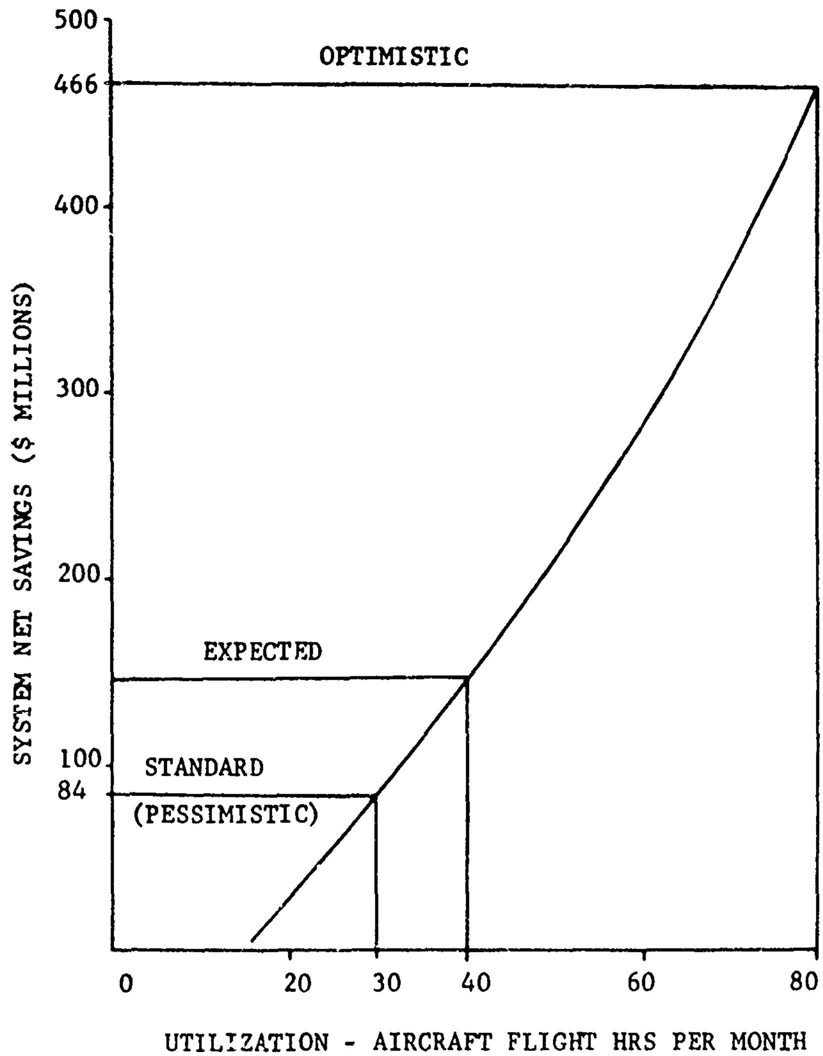


FIGURE 8-51 UH-1 HYBRID I SYSTEM NET SAVINGS VS AIRCRAFT UTILIZATION

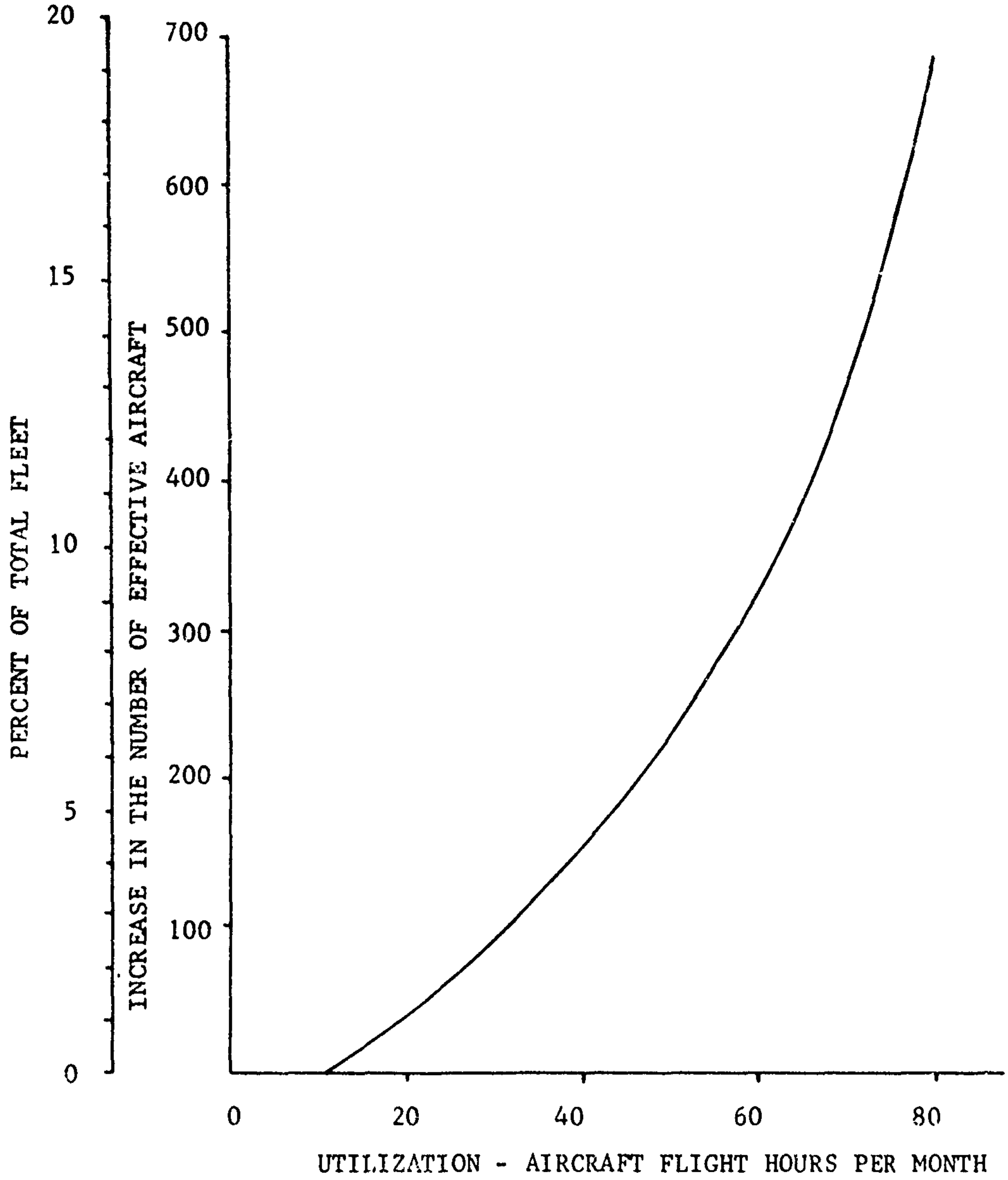


FIGURE 8-52 UH-1 HYBRID I INCREASE IN EFFECTIVE AIRCRAFT VS AIRCRAFT UTILIZATION

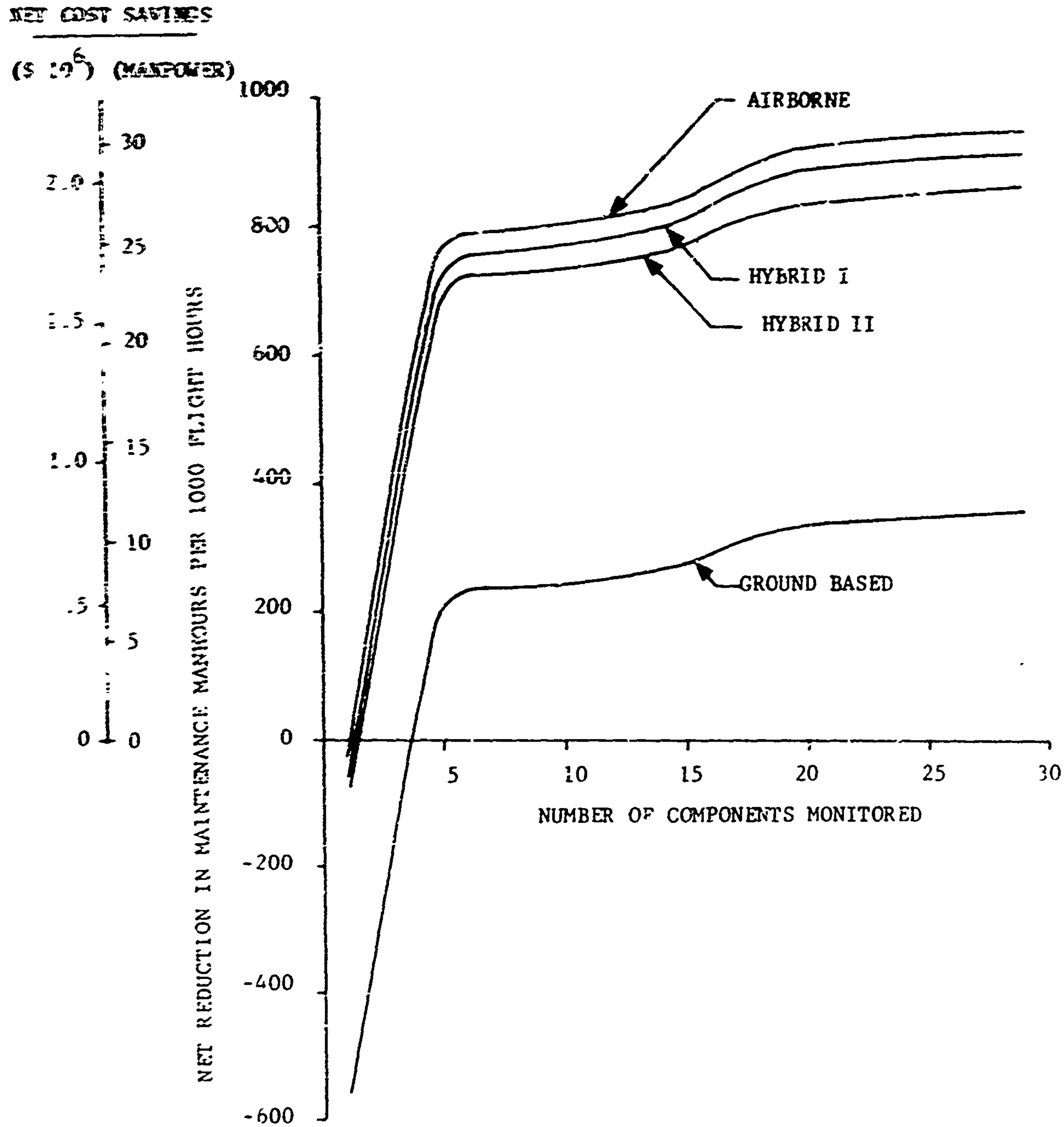


FIGURE 8-54 U-21 PERSONNEL SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

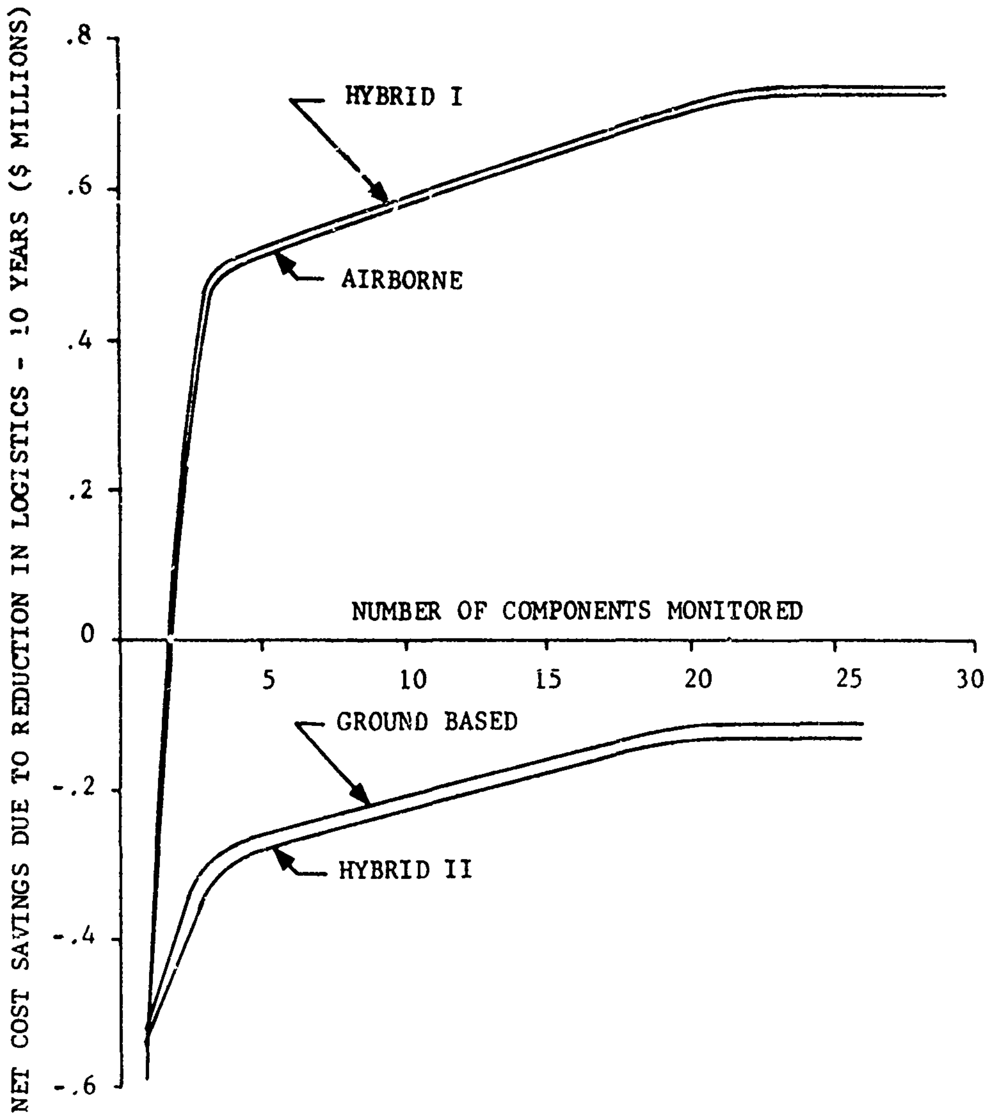


FIGURE 8-55 U-21 LOGISTICS SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITIONS)

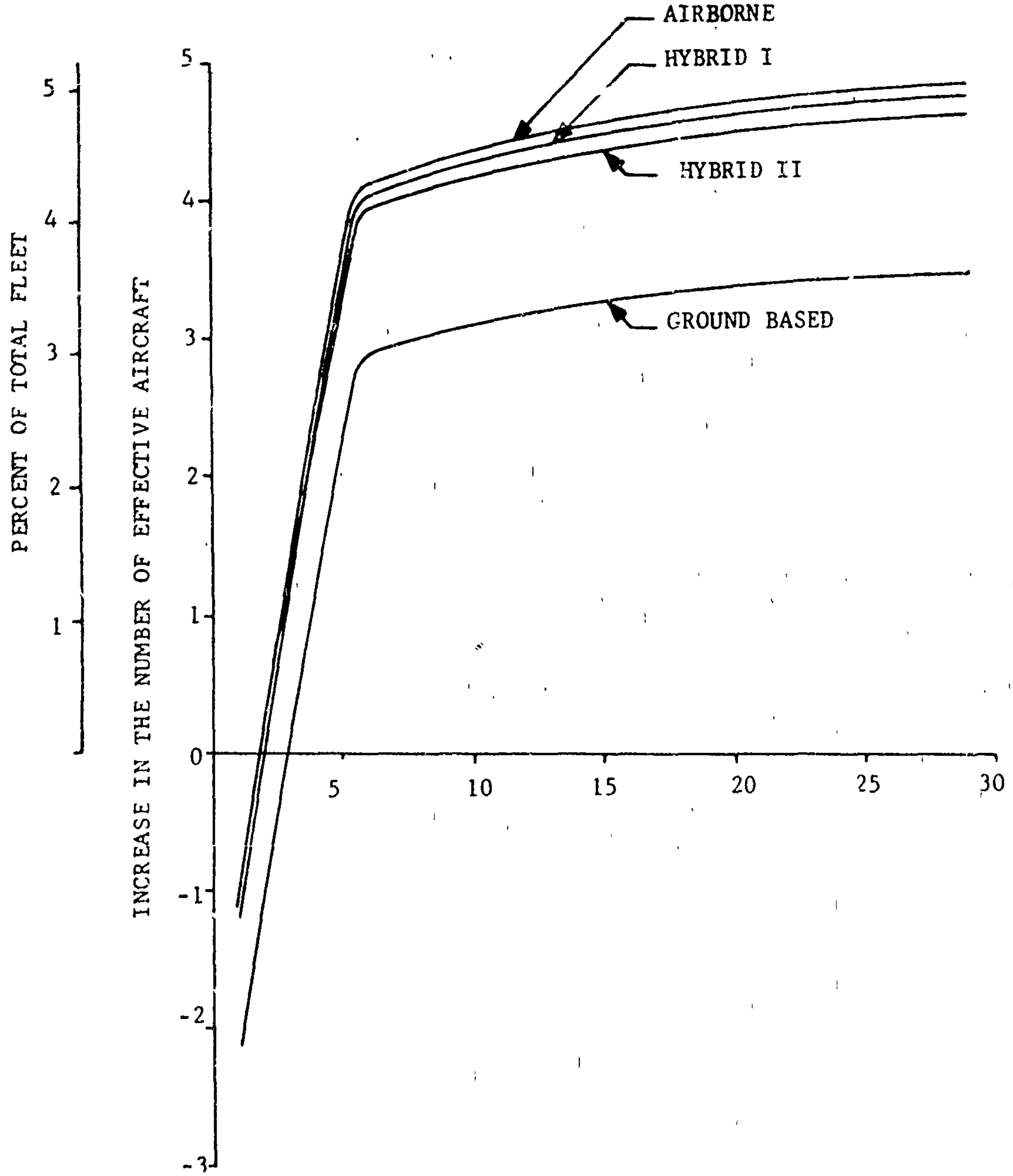


FIGURE 8-56 U-21 INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

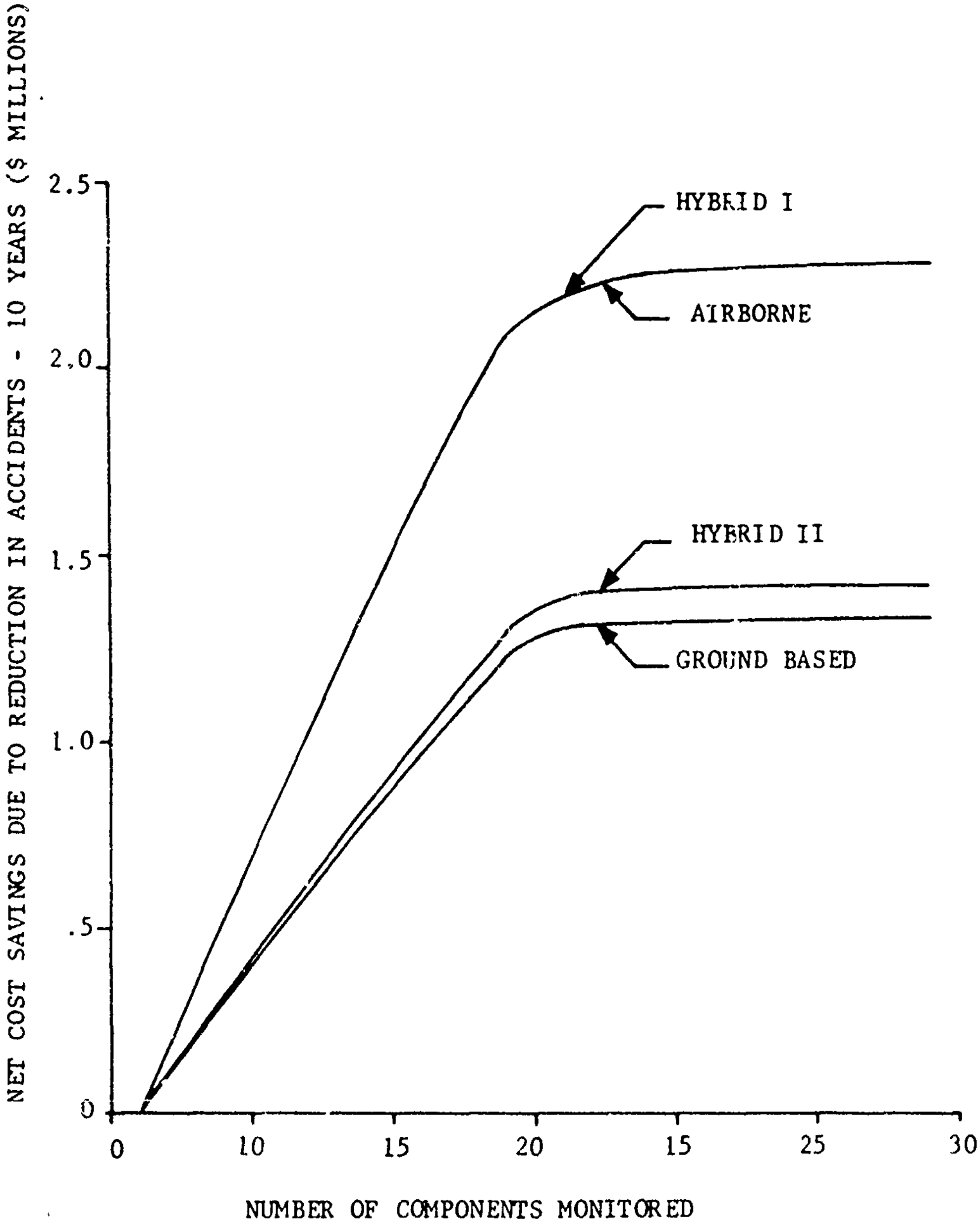


FIGURE 8-57 U-21 ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

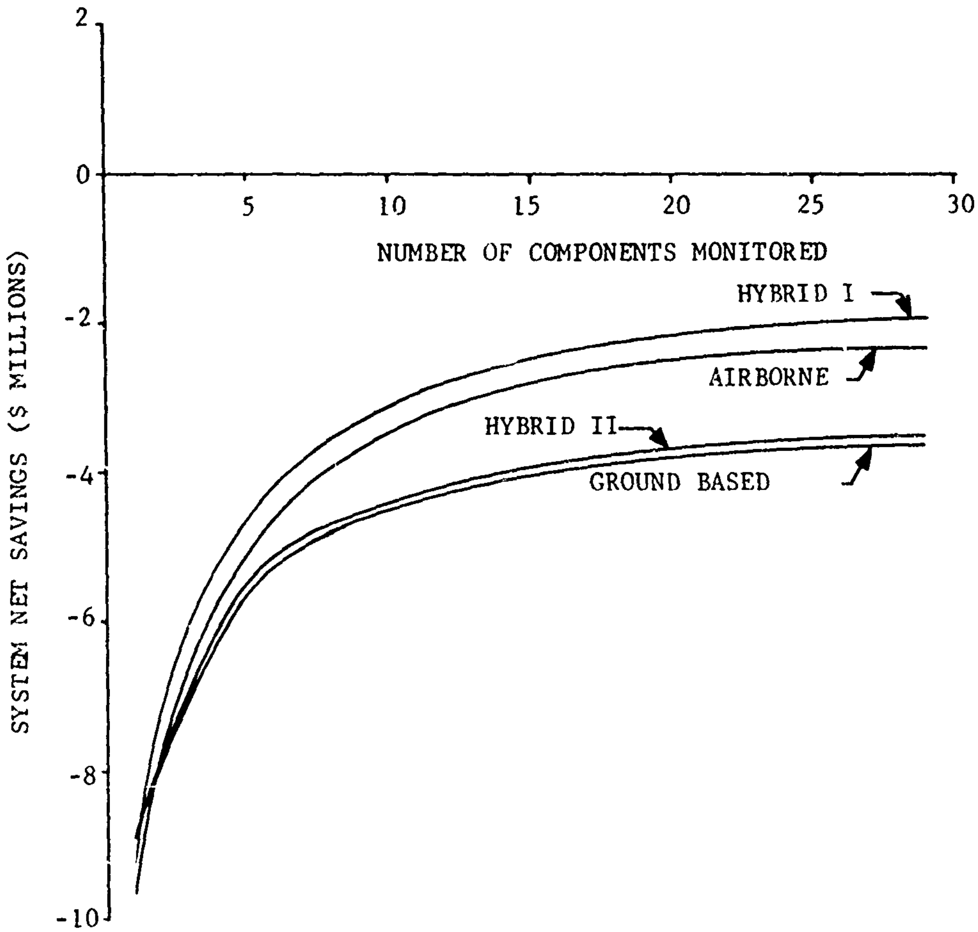


FIGURE 8-58 U-21 SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

8.1.2.9 HLH

Figures 8-59 through 8-64 show the results of the unique AIDAP system tradeoffs for the HLH aircraft. Since this will be the most sophisticated aircraft in the Army inventory, the potential savings due to AIDAPS are large. However, the cost of a Unique AIDAP System for this aircraft is also large primarily due to DDT&E cost.

The logistics cost savings shown on Figure 8-60 are exceptionally large considering the probable small number of aircraft to be procured. This is primarily due to the high cost of the components of aircraft produced in these small quantities. High cost parts create excessive costs for filling the logistics pipeline as well as for overhaul.

The net savings due to reduction in accidents shown in Figure 8-61 are also large. This is due to the high cost of this aircraft, estimated at $9 million. The resulting net savings, Figure 8-63, are significant for all AIDAP System candidates. The Airborne System shows a slight advantage over the Hybrid I due to the shorter processing time. The difference, however, is not sufficient to justify a selection on a cost effectiveness basis. Variations in development or procurement costs may reverse the relationship.

The large potential savings result in a very short break-even period (see Figure 8-64). The savings and benefits exceed the cost of development and procurement before the end of the procurement period. This is partially due to the long procurement program.

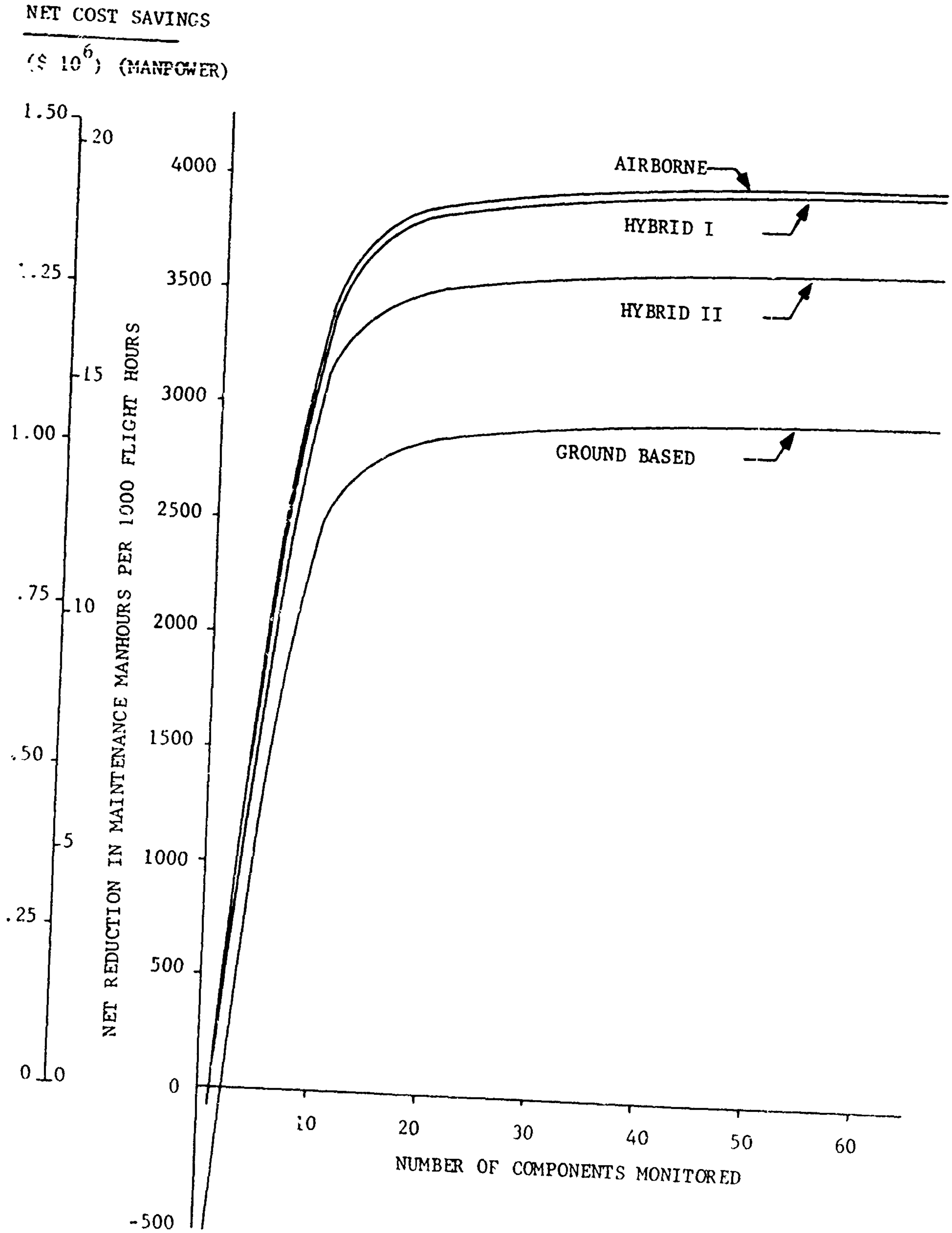


FIGURE 8-59 HLH PERSONNEL SAVINGS VS COMPONENTS MONITORED

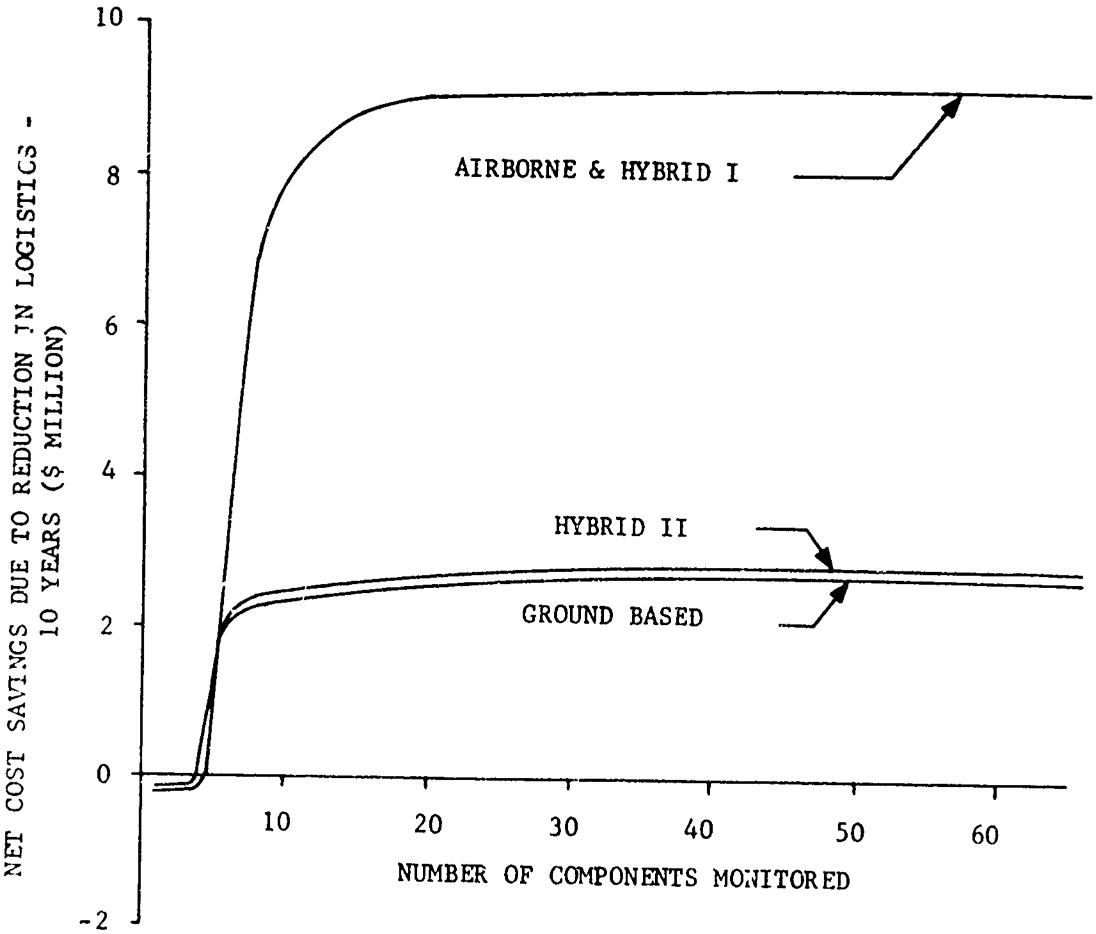


FIGURE 8-60 HLH LOGISTICS SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

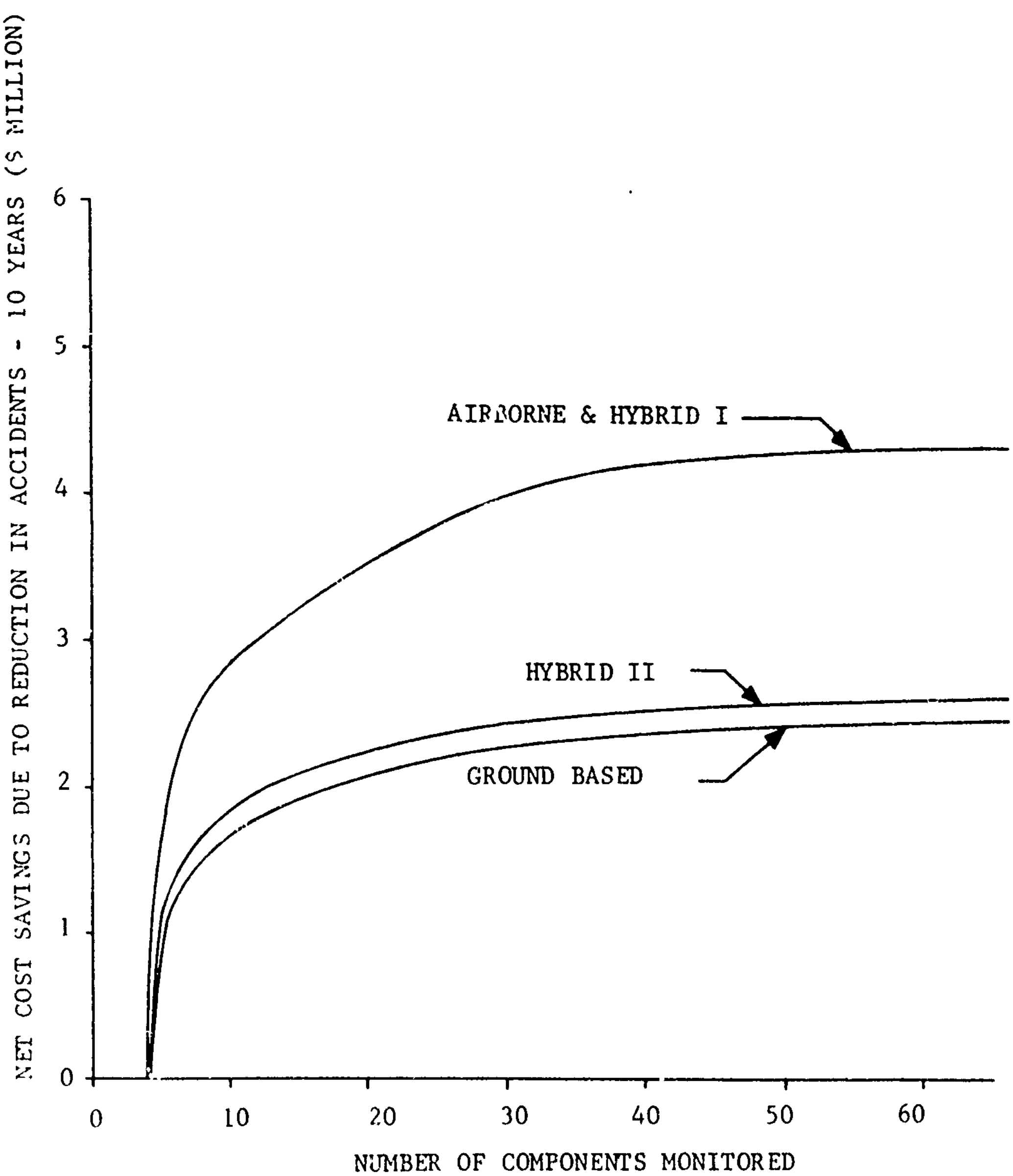


FIGURE 8-61 ULH ACCIDENT SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

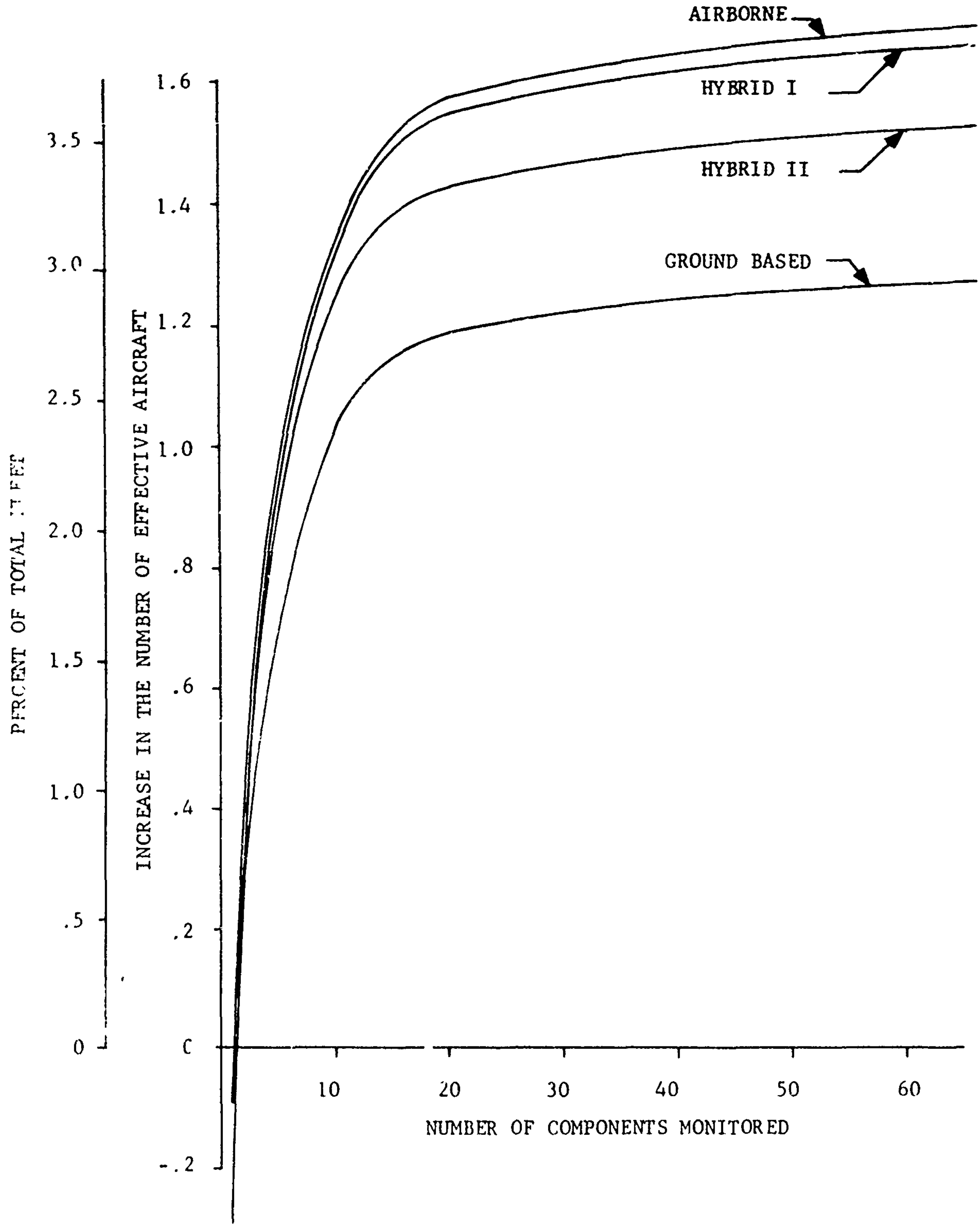


FIGURE 8-62 HLH INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

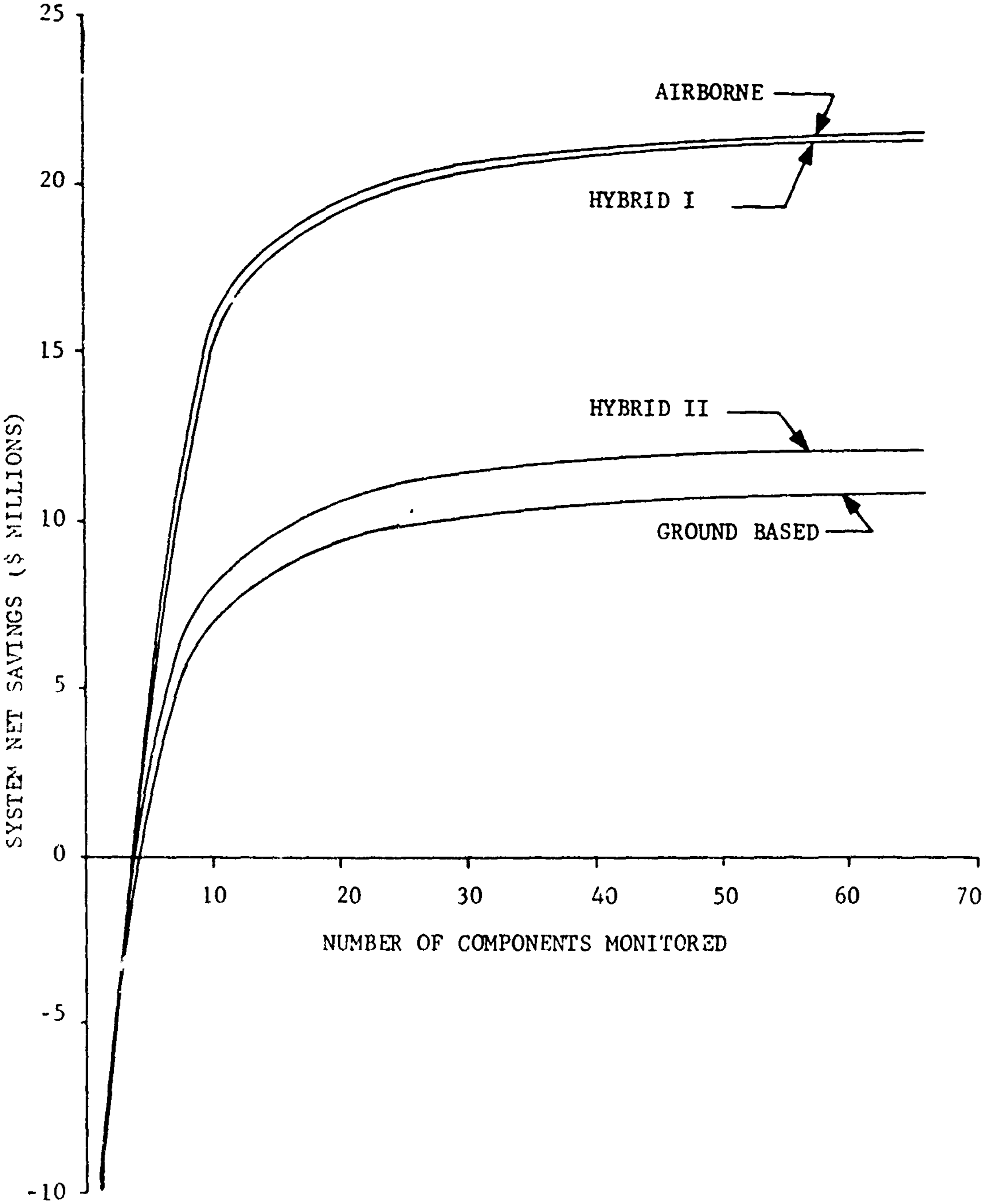


FIGURE 8-63 HLH SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

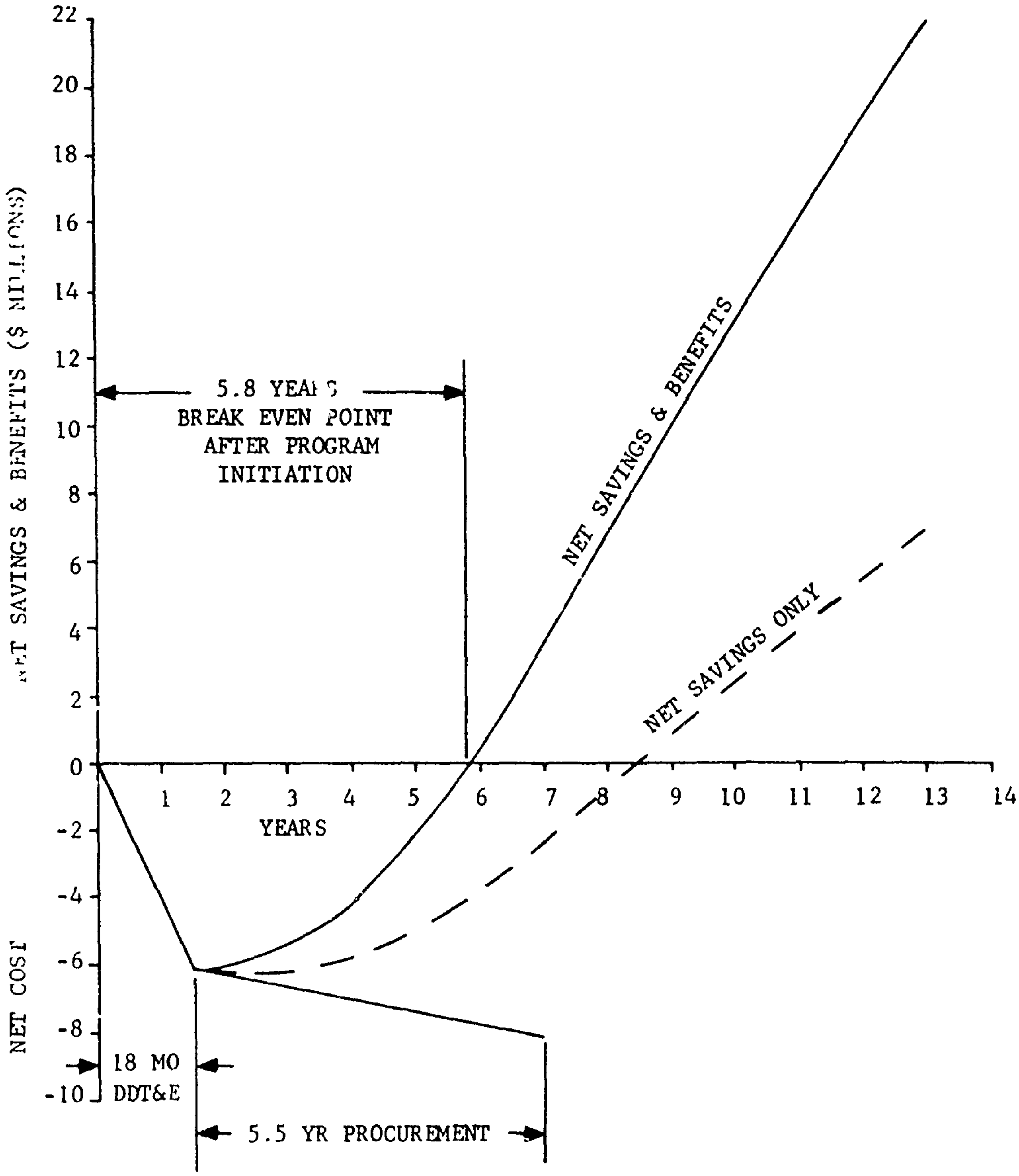


FIGURE 8-64 HLH AIRBORNE UNIQUE AIDAP SYSTEM - TIME PHASED PROGRAM COST SAVINGS & BENEFITS

8.1.2.10 UTTAS

Figures 8-65 through 8-70 present the unique AIDAP system tradeoffs for the UTTAS aircraft. All AIDAP systems are unusually effective on this aircraft. Although this aircraft is programmed as a replacement for the UH-1, it is a much more sophisticated aircraft in terms of number of engines, complexity of transmissions, and flight controls. This, coupled with the high programmed inventory and resulting low AIDAPS development and procurement costs, provides a unique opportunity for the application of the AIDAPS/Aircraft technology. In addition, the high estimated costs of the aircraft and its components permit unusual savings due to accident prevention and logistics cost, as well as increased value from the increase in aircraft effectiveness. Figure 8-70 shows that as a result of these high expected savings, the break-even point occurs shortly after the production program is initiated even though only actual dollar savings are considered.

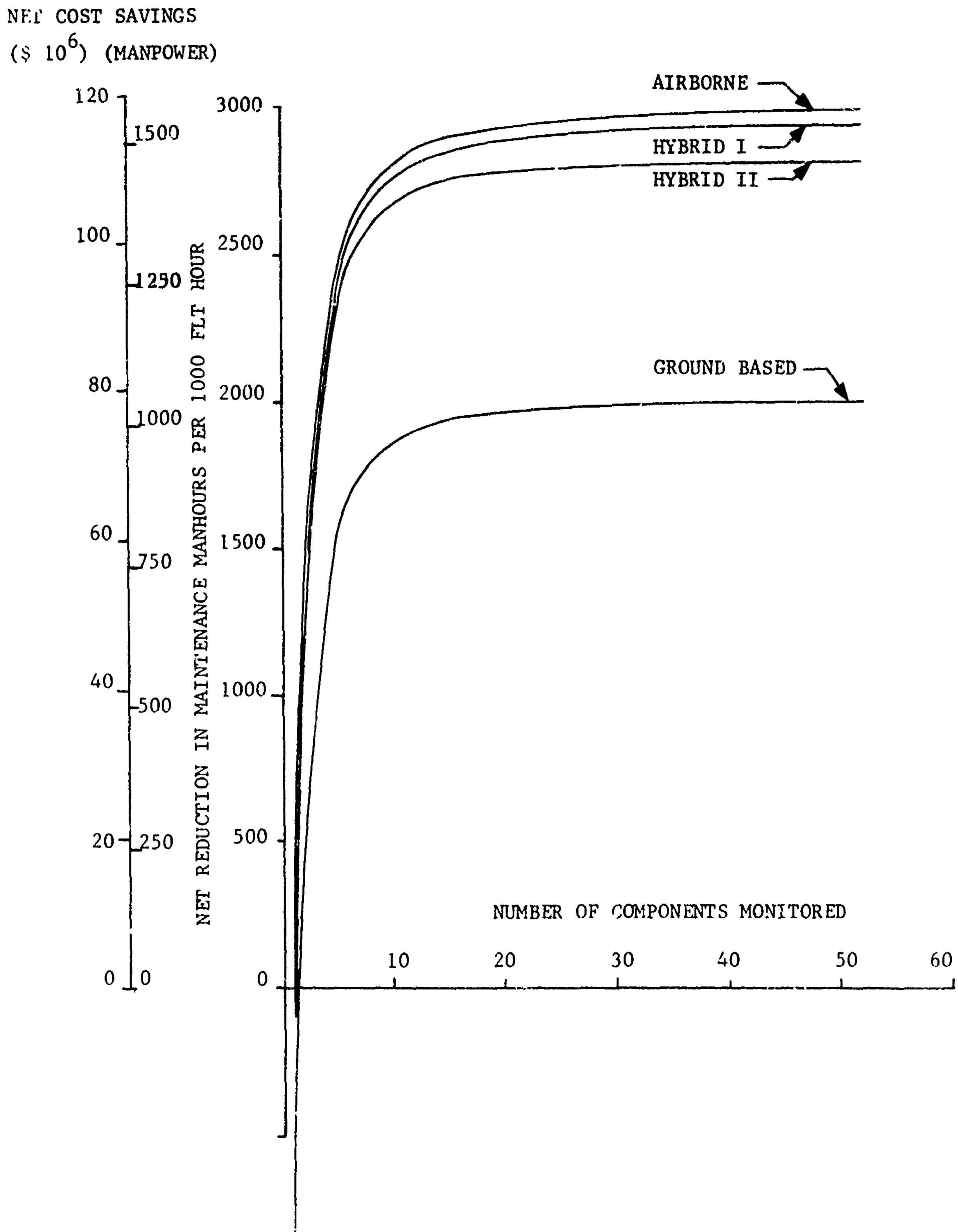


FIGURE 8-65 UTTAS PERSONNEL SAVINGS VS COMPONENTS MONITORED
(STANDARD CONDITION)

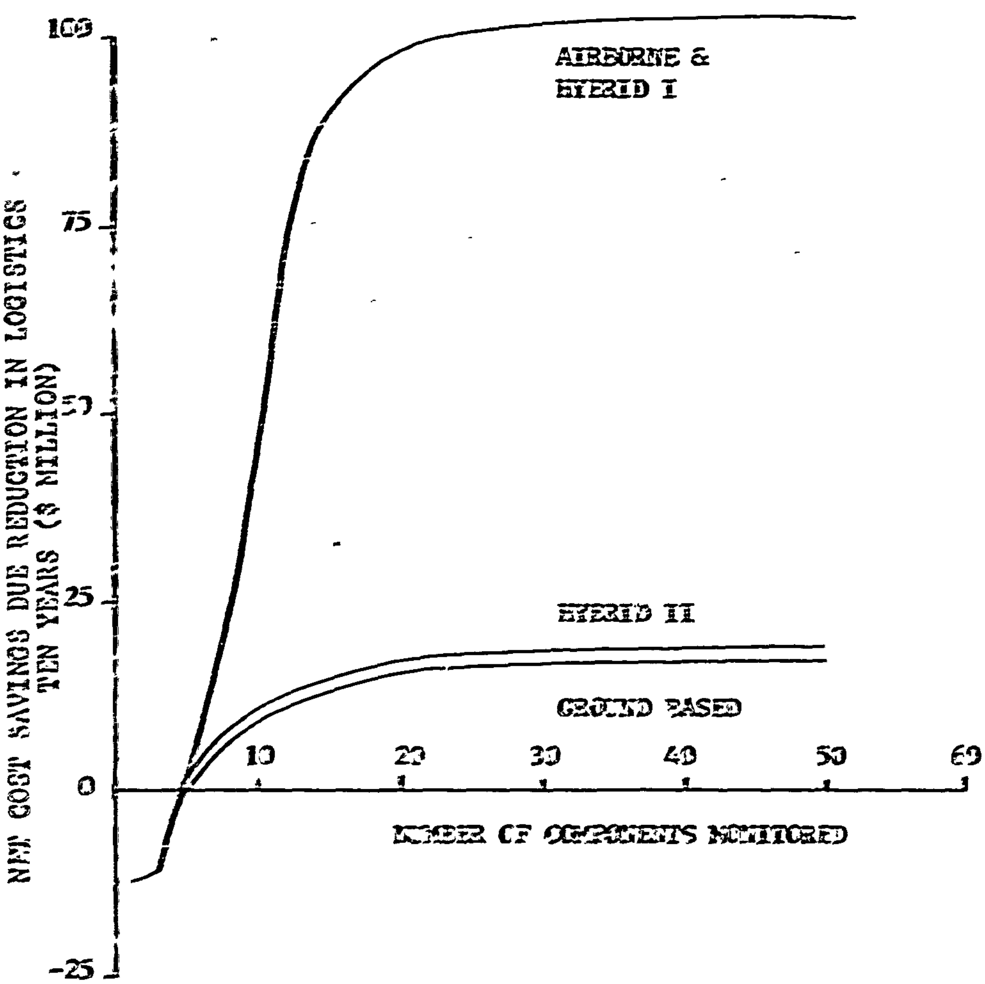


FIGURE 8-66 ITAS LOGISTICS SAVINGS VS COMPONENTS MONITORED
(PLANNED CONDITIONS)

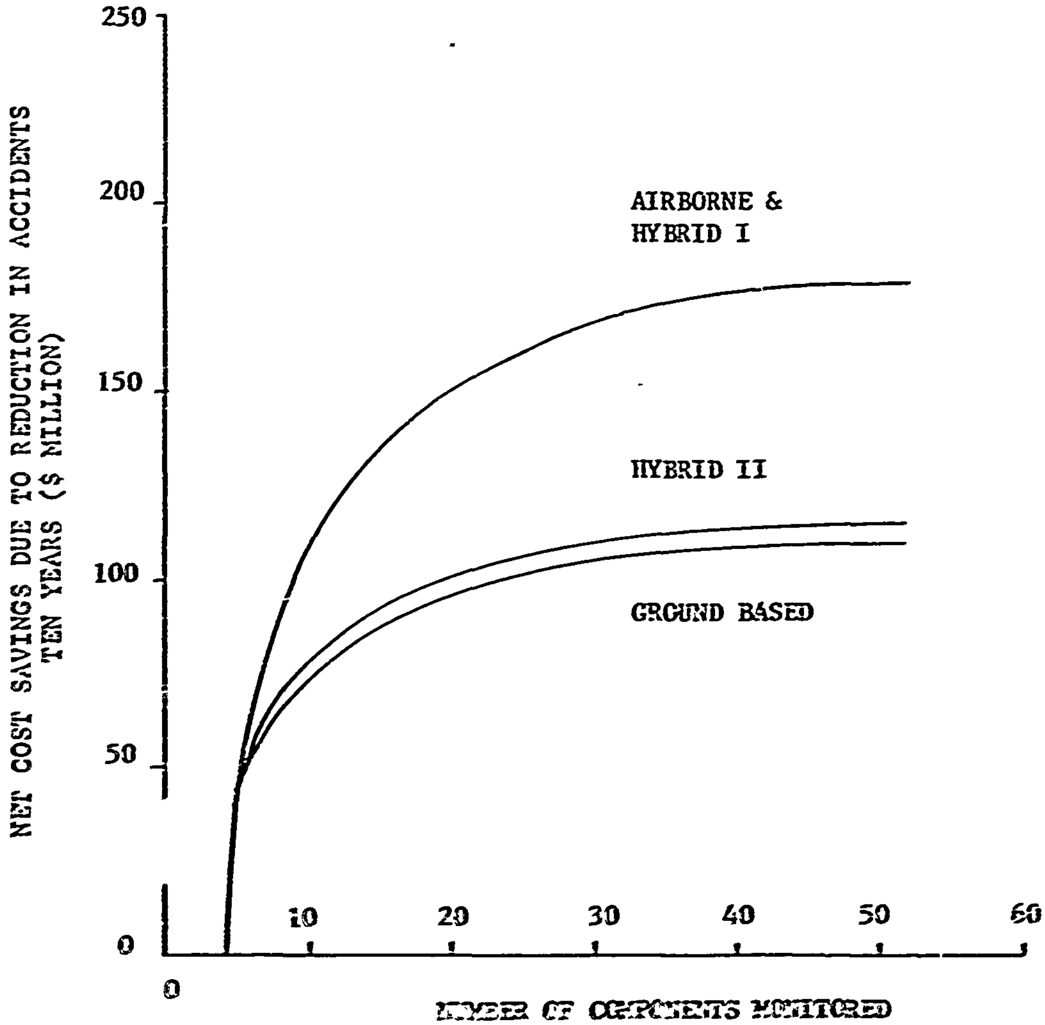


FIGURE 8-67 [illegible]AS ACCIDENT SAVINGS VS COMPONENTS MONITORED

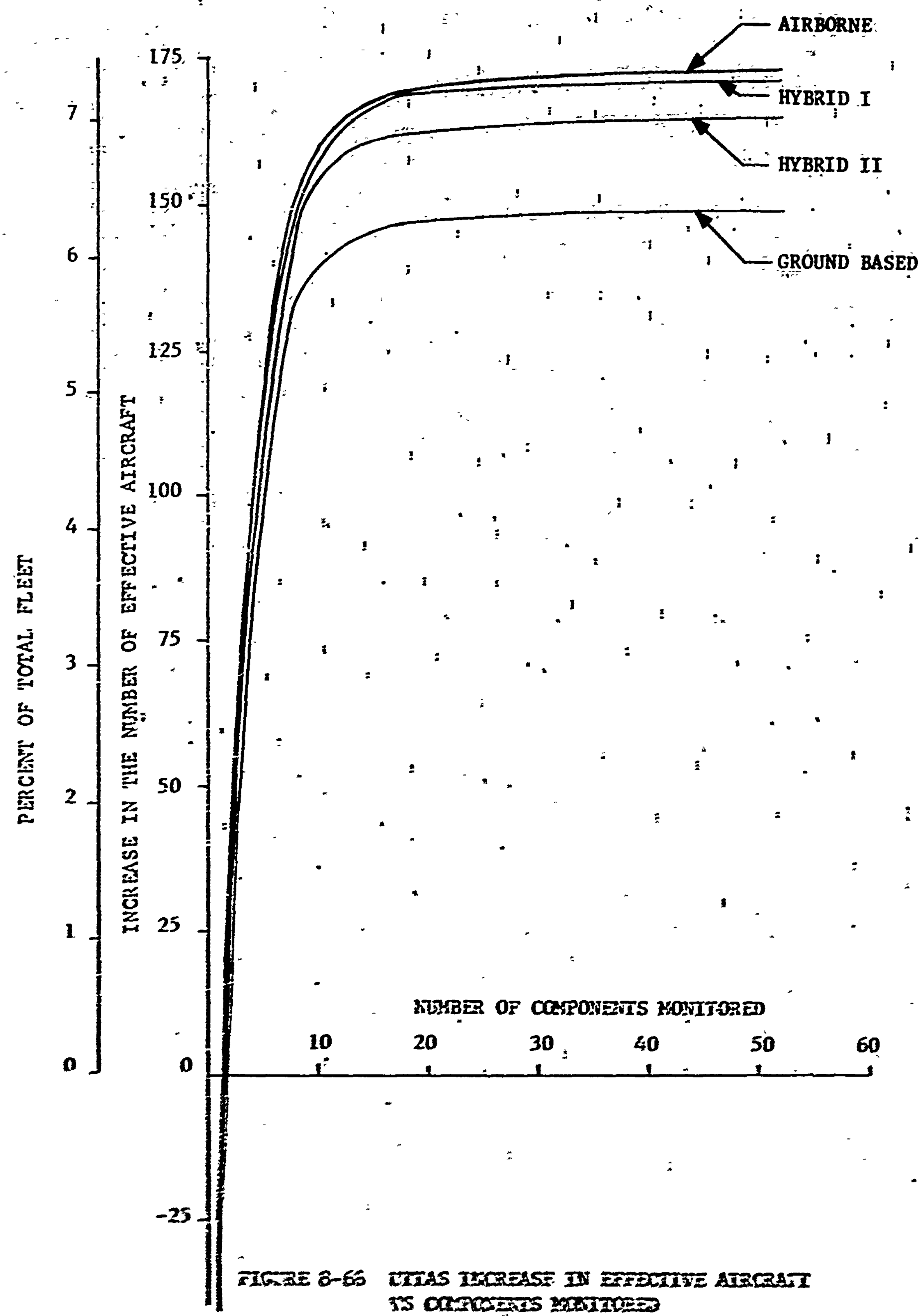


FIGURE 8-66 UTTAS INCREASE IN EFFECTIVE AIRCRAFT VS COMPONENTS MONITORED (STANDARD CONDITIONS)

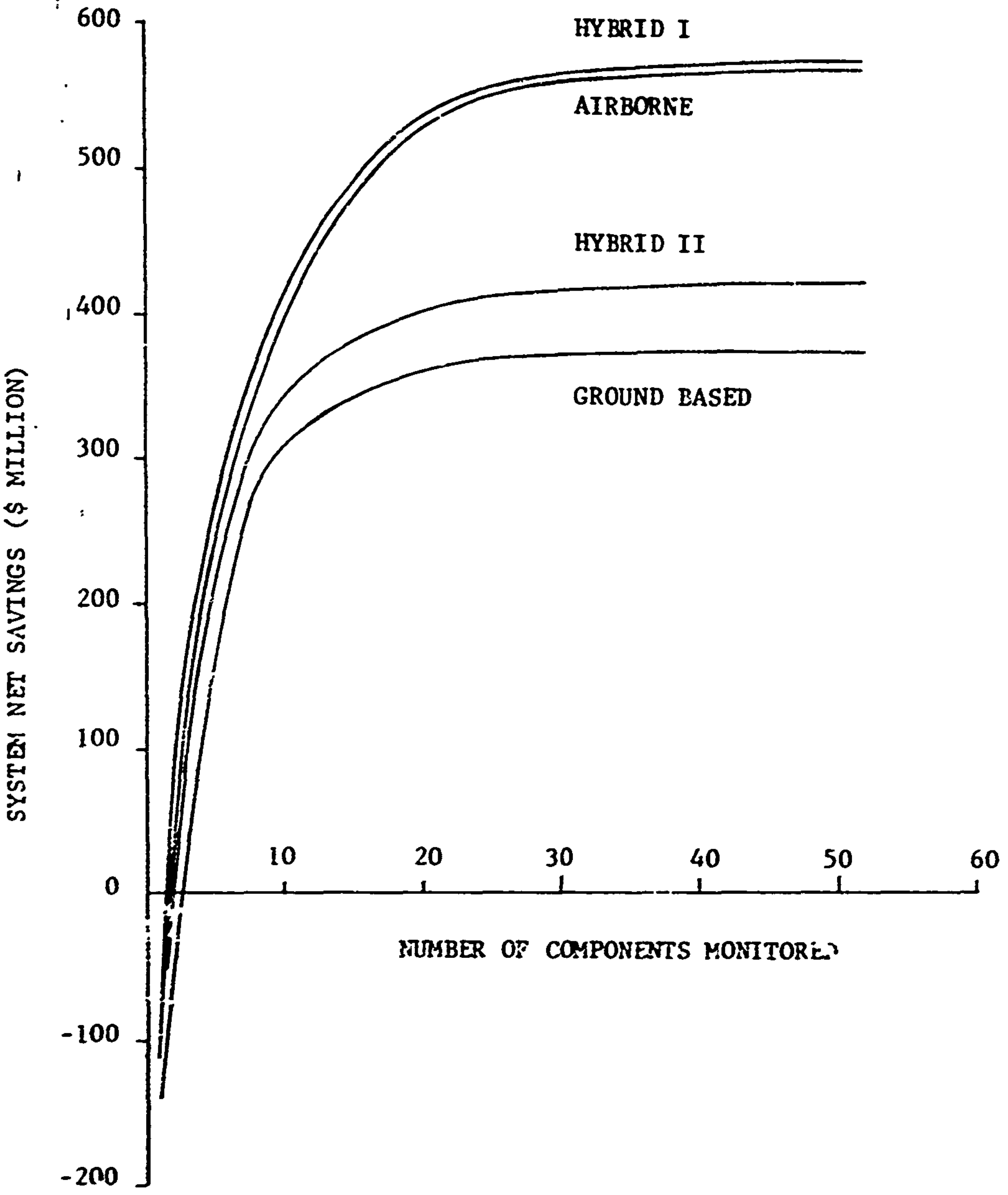


FIGURE 8-69 UTTAS SYSTEM NET SAVINGS VS COMPONENTS MONITORED (STANDARD CONDITIONS)

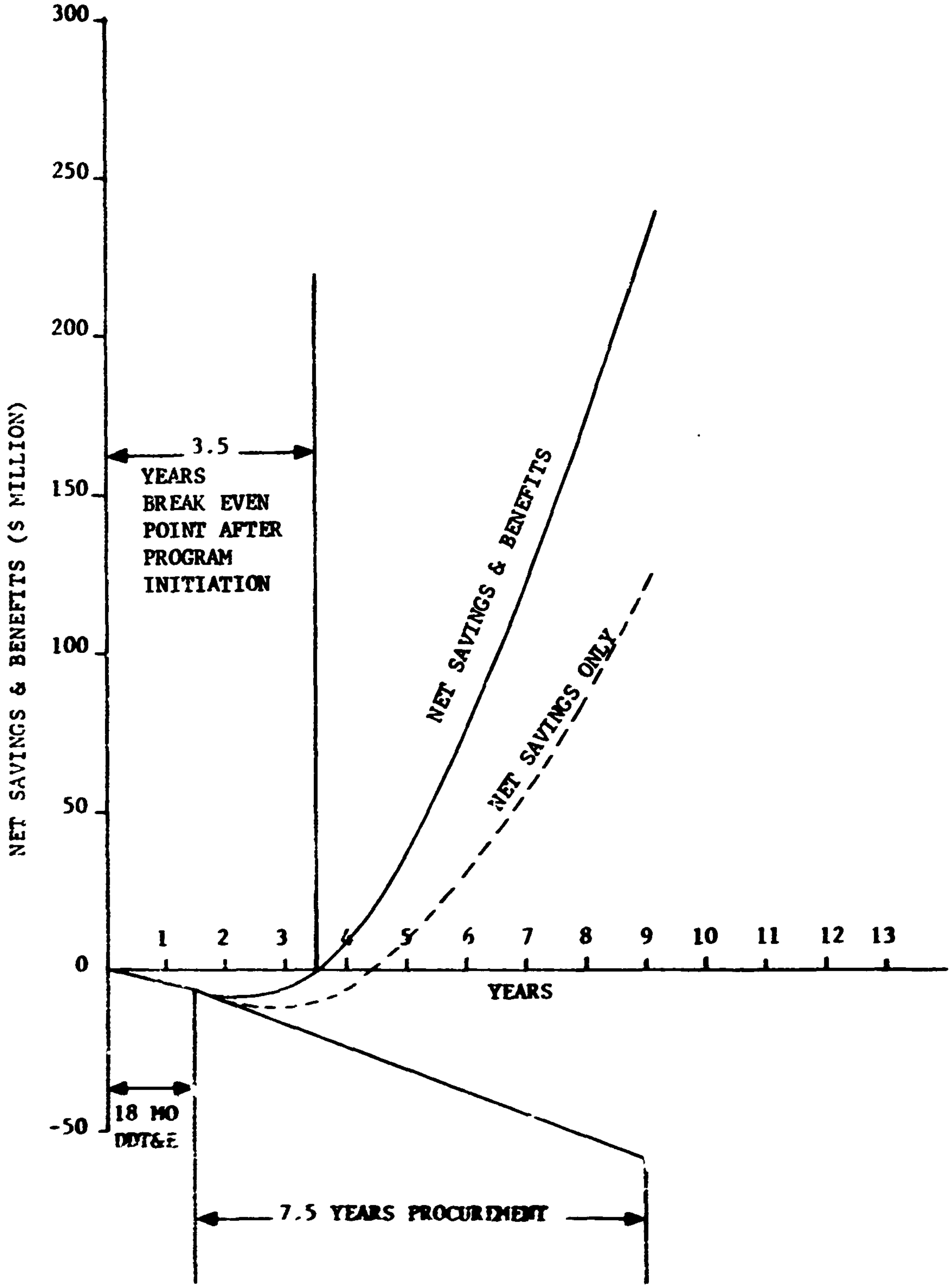


FIGURE 8-70 UTTAS HYBRID I UNIQUE AIDAP SYSTEM -
TIME PHASED PROGRAM COSTS SAVINGS & BENEFITS
(STANDARD CONDITIONS)

8.1.3 AIDAPS DESIGN FEATURE TRADEOFFS

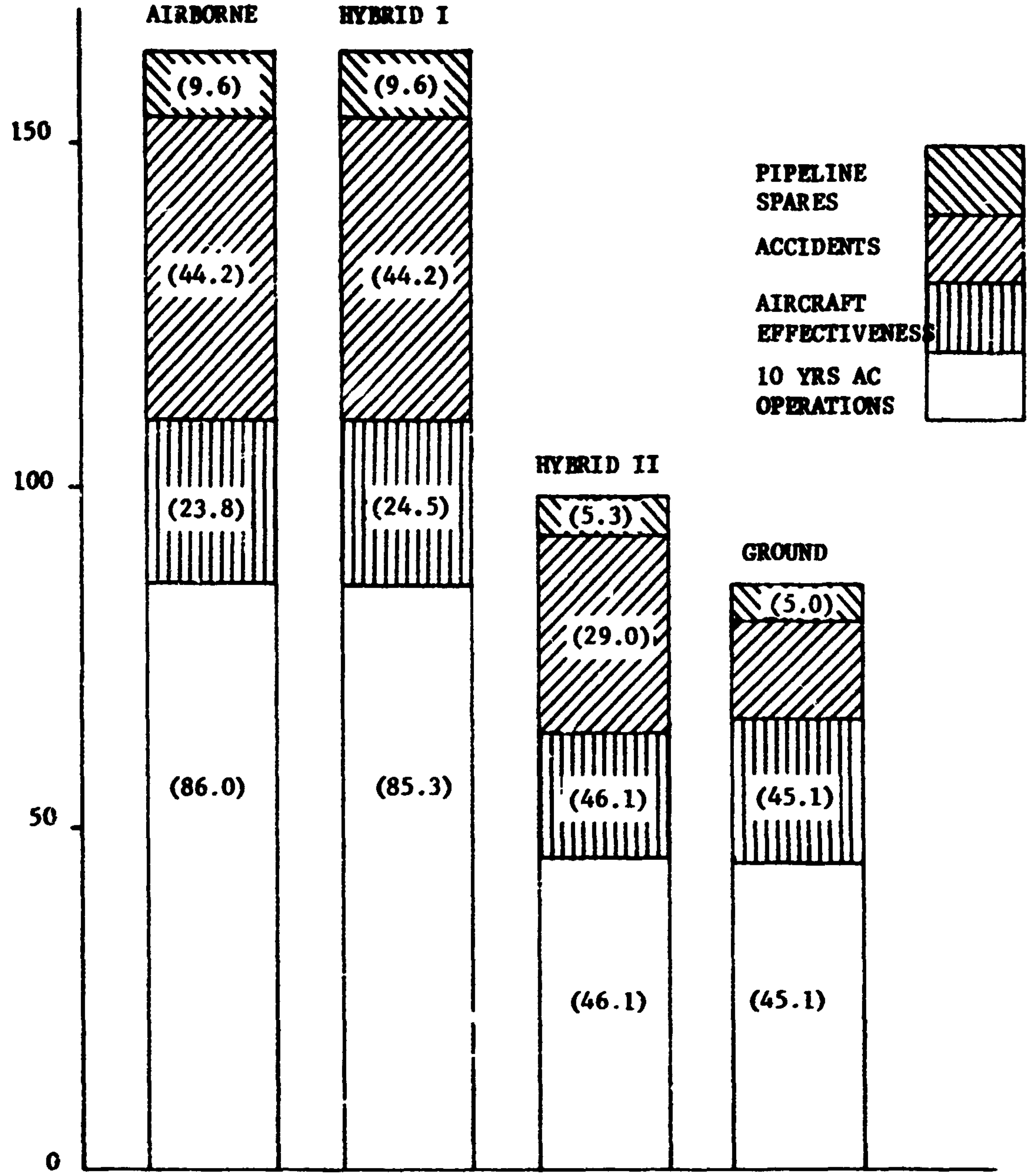
Although the AIDAPS configuration tradeoffs revealed a significant preference for the Airborne and Hybrid I systems, this preference was based on certain performance and design characteristics which have not been completely achieved in present day equipment. Therefore, it is necessary to analyze the sensitivity of the results to these characteristics. The performance and design characteristics include a detailed examination of the capabilities of a ground vs. airborne system, integration with voice warning, effects of aircraft complexity and the individual effect of inspection, diagnosis and prognosis.

8.1.3.1 Ground System Vs. Airborne

In order to gain a more precise insight into the reasons for the low effectiveness of the Ground System, a more detailed analysis of the relationships between the equipment performance characteristics and the system cost effectiveness is necessary. The Ground System has the advantages of light airborne weight and low cost. The Airborne and Hybrid I systems have the advantage of higher test accuracies due to a longer monitoring period, less time required to retrieve data, and the capability of providing signals to the visual, audio or aural airborne warning system.

Figure 8-71 compares the effectiveness as measured by the gross savings and the benefits in aircraft operations due to the four candidate unique AIDAP systems on the UH-1 aircraft. The savings and benefits derived from the Ground System are barely more than one-half the savings and benefits derived from the Hybrid I and Airborne systems. Most of this difference is due to decrease in the savings of operating expense and aircraft accidents. The Ground System has a slightly greater impact on aircraft effectiveness than the Hybrid II system due to the lighter weight of its airborne portion (instruments and wiring).

As an aid to this study, an Idealized Ground System was generated which had all the attributes of the Airborne System, except data retrieval time and airborne warning. Table 8-3 shows a comparison of the performance characteristics of the three systems.



	AIRBORNE	HYBRID I	HYBRID II	GROUND
GROSS SYSTEM SAVINGS: ($M)	163.6	163.6	98.5	85.6
AIDAPS LIFE CYCLE COST: ($M)	93.7	79.5	75.0	72.0
NET SAVINGS & BENEFITS: ($M)	69.9	84.1	23.5	13.6

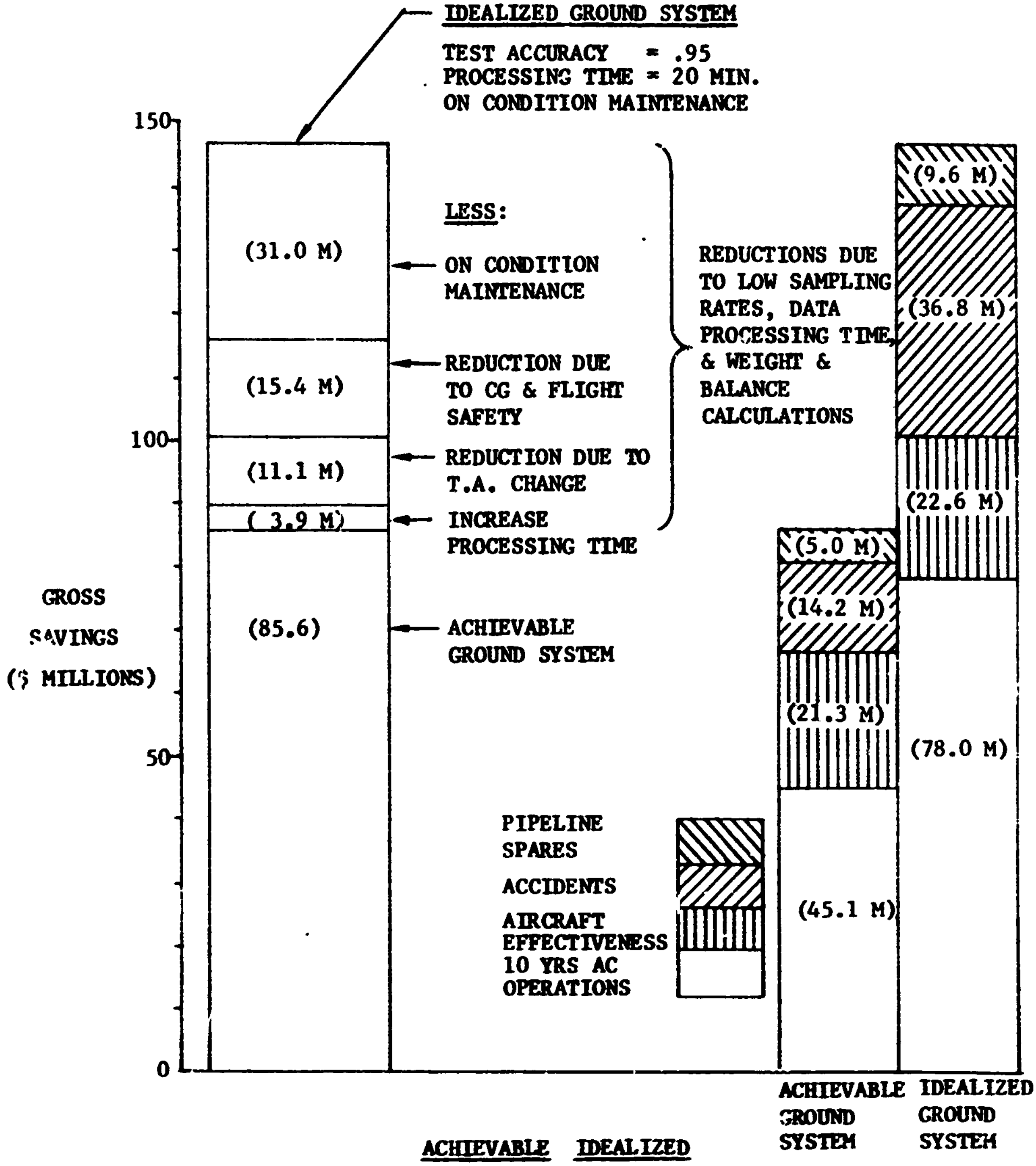
FIGURE 8-71 COMPARISON OF SAVINGS & BENEFITS OF CANDIDATE AIDAP SYSTEMS (UH-1 30 HRS/MO)

TABLE 8-3 COMPARISON OF AIDAPS PERFORMANCE CHARACTERISTICS

Performance Characteristics	Airborne System	Idealized Ground System	Achievable Ground System
Test Accuracy	.95	.95	.65 - .75
Data Processing Time	3 Min.	20 Min.	30 Min.
Airborne Weight (UH-1)	33.8 lbs	17.6	17.6
Air Warning Capability	Yes	No	No
On Condition Maint. Capability	Yes	Yes	No
C.G. and Weight and Balance	Yes	Yes	No

If such a system were possible, Figure 8-72 shows that the gross savings and benefits would be approximately $140 million. This is less than that achieved by the Airborne and Hybrid I systems because of the longer times required for the AIDAPS inspection of the aircraft and for troubleshooting, and due to the lack of air warning. In spite of the lower life cycle cost for the Ground System, the net savings are $75 million vs. $84 million for the Hybrid I and almost $70 million for the Airborne System.

The remaining question to be resolved is the extent to which this Idealized Ground System may be achieved. As Figure 8-72 indicates, the major factors degrading an achievable ground system from the idealized system are on condition maintenance, accident savings due to C.G. and flight safety calculations, the effects of a lower test accuracy, and the increase in time required to perform inspections and troubleshooting. The reasons that on condition maintenance are not achievable with a Ground System are discussed fully in Section 7.0. Central to the argument is the realization that substantially all of the components presently removed on a time basis are safety of flight items. If a change is made to on condition maintenance, the failures which now are prevented by the time removals may then occur in the air. To prevent these air failures, an extremely accurate prognosis capability must be supplied. The state of the art of long term prognosis is not well developed and the Ground System must rely on this long term prognosis to a large extent. This means that the technical risk involved in creating such a Ground System is extremely high.



	ACHIEVABLE	IDEALIZED
GROUND SYSTEM SAVINGS	85.6 M	147.0 M
GROUND SYSTEM LIFE CYCLE COST	72.0 M	72.0 M
NET SAVINGS & BENEFITS	13.6 M	75.0 M

FIGURE 8-72 COMPARISON OF BENEFITS OF AN ACHIEVABLE GROUND SYSTEM WITH AN IDEALIZED SYSTEM (UH-1 AIRCRAFT 30 HRS/MO)

Diagnosis capabilities, however, are well developed as has been demonstrated by the UH-1 Test Bed Program and others. The Airborne and Hybrid I systems back up their long term prognosis capability with short term (airborne prognosis), diagnosis and airborne warning.

The weight and balance capability cannot be achieved by the ground systems with an acceptable operational mode. To be accomplished at all, the aircraft would have to be loaded and prior to each flight the Ground System would have to be connected. Then, if a safe lift-off is indicated, the AIDAPS equipment and personnel would have to be removed before the aircraft could depart. Such procedures are not reasonable during high activity peacetime operations nor in combat. It is precisely at these times that the weight and balance capability is most important.

In the Airborne or Hybrid I systems, no special procedures need be followed. The pilot simply initiates a normal takeoff. If at any time after engine start the C.G. and flight safety calculations show an unsafe condition, the pilot receives a warning.

The next largest increment is due to the reduction in test accuracy from .95 to .75. As discussed in Section 7.0, a .75 test accuracy is somewhat optimistic for a Ground system applied to a helicopter, since it samples only three percent of data sampled by the Airborne and Hybrid I systems. Even more important is the fact that the ground test environment is a low stress environment. and experience on previous flight test programs shows that many prognostic indications are detectable only during high stress flight conditions.

Although a 20-minute aircraft inspection time is possible with a Ground System, the exigencies of operational use generally extend such time estimates. Flying doctrine frequently requires simultaneous missions of many aircraft. Scheduling these aircraft to a special AIDAP test is operationally difficult and not desirable. Hence the Ground AIDAPS will frequently not be available at the time needed or at the place needed. Since pilots may be required for an adequate power run up, the added problem exists of concurrent arrival of pilots, maintenance personnel, the aircraft and the AIDAPS. Therefore, it is believed that the achievement of a 30-minute average inspection time by a Ground AIDAPS is optimistic and 20 minutes is almost impossible to achieve operationally. For the other systems, these tests occur automatically during flight with no requirement for the attention of the pilot or ground crew.

When the above considerations are subtracted from the Idealized Ground Systems, a gross savings of $85.6 million for an achievable system seems reasonable. When the costs of the AIDAPS are subtracted from this, a net of $13.6 million remains.

8.1.3.2 AIDAPS/VWU System Integration

The potential degrees of integration of the Voice Warning Unit (VWU), including signal conditioning, into AIDAPS are defined in the following manner.

a. Total Isolation (Figure 8-73)
   The VWU has no impact on AIDAPS. There is no sharing of signal conditioning. The VWU is totally isolated from AIDAPS. For example, separate wires from the engine RPM sensor to the AIDAPS unit and to the VWU signal conditioner. The VWU is a standard system as used in other applications, although the signal conditioning is determined by specific aircraft requirements and sensors.

b. Partly Shared Signal Conditioning (Figure 8-74)
   A minimum number of complicated signals are conditioned in AIDAPS for the VWU. Signals such as synchros or RPM tach generators are efficiently conditioned by AIDAPS. Other signals requiring only simple filtering or level detection are fed directly to a VWU conditioner of minimum complexity. Solid switched ground sensors go directly to the standard VWU.

c. Integrated Signal Conditioning Parallel Interface (Figure 8-75)
   All signals requiring conditioning are conditioned in AIDAPS. The AIDAPS to VWU interface is parallel. Sensors providing switched grounds may go direct to VWU without conditioning. The VWU is a totally separate standard unit. Solid ground switch sensors go directly to the VWU if no conditioning is required.

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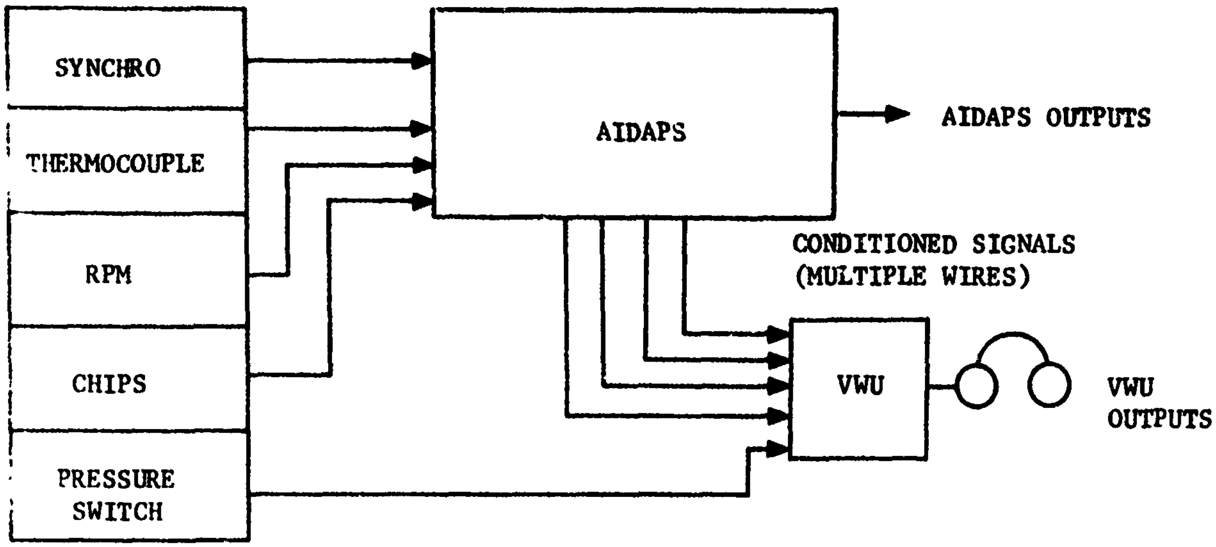


FIGURE 8-75 INTEGRATED AIDAPS/VWU SIGNAL CONDITIONING PARALLEL INTERFACE (CONFIGURATION C)

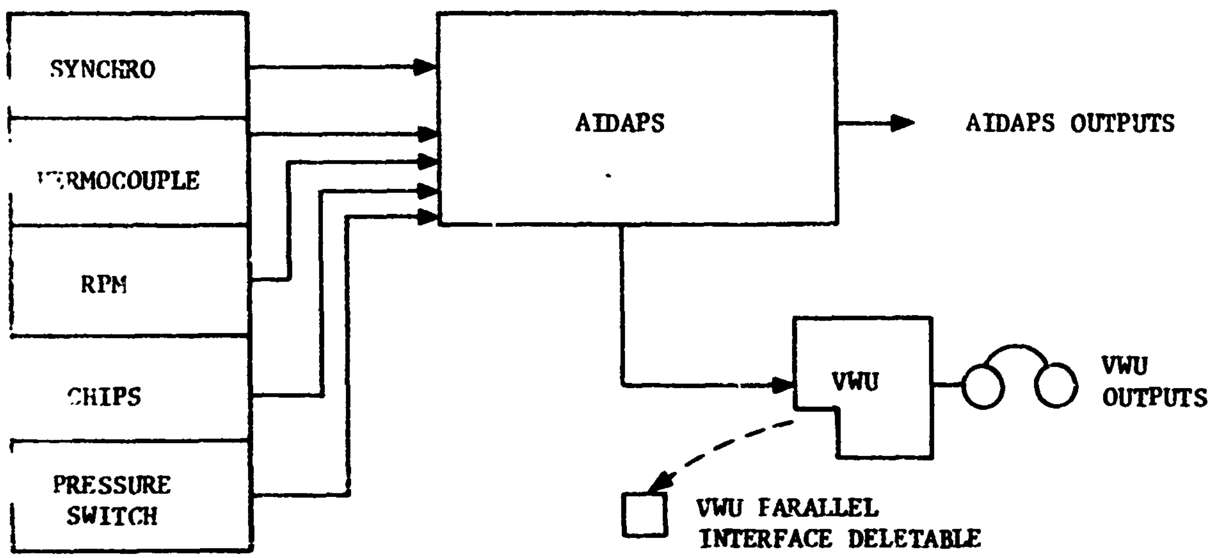


FIGURE 8-76 INTEGRATED AIDAPS/VWU SIGNAL CONDITIONING SERIAL INTERFACE (CONFIGURATION D)

d. Integrated Signal Conditioning Serial Interface (Figure 8-76)

All signals are conditioned in AIDAPS and sent to VWU on a serial (multiplexed) data line. The VWU is a standard unit. However, since the parallel VWU interface is not required, the VWU parallel interface module can be deleted. This reduces system cost and complexity.

e. Total Integration Using Standard VWU Modules (Figure 8-77)

A standard VWU board is packaged inside the AIDAPS with serial interface to AIDAPS signal conditioning. This approach effectively combines VWU and AIDAPS carrier (mother) board interconnect. It permits control of power supply connections so that the required VWU/AIDAPS interface is slightly simplified. The use of standard modules does not permit redesign of VWU boards for optimum mechanical or electrical installation in the AIDAPS.

f. Total Integration (Figure 8-78)

VWU logic is repackaged to optimize AIDAPS combined system. Proven VWU logic can be integrated into the AIDAPS design so that hardware and component complexity is minimized. Some savings in volume and component count are realized. Separation of VWU and AIDAPS usage and resp[illegible]lity is precluded.

The following rationale is valid for AIDAPS installations incorporating new VWU systems. It is not applicable to aircraft already incorporating separate VWU installations.

Only options A, B and C are available for the older MIL-R-81C00-type 20-channel Voice Warning Unit. The newer Northrop production 40-channel VWU incorporates serial and parallel interface capability making all six options (A through F) possible.

Review of historical VWU installation data reveals that more than 80% of the Voice Warning inputs are maintenance related items identical to AIDAPS identified items. Further, 15% use AIDAPS identified sensors and signal conditioning to generate warnings to prevent maintenance required situations from occurring. The remaining 5% are typically flight safety items such as "guns not cleared," or "landing angle of attack high," which are not AIDAPS identified items. However, these items are usually WSC=1 signals already available on the aircraft.

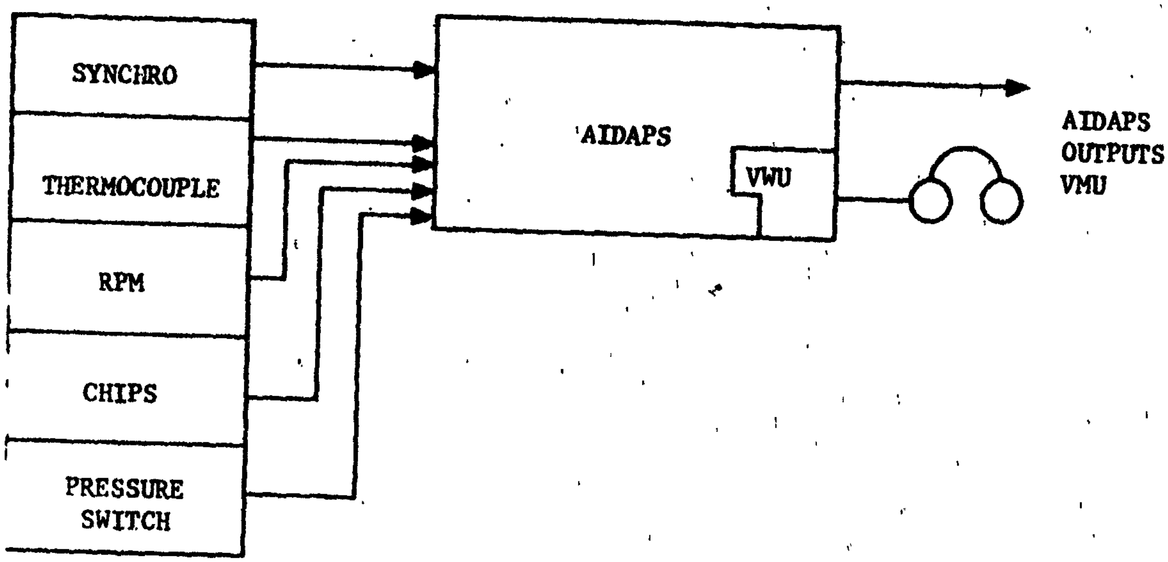


FIGURE 8-77 TOTAL INTEGRATION USING STANDARD VWU MODULES (CONFIGURATION E)

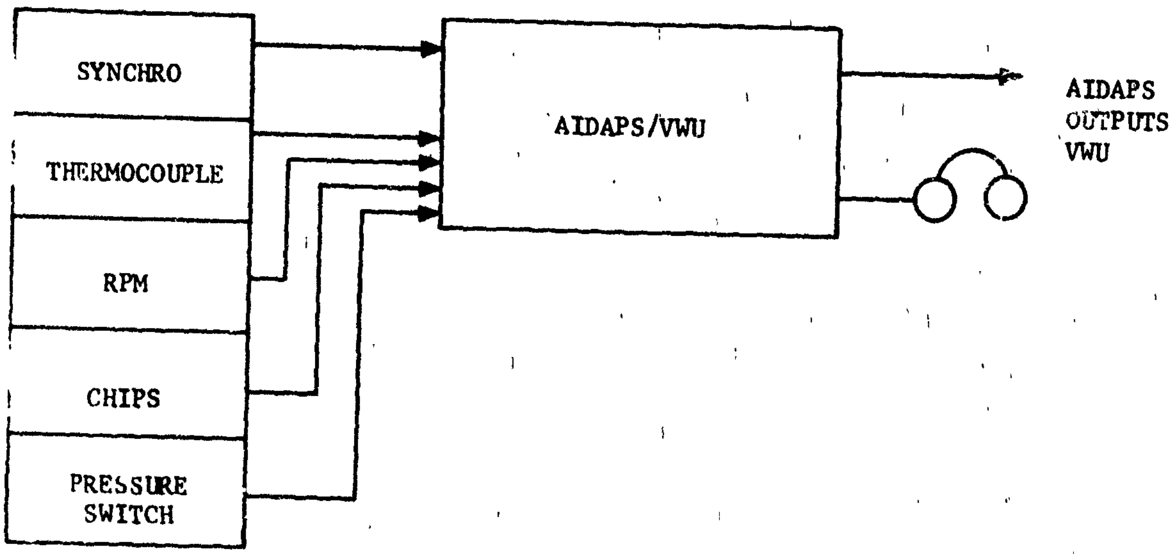


FIGURE 8-78 TOTAL INTEGRATION (CONFIGURATION F)

The implication here is that AIDAPS can directly provide 100% of the signal conditioning required for a VWU without major AIDAPS impact.

Typical VWU installations have had signal conditioners of complexity WSC = 75 to 150. These signal conditioners have necessarily been limited in complexity due to the need for choosing the most cost effective inputs for the Voice Warning System alone.

If the AIDAPS conditioning is available to VWU, a complexity factor in the range of WSC = 200 can be identified for the VWU without significant impact on AIDAPS cost. This additional capability permits improved Voice Warning performance. Flight safety is improved due to early warning of serious impending problems. AIDAPS maintenance impact is also improved due to better pilot reaction to impending or progressive problems.

Table 8-4 is a compilation of WSC factors which can be identified as differences between the various configurations. Table 8-5 shows the total WSC differences between the various configurations as a summation of Table 8-4 identified factors. Figure 8-79 is a graphical comparison of the total relative WSC factors and system costs arrived at in Table 8-5.

The 6 configurations were chosen as approximately equal steps apart in the range from complete VWU - AIDAPS isolation to complete integration.

It can be seen from Figure 8-79 that as each step from total separation toward total integration is taken, the relative WSC decreases. This represents lower hardware cost.

The rate of decrease is rapid as increasing proportions of signal conditioning are taken over by AIDAPS. However, as soon as all signal conditioning is assigned to AIDAPS (including multiplexing data onto a serial data line), the rate of decrease suddenly diminishes and becomes almost flat. The point of diminishing returns has been reached at configuration D, AIDAPS integrated signal conditioning, with serial interface to a standard separate VWU box with its parallel input board deleted. Therefore, new AIDAPS/VWU installations should have the signal conditioning integrated into AIDAPS at least to the point of a serial interface to VWU.

TABLE 8-4

RELATIVE COMPLEXITY AND COST*
OF
AIDAPS TO VWU INTERFACE

INTERFACE	EQUIVALENT WSC	COST
Serial interface inside AIDAPS to VWU	12	$ 240
Parallel interface inside AIDAPS to VWU	25	$ 400
Standard VWU parallel input interface deletable if serial interface is used	20	$ 400
AIDAPS signal conditioning added for VWU	10	$ 200
VWU components deleted when standard VWU components housed inside AIDAPS	8	$ 96
VWU components deleted when VWU repackaged for optimum AIDAPS/VWU	5	$ 100

*Each WSC = 1 is assumed to cost $20.
Therefore, adding circuitry of WSC = 10 complexity adds $200 to the system cost.

TABLE 8-5 AIDAPS/VWU RELATIVE COST OF CANDIDATE CONFIGURATIONS

IMPACT	CONFIGURATION A	B	C	D	E	F
VWU Signal Conditioner	150	50	0	0	0	0
VWU Interface	0	0	0	-20	-20 - 8	-20 - 8 - 5
AIDAPS Interface	0	15	25	12	12	12
AIDAPS Signal Conditioning	0	0	10	10	10	10
Relative WSC	150	65	35	+2	-6	-11

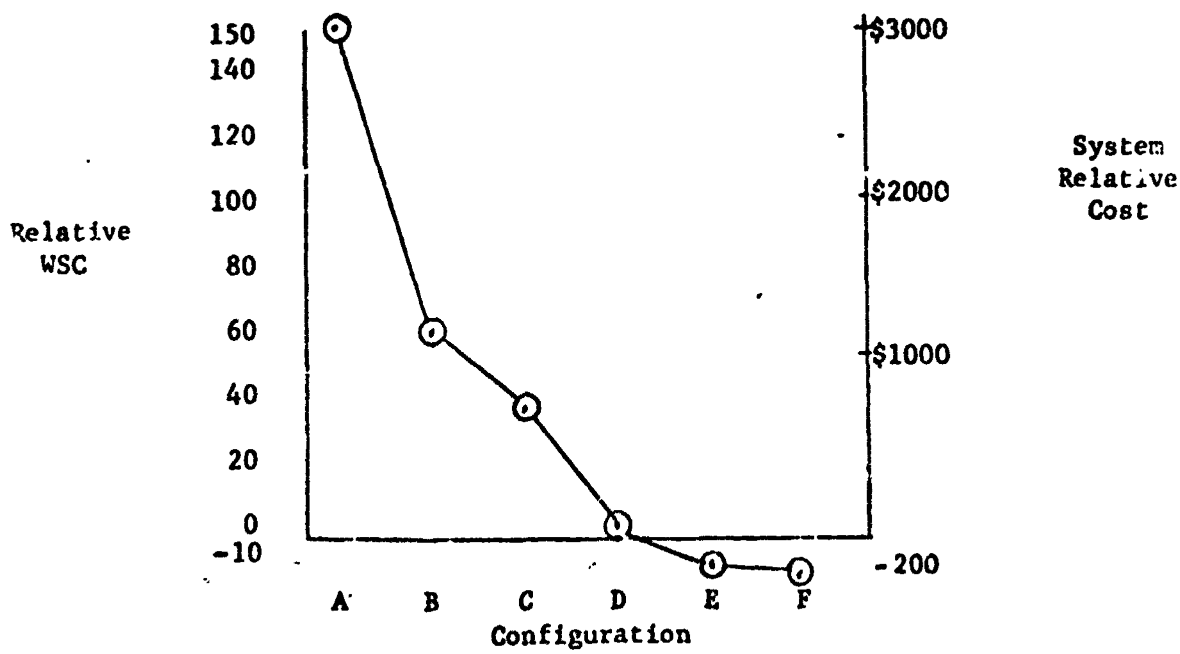


FIGURE 8-79 AIDAPS/VWU CANDIDATE CONFIGURATION TRADEOFF

It was stated earlier that this rationale was not applicable to installations where existing VWU and signal conditioners already exist. However, configuration C is compatible with the MIL-R-81000 VWU if a WSC of 5 is added to the AIDAPS interface. Since improved AIDAPS and VWU performance is expected if the VWU and AIDAPS are combined so they can complement each other, it may be cost effective to use AIDAPS configuration C with existing MIL-R-81000 VWU hardware. Total aircraft system complexity is reduced by abandoning existing VWU specific signal conditioning in favor of the more comprehensive AIDAPS available signals.

Integration of the complete VWU into AIDAPS beyond configuration D yields small return even when only hardware cost is evaluated. Additional reasons for not choosing configuration E or F are as follows:

a. Use of standard VWU modules permits economics of scale to be realized through VWU applications other than AIDAPS.

b. Divorce of the AIDAPS and VWU modules improves maintainability of the AIDAP System proper.

c. Use of standard VWU units permits procurement of the AIDAPS and the VWU from different sources. This will permit more competitive bidding although it also would produce a higher probability of technical interface problems.

d. Separation of AIDAPS and VWU permits consideration of VWU/AIDAPS system integration for improved performance and lower total complexity even where VWU installations already exist.

Conclusions

a. The optimum choice of the interface between AIDAPS and voice warning units for aircraft which do not presently utilize voice warning is configuration D-Integrated AIDAPS/VWU signal conditioning with serial interface.

b. The optimum choice of interface between AIDAPS and voice warning units for aircraft presently equipped with voice warning is Configuration C - Integrated AIDAPS/VWU Signal Conditioning with a parallel interface.

8.1.3.3 Aircraft Complexity Vs Components Monitored and Effectiveness

Figures 8-80 and 8-81 show the AIDAPS effectiveness as a function of aircraft complexity. The measure of effectiveness is gross savings per aircraft. In Figure 8-81 the measure of complexity is the number and complexity of the parameters monitored by the AIDAPS system as expressed by the weighted sensor count (WSC). The measure of aircraft complexity used in Figure 8-80 is aircraft empty weight. In both cases the effectiveness of the AIDAPS increases with aircraft complexity. In Figure 8-81 the increase in gross savings with complexity is nearly linear (top of graphs). The increase in AIDAP system cost also increases with aircraft complexity, but the effect is somewhat masked by the effects of the number of aircraft procured. The OH-58, UH-1, AH-1, and CH-47 exist in larger numbers and exhibit low procurement cost which steadily increases with aircraft complexity. The U-21, OV-1, and CH-54 exist in small numbers and have relatively high procurement costs. For this reason the net savings do not increase regularly with aircraft complexity.

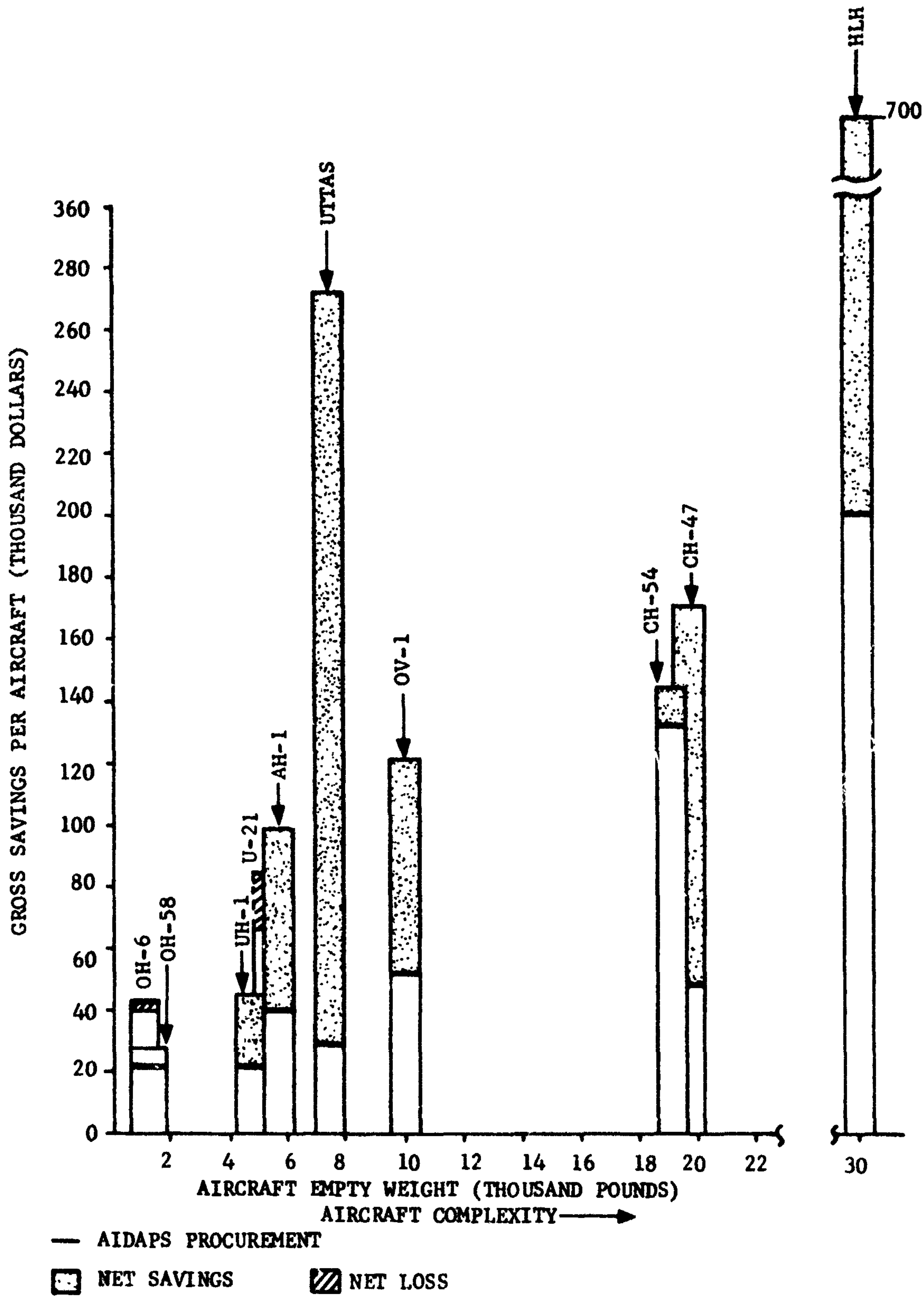


FIGURE 8-80 GROSS SAVINGS PER AIRCRAFT VS AIRCRAFT COMPLEXITY AS MEASURED BY AIRCRAFT EMPTY WEIGHT (UNIQUE SYSTEM - PESSIMISTIC CONDITIONS)

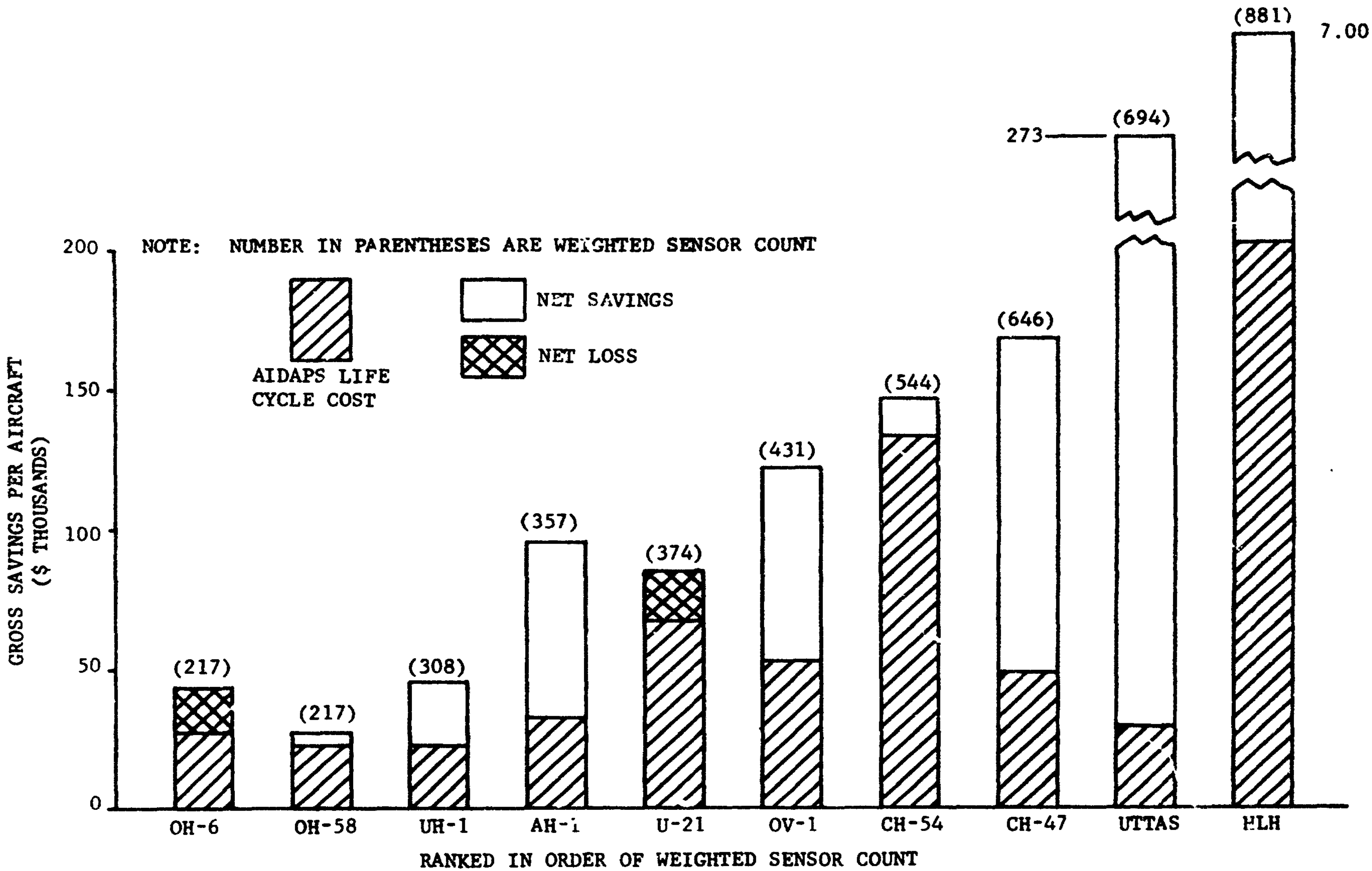


FIGURE 8-81 AIDAP SYSTEM GROSS SAVINGS PER AIRCRAFT VS WEIGHTED SENSOR COUNT
(UNIQUE SYSTEM - PESSIMISTIC CONDITION)

8.1.3.4 <u>Effects of Inspection, Diagnosis and Prognosis</u>

Figures 8-82 through 8-86 show the effects on inspection, diagnosis and prognosis on the cost elements which make up the operating costs of the CH-47. These figures pertain to the Hybrid I System, although the results expressed as a percentage are applicable to the Airborne System.

Separation of detailed maintenance actions and AIDAPS capabilities into inspection, diagnostic and prognostic capabilities is not a precise exercise. For the purpose of this report, inspection is considered to refer to the activities called out in the daily, intermediate, periodic and special inspections appearing in the TO's and maintenance data. The words monitoring or sensing are used to describe the capability of an AIDAPS to examine the integrity of components and parameters. When the ability of the AIDAPS to monitor a parameter or component equals or exceeds the inspection requirements for an action item on an inspection list, it is assumed that the item will be deleted from the manual inspection. Deletion of these items produces savings in inspection man-hours and aircraft downtime. Only these savings are included as inspections in this study. Other savings derived from the automatic monitoring (inspecting) by AIDAPS are really due to its ability to diagnose and prognosticate malfunctions.

Diagnosis is considered to be the actions involved in isolating a malfunction to a particular component or module. These actions are usually coded as tests or checks on TAMMS maintenance reports.

It is difficult to precisely separate diagnostic and prognostic capability. For instance, on many items such as pumps, liquid quantities, engine transmissions, etc., maintenance may be required when a given parameter such as fuel flow, oil quantity or vibration exceeds or falls below a specific value. The critical value is frequently specified by the manufacturer or derived from maintenance or operating experience. In these cases, components may not have completely failed from a functional standpoint. However, the action is considered to be diagnostic in this report.

In other cases, critical values may be established which are within the allowable specified performance ranges, but which indicate that a malfunction is imminent. These values may be established by the AIDAPS or with the use of AIDAPS.

TOTAL COST SAVINGS $31.0 MILLION

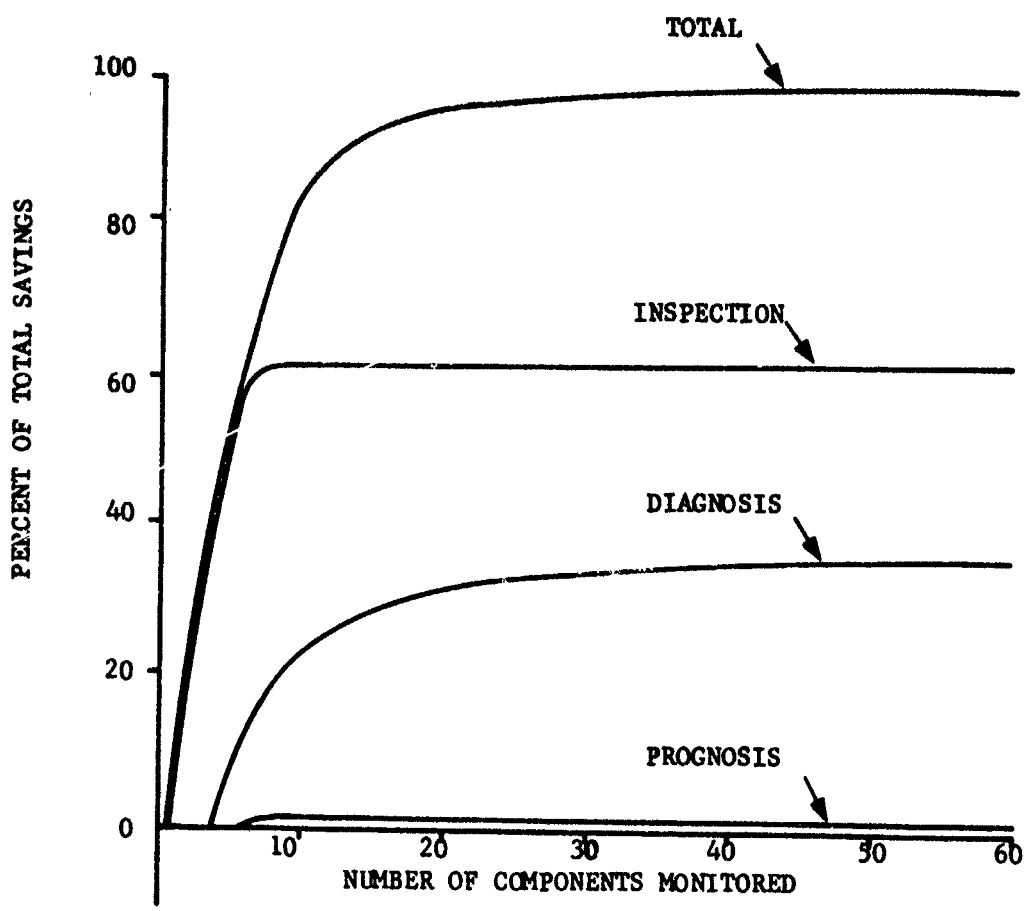


FIGURE 8-82
CH-47
EFFECTS OF INSPECTION, DIAGNOSIS & PROGNOSIS
ON MANPOWER COST SAVINGS
(459 AIRCRAFT - 30 HRS/MO UTILIZATION)

TOTAL COST SAVINGS $29.6 MILLION

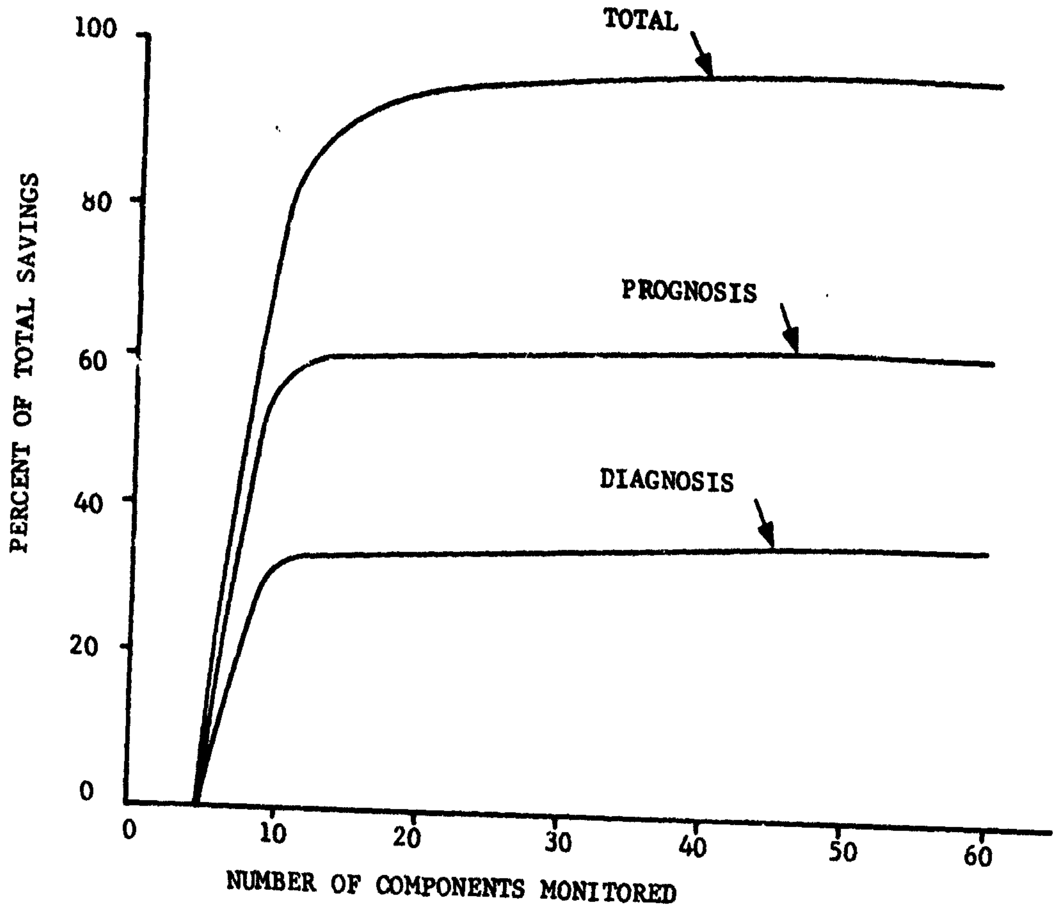


FIGURE 8-83
CH-47
EFFECTS OF DIAGNOSIS & PROGNOSIS
ON SPARES & LOGISTICS COST SAVINGS
(459 AIRCRAFT - 30 HRS/MO UTILIZATION)

TOTAL COST SAVINGS $6.4 MILLION

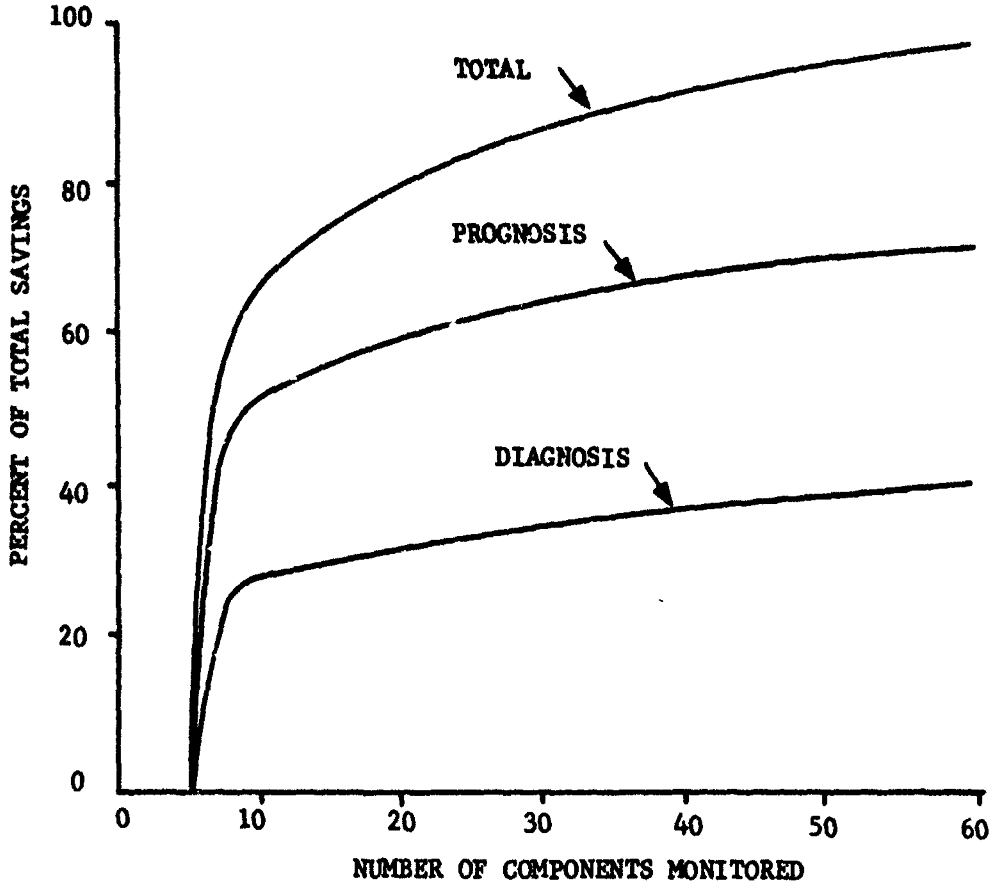


FIGURE 8-84
CH-47
EFFECTS OF DIAGNOSIS & PROGNOSIS ON ACCIDENT COST SAVINGS
(459 AIRCRAFT - 30 HRS/MO UTILIZATION)

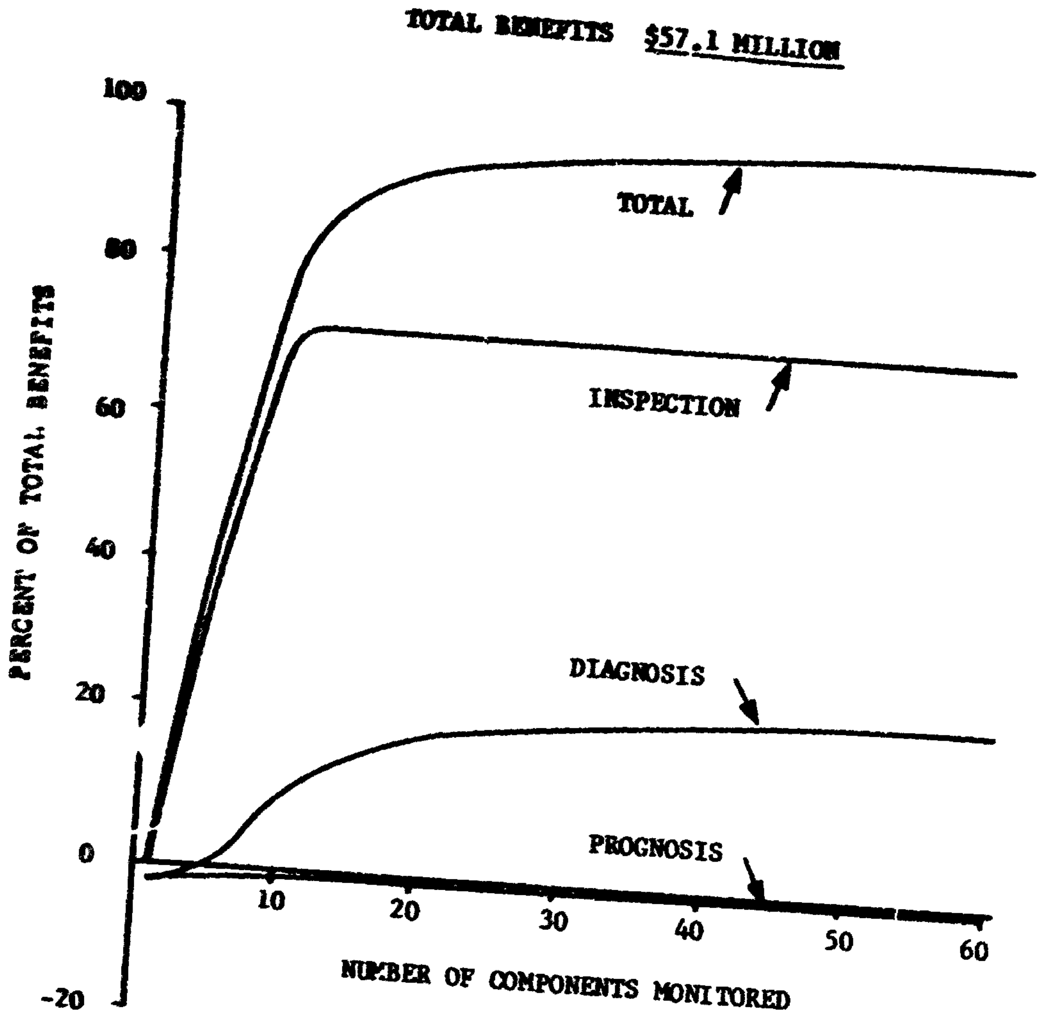


FIGURE 8-85
CH-47
EFFECTS OF INSPECTION, DIAGNOSIS & PROGNOSIS
BENEFITS IN EFFECTIVE NUMBER OF AIRCRAFT
(459 AIRCRAFT - 30 HR/MO UTILIZATION)

TOTAL SAVINGS & BENEFITS $124.1 MILLION

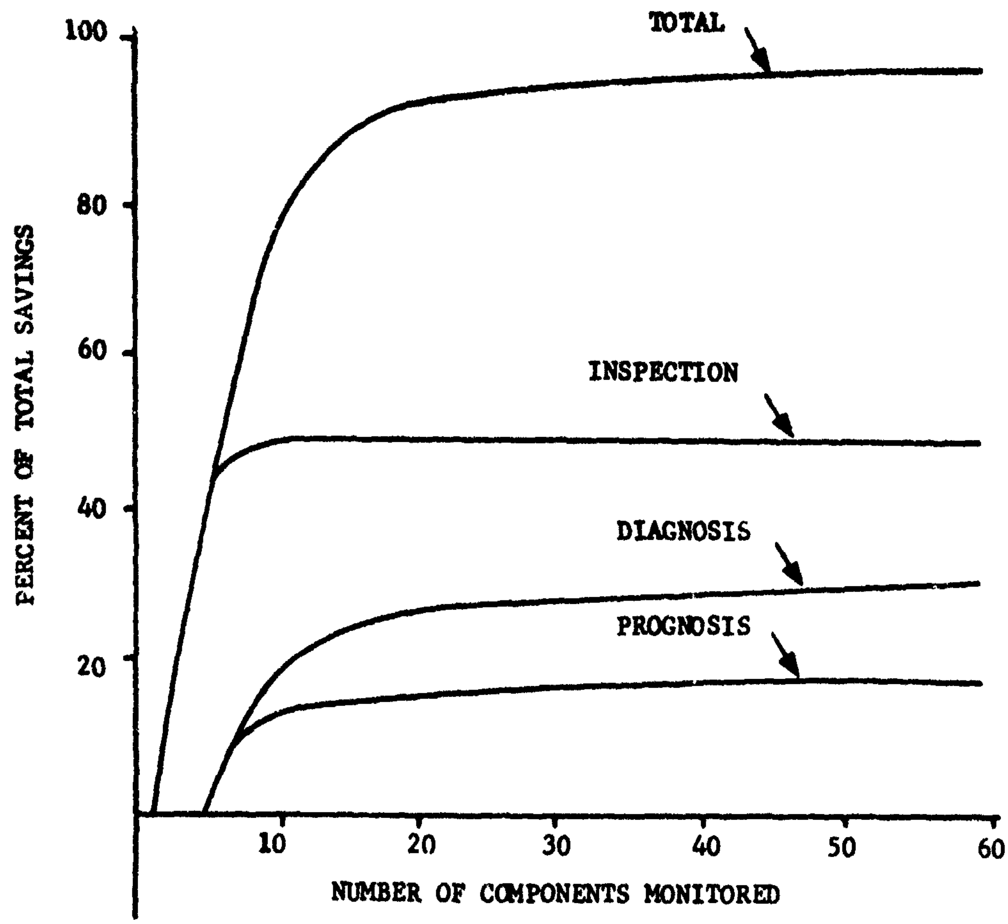


FIGURE 8-86

CH-47

EFFECTS OF INSPECTION DIAGNOSIS & PROGNOSIS
TOTAL SAVINGS & BENEFITS
(459 AIRCRAFT - 30 HR/MO UTILIZATION)

They can be used for short term prognosis and are considered so in all cases except for reduction in hazard rates. In considering the reduction in flight safety hazards through airborne warning, a division between diagnostic and short term prognostic capability is entirely arbitrary. Since the data handling processes involved are substantially identical to diagnostic processes, all savings due to airborne warning are attributed to diagnosis.

Long term prognosis is defined as prediction of impending malfunctions over a period substantially longer than one mission duration. This capability frequently involves a variety of computational methods including deterministic as well as statistical data processing techniques such as trend analysis, averaging, extrapolation, regression analysis, statistical inference, etc.

Long term prognosis aids in the prevention of accidents by reducing the number of failures of critical components in the air. In addition to their effects upon accidents, both long and short term prognoses allow on condition maintenance.

Some specific data regarding the relation of these elements of AIDAPS are presented below for the CH-47.

The curve labeled "inspection" on Figure 8-82 includes only the savings in man-hours for daily, intermediate, and periodic inspections. Since these are the first few items on the component scale, this curve reaches a peak at this point.

The curve labeled "diagnosis" includes man-hours for on aircraft tests and checkouts, troubleshooting time, and unwarranted removals. Since these are a relatively large percent of the total maintenance man-hours, the savings are significant. The curve labeled "prognosis" includes savings in man-hours required for time removals. Although the savings in manhours for this maintenance action are small, savings in other areas become quite large.

Figure 8-83 shows the effects of diagnosis and prognosis on logistics costs. Diagnosis has the smallest effect since it only includes the packaging and shipping and bench check costs for unwarranted removals. Prognosis includes the savings in packaging and shipping costs as well as the savings in depot costs due to reduction in time removals.

Figure 8-84 shows the savings in accidents due to prognosis and diagnosis. For the purpose of this analysis, all actions which prevent faulty components from being flown are considered prognostic actions, while all actions involved in airborne warning of a malfunction or impending malfunctions are considered diagnostic.

These curves show the results of using prognosis alone vs diagnosis (i.e., airborne warning) alone. Hence, the total curve is not the sum of the two, because airborne warning cannot occur for a malfunction which has been prevented by prognosis. The total curve represents airborne warning applied to only those malfunctions which are not prevented by prognosis.

Figure 8-85 shows the effect of each of the Hybrid I AIDAPS capabilities on aircraft effectiveness. The major impact is due to reduction in aircraft downtime and hence is similar to Figure 8-82.

Figure 8-86 shows the total net savings and benefits for all AIDAP system capabilities for the CH-47. Each capability is significant in its own right and makes a significant contribution to the total. However, the inspection capability alone contributes approximately 50%.

8.1.3.5 Unique System Selection

Tables 8-6 and 8-7 show the selected unique AIDAP systems for both the pessimistic and expected conditions. The Hybrid I System is the best system in all cases except for the HLH which has a slight preference for the Airborne System. For the UTTAS and CH-47 the difference between the Hybrid I and Airborne Systems is so slight that a choice cannot be made based on cost effectiveness alone.

All of the aircraft show significant net benefits except the OH-6, OH-58, CH-54, and U-21. The reason for the low savings on the CH-54 is the large DDT&E cost when prorated over the small number of aircraft. If a system were used which was developed primarily for other aircraft, large net savings may accrue. Although the OH-58 shows significant savings for the entire fleet, the cost of procurement systems for this entire fleet is very large and the net return probably does not justify procurement.

TABLE 8-6 COSTS, BENEFITS & NET BENEFITS FOR SELECTED UNIQUE SYSTEMS

PESSIMISTIC CONDITION

AIRCRAFT	NO. OF A/C	SELECTED SYSTEM	AIDAPS COSTS ($ MILLIONS)	TOTAL BENEFITS ($ MILLIONS)	NET BENEFITS ($ MILLIONS)	PAY-OFF* PERIOD (YRS)
OH-6	234	HYBRID I	10.02	6.50	-3.52	--
OH-58	1906	HYBRID I	44.33	52.49	8.17	--
UH-1	3568	HYBRID I	79.47	163.63	84.16	3.1
CH-47	459	HYBRID I (AIRBORNE)	22.12	77.25	55.13	2.1
CH-54	75	HYBRID I	10.02	10.91	0.89	8.4
AH-1	584	HYBRID I	19.07	55.85	36.78	2.4
U-21	104	HYBRID I	8.85	6.94	-1.91	--
OV-1	231	HYBRID I	12.28	28.28	16.00	3.4
UTTAS	2356	HYBRID I (AIRBORNE)	69.38	643.15	573.77	-5.5 **
HLH	43	AIRBORNE (HYBRID I)	8.72	30.46	21.74	-1.2 **

*NUMBER OF YEARS AFTER RETROFIT COMPLETION

**CONCURRENT PROCUREMENT & OPERATIONS. BREAK EVEN POINT OCCURS BEFORE PROCUREMENT OF AIDAPS OR AIRCRAFT IS COMPLETE.

TABLE 8-7 COSTS, BENEFITS & NET BENEFITS FOR SELECTED UNIQUE SYSTEMS

EXPECTED CONDITION

AIRCRAFT	NO. OF A/C	SELECTED SYSTEM	AIDAPS COSTS ($ MILLIONS)	TOTAL BENEFITS ($ MILLIONS)	NET BENEFITS ($ MILLIONS)	PAY-OFF* PERIOD (YRS)
OH-6	234	HYBRID I	10.44	8.67	-1.77	--
OH-58	1906	HYBRID I	46.73	70.00	23.27	--
UH-1	3568	HYBRID I	83.80	218.13	134.33	2.3
CH-47	459	HYBRID I (AIRBORNE)	23.20	115.95	92.75	1.5
CH-54	75	HYBRID I	10.47	18.17	7.70	5.0
AH-1	584	HYBRID I	19.90	74.53	54.63	2.0
U-21	104	HYBRID I	9.12	8.75	-0.37	--
OV-1	231	HYBRID I	12.38	32.23	19.85	2.9
UTTAS	2356	HYBRID I (AIRBORNE)	73.10	857.58	784.48	-6.0**
HLH	43	AIRBORNE (HYBRID I)	9.10	50.16	41.06	-2.4**

*NUMBER OF YEARS AFTER RETROFIT COMPLETION

**CONCURRENT PROCUREMENT & OPERATIONS. BREAK EVEN POINT OCCURS BEFORE PROCUREMENT OF AIDAPS OR AIRCRAFT IS COMPLETE.

8.2 GROUP AIDAP SYSTEMS

The previous cost effectiveness analysis indicated significant AIDAPS development and procurement cost savings can be achieved by integrating the procurement programs. This is particularly true for low inventory aircraft such as the U-21, CH-54, and HLH. In addition, the effectiveness of the systems can be significantly improved by changes in the parameters monitored. Although these changes increase the cost-effectiveness of all AIDAP systems generic types, they have no effect on the relative rankings of these generic types on a given aircraft. Therefore, the results of the unique system trade-offs are correct as far as systems selection is concerned. Hence, the two least cost effective systems, Hybrid II and the Ground Systems were deleted from further analysis.

A Hybrid II and an Airborne System were redefined (see Section 5.0) to be applicable to each of the following aircraft groups.

GROUP I:	OH-6, OH-58
GROUP II:	UH-1, AH-1, U-21, OV-1
GROUP III:	CH-47, CH-54, UTTAS, HLH

By grouping the aircraft in this manner, the cost of implementing a similar AIDAPS configuration within each group is amortized over the total number of aircraft comprising the respective group. The following discussion presents the results of the cost effectiveness analysis of the grouped AIDAP systems. This analysis was performed under three sets of conditions. These conditions are Optimistic, Expected and Pessimistic. The input data which was used to develop each of these conditions for each aircraft are shown on Table 8-8.

The system net savings associated with each of the above conditions and the logistics cost savings for the expected case are presented for each study aircraft as a function of the number of components monitored. The expected condition was chosen for presentation as it provides the most realistic savings which could be expected when operating the study aircraft over an extended period of time. The rationale governing this selection has been discussed previously. Comparison with the appropriate unique system illustrations previously presented will allow determination of the impact of the group system

TABLE 8-8 AIRCRAFT OPERATIONAL DATA FOR GROUPED AND UNIVERSAL AIMAP SYSTEM

Aircraft/Input	Condition		
	Optimistic	Expected	Standard
AH-1			
Utilization[1]	70 FHPM	40 FHPM	30 FHPM
Average Payload	2,699 lbs	1,933 lbs	1,933 lbs
Missions per Day[2]	3.14	1.31	0.985
Percent Overseas	90.0	80.0	80.0
% OR[3]	63.0	72.0	75.0
Probability of Maintenance[4]	0.515	0.856	1.0
Average Maintenance Duration[5]	6.49	4.33	3.60
Manpower Productivity	100.0	133.5	133.5
Corrected Maintenance Factor (CMF)	1.1	1.1	1.0
CH-47			
Utilization	60 FHPM	30 FHPM	20 FHPM
Average Payload	15,390 lbs	6,945 lbs	6,000 lbs
Missions per Day	4.04	1.04	0.693
Percent Overseas	74	50	50
% OR	59	65	82
Probability of Maintenance	0.612	0.989	0.984
Average Maintenance Duration	6.30	4.55	3.12
Manpower Productivity	100 hrs/mo	133.5 hrs/mo	133.5 hrs/mo
CMF	1.1	1.1	1.0
CH-54			
Utilization	50 FHPM	25 FHPM	15 FHPM
Average Payload	20,000 lbs	11,522 lbs	11,522 lbs
Missions per Day	4.65	0.833	0.5
Percent Overseas	90	75	75
% OR	57	69	76
Probability of Maintenance	0.602	1.0	1.0
Average Maintenance Duration	7.01	3.98	2.40
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0

TABLE 8-8 (CONT'D)

Aircraft/Input	Condition		
	Optimistic	Expected	Standard
OH-6			
Utilization	70 FHPM	40 FHPM	30 FHPM
Average Payload	637 lbs	600 lbs	600 lbs
Missions per Day	1.77	1.11	0.835
Percent Overseas	72	60	60
% OR	70	77	80
Probability of Maintenance	0.820	0.9[illegible]5	1.0
Average Maintenance Duration	4.70	3.10	2.40
Manpower Productivity	100 hr/mo	1[illegible]3.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0
OH-58			
Utilization	70 FHPM	40 FHPM	30 FHPM
Average Payload	650 lbs	600 lbs	600 lbs
Missions per Day	1.76	1.11	0.835
Percent Overseas	77	60	60
% OR	73	80	83
Probability of Maintenance	0.820	0.955	1.0
Average Maintenance Duration	4.70	3.98	2.40
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0
OV-1			
Utilization[1]	70 FHPM	40 FHPM	35 FHPM
Average Payload	2,[illegible]94 lbs	1,930 lbs	1,930 lbs
Missions per Day[2]	2.98	1.67	1.46
Percent Overseas	70	60	60
% OR[3]	58	70	72
Probability of Maintenance	0.708	0.827	0.864
Average Maintenance Duration	8.05	5.26	4.80
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0

TABLE 8-8 (CONT'D)

Aircraft/Input	Condition		
	Optimistic	Expected	Standard
UH-1			
Utilization	80 FHPM	40 FHPM	30 FHPM
Average Payload	2,400 lbs	1,800 lbs	1,800 lbs
Missions per Day	2.38	1.11	0.833
Percent Overseas	76	60	60
% OR	66	76	80
Probability of Maintenance	0.664	0.945	1.0
Average Maintenance Duration	6.57	3.99	3.12
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0
U-21			
Utilization	75 FHPM	50 FHPM	40 FHPM
Average Payload	3,000 lbs	2,000 lbs	2,000 lbs
Missions per Day	1.36	0.6	0.477
Percent Overseas	71	60	60
% OR	66	79	82
Probability of Maintenance	0.895	1.0	1.0
Average Maintenance Duration	6.94	3.93	3.12
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0
HLH			
Utilization	69 FHPM	25 FHPM	15 FHPM
Average Payload	60,000 lbs	45,000 lbs	45,000 lbs
Missions per Day	4.65	0.833	0.5
Percent Overseas	90	75	75
% OR	59	65	75
Probability of Maintenance	0.655	1.0	1.0
Average Maintenance Duration	6.32	4.00	2.4
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CMF	1.1	1.1	1.0

TABLE 8-8 (CONT'D)

Aircraft/Input	Condition		
	Optimistic	Expected	Standard
UTTAS			
Utilization[1]	69 FHPM	40 FHPM	30 FHPM
Average Payload	3,640 lbs	2,640 lbs	2,640 lbs
Missions per Day[2]	2.38	1.11	0.835
Percent Overseas	76	60	60
% OR[3]	67	76	80
Probability of Maintenance[4]	0.766	0.963	1.0
Average Maintenance Duration[5]	6.22	3.95	3.12
Manpower Productivity	100 hr/mo	133.5 hr/mo	133.5 hr/mo
CNF	1.1	1.1	1.0

NOTES: 1) FHPM = Flying hours per aircraft per month

2) Depends upon aircraft utilization as well as upon average mission duration and thus upon payload

3) Depends upon NORM rate and thus upon aircraft utilization

4) Depends upon mission duration and aircraft utilization

5) Depends upon average maintenance duration (includes scheduled and unscheduled maintenance)

concept on cost savings. These variations in input data result in three values of cost savings which are associated with each of the three conditions, and provides a band of potential savings for each individual aircraft. The graphical presentations illustrate the amount of potential savings as a function of the number of components monitored based on the input condition.

8.2.1 GROUP 1 AIRCRAFT TRADEOFFS

Figures 8-87 and 8-88 provide the system net savings for the OH-6 and OH-58 that could be realized under the stipulated optimistic, expected and pessimistic conditions. In each case, the Hybrid I exhibits slightly greater net savings than the Airborne System. However, for the OH-6 pessimistic condition, even under the group concept, neither AIDAPS configuration provides a positive system net savings.

8.2.2 GROUP 2 AIRCRAFT TRADEOFFS

Figures 8-89 through 8-92 provide the system net savings for the AH-1, UH-1, OV-1 and U-21 that could be realized under the stipulated optimistic, expected and pessimistic conditions. The Hybrid I exhibits slightly greater net savings than the Airborne System with the exception of the OV-1 where, for the optimistic case, they provide essentially the same savings.

8.2.3 GROUP 3 AIRCRAFT TRADEOFFS

Figures 8-93 through 8-96 provide the system net savings for the CH-47, CH-54, UTTAS and HLH that could be realized under the stipulated conditions. The Hybrid I and Airborne Systems show substantially the same savings on all of these aircraft.

8.2.4 GROUP AIDAP SYSTEM SELECTION

Table 8-9 through 8-11 show a summary of the costs, gross savings and benefits, and net savings and benefits for the group AIDAPS. Under the pessimistic assumptions the net savings range from a loss of $1.6 million for the airborne system applied to the OH-6 aircraft, to $578 million for the Hybrid I applied to the UTTAS aircraft. The largest net savings for existing aircraft is $90.7 million for the UH-1/Hybrid I. In all cases except for the

HLH, the Hybrid I is the preferred system. The difference in net savings for Hybrid I and the Airborne System for the HLH aircraft are not significant.

Under these pessimistic assumptions, the net savings in ten years of operations are not equal to the AIDAPS life cycle costs for the OH-6, OH-58, U-21 and CH-54 aircraft. However, under the expected conditions, the CH-54 net savings are equal to almost four times the AIDAPS costs. Even under the optimistic assumptions, the OH-6 net savings are not significantly greater than the AIDAPS life cycle cost. Since a net savings equal to the AIDAPS cost represents a return on investment of only approximatley 7%, application of AIDAPS to the OH-6, OH-58 and U-21 is not considered economically practical.

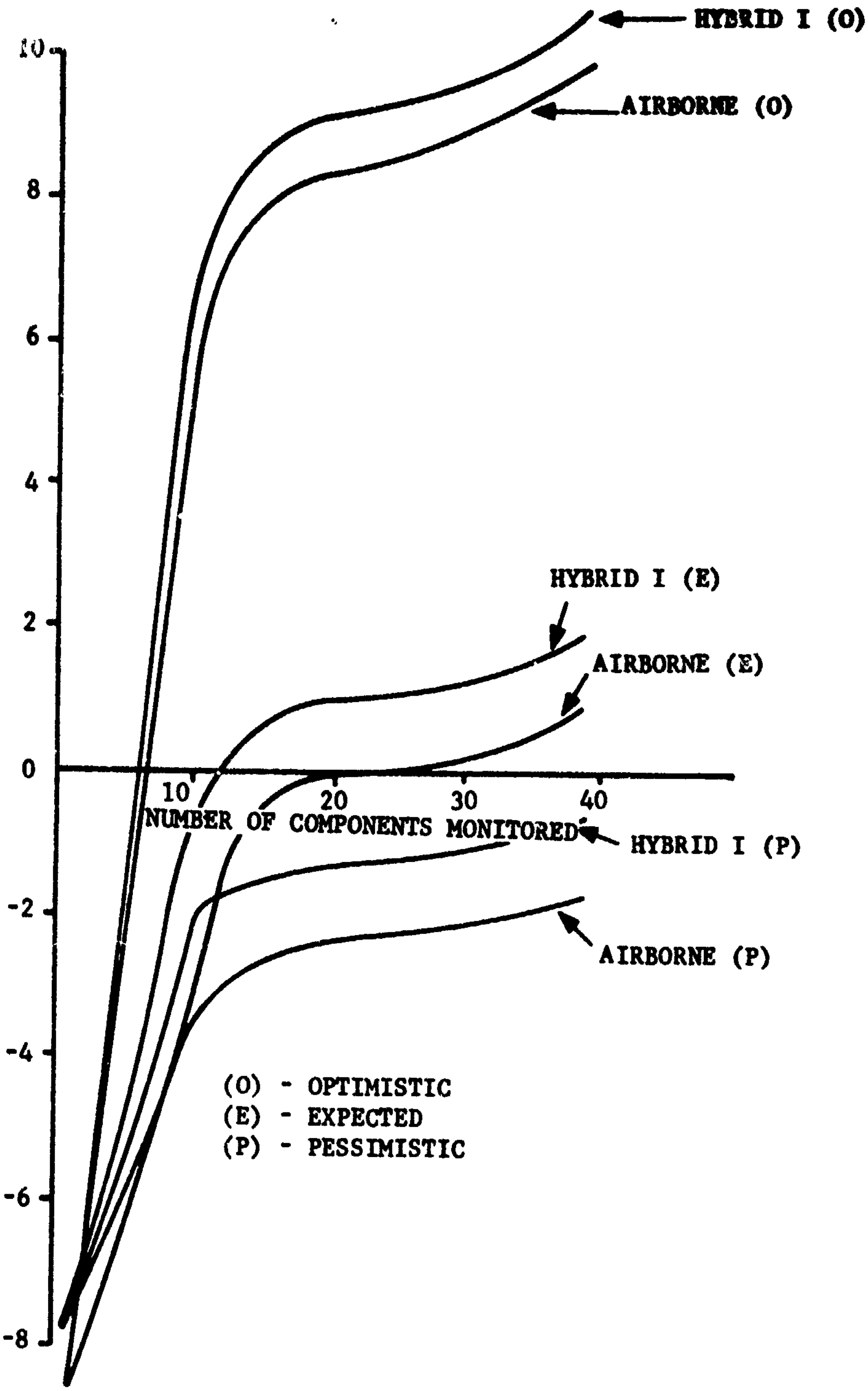


FIGURE 8-87 GROUPED SYSTEMS

OH-6

SYSTEM NET SAVINGS VS COMPONENTS MONITORED

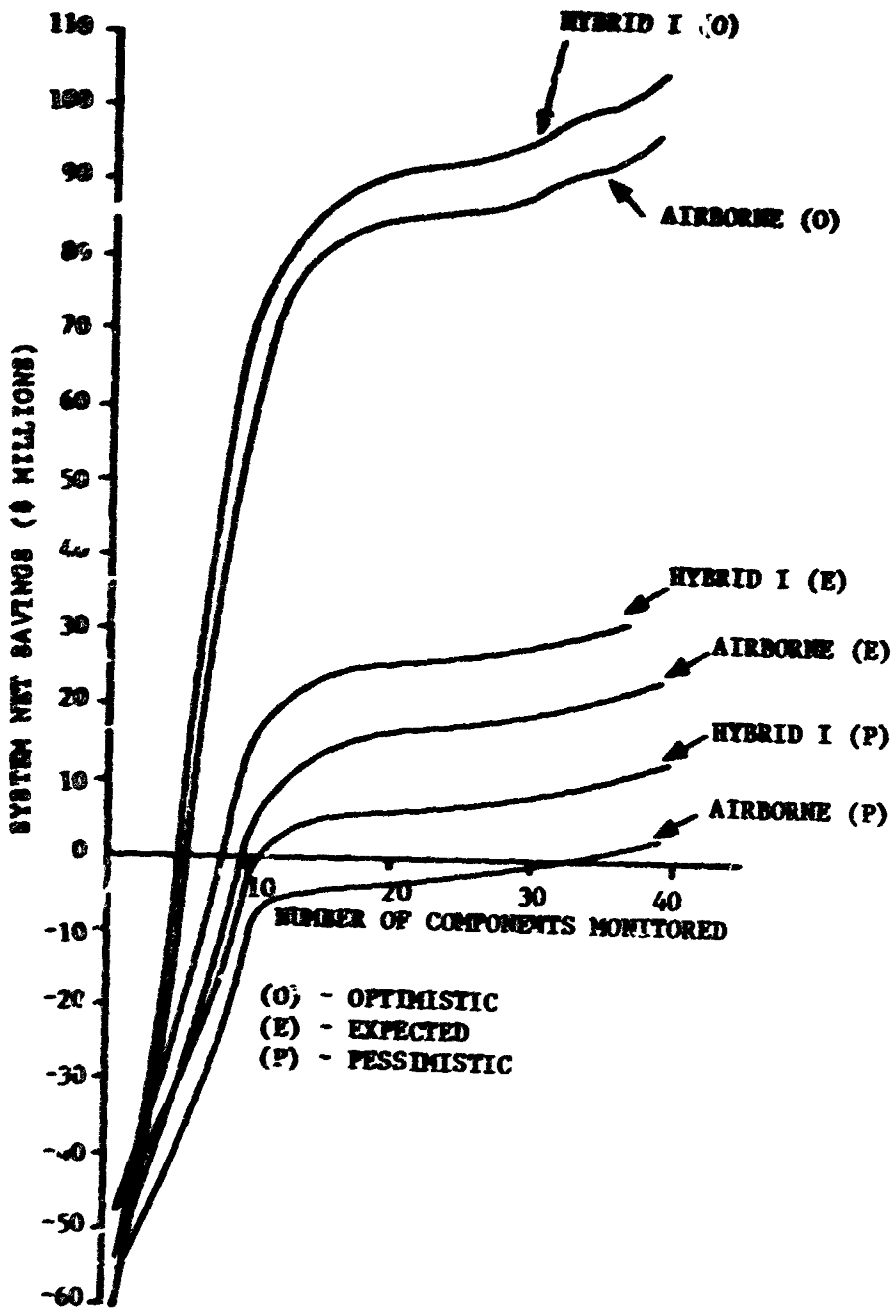


FIGURE 8-88 GROUPED SYSTEMS

OH-58

SYSTEM NET SAVINGS VS COMPONENTS MONITORED

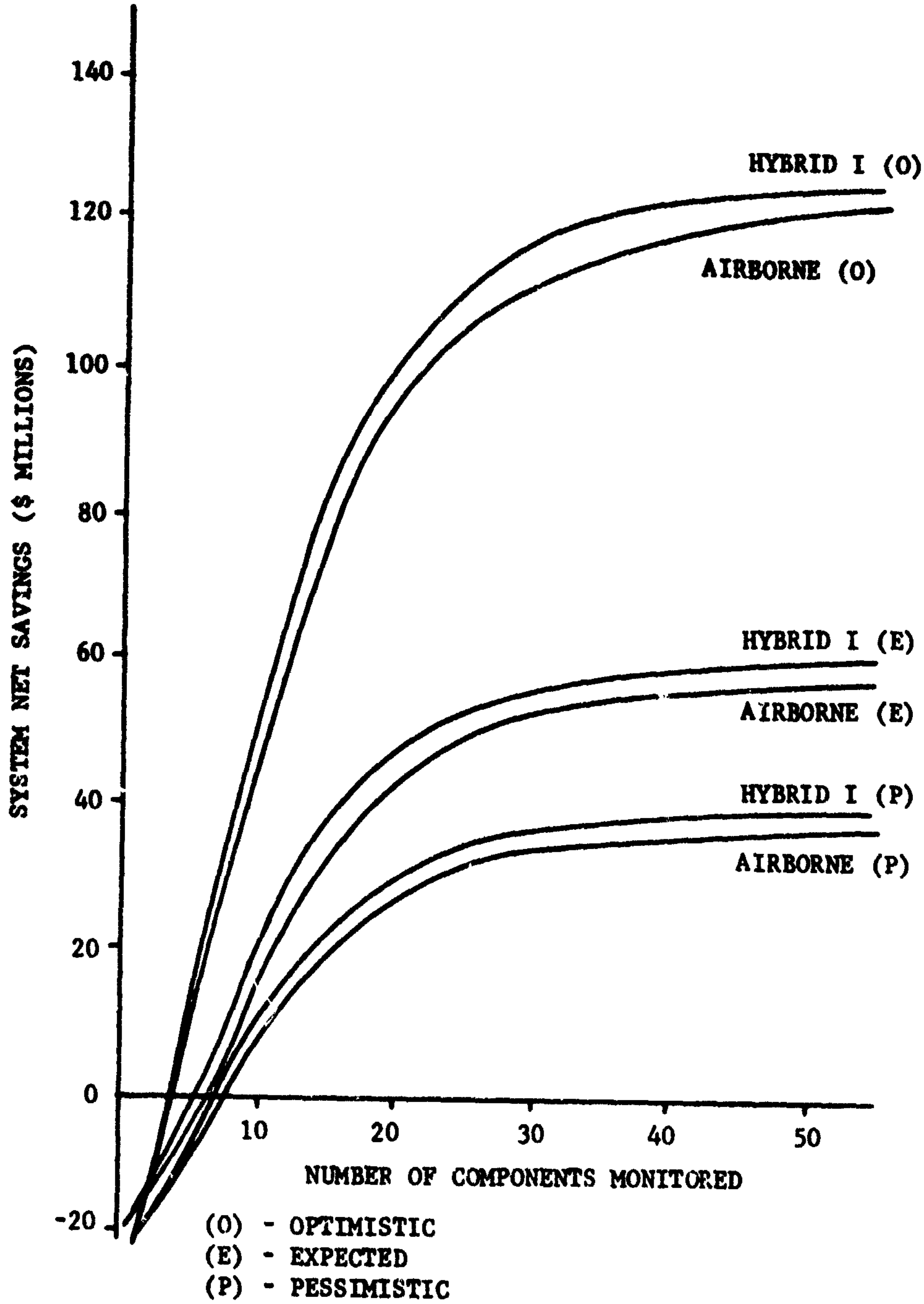


FIGURE 8-89 GROUPED SYSTEMS

AH-1

SYSTEM NET SAVINGS VS COMPONENTS MONITORED

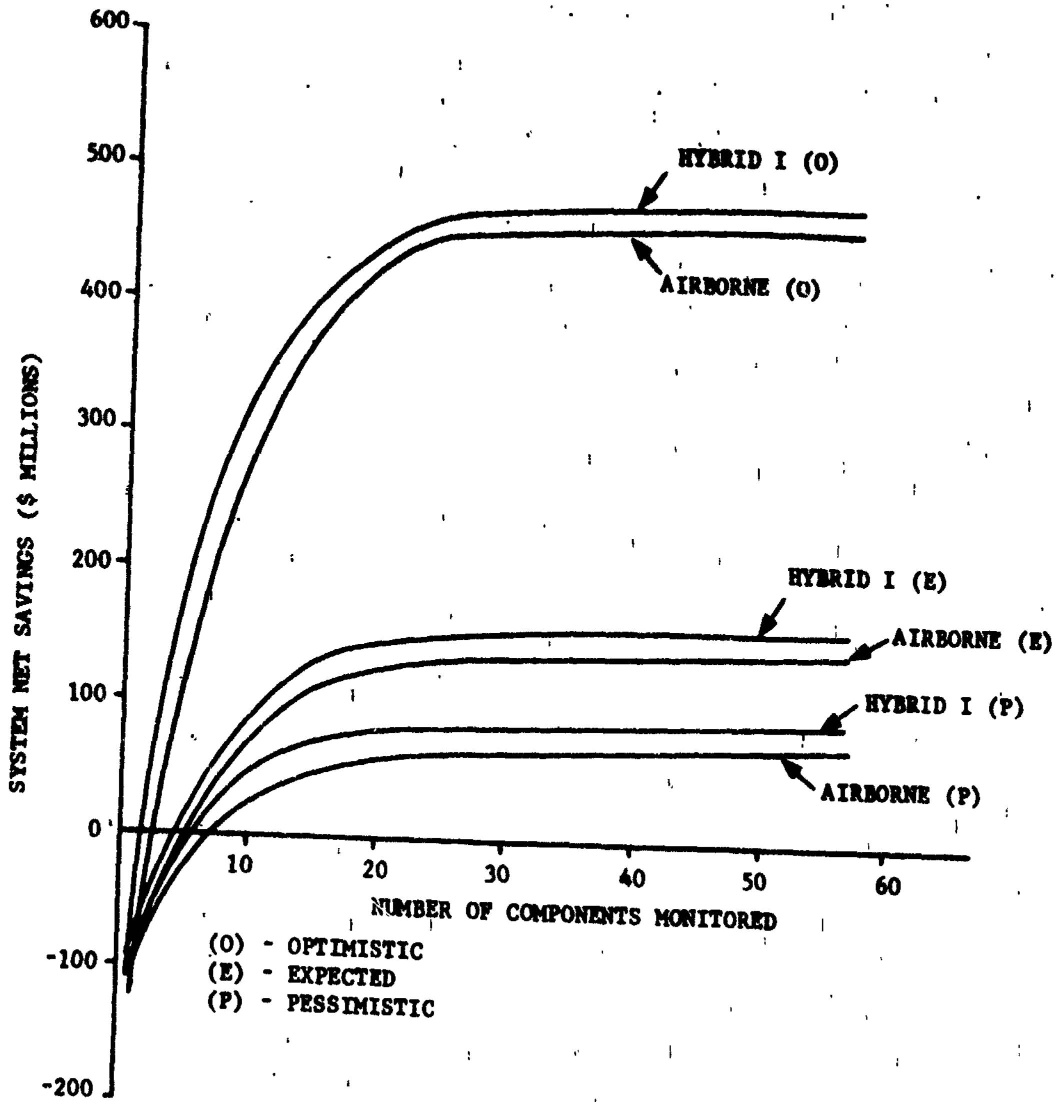


FIGURE 8-90 GROUPED SYSTEMS - UH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

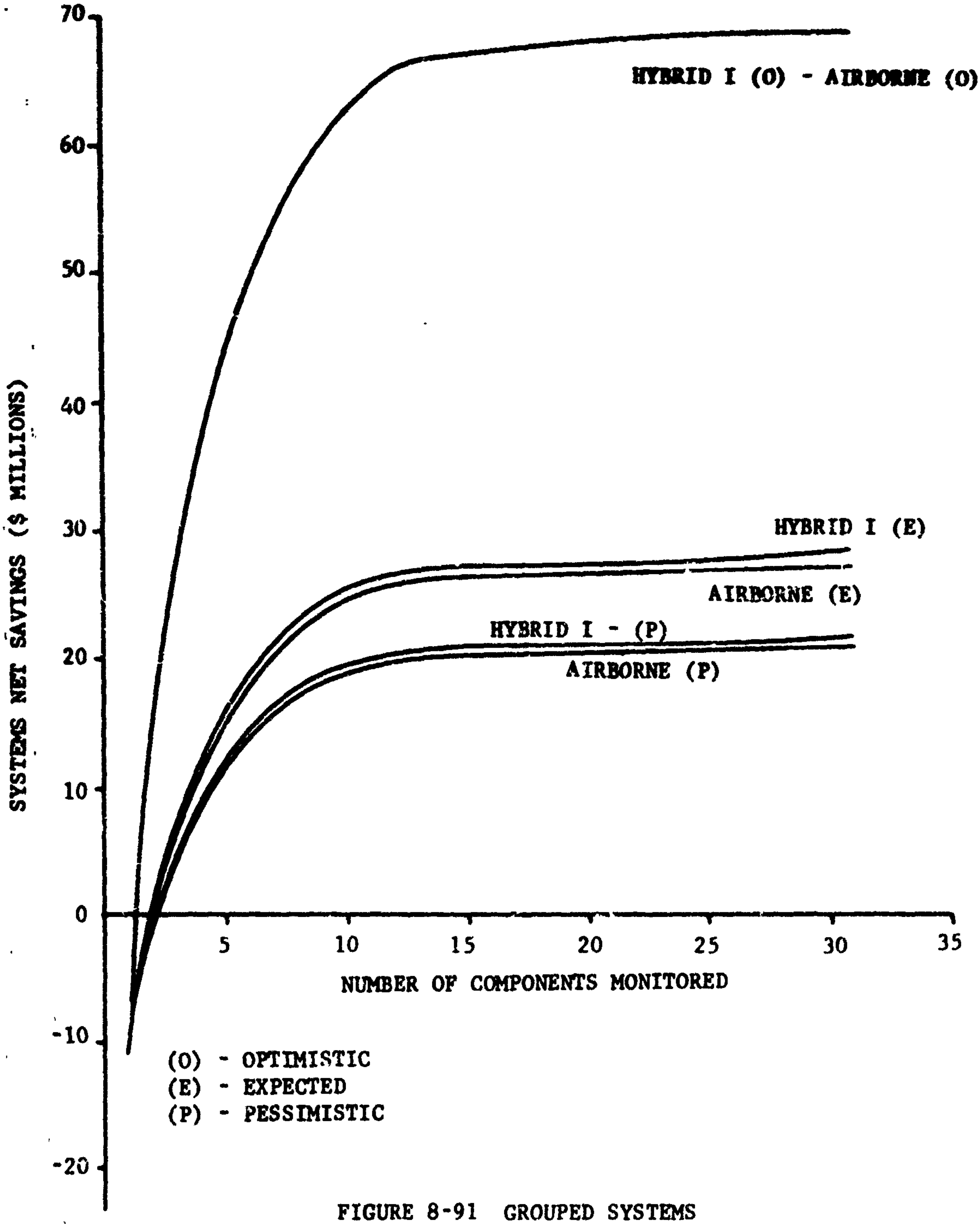


FIGURE 8-91 GROUPED SYSTEMS

OV-1

SYSTEM NET SAVINGS VS COMPONENTS MONITORED

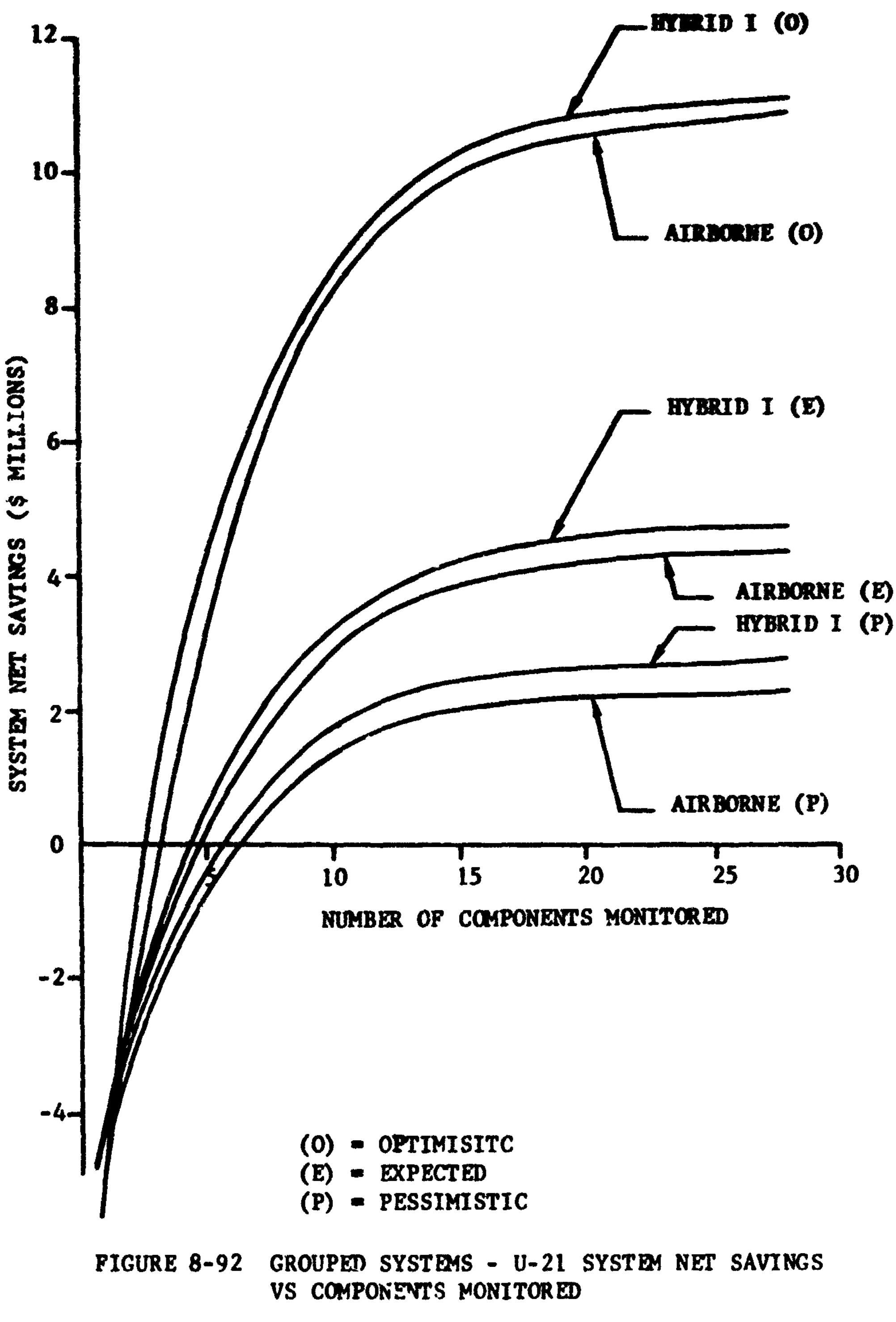
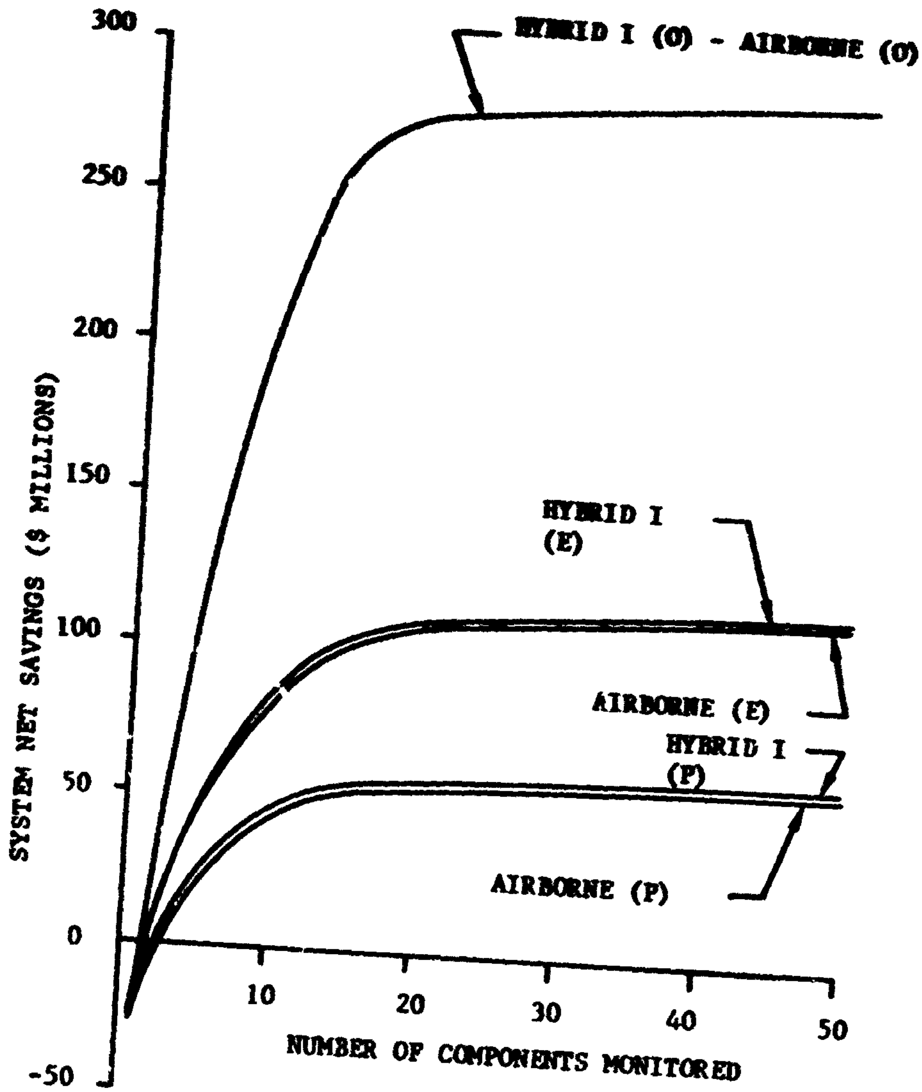
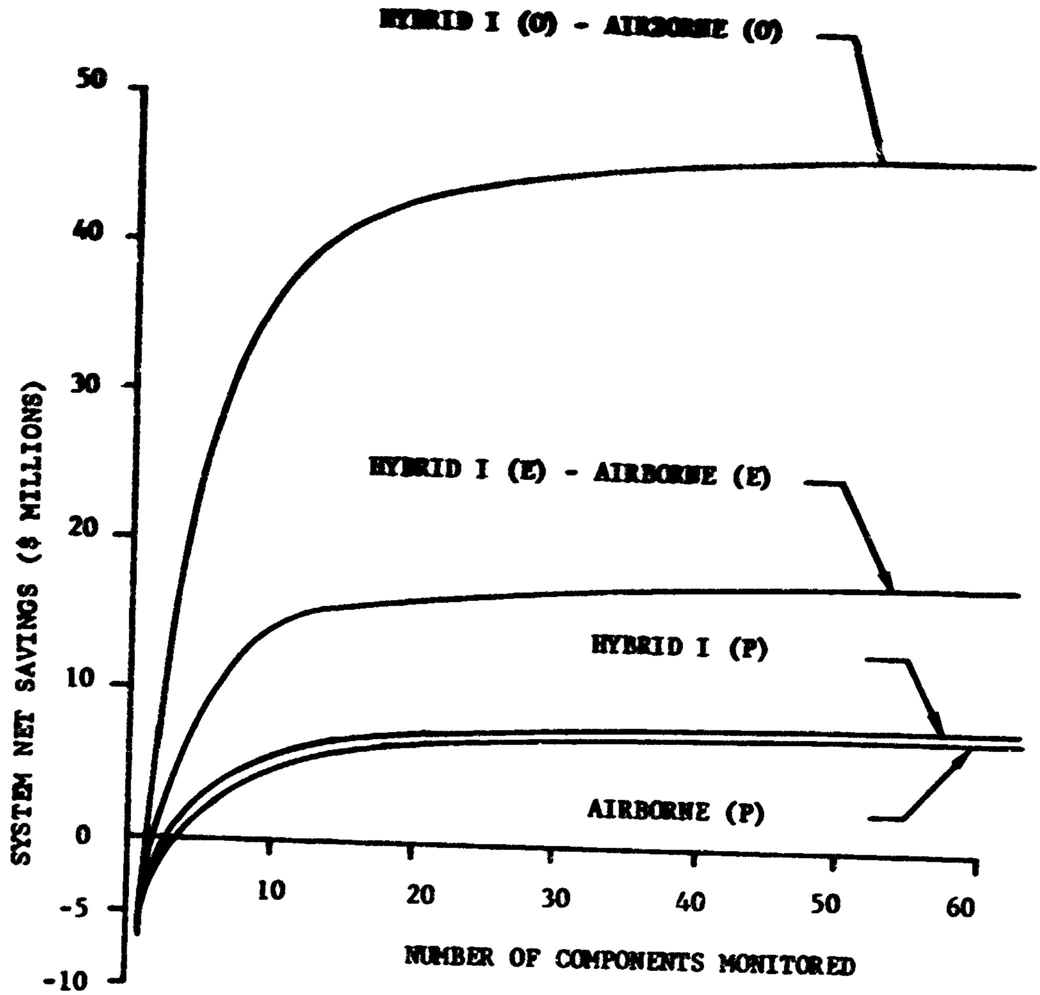


FIGURE 8-92 GROUPED SYSTEMS - U-21 SYSTEM NET SAVINGS VS COMPONENTS MONITORED



(O) = OPTIMISTIC
(E) = EXPECTED
(P) = PESSIMISTIC

FIGURE 8-93 GROUPED SYSTEMS - CH-47 SYSTEM NET SAVINGS VS COMPONENTS MONITORED



(O) = OPTIMISTIC
(E) = EXPECTED
(P) = PESSIMISTIC

FIGURE 8-94 GROUPED SYSTEMS - CH-54 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

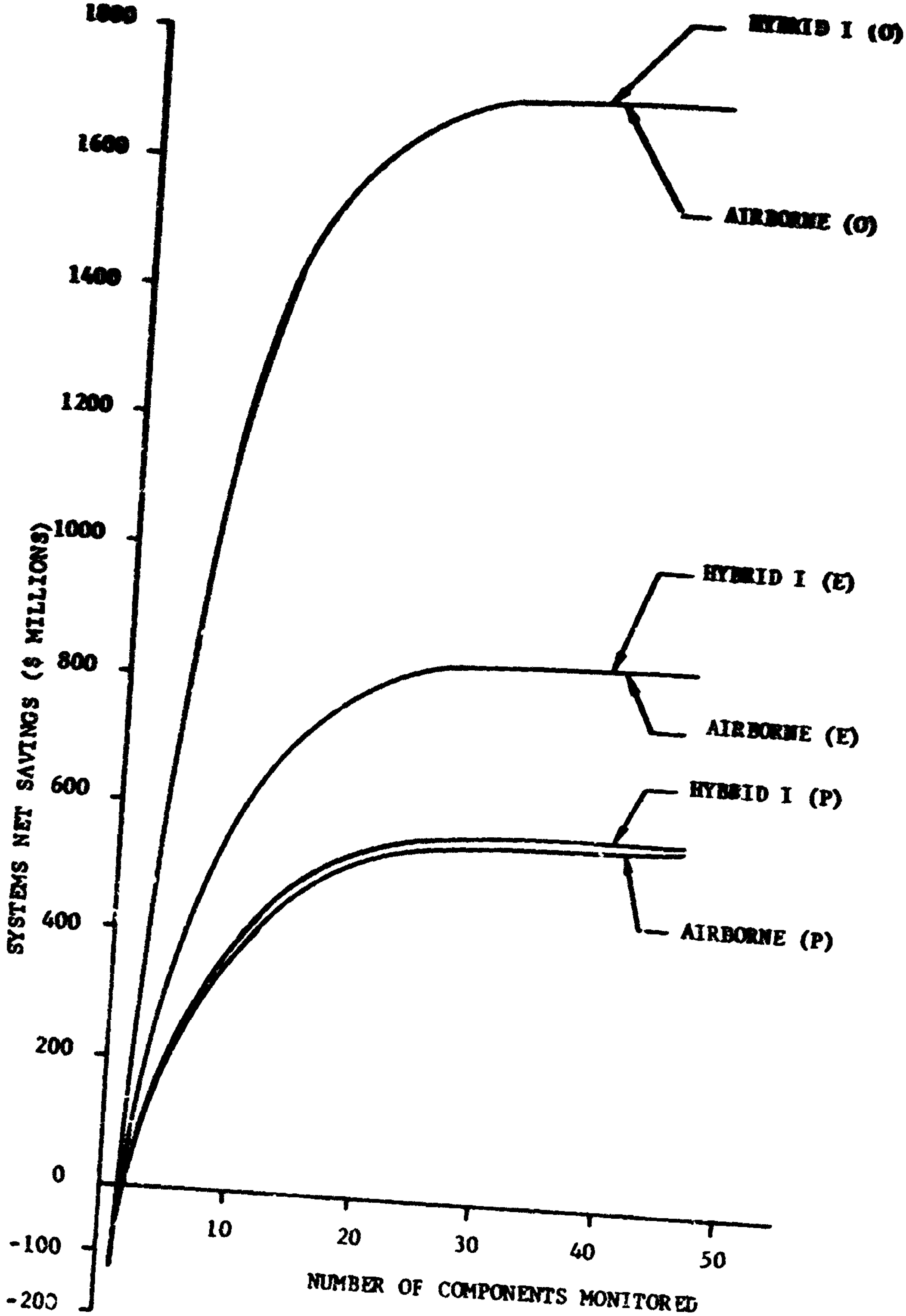


FIGURE 8-95 GROUPED SYSTEMS - UTTAS SYSTEMS NET SAVINGS VS COMPONENTS MONITORED

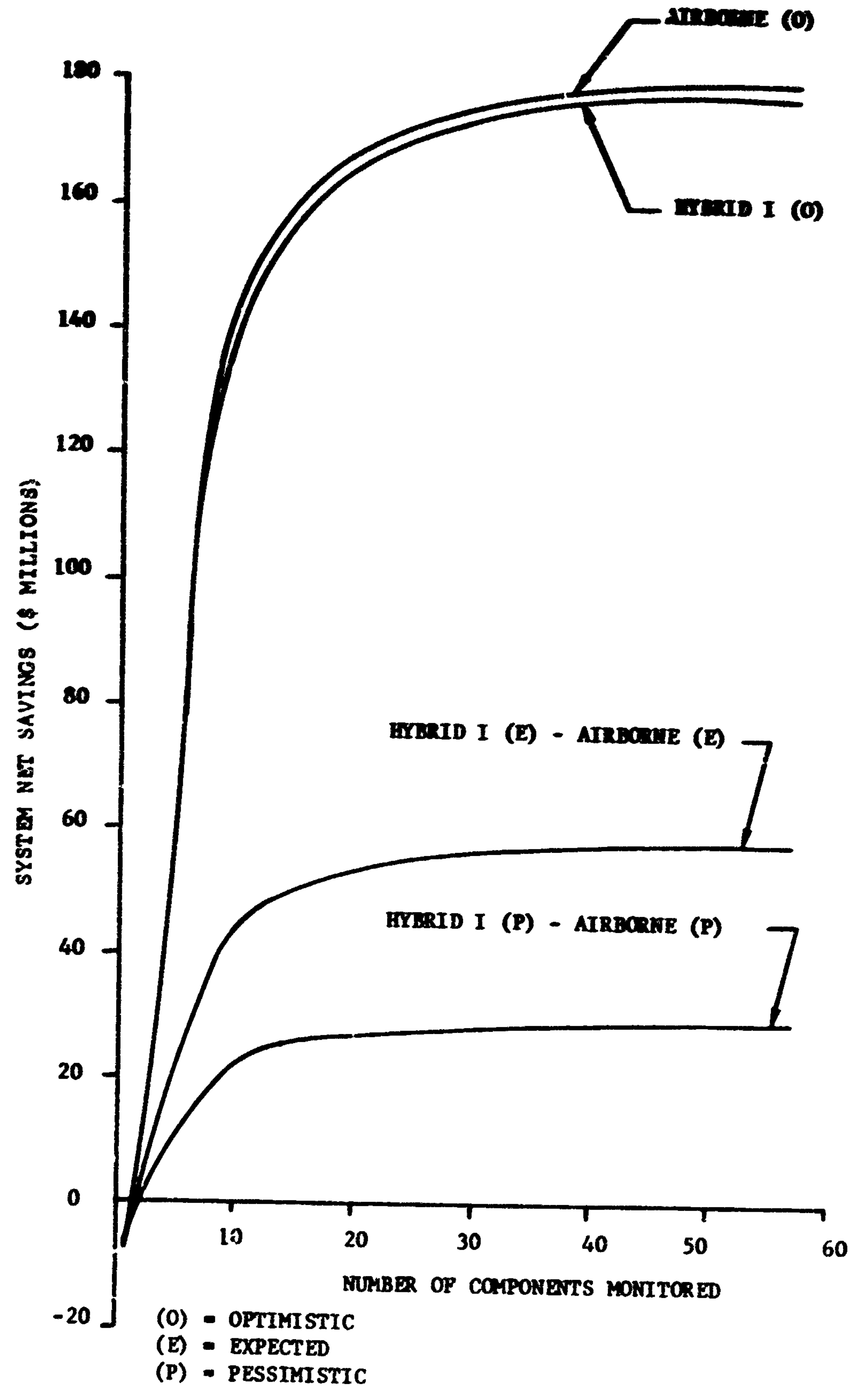


FIGURE 8-96 GROUPED SYSTEMS - HLH SYSTEM NET SAVINGS VS COMPONENTS MONITORED

TABLE 8-9

SUMMARY
AIDAPS 10 YEAR LIFE CYCLE COST
AIRCRAFT SAVINGS & BENEFITS
GROUPED SYSTEMS - PESSIMISTIC CONDITIONS

	CH-6		CH-58		UH-1		U-21		AH-1		UTTAS		OV-1		CH-54		CH-47		HLH	
	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE
AIRCRAFT SAVINGS AND BENEFITS:																				
OPERATIONS	3.9	4.0	29.5	30.2	99.4	100.1	3.4	3.5	13.4	13.5	230.2	231.1	11.4	11.5	4.1	4.1	40.2	40.3	10.8	10.8
EFFECTIVE AIRCRAFT	0.05	0.02	0.03	-0.3	28.3	27.8	1.1	1.1	3.8	3.8	240.9	242.6	16.2	16.3	5.0	5.1	28.3	28.6	15.2	15.5
ACCIDENTS	2.6	2.6	23.0	23.0	44.2	44.2	2.3	2.3	37.8	37.8	175.9	175.9	0.9	0.9	3.2	3.2	7.4	7.4	7.1	7.1
SUBTOTAL	6.55	6.62	52.53	52.9	171.9	172.1	6.8	6.9	55.0	55.1	647.0	649.6	28.5	28.7	12.3	12.4	75.9	76.3	33.2	33.4
AIDAPS COST:																				
DDT&E	1.9	1.8	1.9	1.8	1.3	1.2	1.3	1.2	1.3	1.2	1.8	1.7	1.3	1.2	1.8	1.7	1.8	1.7	1.8	1.7
INVESTMENT	4.3	5.5	34.0	44.1	70.8	89.7	2.0	2.6	11.4	14.5	58.0	71.2	4.2	5.5	2.1	2.5	13.1	15.7	1.2	1.5
OPERATIONS	0.9	0.9	4.5	4.3	9.1	9.2	0.7	0.7	1.9	1.9	9.0	8.4	1.0	1.0	0.3	0.6	1.5	1.5	0.6	0.6
SUBTOTAL	7.1	8.2	40.4	50.2	81.2	100.1	4.0	4.5	14.6	17.6	68.8	81.3	6.5	7.7	4.2	4.8	16.4	18.9	3.6	3.8
NET SAVINGS AND BENEFITS	-0.6	-1.6	12.1	2.7	90.7	72.0	2.8	2.4	40.4	37.5	578.2	568.3	22.0	21.0	8.1	7.6	59.5	57.4	29.5	29.6

IN MILLIONS OF DOLLARS

TABLE 8-10

SUMMARY

AIDAPS 10 YEAR LIFE CYCLE COST

AIRCRAFT SAVINGS & BENEFITS

GROUPED SYSTEMS - EXPECTED CONDITIONS

	OH-6		OH-58		UH-1		U-21		AH-1	
	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE
AIRCRAFT SAVINGS AND BENEFITS:										
OPERATIONS	5.5	5.6	42.1	43.1	140.5	141.5	4.5	4.6	19.2	19.4
EFFECTIVE AIRCRAFT	0.2	0.2	1.8	1.5	44.6	44.3	1.5	1.5	6.4	6.4
ACCIDENTS	3.5	3.5	30.7	30.7	59.3	59.3	2.8	2.8	50.4	50.4
SUBTOTAL	9.2	9.3	74.6	75.3	244.4	245.1	8.8	8.9	76.0	76.2
AIDAPS COST:										
DDT&E	1.9	1.8	1.9	1.8	1.3	1.2	1.3	1.2	1.3	1.2
INVESTMENT	4.3	5.5	34.0	44.2	70.8	89.7	2.0	2.6	11.4	14.5
OPERATIONS	1.1	1.0	5.4	5.1	11.1	11.2	0.7	0.8	2.2	2.2
SUBTOTAL	7.3	8.3	41.3	51.1	83.2	102.1	4.0	4.6	14.9	17.9
NET SAVINGS AND BENEFITS	1.9	1.0	33.3	24.2	161.2	143.0	4.8	4.3	61.1	58.3

	UTTAS		OV-1		CH-54		CH-47		HLH	
	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE
AIRCRAFT SAVINGS AND BENEFITS:										
OPERATIONS	323.3	324.5	13.9	14.0	7.3	7.4	64.1	64.3	19.7	19.7
EFFECTIVE AIRCRAFT	358.0	361.5	20.1	20.3	9.6	9.7	57.2	57.9	30.2	30.8
ACCIDENTS	234.5	234.5	1.0	1.0	5.4	5.4	11.2	11.2	11.8	11.8
SUBTOTAL	915.8	920.5	35.0	35.3	22.3	22.5	132.5	133.4	61.7	62.3
AIDAPS COST:										
DDT&E	1.8	1.7	1.3	1.2	1.8	1.7	1.8	1.7	1.8	1.7
INVESTMENT	58.1	71.2	4.2	5.5	2.1	2.5	13.1	15.7	1.2	1.5
OPERATIONS	11.3	10.4	1.0	1.0	0.6	0.6	1.9	1.9	0.6	0.6
SUBTOTAL	71.2	83.3	6.5	7.7	4.5	4.8	16.8	19.3	3.6	3.8
NET SAVINGS AND BENEFITS	844.6	837.2	28.5	27.6	17.8	17.7	115.7	114.1	58.1	58.5

IN MILLIONS OF DOLLARS

TABLE 8-11

SUMMARY
AIDAPS 10 YEAR LIFE CYCLE COST
AIRCRAFT SAVINGS & BENEFITS
GROUPED SYSTEMS - OPTIMISTIC CONDITIONS

	OH-6		OH-58		UH-1		U-21		AH-1		UTTAS		OV-1		CH-54		CH-47		HLH	
	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE	HYBRID I	AIRBORNE
AIRCRAFT SAVINGS AND BENEFITS:																				
OPERATIONS	11.7	12.0	89.3	91.7	336.2	338.8	8.3	8.4	39.1	39.5	661.2	664.1	29.6	29.8	16.8	16.9	153.9	134.1	57.6	57.7
EFFECTIVE AIRCRAFT	0.7	0.7	7.4	7.4	116.1	117.4	2.9	2.9	15.1	15.3	738.3	748.6	44.7	45.4	23.6	24.0	129.3	131.6	91.6	93.4
ACCIDENTS	6.0	6.0	53.7	53.7	117.9	117.9	4.2	4.2	88.2	88.2	404.6	404.6	1.8	1.8	10.8	10.8	22.3	22.3	32.6	32.6
SUBTOTAL	18.4	18.7	150.4	152.8	570.2	574.1	15.4	15.5	142.4	143.0	1804.1	1817.3	76.1	77.0	51.2	51.7	305.5	307.0	181.8	183.7
AIDAPS COST:																				
DDT&E	[illegible]	1.8	1.9	1.8	1.3	1.2	1.3	1.2	1.3	1.2	1.8	1.7	1.3	1.2	1.8	1.7	1.8	1.7	1.8	1.7
INVESTMENT	[illegible]	5.5	34.1	44.2	71.0	89.8	2.0	2.6	11.5	14.5	58.3	71.3	4.2	5.5	2.1	2.5	13.1	15.7	1.2	1.5
OPERATIONS	[illegible]	1.4	8.6	7.7	20.1	19.8	0.9	0.9	3.2	3.3	19.1	16.7	1.4	1.4	0.8	0.8	3.2	3.0	0.8	0.8
SUBTOTAL	7.7	8.7	44.6	53.7	92.4	110.8	4.2	4.7	16.0	19.0	79.2	89.7	6.9	8.1	4.7	5.0	18.1	20.4	3.8	[illegible]
NET SAVINGS AND BENEFITS	10.7	10.0	105.8	99.1	477.8	463.3	11.2	10.8	126.4	124.0	1724.9	1727.6	69.2	68.9	46.5	46.7	[illegible]	[illegible]	178.0	179.7

IN MILLIONS OF DOLLARS

Figures 8-97 through 8-103 show the AIDAPS costs and net savings as a function of time for each of the aircraft for which AIDAPS is cost effective. The break even time is less than the procurement time for the HLH and UTTAS aircraft. For existing aircraft it ranges from .4 years for the CH-47 to 2.45 years for the OV-1.

Figure 8-104 and 8-105 show the time phased expenditures and net savings for the Group II and III AIDAPS systems. Group I is not shown because it is not sufficiently cost effective. These savings are adjusted for the phase out of the respective aircraft in contrast to the figures shown in Tables 8-9 through 8-11 which assume a constant force size. The group II systems achieve a break even point approximately 1 1/2 years after procurement funds are appended or five years after program initiation.

Figure 8-105 shows the time phasing for the Group III system. The break even point is 9 years before the expenditure of procurement funds is complete and 3.5 years after the program is initiated. These times are strongly influenced by the long procurement times for the aircraft. For the existing aircraft the break even point occurs within one year after procurement funds are expended.

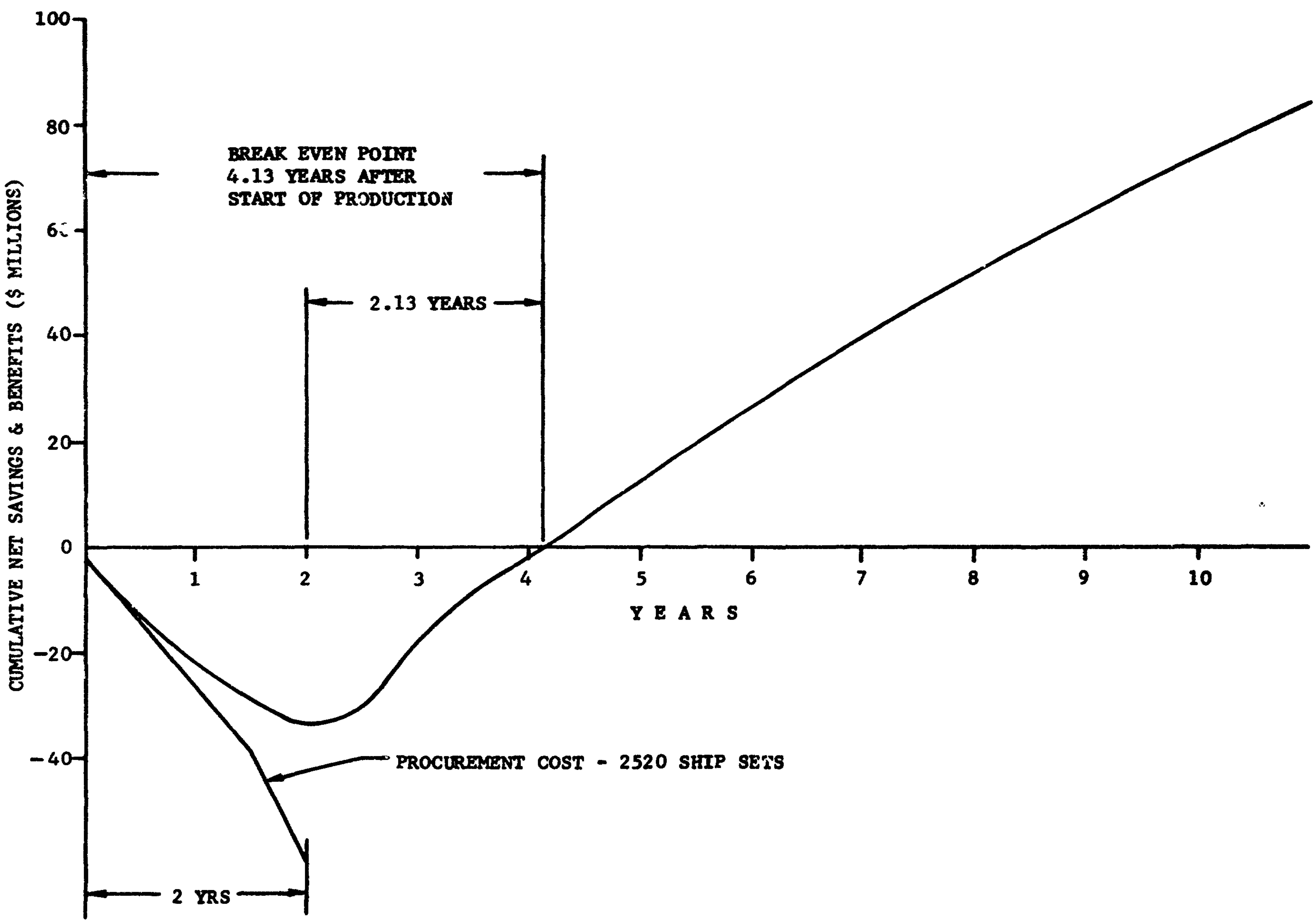


FIGURE 8-97 UH-1 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS (GROUPED SYSTEM - EXPECTED CONDITIONS)

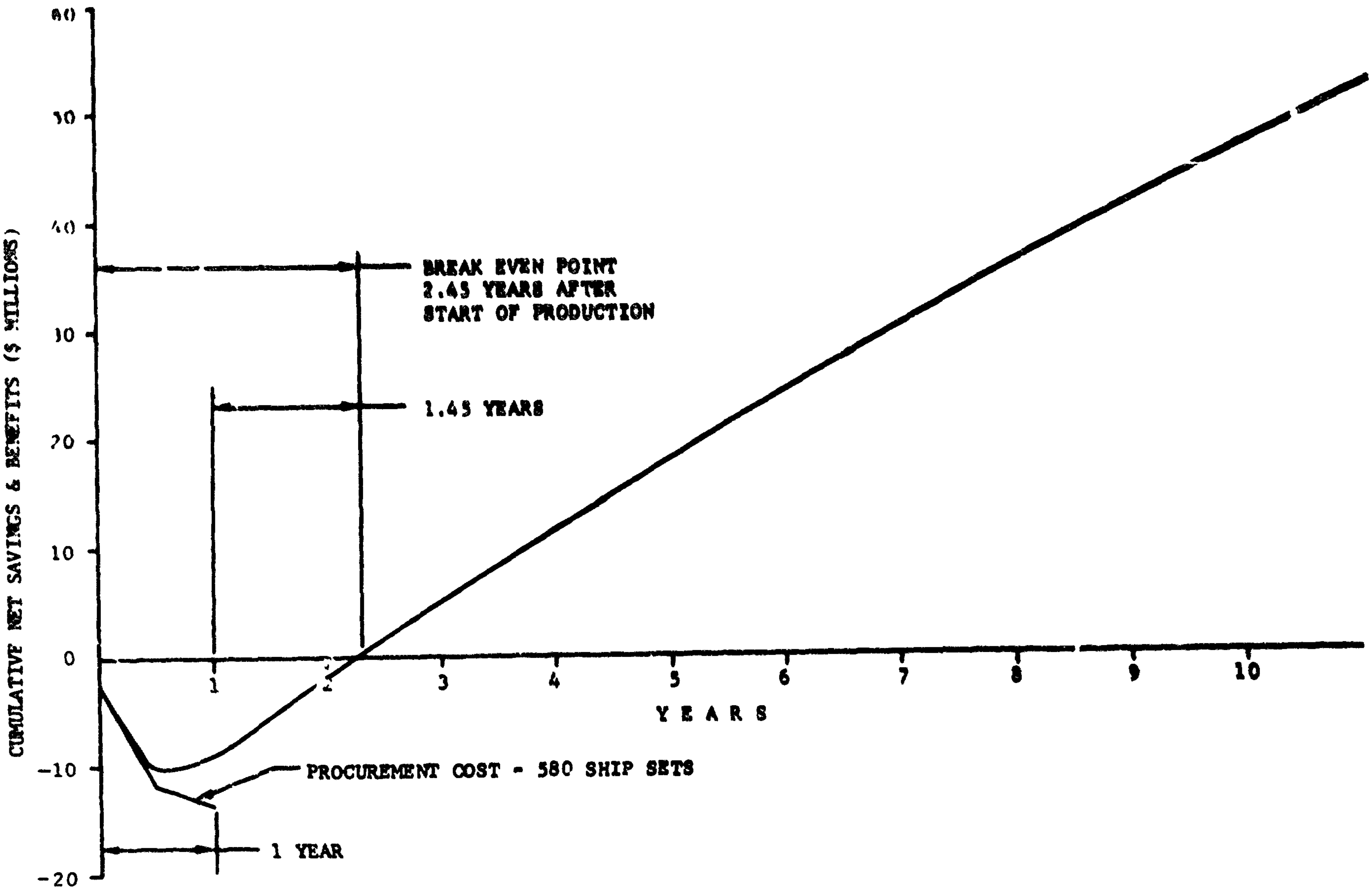


FIGURE 8-98 AH-1 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS (GROUPED SYSTEMS - EXPECTED CONDITIONS)

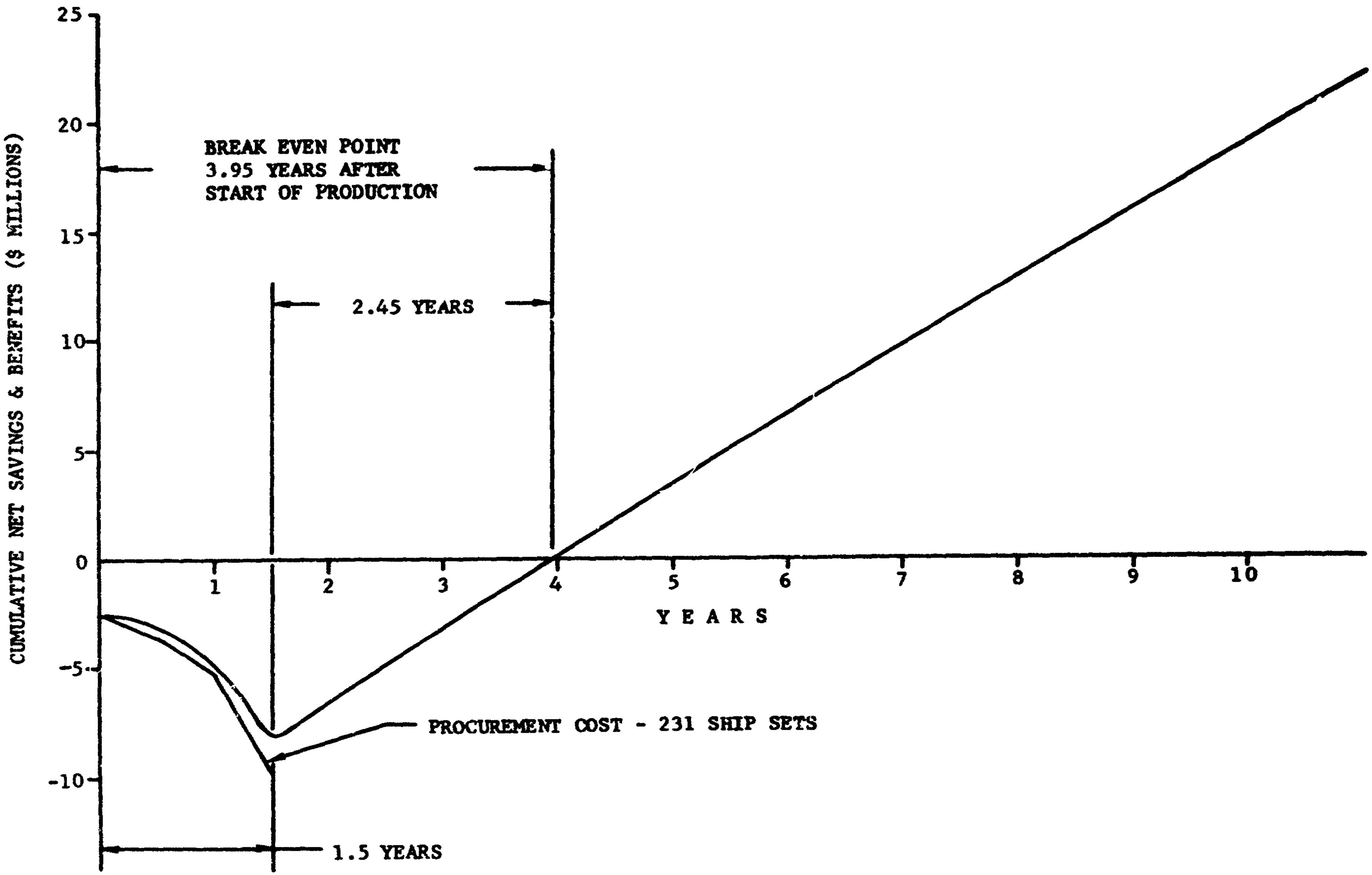


FIGURE 8-99 OV-1 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS (GROUPED SYSTEMS - EXPECTED CONDITIONS)

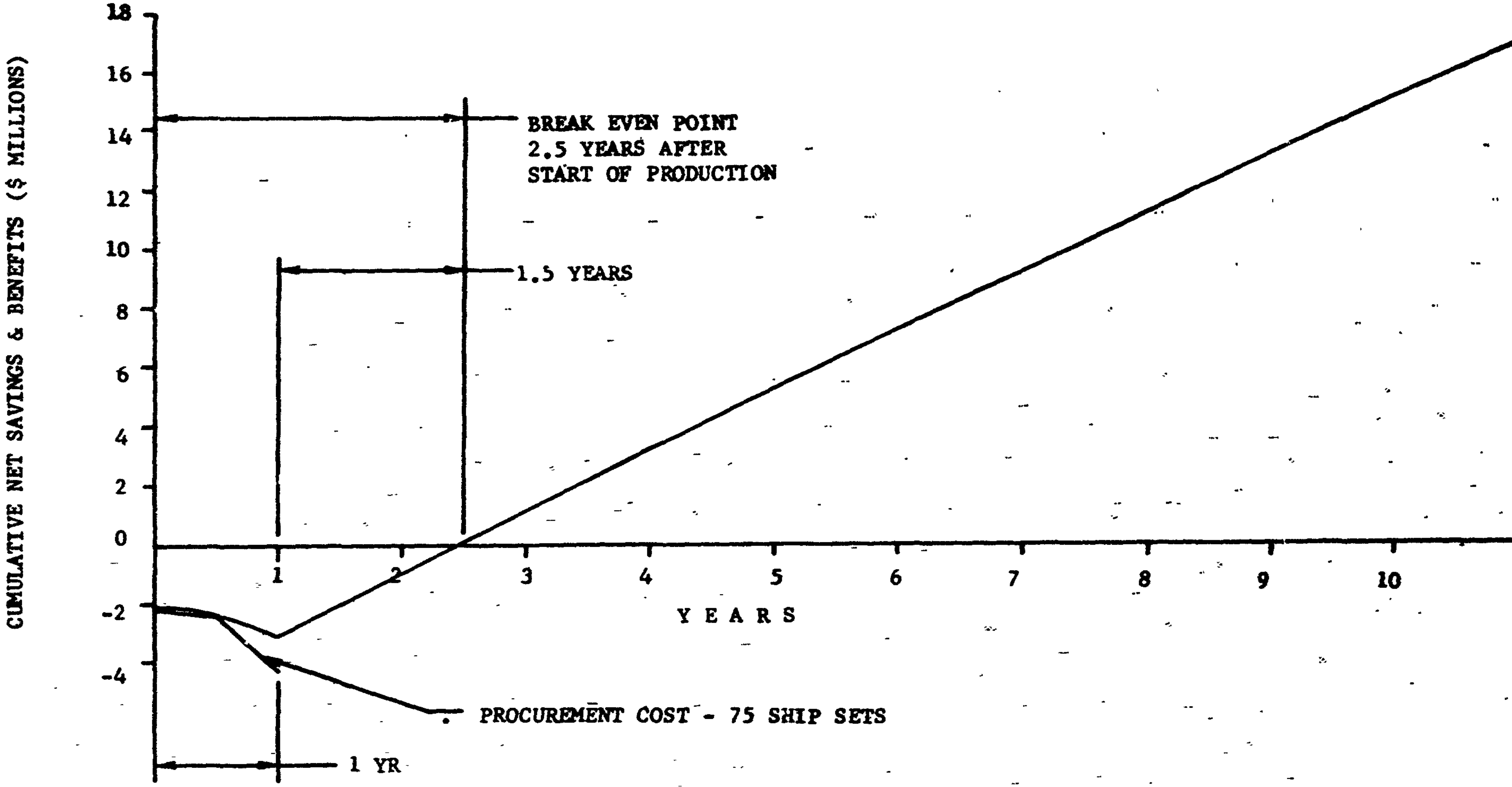


FIGURE 8-100

CH-54
HYBRID I AIDAPS SYSTEM
TIME PHASED PROGRAM
COST SAVINGS & BENEFITS
(GROUPED SYSTEMS - EXPECTED CONDITIONS)

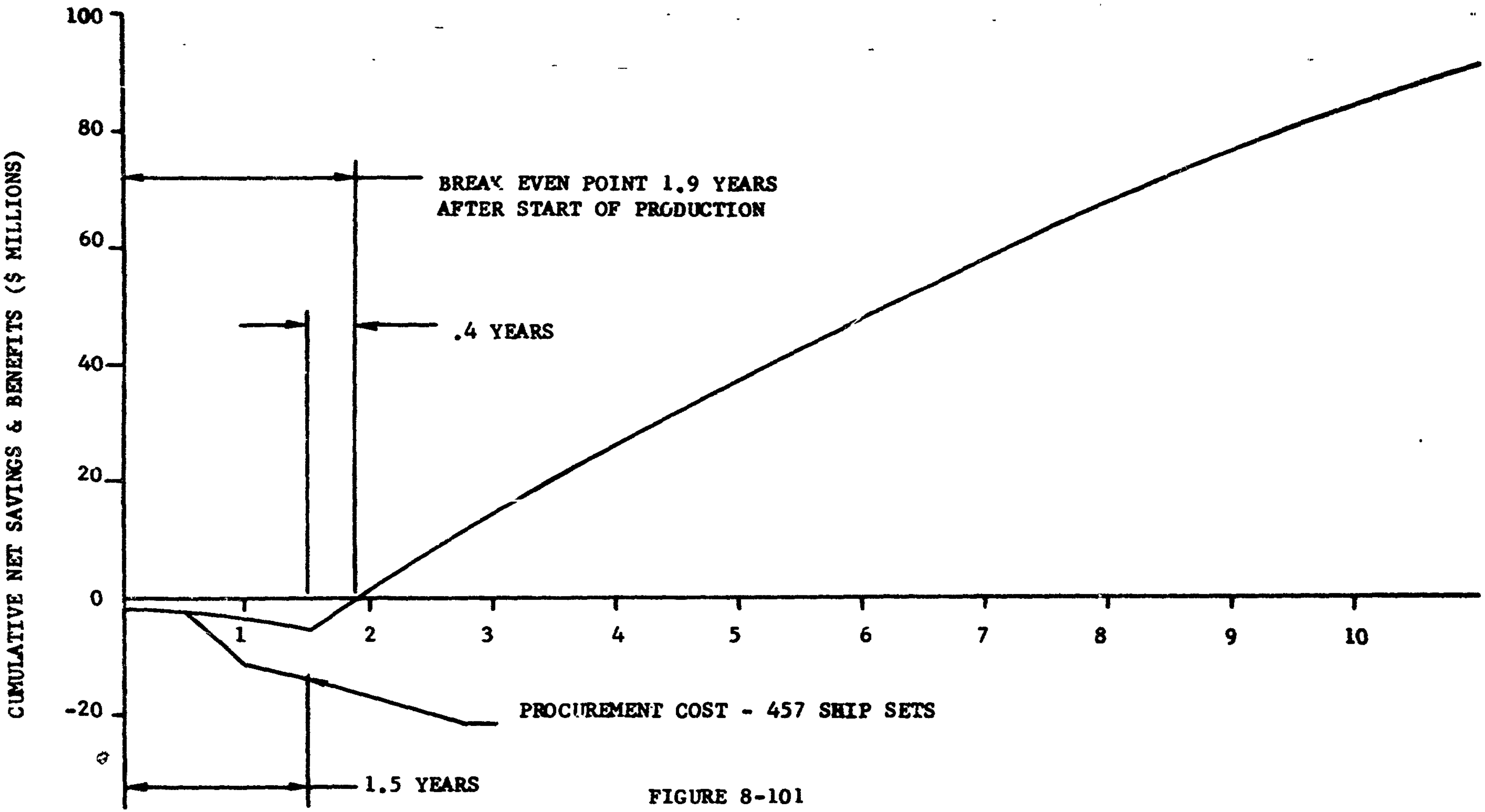


FIGURE 8-101
CH-47
HYBRID I AIDAPS SYSTEM TIME PHASED PROGRAM
COST SAVING & BENEFITS
(GROUPED SYSTEMS - EXPECTED CONDITIONS)

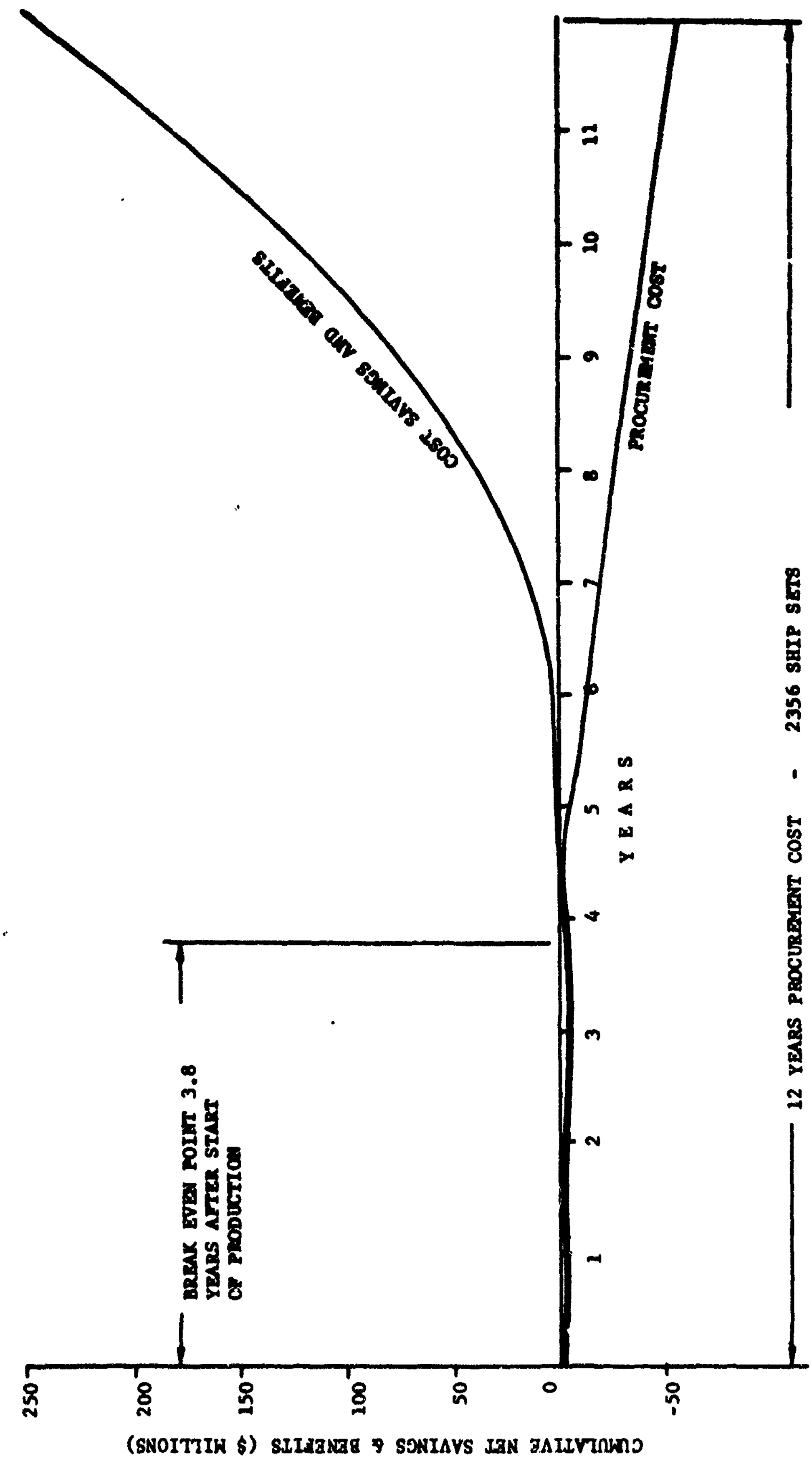


FIGURE 8-102
UTTAS
HYBRID I AIDAPS SYSTEM TIME PHASED PROGRAM
COST SAVINGS & BENEFITS
(GROUPED SYSTEMS - EXPECTED CONDITIONS)

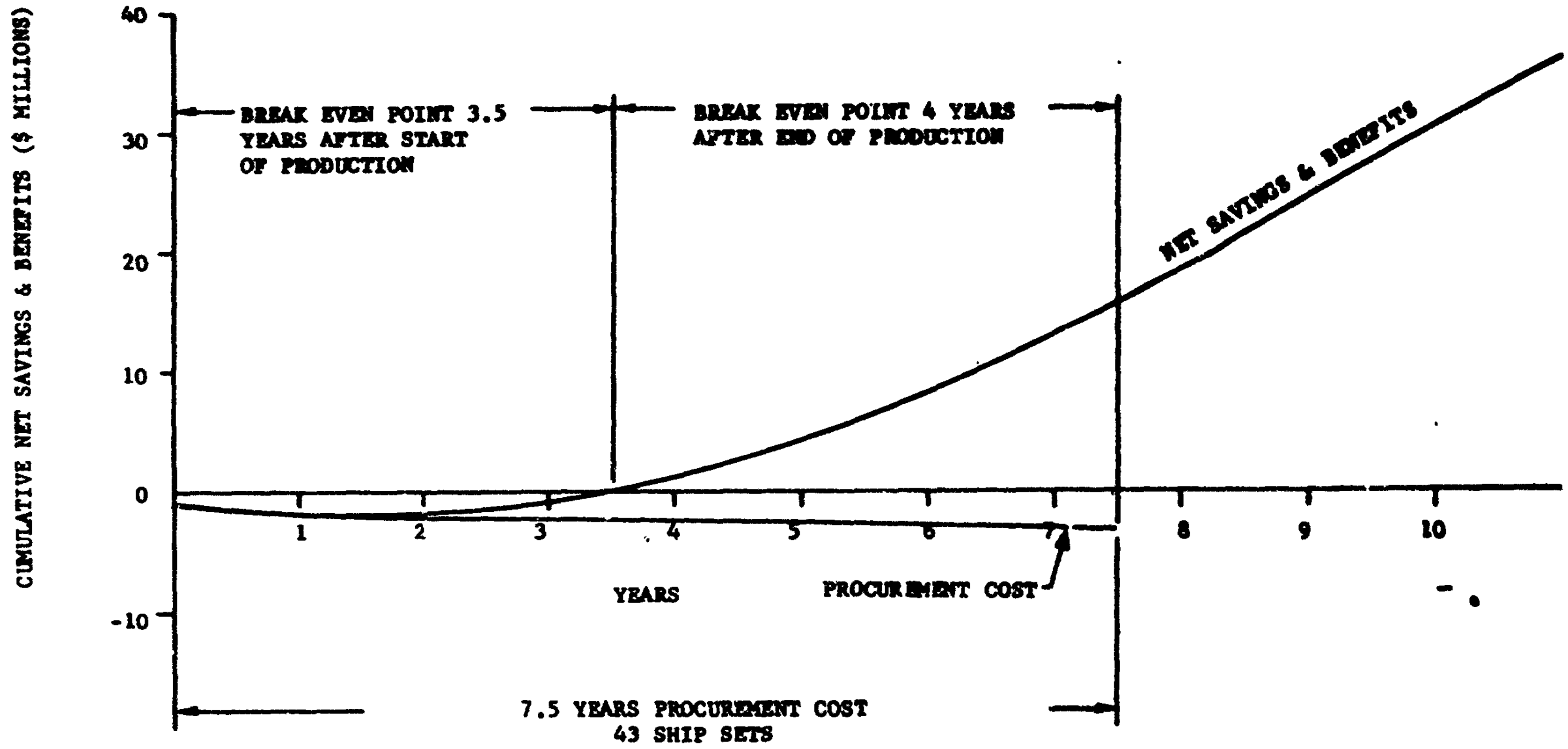


FIGURE 8-103
HLH
HYBRID I AIDAPS SYSTEM
TIME PHASED PROGRAM
COST SAVINGS & BENEFITS
(GROUPED SYSTEMS - EXPECTED CONDITIONS)

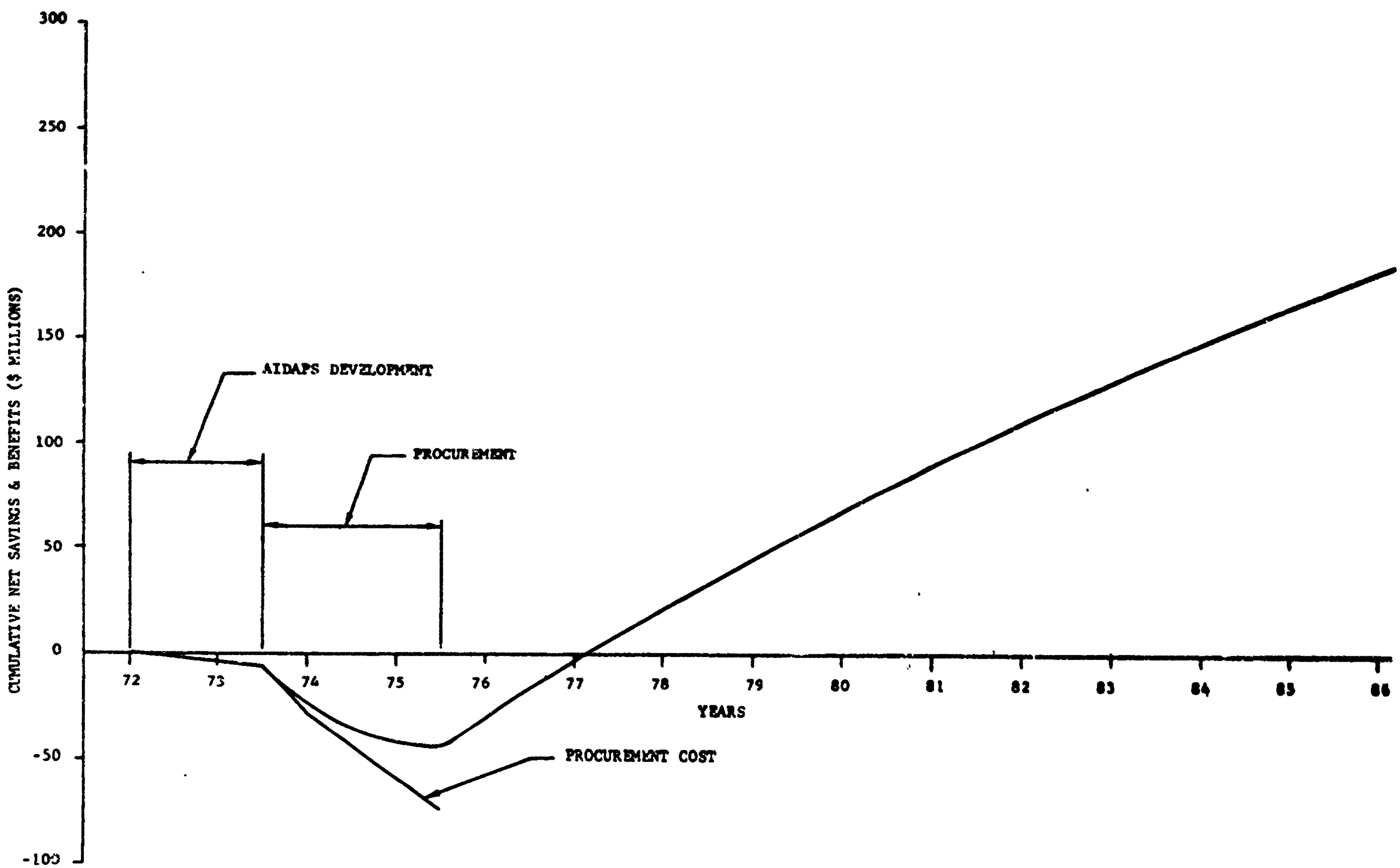


FIGURE 8-104 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS GROUPED SYSTEM - EXPECTED CONDITION (UH-1, AH-1 & OV-1)

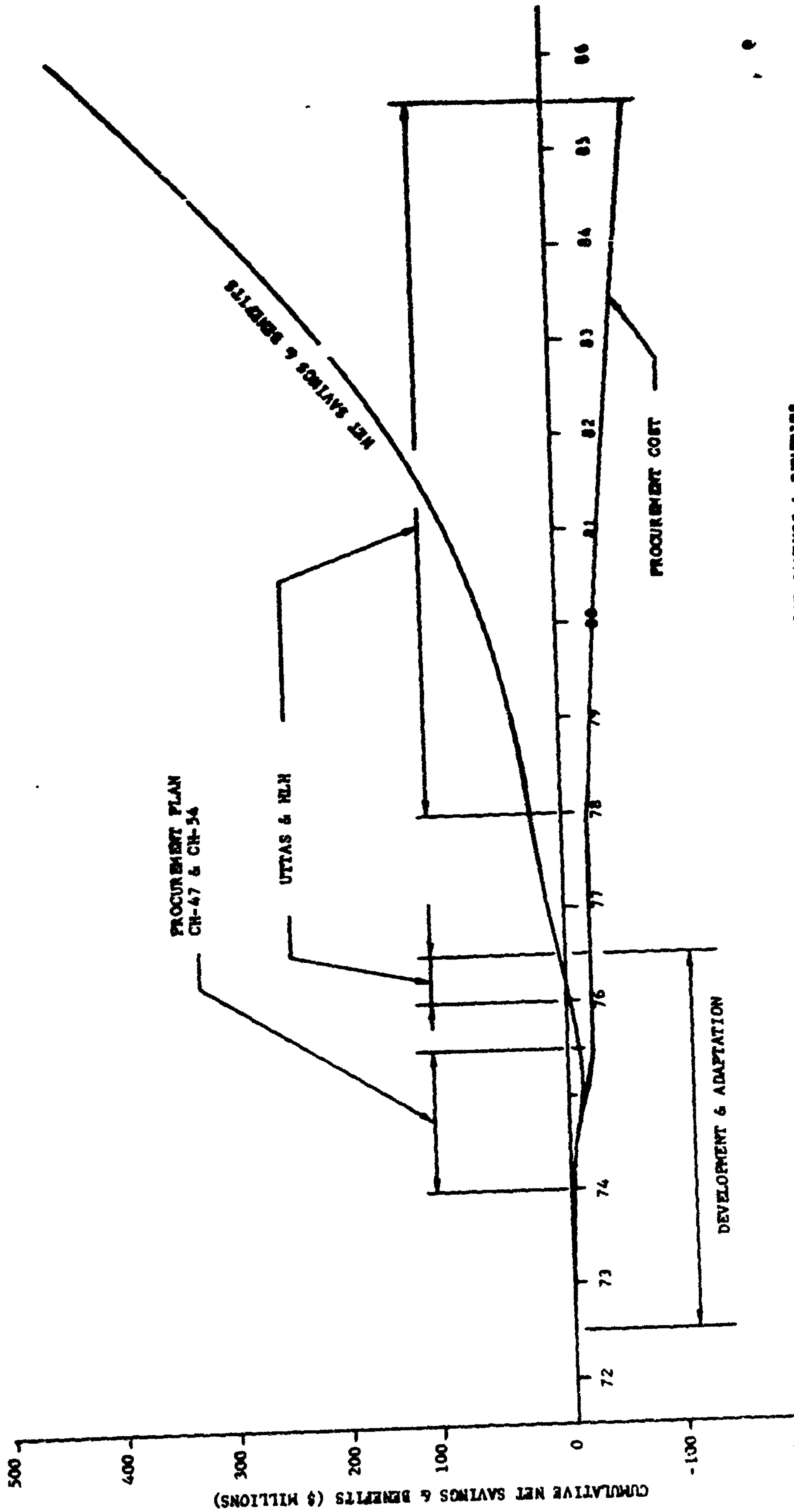


FIGURE 8-105 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS GROUPED SYSTEM - EXPECTED CONDITION (CH-47, CH-54, UTTAS & HLH)

8.3 UNIVERSAL AIDAP SYSTEMS

8.3.1 DETERMINATION OF OPTIMUM UNIVERSAL SYSTEM CHARACTERISTICS

Some elements of the contemplated AIDAPS are inherently "universal". These are the Flight Data Entry Panel, the Recorder or the Printer, and the Ground Processing Unit or Airborne Digital Processor. The alternatives are a reflection of the possibility of selecting either Airborne or Complex Hybrid Systems although some of the airborne items such as the Printer and Digital Processor could be used as parts of the Ground Processing Unit. This tradeoff, therefore, is addressed to the functions which are performed by the airborne Central Electronic Unit (CEU) in either the Airborne or the Hybrid I configuration. Since all the system candidates are almost equally effective, a minimum cost tradeoff is sufficient.

A Universal System is defined as a system with the maximum realizable automatic inspection diagnosis and prognosis capabilities which will operate in all sensor-equipped Army aircraft without modification (some [illegible] method of programming the CEU for each type of aircraft is presumed).

8.3.1.1 Universal System Type A

One possible universal system has a CEU of sufficient capacity to serve the largest and most complex aircraft, the HLH, but uses that same CEU on all the 9548 existing and projected Army aircraft considered by this study.

a) The estimated cost of the CEU for the HLH is $14,300 based upon a quantity of 500 units (see Figure 8-106). In a quantity of 9,548 units, the estimated cost would be $9,200.

b) The estimated costs for unique CEU's for each aircraft, from Figure 8-106 must also be adjusted for the number of each type as shown below:

Type	# of A/C	Base Cost	Ratio*	Extension (cost=f (# of A/C))
OH-6	234	8.7K	1.13	9.82K
OH-58	1906	8.7K	0.82	7.15K
UH-1	3568	10.5K	0.75	7.87K
AH-1	584	10.7K	0.99	10.60K
U-21	104	10.4K	1.16	12.10K
OV-1	228	10.8K	1.14	12.30K
CH-47	451	12.5K	1.02	12.70K
CH-54	74	12.2K	1.34	16.40K
UTTAS	2356	13.5K	0.80	10.80K

*Based on a standard 90% curve

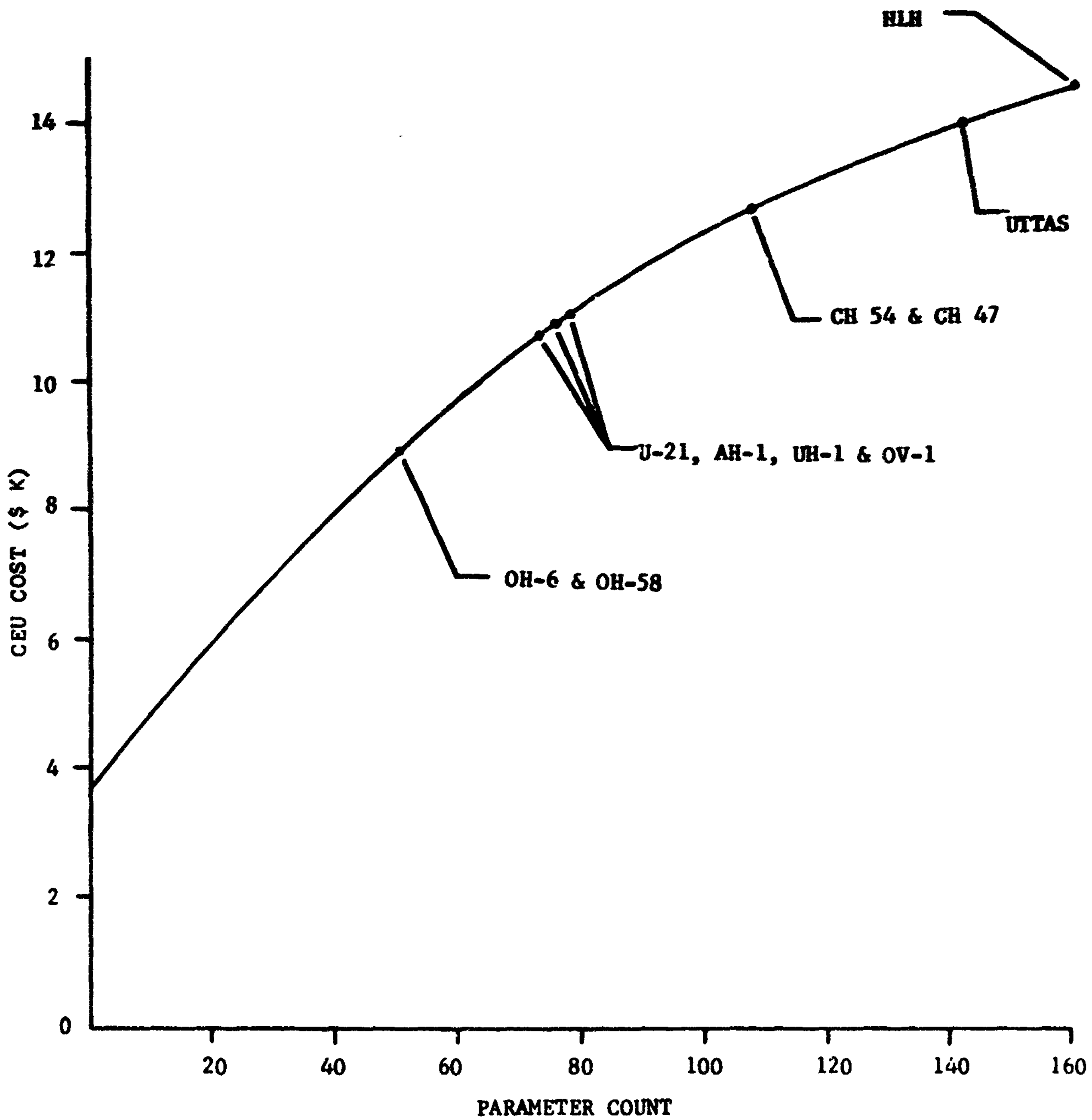


FIGURE 8-106
AIDAPS
AIRCRAFT CEU COST VS PARAMETER COUNT
(UNIT COSTS BASED ON A MFG. QUANTITY OF 500 UNITS)

c) **Using the data from paragraphs a and b above the differential in hardware cost due to using a Universal CEU can be computed as follows:**

A/C Type	Cost as a function of # of A/C	Cost of Univ. CEU	Difference	# of A/C	Added Costs
OH-6	9.82K	9.2K	-0.62K	234	-139 M
OH-58	7.15K	9.2K	2.05K	1906	3,900 M
UH-1	7.87K	9.2K	1.33K	3568	4,750 M
AH-1	10.60K	9.2K	-1.4K	584	-816 M
U-21	12.10K	9.2K	-2.9K	104	-302 M
OV-1	12.3K	9.2K	-3.1K	228	-706 M
CH-47	12.7K	9.2K	-3.5K	451	-1,580 M
CH-54	16.40K	9.2K	-7.2K	74	-533 M
UTTAS	10.80K	9.2K	-1.6K	2356	-3,760 M
					+0.814 M

d) The DDT&E costs for the HLH has been estimated at $6.62M. To this must be added the aircraft adaptation cost for each aircraft type. In the same order as above these are: (in millions of dollars) 0.30, 0.30, 0.34, 0.37, 0.37, 0.38, 0.49, 0.47, 0.50. The sum is $6.62M + $3.52M = $10.14M DDT&E cost for the Universal CEU.

e) The total DDT&E costs for 10 Unique systems is:

A/C Type		Costs
OH-6	=	3.54M
OH-58	=	3.54M
UH-1	=	4.0M
AH-1	=	4.28M
U-21	=	4.27M
OV-1	=	4.41M
CH-47	=	5.65M
CH-54	=	5.44M
UTTAS	=	5.77M
HLH	=	6.62M
		$47.32M

f) From c, a, and e the net savings which would accrue if a Universal System were used can be computed; i.e., 47.32M - 10.14M - 0.81M = $36,37M. This is in comparison with uniquely developed and produced systems for each of the ten aircraft types.

g) In comparison with the Grouped AIDAPS, the ratio of cost reduction as a function of the number of aircraft in each group, and the extension of the costs are tabulated below:

A/C Type	Group	No. of A/C in Group	CEU Base Cost	Ratio	Extension Cost = f(# of A/C)
OH-6 OH-58	I	2140	8.7K	0.8	$ 6.96K
UH-1 AH-1 U-21 OV-1	II	4484	10.8K	0.72	$ 7.78K
CH-47 CH-54 UTTAS HLH	III	2924	14.3K	0.77	$11.0K

h) Using the data from a and b, the differential in hardware costs between the "one box" Universal CEU and a CEU dedicated to each group can be computed:

Group	Cost = f (# of A/C)	Cost of Univ. CEU	Differential	# of A/C	Added Costs
I	6.96K	9.2K	2.24K	2140	4,790M
II	7.88K	9.2K	1.42K	4484	6,360M
III	11.0 K	9.2K	-1.8 K	2924	-5,260M
					+$5,890M

i.e., an additional cost of $5.89M would be incurred if the Universal System were used instead of a system for each group.

i) The DDT&E and the adaptation costs for each group are:

Group	DDT&E	Adapt Costs	Subtotal
I	3.54M	0.30	3.84M
II	4.0 M	0.37 + .37 + 0.38	5.12M
III	5.65M	.47 + .50 + .57	7.19M
			$16.15M

j) From a, h and i the net savings would be $0.16K if a Universal System were used instead of group systems (16.15M-10.1M-5.89M = $160,000).

8.3.1.2 Modular Universal System (Type B)

Another universal type hardware concept must be considered. This is the concept that a CEU of sufficient capacity to handle all of Group II would be used on all aircraft, accepting the cost, size and weight penalties in Group I, and using an ancillary unit (a Remote Data Acquisition Unit (RDAU) to accommodate the Group III aircraft.

a) The Group II CEU, with a capacity of 80 parameters, would have a basic cost of $11.1K for 500 units. If procured for the entire fleet, the unit cost becomes 11.1 x .645 = $7.15K.

b) The estimated base cost for a RDAU with a capacity for 80 parameters is $4,000 (500 unit cost). Since the RDAU is used in only the 2924 aircraft of Group III, the quantity procurement factor is 0.77 and the unit price becomes $3,080.

c) Contrasting the Universal Type A system with the Universal System Type B indicates added costs as follows:

Group	Cost Type B	Cost of Univ. Typed	Differential	# of A/C	Added Costs
I	7.15	9.2	+2.05	2140	$ 4,990M
II	7.15	9.2	+2.05	4484	9,190M
III	10.15	9.2	-0.95	2924	-2,790M
					+$10,790M

d) The DDT&E for the CEU/RDAU system is:

$4.0M basic + $0.5M RDAU + $3.5M adaptation = $8.0M.

Thus, the CEU/RDAU (Universal Type B) system saves $2.1M in DDT&E costs and $10.8M in hardware costs for a total of 12.9 million savings when compared to the Universal Type A Systems.

8.3.1.3 Optimum Universal Systems Conclusions

A Modular Universal System wherein a basic CEU serves the entire AIDAPS equipped inventory, and an ancillary RDAU unit, is added to serve the larger aircraft, is the most economical in terms of DDT&E and hardware procurement. Although this tradeoff was applied to the complex Hybrid configuration, the results apply directly to the airborne configuration since, again, only the CEU/RDAU would be involved.

8.3.2 MODULAR UNIVERSAL SYSTEM COST EFFECTIVENESS

This analysis pertains to the modular Universal Airborne and Hybrid I AIDAP systems. These systems allow the cost of implementing the basic AIDAPS configuration to be amortized over the entire inventory of the study aircraft. The description of the Universal AIDAPS application is presented in Section 5.0. The following discussion presents the results of this analysis. The analysis was performed under three sets of conditions. These conditions are optimistic, expected and pessimistic. The input data used to develop each of these conditions for each aircraft are shown in Tables 8-1 and 8-8. The variation in input data under these three conditions provides a band of potential cost savings for each aircraft with the Universal System concept. Figures 8-107 through 8-116 present the system net savings associated with the Universal System by aircraft type. In each case, Hybrid I provides essentially the same or slightly greater savings than the Airborne System, with the exception of the HLH. The HLH Airborne system provides a slightly greater savings over the three sets of conditions. However, for the pessimistic and optimistic conditions, the savings are so small that the system net savings are essentially the same between the two systems.

Figures 8-117 through 8-126 show the net cost savings for each major savings item and for each aircraft. The curves show that the relative importance of the various cost items vary significantly from aircraft to aircraft. For the AH-1, OH-6, OH-58 and U-21, savings in accidents is the most important cost item. This is due to the relatively high accident rate on these aircraft, and the maturity and/or simplicity of the aircraft designs which prevent high cost savings in maintenance and logistics.

For the CH-47, CH-54, OV-1, HLH and UTTAS, benefits due to increased aircraft effectiveness are the most important. This is due to the large amounts of maintenance downtime on these complex aircraft, and also due to the high cost of these aircraft. The cost of the aircraft is used as a factor in the value of the decreased downtime.

The relative value of personnel savings ranges from the second most important element for the OH-6, OH-58 and OH-1 aircraft the least important item on the HLH. This is primarily due to the relative costs of the aircraft. The aircraft cost effects all cost items except personnel. Even logistic support is affected by the aircraft cost through the cost of aircraft parts. The cost of individual personnel, however, remains constant from aircraft to aircraft.

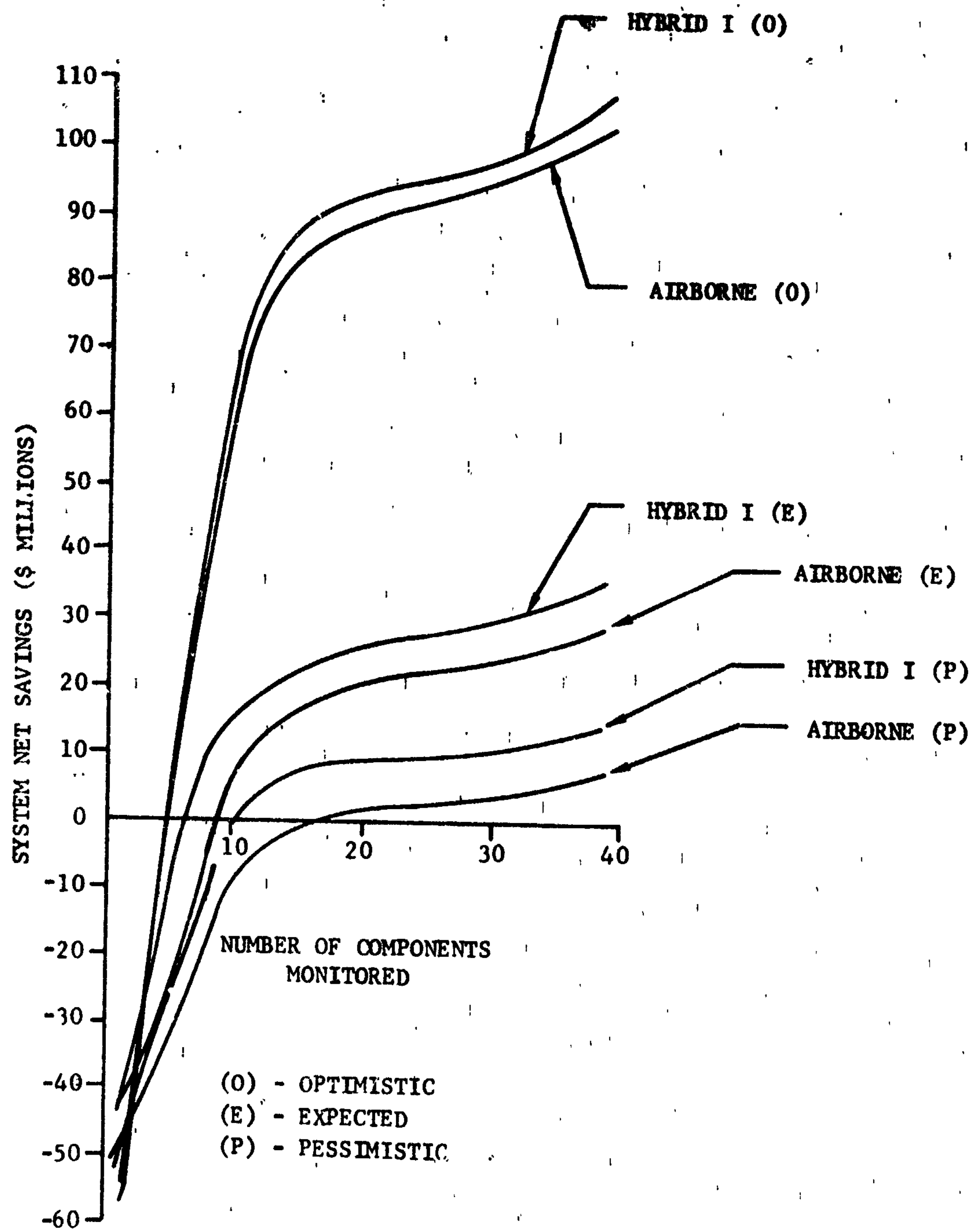


FIGURE 8-107 UNIVERSAL SYSTEMS
OH-58 SYSTEM NET SAVINGS
VS COMPONENTS MONITORED

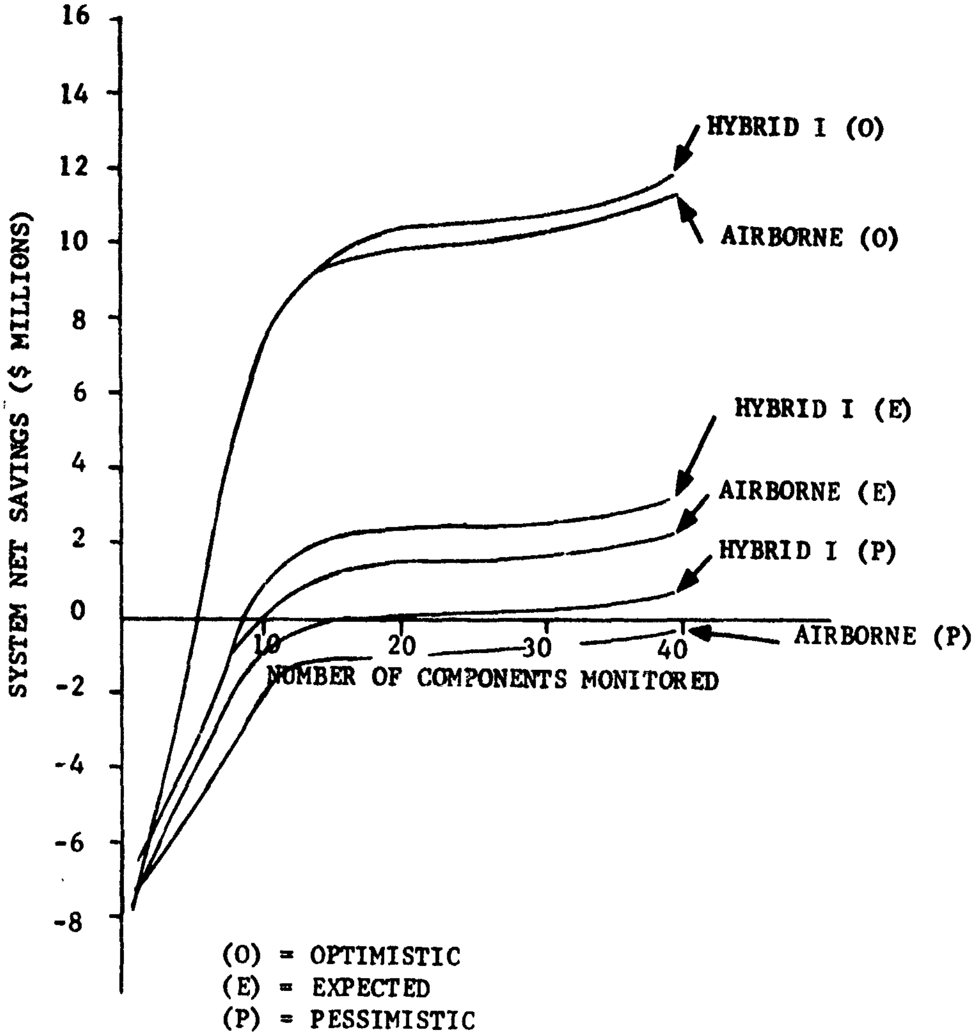


FIGURE 8-108 OH-6 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

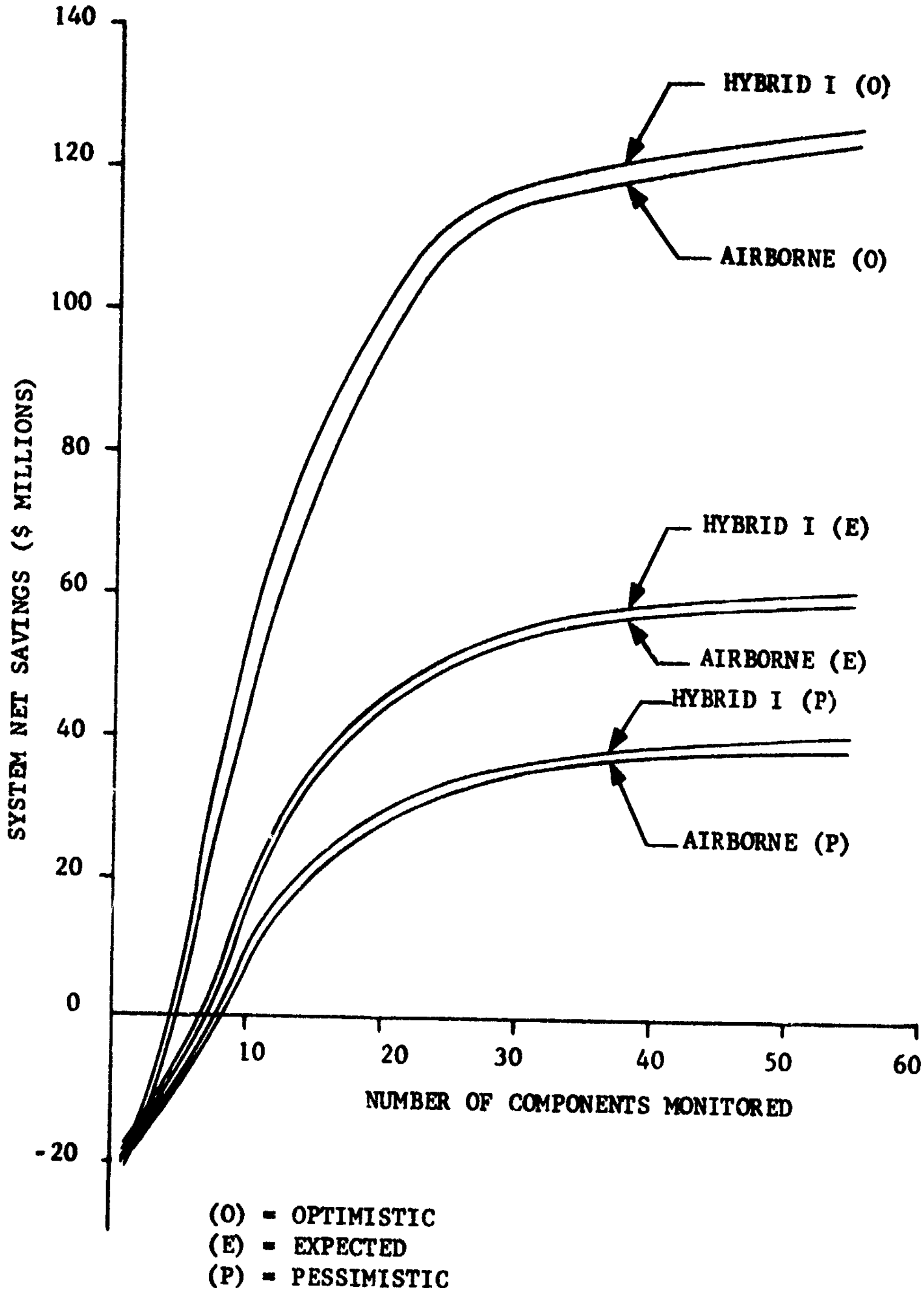


FIGURE 8-109 UNIVERSAL SYSTEMS - AH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

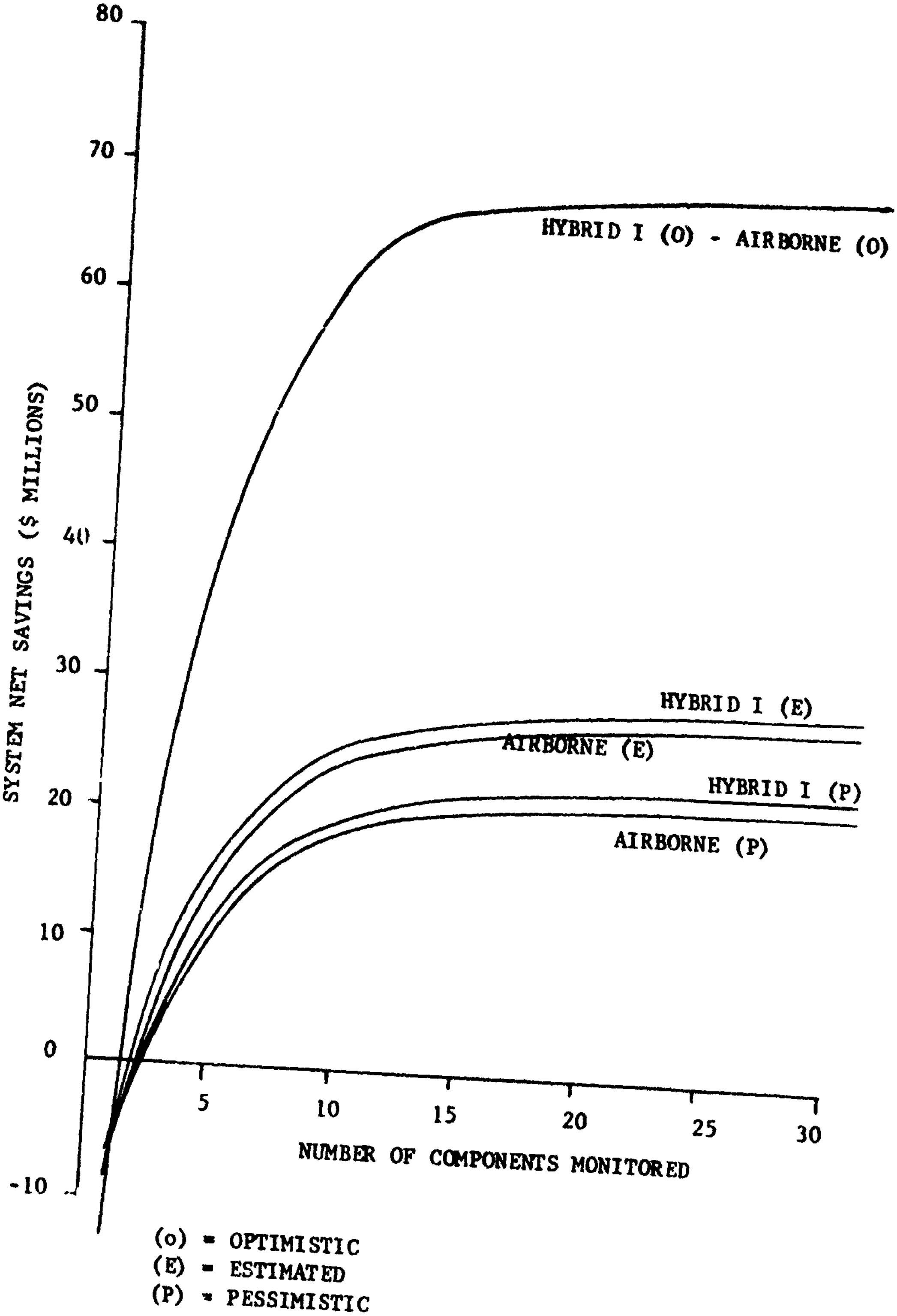


FIGURE 8-110 UNIVERSAL SYSTEMS - OV-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

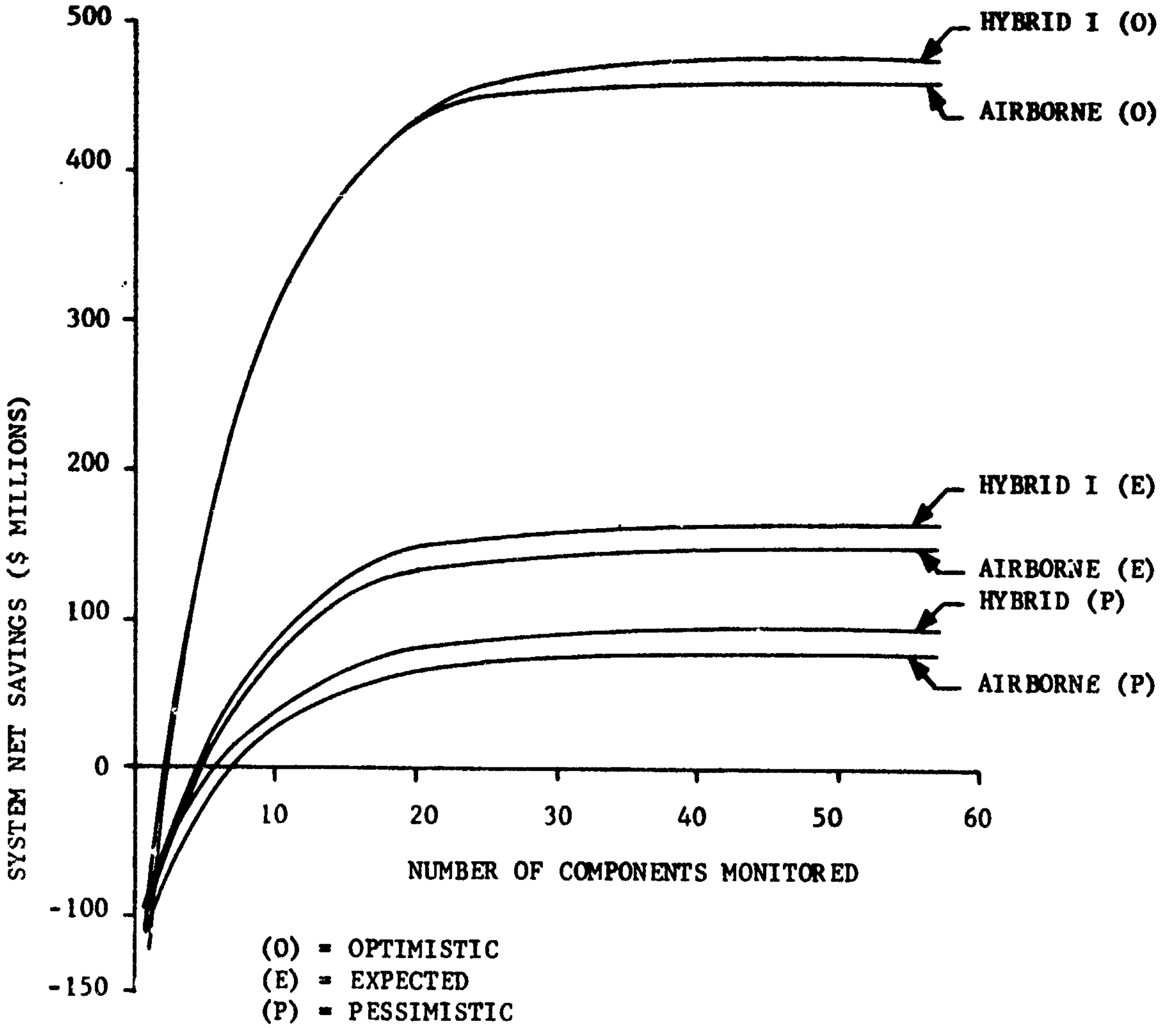


FIGURE 8-111 UH-1 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

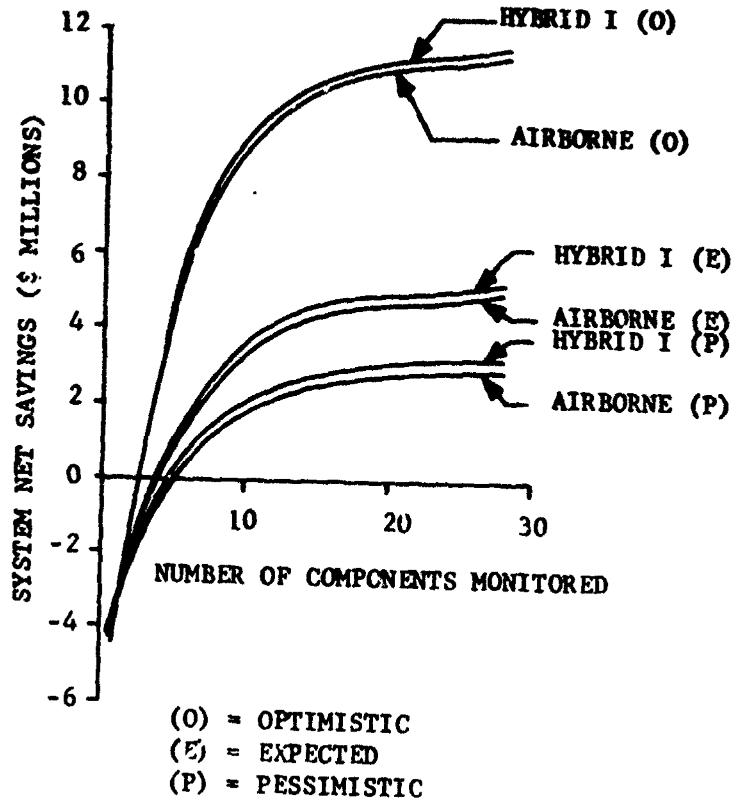


FIGURE 8-112 UNIVERSAL SYSTEMS - U-21 SYSTEM NET SAVINGS VS COMPONENTS MONITORED

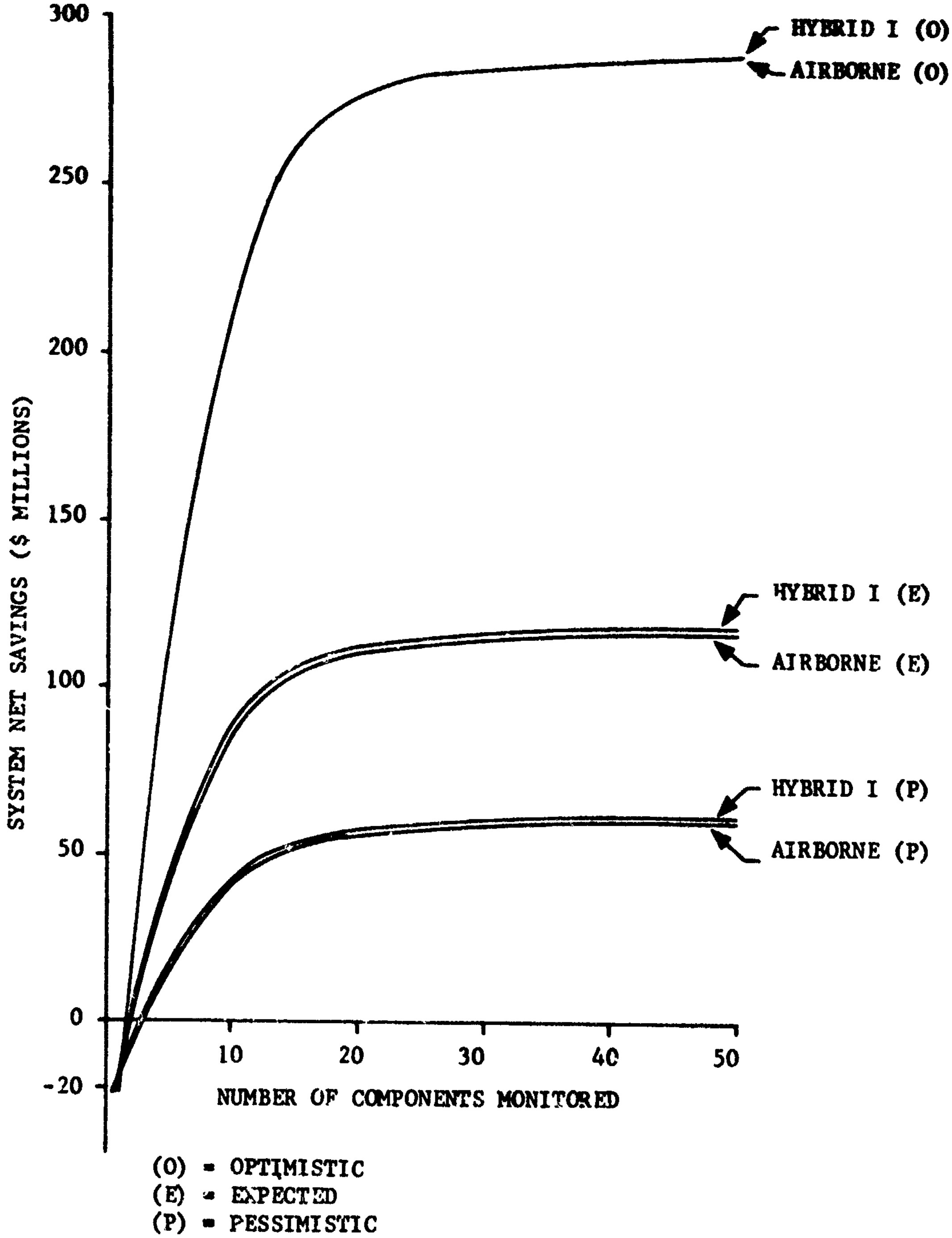
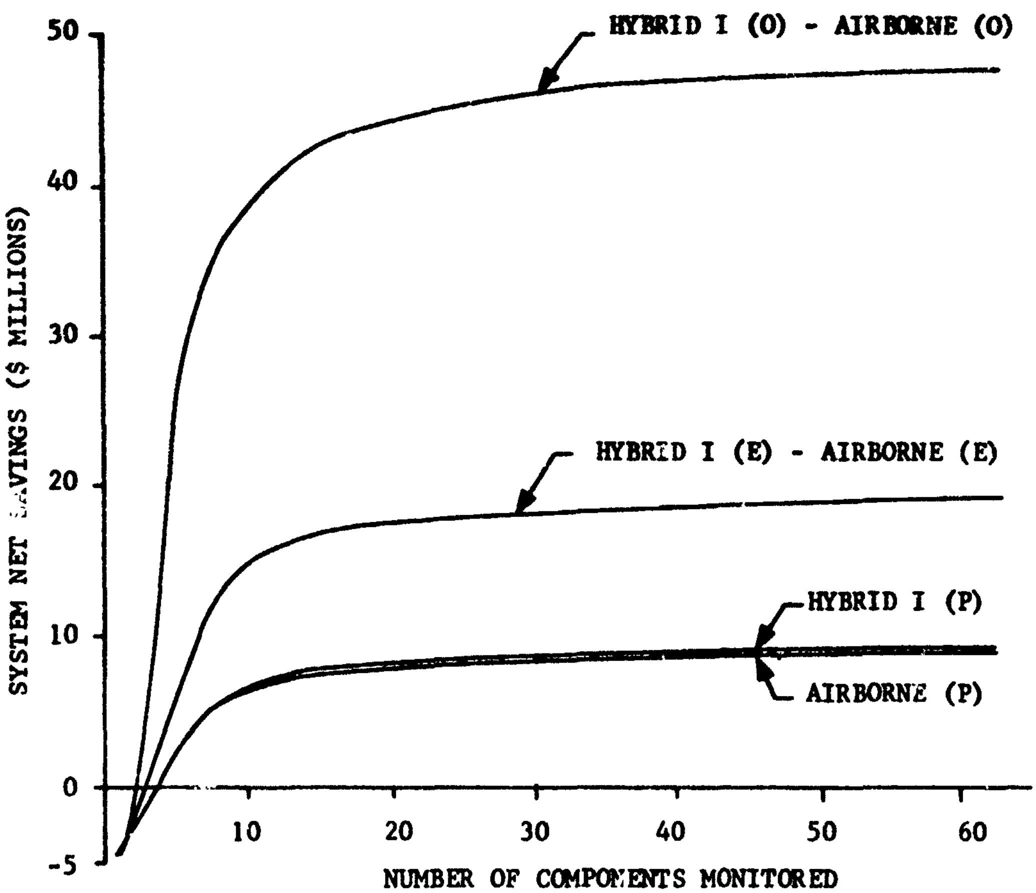
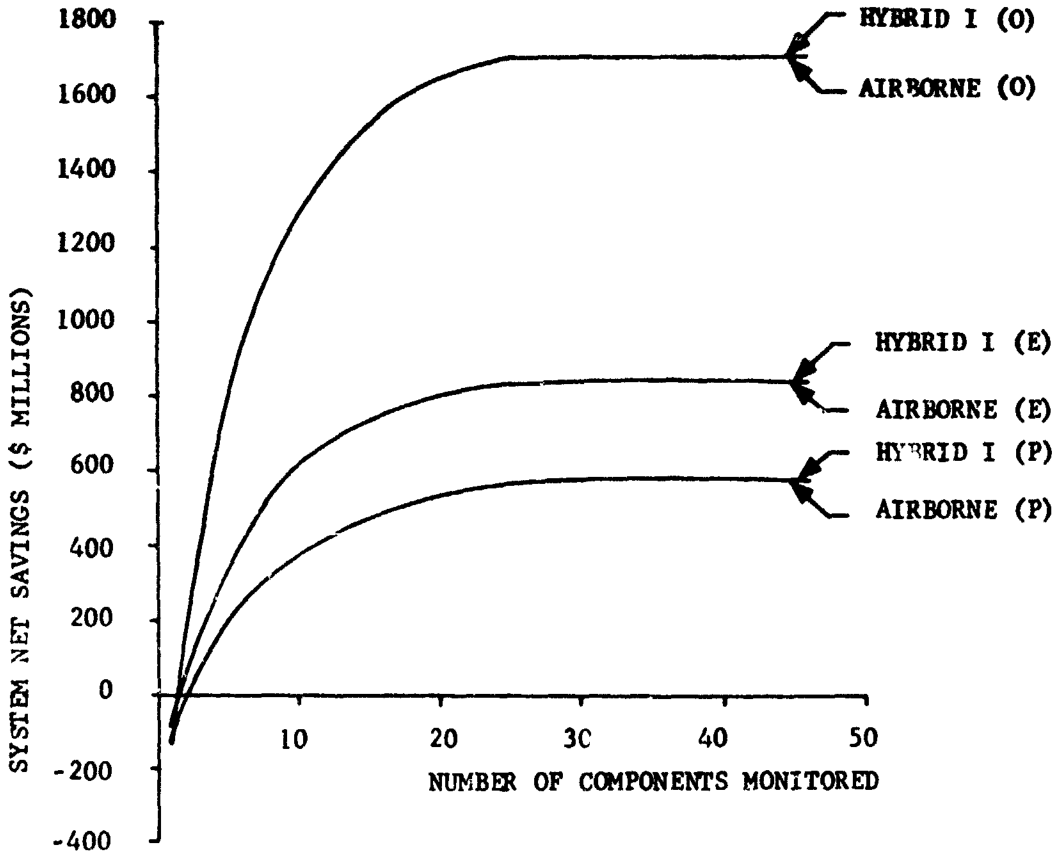


FIGURE 8-113 UNIVERSAL SYSTEMS - CH-47 SYSTEM NET SAVINGS VS COMPONENTS MONITORED



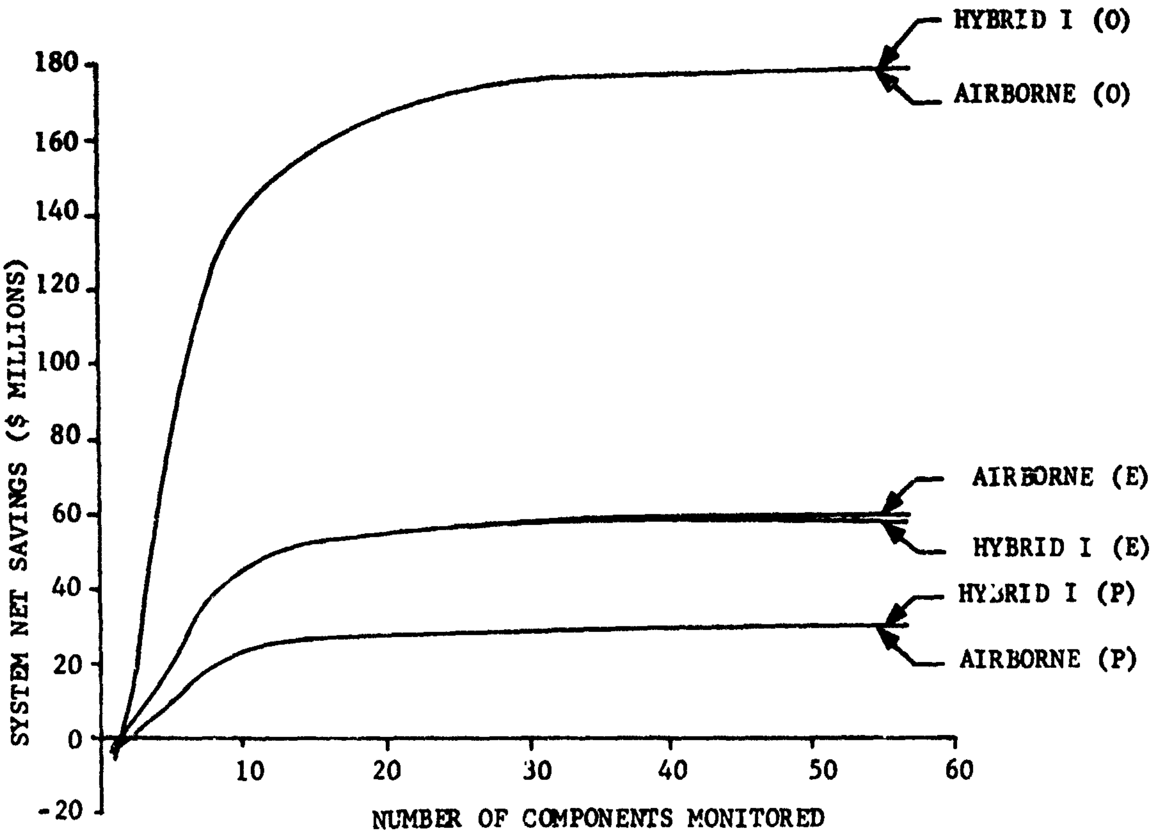
(O) = OPTIMISTIC
(E) = EXPECTED
(P) = PESSIMISTIC

FIGURE 8-114 UNIVERSAL SYSTEMS - CH-54 SYSTEM NET SAVINGS VS COMPONENTS MONITORED



(O) = OPTIMISTIC
(E) = EXPECTED
(P) = PESSIMISTIC

FIGURE 8-115 UNIVERSAL SYSTEMS - UTTAS SYSTEM NET SAVINGS VS COMPONENTS MONITORED



(O) = OPTIMISTIC
(E) = EXPECTED
(P) = PESSIMISTIC

FIGURE 8-116 UNIVERSAL SYSTEMS - HLH SYSTEM NET SAVINGS VS COMPONENTS MONITORED

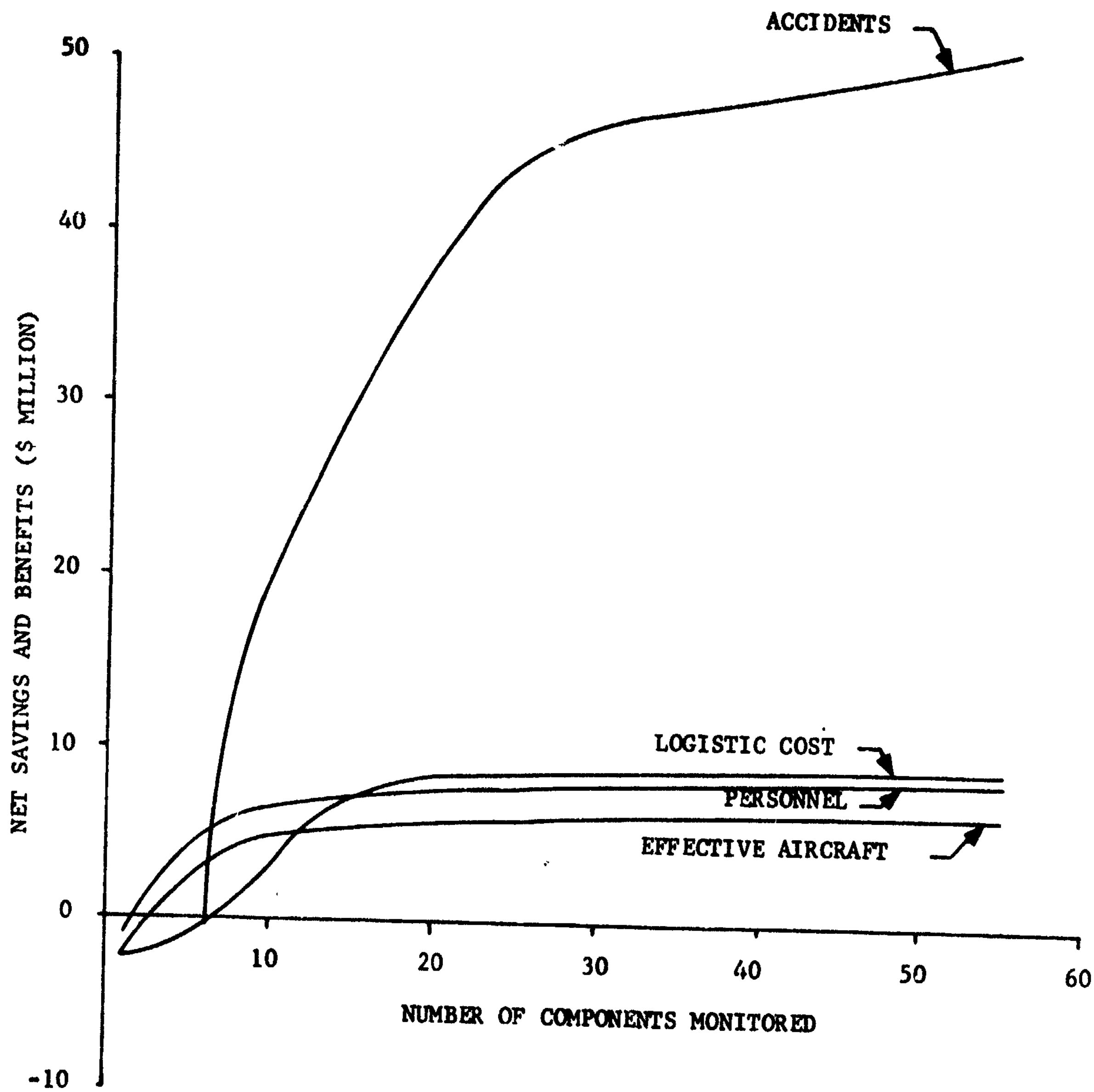


FIGURE 8-117 AH-1 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

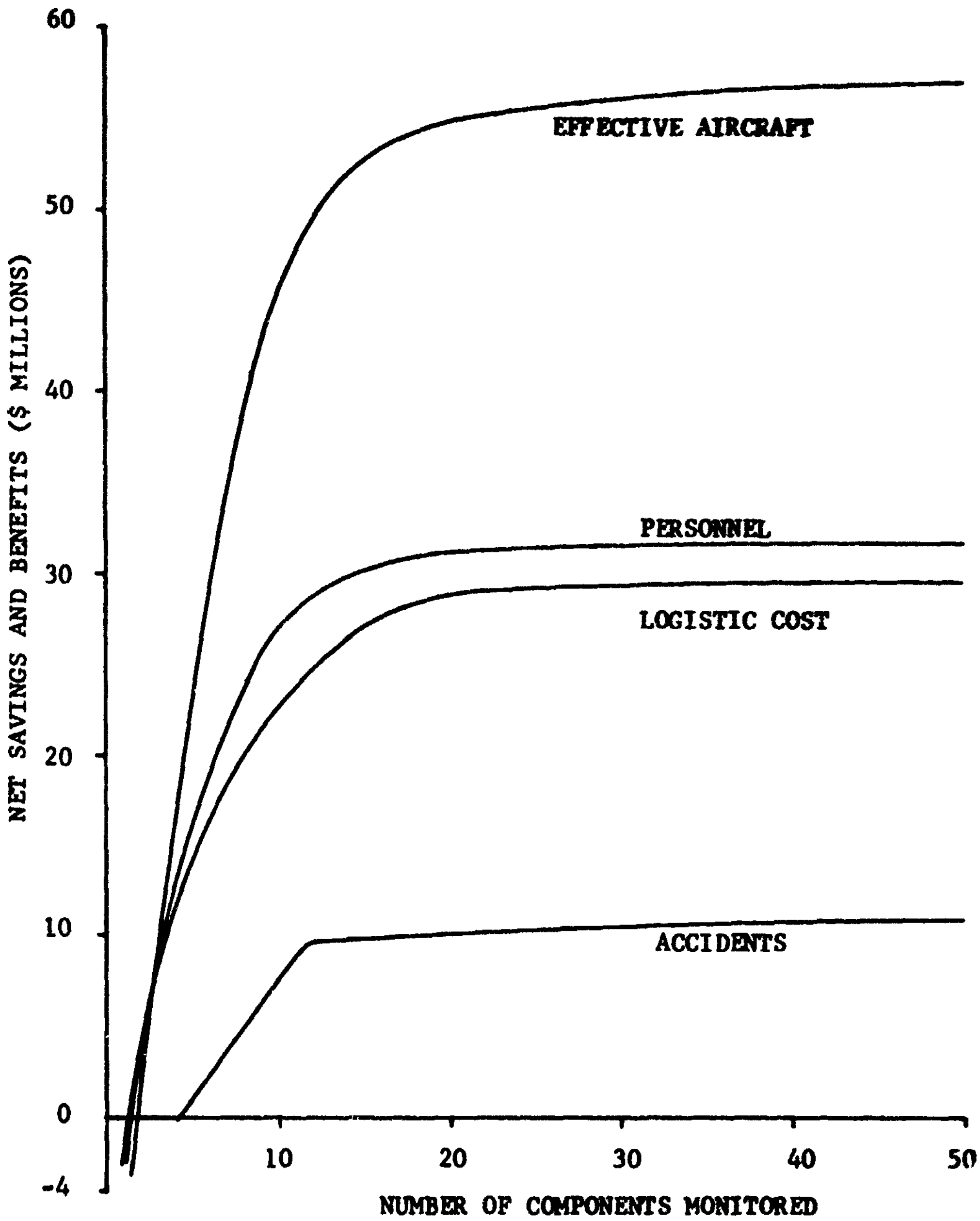


FIGURE 8-118 CH-47 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

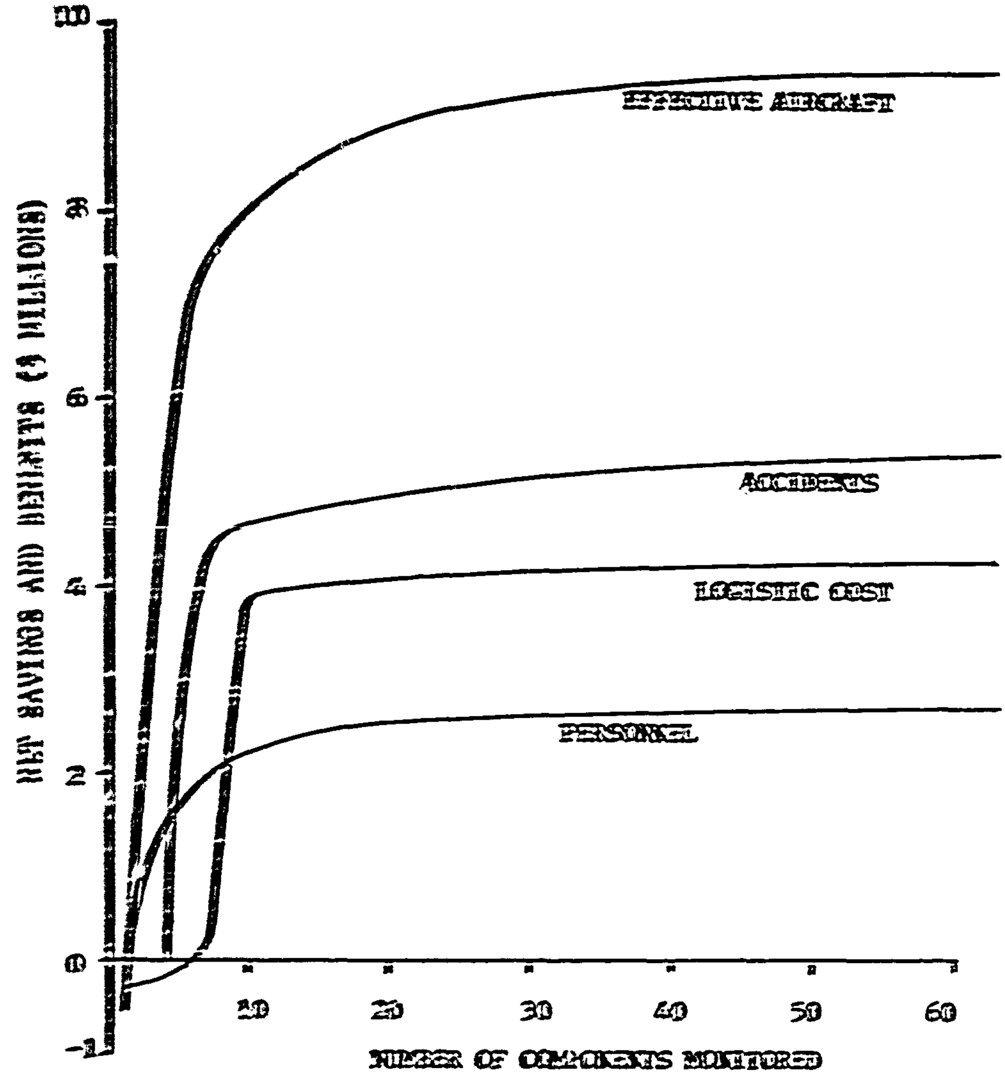


FIGURE 8-119 CH-54 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED
(EXPECTED CONDITION)

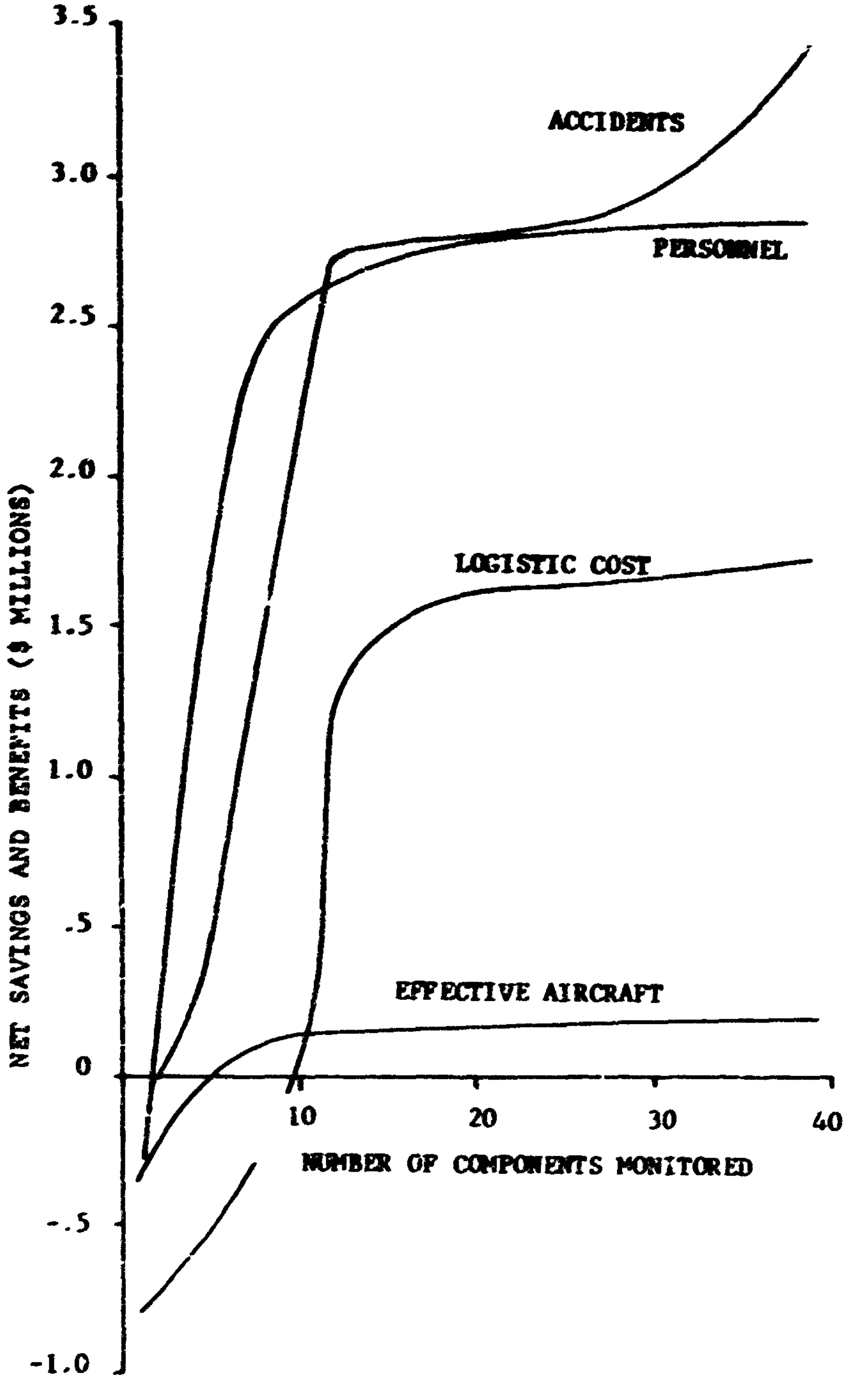


FIGURE 8-120 OH-6 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

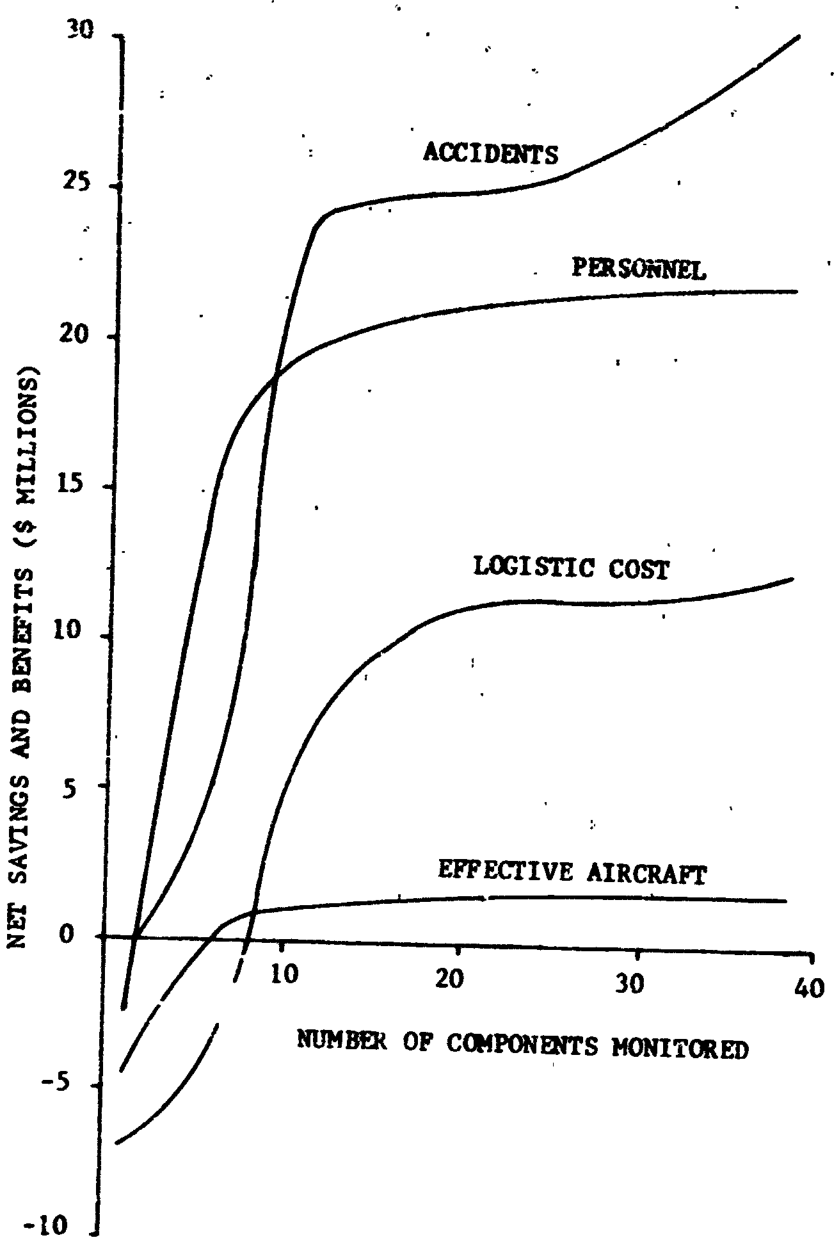


FIGURE 8-121 OH-58 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED
(EXPECTED CONDITION)

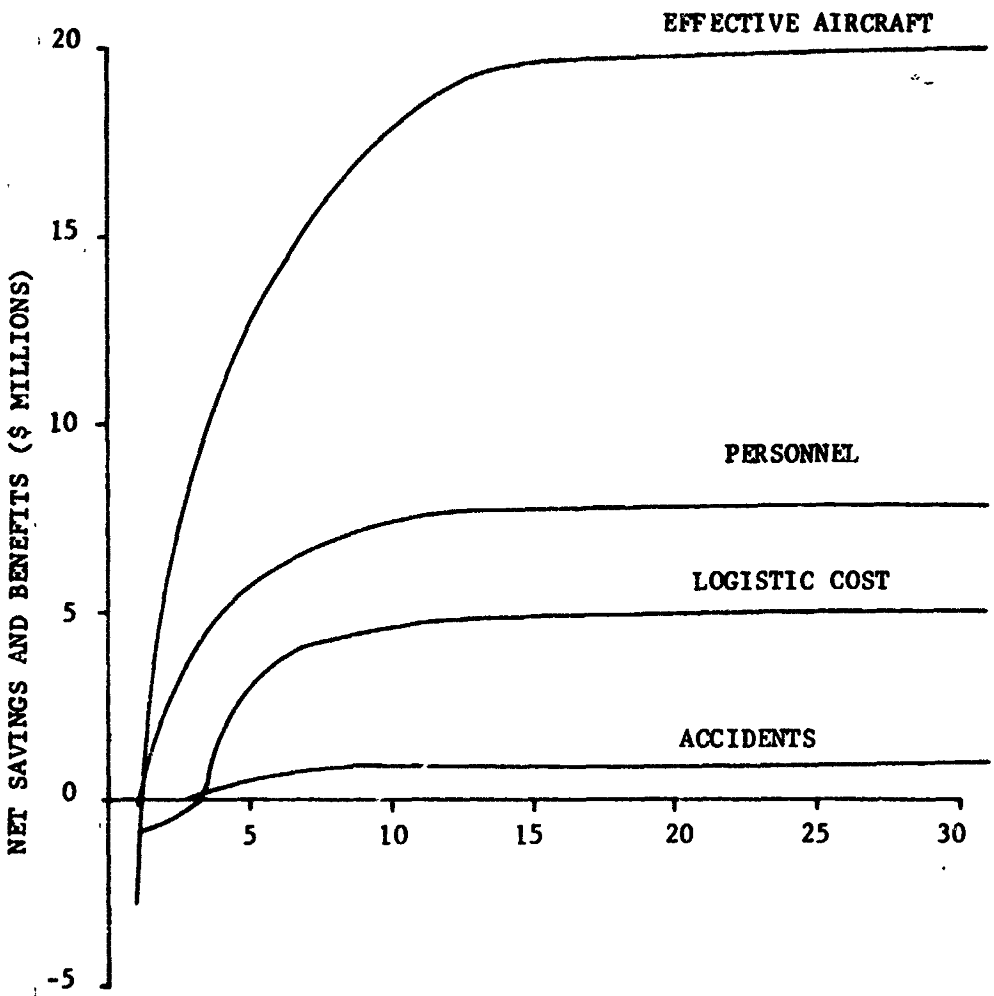


FIGURE 8-122 OV-1 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED
(EXPECTED CONDITION)

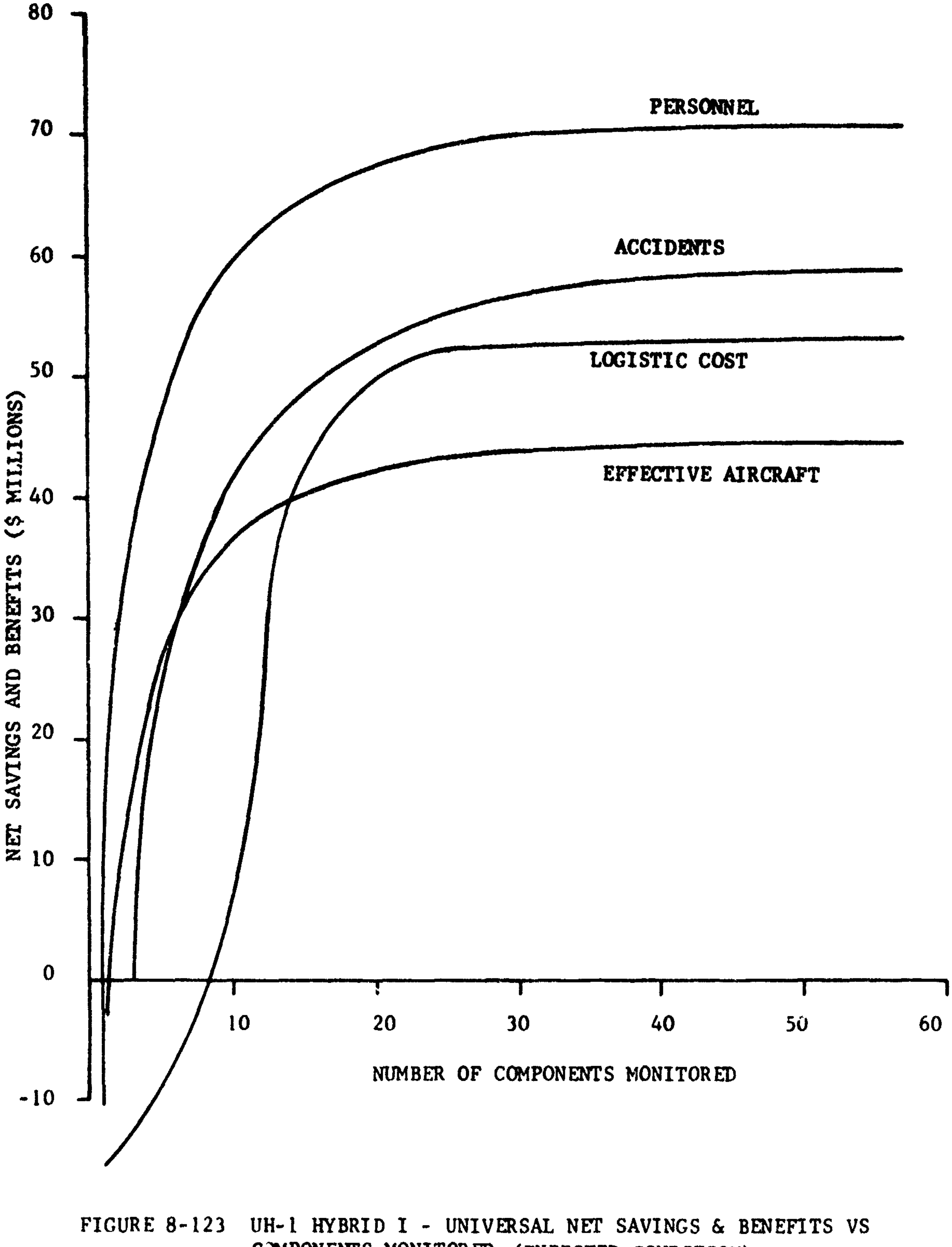


FIGURE 8-123 UH-1 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

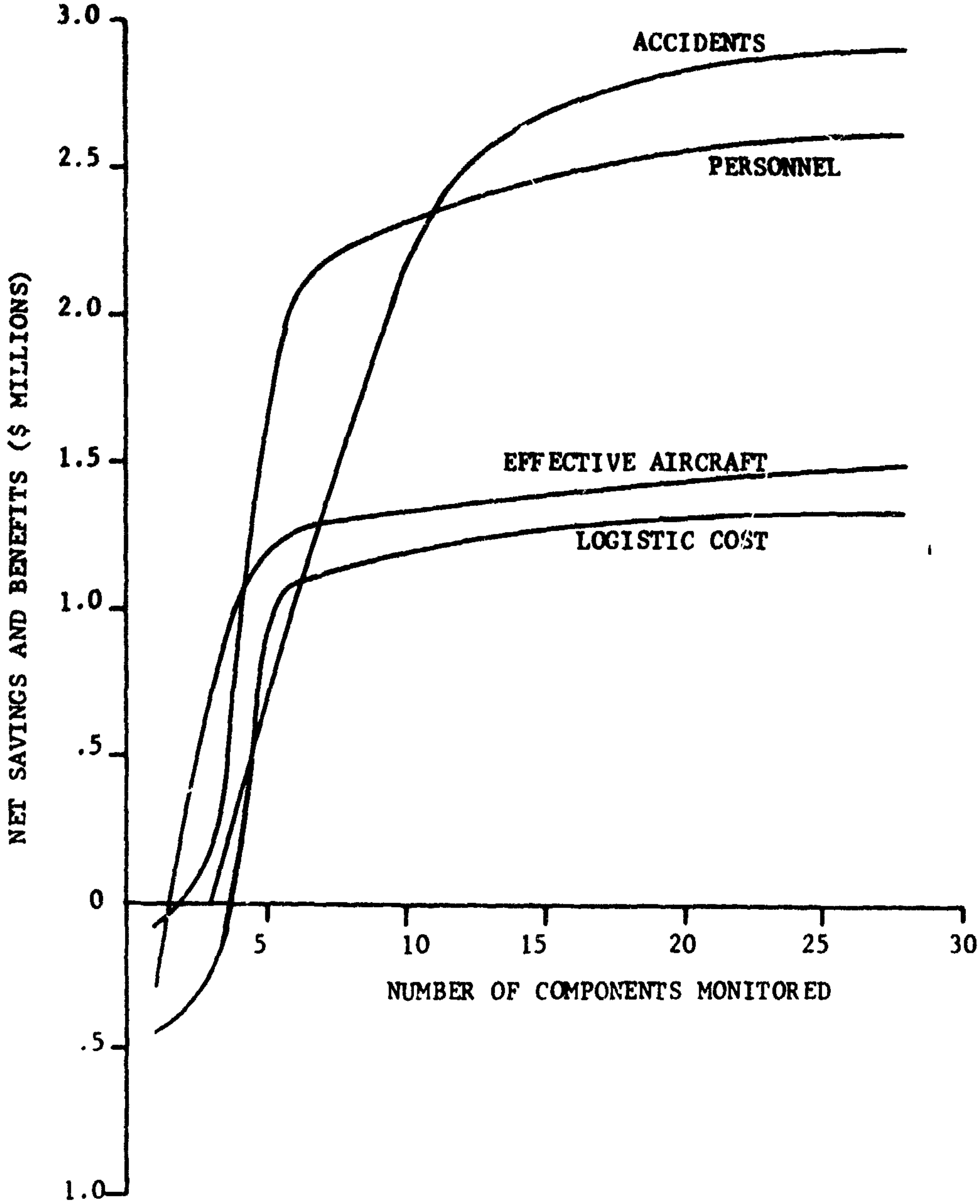


FIGURE 8-124 U-21 HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

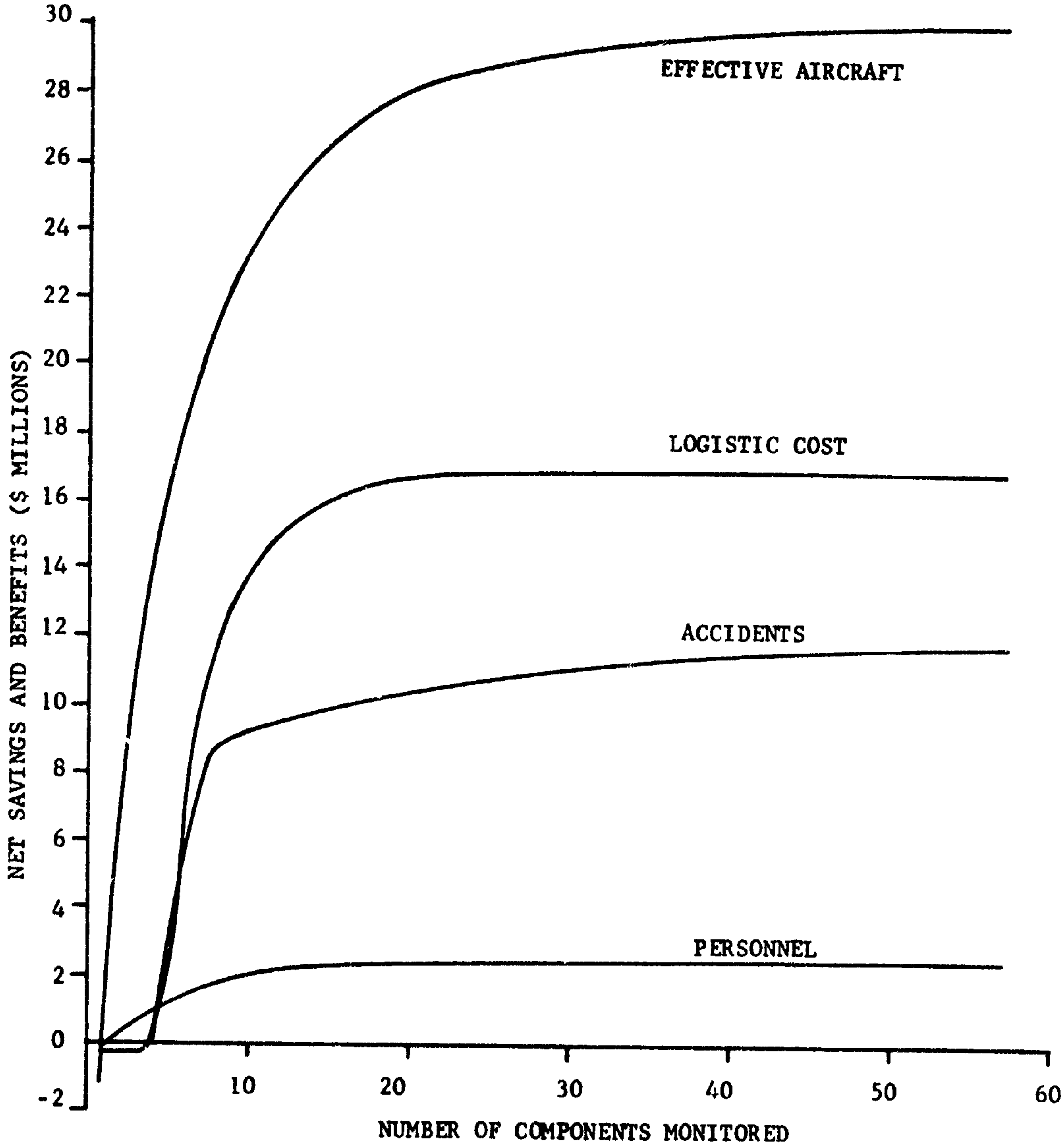


FIGURE 8-125 HLH HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED
(EXPECTED CONDITION)

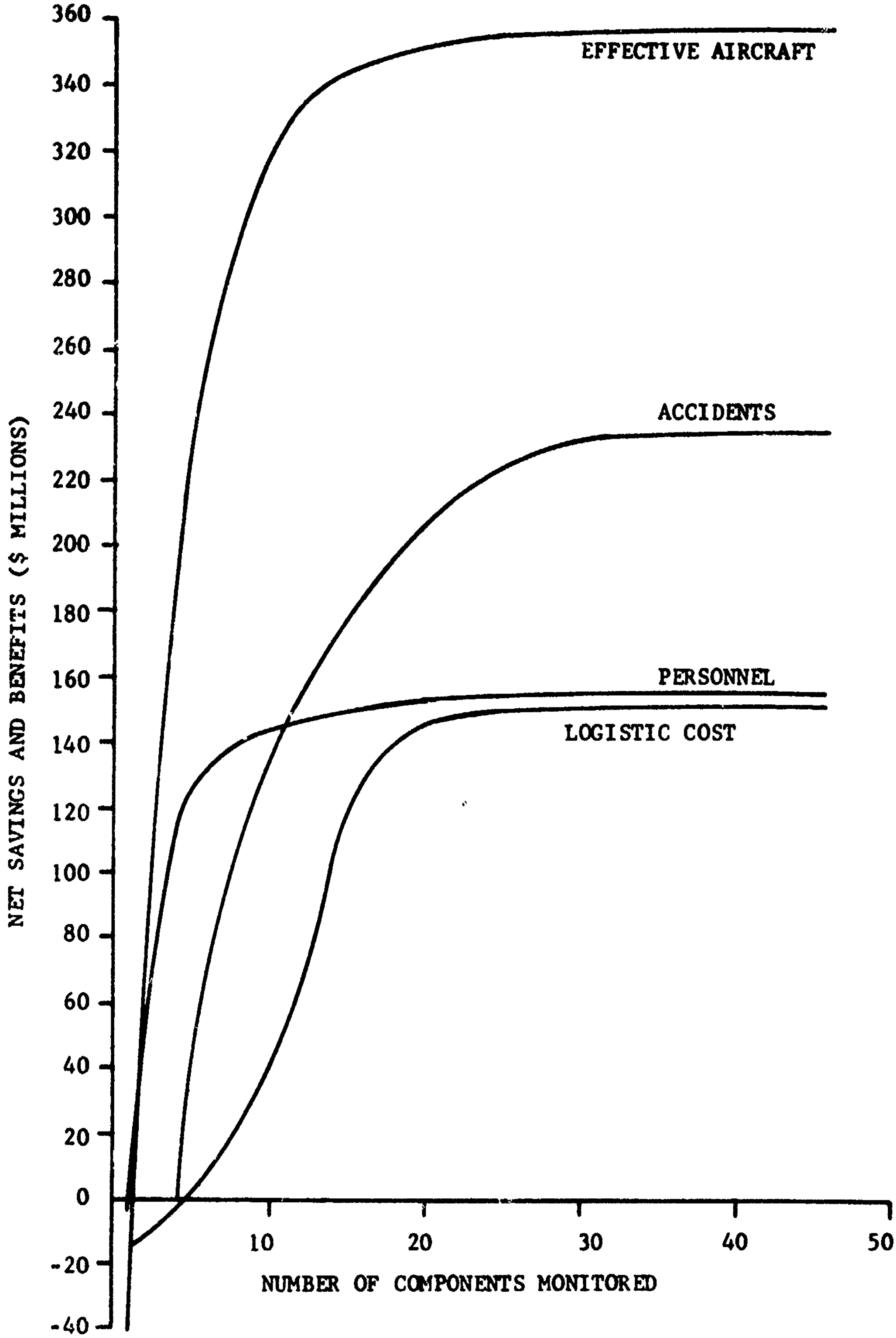


FIGURE 8-126 UTTAS HYBRID I - UNIVERSAL NET SAVINGS & BENEFITS VS COMPONENTS MONITORED (EXPECTED CONDITION)

8.3.3 EFFECTS OF INSPECTIONS, DIAGNOSIS, AND PROGNOSIS

Table 8-12 shows the gross savings due to each of the AIDAPS functional capabilities and Table 8-13 gives the same information expressed as a percentage of the gross savings for the Universal System tradeoff. The relative savings vary significantly from aircraft to aircraft. In most cases, inspections are the most important. These variations are due not only to differences in AIDAPS performance on different aircraft, but are also due to differences in aircraft maintenance or logistics requirements and to accident ratios. The variation in percentage savings between the OH-6 and OH-58 and AH-1 aircraft are primarily due to accident savings. All of these aircraft have high accident values due to engines, transmissions and/or weight and balance, and the accident data revealed that air warning (diagnostic) capability will be effective in reducing these accidents.

TABLE 8-12 SUMMARY GROSS SAVINGS AND BENEFITS ($MILLIONS)

HYBRID I AIDAPS - UNIVERSAL				
AIRCRAFT	INSPECTION	DIAGNOSIS	PROGNOSIS	TOTAL
OH-6	1.58	6.13	1.46	9.17
OH-58	11.33	51.66	11.56	74.55
UH-1	78.43	63.08	102.89	244.40
U-21	3.17	2.16	3.52	8.85
AH-1	7.60	44.69	23.72	76.01
UTTAS	405.67	199.44	310.62	915.73
OV-1	16.00	15.33	3.65	34.98
CH-54	9.12	5.29	7.94	22.35
CH-47	60.89	40.86	30.76	132.51
HLH	20.02	20.74	20.91	61.67

TABLE 8-13 GROSS SAVINGS AND BENEFITS SUMMARY HYBRID I - EXPECTED

SAVINGS AND BENEFITS				
AIRCRAFT	INSPECTION	DIAGNOSIS	PROGNOSIS	TOTAL ($M)
OH-6	17.2%	67.0%	15.8%	9.17
OH-58	15.2%	69.3%	15.5%	74.55
UH-1	32.1%	25.8%	42.1%	244.40
U-21	35.8%	24.4%	39.8%	8.85
AH-1	10.0%	58.8%	31.2%	76.01
UTTAS	44.3%	21.8%	33.9%	915.73
OV-1	45.7%	43.8%	10.5%	34.98
CH-54	40.8%	23.7%	35.5%	22.35
CH-47	46.0%	30.8%	23.2%	132.51
HLH	32.5%	33.6%	33.9%	61.67

8.3.4 UNIVERSAL AIDAPS PERFORMANCE TRADEOFFS

This study uses the term test accuracy (defined in paragraph 7.2.5) as a measure of the ability to perform prognosis and diagnosis. Since the diagnostic and prognostic capabilities of the systems are closely related, the same test accuracies were used for both capabilities. However, the possibility exists that the relative performance of the prognostic capability may not be the same as the diagnostic capability.

Also, the test accuracy may affect the ability to perform inspections. The basic inspection capability is defined by the ability of the AIDAPS to perform the inspection items called out in the inspection procedures. The inspection items selected for AIDAPS application represent only a portion (30% or less) of the total inspection requirements. There is no technical reason to believe the AIDAPS cannot perform inspections of the selected items. However, it is possible that with a low test accuracy, the number of selected inspection items will decrease. However, since there is no direct proportion between the number of inspection items which can be eliminated by AIDAPS and test accuracy, the term inspection efficiency is used. Inspection efficiency is then defined as the ratio of the achieved reduction in inspection requirements to the calculated reduction in inspection requirements in this report.

Figure 8-127, shows the effects of changes in diagnostic test accuracy under various assumptions of prognostic and inspection performance. The origin of each curve on the graph represents the benefits to be derived with a zero test accuracy for diagnosis and the end of each line represents the benefits with a 95 percent test accuracy for diagnosis. Each curve represents a different assumption of inspection efficiency or prognostic test accuracy. The lowest curve represents the performance of AIDAPS if no benefits are derived from inspections or prognosis. The next higher curve shows the benefits if no benefits are derived from inspections but a test accuracy of .95 is achieved for prognosis.

The next two lines represent assumptions of a .95 prognostic test accuracy and a 50 percent and 100% inspection efficiency, respectively.

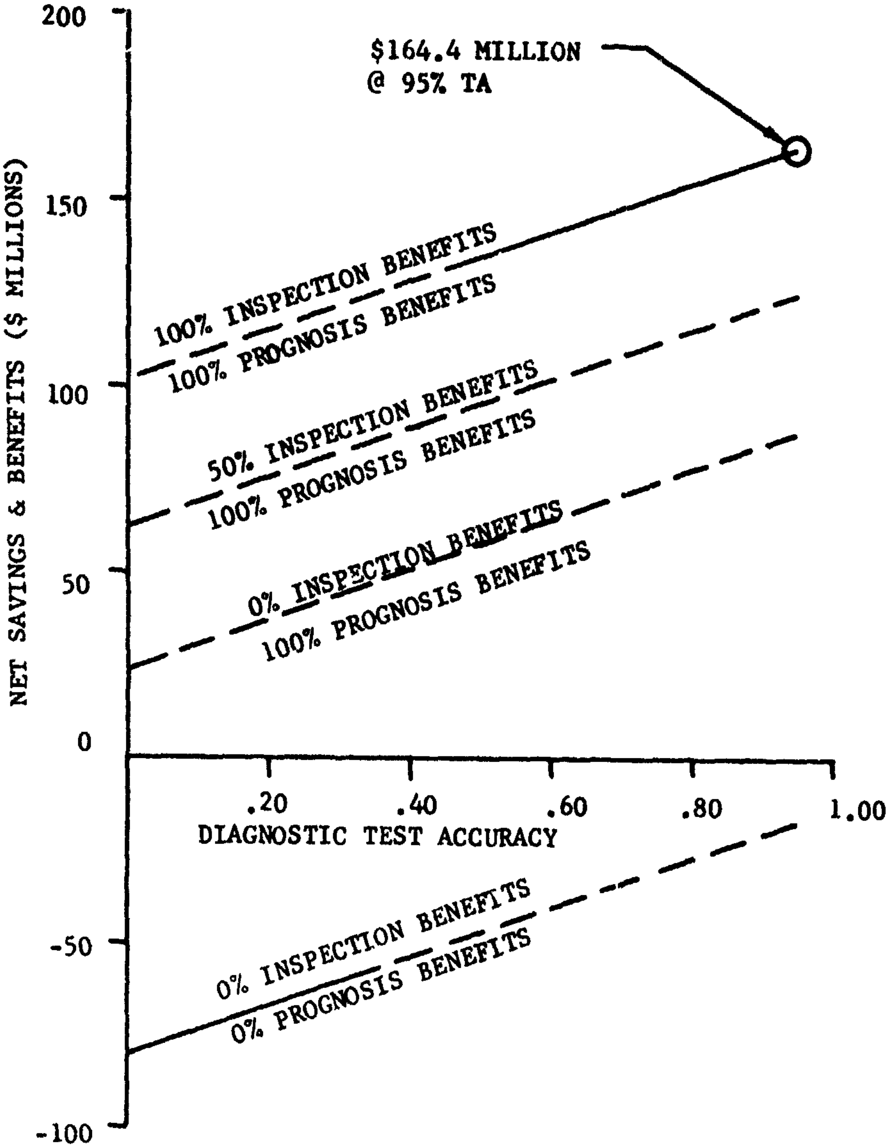


FIGURE 8-127
NET SAVINGS DUE TO DIAGNOSIS VS TEST ACCURACY
(UH-1 HYBRID 1)

Figure 8-128 shows similar data where diagnostic test accuracy and inspection efficiency are held constant at various values and prognostic test accuracies are allowed to vary.

Figure 8-129 shows three assumptions of the relative differences in the diagnostic and prognostic test accuracies and inspection efficiency for the Hybrid I AIDAPS. The lower curve assumes the prognostic test accuracy is identical to the diagnostic test accuracy but that the inspection efficiency is zero. The highest curve makes the same assumption about test accuracies, but assumes the inspection efficiency is 100 percent. The diagonal line assumes that both test accuracies and the inspection efficiency are identical. A break even area is shown which designates where the life cycle cost of the AIDAPS equals the gross savings due to the AIDAPS. These factors are dependent upon the assumptions made as to test accuracy and inspection efficiency.

Figure 8-130 gives shows the same information for the Airborne System

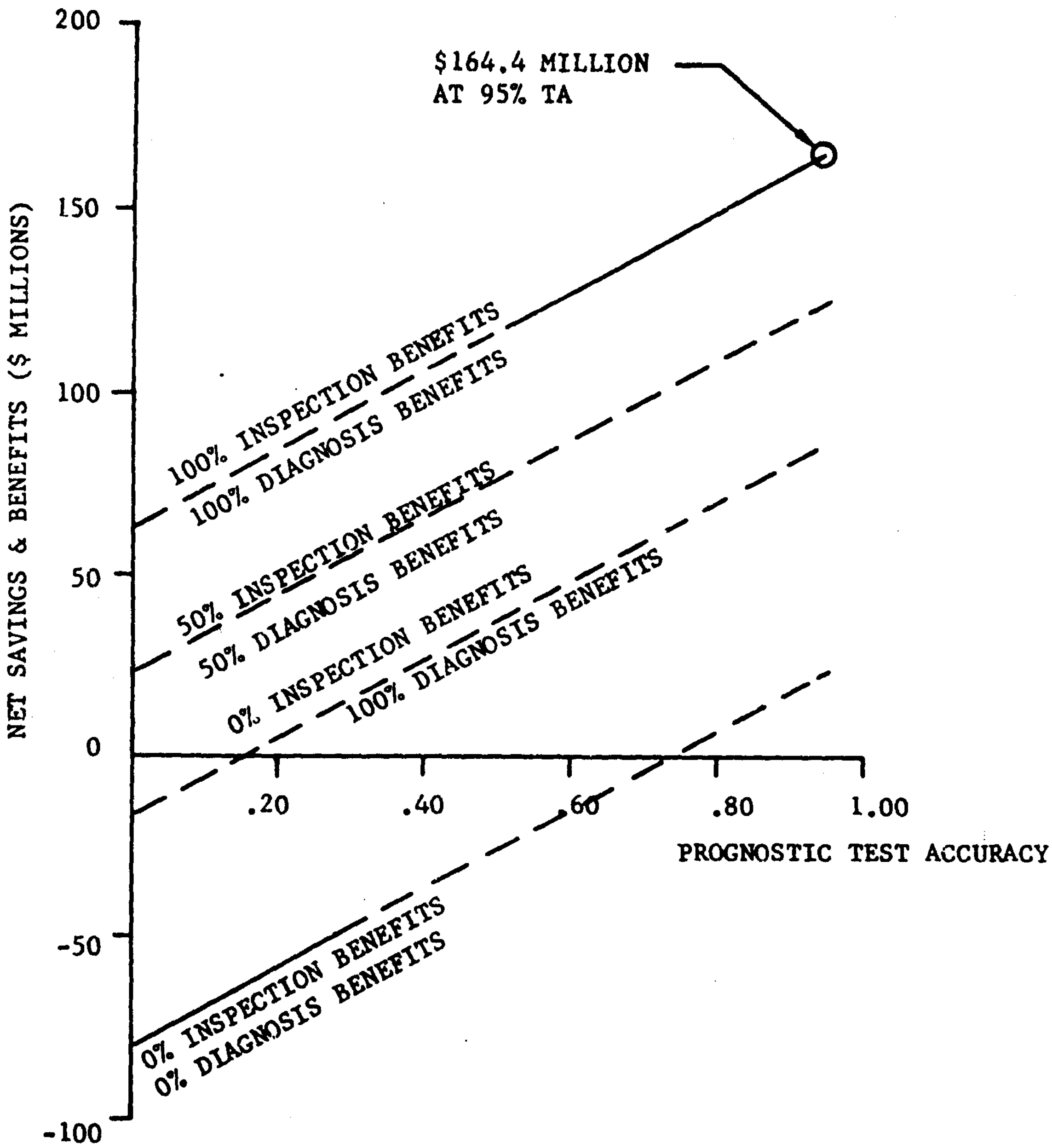


FIGURE 8-128
NET SAVINGS DUE TO PROGNOSIS VS TEST ACCURACY
(UH-1 HYBRID I)

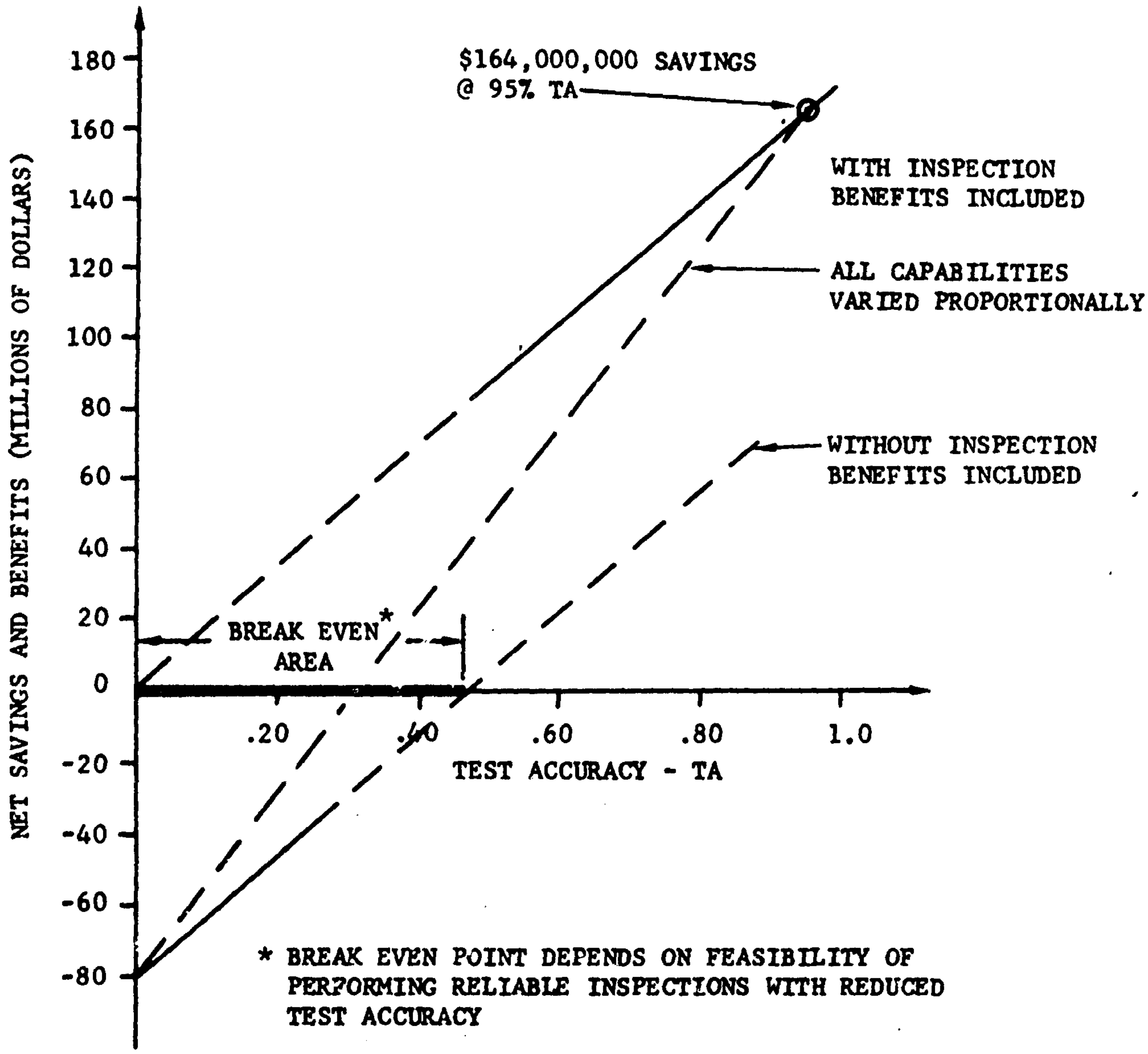


FIGURE 8-129 NET SAVINGS AND BENEFITS VS TEST ACCURACY FOR UH-1 HYBRID I (EXPECTED CONDITIONS)

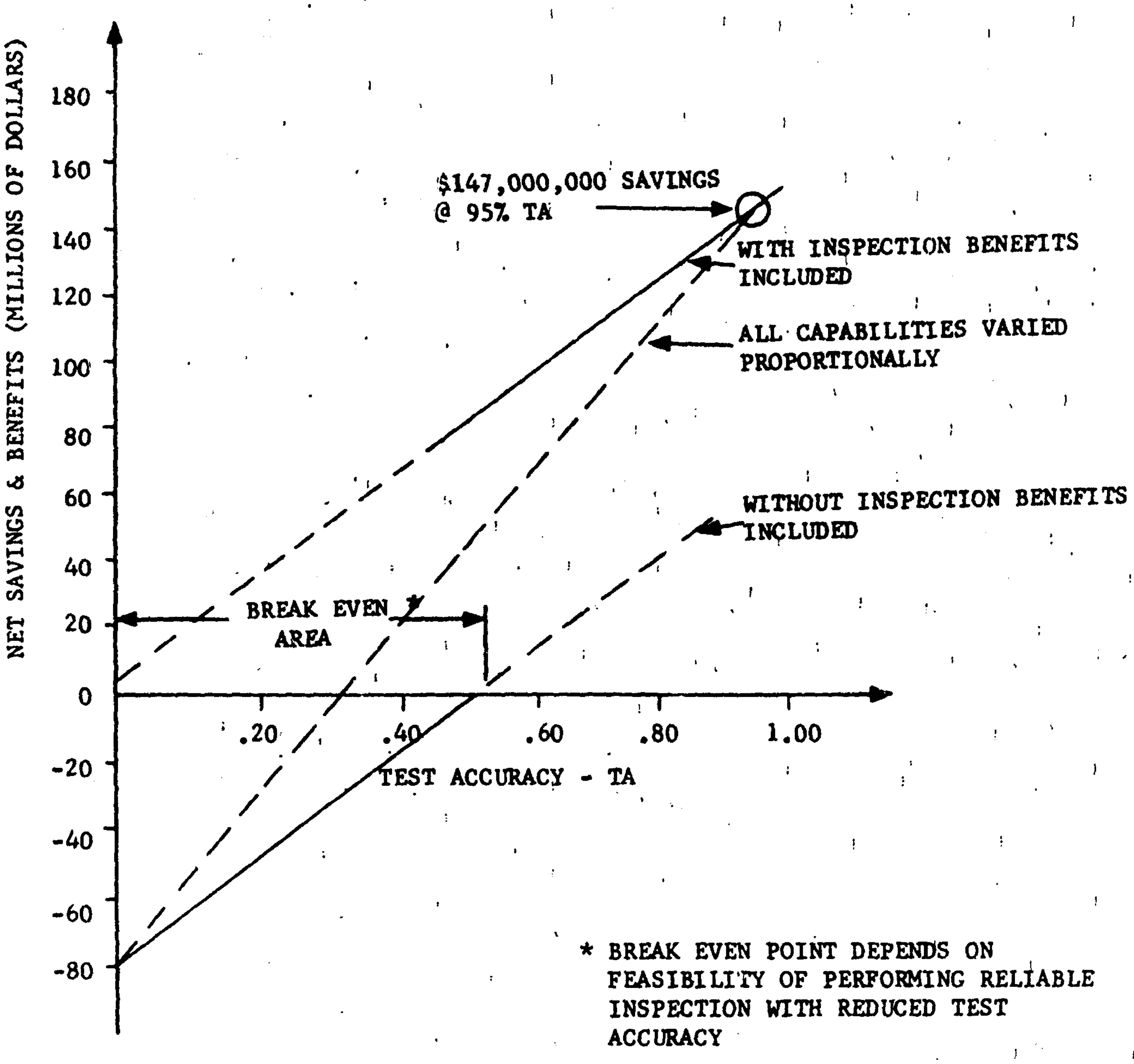


FIGURE 8-130
NET SAVINGS AND BENEFITS VS
TEST ACCURACY FOR UH-1 AIRBORNE

8.3.5 UNIVERSAL AIDAP SYSTEM SELECTION

Tables 8-14 through 8-16 show the results of the analysis of the Universal Systems. The Hybrid I System is the most cost effective system in all cases except for the HLH. However, the difference in net savings for the two AIDAPS configurations on this aircraft are not significant.

Figures 8-131 through 8-137 show the time phasing of procurement costs and net savings and benefits for the modular Universal Hybrid I AIDAP System. In all cases the procurement funds are recovered within approximately two years after procurement funds are expended. For the future aircraft recovery of procurement funds are recovered before they are expended. This is due to the long procurement times for these programs. The AIDAPS procurement program must match the aircraft procurement program in these cases.

TABLE 8-14 SUMMARY AIDAPS 10 YEAR LIFE CYCLE COST AIRCRAFT SAVINGS & BENEFITS UNIVERSAL SYSTEMS-OPTIMISTIC CONDITIONS

	OH-6		OH-58		UH-1		U-21		AH-1		UTTAS		OV-1		CH-54		CH-47		HLH	
AIRCRAFT SAVINGS AND BENEFITS:	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
OPERATIONS	11.7	12.0	89.3	91.7	336.2	338.8	8.3	8.4	39.1	39.5	661.2	664.1	29.6	29.8	16.8	16.9	153.9	154.1	57.6	57.7
EFFECTIVE AIRCRAFT	0.7	0.7	7.4	7.4	116.1	117.4	2.9	2.9	15.1	15.3	738.3	748.6	44.7	45.4	23.6	24.0	129.3	130.6	91.6	93.4
ACCIDENTS	6.0	6.0	53.7	53.7	117.9	117.9	4.2	4.2	83.2	88.2	404.6	404.6	1.8	1.8	10.8	10.8	22.3	22.3	32.6	32.6
SUB-TOTAL	18.4	18.7	150.4	152.8	570.2	574.1	15.4	15.5	142.4	143.0	1804.1	1817.3	76.1	77.0	51.2	51.7	305.5	307.0	181.8	183.7
AIDAPS COST:																				
DOT & E	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
INVESTMENT	4.1	5.2	32.4	42.2	68.2	85.8	2.0	2.5	11.0	13.8	51.2	62.4	4.1	5.2	1.9	2.2	11.7	14.0	1.1	1.3
OPERATIONS	1.4	1.3	8.6	7.9	20.1	19.8	0.9	0.9	3.2	3.3	18.8	16.7	1.4	1.4	0.8	0.8	3.2	3.0	0.8	0.8
SUB-TOTAL	6.3	7.2	41.8	50.7	89.1	106.3	3.7	4.1	15.0	17.8	70.8	79.8	6.3	7.3	3.5	3.8	15.7	17.8	2.7	2.9
NET SAVINGS AND BENEFITS	12.1	11.5	108.6	102.1	481.1	467.8	11.7	11.4	127.4	125.2	1733.3	1737.4	59.8	69.7	47.7	47.9	289.8	289.2	179.1	180.8

IN MILLIONS OF DOLLARS

1 = HYBRID I
2 = AIRBORNE

TABLE 8-15 SUMMARY AIDAPS 10 YEAR LIFE CYCLE COST AIRCRAFT SAVINGS & BENEFITS UNIVERSAL SYSTEMS-PESSIMISTIC CONDITIONS

	OH-6		OH-58		UH-1		U-21		AH-1		UTTAS		OV-1		CH-54		CH-47		HLH	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AIRCRAFT SAVINGS AND BENEFITS:																				
OPERATIONS	3.9	4.0	29.5	30.2	99.4	100.1	3.4	3.5	13.4	13.5	230.2	231.1	11.4	11.5	4.1	4.1	40.2	40.3	10.8	10.8
EFFECTIVE AIRCRAFT	0.05	0.02	0.03	-0.3	28.3	27.8	1.1	1.1	3.8	3.8	240.9	242.6	16.2	16.3	5.0	5.1	28.3	28.6	15.2	15.5
ACCIDENTS	2.6	2.6	23.0	23.0	44.2	44.2	2.3	2.3	37.8	37.8	175.9	175.9	0.9	0.9	3.2	3.2	7.4	7.4	7.1	7.1
SUB-TOTALS	6.55	6.62	52.53	52.9	171.9	172.1	6.8	6.9	55.0	55.1	647.0	649.[illegible]	28.5	28.7	12.3	12.4	75.9	76.3	33.1	33.4
AIDAPS COST:																				
DDT & E	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
INVESTMENT	4.0	5.2	32.2	42.1	68.0	85.7	2.0	2.5	11.0	13.8	50.8	62.3	4.1	5.2	1.9	2.2	11.7	14.0	1.1	1.3
OPERATIONS	1.0	0.9	4.5	4.3	9.2	9.2	0.7	0.7	1.8	1.9	8.8	8.4	1.0	1.0	0.6	0.6	1.5	1.5	0.6	0.5
SUB-TOTAL	5.8	6.8	37.5	47.1	78.0	95.6	3.5	3.9	13.6	16.4	60.4	71.5	5.9	6.9	3.3	3.6	14.0	16.3	2.5	2.6
NET SAVINGS AND BENEFITS	0.8	-0.2	15.0	5.8	93.9	76.5	3.3	3.0	41.4	38.7	586.6	578.1	22.6	21.8	9.0	8.8	61.9	60.0	30.6	30.8

IN MILLIONS OF DOLLARS

1 = HYBRID I
2 = AIRBORNE

TABLE 8-16 SUMMARY AIDAPS 10 YEAR LIFE CYCLE COST AIRCRAFT SAVINGS & BENEFITS UNIVERSAL SYSTEMS-EXPECTED CONDITIONS

	OH-6		OH-58		UH-1		U-21		AH-1		UTTAS		OV-1		CH-54		CH-47		HLH	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
AIRCRAFT SAVINGS AND BENEFITS:																				
OPERATIONS	5.5	5.6	42.1	43.1	140.5	141.5	4.5	4.6	19.2	19.4	323.3	324.5	13.9	14.0	7.3	7.4	64.1	64.3	19.7	19.7
EFFECTIVE AIRCRAFT	0.2	0.2	1.8	1.5	44.6	44.3	1.5	1.5	6.4	6.4	358.0	361.5	20.1	20.3	9.6	9.7	57.2	57.9	30.2	30.8
ACCIDENTS	3.5	3.5	30.7	30.7	59.3	59.3	2.8	2.8	50.4	50.4	234.5	234.5	1.0	1.0	5.4	5.4	11.2	11.2	11.8	11.8
SUB-TOTAL	9.2	9.3	74.6	75.3	244.4	245.1	8.8	8.9	76.0	76.2	915.8	920.5	35.0	35.3	22.3	22.5	132.5	133.4	61.7	62.3
AIDAPS COST:																				
DDT & E	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.7	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8
INVESTMENT	4.0	5.2	32.3	42.1	68.0	85.7	2.0	2.5	11.0	13.8	50.9	62.3	4.1	5.2	1.9	2.2	11.7	14.0	1.1	1.3
OPERATIONS	1.1	1.0	5.4	5.1	11.2	11.2	0.7	0.8	2.2	2.2	11.1	10.4	1.0	1.0	0.6	0.6	0.9	0.9	0.6	0.6
SUB-TOTAL	5.9	6.9	38.5	47.9	80.0	97.6	3.5	4.0	14.0	16.7	62.8	73.5	5.9	6.9	3.3	3.6	14.4	16.7	2.5	2.7
NET SAVINGS AND BENEFITS	3.3	2.4	36.1	27.4	164.4	147.5	5.3	4.9	62.0	59.5	853.0	847.0	29.1	28.4	19.0	18.9	118.1	116.7	59.2	59.6

IN MILLIONS OF DOLLARS

1 = HYBRID I
2 = AIRBORNE

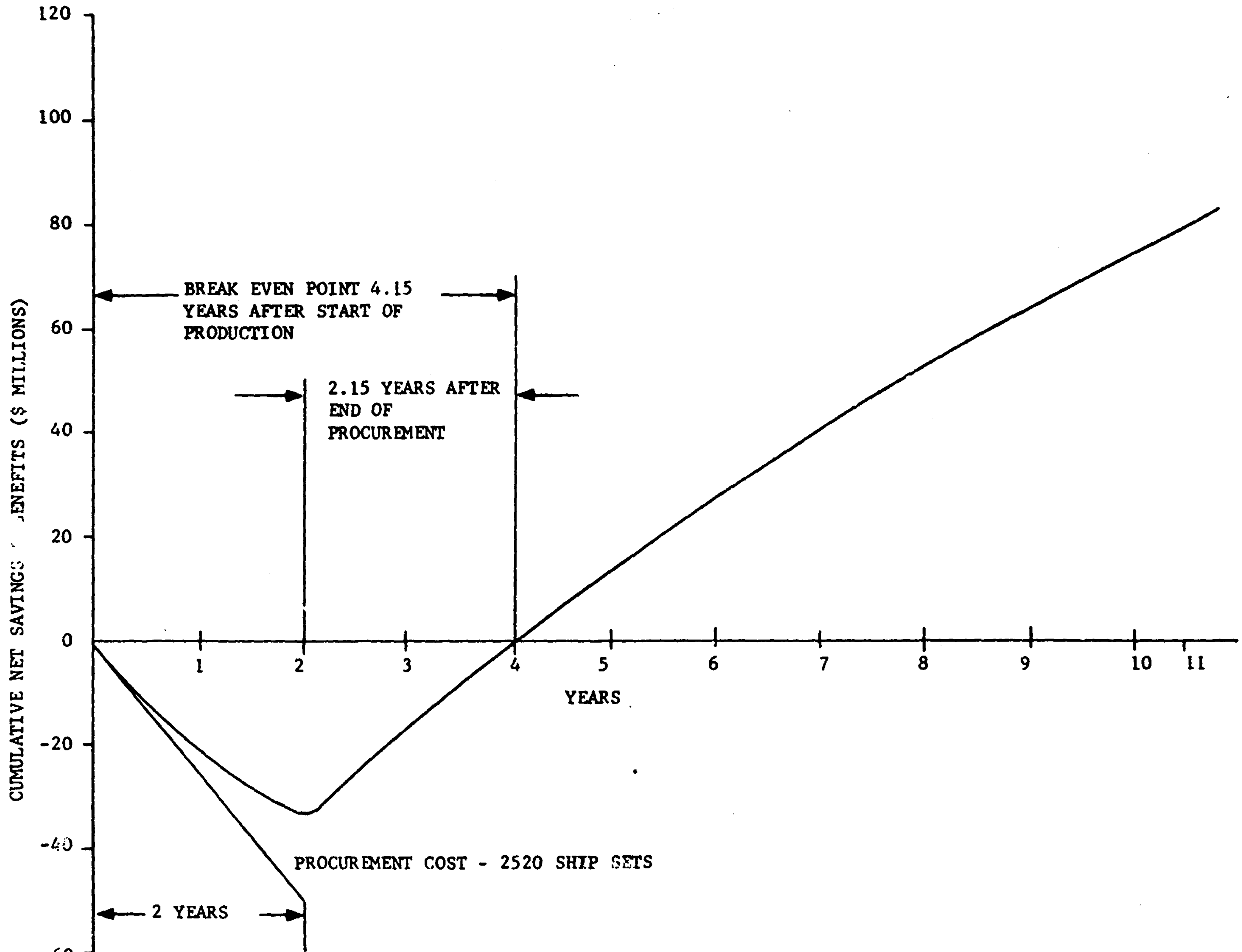


FIGURE 8-131 UH-1 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS
(UNIVERSAL SYSTEMS - EXPECTED CONDITION)

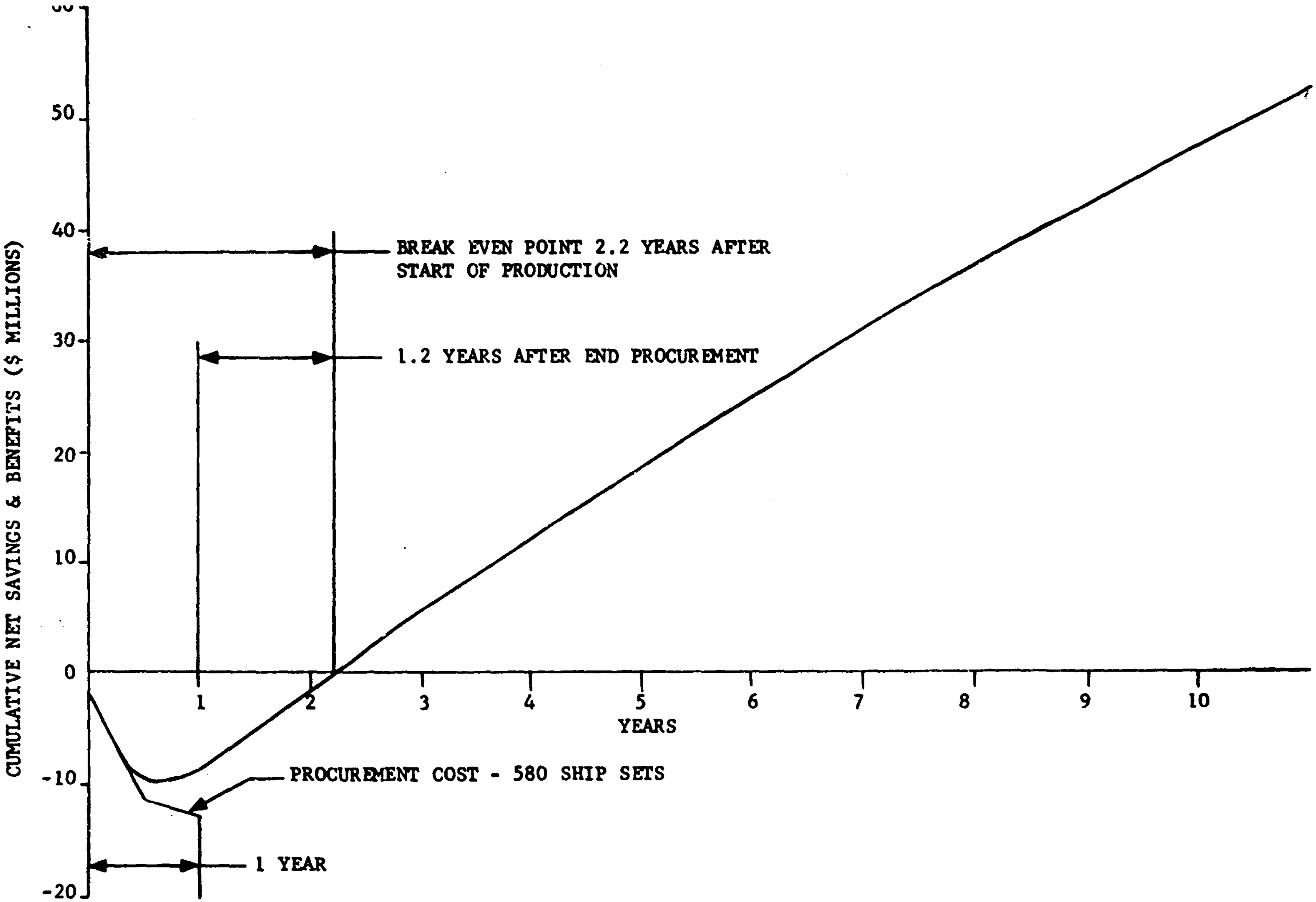


FIGURE 8-132 AH-1 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS
(UNIVERSAL SYSTEMS - EXPECTED CONDITIONS)

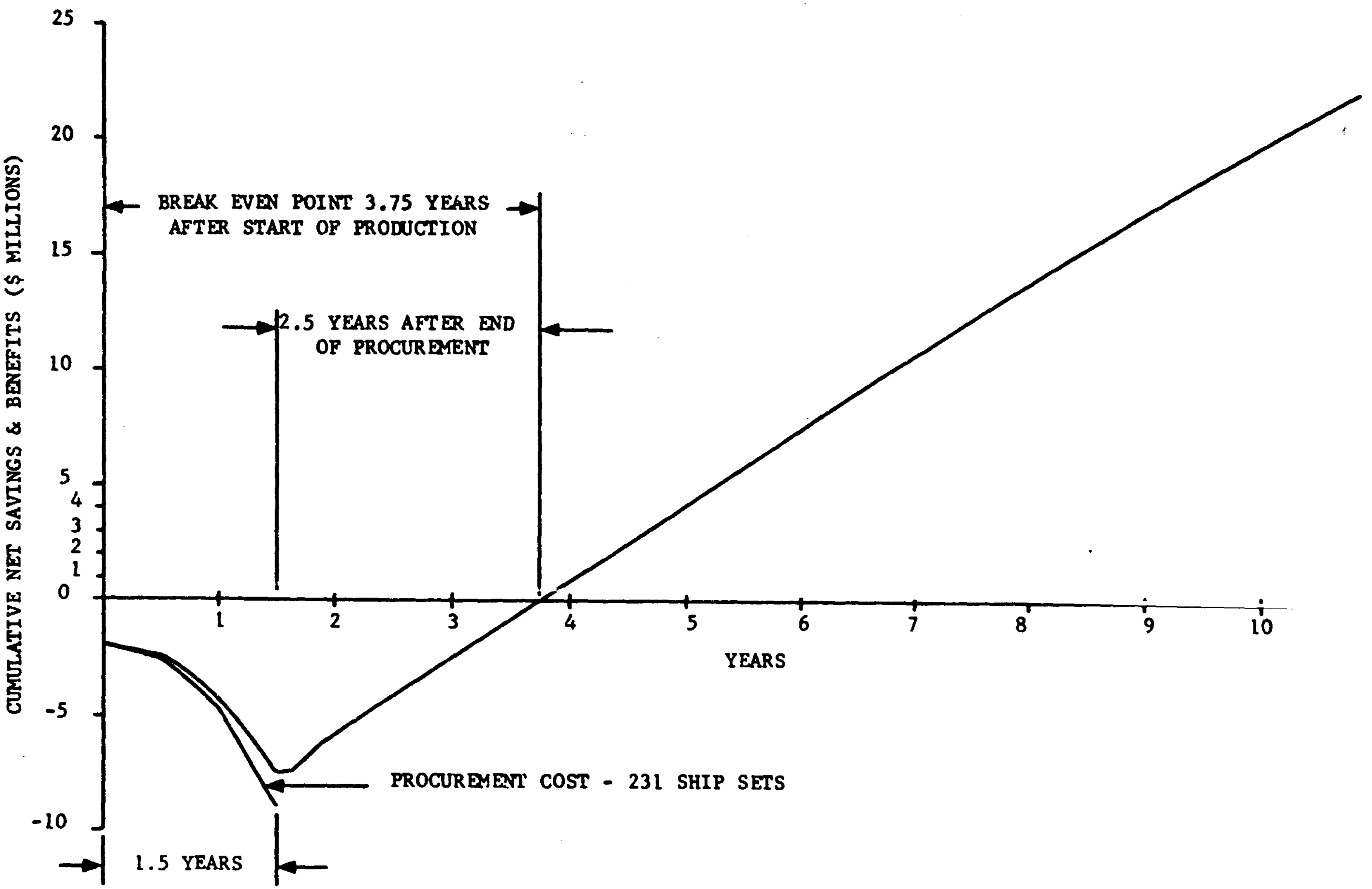


FIGURE 8-133 OV-1 HYBRID I AIDAPS SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS (UNIVERSAL SYSTEMS - EXPECTED CONDITIONS)

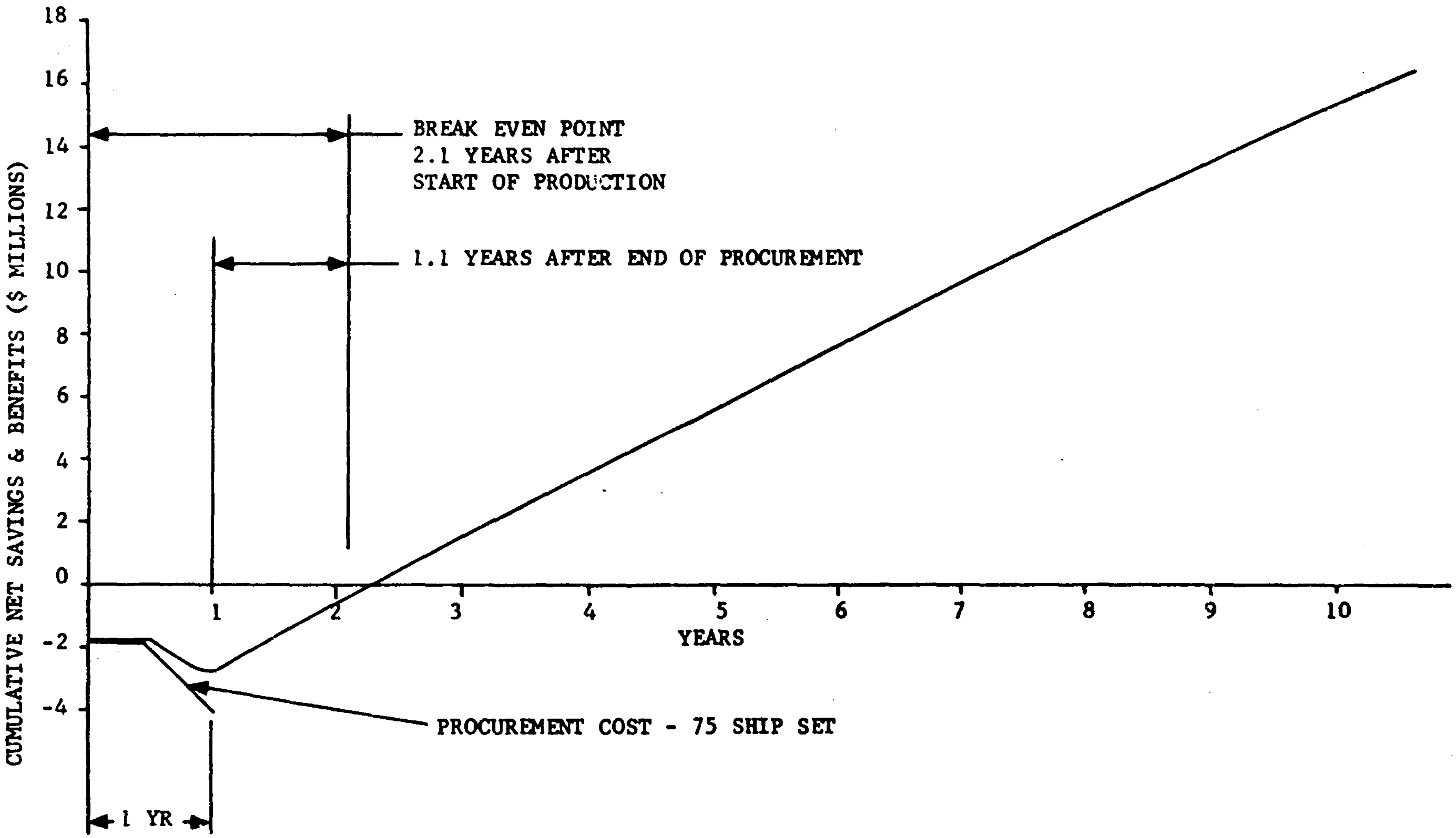


FIGURE 8-134 CH-54 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS
(UNIVERSAL SYSTEMS EXPECTED CONDITIONS)

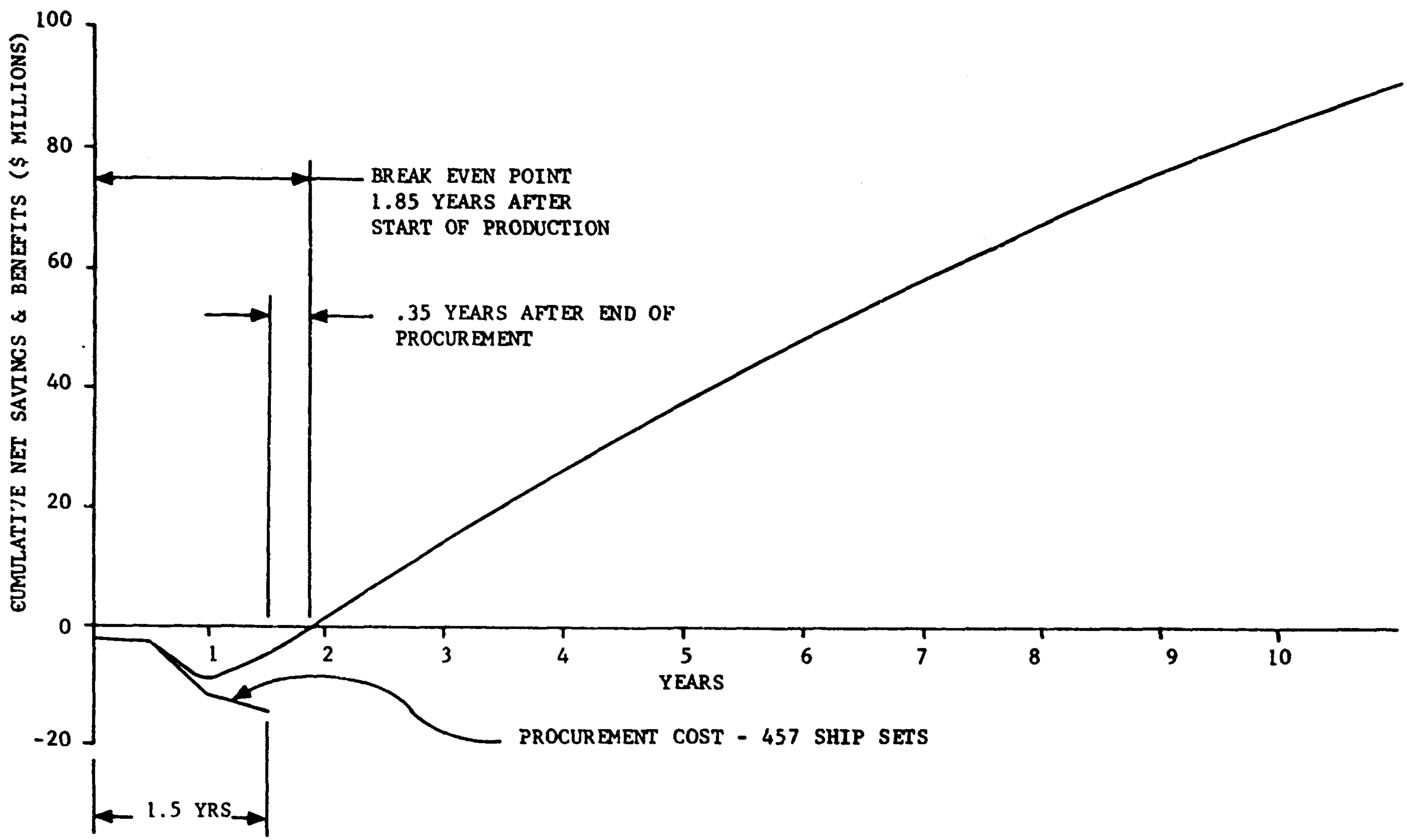


FIGURE 8-135 CH-47 HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS
(UNIVERSAL SYSTEMS EXPECTED CONDITIONS)

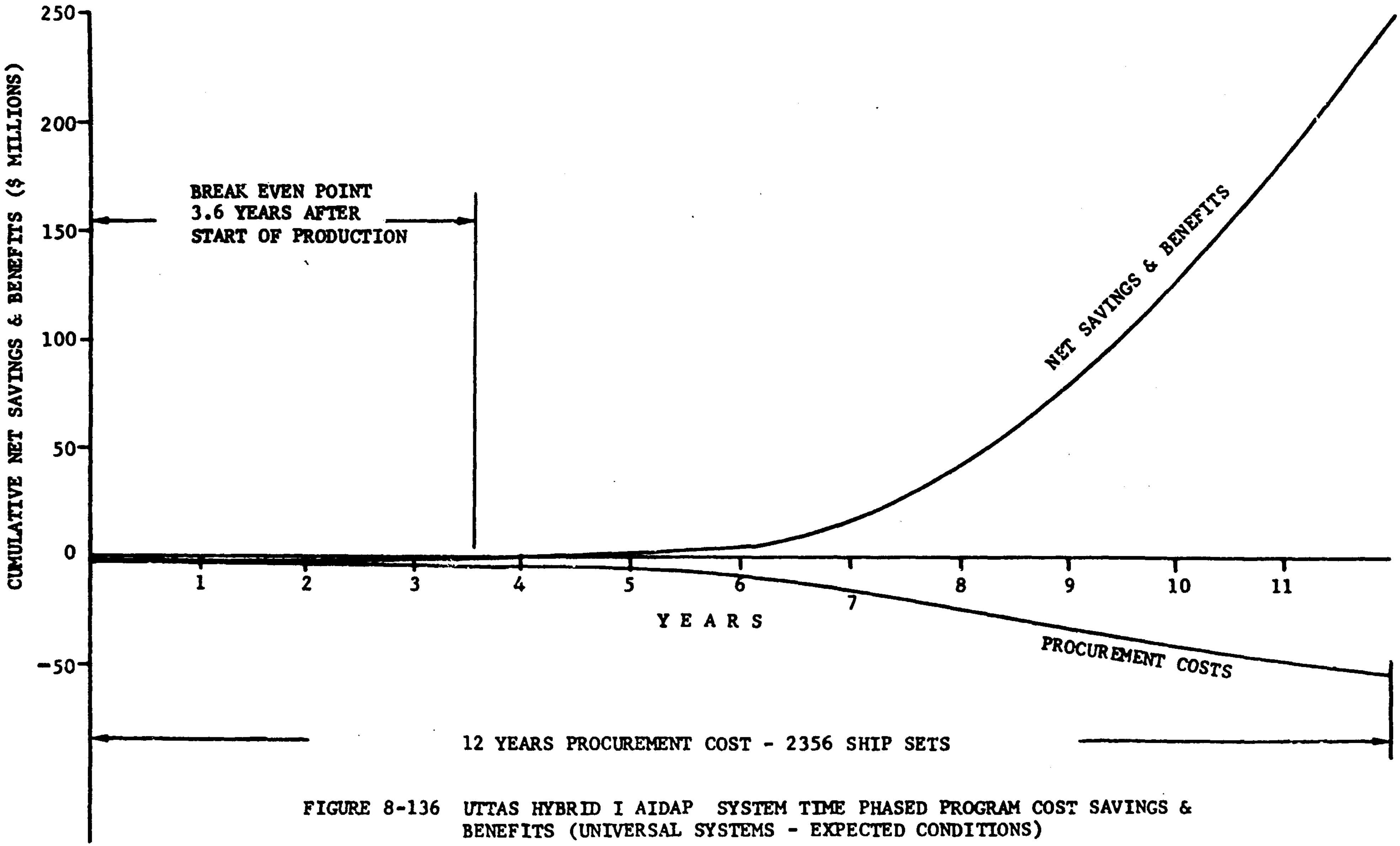


FIGURE 8-136 UTTAS HYBRID I AIDAP SYSTEM TIME PHASED PROGRAM COST SAVINGS & BENEFITS (UNIVERSAL SYSTEMS - EXPECTED CONDITIONS)

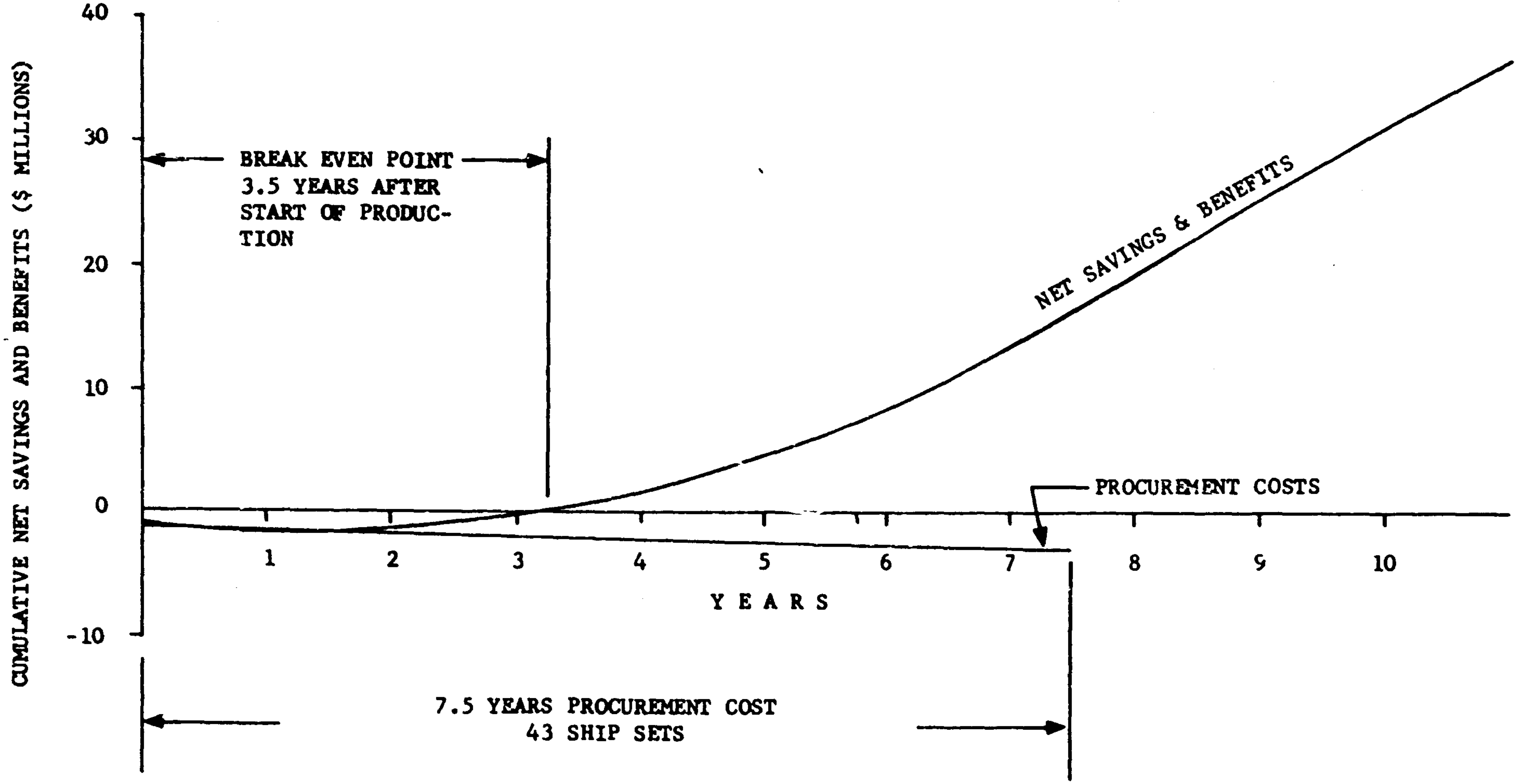


FIGURE 8-137 HLH HYBRID I AIDAP SYSTEMS
TIME PHASED PROGRAM
COST SAVINGS AND BENEFITS
(UNIVERSAL SYSTEMS EXPECTED CONDITIONS)

8.4 SELECTED AIDAP SYSTEM

The Hybrid I is the most cost effective AIDAPS configuration for the Unique, Group and Universal system designs. This configuration has the same capabilities and capacities regardless of whether it is designed as a Unique, Group or Universal system. Therefore, differences in cost effectiveness are entirely due to differences in costs. Table 8-17 shows the net savings achieved by the Hybrid I configuration on each of the study aircraft and each system design type. Both the Group and Universal design types show large cost effectiveness improvements over the Unique systems. These differences are due to spreading the DDT&E costs across larger numbers of aircraft/AIDAPS programs, and due to larger scale production of identical or similar AIDAPS sets.

The difference in cost effectiveness between the Group and Universal systems cost effectiveness is not large except for the aircraft with small fleet sizes. However, it is not recommended that AIDAPS be installed on the OH-6, OH-58, nor the U-21 aircraft. This leaves the CH-54 as the only aircraft with a really significant difference in net benefits between the Universal and Group AIDAPS.

The differences between the Group and Universal systems are due to the commonality of all electronics modules for the Universal system except the RDAU. The RDAU is used only on the CH-47, CH-54, HLH and UTTAS aircraft.

The group systems require three DDT&E programs, one for the OH-6, OH-58 and U-21 systems at a cost of $3.8 million, another for the UH-1, AH-1 and OV-1 aircraft at a cost of approximately $5.2 million, and a third for the CH-47, CH-54, HLH and UTTAS aircraft at a cost of approximately $7.2 million. If the OH-6, OH-58 and U-21 program is eliminated, the $3.8 million DDT&E expenditures as well as the procurement costs for these programs are also eliminated.

For the Universal systems, however, an initial DDT&E program of approximately $4.0 million is required with later adaptation to other aircraft and development of an RDAU at an additional cost of approximately $4.0 million.

TABLE 8-17 SYSTEM NET SAVINGS PER AIRCRAFT (IN THOUSANDS OF DOLLARS)

HYBRID I - EXPECTED CONDITION 10 YEARS OPERATION

	AIDAPS SYSTEM		
AIRCRAFT	UNIQUE	GROUPED	UNIVERSAL
OH-6	-7.6	8.1	14.1
OH-58	12.2	17.5	18.9
UH-1	37.8	45.1	46.1
U-21	-3.6	46.2	51.0
AH-1	93.6	104.6	106.1
UTTAS	333.0	358.4	362.0
OV-1	86.0	123.4	126.0
CH-54	102.6	237.3	253.3
CH-47	202.0	252.1	257.3
HLH	954.9	1348.8	1376.7

The elimination of the OH-6, OH-58 and U-21 programs will cause the prorated DDT&E costs to increase by approximately $200,000 per aircraft type on the remaining aircraft. This is negligible in respect to the total AIDAPS life cycle costs.

Additional savings in procurement cost are realized by the Universal system due to the larger production quantities of all system modules except the RDAU. The production quantities of the RDAU are the same for both the Group and Universal systems although its size and cost is slightly less for the Universal application.

The reduction in procurement costs while maintaining the same system effectiveness results in the modular Universal Hybrid I system achieving the greatest cost effectiveness.

It is recognized that exigencies of the procurement program, as well as design improvements which may be desirable during the long production life of such a system, may prohibit a truly Universal system from being achieved. However, the savings in DDT&E and production costs will be sufficient to justify this choice as the preferred system.

SECTION 9

9-1.1

9.0 AIDAP SYSTEM JUSTIFICATION

The validity of incorporating an AIDAPS concept into the aircraft noted in this study, and the cost savings associated with implementing such a program are summarized for each of the subject aircraft in this section. The AIDAPS configuration presented is the modular Universal Hybrid I System for the expected operating conditions. While the HLH Universal Airborne System provides a slightly greater net savings than the Hybrid I, the difference is so small that savings can be considered essentially the same. The discussions are centered on the various cost savings elements which comprise the total aircraft system net savings.

9.1 EXPENDITURE VS. SAVINGS AND COST TRADEOFFS

The costs of procurring an AIDAPS include the expenditures for DDT&E, investment and a 10-year operation of the AIDAP System. The total expenditures required per aircraft for acquiring and operating the AIDAP System by aircraft type are presented in Figure 9-1. The use of the AIDAP System results in savings in aircraft support costs. These gross savings are also presented in Figure 9-2 along with total AIDAPS life cycle cost and net savings. The difference between the expenditure in incorporating AIDAPS and these gross savings provide the system net savings that can be realized.

9.2 EFFECTS ON LOGISTIC COSTS

The following paragraphs describe the individual effects on logistics cost elements using the selected AIDAPS configuration.

9.2.1 AIRCRAFT INSPECTIONS (MAN-HOURS)

The use of an AIDAP System will generate man-hour savings in the performance of aircraft inspections by reducing or eliminating the time spent in certain portions of the inspections. These savings, expressed as man-hours per 1,000 flight hours, are presented by aircraft type in Figure 9-3. The dollar savings associated with these man-hours are also included.

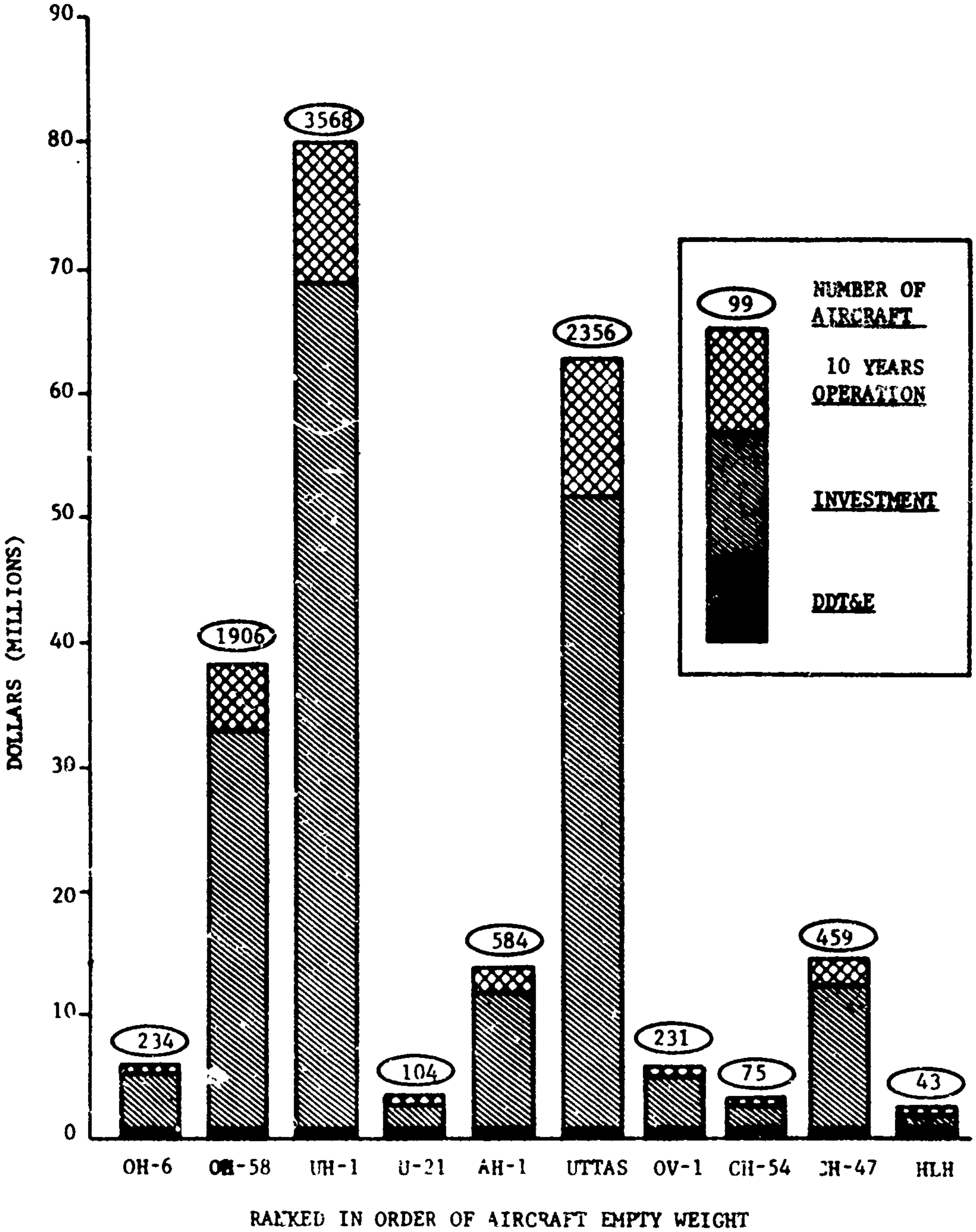


FIGURE 9-1 AIDAPS TOTAL LIFE CYCLE COST
HYBRID I - UNIVERSAL EXPECTED CONDITION

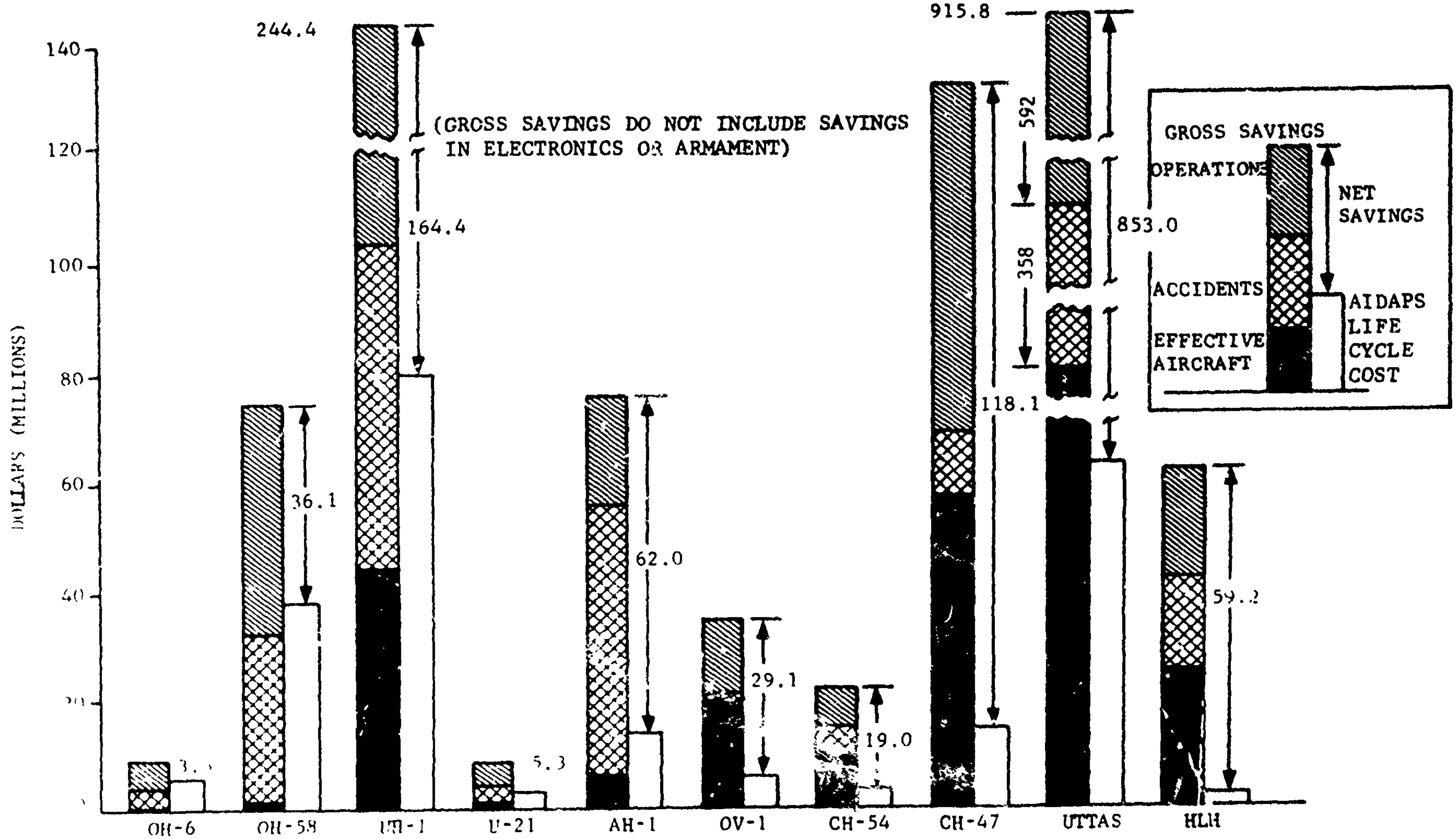


FIGURE 9-2 SYSTEM GROSS SAVINGS, TOTAL PROCUREMENT & NET SAVINGS
HYBRID I - UNIVERSAL EXPECTED CONDITION (10 YEARS OPERATION)

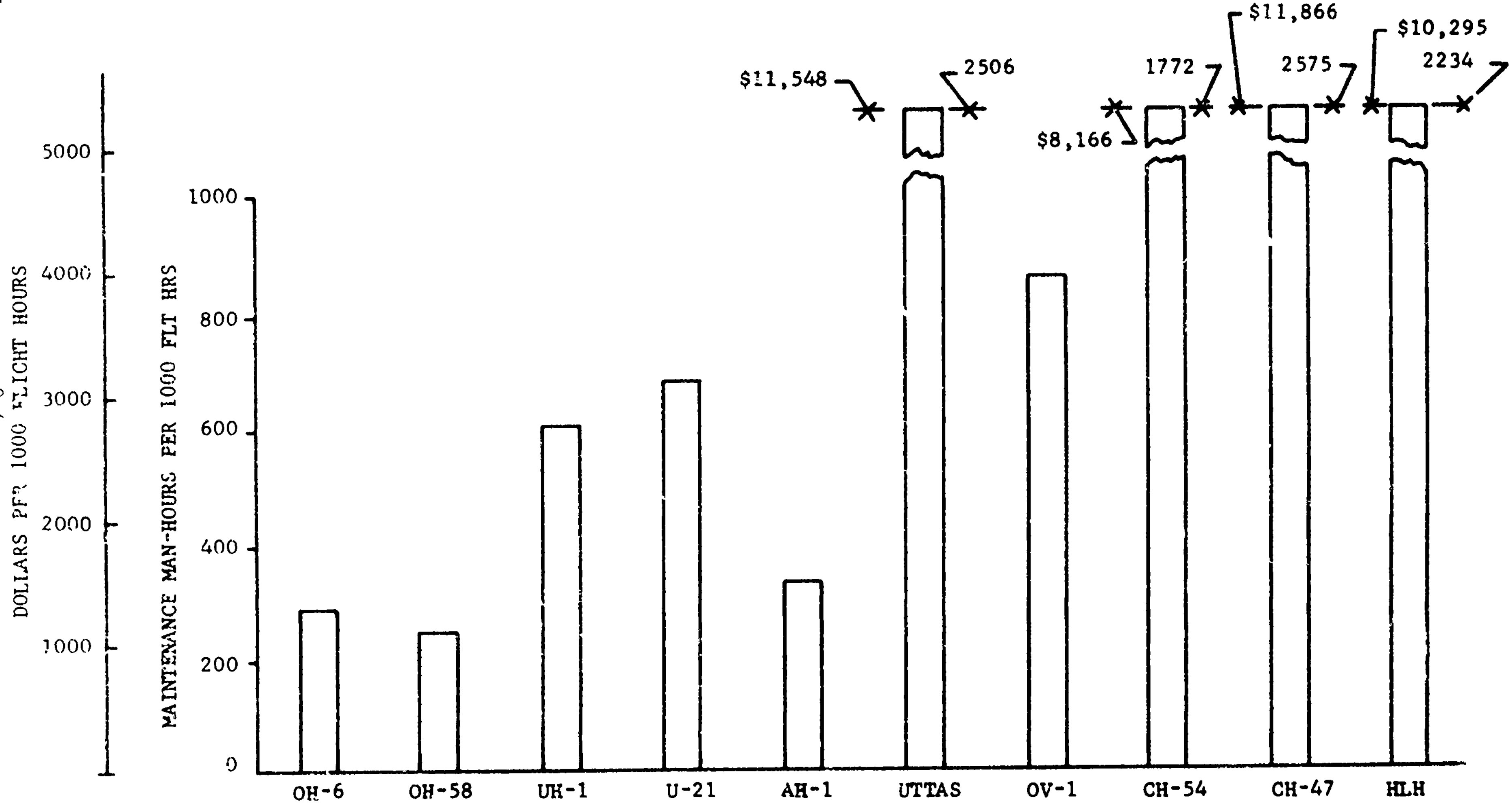


FIGURE 9-3 UNIVERSAL SYSTEMS - MAINTENANCE COST SAVINGS IN INSPECTION
HYBRID I - EXPECTED CONDITION

9.2.2 FAULT ISOLATION (DIAGNOSIS)

The savings attributable to improving fault isolation through the reduction or elimination of unwarranted removals and troubleshooting are presented in Figure 9-4 in both man-hours and dollars. The portion of spares inventory and logistics support cost savings which result from improved diagnostics capabilities are provided in Figure 9-5. The sum of these cost savings due to improved diagnostic capability is presented in Figure 9-6 by aircraft type. Savings in accidents due to the diagnostic capability are described in paragraph 9.2.8.

9.2.3 PROGNOSIS

The cost savings associated with the improved prognosis capability are related to the reductions in depot overhaul requirements and in aircraft accidents. Only the accident reductions due to long-term prognosis are included here. Prevention of accidents due to short-term prognosis re included under diagnosis because it is impossible to separate the effects of short-term prognosis from diagnostic capability and because the compution techniques associated with short-term prognosis are similar to diagnostic techniques. An AIDAPS designed to accomplish diagnosis can also accomplish most short-term prognosis. The savings in both man-hours and labor dollars due to reduction of scheduled removals at organizational and DS maintenance levels are presented in Figure 9-7. The total cost savings associated with overhaul, including material, are presented in Figure 9-8. Savings in accidents due to prognosis are included in paragraph 9.2.8. The sum of these cost savings (less accident savings) attributable to the improved prognosis capability is presented in Figure 9-9.

9.2.4 AIRCRAFT DOWNTIME AND MAINTENANCE MAN-HOURS

The improved maintenance capability results in a reduction in the downtime characteristics of the aircraft and thereby reduces maintenance personnel requirements. The downtime savings expressed as elapsed hours per 1,000 flight hours are presented in Figure 9-10. The total cost savings associated with the reduction in maintenance personnel are presented in Figure 9-11. These include man-hour savings due to inspection, diagnosis, and prognosis.

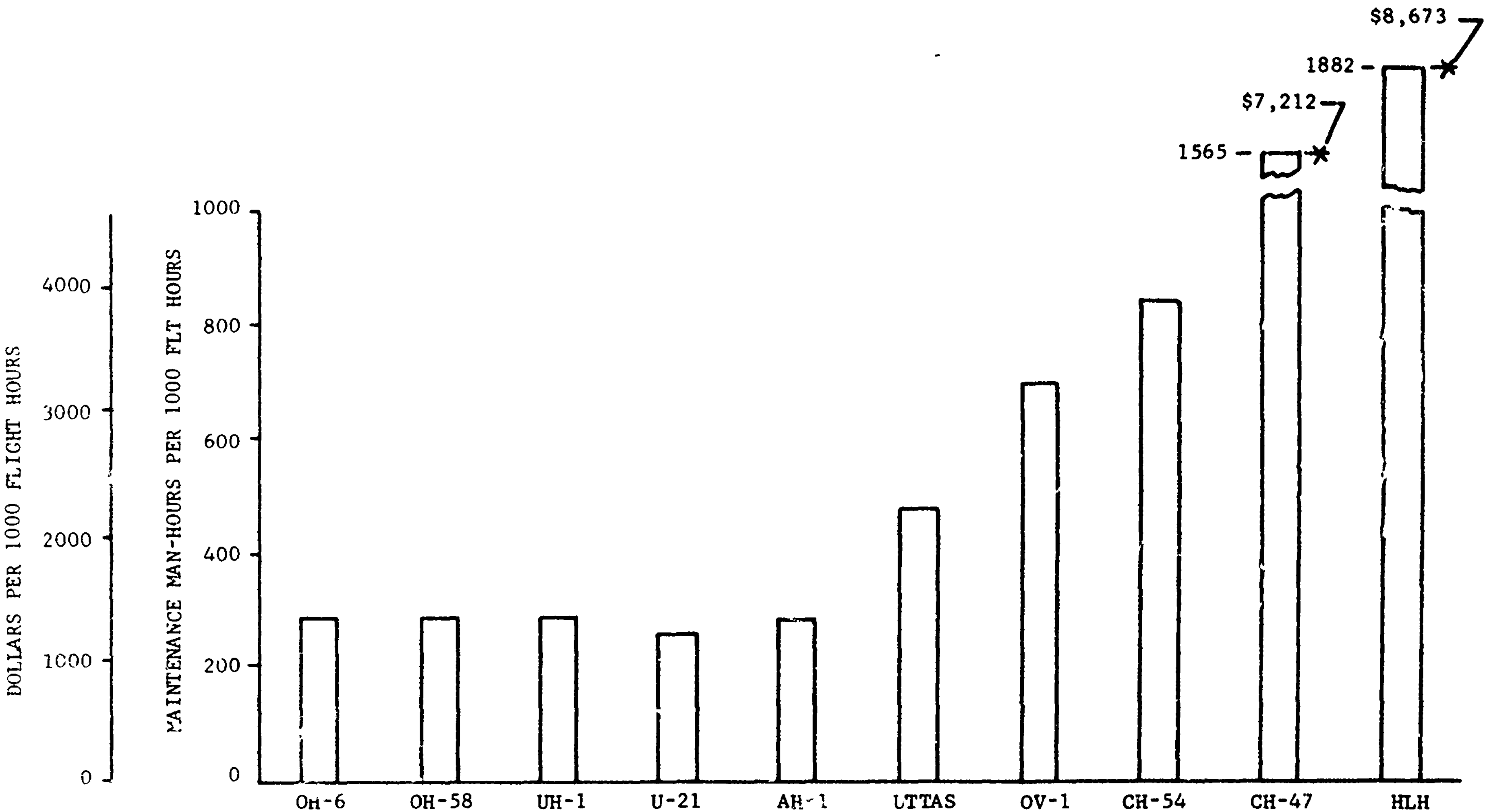


FIGURE 9-4 UNIVERSAL SYSTEMS - MAINTENANCE COST SAVINGS DUE TO DIAGNOSIS HYBRID I EXPECTED CONDITION

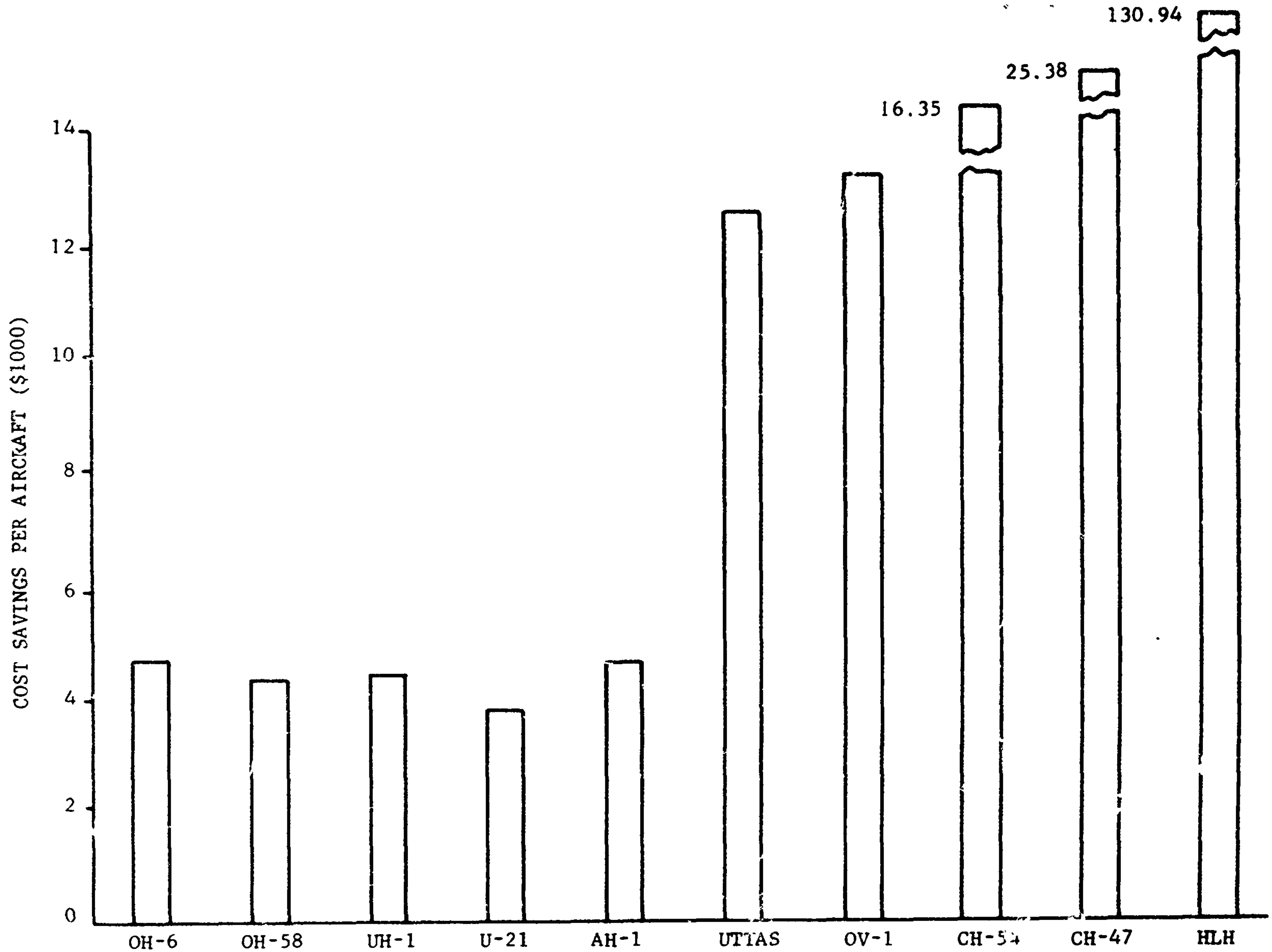


FIGURE 9-5 UNIVERSAL SYSTEMS - LOGISTICS COST SAVINGS DUE TO DIAGNOSIS
HYBRID I - EXPECTED CONDITION /TEN YEARS OPERATION

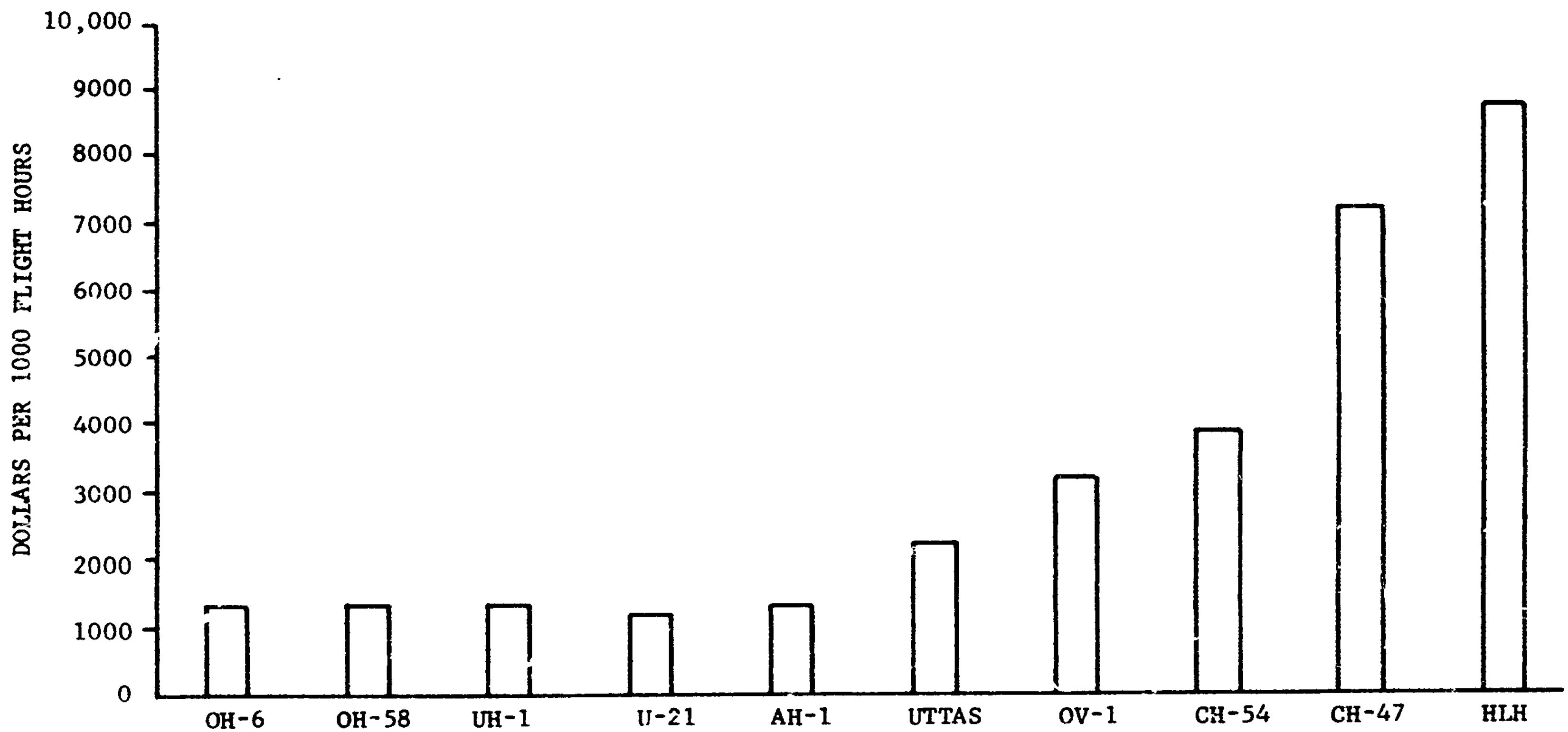


FIGURE 9-6 UNIVERSAL SYSTEM - TOTAL COST SAVINGS DUE TO DIAGNOSIS
HYBRID I - EXPECTED CONDITIONS

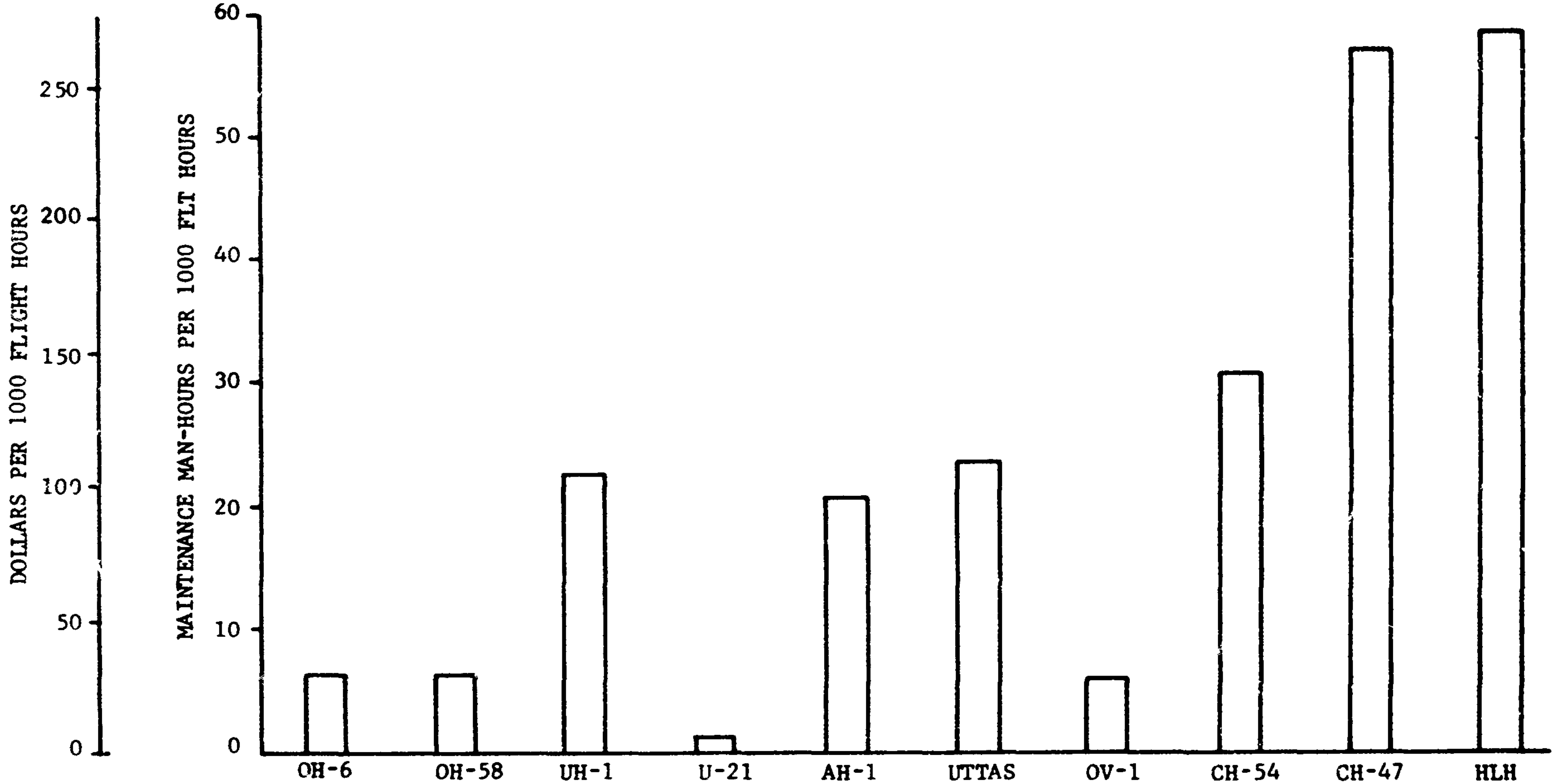


FIGURE 9-7 UNIVERSAL SYSTEMS - MAINTENANCE COST SAVINGS DUE TO PROGNOSIS

HYBRID I - EXPECTED CONDITION

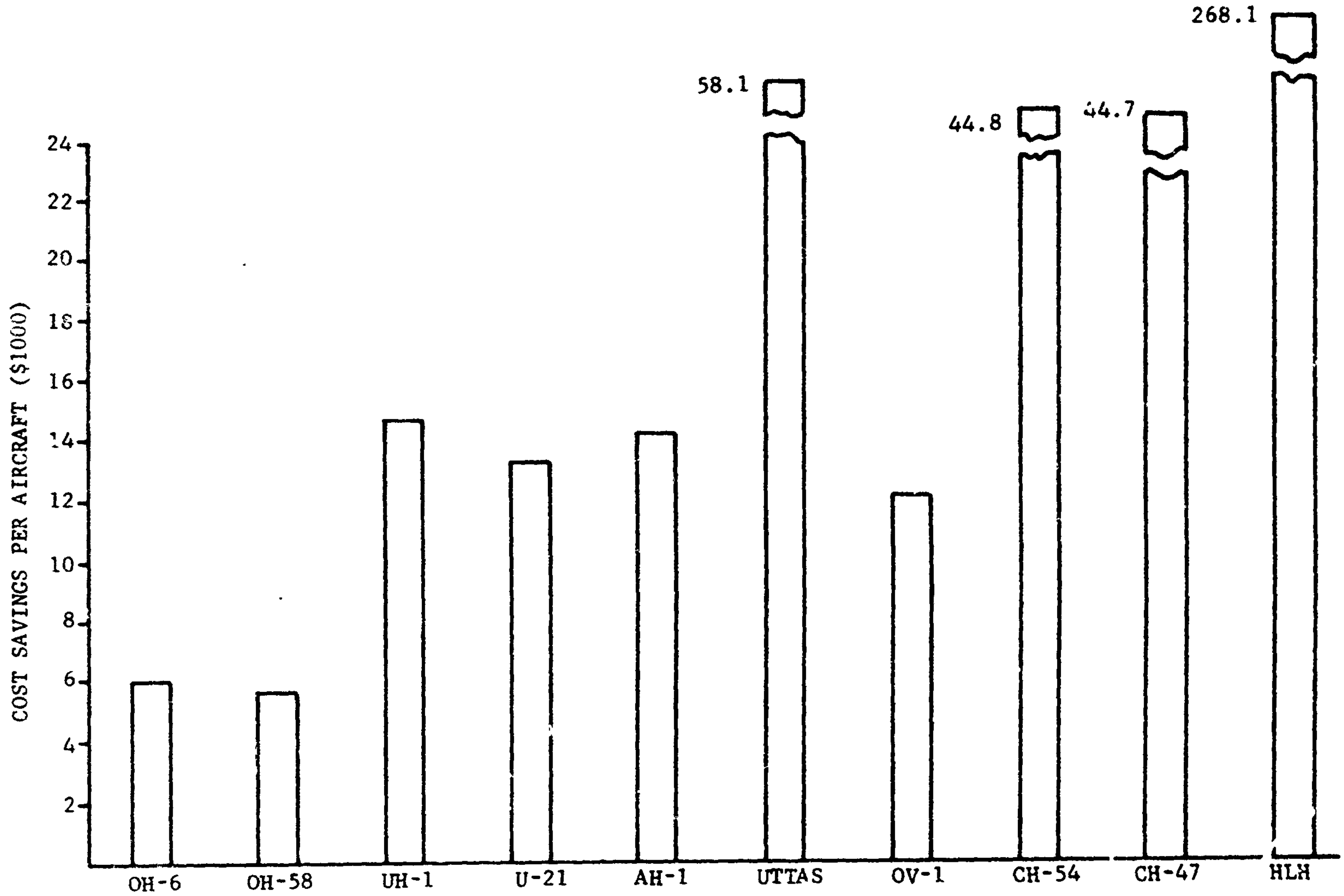


FIGURE 9-8 UNIVERSAL SYSTEMS - LOGISTICS COST SAVINGS DUE TO PROGNOSIS
HYBRID I - EXPECTED CONDITION (TEN YEARS OPERATION)

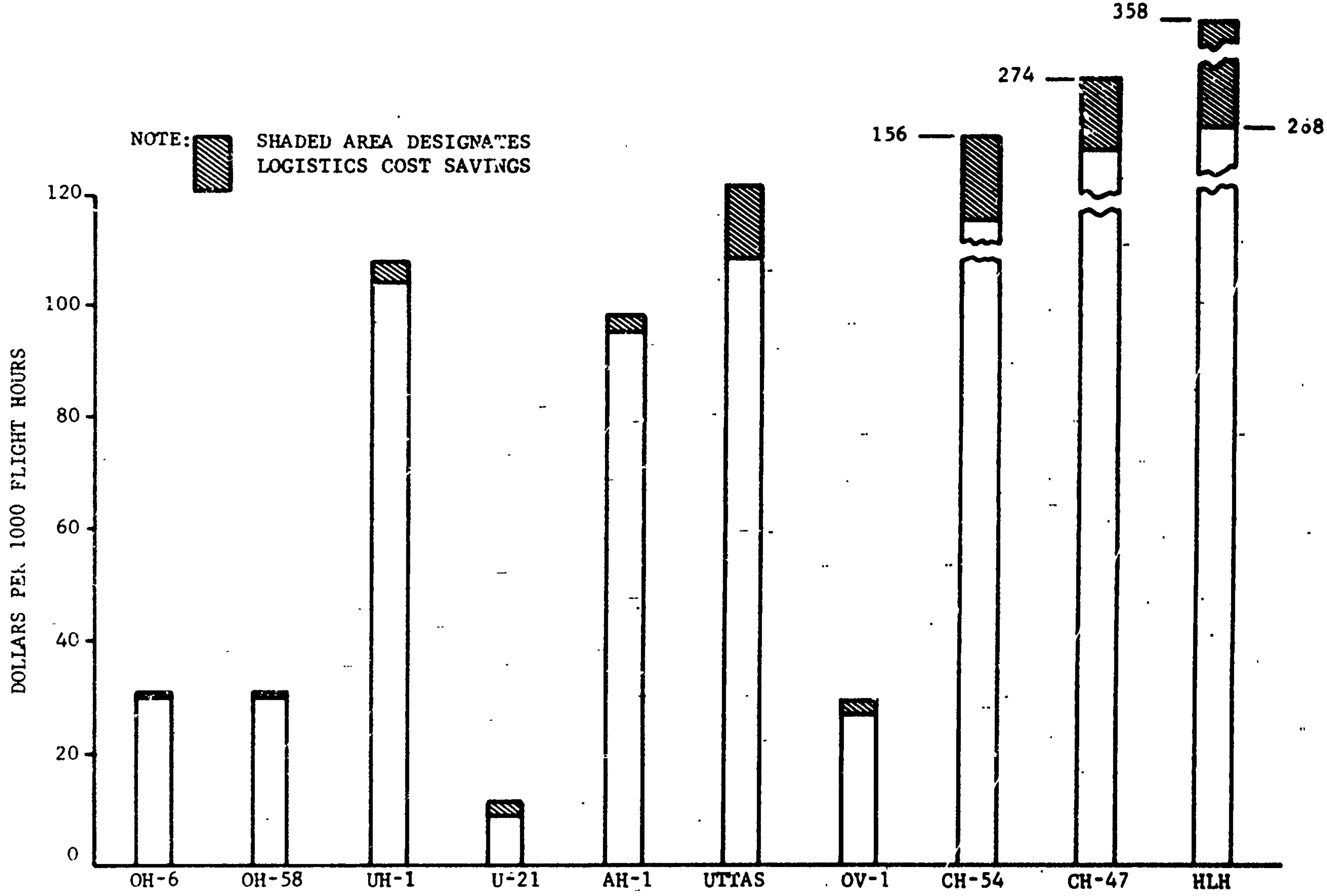


FIGURE 9-9 UNIVERSAL SYSTEMS - TOTAL COST SAVINGS DUE TO PROGNOSIS
HYBRID I - EXPECTED CONDITIONS

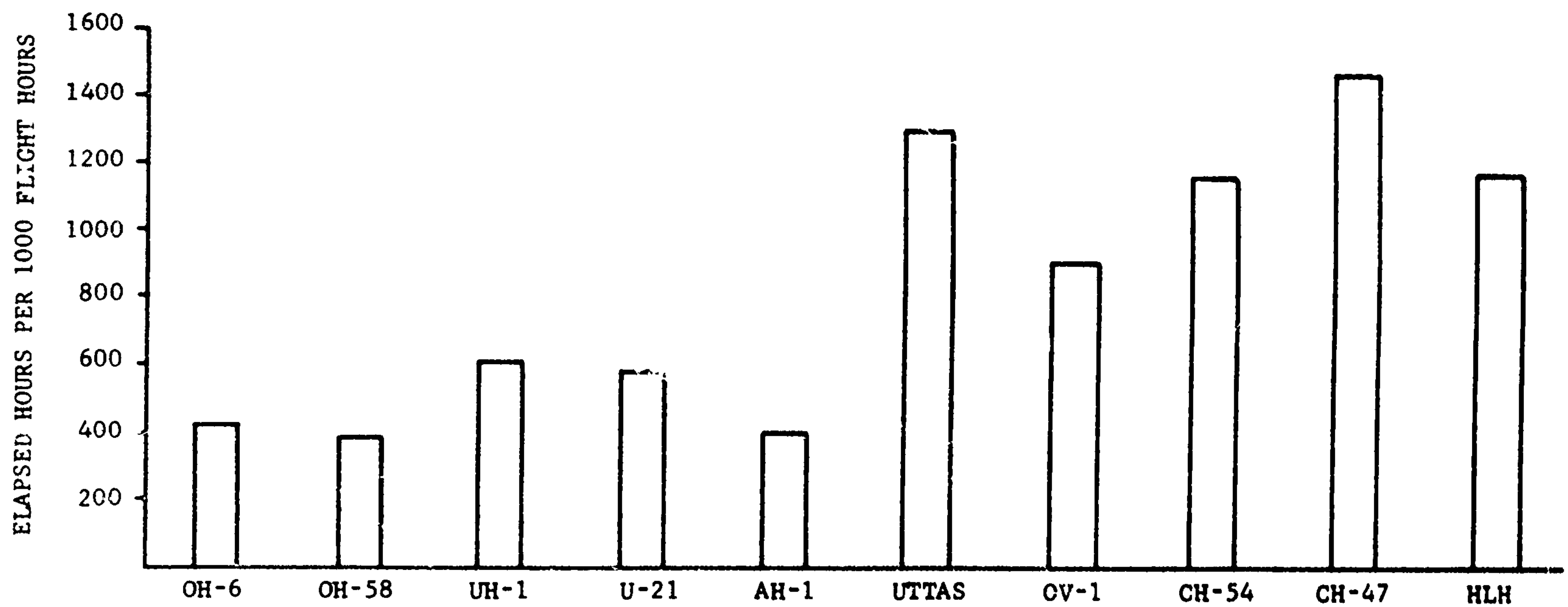


FIGURE 9-10 UNIVERSAL SYSTEMS - REDUCTION IN DOWNTIME
HYBRID I - EXPECTED CONDITION

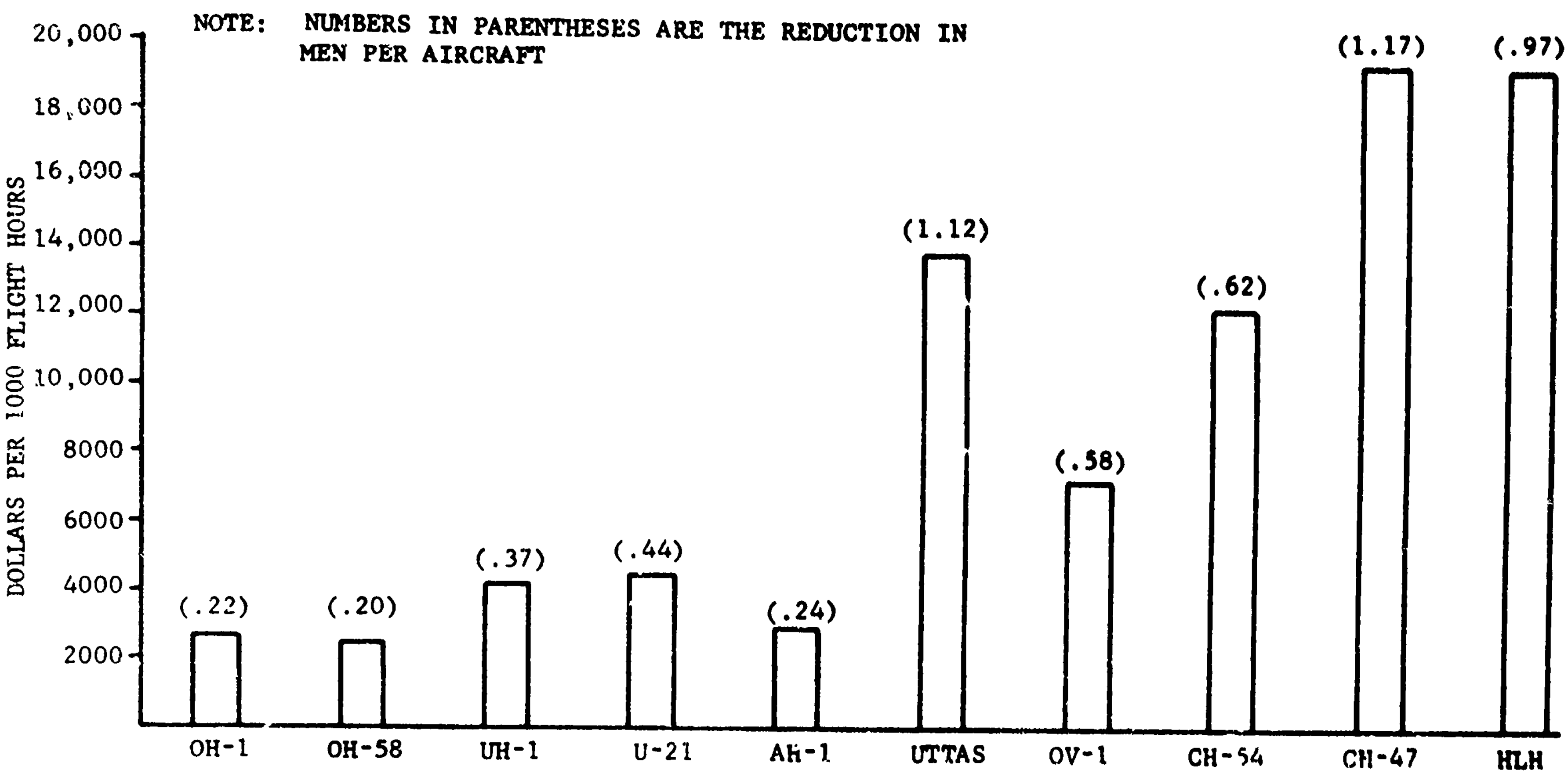


FIGURE 9-11 UNIVERSAL SYSTEMS - MAINTENANCE COST SAVINGS (PERSONNEL)
HYBRID I - EXPECTED CONDITIONS

9.2.5 LOWER MAINTENANCE SKILLS

With the incorporation of an AIDAP System in the study aircraft, the number of maintenance personnel required will be reduced in proportion to the man-hours savings generated. While maintenance skill proficiency required to perform troubleshooting actions may be reduced by AIDAPS, the availability of high proficiency maintenance personnel within the Army will still probably be limited. The net result will be that skill levels will not change, but the maintenance personnel will be able to perform more efficiently.

9.2.6 AIRCRAFT AVAILABILITY

The use of the AIDAP System will improve the downtime characteristics of the aircraft as previously noted. As a result, aircraft availability expressed as precent operationally ready will increase. The impact of the selected AIDAP System on aircraft availability is presented in Figure 9-12.

9.2.7 MAINTENANCE FLOAT

The increase in aircraft availability can also be interpreted as effectively increasing the number of aircraft available to perform the specific mission requirements. This potential increase in aircraft directly effects the number of aircraft categorized in the maintenance float, as shown in Figure 9-13. This is identical to the decrease in the maintenance float. It is also closely associated with the increase in effective aircraft, as presented in Figure 9-14. Average payload, AIDAPS weight, and the aircraft abort ratio also affect the increase in the effective number of aircraft; however, these effects are usually small compared to the effect of increased aircraft availability.

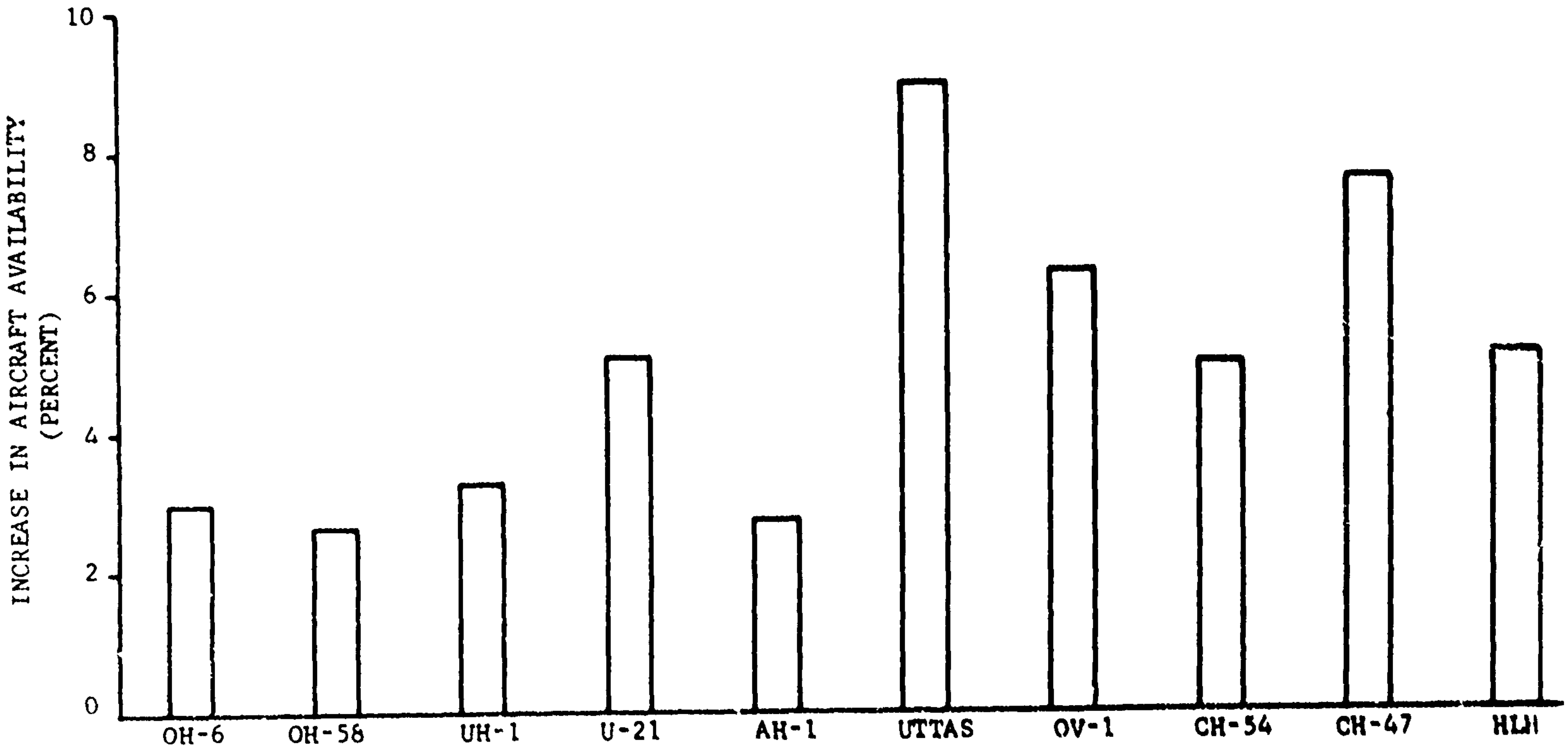


FIGURE 9-12 UNIVERSAL SYSTEMS - EFFECT OF AIDAPS ON AVAILABILITY
HYBRID I - EXPECTED CONDITION

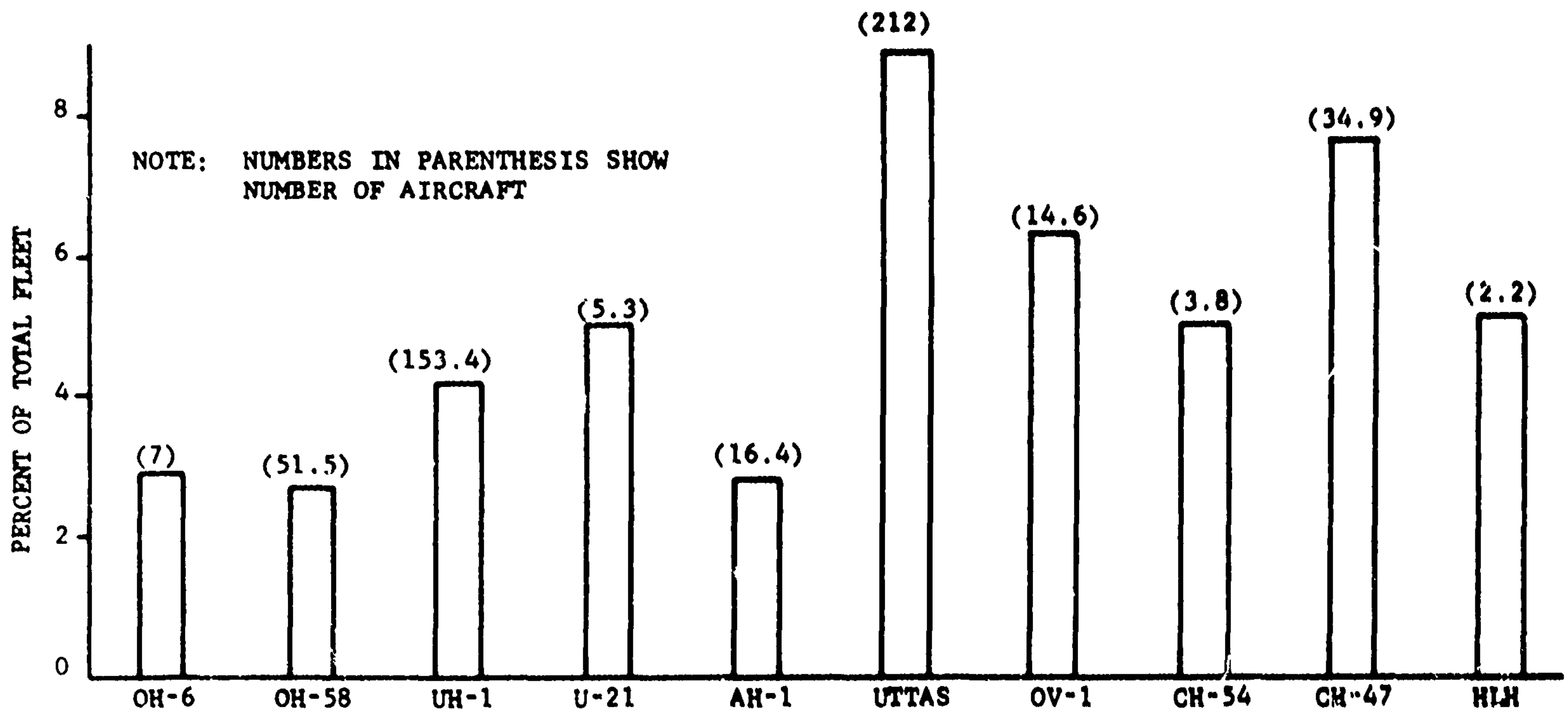


FIGURE 9-13 UNIVERSAL SYSTEMS - AVERAGE REDUCTION IN MAINTENANCE FLOAT HYBRID I - EXPECTED CONDITION

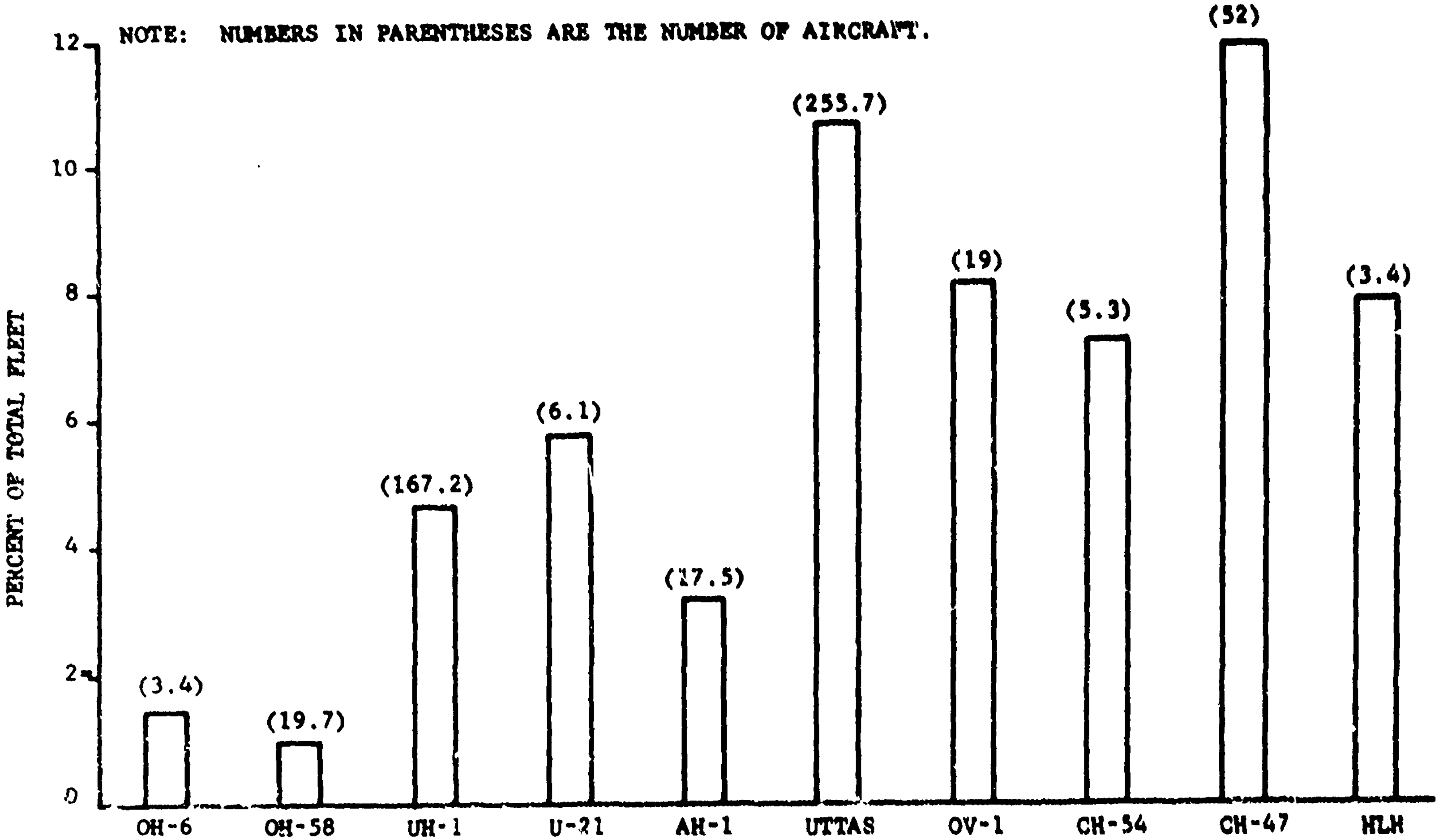


FIGURE 9-14 UNIVERSAL SYSTEMS - INCREASE IN EFFECTIVE AIRCRAFT
HYBRID I - EXPECTED CONDITION (10 YEAR OPERATION)

9.2.8 ACCIDENTS (SECONDARY DAMAGE)

The TAMMS data contained substantially no information on secondary damage to components. However, the accident reports do relate accident causes to components or functional groups wherever applicable. Accidents can be prevented by air warnings of impending failures, or by warnings of a hazardous component status which is associated with a diagnostic capability. They can also be prevented by eliminating component failures during flight through the prognostic capability. Figure 9-15 shows the reduction in accidents due to prognostic and diagnostic capability. The curves for prognostic and diagnostic capability show the results of using either of these capabilities alone. However, since air warning cannot eliminate accidents which are already prevented by the prognostic capability, these curves are not additive. The total curve shows the results of concurrently using both capabilities.

9.2.9 GROUND SUPPORT EQUIPMENT (GSE)

A separate analysis was performed to determine the impact, if any, of an AIDAP System on existing Army aircraft GSE. The only effect was the reduction in the required number of mechanic's hand tools resulting from the decrease in the number of maintenance personnel required. Based on this analysis, there is no significant reduction in the requirements for other GSE. The usage rate of GSE would be reduced but would not warrant elimination of specific items of GSE. The cost savings associated with the reduction in hand tools is part of the equipment and supplies cost factor that was included in the development of personnel downtime cost savings presented in paragraph 9.2.4.

9.2.10 RELIABILITY

The improvement in the reliability characteristics of the aircraft due to the selected AIDAP System is demonstrated by the reduction in aircraft abort rates. This improvement in mission completion capability is presented in Figure 9-16.

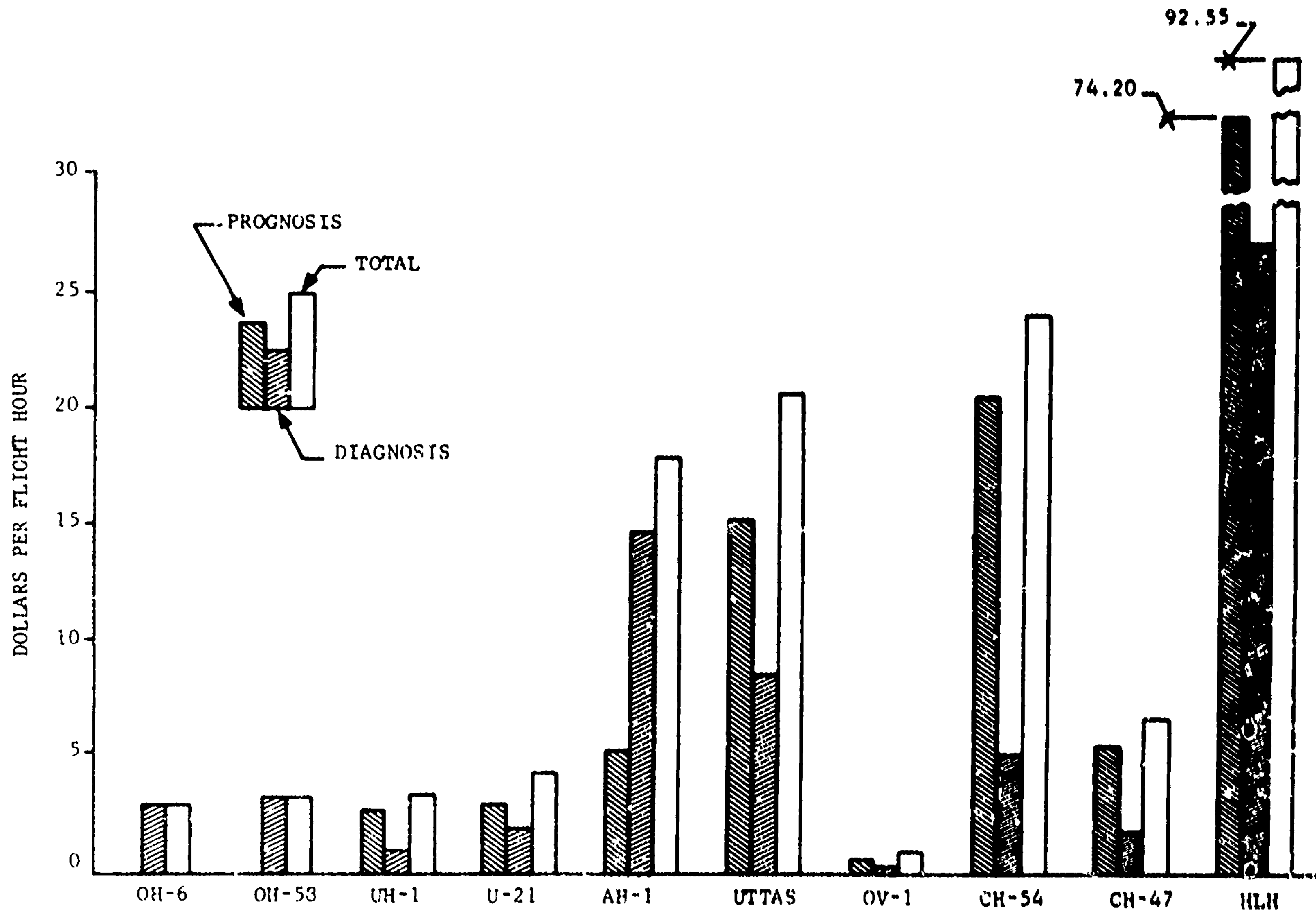


FIGURE 9-15 UNIVERSAL SYSTEMS - ACCIDENT SAVINGS
HYBRID I - EXPECTED CONDITION

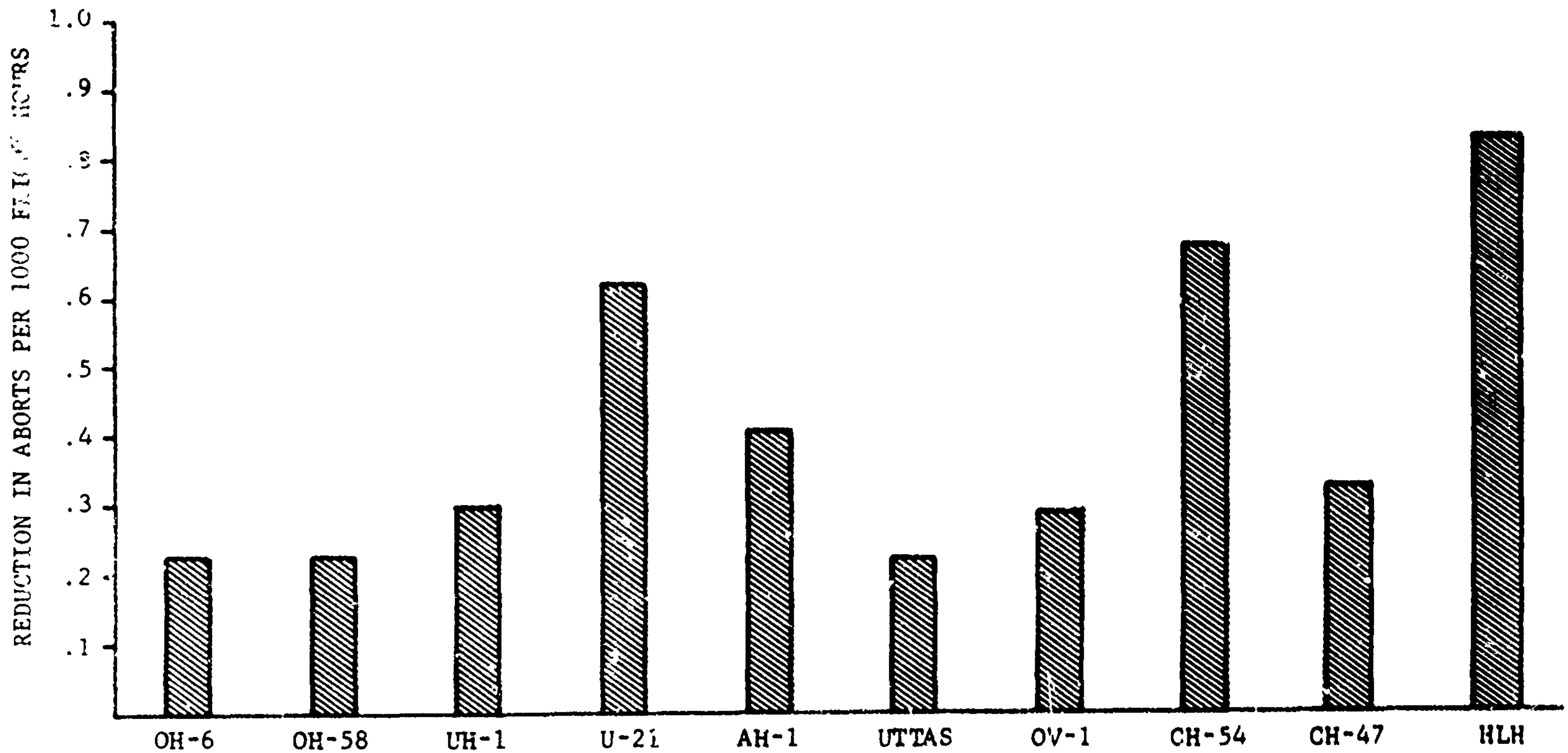


FIGURE 9-16 UNIVERSAL SYSTEMS - REDUCTION IN ABORT RATE
HYBRID I · EXPECTED CONDITIONS

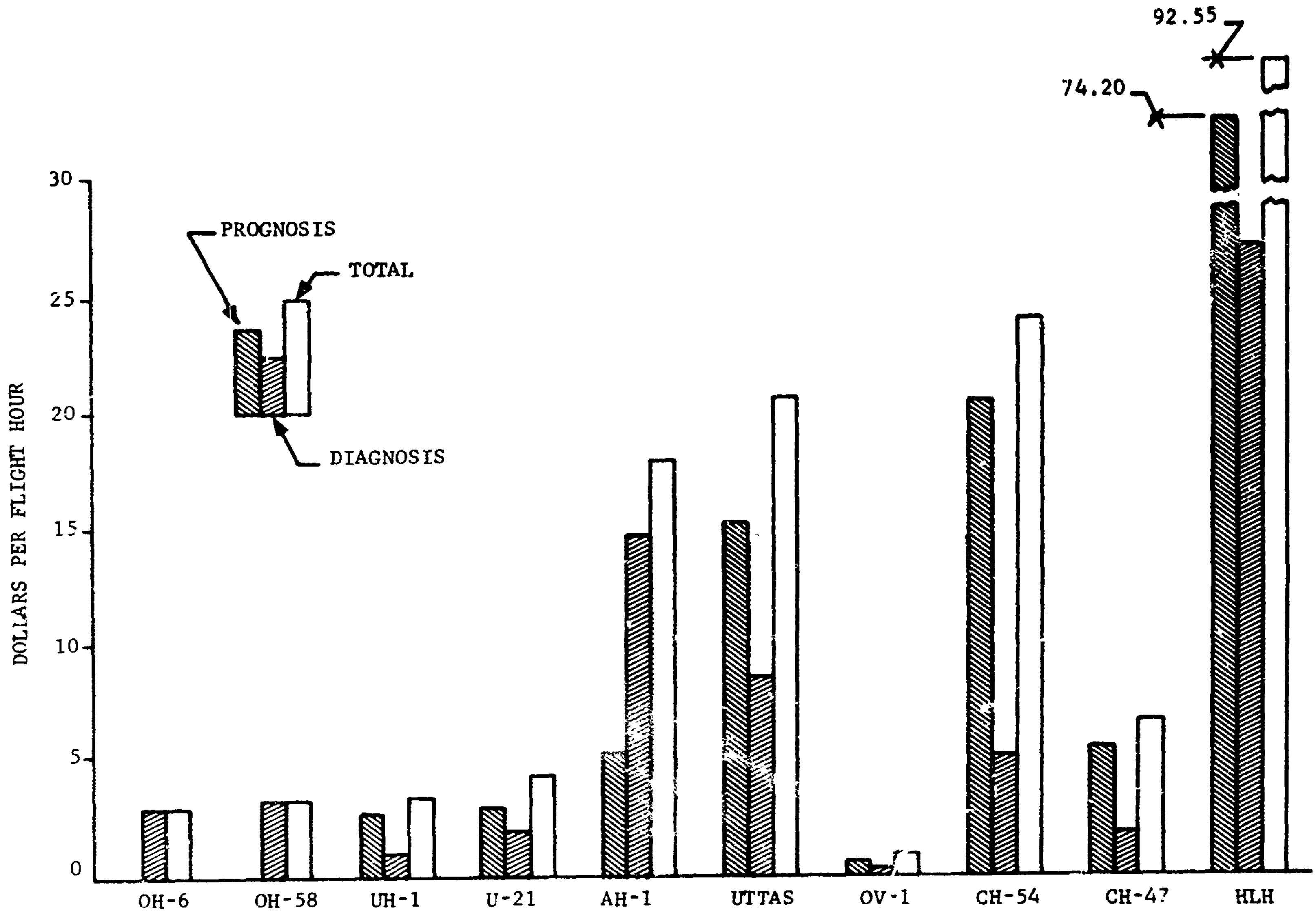


FIGURE 9-15 UNIVERSAL SYSTEMS - ACCIDENT SAVINGS
HYBRID I - EXPECTED CONDITION

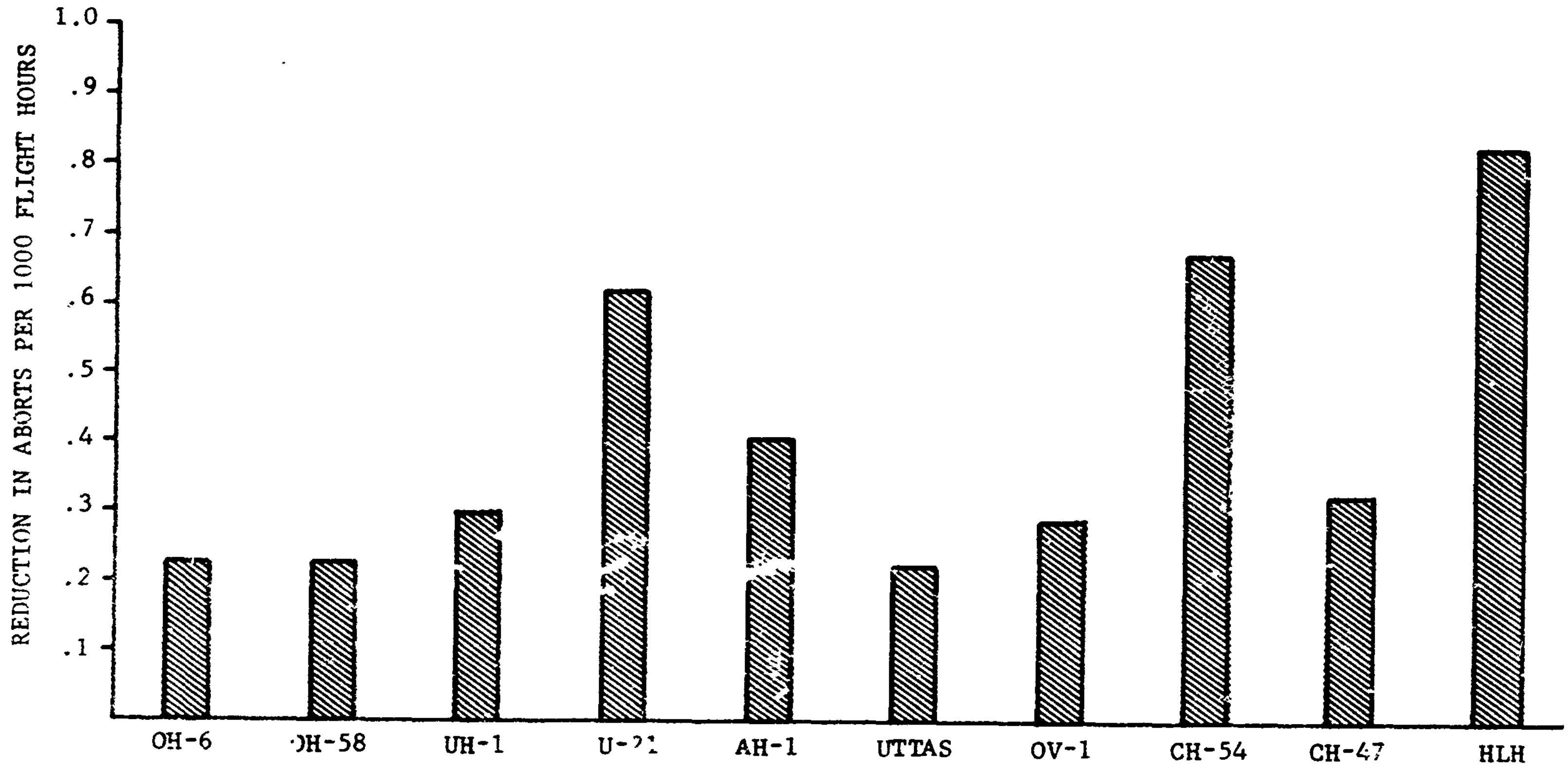


FIGURE 9-16 UNIVERSAL SYSTEMS - REDUCTION IN ABORT RATE
HYBRID I - EXPECTED CONDITIONS

Realized net savings and benefits would have to be considerably smaller than those predicted in this study for a zero net savings to occur; however, since most of the estimating errors that occur in computing net savings are likely to result in an under estimate, this is highly unlikely. If the realized savings are 10 percent of those predicted, they will more than equal AIDAPS life cycle costs for most of the aircraft for which AIDAPS application is recommended.

Although the savings due to AIDAPS are large compared to AIDAPS procurement costs, they represent only a small portion of the total aircraft operating costs. Tables 9-2, 9-3, and 9-4 compare the operating cost savings achieved by AIDAPS with the total aircraft operating costs, the accident cost savings with the total accident costs, and the total cost savings with the total aircraft systems' costs. AIDAPS benefits, due to increased aircraft effectiveness, have been excluded from these figures to make the AIDAPS savings categories comparable with Army cost categories.

9.2.13 COMPARISON OF SAVINGS FOR THE AVIONICS SUBSYSTEM TO SAVINGS ON REMAINDER OF THE AIRCRAFT

Table 9-5 shows the net savings and benefits derived from AIDAPS applied to avionics and from AIDAPS as applied to the remainder of the aircraft systems (less armament and GSE). As can be seen from the figures, the savings from avionics rarely exceed 3 percent of the savings on the rest of the aircraft. The single exception is the application to the OV-1, where the avionics savings is approximately 10 percent. Since the avionic savings are not considered significant, they have been omitted from most of the savings figures in this volume. However, application of AIDAPS to avionic systems is advantageous for certain items of equipment and should be considered for the ultimate AIDAP System design.

9.2.14 TIME PHASED COST SAVINGS

Previous discussions related to the total realized cost savings have assumed a constant force size and a short production program. In order to report the effects of practical AIDAPS procurement programs, as well as a phase-out of aircraft; a time phased implementation of the selected AIDAP System and the cost benefits gained is shown in Figure 9-17.

TABLE 9-2

IMPACT OF AIDAPS ON 10 YEAR OPERATIONS COST

(EXPECTED CONDITIONS)

AIRCRAFT	10 YEAR OPERATIONS COST ($ MILLIONS) *	10 YEAR OPERATIONS COST SAVINGS ** ($ MILLIONS)	PERCENT SAVINGS
AH-1	156.98	5.20	3.3%
CH-47	274.29	49.70	13.1%
CH-54	46.80	4.00	8.5%
UH-1	959.08	60.50	6.3%
U-21	79.25	1.00	1.3%
OH-6	25.83	-.40	-1.5%
OH-58	237.87	3.60	1.5%
OV-1	120.86	8.00	6.6%

* BASED ON FM 101-20 PLANNING FACTORS EXCLUDING POL COSTS

** INCLUDES AIDAPS DDT&E, INVESTMENT AND OPERATIONS COST, EXCLUDES ACCIDENTS AND INCREASED EFFECTIVENESS

TABLE 9-3

IMPACT OF AIDAPS ON TOTAL ACCIDENT COST

(TEN YEARS OF OPERATION - EXPECTED CONDITIONS)

AIRCRAFT	MINOR REPAIR ($ MILLIONS)	MAJOR REPAIR ($ MILLIONS)	TOTAL LOSS ($ MILLIONS)	ACCIDENT TOTAL * ($ MILLIONS)	ACCIDENT SAVINGS ($ MILLIONS)	PERCENT SAVINGS
AH-1	.58	31.56	129.30	161.44	50.40	31.2%
CH-47	.04	19.34	164.16	183.54	11.20	6.1%
CH-54	.23	0	67.30	67.53	5.40	8.0%
UH-1	1.94	82.32	315.84	400.10	59.30	14.8%
U-21	.57	3.48	4.30	8.35	2.80	33.5%
OH-6	0	7.32	13.40	20.72	3.50	16.9%
OH-58	.05	32.22	93.74	126.01	30.70	24.4%
OV-1	.31	.20	78.34	78.85	1.00	1.3%

*BASED ON ACCIDENT DATA PROVIDED BY USABAAR

TABLE 9-4 IMPACT OF AIDAPS ON TOTAL SYSTEMS COST
(EXPECTED CONDITIONS)

AIRCRAFT	TOTAL ACCIDENT AND 10 YEAR OPERATIONS COST ($ MILLIONS)	ACCIDENT AND 10 YEAR OPERATIONS COST SAVINGS ($ MILLIONS)*	PERCENT SAVINGS
AH-1	318.42	55.60	17.5%
CH-47	457.83	60.90	13.3%
CH-54	114.33	9.40	8.2%
UH-1	1359.18	119.80	8.8%
U-21	87.60	3.80	4.3%
OH-6	46.55	3.10	6.6%
OH-58	363.88	34.30	9.4%
OV-1	199.71	9.00	4.5%

*Excludes benefits gained from increase in effective number of aircraft

TABLE 9-5 TOTAL NET SAVINGS INCLUDING AVIONICS

AIRCRAFT	PESSIMISTIC			EXPECTED			OPTIMISTIC		
	SYSTEM NET SAVINGS	AVIONIC SAVINGS	TOTAL NET SAVINGS	SYSTEM NET SAVINGS	AVIONIC SAVINGS	TOTAL NET SAVINGS	SYSTEM NET SAVINGS	AVIONIC SAVINGS	TOTAL NET SAVINGS
OH-6	.719	.042	.761	3.265	.052	3.317	12.082	.081	12.163
CH-58	14.952	.347	15.299	36.069	.425	36.494	108.551	.657	109.208
UH-1	93.984	.651	94.635	164.469	.776	165.245	481.186	1.374	482.560
U-21	3.352	.023	3.375	5.345	.027	5.372	11.741	.038	11.779
AH-1	41.504	.107	41.611	62.110	.130	62.240	127.403	.201	127.604
UTTAS	586.577	5.201	591.778	853.031	6.183	859.214	1733.358	9.031	1742.389
OV-1	22.645	2.086	24.731	29.153	2.254	31.407	69.860	3.260	73.120
CH-54	9.077	.079	9.156	18.980	.101	19.081	47.722	.158	47.880
CH-47	61.914	.822	62.736	118.083	1.013	119.096	289.732	1.587	291.319
HLH	30.634	.068	30.702	59.174	.086	59.260	179.070	.165	179.241

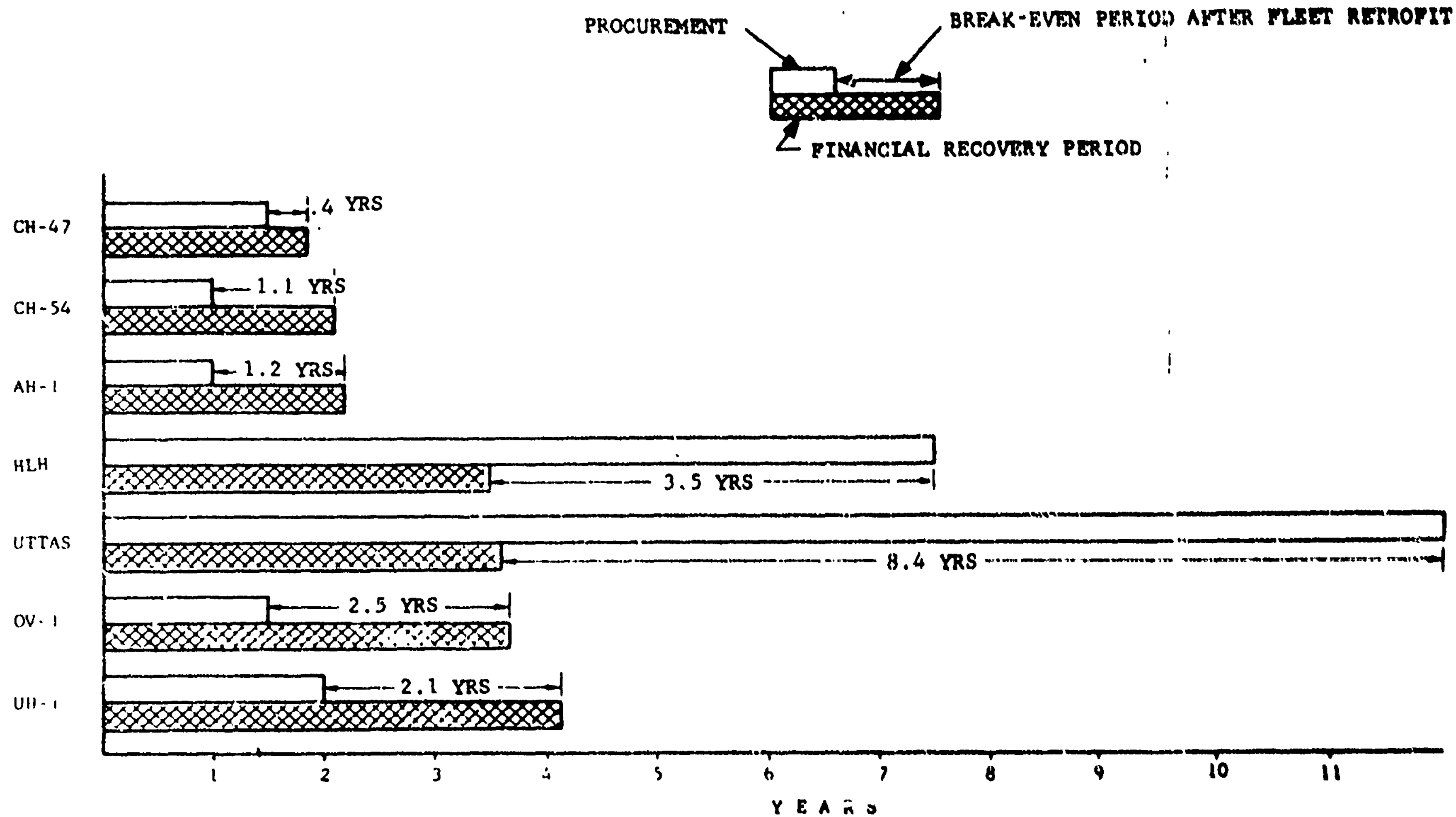


FIGURE 9-17 TIME REQUIRED FOR AIDAPS PROCUREMENT COSTS TO BE RECOVERED
HYBRID I - UNIVERSAL SYSTEMS

9.3 SOURCE MODEL RUNS

In order to verify the realism of the operational benefits calculated by the AIDAPS/Aircraft Maintenance model, comparison with results using a different technique was sought. The AIDAPS/Aircraft Maintenance Analysis model was developed using deterministic computational techniques. A Monte Carlo simulation model, which was developed by Northrop under Contract No. F44620-68-C-0094, was used for this comparison. This model is called the Simulation of Utilization, Resources, Cost, and Efficiency (SOURCE) model.

The SOURCE model is a computer simulation of an aircraft's complete daily operational maintenance cycle. The principal inputs and resultant outputs obtainable from various applications of the SOURCE model are shown in Figure 9-18.

The SOURCE model represents the embodiment of many maintenance techniques and concepts working together as a coherent unit. The SOURCE model is a straightforward analytical tool employing the Monte Carlo sampling procedure. The model is supported by a comprehensive array of specially developed electronic data processing (EDP) programs and statistical techniques which were designed to translate "raw field data" from standard data collection inputs into forms amenable to analysis and usable as model inputs. Thus, the model is tailored to accommodate the types of information which can be obtained from Air Force operational activities and is within the scope of existing data collection systems.

Figure 9-19 shows the major programming elements of the SOURCE model. This model utilizes a sequence register whose basic decisions are triggered by the Monte Carlo technique, and are utilized to establish the aircraft states and maintain an elapsed time counter. The control parameters consist of the flying schedule environmental probability factors, and the program processing data which are inserted to establish the basic criteria being measured. The flying schedule relates the operational commitment being evaluated to the aircraft system characteristics.

The SOURCE model can be segregated into three basic functions:

a) Maintenance Decisions

b) Resource Allocations

c) Cost Determinations

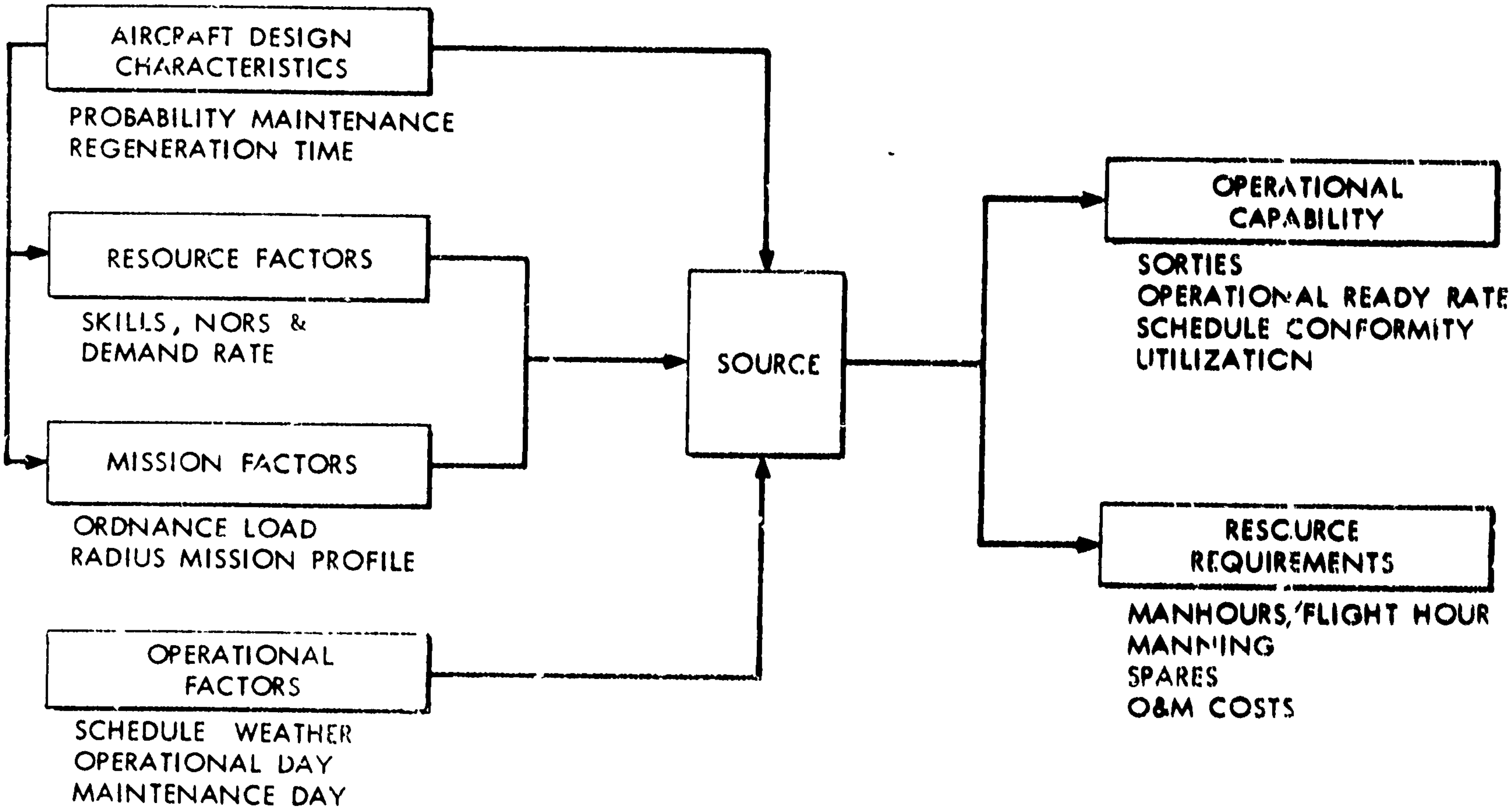


FIGURE 9-18 SOURCE MODEL INPUT/OUTPUT RELATIONSHIPS

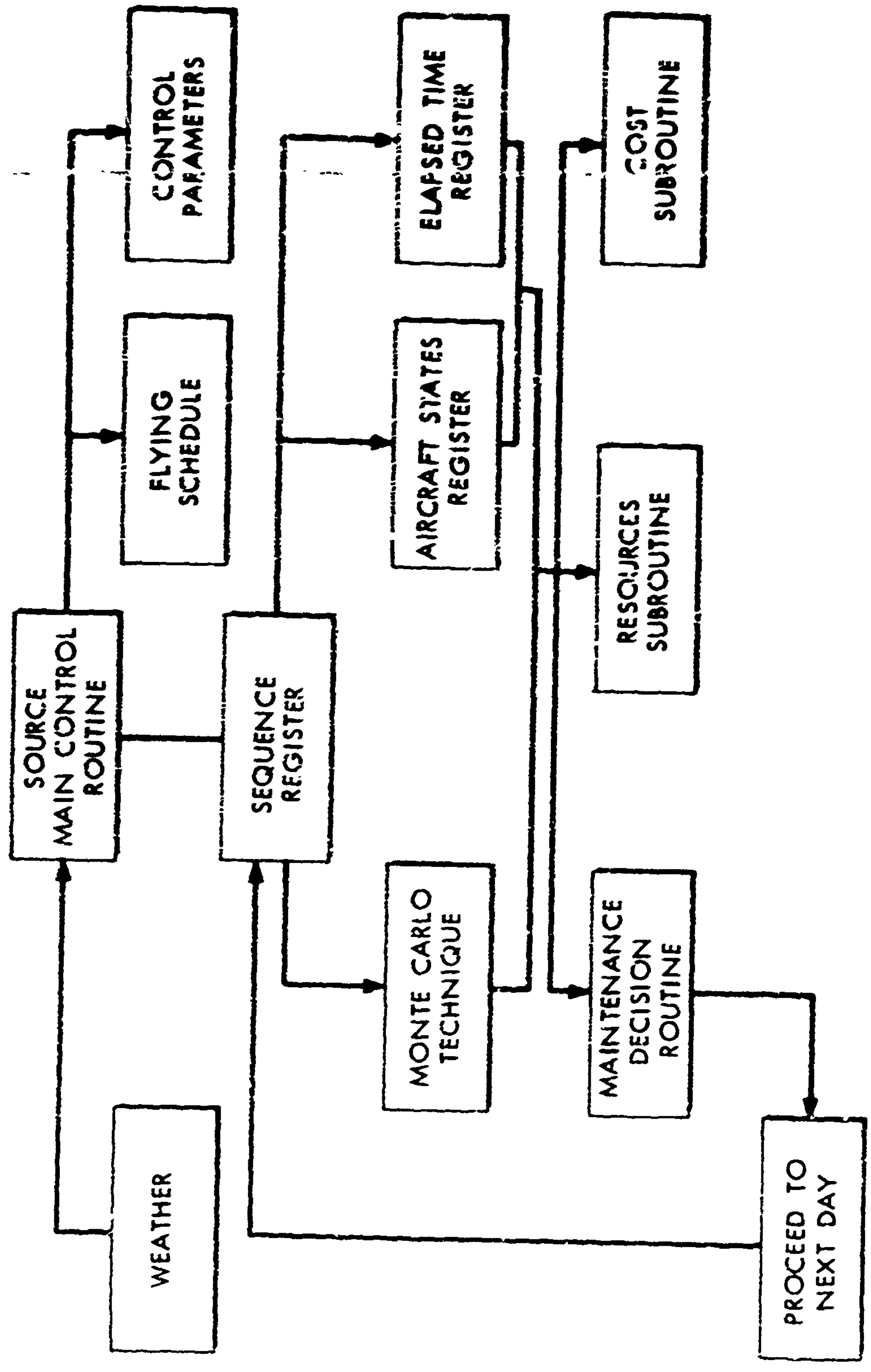


FIGURE 9-19 SOURCE MODEL, MAJOR PROGRAMMING ELEMENTS

Each function, while distinct in category, reflects a continuing daily determination of aircraft capability and support expenditures.

The SOURCE model is relatively insensitive to the small changes in aircraft break rates, abort rates, and reduced maintenance downtime achieved by AIDAPS. In addition, it does not account for reductions in aircraft daily inspection time. Within these constraints however, the results were verified.

Tables 9-6 and 9-7 show a typical operation for the UH-1 aircraft without AIDAPS. The schedule shown in columns two and three of Table 9-6 is an arbitrary schedule input generated to produce approximately forty flying hours per month. In addition, only two flying period per day (12 hours each) were utilized. Therefore, no entries appear under columns 3 through 8 of Table 9-7. Using the schedule shown in columns 2 and 3 of Table 9-6, and based on input maintenance characteristics of the aircraft, the remainder of Table 9-7 shows the average operating results of the aircraft during a one-month period. The average operational readiness attained was .77, which corresponds to .76 attained by the maintenance analysis model.

Tables 9-8 and 9-9 show the results of an AIDAPS equipped UH-1 responding to exactly the same schedule. In this case, the operational ready rate increased to 78 percent, or an increase of 1 percent. The AIDAPS maintenance analysis, under similar conditions, generated an improvement in aircraft availability of 4 percent. When this is converted to an improvement in the operational ready rate, by excluding daily inspections, the improvement amounts to 1.2 percent is in close agreement with the SOURCE model.

Tables 9-10 through 9-13 compare the maximum sortie capability of the UH-1 without AIDAPS to the UH-1 with AIDAPS. These conditions were created by scheduling 6 flights per day for each of the 23 available aircraft. Under these conditions, the UH-1 with AIDAPS achieved 109 flying hours per month per aircraft with an operational ready rate of 57 percent. The UH-1 without AIDAPS achieved only 100 flying hours per month with an operation ready rate of 54 percent.

TABLE 9-6

DAILY SORTIES AND UTILIZATION

A/C PER BASE 25 FLYING DAYS/MO 24 SORTIE CYCLES/DAY 2. SORTIES SCHEDULED/SORTIE CYCLE 14 MISSION DURATION 1.5
ARCRW POST + TURNAROUND 0.3 MAINT TIME BETWEEN FLTS 5.0 ARCRW PRE 0.2 MAINT WORKG HRS/DAY 24.0 NORS RATE 0.07

UH-1 WITHOUT AIDAPS

MAY

DAY	SORTIES SCHEDULED	SORTIES FLOWN	A/C SORTIES PER DAY	AVG SORTIES PER DAY	FLIGHT HOURS SCHEDULED	FLIGHT HOURS FLOWN	A/C FLIGHT HOURS PER DAY	A/C FLIGHT HOURS AVG PER DAY	WK
1	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
2	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
3	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
4	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
5	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
6	28.0	27.0	1.0800	1.1100	42.00	40.50	1.6200	1.6650	0.0
7	28.0	28.0	1.1200	1.1120	42.00	42.00	1.6800	1.6680	0.0
8	28.0	28.0	1.1200	1.1133	42.00	42.00	1.6800	1.6700	0.0
9	0.0	0.0	0.0	1.1133	0.0	0.0	0.0	1.6700	28.0
10	28.0	28.0	1.1200	1.1143	42.00	42.00	1.6800	1.6714	0.0
11	28.0	28.0	1.1200	1.1150	42.00	42.00	1.6800	1.6725	0.0
12	0.0	0.0	0.0	1.1150	0.0	0.0	0.0	1.6725	28.0
13	28.0	28.0	1.1200	1.1156	42.00	42.00	1.6800	1.6733	0.0
14	28.0	28.0	1.1200	1.1160	42.00	42.00	1.6800	1.6740	0.0
15	28.0	28.0	1.1200	1.1164	42.00	42.00	1.6800	1.6745	0.0
16	0.0	0.0	0.0	1.1164	0.0	0.0	0.0	1.6745	28.0
17	28.0	28.0	1.1200	1.1167	42.00	42.00	1.6800	1.6750	0.0
18	28.0	28.0	1.1200	1.1169	42.00	42.00	1.6800	1.6754	0.0
19	28.0	28.0	1.1200	1.1171	42.00	42.00	1.6800	1.6757	0.0
20	28.0	28.0	1.1200	1.1173	42.00	42.00	1.6800	1.6760	0.0
21	28.0	28.0	1.1200	1.1175	42.00	42.00	1.6800	1.6762	0.0
22	28.0	28.0	1.1200	1.1176	42.00	42.00	1.6800	1.6765	0.0
23	0.0	0.0	0.0	1.1176	0.0	0.0	0.0	1.6765	28.0
24	28.0	28.0	1.1200	1.1178	42.00	42.00	1.6800	1.6767	0.0
25	28.0	28.0	1.1200	1.1179	42.00	42.00	1.6800	1.6768	0.0
26	28.0	28.0	1.1200	1.1180	42.00	42.00	1.6800	1.6770	0.0
27	28.0	28.0	1.1200	1.1181	42.00	42.00	1.6800	1.6771	0.0
28	28.0	28.0	1.1200	1.1182	42.00	42.00	1.6800	1.6773	0.0
29	28.0	28.0	1.1200	1.1183	42.00	42.00	1.6800	1.6774	0.0
30	0.0	0.0	0.0	1.1183	0.0	0.0	0.0	1.6774	28.0
31	0.0	0.0	0.0	1.1183	0.0	0.0	0.0	1.6774	28.0
TOTAL	644.0	643.0	25.7200	1.1183	966.00	964.50	38.5799	1.6774	

PERCENT SCHED COMPLETION	SORTIE RATE PER DAY	A/C FLT HRS PER DAY	UTILIZ-A/C FLT HRS PER MO
99.84	1.12	1.60	40.26

TABLE 9-7

OPERATIONAL EFFECTIVENESS

	OPERATIONALLY READY									NOT OPERATIONALLY READY-MAINTENANCE																	
	MAY									UNSCHEDULED									SCHEDULED								
PRO.* DAY	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8
1	0.93	0.77	0.77	0.0	0.0	0.0	0.0	0.0	0.0	.0	.12	.12	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
2	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	0.89	0.61	0.69	0.0	0.0	0.0	0.0	0.0	0.0	.0	.12	.24	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	0.89	0.73	0.53	0.0	0.0	0.0	0.0	0.0	0.0	.04	.20	.40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	0.93	0.65	0.49	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.40	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
7	0.89	0.73	0.69	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.24	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	0.93	0.73	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	0.85	0.49	0.53	0.0	0.0	0.0	0.0	0.0	0.0	.08	.40	.36	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
11	0.85	0.61	0.33	0.0	0.0	0.0	0.0	0.0	0.0	.04	.28	.56	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
12	0.85	0.85	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	0.93	0.73	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	0.93	0.73	0.53	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.36	.0	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0
15	0.81	0.49	0.49	0.0	0.0	0.0	0.0	0.0	0.0	.08	.40	.40	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
16	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
17	0.85	0.53	0.49	0.0	0.0	0.0	0.0	0.0	0.0	.04	.36	.44	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0	.0	.0
18	0.93	0.77	0.69	0.0	0.0	0.0	0.0	0.0	0.0	.0	.16	.24	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
19	0.93	0.69	0.73	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.12	.0	.0	.0	.0	.0	.0	.0	.0	.08	.0	.0	.0	.0	.0	.0
20	0.85	0.67	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.28	.0	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0
21	0.85	0.69	0.45	0.0	0.0	0.0	0.0	0.0	0.0	.04	.20	.44	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
22	0.89	0.57	0.49	0.0	0.0	0.0	0.0	0.0	0.0	.0	.32	.44	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0	.0	.0
23	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
24	0.89	0.61	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.04	.32	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
25	0.93	0.69	0.45	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.48	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
26	0.93	0.89	0.73	0.0	0.0	0.0	0.0	0.0	0.0	.0	.04	.20	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27	0.93	0.65	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.32	.0	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0
28	0.89	0.69	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.24	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
29	0.89	0.53	0.45	0.0	0.0	0.0	0.0	0.0	0.0	.0	.36	.48	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0	.0	.0
30	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

AVERAGE = 0.7

TABLE 9-8

DAILY SORTIES AND UTILIZATION

A/C PER BASE 25 FLYING DAYS/MO 24 SORTIE CYCLES/DAY 2. SORTIES SCHEDULED/SORTIE CYCLE 14 MISSION DURATION 1.5
ARCRW POST + TURNAROUND 0.3 MAINT TIME BETWEEN FLTS 5.0 ARCRW PRE 0.2 MAINT WORKG HRS/DAY 24.0 NORS RATE 0.07
UH-1 WITH AIDAPS

MAY

DAY	SORTIES SCHEDULED	SORTIES FLOWN	A/C SORTIES PER DAY	AVG SORTIES PER DAY	FLIGHT HOURS SCHEDULED	FLIGHT HOURS FLOWN	A/C FLIGHT HOURS PER DAY	A/C FLIGHT HOURS AVG PER DAY	WX
1	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
2	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
3	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
4	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
5	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
6	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
7	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
8	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
9	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
10	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
11	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
12	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
13	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
14	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
15	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
16	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
17	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
18	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
19	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
20	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
21	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
22	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
23	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
24	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
25	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
26	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
27	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
28	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
29	28.0	28.0	1.1200	1.1200	42.00	42.00	1.6800	1.6800	0.0
30	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
31	0.0	0.0	0.0	1.1200	0.0	0.0	0.0	1.6800	28.0
TOTAL	644.0	644.0	25.7599	1.1200	966.00	966.00	38.6399	1.6800	

PERCENT SCHED COMPLETION	SORTIE RATE PER DAY	A/C FLT HRS PER DAY	UTILIZ-A/C FLT HRS PER MO
100.00	1.12	1.68	40.32

TABLE 9-9

OPERATIONAL EFFECTIVENESS

MAY	OPERATIONALLY READY									NOT OPERATIONALLY READY-MAINTENANCE UNSCHEDULED									SCHEDULED								
PRU.# DAY	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5	6	7	8
1	0.93	0.65	0.77	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.16	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	0.89	0.61	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.04	.32	.28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	0.89	0.69	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.04	.20	.32	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
5	0.85	0.85	0.89	0.0	0.0	0.0	0.0	0.0	0.0	.04	.04	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0	.0
6	0.93	0.81	0.77	0.0	0.0	0.0	0.0	0.0	0.0	.0	.12	.16	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7	0.93	0.69	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	0.93	0.85	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.0	.08	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10	0.89	0.65	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.04	.28	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11	0.93	0.57	0.41	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.48	.0	.0	.0	.0	.0	.0	.0	.08	.04	.0	.0	.0	.0	.0	.0
12	0.89	0.89	0.89	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0	.0
13	0.93	0.61	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.32	.36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
14	0.93	0.61	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.36	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0	.0
15	0.89	0.65	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.04	.24	.24	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
16	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
17	0.85	0.53	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.04	.36	.32	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0	.0
18	0.93	0.69	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
19	0.89	0.69	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.04	.20	.28	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
20	0.89	0.61	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.32	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
21	0.89	0.65	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.32	.0	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0	.0	.0	.0	.0
22	0.85	0.57	0.69	0.0	0.0	0.0	0.0	0.0	0.0	.04	.36	.24	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
23	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
24	0.93	0.73	0.65	0.0	0.0	0.0	0.0	0.0	0.0	.0	.20	.28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
25	0.93	0.77	0.73	0.0	0.0	0.0	0.0	0.0	0.0	.0	.16	.20	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
26	0.93	0.65	0.61	0.0	0.0	0.0	0.0	0.0	0.0	.0	.28	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27	0.89	0.77	0.77	0.0	0.0	0.0	0.0	0.0	0.0	.04	.16	.16	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
28	0.89	0.61	0.57	0.0	0.0	0.0	0.0	0.0	0.0	.04	.32	.36	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29	0.93	0.69	0.49	0.0	0.0	0.0	0.0	0.0	0.0	.0	.24	.44	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30	0.93	0.93	0.93	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31	0.89	0.89	0.89	0.0	0.0	0.0	0.0	0.0	0.0	.04	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

$\underbrace{}_{\text{AVERAGE = 0.78}}$

TABLE 9-10

DAILY SORTIES AND UTILIZATION

A/C PER BASE 25 FLYING DAYS/MO 24 SORTIE CYCLES/DAY 6. SORTIES SCHEDULED/SORTIE CYCLE 23 MISSION DURATION 1.5
ARCRW POST + TURNAROUND 0.3 MAINT TIME BETWEEN FLTS 0.0 ARCRW PRE 0.2 MAINT WORKG HRS/DAY 24.0 NORS RATE 0.07
UH-1 WITHOUT AIDAPS

JULY

	SORTIES		A/C SORTIES	AVG SORTIES	FLIGHT HOURS		A/C FLIGHT HOURS		WX
DAY	SCHEDULED	FLOWN	PER DAY	PER DAY	SCHEDULED	FLOWN	PER DAY	AVG PER DAY	
1	138.0	67.0	2.6800	2.6800	207.00	100.50	4.0200	4.0200	0.0
2	138.0	74.0	2.9600	2.8200	207.00	111.00	4.4400	4.2300	0.0
3	138.0	70.0	2.8000	2.8133	207.00	105.00	4.2000	4.2200	0.0
4	138.0	65.0	2.6000	2.7600	207.00	97.50	3.9000	4.1400	0.0
5	0.0	0.0	0.0	2.7600	0.0	0.0	0.0	4.1400	138.0
6	138.0	72.0	2.8800	2.7640	207.00	108.00	4.3200	4.1760	0.0
7	0.0	0.0	0.0	2.7840	0.0	0.0	0.0	4.1760	138.0
8	138.0	76.0	3.0400	2.8267	207.00	114.00	4.5600	4.2400	0.0
9	138.0	72.0	2.8800	2.8343	207.00	108.00	4.3200	4.2514	0.0
10	138.0	68.0	2.7200	2.8200	207.00	102.00	4.0800	4.2300	0.0
11	138.0	82.0	3.2800	2.8711	207.00	123.00	4.9200	4.3067	0.0
12	0.0	0.0	0.0	2.8711	0.0	0.0	0.0	4.3067	138.0
13	138.0	79.0	3.1600	2.9000	207.00	118.50	4.7400	4.3500	0.0
14	0.0	0.0	0.0	2.9000	0.0	0.0	0.0	4.3500	138.0
15	138.0	70.0	2.8000	2.8909	207.00	105.00	4.2000	4.3364	0.0
16	138.0	64.0	2.5600	2.8633	207.00	96.00	3.8400	4.2950	0.0
17	138.0	64.0	2.5600	2.8400	207.00	96.00	3.8400	4.2600	0.0
18	138.0	69.0	2.7600	2.8343	207.00	103.50	4.1400	4.2514	0.0
19	138.0	71.0	2.8400	2.8347	207.00	106.50	4.2600	4.2520	0.0
20	138.0	63.0	2.5200	2.8150	207.00	94.50	3.7800	4.2225	0.0
21	0.0	0.0	0.0	2.8150	0.0	0.0	0.0	4.2225	138.0
22	138.0	78.0	3.1200	2.8329	207.00	117.00	4.6800	4.2494	0.0
23	138.0	69.0	2.7600	2.8289	207.00	103.50	4.1400	4.2433	0.0
24	138.0	66.0	2.6400	2.8189	207.00	99.00	3.9600	4.2284	0.0
25	138.0	52.0	2.0800	2.7820	207.00	78.00	3.1200	4.1730	0.0
26	138.0	68.0	2.7200	2.7790	207.00	102.00	4.0800	4.1686	0.0
27	138.0	73.0	2.9200	2.7855	207.00	109.50	4.3800	4.1782	0.0
28	0.0	0.0	0.0	2.7855	0.0	0.0	0.0	4.1782	138.0
29	138.0	64.0	2.5600	2.7757	207.00	96.00	3.8400	4.1635	0.0
30	138.0	70.0	2.8000	2.7767	207.00	105.00	4.2000	4.1650	0.0
31	0.0	0.0	0.0	2.7767	0.0	0.0	0.0	4.1650	138.0
TOTAL	3312.0	1666.0	66.5598	2.7767	4968.00	2499.00	99.9598	4.1650	

PERCENT SCHED COMPLETION	SORTIE RATE PER DAY	A/C FLT HRS PER DAY	UTILIZ-A/C FLT HRS PER MO
50.30	2.78	4.16	99.96

TABLE 9-11

OPERATIONAL EFFECTIVENESS

PRO.* DAY	OPERATIONALLY READY (JULY) 0	1	2	3	4	5	6	7	8	NOT OPERATIONALLY READY-MAINTENANCE: UNSCHEDULED 0	1	2	3	4	5	6	7	8	SCHEDULED 0	1	2	3	4	5	6	7	8
1	0.93	0.41	0.33	0.29	0.29	0.33	0.29	0.0	0.0	.0	.52	.60	.64	.64	.60	.64	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	0.89	0.37	0.33	0.29	0.45	0.41	0.21	0.0	0.0	.04	.56	.60	.64	.48	.52	.72	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	0.89	0.41	0.25	0.33	0.21	0.37	0.41	0.0	0.0	.04	.52	.68	.60	.72	.56	.52	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	0.81	0.41	0.37	0.33	0.17	0.21	0.09	0.0	0.0	.12	.52	.56	.60	.72	.68	.80	.0	.0	.0	.0	.0	.0	.04	.04	.04	.0	.0
5	0.85	0.85	0.93	0.93	0.93	0.93	0.93	0.0	0.0	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	0.93	0.65	0.33	0.25	0.21	0.29	0.37	0.0	0.0	.0	.24	.56	.64	.68	.56	.48	.0	.0	.0	.04	.04	.04	.04	.08	.08	.0	.0
7	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	0.81	0.57	0.41	0.33	0.37	0.37	0.37	0.0	0.0	.04	.32	.44	.48	.44	.44	.40	.0	.0	.04	.04	.08	.12	.12	.12	.16	.0	.0
9	0.73	0.57	0.45	0.25	0.21	0.25	0.37	0.0	0.0	.04	.32	.44	.60	.64	.60	.48	.0	.0	.04	.04	.04	.08	.08	.08	.08	.0	.0
10	0.77	0.41	0.45	0.33	0.21	0.25	0.21	0.0	0.0	.08	.48	.44	.56	.68	.64	.68	.0	.0	.04	.04	.04	.04	.04	.04	.04	.0	.0
11	0.89	0.57	0.45	0.53	0.29	0.25	0.25	0.0	0.0	.0	.36	.44	.36	.60	.64	.60	.0	.0	.0	.0	.04	.04	.04	.04	.04	.0	.0
12	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.04	.04	.04	.04	.04	.04	.04	.0	.0
13	0.89	0.57	0.41	0.49	0.33	0.29	0.29	0.0	0.0	.0	.36	.40	.32	.48	.48	.48	.0	.0	.0	.0	.12	.12	.12	.16	.16	.0	.0
14	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
15	0.77	0.53	0.45	0.41	0.25	0.17	0.25	0.0	0.0	.0	.28	.36	.40	.56	.64	.56	.0	.0	.12	.12	.12	.12	.12	.12	.12	.0	.0
16	0.77	0.45	0.41	0.37	0.25	0.25	0.33	0.0	0.0	.04	.40	.48	.52	.64	.64	.56	.0	.0	.04	.04	.04	.04	.04	.04	.04	.0	.0
17	0.85	0.41	0.33	0.33	0.13	0.25	0.17	0.0	0.0	.04	.44	.52	.48	.68	.56	.64	.0	.0	.04	.08	.08	.12	.12	.12	.08	.0	.0
18	0.91	0.57	0.49	0.37	0.33	0.25	0.33	0.0	0.0	.04	.36	.44	.56	.60	.68	.60	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
19	0.89	0.57	0.53	0.37	0.29	0.29	0.29	0.0	0.0	.04	.36	.40	.56	.64	.64	.64	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
20	[illegible]	0.57	0.25	0.29	0.29	0.29	0.37	0.0	0.0	.04	.32	.60	.56	.56	.56	.48	.0	.0	.0	.04	.08	.08	.08	.08	.04	.0	.0
21	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
22	0.89	0.61	0.53	0.33	0.45	0.37	0.25	0.0	0.0	.0	.28	.36	.56	.44	.48	.60	.0	.0	.04	.04	.04	.04	.04	.08	.08	.0	.0
23	0.85	0.61	0.33	0.25	0.29	0.49	0.49	0.0	0.0	.0	.28	.56	.64	.60	.40	.40	.0	.0	.04	.04	.04	.04	.04	.04	.04	.0	.0
24	0.89	0.41	0.37	0.25	0.41	0.45	0.33	0.0	0.0	.0	.48	.52	.64	.44	.40	.52	.0	.0	.04	.0	.04	.04	.08	.08	.08	.0	.0
25	0.77	0.45	0.41	0.25	0.21	0.35	0.25	0.0	0.0	.08	.44	.44	.60	.64	.80	.60	.0	.0	.04	.04	.08	.08	.08	.08	.08	.0	.0
26	0.81	0.53	0.41	0.33	0.41	0.33	0.33	0.0	0.0	.04	.36	.48	.52	.48	.56	.56	.0	.0	.0	.04	.04	.04	.04	.04	.0	.0	.0
27	[illegible]	0.57	0.45	0.37	0.37	0.37	0.37	0.0	0.0	.04	.36	.44	.52	.52	.52	.52	.0	.0	.0	.0	.04	.04	.04	.04	.04	.0	.0
28	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29	0.85	0.37	0.41	0.33	0.33	0.37	0.37	0.0	0.0	.04	.56	.52	.60	.60	.56	.56	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
30	0.93	0.57	0.37	0.29	0.37	0.37	0.41	0.0	0.0	.0	.36	.56	.64	.56	.56	.52	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31	0.85	0.85	0.89	0.93	0.93	0.93	0.93	0.0	0.0	.08	.08	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

AVERAGE = 0.54

TABLE 9-12

DAILY SORTIES AND UTILIZATION

A/C PER BASE 25 FLYING DAYS/MO 24 SORTIE CYCLES/DAY 6. SORTIES SCHEDULED/SORTIE CYCLE 23 MISSION DURATION 1.5
ARCRW POST + TURNAROUND 0.3 MAINT TIME BETWEEN FLTS 0.0 ARCRW PRE 0.2 MAINT WORKG HRS/DAY 24.0 NORS RATE 0.07
UH-1 WITH AIDAPS

JULY

DAY	SORTIES SCHEDULED	SORTIES FLOWN	A/C SORTIES PER DAY	AVG SORTIES PER DAY	FLIGHT HOURS SCHEDULED	FLIGHT HOURS FLOWN	A/C FLIGHT HOURS PER DAY	A/C FLIGHT HOURS AVG PER DAY	MX
1	138.0	89.0	3.5600	3.5600	207.00	133.50	5.3400	5.3400	0.0
2	138.0	86.0	3.4400	3.5000	207.00	129.00	5.1600	5.2500	0.0
3	138.0	76.0	3.0400	3.3467	207.00	114.00	4.5600	5.0200	0.0
4	138.0	84.0	3.3600	3.3500	207.00	126.00	5.0400	5.0250	0.0
5	0.0	0.0	0.0	3.3500	0.0	0.0	0.0	5.0250	138.0
6	138.0	73.0	2.9200	3.2640	207.00	109.50	4.3800	4.8960	0.0
7	0.0	0.0	0.0	3.2640	0.0	0.0	0.0	4.8960	138.0
8	138.0	83.0	3.3200	3.2733	207.00	124.50	4.9800	4.9100	0.0
9	138.0	91.0	3.6400	3.3257	207.00	136.50	5.4600	4.9886	0.0
10	138.0	76.0	3.0400	3.2900	207.00	114.00	4.5600	4.9350	0.0
11	138.0	74.0	2.9600	3.2533	207.00	111.00	4.4400	4.8800	0.0
12	0.0	0.0	0.0	3.2533	0.0	0.0	0.0	4.8800	138.0
13	138.0	72.0	2.8800	3.2160	207.00	108.00	4.3200	4.8240	0.0
14	0.0	0.0	0.0	3.2160	0.0	0.0	0.0	4.8240	138.0
15	138.0	74.0	2.9600	3.1927	207.00	111.00	4.4400	4.7891	0.0
16	138.0	75.0	3.0000	3.1767	207.00	112.50	4.5000	4.7650	0.0
17	138.0	76.0	3.0400	3.1662	207.00	114.00	4.5600	4.7492	0.0
18	138.0	67.0	2.6800	3.1314	207.00	100.50	4.0200	4.6971	0.0
19	138.0	74.0	2.9600	3.1200	207.00	111.00	4.4400	4.6800	0.0
20	138.0	78.0	3.1200	3.1200	207.00	117.00	4.6800	4.6800	0.0
21	0.0	0.0	0.0	3.1200	0.0	0.0	0.0	4.6800	138.0
22	138.0	69.0	2.7600	3.0988	207.00	103.50	4.1400	4.6482	0.0
23	138.0	68.0	2.7200	3.0778	207.00	102.00	4.0800	4.6167	0.0
24	138.0	75.0	3.0000	3.0737	207.00	112.50	4.5000	4.6105	0.0
25	138.0	64.0	2.5600	3.0480	207.00	96.00	3.8400	4.5720	0.0
26	138.0	73.0	2.9200	3.0419	207.00	109.50	4.3800	4.5629	0.0
27	138.0	73.0	2.9200	3.0364	207.00	109.50	4.3800	4.5545	0.0
28	0.0	0.0	0.0	3.0364	0.0	0.0	0.0	4.5545	138.0
29	138.0	72.0	2.8800	3.0296	207.00	108.00	4.3200	4.5443	0.0
30	138.0	69.0	2.7600	3.0183	207.00	103.50	4.1400	4.5275	0.0
31	0.0	0.0	0.0	3.0183	0.0	0.0	0.0	4.5275	138.0
TOTAL	3312.0	1811.0	72.4398	3.0183	4968.00	2716.50	108.6598	4.5275	

PERCENT SCHED COMPLETION	SORTIE RATE PER DAY	A/C FLT HRS PER DAY	UTILIZ-A/C FLT HRS PER MO
54.68	3.02	4.53	108.65

TABLE 9-13

OPERATIONAL EFFECTIVENESS

JULY — OPERATIONALLY READY

PRI.* DAY	0	1	2	3	4	5	6	7	8
1	0.93	0.61	0.41	0.49	0.53	0.41	0.53	0.0	0.0
2	0.99	0.61	0.45	0.37	0.57	0.41	0.33	0.0	0.0
3	0.93	0.33	0.33	0.33	0.45	0.49	0.45	0.0	0.0
4	0.89	0.53	0.41	0.49	0.45	0.41	0.37	0.0	0.0
5	0.85	0.65	0.89	0.89	0.93	0.93	0.93	0.0	0.0
6	0.73	0.37	0.37	0.41	0.29	0.33	0.41	0.0	0.0
7	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0
8	0.89	0.61	0.37	0.41	0.33	0.29	0.53	0.0	0.0
9	0.93	0.65	0.61	0.41	0.33	0.33	0.41	0.0	0.0
10	0.93	0.41	0.65	0.45	0.29	0.17	0.37	0.0	0.0
11	0.89	0.49	0.33	0.37	0.33	0.29	0.21	0.0	0.0
12	0.81	0.81	0.89	0.89	0.89	0.89	0.89	0.0	0.0
13	0.93	0.53	0.33	0.33	0.17	0.29	0.41	0.0	0.0
14	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0
15	0.93	0.53	0.45	0.21	0.21	0.41	0.37	0.0	0.0
16	0.85	0.65	0.45	0.21	0.21	0.37	0.25	0.0	0.0
17	0.85	0.33	0.33	0.45	0.45	0.45	0.33	0.0	0.0
18	0.85	0.53	0.33	0.29	0.45	0.29	0.41	0.0	0.0
19	0.85	0.53	0.49	0.37	0.41	0.37	0.45	0.0	0.0
20	0.81	0.49	0.37	0.53	0.57	0.45	0.49	0.0	0.0
21	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0
22	0.93	0.49	0.33	0.49	0.33	0.29	0.37	0.0	0.0
23	0.89	0.41	0.33	0.45	0.37	0.37	0.33	0.0	0.0
24	0.81	0.45	0.53	0.49	0.33	0.45	0.25	0.0	0.0
25	0.89	0.49	0.33	0.09	0.45	0.37	0.33	0.0	0.0
26	0.85	0.57	0.45	0.37	0.37	0.37	0.37	0.0	0.0
27	0.93	0.61	0.29	0.33	0.41	0.49	0.61	0.0	0.0
28	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.0	0.0
29	0.89	0.53	0.37	0.49	0.41	0.25	0.45	0.0	0.0
30	0.89	0.53	0.41	0.29	0.37	0.33	0.17	0.0	0.0
31	0.81	0.31	0.93	0.93	0.93	0.93	0.43	0.0	0.0

AVERAGE = 0.57

NOT OPERATIONALLY READY-MAINTENANCE

PRI.* DAY	Unscheduled 0	1	2	3	4	5	6	7	8	Scheduled 0	1	2	3	4	5	6	7	8
1	.0	.32	.52	.44	.40	.52	.40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.04	.32	.48	.56	.36	.52	.60	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.56	.56	.56	.44	.40	.44	.0	.0	.0	.04	.04	.04	.04	.04	.04	.0	.0
4	.0	.36	.48	.40	.48	.52	.56	.0	.0	.04	.04	.04	.0	.0	.0	.0	.0	.0
5	.08	.08	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6	.0	.52	.52	.48	.64	.56	.48	.0	.0	.0	.04	.04	.0	.0	.04	.04	.0	.0
7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8	.0	.32	.56	.52	.60	.64	.40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9	.0	.28	.32	.48	.56	.56	.52	.0	.0	.0	.0	.0	.04	.04	.0	.0	.0	.0
10	.0	.52	.28	.48	.64	.76	.52	.0	.0	.0	.0	.0	.0	.0	.0	.04	.0	.0
11	.0	.40	.56	.52	.56	.56	.64	.0	.0	.04	.04	.04	.04	.04	.08	.08	.0	.0
12	.04	.04	.04	.04	.04	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
13	.0	.40	.60	.56	.68	.56	.48	.0	.0	.0	.0	.0	.04	.08	.04	.0	.0	.0
14	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
15	.0	.36	.44	.64	.64	.44	.48	.0	.0	.0	.04	.04	.04	.08	.08	.08	.0	.0
16	.0	.20	.32	.56	.56	.44	.60	.0	.0	.08	.08	.16	.16	.08	.08	.04	.0	.0
17	.04	.52	.52	.40	.44	.44	.52	.0	.0	.04	.08	.08	.04	.04	.04	.08	.0	.0
18	.0	.36	.56	.60	.48	.64	.52	.0	.0	.0	.04	.04	.0	.0	.0	.0	.0	.0
19	.08	.36	.40	.48	.44	.48	.40	.0	.0	.0	.04	.04	.08	.08	.08	.08	.0	.0
20	.04	.36	.48	.32	.32	.44	.44	.0	.0	.08	.08	.08	.04	.04	.0	.0	.0	.0
21	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
22	.0	.40	.56	.40	.56	.60	.52	.0	.0	.0	.04	.04	.04	.04	.04	.04	.0	.0
23	.0	.48	.52	.40	.52	.52	.56	.0	.0	.04	.04	.08	.04	.04	.04	.04	.0	.0
24	.08	.44	.36	.40	.52	.44	.64	.0	.0	.04	.04	.04	.04	.04	.04	.04	.0	.0
25	.0	.36	.52	.76	.44	.52	.56	.0	.0	.04	.08	.08	.04	.04	.04	.0	.0	.0
26	.08	.36	.48	.56	.56	.56	.56	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
27	.0	.32	.64	.60	.52	.44	.32	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
28	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
29	.04	.40	.56	.44	.52	.64	.44	.0	.0	.0	.0	.0	.0	.0	.04	.04	.0	.0
30	.0	.36	.48	.60	.52	.56	.68	.0	.0	.04	.04	.04	.04	.04	.04	.08	.0	.0
31	.04	.04	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

SECTION 10

10-1.1

10.0 AVIONICS, ARMAMENT AND GSE

Avionics and armament subsystem maintenance data did not appear in the TAMMS data in sufficient quantities for reliable analysis. Separate studies on these two subsystems were accomplished to compensate for this lack of data. In addition, the effects of AIDAPS on ground support equipment (GSE) required a separate analysis. The result of these analyses are presented in this section.

10.1 AVIONICS

The application of AIDAPS to avionics is limited to monitoring input and output signals for existing aircraft. To modify the avionics for AIDAPS is not economically nor practically feasible, particularly since most of the avionic equipment is used on a variety of aircraft some of which are not candidates for AIDAP systems as defined by the scope of the study. Future avionics, however, could be designed to be compatible with AIDAPS systems.

Some avionics are already designed for self test. Supplying self test signals to the AIDAPS in addition to, or in lieu of, the planned use of conventional indicators would seem to be of limited value. Hence, AIDAPS application would be limited to only a few avionic systems.

10.1.1 AVIONICS INSTALLED ON STUDY AIRCRAFT

The avionic systems employed on the study aircraft are presented in Table 10-1. Many of the systems are used on more than one aircraft.

10.1.1.1 Avionic System Candidates

A detailed examination of the avionic equipment designs was made to determine those systems which might be candidates for monitoring by AIDAPS. The basic criteria used to select candidate avionic systems are that they must be multi-box systems, be amenable to diagnosis, or constitute a significant safety hazard. For many of the systems, no AIDAPS benefits can be derived. Specifically, most equipments are essentially "one box" systems in which AIDAPS is of little service in avoiding unwarranted removals. Further, the common failure mode, second only to mistuning or misoperation, is catastrophic which cannot be trended or predicted by simple input or output measurements. Some systems have two boxes. The control box is included but, short of a parallel unit, there is generally no economical way to inspect or monitor the operation of the control box.

Table 10-1 also presents comments concerning the application of AIDAPS to each avionic system. These comments indicate that the following four systems can be effectively monitored by AIDAPS.

Doppler Navigation System	AN/ASN-64 AN/ASN-64A
Automatic Flight Control System	AN/ASW-12(V) 1 AN/ASW-12(V) 2 AN/ASW-12(V) 3 AN/ASW-12A(V) 1
Gyromagnetic Compass System	AN/ASN-43
Radar Altimeter	AN/APN-22 AN/APN-117

10.1.2 AVIONICS DATA REVIEW

The Army maintenance data on these systems were not available for this study. As a result, Navy F4J maintenance data on similar systems were examined. These data pertained to similar avionics systems but different part numbers. The appropriate Navy avionics data were applied to the corresponding selected Army avionics systems.

10.1.2.1 Ground Rules Used For Data Review

The ground rules used for the maintenance data evaluation are similar to the ones employed for aircraft subsystems. AIDAPS application to the candidate avionics systems reduces the time required for diagnosis and the number of unwarranted remove and replace actions.

TABLE 10-1 AVIONICS APPLICATION TO AIDAPS

AVIONICS SYSTEM	COMMENTS CONCERNING AIDAPS APPLICATION
AN/ARC-44	An old VT-FM set. One box but dynamotor could be monitored. UHF - Single box - not amenable to AIDAPS.
AN/ARC-51 & 51BX	UHF - Single box - not amenable to AIDAPS.
AN/ARC-54	FM set - single box - not amenable to AIDAPS.
AN/ARC-55	UHF set - Single, <u>old</u> box - 70 lbs. - unlikely still used, not amenable to AIDAPS (same as AN/ARC-27).
AN/ARC-73	VHF-AM - An old set but amenable to AIDAPS. Discretes could monitor power, receiver AGC voltage, push-to-talk and RF output.
AN/ARC-102	HF set - Single box - not amenable to AIDAPS.
AN/ARC-114	FM set - single box - panel mounted, not amenable to AIDAPS.
AN/ARC-115	VHF set - Single box - panel mounted, not amenable to AIDAPS.
AN/ARC-116	UHF-AM - Single box - panel mounted, not amenable to AIDAPS.
AN/ARC-30	VHF Nav. set - No information available at this time.
AN/ARN-32	Marker Beacon Receiver - very old set, not cost effective to design for AIDAPS since probably not still in use.
AN/ARN-59	ADF - No information avilable at this time.
AN/ARN-82	VOR and Clide Slope Receiver - Single box - not amenable to AIDAPS.

AVIONICS SYSTEM	COMMENTS CONCERNING AIDAPS APPLICATION
R/941/ARN	Marker Beacon Rec. - Not amenable to AIDAPS.
AN/APX-44	IFF Transponder - Single box - Not amenable to AIDAPS.
AN/APX-72	IFF Transponder - Same comments as for the APX-44.
AN/ASN-43	Gyromag Compass - Possible AIDAPS application.
AN/ASN-64	Doppler Nav. - Possible AIDAPS application.
AN/ASN-72	Position Fixing Nav. Set. - Probably will not use AIDAPS. We do not have sufficient data at this time.
AN/ARA-54	ILS receiver - Not amenable to AIDAPS.
AN/APN-22	Radar Altimeter - Multi-box can be functionally monitored. Possible AIDAPS application.
AN/ARN-12	Marker Beacon Rec. - Not amenable to AIDAPS.
T-366A/ARC	VHF Emergency Transmitter - Single box - Not amenable to AIDAPS.
C-6533/AR.	Intercom - Single box - Not amenable to AIDAPS - Malfunction made most likely would be switch/contact failures.
TSEC/KY28	No information available at this time.
AN/ARN-83	ADF - Multibox system but not amenable to AIDAPS.
AN/ARN-89	ADF - Multibox system, but not amenable to AIDAPS.
AN/ASW-12(V) 1,2+3	AFCS - Assume application of AIDAPS - Assume 3 proportional and 2 discretes.

10.1.2.2 Avionics Maintenance Data Analysis Results

Table 10-2 lists the savings in decreased down time, maintenance man-hours, inventory spares, and packaging and shipping costs for each of the systems. From this table, the 10 year savings for each aircraft is determined based on the monthly flight hours and the avionics system installed.

The avionic systems associated with each aircraft are indicated in Table 10-3. The savings for a ten year period are shown for each aircraft in Table 10-4. These savings assume that each aircraft is equipped with the avionic systems shown in Table 10-3.

10.1.3 COST OF MONITORING AVIONICS

The cost of monitoring each avionic system depends almost exclusively on the parameters monitored. The parameters selected will, in most cases, isolate the system failure to the failed component. The selected parameters are presented in Table 10-5 together with the associated signal type and the components being monitored within each system.

The cost of monitoring each system is determined by examining the parameter signal types and assigning a weighted sensor count (WSC) to each. The cost of monitoring and signal processing for electronic systems is estimated at $10.00 per WSC. The cost calculated for each system is presented in Table 10-6.

10.1.4 AIDAPS COST EFFECTIVENESS FOR AVIONICS

The cost of monitoring the avionic systems on each aircraft is compared against the cost savings for a 10 year operating period in Table 10-7. As a criteria for determining the cost effectiveness of monitoring the avionics; the expected savings over a 10-year period should be twice the initial investment. This is comparable to an investment return of approximately 7.0% per year. A return of less than this would not be practical. From Table 10-7 it can be seen that the only aircraft on which it is cost effective to monitor the avionics are the OV-1, CH-47, CH-54, UTTAS, and HLH, with the OV-1 application being the most effective.

TABLE 10-2 AVIONICS SAVINGS DUE TO AIDAPS

SAVINGS	AVIONICS SYSTEMS			
	RADAR ALTIMETER SYSTEM	AUTOMATIC FLIGHT CONTROL SYSTEM	GYRO-MAGNETIC COMPASS SYSTEM	DOPPLER RADAR NAVIGATION SYSTEM
DOWN TIME ($/1000 FH)	54.63	97.88	535.02	65.72
MAINTENANCE MAN-HOURS ($/1000 FH)	9.92	16.24	61.11	7.59
INVENTORY SPARES ($/AIRCRAFT)	226.10	355.66	2990.46	280.95
PACKAGING AND SHIPPING ($/10,000 FH)	28.35	33.51	361.39	33.45

TABLE 10-3 AVIONICS INSTALLED ON EACH AIRCRAFT

AIRCRAFT	RADAR ALTIMETER SYSTEM	AUTOMATIC FLIGHT CONTROL SYSTEM	GYRO-MAGNETIC COMPASS SYSTEM	DOPPLER RADAR NAVIGATION SYSTEM
OH-6			X	
OH-58			X	
UH-1			X	
AH-1			X	
U-21			X	
OV-1	X	X	X	X
CH-47	X	X	X	
CH-54		X	X	
UTTAS	X	X	X	
HLH	X	X	X	X

TABLE 10-4 AVIONICS 10-YEAR LIFE CYCLE SAVINGS (MILLION DOLLARS)

AIRCRAFT	OPTIMISTIC	EXPECTED	PESSIMISTIC
OH-6	.081	.052	.043
OH-58	.657	.425	.347
UH-1	1.374	.776	.652
AH-1	.201	.130	.107
U-21	.038	.027	.023
OV-1	3.260	2.254	2.086
CH-47	1.587	1.013	.872
CH-54	.158	.101	.079
UTTAS	9.031	6.183	5.201
HLH	.165	.086	.068

TABLE 10-5 AVIONICS PARAMETER LIST

AVIONIC SYSTEM	PARAMETER	SIGNAL TYPE	RELATED COMPONENT
DOPPLER NAVIGATION SYSTEM (AN/ASN-64 & AN/ASN-64A	OUTPUT POWER	(13.325 GHz) 240 MILLIWATTS MINIMUM	DOPPLER RECEIVER/ TRANSMITTER
	RECEIVER IF	3.3 M HZ SIGNAL	ANTENNA, DOPPLER
	PRESENCE OF RECEIVED SIGNAL	DISCRETE	FREQUENCY TRACKER, DOPPLER
	PRESENT POSITION	DC VOLTS	INDICATOR/CONTROL, DOPPLER
	POWER ON	DISCRETE	DOPPLER SYSTEM
AUTOMATIC FLIGHT CONTROL SYSTEM (AN/ASW-12(V) 1,2,3 & AN/ASW-12A(V) 1	ROLL ANGLE	SYNCHRO	DISPLACEMENT GYRO
	ACCELEROMETER OUTPUT	ELECTRIC CHARGE	AIRCRAFT ACCELEROMETER
	STEERING COMMAND	SYNCHRO	NAVIGATION COUPLER
	ROLL CONTROL	SYNCHRO	AUTOMATIC PILOT CONTROL
	AUTOMATIC PILOT	DISCRETE	ACCELEROMETER MONITOR
	POWER ON	DISCRETE	AUTOMATIC FLIGHT CONTROL SYSTEM
GYRO MAGNETIC COMPASS SYSTEM (AN/ASN-43)	OUTPUT SIGNAL	800 CPS	COMPASS TRANS-MITTER FLUX COMPENSATOR
	YAW SIGNAL	SYNCHRO	DIRECTIONAL GYRO
	HEADING ERROR	SYNCHRO	COMPASS CONTROLLER
	POWER ON	DISCRETE	COMPASS SYSTEM
RADAR ALTIMETER SYSTEM (AN/APN-117)	INPUT TO HEIGHT INDICATOR	SYNCHRO	CONTROL AMPLIFIER, RADAR ALTIMETER

TABLE 10-5 AVIONICS PARAMETER LIST (Continued)

	PARAMETER	SIGNAL TYPE	RELATED COMPONENT
	OUTPUT TO AMPLIFIER	VARIABLE FREQUENCY	RECEIVER/TRANSMITTER, RADAR ALTIMETER
	POWER ON	DISCRETE	RADAR ALTIMETER SYSTEM

TABLE 10-6 AVIONICS AIDAPS COST

		WSC	COST
DOPPLER NAVIGATION SYSTEM	Output Parameter	4	$100
	Receiver IF	4	
	Presence of Signals	1	
	Present Position	1	
	TOTAL	10	
AUTOMATIC FLIGHT CONTROL SYSTEM	Roll Angle	8	$310
	Accelerometer Output	5	
	Steering Control	8	
	Roll Control	8	
	Auto Pilot	1	
	Power On	1	
	TOTAL	31	
GYRO-MAGNETIC COMPASS SYSTEM	Output Signal	4	$210
	Yaw Signal	8	
	Heading Error	8	
	Power On	1	
	TOTAL	21	
RADAR ALTIMETER	Input to Indicator	8	$190
	Output to Amplifier	10	
	Power On	1	
	TOTAL	19	

TABLE 10-7 AIRCRAFT AVIONICS COST VS. 10-YEAR SAVINGS

AIRCRAFT	AVIONICS COST (DOLLARS A/C)	AVIONICS SAVINGS (DOLLARS A/C)	NET SAVINGS (DOLLARS/A/C)
OH-6	210	223	13
OH-58	210	223	13
UH-1	210	217	7
AH-1	210	223	13
U-21	210	264	54
OV-1	850	9756	8906
CH-47	710	2208	1498
CH-54	520	1352	832
UTTAS	710	2625	1915
HLH	710	1999	1289

10.2 ARMY AIRCRAFT ARMAMENT SUBSYSTEMS

Except for the Bell AH-1G gunship, all Army aircraft now in the inventory were initially designed without either defensive or offensive armament. Traditionally, Army aircraft have fulfilled the roles of cargo, utility, observation and training services. With the advent of the Vietnam operation, the need for armament onboard Army aircraft became evident. As a result, a number of strap-on systems for existing aircraft were developed along with the gun ship concept as represented by the Bell AH-1G. Table 10-8 presents a matrix of the more commonly used armament subsystems versus the aircraft that they are used on. Except for the XM 28 chin turret designed specifically for the AH-1G, all of these armament subsystems are designed to be installed on existing aircraft. In addition, a number of these devices are designed to be self-supporting and to be used on several different aircraft.

Because of the strap-on nature of most of these devices, only a minimum amount of instrumentation is installed. An AIDAPS installation on these armament devices provides a direct contribution to combat safety by providing the combat crew with indications of armament subsystem health, and its ability to complete a mission before entering the combat area. In addition, ground servicing of the equipment is simplified since maintenance data for ground analysis is gathered in flight while the weapons are being fired. Elimination of weapons firing on the ground for diagnostic purposes also contributes to ground safety of maintenance personnel and equipment.

TABLE 10-8 WEAPON SYSTEM MATRIX CHART

WEAPON SYSTEM A/C	OH-6A	OH-58	UH-1					AH-1G	U-21	CH-47			CH-54		OV-1	UTTAS	HLH
			A	B	C	D	H			A	B	C	A	B			
I GUIDED MISSILES																	
**M-22 SIX SS-11 WIRE GUIDED MISSILES PLUS LAUNCHER AND SUPPORT EQUIPMENT				X													
XM-26 SIX TOW GUIDED MISSILES PLUS LAUNCHER AND SUPPORT EQUIPMENT				X	X												
II. COMBINATIONS OF 7.62MM MACHINE GUN & 2.75" ROCKET LAUNCHER																	
XM-3 DUAL 24-TUBE, 2.75" ROCKET LAUNCHERS				X	X	X											
M-6 QUAD 7.62 MM MACHINE GUNS				X	X												
M-16 QUAD 7.62 MM MACHINE GUNS PLUS M-157 OR M-158 7-TUBE 2.75" ROCKET LAUNCHERS				X	X												
**XM-18, XM-18E POD MOUNTED, 6-BARREL 7.62 MM, M-134 MACHINE GUN								X		X							
**M-21 DUAL 6-BARREL 7.62MM M-134 MACHINE GUNS & DUAL 7-TUBE 2.75" M-158AI ROCKET LAUNCHERS				X	X												
**XM-27E POD MOUNTED, 6-BARREL 7.62 MM, M-134 MACHINE GUN	X	X															
M-158A1 7-TUBE 2.75" ROCKET LAUNCHER				X	X			X									
XM-200 19-TUBE 2.75" ROCKET LAUNCHER				X	X			X									
TAT102A TURRET-MOUNTED, 6-BARREL, 7.62 MM MACHINE GUN								X									
III. POD-MOUNTED, LARGE CALIBER MACHINE GUNS																	
XM-14 50 CALIBER MACHINE GUN				X													
XM-30 TWIN 30 MM AUTOMATIC GUNS					X												
**XM-35 6-BARRELL, 20 MM AUTOMATIC GUN								X									
IV. TURRET-MOUNTED AUTOMATIC GUNS AND GRENADE LAUNCHERS																	
**XM-28E COMBINATIONS OF 6-BARREL, 7.62MM MACHINE GUNS AND 40MM GRENADE LAUNCHERS								X									
V. GRENADE LAUNCHERS																	
**M-5 40MM GRENADE LAUNCHER					X	X				X							
XM-8 40MM GRENADE LAUNCHER	X																
VI. OTHER SYSTEMS NOT APPLICABLE TO AIDAPS																	
M-23 DOOR-MOUNTED 7.62MM MACHINE GUN						X	X										
XM-23 SIMILAR TO M-23				X													
M-24 DOOR MOUNTED 7.62MM MACHINE GUN										X	X	X					
XM-32 FOUR WINDOW-MOUNTED, 50-CALIBER MACHINE GUNS										X							
XM-33 PEDESTAL MOUNTED, 50-CALIBER MACHINE GUN										X							
XM-156 HELICOPTER MULTI-ARMAMENT MOUNT				X	X												

**Selected for Detailed Analysis

For purposes of the armament portion of the AIDAPS study the armament systems listed in Table 10-8 were divided into six categories according to type as follows:

I. Guided missiles

II. Combinations of 7.62mm machine gun and 2.75" rocket launcher

III. Pod-mounted large caliber machine guns

IV. Turret-mounted automatic guns and grenade launchers

V. Grenade launchers

VI. Other systems not applicable to AIDAPS

Representative systems chosen for detailed analysis from each of the first five categories are shown in Table 10-9. Category VI was not represented because these systems consist of simple hand-held machine guns and gun mounts considered impractical for interface with an AIDAPS. A single system was chosen from each of Categories I, III, IV and V, while three systems were chosen to represent Category II.

Table 10-9 lists and describes the selected systems.

10.2.1 SUBSYSTEM ANALYSIS

The analysis of the selected subsystems is presented in paragraphs 10.2.1.1 through 10.2.1.7. Each analysis contains the following:

a) A list of major subsystem components

b) A list of common subsystem failure modes. Of primary importance are those failure modes that contribute to a lack of combat safety. For example, the potential failure of a rocket to fire due to a lack of continuity in a firing circuit should be known before entering the combat zone. Advanced knowledge of armament subsystem performance capability should be a basic goal of an armament AIDAPS. The various failure modes listed for the seven subsystems are taken from the mechanical and electrical troubleshooting charts found in the organizational maintenance manuals. The most probable components at fault are also listed.

TABLE 10-9 REPRESENTATIVE ARMY ARMAMENT SYSTEMS

SYSTEM		DESCRIPTION
I-1.	M22	Six AGM22B wire guided missiles launched and guided from UH-1B helicopter.
II-2.	XM18/XM18E1	Pod mounted 7.62mm machine gun carried by either helicopters or high speed fixed wing aircraft.
II-3.	M21	Combination of M158 2.75mm rocket launchers and M134 7.62mm machine guns installed on UH-1B and C helicopters.
II-4.	XM27E1	M134 7.62mm machine gun installed on the OH-6A helicopter.
III-5.	XM35	XM195 20mm automatic gun installed on the AH-1G gun ship.
IV-6.	XM28/XM28E1	Various combinations of the M134 machine gun and XM129 40mm grendade launcher installed in a hydraulically operated chin turret on the AH-1G helicopter gun ship.
V-7	M5	M75 40mm grenade launcher installed in a remote controlled turret attached to the nose of UH-1B and C helicopters.

c) A list of recommended subsystem performance parameters. The parameters are also selected on the basis of their ability to isolate a subsystem fault to the major line replaceable units (LRU's) at the organizational level. For example, where a subsystem includes a gun or grenade launcher drive motor, drive motor lead (current) is monitored during operation along with feed-bus voltage. If a gun or launcher jams, these parameters should allow a determination of a basic mechanical fault in the gun or launcher mechanism or a defect in the drive motor itself. In a similar manner, the monitoring of basic electrical signals from the weapon sights, servo amplifiers, and feedback loops provide insight into the overall electrical operation of a subsystem. Monitoring of gun and grenade launcher mount vibrations provide an indication of an impending mechanical failure.

10.2.1.1 M22 Armament Subsystem

The M22 armament subsystem consists of six AGM22B wire guided missiles which are transported on, and fired from, dual launcher assemblies attached to the Bell UH-1B helicopter. The missiles are fired and guided to the target by the helicopter gunner using an optical sight and control stick to command missile maneuvering. Major components of the subsystem are shown in Table 10-10. Table 10-11 lists the failure modes, Table 10-12 presents the parameters, and Table 10-13 shows the recommended sensors.

TABLE 10-10 M22 MAJOR COMPONENTS

1. Missile airframe
2. Booster motor
3. Sustainer motor
4. Launcher support assembly
5. Housing assembly
6. Fixed housing
7. Missile launcher
8. Missile control stick
9. Remote firing switch
10. Missile selection box
11. Guidance control unit
12. Gunner's sight
13. Pilot's sight
14. Cabling and connectors

TABLE 10-11 M22 COMMON FAILURE MODES

FAILURE MODES	COMPONENT AT FAULT
1. No ignition of explosive cartridge, flare or booster	
2. Ignition of explosive cartridge, release hook disengages,	1, 10, 14
3. Explosive cartridge ignites, but release hook does not disengage	7.
4. Ignition of explosive cartridge and flares, but no ignition of booster	2.
5. Missile flies a ballistic path	1.
6. Missile flies a spiraling path	1.
7. Missile flies down and right	1,8,11,14
8. Missile flies hard left or right	1,8,11,14
9. Missile flies hard up or down	1,8,11,14
10. Missile flies hard up and hard left or right	1,8,10,11,14

TABLE 10-12 M22 SUBSYSTEM PERFORMANCE PARAMETERS

1. Explosive bolt circuit continuity (6)
2. 24 volt main power
3. Missile jettison power (6)
4. Pitch signal in
5. Pitch signal out
6. Yaw signal in
7. Yaw signal out

TABLE 10-13 M22 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	NO. REQD.	SENSOR	LOCATION	Added Sensor Wt. (Lbs.) w/Wire Estimated		Added Sensor Unit Cost Estimated (Thousands of Dollars)		WSC
				UNIT	EXT.	UNIT	EXT.	
Continuity	6	Resistance	Explosive Bolt Circuit	0.1	0.6	0.01	0.06	24
A/C Voltage	1	Proportional Voltage	M22 Feed Bus	0.1	0.1	0.01	0.01	4
Voltage	6	Proportional Voltage	Missile Jettison Circuit	0.1	0.6	0.01	0.06	24
Voltage	1	Proportional Voltage	Pitch Signal In	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Pitch Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Yaw Signal In	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Yaw Signal Out	0.1	0.1	0.01	0.01	4
					1.7		0.17	68

10.2.1.2 XM18 and XM18E1 Armament Subsystem

The XM18/XM18E1 armament subsystem consists of an M 134 7.62 millimeter machine gun and supporting equipment incorporated into an aerodynamically clean pod that can be carried externally on an aircraft up to Mach 1.2. The pod contains its own power source (battery) that drives the gun at a high firing rate. Differences between the XM18 and XM18E1 are as follows:

a) Early models of the XM18 had a fitting in the top of the drum assembly to accommodate a single (NATO) suspension lug.

b) The XM18E1 incorporates increased starting torque, greater clearing reliability and circuitry which permits dual rates of fire.

Major components of the subsystem are shown in Table 10-14. Table 9-15 presents the failure modes, Table 9-15 the parameter and Table 9-17 the sensors.

TABLE 10-14 XM18 AND XM18E1 MAJOR COMPONENTS

1. M 134 7.62 millimeter machine gun
2. Electric gun drive assembly
3. Recoil adapter assembly
4. Automatic gun feeder
5. Pod front fairing assembly
6. Loader assembly
7. Exit unit assembly
8. Counter and drive assembly
9. Pod aft fairing assembly
10. Battery and control assembly
11. Gun support assembly
12. Drum assembly
13. Cabling and connectors
14. Cable adapter assembly

TABLE 10-15 XM18/XM18E1 COMMON FAILURE MODES

	FAILURE MODES	COMPONENT AT FAULT
1.	Gun fails to rotate or fire	1,2,10,13
2.	Gun stops firing	4,7,10,12,13
3.	Low firing rate	4,10

TABLE 10-16 XM18/XM18E1 SUBSYSTEM PERFORMANCE PARAMETERS

1.	Battery voltage
2.	M134 drive motor load (current)
3.	Battery charge load (current)
4.	Battery temperature
5.	Gun mount vibration

TABLE 10-17 XM18/XM18E1 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	NO REQD.	SENSOR	LOCATION	Added Sensor Wt. (Lbs.) w/Wire Estimated		Added Sensor Unit Cost Estimated (Thousands of Dollars)		WSC
				UNIT	EXT.	UNIT	EXT.	
Voltage	1	Proportional Voltage	Battery	0.1	0.1	0.01	0.01	4
Current	1	Shunt	M134 Gun Motor	0.3	0.3	0.01	0.01	4
Current (Charge)	1	Shunt	Battery	0.3	0.3	0.01	0.01	4
Temperature	1	Resistance Bulb	Battery Case	0.2	0.2	0.08	0.08	4
Vibration	1	Piezoelectric Accel.	Gun Mount	0.5	0.5	0.11	0.11	5
TOTALS					1.4		0.22	21

10.2.1.3 M21 Armament Subsystem

The M21 armament subsystem consists of two M134 7.62mm machine guns and two M158 2.75 inch seven tube rocket launchers installed on Bell UH-1B and C helicopters. Major components of the subsystem are shown in Table 10-18. Table 10-19 presents the failure modes. Table 10-20 defines the sensors required to monitor these parameters. Table 10-21 lists each parameter, the required sensor type, number needed per aircraft installation, location, cost of the added equipment both in weight and dollars and WSC - a factor used to rate the overall sensor complexity.

TABLE 10-18 M21 MAJOR COMPONENTS

M158

1. Rack and support assembly (includes components using hydraulic power from helicopter).
2. 2.75 inch rocket launcher (M158 or M158A1/E/M158E1).
3. Intervalometer
4. Reflex sight (XM60 or XM60E1) - same sight used for both machine gun and rocket launcher.
5. Sight mount.
6. 2.75 inch rocket (14)
7. Cabling and connectors

M134

8. Mount Assembly
9. M134 7.62mm machine gun assembly (including electric drive assembly).
10. Ammo chute.
11. Ammo box assembly.
12. Control box assembly.
13. Control panel.
14. Cabling and connectors.

TABLE 10-19 M21 COMMON FAILURE MODES

FAILURE MODES	COMPONENT AT FAULT
1. Rockets fail to fire	
2. Rack and support assembly cannot be adjusted in	
3. Mount assemblies fail to follow elevation and deflection commands from sight station	1,7,13
4. M134 will not rotate or fire	9
5. M134 stops firing	9

TABLE 10-20 M21 SUBSYSTEM PERFORMANCE PARAMETERS

1. Aircraft to M21 power (voltage).
2. Left and right M134 gun motor load (current) (2)
3. Rocket ignition circuit continuity (2)
4. Sight elevation signal out
5. Sight deflection signal out
6. Servo amp. elevation signals out (2)
7. Servo amp. deflection signals out (2)
8. Left and right gun mount accelerations (Vibration) (2)
9. Mount elevation feedback signals (2)
10. Mount deflection feedback signals (2)

TABLE 10-21 M21 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	REQD.	SENSOR	LOCATION	Added Sensor Wt. (Lbs.) w/Wire Estimated		Added Sensor Unit Cost Estimated (Thousands of Dollars)		WSC
				UNIT	EXT.	UNIT	EXT.	
A/C Voltage	1	Proportional Voltage	M21 Feed Bus	0.1	0.1	0.01	0.01	4
Current	2	Shunt	M134 Gun Motor	0.3	0.6	0.01	0.02	8
Continuity	2	Resistance	Rocket Ignition Circuit	0.1	0.2	0.01	0.02	8
Voltage	1	Proportional Voltage	Sight Elevation Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Sight Deflection Signal Out	0.1	0.1	0.01	0.01	4
Voltage	2	Proportional Voltage	Servo Amp. Elevation Servo Out	0.1	0.2	0.01	0.02	8
Voltage	2	Proportional Voltage	Servo Amp. Deflection Signal Out	0.1	0.2	0.01	0.02	8
Voltage	2	Proportional Voltage	Mount Elevation Feedback Signal	0.1	0.2	0.01	0.02	8
Voltage	2	Proportional Voltage	Mount Deflection Feedback Signal	0.1	0.2	0.01	0.02	8
Vibration	2	Piezoelectric Accel.	Gun Mount	0.5	1.0	0.11	0.22	10
TOTALS					2.9		0.37	70

10.2.1.4 XM27E1 Armament Subsystem

The XM27E1 armament subsystem consists of a single rapid fire M134 7.62 millimeter machine gun that mounts on the left side of the OH-6 helicopter. Major components of the subsystem are shown in Table 10-22. Table 10-23 presents the failure modes, Table 10-24 shows the parameters recommended, and Table 10-25 lists the suggested sensors.

TABLE 10-22 XM27E1 MAJOR COMPONENTS

1. M134 gun assembly
2. Gun electric drive assembly
3. Delinking feeder assembly
4. Fairing assembly
5. Mount assembly (includes control box assembly)
6. Reflex sight
7. Control panel

TABLE 10-23 XM27E1 COMMON FAILURE MODES

	FAILURE MODES	COMPONENT AT FAULT
1.	Gun does not rotate	1,2,5,7.
2.	Gun rotates at slow rate but will not change to fast rate	2.
3.	"Gun Not Cleared" light remains on after firing to clear	2.
4.	Gun rotates for excessive time after trigger release during fire to clear	5.
5.	Gun elevation motor operation faulty	5.
6.	"Ammo Low" light inoperative (bulb okay)	5.

TABLE 10-24 XM27E1 PERFORMANCE PARAMETERS

1. Aircraft to XM27E1 power (voltage)
2. Gun drive motor load (current)
3. "Ammo Low" warning
4. "Gun Not Cleared" warning
5. Sight elevation signal out
6. Elevation motor drive signal in
7. Gun mount vibration
8. Mount elevation feedback signal

TABLE 10-25 XM27E1 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	NO. REQD.	SENSOR	LOCATION	Added Sensor Wt. (Lbs.) w/Wire Estimated		Added Sensor Unit Cost Estimated (Thousands of Dollars)		WSC
				UNIT	EXT.	UNIT	EXT.	
A/C Voltage	1	Proportional Voltage	XM27E1 Feed Bus	0.1	0.1	0.01	0.01	4
Current	1	Shunt	M134 Gun Motor	0.3	0.3	0.01	0.01	4
Voltage	1	Discrete	"Ammo Low" Warning	0.1	0.1	0.01	0.01	1
Voltage	1	Discrete	"Gun Not Cleared" Warning	0.1	0.1	0.01	0.01	1
Voltage	1	Proportional Voltage	Sight Elevation Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Elevation Motor Drive Signal In	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Mount Elevation Feedback Signal	0.1	0.1	0.01	0.01	4
Vibration	1	Piezoelectric Accel.	Gun Mount	0.5	0.5	0.11	0.11	5
TOTALS					1.4		0.18	27

10.2.1.5 XM 35 Armament Subsystem

The XM35 armament subsystem consists of an XM195 six-barrel 20 millimeter automatic gun and its supporting equipment. The gun and the bulk of the support equipment are housed in fairings which are attached to the fixed wings on the AH-1G helicopter. The gun is fixed in relation to the aircraft and is bore-sighted to the pilot's M73 reflex sight. The pilot normally fires the guns; however, the gunner can fire the weapon by using the existing override on the gunner's control panel. Major components of the subsystem are shown in Table 10-26. Table 10-27 defines the failure modes, Table 10-28 the parameters, and Table 10-29 the recommended sensors.

TABLE 10-26 XM35 MAJOR COMPONENTS

1.	XM195 20 millimeter automatic gun assembly
2.	Gun electric drive assembly
3.	Delinking feeder assembly
4.	Gun mount assembly
5.	Ammo feed and storage assemblies (including aerodynamic fairings)
6.	Gun firing control unit
7.	Pilot's control panel assembly
8.	Copilot's control panel assembly
9.	Cabling and connections

TABLE 10-27 COMMON FAILURE MODES

	FAILURE MODES	COMPONENT AT FAULT
1.	Gun drive does not rotate	2,9
2.	Gun rotor does not rotate	1,
3.	Gun fires slow or erratically	1,2,6,9
4.	Gun does not fire	1,6
5.	Erratic dispersion pattern	4
6.	Excessive vibration	1,4

TABLE 10-28 XM35 SUBSYSTEM PERFORMANCE PARAMETERS

1.	Gun drive motor load (current)
2.	Aircraft to XM35 24 VDC
3.	Aircraft to XM35 28 VDC
4.	Ammo 330 VDC firing voltage (DC to DC converter performance)
5.	Gun mount vibration
6.	Number of rounds cycled through gun

TABLE 10-29 XM35 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	NO. REQD.	SENSOR	LOCATION	Added Sensor Wt. (Lbs.) w/Wire Estd.		Added Sensor Unit Cost Estd. (Thousands of Dollars)		
				UNIT	EXT.	UNIT	EXT.	WSC
A/C Voltage	1	Proportional Voltage	A/C Battery Bus	0.1	0.1	0.01	0.01	4
A/C Voltage	1	Proportional Voltage	M35 Feed Bus	0.1	0.1	0.01	0.01	4
Current	1	Shunt	M35 Gun Motor	0.3	0.3	0.01	0.01	4
Voltage	1	Proportional Voltage	DC to DC Ammo Firing Converter Out	0.1	0.1	0.01	0.01	4
Vibration	1	Piezoelectric Accel.	Gun Mount	0.5	0.5	0.11	0.11	5
Rounds Expended Count	1	Counter	Gun Feed	N/A	N/A	0.04	0.04	1
TOTALS					1.1		0.19	22

10.2.1.6 <u>XM 28 and XM28E1 Armament Subsystem</u>

The XM28/XM28E1 armament subsystem consists of a hydraulically and electrically operated dual weapon package installed on the AH-1G helicopter. Any of the following combinations of weapons may be used in the chin mounted turret:

a) One left-hand 7.62 millimeter M134 machine gun and one right-hand 40 millimeter XM129 grenade launcher.

b) One right-hand M134 gun and one left-hand XM129 launcher.

c) Two M134 guns.

d) Two XM129 launchers.

Also included in this subsystem are four stub wing stores positions that can accommodate a number of different combinations of 2.75 millimeter rocket launchers and pod-mounted machine guns. These weapons will not be discussed here since they are covered elsewhere in this report.

Several differences exist between the XM28 and XM28E1 as follows:

a) Armament subsystem XM28E1 uses a two-speed M134 machine gun drive assembly; while XM28 is supplied with a single-speed gun drive. The weapons controllers are also different and non-interchangeable between the two subsystems.

b) Either subsystem may use either of two M134 gun ammo storage containers, ammo boxes with crossover assembly or 7.62 millimeter ammo, magazine assembly.

Major components of the subsystem are shown in Table 10-30. Table 10-31 presents the failure modes, Table 10-32 the parameters, and Table 10-33 the recommended sensors.

TABLE 10-30 XM28 AND XM28E1 MAJOR COMPONENTS

<u>M134</u>

1. M134 machine gun assembly
2. Gun electric drive assembly
3. Delinking feeoer
4. Ammo chute
5. Flexible shaft assembly
6. Ammo storage containers

<u>XM129</u>

7. XM129 grenade launcher
8. Gun cradle assembly
9. Gun drive assembly
10. Gun drive shaft assembly
11. Ammo chute
12. Ammo magazine

<u>Support Equipment</u>

13. Weapon turret and chute separator assembly
14. Weapons controllers (left and right hand)
15. Electronic components assembly
16. Intervolometer (2)
17. Gunner's reflex sight assembly (turret sight)
18. Gunner's control panel
19. Pilot's reflex sight assembly
20. Pilot's control panel
21. Pilot's wing stores control panel
22. Cabling and connectors

TABLE 10-31 XM28 AND XM28E1 COMMON FAILURE MODES

		COMPONENT AT FAULT
1.	A turret weapon does not respond to pilot's firing commands.	2 or 9, 14,15,2.
2.	System does not remain in stowed position when operated correctly by pilot.	15,20.
3.	Turret does not respond to data inputs from pilot's reflex sight.	15.
4.	Range adjust control inoperative	15,17
5.	Turret does not respond to positioning commands (azimuth and/or elevation).	15,17,22
6.	Turret assembly response to positioning commands is sluggish or erratic.	15,17.
7.	A turret weapon does not respond to gunner's firing commands.	2 or 9, 14,15,17, 18.
8.	M134 gun operates but does not fire.	3,15,22.
9.	XM129 launcher operates but does not fire.	9,12,15.

TABLE 10-32 XM28/XM28E1 PERFORMANCE PARAMETERS

1.	Aircraft to XM28/XM28E1 power (voltage)
2.	M134 gun drive motor load (current)
3.	XM129 launcher drive motor load (current)
4.	Turret hydraulic system oil pressure
5.	Airspeed
6.	Sighting station elevation signal out
7.	Sighting station azimuth signal out
8.	Turret elevation signal to elevation servo valve
9.	Turret azimuth signal to azimuth servo valve
10.	Turret elevation position feedback signal
11.	Turret azimuth position feedback signal
12.	Turret mount vibration

TABLE 10-33 XM28/XM28E1 ARMAMENT SUBSYSTEM SENSORS

PARAMETER PARAMETER	NO. REQD.	SENSOR	LOCATION	Added Sensor Wt.(Lbs.) w/Wire Estd. UNIT	Added Sensor Wt.(Lbs.) w/Wire Estd. EXT.	Added Sensor Unit Cost Estd. (Thousands of Dollars) UNIT	Added Sensor Unit Cost Estd. (Thousands of Dollars) EXT.	WSC
A/C Voltage	1	Proportional Voltage	XM28/XM28E1 Feed Bus	0.1	0.1	0.01	0.01	4
Current*	0-2	Shunt	M134 Gun Motor	0.3	0-0.6	0.01	0-0.02	0-8
Current*	0-2	Shunt	XM129 Launcher Motor	0.3	0-0.6	0.01	0-0.02	0-8
Oil Pressure	1	S.G. Bridge Diaphragm	Turret Hyd. System	0.5	0.5	0.09	0.09	4
Airspeed	1	S.G. Bridge Diaphragm	A/C Pitot System	0.5	0.5	0.09	0.09	4
Voltage	1	Proportional Voltage	Sight Elevation Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Sight Azimuth Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Turret Servo Elevation Signal	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Turret Servo Azimuth Signal	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Turret Elevation Feedback Signal	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Turret Azimuth Feedback Signal	0.1	0.1	0.01	0.01	4
Vibration	1	Piezoelectric Accel.	Turret Mount	0.5	0.5	0.11	0.11	5
TOTALS					2.8		0.38	49

*Depending on Weapons Mix in Turret

10.2.1.7 M5 Armament Subsystem

The M5 armament subsystem consists of a 40 millimeter grenade launcher installed in a remote controlled turret attached to the outside of the UH-1 B or C helicopter electric equipment compartment (nose). Major components of the subsystem are shown in Table 10-34. Table 10-35 presents the failure modes, Table 10-36 the parameters, and Table 10-27 the sensors.

TABLE 10-34 M5 MAJOR COMPONENTS

1. M75 40 millimeter grenade launcher.
2. Turret support assembly
3. Gimbal assembly
4. Saddle assembly
5. Elevation and azimuth powered trunnion assemblies
6. Launcher drive assembly
7. Ammo handling assemblies (chutes, booster, can)
8. Servo amplifier junction box assembly
9. Turret control panel assembly
10. Sight assembly
11. Sight mount bracket assembly
12. Cabling and connectors

TABLE 10-35 M5 COMMON FAILURE MODES

	FAILURE MODES	COMPONENT AT FAULT
1.	Launcher will not cycle	6,9,12
2.	"Operate" indicator light does not illuminate when "Main Power" switch on turret control panel assembly is moved to "ON".	8,12.
3.	Turret assembly runs to either an azimuth or elevation limit when turret control panel assembly and sight assembly switches are on.	8.
4.	Turret assembly will not follow sight assembly in azimuth and/or elevation.	8,10,12
5.	Turret assembly oscillates in either azimuth or elevation.	8.

TABLE 10-35 M5 COMMON FAILURE MODES((Continued)

FAILURE MODES	COMPONENT AT FAULT
6. Sight reticle image does not flash when turret assembly is at an azimuth or elevation limit, when turret assembly position is more than 35 mils in error with psoition of sight assembly, or when sight assembly is in operating position but mount assembly control switch is not closed.	8.
7. Launcher drive motor does not apply braking force properly to grenade launcher	7,9,9.

TABLE 10-36 M5 SUBSYSTEM PERFORMANCE PARAMETERS

1. Aircraft AC and DC power (voltage to M5 subsystem)
2. Launcher motor load (current)
3. Azimuth and elevation motor loads (current) (2)
4. Sight azimuth signal out
5. Sight elevation signal out
6. Servo amp. azimuth signal out
7. Servo amp. elevation signal out
8. Airspeed
9. Launcher mount vibration
10. Turret azimuth feedback signal
11. Turret elevation feedback signal

TABLE 10-37 M5 ARMAMENT SUBSYSTEM SENSORS

PARAMETER	NO. REQD.	SENSOR	LOCATION	Added Sensor Wt.(Lbs.) w/Wire Estd. UNIT	EXT.	Added Sensor Unit Cost Estd. (Thousands of Dollars) UNIT	EXT.	WSC
A/C AC Voltage	1	Proportional Voltage	M5 Feed Bus (AC)	0.1	0.1	0.01	0.01	4
A/C DC Voltage	1	Proportional Voltage	M5 Feed Bus (DC)	0.1	0.1	0.01	0.01	4
Current	1	Shunt	Launcher Motor	0.3	0.3	0.01	0.01	4
Current	1	Shunt	Azimuth Motor	0.3	0.3	0.01	0.01	4
Current	1	Shunt	Elevation Motor	0.3	0.3	0.01	0.01	4
Voltage	1	Proportional Voltage	Sight Azimuth Signal Out	0.1	0.1	0.01	0.01	[illegible]
Voltage	1	Proportional Voltage	Sight Elevation Signal Out	0.1	[illegible]			
Voltage	1	Proportional Voltage	Servo Amp. Azimuth Signal Out	0.1	0.1	0.01	[illegible]	
Voltage	1	Proportional Voltage	Servo Amp. Elevation Signal Out	0.1	0.1	0.01	0.01	4
Voltage	1	Porportional Voltage	Turret Azimuth Feedback Signal	0.1	0.1	0.01	0.01	4
Voltage	1	Proportional Voltage	Turret Elevation Feedback Signal	0.1	0.1	0.01	0.01	4
Airspeed	1	S.G. Bridge Diaphragm	A/C Pitot System	0.5	0.5	0.09	0.09	4
Vibration	1	Piezoelectric Accel.	Launcher Mount	0.5	0.5	0.11	0.11	5
TOTALS					2.7		0.31	53

10.2.2 ARMAMENT COST BENEFITS

Although no maintenance data were available to allow quantification of the cost effectiveness of AIDAPS application to armament systems, significant qualitative benefits can be achieved. Some of these are:

a) The frequency of misfires will be reduced. This is particularly important during combat engagement of targets of opportunity.

b) Selection of alternate weapons in the event of primary weapon failure can be accomplished on a more timely basis.

c) Fault isolation can be accomplished without extensive ground testing.

10.2.3 AIRCRAFT-ARMAMENT INTERFACE

It is recognized that most of the Army armament systems are not a permanent part of any particular aircraft. As was shown in Table 10-8, several of the systems can be installed on more than one aircraft, and most can be removed from the aircraft when the need arises. Selection of AIDAPS parameters is made with this interface problem in mind. The bulk of the parameters selected are represented by electrical signals and can be taken from equipment installed within the aircraft or by wiring that already exists between the aircraft and the external store location. Some new wiring must be added as is the case with vibration sensors mounted on guns installed in external poles. However, wire routing can follow existing paths. New sensors required, such as vibration pickup, load shunts, etc., can be permanently installed and become a part of the armament system and not the aircraft.

10.2.4 SUMMARY

Results of the AIDAPS analysis on the seven representative armament systems indicate that many key performance parameters are common to similar equipment. Specifically, the study has shown the following ground rules should be followed when AIDAPS parameter selection is made:

a) Remotely fired automatic single and multi-barrel machine gun mounting vibrations should be monitored during gun operation as an aid in sensing early deterioration of gun components.

b) Automatic guns, grenade launchers, turret mountings and electric drive motor loads should be monitored to detect motor deterioration and excessive drag buildup of ammunition feed systems and aiming linkages.

c) Sighting station output signals, amplifier signals (where applicable) and mount position feedback signals should be simultaneously monitored to aid in the diagnosis of sighting subsystem faults.

d) Armament system power supply bus voltage (either aircraft armament feed bus or internal battery bus) should be monitored during firing to detect degradation of the power supply.

e) Rocket and guided missile circuits (ignition, ejection, etc.) should be frequently verified to confirm the weapons subsystems are in working order, and to permit rapid fault isolation of a misfire or hang-fire occurs.

In addition to the five basic parameter selection ground rules listed above, other equally important special parameters which are unique to each specific armament system should be included

In summary, parameters were selected primarily on the basis of their ability to determine the safety and reliability of components for the next mission. Parameters were also selected so that if a failure does occur, the defect can be rapidly isolated to a line replaceable unit without the need to operate the system on the ground.

10.3 AIDAPS - SPECIAL TOOLS AND GSE STUDY

This report presents the results of a study conducted to determine the extent to which the ground support equipment (GSE) inventory at the various Army aircraft maintenance levels can be reduced or eliminated. The assumption is made that an Automatic Inspection, Diagnostic and Prognostic System (AIDAPS) is installed on each of the aircraft being maintained. For purposes of this study, a representative aircraft (the Bell UH-1H helicopter) was chosen for detailed examination. As part of this effort the Army's TAMMS data for the UH-1H were analyzed to determine the aircraft subsystems that accounted for the bulk of the maintenance being performed. Lists of special UH-1H GSE were then compiled from maintenance publications, and a survey was conducted to determine locations of this equipment within the Army's maintenance structure. Finally, conclusions were drawn concerning AIDAPS effect on the GSE inventory.

Examination of the UH-1 TAMMS data indicated that the engine and powertrain subsystems account for over 80 percent of the maintenance performed on the vehicle as shown in Figure 10-1. In order to analyze the most important maintenance areas in more detail, and to determine those components requiring the most ground support equipment, only the engine and the transmission/rotor were analyzed in depth.

10.3.1 BASIC TOOLS

The Army aviation maintenance system is supported by a number of different tool sets, each used for a specific purpose at a specific maintenance level. Basic hand tool sets are issued to the individual mechanics at the organizational level. These tool sets include hand wrenches, hammers, screw drivers, elementary socket sets, etc., that are not peculiar to any specific aircraft. In addition to these basic tools, each organization is also authorized supplemental tool sets based on the type of aircraft being serviced and repaired. Although these tool sets are issued on the basis of aircraft type, they still fall into the category of multi-purpose equipment.

Direct Support (DS) and General Support (GS) maintenance units are issued basic tool kits similar to organizational level kits. They also receive maintenance shop sets that reflect special functions such as working with sheet metal, hydraulics, avionics, etc. The DS shop sets are considered to be portable and are easily moved from site to site.

10.3.2 SPECIAL TOOLS

Other groups of maintenance tools fall into the category of special, single-purpose devices designed for use on a specific aircraft type, model, and series (TMS). The groups that are issued these special, single-purpose tools are the user organizations and the DS and GS units. Special tools issued to an organization are duplicated at the DS and GS levels if the DS and GS units do regular maintenance on the same aircraft.

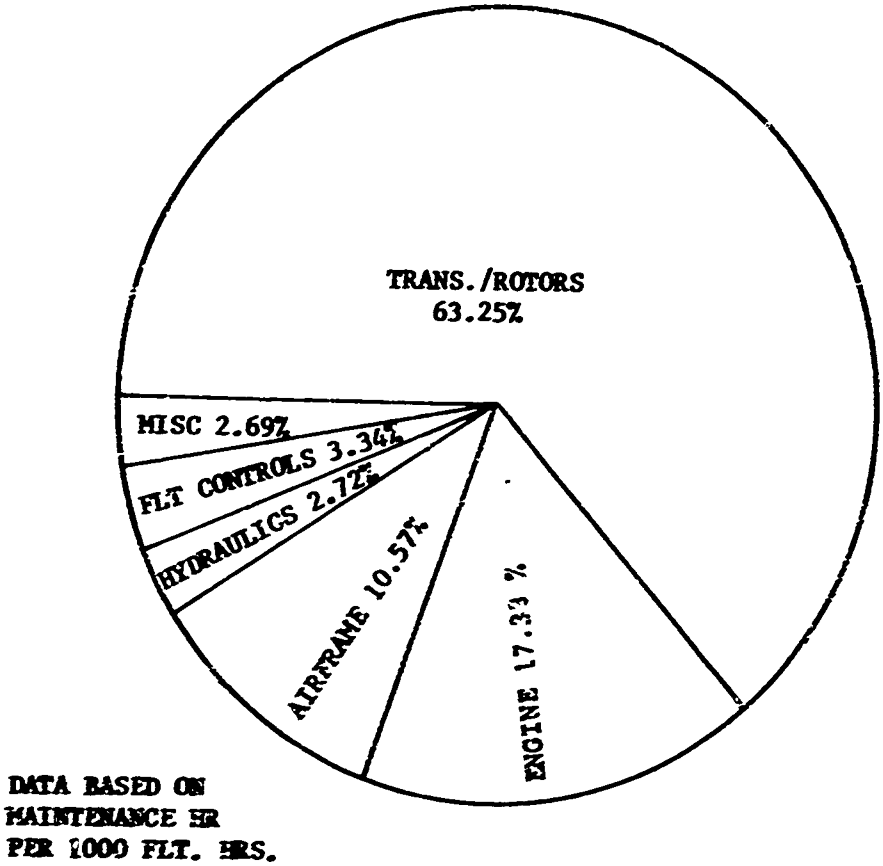


FIGURE 10-1 UH-1H MAINTENANCE AREAS

10.3.3 GROUND SUPPORT EQUIPMENT

Specific ground handling, test and service equipment, more commonly known as ground support equipment (GSE), is authorized at the DS and GS levels as well as the organizational level. Equipment in this category ranges from a simple, hand-held material hardness tester to an engine fuel control test stand. More specifically, GSE consists of equipment in the following groups.

a) Ground Handling and Servicing
b) Electrical and Instruments
c) Structural Repairs and Flaw Detection
d) Power Plants and Propellers
e) Hydraulic and Pneumatic
f) Fuel, Oil and Oxygen

None of this GSE is unique to a specific type model or series of aircraft being maintained. Instead, adapters are supplied where required when using the equipment to test or service two or more different models or series of hardware. For example, a full control test bench can be used to test more than one model of fuel control by simply using different drive plate adapters.

10.3.4 UH-1H SPECIAL TOOLS AND GSE

UH-1H special tools and GSE for the organizational, DS and GS levels are shown in the following tables: Table 10-38 lists UH-1H organizational special tools. Table 10-39 lists special tools used on the engine subsystem. Table 10-40 lists test and ground support equipment for use in maintaining the engine subsystem. Table 10-41 lists organizational special tools, and Table 10-42 lists special tools to be used in maintaining UH-1H transmission and rotors.

Examination of the preceeding tables shows that the usage of the Multimeter (AN/PSM6B) and the Ohmmeter (WV-77E) could possibly be reduced if an AIDAP System were installed to monitor the UH-1H engine. However, these two instruments would still be required in the special tool and GSE inventory. All of the other special tools and GSE listed would also be required to support actual maintenance actions that an AIDAPS is incapable of accomplishing. In a similar manner, examination of the lists of special tools needed for UH-1H transmission and rotor maintenance (Tables 10-41 and 10-42) indicates that none of the tools can be eliminated from stock as a result of an AIDAPS installation.

10.3.5 CONCLUSIONS - SPECIAL TOOLS AND GSE STUDY

Army policy dictates that a complete set of special tools and GSE as outlined in the Army TM 55 manuals be available at each working site. For example, a maintenance section doing repair work on the UH-1H helicopter is allowed one full set of special tools as called out in TM55-1520-210-20.

Installation of an AIDAPS on the UH-1H would result in the fault isolation and identification of a number of LRU's on the aircraft at the organizational level, but could not reduce the number of special tools required for fault repair after fault isolation. The basic reason for this conclusion centers around the Army's need to do the bulk of its aircraft repair work in the field and, where necessary, under battle conditions. AIDAPS will reduce the amount of maintenance required due to its ability to automatically perform inspection, diagnosis and prognosis. However, it cannot reduce the need for special tools and GSE used to accomplish need repairs in the field. An AIDAPS can only identify the maintenance problem, it cannot actually perform the maintenance action required.

TABLE 10-38 ENGINE SUBSYSTEM
UH-1H ORGANIZATIONAL SPECIAL TOOLS
REF: Army TM55-1520-210-20

PART, MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
LTCT99	Installation & Removal Tool	Accessory drive gearbox maintenance
LTCT100	Oil Seal Installation & Removal Tool	
LTCT270	Accessory Gearbox Seal Installer	
LTCT501 & 511	Seal Installation Tool(s)	
LTCT 3648	Seal Removal Tool	
AN/PSM6B	Multimeter	Check continuity of 6-probe exhaust thermocouple
WV-77E	Ohmmeter	Check continuity of 3-probe exhaust thermocouple assembly
LTCT2051	Fuel Harness Wrench	Maintenance-engine fuel manifold
LTCT4174	Alignment fixture for atomizer parts	
SPT107	Cleaning Fixture-Oil Fixture	Oil system maintenance
LTCT215	Face Spanner Socket Wrench	
LTCT4457	Socket Adapter	Ignition System
STD-63557	Puller	Fuel Control Maintenance
LTCT6763 & 461	Cold Weather Trim Stop	
LTCT4174	Combustion Chamber Alignment Fixture	

TABLE 10-39 ENGINE SUBSYSTEM UH-1H DS AND GS SPECIAL TOOLS

REF: ARMY TM 55-1520-210-35

PART, MODEL OR MIL DES	NOMENCLATURE	PART, MODEL OR MIL DES	NOMENCLATURE
LTCT100	Installing Tool	LTCT2079	Tool Socket and Pilot
LTCT107	Accessory Gear Spanner Wrench	LTCT2080	Face Spanner Wrench and Pilot
LTCT1109	Face Spanner Socket Wrench	LTCT2086	Removing Tool
LTCT115	Holding Fixture	LTCT2094	Staking Tool Assembly
LTCT1218	Mechanical Puller	LTCT2099	Backlash Gage
LTCT1409	Wrench	LTCT212	Mechanical Puller
LTCT143	Mechanical Puller	LTCT2142	Mechanical Puller
LTCT153	Power Turbine Locating Button Bar	LTCT215	Face Spanner Socket Wrench
LTCT1643 replaces LTCT385	Compressor Blade Drift Assembly	LTCT2161 replaces LTCT213	Gearshaft Nut Spanner Wrench
LTCT1644 replaces LTCT90	Compress Blade Drift Assembly	LTCT231	Bearing Removing Tool
		LTCT256	Compressor Rotor Disc Pin Installer
LTCT2020	First Stage Turbine Nozzle Maintenance Kit	LTCT258	Driver Wrench
		LTCT270	Accessory Gearbox Seal Installer
LTCT2021	Puller Mechanical		
LTCT2037	Shaftgear Assembly Holding Device	LTCT3039	Power Shaft Bolt Measuring Tool
LTCT2044	Overspeed Gearbox Holding Device	LTCT3167	Power Turbine Vibration Pick-up Mount Assembly
LTCT2067	Mechanical Puller	LTCT3492	Bushing
LTCT2072 replaces LTCT548	Staking Fixture Assembly Turbine Wheels	LTCT3636	Sleeve Bushing

TABLE 10-39 ENGINE SUBSYSTEM UH-1H DS AND GS SPECIAL TOOLS

REF: ARMY TM 55-1520-210-35

(Continued)

PART, MODEL OR MIL DES	NOMENCLATURE	PART, MODEL OR MIL DES	NOMENCLATURE
LTCT2073	Mechanical Puller	LTCT3637	Seal Removal Tool
LTCT2075	Sun Gear Holding Fixture	LTCT3638	Output Shaft Seal Removal and Installation Tool
LTCT2076	Mechanical Puller	LTCT3640	Sleeve Bushing
LTCT3658	Sleeve Bushing	LTCT3648	Seal Removal Tool
LTCT3659	Sleeve Bushing	LTCT3654	Sleeve Bushing
LTCT3660	Sleeve Bushing	LTCT4174	Combustion Chamber Alignment Fixture
LTCT3661	Sleeve Bushing		
LTCT3663	Sleeve Bushing	LTCT4179	Compressor Rotor Blade Installation Tool
LTCT3664	Sleeve Bushing	LTCT4181	Face Spanner Wrench Socket
LTCT3665 replaces LTCT2089	Combustor Hoisting Adapter	LTCT4182 replaces LTCT892	Reduction Gear Assembly Lifting Fixture
LTCT3685	Adapter and Guide		
LTCT3738	Power Turbine Rotor Staking Tool Assembly	LTCT4190 replaces LTCT719	Spanner Wrench Assembly
LTCT3813	Kit	LTCT433	Adapter Assembly
LTCT3833 replaces LTCT2039	Gearshaft Holder Assembly	LTCT434	Aircraft Engine Maintenance Stand
LTCT393	Wrench	LTCT44	Holding Fixture
LTCT3938 replaces LTCT463	Wrench	LTCT4533 replaces LTCT576	Shaft Holding Fixture
LTCT4013	Compressor Shaft Forward Cone Installing Tool	LTCT4553	Torqueing Holding Fixture
		LTCT4560	Gear Alignment Fixture

TABLE 10-39 ENGINE SUBSYSTEM UH-1H DS AND GS SPECIAL TOOLS

REF: ARMY TM 55-1520-210-35

(Continued)

PART, MODEL OR MIL DES	NOMENCLATURE	PART, MODEL OR MIL DES	NOMENCLATURE
LTCT4018	Gear Holding Fixture	LTCT4568	Diffuser Housing Forward Seal Puller
LTCT4019	Ring Assembly	LTCT4571	Compressor Rear Shaft Arbor
LTCT4044	Forward Seal Installing Tool	LTCT4572	Diffuser Housing Forward Seal Installing Tool
LTCT413	Fuel Injector Disassembly Fixture	LTCT4576	Drive Gear Installation Tool
LTCT4155	Metal Seal Ring Compressor	LTCT4602	Retainer to Sun Gear Guide
LTCT4172	First and Second Stage Turbine Flange Finishing Adapter Kit	LTCT461	Cold Weather Step Assembly
LTCT4677 replaces LTCT786	Removal Tool	LTCT4650	Turbine Rotor Hand Crank
LTCT4680	Mechanical Puller	LTCT4670	Gearshaft Bearings Mechanical Puller
LTCT4692	Locating Pin Removal Tool	LTCT4676 replaces LTCT786	Nut and Cone Removal Kit
LTCT4696	Removal Kit	LTCT509	Locking and Unlocking Cup Tool Set
LTCT4718	Loop Clamp	LTCT511	Installation Tool
LTCT4726	First Stage Turbine Rotor Removal Kit	LTCT519	Installer and Remover
LTCT4800 replaces LTCT2023	Exhaust Diffuser Assembly Mechanical Puller	LTCT531	Ring Assembly Blade Removal Fixture
LTCT4809	Bearing Mechanical Puller	LTCT535	Inlet Housing Vibration Pickup Adapter
LTCT482	Installing Tool	LTCT552	Punch and Drift Kit

TABLE 10-39 ENGINE SUBSYSTEM UH-1H DS AND GS SPECIAL TOOLS

REF: ARMY TM 55-1520-210-35

(Continued)

PART, MODEL OR MIL DES	NOMENCLATURE	PART, MODEL OR MIL DES	NOMENCLATURE
LTCT4842 replaces LTCT4045	Spacer Mechanical Puller	LTCT675	Accessory Gearbox Mechanical Bearing Puller
LTCT4846 replaces LTCT4700	Seal Ring Mechanical Puller	LTCT68	Sleeve Bushing
LTCT4895 replaces LTCT468 and LTCT504	Pin Removal Tool	LTCT891	Mechanical Puller
LTCT4904	Starter Drive Shaft Holding Fixture	LTCT716	Overspeed Tachometer Drive Backlash Gage
LTCT496	Output Gearshaft Holding Fixture	LTCT716	Internal Wrenching Bolt
LTCT4947	Removal and Installation Tool Bushing and Base Assembly	LTCT722	Seal Installation Tool
LTCT501	Seal Installing Tool	LTCT752	Planet Gear Rear Bearing Mechanical Puller
LTCT505	Face Spanner Socket Wrench	LTCT773 replaces LTCT334	Engine Lifting Sling
LTCT506	Face Spanner Socket Wrench	LTCT791	Compressor Shaft Rear Bearing Installing Tool
LTCT916	Mechanical Puller	LTCT863	Interstage Airbleed Actuator Test Stand
LTCT962	Torque Adjustment Fixture	LTCT910	Bracket
RC40C	Ring Compressor	LTCT915	Face Spanner Wrench Assembly
LTCT58	Power Turbine Assembly Fixture	TQ-1	Torque Wrench
LTCT8000	Anchor Nut Installation Tool	TQ-6	Torque Wrench
		42M76	Stand

TABLE 10-40 ENGINE SUBSYSTEM UH-1H DS AND GS TEST AND GROUND SUPPORT EQUIPMENT

REF: ARMY TM 55-1520-210-35

PART, MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
BH112JA-36	Portable Jetcal Analyzer	Provide a means of checking exhaust thermocouple
LTCT1452	Thermocouple Temperature Bulb Test Unit	To functional-test oil temperature bulb
LTCT2029	Reduction Gear Assembly Pressure Test Fixture	To aid in pressure checking output reduction carrier and gear assembly
LTCT2052 replaces LTCT425	Test Fixture	To flow-check oil transfer tubes
LTCT207	Gearbox Test Fixture	To pressure-test accessory drive gearbox
LTCT216	Filter Test Fixture Assembly	To functional-test throttle assembly
LTCT313	Oil Flow Stand	To functional-test throttle assembly, and to flow-test oil supply nozzle assembly and output reduction carrier and gear assembly
LTCT315	Ignition Components Test Unit	To functional-test the lead and coil assembly, igniter plugs, oil temperature bulb and exhaust thermocouple
LTCT316	Anti-Icing Components Test Stand	To functional-test hot air solenoid valve
LTCT317	Test Set	To functional-test wiring harness
LTCT340	Lube and Scavenge Pump Test Stand	To functional-test power-driven rotary (oil) pump
BH361-5	Junction Box	To aid in functional testing of exhaust thermocouple
BH361-8	Junction Box	To aid in functional testing of exhaust thermocouple

TABLE 10-40 ENGINE SUBSYSTEM UH-1H DS AND GS TEST AND GROUND SUPPORT EQUIPMENT

REF: ARMY TM 55-1520-210-35

PART, MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
LTCT415 replaces BH996-40	Heater Probes Test Fixture	To provide a means of inducing heat to thermocouple probes for test
LTCT421	Compressor Bleed Valve Test Stand	To perform functional test of air-bleed actuator
LTCT422	Torquemeter Oil Pump Test Stand	To functional-test lubrication Components
LTCT423	Test Fixture Adapter Assembly	To aid in functional test of power-driven rotary (oil) pump
LTCT434	Vibration Check Tool	To check engine vibration and identify the system which may be exceeding vibration limits
LTCT713	Support Assembly Test Fixture	To aid in flow test of output reduc- carrier and gear assembly
LTCT744	Mobile Engine Test Unit	To perform ground operation or testing of engine
LTCT859	Valve Assembly Test Fixture	To aid in functional testing of combustion chamber drain valve
LTCT865	Pressure Test Mounting Stand	To mount oil filter to test stand for functional test
LTCT896	Holding Fixture	To hold igniter plug during functional test
TE12061	Water Tower Trailer Assembly	To provide facilities for extensive ground testing of engine after maintenance
TE12063	Mobile Engine Test Trailer	To provide facilities for extensive test of engine after maintenance.
LTCT2169	Union	To functional-test throttle assembly
LTCT2170	Handle	To functional-test throttle assembly

TABLE 10-40 ENGINE SUBSYSTEM UH-1H DS AND GS TEST AND GROUND SUPPORT EQUIPMENT

REF: ARMY TM 55-1520-210-35

PART, MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
LTCT318	Console Tester	To functional-test exhaust thermocouple
BH434-40	Heater Probes	To aid in functional-test of exhaust thermocouple
LTCT9271	Lead	To aid in functional testing of lead and coil assembly
WV-77E	Ohmmeter	To perform continuity check of engine electrical system
11-6532	Adapter	To aid in functional-test of ignition unit

TABLE 10-41 TRANSMISSION & ROTORS
UH-1H ORGANIZATIONAL SPECIAL TOOLS
REF: Army TM55-1520-210-20

PART, MODEL OR MIL DES.	NOMENCLATURE	TECHNICAL DESCRIPTION
T100220	Lifting Slings	Remove - Install main rotor, hub and blade assembly, and stabilizer bar assembly.
T101358	Wrench Adapter	
T101402	Grip Positioning Link	
T101306	Splined Wrench	Remove - replace - repair main drive shaft.
T101419	Alignment Tool Set	
T101420	Holding Fixture	
T101400	Leveling Jacks	
T101452	Maintenance Hoist	
T101414	Wrench	Remove main rotor blade
T101402	Grip Positioning Links	

TABLE 10-42 TRANSMISSION & ROTORS UH-1H & GS SPECIAL TOOLS

REF: Army TM551-1520-210-35

PART MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
SWE13855	Stand	Remove-install transmission
SWE13855-40	Adapter	↓
T100929	Jack Screws	↓
T101488	Wrench	↓
T101308	Jack Screws *	↓
T101304	Adapter	↓
T101303	Socket	↓
T101965	Power Wrench	↓
T101068	Anchor Plate	↓
T101436	Wrench	↓
T101338	Jack Screws	Remove-install intermediate gearbox drive, quills
T101307	Wrench *	↓
T101455	Fixture *	↓
T101336	Wrench *	↓
T101388	Jack Screws	* Remove-install tail rotor gearbox
T101365	Fixture	↓
T101449	Wrench	↓
T101486	Trim Tab Bending Tool	Repair main rotor blades
T101402	Grip Positioning Links	↓
T101356	Buildup Bench	↓

TABLE 10-42 TRANSMISSION & ROTORS UH-1H & GS SPECIAL TOOLS (Continued)

PART MODEL OR MIL DES	NOMENCLATURE	TECHNICAL DESCRIPTION
T101400	Support Assembly	Repair main rotor blades
T101401	Scope Assembly	
T101474	Grip Spacing Gage	
7A050	Hoist Support Structure Kit	
T101424	Bearing Removal Bar	Assemble-disassemble-scissors and sleeve assembly
T101392	Wrench Assembly	
T101382	Ram Adapter	
T101369	Support Assembly	
T101407	Seal Bearing Tool	Tail Rotor Hub and Blade Remove-Replace
7HEL065 7HEL153 7A050	Kit, Blade Balancing	
7HEL053	Kit, Balancing	

SECTION 11

11.1.1

11.0 FUTURE AIRCRAFT DESIGN CRITERIA

This section presents the design criteria for providing an efficient AIDAPS installation in the HLH and UTTAS aircraft. The selected AIDAPS for these aircraft is the modular, Universal Hybrid I AIDAPS described in Section 5.

It was requested that, in addition to the ten aircraft selected for detailed evaluation in this study, the AH-56A helicopter be examined briefly and a preliminary judgement be made regarding the application of an AIDAPS to this vehicle. The results of this effort are also presented in this section.

11.1 HEAVY LIFT HELICOPTER (HLH) DESIGN CRITERIA

11.1.1 AIRCRAFT DESCRIPTION

Throughout the course of this study the HLH was assumed to have the following characteristics. The HLH will be powered by three gas turbine engines of advanced design mounted on top of the fuselage to minimize the visibility of engine exhaust to ground observers, and to reduce ingestion of sand, dust, grass and other foregin objects into the engine air induction system. The HLH will be capable of maintaining forward flight in the event of a loss of a single gas turbine. A gas turbine auxiliary power plant will provide ground starting of the engines and ground operation of the hydraulic and electrical systems. Engine torque will be transmitted through a system of gear boxes and drive shafts to the rotors. The main gear box will reduce the engine RPM and interconnect the engines to the tandem rotor system. A cargo hook assembly will be provided for transporting the heavy load. The anticipated general HLH configuration is shown as Figure 11-1. Any alterations to the assumptions outlined above will obviously affect the details of the selected AIDAPS and the associated parameter list.

11.1.2 RECOMMENDED PARAMETER LIST AND HARDWARE DESCRIPTION

A tentative list of sensors and their general location is provided in Table 11-1. The estimated weight of the sensor and wire, as well as the estimated incremental costs and the Weighted Sensor Count (WSC), are also tabulated and summed. The suggested hardware physical characteristics and estimated equipments costs are indicated in Table 11-2.

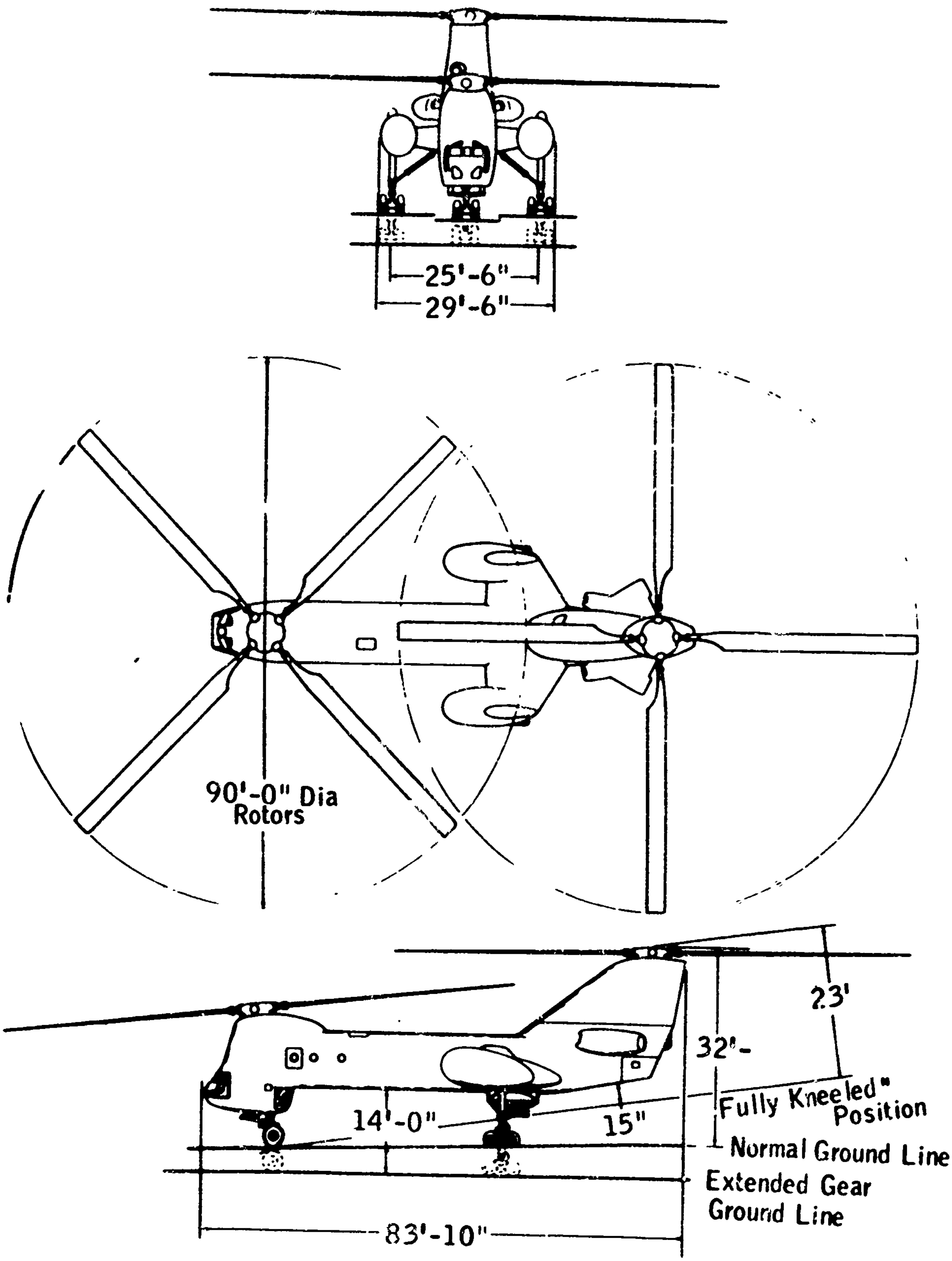


FIGURE 11-1 HLH HELICOPTER (THREE VIEW)

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
ALIGHTING GEAR OLEO POSITION	02	2,8	3	LVDT	LANDING GEAR	0.6	1.8	0.09	0.27	24	NO
EXHAUST GAS TEMPERATURE (EGT)	03	1,3	3*	THERMOCOUPLE *ASSUMED 3 SETS OF 3 IN PARALLEL	ENGINE TURBINE OUT STATION	0.1	0.3	0.01	0.03	18	YES
TURBINE INLET TEMPERATURE (TIT)	03	1,3	3	THERMOCOUPLE	ENGINE TURBINE INLET STATION	0.2	0.6	0.04	0.12	18	NO
GAS PRODUCER ROTOR SPEED (N_1)	03	1,3	3	TACH GENERATOR	ENGINE GAS PRODUCER SHAFT	0.1	0.3	0.01	0.03	30	YES
POWER TURBINE ROTOR SPEED (N_2)	03	1,3	3	TACH GENERATOR	ENGINE OUTPUT SHAFT	0.1	0.3	0.01	0.03	30	YES
AIR TEMPERATURE (OAT)	03	1,9	1	RESISTANCE BULB	UNDISTURBED AIRSTREAM	0.2	0.2	0.08	0.08	4	NO
STATIC PRESSURE	03	1	3	S.G. BRIDGE DIAPHRAGM	ENGINE CUSTOMER BLEED AIR PORT	0.5	1.5	0.09	0.27	12	NO
VIBRATION	03	1,7,12	3	PIEZOELECTRIC ACCEL	NEAR ENGINE COMPRESSOR BEARING	0.1	0.3	0.01	0.03	15	YES
VIBRATION	03	1,7,12	3	PIEZOELECTRIC ACCEL	NEAR ENGINE TURBINE BEARING	0.1	0.3	0.01	0.03	15	YES
FUEL FLOW RATE	03	1,4	3	FLOW TRANSMITTER	ENGINE FUEL FEEDLINE	0.1	0.3	0.01	0.03	30	YES
FUEL FILTER Δ P	03	3,5	3	DIFFERENTIAL PRESSURE SWITCH	ACROSS ENGINE FUEL FILTER	0.2	0.6	0.03	0.09	3	NO
FUEL LEAKAGE	03	3	3	S.S. LEAK DETECTOR	NEAR ENGINE FUEL CONTROL	0.3	0.9	0.07	0.21	12	NO

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL TEMPERATURE	03	1	3	TEMPERATURE PROBE	ENGINE OIL SYSTEM	0.1	0.3	0.01	0.03	12	YES
OIL FILTER ΔP_1	03	1	3	DIFFERENTIAL PRESSURE SWITCH	ACROSS ENGINE OIL FILTER	0.1	0.3	0.01	0.03	3	YES
OIL FILTER ΔP_2	03	1	3	S.G. BRIDGE DIAPHRAGM	ACROSS ENGINE OIL FILTER	0.1	0.3	0.01	0.03	12	YES
OIL QUANTITY	03	1	3	CAPACITIVE LEVEL SENSOR	ENGINE OIL TANK	0.1	0.3	0.01	0.03	18	YES
AIR FILTER ΔP	03	6	3	DIFFERENTIAL PRESSURE SWITCH	ENGINE AIR PARTICLE SEPARATOR	0.1	0.3	0.01	0.03	3	YES
TORQUE	03	1,11	3	LOAD CELL	ENGINE OUTPUT SHAFT	0.1	0.3	0.01	0.03	12	YES
OIL PRESSURE	03	1	3	PRESSURE SYNCHRO	ENGINE OIL SYSTEM	0.1	0.3	0.01	0.03	36	YES
OIL ANALYSIS	03	1	3	OPTICAL ANALYZER	ENGINE OIL SYSTEM	0.1	0.3	0.01	0.03	36	YES
COMPRESSOR EROSION	03	1	3	ENGINE PRESSURE RATIO	ENGINE COMPRESSOR	0.1	0.3	0.01	0.03	12	YES
EVENTS:				TRIGGERED BY ENGINE OIL PRESSURE, TEMP. & SPEED ACCUMULATED BY AIDAPS	ENGINE						
a. NO. OF STARTS	03	1	3			N/A		N/A		3	YES
b. DURATION OF ENGINE OPERATION	03	1	3			N/A		N/A		3	YES
c. NO. OF OVER TEMP.	03	1	3			N/A		N/A		3	YES
d. NO. OF OVERSPEED	03	1	3			N/A		N/A		3	YES
e. DURATION OF OVERTEMP	03	1	3			N/A		N/A		3	YES
f. DURATION OF OVER-SPEED	03	1	3			N/A		N/A		3	YES

TABLE 11-1 HLH SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
AIRSPEED	03	1	1	S.G. BRIDGE DIAPHRAGM	A/C PITOT SYSTEM	0.5	0.5	0.09	0.09	4	NO
STATIC PRESSURE (OAP)	03	1	1	S.G. BRIDGE DIAPHRAGM	A/C STATIC SYSTEM	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	03		3	CHIP DETECTOR	ENGINE OIL SYSTEM	0.1	0.3	0.01	0.03	3	YES
OIL PRESSURE	04	7,10, 14	3	S.G. BRIDGE DIAPHRAGM	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.3	0.01	0.03	12	YES
OIL TEMPERATURE	04	7,10, 19	3	RESISTANCE BULB	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.3	0.01	0.03	12	YES
OIL QUANTITY	04	7,10	3	CAPACITANCE BRIDGE	ENGINE TRANSMISSION OIL SYSTEM	0.6	1.8	0.14	0.42	18	NO
OIL FILTER ΔP	04	7,10	3	S.G. BRIDGE DIAPHRAGM	ENGINE TRANSMISSION OIL FILTER	0.5	1.5	0.09	0.27	12	NO
OIL CONTAMINATION (CHIPS)	04	7,10	3	CHIP DETECTOR	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.3	0.01	0.03	3	YES
VIBRATION	04	7,10, 15	3	PIEZOELECTRIC ACCEL	ENGINE TRANSMISSION CASE	0.5	1.5	0.11	0.33	15	NO
OIL PRESSURE	04	4,7,14	1	S.G. BRIDGE DIAPHRAGM	FORWARD TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL TEMPERATURE	04	4,7,19	1	RESISTANCE BULB	FORWARD TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL QUANTITY	04	4,7	1	CAPACITANCE BRIDGE	FORWARD TRANSMISSION OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL FILTER ΔP	04	4,7	1	S.G. BRIDGE DIPAHRAGM	FORWARD TRANSMISSION OIL FILTER	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	04	4,7	1	CHIP DETECTOR	FORWARD TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	1,2,4, 5,7,9, 13,15, 18,20	1	PIEZOELECTRIC ACCEL	FORWARD TRANSMISSION CASE	0.5	0.5	0.11	0.11	5	NO
OIL PRESSURE	04	4,7,14	1	S.G. BRIDGE DIAPHRAGM	AFT TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL TEMPERATURE	04	4,7,19	1	RESISTANCE BULB	AFT TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL QUANTITY	04	4,7	1	CAPACITANCE BRIDGE	AFT TRANSMISSION OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO
OIL FILTER ΔP	04	4,7	1	S.G. BRIDGE DIAPHRAGM	AFT TRANSMISSION OIL SYSTEM	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	04	4,7	1	CHIP DETECTOR	AFT TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	1,2,4, 5,7,9, 13,15, 18,20	1	PIEZOELECTRIC ACCEL	AFT TRANSMISSION CASE	0.5	0.5	0.11	0.11	5	NO
OIL PRESSURE	04	7,8,14	1	S.G. BRIDGE DIAPHRAGM	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL TEMPERATURE	04	7,8,19	1	RESISTANCE BULB	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL QUANTITY	04	7,8	1	CAPACITANCE BRIDGE	MAIN TRANSMISSION OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO
OIL FILTER Δ P	04	7,8	1	S.G. BRIDGE DIAPHRAGM	MAIN TRANSMISSION OIL FILTER	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	04	7,8	1	CHIP DETECTOR	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	7,8,15	1	PIEZOELECTRIC ACCEL	MAIN TRANSMISSION CASE	0.5	0.5	0.11	0.11	5	NO
HYDR OIL LEAKAGE	04	11,12	1	S.S. LEAK DETECTOR	ROTOR BRAKE PACKAGE	0.3	0.3	0.07	0.07	4	NO
HYDR OIL PRESSURE	06	1,2	1	PRESSURE TRANSMITTER	NO. 1 FLIGHT CONTROL SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL PRESSURE	06	1,2	1	PRESSURE TRANSMITTER	NO. 2 FLIGHT CONTROL SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL FILTER Δ P	06	1,2,5, 9	1	S.G. BRIDGE DIAPHRAGM	NO. 1 FLIGHT CONTROL SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO
HYDR OIL FILTER Δ P	06	1,2,5, 9	1	S.G. BRIDGE DIAPHRAGM	NO. 2 FLIGHT CONTROL SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO
HYDR OIL LEAKAGE	06	2,6	1	S.S. LEAK DETECTOR	NO. 1 FLIGHT CONTROL SYSTEM OIL RESERVOIR	0.3	0.3	0.07	0.07	4	NO
HYDR OIL LEAKAGE	06	2,6	1	S.S. LEAK DETECTOR	NO. 2 FLIGHT CONTROL SYSTEM OIL RESERVOIR	0.3	0.3	0.07	0.07	4	NO

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
MAIN ROTOR SPEED	06	6	1	TACH GENERATOR	ROTOR SHAFT	0.1	0.1	0.01	0.01	10	YES
HYDR OIL PRESSURE	06	2,4	1	PRESSURE TRANSMITTER	UTILITY HYDR SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL FILTER Δ P	06	2	1	S.G. BRIDGE DIAPHRAGM	UTILITY HYDR SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO
HYDR OIL LEAKAGE	06	6	1	S.S. LEAK DETECTOR	UTILITY HYDR SYSTEM RESERVOIR	0.3	0.3	0.07	0.07	4	NO
HYDR OIL LEAKAGE	06		6	S.S. LEAK DETECTOR	FLIGHT CONTROL SYSTEM IRREVERSIBLE VALVES	0.3	1.8	0.07	0.42	24	NO
HYDR OIL LEAKAGE	06		6	S.S. LEAK DETECTOR	FLIGHT CONTROL SYSTEM SERVO CYLINDERS	0.3	1.8	0.07	0.42	24	NO
DISPLACEMENT	05		6	LVDT	FLIGHT CONTROL SYSTEM SERVO CYLINDERS	0.6	3.6	0.09	0.54	48	NO
VOLTAGE	09	2	3	PROPORTIONAL VOLTAGE	NO. 1 AC PRIMARY BUS (ϕ A, B, & C)	0.1	0.3	0.01	0.03	12	YES
VOLTAGE	09	2	3	PROPORTIONAL VOLTAGE	NO. 2 AC PRIMARY BUS (ϕ A, B, & C)	0.1	0.3	0.01	0.03	12	YES
VOLTAGE	09		1	PROPORTIONAL VOLTAGE	117 VAC ESSENTIAL BUS	0.1	0.1	0.01	0.01	4	YES
VOLTAGE	09		1	PROPORTIONAL VOLTAGE	26 VAC ESSENTIAL BUS	0.1	0.1	0.01	0.01	4	YES
GENERATOR LOAD	09		3	CURRENT SHUNT	A/C GENERATORS	0.2	0.6	0.03	0.09	12	NO

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST UNIT	ADDED SENSOR WT (LBS) W/WIRE EST EXT.	ADDED SENSOR UNIT COST ($K) EST UNIT	ADDED SENSOR UNIT COST ($K) EST EXT.	WSC	A/C EXISTING
LEAKAGE	09	1	1	S.S. LEAK DETECTOR	STORAGE BATTERY CASE	0.3	0.3	0.07	0.07	4	NO
FUEL LEAKAGE	10	1,2	3	S.S. LEAK DETECTOR	NEAR FUEL TANKS	0.3	0.9	0.07	0.21	12	NO
EXHAUST GAS TEMPERATURE	18	1,3	1	THERMOCOUPLE	APU TAILPIPE	0.1	0.1	0.01	0.01	6	YES
ROTOR SPEED	18	1,2	1	TACH GENERATOR	APU ROTOR	0.1	0.1	0.01	0.01	10	YES
OIL QUANTITY	18	1	1	CAPACITANCE BRIDGE	APU OIL TANK	0.6	0.6	0.14	0.14	6	NO
OIL CONTAMINATION (CHIPS)	18	1	1	CHIP DETECTOR	APU OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
OIL PRESSURE	18	1	1	S.G. BRIDGE DIAPHRAGM	APU OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
VIBRATION	18	1	1	PIEZOELECTRIC ACCEL	APU COMBUSTOR CASE	0.5	0.5	0.11	0.11	5	NO
CONTINUITY	MISC	2	3	RESISTOR (DISCRETE VOLTAGE DROP)	ENGINE GROUND STRAP	0.1	0.3	0.01	0.03	3	YES
GYRO POWER ON-OFF	19		1	DISCRETE	GYRO MAGNETIC COMPASS POWER CIRCUIT	0.1	0.1	0.01	0.01	1	YES
GYRO MAGNETIC COMPASS OUTPUT	19	10,12	1	PROPORTIONAL SIGNAL	GYRO MAGNETIC COMPASS TRANSMITTER FLUX COMPENSATOR	0.1	0.1	0.01	0.01	4	YES
GYRO MAGNETIC COMPASS YAW SIGNAL	19	14	1	SYNCHRO	GYRO MAGNETIC COMPASS DIRECTIONAL GYRO OUTPUT	0.1	0.1	0.01	0.01	12	YES
GYRO MAGNETIC COMPASS HEADING ERROR	19	15	1	SYNCHRO	GYRO MAGNETIC COMPASS CONTROLLER OUTPUT	0.1	0.1	0.01	0.01	12	YES
VOLTAGE INPUT TO HEIGHT INDICATOR	19	16	1	SYNCHRO	RADAR ALTIMETER CONTROL AMPLIFIER OUTPUT	0.1	0.1	0.01	0.01	12	YES

TABLE 11-1 HLH AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
VOLTAGE INPUT TO AMPLIFIER	19	17	1	PROPORTIONAL VOLTAGE	RADAR ALTIMETER RECEIVER/ TRANSMITTER OUTPUT	0.1	0.1	0.01	0.01	4	YES
POWER (VOLTAGE) TO RADAR ALTIMETER	19		1	DISCRETE	A/C RADAR ALTIMETER FEED BUS	0.1	0.1	0.01	0.01	1	YES
POWER (VOLTAGE) TO AFCS	19		1	DISCRETE	A/C AFCS FEED BUS	0.1	0.1	0.01	0.01	1	YES
AFCS DISCONNECT	19	8	1	DISCRETE	AFCS ACCELEROMETER MONITOR OUTPUT	0.1	0.1	0.01	0.01	1	YES
AFCS ROLL CONTROL OUTPUT	19	7	1	SYNCHRO	AUTOPILOT CONTROL OUTPUT	0.1	0.1	0.01	0.01	12	YES
AFCS STEERING	19	5	1	SYNCHRO	NAVIGATION COUPLER OUTPUT	0.1	0.1	0.01	0.01	12	YES
AFCS ACCELEROMETER OUTPUT SIGNAL	19	3	1	PROPORTIONAL VOLTAGE	A/C ACCELEROMETER OUTPUT	0.1	0.1	0.01	0.01	4	YES
AFCS ROLL ANGLE	19	1,6	1	SYNCHRO	DISPLACEMENT GYRO & ATTITUDE CONTROL OUTPUTS	0.1	0.1	0.01	0.01	12	YES
					TOTAL	-	-	-	6.79	881	

11.1.3 VOICE WARNING FOR HLH

Physical data concerning the Voice Warning Unit (VWU) was provided in Table 11-2 for information purposes. A suggested VWU message list is shown in Table 11-3. The triplication of some of the major systems on the HLH, and the numerous transmissions that will be required, do not allow specific messages in all instances. Examples are; 15, "TRANSMISSION CHIPS"; 14, "ENGINE CHIPS"; and 21, "TORQUE, ENGINE OVERTORQUE." These messages could be made specific to a single unit but at the expense of other warnings. The parameters concerned are either instrumented or are associated with a warning light. The general voice warning, therefore, alerts the aviator to either scan his instruments or operate a selector switch as suggested for Priorities 1 and 15.

TABLE 11-2 HARDWARE CONFIGURATIONS FOR HLH

UNITS OF THE SYSTEM	DESIGNATION	WEIGHT (POUNDS)	DIMENSIONS	POWER (WATTS)
AIRBORNE CONFIGURATION:				
CENTRAL ELECTRONICS UNIT	CEU	9.0	12" x 6" x 7"	30
COMMUNICATION UNIT (PRINTER)	CU	6.0	8" x 6" x 6"	10
REMOTE DATA ACQUISITION UNIT	RDAU	6.0	7-1/2" x 6" x 7"	20
		21.0		60
VOICE WARNING UNIT	VWU	4.5	6-1/2" x 4-3/8" x 5"	15
COMPLEX HYBRID CONFIGURATION:				
CENTRAL ELECTRONICS UNIT	CEU	10.0	12" x 6" x 7"	40
COMMUNICATION UNIT (DATA STORAGE)	(PART OF CEU)	-	-	-
COMMUNICATION UNIT (GROUND)	CU	30*	17" x 6" x 6"	25**
REMOTE DATA ACQUISITION UNIT	RDAU	6.0	4" x 4" x 5"	20
		16.0 (does not include *)		60 (does not include **)

TABLE 11-3 SUGGESTED VOICE WARNING MESSAGES FOR THE HLH

PRIORITY	MESSAGE
1*	LOAD ERROR (3 position switch either excessive C.G. shift or overload, as function of total weight, pressure altitude and ambient temperature, before liftoff, yields warning light. Pilot determines which condition by switching either direction from neutral position, similarly to chip switch for 42°/92° gearbox and transmission on UH-1).
2	FIRE, ENGINE FIRE (any engine activates)
3*	HOT START (any engine activates)
4*	ENGINE ONE OUT
5*	ENGINE TWO OUT
6*	ENGINE THREE OUT
7*	EGT ONE HIGH
8*	EGT TWO HIGH
9*	EGT THREE HIGH
10*	N_1 ONE LOW
11*	N_1 TWO LOW
12*	N_1 THREE LOW
13	SPARE
14*	SAS OUT
15*	TRANSMISSION SHIPS (3 position switch which differentiates between basic rotor transmissions and common transmissions (see "Load Error" above).
16*	ENGINE CHIPS (any engine)
17*	TRANSMISSION OIL PRESSURE LOW (any transmission)
18*	ENGINE ONE OIL PRESSURE LOW
19*	ENGINE TWO OIL PRESSURE LOW

TABLE 11-3 (Continued)

PRIORITY	MESSAGE
20*	ENGINE THREE OIL PRESSURE LOW
21*	TORQUE, ENGINE OVERTORQUE (any engine)
22*	HYDRAULIC PRESSURE LOW (3-position switch, 1, 2 and utility)
23*	FUEL PRESSURE LOW (any engine)
24*	FUEL BOOST ONE OUT
25*	FUEL BOOST TWO OUT
26*	FUEL BOOST THREE OUT
27*	"X" MINUTES FUEL REMAINING
28*	FUEL FILTER ONE CLOGGED
29*	FUEL FILTER TWO CLOGGED
30*	FUEL FILTER THREE CLOGGED
31*	AC GENERATOR ONE OUT
32*	AC GENERATOR TWO OUT
33*	EXTERNAL POWER ON
34*	ICING
35*	ICE DETECTOR OUT
36*	AIR FILTER ONE CLOGGED
37*	AIR FILTER TWO CLOGGED
38*	AIR FILTER THREE CLOGGED
39*	IFF FAILURE
40*	CHECK CAUTION PANEL

*Will be used by AIDAPS

11.2 UTTAS DESIGN CRITERIA

11.2.1 AIRCRAFT DESCRIPTION

The Utility Tactical Transport Aircraft System (UTTAS) is assumed to be a twin engine aircraft with one main rotor and one anti-torque rotor. The gas turbine engines each have a separate transmission. The output torque from each engine transmission is transmitted to the rotor via a combining transmission. A drive shaft from the combining transmission drives an intermediate gear box which in turn drives a 90° gear box for operation of the tail rotor system. Additional information available from the PQMR has also been utilized in defining this vehicle for application of an AIDAPS.

11.2.2 RECOMMENDED PARAMETERS AND AIDAPS HARDWARE DESCRIPTION

Recommended system parameters for the UTTAS, the sensors involved and their general locations are shown in Table 11-4. The estimated weight of the sensor and necessary wiring as well as the incremental cost and the WSC are also noted. The last column designates whether the parameter is one that is usually instrumented on an aircraft, or is one that would be primarily necessary for AIDAPS. The estimated cost columns reflect only a small incremental cost if the sensor would be found on the aircraft, while the full procurement cost is assumed if the sensor will be added exclusively for AIDAPS.

Table 11-5 gives the airborne hardware physical characteristics for both airborne and hybrid systems, and a preliminary estimate of costs.

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE CST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
ALIGHTING GEAR OLEO POSITION	02	1,8	3	LVDT	LANDING GEAR	0.6	1.8	0.09	0.27	24	NO
EXHAUST GAS TEMPERATURE (EGT)	03	1,4,8, 9	2*	THERMOCOUPLE *ASSUMED 2 SETS OF 3 IN PARALLEL	ENGINE TURBINE OUT STATION	0.1	0.2	0.01	0.02	12	YES
TURBINE INLET TEMPERATURE (TIT)	03	1,4,5, 9	2	THERMOCOUPLE	ENGINE TURBINE INLET STATION	0.2	0.4	0.04	0.08	12	NO
GAS PRODUCER ROTOR SPEED (N_1)	03	1,4,5, 8,9,11	2	TACH GENERATOR	ENGINE GAS PRODUCER SHAFT	0.1	0.2	0.01	0.02	20	YES
POWER TURBINE ROTOR SPEED (N_2)	03	1,4,5, 8,9,11	2	TACH GENERATOR	ENGINE OUTPUT SHAFT	0.1	0.2	0.01	0.02	20	YES
AIR TEMPERATURE (OAT)	03	1,4	1	RESISTANCE BULB	UNDISTURBED AIRSTREAM	0.2	0.2	0.08	0.08	4	NO
STATIC PRESSURE	03	1,4,5, 8	2	S.G. BRIDGE DIAPHRAGM	ENGINE CUSTOMER BLEED AIR PORT	0.5	1.0	0.09	0.18	8	NO
VIBRATION	03	1,4,9	2	PIEZOELECTRIC ACCEL	NEAR ENGINE COMPRESSOR BEARING	0.1	0.2	0.01	0.02	10	YES
VIBRATION	03	1,4,5	2	PIEZOELECTRIC ACCEL	NEAR ENGINE TURBINE BEARING	0.1	0.2	0.01	0.02	10	YES
FUEL FLOW RATE	03	1,2,4, 7,8	2	FLOW TRANSMITTER	ENGINE FUEL FEED LINE	0.1	0.2	0.01	0.02	20	YES
FUEL FILTER ΔP	03	2,7,8	2	DIFFERENTIAL PRESSURE SWITCH	ACROSS ENGINE FUEL FILTER	0.2	0.4	0.03	0.06	2	NO

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
FUEL LEAKAGE	03	1,7,8	2	S.S. LEAK DETECTOR	NEAR ENGINE FUEL CONTROL	0.3	0.6	0.07	0.14	8	NO
OIL TEMPERATURE	03	1,4	2	TEMPERATURE PROBE	ENGINE OIL SYSTEM	0.1	0.2	0.01	0.02	8	YES
OIL FILTER ΔP_1	03	2,10	2	DIFFERENTIAL PRESSURE SWITCH	ACROSS ENGINE OIL FILTER	0.1	0.2	0.01	0.02	2	YES
OIL FILTER ΔP_2	03	2,10	2	S.G. BRIDGE DIAPHRAGM	ACROSS ENGINE OIL FILTER	0.1	0.2	0.01	0.02	8	YES
OIL QUANTITY	03	1	2	CAPACITIVE LEVEL SENSOR	ENGINE OIL TANK	0.1	0.2	0.01	0.02	12	YES
AIR FILTER ΔP	03	10, 12	2	DIFFERENTIAL PRESSURE SWITCH	ENGINE AIR PARTICLE SEPARATOR	0.1	0.2	0.01	0.02	2	YES
TORQUE	03	1,9	2	LOAD CELL	ENGINE OUTPUT SHAFT	0.1	0.2	0.01	0.02	8	YES
OIL PRESSURE	03	1,4	2	PRESSURE SYNCHRO	ENGINE OIL SYSTEM	0.1	0.2	0.01	0.02	24	YES
OIL ANALYSIS	03	1,4	2	OPTICAL ANALYZER	ENGINE OIL SYSTEM	0.1	0.3	0.01	0.02	24	YES
COMPRESSOR EROSION	03	1,4	2	ENGINE PRESSURE RATIO	ENGINE COMPRESSOR	0.1	0.2	0.01	0.02	8	YES
EVENTS:				TIME BASE & COUNTER TRIGGERED BY ENGINE OIL PRESSURE, TEMP, & SPEED ACCUMULATED BY AIDAPS	ENGINE						
a. NO. OF STARTS	03	1,4	2			N/A		N/A		2	YES
b. DURATION OF ENGINE OPERATION	03	1,4	2			N/A		N/A		2	YES
c. NO. OF OVERTEMP	03	1,4	2			N/A		N/A		2	YES
d. NO. OF OVERSPEED	03	1,4	2			N/A		N/A		2	YES
e. DURATION OF OVERTEMPERATURE	03	1,4	2			N/A		N/A		2	YES

TABLE 11 4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
f. DURATION OF OVERSPEED	03	1,4	2			N/A		N/A		2	YES
AIRSPEED	03	1	1	S.G. BRIDGE DIAPHRAGM	A/C PITOT SYSTEM	0.5	0.5	0.09	0.09	4	NO
STATIC PRESSURE	03	1,4,8	1	S.G. BRIDGE DIAPHRAGM	A/C STATIC SYSTEM	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	03	11	2	CHIP DETECTOR	ENGINE OIL SYSTEM	0.1	0.2	0.01	0.02	2	YES
OIL PRESSURE	04	10	2	S.G. BRIDGE DIAPHRAGM	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.2	0.01	0.02	8	YES
OIL TEMPERATURE	04	10	2	RESISTANCE BULB	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.2	0.01	0.02	8	YES
OIL QUANTITY	04	10	2	CAPACITANCE BRIDGE	ENGINE TRANSMISSION OIL SYSTEM	0.6	1.2	0.14	0.28	12	NO
OIL FILTER ΔP	04	10	2	S.G. BRIDGE DIAPHRAGM	ENGINE TRANSMISSION OIL FILTER	0.5	1.0	0.10	0.20	8	NO
OIL CONTAMINATION (CHIPS)	04	10	2	CHIP DETECTOR	ENGINE TRANSMISSION OIL SYSTEM	0.1	0.2	0.01	0.02	2	YES
VIBRATION	04	10	2	PIEZOELECTRIC ACCEL	ENGINE TRANSMISSION CASE	0.5	1.0	0.11	0.22	10	NO
OIL PRESSURE	04	11	1	S.G. BRIDGE DIAPHRAGM	INTERMEDIATE GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL TEMPERATURE	04	11	1	RESISTANCE BULB	INTERMEDIATE GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL QUANTITY	04	11	1	CAPACITANCE BRIDGE	INTERMEDIATE GEAR BOX OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO
OIL FILTER Δ P	04	11	1	S.G. BRIDGE DIAPHRAGM	INTERMEDIATE GEAR BOX OIL FILTER	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	04	11	1	CHIP DETECTOR	INTERMEDIATE GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	11	1	PIEZOELECTRIC ACCEL	INTERMEDIATE GEAR BOX CASE	0.5	0.5	0.11	0.11	5	NO
OIL PRESSURE	04	7	1	S.G. BRIDGE DIAPHRAGM	TAIL ROTOR GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL TEMPERATURE	04	7	1	RESISTANCE BULB	TAIL ROTOR GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL QUANTITY	04	7	1	CAPACITANCE BRIDGE	TAIL ROTOR GEAR BOX OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO
OIL FILTER Δ P	04	7	1	S.G. BRIDGE DIAPHRAGM	TAIL ROTOR GEAR BOX OIL FILTER	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIP)	04	7	1	CHIP DETECTOR	TAIL ROTOR GEAR BOX OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	2,7,19	1	PIEZOELECTRIC ACCEL	TAIL ROTOR GEAR BOX CASE	0.5	0.5	0.11	0.11	5	NO
OIL PRESSURE	04	10	1	S.G. BRIDGE DIAPHRAGM	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL TEMPERATURE	04	10,23	1	RESISTANCE BULB	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
OIL QUANTITY	04	10	1	CAPACITANCE BRIDGE	MAIN TRANSMISSION OIL SYSTEM	0.6	0.6	0.14	0.14	6	NO
OIL FILTER ΔP	04	10	1	S.G. BRIDGE DIAPHRAGM	MAIN TRANSMISSION OIL FILTER	0.5	0.5	0.09	0.09	4	NO
OIL CONTAMINATION (CHIPS)	04	10	1	CHIP DETECTOR	MAIN TRANSMISSION OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES
VIBRATION	04	1,4,6, 9,10,12, 14,17, 18,20, 24	1	PIEZOELECTRIC ACCEL	MAIN TRANSMISSION CASE	0.5	0.5	0.11	0.11	5	NO
MAIN ROTOR SPEED	04	10	1	TACH GENERATOR	MAIN ROTOR SHAFT	0.1	0.1	0.01	0.01	10	YES
ROTOR BRAKE OIL LEAKAGE	04	10	1	S.S. LEAK DETECTOR	ROTOR BRAKE PACKAGE	0.3	0.3	0.07	0.07	4	NO
HYDR OIL PRESSURE	06	3	1	PRESSURE TRANSMITTER	NO. 1 FLIGHT CONTROL SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL PRESSURE	06	3	1	PRESSURE TRANSMITTER	NO. 2 FLIGHT CONTROL SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL FILTER ΔP	06	4	1	S.G. BRIDGE DIAPHRAGM	NO. 1 FLIGHT CONTROL SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
HYDR OIL FILTER ΔP	06	4	1	S.G. BRIDGE DIAPHRAGM	NO. 2 FLIGHT CONTROL SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO
HYDR OIL LEAKAGE	06	3	1	S.S. LEAK DETECTOR	NO. 1 FLIGHT CONTROL SYSTEM RESERVOIR	0.3	0.3	0.07	0.07	4	NO
HYDR OIL LEAKAGE	06	3	1	S.S. LEAK DETECTOR	NO. 2 FLIGHT CONTROL SYSTEM RESERVOIR	0.3	0.3	0.07	0.07	4	NO
OIL LEAKAGE	06	3	1	S.S. LEAK DETECTOR	TAIL ROTOR GEAR BOX INPUT SEAL	0.3	0.3	0.07	0.07	4	NO
HYDR OIL PRESSURE	06	3	1	PRESSURE TRANSMITTER	UTILITY HYDR SYSTEM PUMP	0.1	0.1	0.01	0.01	12	YES
HYDR OIL FILTER ΔP	06	4	1	S.G. BRIDGE DIAPHRAGM	UTILITY HYDR SYSTEM FILTER	0.5	0.5	0.09	0.09	4	NO
HYDR OIL LEAKAGE	06	4	1	S.S. LEAK DETECTOR	UTILITY HYDR SYSTEM RESERVOIR	0.3	0.3	0.07	0.07	4	NO
HYDR OIL LEAKAGE	06	1	3	S.S. LEAK DETECTOR	FLIGHT CONTROL SYSTEM IRREVERSIBLE VALVES	0.3	0.9	0.07	0.21	12	NO
HYDR OIL LEAKAGE	06	2	4	S.S. LEAK DETECTOR	FLIGHT CONTROL SYSTEM SERVO CYLINDERS	0.3	1.2	0.07	0.28	16	NO
DISPLACEMENT	06	2	4	LVDT	FLIGHT CONTROL SYSTEM SERVO CYLINDERS	0.6	2.4	0.09	0.36	32	NO
GENERATOR LOAD	09	2	2	CURRENT SHUNT	A/C GENERATORS	0.2	0.4	0.03	0.06	8	NO

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
VOLTAGE	09	3	3	PROPORTIONAL VOLTAGE	NO. 1 A.C. PRIMARY BUS (ϕ A,B, & C)	0.1	0.3	0.01	0.03	12	YES
VOLTAGE	09	3	3	PROPORTIONAL VOLTAGE	NO. 2 A.C. PRIMARY BUS (ϕ A, B, & C)	0.1	0.3	0.01	0.03	12	YES
VOLTAGE	09		1	PROPORTIONAL VOLTAGE	117 VAC ESSENTIAL BUS	0.1	0.1	0.01	0.01	4	YES
VOLTAGE	09		1	PROPORTIONAL VOLTAGE	26 VAC ESSENTIAL BUS	0.1	0.1	0.01	0.01	4	YES
LEAKAGE	09	1	1	S.S. LEAK DETECTOR	STORAGE BATTERY CASE	0.3	0.3	0.07	0.07	4	NO
FUEL LEAKAGE	10	1	2	S.S. LEAK DETECTOR	NEAR FUEL TANK	0.3	0.6	0.07	0.14	8	NO
PITCH ATTITUDE	11		1	SYNCHRO	SAS GYRO	0.1	0.1	0.01	0.01	12	YES
LATERAL ATTITUDE	11		1	SYNCHRO	SAS GYRO	0.1	0.1	0.01	0.01	12	YES
SAS AMPLIFIER OUTPUT	11		2	PROPORTIONAL SIGNAL	SAS AMPLIFIERS	0.1	0.2	0.01	0.02	8	YES
A/C SLIP Δ P	11		1	S.G. BRIDGE DIAPHRAGM	SAS SLIP INDICATOR	0.1	0.1	0.01	0.01	4	YES
EXHAUST GAS TEMPERATURE	18	1	1	THERMOCOUPLE	APU TAILPIPE	0.1	0.1	0.01	0.01	6	YES
ROTOR SPEED	18	1,2	1	TACH GENERATOR	APU ROTOR	0.1	0.1	0.01	0.01	10	YES
OIL QUANTITY	18	1	1	CAPACITANCE BRIDGE	APU OIL TANK	0.6	0.6	0.14	0.14	6	NO
OIL CONTAMINATION (CHIPS)	18	1	1	CHIP DETECTOR	APU OIL SYSTEM	0.1	0.1	0.01	0.01	1	YES

TABLE 11-4 UTTAS AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP	Kth ID	NO. REQD.	SENSOR	LOCATION	ADDED SENSOR WT (LBS) W/WIRE EST		ADDED SENSOR UNIT COST ($K) EST		WSC	A/C EXISTING
						UNIT	EXT.	UNIT	EXT.		
OIL PRESSURE	18	1	1	S.G. BRIDGE DIAPHRAGM	APU OIL SYSTEM	0.1	0.1	0.01	0.01	4	YES
VIBRATION	18	1	1	PIEZOELECTRIC ACCEL	APU COMBUSTOR CASE	0.5	0.5	0.11	0.11	5	NO
GROUND CONTINUITY	MISC	2	2	RESISTOR (DISCRETE VOLTAGE DROP)	ENGINE GROUND STRAP	0.1	0.2	0.01	0.02	2	YES
GYRO POWER ON-OFF	19		1	DISCRETE	GYRO MAGNETIC COMPASS POWER CIRCUIT	0.1	0.1	0.01	0.01	1	YES
GYRO MAGNETIC COMPASS OUTPUT	19	10,12	1	PROPORTIONAL SIGNAL	GYRO MAGNETIC COMPASS TRANSMITTER FLUX COMPENSATOR	0.1	0.1	0.01	0.01	4	YES
GYRO MAGNETIC COMPASS YAW SIGNAL	19	14	1	SYNCHRO	GYRO MAGNETIC COMPASS DIRECTIONAL OUTPUT	0.1	0.1	0.01	0.01	12	YES
GYRO MAGNETIC COMPASS HEADING ERROR	19	15	1	SYNCHRO	GYRO MAGNETIC COMPASS CONTROLLER OUTPUT	0.1	0.1	0.01	0.01	12	YES
VOLTAGE INPUT TO HEIGHT INDICATOR	19	16	1	SYNCHRO	RADAR ALTIMETER CONTROL AMPLIFIER OUTPUT	0.1	0.1	0.01	0.01	12	YES
VOLTAGE INPUT TO AMPLIFIER	19	17	1	PROPORTIONAL VOLTAGE	RADAR ALTIMETER RECEIVER/ TRANSMITTER OUTPUT	0.1	0.1	0.01	0.01	4	YES
POWER (VOLTAGE) TO RADAR ALTIMETER	19		1	DISCRETE	A/C RADAR ALTIMETER FEED BUS	0.1	0.1	0.01	0.01	1	YES
					TOTAL	-	-	-	5.32	694	

TABLE 11-5 HARDWARE CONFIGURATION FOR UTIAS

UNITS OF THE SYSTEM	DESIGNATION	WEIGHT (POUNDS)	DIMENSIONS	POWER (WATTS)
AIRBORNE CONFIGURATION:				
CENTRAL ELECTRONICS UNIT	CEU	9.0	12" x 6" x 7"	30
COMMUNICATION UNIT (PRINTER)	CU	6.0	8" x 6" x 6"	10
REMOTE DATA ACQUISITION UNIT	RDAU	6.0	7-1/2" x 6" x 7"	20
		21.0		60
VOICE WARNING UNIT	VWU	4.5	6-1/2" x 4-3/8" x 5"	15
COMPLEX HYBRID CONFIGURATION:				
CENTRAL ELECTRONICS UNIT	CEU	10.0	12" x 6" x 7"	40
COMMUNICATION UNIT (DATA STORAGE)	PART OF CEU	-	-	-
COMMUNICATION UNIT (GROUND)	CU	30*	17" x 6" x 6"	25**
REMOTE DATA ACQUISITION UNIT	RDAU	6.0	4" x 4" x 5	20
		16.0 (does not include *)		60 (does not include **)

11.2.3 VOICE WARNING FOR UTTAS

A suggested message list for voice warning is given for the UTTAS in Table 11-6. All of the implied parameters, both proportional and discrete, with the exception of the fire warning, have an impact on the AIDAPS for inspection. diagnostic and prognostic purposes. This allows processing by the AIDAPS logic even though the signal may exist as a discrete to the caution panel or other indicator. For example, presently the "CHIPS" signals are delayed until the signal becomes steady to prevent the occurrence of a voice warning due to transients or momentary particles. This "conditioning" can be done by the AIDAPS as a part of its processing without the addition of any special circuits or devices. Similarly, the data may be improved by correlation of several parameters. An example is "VIBRATION HIGH, POWER TRAIN". Under certain conditions of high power demands, a higher vibration level may be expected and would be no indication of malfunction. Conversely, a much lower vibration level at lower power demands can be indicative of serious trouble.

TABLE 11-6 SUGGESTED VOICE WARNING MESSAGES FOR THE UTTAS

PRIORITY	MESSAGE
1*	LOAD ERROR (3 position switch either excessive C.G. shift or overload, as function of total weight, pressure altitude and ambient temperature, before liftoff, yields warning light. Pilot determines which condition by switching either direction from neutral position, similarly to chip switch for 42°/92° gearbox and transmission on UH-1).
2	FIRE, ENGINE FIRE (either engine activates)
3*	HOT START (either engine activates)
4*	ROTOR RPM LOW
5*	AUTOROTATION LOW
6*	HIGH AUTOROTATION
7*	ROTOR RPM HIGH
8*	EGT ONE HIGH
9*	EGT TWO HIGH
10*	N_1 LOW, ENGINE ONE
11*	N_1 LOW, ENGINE TWO
12*	SAS OUT
13*	TRANSMISSION CHIPS (3 position switch which differentiates between basic rotor transmission and tail rotor gearboxes see "Load Error" above).
14*	ENGINE CHIPS
15*	TRANSMISSION OIL PRESSURE LOW
16*	ENGINE ONE OIL PRESSURE LOW
17*	ENGINE TWO OIL PRESSURE LOW
18*	VIBRATION HIGH, POWER TRAIN

*Will be used by AIDAPS

TABLE 11-6 (Continued)

PRIORITY	MESSAGE
19*	TRANSMISSION OIL TEMPERATURE HIGH
20*	ENGINE OIL TEMPERATURE HIGH
21*	TORQUE, ENGINE OVERTORQUE
22*	HYDRAULIC PRESSURE LOW (3 position switch, 1, 2 and utility)
23*	FUEL PRESSURE LOW (check gages to determine engine)
24*	FUEL BOOST ONE OUT
25*	FUEL BOOST TWO OUT
26*	"X" MINUTES FUEL REMAINING
27*	FUEL FILTER ONE CLOGGED
28*	FUEL FILTER TWO CLOGGED
29*	RADAR ALTITUDE LOW
30*	AC POWER OUT
31*	DC POWER OUT
32*	EXTERNAL POWER ON
33*	ICING
34*	ICE DETECTOR OUT
35*	AIR FILTER ONE CLOGGED
36*	AIR FILTER TWO CLOGGED
37*	IFF FAILURE
38*	SPARE } MAY BE INTERSPERSED EARLIER IN PRIORITY LIST
39*	SPARE
40*	CHECK CAUTION PANEL

*Will be used by AIDAPS

11.3 AH-56 (CHEYENNE) DESIGN CRITERIA

11.3.1 AIRCRAFT DESCRIPTION

The Lockheed AH-56A Cheyenne (see Figure 11-2) is a two-place compound helicopter gunship specifically designed for the Army's close ground support role. In fulfilling this support role, it will be necessary for the Cheyenne to conduct nap of the earth operations at speeds ranging from hover to over 250 mph by day and night and in all weather conditions. The purpose of this section is to describe the AH-56 aircraft system in relation to its complexity to existing Army aircraft. In addition, a candidate list of aircraft subsystem performance parameters applicable to an AIDAP system is presented. The AH-56 AIDAPS is also compared with other Army aircraft analyzed in this study.

The AH-56A is the first Army helicopter specifically developed as an integrated weapons system. The system includes a compound helicopter which derives lift from a rigid rotor at low speeds and fixed stub wings at high speed, plus all avionics, fire control, weapon and ground support equipment. The design also includes a ten foot diameter pusher propeller mounted at the extreme tail location. The propeller, a variable pitch design driven from the same gearbox that drives the anti-torque rotor, is capable of absorbing the T64-GE-16 engine's entire power output at high aircraft speed. During high speed flight, enough power (approximately 300 HP) is directed to the main rotor to overcome windmilling drag. The main rotor, a four bladed rigid design, uses a mechanical stabilizing gyro located in series between the blades and the pilot's controls. The anti-torque tail rotor is also of four bladed design.

The AH-56 landing gear is of the tailwheel type with the main gear retracting rearward into fairings on each side of the fuselage. Comprehensive avionics equipment for all-weather flight includes automatic terrain-following radar, an automatic flight control system, and a Doppler radar and inertial navigation system. Armament consists of a nose tunnel housing either a 40 mm grenade launcher or 7.62 automatic G.E. Minigun, a belly turret carrying a 30 mm cannon, and external stores positions under each stub wing. The weapons are aimed from the cockpit by means of an advanced optical sighting system.

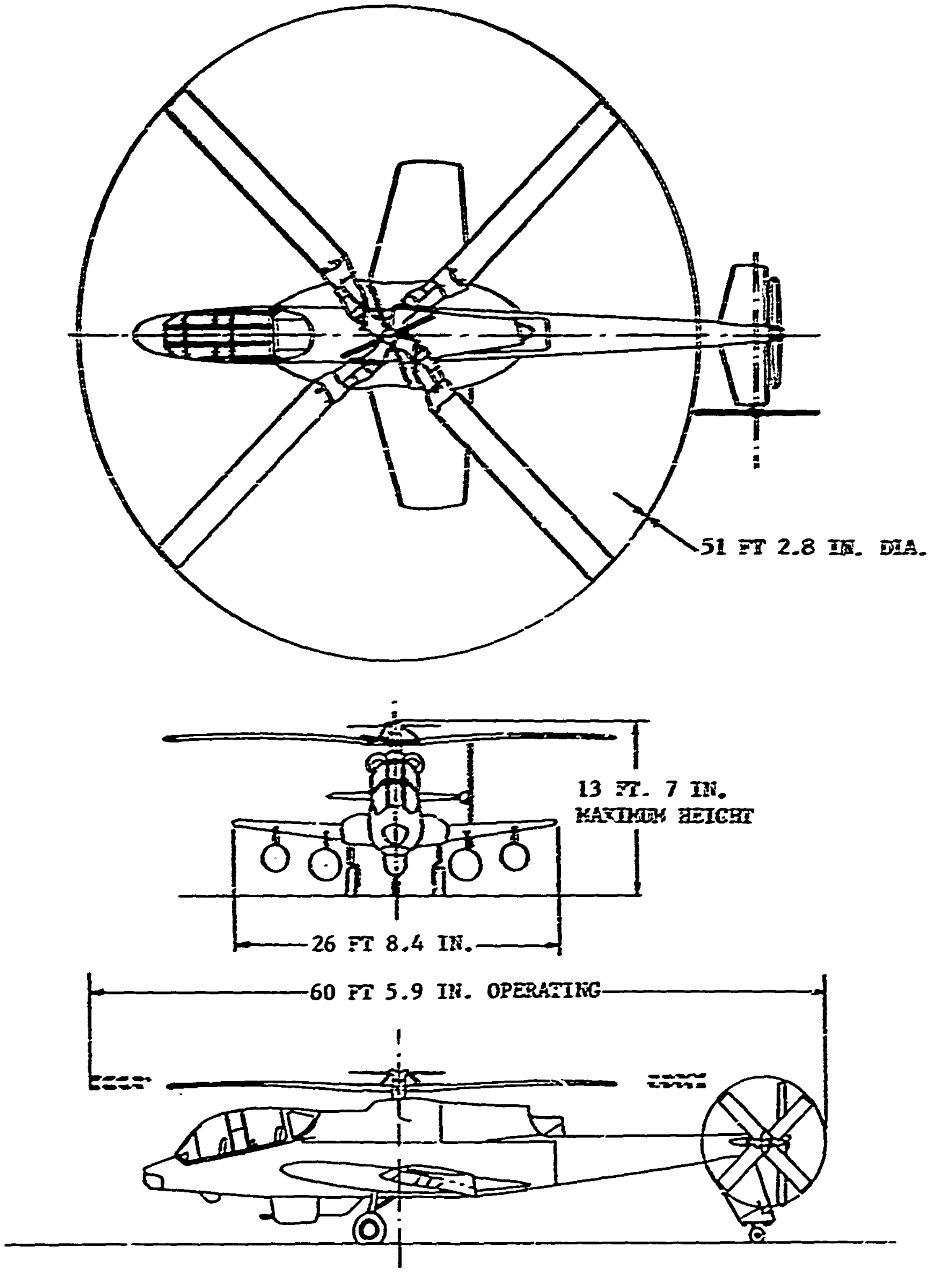


FIGURE 11-2 AH-56 AIRCRAFT THREE VIEW

The Cheyenne is a single-engine helicopter in the AH-1 class. The basic airframe is slightly more complex than the AH-1 due to the addition of the pusher propeller with its blade pitch control mechanism and the retractible undercarriage. Further, the avionics package is considerably more complicated because of the terrain-following radar, and the Doppler radar and inertial navigation system.

11.3.2 AH-56A AIDAPS SYSTEM PARAMETER LIST

Table 11-7 presents a list of candidate AIDAPS system parameters for the AH-56. The list is the result of an analysis of the aircraft subsystems using the limited technical information available. Table 11-7 contains a detailed description of each parameter, identification of the sensor used to monitor each parameter, along with sensor location, a weighted sensor count (WSC) factor indicating the relative sensor complexity, and an indication as to whether or not the sensor to be used exists on the aircraft.

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	MSC	A/C EXISTING
MAIN LANDING GEAR POSITION	02	2	DISCRETE (MICRO SWITCH)	MAIN LANDING GEAR POSITION SWITCH(S)	2	YES
HYD. OIL LEAKAGE	02	2	S.S. LEAK DETECTOR	MAIN LANDING GEAR HYD ACTUATOR(S)	8	NO
TURBINE INLET TEMPERATURE (TIT)	03	1*	THERMOCOUPLE *1 SET OF 3 IN PARALLEL	ENGINE TURBINE INLET STATION	6	YES
EXHAUST GAS TEMPERATURE (EGT)	03	1	THERMOCOUPLE	ENGINE TURBINE OUT STATION	6	NO
GAS PRODUCER ROTOR SPEED (N_1)	03	1	TACH GENERATOR	ENGINE GAS PRODUCER SHAFT	10	YES
POWER TURBINE ROTOR SPEED (N_2)	03	1	TACH GENERATOR	ENGINE OUTPUT SHAFT	10	YES
ENGINE TORQUE	03	1	LOAD CELL		4	YES
STATIC PRESSURE (COMPRESSOR DISCHARGE PRESSURE)	03	1	S.G. BRIDGE DIAPHRAGM	ENGINE CUSTOMER BLEED AIR PORT	4	NO
FUEL FLOW RATE	03	1	FLOW RATE (TURBINE) SENDER	ENGINE FUEL FEED FEED LINE	10	YES
AIR TEMPERATURE (OAT)	03	1	RESISTANCE BULB	UNDISTURBED AIRSTREAM	4	NO
INLET GUIDE VANE (IGV) POSITION	03	1	LVDT	ENGINE IGV ACTUATOR ROD	8	NO
VIBRATION	03	1	PIEZOELECTRIC ACCEL.	ENGINE COMPRESSOR FLANGE	5	NO
VIBRATION	03	1	PIEZOELECTRIC ACCEL.	ENGINE COMBUSTOR FLANGE	5	NO
VIBRATION	03	1	PIEZOELECTRIC ACCEL.	ENGINE TURBINE FLANGE	5	NO

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
OIL CONTAMINATION (CHIPS)	03	1	CHIP DETECTOR	ENGINE OIL TANK	1	YES
OIL CONTAMINATION (CHIPS)	03	1	CHIP DETECTOR	ENGINE ACCESSORY DRIVE GEARBOX SUMP	1	YES
OIL FILTER ΔP	03	1	DIFF. PRESSURE SWITCH	ACROSS ENGINE OIL FILTER	1	NO
OIL FILTER ΔP	03	1	S.G. BRIDGE DIAPHRAGM	ACROSS ENGINE OIL FILTER	4	NO
OIL PRESSURE LOW	02	1	PRESSURE SWITCH	ENGINE OIL PUMP OUTPUT LINE	1	YES
OIL PRESSURE	03	1	SYNCHRO	ENGINE OIL FILTER OUTPUT LINE	12	YES
OIL TEMPERATURE HIGH	03	1	THERMAL SWITCH	ENGINE OIL TANK RETURN LINE	1	YES
OIL TEMPERATURE	03	1	TEMPERATURE BULB	ENGINE OIL FILTER OUTPUT LINE	4	YES
VOLTAGE (OIL COOLER BYPASS VALVE POSITION)	03	1	DISCRETE (MICRO SWITCH)	ACTUATOR ARM OF ENGINE OIL COOLER BYPASS VALVE	1	NO
VOLTAGE (OIL COOLER BYPASS VALVE SWITCH POSITION)	03	1	DISCRETE	ENGINE OIL COOLER BYPASS VALVE SWITCH	1	YES
OIL QUANTITY	03	1	FLOAT SWITCH	ENGINE OIL TANK (ONE GALLON LEVEL)	1	YES
OIL COOLER AIR FLOW	03 04 06	1	DISCRETE - AIRFLOW SENSING VANE (& SWITCH)	OIL COOLER FAN EXIT DUCT	1	YES
FUEL LEAKAGE	03	1	S.S. LEAK DETECTOR	ENGINE FUEL CONTROL	4	NO

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
STATIC PRESSURE (OAP)	03	1	S.G. BRIDGE DIAPHRAGM	A/C STATIC SYSTEM	4	NO
AIRSPEED	03	1	S.G. BRIDGE DIAPHRAGM	A/C PITOT SYSTEM	4	NO
OIL PRESSURE	04	1	SYNCHRO	TRANMISSION OIL PUMP OUTPUT	12	YES
OIL PRESSURE LOW	04	1	PRESSURE SWITCH	TRANSMISSION OIL PUMP OUTPUT	1	YES
OIL TEMPERATURE	04	1	TEMPERATURE BULB	TRANSMISSION OIL PUMP OUTPUT	4	YES
OIL TEMPERATURE HIGH	04	1	THERMAL SWITCH	TRANSMISSION OIL PUMP OUTPUT	1	YES
OIL QUANTITY	04	1	FLOAT SWITCH	TRANSMISSION OIL TANK (? GALLON LEVEL)	1	YES
OIL FILTER ΔP	04	1	DIFF. PRESSURE SWITCH	ACROSS TRANS-MISSION OIL FILTER	1	
OIL FILTER ΔP	04	1	S.G. BRIDGE DIAPHRAGM	ACROSS TRANS-MISSION OIL FILTER	4	
OIL CONTAMINATION (CHIPS)	04	2	CHIP DETECTOR	TRANSMISSION OIL SUMP	2	YES
OIL CONTAMINATION (CHIPS)	04	1	CHIP DETECTOR	SWASNPLATE	1	YES
VIBRATION	04	2	PIEZOELECTRIC ACCEL.	TRANSMISSION CASE (ONE LATERAL, ONE VERTICLE)	10	NO
OIL PRESSURE LOW	04	1	PRESSURE SWITCH	TAIL ROTOR GEAR-BOX OIL PUMP OUT-PUT	1	

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
OIL TEMPERATURE	04	1	THERMAL SWITCH	TAIL ROTOR GEAR-BOX OIL PUMP OUTPUT	1	
OIL QUANTITY	04	1	FLOAT SWITCH	TAIL ROTOR GEAR-BOX OIL SUMP	1	NO
OIL FILTER ΔP	04	1	DIFF. PRESSURE SWITCH	ACROSS TAIL ROTOR GEARBOX OIL FILTER	1	
OIL CONTAMINATION (CHIPS)	04	1	CHIP DETECTOR	TAIL ROTOR GEAR-BOX OIL SUMP	1	YES
VIBRATION	04	2	PIEZOELECTRIC ACCEL.	TAIL ROTOR GEAR-BOX CASE (ONE VERTICLE, ONE AXIAL)	10	NO
MAIN ROTOR SPEED	04	1	TACH GENERATOR	MAIN TRANSMISSION OUTPUT SHAFT	10	YES
BETA ANGLE	05	1	POTENTIOMETER	PROPELLER PITCH CONTROL SYSTEM	4	YES
PROPELLER BLADE ANGLE	05	1	POTENTIOMETER	PROPELLER PITCH CONTROL SYSTEM	4	YES
DELTA-BETA PRESSURE	05	1	PRESSURE SWITCH	DELTA-BETA SYSTEM PRESSURE LINE	1	YES
DELTA-BETA SOLENOID VALVE POSITION	05	1	MICRO SWITCH	VALVE BODY	1	NO
TRANSMISSION NEGATIVE TORQUE VALVE POSITION	05	1	MICRO SWITCH	VALVE BODY	1	NO
HYD SYSTEM PRESSURE	06	1	S.G. BRIDGE DIAPHRAGM	NO. 1 HYD PUMP PRESSURE LINE	4	YES
HYD SYSTEM PRESSURE	06	1	S.G. BRIDGE DIAPHRAGM	NO. 2 HYD PUMP PRESSURE LINE	4	YES
HYD OIL (PRESSURE) FILTER ΔP	06	1	DIFF. PRESSURE SWITCH	ACROSS NO. 1 HYD SYSTEM PRESSURE FILTER	1	NO

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
HYD OIL (PRESSURE) FILTER ΔP	06	1	DIFF. PRESSURE SWITCH	ACROSS NO. 2 HYD SYSTEM PRESSURE FILTER	1	NO
HYD OIL (RETURN) FILTER ΔP	06	1	DIFF. PRESSURE SWITCH	ACROSS NO. 1 HYD SYSTEM RETURN FILTER	1	NO
HYD OIL (RETURN) FILTER ΔP	06	1	DIFF. PRESSURE SWITCH	ACROSS NO. 2 HYD SYSTEM RETURN FILTER	1	NO
HYD OIL LEAKAGE	06	2	S.S. LEAK DETECTOR	NO.'s 1 AND 2 HYD POWER PACKAGES	8	NO
HYD OIL LEAKAGE	06	3	S.S. LEAK DETECTOR	SERVO ACTUATORS IN SERVO ACTUATOR PACKAGE	12	NO
HYD OIL LEAKAGE	06	1	S.S. LEAK DETECTOR	MAIN ROTOR BRAKE	4	NO
ENGINE STARTER HYD OIL PRESSURE	06	1	S.G. BRIDGE DIAPHRAGM	PRESSURE PORT TO ENGINE STARTER	4	NO
AC GENERATOR FAILURE	09	2	DISCRETE	AC GENERATOR (2) OUTPUT	2	YES
DC TRANSFORMER - RECTIFIER FAILURE	09	2	DISCRETE	DC TRANSFORMER RECTIFIER	2	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	NO. 1 PRIMARY AC BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	NO. 1 SECONDARY AC BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	NO. 2 AC BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	ESSENTIAL AC BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	NO. 1 DC BUS	4	YES

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	NO. 2 DC BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	ESSENTIAL DC BUS	4	YES
CURRENT OVERLOAD	09	2	SHUNT	DC TRANSFORMER-RECTIFIER	8	YES
TEMPERATURE HIGH	09	2	THERMAL SWITCH	DC TRANSFORMER-RECTIFIER	2	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	MAIN BATTERY BUS	4	YES
VOLTAGE	09	1	PROPORTIONAL VOLTAGE	EMERGENCY BATTERY BUS	4	YES
LEAKAGE	09	2	S.S. LEAK DETECTOR	BATTERY CASES	4	NO
FUEL PRESSURE	10	1	PRESSURE SWITCH	BOOST PUMP OUTLET LINE	1	YES
FUEL LEAKAGE	10	3	S.S. LEAK DETECTOR	INTERNAL FUEL CELLS	4	NO
FUEL STRAINER ΔP	10	1	DIFF. PRESSURE SWITCH	ACROSS FUEL STRAINER	1	YES
FUEL LEVEL LOW	10	1	FLOAT SWITCH	MAIN FUEL TANK	1	YES
PROP TANK AIR PRESSURE	10	1	S.G. BRIDGE DIAPHRAGM	PRESSURE LINE DOWNSTREAM OF AIR PRESSURE REGULATOR	4	NO
HYD OIL LEAKAGE	11	4	S.S. LEAK DETECTOR	FLIGHT CONTROL SYSTEM SERVO PACKAGES	16	NO
PITCH ATTITUDE	11	1	SYNCHRO	S.A.S. GYRO	12	YES
LATERAL ATTITUDE	11	1	SYNCHRO	S.A.S. GYRO	12	YES

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
S.A.S. AMPLIFIER OUTPUT	11	2	PROPORTIONAL VOLTAGE	S.A.S. AMPLIFIER	8	YES
A/C SHP P	11	1	S.G. BRIDGE DIAPHRAGM	S.A.S. SLIP INDICATOR	4	YES
VALVE POSITION	12	1	MICRO SWITCH	ECU FLOW CONTROL AND SHUT OFF VALVE	1	YES
ROTOR SPEED	18	1	TACH GENERATOR	APU ROTOR SHAFT	10	YES
EXHAUST GAS TEMPERATURE (EGT)	18	1	THERMOCOUPLE	APU TAIL PIPE	6	YES
OIL PRESSURE	18	1	S.G. BRIDGE DIAPHRAGM	APU OIL PRESSURE	4	
OIL TEMPERATURE	18	1	TEMPERATURE	APU OIL TEMPERATURE	4	YES
OIL CONTAMINATION (CHIPS)	18	1	CHIP DETECTOR	APU OIL SUMP	1	NO
VIBRATION	18	1	PIEZOELECTRIC ACCEL.	APU COMBUSTOR CASE	5	NO
GYRO MAG. COMPASS OUTPUT SIGNAL	19	1	PROPORTIONAL VOLTAGE	GYRO MAG. COMPASS TRANSFORMER FLUX COMPENSATOR	4	YES
GYRO MAG. COMPASS YAW SIGNAL	19	1	SYNCHRO	GYRO MAG. COMPASS DIRECTIONAL GYRO OUTPUT	12	YES
GYRO MAG. COMPASS HEADING ERROR	19	1	SYNCHRO	GYRO MAG. COMPASS CONTROLLER OUTPUT	12	YES
GYRO MAG. COMPASS POWER ON-OFF	19	1	DISCRETE	GYRO MAG. COMPASS POWER CIRCUIT	1	YES
VOLTAGE INPUT TO HEIGHT INDICATOR	19	1	SYNCHRO	RADAR ALT/METER	12	YES

TABLE 11-7 AH-56A AIDAP SYSTEM PARAMETERS (Continued)

PARAMETER	J GRP.	NO. REQD.	SENSOR	LOCATION	WSC	A/C EXISTING
VOLTAGE INPUT TO AMPLIFIER	19	1	PROPORTIONAL VOLTAGE	RADAR ALTIMETER RECEIVER/TRANSMITTER OUTPUT	4	YES
POWERS (VOLTAGE) TO RADAR ALTIMETER	19	1	DISCRETE	A/C RADAR ALTIMETER FEED BUS	1	YES
				TOTAL	435	

11.3.3 VOICE WARNING FOR THE AH-56A

Voice warning equipment is presently being flown on almost all of the existing AH-56A aircraft. Signal conditioning necessary to activate the voice warning messages is provided as a separate electronics package at the present time. Implementation of an AIDAPS would reduce the need for this equipment and the VWS could directly interface with the AH-56A AIDAPS sensing and collection functions and signal outputs. The existing voice warning equipment onboard the Cheyenne has a forty message capacity. While the specific messages for this vehicle have been modified from time to time, Table 11-8 presents a typical listing of the messages employed.

TABLE 11-8 VOICE WARNING MESSAGES FOR THE AH-56A

PRIORITY	MESSAGE
1	ENGINE FIRE
2	ENGINE OUT - LOWER GEAR
3	RPM LOW
4	GEAR NOT DOWN
5	RPM HIGH
6	OIL COLLER BYPASS
7	FIRE - APU
8	CHIPS - TRANSMISSION
9	CHIPS - ENGINE
10	CHIPS - PROPELLER GEAR BOX
11	TRANSMISSION OIL
12	ENGINE OIL PRESSURE LOW
13	BOOST PUMP FAILURE
14	HOT ENGINE - OIL
15	CANOPY UNSAFE
16	OIL COLLER FAN OUT
17	FUEL LOW
18	EXHAUST COMPARTMENT HOT
19	PROPELLER OIL
20	HYDRAULIC ONE PRESSURE LOW
21	HYDRAULIC TWO PRESSURE LOW

TABLE 11-8 (Continued)

PRIORITY	MESSAGE
22	GENERATOR ONE FAILURE
23	GENERATOR TWO FAILURE
24	DC ONE FAILURE
25	DC TWO FAILURE
26	CHANNEL 26 SPARE
27	TERRAIN FOLLOWING OUT
28	AUTO PILOT OUT
29	TERRAIN AVOIDANCE OUT
30	CHANNEL 30 SPARE
31	CHANNEL 31 SPARE
32	FUEL FILTER
33	CHANNEL 33 SPARE
34	USE STANDBY ATTITUDE AND WHISKEY COMPASS
35	CHANNEL 35 SPARE
36	ENGINE OIL LEVEL LOW
37	TRANSMISSION OIL LEVEL LOW
38	BELLY OUT OF BORE SIGHT
39	NOSE OUT OF BORE SIGHT
40	COMPUTER OUT

11.3.4 AH-56A GROUPING BASED ON AIDAP SYSTEM RELATIVE COMPLEXITY

Table 11-9 presents a summary of the parameter count by subsystem, along with totals. Table 11-10 lists parameter and WSC totals for the other study aircraft. A comparison shows the parameter total about equal to that for the CH-47, and the WSC total is about equal to that for the OV-1. It is likely that the weighted sensor count will rise as additional data is accumulated and/or the aircraft design is further refined. As a practical matter the WSC will probably reach 550 to 600; placing it very close to the AIDAPS complexity required for the CH-54 and the CH-47 helicopters.

TABLE 11-9 AH-56A PARAMETER COUNT & WSC

SUBSYSTEM NO.	SUBSYSTEM	PARAMETER COUNT	WSC
02	LANDING GEAR	4	10
03	ENGINE	27	118
04	POWER TRAIN & ROTORS	20	62
05	PROPELLER	5	11
06	HYDRAULICS	13	40
09	ELECTRICAL	19	54
10	FUEL	7	11
11	FLIGHT CONTROLS	9	52
12	ENVIRONMENTAL CONTROL	1	1
18	APU	6	30
19	AVIONICS	7	46
	TOTAL	118	435

TABLE 11-10

AIDAPS AIRCRAFT PARAMETER COUNT & WSC

AIRCRAFT	PARAMETER COUNT	WSC
OH-6	47	217
OH-58	47	217
UH-1	70	308
AH-1	79	357
U-21	65	374
OV-1	84	431
CH-54	106	646
CH-47	116	544
UTTAS	144	694
HLH	186	881