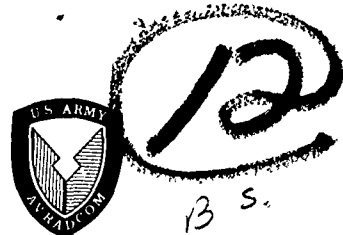


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LEVEL II



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**STRUCTURAL INTEGRITY RECORDING SYSTEM (SIRS) FOR
U.S. ARMY AH-1G HELICOPTERS**

Thomas G. Farrell, Raymond B. Johnson, Michael C. Tyler
TECHNOLOGY INCORPORATED
Dayton, Ohio 45431

March 1981

Final Report for Period July 1975 - November 1979

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Prepared for
APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

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APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

This report was prepared by Technology Incorporated under Contract DAAJ02-75-C-0050. The report documents the design, fabrication, and testing of a Structural Integrity Recording System (SIRS). The SIRS is a total system including a flight recorder, data retrieval unit, and computer software that permits calculation of dynamic component fatigue lives based on the monitored flight condition spectrum of the AH-1G aircraft. Results of this program provide the design data required to develop usage spectrum recording systems for Army helicopters.

Duane M. Saylor of the Structures Technical Area, Aeronautical Technology Division, served as project engineer on this effort.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A Structural Integrity Recording System (SIRS) was designed and developed to track the fatigue damage accumulation on 10 critical helicopter components for the subsequent timely replacement of such components for safer and more economical helicopter operation. SIRS comprises three discrete but interrelated subsystems: an airborne microprocessor-based recorder, a portable flight-line data retrieval unit, and a software system. The validation of SIRS, initially configured for the AH-1G helicopter, consisted of two phases.		

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Phase I (Development Test and Evaluation - DT&E) covered the design, fabrication, laboratory qualification testing, reliability analysis, and flight-testing of the prototype SIRS recorder. Phase II (Initial Operational Test and Evaluation - IOT&E) covered the evaluation of the entire system operation and the resultant data acquired during a 3-month recording period with five AH-1G's, each equipped with a SIRS recorder. As the documentation of both DT&E and IOT&E, this report describes the characteristics and functions of the entire system and details the successful performance of the SIRS recorder in the laboratory qualification testing and the flight environment. The SIRS recorder performed as designed, operated reliably, and yielded valid data.

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PREFACE

Technology Incorporated, Dayton, Ohio, prepared this report to document the results of validation of the operation of the Structural Integrity Recording System (SIRS). This report covers those activities conducted under Contract DAAJ02-75-C-0050, which was sponsored by the Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia. The Army project monitor was Mr. Duane Saylor.

The principal Technology Incorporated personnel on this program were T. G. Farrell, program manager; R. B. Johnson, systems engineer; M. C. Tyler, principal design engineer; G. E. Brazier, principal software programmer; T. L. Cox, flight test engineer; and C. A. Shope, data analysis manager.

Acknowledgement is given to Captain W. Benjamin and Captain J. Pepper, U. S. Army Aviation Test Board, Fort Rucker, Alabama, who supported the Development Test and Evaluation flight test program and contributed to its timely completion. In addition, appreciation is extended to Mr. M. L. Wilker who served as test coordinator during the Initial Operational Test Evaluation flight test program.

The knowledgeable support of Mr. Duane Saylor in his role as project monitor is recognized. His effective direction was central to all activities culminating in the events documented in this report.

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CHAPTER 1.

INTRODUCTION

There is an ever-increasing emphasis throughout the Department of Defense (DoD) on reducing the costs and improving the effectiveness of military equipment. Constraints on military budgets, coupled with inflation and mounting operation and support costs, are prompting a search for positive methods of cost reduction in the acquisition and life cycle of all vehicles and equipment. The traditional effort has been a comprehensive reliability-improvement program involving parts screening, predictions, more stringent specifications, and rigorous demonstration and acceptance testing. While some improvements have been made, such programs have produced less than the desired overall result.

The effort reported here represents one element of a new initiative by the U. S. Army Applied Technology Laboratory to reduce Operating and Support (O&S) costs for Army helicopters.

PURPOSE

U. S. Army Contract DAAJ02-75-C-0050 was performed to develop, qualify, flight test, and demonstrate the Structural Integrity Recording System (SIRS). SIRS incorporates advanced technology hardware to provide a cost-effective method of tracking the accumulation of fatigue damage on critical helicopter dynamic components. The system monitors the variations in fleet utilization on a helicopter-by-helicopter basis so that helicopter components may be replaced according to helicopter usage for safer and more economical operation. The high-value, fatigue-sensitive components selected for the SIRS Development Test and Evaluation (DT&E) and Initial Operational Test & Evaluation (IOT&E) are identified in Table 1. These components were carefully selected since they have been found to be O&S cost drivers through years of service experience that includes operations in Southeast Asia. Illustrations of these components may be seen in Figures 1 through 6. They represent three elements of the AH-1G fatigue-sensitive dynamic assemblies, which are:

- Main Rotor Hub and Blade Assembly
- Main Rotor Control System
- Tail Rotor and Control System



Figure 1. AH-1G Helicopter.

Main Rotor Hub and Blade Assy

1. Main Rotor Blade
2. Main Rotor Yoke Extension
3. Main Rotor Grip
4. Main Rotor Pitch Horn
5. Main Rotor Retention Strap Fitting/Nut

Main Rotor Control System

6. Swashplate Drive Link (Scissors Assy)
7. Swashplate Outer Ring
8. Swashplate Inner Ring
9. Hydraulic Boost Cylinder Assy

Tail Rotor and Control System

10. Tail Rotor Blade

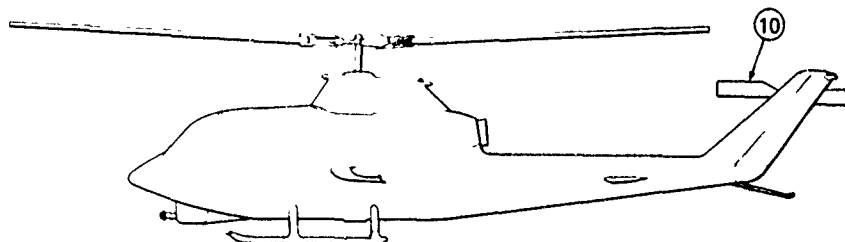
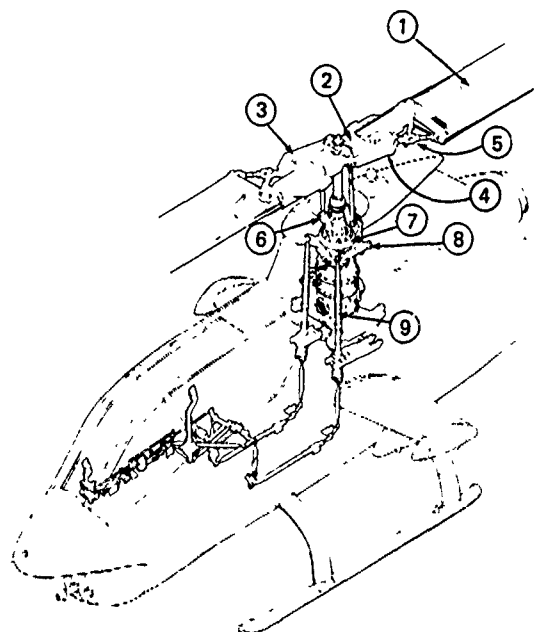


Figure 2. Location of Selected Fatigue-Critical Components for the AH-1G/SIRS Program. (TH-1 helicopter shown)

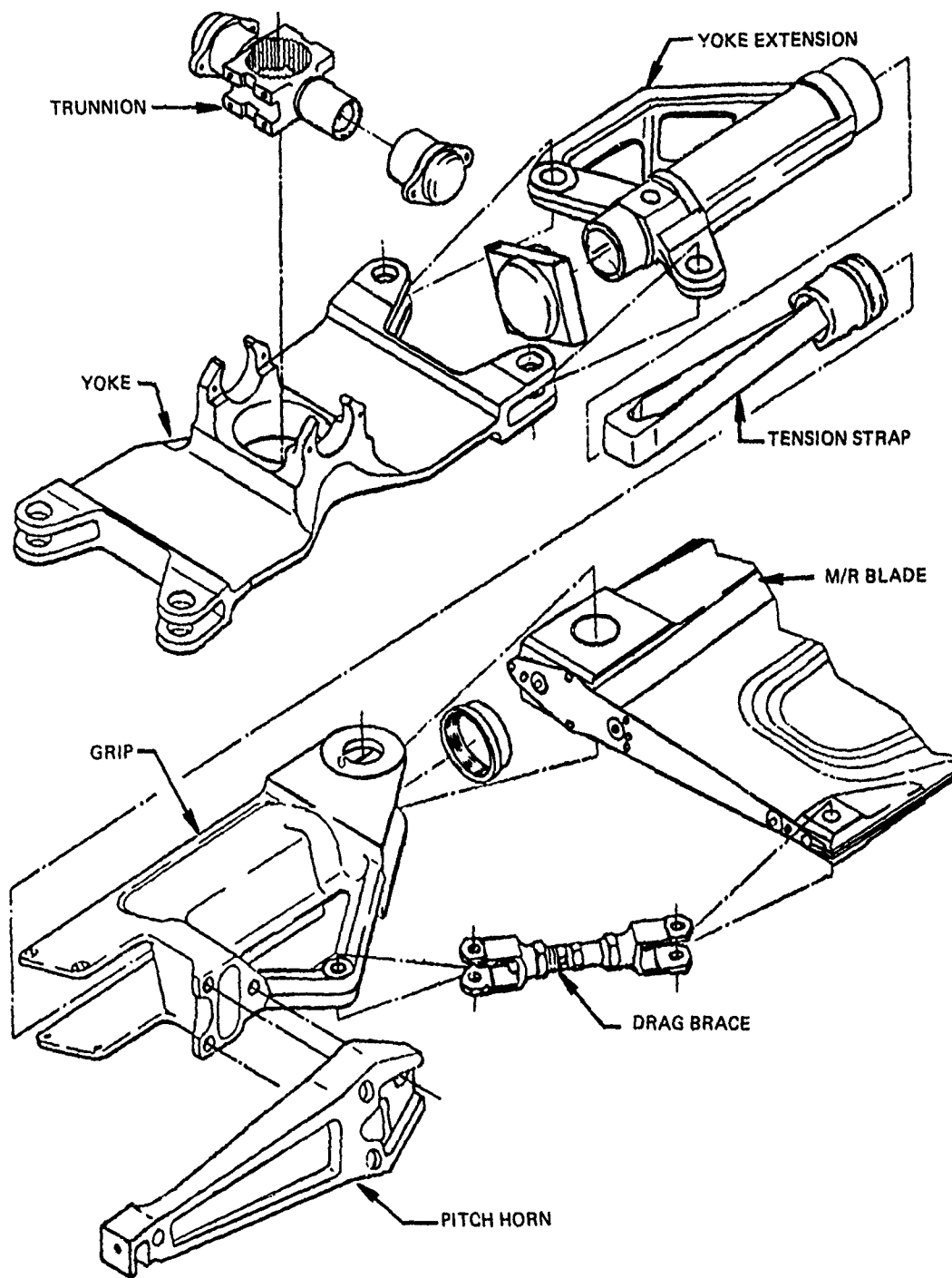


Figure 3. Main Rotor Hub and Blade Assembly.

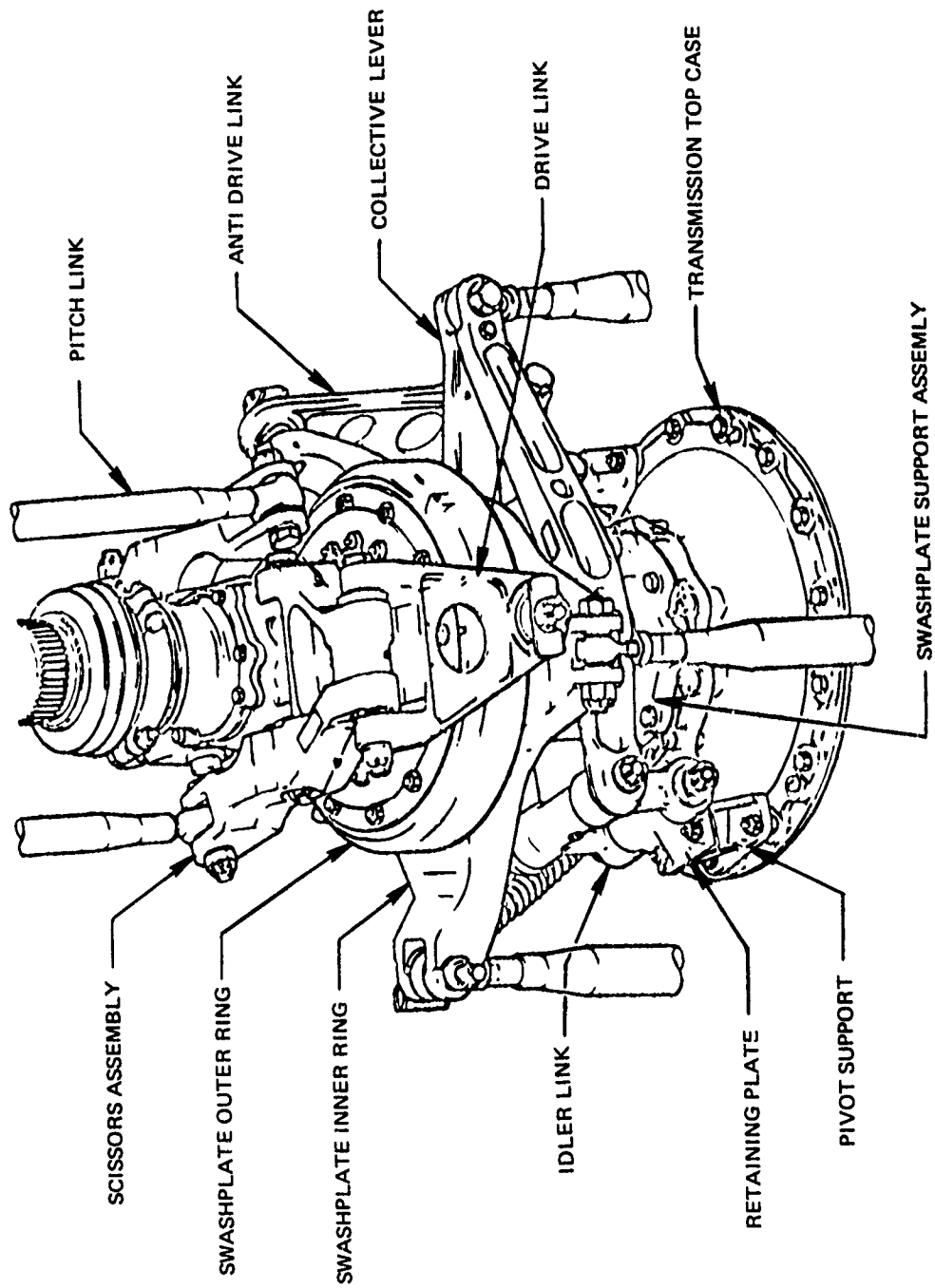


Figure 4. Main Rotor Control System.

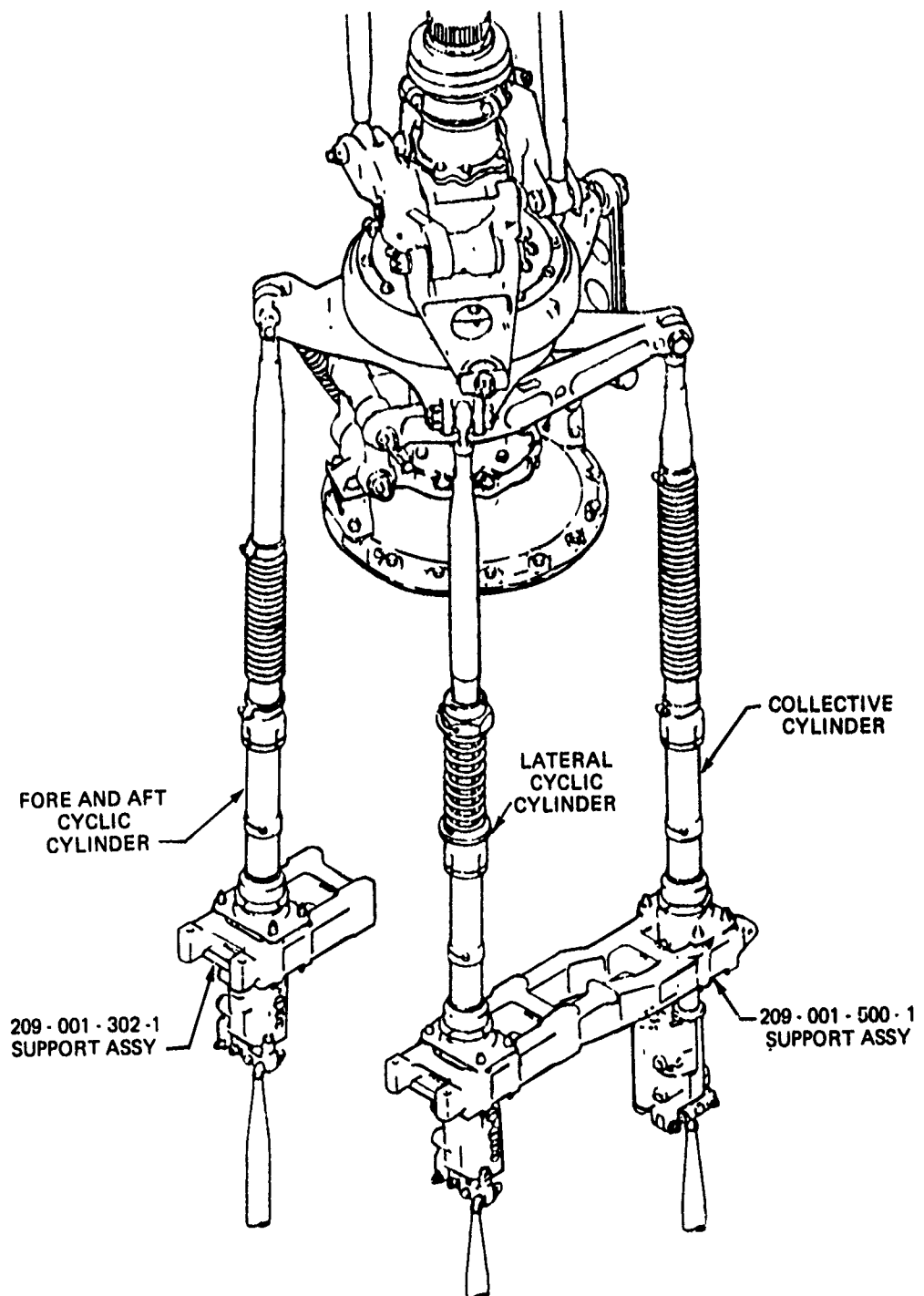


Figure 5. Hydraulic Boost Cylinders and Supports.

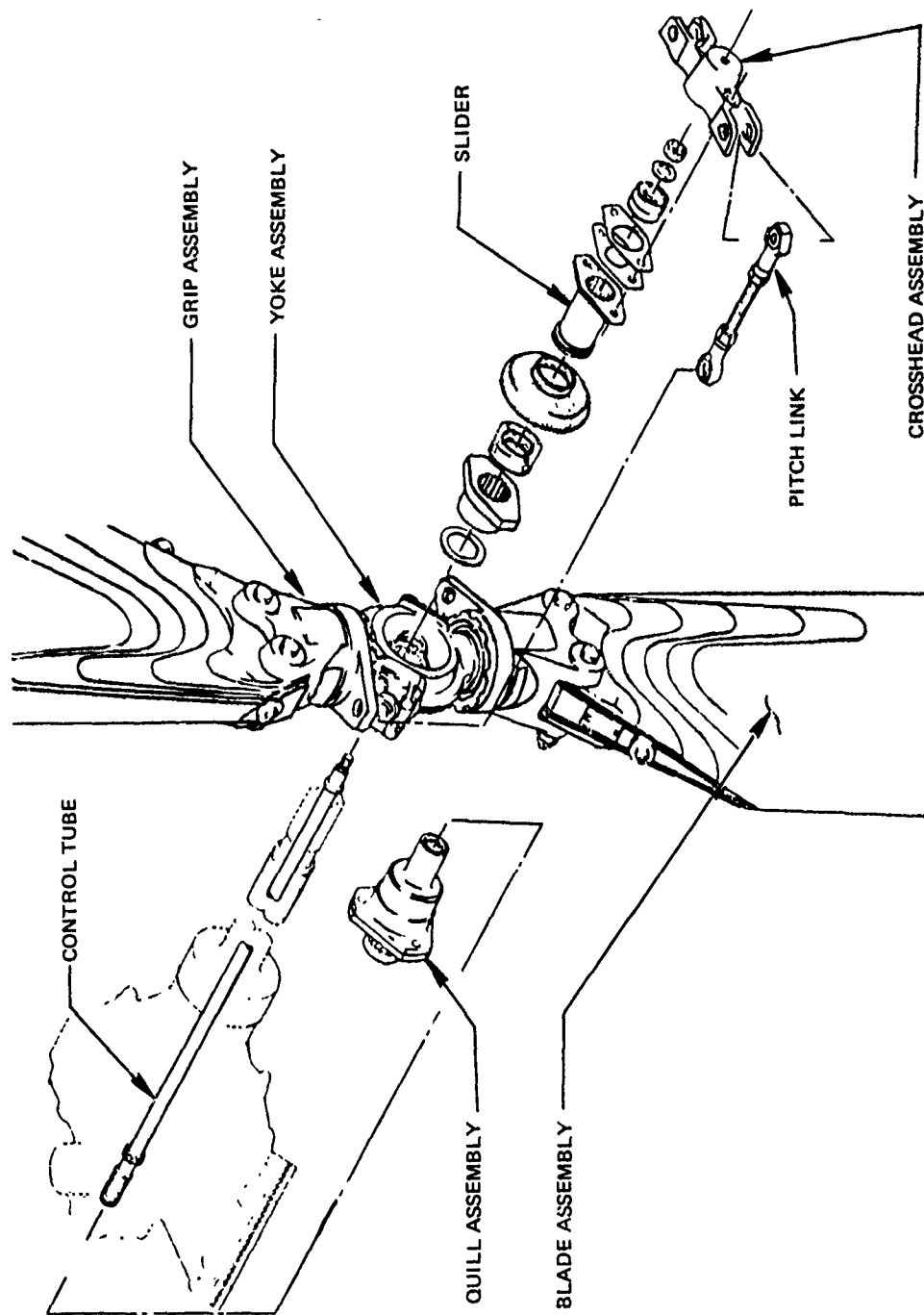


Figure 6. AH-1G Tail Rotor Components

TABLE 1. SELECTED FATIGUE-CRITICAL COMPONENTS FOR THE AH-1G HELICOPTER/SIRS PROGRAM

<u>Nomenclature</u>	<u>Part Number</u>
Main Rotor Blade	540-011-250-1
Main Rotor Yoke Extension	540-011-102-13, -15
Main Rotor Grip	540-011-154-5
Main Rotor Pitch Horn	209-010-109-5
M/R Retention Strap Fitting/Nut	540-011-113-1, -177-1
Swashplate Drive Link	209-010-408-7
Swashplate Outer Ring	209-010-403-1
Swashplate Inner Ring	209-010-402-1
Hydraulic Boost Cylinder Assy	209-076-021-1, -3, -5
Tail Rotor Blade	204-011-702-17

SIRS OVERVIEW

SIRS is a total system comprising an airborne micro-processor-based recorder, a portable flight-line retrieval unit, and a data processing package. The recorder monitors various flight parameters and stores preselected types of operational data within the recorder's solid-state memory. Data are retrieved by a portable flight-line retrieval unit that transfers the recorded data onto removable, miniature, computer-compatible tape cassettes. Each cassette can store the average monthly operational data of 50 helicopters. The data are processed and analyzed automatically by a software system that prints out the results in specifically formatted reports.

APPROACH

The contract performance consisted of two phases. Phase I (DT&E) covered these phases of SIRS: design, fabrication, qualification testing, reliability analysis, and flight testing at Fort Rucker, Alabama, on an AH-1G helicopter. The ultimate objective of Phase I was to verify that the SIRS recorder and data retrieval unit functioned as designed, operated reliably, and yielded accurate data.

In order to determine the fatigue life of any structure, three basic factors must be known. These factors are (1) some knowledge of the fatigue characteristics of the structure, (2) a knowledge of the loads or stresses to be expected in flight, and (3) a knowledge of the frequency of occurrence of these loads or stresses.

The information to fulfill the first item is obtained from the fatigue test program and the information to fulfill the second item is available from the flight loads survey. Information to fulfill the third basic requirement is the

purpose of SIRS. Thus, Phase II (IOT&E) was intended to evaluate the entire SIRS in a practical application. To this end, the SIRS recorder was installed in each of five AH-1G helicopters at Fort Rucker, Alabama, while these helicopters performed normal operations during a 3-month period. During Phase II, all processes in the SIRS were evaluated: the in-flight recording and data storage, the data retrieval, and the data processing and analyses. Finally, the resultant data in prescribed formats were evaluated to determine (1) their validity in representing incremental damage rates for the respective helicopter components and (2) their usefulness in indicating the times at which the various components should be replaced.

PROGRAM EXECUTION

Contract DAAJ02-75-C-0050 was issued 26 June 1975 on a cost-plus-fixed-fee basis. The estimated manpower requirement was 31,029 man-hours. The contract was modified eight times during the performance period. These modifications essentially involved detail changes. Residual Government property was transferred to Contract DAAJ02-77-C-0079 upon completion of this effort. Technical objectives were met, and should result in a more cost-effective execution of the Army attack helicopter program through the 1990's time frame. The feasibility of using a flight condition monitoring concept to extend the service life of high-cost parts on the AH-1G fleet was demonstrated. The effort provides a continuum between phasedown of the AH-1G project and initiation of the AH-1S technical support program.

CHAPTER 2.

SYSTEM DEFINITION

INTRODUCTION

As demonstrated in Reference 1, the flight condition monitoring (FCM) method can be used to assess the fatigue damage accrued in critical helicopter dynamic components. The development of an FCM system requires first defining given flight conditions (which describe the mission profile) in terms of flight parameter ranges and then establishing flight condition categories (representing one or more flight conditions) that account for the entire spectrum of fatigue-damaging flight operations. By monitoring the time spent in each flight condition category, the damage accrued by each component may be assessed on the basis of actual operation.

The following sections describe the FCM methodology as well as the development of an FCM system for the AH-1G helicopter.

FLIGHT CONDITION MONITORING METHODOLOGY

The FCM method of fatigue damage assessment is structured as follows: Defined in terms of specific combinations of flight parameter ranges, each flight condition category (FCC) represents one or more flight conditions. The component damage due to each flight condition may be determined when the loads during the flight condition, the number of flight occurrences, and the component fatigue strength are known. To ensure that the damage rate for each flight condition category is conservative, the maximum flight condition damage rate within the given flight condition category is chosen. Then the component damage accrued during a given recording period may be computed by Equation (1), and the flight condition category incremental damage may be summed to yield the total component damage. The total recorded time is calculated by Equation (2), and the fatigue life is predicted by Equation (3).

1. Johnson, R.B., Martin, G.L., and Moran, M.S., A FEASIBILITY STUDY FOR MONITORING SYSTEMS OF FATIGUE DAMAGE TO HELICOPTER COMPONENTS, Technology Incorporated; USAAMRDL Technical Report 74-92, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis Virginia, January 1975, AD A006641.

$$D = \sum_{k=1}^m D_k = \sum_{k=1}^m C_k T_k \quad (1)$$

$$T_t = \sum_{k=1}^m T_k \quad (2)$$

$$FL = \frac{T_t}{D} \quad (3)$$

where D = total damage to a component during the usage spectrum

D_k = component damage accrued during the kth flight condition category

C_k = damage rate in kth flight condition category for a particular component

T_k = amount of flight time spent in kth flight condition category

T_t = total flight time

FL = component fatigue life

m = number of flight condition categories

The FCM method of fatigue damage assessment requires analyzing the manufacturer's fatigue analysis to first define a technically feasible FCM system and then to establish damage rates for each component in each flight condition category. After these data have been developed and substantiated, the selected flight parameters may be monitored to assess the accrued fatigue damage of critical helicopter dynamic components.

ELEMENTS OF AH-1G FATIGUE ANALYSIS PERTINENT TO FCM SYSTEM DEVELOPMENT

As discussed in Reference 2 and summarized in Table 2, the AH-1G design utilization spectrum is defined in terms of specific flight conditions and the percentage of flight time spent in these flight conditions.

2. Seibel, J., FATIGUE LIFE SUBSTANTIATION OF DYNAMIC COMPONENTS OF THE AH-1G HELICOPTER, Report No. 209-099-064, Bell Helicopter Company, Fort Worth, Texas, June 1968.

TABLE 2. DESIGN UTILIZATION SPECTRUM

Flight Conditions	% of Flight Time	
	Total	Gross Weight Breakdown
I. Ground Conditions		
A. Normal Start	0.5000	
B. Shutdown	0.5000	
II. IGE Maneuvers		
A. Takeoff		
1. Normal		L-GW 0.180
		M-GW 0.450
		H-GW 0.270
	0.9000	
2. Jump		L-GW 0.020
		M-GW 0.050
		H-GW 0.030
	0.1000	
B. Hovering		
1. Steady		L-GW 0.434
		M-GW 1.085
		H-GW 0.651
	2.1700	
2. Right Turn		L-GW 0.020
		M-GW 0.050
		H-GW 0.030
	0.1000	
3. Left Turn		L-GW 0.020
		M-GW 0.050
		H-GW 0.030
	0.1000	
4. Control Correction		
(A) Longitudinal		L-GW 0.002
		M-GW 0.005
		H-GW 0.003
	0.0100	
(B) Lateral		L-GW 0.002
		M-GW 0.005
		H-GW 0.003
	0.0100	
(C) Rudder		L-GW 0.002
		M-GW 0.005
		H-GW 0.003
	0.0100	
C. Sideward Flight		
1. To the Right		L-GW 0.050
		M-GW 0.125
		H-GW 0.075
	0.2500	
2. To the Left		L-GW 0.050
		M-GW 0.125
		H-GW 0.075
	0.2500	
D. Rearward Flight		L-GW 0.050
		M-GW 0.125
		H-GW 0.075
	0.2500	

TABLE 2. Continued

<u>Flight Conditions</u>		<u>% of Flight Time</u>	
		<u>Total</u>	<u>Gross Weight Breakdown</u>
E. Acceleration Hover to Climb A/S	L-GW		0.100
	M-GW		0.250
	H-GW		0.150
		0.5000	
F. Deceleration	1. Normal	L-GW	0.140
		M-GW	0.350
		H-GW	0.210
			0.7000
	2. Quick Stop	L-GW	0.050
		M-GW	0.150
		H-GW	0.090
			0.3000
G. Approach and Landing	L-GW		0.200
	M-GW		0.500
	H-GW		0.300
		1.0000	
III. Forward Level Flight			
Airspeed	RPM		
A. 0.50 VH	314	L-GW	0.100
		M-GW	0.250
		H-GW	0.150
			0.5000
	324	L-GW	0.900
		M-GW	2.250
		H-GW	1.350
			4.5000
B. 0.60 VH	314	L-GW	0.040
		M-GW	0.100
		H-GW	0.060
			0.2000
	324	L-GW	0.360
		M-GW	0.900
		H-GW	0.540
			1.8000
C. 0.70 VH	314	L-GW	0.060
		M-GW	0.150
		H-GW	0.090
			0.3000
	324	L-GW	0.540
		M-GW	1.350
		H-GW	0.810
			2.7000
D. 0.80 VH	314	L-GW	0.300
		M-GW	0.750
		H-GW	0.450
			1.5000
	324	L-GW	2.700
		M-GW	6.750
		H-GW	4.050
			13.5000

TABLE 2. Continued

Flight Conditions			% of Flight Time	
			Total	Gross Weight Breakdown
E. 0.90 VH	314	L-GW		0.500
		M-GW		1.250
		H-GW		0.750
			2.5000	
	324	L-GW		4.500
		M-GW		11.250
		H-GW		6.750
			22.5000	
F. VV	314	L-GW		0.200
		M-GW		0.500
		H-GW		0.300
			1.0000	
	324	L-GW		1.800
		M-GW		4.500
		H-GW		2.700
			9.0000	
IV. Non-Firing Maneuvers				
A. Full Power Climb				
1. Normal		L-GW		0.800
		M-GW		2.000
		H-GW		1.200
			4.0000	
	2. High-Speed	L-GW		0.200
		M-GW		0.500
		H-GW		0.300
			1.0000	
B. Maximum Rate Accel. Climb - Cruise A/S		L-GW		0.560
		M-GW		1.400
		H-GW		0.840
			2.8000	
	C. Normal Turns			
1. To the Right	(A) 0.5 VH	L-GW		0.200
		M-GW		0.500
		H-GW		0.300
			1.0000	
	(B) 0.7 VH	L-GW		0.200
		M-GW		0.500
		H-GW		0.300
			1.0000	
	(C) 0.9 VH	L-GW		0.400
		M-GW		1.000
		H-GW		0.600
			2.0000	
2. To the Left	(A) 0.5 VH	L-GW		0.200
		M-GW		0.500
		H-GW		0.300
			1.0000	

TABLE 2. Continued

Flight Conditions	% of Flight Time	
	Total	Gross Weight Breakdown
(B) 0.7 VH	L-GW M-GW H-GW	0.200 0.500 0.300
	1.0000	
(C) 0.9 VH	L-GW M-GW H-GW	0.400 1.000 0.600
	2.0000	
D. 0.9 VH Control Corr.		
1. Longitudinal	L-GW M-GW H-GW	0.010 0.025 0.015
	0.0500	
2. Lateral	L-GW M-GW H-GW	0.010 0.025 0.015
	0.0500	
3. Rudder	L-GW M-GW H-GW	0.010 0.025 0.015
	0.0500	
L. Sideslip	L-GW M-GW H-GW	0.100 0.250 0.150
	0.5000	
F. Part Power Descent	L-GW M-GW H-GW	0.510 1.275 0.765
	2.5500	
V. Gunnery Maneuvers		
A. Firing in a Hover	L-GW M-GW H-GW	0.015 0.038 0.023
	0.0750	
B. Strating in Accel. From a Hover	L-GW M-GW H-GW	0.010 0.025 0.015
	0.0500	
C. Gunnery Runs		
1. Point Target Runs		
(A) To 0.6 VL	L-GW M-GW H-GW	0.056 0.140 0.084
	0.2800	
(B) To 0.8 VL	L-GW M-GW H-GW	0.168 0.420 0.252
	0.8400	
(C) To 0.9 VL	L-GW M-GW H-GW	0.280 0.700 0.420
	1.4000	

TABLE 2. Continued

Flight Conditions		% of Flight Time		
		Total	Gross Weight Breakdown	
(D) To VL	L-GW M-GW H-GW	0.2800	0.056 0.140 0.084	
2. Spray Fire Dives				
(A) To 0.6 VL	L-GW M-GW H-GW		0.1200	0.024 0.060 0.036
(B) To 0.8 VL	L-GW M-GW H-GW		0.3600	0.072 0.180 0.108
(C) To 0.9 VL	L-GW M-GW H-GW	0.6000	0.120 0.300 0.180	
(D) To VL	L-GW M-GW H-GW	0.1200	0.024 0.060 0.036	
D. Gunnery Run Pullup				
1. To the Right				
(A) 0.6 VL	L-GW M-GW H-GW	0.1000	0.020 0.050 0.030	
(B) 0.8 VL	L-GW M-GW H-GW	0.3000	0.060 0.150 0.090	
(C) 0.9 VL	L-GW M-GW H-GW	0.5000	0.100 0.250 0.150	
(D) VL	L-GW M-GW H-GW	0.1000	0.020 0.050 0.030	
2. To the Left				
(A) 0.6 VL	L-GW M-GW H-GW	0.1000	0.020 0.050 0.030	
(B) 0.8 VL	L-GW M-GW H-GW	0.3000	0.060 0.150 0.090	
(C) 0.9 VL	L-GW M-GW H-GW	0.5000	0.100 0.250 0.150	

TABLE 2. Continued

<u>Flight Conditions</u>		<u>% of Flight Time</u>	
		<u>Total</u>	<u>Gross Weight Breakdown</u>
(D) VL	L-GW		0.020
	M-GW		0.050
	H-GW		0.030
		0.1000	
3. Symmetrical			
(A) 0.6 VL	L-GW		0.032
	M-GW		0.005
	H-GW		0.003
		0.0100	
(B) 0.8 VL	L-GW		0.006
	M-GW		0.015
	H-GW		0.009
		0.0300	
(C) 0.9 VL	L-GW		0.010
	M-GW		0.025
	H-GW		0.015
		0.0500	
(D) VL	L-GW		0.002
	M-GW		0.005
	H-GW		0.003
		0.0100	
E. Gunnery Turns			
1. To the Right			
(A) 0.5 VH	L-GW		0.075
	M-GW		0.188
	H-GW		0.113
		0.3750	
(B) 0.7 VH	L-GW		0.075
	M-GW		0.188
	H-GW		0.113
		0.3750	
(C) 0.9 VH	L-GW		0.150
	M-GW		0.375
	H-GW		0.225
		0.7500	
2. To the Left			
(A) 0.5 VH	L-GW		0.075
	M-GW		0.188
	H-GW		0.113
		0.3750	
(B) 0.7 VH	L-GW		0.075
	M-GW		0.188
	H-GW		0.113
		0.3750	
(C) 0.9 VH	L-GW		0.150
	M-GW		0.375
	H-GW		0.225
		0.7500	

TABLE 2. Continued

<u>Flight Conditions</u>	<u>% of Flight Time</u>	
	<u>Total</u>	<u>Gross Weight Breakdown</u>
F. S-Turns		
1. At 0.8 VH	L-GW	0.040
	M-GW	0.100
	H-GW	0.060
	0.2000	
2. At VH	L-GW	0.015
	M-GW	0.038
	H-GW	0.022
	0.0750	
VI. Power Transitions		
A. Power to Auto		
1. 0.5 VH	L-GW	0.010
	M-GW	0.025
	H-GW	0.015
	0.0500	
2. 0.7 VH	L-GW	0.025
	M-GW	0.063
	H-GW	0.038
	0.1250	
3. 0.9 VH	L-GW	0.035
	M-GW	0.088
	H-GW	0.053
	0.1750	
B. Auto to Power		
1. In Ground Effect	L-GW	0.030
	M-GW	0.075
	H-GW	0.045
	0.1500	
2. 0.4 VH	L-GW	0.020
	M-GW	0.050
	H-GW	0.030
	0.1000	
3. 0.6 VH	L-GW	0.015
	M-GW	0.038
	H-GW	0.023
	0.0750	
4. Max Auto A/S	L-GW	0.005
	M-GW	0.013
	H-GW	0.008
	0.0250	
VII. Autorotation		
A. Stabilized Flight		
1. 0.4 VH	L-GW	0.040
	M-GW	0.100
	H-GW	0.060
	0.2000	
2. 0.6 VH	L-GW	0.280
	M-GW	0.700
	H-GW	0.420
	1.4000	

TABLE 2. Concluded

<u>Flight Conditions</u>	<u>% of Flight Time</u>	
	<u>Total</u>	<u>Gross Weight Breakdown</u>
3. Max Auto A/S		
L-GW		0.060
M-GW		0.150
H-GW		0.090
	0.3000	
B. Auto Turns		
1. To the Right		
(A) 0.4 VH		
L-GW		0.010
M-GW		0.025
H-GW		0.015
	0.0500	
(B) 0.6 VH		
L-GW		0.080
M-GW		0.200
H-GW		0.120
	0.4000	
(C) Max Auto A/S		
L-GW		0.010
M-GW		0.025
H-GW		0.015
	0.0500	
2. To the Left		
(A) 0.4 VH		
L-GW		0.010
M-GW		0.025
H-GW		0.015
	0.0500	
(B) 0.6 VH		
L-GW		0.080
M-GW		0.200
H-GW		0.120
	0.4000	
(C) Max Auto A/S		
L-GW		0.010
M-GW		0.025
H-GW		0.015
	0.0500	
C. Auto Landing		
L-GW		0.050
M-GW		0.125
H-GW		0.075
	0.2500	

The manufacturer assumed that the AH-1G operational time would be distributed as follows in three gross weight ranges: (1) 20 percent in a light gross weight (L-GW) range (less than 7750 pounds), (2) 50 percent in a middle gross weight (M-GW) range (7750 to 8750 pounds), and (3) 30 percent in a high gross weight (H-GW) range (more than 8750 pounds). This gross weight distribution was also used in the preliminary development of the FCM system for the AH-1G.

The fatigue-critical AH-1G components to be used in the FCM method were selected by determining those major life-limited components in the main and tail rotor systems that have a significant effect on the AH-1G life-cycle cost. As a result, 10 components were selected. For each of these components, Table 3 lists the part number along with the manufacturer-computed fatigue life and the recommended retirement life. The component fatigue damage data along with other information (e.g., component loads data and component S/N data) needed for performing a fatigue analysis were extracted from the fatigue substantiation report (Reference 2).

TABLE 3. SELECTED FATIGUE-CRITICAL COMPONENTS
FOR THE AH-1G HELICOPTER

<u>Nomenclature</u>	<u>Part Number</u>	<u>Calculated Fatigue Life(hr)</u>	<u>Recommended Retirement Life (hr)</u>
Main Rotor Blade	540-011-250-1	2,792	1,100
Main Rotor Yoke Extension	540-011-102-13,15	10,633	3,300
Main Rotor Grip	540-011-154-5	95,057	--
Main Rotor Pitch Horn	209-010-109-5	9,105	6,600
M/R Retention Strap Fitting/Nut	540-011-113-1,-177-1	2,760	2,200
Swashplate Drive Link	209-010-408-7	13,953	11,000
Swashplate Outer Ring	209-010-403-1	9,806	3,300
Swashplate Inner Ring	209-010-402-1	10,453	3,300
Hydraulic Boost Cylinder Assy	209-076-021-1,3,5	3,345	3,300
Tail Rotor Blade	204-011-702-17	3,764	1,100

TECHNICAL ACCEPTANCE CRITERIA FOR FCM SYSTEMS

Basic Definition of Technical Acceptance Criteria

In the development of the FCM system for the AH-1G, the technical acceptance criteria developed in Reference 1 were applied to several candidate systems.

According to these criteria, an FCM system must be capable of predicting, for each component, fatigue lives that fall between a conservative lower bound and realistic upper bounds. One upper bound is defined for mild aircraft usage and another upper bound for severe aircraft usage (see Figure 7). The intent in these criteria of the upper bounds for both mild and severe conditions is to evaluate candidate FCM systems relative to the usage variations in the expected fleet operation spectrum.

The application of the technical acceptance criteria requires the following: (1) the definition of the lower bounds for the component fatigue lives, (2) the substantiation of a fatigue damage assessment model (specifically, the computer program FATHIP) that closely parallels the fatigue analysis used by the AH-1G manufacturer and which may be validly used in the applications discussed later in this section, and (3) the derivation of realistic upper bounds for the component fatigue lives in both a mild and a severe usage spectrum by applying the substantiated fatigue damage assessment model.

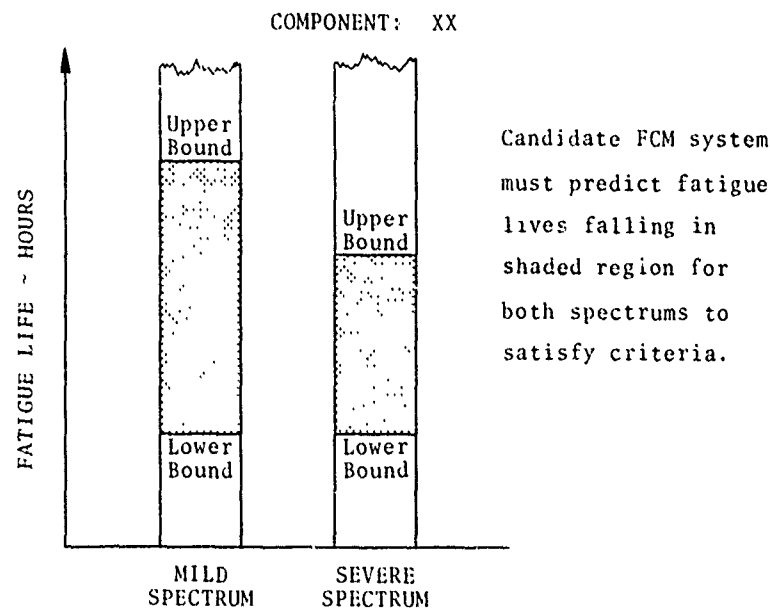


Figure 7. Depiction of Technical Acceptance Criteria.

Definition of Lower Bounds for Component Fatigue Lives

Table 3 includes the manufacturer-computed fatigue lives and the recommended retirement lives for the 10 selected components. The manufacturer's computations were based on the design utilization spectrum summarized in Table 2. Since such a spectrum is conventionally more severe than the actual usage anticipated during the helicopter life, the computed fatigue lives are conservative. As is apparent in Table 2, the recommended retirement lives are generally much shorter than the fatigue lives.

To conform with the philosophy in previous studies, the recommended retirement lives were defined as the lower bounds.

Substantiation of Fatigue Damage Assessment Model (FATHIP)

FATHIP, the fatigue damage assessment model used in the following applications, computes fatigue damage in a manner similar to the AH-1G manufacturer's process. To substantiate this model, the same component load, S/N, and frequency of occurrence data used in the manufacturer's computations were also used as input in FATHIP. Obviously, if FATHIP could yield fatigue lives agreeing closely with those derived by the manufacturer, the model would be substantiated.

For both the manufacturer and the FATHIP computations, Table 4 lists the fatigue damage accrued by each of the 10 selected AH-1G components during 100 hours of operation in the design utilization spectrum. The close correlation of the two sets of data verifies FATHIP as a valid fatigue damage assessment model for the AH-1G helicopter.

TABLE 4. COMPARISON OF MANUFACTURER AND FATHIP FATIGUE DAMAGE AND FATIGUE LIFE COMPUTATIONS

* Reference 2 Component	Design Spectrum			
	Manufacturer's Computations*		FATHIP Results	
	Fatigue Damage in 100 hr	Fatigue Life (hr)	Fatigue Damage in 100 hr	Fatigue Life (hr)
Main Rotor Blade	0.035810	2,792	0.035806	2,793
Main Rotor Yoke Extension	0.009404	10,633	0.009403	10,635
Main Rotor Grip	0.001052	95,057	0.001053	95,012
Main Rotor Pitch Horn	0.010983	9,105	0.010982	9,106
M/R Retention Strap Fitting/Nut	0.036232	2,760	0.036232	2,760
Swashplate Drive Link	0.007167	13,953	0.007164	13,959
Swashplate Outer Ring	0.010197	9,806	0.010196	9,808
Swashplate Inner Ring	0.009566	10,453	0.009562	10,458
Hydraulic Boost Cylinders	0.029890	3,345	0.029895	3,345
Tail Rotor Blade	0.026567	3,764	0.026568	3,764

Derivation of Upper Bounds for Component Fatigue Lives in Both Mild and Severe Utilization Spectra

Without regard at the outset to which might be the more severe spectrum, two utilization spectra were derived independently from separate sources: (1) the AH-1G operational usage data collected in Southeast Asia (Reference 3), and (2) the expected future mission utilization data for attack-type helicopters (also documented in Reference 3). As listed in Table 5, each spectrum was defined in terms of the same flight conditions that were used to define utilization spectrum. In addition, the gross weight distribution assumed in Reference 2 was used for each spectrum.

To assess the relative severity of the two utilization spectra from a fatigue damage standpoint, the two spectra were then processed in FATHIP to predict the fatigue life for each of the 10 selected components. On the basis of the resulting fatigue life predictions, the spectrum representing the Southeast Asia data was judged more severe than the spectrum representing the other data. Consequently, the former was termed the severe spectrum and the latter the mild spectrum. However, these spectra are not to be interpreted as worst-case usage, but rather as the mild and severe usage that would normally occur with some regularity.

The two sets of fatigue lives derived by FATHIP for each of the 10 selected components were defined as the upper fatigue life bounds, one set for the mild and the other set for the severe utilization spectrum. Table 6 lists these bounds. Since this table also includes the lower fatigue bounds as previously listed in Table 3, it summarizes the constraints for the application of the technical acceptance criteria to the candidate FCM systems for the AH-1G helicopter.

Therefore, to be considered technically acceptable, a candidate FCM system must be capable of predicting, for each component, a fatigue life within these bounds when the basic frequency of occurrence data in either the mild or the severe spectrum is the simulated output of an airborne FCM recorder.

3. Cox, T.L., Johnson, R.B., and Russell, S.W., DYNAMIC LOADS AND STRUCTURAL CRITERIA, Technology Incorporated; USAAMRDL Technical Report 75-9, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, April 1975, AD A009759.

TABLE 5. MILD AND SEVERE SPECTRUM DEFINITIONS

FLIGHT CONDITION		DESIGN	MILD	SEVERE
1	NORMAL START SHUTDOWN (W/COLL.)	1.000	.290	.616
2	NORMAL TAKE-OFF	.900	2.558	.750
3	JUMP TAKE-OFF	.100	.656	.188
4	STEADY HOVER	2.170	11.530	12.958
5	HOVERING RIGHT TURN	.100	2.887	.817
6	HOVERING LEFT TURN	.100	2.887	.817
7	HOVERING LONGITUDINAL CONTROL CORR.	.010	.126	.027
8	HOVERING LATERAL CONTROL CORR.	.010	.126	.027
9	HOVERING RUDDER CONTROL CORR.	.010	.126	.027
10	SIDEWARD FLIGHT TO THE RIGHT	.250	2.110	.409
11	SIDEWARD FLIGHT TO THE LEFT	.250	2.110	.409
12	REARWARD FLIGHT	.250	1.600	.241
13	ACCELERATION HOVER TO CLIMB A 3	.500	3.248	.456
14	NORMAL DECELERATION	.700	.823	2.519
15	QUICK STOP DECELERATION	.300	.823	2.519
16	APPROACH AND LANDING	1.000	.385	4.529
17	FORWARD LEVEL FLIGHT 0.50 VH AT 314 RPM	.500	1.550	1.260
18	FORWARD LEVEL FLIGHT 0.50 VH AT 324 RPM	4.500	.180	11.296
19	FORWARD LEVEL FLIGHT 0.60 VH AT 314 RPM	.200	1.040	1.206
20	FORWARD LEVEL FLIGHT 0.60 VH AT 324 RPM	1.800	.115	10.867
21	FORWARD LEVEL FLIGHT 0.70 VH AT 314 RPM	.300	.350	.657
22	FORWARD LEVEL FLIGHT 0.70 VH AT 324 RPM	2.700	.040	5.856
23	FORWARD LEVEL FLIGHT 0.80 VH AT 314 RPM	1.500	.171	.241
24	FORWARD LEVEL FLIGHT 0.80 VH AT 324 RPM	13.500	.020	2.171
25	FORWARD LEVEL FLIGHT 0.90 VH AT 314 RPM	2.500	.313	.013
26	FORWARD LEVEL FLIGHT 0.90 VH AT 324 RPM	22.500	.232	.157
27	FORWARD LEVEL FLIGHT VH AT 314 RPM	1.000	.010	.013
28	FORWARD LEVEL FLIGHT VH AT 324 RPM	9.000	.001	.161
29	NORMAL FULL POWER CLIMB	4.000	5.375	6.172
30	HIGH-SPEED FULL POWER CLIMB	1.000	2.190	2.644
31	MAX. RATE ACCEL. FULL POWER CLIMB TO CRUISE A 3	2.800	2.848	8.154
32	NORMAL RIGHT TURN AT 0.5 VH	1.000	6.122	1.116
33	NORMAL RIGHT TURN AT 0.7 VH	1.000	2.188	1.116
34	NORMAL RIGHT TURN AT 0.9 VH	2.000	.438	.248
35	NORMAL LEFT TURN AT 0.5 VH	1.000	5.671	1.116
36	NORMAL LEFT TURN AT 0.7 VH	1.000	2.026	1.116
37	NORMAL LEFT TURN AT 0.9 VH	2.000	.406	.248
38	LONGITUDINAL CONTROL CORR. AT 0.9 VH	.050	.050	.001
39	LATERAL CONTROL CORR. AT 0.9 VH	.050	.050	.001
40	RUDDER CONTROL CORR. AT 0.9 VH	.050	.050	.001
41	SIDESLIP	.500	.113	.013
42	PART POWER DESCENT	2.550	6.471	7.679
43	FIPIG IN A HOVER	.075	19.047	.230
44	STRAFING IN ACCEL. FROM A HOVER	.050	.672	.270

TABLE 5. Concluded

FLIGHT CONDITION		DESIGN	MILD	SEVERE
45 GUNNERY RUN-PT. TARGET DIVE AT 0.6 VL		.280	.656	.734
46 GUNNERY RUN-PT. TARGET DIVE AT 0.8 VL		.340	.252	.734
47 GUNNERY RUN-PT. TARGET DIVE AT 0.9 VL		1.400	.051	.201
48 GUNNERY RUN-PT. TARGET DIVE AT VL		.280	.051	.201
49 GUNNERY RUN-SPRAY FIRE DIVE AT 0.6 VL		.120	.656	1.136
50 GUNNERY RUN-SPRAY FIRE DIVE AT 0.8 VL		.360	.252	1.136
51 GUNNERY RUN-SPRAY FIRE DIVE AT 0.9 VL		.600	.051	.300
52 GUNNERY RUN-SPRAY FIRE DIVE AT VL		.120	.051	.300
53 GUNNERY RUN-P/U TO THE RIGHT AT 0.6 VL		.100	.249	.440
54 GUNNERY RUN-P/U TO THE RIGHT AT 0.8 VL		.300	.249	.450
55 GUNNERY RUN-P/U TO THE RIGHT AT 0.9 VL		.500	.062	.120
56 GUNNERY RUN-P/U TO THE RIGHT AT VL		.100	.062	.110
57 GUNNERY RUN-P/U TO THE LEFT AT 0.6 VL		.100	.249	.440
58 GUNNERY RUN-P/U TO THE LEFT AT 0.8 VL		.300	.249	.450
59 GUNNERY RUN-P/U TO THE LEFT AT 0.9 VL		.500	.062	.120
60 GUNNERY RUN-P/U TO THE LEFT AT VL		.100	.062	.110
61 GUNNERY RUN-P/U SYMMETRICAL AT 0.6 VL		.010	.055	.100
62 GUNNERY RUN-P/U SYMMETRICAL AT 0.8 VL		.030	.055	.100
63 GUNNERY RUN-P/U SYMMETRICAL AT 0.9 VL		.050	.014	.025
64 GUNNERY RUN-P/U SYMMETRICAL AT VL		.010	.014	.025
65 GUNNERY TURN TO THE RIGHT AT 0.5 VH		.375	1.375	.248
66 GUNNERY TURN TO THE RIGHT AT 0.7 VH		.375	1.375	.198
67 GUNNERY TURN TO THE RIGHT AT 0.9 VH		.750	.306	.100
68 GUNNERY TURN TO THE LEFT AT 0.5 VH		.375	1.375	.248
69 GUNNERY TURN TO THE LEFT AT 0.7 VH		.375	1.375	.198
70 GUNNERY TURN TO THE LEFT AT 0.9 VH		.750	.306	.100
71 GUNNERY S-TURN AT 0.5 VH		.200	.330	.150
72 GUNNERY S-TURN AT VH		.075	.037	.093
73 POWER TO AUTO. TRANSITION AT 0.5 VH		.050	.007	.007
74 POWER TO AUTO. TRANSITION AT 0.7 VH		.125	.013	.011
75 POWER TO AUTO. TRANSITION AT 0.9 VH		.175	.013	.012
76 AUTO. TO POWER TRANSITION IGE		.150	.007	.007
77 AUTO. TO POWER TRANSITION AT 0.4 VH		.100	.010	.010
78 AUTO. TO POWER TRANSITION AT 0.6 VH		.075	.007	.007
79 AUTO. TO POWER TRANSITION AT MAX. AUTO. A :		.025	.002	.003
80 STABILIZED AUTO. FLIGHT AT 0.4 VH		.200	.004	.004
81 STABILIZED AUTO. FLIGHT AT 0.6 VH		1.400	.012	.012
82 STABILIZED AUTO. FLIGHT AT MAX. AUTO. A :		.300	.004	.004
83 AUTO. TURN TO THE RIGHT AT 0.4 VH		.050	.001	.001
84 AUTO. TURN TO THE RIGHT AT 0.6 VH		.400	.002	.002
85 AUTO. TURN TO THE RIGHT AT MAX. AUTO. A :		.050	.001	.001
86 AUTO. TURN TO THE LEFT AT 0.4 VH		.050	.001	.001
87 AUTO. TURN TO THE LEFT AT 0.6 VH		.400	.002	.002
88 AUTO. TURN TO THE LEFT AT MAX. AUTO. A :		.050	.001	.001
89 AUTODROTATION LANDING		.250	.007	.007
		100,000	100,000	100,000

TABLE 6. UPPER AND LOWER BOUNDS FOR TECHNICAL ACCEPTANCE CRITERIA

Component	Lower Fatigue Life Bounds	Upper Fatigue Life Bounds	
	Recommended Lives	Mild Spectrum	Severe Spectrum
Main Potor Blade	1,100	4,307	3,542
Main Rotor Yoke Extension	3,300	24,917	14,779
Main Rotor Grip	Unlimited	190,042	69,686
Main Rotor Pitch Horn	6,600	17,953	10,596
M/R Retention Strap Ftg./Nut	2,200	9,517	4,488
Swashplate Drive Link	11,000	27,353	16,513
Swashplate Outer Ring	3,300	18,707	12,325
Swashplate Inner Ring	3,300	25,128	15,481
Hydraulic Boost Tube	3,300	8,635	5,145
Tail Rotor Blade	1,100	12,106	7,192

DEVELOPMENT OF A CANDIDATE FCM SYSTEM FOR THE AH-1G HELICOPTER

The development of a candidate FCM system for the AH-1G helicopter requires the following procedure: (1) the identification of those flight conditions that have the greatest fatigue-damaging effect on the critical AH-1G components, (2) the ranking of the fatigue-damaging flight conditions according to both the degree of their damaging effects on the helicopter as a whole and the relative costs to replace the selected components, (3) the selection of the measurable flight parameters whose collective variations will characterize the flight conditions identified in (1), and (4) the final definition of an FCM system in terms of specific combinations of flight parameters and the threshold levels of these parameters.

The following sections summarize the analytical processes used in developing an FCM system for the AH-1G.

Flight-Condition Ranking

Of the 89 flight conditions (each with three gross weight ranges) identified in the AH-1G design fatigue spectrum, some are damaging to the 10 selected components in varying degrees while others are not damaging at all. Consequently, the damaging flight conditions had to be first identified and then ranked according to both the degree of their damaging effects on the helicopter as a whole and the costs to replace the selected components.

As was done previously in Reference 1, the fatigue-damaging (sensitivity) rank of each AH-1G flight condition was computed by Equation (4). With relative expense and complexity of the selected dynamic components being significant factors, this equation provides the means for representing each flight condition relative to its rate of producing fatigue damage to the helicopter as a whole. A normalized rank value was also computed by Equation (5). The results of the ranking procedure are shown in Table 7.

$$R = \sum_{\text{all components}} (C_F \cdot \left(\frac{L_R}{L_A}\right) \cdot n \cdot D) \quad (4)$$

$$\bar{R} = \frac{R}{t} \quad (5)$$

where R = sensitivity rank value

C_F = estimated relative cost factor for each component
(each component was normalized to 1.0 for the main rotor blade)

$\frac{L_R}{L_A}$ = ratio of recommended life of each component to an
assumed aircraft life of 7200 hours

n = number of components per aircraft

D = percentage of fatigue damage to each component due to
a given flight condition

R = normalized rank value

t = flight condition frequency in the design usage spectrum

TABLE 7. RESULTS OF RANKING PROCEDURE

FLIGHT CONDITION	SENSITIVITY RANK VALUE	NORMALIZED RANK VALUE
Gunnery Run P/U (symmetrical) at VI	.4289	12.8916
Gunnery S-turn at VH	2.4017	32.0233
Gunnery Run P/U to the Left at VI	2.6629	26.6288
Gunnery Run P/U to the Right at VI	2.1912	21.9116
Gunnery Run P/U (symmetrical) at 0.9 VI	.7996	15.9910
Gunnery Run P/U to the Left at 0.9 VI	5.0312	10.0623
Gunnery Run P/U to the Right at 0.9 VI	3.6742	7.3485
Gunnery Run P/U (symmetrical) at 0.8 VI	.1522	5.0735
Normal Start/Shutdown (w/coll.)	3.9272	3.9272
Gunnery S-turn at 0.8 VH	.7270	3.6352
Gunnery Run P/U to the Left at 0.8 VI	.9580	3.1934
Autototation Landing	.7414	2.9777
Gunnery Run P/U to the Right at 0.8 VI	.8523	2.8109
Gunnery Turn to the Right at 0.9 VH	1.9089	2.5452
Gunnery Turn to the Left at 0.9 VH	1.5982	2.1309
Gunnery Run-Pt. Target Dive at VI	.5653	2.0188
Lateral Control Corr. at 0.9 VH	.0910	1.8191
Gunnery Run-Spray Fire Dive at VI	.2160	1.8001
Auto. to Power Transition at Max. Auto. A/S	.0286	1.1140
Hovering Longitudinal Control Corr. (IGL Maneuver)	.0107	1.0732
Rudder Control (corr. at 0.9 VH	.0435	.8692
Gunnery Run P/U (symmetrical) at 0.6 VI	.0082	.8179
Gunnery P/U to the Left at 0.6 VI	.0794	.7944
Gunnery Run P/U to the Right at 0.6 VI	.0718	.7184
Forward Level Flight VH at 314 RPM	.5478	.5478
Normal Left Turn at 0.9 VH	.9934	.4967
Gunnery Turn to the Left at 0.5 VH	.1675	.4465
Gunnery Turn to the Left at 0.7 VH	.1398	.3728
Gunnery Turn to the Right at 0.7 VH	.1361	.3630
Gunnery Turn to the Right at 0.5 VH	.1087	.2898
Gunnery Run-Spray Fire Dive at 0.9 VI	.1731	.2885
Quick Stop Deceleration (IGL Maneuver)	.0826	.2754
Approach and Landing (IGL Maneuver)	.2285	.2285
High-Speed Full Power Climb	.1247	.1247
Forward Level Flight VH at 324 RPM	1.0412	.1157
Auto. to Power Transition at 0.6 VH	.0077	.1024
Auto. Turn to the Right at Max. Auto. A/S	.0040	.0809
Longitudinal Control (corr. at 0.9 VH	.0037	.0731
Gunnery Run-Pt. Target Dive at 0.9 VI	.0983	.0702
Gunnery Run-Spray Fire Dive at 0.8 VI	.0205	.0569
Normal Right Turn at 0.7 VH	.0384	.0384
Gunnery Run-Pt. Target Dive at 0.8 VI	.0271	.0322
Auto. Turn to the Left at Max. Auto. A/S	.0012	.0235
Normal Right Turn 0.9 VH	.0402	.0201
Hovering Lateral Control (corr. (IGL Maneuver)	.0001	.0088

Selection of Characteristic Parameters and Parameter Thresholds

References 4 and 5 were thoroughly searched for those flight parameters that have a consistent response to specific flight conditions. These documents contain pilot stick and pedal position data, component load data, and helicopter response data (such as roll rate, pitch rate, and pitch attitude). The documented flights, where each flight condition was flown many times in various gross weight-altitude combinations, were examined to detect the behavior of each recorded parameter during the defined flight conditions. (In describing the data reduction procedure, Reference 4 states that the maximum mean helicopter attitude and attitude rate values were measured and processed for each maneuver, but not for the level-flight flight conditions. The mean and oscillatory center-of-gravity vertical acceleration levels were measured and recorded at the maximum mean level for maneuvers and at the maximum oscillatory peak for the level-flight flight conditions.) The flight conditions that had ranked highly were examined very closely.

Each of the measurable flight parameters listed in Table 8 was considered individually or in combination with others to determine their potential in flight condition monitoring.

TABLE 8. CANDIDATE MONITORING PARAMETERS
FOR FCM RECORDING SYSTEM

Vertical Acceleration @ c.g.	Pitch Attitude
Indicated Airspeed	Roll Attitude
Main Rotor Velocity	Pitch Rate
Landing Gear Touchdown	Roll Rate
Engine Torque Pressure	Yaw Rate

Table 9 shows sample data extracted from References 4 and 5 for two flight conditions: the gunnery run pullups to the right and left at V_L (V_L indicates limit velocity). These two flight conditions were ultimately considered sufficiently

4. Wettengel, W.O., MODEL AH-1G NONFIRING LOAD LEVEL SURVEY, VOLUMES I THROUGH IX, Report No. 209-099-041, Bell Helicopter Company, Fort Worth, Texas, June 1967.
5. Long, D.B., MODEL AH-1G HELICOPTER ARMAMENT QUALIFICATION TEST AND FIRING LOAD LEVEL SURVEY, Report No. 209-099-031, Bell Helicopter Company, Fort Worth, Texas, November 1967.

similar to be monitored as one flight condition category defined as follows:

Vertical Acceleration at c.g. $\geq 1.5g$
 Airspeed $> 0.95 V_L$
 $10^\circ < \text{Roll Attitude} < 35^\circ$

TABLE 9. SAMPLE LOAD LEVEL SURVEY DATA

Flight Condition: Gunnery Run Pullup to the Right @ V_L

Origin of Data*	Vertical Acceleration @ c.g. (g)	Pitch Rate (deg/sec)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Pitch Attitude (deg)	Roll Attitude (deg)
N ₁	1.94	8	11	5	25	26
N ₂	1.64	6	12	3	9	22
N ₃	2.07	9	11	3	18	25
N ₄	1.77	7	13	6	23	30
N ₅	1.64	7	8	3	8	24
N ₆	1.75	7	8	3	8	21
N ₇	1.62	6	-3	4	-7	20
N ₈	1.21	2	-2	2	-2	7
N ₉	1.41	5	10	4	-7	23
N ₁₀	1.63	7	13	3	15	25
F ₁	2.01	11	18	5	6	26
F ₂	2.16	11	17	5	-5	13
F ₃	2.09	12	12	6	11	18
F ₄	1.94	15	12	7	-5	13
F ₅	1.75	11	18	2	1	16
F ₆	1.82	10	17	0	1	13
F ₇	1.72	8	17	4	-4	33
F ₈	2.23	17	-2	8	12	34
F ₉	1.82	7	-1	6	11	28
F ₁₀	1.79	9	8	5	17	24

* NOTE:

N_i indicates data was taken from nonfiring load level survey

F_i indicates data was taken from firing load level survey

i indicates number of times flight condition was performed in load level survey

TABLE 9. Concluded

Flight Condition: Gunnery Run Pullup to the Left @ V_L

Origin of Data*	Vertical Acceleration @ c.g. (g)	Pitch Rate (deg/sec)	Roll Rate (deg/sec)	Yaw Rate (deg/sec)	Pitch Attitude (deg)	Roll Attitude (deg)
N ₁	2.03	10	-9	-6	23	-35
N ₂	1.73	8	-12	-5	9	-31
N ₃	1.97	8	-14	-4	13	-33
N ₄	1.78	8	-12	-4	21	-29
N ₅	1.63	6	5	0	16	-21
N ₆	1.66	4	11	-5	10	9
N ₇	1.56	5	-7	-5	-12	-22
N ₈	1.17	2	-4	-3	-5	-4
N ₉	1.43	6	7	-4	8	-21
N ₁₀	1.59	7	-15	-7	14	-31
F ₁	2.19	12	-18	2	6	-24
F ₂	2.20	11	-18	4	-6	-11
F ₃	1.83	7	-5	-4	4	-9
F ₄	1.85	9	-11	0	5	-13
F ₅	1.86	10	-9	0	18	-10

* NOTE:

N_i indicates data was taken from nonfiring load level survey.F_i indicates data was taken from firing load level survey.

i indicates number of times flight condition was performed in load level survey

In Table 2, where all airspeeds are expressed in terms of V_H (the maximum attainable level flight airspeed) or V_L (the limit airspeed), the V_H of 144 KTAS is defined in Reference 6, and V_L is defined in Reference 7 and shown in Figure 8. In

6. Finnestead, R.L., Laing, E., Connor, W.J., and Buss, M.W., ENGINEERING FLIGHT TEST, AH-1G HELICOPTER (HUEY/COBRA), PHASE D PART 2, PERFORMANCE, USAASTA 66-06, U.S. Army Aviation Systems Test Activity, Edwards Air Force Base, California, April 1970, AD 874210.
7. Technical Manual, TM 55-1520-221-10, OPERATOR'S MANUAL: ARMY MODEL AH-1G HELICOPTER, Headquarters, Department of the Army, Washington, D.C., 12 December 1975.

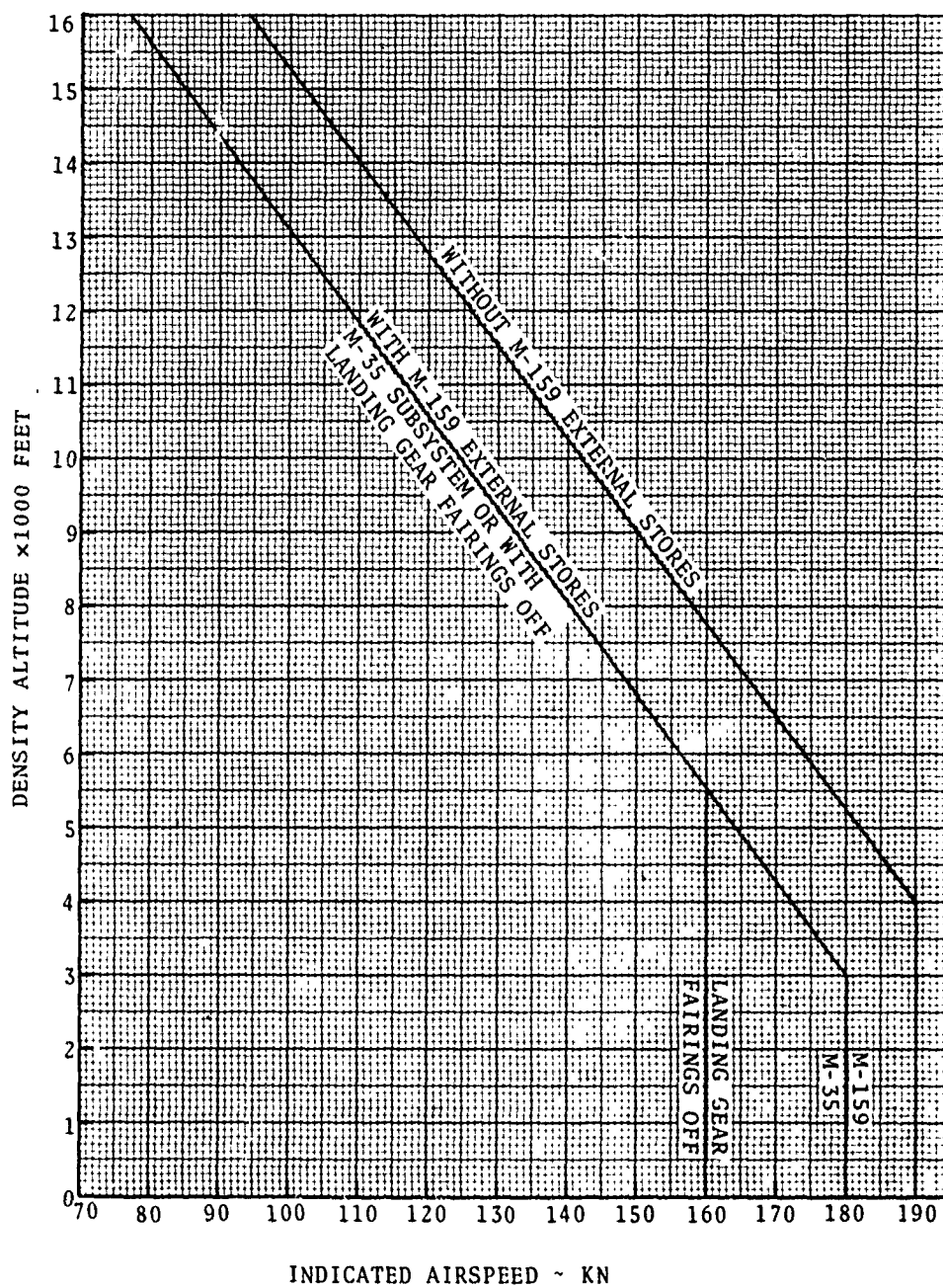


Figure 8. Limit Velocity (V_L) Definition.

this figure the airspeed limitation for the M-159 external stores configuration will be incorporated in the FCM system as a reasonable, although conservative, V_L definition. Since both V_H and V_L are a function of density altitude, pressure altitude and outside air temperature were included among the required parameters so that they could be monitored in conjunction with indicated airspeed. V_H and V_L can be calculated from the following equations:

$$V_H = 144 - \frac{H_d}{500} \quad (6)$$

and $V_L = 180$ knots below $H_d = 3000$ ft (7)

$$V_L = 180 - 8 \left[\frac{H_d}{1000} - 3 \right] \text{ for } H_d \text{ above } 3000 \text{ ft} \quad (8)$$

where V_H = maximum level flight airspeed, knots

V_L = limit airspeed, knots

H_d = density altitude, feet

the density altitude is calculated from:

$$H_d = 145,447 \left[1 - \left(\frac{9.6307 P_a}{T + 273.18} \right)^{.235} \right] \quad (9)$$

where P_a = static pressure, inches mercury

T = outside air temperature, °C.

Since the damage rates for the AH-1G flight conditions vary significantly with gross weight, that parameter was included in the FCM system to further enhance the validity of the FCM system damage assessment model. The ranges chosen to represent the low, medium, and high gross weight categories are listed in Table 10.

TABLE 10. GROSS WEIGHT RANGES

<u>Range Nomenclature</u>	<u>Gross Weight Range (lb)</u>
L-GW	less than 7750
M-GW	7750 through 8750
H-GW	greater than 8750

The following method was chosen as the most practical means of reasonably estimating the instantaneous gross weight: (1) measure the takeoff gross weight by a landing skid deflection technique, and (2) conservatively estimate the instantaneous gross weight of the helicopter by only assuming that the gross weight linearly decreases with fuel burnoff.

Description of Recommended FCM System

The evaluation of all fatigue-damaging flight conditions relative to the previously described flight parameter behavior led to the selection of the parameters listed in Table 11 as the set of coordinated parameters which may best describe the

TABLE 11. SELECTED MONITORING PARAMETERS FOR FCM RECORDING SYSTEM

<u>Directly Monitored Parameters</u>	<u>Symbol</u>
Indicated Airspeed	A/S
Pressure Altitude	H_p
Outside Air Temperature	T
Main Rotor Velocity	MRV
Roll Attitude	β
Pitch Attitude	θ
Vertical Acceleration @ c.g.	n_z
Landing Gear Touchdown	TD
Engine Torque Pressure	ET
Takeoff Gross Weight	TGW
<u>Computed Parameters</u>	<u>Symbol</u>
Rate of Descent	RD
Maximum (Level Flight) Airspeed	V_H
Limit Airspeed	V_L
Instantaneous Gross Weight	GW

fatigue design spectrum in terms of a unique set of flight condition categories (FCC) (See Table 12). Although FCC 83 through 85, 89 through 91, and 95 through 97 do not specifically represent any of the flight conditions defined in the fatigue design spectrum, they enhance understanding of the AH-1G operational usage spectrum. (For example, FCC 96 was intended to measure and record the magnitude of the largest vertical acceleration peak during a recording period.) Table 12 summarizes the resultant FCM system recommended for the AH-1G helicopter. For simplicity, the breakdown of the 89 flight conditions by gross weight range was not shown in this table.

Note in Table 12 that it was necessary to formulate six flight condition categories that are not directly recorded (FCC 98 through 103). These FCC are reserved for estimations of time spent in making control corrections during hover and control corrections at $0.9 V_H$. This provision was made because the data in Reference 4 revealed that although these flight conditions could not be confidently detected, their damage rates were of sufficient magnitude to warrant due recognition.

Therefore, since the control corrections occur on a statistical basis, it was decided to account for them by first defining the FCC in which their time would be included (the hovering control correction times would appear in FCC 1, 2, and 3, and the control correction times at $0.9 V_H$ would appear in FCC 14, 15, and 16). A liberal percentage of time (2 percent was chosen) was deducted from these recorded flight condition categories and assigned to FCC 98 through 103.

TABLE 12. FCM SYSTEM SUMMARY

Flt. Cond. Cat. No.			Flight Condition Category Description	(a) Type Desig.		Flight Conditions Included	
L-GW	M-GW	H-GW		No.(b)	Description		
1	2	3	Flight Clock Time	T	2	Normal Takeoff (IGE)	
					3	Jump Takeoff (IGE)	
					4	Steady Hover (IGE)	
					5	Hovering Right Turn (IGE)	
					6	Hovering Left Turn (IGE)	
					10	Sideward Flight to the Right (IGE)	
					11	Sideward Flight to the Left (IGE)	
					12	Rearward Flight (IGE)	
					13	Acceleration Hover to Climb A/S (IGE)	
					14	Normal Deceleration (IGE)	
					41	Sideslip	
					43	Firing in a Hover	
					44	Strafing in Acceleration from a Hover	
	4		Rotor Start/Stop	C	1*	Normal Start/Shutdown (IGE)	
5	6	7	Quick Stop	T	15*	Quick-Stop Deceleration (IGE)	
8	9	10	Normal Landing	C	16*	Approach and Landing (IGE)	
11	12	13	Low-Velocity Flight	T	17	Forward Level Flt. @ 0.50 V_H and 314 RPM	
					18	Forward Level Flt. @ 0.50 V_H and 324 RPM	
					19	Forward Level Flt. @ 0.60 V_H and 314 RPM	
					20	Forward Level Flt. @ 0.60 V_H and 324 RPM	
					29	Normal Full Power Climb	
					32	Normal Right Turn @ 0.50 V_H	
					35	Normal Left Turn @ 0.50 V_H	
14	15	16	High-Velocity Flight	T	21	Forward Level Flt. @ 0.70 V_H and 314 RPM	
					22	Forward Level Flt. @ 0.70 V_H and 324 RPM	
					23	Forward Level Flt. @ 0.80 V_H and 314 RPM	
					24	Forward Level Flt. @ 0.80 V_H and 324 RPM	
					25	Forward Level Flt. @ 0.90 V_H and 314 RPM	
					26	Forward Level Flt. @ 0.90 V_H and 324 RPM	
					42	Part Power Descent	
17	18	19	Maximum Velocity Flight	T	27*	Forward Level Flt. @ V_H and 314 RPM	
					28*	Forward Level Flt. @ V_H and 324 RPM	
20	21	22	High-Speed Full Power Climbs	T	30*	High-Speed Full Power Climbs	
					31	Max. Rate Accel. Full Power Climb to Cruise A/S	
23	24	25	Normal (High-Speed) Turns	T	33*	Normal Right Turn @ 0.70 V_H	
					36	Normal Left Turn @ 0.70 V_H	
26	27	28	Normal (High-Speed) Turns	T	34*	Normal Right Turn @ 0.90 V_H	
					37	Normal Left Turn @ 0.90 V_H	
29	30	31	Low-velocity Dives	T	45	Gunnery Run-Pt. Target Dive @ 0.60 V_L	
					49	Gunnery Run-Spray Fire Dive @ 0.60 V_L	
32	33	34	Moderate-Velocity Dives	T	46*	Gunnery Run-Pt. Target Dive @ 0.80 V_L	
					50*	Gunnery Run-Spray Fire Dive @ 0.80 V_L	
35	36	37	High-Velocity Dives	T	47*	Gunnery Run-Pt. Target Dive @ 0.90 V_L	
					51*	Gunnery Run-Spray Fire Dive @ 0.90 V_L	
38	39	40	Maximum-Velocity Dives	T	48*	Gunnery Run-Pt. Target Dive @ V_L	
					52*	Gunnery Run-Spray Fire Dive @ V_L	
41	42	43	Asymmetrical Pullups	T	53*	Gunnery Run-P/U to the Right @ 0.60 V_L	
					57*	Gunnery Run-P/U to the Left @ 0.60 V_L	
44	45	46	Asymmetrical Pullups	T	54*	Gunnery Run-P/U to the Right @ 0.80 V_L	
					58*	Gunnery Run-P/U to the Left @ 0.80 V_L	
47	48	49	Asymmetrical Pullups	T	55*	Gunnery Run-P/U to the Right @ 0.90 V_L	
					59*	Gunnery Run-P/U to the Left @ 0.90 V_L	
50	51	52	Asymmetrical Pullups	T	56*	Gunnery Run-P/U to the Right @ V_L	
					60*	Gunnery Run-P/U to the Left @ V_L	

TABLE 12. Concluded

Flt. Cond. Cat. No.			Flight Condition Category Description	Type ^(a) Desig.	No. ^(b)	Flight Conditions Included	
L-GW	M-GW	H-GW				Description	
53	54	55	Symmetrical Pullups	T	61*	Gunnery Run-P/U (Symmetrical) @ 0.60 V_L	
56	57	58	Symmetrical Pullups	T	62*	Gunnery Run-P/U (Symmetrical) @ 0.80 V_L	
59	60	61	Symmetrical Pullups	T	63*	Gunnery Run-P/U (Symmetrical) @ 0.90 V_L	
					64*	Gunnery Run-P/U (Symmetrical) @ V_L	
62	63	64	Gunnery Turns	T	65*	Gunnery Turn to the Right @ 0.50 V_H	
					68*	Gunnery Turn to the Left @ 0.50 V_H	
65	66	67	Gunnery Turns	T	66*	Gunnery Turn to the Right @ 0.70 V_H	
					69*	Gunnery Turn to the Left @ 0.70 V_H	
68	69	70	Gunnery Turns	T	67*	Gunnery Turn to the Right @ 0.90 V_H	
					70*	Gunnery Turn to the Left @ 0.90 V_H	
71	72	73	High-Velocity S-Turn	T	71*	Gunnery S-Turn @ 0.80 V_H	
74	75	76	Maximum-Velocity S-Turn	T	72*	Gunnery S-Turn @ V_H	
77	78	79	Autorotation Clock Time	T	73	Power to Auto. Transition @ 0.50 V_H	
					74	Power to Auto. Transition @ 0.70 V_H	
					75	Power to Auto. Transition @ 0.90 V_H	
					76	Auto. to Power Transition (IGL)	
					77	Auto. to Power Transition @ 0.40 V_H	
					80	Stabilized Auto. Flt. @ 0.40 V_H	
					81	Stabilized Auto. Flt. @ 0.60 V_H	
					82	Stabilized Auto. Flt. @ Max. Auto. A/S	
					83	Auto. Turn to the Right @ 0.40 V_H	
					84	Auto. Turn to the Right @ 0.60 V_H	
					86	Auto. Turn to the Left @ 0.40 V_H	
					87	Auto. Turn to the Left @ 0.60 V_H	
80	81	82	Auto. to Power Transition	C	78*	Auto. to Power Transition @ 0.60 V_H	
					79*	Auto. to Power Trans. @ Max. Auto. A/S	
84	85		Auto. to Power Transition	C	--	-----	
86	87	88	High-Speed Auto. Turns	T	85*	Auto. Turn to the Right @ Max. Auto. A/S	
					88*	Auto. Turn to the Left @ Max. Auto. A/S	
89	90	91	High-Speed Auto. Turns	T	--	-----	
92	93	94	Autorotation Landing	C	89*	Autorotation Landing	
	95		Misc High-G Maneuvers	M	--	-----	
	96		Maximum n_z Experienced	M	--	-----	
	97		Maximum A/S Experienced	M	--	-----	
98	99	100	Hovering Control Corrections	H	7*	Hovering Longitudinal Control Corr. (IGE)	
					8*	Hovering Lateral Control Corr. (IGE)	
					9	Hovering Rudder Control Corr. (IGE)	
101	102	103	High-Speed Control Corr.	N	38*	Longitudinal Control Corr. @ 0.90 V_H	
					39*	Lateral Control Corr. @ 0.90 V_H	
					40*	Rudder Control Corr. @ 0.90 V_H	

NOTE (a) T = category timer
 C = category occurrence timer
 M = maximum parameter magnitude attained
 N = null recording category (control corrections times are conservatively estimated from other category timers)

NOTE (b) * Indicates Damaging Flight Conditions

DETERMINATION OF FCM SYSTEM TECHNICAL ACCEPTABILITY

The assessment of the technical acceptability of a candidate FCM system, such as the one described in Table 12, requires analyzing the proposed system with the aid of two computer programs, FCMMOD and SIMULE, which are documented in Reference 1.

Program FCMMOD uses the fatigue design spectrum and associated component damage rates, together with the FCM system definition, to compute appropriate fatigue-damage coefficients for each flight condition category. FCMMOD has a degree of built-in conservativeness since it increases the effect of the highly fatigue-damaging flight conditions in the derivation of flight condition category damage coefficients by simply assigning the maximum flight condition damage rate within each FCC as the damage coefficient for that category.

Program SIMULE simulates the operation of an FCM system by computing component fatigue lives from the FCMMOD-generated fatigue-damage coefficients in a given utilization spectrum, namely, the previously described mild and severe spectra in this application.

Fatigue-Damage Coefficients for FCM System

Table 13 presents the fatigue-damage coefficients for the FCM system described in Table 12. Any damage coefficient with a zero value indicates that the corresponding flight condition category is not fatigue-damaging for the particular component. Accordingly, since flight condition categories 95, 96, and 97 are not specifically representative of fatigue design spectrum flight conditions, their damage coefficients are zero.

Proposed FCM System Compliance with Technical Acceptance Criteria

For both the mild and the severe spectrum, Table 14 lists the SIMULE-computed fatigue lives for each of the 10 AH-1G components and the upper and lower fatigue life bounds for these components.

Since all fatigue lives fall within the respective bounds, the proposed FCM system and the associated FCM system damage model satisfy the technical acceptance criteria and therefore are valid means for assessing fatigue damage in AH-1G fatigue-critical components.

Detailed FCM System Description

Although the technically acceptable FCM system described in Table 12 defines the system parameter combinations and associated threshold levels, it does not define a completely workable system. For example, consider flight condition

TABLE 13. FATIGUE DAMAGE COEFFICIENTS FOR EACH COMPONENT
IN EACH FLIGHT CONDITION CATEGORY

<u>Flight Condition Category</u>	<u>Main Rotor Blade</u>	<u>Main Rotor Yoke Extension</u>	<u>Main Rotor Grip</u>	<u>Main Rotor Pitch Horn</u>	<u>Retention Strap Ftg./Nut</u>
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	.3623E-01
5	0.	0.	0.	0.	0.
6	.4267E-03	0.	0.	0.	0.
7	.1789E-02	0.	0.	0.	0.
8	0.	0.	0.	0.	0.
9	.8420E-03	0.	0.	0.	0.
10	.6800E-03	0.	0.	0.	0.
11	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.
17	.4245E-02	0.	0.	0.	0.
18	.2900E-03	0.	0.	0.	0.
19	.2867E-03	0.	0.	0.	0.
20	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.
22	.1137E-02	0.	0.	0.	0.
23	0.	0.	0.	0.	0.
24	.2100E-03	0.	0.	0.	0.
25	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.
28	.1833E-03	0.	0.	0.	0.
29	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.
34	.5185E-03	0.	0.	0.	0.
35	.2917E-03	0.	0.	0.	0.
36	.2700E-03	0.	0.	0.	0.
37	.1094E-02	0.	0.	0.	0.
38	.4482E-02	0.	0.	0.	0.
39	.1429E-03	0.	0.	0.	0.
40	.6778E-02	0.	0.	0.	0.
41	0.	0.	0.	0.	0.
42	.8200E-03	0.	0.	0.	0.
43	.3700E-02	0.	0.	.6233E-02	0.
44	.2867E-02	0.	0.	.1167E-02	0.
45	.4193E-02	0.	0.	.1400E-02	0.
46	.5567E-02	0.	0.	.9478E-02	0.
47	.1440E-02	.2970E-02	0.	.7500E-03	0.
48	.5904E-02	.7080E-02	0.	.3156E-02	0.
49	.1717E-01	.5107E-02	0.	.1499E-01	0.
50	.3900E-01	.1250E-01	0.	.2400E-02	0.
51	.1640E-01	.2366E-01	0.	.4840E-02	0.
52	.5860E-01	.2437E-01	0.	.2223E-01	0.

TABLE 13. Continued

Flight Condition Category	Main Rotor Blade	Main Rotor Yoke Extension	Main Rotor Grip	Main Rotor Pitch Horn	Retention Strap Ftg./Nut
53	0.	0.	0.	0.	0.
54	.8000E-03	0.	0.	0.	0.
55	.3667E-02	0.	0.	.6333E-02	0.
56	.6667E-03	0.	0.	.3333E-03	0.
57	.5600E-02	0.	0.	.1120E-01	0.
58	.1244E-01	.1044E-01	0.	.1933E-01	0.
59	.1085E+00	.1400E-01	0.	.1050E-01	0.
60	.7780E-01	.1140E-01	0.	.1700E-01	0.
61	.1173E+00	.1153E-01	0.	.3733E-01	0.
62	0.	0.	0.	0.	0.
63	.3467E-03	0.	0.	0.	0.
64	.4053E-02	0.	0.	0.	0.
65	.5333E-03	0.	0.	0.	0.
66	.6880E-03	0.	0.	0.	0.
67	.2267E-02	0.	0.	.3644E-03	0.
68	.4080E-02	0.	0.	0.	0.
69	.7445E-02	0.	0.	.4560E-03	0.
70	.6489E-02	0.	0.	.1204E-02	0.
71	.2900E-02	.9050E-02	0.	0.	0.
72	.5100E-02	0.	0.	0.	0.
73	.1123E-01	0.	0.	0.	0.
74	.1773E-01	.2133E-01	0.	0.	0.
75	.9921E-02	.3605E-02	0.	0.	0.
76	.1245E-01	.1705E-01	.4786E-01	0.	0.
77	0.	0.	0.	0.	0.
78	0.	0.	0.	0.	0.
79	.2511E-02	0.	0.	0.	0.
80	.4000E-03	0.	0.	0.	0.
81	.1600E-03	0.	0.	0.	0.
82	.8667E-02	0.	0.	0.	0.
83	.4000E-03	0.	0.	0.	0.
84	.1600E-03	0.	0.	0.	0.
85	.8667E-02	0.	0.	0.	0.
86	0.	0.	0.	0.	0.
87	0.	0.	0.	0.	0.
88	0.	0.	0.	0.	0.
89	0.	0.	0.	0.	0.
90	0.	0.	0.	0.	0.
91	0.	0.	0.	0.	0.
92	.1114E-01	0.	0.	0.	0.
93	.5320E-02	0.	0.	0.	0.
94	.3947E-02	.1005E-01	0.	0.	0.
95	0.	0.	0.	0.	0.
96	0.	0.	0.	0.	0.
97	0.	0.	0.	0.	0.
98	.8000E-02	0.	0.	0.	0.
99	.1400E-02	0.	0.	0.	0.
100	.1000E-02	0.	0.	0.	0.
101	.8100E-02	0.	0.	0.	0.
102	.1140E-01	0.	0.	0.	0.
103	.5867E-02	0.	0.	0.	0.

TABLE 13. Continued

Flight Condition Category	Swashplate Drive Link	Swashplate Outer Ring	Swashplate Inner Ring	Hydraulic Boost Cylinder	Tail Rotor Blade
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.
17	0.	0.	.4450E-03	0.	0.
18	0.	0.	0.	0.	.5340E-03
19	0.	0.	0.	0.	.7467E-03
20	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	.2592E-02
28	0.	0.	0.	0.	.4800E-03
29	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	.5667E-03
37	0.	0.	.3952E-03	0.	0.
38	0.	0.	.5893E-03	0.	0.
39	0.	0.	.1657E-02	.2214E-03	.1707E-02
40	0.	.2024E-02	.7655E-02	.1155E-02	.7278E-02
41	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.
43	.1567E-02	.1043E-01	.4000E-03	.1500E-02	0.
44	0.	.1067E-02	0.	.1017E-02	.1000E-02
45	.3727E-02	.4087E-02	.2953E-02	.2893E-02	.5067E-03
46	.3222E-02	.1052E-01	.8744E-02	.1322E-01	.5889E-02
47	.1830E-02	.7600E-02	.5640E-02	.3410E-02	.3107E-01
48	.9200E-03	.4536E-02	.3784E-02	.1265E-01	.9344E-02
49	.5420E-02	.4553E-02	.5353E-02	.4299E-01	.1360E-01
50	.4000E-03	.1350E-02	.1300E-02	.1460E-01	.1830E-01
51	.1022E-01	.3400E-02	.3220E-02	.3312E-01	.1916E-01
52	.2693E-01	.6267E-02	.8733E-02	.7277E-01	.3733E-01

TABLE 13. Concluded

Flight Condition Category	Swashplate Drive Link	Swashplate Outer Ring	Swashplate Inner Ring	Hydraulic Boost Cylinder	Tail Rotor Blade
53	0.	0.	0.	0.	0.
54	0.	0.	0.	0.	0.
55	.1667E-02	0.	.6667E-03	.1367E-01	0.
56	0.	0.	0.	.1667E-02	.1167E-02
57	.3267E-02	.6667E-03	.2000E-02	.4867E-02	.1333E-02
58	.6333E-02	.4333E-02	.6667E-02	.1456E-01	.3556E-02
59	.3000E-02	.1300E-02	.2000E-02	.1400E-01	.1000E-01
60	.7800E-02	.1400E-02	.2720E-02	.2040E-01	.7000E-02
61	.1400E-01	.9600E-02	.6333E-02	.3800E-01	.1680E-01
62	0.	0.	0.	0.	0.
63	0.	0.	0.	0.	0.
64	0.	0.	0.	.6844E-03	0.
65	0.	0.	0.	0.	0.
66	0.	0.	0.	.1600E-04	0.
67	0.	0.	0.	0.	0.
68	0.	.2880E-02	.1487E-02	0.	.3327E-02
69	.1453E-02	.2560E-03	0.	.2413E-03	.3840E-03
70	.3289E-03	.5040E-02	.5244E-02	.9556E-03	.6324E-02
71	0.	.2250E-03	.2175E-02	0.	.5750E-03
72	0.	0.	0.	.2000E-04	.2740E-02
73	0.	.1583E-02	.3917E-02	0.	.8333E-03
74	0.	.2600E-02	.4133E-02	.4000E-03	.1667E-01
75	0.	.4737E-03	.2763E-02	.3421E-03	.1866E-01
76	0.	.2273E-02	.1055E-01	0.	.6377E-01
77	0.	0.	0.	0.	0.
78	0.	0.	0.	0.	0.
79	0.	0.	0.	0.	0.
80	0.	0.	0.	0.	0.
81	0.	0.	0.	0.	0.
82	0.	.1200E-02	.8000E-03	0.	.6667E-03
83	0.	0.	0.	0.	0.
84	0.	0.	0.	0.	0.
85	0.	.1200E-02	.8000E-03	0.	.6667E-03
86	0.	0.	0.	0.	0.
87	0.	0.	0.	0.	0.
88	0.	.8000E-03	0.	0.	.5333E-03
89	0.	0.	0.	0.	0.
90	0.	0.	0.	0.	0.
91	0.	.8000E-03	0.	0.	.5333E-03
92	0.	0.	0.	0.	0.
93	0.	0.	0.	0.	0.
94	0.	0.	0.	0.	.5733E-03
95	0.	0.	0.	0.	0.
96	0.	0.	0.	0.	0.
97	0.	0.	0.	0.	0.
98	0.	0.	0.	.1000E-02	0.
99	0.	0.	0.	.5600E-02	0.
100	0.	0.	0.	0.	0.
101	0.	.4000E-03	0.	0.	.1260E-01
102	0.	0.	0.	0.	0.
103	0.	0.	0.	0.	.4667E-03

TABLE 14. TECHNICAL ACCEPTABILITY RESULTS

Component Identification	FCM System Performance		Fatigue Life Bounds	
	Assessed Damage	Projected Life	Lower	Upper
Mild Utilization Spectrum				
Main Rotor Blade	.324574E-01	3,081	1,100	4,307
Main Rotor Yoke Extension	.493331E-02	20,271	3,300	24,917
Main Rotor Grip	.526500E-03	189,934	Unlimited	190,042
Main Rotor Pitch Horn	.681070E-02	14,683	6,600	17,953
M/R Retention Strap Ftg./Nut	.105077E-01	9,517	2,200	9,517
Swashplate Drive Link	.458481E-02	21,812	11,000	27,353
Swashplate Outer Ring	.723471E-02	13,823	3,300	18,707
Swashplate Inner Ring	.573742E-02	17,430	3,300	25,128
Hydraulic Boost Cylinder	.161467E-01	6,134	3,300	8,635
Tail Rotor Blade	.118041E-01	8,472	1,100	12,106
Severe Utilization Spectrum				
Main Rotor Blade	.400355E-01	2,498	1,100	3,542
Main Rotor Yoke Extension	.843841E-02	11,851	3,300	14,779
Main Rotor Grip	.143591E-02	69,643	Unlimited	69,686
Main Rotor Pitch Horn	.112521E-01	8,888	6,600	10,596
M/R Retention Strap Ftg./Nut	.223197E-01	4,481	2,200	4,488
Swashplate Drive Link	.747809E-02	13,373	11,000	16,513
Swashplate Outer Ring	.110711E-01	9,033	3,300	12,325
Swashplate Inner Ring	.925062E-02	10,811	3,300	15,481
Hydraulic Boost Cylinder	.233981E-01	4,274	3,300	5,145
Tail Rotor Blade	.190302E-01	5,255	1,100	7,192

categories 50, 51, and 52, which represent high-speed asymmetrical gunnery run pullups. Although these maneuvers are identified by the combination of a vertical acceleration above 1.5g, a roll attitude between 10° and 35°, and an airspeed greater than 0.95 V_i , they are not adequately represented by simply measuring the time within which the parameters are attaining the foregoing values simultaneously. Rather, these maneuvers would likely be better represented by the time duration of the roll attitude while it exceeded and returned to 10° but did not reach 35°, provided that the airspeed is above 0.95 V_i at the initial 10° crossing and that the vertical acceleration exceeds 1.5g within a prescribed time after the initial 10° crossing.

Various considerations, such as the reasoning in the foregoing example, led to the definition of a much more detailed FCM system. Because of the lengthy description needed to define each flight condition category in the resultant FCM system, these flight condition categories are depicted and defined in Appendix A.

Because of the complexity of many of the flight condition categories and the parameter monitoring requirements, the FCM

recorder incorporates a microprocessor. During the development of the FCM system, the airborne recorder was flight-tested with an oscillograph recorder capable of monitoring those parameters listed in Table 8. Then the two sets of data were compared to evaluate the functioning of the FCM recorder and to adjust the parameter threshold levels in the FCM system so that the established flight conditions could be better defined.

CHAPTER 3.

SYSTEM DESCRIPTION

The SIRS system consists of three discrete but inter-related subsystems. The airborne SIRS recorder monitors helicopter usage by identifying and storing the occurrences of various flight conditions. The ground-based, portable data retrieval unit transfers the recorder-stored data onto a miniature data tape cassette on a monthly basis. At a central data processing site, the software system automatically processes and analyzes the data, and then generates tailored reports that present the usage and corresponding incremental fatigue damage to each component for each monitored helicopter. The complete system is pictured in Figure 9.

SIRS RECORDER

The SIRS recorder, viewed in Figure 10, incorporates a Motorola Model 6800 microprocessor. This microprocessor monitors the nine flight parameters listed in Table 15 and from them calculates the density altitude and adjusted airspeed limits.

When these flight parameters fall in preset ranges or form certain flight conditions, the microprocessor accumulates their occurrences or the amount of time associated with them in the recorder's data-storage memory. The flight conditions are defined generally as various combinations of flight parameters, each in a preset range. Examples of flight conditions are flight time, rotor starts, and maximum vertical acceleration. Table 16 lists the 22 flight condition categories established for the AH-1G.

As shown in Figure 11, the SIRS recorder processes the inputs from the transducers for the nine monitored parameters. Each of the inputs is conditioned to a desired full-scale signal level, multiplexed, and converted from an analog to a digital signal to be processed by the microprocessor. The recorder software logic identifies the flight conditions by associating the variation and corresponding time of each input parameter with those of the other input parameters. While these conditions are being identified, the microprocessor calculates the density altitude and limit velocities and temporarily stores the calculations in the recorder's scratch pad memory. The programs for these calculations and the flight condition software logic are contained in EPROM (erasable programmable read-only memory) integrated circuits. The time spent in or the number of occurrences of the various flight conditions is stored in the recorder's data-storage memory, which consists of RAM (random access memory) integrated circuits. Since these circuits are volatile, the recorder

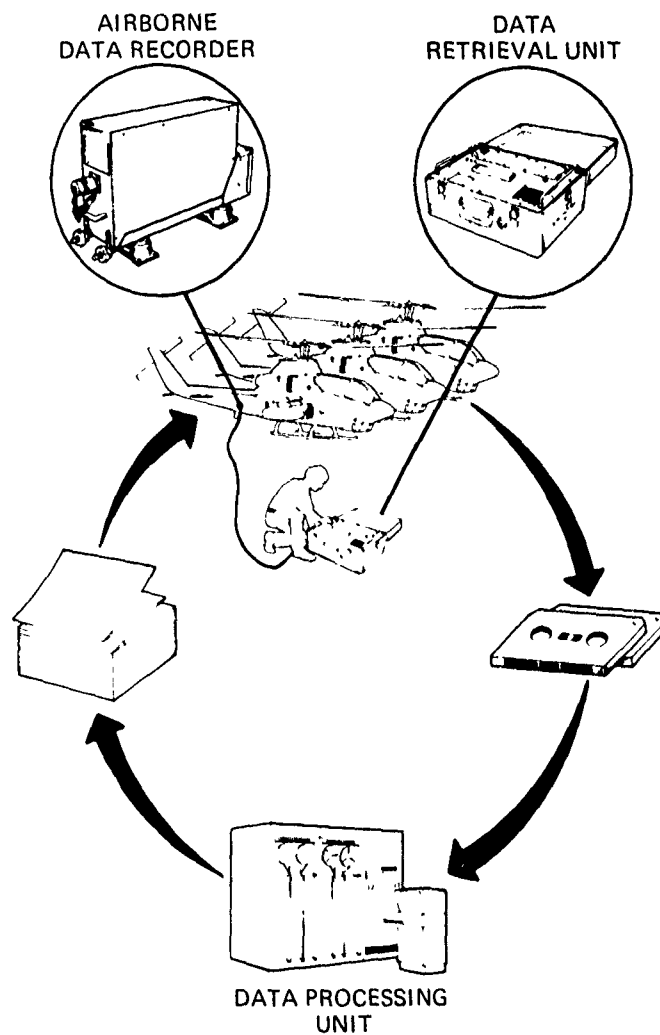


Figure 9. Structural Integrity Recording System.

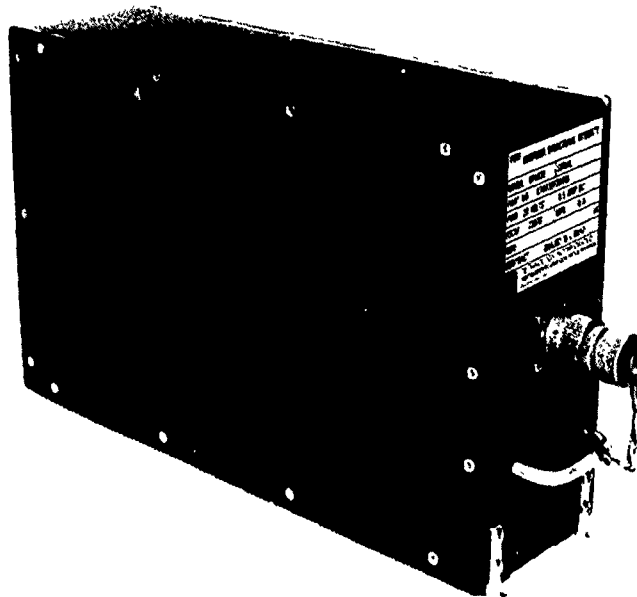


Figure 10. SIRS Recorder.

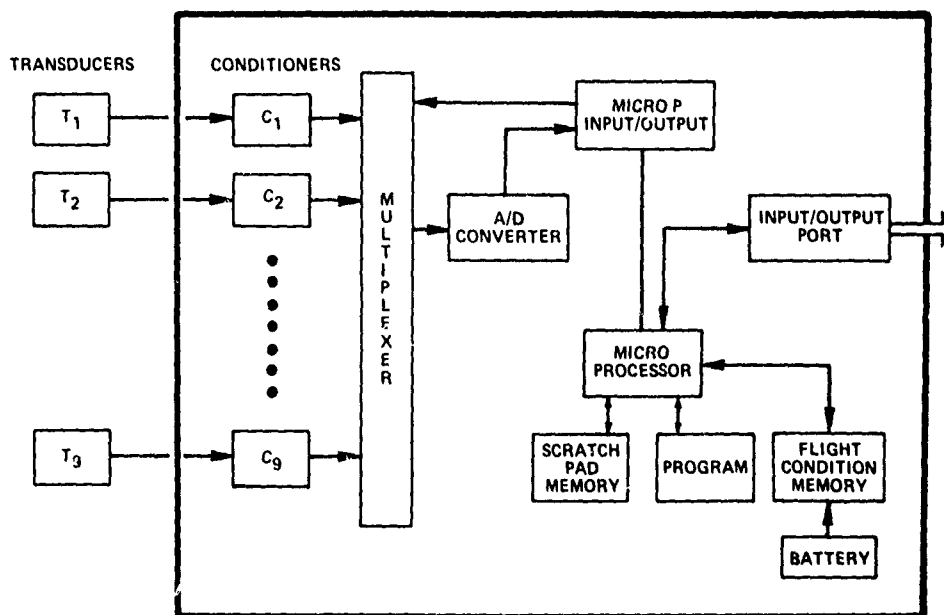


Figure 11. Schematic of Structural Integrity Recorder.

TABLE 15. SIRS PARAMETERS

<u>Measured</u>	<u>Computed</u>
Airspeed	Percent V_L Airspeed
Pressure Altitude	Percent V_H Airspeed
Outside Air Temperature	Density Altitude
Gross Weight	
Pitch Attitude	
Roll Attitude	
Engine Torque	
Main Rotor Speed	
Vertical Acceleration	
Touchdown	

TABLE 16. FLIGHT CONDITION CATEGORIES

<u>Title</u>	<u>Measured Quantity</u>		
	<u>Occurrences</u>	<u>Time</u>	<u>Measured Value</u>
Flight Time		*	
Rotor Start/Stop	*		
Full Power Climb		*	
Low-Speed Flight		*	
High-Speed Flight		*	
Maximum-Speed Flight		*	
Normal High-Speed Turns		*	
Gunnery Turns		*	
Gunnery S-Turns		*	
Gunnery Run Dives-Symmetrical		*	
-Asymmetrical		*	
Symmetrical Pullouts		*	
Asymmetrical Pullouts		*	
High n_z Maneuvers	*		
Normal Landings	*		
Autorotation Time		*	
Autorotation Turns		*	
Autorotation to Power			
Transition	*		
Autorotation Landings	*		
Quick-Stop Deceleration		*	
Maximum % V_L			*
Maximum n_z			*

incorporates dual batteries with a one-year operational capacity to retain the stored data when aircraft power is turned off. The recorder software package is listed in Appendix B.

The recorder installation, including recorder, shock mount, transducers, and harnesses, weighs 20.3 pounds; a detailed breakdown of the installation's weight is presented in Table 17. The recorder, including mounting rack and electromagnetic-interference-shielded connector, is 17.50 inches long, 6.50 inches wide, and 10.15 inches high; these dimensions include the necessary space for recorder/shock mount sway. The recorder operates on 28 Vdc supplied by the aircraft and consumes approximately 7 watts.

RETRIEVAL UNIT

SIRS is designed so that data need be retrieved only once a month by the portable, flight-line data retrieval unit pictured in Figure 12. During the transcription of the recorder data onto the miniature magnetic tape cassette, the operator interacts with the unit. While the unit displays messages, the operator communicates with the unit through a keyboard. Because of the on-board processing of the flight data, the data recorded during the normal monthly operation of more than 50 helicopters can be stored on a single data cassette. The program used to permit retrieval unit and recorder interactions is called the Initial Processing System (IPS). The data retrieval, including setup, takes less than 5 minutes and can be performed on a flexible schedule. In addition to data retrieval, the data retrieval unit performs diagnostic checks of the recorder, on-board recorder battery, and transducers. It can also be used as a readout device during the transducer calibrations.

During the retrieval process, limited operator inputs listed in Table 18 are requested to supplement data contained within the recorder. The aircraft serial number is entered in the format of fiscal year and aircraft number, xx-xxxxx, and supplements the recorder serial number, which is permanently stored electronically within the recorder. Since retrievals are not performed on a fixed schedule, the retrieval data, in the format of day, month, and year, is another entry; this information is used to indicate trends in the retrieval data. The chronology of the data is identified by a numbering device built into the recorder that increments each time a retrieval is made. Logbook flight hours are entered to track the variation between the actual flight and ground-operating time and the logged time. The operating base is entered to permit analyzing the fleet-wide variation in helicopter usage. Finally, as requested by the display, the operator enters the reason for the data retrieval. There are three acceptable reasons: monthly retrieval, component replacement, and re-

6
B

TABLE 17. SIRS RECORDER WEIGHT BREAKDOWN

<u>Component</u>	<u>Weight (lb)</u>
Recorder/Rack	9.25
Airspeed/Altitude Transducer and Brackets	1.6
OAT	0.07
Vertical Acceleration Transducer and Bracket	1.2
Gross Weight Transducer and Bracket	0.14
Harnesses and misc. hardware	<u>8.0</u>
Total	20.26

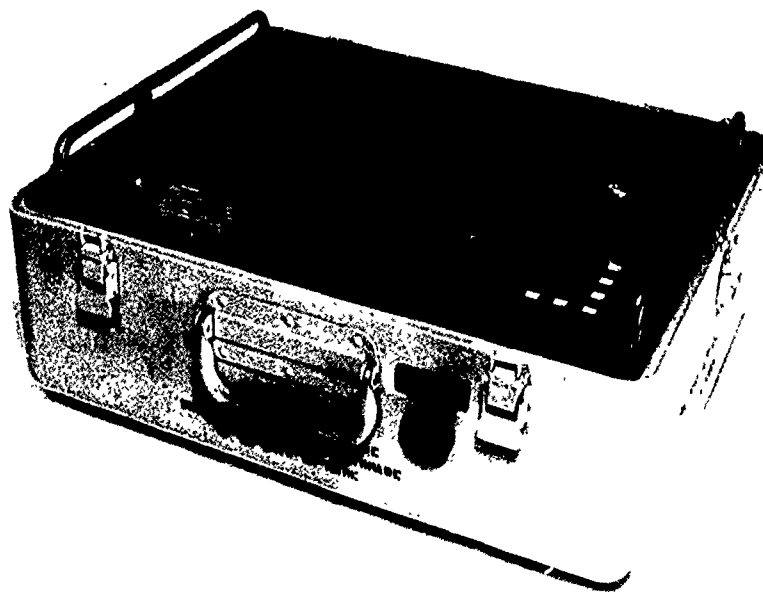


Figure 12. SIRS Retrieval Unit.

corder maintenance. After the operator enters the supplemental data, the data retrieval unit performs a diagnostic check of the recorder including its memory, makes a copy of the recorder data residing in memory, and records the current static values of each of the transducers. These data, together with the supplemental data previously entered by the operator, are recorded on the miniature magnetic tape cassettes. Each time the data is transferred, that is, from the memory in the recorder to that in the data retrieval unit and from the latter to the cassette, it is checked to verify the validity of the transfer.

TABLE 18. SIRS RETRIEVAL UNIT OPERATOR INPUTS

Aircraft Serial Number	Base of Operation
Date of Retrieval	Reason for Retrieval
Log Book Flight Hours	

The various error messages listed in Table 19 are displayed when the diagnostic check detects recorder deficiencies, when data cannot be retrieved or written on the tape cassette, or when the tape cassette is not installed or is full. Each coded error message (instructions for each are mounted inside the cover of the data retrieval unit) leads the operator to the necessary corrective action.

The data retrieval unit is 19.1 inches long, 15.6 inches wide, and 9.8 inches high and weighs 45.4 pounds. The retrieval unit has a rechargeable power system and is housed in a flight-line styled container. The recharging power required is 110 to 120 Vac, 60 Hz.

SOFTWARE

Upon receiving the data from the miniature cassettes, the software system first performs an initial data processing to (1) verify the recorder operation and transducer functioning and (2) to review the long-term trend of the transducer static readings, and then analyzes the data. The analysis includes the data segregation by specific flight condition categories, the data conversion to a 100-flight-hour basis, and the data presentation in terms of a usage spectrum. An example of this data presentation is shown in Figure 13. Next the software system governs three techniques to further analyze the data by calculating the incremental fatigue damage for each critical tracked component. The first technique is based on the relationship of the recorder data with the SIRS fatigue model developed for the AH-1G helicopter. In the second technique the calculations are based on the rates established by current Army-approved component replacement times and the logbook flight hours. The third technique is the same as the second

SIRS SPECTRUM USAGE

AIRCRAFT: 66-15254 LOG TIME: 1985.6 RETRIEVAL DATE: 50477 REASON: SCHEDULED
 RECORDER: 1030 BASE: 1
 DELTA LOG TIME: 1.0 HOURS
 VALUES PER 100 HOURS WERE COMPUTED USING THE RETRIEVAL TIME.

FLIGHT CONDITION	GROSS WEIGHT (LR)	TIME (HOURS)		OCCURRENCE	
		RETRIEVAL	PER 100 HOURS	RETRIEVAL	PER 100 HOURS
FLIGHT TIME	TOTAL	0.9	100.0		
1	<7750	0.5	56.9		
2	7750-8750	0.4	43.1		
3	>8750	0.0	0.0		
ROTOR CYCLES	TOTAL			1	113.8
4				1	113.8
QUICK STOPS	TOTAL	0.0	0.0		
5	<7750	0.0	0.0		
6	7750-8750	0.0	0.0		
7	>8750	0.0	0.0		
NORMAL LDGS	TOTAL			1	113.8
8	<7750			1	113.8
9	7750-8750			0	0.0
10	>8750			0	0.0
LOW SPEED FLT	TOTAL	0.0	4.3		
11	<7750	0.0	0.4		
12	7750-8750	0.0	3.9		
13	>8750	0.0	0.0		
HIGH SPEED FLT	TOTAL	0.5	52.6		
14	<7750	0.3	29.5		
15	7750-8750	0.2	23.1		
16	>8750	0.0	0.0		
MAX SPEED FLT	TOTAL	0.0	3.7		
17	<7750	0.0	1.7		
18	7750-8750	0.0	2.0		
19	>8750	0.0	0.0		
HIGH TORQUE FLT	TOTAL	0.0	0.0		
20	<7750	0.0	0.0		
21	7750-8750	0.0	0.0		
22	>8750	0.0	0.0		
LOW SPEED TURNS	TOTAL	0.0	0.0		
23	<7750	0.0	0.0		
24	7750-8750	0.0	0.0		
25	>8750	0.0	0.0		

Figure 13. Sample of Spectrum Generated by SIRS Software.

SIRS SPECTRUM USAGE

AIRCRAFT: 66-15254 LOG TIME: 1985.6 RETRIEVAL DATE: 50477 REASON: SCHEDULED
 RECORDER: 1030 BASE: 1
 DELTA LOG TIME: 1.0 HOURS
 VALUES PER 100 HOURS WERE COMPUTED USING THE RETRIEVAL TIME.

FLIGHT CONDITION	GROSS WEIGHT (LB)	TIME (HOURS) RETRIEVAL	PER 100 HOURS	OCCURRENCE RETRIEVAL	PER 100 HOURS
-----	-----	-----	-----	-----	-----
HIGH SPEED TURNS	TOTAL	0.1	8.3		
26	<7750	0.1	7.0		
27	7750-8750	0.0	1.2		
28	>8750	0.0	0.0		
LOW SPEED DIVES	TOTAL	0.0	0.0		
29	<7750	0.0	0.0		
30	7750-8750	0.0	0.0		
31	>8750	0.0	0.0		
MED SPEED DIVES	TOTAL	0.0	0.3		
32	<7750	0.0	0.2		
33	7750-8750	0.0	0.2		
34	>8750	0.0	0.0		
HIGH SPEED DIVES	TOTAL	0.0	0.1		
35	<7750	0.0	0.0		
36	7750-8750	0.0	0.1		
37	>8750	0.0	0.0		
MAX SPEED DIVES	TOTAL	0.0	0.0		
38	<7750	0.0	0.0		
39	7750-8750	0.0	0.0		
40	>8750	0.0	0.0		
LOW SPD ASYM P/U	TOTAL	0.0	0.0		
41	<7750	0.0	0.0		
42	7750-8750	0.0	0.0		
43	>8750	0.0	0.0		
MED SPD ASYM P/U	TOTAL	0.0	0.0		
44	<7750	0.0	0.0		
45	7750-8750	0.0	0.0		
46	>8750	0.0	0.0		
HI SPD ASYM P/U	TOTAL	0.0	0.0		
47	<7750	0.0	0.0		
48	7750-8750	0.0	0.0		
49	>8750	0.0	0.0		
MAX SPD ASYM P/U	TOTAL	0.0	0.0		
50	<7750	0.0	0.0		
51	7750-8750	0.0	0.0		
52	>8750	0.0	0.0		

Figure 13. Continued

SIRS SPECTRUM USAGE

AIRCRAFT: 66-15254 LOG TIME: 1985.6 RETRIEVAL DATE: 50477 REASON: SCHEDULED
 RECORDER: 1030 RASE: 1
 DELTA LOG TIME: 1.0 HOURS
 VALUES PER 100 HOURS WERE COMPUTED USING THE RETRIEVAL TIME.

FLIGHT CONDITION	GROSS WEIGHT (LB)	TIME (HOURS) RETRIEVAL	PER 100 HOURS	OCCURRENCE RETRIEVAL	PER 100 HOURS
-----	-----	-----	-----	-----	-----
LOW SPD SYM P/U	TOTAL	0.0	0.0		
53	<7750	0.0	0.0		
54	7750-8750	0.0	0.0		
55	>8750	0.0	0.0		
MED SPD SYM P/U	TOTAL	0.0	0.0		
56	<7750	0.0	0.0		
57	7750-8750	0.0	0.0		
58	>8750	0.0	0.0		
HIGH SPD SYM P/U	TOTAL	0.0	0.0		
59	<7750	0.0	0.0		
60	7750-8750	0.0	0.0		
61	>8750	0.0	0.0		
LOW SPD GUN TURN	TOTAL	0.0	0.0		
62	<7750	0.0	0.0		
63	7750-8750	0.0	0.0		
64	>8750	0.0	0.0		
MED SPD GUN TURN	TOTAL	0.0	0.0		
65	<7750	0.0	0.0		
66	7750-8750	0.0	0.0		
67	>8750	0.0	0.0		
HI SPD GUN TURN	TOTAL	0.1	5.9		
68	<7750	0.0	0.8		
69	7750-8750	0.0	5.1		
70	>8750	0.0	0.0		
GUN 3-TURN	TOTAL	0.0	4.4		
71	<7750	0.0	4.4		
72	7750-8750	0.0	0.0		
73	>8750	0.0	0.0		
MAX SPD 3-TURN	TOTAL	0.0	0.0		
74	<7750	0.0	0.0		
75	7750-8750	0.0	0.0		
76	>8750	0.0	0.0		
AUTO TIME	TOTAL	0.0	2.1		
77	<7750	0.0	2.1		
78	7750-8750	0.0	0.0		
79	>8750	0.0	0.0		

Figure 13. Continued

SIRS SPECTRUM USAGE

AIRCRAFT: 66-15254 LOG TIME: 1985.6 RETRIEVAL DATE: 50477 REASON: SCHEDULED
 RECORDER: 1030 BASE: 1
 DELTA LOG TIME: 1.0 HOURS
 VALUES PER 100 HOURS WERE COMPUTED USING THE RETRIEVAL TIME.

FLIGHT CONDITION	GROSS WEIGHT (LB)	TIME (HOURS)		OCCURRENCE	
		RETRIEVAL	PER 100 HOURS	RETRIEVAL	PER 100 HOURS
LOW NZ AUTO/PWR	TOTAL			0	0.0
80	<7750			0	0.0
81	7750-8750			0	0.0
82	>8750			0	0.0
HIGH NZ AUTO/PWR	TOTAL			0	0.0
83	<7750			0	0.0
84	7750-8750			0	0.0
85	>8750			0	0.0
LOW NZ AUTO TURN	TOTAL	0.0	0.0		
86	<7750	0.0	0.0		
87	7750-8750	0.0	0.0		
88	>8750	0.0	0.0		
HI NZ AUTO TURN	TOTAL	0.0	0.0		
89	<7750	0.0	0.0		
90	7750-8750	0.0	0.0		
91	>8750	0.0	0.0		
AUTO LOGS	TOTAL			0	0.0
92	<7750			0	0.0
93	7750-8750			0	0.0
94	>8750			0	0.0
95	HIGH NZ COUNTER	12			
96	MAX NZ VALUE	2.4			
97	MAX A/S VALUE	1.0			

Figure 13. Concluded

except that the recorder flight time is used instead of the logbook flight time. Figure 14 is a sample of the format used in presenting the data calculated by each technique. The software package permitting these calculations is called the Fatigue Damage Assessment System (FDAS).

TABLE 19. RETRIEVAL UNIT ERROR MESSAGES

LINE ABORT?	-	Denotes that the retrieval unit-to-recorder communications were not properly established or were interrupted.
DATA ABORT?	-	Denotes that there was an error condition during the transmission of the recorder data onto the retrieval unit's temporary data-storage memory.
WRITE ABORT?	-	Denotes that there was an error condition during the data writing on the magnetic tape.
FULL ABORT?	-	Denotes that sufficient space could not be found on the magnetic tape for the data writing.
TAPE ABORT?	-	Denotes that the tape cassette is not capable of reading or writing because of its malfunctioning or improper positioning.
COUNTER	-	Denotes that a bad memory location was detected during the diagnostic check of the recorder's data storage memory.
BATTERY	-	Denotes that the recorder's battery power supply is marginal.

Software Concept

The data processing and management system is composed of three parts: the Initial Processing System (IPS), the Fatigue Damage Assessment System (FDAS), and the Component Tracking Management System (CTMS). Each of the three modules of the system was treated and designed as a separate entity. This allows for ease of maintenance of the system and flexibility in the operation of the system.

COMPONENT DAMAGE

AIRCRAFT: 66-15254 LOG TIME: 1985.6 RETRIEVAL DATE: 50477 REASON: SCHEDULED
 RECORDER: 1030 BASE: 1
 DELTA LOG TIME: 1.0 HOURS
 DELTA RECORDER TIME: 0.9 HOURS

COMPONENT	SIRS DAMAGE	FLIGHT HOUR DAMAGE RECORDER	LOG
MAIN ROTOR BLADE	0.00072	0.00080	0.00091
MAIN ROTOR YOKE EXTENSION	0.00035	0.00027	0.00030
MAIN ROTOR GRIP	0.0	0.00009	0.00010
MAIN ROTOR PITCH HORN	0.00002	0.00013	0.00015
RETENTION STRAP FTG/NUT	0.00009	0.00040	0.00045
SWASHPLATE DRIVE LINK	0.00007	0.00008	0.00009
SWASHPLATE OUTER RING	0.00004	0.00027	0.00030
SWASHPLATE INNER RING	0.00010	0.00027	0.00030
HYDRAULIC BOOST CYLINDER	0.00010	0.00027	0.00030
TAIL ROTOR BLADE	0.00017	0.00080	0.00091

Figure 14. Sample of Component Damage Generated by SIRS Software.

The first two modules, IPS and FDAS, were written in FORTRAN in accordance with contract requirements, but the CTMS was written in COBOL. This was done to maintain a uniformity with the data management techniques being employed by the AVRADCOM computer center. This was in the best interest of the Government, since AVRADCOM is postulated as the eventual user of the system and the development was to be performed on AVRADCOM equipment.

The development was to take place by utilizing a Remote Job Entry terminal located at Technology Incorporated and connected to the AVRADCOM computer via a dial-up communication link.

The following paragraphs briefly describe the main functions of the three modules, and Figures 15, 16, and 17 present system flow.

IPS. The Initial Processing System checks for proper operation of the recorder, the recording medium, and the retrieval unit. This is performed in a number of ways; initially, the IPS checks the parity of the data and the results of the built-in test. The data from the individual counters are then tested for validity to assure that they are within reasonable tolerances.

If the data or any part thereof are determined to be invalid, conservative estimates based on past usage and engineering judgment are made for the erroneous data.

The valid data and/or the estimated data from the various counters are then written on an output tape and identified as actual or estimated for further processing. A printout identifying any equipment problems is also prepared for submission to the appropriate activity.

FDAS. The Fatigue Damage Assessment System takes each of the forwarded counter values and assigns a damage value to each component according to the model established for the monitored aircraft type. The actual and estimated incremental damages are kept separate for each component.

A data tape is then written and forwarded for further processing. This tape contains the actual or estimated incremental damage for each component type, identified by aircraft serial number. The date of the data is also forwarded.

CTMS. The Component Tracking Management System is the main data management module of the overall system. Its primary function is to update and maintain two tracking files and to generate data reports for field and management usage.

The programs take the data passed on from the FDAS and check the date, in case of removal, to determine with which components the data is associated. The appropriate component's damage fraction is then updated, still retaining the identity of the actual and estimated parts.

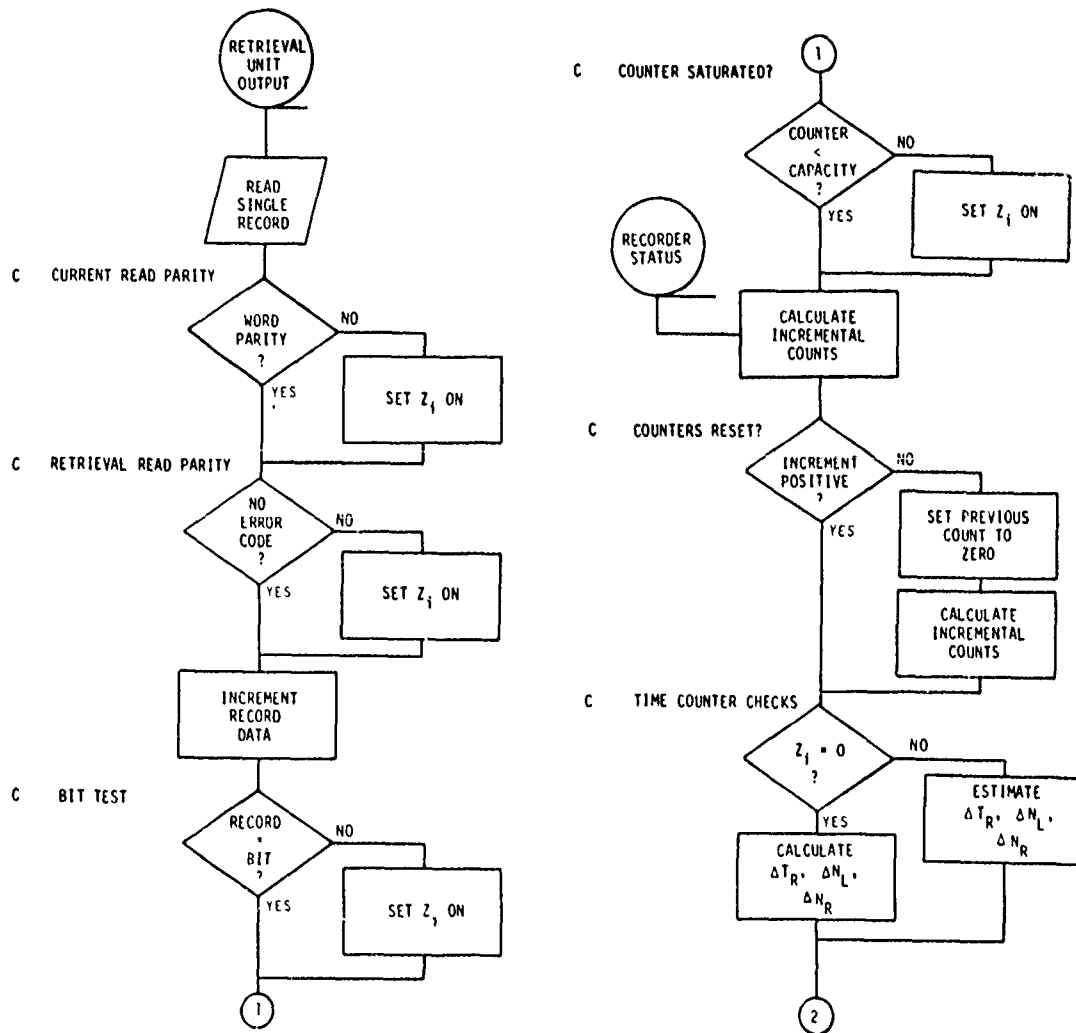


Figure 15. Flow Chart of IPS Processing.

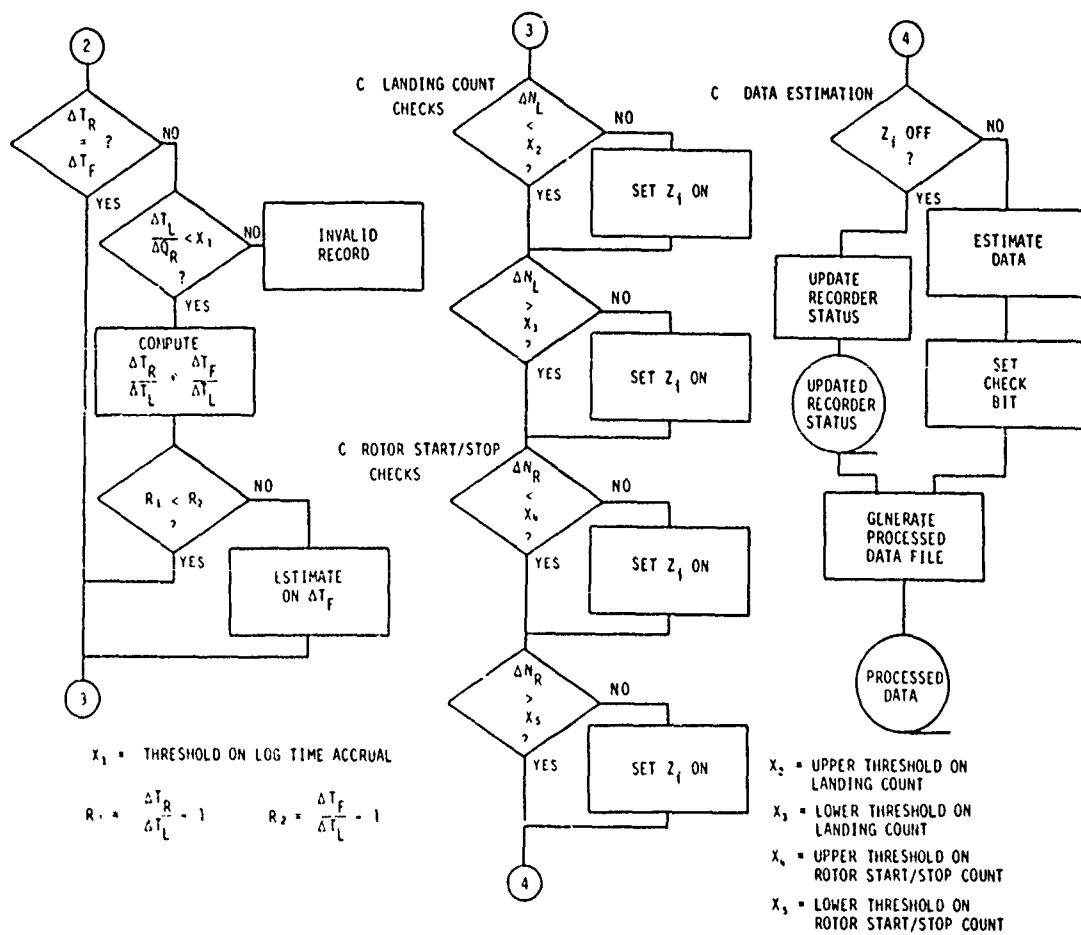


Figure 15. Concluded

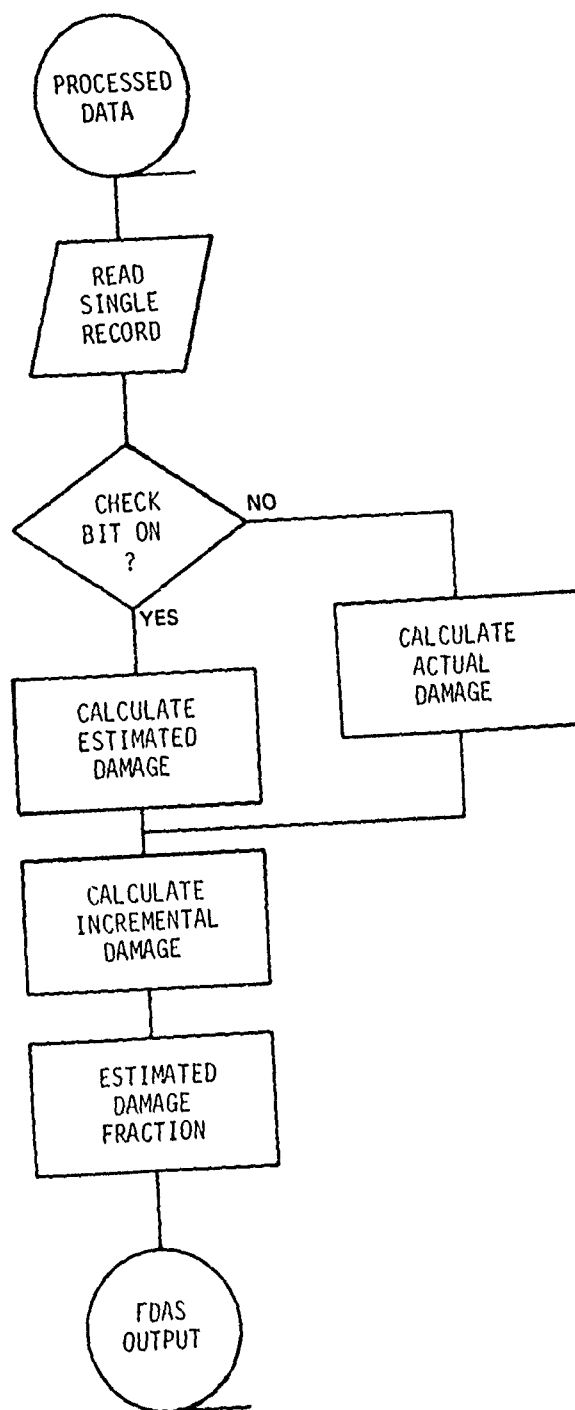


Figure 16. Flow Chart of FDAS Processing.

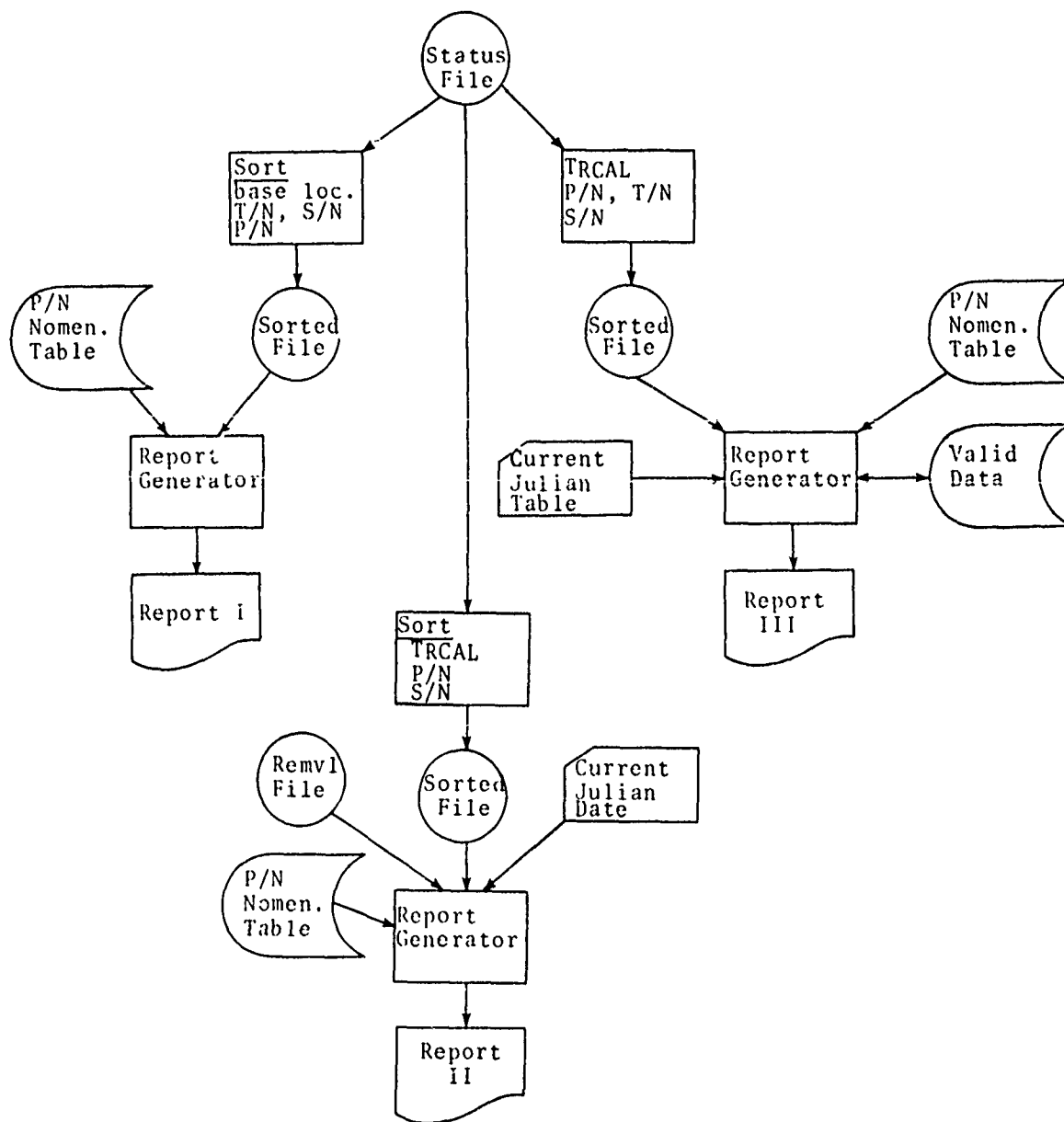


Figure 17. Report Generation Processing.

The status file is then updated with the new damage fractions. The status file contains the historical information concerning each aircraft. This includes the configuration of each aircraft and the time and damage fraction associated with each fatigue-critical component. It is from this file that the majority of the data reports are generated.

A secondary file, the removal file, is maintained for all removed components. This file is used to provide statistical information on removals and to track components removed for overhaul or for other reasons.

It is from these files that the various data reports are generated. Figures 18, 19, and 20 give samples of the reports that will be presented. The reports deal with status of the various components once a certain damage fraction is attained, life projections over selected periods of time, and component replacements due or overdue. The reports will be used for maintenance, management, and planning.

Supplemental Data. In the event of component removals, a supplemental update form (Figure 21) will be completed. This data will be entered into the FDAS to ensure the proper accountability and tracking of the various components.

INSTALLATION KIT

The SIRS recording system was married to the AH-1G airframe via an installation kit consisting of miscellaneous structural hardware, cabling, and specialized instruments. All of the mounting systems were designed to withstand crash loads. This discussion focuses on the sensor suite providing the inputs to the recorder.

The remote sensors required to obtain the data are grouped into the following four categories:

- Pressure transducers
- Accelerometers
- Position potentiometers
- Miscellaneous sensors

Pressure Transducers

The pressure transducers are capacitive type, providing a 0-5 Vdc output signal. For airspeed, a differential pressure transducer that senses the difference between the pitot and static pressures is used. For altitude, an absolute pressure transducer senses the aircraft static pressure.

Accelerometers

The transducer used to sense the normal (vertical) acceleration is a servo force balance type providing a 0-5 Vdc output signal.

 * SELECTED COMPONENT STATUS *
 * DAMAGE FRACTION GREATER THAN 0.7 *

A/C TYPE/MODEL: CH-47C
 AIRCRAFT NO: 66-13145
 BASE: FT RUCKER
 DATA THRU: 05/01/74
 REPORT DATE: 05/15/74

COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	COMPONENT SERIAL NUMBER	DAMAGE ACCURAL RATE	DAMAGE FRACTION	PERCENTAGE OF DAMAGE FRACTION ESTIMATED	REMAINING LIFE (HRS)	REPLACEMENT DATE JULIAN DATE
114R2196-2	PIN HORIZONTAL HINGE	PL593	.00034 P	0.971	3.2	0	74130 ***
114R1543-4	BLADE SOCKET ROTOR HUB	7-5669-1	.00063 P	0.891	4.1	94	74176 *
114R2155	TIE BAR AFT ROTOR HUB	W-411-0	.00056 S	0.733	0.9	388	74330
114R1502-33	ROTOR BLADE, AFT	5988413	.00074 T	0.784	2.7	224	74217 *
114R1543-3	BLADE SOCKET, FWD HUB	67-33921	.00042 P	0.716	1.4	557	74053
11403250	AFT ROTOR SHAFT	5L-41194	.00055 T	0.711	3.2	435	74348

*** THIS MAJOR COMPONENT HAS REACHED OR EXCEEDED 0.95 DAMAGE AND REPLACEMENT IS OVERDUE
 * THIS MAJOR COMPONENT IS DUE FOR REPLACEMENT IN 0-3 MONTHS
 P - DAMAGE ACCURAL RATE BASED ON DATA FROM THE PREVIOUS MONTH
 S - DAMAGE ACCURAL RATE BASED ON DATA FROM THE PREVIOUS 6 MONTHS
 T - DAMAGE ACCURAL RATE BASED ON TOTAL PREVIOUS DATA

Figure 18. Report I, Selected Component Status.

 *
 * SELECTED COMPONENT *
 * USEFUL LIFE PROJECTIONS *

A/C TYPE: CH-47C
 BASE: FT RUCKER
 DATA PERIOD: JAN-MAR 1974
 REPORT DATE: 05/15/74

COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	REMOVALS LAST QUARTER	PROJECTED REMOVALS FOR 0-3 MONTHS	PROJECTED REMOVALS FOR 0-12 MONTHS	PROJECTED REMOVALS FOR 12-15 MONTHS	PROJECTED REMOVALS FOR 12-24 MONTHS
114R2050	HEAD ASSY (HUB) - ROTARY	13	20	87	30	186
114R2196-2	PIN HORIZONTAL HINGE	54	63	274	110	572
114R2088	PITCH SHAFT AFT ROTOR	49	58	289	131	593
114R1543-4	BLADE SOCKET AFT ROTOR	79	50	265	99	509
114R2155	TIE BAR AFT ROTOR HUB	58	56	256	147	388
114R1502-33	AFT ROTOR BLADE	53	61	269	125	587
114D3250	AFT ROTOR SHAFT	18	22	90	41	232
114R2197	PITCH SHAFT FWD HUB	56	62	257	115	568
114R2155	TIE BAR FWD ROTOR HUB	56	53	263	122	611
114R1543-3	BLADE SOCKET FWD HUB	59	60	272	143	556

Figure 19. Report II, Selected Component Removal Projections.

***** * * REPLACEMENTS DUE 0-3 MONTHS * *****					
A/C TYPE/MODEL: CH-47C DATA PERIOD: MAY-JULY 1974 REPORT DATE: 05/15/74					
COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	COMPONENT SERIAL NUMBER	A/C NO.	BASE	REMOVAL DATE
-----	-----	-----	-----	-----	-----
114R2088	PITCH SHAFT AFT ROTOR	M5421	68-43110	FT RUC	05/30/74
114R2088	PITCH SHAFT AFT ROTOR	C4701	67-55462	FT RUC	06/15/74
114R1543-4	BLADE SOCKET AFT ROTOR	VY1022	67-22629	FT RUC	05/30/74
114R2196-2	PIN HORIZONTAL HINGE	A510	68-43110	FT RUC	06/03/74
114R2196-2	PIN HORIZONTAL HINGE	VY4149	67-55462	FT RUC	07/28/74
114R2155	TIE BAR AFT ROTOR HUB	PL248-14	68-43110	FT RUC	06/17/74
114R2155	TIE BAR AFT ROTOR HUB	A1244	67-22629	FT RUC	07/09/74
114R2155	TIE BAR FWD ROTOR HUB	VF0110	67-55462	FT RUC	07/13/74
114R1502-33	AFT ROTOR BLADE	A913	67-55462	FT RUC	06/23/74
114R1502-33	AFT ROTOR BLADE	A84277	68-43110	FT RUC	07/14/74
114R2197	PITCH SHAFT FWD HUB	NL11740	67-22629	FT RUC	07/05/74
114R1543-3	BLADE SOCKET FWD HUB	VE20112	67-55462	FT RUC	07/15/74

Figure 20. Report III, Replacements Due in 0-3 Months,
by Component Number.

 *
 * REPLACEMENTS DUE 0-3 MONTHS *
 *

A/C TYPE/MODEL: CH-47C
 DATA PERIOD: MAY-JULY 1974
 REPORT DATE: 05/15/74

A/C NUMBER	BASE	COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	COMPONENT SERIAL NUMBER	REMOVAL DATE
67-22629	FT RUC	114R1543-4	BLADE SOCKET AFT ROTOR	VV1022	05/30/74
67-22629	FT RUC	114R2197	PITCH SHAFT FWD HUB	NL11740	07/05/74
67-22629	FT RUC	114R2155	TIE BAR AFT ROTOR HUB	A1244	07/09/74
67-55462	FT RUC	114R2088	PITCH SHAFT AFT ROTOR	C4701	06/15/74
67-55462	FT RUC	114R1502-33	AFT ROTOR BLADE	A913	06/23/74
67-55462	FT RUC	114R2196-2	PIN HORIZONTAL HINGE	VY4149	07/28/74
67-55462	FT RUC	114R2155	TIE BAR FWD ROTOR HUB	VE0110	07/13/74
67-55462	FT RUC	114R1543-3	BLADE SOCKET FWD HUB	VEZ0112	07/15/74
68-43110	FT RUC	114R2088	PITCH SHAFT AFT ROTOR	M5421	05/30/74
68-43110	FT RUC	114R2196-2	PIN HORIZONTAL HINGE	A510	06/03/74
68-43110	FT RUC	114R2155	TIE BAR AFT ROTOR HUB	PL248-14	06/17/74
68-43110	FT RUC	114R1502-33	AFT ROTOR BLADE	A84277	07/14/74

Figure 20. Continued

 * OVERDUE REPLACEMENTS *

A/C TYPE/MODEL: CH-47C
 REPORT DATE: 05/15/74

COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	COMPONENT SERIAL NUMBER	A/C NO.	BASE	REMOVAL DATE
11403250	AFT ROTOR SHAFT	55-3104	67-22629	FT RUC	01/03/74
11403250	AFT ROTOR SHAFT	76299	68-43110	FT RUC	04/23/74
11403250	AFT ROTOR SHAFT	R2327	67-55462	FT RUC	05/01/74
114R2088	PITCH SHAFT AFT ROTOR	VZ10043	65-10143	FT RUC	03/03/74
114R2089	PITCH SHAFT AFT ROTOR	L439218	67-22629	FT RUC	03/28/74
11472050	HEAD ASSY (HUB) - ROTARY	EX124	66-05372	FT RUC	03/18/74
114R1502-33	AFT ROTOR BLADE	4-316-9	66-05372	FT RUC	04/10/74
114R1502-13	AFT ROTOR BLADE	4438	67-22629	FT RUC	05/01/74
114R2155	TIE BAR FWD ROTOR HUB	LR431	65-10143	FT RUC	04/11/74
114R2155	TIE BAR FWD ROTOR HUB	A6464	66-05372	FT RUC	04/30/74
114R2196-7	PIN HORIZONTAL HINGE	VA4335	65-10143	FT RUC	04/23/74
114R2197	PIN HORIZONTAL HINGE	JU52030	66-05372	FT RUC	05/02/74

Figure 20. Continued

A/C TYPE/MODEL: CH-47C REPORT DATE: 05/15/74				***** * OVERDUE REPLACEMENTS * *****			
A/C NUMBER	BASIC	COMPONENT PART NUMBER	COMPONENT NOMENCLATURE	COMPONENT SERIAL NUMBER	REMOVAL DATE		
65-10143	FT RUC	114R2088	PITCH SHAFT AFT ROTOR	VZ10043	03/03/74		
65-10143	FT RUC	114R2155	TIE BAR FWD ROTOP HUB	LN431	04/11/74		
65-10143	FT RUC	114R2196-2	PIN HORIZONTAL HINGE	VA4335	04/23/74		
66-05372	FT RUC	114R2050	HEAD ASSY (HUB) ROTARY	EX124	03/18/74		
66-05372	FT RUC	114R102-33	AFT ROTOR BLADE	4-316-9	04/10/74		
66-05372	FT RUC	114R2155	TIE BAR FWD ROTOP HUB	A6464	04/30/74		
66-05372	FT RUC	114D3250	AFT ROTOP SHAFT	R2327	05/01/74		
66-05372	FT RUC	114R2197	PIN HORIZONTAL HINGE	JU52038	05/02/74		
67-22629	FT RUC	114D3250	AFT ROTOR SHAFT	55-3104	01/03/74		
67-22629	FT RUC	114R2088	PITCH SHAFT AFT ROTOR	L439218	03/28/74		
67-22629	FT RUC	114R1502-33	AFT ROTOR BLADE	4338	05/01/74		
68-43110	FT RUC	114D3250	AFT ROTOR SHAFT	T6299	04/23/74		

Figure 20. Concluded

U.S. ARMY CRITICAL PARTS MANAGEMENT PROGRAM
FATIGUE-CRITICAL COMPONENT REPLACEMENT FORM

BASE: >			A/C TAIL NO. >			A/C TYPE/MODEL >		
REPLACEMENTS ACCOMPLISHED			REASON REMOVED (X)					
A/C HOURS	MO/DAY/YEAR	MECHANIC	TIME EXPIRED	FAILED	PRE-CAUTION	MOD	SERVICE	
			1	2	3	4	5	
C O M P O N E N T S	REMOVED PART P/N _____		S/N _____					
	INSTALLED PART P/N _____		S/N _____					
	TSN: _____		TSO: _____					
	REMARKS:							

Figure 21. Update Form for Component Removals.

Flight Control Positions

To sense rudder pedal position, an infinite resolution potentiometer is used. This unit is wired such that the potentiometer acts as two arms of a Wheatstone bridge circuit. Connected by special actuators to the control linkage, this potentiometer senses the movement of the respective control system. The mechanical attachments between the potentiometer and the control linkages are designed so that binding of the mechanisms will cause them to fail; hence, control of the helicopter cannot be inhibited by the instrumentation system.

Miscellaneous Sensors

Several parameters either require sensing the aircraft's flight instruments or cannot be placed in one of the above categories. The following paragraphs discuss these sensors.

Outside Air Temperature. The outside air temperature is monitored with a thermal ribbon. The ribbon is attached to, but insulated from, the outer skin of the aircraft. The ribbon is a resistor whose resistance varies with the temperature and is used as the active arm of a Wheatstone bridge circuit.

Rotor Speed. To monitor the main rotor rpm, a special circuit was designed and fabricated. The circuit is composed of all solid-state materials and is mounted on a printed circuit board within the signal conditioning section of the recorder. The output of the counter controls a gate which varies a +5 Vdc circuit between +5 Vdc and ground. The resultant voltage is filtered and reduced to a pure dc signal acceptable to the recorder.

Engine Torque. Engine torque data is acquired from the aircraft's torque transmitter by utilizing a differential amplifier input circuit for isolation and a converter to condition the torque signal. The initial signal is a fixed-frequency, varying amplitude, engine torque signal that is converted to an appropriate dc signal. Variations in this signal due to changes in the torque reference are nullified by monitoring the reference and having the recorder perform a division.

Roll and Pitch Attitudes. Attitude data is obtained from the roll and pitch outputs of the aircraft's attitude gyro. This interface uses solid-state, modular, synchro-to-dc converters with the reference and synchro inputs fully isolated to prevent any degradation of the aircraft's attitude indicator system.

Gross Weight (GW) Indicator. The parameters to compute the gross weight of the helicopter were originally measured prior to each takeoff by two Kistler Morse Model DMC-3-FF-4-1-03 piezoelectric beam sensors attached to the midpoint of the fore-and-aft crosstube members of the skid landing gear. While the helicopter was on the ground the rotor speed was less than 250 rpm, the SIRS recorder processed the sensor outputs to yield the gross weight. An algorithm incorporated in the recorder decreased the gross weight value as fuel was burned. No adjustment was made for the decrease in gross weight due to stores or ammunition dispensing. When this procedure was found inadequate, another approach was used.

The second GW sensor system involved bonding strain gauges to the lift links' transmission mounting members. This was intended to give positive, real-time GW data.

Power and Signal Interconnections

A system wiring harness includes all wiring between the recorder, remote sensors, and aircraft power. The 28 Vdc is acquired by installing circuit breakers in the pilot's right-hand breaker panel and connecting to the nonessential dc bus.

CHAPTER 4.

TEST PROGRAM

A test program was conducted to evaluate the concept of flight condition recording as a means of collecting usage spectrum data. The test program consisted of five elements.

- Brassboard Evaluation
- Laboratory Qualification Testing
- Reliability Analysis
- Prototype Flight Test
- Usage Spectrum Data Collection

Brassboard Evaluation

From the outset, critical elements of SIRS were identified for early testing. The final product was quite close to the original conception.

On-Board Recorder. The recorder circuit can be functionally divided into two primary sections, analog and digital. The analog section consisted of a reference voltage source, individual circuits for each input parameter, and the A/D multiplexer. The digital section consisted of the processor system (CPU, memory, serial and parallel I/O ports), a timing circuit, address decoding, power fail-restart, and an aircraft power-to-battery switchover circuit.

Analog circuits for engine torque, temperature, roll attitude, the reference voltage, and A/D multiplexer circuits were provided. The circuit for the main rotor rpm is presented in Figure 22. The circuit for the outside air temperature measurement is presented in Figure 23. Figures 24 and 25 depict circuits used for various buffered circuits.

Preliminary tests of the digital section of the recorder provided FCC counter data to be stored in one MC5-101L-4 CMOS memory chip. Although satisfactory for the 36 flight condition categories presently defined, the possibility that gross weight considerations could double this number led to the suggestion that the digital printed circuit board layout should allow for the addition of a second memory chip. The brassboard configuration was modified to include the additional memory. Laboratory tests confirmed this to be satisfactory.

The flight recorder case size was to conform to Drive 404, 3/8 airborne transmitter rack. The case was constructed of 19-gauge (0.042") 0.1018 cold-drawn steel.

The finish applied to all steel parts was according to QQ-P-416 Type 2, Class 2 (chromium and chromate plating). All parts internal to the flight recorder with the exception of the power filter were mounted on the PC boards. The power

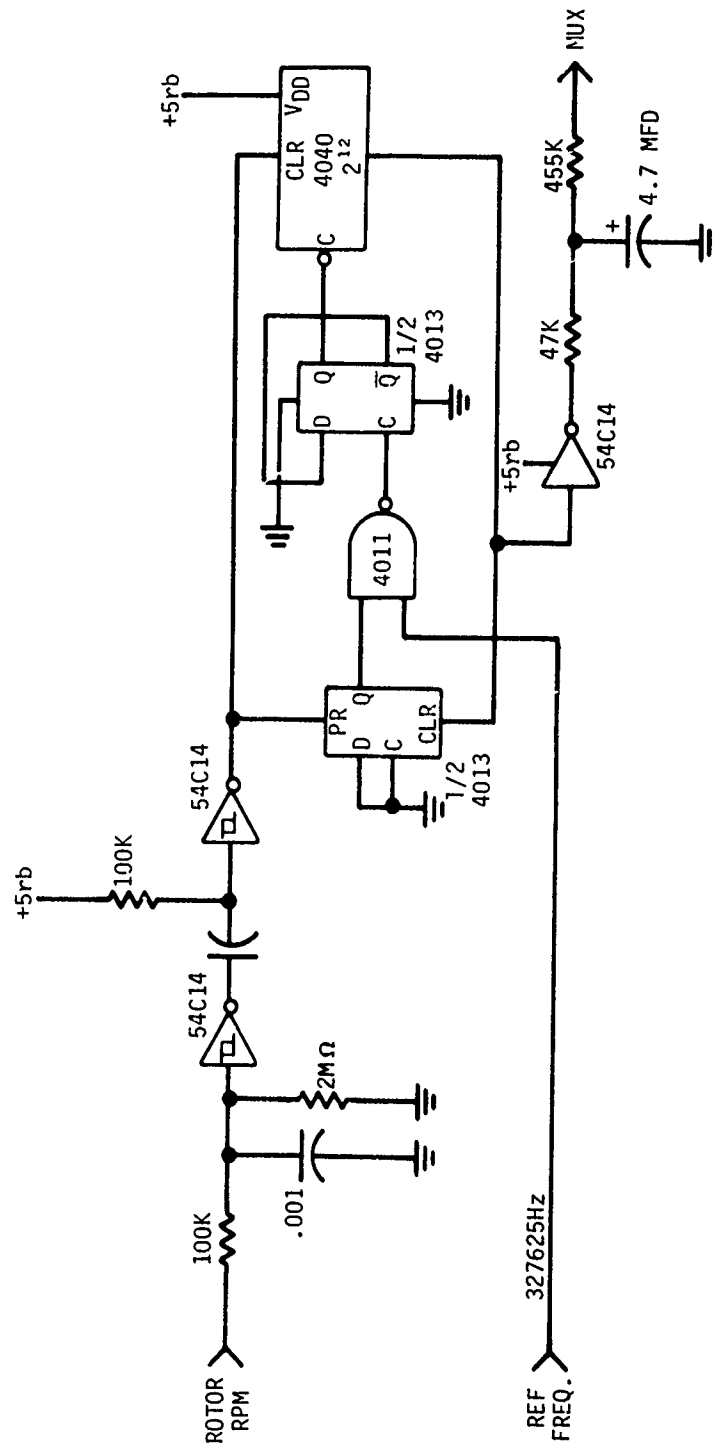
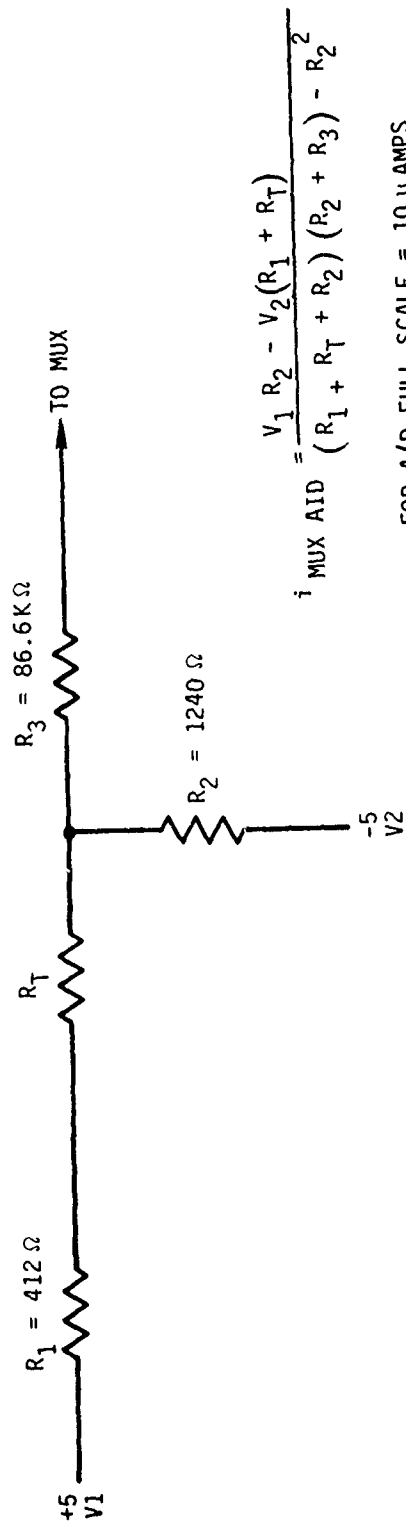


Figure 22. Rotor RPM Measurement.



$$i_{\text{MUX AID}} = \frac{V_1 R_2 - V_2 (R_1 + R_T)}{(R_1 + R_T + R_2) (R_2 + R_3) - R_2^2}$$

FOR A/D FULL SCALE = 10 μ AMPS

$$\text{A/D OUT} = i_{\text{MUX AID}} \times 100,000 \times 256$$

$$\text{A/D OUT} = i \times 25,600,000$$

FOR $R_1 = 412$, $R_2 = 1240$, $R_3 = 86.6 K$

$$V_1 = V_2 = 5.000 \text{ VDC}$$

$$\text{A/D OUT} = \frac{256 (828 - R_T)}{.17568 R_T + 287.14816}$$

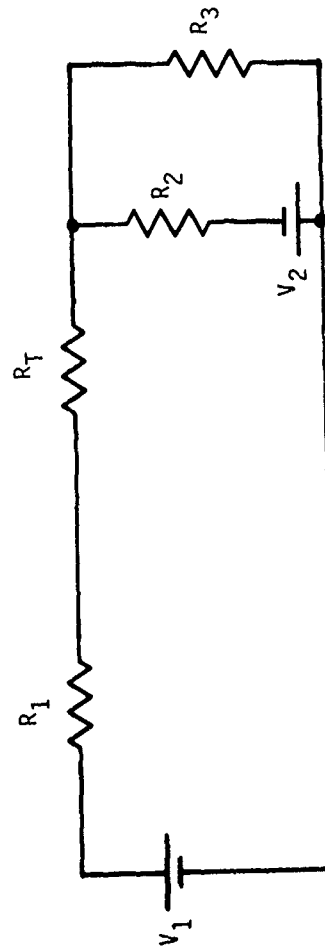


Figure 23. OAT Measurement.

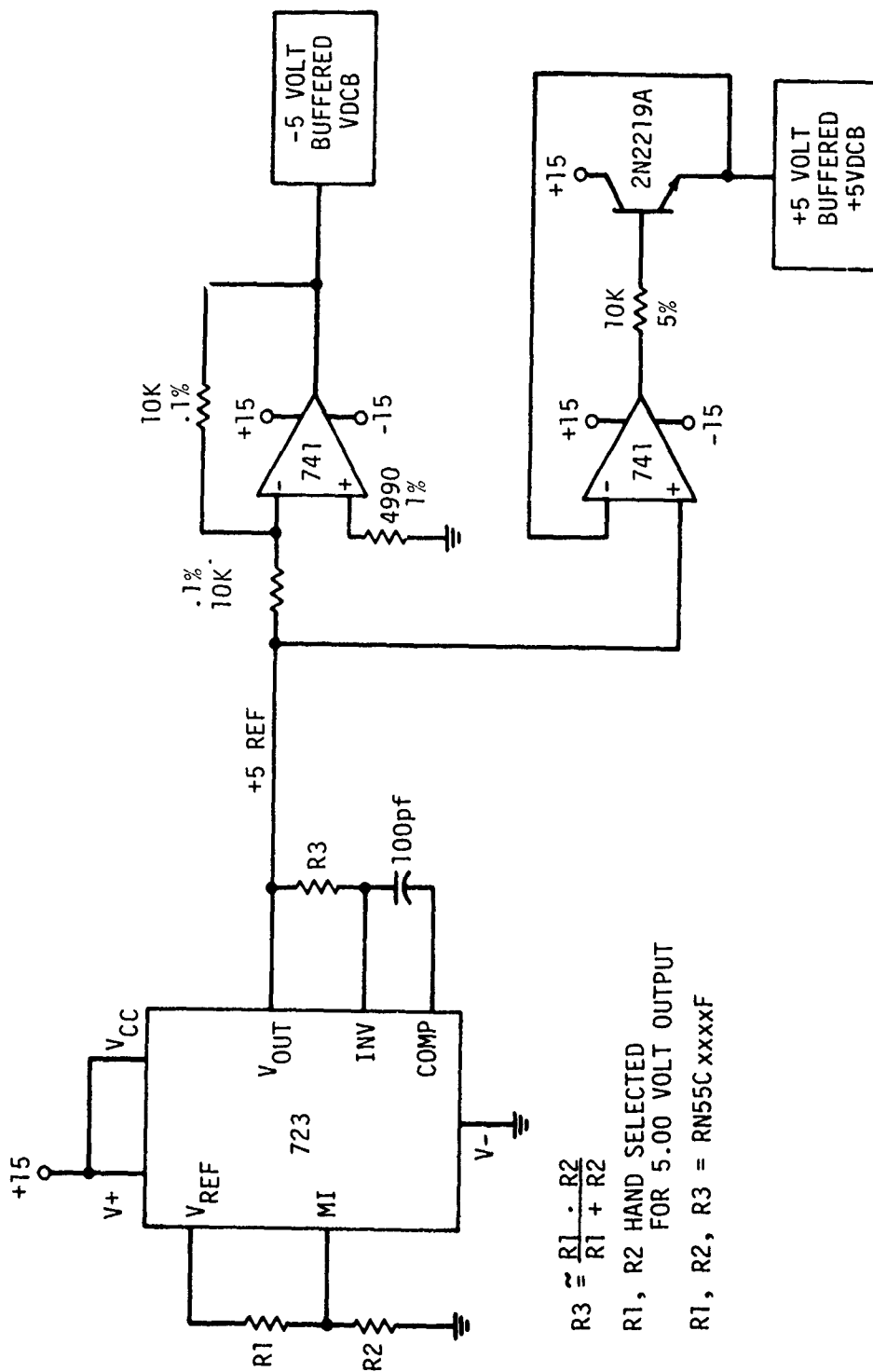
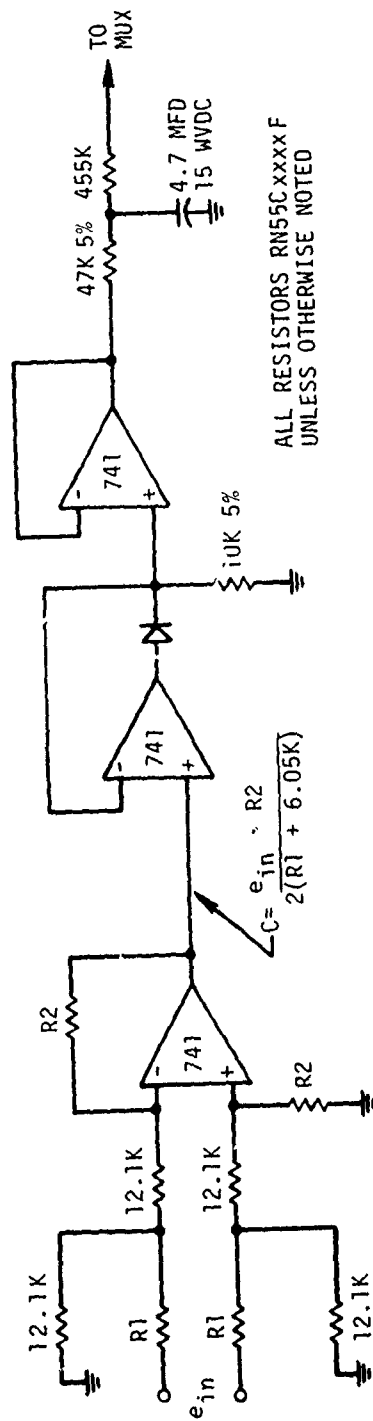


Figure 24. +5 Volt Buffered Reference Voltages.



$$e_{odc} = \frac{e_{in} R_2}{2(R_1 + 6050)} \cdot \frac{1}{2} \cdot \left(\sqrt{2} \cdot \frac{2}{\pi} \right)$$

$$e_{odc} = \frac{e_{in} R_2}{\pi \sqrt{2} (R_1 + 6050)} \quad \text{RIPPLE} < 1/256 \text{ F.S.}$$

e_{in} IS RMS MEASUREMENT

Figure 25. Buffered AC-to-DC Circuit for Roll Attitude, Engine Torque, and References.

filter was mounted to a bracket on the bottom of the case.

Two PC boards were used, one for the analog section and one for the digital section of the recorder. The PC boards were mounted to the side cover plates with standoffs positioned to minimize vibrations.

A 3M connector system was used on the PC boards to enhance maintainability. A retention clip was used to lock the plug to the receptacle. A Cannon-type PSE connector on the front panel provided access for the retrieval unit. This connector was normally capped. A Cannon PDP connector mounted on the rear panel of the case provided connection to both the transducers and the input power.

Gaskets on the side covers were a combination of woven Monel for electromagnetic interference (EMI) protection and sponge silicone to provide a moisture/dust seal. The connector gaskets were Monel-impregnated silicone. Metal slugs were provided as part of the cover gaskets to preclude the possibility of overcompensation of the gaskets. All fasteners were specified to MIL-N-25029.

The flight recorder was mounted in a Barry Controls 3/8 ATR tray with helicopter shock mounts.

Data Transfer Unit (DTU). The original design concept required the DTU to serve a dual role - as a retrieval unit in extracting data from the recorder and storing it on cassette tape, and as a test unit to enable an operator to view the extracted data.

As a brassboard retrieval unit, operator inputs would be requested via a six-character alphanumeric display. The operator inputs would be entered through a numeric keyboard. After these operator inputs were accepted, the recorder, on request of the retrieval unit, would send the counter data, all digitized analog channels, and a repeat of the counter data following a test routine. The retrieval unit stored all information and at retrieval conclusion stored it on cassette tape. The alphanumeric display was used to notify the operator of any failures or incorrect inputs. The software flowchart of the communication between recorder and retrieval unit describes the data extraction procedure and is presented in Figure 26.

Following data retrieval, any of the information resident in the retrieval unit was viewed by entering an address via the keyboard.

Data Processing Software. As stated, the data processing software system was to consist of three major elements: the Initial Processing System, the Fatigue Damage Assessment System, and the Component Tracking Management System. Detailed information concerning each of these systems and their operation had been previously planned (Reference 1, p. 76).

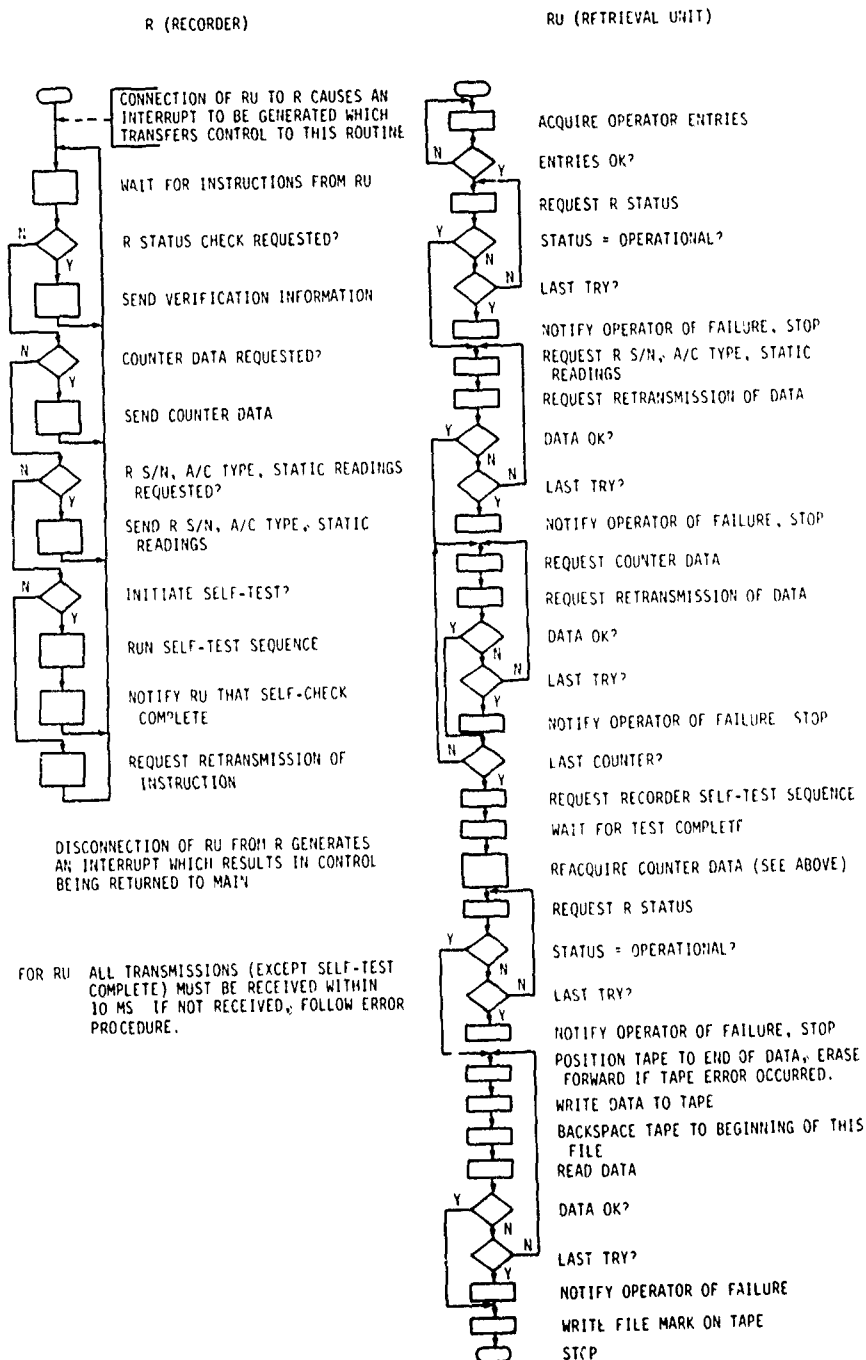


Figure 26. Retrieval Unit Recorder Communications.

The brassboard and supporting software evaluations were essentially complete by the time Critical Design Review was completed. The conceptual approach was found satisfactory and preparation of test articles was begun. It was recognized that reliability was of primary importance to the SIRS equipment. Thus a reliability assessment was provided.

Reliability Analysis

A reliability analysis was performed using MIL-HDBK-217B and the component manufacturers' data to predict the mean-time-between-failure (MTBF) for the SIRS recorder. The results of the analysis are summarized in Table 20. The calculated MTBF of about 7300 hours for the SIRS recorder includes consideration of a helicopter operational environment in a worldwide scenario. As such, the 7300 hours MTBF is considered realistic. The analysis did not include the processor board batteries, which in this application were expected to have a lifetime well in excess of 6 months. Furthermore, although only one such battery is required, a second battery is included in the design as a redundant feature to enhance the operational reliability. The MTBF of the transducers and installation kit is about 1400 hours, resulting in an overall system MTBF of about 1200 hours. However, loss of a transducer input does not result in invalid recorded data. The missing input can be synthesized during data processing. In addition, periodic calibrations and other maintenance actions should identify potential transducer failures before they occur. Operation of four recorders during software development, burn-in prior to qualification test, and qualification and flight tests resulted in an accumulated operating time in excess of 500 hours. Only one failure was recorded. This occurred during the environmental portion of the qualification tests. Upon conclusion of the temperature-humidity-altitude test, the recorder did not operate. The cause was identified as leaking batteries and the resulting contact corrosion.

Laboratory Qualification Testing

The qualification testing was designed to assess the performance of the SIRS recorder in simulated EMI/electromagnetic compatibility and normal airborne environments conforming to MIL-STD-461/462 and MIL-STD-810, respectively. Table 21 summarizes the test conditions for each environment. Figure 27 shows a typical test setup.

Two recorders were subjected to the testing: S/N 005, which was packaged in a steel box, and S/N 1007, which was contained in an aluminum box for potential weight savings if the aluminum base proved adequate during the testing. S/N 005 was used in the normal airborne environment test while S/N 1007 was

TABLE 20. RELIABILITY ANALYSIS SUMMARY

<u>Component</u>	<u>Part No.</u>	<u>Failure Rate(a)</u>	<u>MTBF(hr)</u>
Processor Board	074032D30014	55.9854	17,862
Signal Condition- ing Board	074032D30019	50.6592	19,740
Power Supply	C5/T15/165/x	16.6667	60,000
Filter	RF6125	0.0560	17,857,143
Termination Assembly	074032C30011	0.5820	1,718,213
Internal Cables/ Connections	-	11.7040	85,441
Connector	KP5E02A12-10S	1.8630	536,769
SIRS Total		137.5163	7,272
Circuit Breaker	MS22073-3/4	1.9650	508,906
Gross Weight Sensor	DCMC3FF41	254.2370	3,934
OAT Sensor	S6B	97.1930	10,289
Altitude Sensor	1332A3	94.5200	10,580
Airspeed Sensor	1332D1	94.5200	10,580
Accelerometer	SA109-B-1/+3SL	174.1940	5,741
Miscellaneous Connections	-	0.7300	1,369,863
Transducers and Installation Kit Total		717.3590	1,394
System Total (b)		854.8753	1,170

Notes:

- (a) Estimated number of failures per million hours.
 (b) Excludes aircraft inputs.

TABLE 21. SUMMARY OF QUALIFICATION TESTS

a. MIL-STD-461/462 Tests

<u>Test Method</u>	<u>Description</u>	<u>Remarks</u>
CE01	Conducted Emission, 30 Hz to 20 kHz, Power Leads	Info. Only
CE02	Conducted Emission, 30 Hz to 20 kHz, Control and Signal Leads	Info. Only
CE03	Conducted Emission, 20 kHz to 50 mHz, Power Leads	
CE04	Conducted Emission, 20 kHz to 50 mHz, Control and Signal Leads	Info. Only
CS01	Conducted Susceptibility, 30 Hz to 50 kHz, Power Leads	
CS02	Conducted Susceptibility, 50 kHz to 400 mHz, Power Leads	
CS06	Conducted Susceptibility, Spike, Power Leads	
RE02	Radiated Emission, 0.014 to 10 GHz, Electric Field	
RS02	Radiated Susceptibility, Magnetic Induction Fields	
RS03	Radiated Susceptibility, 14 kHz to 10 GHz, Electric Field	

b. MIL-STD-810 Tests

<u>Test Method</u>	<u>Procedure</u>	<u>Description</u>
504	I	Temperature Altitude: -25°C to 50°C, 0-20,000 ft.
518	I	Temperature, Humidity, Altitude: -40°C to 50°C, 0-95% RH, 0-20,000 ft.
507	I	Humidity: 0-95% RH
513.1	1I	Acceleration
511	I	Explosive Atmosphere
510	I	Dust
514.1	I	Vibration (Category C Equipment)

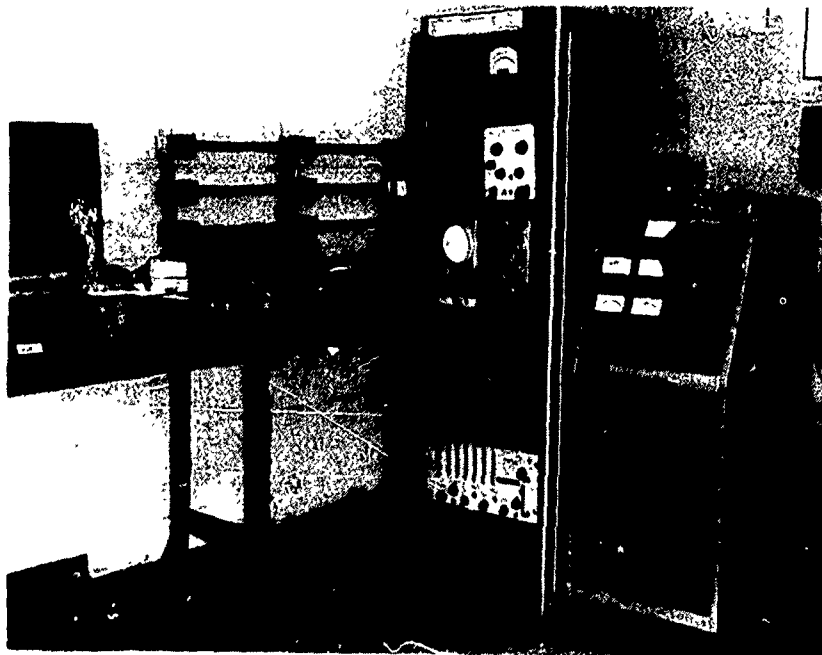


Figure 27. Test Setup for SIRS Recorder Qualification.

used in the EMI/EMC environment test; its test results could be applied to S/N 005 whereas the converse would not be possible.

The tests were successful in that the few operational discrepancies that occurred during the tests could be eliminated by simple corrective actions. The correction actions were such that the high level of confidence in their effectiveness precluded the requirement for retests. Of the five discrepancies observed, four occurred during the EMI tests and three of the four were correctible by proper termination of shields in the signal cable, shorter wire lengths, and improved wire routing. The fourth discrepancy was due to the SIRS recorder logic test program and could not be attributed to the EMI environment. The fifth discrepancy was a leaking battery condition that developed during temperature-humidity-altitude testing. A suitable battery replacement eliminated the problem.

Phase I Prototype Flight Test

The prototype flight test was held and the program was formally introduced to Fort Rucker personnel on 5 November 1976.

Instrumentation System. To obtain the data for the validation of the SIRS recorder, two Century Model 409B oscillograph recorders, each with 14 data channels and capable of recording numerous dynamic parameters on 3-5/8-inch-wide photosensitive paper, were used in this program. One oscillograph was to record FCR (Flight Condition Recognition) data and the other to record SIRS flag data. The FCR oscillograph recorded the dynamic parameters that would permit identifying the various flight conditions encountered during the flight test program. The SIRS flag oscillograph recorded the various SIRS parameter levels that would trigger the logic routine operations and consequently provided the data to verify the functioning of the logic routines.

In general, each oscillograph had 12 channels available for recording the in-flight parameters. Of the remaining two channels, one was used to delineate a time pattern reflecting a 1-minute cycling, and the other was used to trace a static line for measurement reference. Table 22 presents the parameters recorded on each oscillograph. As apparent in this table, several parameters were recorded by both oscillographs so that the two oscillographs could be readily correlated. The FCR oscillograph parameters were recorded as analog values while the flag oscillograph parameters were presented either as analog values for the parameters in common with both oscillographs or as ranged data for the output of the SIRS recorder.

The signal conditioning units used to regulate the voltage signals from the various transducers were the Technology Incorporated Models 074037D30007-1 and -2 for the flag and the FCR oscillographs, respectively.

TABLE 22. RECORDED PARAMETERS

<u>Parameter</u>	<u>FRC Oscillograph</u>	<u>Flag Oscillograph</u>
Airspeed	Analog	Range
Pressure		
Altitude	Analog	-
Outside Air		
Temperature	Analog	-
Density		
Altitude	-	Range
Main Rotor		
Speed	Analog	Range
Vertical		
Acceleration	Analog	Analog and Range
Engine Torque	Analog	Analog and Range
Roll Attitude	Analog	Range
Pitch Attitude	Analog	Range
Gross Weight	-	Range
Touchdown	-	Range
Time	Analog	Analog
Reference	Analog	Analog

For a description of the recording system, refer to Chapter 3.

Installation of Recording System. The SIRS recorder was installed in the helicopter's battery compartment on a shelf accessible from the right-hand side of the helicopter. The airspeed and altitude transducers were mounted on the left-hand side of the aircraft in the area adjacent to the pilot's compartment where the aircraft's pitot and static system was accessible. The vertical accelerometer was mounted on a bracket attached to the bulkhead beneath the transmission. The outside air temperature transducer was mounted on the skin of the helicopter on the underside at Station 220. Rotor speed was taken from the helicopter's rotary tach generator. Engine torque was taken from the engine torque transmitter. A circuit breaker was installed in the pilot's right-hand aft circuit breaker panel and was connected to the dc bus to provide 28 Vdc power. Provisions were made to take the roll and pitch attitude signals from the aircraft's roll and pitch gyro located in the same area as the airspeed and altitude transducers. The gross weight sensors were installed at the midpoint of the fore-and-aft skid crosstubes. Cabling between the SIRS recorder and transducers was routed through the compartments along the underside of the helicopter. Figure 28 is an outline drawing of the AH-1G helicopter showing the recorder system component locations.

1. SIRS Recorder (Aft Battery Compartment)
2. OAT Ribbon (Skin, Underside)
3. Vertical Acceleration Transducer (Lower Transmission Compartment)
4. Gross Weight/Touchdown Indicator (Skid Crossbars)
5. Roll, Pitch Attitude Gyro
6. Airspeed, Altitude Transducers
7. Rotor Speed Tach-generator
8. Engine Torque Transmitter

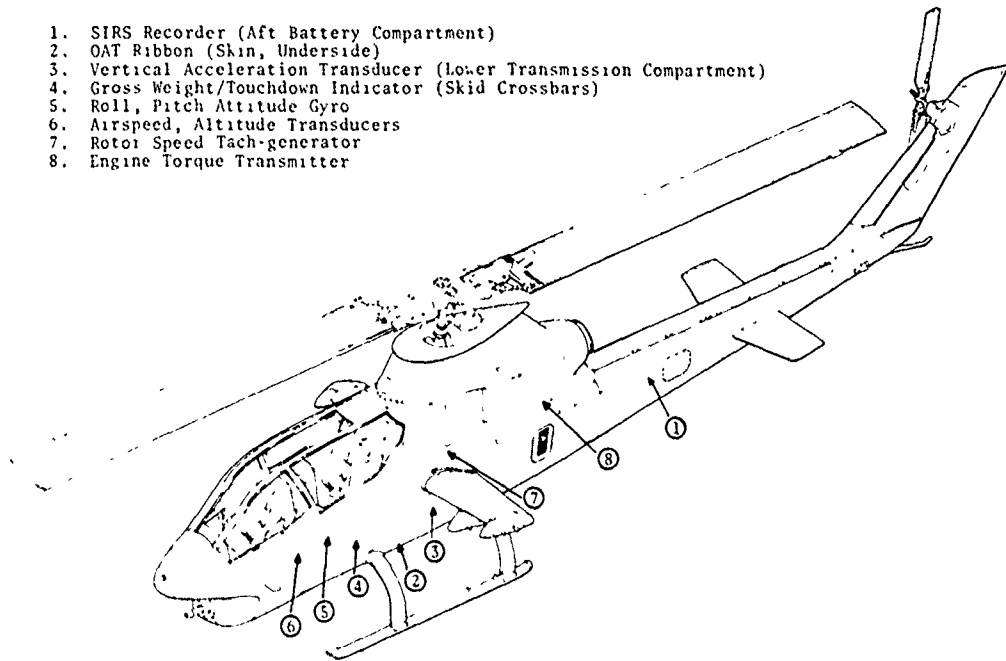


Figure 28. Installation Schematic.

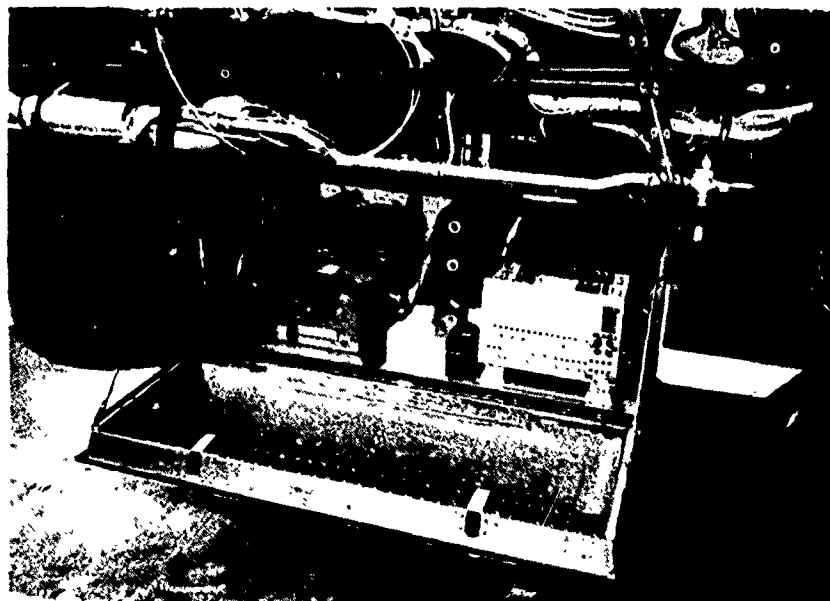


Figure 29. Flight Test Instrumentation System.

The instrumentation system used to evaluate the performance of the SIRS recorder, including the FCR oscillograph, flag oscillograph, signal conditioning system, and digital-to-analog converter, was mounted in the ammunition bay under the pilot and gunner's compartment. In addition, a junction box was installed in the battery compartment to tap into the SIRS recorder's analog and digital flag signals. Figure 29 is a photograph of the flight test instrumentation system.

The SIRS and flight test recording systems were installed and checked between 23 February and 15 March 1977.

Recorder Flight Testing. The flight performance of the SIRS recorder was evaluated by flying various flight conditions and by analyzing the degree to which the SIRS recorder could identify and correctly time the flight conditions. Examples of the flight conditions flown are listed in Table 23. In addition, several nap-of-the-earth flights, both simulated and actual, were performed.

Seven useful data flights, which yielded 7.5 hours of in-flight data, were made during the 4 weeks of the flight test program. An additional 22 flights, yielding 19.9 hours of in-flight data, were made; these flights included instrumentation check flights, nap-of-the-earth training flights flown in conjunction with the test program, and landing check flights. Although limited data from these flights were processed to verify the operation of the SIRS recorder, they were not specifically used to validate the recorder performance. Table 24 summarizes the 29 flights.

During the early portions of the flight test program, each flight generally lasted an hour and most of the flight conditions listed in Table 23 were flown. Beginning on flight 21, the digital-to-analog converter used to establish the signal levels for the flag oscillograph malfunctioned occasionally. The malfunction was a random disruption of all the traces on the flag oscillograph. Consequently, the later flights in the program were generally shorter and designed to investigate fewer flight conditions with only the FCR oscillograph.

Recorder Performance. The following summary of the SIRS recorder performance consists of detailed discussions of how the recorder identified and recorded occurrences of flight conditions, time within certain prescribed flight conditions, and maximum parameter occurrences. Not all of the 22 flight condition categories will be discussed in detail. Rather, examples of each of the three types of data recording techniques, that is, occurrences, times, and maximums, will be presented. In addition, during the test program several of the encountered flight conditions required logic modifications or improvements before they could be identified. These modifications are discussed in general, but an example of a required logic change is illustrated.

TABLE 23. FLIGHT TEST FLIGHT CONDITIONS

Rotor Start/Stop	Dive:
Level Flight	Symmetric
Hover:	To Left
IGE	To Right
OGE	Pullout:
Quick Stop:	Symmetric
IGE	To Left
OGE	To Right
Full Power Climb	Pullup (Cyclic Climb):
Maximum Performance Takeoff	Symmetric
Maximum Rate Acceleration	To Left
Autorotation:	To Right
Power to Autorotation	Turns:
Steady	Normal
Turns	Gunnery
Landings	S-Type
Approach and Landing	

TABLE 24. FLIGHT LOG SUMMARY

Flt. No.	Predominant Maneuvers	Valid Data			Flight Duration(hr)
		SIRS	FCR	Flag	
1	Ground Run		*		-
2	Functional Check		*		0.4
3	Functional Check		*		0.3
4	Pilot Currency		*		1.0
5	Entire Profile	*	*		1.5
6	Level Flight, Turns	*	*		0.5
7	Level Flight, Turns	*	*		0.7
8	Level Flight, Turns	*	*		0.7
9	Functional Check	*	*		0.3
10	Level Flight, Turns	*	*	*	0.8
11	Entire Profile	*	*	*	1.4
12	Entire Profile	*	*	*	1.0
13	IP Check, Auto Landings		*	*	1.8
14	Dives, Turns	*	*	*	1.0
15	Nap-of-Earth		*		1.5
16	Nap-of-Earth		*		1.5
17	Nap-of-Earth	*	*	*	1.6
18	Nap-of-Earth	*	*		1.7
19	Nap-of-Earth	*	*		1.8
20	Functional Check	*	*		0.8
21	Entire Profile	*	*		1.5
22	Level Flight, Takeoffs		*		0.6
23	Check Flight	*	*		0.8
24	Level Flight, Quick Stops	*	*		0.5
25	Landing Check	*	*	*	0.3
26	High Gross Weight/ Landing Check	*	*	*	0.3
27	Low Gross Weight/ Landing Check	*	*	*	0.4
28	Level Flight/ Airspeed Check	*	*	*	1.5
29	Low Gross Weight/ Landing Checks, Quick Stops	*	*	*	1.2

Of the flight conditions that are recorded as occurrences, rotor start/stop and takeoff/landing cycles are the principal ones discussed in this section. The timed flight conditions to be discussed include total flight time, cruise, and various types of turns. Finally, this section discusses the measurement of peak vertical accelerations.

Computed Parameters. The SIRS recorder monitors airspeed, pressure altitude, and outside air temperature. From these parameters, the SIRS recorder computes the density altitude, the maximum level-flight velocity, and the limit velocity for the helicopter. In addition, the SIRS recorder monitors inputs from the gross weight sensors and computes gross weight ranges during a flight.

Maximum airspeed limit V_H , which represents the maximum level flight limit for the aircraft and the limit velocity V_L , which is the maximum airspeed permitted for the AH-1G helicopter are calculated from Equations 6, 7, and 8. The density altitude is computed in Equation 9.

Each of these calculations is continuously performed within the SIRS recorder, and the various identified flight conditions are categorized by the appropriate percentage of either of these limits.

Table 25 summarizes the airspeed limits, V_H and V_L , calculated by the SIRS recorder as represented on the flag oscillogram and those calculated manually from the FCR oscillogram for Flight 28. This flight was flown at two density altitudes and was typical of the calculating performance of the SIRS recorder.

The SIRS recorder monitors the input from the two piezoelectric beam sensors and computes a takeoff gross weight. During each flight, this gross weight is reduced at a fixed rate to account for fuel consumption. Throughout the flight, the various flight conditions are each categorized as being in one of three gross weight ranges: below 7750 pounds, 7750 to 8750 pounds, and above 8750 pounds.

As shown in Table 26, the system did not reliably compute the takeoff gross weight, since it yielded correct values for only five of the twelve flights. However, it generally computed the correct gross weight for the first flight of the day as evidenced in the data for Flights 11, 21, and 23. These correct values were due to the ability of the skid landing gear to assume its natural position when the helicopter was positioned on the flight line each morning. The flight test log does not indicate whether the helicopter was refueled before or after it was moved for Flights 31 and 26. The system did operate correctly after the wing stores were removed prior to Flight 27. Except for Flight 14, the system did not correctly compute the takeoff gross weight when the mission was the second or third flight of the day. When the helicopter was refueled

TABLE 25. COMPARISON OF PERCENT V_H AND V_L CALCULATIONS
FOR LEVEL FLIGHT CONDITIONS (FLIGHT 28)

<u>Indicated Airspeed</u>	<u>Density Altitude</u>	<u>%V_H</u>		<u>%V_L</u>	
		<u>FCR</u>	<u>Flag</u>	<u>FCR</u>	<u>Flag</u>
118	2155	0.84	0.8-0.9	0.66	≤ 0.7
109	2155	0.78	0.65-0.8	0.60	≤ 0.7
134	2271	0.96	0.9-0.95	0.74	0.7-0.85
127	2327	0.91	0.8-0.9	0.70	0.7
148	2155	1.06	>0.95	0.82	0.7-0.85
134	2348	0.96	0.9-0.95	0.75	0.7-0.85
140	2325	1.01	>0.95	0.78	0.7-0.85
156	2350	1.12	>0.95	0.86	0.7-0.85
166	2300	1.19	>0.95	0.92	0.85-0.95
153	2275	1.10	>0.95	0.85	0.7-0.85
109	6675	0.84	0.8-0.9	0.73	0.7-0.85
103	6648	0.79	0.65-0.8	0.68	≤ 0.7
120	6600	0.92	0.9-0.95	0.79	0.7-0.85
114	6664	0.87	0.8-0.9	0.76	0.7-0.85
128	6719	0.98	>0.95	0.85	0.85-0.95
124	6694	0.95	0.9-0.95	0.82	0.7-0.85

TABLE 26. TAKEOFF GROSS WEIGHT COMPARISON

<u>Flight No.</u>	<u>Date</u>	<u>Log</u>	<u>Flag</u>	<u>SIPS</u>
11	31 Mar 77	8317	7750-8750	-
12	"	8317	<7750	<7750
13	5 Apr 77	8317	≥ 8750	-
14	"	8317	7750-8750	7750-8750
21	12 Apr 77	9500	≥ 8750	≥ 8750
22	"	9500	<7750	-
23	13 Apr 77	9500	-	≥ 8750
24	"	9500	-	7750-8750
26	14 Apr 77	9500	-	7750-8750
27	"	8317	-	7750-8750
28	"	8317	<7750	<7750
29	"	8317	<7750	<7750

between flights, the static friction between the skid landing gear and ground prevented the skid gear from readjusting for the increased weight of the fuel.

The algorithm used to decrease gross weight due to fuel consumption worked correctly. In addition, during one flight after a landing, the rotor speed decreased below 250 rpm, and the gross weight system updated itself correctly.

Occurrences. The SIRS recorder is designed to monitor the various input parameters and, through the microprocessor logic, to identify occurrences of flight conditions. Such typical flight conditions include rotor start/stop cycles, power-on landings, autorotative landings, high n_z maneuvers, and auto-rotation-to-power transitions. In this² section, the first three occurrences will be discussed.

The SIRS recorder identified the eight rotor starts that occurred during the seven data flights shown in Table 27 and one extra cycle on Flight 12. The extra start was counted because of an accidental pulling of the circuit breaker of the instrumentation system, which caused the signal to behave as though a shutdown was occurring.

In general, the SIRS recorder correctly identified the normal landings performed during the flight test program. Table 28 summarizes the normal and autorotative landings detected by the SIRS recorder and identified on the FCR oscillogram. An example of a typical landing is shown in Figure 30, which includes the FCR and flag oscillograms. Table 28 shows differences between the FCR and SIRS data due to two types of problems, one in Flights 12, 28, and 29, and the second in Flights 23, 24, 28, and 29.

The normal landings of Flights 12, 28, and 29 not recorded by the SIRS recorder were missed because the recorder's logic requires 10 seconds of flight before subsequent landing can be considered valid, and 5 seconds on the ground before the landing is considered valid. During Flights 12, 28, and 29, multiple landings were made as part of the investigation of the performance of the gross weight sensing system; not all of these takeoffs and landings satisfied the logic of the recorder. No changes to the recorder logic are planned since this problem is not considered one that will exist in the operational environment.

For the identified autorotative landings of Flights 23, 24, 28, and 29, the logic had to be modified because the SIRS recorder was identifying normal power-on landings performed at high gross weights as autorotative landings. This occurred because the engine torque dropped below 5 psi sometime during the 10 seconds prior to touchdown. The subsequent logic changes will preclude the misidentification of normal landings.

Only three full autorotative landings were performed during the flight test program because of pilot restrictions and availability. All of these landings occurred during

TABLE 27. COMPARISON OF FLIGHT LENGTH AND ROTOR STARTS

<u>Flt.No.</u>	<u>Flt. Time (min)</u>		<u>Rotor Starts</u>	
	<u>FCR</u>	<u>SIRS</u>	<u>FCR</u>	<u>SIRS</u>
12	55.60	56.32	1	2 (a)
14	52.57	52.72	1	1
21	73.86	74.69	1	1
23	37.77	38.03	1	1
24	25.29	25.39	1	1
28	85.81	85.69	1	1
29	60.97	61.89	2	2

Note:

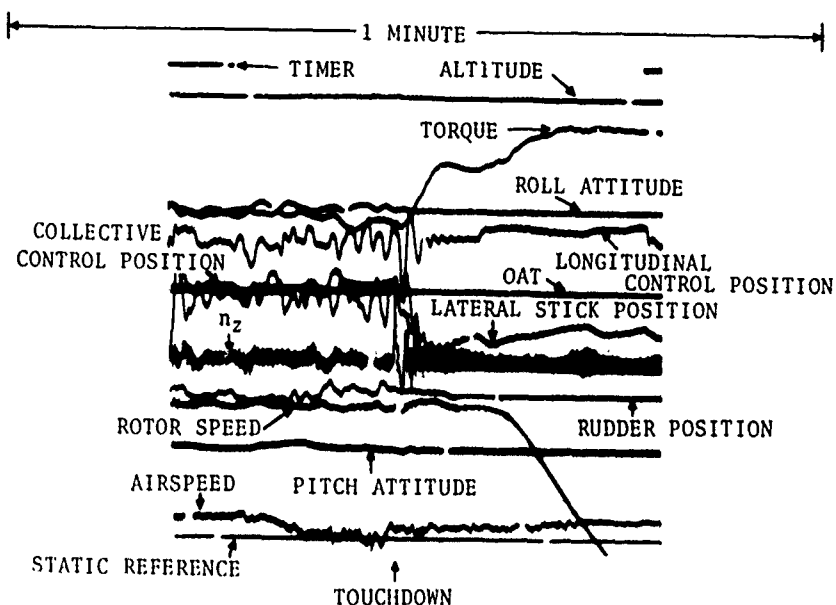
(a) Caused by accidently pulling circuit breaker for the instrumentation's electrical system.

TABLE 28. COMPARISON OF LANDINGS

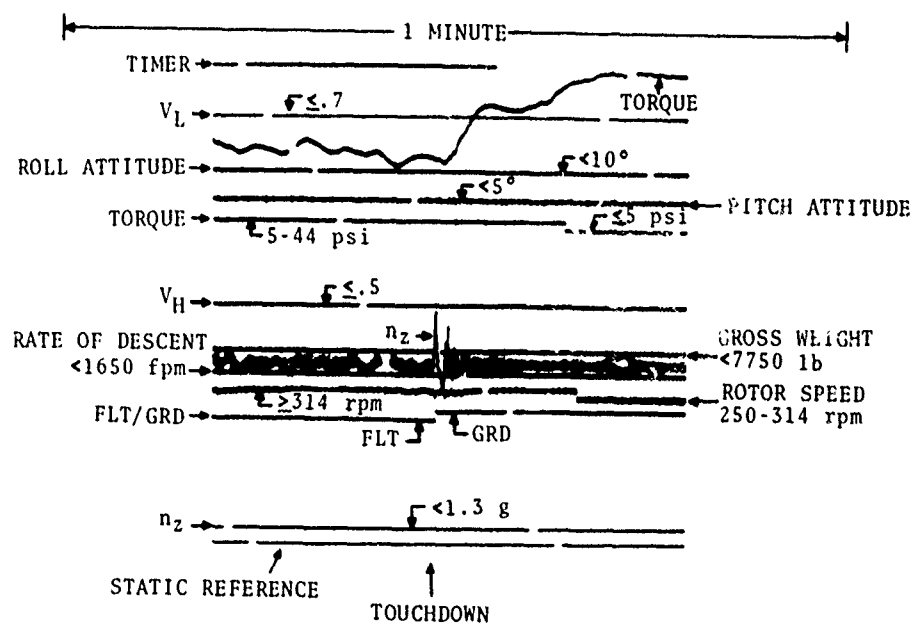
<u>Flt.No.</u>	<u>Normal Landing</u>		<u>Aut rotorative Landing</u>	
	<u>FCR</u>	<u>SIRS(a)</u>	<u>FCR</u>	<u>SIRS(a)</u>
12	4	2	0	0
14	1	1	0	0
21	9	9	0	0
23	5	4	0	1
24	4	3	0	1
28	3	1	0	1
29	13	7	0	2

Note:

(a) Discrepancies in the data are discussed in the text.



(a) FCR Oscillograph



(b) Flag Oscillograph

Figure 30. Normal Landing.

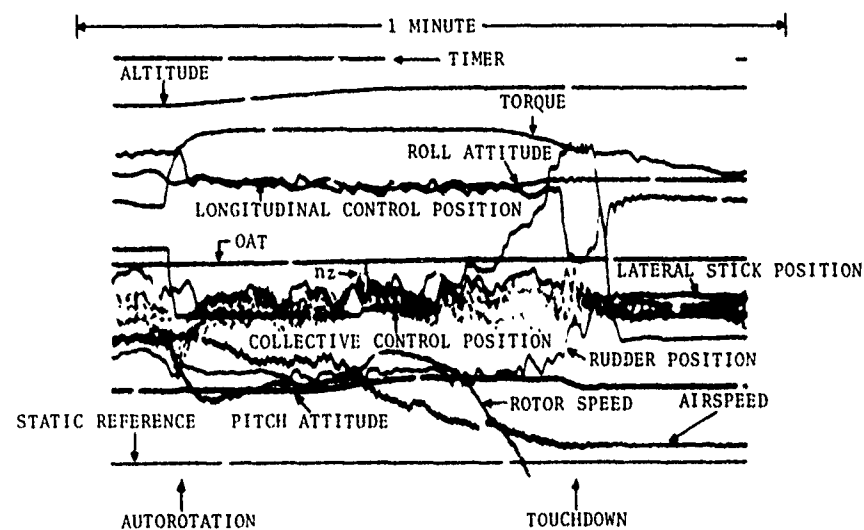
Flight 13. Unfortunately, the temporary mercury batteries, installed after the failure of the lithium batteries in the qualification testing, lost contact in flight and the recorder memory was lost; these slightly undersized batteries were subsequently soldered in place. However, the FCR and flag oscillograms in Figure 31 show that the SIRS recorder would have identified the landing as an autorotative landing since the engine torque was below 5 psi for the entire 10 seconds prior to the landing as required by the SIRS recorder logic.

Timed Flight Conditions. The SIRS recorder can record the duration of flight conditions in a manner similar to the recognition of occurrences procedure. The microprocessor logic identifies the flight conditions according to the individual or collective flight parameter changes, each within a preset range. For example, the duration of flight time is determined by the length of time that the touchdown indicator indicates an airborne condition. Likewise, a turn is identified as the duration of time that roll attitude is beyond the threshold if a vertical acceleration peak in excess of 1.3g occurs sometime during the period; the turn is then characterized by the airspeed and gross weight at which it was performed.

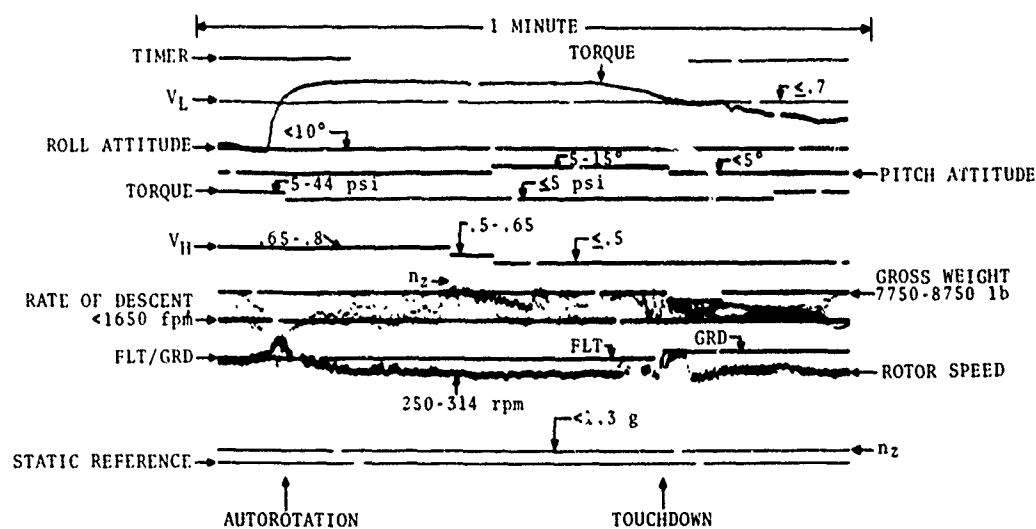
The durations of the seven data flights as measured by the FCR oscillograph and the SIRS recorder are listed in Table 27. The maximum variation in the two measurements is 1.5 percent; it should be noted that the potential for error in measurement is greater with the oscillograph than with the SIRS recorder because of the mechanical aspects of the oscillograph.

In addition to the total flight time, the SIRS recorder also measured the time spent in cruise at various airspeed levels. Low-speed flight is defined by speeds of 50 to 65 percent V_H ; high-speed flight is defined by speeds of 65 to 95 percent V_H ; and maximum-speed flight is defined by speeds in excess of 95 percent V_H . For all level flight conditions, the airspeed is converted to the equivalent percent V_H for that gross weight and density altitude condition. As presented in Table 29, the SIRS recorder accurately measured the time in various cruise conditions. For the same flight, a comparison of measured and recorded values for V_H throughout the cruise conditions are presented in Table 30.

As discussed earlier, the SIRS recorder includes logic to identify various types of turns, including normal, gunnery, and gunnery S-turns. The turns are categorized by airspeed and vertical acceleration for a given gross weight condition. For Flight 14, normal, gunnery, and S-turns were analyzed by processing data from the FCR and flag oscillographs and comparing these data with the output of the SIRS recorder. As shown in Table 31, the agreement is very good between the flag and SIRS data.



(a) FCR Oscillograph



(b) Flag Oscillograph

Figure 31. Autorotative Landing.

TABLE 29. COMPARISON OF CRUISE TIMES
FOR FLIGHT 14

	<u>Flag Oscillograph</u>	<u>SIRS</u>
Low-Speed Flight	11 sec	12 sec
High-Speed Flight	934 sec	934 sec
Max. Speed Flight	53 sec	54 sec

TABLE 30. COMPARISON OF PERCENT V_H CALCULATIONS
DURING CRUISE FOR FLIGHT 14

<u>Flight Condition</u>	<u>Indicated Airspeed</u>	<u>Density Altitude</u>	<u>%V_H</u>	
			<u>FCR</u>	<u>Flag</u>
Low-Speed Flight	91	2410	0.65	0.5-0.65
"	84	1048	0.59	0.5-0.65
High-Speed Flight	100	2492	0.72	0.65-0.8
"	133	2724	0.96	0.9-0.95
"	125	2807	0.91	0.8-0.9
"	100	2409	0.72	0.65-0.8
"	124	2291	0.89	0.8-0.9
"	131	2256	0.94	0.9-0.95
"	110	2208	0.79	0.65-0.8
"	124	2291	0.89	0.8-0.9
"	127	2005	0.91	0.8-0.9
"	113	2009	0.81	0.65-0.8
"	132	1969	0.94	0.9-0.95
"	115	2005	0.82	0.65-0.8
"	120	2005	0.86	0.8-0.9
"	131	1995	0.94	0.9-0.95
"	126	1969	0.90	0.8-0.9
"	124	1900	0.89	0.8-0.9
"	134	1827	0.96	0.9-0.95
"	135	1298	0.95	0.9-0.95
"	124	1252	0.88	0.8-0.9
"	106	1174	0.75	0.65-0.8
Max. Speed Flight	140	2800	1.01	>0.95
"	140	2020	1.00	>0.95
"	142	2030	1.01	>0.95
"	143	1703	1.02	>0.95

TABLE 31. COMPARISON OF VARIOUS TURNS FOR
FLIGHT 14

Type	Gross Weight	Duration (sec)		
		FCR	Flag	SIRS
Normal Turn	<7750	234	222	222
"	7750-8750	40	39	39
Gunnery Turn	<7750	28	27	27
"	7750-8750	167	158	161
Gunnery S-Turn	7750-8750	140	139	138

The measurement accuracy of the FCR and flag oscillographs is less than that of the SIRS recorder because the crystal clock in the recorder functions more precisely than the mechanical drives in the oscillographs. Minor variations in the drive speed of the oscillographs cause corresponding variations in the timed events. For illustrative purposes, Figure 32 presents the FCR and flag oscillograms for a typical turn. This turn, as recorded by the SIRS recorder lasted 39.2 seconds. In comparison, by analyzing when the roll flag changed from within threshold to outside threshold and then back again, the turn duration would be 39 seconds. Note that near the end of the turn, the n_z flag changed from threshold to the range of 1.3 to 1.5g. In the FCR chart, the turn duration is slightly longer, 40 seconds, since the turn was identified at the instant of roll attitude change rather than when it passes through 10° .

Maximum Parameter Value. The SIRS recorder can identify the maximum value of a parameter during the interval between data retrievals. During the flight test program, the maximum values of vertical acceleration and V_L (limit velocity) were recorded.

Table 32 compares the maximum n_z peaks identified by the SIRS recorder during each flight with the corresponding values read from the FCR oscillograph. The largest positive peak recorded during the program was 2.73g, which occurred during a turn at an airspeed of 97 percent V_H and with a roll angle greater than 50° , as shown in Figure 33. The lowest positive peak recorded during the program was 1.08g, which occurred in a hover during Flight 25.

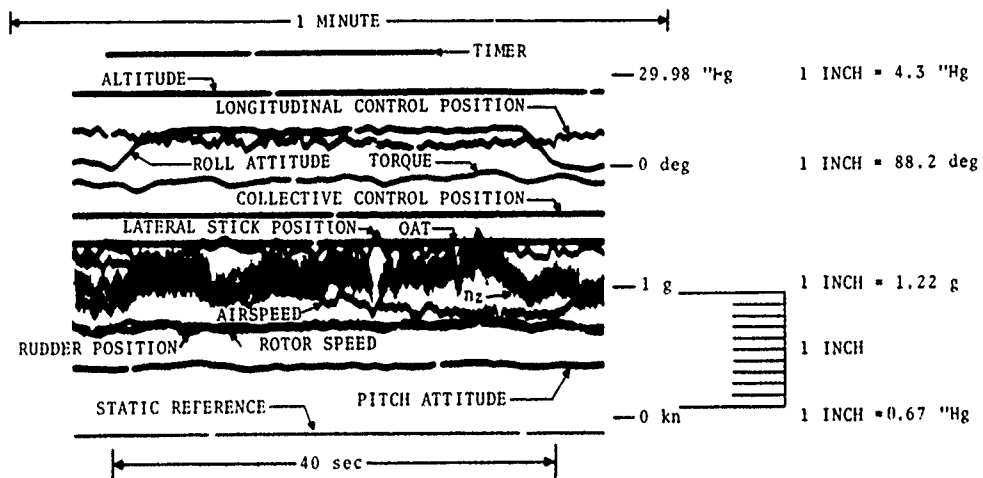
TABLE 32. COMPARISON OF MAXIMUM n_z VALUES

<u>Flight No.</u>	<u>Flight Condition</u>	<u>Maximum n_z (g)</u>	
		<u>FCR</u>	<u>SIRS</u>
10	Turn	1.4	1.4
12	Dive	2.2	2.3
14	"	2.3	2.3
21	Turn	2.7	2.7
23	Dive	2.5	2.5
24	Quick Stop	1.6	1.6
25	Hover	1.1	1.1
26	"	1.1	1.1
27	Turn	1.7	1.7
28	Cyclic Pullup	1.6	1.6
29	Autoration to Power	1.5	1.4

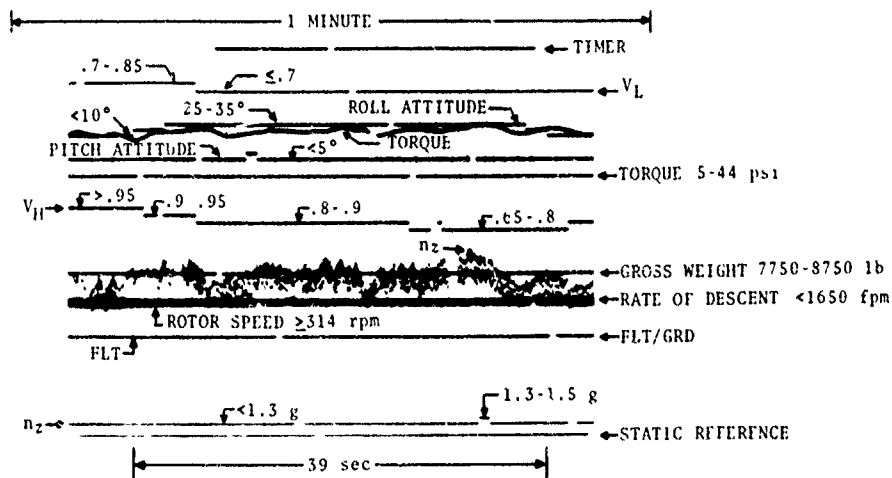
Although the SIRS recorder was programmed to also identify the maximum V_L condition, the lack of a time delay in the recorder caused false V_L values as the recorder and transducers were powered up. Since the altitude transducer has an equivalent altitude of 21,200 feet at zero volts, during the power-up cycle the recorder incorrectly calculated the V_L value. The software logic has since been changed to include a time delay that will prevent erroneous calculations. The recorder capability of measuring maximum V_L peaks has since been demonstrated in the laboratory. In addition, follow-on IOT&E flight tests with the AH-1S have confirmed the laboratory findings.

Summary and Conclusions. The purpose of the Phase I testing was to verify that the SIRS recorder would operate reliably in an operational helicopter environment and yield flight data. The SIRS recorder successfully demonstrated that it can perform its intended function.

Minor improvements recommended for the SIRS recorder hardware and software were incorporated in the SIRS recorders assigned to the Phase II Operational Evaluation. No major changes in the recorder design were required.



(a) FCR Oscillograph



(b) Flag Oscillograph

Normal Turn Time	
SIRS	39 sec
Flag Oscillograph	39 sec
FCR Oscillograph	40 sec

Figure 32. Normal Turn.

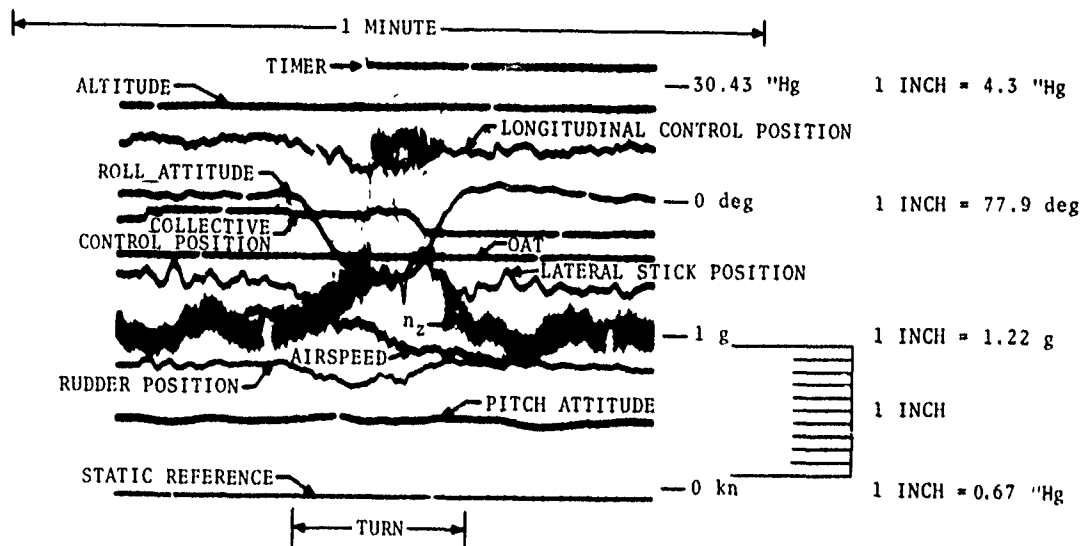


Figure 33. FCR Oscillograph Showing the Largest Positive n_z Peak Recorded During the Program.

The application of the lift link system to the AH-1G was to be researched further; if acceptable results were obtained, it would be incorporated into the SIRS recorder system. In addition, the measurement of pitch in conjunction with the lift link should be considered as a method for decreasing the sensitivity of the lift link system to center-of-gravity changes.

With the incorporation of the recommended hardware and software improvements, the SIRS recorder was declared acceptable for the Phase II Operational Evaluation.

IOT&E

The IOT&E was entitled "Phase II Operational Flight Test for the SIRS AH-1G Program." It was concerned with determining if there were any deficiencies that would inhibit or limit the operational employment of the system. In addition, this was the opportunity to show the user the design that his original concepts produced, what he could expect to accomplish with the system, and, more importantly, what it would cost the user in terms of resources and manpower to accomplish his operational task.

The major objectives of the IOT&E were to:

- Estimate the operational effectiveness and suitability of the system as well as other operational aspects of its military utility.
- Identify any operational deficiencies.
- Recommend and evaluate desirable changes and trade-offs in production configuration.
- Obtain operational information for:
 - Refinement of official program operating and support cost estimates.
 - Identify system characteristics or deficiencies that significantly impact O&S costs.

IOT&E Test Support

During October 1977 the test article installation was essentially completed. At the time of departure of the installation team from Fort Rucker, four of five SIRS recorders were installed and operational. The fifth recorder was not installed because of a malfunctioned vertical accelerometer

that was being repaired. The helicopters in which the recorders were installed are listed below:

<u>Aircraft</u>	<u>Recorder Serial Number</u>
66-15254	1008
66-15252	1009
66-15286	1010
66-15473	1011
66-15356	Installation of 1012 completed December 1977

A data collection trip was made on 15-17 November 1977 to Fort Rucker to retrieve data from the four SIRS recorders and to perform any required maintenance. The status of each recorder was summarized by aircraft tail number. The report at that time was as follows:

"66-15254 - System Functioning properly."

"66-15252 - Aircraft is in maintenance hangar for replacement of rotor mast. System was inoperative due to large unbalance in the strain gauge bridge. We were unable to compensate for the unbalance and traced the problem to a faulty strain gauge. It will require the installation of a new instrumented lift link."

"66-15286 - Attempted to retrieve data prior to the morning mission and found the system inoperative. Investigation showed that the strain gauge bridge had been destroyed during aircraft maintenance. The strain gauge bridge appeared to have been hit with a wrench. It will require the installation of a new instrumented lift link."

"66-15473 - System functioning properly."

"66-15356 - System inoperative due to faulty n_z transducer. (Sent to factory for repair.)"

A data collection trip was made on 27-29 December 1977 to Fort Rucker to retrieve data and to perform any required maintenance. The status of each recorder was summarized by aircraft tail number. The report of findings at that time was as follows:

"66-15254 - Retrieved data on 28 December 1977. Upon checking the static gross weight parameter, a zero condition was found. Further investigation found a negative 0.3-volt signal from the gross weight in-line amplifier. Rebalancing of the strain gauge bridge produced a 70-count static indication on the Retrieval Unit. While closing up the aircraft, the Retrieval Unit was left on (approximately 3 minutes) and the 70-count reading drifted down to 46 counts. The 46-count reading did not drift over the next 1-minute interval. The Retrieval Unit was turned off for approximately 2 minutes and back on to monitor gross weight. A 54-count reading was observed this second time and a slow drift downward to 50 counts took an estimated 52 seconds. It appears that the strain gauge bridge is drifting."

"66-15252 - Aircraft is still in maintenance hangar awaiting rotor mast change. The strain gauge bridge is still unbalanced due to a faulty bridge. The system is still inoperative and will need a new instrumented lift link."

"66-15286 - System inoperative due to a completely destroyed strain gauge on the lift link. This system will need a new instrumented lift link."

"66-15273 - Data retrieved and static condition checkout show this system functioning properly."

The IOT&E flight test continued into the February 1978 time frame. By that time the AH-1G program had been phased down and replaced by the follow-on IOT&E with the AH-1S used as the test vehicle.

Evaluation of an AH-1G Fleet Operating Parameter That Impacts O&S Costs

It was noted that conventional calculated component damage was arrived at by using official logbook hours reported on each airframe. Further, it was observed that calculated SIRS spectrum damage and component damage arrived at by using recorder clock time would both lead to extended service lives of the

10 high-value, fatigue-sensitive components under study in this program. This is attributed to the fact that the recorder electronics is made to function only at the onset of events leading to component damage. This typically begins at rotor start. Component damage is not accumulated during engine run-up although the aircrew would be expected to include all operating times in logbook hours independent of whether they contribute to component damage. An example of the results for aircraft 66-15473 is reproduced in Table 33. A statistical treatment of the calculated component damage throughout this limited flight test program may be seen in Table 34.

The planned DT&E and IOT&E programs for the SIRS concept were completed in December 1977. The follow-on IOT&E was phased in at that time with the AH-1S as the test vehicle. While the AH-1G DT&E and IOT&E programs were quite compressed, a number of significant findings were derived from the effort.

TABLE 33. CALCULATED COMPONENT DAMAGE

Component	SIRS Spectrum	Predicted Spectrum	
		Recorder Hours	Logbook Hours
Main Rotor Blade	0.00706	0.05477	0.08227
Main Rotor Yoke Extension	0.0	0.01826	0.02742
Main Rotor Grip	0.0	0.00602	0.00905
Main Rotor Pitch Horn	0.00002	0.00913	0.01371
Retention Strap Ftg/Nut	0.02563	0.02738	0.04114
Swashplate Drive Link	0.00001	0.00548	0.00823
Swashplate Outer Ring	0.00025	0.01826	0.02742
Swashplate Inner Ring	0.00007	0.01826	0.02742
Hydraulic Boost Cylinder	0.00080	0.01826	0.02742
Tail Rotor Blade	0.00130	0.05477	0.08227

TABLE 34. STATISTICAL EVALUATION OF CALCULATED COMPONENT DAMAGE (ALL FLIGHTS)

	SIRS Damage Spectrum	S_x	Flight Hour Damage			
			Recorder Spectrum	S_x	Logbook Spectrum	S_x
Main Rotor Blade	0.01041	0.01139	0.04586	0.02679	0.08491	0.01206
Main Rotor Yoke Extension	0.000594	0.01314	0.01462	0.00893	0.02833	0.00400
Main Rotor Grip	0.01106	0.02957	0.00514	0.00317	0.00910	0.00177
Main Rotor Pitch Horn	0.00023	0.00091	0.00779	0.00480	0.01379	0.00269
Retention Strap Ftg/Nut	0.03272	0.01732	0.02338	0.01439	0.04137	0.00807
Swashplate Drive Link	0.00020	0.00081	0.00468	0.00288	0.00828	0.00161
Swashplate Outer Ring	0.01870	0.06998	0.01559	0.00960	0.02758	0.00538
Swashplate Inner Ring	0.00320	0.00709	0.01694	0.00992	0.02923	0.00432
Hydraulic Boost Cylinder	0.00037	0.00035	0.01462	0.00893	0.02830	0.00402
Tail Rotor Blade	0.02723	0.04352	0.05080	0.02976	0.08771	0.01296

CHAPTER 5.

FINDINGS

DT&E FLIGHT TEST (PHASE I PROTOTYPE FLIGHT TEST)

Software Modifications

During the flight test program, several flight conditions were identified that required computer logic modification to properly identify or time them. These flight conditions are identified in Table 35.

Hardware Modifications

Several findings resulted from the qualification program. Assorted internal wire routing and terminations were shown to need improvement. The lithium battery failed during the temperature-altitude-humidity test. The gross weight system operated correctly during the flight test program in all modes except one. When the helicopter landed at a low gross weight and then refueled, an error was introduced because the skid landing gear could not assume a new position due to the static friction between the skid gear and the ground. This problem could be solved by requiring a brief lift-off and touchdown before flight takeoff so that the skid gear could assume its normal position for the existing gross weight. This solution, however, is not considered practical in the operational environment.

IOT&E (PHASE II OPERATIONAL EVALUATION)

Following satisfactory completion of the prototype flight testing, it was determined that the follow-on operational test program would be pursued. Five AH-1G aircraft were selected to participate in this program. The aircraft identified for participation in the program were: 66-15254, 66-15252, 66-15286, 66-15473, and 66-15356.

Before the flight test was initiated, a number of modifications to the SIRS equipment were implemented to improve its performance. After transmission lift links were strain gauged and calibrated, and software modifications were made to the EPROM resident software, the mission equipment was installed on the five test aircraft. On aircraft 66-15356, the n₇ transducer was inoperative for the first three months of operation. This negated effective data gathering on this airframe for the entire operational test program. During the data retrieval of 15-17 November, the strain gauge deficiencies were noted on the lift links of two aircraft. Aircraft 66-15286 had a defective strain gauge that appeared to have been damaged during a routine

TABLE 35. FLIGHT CONDITION LOGIC MODIFICATIONS

<u>Flight Condition</u>	<u>Modification</u>
Normal/Autorotation Landing	Minor changes to lengthen period required for low torque and average torque values
Gunnery Run Dive	Major logic change (see Chapter 4)
Pullup - Symmetrical and Asymmetrical	Major logic change to be compatible with Dive Logic (see Chapter 4)
Autorotation Time	Minor change to correct software coding error
Full Power Climb	Minor change to provide category for low-speed, high-power climb
Maximum V_L	Minor change to require time delay prior to start of recorder operation
Quick Stops	Minor change to require decrease in airspeed during maneuver

maintenance operation. Aircraft 66-15252 was found to have a defective strain gauge bridge. Thus, three aircraft were essentially unable to provide useful data during the operation test program.

Aircraft 66-15473, and 66-15254 systems were operational for the entire test period from 1 October to 28 December 1977. During that 90-day period, 132.3 hours of data were captured on aircraft 66-15254. A total of 128.7 hours were retrieved from aircraft 66-15473.

Explicit Determination of Gross Weight (GW)

As noted previously, the attempt to determine AH-1G gross weight by strain gauging the landing gear was unsuccessful. During the IOT&E flight test program (Phase II Operational Flight Test), an alternate approach was to strain gauge the lift links to explicitly measure gross weight. The gross weight parameter is important to calculation of fatigue lives of the 10 parts under consideration.

From the R&D standpoint, it was found to be possible to determine GW by instrumenting the lift links. However, the concept produced consistently erratic data, required close technical attention, and was failure prone. The concept involved bonding strain gauges to the lift link. This was generally found unsatisfactory due to lack of good mechanical bond to the shot-peened surfaces. When operative, this was found to be marginally unsatisfactory due to the high vibration environment. Thus from an R&D standpoint, the lift link concept of instrumentation appeared feasible but from an operational viewpoint (IOT&E) the scheme was judged a failure. This short IOT&E suggests that the technique is too exotic for successful fleet-wide, operational deployment.

Tracking of High-Value, Fatigue Sensitive Parts

During the IOT&E flight test program the practical matter of keeping track of the 10 selected parts became difficult. Nevertheless, as parts are installed or removed for whatever reason, SIRS logistical integrity requires close attention to service lives of all parts on all aircraft that are involved. This IOT&E flight test program, while short, was adequate to sharply focus on the need for a simple, effective parts tracking procedure.

DTU Packaging

DTU operators were required to travel from contractor facilities to the responsible test organization at Fort Rucker throughout this limited IOT&E program. The mode of transportation selected, normally commercial air, resulted in considerable experience with operator transportation of the DTU. Early in

the program, operator observations began to accumulate as to the unwieldy nature of the packaging concept selected for this ground support equipment. Flight test time was inadequate for thorough evaluation of this equipment. Thus it was not determined whether an alternative packaging concept would be a nice-to-have operational attribute or a mission-essential factor.

DTU Tape Drive

During the course of this limited IOT&E program, the use of a one-way controller on the DTU tape drive was found to be a defective design concept. During DTU operations requiring tape search, the design concept that uses rewind times to find a specific record consistently resulted in selection of the incorrect record. This was due to system hysteresis from wear and varying ambient temperature, which caused inconsistent operation of the mechanical elements of the winding and re-winding mechanisms.

Use of DTU During Battery Charging Operation

The design concept was found to preclude DTU operations for other tasks during battery recharging operations. This was of no particular import in the R&D environment during DT&I. However, the operational import became clear during the IOT&E phase of this testing. Corrective action is indicated as this attribute of the design reduces maintenance productivity.

Logistics of Data Reduction

The IOT&E portion of the AH-1G flight test program was an opportunity to proof-test the original data reduction concept. In that capacity the contractor emulated the postulated Data Processing Center. The concept is summarized as follows:

At the Data Processing Center, the recorded data would be converted into assessment of fatigue damage. The effort would be divided into three tasks: initial processing (IPS), fatigue damage assessment (FDAS), and component tracking management (CTMS). Each task, as described in Chapter 3, was developed as a separate system, with appropriate interfaces, to form the data processing system.

During this IOT&E both the IPS and FDAS were satisfactorily demonstrated. No attempt was made to test or evaluate the CTMS.

Statistical Evaluation of Calculated Component Damage

From the test data reported in Chapter 4, it seems apparent that the damage values for the 10 components under consideration differ according to the technique used to calculate the cumulative damage. Here we will statistically test that observation. Three null hypotheses will be tested:

$H_0(1)$: Component damage = Component damage
recorder-derived logbook-derived

$H_0(2)$: Component damage = Component damage
SIRS-derived logbook-derived

$H_0(3)$: Component damage = Component damage
recorder-derived SIRS-derived

The approach used is to take the smallest difference between the respective values for the test of these hypotheses. From Table 34 the smallest delta was found. Table 36 summarizes the deltas and associated calculations. $H_0(1)$ is tested via Main Rotor Grip data. $H_0(2)$ will be tested with Swashplate Drive Link data, and $H_0(3)$ will be tested with Swashplate Outer Ring data. All null hypotheses were rejected at the 5-percent significance level. Sample Calculation 1 using small sampling theory is shown.

Sample Calculation 1

Test Null Hypothesis $H_0(1)$: $0.00514 = 0.00910$ (from Reference 8, p. 261) to a 5-percent level of significance:

$$N_1 = 16$$

$$N_2 = 16$$

$$\bar{x}_1 = 0.00514$$

$$\bar{x}_2 = 0.00910$$

$$S_{\bar{x}_1} = 0.00317 \text{ (Std. Error)}$$

$$S_{\bar{x}_2} = 0.001777 \text{ (Std. Error)}$$

$$V_1 = 0.0000100489$$

$$V_2 = 0.0000031577$$

8. Tintner, G., MATHEMATICS AND STATISTICS FOR ECONOMISTS, New York: Holt, Rinehart, and Winston, 1965.

$$\begin{aligned}
S^2_{\bar{x}_1 - \bar{x}_2} &= \frac{[N_1 - 1)V_1 + (N_2 - 1)V_2](N_1 + N_2)}{N_1 N_2 (N_1 + N_2 - 2)} \\
&= \frac{[(16-1)0.0000100489 + (16-1)(0.0000031577)](16+16)}{16(16)(16+16-2)} \\
&= \frac{[15(0.0000100489) + 15(0.0000031577)](32)}{16(16)(30)} \\
&= \frac{(0.0001507335 + 0.0000473655)(32)}{7680} \\
&= \frac{(0.000198099)32}{7680} = \underline{\underline{0.0000008254}}
\end{aligned}$$

$$t(\text{empirical}) = \frac{(0.00514 - 0.00910)}{8.254 \times 10^{-7}} = 4797.60$$

$$n \text{ (degree of freedom)} = N_1 + N_2 - 2 = 16 + 16 - 2 = 30$$

$$t \text{ (at 5-percent significance)} = 2.042$$

Since $t(\text{empirical}) \gg t(\text{required at 5-percent significance})$, null hypothesis is rejected.

Of final concern is whether the standard deviations observed during the IOT&E flight test are statistically substantiative. Therefore three additional hypotheses will be tested:

$$H_0(4): \sigma \begin{pmatrix} \text{Component damage} \\ \text{recorder-derived} \end{pmatrix} = \sigma \begin{pmatrix} \text{Component damage} \\ \text{logbook-derived} \end{pmatrix}$$

$$H_0(5): \sigma \begin{pmatrix} \text{Component damage} \\ \text{SIRS-derived} \end{pmatrix} = \sigma \begin{pmatrix} \text{Component damage} \\ \text{logbook-derived} \end{pmatrix}$$

$$H_0(6): \sigma \begin{pmatrix} \text{Component damage} \\ \text{recorder-derived} \end{pmatrix} = \sigma \begin{pmatrix} \text{Component damage} \\ \text{SIRS-derived} \end{pmatrix}$$

The same methodology previously used is repeated here. $H_0(4)$ will be tested via swashplate drive link data. $H_0(5)$ will be tested with main rotor blade data, and $H_0(6)$ will be tested with swashplate drive link data. Table 37 shows the smallest ΔS_x selected. Sample Calculation 2 is similar to that previously shown (Reference 8).

TABLE 36. EVALUATION OF $\Delta\bar{x}$ FOR CALCULATED COMPONENT DAMAGE

	① SIRS Spectrum	② Recorder Spectrum	③ Logbook Spectrum	②-③ Absolute Value	①-③ Absolute Value	①-② Absolute Value
Main Rotor Blade	0.01041	0.04386	0.08491	0.04105	0.0745	0.03345
Main Rotor Yoke Extension	0.000594	0.01462	0.02833	0.01371	0.027736	0.014026
Main Rotor Grip	0.01106	0.00514	0.00910	0.00396	0.00196	0.00592
Main Rotor Pitch Horn	0.00023	0.00779	0.01379	0.006	0.10356	0.00327
Retention Strap Ftg/Nut	0.03272	0.02338	0.04137	0.01799	0.00865	0.00934
Swashplate Drive Link	0.00020	0.00468	0.00828	0.0036	0.00808	0.00448
Swashplate Outer Ring	0.01870	0.01559	0.02758	0.01199	0.00888	0.00311
Swashplate Inner Ring	0.00320	0.01694	0.02923	0.01229	0.02603	0.01374
Hydraulic Boost Cylinder	0.00037	0.01462	0.02830	0.01368	0.02793	0.01425
Tail Rotor Blade	0.02723	0.05080	0.08771	0.03691	0.06048	0.02357

TABLE 37. EVALUATION OF ΔS_x FOR CALCULATED COMPONENT DAMAGE

	① SIRS Spectrum	② Recorder Spectrum	③ Logbook Spectrum	②-③ Absolute Value	①-③ Absolute Value	①-② Absolute Value
Main Rotor Blade	0.01139	0.02679	0.01206	0.01473	0.00067	0.0154
Main Rotor Yoke Extension	0.01314	0.00893	0.00400	0.00493	0.00914	0.00421
Main Rotor Grip	0.02957	0.00317	0.00177	0.0014	0.0278	0.0264
Main Rotor Pitch Horn	0.00091	0.00480	0.00269	0.00211	0.00178	0.00389
Retention Strap Ftg/Nut	0.1732	0.01439	0.0080	0.00632	0.00925	0.00293
Swashplate Drive Link	0.00081	0.00288	0.00161	0.00127	0.0008	0.00207
Swashplate Outer Ring	0.06998	0.00960	0.00538	0.00422	0.0646	0.06038
Swashplate Inner Ring	0.00709	0.00992	0.00432	0.0056	0.00277	0.00283
Hydraulic Boost Cylinder	0.00035	0.00893	0.00402	0.00491	0.00367	0.00858
Tail Rotor Blade	0.04352	0.02976	0.01296	0.0168	0.03056	0.01376

Sample Calculation 2

$$N_1 = 11$$

$$N_2 = 11$$

$$\bar{x}_1 = 0.01139$$

$$\bar{x}_2 = 0.01206$$

$$S_{\bar{x}_1} = 0.00343 \text{ (Std. Error)}$$

$$S_{\bar{x}_2} = 0.00364 \text{ (Std. Error)}$$

$$V_1 = 0.00001176$$

$$V_2 = 0.0000132496$$

$$\begin{aligned} S^2_{\bar{x}_1 - \bar{x}_2} &= \frac{[(N_1 - 1)V_1 + (N_2 - 1)V_2](N_1 + N_2)}{N_1 N_2 (N_1 + N_2 - 2)} \\ &= \frac{[10(0.00001176) + 10(0.0000132496)](22)}{121(20)} \\ &= \frac{(0.0001176 + 0.000132496)22}{2420} \\ &= \frac{(0.000250096)22}{2420} \\ &= 0.000022736 \\ t(\text{empirical}) &= \frac{(0.01139 - 0.01206)}{2.2736 \times 10^{-6}} \\ &= \underline{\underline{-294.68}} \end{aligned}$$

$$n \text{ (degrees of freedom)} = N_1 + N_2 - 2 = 11 + 11 - 2 = 20$$

$$t \text{ (at 5-percent significance)} = 2.086$$

Since $t(\text{empirical}) \gg t(\text{required at 5-percent significance})$, null hypothesis is rejected.

In summary, $H_0(1)$, $H_0(2)$, $H_0(3)$, $H_0(4)$, $H_0(5)$, and $H_0(6)$ are rejected at the 5-percent level of significance. This means that the deltas are due to a systematic assignable difference and cannot be attributed to a random phenomenon. The relationships of each technique to the implied service lives of these high-value, fatigue-sensitive assemblies may be observed in Figures 34 through 43.

It will be noted that the "greater than" ogives used in the figures imply a normal distribution. In an attempt to determine whether a normal distribution represented a good fit for a given data, normal curve graph paper was used to check closeness of fit on four randomly selected samples of the SIRS data. The plotted points fell reasonably close to a straight line. Hence the data was treated as normally distributed for purposes of the preliminary evaluation.

The means for each type of failure calculation are significantly different. The standard deviations for each type of failure calculation are significantly different. The standard deviations found for the SIRS throughout this test series must be considered marginally satisfactory.

Software

Three software concepts were open for evaluation during the IOT&E. The IPS, FDAS, and CMTS require close examination prior to a SIRS deployment decision. The IPS and FDAS were both exercised with satisfactory results. The CMTS remains untested in the IOT&E environment.

10
B

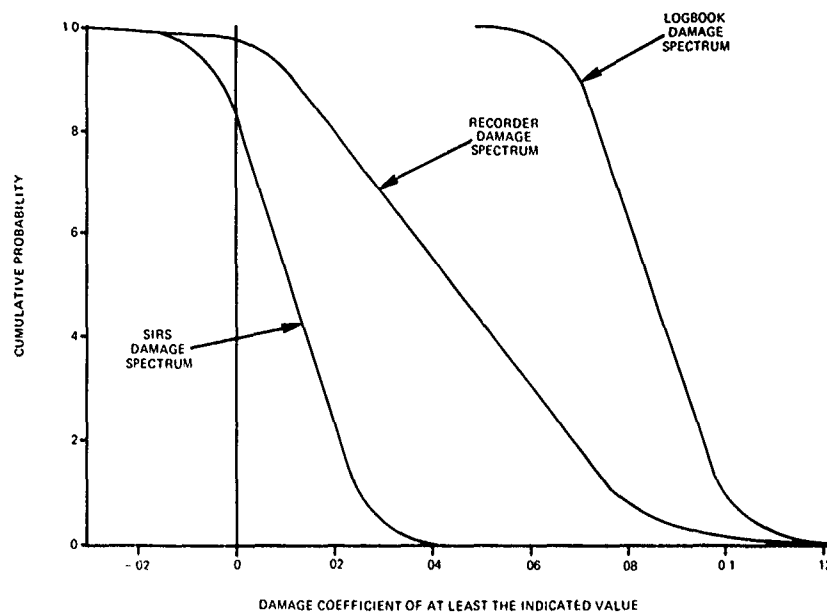


Figure 34. Main Rotor Blade Damage Spectrums.

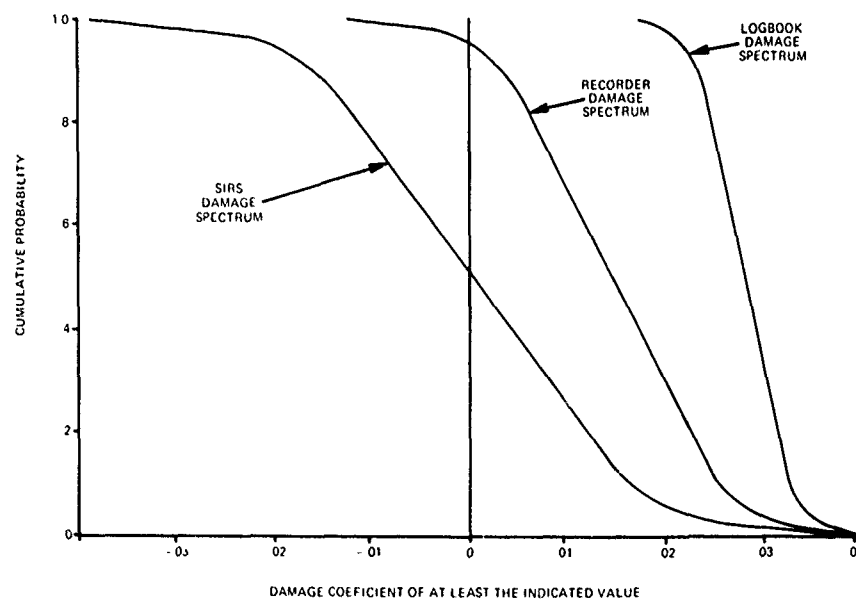


Figure 35. Main Rotor Yoke Extension Damage Spectrums.

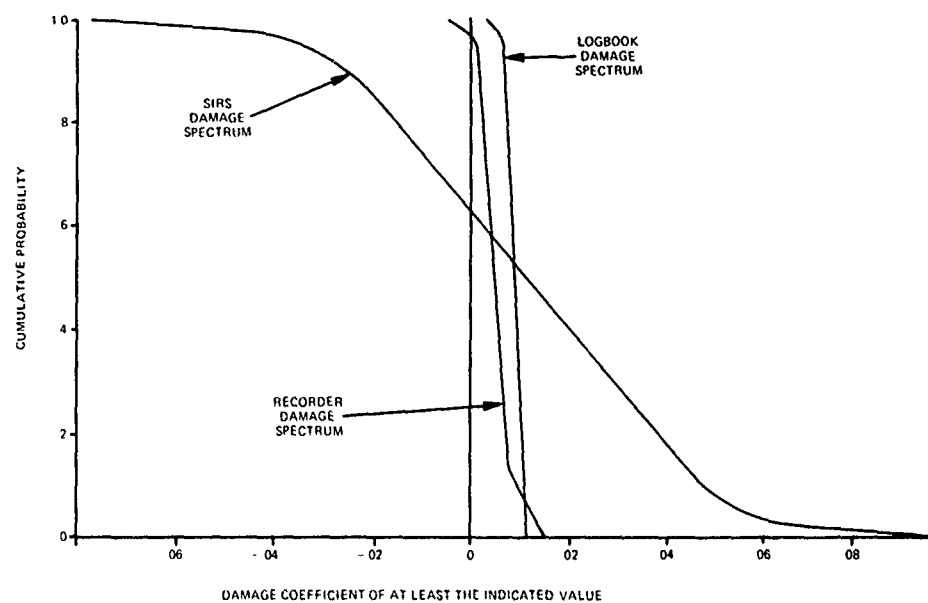


Figure 36. Main Rotor Grip Damage Spectrums.

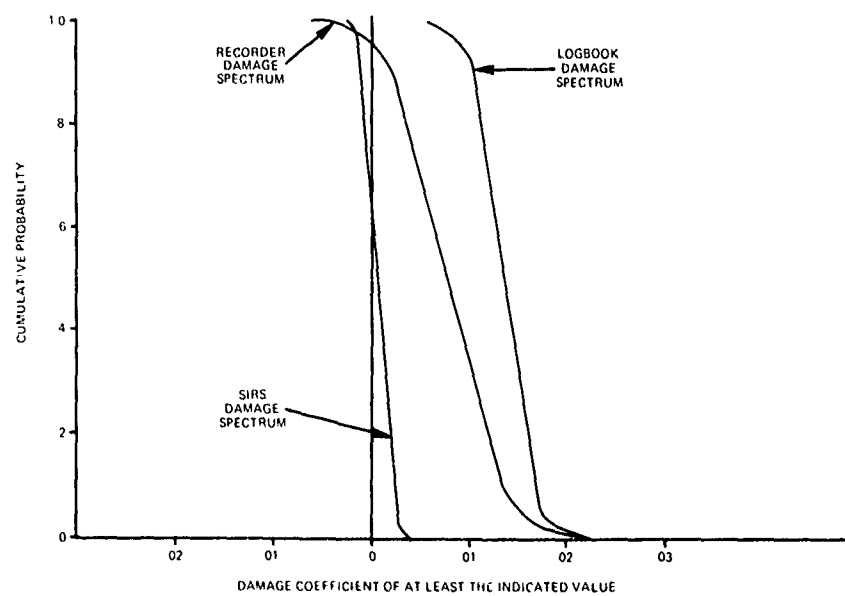


Figure 37. Main Rotor Pitch Horn Damage Spectrums.

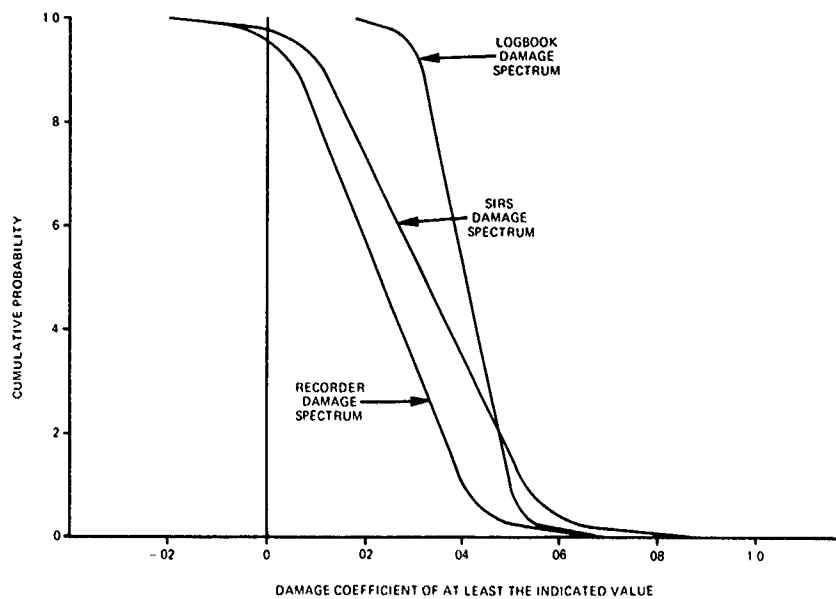


Figure 38. Retention Strap Fitting/Nut Damage Spectrums.

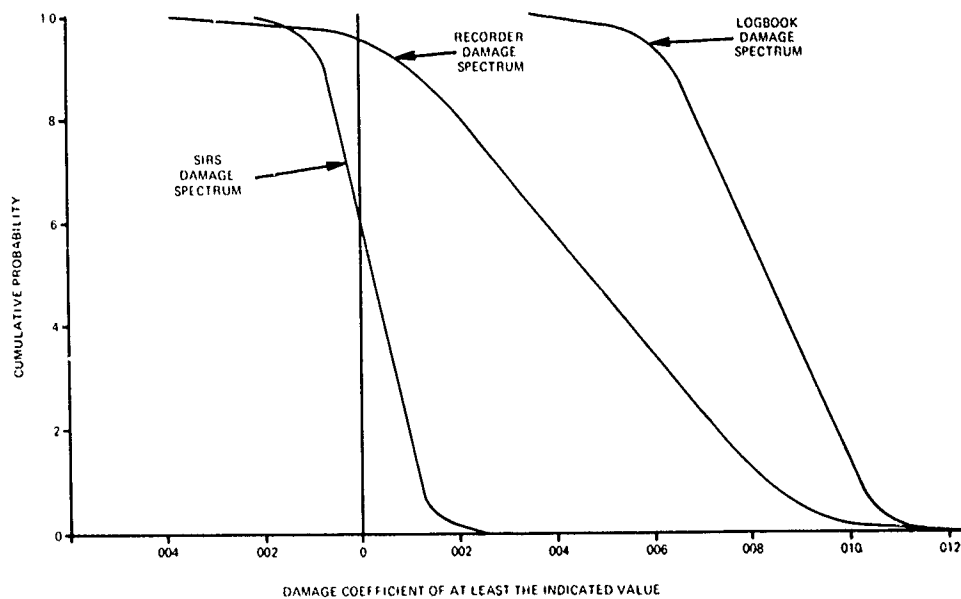


Figure 39. Swashplate Drive Link Damage Spectrums.

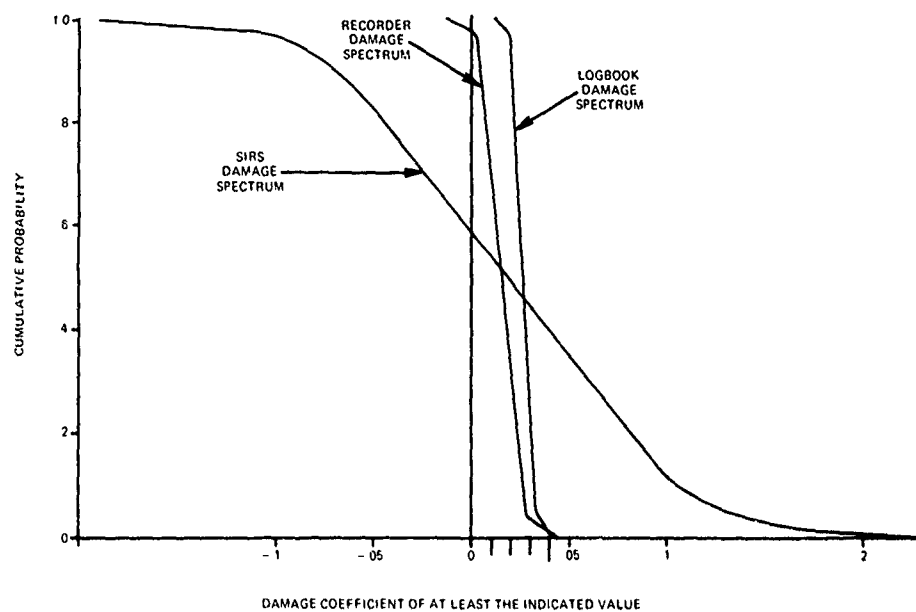


Figure 40. Swashplate Outer Ring Damage Spectrums.

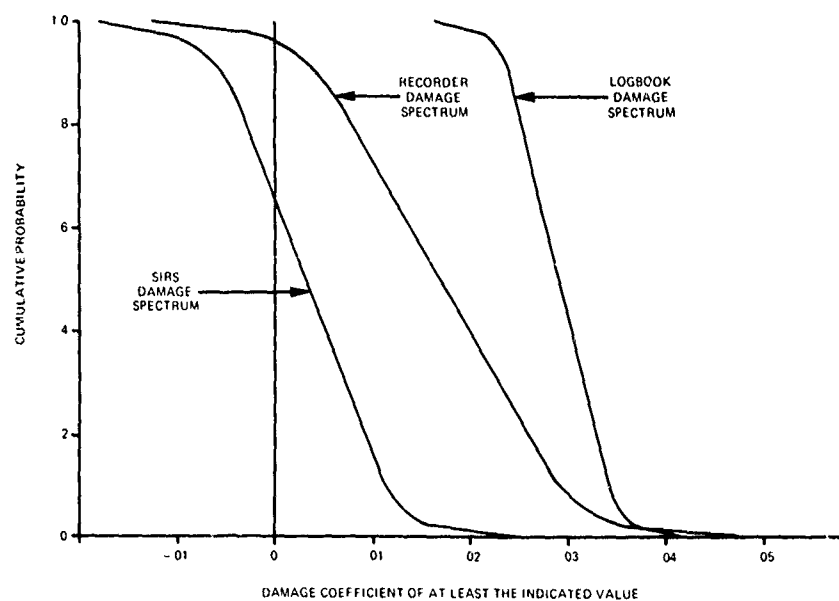


Figure 41. Swashplate Inner Ring Damage Spectrums.

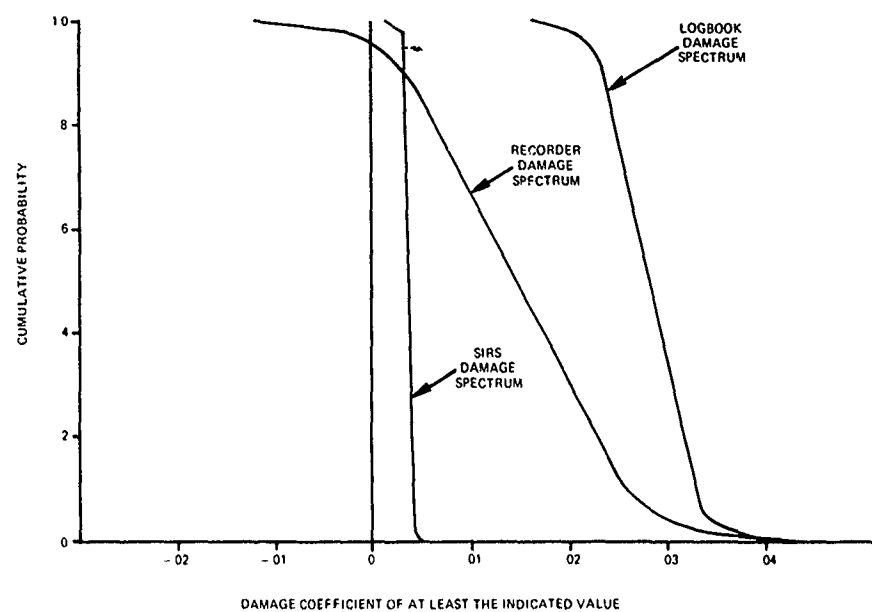


Figure 42. Hydraulic Boost Cylinder Damage Spectra.

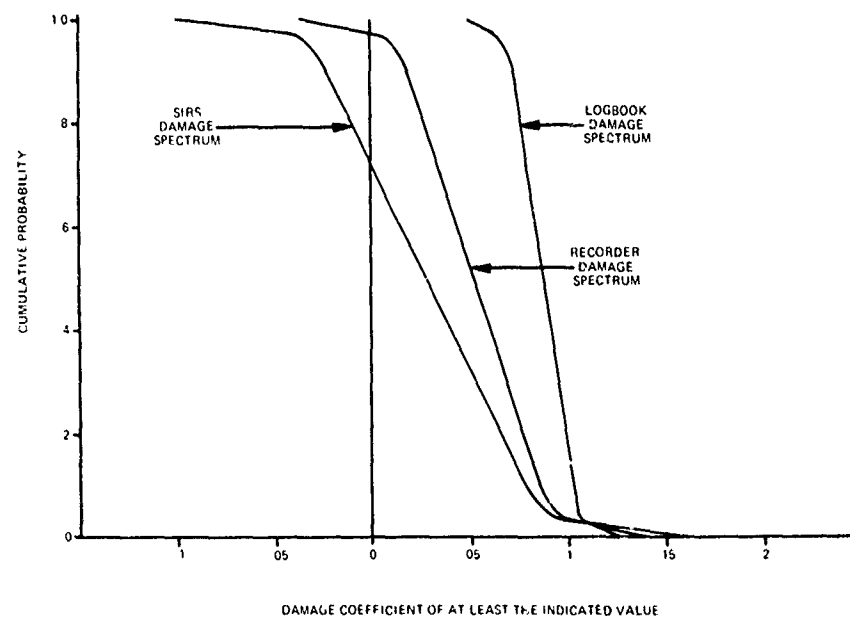


Figure 43. Tail Rotor Blade Damage Spectra.

CHAPTER 6.

CONCLUSIONS

DT&E FLIGHT TEST (PHASE I PROTOTYPE FLIGHT TEST)

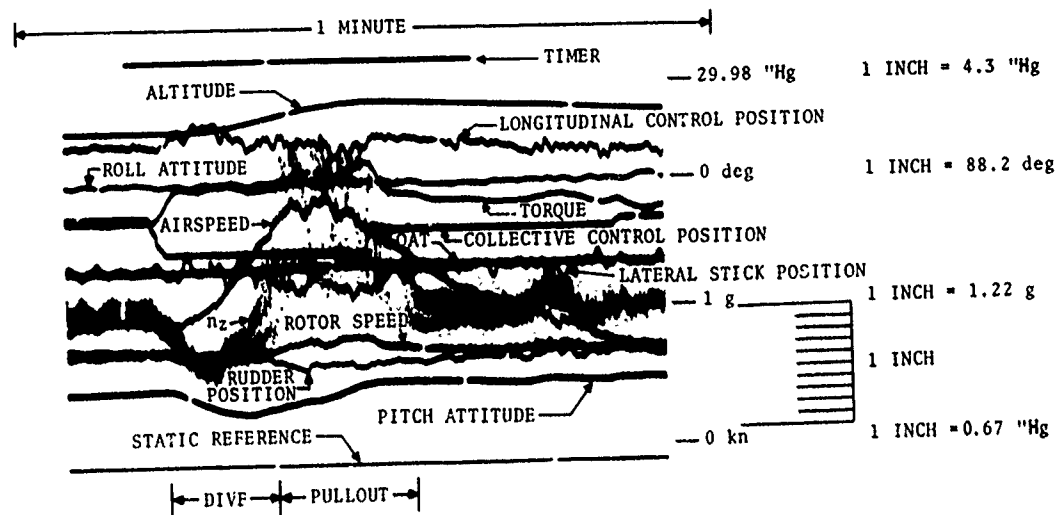
Software Modifications

Of the seven modifications identified, two have already been discussed, i.e., normal versus autorotational landing and maximum V_L detection. The logic change for measuring autorotative time was required because the software had a design error. That is, the logic included a timer designed to filter transients from the torque transducer output, but the logic did not properly clear this timer, thereby causing random amounts of time to be put into this flight condition category whenever a transient occurred. For the full-power climb condition, additional memory was allocated to permit recording both low-speed and high-speed climbs at high power settings. A minor change was made to the software, defining a Quick Stop so that the airspeed would have to decrease during the maneuver before it could be recorded.

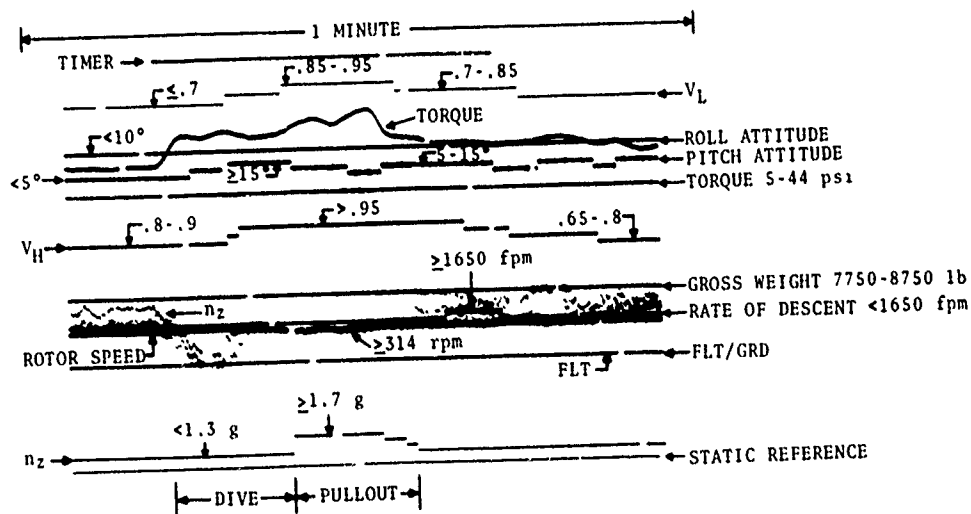
During the flight test program, numerous dives and corresponding pullouts were performed, but very little time was recorded by the SIRS recorder in either type of flight condition. In most instances, the logic relationships between rate of descent, airspeed, and vertical acceleration did not correlate with the actual relationships. A review of the data collected during the various symmetrical and asymmetrical dives and the resulting pullouts, such as the example shown in Figure 44, led to a simple method for identifying the dives. The SIRS recorder logic now "looks for" a negative vertical acceleration greater than 0.8g followed by a positive vertical acceleration of 1.3g or greater; during this interval, the airspeed must increase and the altitude must decrease by certain prescribed amounts. The dive is then categorized by the gross weight, airspeed, and vertical acceleration levels once it has been determined to be a symmetrical or asymmetrical (roll attitude outside of threshold) dive. The resulting pullout from a dive is defined as the duration that the vertical acceleration is between 1.3g and 1.1g; it is categorized by airspeed, gross weight, and its symmetrical or asymmetrical configuration.

Hardware Modifications

An alternate gross weight monitoring approach that measures gross weight in flight was identified during a joint in-house investigation conducted by Bell Helicopter Textron and Technology Incorporated. This system would measure the axial load within the lift link, a transmission mounting member. Such a system



(a) FCR Oscillograph



(b) Flag Oscillograph

Figure 44. Dive/Dive Pullout.

would update the aircraft gross weight of the helicopter whenever the helicopter is in level, unaccelerated flight. Consequently, this system would measure the gross weight more accurately than the skid landing gear technique because it could detect gross weight changes due to weapons firing.

IOT&E (PHASE II OPERATIONAL EVALUATION)

Explicit Determination of Gross Weight

During the DT&E and IOT&E program two procedures were evaluated to explicitly measure the GW parameter during flight operations of the AH-1G. One was found to be marginally satisfactory from a technical standpoint (DT&E). Both were unsatisfactory from an operational standpoint (IOT&E).

It must be recognized that the GW parameter is important in calculating fatigue lives of the 10 selected parts. However, it is additionally recognized that explicit measurement of this parameter comprises a state-of-the-art challenge. In addition, explicit measurement will be expensive. A fresh look at the problem is in order.

A cursory examination of the fatigue life calculations and the recommended service lives of the 10 selected parts implies a large error budget. This is not surprising due to the empirical nature of the phenomena. It is suggested that within the existing error budget, the GW parameter could be imputed with a priori knowledge of the part usage. Finally, all possible instrumentation options should be considered if explicit GW measurement is essential.

Tracking of High-Value, Fatigue-Sensitive Parts

The need for a simple, effective parts tracking procedure for the many high-value, fatigue-sensitive parts under surveillance by the SIRS concept became apparent during this short IOT&E flight test program. In addition, the process must minimally impact the logistics support of the U.S. Army aviation program.

DTU Packaging

The reported unwieldy nature of the DTU package was noted during this brief IOT&E flight test program. This package requires more in-depth evaluation. A number of alternate DTU packaging concepts could be postulated; for example, a two-package concept with rugged elements in one box and the more sensitive elements in another.

DTU Tape Drive

The selected design concept using a single capstan controller was found to be operationally inadequate and demanded

corrective action. The tape drive vendor was contacted on this matter. It was determined that an applicable cure would be to adjust the design, providing for dual-direction capstan controllers and thus ensuring positive authority over the operation of the tape location at all times. This would enable effective data manipulation and reference in a time-efficient manner.

Use of DTU During Battery Charging Operation

The inoperability of the DTU during battery charging operations was noted. The adverse impact on productivity was deemed unnecessary since a relatively minor design adjustment would readily render the DTU available for other tasks during DTU battery charging operations.

Logistics of Data Reduction

The time invested in this short IOT&E was inadequate to completely or accurately assess the logistics of the original SIRS data reduction concept.

Statistical Evaluation of Calculated Component Damage

The test results of Chapter 4 and findings reported in Chapter 5 demonstrate that the method selected to calculate service lives of the 10 selected assemblies significantly influences the economics of AH-1G life-cycle cost for those parts.

Use of logbook data to calculate component fatigue damage produces an extravagant replenishment spares requirement.

Use of recorder data to calculate component fatigue damage will yield a significantly more economical approach to logistical support of the 10 parts under consideration. This is attributed to the fact that the recorder electronics only count fatigue-damaging phenomena beginning after rotor start. Engine run time and mission planning times, for example, are not included in calculations. Thus it may be concluded that the Army might consider a counting device (recorder values) rather than operational logbook times to arrive at component retirement lives.

The optimum service life for the 10 high-value, fatigue-sensitive parts was yielded by SIRS spectrum monitoring.

Finally, it must be concluded that the scatter of SIRS component damage data during this brief IOT&E is systematic. Examination revealed a single-point failure mechanism within the recorder; i.e., the GW sensor channel was multiplexed such that it affected all other channels. Further, the GW sensor was quite troublesome throughout the IOT&E as reported in Chapter 4. Thus SIRS performance will be significantly enhanced by implementing corrective action on the GW sensing channel and the recorder multiplexing scheme.

Software

Since the IPS and FDAS have been demonstrated and found to be satisfactory, they are considered ready for OT&E testing. It is noted that the CMTS package remains untested in the DT&E and IOT&E mode.

CHAPTER 7.

RECOMMENDATIONS

As a result of the DT&E and IOT&E flight testing, several modifications of the SIRS concept are recommended. These recommendations include software logic changes to better identify certain flight conditions and hardware modifications to better survive the operational environment. In addition, operational considerations are recommended.

DT&E FLIGHT TEST (PHASE I PROTOTYPE FLIGHT TEST)

Software Modifications

A total of seven needed software changes that were recommended were made to the SIRS recorder logic and tested in the laboratory on a SIRS recorder simulator. No further action is required on this recommendation.

Hardware Modifications

As a result of the qualification program, several hardware modifications were recommended for incorporation into the recorders to be used during the Phase II Operational Evaluation. These modifications include the improvement of some of the internal wire routing and terminations. In addition, the lithium battery that failed during the temperature-altitude-humidity test was replaced by an improved, qualified lithium battery. No retesting was contemplated since this battery has been successfully tested under similar environmental conditions.

Flight testing on a Bell Model 212 helicopter equipped with both a SIRS recorder and a magnetic tape instrumentation system indicated that the in-flight gross weight measuring system would yield valid data if the center-of-gravity excursions were not large. Because the c.g. excursion on operational AH-1G helicopters is about 5 inches for gross weights ranging between 7000 and 9500 pounds, it was felt that the lift link measurement system could be adjusted for these excursions. Moreover, this system would yield data more accurately than the skid landing gear system since the latter has the limitation of an assumed fuel burn-off rate and a fixed weight for all weapons configurations.

All of these recommended alterations were executed and were successful except for the GW sensing scheme. Details of those results are cited under the IOT&E flight test program findings (Chapter 5).

IOT&E (PHASE II OPERATIONAL EVALUATION)

Explicit Determination of Gross Weight

Since the two sensor techniques selected to explicitly measure GW were unsatisfactory, a new approach is recommended for determining this important parameter. The scheme should conform to the error budget existing within the theoretical calculated fatigue life and recommended service lives of the 10 parts under evaluation in the SIRS program. In addition, a clamped-on, piezoelectric strain gage approach should be used for instrumenting the AH-1S lift link. This will eliminate the need to mechanically bond the sensor to the shot-peened lift link surface. Thorough concept testing by follow-on IOT&E with confirmed, satisfactory results prior to implementation/deployment is recommended.

Tracking of High-Value, Fatigue-Sensitive Parts

As the DT&E program merged into the IOT&E program the importance of tracking the high-value, fatigue-sensitive parts under SIRS surveillance became unmistakable. It is recommended that the SIRS DTU be modified to provide for operator inputs when a part is changed. This will minimize the need for additional paperwork at the organizational level while capturing this vital data essential to operational utility of SIRS. This concept should be tested and evaluated via a follow-on IOT&E, with using command and logistical command inputs to the evaluations.

DTU Packaging

The reported unwieldy nature of the DTU packaging should be investigated within the operational environment. The selected design is inconvenient to the operator from the standpoint of transportation. Nevertheless, execution of alternative packaging concepts entails life-cycle-cost implications. Further IOT&E of the DTU packaging should be accompanied by a cost-benefit evaluation of postulated alternatives.

DTU Tape Drive

The single DTU tape drive capstan control concept required rectification. The appropriate corrective action was to provide for dual wind/rewind capstan controllers. This recommendation was implemented and was subsequently found to be satisfactory. The DTU employed in the follow-on IOT&E flight test program of AH-1S employs this design concept. No further action is required.

Use of DTU During Battery Charging Operation

It is recommended that the DTU circuitry be redesigned to provide for operability during the battery recharging operation and that the redesign be evaluated during follow-on IOT&E.

Logistics of Data Reduction

The postulated data processing system in support of the SIRS concept was inadequately tested or evaluated due to the compressed time schedule. Complete and thorough testing and evaluation of the system via an appropriate extension of the IOT&E period is recommended. The IPS, FDAS, and CTMS should be closely examined as an integral part of the AVSCOM RAMMIT system.

Statistical Evaluation of Calculated Component Damage

The use of operational logbook hours to calculate component fatigue damage for high-value, fatigue-sensitive assemblies yields extravagant results. It is recommended that SIRS be used to compute service lives of these parts.

Since the standard deviations of SIRS results can be reduced by altering the GW sensor methodology and recorder multiplexing scheme, these changes should be implemented.

The alterations should be carefully and adequately tested via a follow-on IOT&E. Assessments by using command and logistical command should be provided prior to a deployment decision.

Software

The IPS and FDAS packages are operational. The CMTS concept should be reviewed to ensure its capability with U.S. Army aviation program needs.

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ABBREVIATIONS

ATR	Airborne Transmitter Rack
BIT	Built-In Test
CTMS	Component Tracking Management System
DoD	Department of Defense
DT&E	Development Test and Evaluation
DTU	Data Transfer Unit
EMI	Electromagnetic Interference
EMC	Electromagnetic Compatability
EPROM	Erasable Programmable Read-Only Memory
FCC	Flight Condition Category
FCM	Flight Condition Monitoring
FCR	Flight Condition Recognition
FDAS	Fatigue Damage Assessment System
GW	Gross Weight
H-GW	High Gross Weight
IOT&E	Initial Operational Test and Evaluation
IPS	Initial Processing System
L-GW	Light Gross Weight
M-GW	Medium Gross Weight
MTBF	Mean-Time-Between-Failures
O&S	Operating and Support
PC	Printed Circuit
R&D	Research and Development
RAM	Random Access Memory
RAMMIT	Reliability and Maintainability Management Improvement Techniques

ABBREVIATIONS - Concluded

RJE	Remote Job Entry
SIRS	Structural Integrity Recording System
V_H	Maximum Attainable (Level Flight) Velocity
V_L	Limit Velocity

APPENDIX A

DETAILED FCM SYSTEM DESCRIPTION

This appendix describes the flight condition categories in terms of the pertinent flight parameters by indicating the criteria that govern (1) the definition and identification of each flight condition category, and (2) the requirements for monitoring the flight condition categories. These criteria are defined by sample (theoretical) time-history traces and written descriptions.

The 103 flight condition categories are summarized in Table A-1. The letters in the column entitled "Type" are defined as follows:

- T = accumulated time spent in the flight condition category during a specified recording period
- C = accumulated occurrences of the flight condition category during a specified recording period
- M = maximum parameter magnitude during a specified recording period
- N = null recording category

The system parameters, both those directly recorded and those computed, are summarized in Table A-2.

TABLE A-1. FCM SYSTEM SUMMARY

Flt. Cond. Cat. No.			Parameters	Type	Thresholds
Gross Weight (lb)					
<7750	7750-8750	>8750			
1	2	3	Clock Time	T	.....
	4		Rotor Speed Above or Below Threshold	C	100 RPM
5	6	7	Vertical Accel. Below Threshold A/S Below Threshold Roll Attitude Below Threshold Pitch Attitude Above Threshold Engine Torque Press. Above Threshold	T	$n_z < 1.3g$ $A/S < 0.50 V_H$ $\beta < 10^\circ$ $\theta > 15^\circ$ $ET > 5 \text{ psi}$
8	9	10	Engine Torque Press. Above Threshold Touchdown Occurs	C	$ET > 5 \text{ psi}$
11	12	13	Vertical Accel. Below Threshold A/S Between Threshold Roll Attitude Below Threshold Rate of Descent Below Threshold	T	$n_z < 1.3g$ $0.50 V_H < A/S < 0.65 V_H$ $\beta < 10^\circ$ $RD < 1650 \text{ fpm}$
14	15	16	Vertical Accel. Below Threshold A/S Between Threshold Roll Attitude Below Threshold Rate of Descent Below Threshold Engine Torque Press. Between Thresholds	T	$n_z < 1.3g$ $0.65 V_H < A/S < 0.95 V_H$ $\beta < 10^\circ$ $RD < 1650 \text{ fpm}$ $5 \text{ psi} < ET \leq 44 \text{ psi}$
17	18	19	Vertical Accel. Below Threshold A/S Above Threshold Roll Attitude Below Threshold Rate of Descent Below Threshold	T	$n_z < 1.3g$ $A/S \geq 0.95 V_H$ $\beta < 10^\circ$ $RD < 1650 \text{ fpm}$
20	21	22	Vertical Accel. Below Threshold A/S Between Thresholds Roll Attitude Below Threshold Rate of Descent Below Threshold Engine Torque Press. Above Threshold	T	$n_z < 1.3g$ $0.50 V_H < A/S < 0.65 V_H$ $\beta < 10^\circ$ $RD < 1650 \text{ fpm}$ $ET > 44 \text{ psi}$
23	24	25	Vertical Accel. Between Threshold A/S Between Thresholds Roll Attitude Above Threshold	T	$1.3 \leq n_z < 1.5$ $0.65 V_H < A/S < 0.80 V_H$ $\beta \geq 10^\circ$
26	27	28	Vertical Accel. Between Threshold A/S Above Threshold Roll Attitude Above Threshold	T	$1.3 \leq n_z < 1.5$ $A/S \geq 0.80 V_H$ $\beta \geq 10^\circ$
29	30	31	Vertical Accel. Below Threshold A/S Below Threshold Roll Attitude Below Threshold Rate of Descent Above Threshold	T	$n_z < 1.3g$ $A/S < 0.70 V_L$ $\beta < 10^\circ$ $RD \geq 1650 \text{ fpm}$
32	33	34	Vertical Accel. Below Threshold A/S Between Thresholds Roll Attitude Below Threshold Rate of Descent Above Threshold	T	$n_z < 1.3g$ $0.70 V_L < A/S \leq 0.85 V_L$ $\beta < 10^\circ$ $RD \geq 1650 \text{ fpm}$
35	36	37	Vertical Accel. Below Threshold A/S Between Thresholds Roll Attitude Below Threshold Rate of Descent Above Threshold	T	$n_z < 1.3g$ $0.85 V_L < A/S \leq 0.95 V_L$ $\beta < 10^\circ$ $RD \geq 1650 \text{ fpm}$
38	39	40	Vertical Accel. Below Threshold A/S Above Threshold Roll Attitude Below Threshold Rate of Descent Above Threshold	T	$n_z < 1.3g$ $A/S \geq 0.95 V_L$ $\beta < 10^\circ$ $RD \geq 1650 \text{ fpm}$
41	42	43	Vertical Accel. Above Threshold A/S Below Threshold Roll Attitude Between Threshold	T	$n_z > 1.5g$ $A/S < 0.70 V_L$ $10^\circ < \beta < 35^\circ$
44	45	46	Vertical Accel. Above Threshold A/S Between Thresholds Roll Attitude Between Threshold	T	$n_z > 1.5g$ $0.70 V_L < A/S < 0.85 V_L$ $10^\circ < \beta < 35^\circ$
47	48	49	Vertical Accel. Above Threshold A/S Between Thresholds Roll Attitude Between Thresholds	T	$n_z > 1.5g$ $0.85 V_L < A/S < 0.95 V_L$ $10^\circ < \beta < 35^\circ$
50	51	52	Vertical Accel. Above Threshold A/S Above Threshold Roll Attitude Between Thresholds	T	$n_z > 1.5g$ $A/S \geq 0.95 V_L$ $10^\circ < \beta < 35^\circ$

TABLE A-1. Concluded

Flt. Cond. Cat. No.			Parameters	Type (*)	Thresholds
Gross Weight (lb)					
<7750	7750-8750	>8750			
53	54	55	Vertical Accel. Above Threshold A/S Below Threshold Roll Attitude Below Threshold Pitch Attitude Above Threshold	T	$n_z \geq 1.3g$ $A/S \leq 0.70 V_L$ $\beta \leq 10^\circ$ $\theta \geq 5^\circ$
56	57	58	Vertical Accel. Above Threshold A/S Between Thresholds Roll Attitude Below Threshold Pitch Attitude Above Threshold	T	$n_z \geq 1.3g$ $0.70 V_L \leq A/S \leq 0.85 V_L$ $\beta \leq 10^\circ$ $\theta \geq 5^\circ$
59	60	61	Vertical Accel. Above Threshold A/S Above Threshold Roll Attitude Below Threshold Pitch Attitude Above Threshold	T	$n_z \geq 1.3g$ $A/S \geq 0.85 V_L$ $\beta \leq 10^\circ$ $\theta \geq 5^\circ$
62	63	64	Vertical Accel. Above Threshold A/S Below Threshold Initial Roll Attitude Above Threshold Subsequent Roll Attitudes Below Threshold	T	$n_z \geq 1.5g$ $A/S \leq 0.65 V_H$ $\beta \geq 35^\circ$ $\theta \leq 25^\circ$
65	66	67	Vertical Accel. Above Threshold A/S Between Thresholds Initial Roll Attitude Above Threshold Subsequent Roll Attitudes Below Threshold	T	$n_z \geq 1.5g$ $0.65 V_H \leq A/S \leq 0.80 V_H$ $\beta \geq 35^\circ$ $\theta \leq 25^\circ$
68	69	70	Vertical Accel. Above Threshold A/S Above Threshold Initial Roll Attitude Above Threshold Subsequent Roll Attitudes Below Threshold	T	$n_z \geq 1.5g$ $A/S \geq 0.80 V_H$ $\beta \geq 35^\circ$ $\theta \leq 25^\circ$
71	72	73	Vertical Accel. Above Threshold A/S Below Threshold Initial Roll Attitude Above Threshold Subsequent Roll Attitude Above Threshold	T	$n_z \geq 1.5g$ $A/S \leq 0.90 V_H$ $\beta \geq 35^\circ$ $\theta \geq 25^\circ$
74	75	76	Vertical Accel. Above Threshold A/S Above Threshold Initial Roll Attitude Above Threshold Subsequent Roll Attitudes Above Threshold	T	$n_z \geq 1.5g$ $A/S \geq 0.90 V_H$ $\beta \geq 35^\circ$ $\theta \geq 25^\circ$
77	78	79	Flight Clock Time Engine Torque Press. Below Threshold	T	 $ET \leq 5 \text{ psi}$
80	81	82	Vertical Accel. Between Thresholds A/S Above Threshold Engine Torque Press. Crosses Threshold (4.6 psi)	C	$1.3 \leq n_z \leq 1.5$ $A/S \geq 0.65 V_H$ 5 psi
83	84	85	Vertical Accel. Above Threshold A/S Above Threshold Engine Torque Press. Crosses Threshold (4.6 psi)	C	$n_z \geq 1.5$ $A/S \geq 0.65 V_H$ 5 psi
86	87	88	Vertical Accel. Between Thresholds A/S Above Threshold Engine Torque Press. Below Threshold Roll Attitude Above Threshold	T	$1.3 \leq n_z \leq 1.5$ $A/S \geq 0.65 V_H$ 5 psi $\beta \geq 10^\circ$
89	90	91	Vertical Accel. Above Threshold A/S Above Threshold Engine Torque Press. Below Threshold Roll Attitude Above Threshold	T	$n_z \geq 1.5g$ $A/S \geq 0.65 V_H$ 5 psi $\beta \geq 10^\circ$
92	93	94	Engine Torque Press. Below Threshold Touchdown Occurs	C	5 psi
		95	Vertical Accel. Above Threshold A/S Above Threshold	C	$n_z \geq 1.7g$ $A/S \geq 0.50 V_H$
		96	Maximum n_z Magnitude Attained	M	.....
		97	Maximum A/S Magnitude Attained	M	$A/S = f(V_L)$
98	99	100	Not Recorded Directly	N	Not Applicable
101	102	103	Not Recorded Directly	N	Not Applicable

TABLE A-2. SYSTEM PARAMETERS

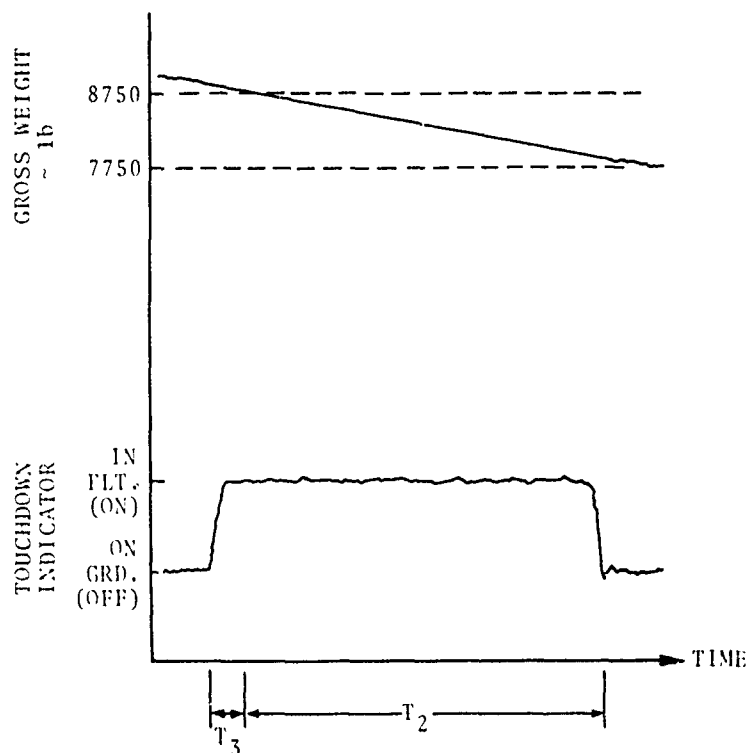
System Parameters		Directly Recorded	Computed	Sign Convention for Positive Number
Indicated Airspeed	(A/S)	X		.....
Max. Level Flight	(V_H)		$V_H = f(T, H_p)$	.....
Limit Velocity	(V_L)		$V_L = f(t, H_p)$	.....
Pressure Altitude	(H_p)	X		.....
Outside Air Temperature	(T)	X		.....
Rate of Descent	(RD)		$RD = f(H_p, \text{Time})$	Decreasing Altitude
Main Rotor Velocity	(MRV)	X		.....
Roll Attitude	(β)	X		.....
Pitch Attitude	(θ)	X		.....
Vertical Acceleration	(n_z)	X		Ship Accelerates Up
Landing Gear Touchdown	(TD)	X		.....
Engine Torque Pressure	(ET)	X		Increasing Torque
Takeoff Gross Weight	(TGW)	X		.....
In-Flight Gross Weight	(GW)		$GW = f(\text{TGW}, \text{Time})$	.....

Each type of flight condition category is depicted in Figures A-1 through A-20. In examining these figures, the following statements are applicable to all flight condition categories:

1. Unless otherwise indicated, the engine torque pressure in each flight condition category must be greater than 5 psi.
2. Whenever a roll or a pitch attitude threshold is defined (e.g., $\beta > 10^\circ$), it represents the absolute value of roll or pitch attitude (i.e., $|\beta| \geq 10^\circ$).

Represents: Flight Clock Time

FCC Applicability	TD ON/OFF
FCC #1	GW < 7750 lb
FCC #2	7750 lb < GW ≤ 8750 lb
FCC #3	GW > 8750



T_1 = FCC #1 Timer
 T_2 = FCC #2 Timer
 T_3 = FCC #3 Timer

Description

Monitor the clock time accrued by the helicopter while airborne.

Figure A-1. Flight Condition Categories 1, 2, and 3 (In-Flight Time).

Represents: Rotor Start/Stop

MRV ≥ 100 rpm



C_4 = FCC #4 counter

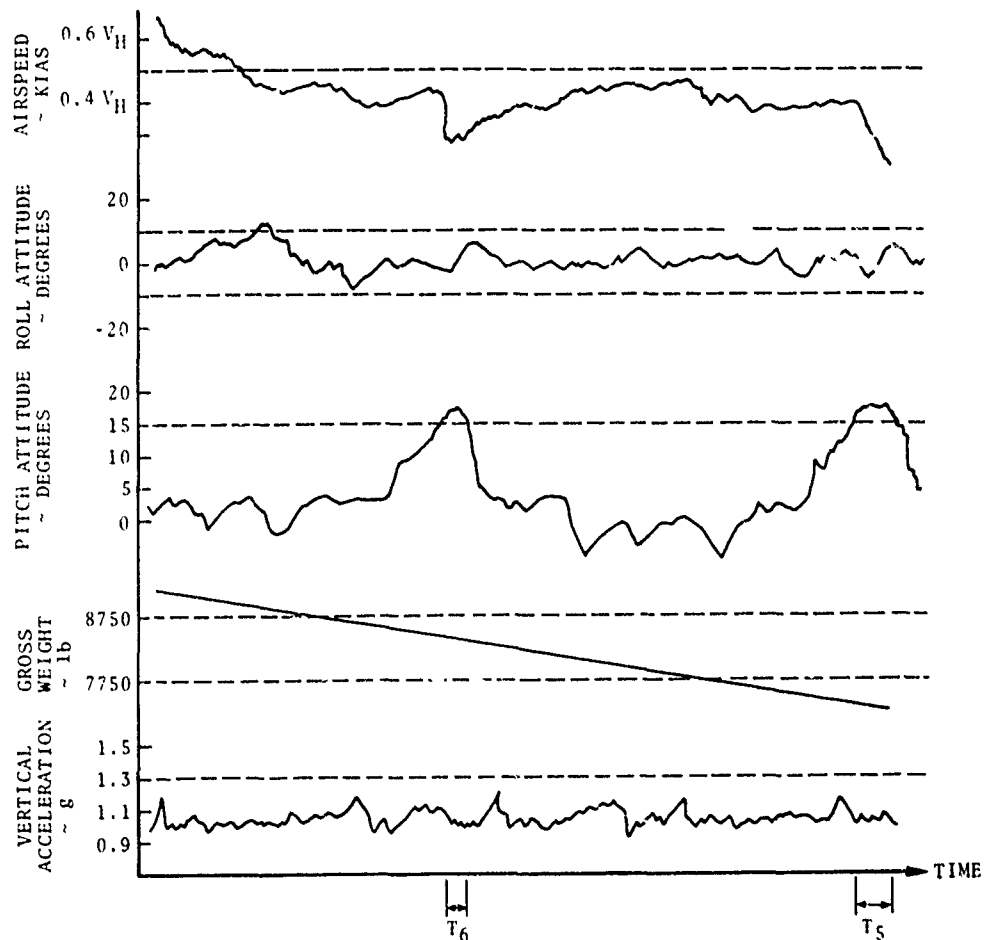
Description

Monitor the number of times the main rotor velocity passes through the 100 rpm regime. To ensure against extra C_4 counts due to small perturbations of the main rotor velocity, require that all C_4 events must occur at least 10 seconds apart.

Figure A-2. Flight Condition Category 4 (Rotor Start/Stop).

Represents: Quick-Stop Deceleration

FCC Applicability	$n_z < 1.3g$
	$A/S < 0.50 V_H$
	$\beta < 10^\circ$
	$\theta > 15^\circ$
FCC #5	$ET > 5 \text{ psi}$
FCC #6	$GW < 7750 \text{ lb}$
FCC #7	$7750 \text{ lb} < GW \leq 8750 \text{ lb}$
	$GW > 8750 \text{ lb}$



T_5 = FCC #5 Timer
 T_6 = FCC #6 Timer
 T_7 = FCC #7 Timer

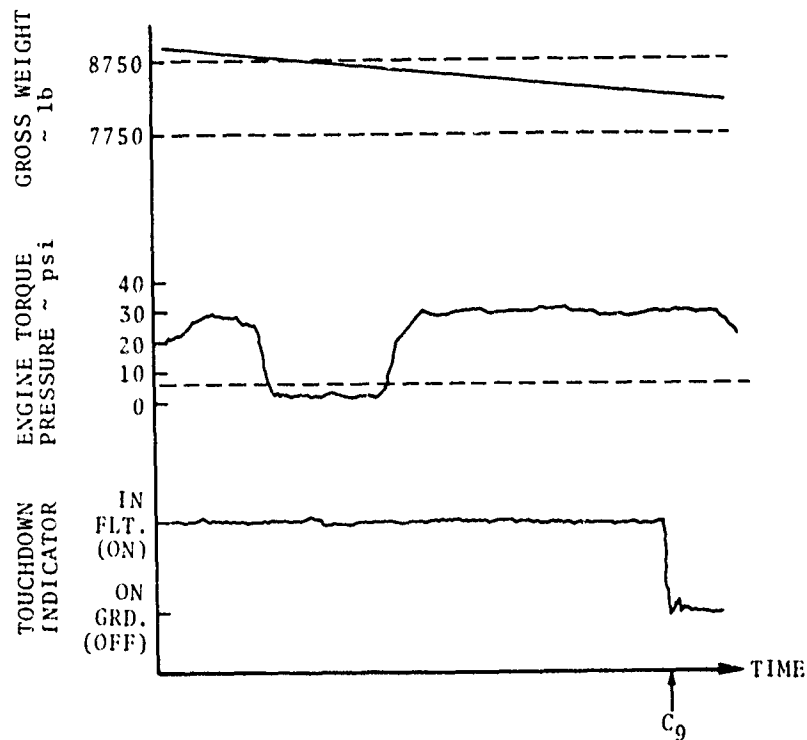
Description

Monitor the clock time accrued by the helicopter during which all six parameter threshold definitions are being satisfied simultaneously. The airspeed requirement is based on maximum attainable velocity at constant altitude (V_H), which is a function of density altitude.

Figure A-3. Flight Condition Categories 5, 6, and 7 (Quick-Stop Deceleration).

Represents: Normal Landing

FCC Applicability	ET > 5 psi TD ON/OFF
FCC #8	GW < 7750 lb
FCC #9	7750 lb < GW ≤ 8750 lb
FCC #10	GW > 8750 lb



C₈ = FCC #8 Counter
 C₉ = FCC #9 Counter
 C₁₀ = FCC #10 Counter

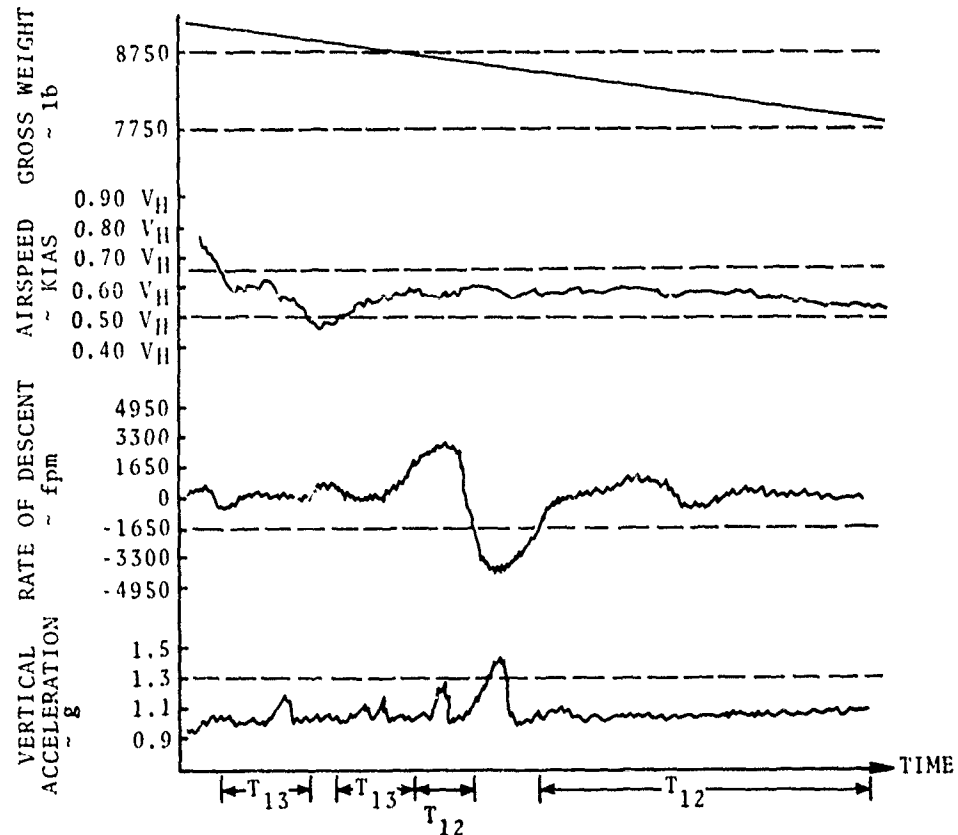
Description

The engine torque pressure must be above threshold immediately prior to (at least 10 seconds), and at the time of, touchdown. Once a touchdown has been recorded, a rebounding helicopter should not register additional counts.

Figure A-4. Flight Condition Categories 8,9, and 10 (Normal Landing).

Represents: Low-Velocity Flight Conditions
(e.g., Forward Level Flight, Normal Full
Power Climbs, and Low-Speed Turns)

FCC Applicability	$n_z < 1.3g$
	$0.50 V_H \leq A/S < 0.65 V_H$
	$\beta < 10^\circ$
	$RD < 1650 \text{ fpm}$
FCC #11	$GW < 7750 \text{ lb}$
FCC #12	$7750 \text{ lb} < GW \leq 8750 \text{ lb}$
FCC #13	$GW > 8750 \text{ lb}$



T_{11} = FCC #11 Timer
 T_{12} = FCC #12 Timer
 T_{13} = FCC #13 Timer

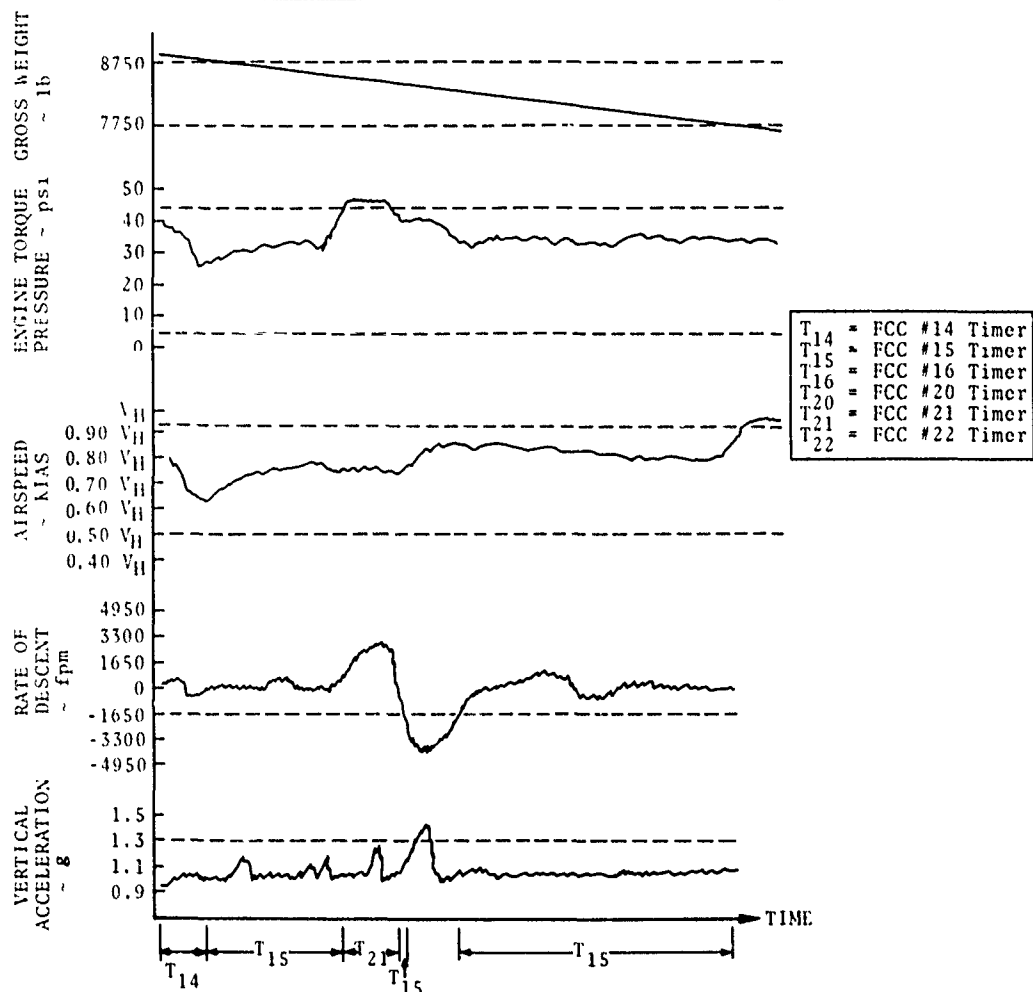
Description

Monitor the clock time accrued by the helicopter during which all five parameter threshold definitions are being satisfied simultaneously. The airspeed classification is based on maximum attainable velocity at constant altitude (V_H), which is a function of density altitude.

Figure A-5. Flight Condition Categories 11, 12, and 13 (Low-Velocity Flight).

Represents: High-Velocity Flight Conditions
(e.g., Forward Level Flight, Part Power Descent,
High-Speed Control Corrections, and High-Speed
Full Power Climbs)

FCC Applicability		$n_z < 1.3g$ $0.50 V_H \leq A/S \leq 0.95 V_H$ $\beta < 10^\circ$ $RD < 1650 \text{ fpm}$ $GW < 7750 \text{ lb}$ $7750 \text{ lb} < GW \leq 8750 \text{ lb}$ $GW > 8750 \text{ lb}$
—For—	—For—	
$5 < ET \leq 44$	$ET > 44$	
FCC #14	FCC #20	
FCC #15	FCC #21	
FCC #16	FCC #22	



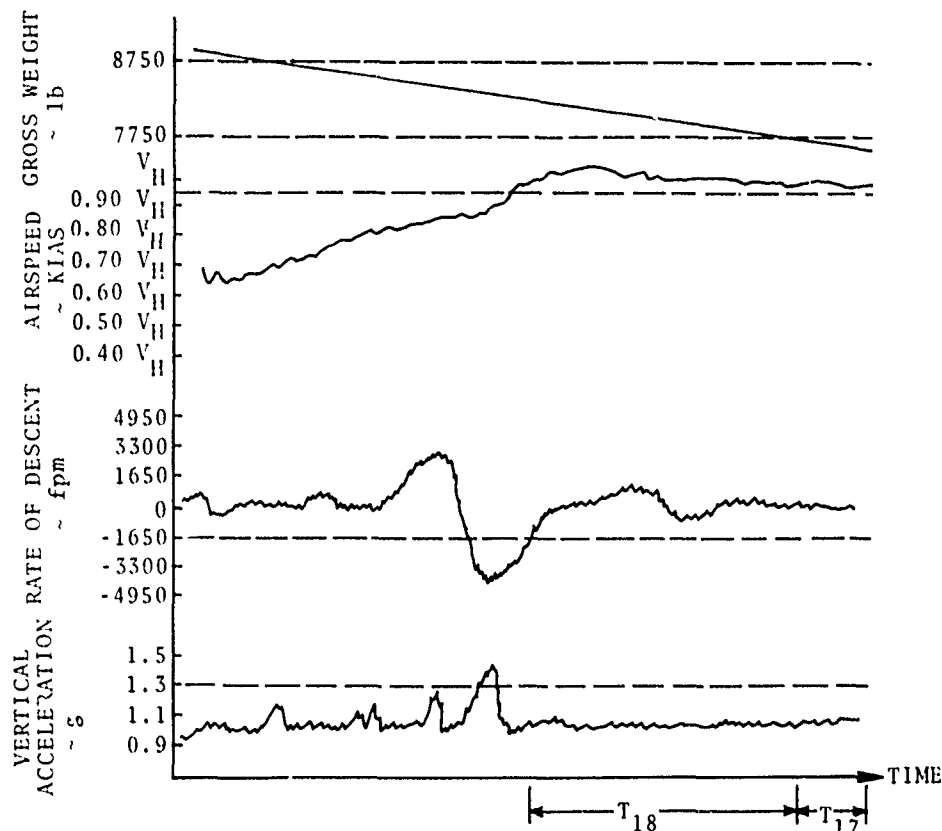
Description

Monitor the clock time accrued by the helicopter during which all six parameter threshold definitions are being satisfied simultaneously. The airspeed classification is based on maximum attainable velocity at constant altitude (V_H), which is a function of density altitude.

Figure A-6. Flight Condition Categories 14, 15, 16, 20, 21, and 22 (High-Velocity Flight).

Represents: Maximum-Velocity Flight Conditions
(e.g., Forward Level Flight)

FCC Applicability	$n_z < 1.3g$
	$A/S > 0.95 V_H$
	$\beta < 10^\circ$
	$RD < 1650 \text{ fpm}$
FCC #17	$GW < 7750 \text{ lb}$
FCC #18	$7750 \text{ lb} < GW \leq 8750 \text{ lb}$
FCC #19	$GW > 8750 \text{ lb}$



T_{17} = FCC #17 Timer
 T_{18} = FCC #18 Timer
 T_{19} = FCC #19 Timer

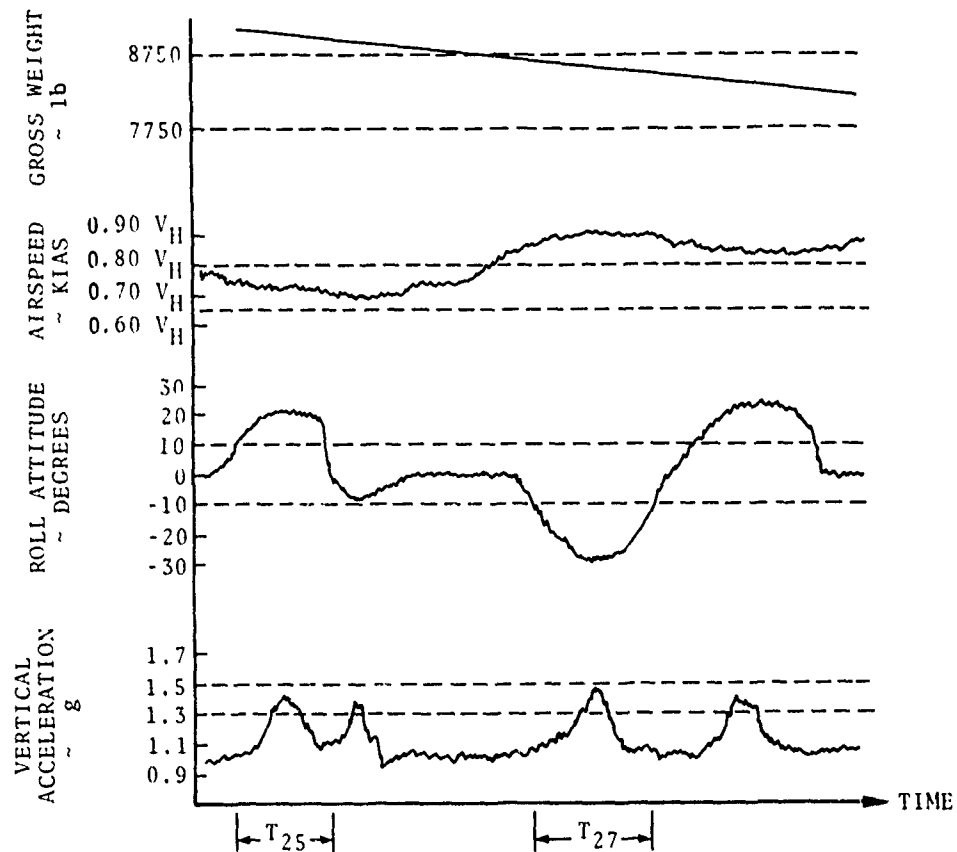
Description

Monitor the clock time accrued by the helicopter during which all five parameter threshold definitions are being satisfied simultaneously. The airspeed classification is based on maximum attainable velocity at constant altitude (V_H), which is a function of density altitude.

Figure A-7. Flight Condition Categories 17, 18, and 19 (Maximum-Velocity Flight).

Represents: Normal (High-Speed) Turns

FCC Applicability		1.3g < n _z < 1.5g β > 10°
For	For	
0.65V _H < A/S < 0.8V _H	A/S ≥ 0.8V _H	GW < 7750 lb
FCC #23	FCC #26	7750 lb < GW ≤ 8750 lb
FCC #24	FCC #27	GW > 8750 lb
FCC #25	FCC #28	

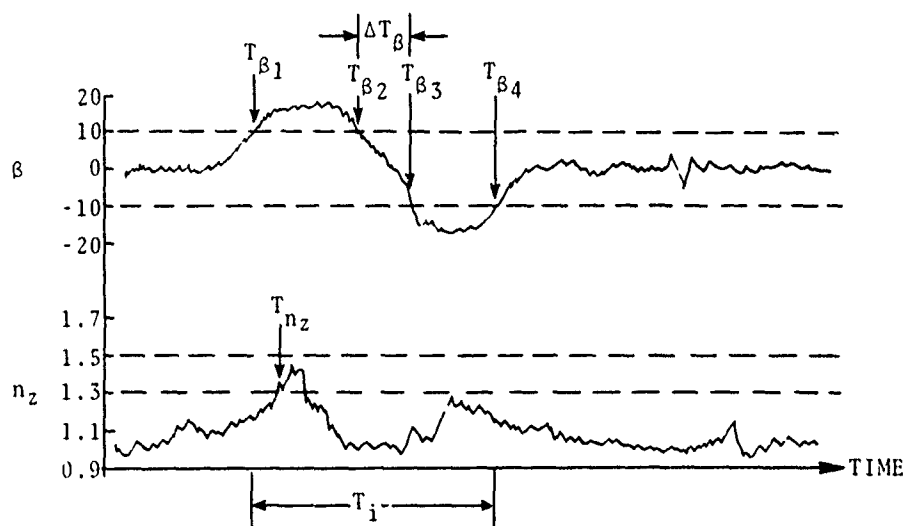


T₂₃ = FCC #23 Timer
 T₂₄ = FCC #24 Timer
 T₂₅ = FCC #25 Timer
 T₂₆ = FCC #26 Timer
 T₂₇ = FCC #27 Timer
 T₂₈ = FCC #28 Timer

Figure A-8. Flight Condition Categories 23 through 28 (Normal (High-Speed) Turns).

Description

The following graphical characterization demonstrates how the time spent in normal turns should be defined.



$T_{\beta 1}$ = time at which roll attitude first exceeds 10° threshold

$T_{\beta 2,3,4}$ = respective times at which roll attitude crosses 10° threshold

T_{nz} = time at which vertical acceleration exceeds threshold

ΔT_β = time between roll attitude threshold exceedances (see figure)

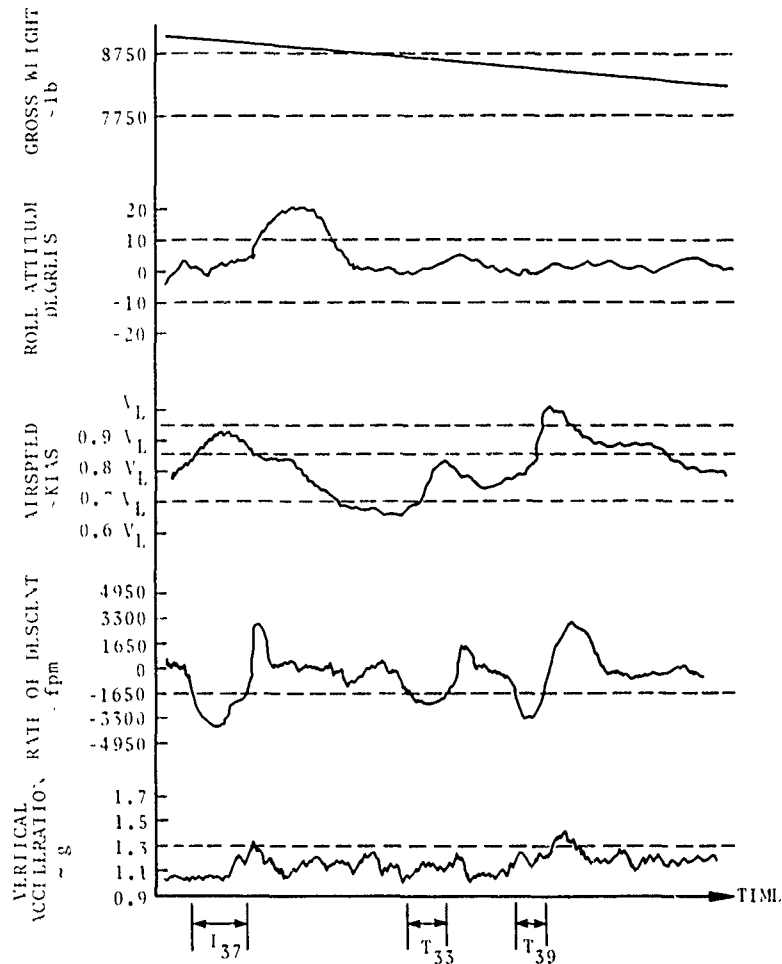
T_i = normal turn occurrence timer for FCC #i, $i = 23, 28$

The time between $T_{\beta 1}$ and T_{nz} is defined as less than 10 seconds. Upon confirmation that the roll attitude peaks at a magnitude greater than 10° and the vertical acceleration also peaks between 1.3 and 1.5 g within the prescribed time, the timer (T_i) should be initiated at $T_{\beta 1}$. If ΔT_β is subsequently less than 10 seconds, T_i should be allowed to continue timing until the roll attitude again returns below threshold (at $T_{\beta 4}$); otherwise, terminate T_i and $T_{\beta 2}$. The airspeed classification is based on maximum attainable velocity at constant altitude (V_H) which is a function of density altitude. The airspeed categorization, for a given turn, is defined at $T_{\beta 1}$. If the gross weight classification should change during the turn, the entire T_i should be entered in the category corresponding to the greater gross weight.

Figure A-8. Concluded

Represents: Gunnery Run Dives

FCC Applicability				$n_z < 1.3g$ $\theta < 10^\circ$ $RD > 1650 \text{ fpm}$ $GW < 7750 \text{ lb}$ $7750 \text{ lb} < GW \leq 8750 \text{ lb}$ $GW > 8750 \text{ lb}$
For $A/S \leq 0.70V_L$	For $0.70V_L < A/S \leq 0.85V_L$	For $0.85V_L < A/S \leq 0.95V_L$	For $A/S > 0.95V_L$	
FCC #29	FCC #32	FCC #35	FCC #38	
FCC #30	FCC #33	FCC #36	FCC #39	
FCC #31	FCC #34	FCC #37	FCC #40	



T_{29} = FCC #29 Timer	T_{35} = FCC #35 Timer
T_{30} = FCC #30 Timer	T_{36} = FCC #36 Timer
T_{31} = FCC #31 Timer	T_{37} = FCC #37 Timer
T_{32} = FCC #32 Timer	T_{38} = FCC #38 Timer
T_{33} = FCC #33 Timer	T_{39} = FCC #39 Timer
T_{34} = FCC #34 Timer	T_{40} = FCC #40 Timer

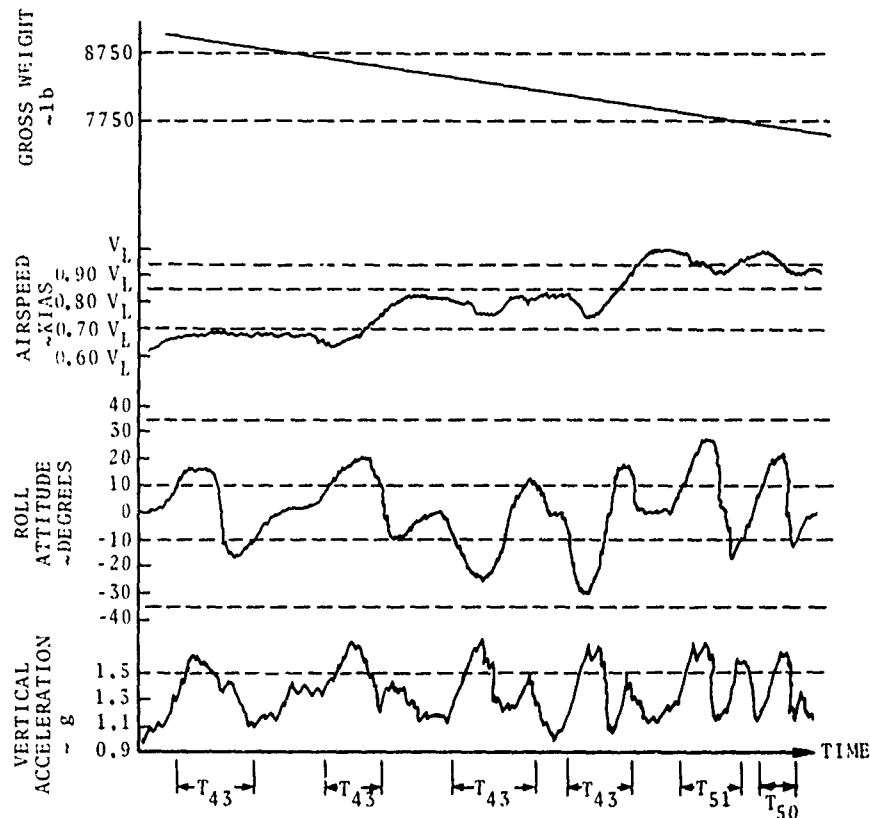
Description

Monitor the clock time accrued by the helicopter during which all parameter threshold definitions are being satisfied simultaneously. The airspeed classification is based on percentage of limit velocity (V_L), which is a function of density altitude. Airspeed is categorized near the end of the dive.

Figure A-9. Flight Condition Categories 24 through 40 (Gunnery Run Dives).

Represents: Asymmetrical Pullups

FCC Applicability				$n_z > 1.5g$ $10^\circ < \beta < 35^\circ$ $GW < 7750 \text{ lb}$ $7750 \text{ lb} < GW \leq 8750 \text{ lb}$ $GW > 8750 \text{ lb}$
For $A/S \leq 0.70V_L$	For $0.70V_L < A/S \leq 0.85V_L$	For $0.85V_L < A/S \leq 0.95V_L$	For $A/S > 0.95V_L$	
FCC #41	FCC #44	FCC #47	FCC #50	
FCC #42	FCC #45	FCC #48	FCC #51	
FCC #43	FCC #46	FCC #49	FCC #52	



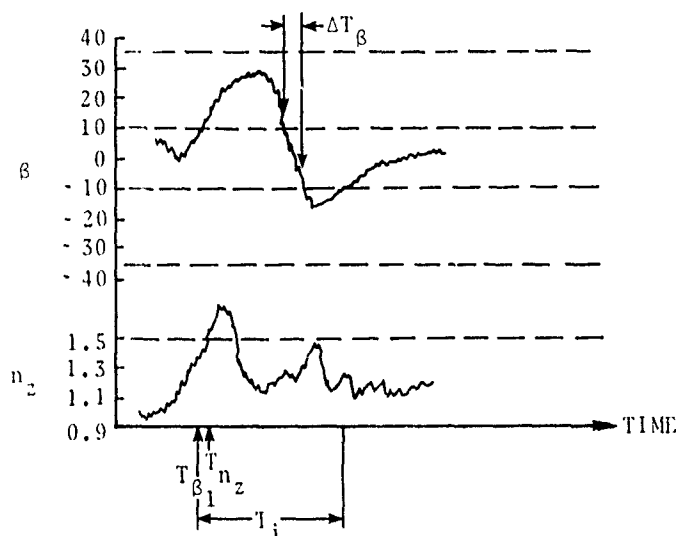
T_{41} = FCC #41 Timer
 T_{42} = FCC #42 Timer
 T_{43} = FCC #43 Timer
 T_{44} = FCC #44 Timer
 T_{45} = FCC #45 Timer
 T_{46} = FCC #46 Timer

T_{47} = FCC #47 Timer
 T_{48} = FCC #48 Timer
 T_{49} = FCC #49 Timer
 T_{50} = FCC #50 Timer
 T_{51} = FCC #51 Timer
 T_{52} = FCC #52 Timer

Figure A-10. Flight Condition Categories 41 through 52 (Asymmetrical (Gunnery Run) Pullups).

Description

The following graphical characterization demonstrates how the time spent in asymmetrical pullups should be defined:



T_i = asymmetrical pullup occurrence timer for FCC #i, $i = 41, 52$
 $T_{\beta 1}$ = time at which roll attitude first exceeds 10° threshold
 T_{n_z} = time at which n_z exceeds 1.5 g threshold
 ΔT_β = time between roll attitude threshold exceedances

The time between $T_{\beta 1}$ and T_{n_z} should be defined at less than 10 seconds. The timer (T_i) initiates at $T_{\beta 1}$. If ΔT_β is less than 10 seconds, T_i should be allowed to continue timing until the roll attitude once again drops below threshold; otherwise, terminate T_i at the time the roll attitude first drops back across the 10° threshold. Recall that the roll attitude peak must fall between 10° and 35° ; if it peaks above 35° it will be categorized as a different flight condition. The airspeed classification is based on percentage of limit velocity (V_L), which is a function of density altitude. The airspeed categorization, for a given pullup, is defined at $T_{\beta 1}$.

Figure A-10. Concluded

Represents: Symmetrical (Gunnery Run) Pullups

FCC Applicability			$n_z \geq 1.3g$ $\beta < 10^\circ$ $\theta > 5^\circ$ $GW < 7750 \text{ lb}$ $7750 \text{ lb} < GW \leq 8750 \text{ lb}$ $GW > 8750 \text{ lb}$
For $A/S < 0.70V_L$	For $0.70V_L < A/S < 0.85V_L$	For $A/S > 0.85V_L$	
FCC #53	FCC #56	FCC #59	
FCC #54	FCC #57	FCC #60	
FCC #55	FCC #58	FCC #61	

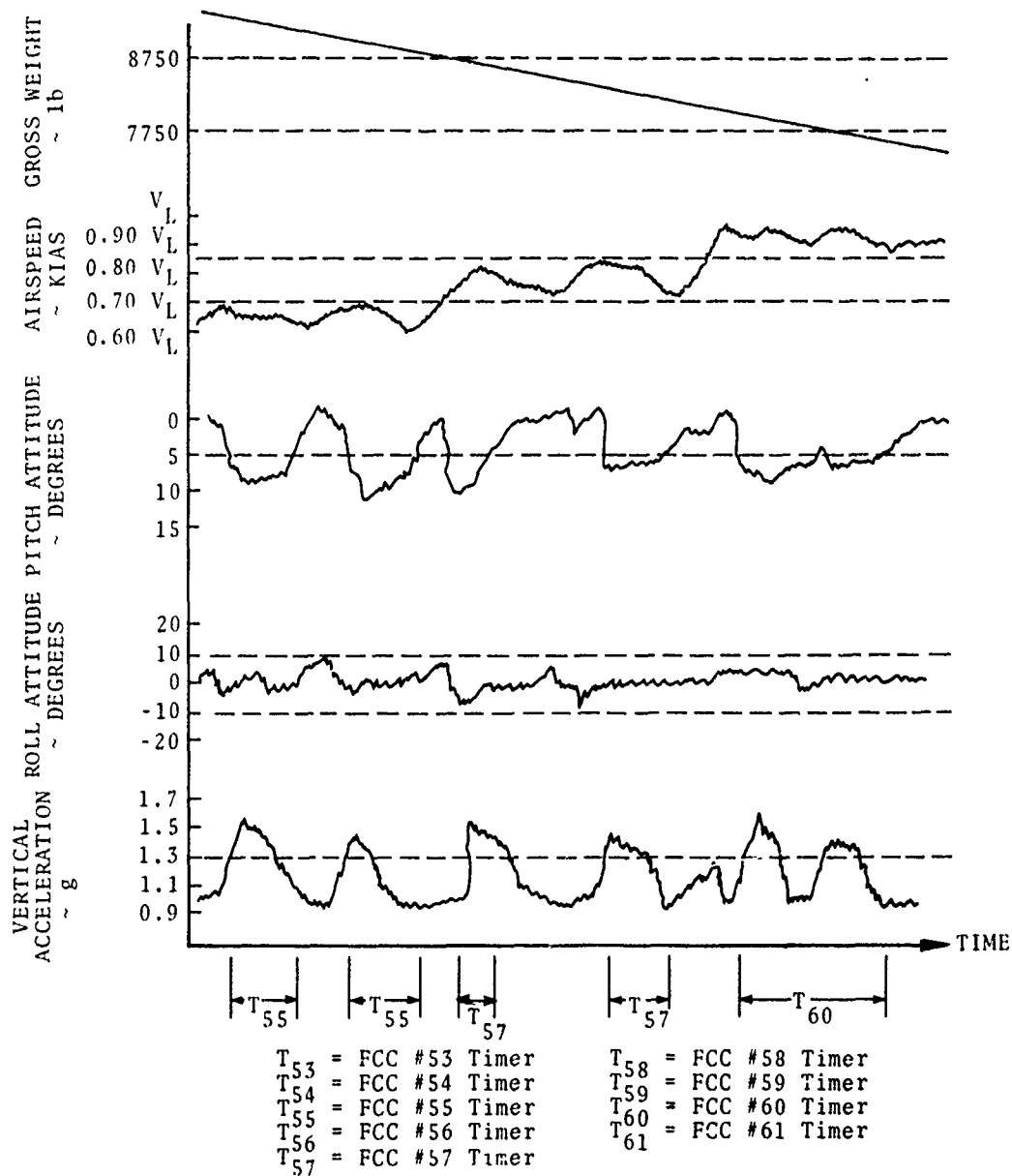
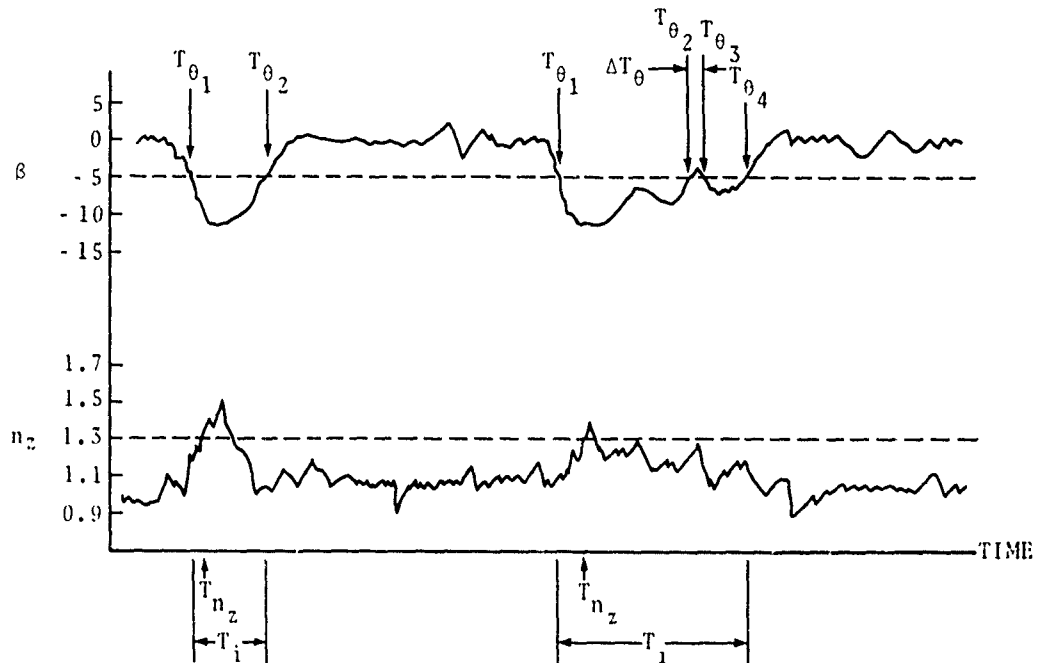


Figure A-11. Flight Condition Categories 53 through 61 (Symmetrical (Gunnery Run) Pullups).

Description

The following graphical characterization demonstrates how the time spent in symmetrical pullups should be defined.



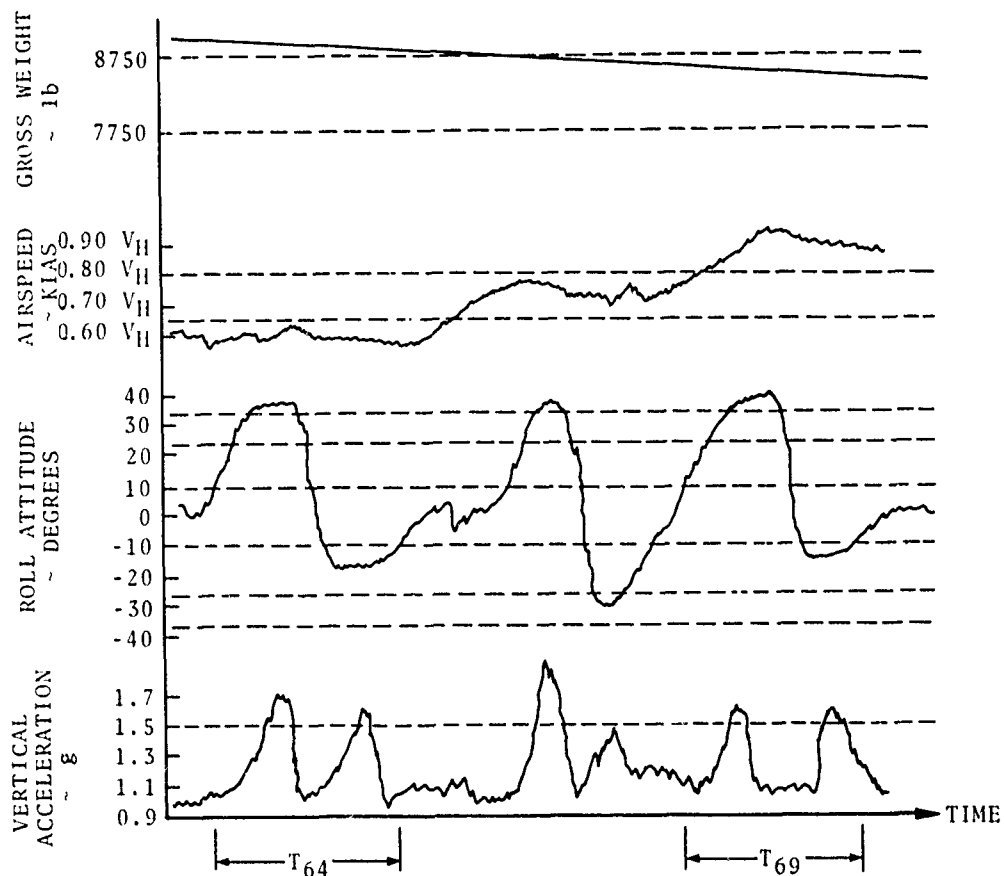
- $T_{\theta 1}$ = time at which pitch attitude first exceeds -5°
- $T_{\theta 2,3,4}$ = second, third, and fourth times the pitch attitude exceeds the -5° threshold
- T_{n_z} = time at which n_z exceeds $1.3g$ threshold
- ΔT_θ = time between pitch attitude -5° threshold exceedances

A gunnery run symmetrical pullup is confirmed when, and only when, T_{n_z} is sensed within 10 seconds after $T_{\theta 1}$ is sensed. The timer T_i initiates at $T_{\theta 1}$ and terminates at $T_{\theta 2}$. The exception is when the pitch attitude briefly crosses inside the -5° threshold and then immediately returns outside threshold ($\Delta T_\theta < 5$ seconds). In this case the threshold crossing defined by ΔT_θ is ignored and T_i continues to time the maneuver until a normal termination is sensed. The airspeed classification is based on percentage of limit velocity (V_L), which is a function of density altitude. Airspeed is categorized at the time the vertical acceleration exceeds $1.3g$.

Figure A-11. Concluded

Represents: Gunnery Turns

FCC Applicability			$n_z \geq 1.5g$ $\beta_{\text{initial}} \geq 35^\circ$ $\beta_{\text{subsequent}} < 25$ $GW < 7750 \text{ lb}$ $7750 \text{ lb} < GW \leq 8750 \text{ lb}$ $GW > 8750 \text{ lb}$
For	For	For	
$A/S \leq 0.65V_H$	$0.65V_H < A/S \leq 0.80V_H$	$A/S > 0.80V_H$	
FCC #62	FCC #65	FCC #68	
FCC #63	FCC #66	FCC #69	
FCC #64	FCC #67	FCC #70	



T_{62} = FCC #62 Timer
 T_{63} = FCC #63 Timer
 T_{64} = FCC #64 Timer

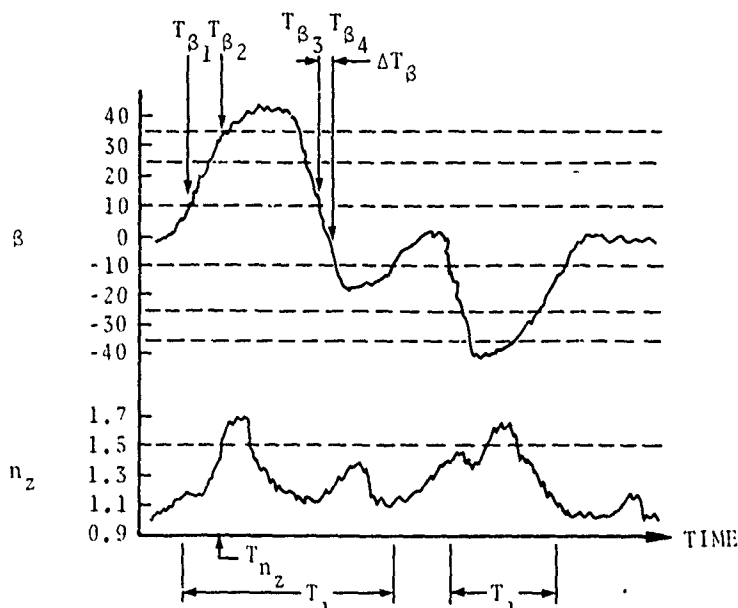
T_{65} = FCC #65 Timer
 T_{66} = FCC #66 Timer
 T_{67} = FCC #67 Timer

T_{68} = FCC #68 Timer
 T_{69} = FCC #69 Timer
 T_{70} = FCC #70 Timer

Figure A-12. Flight Condition Categories 62 through 70 (Gunnery Turns).

Description

The following graphical characterization demonstrates how the time spent in gunnery turns should be defined:



- $T_{\beta 3,4}$ = second and third times the roll attitude crosses the 10° threshold level
- T_i = gunnery turn occurrence timer for FCC #i, $i = 22, 24$
- $T_{\beta 1}$ = time at which roll attitude first exceeds 10° threshold
- $T_{\beta 2}$ = time at which roll attitude first exceeds 35° threshold
- T_{nz} = time at which n_z exceeds $1.5g$ threshold
- ΔT_{β} = time between roll attitude 10° threshold exceedances

The time between $T_{\beta 2}$ and T_{nz} should be defined as less than 10 seconds. Upon confirmation that the roll attitude crosses the 35° threshold (the time between $T_{\beta 1}$ and $T_{\beta 2}$ should also be less than 10 seconds), the timer (T_i) initiates at $T_{\beta 1}$. If ΔT_{β} is less than 10 seconds, T_i should be allowed to continue timing until the roll attitude, once again, drops below the 10° threshold (at $T_{\beta 4}$), if and only if, the second roll attitude peak does not exceed 25° . Otherwise, terminate T_i at $T_{\beta 3}$. (The "subsequent peak" requirement is designed to differentiate gunnery turns from gunnery S-turns.) The airspeed classification is based on maximum attainable velocity at constant attitude (V_H), which is a function of density altitude. The airspeed categorization, for a given turn, is defined at $T_{\beta 1}$.

Figure A-12. Concluded

Represents: Gunnery S-Turn

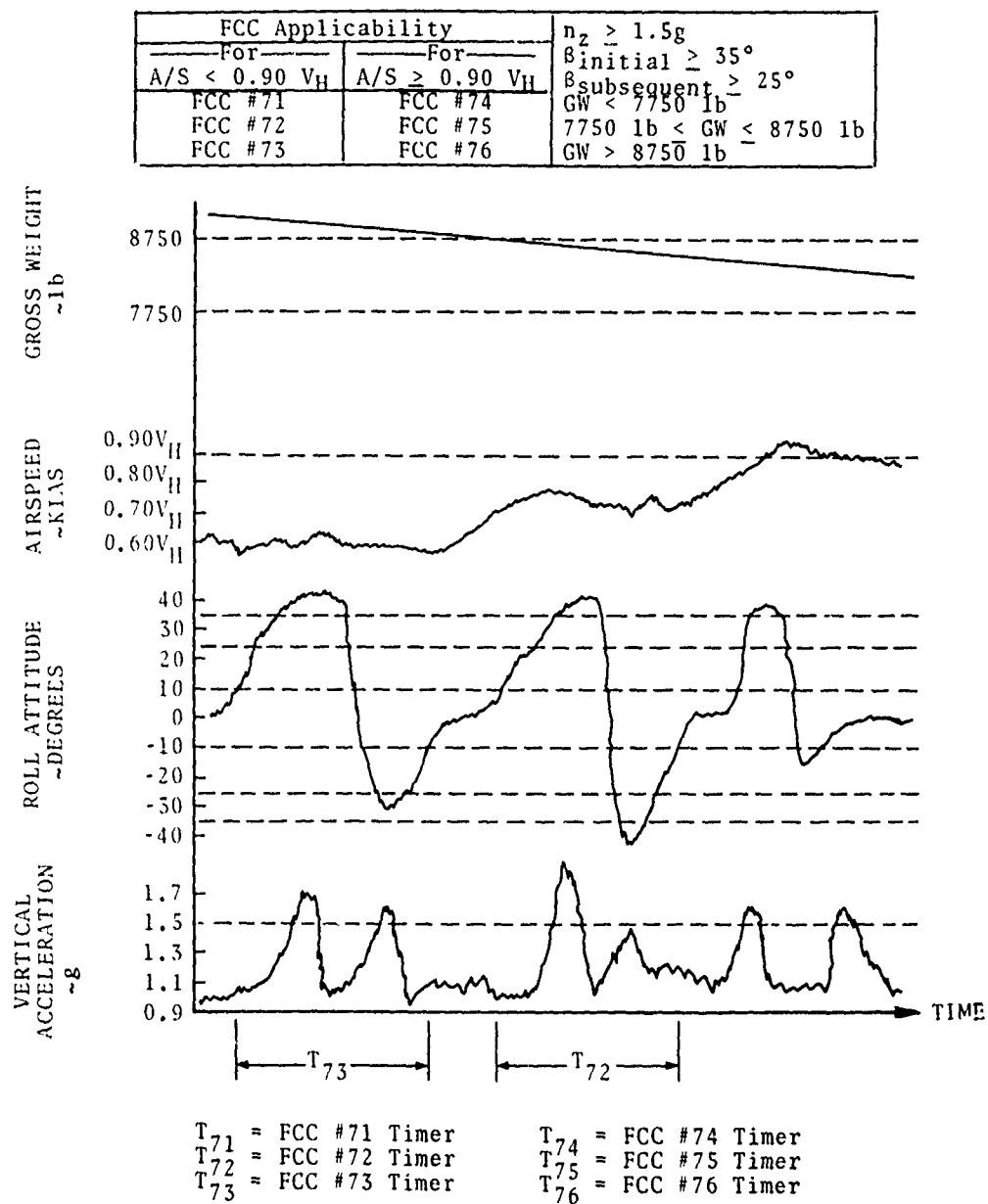
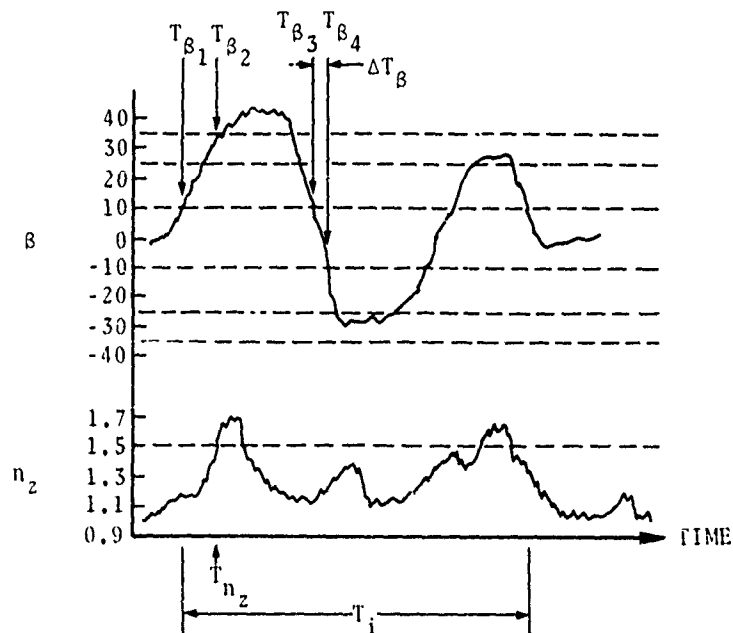


Figure A-13. Flight Condition Categories 71 through 76 (Gunnery S-Turns).

Description

The following graphical characterization demonstrates how the time spent in gunnery S-turns should be defined:



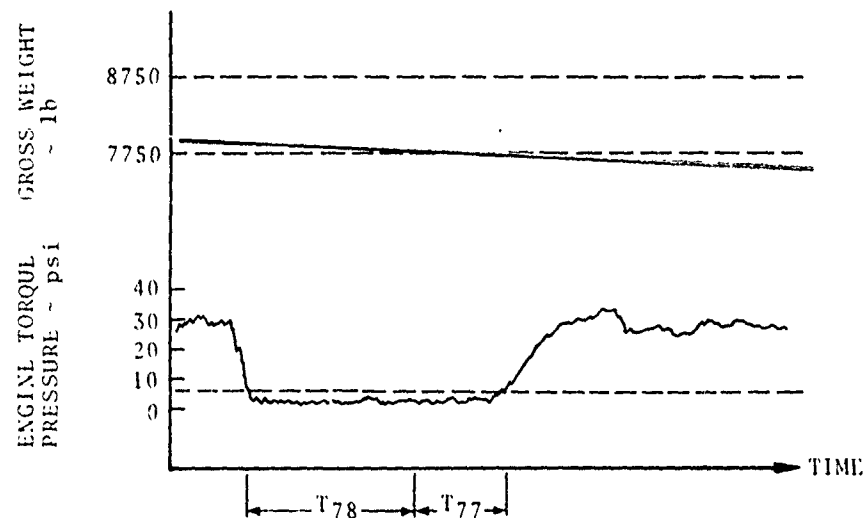
- $T_{\beta 3,4}$ = second and third times the roll attitude crosses the 10° threshold level
- T_i = gunnery turn occurrence timer for FCC #i, $i = 22, 24$
- $T_{\beta 1}$ = time at which roll attitude first exceeds 10° threshold
- $T_{\beta 2}$ = time at which roll attitude first exceeds 35° threshold
- T_{nz} = time at which n_z exceeds 1.5g threshold
- ΔT_{β} = time between roll attitude 10° threshold exceedances

The time between $T_{\beta 2}$ and T_{nz} should be defined at less than 10 seconds. Upon confirmation that the roll attitude crosses the 35° threshold (the time between $T_{\beta 1}$ and $T_{\beta 2}$ should also be less than 10 seconds), the timer (T_i) initiates at $T_{\beta 1}$. If ΔT_{β} is less than 10 seconds, T_i should be allowed to continue timing until the roll attitude, once again, drops below the 10° threshold (at $T_{\beta 4}$), if and only if, the second (and any subsequent) roll attitude peaks exceed 25°. By definition, the gunnery S-turn is characterized by at least two excessive roll attitude peaks occurring in rapid succession. Therefore, the foregoing criteria concerning "subsequent peaks" was designed to differentiate the gunnery S-turn from normal gunnery turns. The airspeed classification is based on maximum attainable velocity at constant attitude (V_H), which is a function of density altitude. The airspeed categorization, for a given turn, is defined at $T_{\beta 1}$.

Figure A-13. Concluded

Represents: Clock Time in Autorotation

FCC Applicability	ET < 5 psi
FCC #77	GW < 7750 lb
FCC #78	7750 lb < GW < 8750 lb
FCC #79	GW > 8750 lb



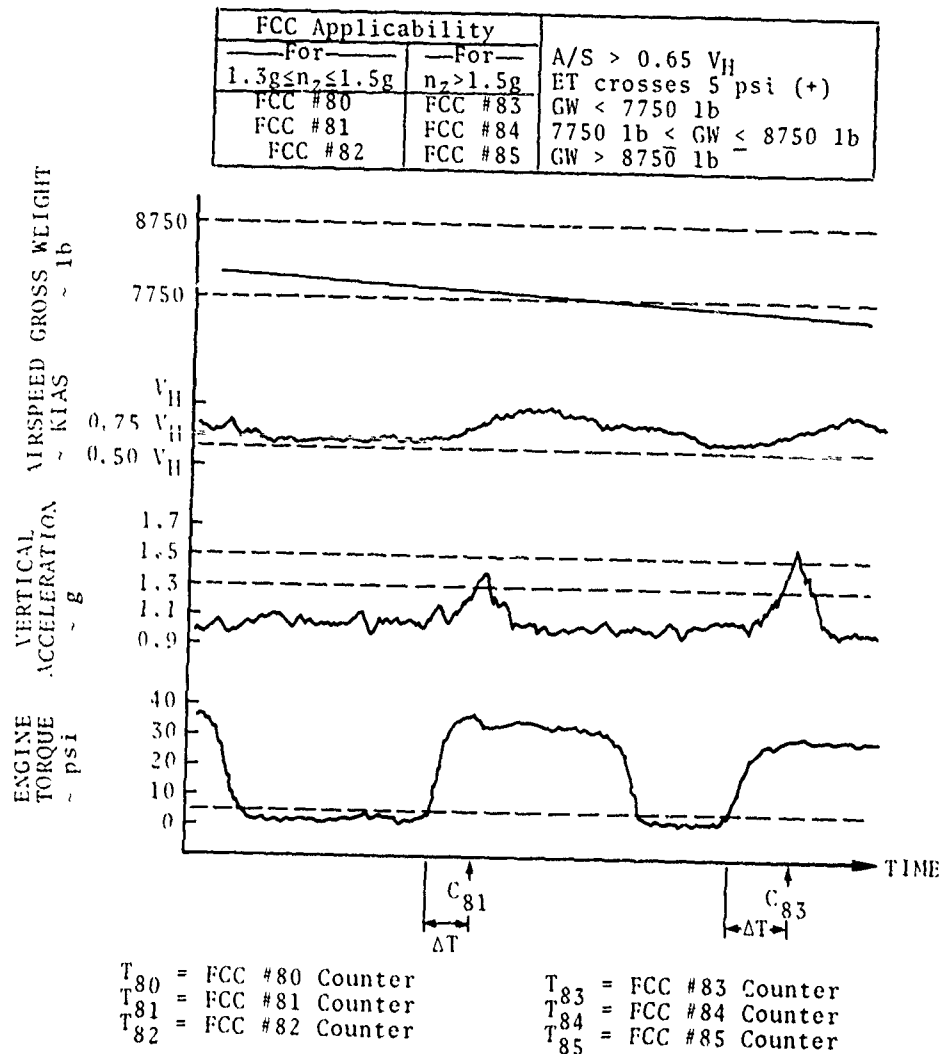
T₇₇ = FCC #77 Timer
T₇₈ = FCC #78 Timer
T₇₉ = FCC #79 Timer

Description

Monitor the total flight spent in the autorotation mode of operation. Small perturbations in engine torque pressure (such as the torque pressure jumping above the 5 psi threshold for very short periods of time) of less than 2-second duration are ignored.

Figure A-14. Flight Condition Categories 77, 78, and 79 (Time in Autorotation).

Represents: Autorotation to Power Transition



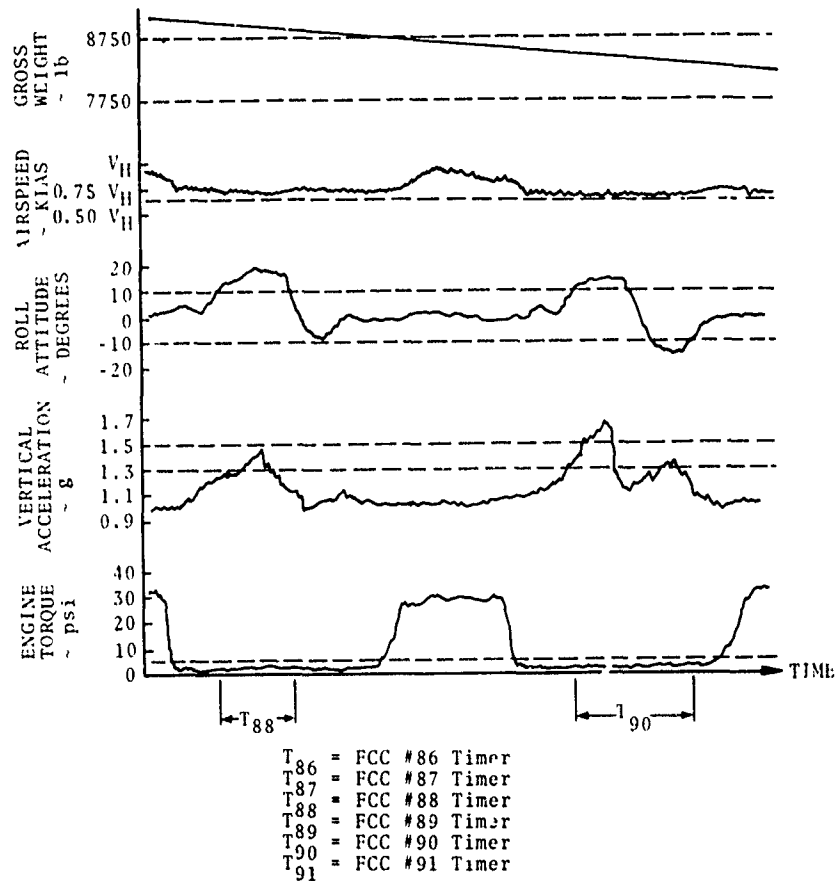
Description

Whenever the engine torque pressure crosses the 5 psi threshold in a positive direction and is followed (ΔT less than 5 seconds) by a vertical acceleration satisfying the threshold definition, the event should be recorded. The airspeed classification is based on a maximum attainable velocity at constant altitude (V_H), which is a function of density altitude. The airspeed categorization is defined at the time the vertical acceleration exceeds threshold.

Figure A-15. Flight Condition Categories 80 through 85 (Autorotation-to-Power Transition).

Represents: High-Speed Autorotation Turns

FCC Applicability		A/S > 0.65 V _H ET < 5 psi $\beta > 10^\circ$
For	For	
$1.3g \leq n_z < 1.5g$	$n_z > 1.5g$	GW < 7750 lb
FCC #86	FCC #89	7750 lb < GW ≤ 8750 lb
FCC #87	FCC #90	
FCC #88	FCC #91	



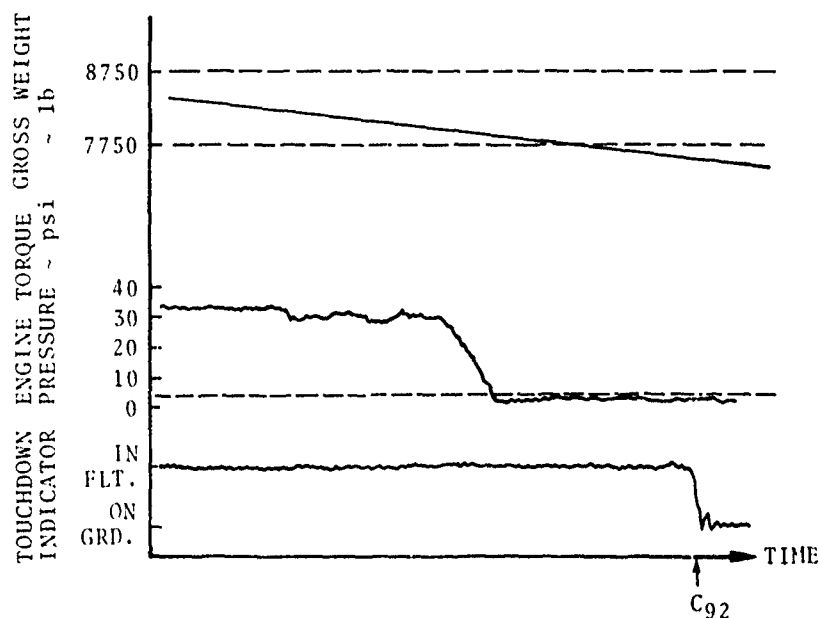
Description

Monitor the clock time accrued by the helicopter in autorotation while its roll attitude is greater than 10° only if it is accompanied by a vertical acceleration peak (within 5 seconds) in the prescribed threshold levels. The duration of the maneuver is defined the same as the Normal High-Speed Turn (FCC #23 through 28). The airspeed classification is based on maximum attainable velocity (V_H), which is a function of density altitude. The airspeed categorization for a given turn is defined at the time the roll attitude exceeds 10° .

Figure A-16. Flight Condition Categories 86 through 91 (High-Speed Autorotation Turns).

Represents: Autorotation Landing

FCC Applicability	ET < 5 psi
FCC #92	TD ON/OFF
FCC #93	GW < 7750 lb
FCC #94	7750 lb < GW ≤ 8750 lb
	GW > 8750 lb



C₉₂ = FCC #92 Counter
 C₉₃ = FCC #93 Counter
 C₉₄ = FCC #94 Counter

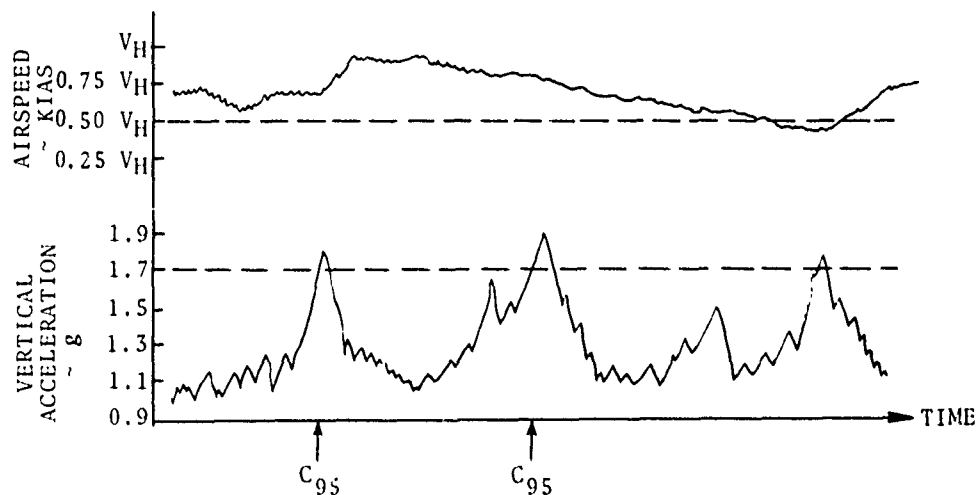
Description

The engine torque pressure must be below threshold immediately prior to (at least 10 seconds), and at the time of, touchdown. Once a touchdown has been recorded a rebounding helicopter should not register additional counts.

Figure A-17. Flight Condition Categories 92, 93, and 94 (Autorotation Landing).

Represents: Misc. High-G Maneuvers

$n_z > 1.7 \text{ g}$
 $A/S \geq .50 V_H$



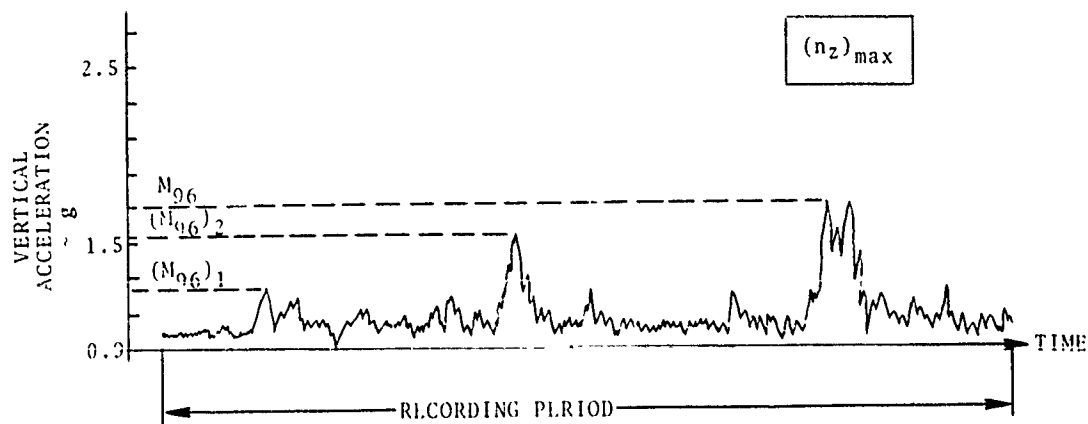
C_{95} = FCC #95 counter

Description

It is simply intended to count the number of times the helicopter experiences vertical accelerations in excess of 1.7 g while flying at significant airspeeds. This implies that the touchdown indicator must be registering in-flight operation.

Figure A-18. Flight Condition Category 95
 (Miscellaneous High-G Maneuvers).

Represents: Maximum Vertical Acceleration



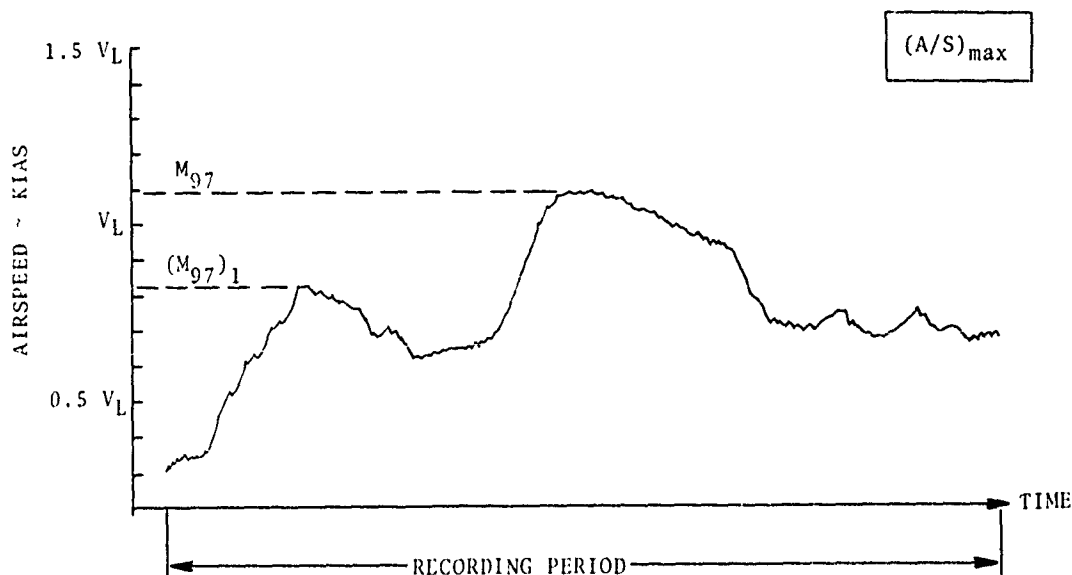
M_{96} = maximum n_z magnitude recorded during prescribed period
 $(M_{96})_{\xi 2}$ = intermediate maxima whose n_z values were subsequently surpassed during the recording period

Description

Record the magnitude of the largest vertical acceleration experienced during the recording period. The $(n_z)_{\max}$ may occur in any flight condition category (which implies that the in-flight indicator must be registering in-flight operation).

Figure A-19. Flight Condition Category 96
 (Maximum Vertical Acceleration).

Represents: Maximum Airspeed
Attained During All
Flight Conditions



M_{97} = maximum airspeed magnitude recorded during pre-scribed period
 $(M_{97})_1$ = intermediate maxima whose airspeed values were subsequently surpassed during the recording period

Description

Record the magnitude of the highest airspeed experienced during the recording period expressed in terms of percent of V_L . The $(A/S)_{max}$ may occur in any flight condition category. (Recall that the value of V_L is a function of density altitude.)

Figure A-20. Flight Condition Category 97
(Maximum Airspeed (V_L)).

APPENDIX B SIRS RECORDER SOFTWARE

PAGE 001 SIRS

		NAM	SIPS	
		OPT	NOG	
00001				
00002				
00003				
00004		***** STRUCTURAL INTEGRITY RECORDING SYSTEM *****		
00005		***** RECORDER PROGRAM *****		
00006				
00008	2000	AD	EQU	\$2000 A/D INPUT REGISTER
00009	2001	ADCR	EQU	\$2001 A/D CONTROL REGISTER
00010	2002	MUX	EQU	\$2002 MUX OUTPUT REGISTER
00011	2003	MUXCR	EQU	\$2003 MUX CONTROL REGISTER
00012	1000	ACIACS	EQU	\$1000 ACIA CONTROL/STATUS REGISTER
00013	1001	ACIACR	EQU	\$1001 ACIA TRANSMIT/RECEIVE REGISTER
00014	000F	MUXIO	EQU	\$0F PB3 - PRO ARE OUTPUTS
00015	0034	ADCM	EQU	\$00110100 A/D CONTROL WORD
00016	003C	ADSTPT	EQU	\$00111100 A/D START WORD
00017	0004	MUXCM	EQU	\$00000100 MUX CONTROL WORD
00018	0029	ACIACM	EQU	\$10001001 ACIA CONTROL WORD
00019	0310	GMTIME	EQU	\$0310 TIME TO DECREASE GROSS WT
00020	000F	GW7750	EQU	175 7750 LB THRESHOLD
00021	00E1	GW8750	EQU	225 8750 LB THRESHOLD
00022	000D	PT05	EQU	13 13/256 = 0.05
00023	001A	PT10	EQU	26 26/256 = 0.10
00024	0026	PT15	EQU	38 38/256 = 0.15
00025	00F3	PT95	EQU	243 243/256 = 0.95
00026	0016	DEG5	EQU	22 PITCH = 5 DEG THRESHOLD
00027	002C	DEG10	EQU	44 ROLL = 10 DEG THRESHOLD
00028	0040	DEG15	EQU	64 PITCH = 15 DEG THRESHOLD
00029	006E	DEG25	EQU	110 ROLL = 25 DEG THRESHOLD
00030	00B3	DEG35	EQU	147 ROLL = 35 DEG THRESHOLD
00031	000A	PS15	EQU	10 LOW TORQUE THRESHOLD
00032	00DC	PS144	EQU	220 HIGH TORQUE THRESHOLD
00033	0014	GMGND	EQU	20 GROUND THRESHOLD
00034	00C8	RPM200	EQU	200 RPM = 200 THRESHOLD
00035	0064	RPM100	EQU	100 RPM = 100 THRESHOLD
00036	01F7	GPOSWT	EQU	\$01F7 GROSS WEIGHT LOCATION
00037	01F8	NZPK	EQU	\$01F8 NZ PEAK LOCATION
00038	01F9	VLPK	EQU	\$01F9 VL PEAK LOCATION
00039	01FA	NZINT	EQU	\$01FA NZ CORRECTION INTERCEPT
00040	01FB	NZSLP	EQU	\$01FB NZ CORRECTION SLOPE
00041	01FC	ALTINT	EQU	\$01FC ALTITUDE CORRECTION INTERCEPT
00042	01FD	ALTSLP	EQU	\$01FD ALTITUDE CORRECTION SLOPE
00043	01FE	ASINT	EQU	\$01FE AIRSPEED CORRECTION INTERCEPT
00044	01FF	ASSLP	EQU	\$01FF AIRSPEED CORRECTION SLOPE
00045	00FF	STACK	EQU	\$00FF START STACK HERE

```

00047 *****
00048 **  PARAMETER CODES  **
00049 *****
00050 * THE FOLLOWING CODES ARE SETUP BY THE DATA
00051 * ACQUISITION PORTION OF THE SIRS PROGRAM. THEY
00052 * ARE USED BY THE EVENT RECOGNITION ROUTINES
00053 * IN THE DEFINITION OF SIGNIFICANT FLIGHT
00054 * CONDITIONS.
00055 *
00056 * PARAMETER CODE INTERPRETATION
00057 *
00058 *   CVL      -1   A/S<=.7VL
00059 *             0   .7VL<A/S<=.85VL
00060 *             1   .85VL<A/S<=.95VL
00061 *             2   .95VL<A/S
00062 *
00063 *   CVH      -2   A/S<.5VH
00064 *             -1  .5VH<=A/S<.65VH
00065 *             0   .65VH<=A/S<.8VH
00066 *             1   .8VH<=A/S<.9VH
00067 *             2   .9VH<=A/S<.95VH
00068 *             3   .95VH<=A/S
00069 *
00070 *   CROL     -1   ROLL<10 DEG
00071 *             0   10<=ROLL<25 DEG
00072 *             1   25<=ROLL<35 DEG
00073 *             2 S  35<=ROLL
00074 *
00075 *   CQ       0 S  TORQUE<=5 PSI
00076 *             1   5<TORQUE<=44 PSI
00077 *             2   44<TORQUE
00078 *
00079 *   CRD      -1 S  NOT VALID
00080 *             0   PD<1650 FPM
00081 *             1   RD>=1650 FPM
00082 *
00083 *   CPPM     -1   RPM<100
00084 *             0   100<=RPM<=200
00085 *             1 S  RPM>200
00086 *
00087 *   CT       0 S  FLIGHT
00088 *             1   GROUND
00089 *
00090 *   CNZ      -1   NZ<=1.3 G
00091 *             0   1.3<NZ<=1.5 G
00092 *             1   1.5<NZ<=1.7 G
00093 *             2 S  NZ>1.7 G
00094 *
00095 *   CGW      0 S  GW<7750 LB
00096 *             1   7750<=GW<=8750 LB
00097 *             2   GW>8750 LB
00098 *
00099 *   CPIT     -1   0<PITCH<=5 DEG
00100 *             0   5<PITCH<=15 DEG
00101 *             1 S  PITCH>15 DEG
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00101	0000	ORG	\$0
00102		♦	
00103		♦ PARAMETER VALUE CODES	
00104	0000 0001	CVL PMB	1 0
00105	0001 0001	CVH PMB	1 1
00106	0002 0001	CRDL PMB	1 2
00107	0003 0001	CR	1 3
00108	0004 0001	CRD PMB	1 4
00109	0005 0001	CRPM PMB	1 5
00110	0006 0001	CT PMB	1 6
00111	0007 0001	CNZ PMB	1 7
00112	0008 0001	CGW PMB	1 8
00113	0009 0001	CPIT PMB	1 9
00114		♦ MISC FLAGS AND SWITCHES	
00115	000A 0001	IFLAG PMB	1 10
00116	000B 0001	ARM2 PMB	1 11
00117	000C 0001	OTIM PMB	1 12
00118	000D 0001	AIR PMB	1 13
00119	000E 0001	T77 PMB	1 14
00120	000F 0002	T23A PMB	2 15
00121	0011 0001	MODE PMB	1 17
00122	0012 0001	TOWI PMB	1 18
00123	0013 0001	TOLD PMB	1 19
00124	0014 0001	M PMB	1 20
00125	0015 0001	NZE PMB	1 21
00126	0016 0001	NCHI PMB	1 22
00127	0017 0001	NZLO PMB	1 23
00128	0018 0001	HIROL PMB	1 24
00129	0019 0001	EVH PMB	1 25
00130	001A 0001	CVL PMB	1 26
00131	001B 0001	CGW PMB	1 27
00132	001C 0002	T86 PMB	2 28
00133	001E 0001	QMOD PMB	1 30
00134	001F 0001	ASF PMB	1 31
00135	0020 0001	PUFLAG PMB	1 32
00136	0021 0001	T80 PMB	1 33
00137	0022 0001	NZF PMB	1 34
00138	0023 0001	APM31 PMB	1 35
00139	0024 0001	LDAS PMB	1 36
00140	0025 0002	ASV PMB	2 37
00141	0027 0002	NDX PMB	2 39
00142	0029 0002	INDX PMB	2 41
00143	002B 0001	GTS PMB	1 43
00144	002C 0003	BAA PMB	3 44
00145	002F 0001	PUFCTM PMB	1 47
00146	0030 0001	NOPUF6 PMB	1 48
00147	0031 0001	PU10 PMB	1 49
00148	0032 0001	GSV53 PMB	1 50
00149	0033 0001	VSV53 PMB	1 51
00150	0034 0002	T23 PMB	2 52
00151	0036 0001	Y3PUF6 PMB	1 54
00152	0037 0004	PMB	4 55-58-SPARE)
00153	003B 0001	AIPTIM PMB	1 59
00154	003C 0003	CONE PMB	3 60

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00155	003F	0001	ONEVH	RMB	1	63
00156	0040	0001	DENDM	RMB	1	64
00157	0041	0001	ZERO1	RMB	1	65
00158	0042	0001	AMS	RMB	1	66
00159	0043	0001	NUM	RMB	1	67
00160	0044	0001	SHFTCT	RMB	1	68
00161	0045	0002	SAVADR	RMB	2	69
00162	0047	0002	SAVCNV	RMB	2	71
00163	0049	0001	RTUFLG	RMB	1	73
00164	004A	0010	CNVTAB	RMB	16	74
00165	005A	0001	KNOTS	RMB	1	90
00166	005B	0001	ALTFT	RMB	1	91
00167	005C	0001	GMTH	RMB	1	92
00168	005D	0001	GMTL	RMB	1	93
00169	005E	0001	GMCNT	RMB	1	94
00170	005F	0001	GM1ST	RMB	1	95
00171	0060	0001	GMH	RMB	1	96
00172	0061	0001	GML	RMB	1	97
00173	0062	0044	DVTAPL	RMB	68	98
00174	00A6	0001	AVGDVH	RMB	1	166
00175	00A7	0001	AVGDVL	RMB	1	167
00176	00A8	0001	AVGDVC	RMB	1	168
00177		003F	ONEVL	EQU	ONEVH	
00178		0045	SAVSTK	EQU	SAVADR	

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00181	0100	0100	CNTPS	PMB	256
00182	0200	0100	ACNTR	RMB	256

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00184 3000 ORG \$3000

00186 3000 0F	ADPTAR FCB	15	(0) RPM
00187 3001 01	FCB	1	(1) POLL ATTITUDE
00188 3002 02	FCB	2	(2) POLL REFERENCE
00189 3003 08	FCB	8	(3) PITCH
00190 3004 09	FCB	9	(4) TORQUE
00191 3005 08	FCB	11	(5) TORQUE REFERENCE
00192 3006 03	FCB	3	(6) VERTICAL ACCEL. (NZ)
00193 3007 04	FCB	4	(7) ALTITUDE
00194 3008 07	FCB	7	(8) AIRSPEED
00195 3009 0A	FCB	10	(9) OUTSIDE AIR TEMP. (OAT)
00196 300A 00	FCB	0	(10) GROSS WEIGHT
00197 300B 05	FCB	5	(11) BATTERY VOLTAGE
00198 300C 0E	FCB	14	(12) RECORDER S/N LO
00199 300D 0C	FCB	12	(13) RECORDER S/N HIGH
00200 300E 06	FCB	6	(14) SPARE 1
00201 300F 0D	FCB	13	(15) SPARE 2

00203 3010 8E 00FF	PESTAR LDI	#STACK	SET UP STACK
00204 3013 94 0F	LDA A	#MUXID	PB0 - PB3 OUTPUTS
00205 3015 B7 2002	STA A	MUX	FOR MUX ADDRESS
00206 3018 86 34	LDA A	#ADCM	CR2 IS OUTPUT
00207 301A B7 2001	STA A	ADCP	
00208 301D 86 04	LDA A	#MUXCM	
00209 301F B7 2003	STA A	MUXCR	
00210 3022 86 89	LDA A	#ACIACM	
00211 3024 B7 1000	STA A	ACIACS	
00212 3027 CE 02FF	LDX	#\$02FF	

00214 302A 4F	CLP A		*****
00215 302B A7 00	CLRMOR STA A	0-X	• CLEAR •
00216 302D 09	DEX		• SCRATCHPAD MEMORY •
00217 302E 26 FB	BNE CLRMOR		*****

00219 3030 0E	CLI		ENABLE INTERRUPT
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00221 3031 CE 0203	CLRFLG LDX	#\$0203	
00222 3034 DF 00	STX	CVL	CVL+1 = CVH
00223 3036 CE 0200	LDX	#\$0200	
00224 3039 DF 02	STX	CRDL	CRDL+1 = CR
00225 303B CE 0001	LDX	#\$0001	
00226 303E DF 04	STX	CRD	CRD+1 = CPPM
00227 3040 7A 0004	DEC	CRD	
00228 3043 DF 08	STX	CGM	CGM+1 = CPIT
00229 3045 08	INX		
00230 3046 DF 06	STX	CT	CT+1 = CNZ

00232 3048 8D 02	BSR	ADCNVT
00233 304A 20 43	BRA	CORNZ

```

00235 *****
00236 ♦MAKE A/D CONVERSIONS ♦
00237 ♦STORE RESULTS IN ♦
00238 ♦CONVERSION TABLE ♦
00239 *****
00240 ♦ SUBROUTINE ♦
00241 *****

00243 304C 4F ADCNVT CLR A *****
00244 304D 86 08 LDA A #11 ♦GET # OF CONVERSIONS♦
00245 304F D6 49 LDA B RTUFLG ♦11 DURING RECORDING ♦
00246 3051 26 02 BNE SKP1 ♦16 DURING RETRIEVAL ♦
00247 3053 96 10 LDA A #16 *****

00249 3055 CE 3000 SKP1 LDX #ADRTAB MUX ADDRESS TABLE
00250 305A DF 45 STX SAVADR
00251 305A CE 004A LDX #CNVTAB TABLE FOR RESULTS
00252 305D DF 47 STX SAVCNV
00253 305F DE 45 REPEAT LDX SAVADR GET MUX ADDRESS
00254 3061 E6 00 LDA B 0*X
00255 3063 F7 2002 STA B MUX SEND MUX ADDRESS
00256 3066 5F CLR B
00257 3067 09 DELAY DEB *****
00258 3068 08 INX ♦DELAY FOR MUX♦
00259 3069 5A DEC B ♦TO SETTLE ♦
00260 306A 26 FB BNE DELAY *****
00261 306C F6 2000 LDA B AD CLEAR A/D DONE
00262 306F C6 3C LDA B #ADSTPT *****
00263 3071 F7 2001 STA B ADCR ♦ START CONVERSION ♦
00264 3074 C6 34 LDA B #ADCN ♦READY FOR NEXT TIME♦
00265 3076 F7 2001 STA B ADCP *****
00266 3079 7C 0045 INC SAVADR PREPARE FOR NEXT ADDRESS
00267 307C DE 47 LDX SAVCNV
00268 307E F6 2001 ENDCVT LDA B ADCP
00269 3081 2A FB BPL ENDCVT WAIT FOR END OF CONVERSION
00270 3083 F6 2000 LDA B AD GET CONVERSION
00271 3086 E7 00 STA B 0*X STORE IN CONVERSION TABLE
00272 3088 7C 0047 INC SAVCNV PREPARE FOR NEXT CONVERSION
00273 308B 4A DEC A CHECK FOR LAST CONVERSION
00274 308C 26 D1 BNE REPEAT
00275 308E 39 RTS

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00277 *****
00278 * CORRECT NZ *
00279 *****

00281 308F B6 01FA CORNZ LDA A NZINT INTERCEPT CORRECTION
00282 3092 D6 50 LDA B CNVTAB+6 NZ CONVERSION
00283 3094 97 43 STA A NUM STORE INTERCEPT FOR XCER
00284 3096 B6 01FB LDA A NZSLP SLOPE CORRECTION
00285 3099 8D 48 BSR XCER PUTS CORRECTED NZ IN ACC A
00286 309B 97 50 STA A CNVTAB+6 RETURN CORRECTED NZ

00288 *****
00289 * SET CNZ FLAG *
00290 *****

00293 309D CE 30AA LDX #NZTABL
00294 30A0 A1 00 LOOP CMP A 0,X (NZ 1.7, 1.5, 1.3, OR 0)
00295 30A2 24 0A BCC NZPEAK BR IF NZ > TABLE VALUE
00296 30A4 7A 0007 DEC CNZ
00297 30A7 08 INX
00298 30A8 20 F6 BRA LOOP

00300 30AA 5A NZTABL FCB 90,64,38,0 1.7,1.5,1.3 G THRESHOLDS

00302 *****
00303 * CHECK NZ PEAK FCC *
00304 *****

00306 30AE F6 01F8 NZPEAK LDA B NZPK GET PEAK NZ VALUE LDX #NZPK
00307 30B1 11 CBA (PRESENT NZ - FCC PEAK)
00308 30B2 25 03 BCS ASCOR BR IF PEAK > PRESENT VALUE
00309 30B4 B7 01F8 STA A NZPK STORE IF LARGER

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00311 ~~~~~
00312 ~CORRECT DIFFERENTIAL PRESSURE~
00313 ~~~~~

00315 30B7 B6 01FE ASCOR LDA A ASINT INTERCEPT CORRECTION
00316 30BA D6 52 LDA B CNVTAB+8 DIFFERENTIAL PRESSURE
00317 30BC 97 43 STA A NUM STORE INTERCEPT FOR XCEP
00318 30BE B6 01FF LDA A ASSLP SLOPE CORRECTION
00319 30C1 8D 20 BSR XCEP PUTS CORRECTED PDIFF IN ACC A
00320 30C3 97 52 STA A CNVTAB+8 RETURN CORRECTED PDIFF

00322 ~~~~~
00323 ~ CONVERT TO KNOTS ~
00324 ~STOPE RESULTS AT "KNOTS"~
00325 ~~~~~

00327 30C5 CE 33B3 LDX #ASTABL
00329 30C8 8D 2F BSR LINEAR
00330 30CA D7 5A STA B KNOTS

00332 ~~~~~
00333 ~CORRECT ABSOLUTE PRESSURE~
00334 ~~~~~

00336 30CC B6 01FC LDA A ALTINT INTERCEPT CORRECTION
00337 30CF D6 51 LDA B CNVTAB+7 ABSOLUTE PRESSURE
00338 30D1 97 43 STA A NUM STORE INTERCEPT FOR XCEP
00339 30D3 B6 01FD LDA A ALTSLP SLOPE CORRECTION
00340 30D6 8D 0B BSR XCEP PUTS CORRECTED PABS IN ACC A
00341 30D8 97 51 STA A CNVTAB+7 RETURN CORRECTED PABS

00343 ~~~~~
00344 ~CONVERT TO FEET ~
00345 ~12 COUNTS = 1000 FT~
00346 ~~~~~

00348 30DA CE 3398 LDX #ALTABL
00350 30DD 8D 1A BSR LINEAR
00351 30DF D7 5B STA B ALTF
00352 30E1 20 28 BSR DALTI

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00361 30E3 8D 59      XCEB      BSR      MPY7
00362 30E5 4D          TST      A      TEST FOR OVERFLOW
00363 30E6 26 0E          BNE      ALLONE  BR IF OVERFLOW
00364 30E8 96 43          LDA      A      NUM      GET INTERCEPT
00365 30EA 4D          TST      A      + OR - INTERCEPT?
00366 30EB 2A 06          BPL      PLUSA    BR IF INTERCEPT POSITIVE
00367 30ED 1B          ABA          -INTERCEPT
00368 30EE 25 08          BCS      END      BR IF RESULT IS NOT < 0
00369 30F0 4F          ZEPO  CLR      A      RESULT < ZERO
00370 30F1 20 05          BRA      END
00371 30F3 1B          PLUSA  ABA          + INTERCEPT
00372 30F4 24 02          BCC      END      BR IF RESULT IS 256
00373 30F6 86 FF          ALLONE LDA      A      $FF    RESULT > 255
00374 30F8 39          END      RTS

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[illegible]

00384	30F9	A1	00	LINEAR	CMP	A	0×X	
00385	30FB	24	05		BCC		DELTA	
00386	30FD	08			INX			
00387	30FE	08			INX			
00388	30FF	08			INX			
00389	3100	20	F7		BRA		LINEAR	
00390	3102	A0	00	DELTA	SUB	A	0×X	
00391	3104	E6	02		LDA	B	2×X	SLOPE
00392	3106	8D	3D		BSR		MPY5	
00393	3108	EB	01		ADD	B	1×X	
00394	310A	39			RTS			

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00396
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00400
*****
♦DENSITY ALTITUDE RTN ♦
♦ALTFT IS IN ACC B ♦
♦RESULT STORED ON STACK ♦
*****

00402 310B 86 54 DALT1 LDA A #84
00403 310D 8D 28 BSR MPY8
00404 310F 86 6E NXT1 LDA A #110
00405 3111 1B ABA
00406 3112 D6 53 LDA B CNYTA3+9 GET TEMPERATURE
00407 3114 10 SBA
00408 3115 24 0D BCC PLSCOR
00409 3117 40 NEG A
00410 3118 C6 BF LDA B #191
00411 311A 8D 1B BSR MPY8
00412 311C 96 5B NXT2 LDA A ALTFT
00413 311E 11 CBA
00414 311F 25 0E BCS NEGALT
00415 3121 10 CBA
00416 3122 20 10 BRA GD
00417 3124 C6 AE PLSCOR LDA B #174
00418 3126 8D 0F BSR MPY8
00419 3128 96 5B NXT3 LDA A ALTFT
00420 312A 1B ABA
00421 312B 25 05 BCS HIALT BP IF DALT > 255
00422 312D 20 05 BRA GD
00423 312F 4F NEGALT CLR A
00424 3130 20 02 BRA GD
00425 3132 86 FF HIALT LDA A #FFF
00426 3134 36 GO PSH A
00427 3135 20 41 BRA VL

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00429
00430
00431
00432
00433
*****
*   MULTIPLY SUBROUTINE ACC A X ACC B   *
* MOST SIG. HALF OF RESULT RETURNED IN ACC A *
* LEAST SIG. HALF RETURNED IN ACC B   *
*****

00435 3137 36      MPY8  PSH A      *
00436 3138 86 08      LDA A  #8      * ZERO1 NOT 0 *
00437 3139 97 41      STA A  ZERO1  * ROUND OFF RESULT *
00438 313C 20 0D      BPA  MPY      *
00439 313E 36      MPY7  PSH A      * STORE NUMBER OF *
00440 313F 86 07      LDA A  #7      * FINAL SHIFTS *
00441 3141 97 41      STA A  ZERO1  *
00442 3143 20 06      BPA  MPY      *
00443 3145 36      MPY5  PSH A      * ZERO1 = 0 *
00444 3146 86 05      LDA A  #5      * DO NOT ROUND OFF *
00445 3148 7F 0041    CLR  ZERO1    *
00446 3148 97 44      MPY  STA A  SHFTCT
00447 314D 86 08      LDA A  #8
00448 314F 36      PSH A
00449 3150 DF 29      STX  ENDX
00450 3152 30      TX
00451 3153 4F      LLP A
00452 3154 56      ROR B
00453 3155 24 02      M3  BCC  M4
00454 3157 AB 01      ADD A  1*X
00455 3159 46      M4  ROR A
00456 315A 56      ROR B
00457 315B 6A 00      DEC  0*X
00458 315D 26 F6      BNE  M3
00459 315F 31      INS
00460 3160 31      INS
00461 3161 7D 0044    TST  SHFTCT  ANY FINAL SHIFTS
00462 3164 27 0F      BEQ  PTN
00463 3166 44      SHIFT LSR A
00464 3167 56      ROR B
00465 3168 7A 0044    DEC  SHFTCT
00466 316B 26 FA      BNE  SHIFT  BRANCH FOR ANOTHER SHIFT
00467 316D 24 06      BCC  PTN    BR IF FRACTIONAL PART OF
00468                      *      MULTIPLICATION < 0.5
00469 316F 7D 0041    TST  ZERO1
00470 3172 27 01      BEQ  PTN    BR IF NO ROUND OFF
00471 3174 5C      INC  B

00473 3175 DE 29      RTN  LDX  ENDX
00474 3177 39      RTS

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00476
00477
00478
00479
*****
♦ CALCULATE ONEVL ♦
♦ DALT STARTS IN ACC A ♦
*****

00481 3178 80 24 VL SUB A #36
00482 317A 25 09 BCS LOW BR IF DALT < 36 (3000 FT)
00483 317C 06 AB LDA B #171
00484 317E 8D B7 BSR MPY8
00485 3180 86 B4 LDA A #180
00486 3182 10 SBA
00487 3183 20 02 BRR ENDOVL
00488 3185 86 B4 LOW LDA A #180
00489 3187 97 3F ENDOVL STA A ONEVL
00490
00491
00492
*****
♦ SET CVL FLAG ♦
*****

00493 3189 06 F3 LDA B #PT95
00494 318B 8D AA BSR MPY8 .95VL RET'N IN ACC B
00495 318D D1 5A CMP B KNOTS .95VL - KNOTS
00496 318F 25 14 BCS VLPEAK BR IF KNOTS > .95VL
00497 3191 06 26 LDA B #PT15
00498 3193 96 3F LDA A ONEVL
00499 3195 8D A0 BSR MPY8 .15VL RET'N IN ACC B
00500 3197 96 3F LDA A ONEVL
00501 3199 7A 0000 AGAIN1 DEC CVL
00502 319F 2B 07 BMI VLPEAK BR IF CVL = -1 (<.7VL)
00503 31A0 10 SBA
00504 31A2 91 5A CMP A KNOTS
00505 31A4 25 02 BCS VLPEAK BR IF %VL < KNOTS
00506 31A6 20 F4 BRR AGAIN1

00508
00509
00510
*****
♦ CHECK VL PEAK FCC ♦
*****

00512 31A5 96 5A VLPEAK LDA A KNOTS
00513 31A7 D6 3F LDA B ONEVL
00514 31A9 8D 48 BSR DIVIDE %VL IN ACC A
00515 31AB F6 01F9 LDA B VLPK
00516 31AD 11 CBA PRESENT VL - PEAK VL
00517 31AF 25 03 BCS VH BR IF PEAK > PRESENT
00518 31B1 B7 01F9 STA A VLPK

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00520          *****
00521          *CALCULATE ONEVH*
00522          *****

00524 31B4 32      VH      PUL A          GET DENSITY ALTITUDE
00525 31B5 06 2B      LDA B  #43
00526 31B7 BD 3137      JSR  MPY8
00527 31BA 86 90      LDA A  #144
00528 31BC 10          SBA
00529 31D0 97 3F      STA A  ONEVH
00530          *****
00531          *SET CVH FLAG*
00532          *****

00534 31BF 9F 45      STS  SAVSTK
00535 31C1 86 26      LDA A  #PT15
00536 31C3 D6 3F      LDA B  ONEVH
00537 31C5 BD 3137      JSR  MPY8
00538 31C8 37          PSH B          .15 VH ON STACK
00539 31C9 86 1A      LDA A  #PT10
00540 31CB D6 3F      LDA B  ONEVH
00541 31CD BD 3137      JSR  MPY8
00542 31D0 37          PSH B          .10 VH ON STACK
00543 31D1 86 0D      LDA A  #PT05
00544 31D3 D6 3F      LDA B  ONEVH
00545 31D5 BD 3137      JSR  MPY8          .05 VH IN ACC B

00547 31D8 96 3F      LDA A  ONEVH
00548 31DA 8D 0E      BSR  CMPKN      1 - .05 = .95
00549 31DC 8D 0C      BSR  CMPKN      .95 - .05 = .90
00550 31DE 33          PUL B          .1
00551 31DF 8D 09      BSR  CMPKN      .9 - .1 = .8
00552 31E1 33          PUL B          .15
00553 31E2 8D 06      BSR  CMPKN      .8 - .15 = .65
00554 31E4 8D 04      BSR  CMPKN      .65 - .15 = .5

00556 31E6 9E 45      PLENTA LDS  SAVSTK
00557 31E8 20 2B      BRA  ROLL

00559 31EA 10          CMPKN  SBA
00560 31EB 91 5A      CMP A  KNOTS
00561 31ED 25 F7      BCS  PLENTA  BR IF KNOTS > %VH
00562 31EF 7A 0001      DEC  CVH
00563 31F2 39          RTS

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00565 *****
00566 *   DIVIDE SUBROUTINE   *
00567 *****
00568 *   NUMERATOR IN ACC A  *
00569 *   DENOMINATOR IN ACC B *
00570 *   NUM * 128 / DEN = ANS *
00571 *****

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00573 31F3 D7 40   DIVIDE STA B  DENOM
00574 31F5 5F     CLR B
00575 31F6 D7 41   STA B  ZERO1
00576 31F8 D7 42   STA B  ANS      CLEAR ZERO & ANS
00577 31FA 97 43   STA A  NUM
00578 31FC 44     LSP A
00579 31FD 5A     RDR B
00580 31FE 4E     TCT A
00581 31FF 2E 04   BNE     SUBT      BP IF NUM WAS 1
00582 3201 D1 40   CMP B  DENOM
00583 3203 25 0F   RCL     SMALL    BP IF DENOM > NUM * 128
00584 3205 D0 40   SUBT     SUB B  DENOM
00585 3207 7C 0042 INC     ANS
00586 320A 92 41   DEC A  ZERO1    SUBTRACT POSSIBLE BORROW
00587 320C 25 F7   BNE     SUBT      BP IF NOT ZERO
00588 320E D1 40   CMP B  DENOM
00589 3210 24 F3   RCL     SUBT      BP IF ACC B  DENOM
00590 3212 4E 42   LDA A  ANS
00591 3214 3A     SMALL RTE

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00593
00594
00595

* CORRECT ROLL *

00597	3215	D6	4C	POLL	LDA B	CONVTAB+2	SYNCHRO REFERENCE
00598	3217	96	4B		LDA A	CONVTAB+1	ROLL
00599	3219	C1	91		CMP B	#145	
00600	321B	24	31		BCC	OUT1	BP IF REF > 145
00601	321D	C1	6F		CMP B	#111	
00602	321F	25	2D		BCS	OUT1	BP IF REF < 111
00603	3221	8D	D0		BSR	DIVIDE	CORRECT ROLL RETN IN ACC A

00604
00605
00606

* SET CROL FLAG *

00607	3223	81	93		CMP A	#DEG35	
00608	3225	24	11		BCC	PITCH	BP IF ROLL > 35
00609	3227	7A	0002		DEC	CROL	
00610	3229	81	6E		CMP A	#DEG25	
00611	322C	24	0A		BCC	PITCH	BP IF ROLL > 25
00612	322E	7A	0002		DEC	CROL	
00613	3231	81	2C		CMP A	#DEG10	
00614	3233	24	03		BCC	PITCH	BP IF ROLL > 10
00615	3235	7A	0002		DEC	CROL	

00617
00618
00619

* CORRECT PITCH *

00621	3238	D6	4C	PITCH	LDA B	CONVTAB+2	SYNCHRO REFERENCE
00622	323A	96	4D		LDA A	CONVTAB+3	PITCH
00623	323C	8D	B5		BSR	DIVIDE	CORRECT PITCH RETN IN ACC A

00625
00626
00627

* SET CPIT FLAG *

00629	323E	81	40		CMP A	#DEG15	
00630	3240	24	12		BCC	CORPTO	BP IF PITCH > 15
00631	3242	7A	0009		DEC	CPIT	
00632	3245	81	16		CMP A	#DEG5	
00633	3247	24	0B		BCC	CORPTO	BP IF PITCH > 5
00634	3249	7A	0009		DEC	CPIT	
00635	324C	20	06		BRA	CORPTO	

00637	324E	86	FF	OUT1	LDA A	#FFF
00638	3250	97	0A		STA A	CPIT
00639	3252	97	02		STA A	CROL

00641
00642
00643

♦ CORRECT TORQUE ♦

00645	3254	D6	4F	CORRTQ	LDA B	CNVTAB+5	TORQUE REFERENCE
00646	3256	96	4E		LDA A	CNVTAB+4	TORQUE
00647	3258	C1	91		CMP B	#145	
00648	3259	24	16		BCC	OUT2	BR IF REF > 145
00649	325C	C1	6F		CMP B	#111	
00650	325E	25	12		BCS	OUT2	BR IF REF < 111
00651	3260	8D	91		BSR	DIVIDE	

00653
00654
00655

♦ SET CO FLAG ♦

00657	3262	91	0A		CMP A	PS15	
00658	3264	25	0F		BCS	SETCT	BR IF TO < 5 PSI
00659	3266	7C	0003		INC	CO	
00660	3269	91	0C		CMP A	PS144	
00661	326E	25	08		BCS	SETCT	BR IF TO < 44 PSI
00662	326D	7C	0003		INC	CO	
00663	3270	20	03		BRA	SETCT	
00664	3272	4F		OUT2	CLR A		
00665	3273	97	03		STA A	CO	

00666
00667
00668

♦ SET CT FLAG ♦

00670	3275	96	54	SETCT	LDA A	CNVTAB+10	GROSS WEIGHT TRANSDUCER
00671	3277	81	14		CMP A	#GMGND	GROSS WEIGHT - GND THRESHOLD
00672	3279	25	03		BCS	RPM	BR IF GM < GND THRESHOLD
00673	327B	7C	0006		INC	CT	

00675
00676
00677

♦ SET CRPM FLAG ♦

00679	327E	96	4A	RPM	LDA A	CNVTAB	RPM
00680	3280	81	08		CMP A	#RPM200	RPM - 200
00681	3282	24	0A		BCC	AVGGW	BR IF RPM > 200
00682	3284	7A	0005		DEC	CRPM	
00683	3287	81	64		CMP A	#RPM100	RPM - 100
00684	3289	24	03		BCC	AVGGW	BR IF RPM > 100
00685	328B	7A	0005		DEC	CRPM	

PHASE 017 JIPSP

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00697
00698
00699
*****
*   AVERAGE GROSS WEIGHT   *
*****

00691 328E 5F      AVGGW CLR B
00692 328F 96 05    LDA A  CPPM
00693 3291 2E 23    BMI     SKPCLR BR IF RPM < 100

00695 3293 0E 005E   LDX     #GMONT *****
00696 3296 E7 00     CLRGW STA B 0,X  *   CLEAR   *
00697 3298 08        INX     *GMONT, GM1ST, GML, ISML *
00698 3299 2C 0062   CPX     #GML+1 *   IF RPM > 100 *
00699 329C 26 F8     BNE     CLRGW *****

00701 329E 7C 005D   INC     GMTL *****
00702 32A1 26 03     BNE     SK2    *INCREMENT FUEL BURN TIME*
00703 32A3 7C 005C   INC     GMTH * (GMTH * GMTL) *
00704 32A6 0E 5C     SK2    LDX     GMTH *
00705 32A9 8C 0310   CPX     #GMTIME * IF EQUAL TO #GMTIME *
00706 32AB 26 47     BNE     SETCGW * DECREMENT GROSS WEIGH *
00707 32AD 7A 01F7   DEC     GROSSMT * (GROSSMT) * CLEAR TIME*
00708 32B0 D7 5C     STA B  GMTH *
00709 32B2 D7 5D     STA B  GMTL *
00710 32B4 20 3E     BRA     SETCGW *****

00712 32B6 D7 5C     SKPCLR STA B  GMTH *   CLEAR
00713 32B8 D7 5D     STA B  GMTL *FUEL BURN TIME*
00714 32BA 96 54     LDA A  CNVTAB+10 GROSS WEIGHT
00715 32BC 9B 61     ADD A  GML *****
00716 32BE 97 61     STA A  GML *ADD FOR*
00717 32C0 14 03     BCC     NXT4 *AVERAGE*
00718 32C2 7C 0060   INC     GML *****
00719 32C5 7C 005E NXT4 INC     GMONT *INPUTS FOR AVERAGE
00720 32C8 96 07     LDA A  #7
00721 32CA 95 5E     BIT A  GMONT
00722 32CC 26 26     BNE     SETCGW BR IF NOT 8 INPUTS

00724
00725
00726
00727
*****
*   DIVIDE SUM OF   *
*   8 INPUTS BY 8   *
*****

00729 32CE 96 03     LDA A  #3
00730 32D0 97 44     STA A  SHFTCT
00731 32D2 96 60     LDA A  GML
00732 32D4 D6 61     LDA B  GML
00733 32D6 20 3166   JBR     SHFT

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00735
00736
00737
00738
00739 32D9 17
00740 32DA 97 61
00741 32DC D6 5F
00742 32DE 27 0B
00743 32E0 10
00744 32E1 2A 01
00745 32E3 43
00746 32E4 80 04
00747 32E6 24 03
00748 32E8 F7 01F7
00749 32EB 96 61
00750 32ED 97 5F
00751 32EF 4F
00752 32F0 97 61
00753 32F2 97 60

00755
00756
00757

00759 32F4 B6 01F7
00760 32F7 81 AF
00761 32F9 25 0A
00762 32FB 7C 0008
00763 32FE 81 E1
00764 3300 25 03
00765 3302 7C 0008

```

 * CHECK PREVIOUS GROSS WEIGHT *
 * UPDATE IF DIFFERENCE < 4 *

TBA PUT AVG GROSS WEIGHT IN ACC A
 STA A GNL
 LDA B GW1ST GET PREVIOUS AVERAGE
 BEQ TO1ST BR IF NO PREVIOUS AVERAGE
 SBA GET DIFFERENCE OF AVERAGES
 BPL TST1 BR IF PLUS
 COM A MAKE IT PLUS
 SUB A #4
 BCC TO1ST BR IF DIFFERENCE > 3
 STA B GROSSWT UPDATE GROSS WEIGHT
 TO1ST LDA A GNL * BUMP PRESENT GW
 STA A GW1ST * TO "PREVIOUS" LOCATION
 CLR A
 STA A GNL
 STA A GNL

 * SET CGW FLAG *

SETCGW LDA A GROSSWT
 CMP A #GW7750
 BCS DECENT BR IF GW < 7750
 INC CGW
 CMP A #GW8750
 BCS DECENT BR IF GW < 8750
 INC CGW

14
F

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00767
00768
00769
00770
*****
*   GET 1 SECOND ALTITUDE AVERAGE   *
*   LOAD DIVE TABLE FOR TIME 0     *
*****

00772 3305 96 02  DECENT LDA A  CROL
00773 3307 2B 03      BMI  3F5      BR IF ROLL = 10
00774 3309 7C 0055      INC  DVTABL+4
00775 330C 96 03  SK5  LDA A  C0
00776 330E 26 03      BNE  3F6      BR IF TORQUE = 5
00777 3310 7C 0065      INC  DVTABL+3
00778 3313 96 07  SK6  LDA A  C02
00779 3315 2B 03      BMI  3F7      BR IF N2 = 1.3
00780 3317 7C 0067      INC  DVTABL+5
00781 331A 7C 00A8  SK7  INC  AVGDVC  INC AVERAGE COUNTER
00782 331D 96 A8      LDA A  AVGDVC
00783 331F 81 0A      CMP A  #9
00784 3321 24 11      BCC  CHK10  BR IF 9 OR 10 AVERAGE INPUTS
00785 3323 7F 00A8      CLP  AVGDVC
00786 3326 D6 5F      LDA B  ALTFT *****
00787 3328 DB A7      ADD B  AVGDVL  *
00788 332A D7 A7      STA B  AVGDVL  *   ADD FOR AVERAGE   *
00789 332C 24 03      BCC  CHK4   *
00790 332E 7C 00A6      INC  AVGDVH *****
00791 3331 7E 366F  SKP4  JMP  F1

00793 3334 81 0A  CHK10  CMP A  #10
00794 3336 25 5E      BCC  BRAF1  BR IF AVGDVC = 9
00795 3338 26 03      LDA A  #3
00796 333A 97 44      STA A  CHATCT
00797 333C 96 A6      LDA A  AVGDVH
00798 333E D6 A7      LDA B  AVGDVL
00799 3340 ED 3166      JIR  CHIFT  AVG RETN IN ACC 6
00800 3343 D7 68      STA B  DVTABL+6  1 SEC ALTFT AVERAGE
00801 3345 5F      CLP B
00802 3346 D7 A7      STA B  AVGDVL
00803 3348 D7 A6      STA B  AVGDVH
00804 334A D6 01      LDA B  CVH
00805 334C D7 63      STA B  DVTABL+1
00806 334E D6 00      LDA B  CVL
00807 3350 D7 64      STA B  DVTABL+2
00808 3352 96 5A      LDA A  KNOTS
00809 3354 D7 69      STA B  DVTABL+7

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00811
00812
00813
00814
*****
♦   SET DELTA FLAG IF   ♦
♦   ALT(-6) - ALT(0) > 1 ♦
*****

00816 3356 CE 0062      LDY    #DVTABL
00817 3359 5F 00      CLP     0,X
00818 335B E6 06      LDA B    6,X      ALT(0)
00819 335D CB 02      ADD B    #2
00820 335F A6 36      LDA A    54,X      ALT(-6)
00821 3361 10        SRA      ALT(-6) - ALT(0) - 2
00822 3362 25 02      BCS     CHK9      BR IF ALT DID NOT DECREASE
00823                      BY 2 CNTS IN LAST 6 SEC
00824 3364 6C 00      INC     0,X

00826
00827
00828
00829 3366 5C        CHA9    INC B      ALT(0) + 3
00830 3367 A6 3C      LDA A    60,X      ALT(-9)
00831 336A 10        SBA      ALT(-9) - ALT(0) - 3
00832 336A 25 27      BCS     SKP3      BR IF ALT DID NOT DECREASE
00833                      BY 3 CNTS IN LAST 9 SEC

00835 336C E6 43      LDA B    67,X      A(-12)
00836 336E CB 23      ADD B    #35
00837 3370 A6 37      LDA A    55,X      A(-6)
00838 3372 10        SBA      A(-6) - A(-12) - 35 KNOTS
00839 3373 25 1E      BCS     CYP3      BR IF A-6 DID NOT INCREASE BY
00840                      35 KNOTS FROM (-12) TO (-6)

00842 3375 5F        CLR B
00843 3376 86 F9      LP5     LDA A    #5F8      (-9)
00844 3378 EB 00      ADD B    0,X
00845 337A 09        LP6     INX
00846 337B 4C        INC A      ♦ INC X BY 8
00847 337C 36 FC      BNE     LP6
00848 337E 9C 009A    CPX     #DVTABL+56
00849 3381 26 F3      BNE     LP5      BR IF THERE MORE DELTAS
00850 3383 C1 05      CMP B    #5
00851 3385 25 0C      BCS     SKP3      BR IF SUM OF DELTAS < 5

00853 3387 96 5B      LDA A    ALTFT      ALTITUDE IN FEET
00854 3389 81 78      CMP A    #120      10,000 FEET
00855 338B 24 06      BCC     SKP3      BR IF ALTITUDE > 10,000 FT
00856 338D 7C 0004    INC     CRD
00857 3390 BD 3600    JCP     $3600      BUMP
00858 3393 7C 0004    SKP3    INC     CRD
00859 3396 20 39      BRAF1    BRA     DLOOPB

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PAGE 021 SIRSP

00861 3398 FC	ALTABL FCB	252,255. 0
00862 3398 E5	FCB	229. 225. 44
00863 339E C7	FCB	199. 187. 40
00864 33A1 9C	FCB	156. 138. 36
00865 33A4 7C	FCB	124. 105. 34
00866 33A7 5A	FCB	90. 74. 30
00867 33AA 40	FCB	64. 51. 29
00868 33AD 25	FCB	37. 29. 26
00869 33B0 00	FCB	0. 0. 25
00870 33B3 FA	ASTABL FCB	250. 202. 0
00871 33B6 B0	FCB	176. 171. 14
00872 33B9 70	FCB	112. 137. 17
00873 33BC 50	FCB	80. 116. 21
00874 33BF 32	FCB	50. 32. 26
00875 33C2 1E	FCB	30. 71. 32
00876 33C5 15	FCB	21. 59. 47
00877 33C8 0C	FCB	12. 45. 54
00878 33CB 05	FCB	5. 29. 77
00879 33CE 00	FCB	0. 0. 196

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00881 33D1 CE 2800 DLOOPB LDX #MES2
00882 33D4 BD 3554 JSR PRT
00883 33D7 BD 35C1 JSR INP
00884 33DA CE 2869 LDX #MES7
00885 33DD BD 3559 JSR PTRR
00886 33E0 CE 286E LDX #BUFFER
00887 33E3 A6 00 LDA A 0,X
00888 33E5 81 4E CMP A #$4E N?
00889 33E7 27 12 BEQ JF4X
00890 33E9 81 4C CMP A #$4C L?
00891 33EB 27 11 BEQ JLO
00892 33ED 94 4F AND A #$4F
00893 33EF 81 09 CMP A #$09
00894 33F1 2F 0E BLE DLOOPJ
00895 33F3 CE 281C LDX #MES3
00896 33F6 BD 3559 JSR PTRR
00897 33F9 20 D6 BRA DLOOPB
00898 33FB 7E 3499 JF4X JMP JF4
00899 33FE 7E 345A JLO JMP DLOOPS
00900 3401 B7 340D DLOOPJ STA A DLOOPK+1
00901 3404 B7 3456 STA A DLOOPQ+1
00902 3407 CE 0000 LDX #CVL
00903 340A C4 30 LDA B #$30
00904 340C A6 00 DLOOPK LDA A 0,X
00905 340E 2A 04 BPL DLOOPI
00906 3410 43 COM A
00907 3411 4C INC A
00908 3412 C6 2D LDA B #$2D
00909 3414 8A 30 DLOOPI ORA A #$30
00910 3416 CE 286E LDX #BUFFER
00911 3419 E7 02 STA B 2,X
00912 341B A7 03 STA B 3,X
00913 341D 5F CLR B
00914 341E E7 04 STA B 4,X
00915 3420 C6 2A LDA B #$2A
00916 3422 E7 00 STA B 0,X
00917 3424 C6 20 LDA B #$20
00918 3426 E7 01 STA B 1,X
00919 3428 BD 3554 JSR PRT
00920 342B CE 282F LDX #MES4
00921 342E BD 3554 JSR PRT
00922 3431 BD 35C1 JSR INP
00923 3434 CE 2869 LDX #MES7
00924 3437 BD 3559 JSR PTRR
00925 343A CE 286E LDX #BUFFER
00926 343D A6 00 LDA A 0,X
00927 343F 81 0D CMP A #$0D
00928 3441 27 14 BEQ DLOOPI
00929 3443 81 2D CMP A #$2D
00930 3445 26 01 BNE DLOOPI
00931 3447 03 INX
00932 344A E6 00 DLOOPI LDA B 0,X
00933 344A C4 0F AND B #$0F
00934 344C 81 2D CMP A #$2D

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00935 344E 26 02      BNE      DLOOPP
00936 3450 53          COM B
00937 3451 5C          INC B
00938 3452 CE 0000 DLOOPP LDX      #CVL
00939 3455 E7 00 DLOOPP STA B      0,X
00940 3457 7E 33D1 DLOOPP JMP      DLOOPE
00941 345A 7F 2855 DLOOPP CLR      COUNT
00942 345D 7A 2855      DEC      COUNT
00943 3460 CE 0000 DLOOPT LDX      #CVL
00944 3463 7C 2855      INC      COUNT
00945 3466 B6 2855      LDA A      COUNT
00946 3469 81 09      CMP A      #9
00947 346B 2E EA      BGT      DLOOPP
00948 346D B7 3476      STA A      DLOOPI+1
00949 3470 8A 30      ORA A      #$30
00950 3472 B7 286E      STA A      BUFR
00951 3475 A6 00 DLOOPI LDA A      0,X
00952 3477 CE 286E      LDX      #BUFR
00953 347A C6 20      LDA B      #$20
00954 347C E7 01      STA B      1,X
00955 347E E7 02      STA B      2,X
00956 3480 C6 30      LDA B      #$30
00957 3482 E7 03      STA B      3,X
00958 3484 40          TST A
00959 3485 2A 06      BPL      DLOOPI
00960 3487 C6 20      LDA B      #$20
00961 3489 E7 03      STA B      3,X
00962 348B 43          COM A
00963 348C 4C          INC A
00964 348D 8A 30 DLOOPI ORA A      #$30
00965 348F A7 04      STA A      4,X
00966 3491 5F          CLP B
00967 3493 E7 05      STA B      5,X
00968 3494 BD 355A      JSR      PTR
00969 3497 20 C7      BRA      DLOOPT
00970 3499 CE 2835 JF4   LDX      #ME35
00971 349C BD 355A      JSR      PTR
00972 349F BD 35C1      JSR      INP
00973 34A2 CE 2869      LDX      #ME37
00974 34A5 BD 355A      JSR      PTR
00975 34A8 5F          CLR B
00976 34A9 F7 34C9      STA B      JF4D+1
00977 34AC CE 286E      LDX      #BUFR
00978 34AF A6 01 JF4B   LDA A      1,X
00979 34B1 81 00      CMP A      #$00
00980 34B3 27 06      BEQ      JF4C
00981 34B5 7C 34C9      INC      JF4D+1
00982 34B8 08          INX
00983 34B9 20 F4      BRA      JF4B
00984 34BB CE 286E JF4C   LDX      #BUFR
00985 34BE A6 00 JF4C1  LDA A      0,X
00986 34C0 84 0F      AND A      #$0F
00987 34C2 FF 2882      STX      DAVEX
00988 34C5 CE 284F      LDX      #1

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00989 3408 EB 00 JF4D ADD B 0.X
00990 340A 4A DEC A
00991 340B 26 FB BNE JF4D
00992 340D B6 34C9 LDA A JF4D+1
00993 3400 27 0A BEQ JF4F
00994 34D2 4A DEC A
00995 34D3 B7 34C9 STA A JF4D+1
00996 34D6 FE 2882 LDX SAVEX
00997 34D9 08 INX
00998 34DA 20 E2 BRA JF4C1
00999 34DC F7 2854 JF4F STA B LOOPCT
01000 34DF 7E 360A JMP F4
01001
01002 ♦ AT END OF PASS
01003 ♦
01004 34E2 7A 2854 FLOOPA DEC LOOPCT
01005 34E5 27 03 BEQ FLOOP1
01006 34E7 7E 360A JMP F4
01007 34EA CE 0100 FLOOP1 LDX #100
01008 34ED 5F CLR B
01009 34EE 7F 2882 CLR SAVEX
01010 34F1 A6 00 FLOOPB LDA A 0.X
01011 34F3 08 INX
01012 34F4 9C 0200 CPX #200
01013 34F7 27 07 BEQ FLOOP5
01014 34F9 A1 FF CMP A 255.X
01015 34FB 26 13 BNE FLOOPD
01016 34FD 5C FLOOP4 INC B
01017 34FE 20 F1 BRA FLOOPB
01018 3500 CE 0100 FLOOP5 LDX #100
01019 3503 86 FF LDA A #255
01020 3505 E6 00 FLOOPC LDA B 0.X
01021 3507 08 INX
01022 3508 E7 FF STA B 255.X
01023 350A 4A DEC A
01024 350B 26 FB BNE FLOOPC
01025 350D 7E 33D1 JMP FLOOPB
01026 3510 7D 2882 FLOOPD TST SAVEX
01027 3513 26 08 BNE FLOOPE
01028 3515 FF 2882 STX SAVEX
01029 3518 CE 2856 LDX #MES6
01030 351B BD 3559 JCR PTRP
01031 351E 20 03 BRA FLOOPF
01032 3520 FF 2882 FLOOPE STX SAVEX
01033 3523 37 FLOOPF PSH B
01034 3524 C6 20 LDA B #20
01035 3526 BD 3575 JCR PUTC
01036 3529 33 PUL B
01037 352A 37 PSH B
01038 352B 36 PSH A
01039 352C 17 TBA
01040 352D BD 35D6 JCR PRTDEC
01041 3530 CE 2869 LDX #MES7
01042 3533 BD 3554 JCR PRT

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01043	3536	FE	2882	LDX	SAVEX
01044	3539	AA	FF	LDA A	255.X
01045	353B	BD	35D6	JSP	PRTDEC
01046	353E	CE	2969	LDX	#MES7
01047	3541	BD	3554	JSP	PRT
01048	3544	32		PUL A	
01049	3545	BD	35D6	JSP	PRTDEC
01050	3548	CE	2969	LDX	#MES7
01051	354B	BD	3559	JSP	PPTR
01052	354E	FE	2882	LDX	SAVEX
01053	3551	33		PUL B	
01054	3552	20	AA	BPA	FLOOP4

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01056
01057
01058
01059
01060
01061
01062
01063
01064 3554 36
01065 3555 37
01066 3556 4F
01067 3557 20 04
01068 3558 36
01069 3559 37
01070 355A 36 AA
01071 355B 06 09
01072 355C F7 1000
01073 355D E6 00
01074 355E 27 06
01075 355F BD 3575
01076 3560 08
01077 3561 20 F6
01078 3562 4D
01079 3563 27 03
01080 3564 BD 3575
01081 3565 23
01082 3566 32
01083 3567 39
01084
01085
01086
01087 3568 36
01088 3569 B6 1000
01089 356A 47
01090 356B 47
01091 356C 34 F9
01092 356D F7 1001
01093 356E C1 7F
01094 356F 27 11
01095 3570 BD 35AE
01096 3571 5D
01097 3572 26 0B
01098 3573 C6 0D
01099 3574 BD 3575
01100 3575 C6 0A
01101 3576 BD 3575
01102 3577 5F
01103 3578 32
01104 3579 39
01105
01106
01107
01108 357A 36
01109 357B B6 1000

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♦ THE FOLLOWING ROUTINES HAVE BEEN INSERTED
 ♦ FOR DEBUGGING PURPOSES ONLY AND WILL NOT
 ♦ APPEAR IN THE FINAL VERSION OF THE SOFTWARE.

♦ PRINT SUBROUTINE

```

PRT   PSH A
      PSH B
      CLR A
      BRA PRT3
PTRR  PSH A
      PSH B
      LDA A 0$AA
      LDA B 0$09
      STA B ACIACS
      LDA B 0.X
      BEQ PRTX
      JCR PUTC
      INX
      BRA PRT4
PRTX  TST A
      BEQ PRTX
      JCR PUTC
PRTX  PUL B
      PUL A
      RTS

```

♦ PUTC SUBROUTINE

```

PUTC  PSH A
PUTC1 LDA A ACIACS
      AER A
      AER A
      BCC PUTC1
      STA B ACIAXR
      CMP B 0$7F
      BEQ PUTF
      JCR DLAY
      TCT B
      BNE PUTF
      LDA B 0$0D
      JCR PUTC
      LDA B 0$0A
      JCR PUTC
      CLR B
      PUL A
      RTS

```

♦ GETC SUBROUTINE

```

GETC  PSH A
GETC1 LDA A ACIACS

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01110 3598 47          ASR A
01111 359C 24 FA      BCC     GETC1
01112 359E 48          ASL A
01113 359F 36          PSH A
01114 35A0 25 70      BIT A    #$70
01115 35A2 27 02      BEQ     GETEX
01116 35A4 32          PUL A
01117 35A5 3F          BMI
01118 35A6 32      GETEX PUL A
01119 35A7 F6 1001    LDA B    ACIAXR
01120 35AA C4 7F      AND B    #$7F
01121 35AC 32          PUL A
01122 35AD 3A          RTS
01123
01124      ♦ DELAY SUBROUTINE
01125      ♦
01126 35AF 37      DELAY PSH B
01127 35B0 36 03      LDA A    #3
01128 35B1 C1 00      CMP B    #$00
01129 35B2 26 02      BNE     DELAY1
01130 35B5 36 13      LDA A    #19
01131 35B7 C2 7F      DELAY1 LDA B    #$7F
01132 35B9 8D 3575    JCR     PUTC
01133 35B1 4A          DEC A
01134 35BD 26 FA      BNE     DELAY1
01135 35BF 33          PUL B
01136 35C0 3A          RTS
01137
01138 35C1 CE 286E    INP     LDY    #BUFFER
01139 35C4 8D 35A7    INP1    JCR     GETC
01140 35C7 8D 3575    JCR     PUTC
01141 35C9 C1 0A      CMP B    #$0A      LFT
01142 35C7 27 F3      BEQ     INP
01143 35CE E7 00      LTR B    0x
01144 35D0 02          INX
01145 35D1 C1 00      CMP B    #$00
01146 35D3 26 EF      BNE     INP1
01147 35D5 3A          RTS
01148
01149      ♦ PRIDEC
01150 35D6 36      PRIDEC PSH A
01151 35D7 37      PSH B
01152 35D9 FF 28A4    LTX     IAVE+2
01153 35DB CE 2852    LDX     #K10
01154 35DE 5F      CVHTD1 CLP B
01155 35DF 40 00      CVHTD2 SUB A    0x
01156 35E1 25 03      BCC     CVHTD4
01157 35E3 5C          INC B
01158 35E4 20 F9      BPA     CVHTD2
01159 35E6 AB 00      CVHTD4 ADD A    0x
01160 35E8 CA 30      ORA B    #$30
01161 35EA 8C 2853    CPX     #K10+1
01162 35ED 27 06      BEQ     CVHTD5
01163 35EF C1 20      CMP B    #$30

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01164	35F1	26	02	BNE	CVHTD5
01165	35F2	06	20	LDA B	#\$20
01166	35F5	BD	3575	JSR	PUTC
01167	35F8	08		INX	
01168	35F9	8C	2854	CPX	#\$K10+2
01169	35FC	26	E0	BNE	CVHTD1
01170	35FE	16		TAB	
01171	35FF	0A	30	DRA B	#\$30
01172	3601	BD	3575	JSR	PUTC
01173	3604	FE	2884	LDX	SAVEX2
01174	3607	33		PUL B	
01175	3608	32		PUL A	
01176	3609	39		PTS	

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01178
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01188 360A CE 0000 F4 LDX #CVL SETUP INDEX
01189 360D 6F 3D CLR 61,X SET CONE=1
01190 360F 6F 3E CLR 62,X
01191 3611 86 01 LDA A #1
01192 3613 A7 3C STA A 60,X
01193 3615 6D 0B TST 11,X ARM?
01194 3617 27 11 BEQ F4A NO,BR
01195 3619 6D 05 TST 5,X RPM<100?
01196 361B 2C 13 BGE F8 NO,BR
01197 361D 5F CLR B
01198 361E CE 00F9 LDX #249 ROTOR CYCLES
01199 3621 86 3C LDA A #60 CONSTANT "1"
01200 3623 8D 39A9 JSR BUMP COUNT CYCLE
01201 3626 6F 0B CLR 11,X NEARM
01202 3628 2D 06 BRA F8
01203 362A 6D 05 F4A TST 5,X RPM>200?
01204 362C 2F 02 BLE F8 NO,CONTINUE
01205 362E 63 0B COM 11,X ARM
01206
01207
01208
01209
01210
01211
01212 3630 6D 06 F8 TST 6,X GROUND?
01213 3632 27 1F BEQ F86 NO,BR
01214 3634 6F 3B CLR 59,X CLR AIRTIME
01215 3636 6D 0D TST 13,X AIR SET?
01216 3638 27 35 BEQ F1 NO,BR
01217 363A A6 0C LDA A 12,X
01218 363C 81 64 CMP A #100 TO TIMER>=10 SEC?
01219 363E 2D 05 BLT F8D NO,BR
01220 3640 CE 0000 LDX #0 NORMAL LNDGS
01221 3643 2D 03 BRA F8E
01222 3645 CE 0006 F8D LDX #6 AUTOROTATIVE LNDGS
01223 3648 86 3C F8E LDA A #60 CONSTANT "1"
01224 364A 8D 39A4 JSR BUMP COUNT LANDING
01225 364D 6F 0D CLR 13,X SET GND
01226 364F 6F 0C F8F CLR 12,X CLR TO TIMER
01227 3651 2D 1C BRA F1
01228 3653 A6 3B F86 LDA A 59,X
01229 3655 81 63 CMP A #99 AIRBORNE FOR >10 SEC?
01230 3657 2E 05 BGT F8H YES,BR
01231 3659 4C INC A BUMP AIRTIME

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01232	365A	A7	3B		STA A	59,X	
01233	365C	20	11		BRA	F1	
01234	365E	96	01	F8H	LDA A	#1	
01235	3660	A7	0D		STA A	13,X	SET AIR
01236	3662	6D	03		TST	3,X	TQ>5?
01237	3664	27	E9		BEO	F8F	NO, BR
01238	3666	A6	0C		LDA A	12,X	INC TO TIMER
01239	3668	81	64		CMP A	#100	
01240	366A	27	03		BEO	F1	
01241	366C	4C			INC A		
01242	366D	A7	0C		STA A	12,X	

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01244
01245
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01249
01250 366F 6D 0D F1 TST 13.X AIR CONDS?
01251 3671 27 37 BEQ F1N NO.BP
01252 3673 CE 0096 LDX #150 FLIGHT TIME
01253 3676 86 3C LDA A #60 CONSTANT "1"
01254 3678 BD 39A4 JSR BUMP COUNT FLIGHT TIME
01255 367B 6D 03 TST 3.X TO>5?
01256 367D 27 0C BEQ F1C NO.BP
01257 367F 6C 0E INC 14.X INC T77 CNTR
01258 3681 6D 02 TST 2.X ROLL<10?
01259 3683 2C 22 BGE F1G NO.BP
01260 3685 6D 07 TST 7.X NZ<1.3?
01261 3687 2B 2F BMI F29 YES.BP
01262 3689 20 68 BRA F53XX
01263 368B A6 0E F1C LDA A 14.X
01264 368D 81 14 CMP A #20 T77>2 SECS?
01265 368F 2F 02 BLE F1F NO.BP
01266 3691 6F 0E CLR 14.X CLR T77
01267 3693 6C 0E F1F INC 14.X INC T77
01268 3695 A6 0E LDA A 14.X AUTOROTATIVE CLOCK TIME
01269 3697 A7 2C STA A 44.X
01270 3699 6F 2D CLR 45.X
01271 369B 6F 2E CLR 46.X
01272 369D 86 2C LDA A #44
01273 369F CE 00CC LDX #204
01274 36A2 BD 39A4 JSR BUMP
01275 36A5 6F 0E CLR 14.X CLR T77
01276 36A7 7E 37D4 F1G JMP F53Y
01277 36AA 86 2D F1N LDA A #45 CLR MISC FLAGS, CNTRS
01278 36AC CE 000E LDX #T77 START AT T77
01279 36AF 6F 00 CLRF CLR 0.X
01280 36B1 08 INX
01281 36B2 4A DEC A
01282 36B3 26 FA BNE CLRF
01283 36B5 7E 3987 JMP F95J

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01285
01286
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01290 3688 6D 04 F29 TST 4,X RD VALID?
01291 368A 2B 39 BMI F5XX NO,BR
01292 368C 7D 0096 TST DVTABL+52 ROLL=0?
01293 368F 26 5F BNE F29X NO,BR
01294 36C1 7D 0097 TST DVTABL+53 MZ=0?
01295 36C4 26 5A BNE F29X NO,BR
01296 36C6 7D 0095 TST DVTABL+51 Q=0?
01297 36C9 27 55 BEQ F29X NO,BR
01298 36CB 6D 04 TST 4,X RD-1650 FPM?
01299 36CD 27 28 BEQ F29H NO,BR
01300 36CF 96 94 LDA A DVTABL+50 GET VL
01301 36D1 81 02 CMP A #2 A/S>.95VL?
01302 36D3 26 05 BNE F29B NO,BR
01303 36D5 CE 001E LDX #30
01304 36D8 20 12 BRA F296
01305 36DA 4D F29B TST A
01306 36DB 2D 0C BLT F29D A/S<=.7VL
01307 36DD 27 05 BEQ F29C .7VL<A/S<=.95VL
01308 36DF CE 0018 LDX #24 .95VL<A/S<=.95VL
01309 36E2 20 08 BRA F296
01310 36E4 CE 0012 F29C LDX #18
01311 36E7 20 03 BRA F296
01312 36E9 CE 000C F29D LDX #12
01313 36EC 86 3C F296 LDA A #60 CONSTANT "1"
01314 36EE 2D 39A4 JIR BUMP INC FCC
01315 36F1 2D 2D BPA F29X
01316
01317 36F3 2D 5D F53XX BRA F53
01318 36F5 2D 4F F5XX BRA F5
01319
01320
01321
01322
01323
01324
01325 36F7 96 93 F29H LDA A DVTABL+49 GET VH
01326 36F9 81 03 CMP A #3 A/S>.95VH?
01327 36FB 26 05 BNE F29X NO,BR
01328 36FD CE 00BA LDX #186 A/S>=.95VH
01329 3700 20 EA BRA F296
01330 3702 81 FE F29X CMP A #3FE A/S<.5VH
01331 3704 27 1A BEQ F29X YES,BR
01332 3706 4D TST A A/S<.65VH?
01333 3707 2C 05 BGE F29H YES,BR
01334 3709 CE 00A8 LDX #168 .5VH<=A/S<.65VH
01335 370C 20 DE BRA F296
01336 370E 96 95 F29H LDA A DVTABL+51 GET Q
01337 3710 81 01 CMP A #1
01338 3712 2D 0C BLT F29X TQ<=5?

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01339	3714	27	05	BEQ	F29P	5<TORQUE<=44?
01340	3716	CE	00C3	LDX	#195	TORQUE>44
01341	3719	20	D1	BRA	F296	
01342	371B	CE	00B1	LDX	#177	
01343	371E	20	CC	BRA	F296	
01344	3720	CE	00A3	LDX	#DVTABL+65	
01345	3723	A6	00	LDA A	0*X	
01346	3725	A7	02	STA A	2*X	
01347	3727	09		DEX		
01348	3728	8C	0097	CPX	#DVTABL+53	
01349	372B	26	F6	BNE	LOOP1	
01350	372D	CE	0092	LDX	#DVTABL+48	
01351	3730	09		DEX		
01352	3731	A6	00	LDA A	0*X	
01353	3733	A7	08	STA A	3*X	
01354	3735	9C	0062	CPX	#DVTABL	
01355	3738	26	F6	BNE	LOOP2	
01356	373A	CE	0062	LDX	#DVTABL	
01357	373D	6F	03	CLR	3*X	
01358	373F	6F	04	CLR	4*X	
01359	3741	6F	05	CLR	5*X	
01360	3743	CE	0000	LDX	#CVL	

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01362      *
01363      .....
01364      *** FCC 5-7 - QUICK STOP DECELEPATIONS ***
01365      .....
01366      *
01367 3746 6D 09 F5    TST    9,X    PITCH*15?
01368 3748 2F 08      BLE    F53    NO.BR
01369 374A CE 009F      LDX    #159  QUICK STOPS
01370 374D 86 3C      LDA    A    #60  CONSTANT "1"
01371 374F BD 39A4      JSR      BUMP
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01373
01374
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01378 3752 6D 04 F53 TST 4.X CRD VALID?
01379 3754 2B 5A BMI F53S NO.BR
01380 3756 6D 20 TST 32.X PUFLAG SET?
01381 3758 26 36 BNE F53H YES.BR
01382 375A 6D 09 TST 9.X PITCH<5?
01383 375C 2C 52 BGE F53S NO.BR
01384 375E 06 01 LDA B #1 SET PUFLAG
01385 3760 E7 20 STA B 32.X
01386 3762 6D 04 TST 4.X PD>1650?
01387 3764 26 02 BNE F53C YES.BR
01388 3766 E7 30 STA B 48.X SET NOPUFG
01389 3768 A6 08 F53C LDA A 8.X SAVE GM
01390 376A A7 32 STA A 50.X
01391 376C A6 00 LDA A 0.X SAVE VL
01392 376E A7 33 STA A 51.X
01393 3770 06 06 LDA B #6 START LOOP
01394 3772 86 35 LDA A #53
01395 3774 B7 377B STA A F53E+1
01396 3777 CE 0062 LDX #DVTABL
01397 377A A6 00 F53E LDA A 0.X NZ<-X>>1.3?
01398 377C 2C 0D BGE F53H YES.BR
01399 377E 5A DEC B
01400 377F 27 0A BEQ F53H
01401 3781 B6 377B LDA A F53E+1 SET UP NEXT (-X)
01402 3784 20 08 LUB A #8
01403 3786 B7 377B STA A F53E+1
01404 3789 20 EF BRA F53E
01405 378B CE 0000 F53H LDX #CVL
01406 378E E7 2F STA B 47.X SAVE PUFCTM
01407 3790 06 01 F53H LDA B #1
01408 3792 6D 02 TST 2.X POLL<10?
01409 3794 2C 04 BGE F53P YES.BR
01410 3796 6D 03 TST 3.X TORQUE<5?
01411 3798 26 02 BNE F53D NO.BR
01412 379A E7 30 F53P STA B 48.X SET NOPUFG
01413 379C 6C 31 F53D INC 49.X INC PU10
01414 379E A6 31 LDA A 49.X
01415 37A0 81 64 CMP A #100 PU10=10 DECS?
01416 37A2 27 30 BEQ F53Y YES.BR
01417 37A4 6D 09 TST 9.X PITCH<5?
01418 37A6 2C 0A BGE F53T NO.BR
01419 37A8 6C 2F INC 47.X INC PUFCTM
01420 37AA 6D 07 TST 7.X NZ 1.3?
01421 37AC 2B 02 BMI F53S
01422 37AE E7 36 STA B 54.X SET YSPUFG
01423 37B0 20 2C F53S BRA F13
01424 37B2 6D 36 F53T TST 54.X YSPUFG SET?
01425 37B4 27 1E BEQ F53Y NO.BR
01426 37B6 6D 30 TIT 48.X NOPUFG SET?

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01427	37B8	26	1A	BNE	F53Y	YES, BR
01428	37BA	6D	33	TST	51,X	CLASSIFY BY VL
01429	37BC	2B	07	BMI	F53TE	
01430	37BE	27	0A	BEQ	F53TF	
01431	37C0	CE	0030	LDX	#48	A/S>.85VL
01432	37C3	20	08	BRA	F53TG	
01433	37C5	CE	0024	F53TE	LDX	#36
01434	37C8	20	03	BRA	F53TG	A/S<.7VL
01435	37CA	CE	002A	F53TF	LDX	#42
01436	37CD	D6	32	F53TG	LDA B	GSV53
01437	37CF	86	2F	LDA A	#47	GET GW
01438	37D1	BD	39A9	JSR	BUMPN	
01439	37D4	6F	2F	F53Y	CLR	47,X
01440	37D6	6F	30	CLR	48,X	CLR PUFCTM
01441	37D8	6F	31	CLR	49,X	NOPUG
01442	37DA	6F	20	CLR	32,X	PU10
01443	37DC	6F	36	CLR	54,X	PUFLAG
						YSPUG

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01445
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01455 37DE C6 01 F13 LDA B #1
01456 37E0 6D 02 TST 2,X ROLL>=10?
01457 37E2 2B 74 BMI F13H NO, BR
01458 37E4 86 34 LDA A #52
01459 37E6 BD 39BE JSR BUMPT
01460 37E9 6D 11 TST 17,X MODE=X? (0)
01461 37EB 26 14 BNE F13D NO, BR
01462 37ED 6D 07 TST 7,X NZ>=1.3?
01463 37EF 2C 0E BGE F13C YES, BR
01464 37F1 A6 00 LDA A 0,X SAVE CVH, CVL, CGM
01465 37F3 A7 1A STA A 26,X
01466 37F5 A6 01 LDA A 1,X
01467 37F7 A7 19 STA A 25,X
01468 37F9 A6 08 LDA A 8,X
01469 37FB A7 1B STA A 27,X
01470 37FD 20 02 BRA F13D
01471 37FF E7 15 F13C STA B 21,X SET NZE FLAG
01472 3801 6F 11 F13D CLR 17,X SET MODE=Y (-1)
01473 3803 6A 11 DEC 17,X
01474 3805 6D 03 F13E TST 3,X TO<5?
01475 3807 27 0F BEQ F13F YES, BR
01476 3809 86 1C LDA A #28 INC T86
01477 380B BD 39BE JSR BUMPT
01478 380E A6 1C LDA A 28,X
01479 3810 81 14 CMP A #20 #2 SECS?
01480 3812 26 0A BNE F13G NO, BR
01481 3814 E7 12 STA B 18,X SET HITQ FLAG
01482 3816 20 06 BRA F13G
01483 3818 E7 13 F13F STA B 19,X SET LOTQ FLAG
01484 381A 6F 1C CLR 28,X CLEAR T86
01485 381C 6F 1D CLR 29,X
01486 381E 6D 14 F13G TST 20,X M SET?
01487 3820 26 14 BNE F13J YES, BR
01488 3822 A6 02 LDA A 2,X ROLL>=35?
01489 3824 91 02 CMP A #2
01490 3826 26 02 BNE F13H NO, BR
01491 3828 E7 18 STA B 24,X SET HI ROLL FLAG
01492 382A 6D 07 F13H TST 7,X
01493 382C 27 04 BEQ F13I2 1.3<=NZ<1.5
01494 382E 2B 0C BMI F13J1 NZ<1.3, BR
01495 3830 E7 16 F13I STA B 22,X SET HI NZ FLAG
01496 3832 E7 17 F13I2 STA B 23,X SET LO NZ FLAG
01497 3834 20 06 BRA F13J1
01498 3836 6D 02 F13J TST 2,X ROLL>25?
01499 3838 2F 02 BLE F13J1 NO, BR

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01500	383A	E7 2B		STA B	43,X	SET GTS
01501	383C	6D 06	F13J1	TST	6,X	GND COND?
01502	383E	26 04		BNE	F13K	YES, BR
01503	3840	6D 05		TST	5,X	RPM<100?
01504	3842	2C 11		BGE	F13L	NO, EXIT
01505	3844	86 0F	F13K	LDA A	#15	CLR FLAGS
01506	3846	6F 0F	F13K1	CLR	15,X	AND SET MODE=X
01507	3848	08		INX		
01508	3849	4A		DEC A		
01509	384A	26 FA		BNE	F13K1	
01510	384C	CE 0000		LDX	#CVL	
01511	384F	6F 2B		CLP	43,X	
01512	3851	6F 34		CLR	52,X	
01513	3853	6F 35		CLR	53,X	
01514	3855	7E 390D	F13L	JMP	F80	
01515	3858	6D 11	F13N	TST	17,X	MODE=X?
01516	385A	27 F9		BEQ	F13L	YES, EXIT
01517	385C	2B 0F		BMI	F13R	MODE=Y? YES, BR
01518	385E	A6 34		LDA A	52,X	
01519	3860	81 64		CMP A	#100	10 SECS UP?
01520	3862	27 2E		BEQ	F13RZ	YES, BR
01521	3864	86 34	F13P	LDA A	#52	INC T23
01522	3866	BD 398E		JSR	BUMPT	
01523	3869	A7 11		STA A	17,X	SET MODE=2 (1)
01524	386B	20 98		BRA	F13E	
01525	386D	6D 17	F13R	TST	23,X	NZLO SET?
01526	386F	27 D3		BEQ	F13K	NO, BR
01527	3871	E7 14		STA B	20,X	SET M
01528	3873	6D 15		TST	21,X	NZE SET?
01529	3875	26 15		BNE	F13RC	YES, BR
01530	3877	6D 13		TST	19,X	TQLO SET?
01531	3879	27 04		BEQ	F13RA	NO, BR
01532	387B	6D 12		TST	18,X	TQHI SET?
01533	387D	26 0D		BNE	F13RC	YES, BR
01534	387F	A6 34	F13RA	LDA A	52,X	
01535	3881	A7 2C		STA A	44,X	
01536	3883	A6 35		LDA A	53,X	
01537	3885	A7 2D		STA A	45,X	
01538	3887	86 0F		LDA A	#15	
01539	3889	BD 3998		JSR	BUMPT2	ADD T23 TO T23A
01540	388C	6F 34	F13RC	CLR	52,X	
01541	388E	6F 35		CLR	53,X	
01542	3890	20 D2		BRA	F13P	
01543			♦			
01544			♦♦ MISC MANEUVERS GROUP 5 (FCC 86-91)			
01545			♦			
01546	3892	6F 11	F13RZ	CLR	17,X	CLR MODE BYTE
01547	3894	6D 13		TST	19,X	TQ LO SET?
01548	3896	27 0E		BEQ	F13T	NO, BR
01549	3898	6D 16		TST	22,X	NZHI SET?
01550	389A	27 05		BEQ	F13S	NO, BR
01551	389C	CE 0072		LDX	#114	
01552	389F	20 62		BRA	F132A	
01553	38A1	CE 006C	F13S	LDX	#108	

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01554 38A4 20 5D      BRA      F132A
01555
01556      ♦♦ MISC MANEUVERS GROUP 1 (FCC 23-28)
01557      ♦
01558 38A6 6D 16      F13T      TST      22,X      NZHI SET?
01559 38A8 26 0E              BNE      F13V      YES,BR
01560 38AA 6D 19              TST      25,X      A/S>=.8VH?
01561 38AC 2F 05              BLE      F13U      NO,BR
01562 38AE CE 00DE              LDX      #222
01563 38B1 20 50              BRA      F132A
01564 38B3 CE 00D5 F13U      LDX      #213
01565 38B6 20 4B              BRA      F132A
01566
01567      ♦♦ MISC MANEUVERS GROUP 2 (FCC 41-52)
01568      ♦
01569 38B8 6D 18      F13V      TST      24,X      HIGH ROLL SET?
01570 38BA 26 20              BNE      F13Y      YES,BR
01571 38BC A6 1A              LDA A      26,X
01572 38BE 81 01              CMP A      #1      CHK A/S<VL
01573 38C0 2E 15              BGT      F13W2      BR IF A/S>.95VL
01574 38C2 27 0E              BEQ      F13W1      BR IF .85VL<A/S<=.95VL
01575 38C4 6D 1A              TST      26,X
01576 38C6 27 05              BEQ      F13W0
01577 38C8 CE 0036              LDX      #54      A/S<.7VL
01578 38CB 20 36              BRA      F132A
01579 38CD CE 003C F13W0      LDX      #60      .7VL<A/S<=.85VL
01580 38D0 20 31              BRA      F132A
01581 38D2 CE 0042 F13W1      LDX      #66
01582 38D5 20 2C              BRA      F132A
01583 38D7 CE 0048 F13W2      LDX      #72
01584 38DA 20 27              BRA      F132A
01585
01586      ♦♦ MISC MANEUVERS GROUP 3 (FCC 62-70)
01587      ♦
01588 38DC 6D 28      F13Y      TIT      43,X      GUN S-TURN?
01589 38DE 26 15              BNE      F13YA      YES,BR
01590 38E0 6D 19              TST      25,X
01591 38E2 2E 0C              BGT      F13Y2      BR IF A/S>=.8VH
01592 38E4 27 05              BEQ      F13Y1      BR IF .65VH<A/S<.8VH
01593 38E6 CE 004E              LDX      #78      A/S<.65VH
01594 38E9 20 18              BRA      F132A
01595 38EB CE 0054 F13Y1      LDX      #84
01596 38EE 20 13              BRA      F132A
01597 38F0 CE 005A F13Y2      LDX      #90
01598 38F3 20 0E              BRA      F132A
01599
01600      ♦♦ MISC MANEUVERS GROUP 4 (FCC 71-76)
01601      ♦
01602 38F5 A6 19      F13YA      LDA A      25,X
01603 38F7 81 02              CMP A      #2
01604 38F9 2D 05              BLT      F13YB      BR IF A/S<.3VH
01605 38FB CE 0066              LDX      #102      A/S>=.9VH
01606 38FE 20 03              BRA      F132A
01607 3900 CE 0060 F13YB      LDX      #96

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01608	3903	86	0F	F132A	LDA	A	#15	
01609	3905	D6	1B		LDA	B	SGW	GET GROSS WT
01610	3907	BD	39A9		JSR		BUMPN	
01611	390A	7E	3644		JMP		F13K	

01613

01614

01615

01616

01617

01618 390D C6 01

01619 390F 6D 03

01620 3911 27 18

01621 3913 6D 1E

01622 3915 26 08

01623 3917 E7 1E

01624 3919 6D 01

01625 391B 2B 02

01626 391D E7 1F

01627 391F 6C 21

01628 3921 6D 07

01629 3923 2B 10

01630 3925 27 09

01631 3927 E7 22

01632 3929 20 0A

01633 392B 6F 1E

01634 392D 20 22

01635 392F 6D 22

01636 3931 2E 02

01637 3933 6F 22

01638 3935 A6 21

01639 3937 91 32

01640 3939 26 1E

01641 393B 6D 1F

01642 393D 27 12

01643 393F 6D 22

01644 3941 2B 0E

01645 3943 27 05

01646 3945 CE 007E

01647 3948 20 03

01648 394A CE 0078

01649 394D 86 3C

01650 394F 8D 53

01651 3951 6F 1F

01652 3953 6F 21

01653 3955 6F 22

01654 3957 6A 22

 *** FCC 80-85 - AUTOROTATION TO POWER TRANSITION ***

F80	LDA B	#1	TO<5?
	TST	3,X	YES, BR
	BEQ	F80H	LOTO MODE?
	TST	30,X	NO, BR
	BNE	F80G	SET HITQ
	STA B	30,X	A/S > .65VH
	TST	1,X	NO, BR
	BMI	F80G	SET A/S FLAG
	STA B	31,X	BUMP T80 CNTR
F80G	INC	33,X	
	TST	7,X	
	BMI	F80K	BR IF NZ<1.3
	BEQ	F80J	BR IF NZ<1.5
	STA B	34,X	SET NZ FLAG
	BRA	F80K	
F80H	CLR	30,X	CLR LQ TO MODE
	BRA	F80R	
F80J	TST	34,X	NZ>1.5 FOUND?
	BGT	F80K	YES, BR
	CLR	34,X	NO, CLR NZ FLAG
F80K	LDA A	33,X	
	CMP A	#50	5 SECS ELAPSED?
	BNE	F95	NO, BR
	TST	31,X	REQ'D A/S OK?
	BEQ	F80R	NO, BR
	TST	34,X	
	BMI	F80R	BR IF NO NZ FOUND
	BEQ	F80L	
	LDX	#126	
	BRA	F80M	
F80L	LDX	#120	
F80M	LDA A	#60	INC CNTR
	BSR	BUMP	CLR FLAG
F80R	CLR	31,X	
	CLR	33,X	
	CLR	34,X	SET NZF TO -1
	DEC	34,X	

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01856
01857
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01860
01861 3959 06 01 F95 LDA B #1
01862 395A 6D 23 TST 35,X ARM?
01863 395D 27 18 BEQ F95F NO,BR
01864 395F 6D 07 TST 7,X NZ<1,3?
01865 3961 2C 1A BGE F95G NO,BR
01866 3963 6D 24 TST 36,X LD A/S SET?
01867 3965 26 0A BNE F95C YES,BR
01868 3967 86 3C LDA A #60
01869 3969 5F CLR B
01870 396A CE 00FB LDX #251
01871 396D 8D 3A BSR BUMPB INTR FCC
01872 396F 20 02 BRA F95E
01873 3971 6F 24 F95C CLR 36,X CLR LD A/S FLAG
01874 3973 6F 23 F95E CLR 35,X REARM
01875 3975 20 10 BRA F95J
01876 3977 A6 07 F95F LDA A 7,X
01877 3979 81 02 CMP A #2 NZ>1,??
01878 397B 26 0A BNE F95J NO,BR
01879 397D A6 01 F95G LDA A 1,X
01880 397F 81 FE CMP A #5FE A/S<.5VH
01881 3981 26 02 BNE F95H NO,BR
01882 3983 E7 24 STA B 36,X SET LD A/S FLAG
01883 3985 E7 23 F95H STA B 35,X ARM
01884
01885
01886 3987 73 000A F95J COM IFLAG SET DONE
01887 398A 01 WAIT NOP WAIT FOR NEXT TIME INTRUPT
01888 398B 7E 34E2 JMP FLODPA (WAI,JMP F4)

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01690
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01695 398E 36
01696 399F 6F 2D
01697 3991 6F 2E
01698 3993 86 01
01699 3995 A7 2C
01700 3997 32
01701 3998 A7 28
01702 399A 5F 27
01703 399C DE 27
01704 399E 8D 48
01705 39A0 CE 0000
01706 39A3 39
01707
01708
01709
01710
01711
01712 39A4 37
01713 39A5 D6 08
01714 39A7 20 01
01715 39A9 37
01716 39AA DF 27
01717 39AC 7F 0025
01718 39AF 97 26
01719 39B1 DE 25
01720 39B3 A6 00
01721 39B5 97 2C
01722 39B7 A6 01
01723 39B9 97 2D
01724 39BB A6 02
01725 39BD 97 2E
01726 39BF 17
01727 39C0 97 29
01728 39C2 48
01729 39C3 D6 28
01730 39C5 C1 96
01731 39C7 25 02
01732 39C9 9B 29
01733 39CB 9B 28
01734 39CD 97 28
01735 39CF C6 01
01736 39D1 D7 27
01737 39D3 DE 27
01738 39D5 0F
01739 39D6 96 28
01740 39D8 81 96
01741 39DA 24 04
01742 39DC 8D 0A
01743 39DE 20 02

♦
*****
*** BUMP SELECTED TIMER (BY 1) ***
*****
♦
BUMPT PSH A
      CLR 45,X      SET BAA = 1
      CLP 46,X
      LDA A #1
      STA A 44,X
      PUL A
BUMPT2 STA A 40,X
      CLR 39,X
      LDX NDX      GET ADDR OF TIMER
      BSR MPBA2    BUMP TIMER
      LDX #CVL
      RTS          EXIT

♦
*****
*** FCC TABULATION ROUTINE ***
*****
♦
BUMP PSH B
      LDA B CGW      GET GROSS WEIGHT
      BRA BUMP3
BUMP4 PSH B
      STX NDX      SAVE ADDEND ADDR
      CLR ASV
      STA A ASV+1
      LDX ASV
      LDA A 0,X      MOVE 2ND ADDEND TO BAA
      STA A BAA
      LDA A 1,X
      STA A BAA+1
      LDA A 2,X
      STA A BAA+2
      TBR
      STA A SNDX      SAVE GW
      ASL A          CVT TO NDX
      LDA B NDX+1
      CMP B #150     WHICH PREC?
      BCS BUMP4      BR IF 2
      ADD A SNDX      MUST BE 3
BUMP4 ADD A NDX+1
      STA A NDX+1
      LDA B #1
      STA B NDX
      LDX NDX
      SEI          DISABLE INTERRUPTS TEMPORARIL
      LDA A NDX+1    WHICH PRECISION?
      CMP A #150
      BCC BUMP5      IF TRIPLE, BR
      BSR MPBA2      DOUBLE
      BRA BUMPX

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01744	39E0	8D	0A	BUMP5	BSR	MPBA3	
01745	39E2	0E		BUMPX	CLI		REENABLE INTERRUPTS
01746	39E3	33			PUL B		
01747	39E4	CE	0000		LDX	#CVL	
01749	39E7	39			RTS		EXIT

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01750
01751
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01755 39E8 37
01756 39E9 5F
01757 39EA 20 03
01758 39EC 37
01759 39ED C6 01
01760 39EF 36
01761 39F0 96 2C
01762 39F2 AB 00
01763 39F4 A7 00
01764 39F6 96 2D
01765 39F8 A9 01
01766 39FA A7 01
01767 39FC 5D
01768 39FD 27 06
01769 39FF 96 2E
01770 3A01 A9 02
01771 3A03 A7 02
01772 3A05 32
01773 3A06 33
01774 3A07 39
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01780 2800		DPG	\$2800
01781 2800 41	MES2	FCC	/ALTER PARAMETER? (0-9,N,L) /
01782 281B 00		FCB	0
01783 281C 49	MES3	FCC	/ILLEGAL PARAMETER! /
01784 282E 00		FCB	0
01785 282F 20	MES4	FCC	/ # /
01786 2834 00		FCB	0
01787 2835 45	MES5	FCC	/ENTER PASS COUNT (1-255) /
01788 284E 00		FCB	0
01789 284F 01	K1	FCB	1,10,100
01790 2852 54	K10	FCB	100,10
01791 2854 0001	LOOPCT	RMB	1
01792 2855 0001	COUNT	RMB	1
01793 2856 42	MES6	FCC	/BYTE WAS IS /
01794 2868 00		FCB	0
01795 2869 20	MES7	FCC	/ /
01796 286D 00		FCB	0
01797 286E 0014	BUFFER	RMB	20
01798 2882 0002	SAVEK	RMB	2
01799 2884 0002	SAVEK2	RMB	2

01501 END

TOTAL ERRORS 00000