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HELICOPTER MAINTENANCE EFFECTIVENESS ANALYSIS

Calvin Holbert, et al

United Technologies Corporation

Prepared for:

Army Air Mobility Research and Development Laboratory

May 1975

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HELICOPTER MAINTENANCE EFFECTIVENESS ANALYSIS

Sikorsky Aircraft Division
United Aircraft Corporation
Stratford, Conn. 06602

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Final Report

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EUSTIS DIRECTORATE
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Fort Eustis, Va. 23604

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EUSTIS DIRECTORATE POSITION STATEMENT

A questionnaire was developed to use the knowledge of experienced U. S. Army aviation maintenance personnel. Over 500 UH-1H and CH-47 helicopter mechanics completed the questionnaires. Analysis of the answers to the 50 questions identified areas in Army aviation maintenance that merit further study. Potential areas of improvement in environment, resources (manuals, tools, personnel, etc.), diagnostics (test equipment, troubleshooting procedures, etc.), applications (aircraft and supporting equipment design), and logistics (spare parts supply) are identified.

UH-1H and CH-47 aircraft log books, and CH-54 Operational Reliability and Maintainability Engineering (ORME) data analysis identified over 1200 repetitive maintenance events. These were analyzed to determine the probable cause of the failure to repair the deficiency correctly on the first attempt.

The conclusions and recommendations contained herein are concurred in by this directorate.

The technical monitors for this contract were Mr. Howard M. Bratt and Mr. Gary R. Newport, Military Operations Technology Division.

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A study has been made of U. S. Army maintenance operations to determine the significance of repetitive maintenance and incorrect diagnoses in regard to U. S. Army maintenance efficiency. A questionnaire was distributed to Army maintenance personnel to solicit their views on maintenance efficiency. In addition, Army aircraft inspection and maintenance data (DA Form 2408-13 and Operations Reliability Maintainability Engineering Data) were reviewed to quantify the number of repetitive maintenance actions. These data included

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20. Abstract (Continued)

maintenance personnel and maintenance actions for the UH-1H, CH-47C, and CH-54B model helicopters.

The study results indicated that over 50% of the repetitive maintenance actions on the CH-47C and CH-54B and 45% of the UH-1H repetitive maintenance actions were caused by poor diagnostics procedures, inadequate test equipment, trial-and-error troubleshooting procedures, and unimplemented standard maintenance practices. Other major contributing causes of repetitive maintenance actions were resources and applications.

A comparison of aircraft utilization with repetitive maintenance actions showed a repetitive action rate of 0.3 action per flight hour.

Although differences in depot record-keeping procedures prevented quantification of incorrect diagnoses and removal of components, depot personnel estimated that, in the case of one component, 15% to 25% had been overhauled without justifiable cause.

Implementation of eight recommended improvements in maintenance procedures can reduce the number of costly repetitive repairs now experienced in helicopter operations.

PREFACE

The work for this study was authorized by Contract DAAJ02-73-C-0029 by the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia under the technical cognizance of Mr. Howard Bratt and Mr. Gary Newport.

The Sikorsky Aircraft personnel involved in performing and contributing to this study were:

Mr. A. A. Wolf, Supervisor of Reliability and Maintainability
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INTRODUCTION

Repetitive maintenance actions and incorrect diagnoses of components have long been suspected of causing removal for overhaul or repair and contributing significantly to reduced efficiency of U. S. Army aviation maintenance.

The objective of this study was to identify and evaluate the attributes that cause loss in maintenance effectiveness by incurring repetitive actions and incorrect diagnoses of components at the organizational level of maintenance. Maintenance is assumed to be performed by skilled personnel in varied operational environments within logistical support constraints. Representative responses from these personnel and from records relative to the causes of ineffective maintenance were obtained by direct interview and by the use of a widely distributed questionnaire. Detailed searches were made of standard maintenance forms and records to assess repetitive maintenance at organizational, direct support, and depot maintenance levels.

This report describes the procedures used in analysis of the questionnaire and Army maintenance records. Analysis of these data confirms that repetitive maintenance and incorrect diagnostics are a serious problem and that diagnostics, resources, and applications are the primary causes of the problem.

Recommendations are made to improve the use of test equipment, to develop improved troubleshooting guides, to enforce standard maintenance procedures, and to encourage depot operations to determine cause of failure on major components in the interest of improving Army maintenance efficiency.

The questionnaire, developed to gain responses from operational maintenance personnel, was distributed to six active operational U.S. Army bases within CONUS that maintain large quantities of UH-1H and CH-47C helicopters. The questionnaire and instructions for completing it in the field are presented on pages 11-23 exactly as they were used for this program.

MAINTENANCE EFFECTIVENESS ANALYSIS QUESTIONNAIRE

THIS IS A QUESTIONNAIRE TO PROVIDE INFORMATION ON THE CAUSE AND FREQUENCY OF MAINTENANCE TASKS WHICH REQUIRE REPEATED EFFORT BEFORE BEING SUCCESSFULLY REPAIRED. THE REASON FOR PERFORMING THIS STUDY IS TO DEVELOP IMPROVED DESIGNS AND MAINTENANCE PROCEDURES FOR FUTURE ARMY HELICOPTERS. UH-1 AND CH-47 HELICOPTER MAINTENANCE AND OPERATIONS COMPANIES ARE BEING SURVEYED BECAUSE THESE TWO AIRCRAFT REPRESENT THE LARGEST INVENTORY IN THE ARMY TODAY.

IT IS REQUESTED THAT YOU COMPLETE THIS QUESTIONNAIRE TO THE BEST OF YOUR ABILITY AND:

- ANSWER ALL QUESTIONS
- WRITE OR PRINT LEGIBLY
- COMMENTS ARE WELCOMED

THE QUESTIONNAIRE CONTAINS QUESTIONS THAT REQUIRE "YES" OR "NO" ANSWERS, AND OTHER QUESTIONS THAT NEED MORE TIME AND EFFORT TO COMPLETE. YOUR RESPONSE TO ALL QUESTIONS IS IMPORTANT. PLEASE BE FRANK AND HONEST IN YOUR ANSWERS. YOU, AS AN INDIVIDUAL, HAVE THE OPPORTUNITY TO EXPRESS YOUR FEELING AND TO USE YOUR EXPERIENCE TO HELP MAKE BETTER ARMY HELICOPTERS FOR THE FUTURE. YOU MAY FIND QUESTIONS THAT DO NOT APPLY TO YOUR CURRENT MOS OR JOB. ANSWER THESE QUESTIONS TO THE BEST OF YOUR ABILITY. FEEL FREE TO CRITICIZE ANY QUESTION. IT IS YOUR EXPERIENCE AND KNOWLEDGE ABOUT ARMY MAINTENANCE THAT IS IMPORTANT.

PLEASE FOLLOW INSTRUCTIONS NOTED WITH SPECIFIC QUESTIONS AS REQUIRED.

QUESTIONNAIRE

A. General Questions

1. Please list your M.O.S., rank and experience in aircraft maintenance:

CURRENT M.O.S._____ RANK ______ CURRENT M.O.S. EXPERIENCE (YEARS) __________

TOTAL AIRCRAFT EXPERIENCE (YEARS)______

TYPE OF HELICOPTERS ____

LOCATION__________________ UNIT ___________________________

2. You are presently assigned to:

_____Organizational _____Direct Support _____General Support _____AVUM _____I.S.

3. Which aircraft systems do you work on?

_______Hydraulics ______Airframe ______Engines

_______Flight Control ______Armament ______Electrical

_______Powertrain ______Rotor Systems ______Avionics

4. Were you school trained in the MOS in which you are assigned?

_________Yes _________No

5. Do you think the trouble-shooting tables in the maintenance manuals are adequate for your work?

_________Yes _________No

6. Do you have all shop tools listed in your TO&E?

_________Yes _________No

7. Are there shop tools you need that are not TO&E authorized?

_________Yes _________No

8. Trial and error is used to trouble-shoot a maintenance problem because,

______ it is an easy way to correct the problem

______ it is fast

______ lack of experience

______ T.M. covers only obvious causes

9. Which of the following gripes are hardest for you to diagnose on the first try?

_____Vibrations
_____Electrical
_____Engine (including APU)
_____Avionics
_____Flight Control
_____Hydraulics
_____Fuel System
_____Rotor System

10. Before a repairable part is sent out of your unit for analysis and repair it is:

______ operationally tested to see if it is unserviceable

______ packaged and shipped without further checking

______ bench tested

______ checked by Tech. Inspector

11. Excessive leakage from gear boxes, pumps and servos is determined by:

Gear Boxes	Pumps	Servos	
			.observing sight gage
			.collecting fluid in a container for accurate measurement
			.counting drops per minute (static)
			.counting drops per minute while operating
			.wiping part and watch for seepage
			.cannot be measured
			.guessing that the leakage is excessive

12. Are recoverable parts frequently sent out for repair because trained personnel are not available.

______Yes ______No

13. Is test equipment used to check out removed parts to determine if they are serviceable before turning them in to supply?

______Yes ______No

14. When you perform corrective maintenance, how often does the first fix fail to work?

______less than 10% of the time

______less than 50% of the time

______more than 50% of the time

15. Where do you go to get trouble-shooting assistance for maintenance problems? Who do you see first, second, third, etc.

______Go to fellow mechanic

______Go to Maintenance Officer

______Rely on my own knowledge and experience

______Go to Maintenance Supervisor

______Use tech manuals

______Go to Tech. Inspector

16. Do you feel you would perform better maintenance if you were permitted to disassemble repairable components to find out what caused a failure?

______Yes ______No

17. What is it about your job that bugs you most?

______Paper work

______Supervision

______Lack of manuals

______Lack of spare parts

______Lack of tools

______Extra duties

______Not allowed to do work I am capable of doing

______Nothing bugs me

18. List maintenance tasks that have caused more than one part to be replaced before the right part was identified. Put parts in order of removal, the last one being the one that solved the problem.

	Maintenance Tasks	Order of Parts Replaced
a.	____________	________, ________, ________
b.	____________	________, ________, ________
c.	____________	________, ________, ________

19. When an unusual vibration occurs, you identify the cause of the vibration(s) by

________Serviceability check

________Replacement of component(s)

________Letting someone else make the decision?

20. Do you have a vibration meter available for your use?

______Yes ______No

21. How many defective parts have you been issued from supply in the past year? Number of Parts __________

22. What are the reason(s) for defective parts being issued from supply? Check one which occurs most often.

_________ Mis-identified part
_________ no historical record card
_________ improper service check before issuing part
_________ poor quality control

23. How many wrong parts have you been issued in the past year?
_________ Number of parts.

24. What are the reason(s) for wrong parts being issued from supply? Double check the one that occurs most often.

_________ wrong FSN ordered
_________ wrong FSN supplied
_________ outdated part
_________ T.M. not clear

25. Example(s) of wrong parts from supply having been installed on the aircraft include

________________________, ________________________.

26. Who usually decides that a major component is defective and requires replacement:

______ Maintenance Officer ______ Maintenance Supervisor

______ Tech. Inspector ______ Tech. Rep.

27. As the result of trial and error trouble-shooting, serviceable parts are turned into supply as unserviceable. Why does this happen?

______ Afraid part is contaminated

______ No way of accounting for extra part

______ Easier

______ Otherwise supply will not take it back

28. What serviceable part(s) have you seen turned in to supply as unserviceable (in the past year)?

Part	Reason Claimed for Unserviceability
a. ________________	______________________________
b. ________________	______________________________
c. ________________	______________________________

29. What percent of the time do parts get condemned as defective when actually they were serviceable?

____________less than 10%

____________11% to 25%

____________more than 25%

30. After removal, is a suspected failed part again checked before being sent out of your unit for analysis and repair?

______ Yes ______ No

31. When a non-repairable part has failed, do you attempt to find out why it failed?

______ Yes _______ No

32. In general, how accurate is the flight crew -13 write-up?

______ Poor

______ Fair

______ Good

33. What areas related to Army maintenance could be improved? Check the important ones and number them in order of importance.

______ Special tools

______ Test equipment

______ Parts supply

______ Tech. Manuals

______ Work environment

______ Technical Supervision

______ Aircraft too complicated

_____ Training

34. Is the location of a part on the aircraft an important cause of repeated maintenance actions (two or more actions required to solve the problem)?

_____ Yes _______ No

35. Is lack of special tools an important cause of repeated maintenance actions?

_____ Yes _______ No

36. What percent of the time is trial and error used to correct a maintenance problem?

_____ 0 - 30%

_____ 31 - 50%

_____ 51 - 100%

37. Do you think that a maintenance test flight before each Periodic Inspection would reduce the number of repeated maintenance action(s) required after Periodic Inspection?

_____ Yes _______ No

38. Did school training cover the use of diagnostic equipment for trouble shooting?

_____ Yes _______ No

39. What problems do you have in using maintenance manuals? Check most important ones and number in order of importance.

_____ Not up to date

_____ Poor trouble shooting tables

_____ Pages fall out

_____ Instruction not clear

_____ Not enough manuals

_____ Changes are not correct

UH-1H

The following questions should be answered by personnel with UH-1 experience. CH-47 questions begin two pages later.

B. UH-1H Questions

40. Which of the following repairs on the UH-1H are the most difficult to repair successfully on the first attempt?

______rigging tail rotor

______tracking main rotor

______hydraulics

______engine throttle linkage

______shimming sync. elevator

______rear damper mounts

______linear actuator adjustment

41. Several attempts are necessary to properly adjust cyclic stick rigging because:

______lack of proper tools

______too many adjustment points

______location of adjustment points

42. Several replacements of a main rotor head to correct 1 to 1 vibration is a common maintenance requirement.

______Yes ______No

43. Which of the following items are hardest to trouble-shoot? Check the most important items and number in order of importance.

_____Fore and aft force gradient spring

_____Collective servo

_____Main transmission oil filter

_____Transmission damper mount bearings

_____Starter generator

_____Cyclic torque tube

_____Irreversible valves

_____Fuel probes

_____Oil cooler

_____Inverters

_____Flux valve on RMI

_____Engine

44. What additional test equipment would be of value to you?

_____vibration meter

_____hydraulic mule

_____thermocouple probe tester

_____temperature gage tester

_____frequency meter

_____fuel probe tester

C. CH-47C Questions

45. Which of the following at repairs on the CH-47C are the most difficult to repair successfully on the first attempt?

______tracking blades

______flight control rigging

______electrical

______safetying aft trans. oil filter

______engine controls

______engine tach. generator

______adjusting N-1 actuator

______generator

______SAS

______APU

46. What per cent of the maintenance actions on landing gear power steering fail to work the first time?

______less than 25%

______more than 25%

47. Excessive vibration is reported as a -13 write-up.

______after every flight

______once out of every 2 flights

______once out of every 4 flights

______once out of every 10 flights

______once out of every 25 flights.

48. Which of the following most commonly cause a high frequency vibration and require maintenance action? Number in order of most common cause.

_____hydraulic pumps

_____cooler fan motor

_____engine gearbox (90°)

_____aft transmission

_____forward transmission

_____combining gearbox

_____forward synchronizer shafts

_____engine drive shafts

_____hanger bearings

_____engine mounts

_____aft synchronizer shafts

_____forward rotor

_____aft rotor

49. What is the cause when repairs on flight boost accumulators are not successful?

_____use of incorrect seals

_____not submerged or bench tested

_____improper assembly

50. Repeat maintenance actions on the P-SAS are caused by:

_____adjustment is difficult

_____one component has high failure rate

_____availability of parts

_____lack of test equipment

_____lack of training

BACKGROUND AND APPROACH

Over 50% of Army aircraft maintenance diagnoses at organizational level were reported as being incorrect by a high ranking military official. U. S. Army Agency for Aviation Safety (USAAAVS) reported that poor inspections and/or improperly performed maintenance actions were frequently the cause of helicopter mishaps. Analysis of those maintenance problems that were difficult to diagnose and repair was considered to be a potential source of recommendations to improve maintenance efficiency, that is, to have maintenance done correctly on the first attempt. An evaluation of U. S. Army maintenance operations has been conducted to determine the extent and causes of incorrectly diagnosed troubles and improperly performed corrective maintenance actions. The aircraft chosen for this study were the UH-1H and CH-47C helicopters, because they represent the largest fleets of helicopters in the Army inventory. In addition, CH-54B helicopter data already compiled was examined for comparison with UH-1H and CH-47C field experience.

To accomplish the program objectives, three efforts were implemented to obtain the required information from organizational maintenance activities:

1. A questionnaire was developed and distributed to Army organizational maintenance personnel to obtain views on U. S. Army maintenance operations.

2. A search was made of Aircraft Inspection and Maintenance Records, DA Form 2408-13, at typical U. S. Army operational bases to identify repetitive maintenance actions.

3. A search was made of Component Removal and Repair/Overhaul Records, DA Form 2410, at typical operational bases and depots to identify component reasons-for-removal at the operational level and to correlate them with causes-of-failure found during disassembly and inspection at the depot. This correlation, or lack of correlation, would be a measure of the accuracy of field diagnostics.

Each of the above efforts employed to the extent possible the same U. S. Army bases and military activities as data sources. Three typical U. S. Army activities and one National Guard unit with large fleets of UH-1H and CH-47C helicopters were visited to test the questionnaire, interview maintenance personnel, and collect data on repetitive maintenance actions and incorrect diagnoses. Two U. S. Army depots were visited to assess teardown and inspection overhaul data.

Over 940 questionnaires were distributed to six U. S. Army bases to obtain responses on which to base evaluation of maintenance operations.

DEVELOPMENT OF QUESTIONNAIRE

The questionnaire, which consisted of 50 questions, was developed as the result of extensive field testing, assessment, and retesting. The purpose of the questionnaire was to obtain the views and attitudes of organizational maintenance personnel and their reactions to current U. S. Army maintenance operations and procedures.

The questions were evaluated by maintainability engineers, statisticians, human factors engineers, product support technicians, and service school instructors to establish question structuring and type. The questions were modified and improved as experience and testing inputs required. To facilitate analysis, questions were structured as single response, multiple choice, ranked multiple choice, and essay. The essay questions were kept to a minimum, as they elicited subjective responses that were difficult to analyze and quantify. The final questionnaire contains questions of the type shown in Table 1.

TABLE 1. QUESTIONS BY TYPE

Type	Quantity
Yes/No	15
Quantitative answer	2
Multiple choice where answer categories are mutually exclusive	7
Multiple choice with more than one answer permitted	15
Multiple choice with more than one answer solicited and ranked	7
Multiple choice from a matrix of categories	1
Multiple essay answers	3
Total Number of Questions	50

Questions that were deleted as a result of the testing phase fall into several categories. Some were found to be redundant, ineffective, or unnecessary. Other questions generated sufficient responses to enable discontinuation of a particular line of questioning. An example of this was a question relating to training: "Is on-the-job training better than school training?" The answers depended on the background and experience of the respondent. The general conclusion was that the quality of training programs varied. On-the-job training quality varied from base to base and depended on supervision and procedures employed. Formal classroom training was more structured than on-the-job training, but gave the mechanic only limited opportunity to practice a skill.

The questionnaire was field tested at four locations, and six iterations of content were made, as shown in Table 2. Only then was the final questionnaire approved for wide distribution. After each field test, observations were made relative to: (1) time to complete questionnaire, (2) percentage of response to each question, (3) consistency in response, and (4) importance of question. At first, several questions were asked relating to the same subject in order to find the best approach or wording. Questions relating to the same subject were generally grouped together. In some cases, to reduce dependency between questions, some related questions were dispersed throughout the questionnaire.

As questions were field tested, interviews were conducted to gain knowledge of completeness and reaction by respondents. For example, it was found to be important to include initial questions in the questionnaire that encouraged participation. This was accomplished by including an introductary page explaining the reason for the questionnaire, followed by questions about the individual's experience, skill, and location.

As a result of field testing of the questionnaire, the number of attributes considered to affect maintenance operations increased from five to ten. These attributes, as defined in Table 3, formed the basis for the final phase of questionnaire development.

Each question was assessed relative to its application to a particular attribute. As shown in Table 4, several questions applied to more than one attribute.

TABLE 2. QUESTIONNAIRE DEVELOPMENT SUMMARY

Location/Activity	Date	No. of Q's	Special Q UH-1	Special Q CH-47	No. of Responses UH-1H	No. of Responses CH-47	Average Response Time(Min)	No. of Q's Retained	No. of Q's Modified	No. of Q's Dropped	No. of New Q's Added	Experience	Training	Supply	Tools	Test Equip	Trouble-shooting	Procedures	Job Eval.	Design	Maint. Manual
												Attribute No. of Questions									
Conn. Air Natl. Guard Hartford, CT	21 Jun 73	83			15/9		120						3		12			48		12	8
Fort Bragg, NC	9-13 July							11	45	27	16		7		11			40		7	7
119th Ar. Co. (UH-1H)		72			30		80														
196th Ar. Co. (CH-47C)		72				24	90														
USAAMRDL Iteration																					
Fort Rucker, AL	10-21 Sept							5	20	18	49		4		6		8	18	5	1	4
Civilian Mech.		74	12	16	27	29	54														
CH-47 Tech. Insp. Crew Chief		62	12	16	4	14	45														
UH-1 Tech Insp. Crew Chief		55	12	16	17		50														
Ft. Campbell, KY	26-30 Nov				24	23	32	3	38	33	14	2	2	6	5	2	10	10	5	10	2
CH-47 Co.		55	5																		
UH-1 Co.		55		6																	
Draft Question-naire Submitted for Approval	14 Dec	50	5	6				24	26	7	0	2	2	5	3	2	10	10	5	9	2
Revised Questionnaire Transportation School Ft. Eustis, VA	16 Jan	50	5	6	10	10	30	50	2	-	-	3	4	10	6	5	12	9	3	10	5
Final Questionnaire	22 Jan	50	5	6	283	124	-	-	-	-	-	3	4	10	6	5	12	9	3	10	5

TABLE 3. DEFINITION OF ATTRIBUTES

	Attribute	Definition
1.	Experience	Skill in MOS and type of helicopter or systems based on years assigned to MOS and years of experience in Army aviation.
2.	Training	School and/or on-the-job, special, or identifiable education related to skill.
3.	Supply	Aircraft replacement parts requisition and logistics support.
4.	Tools	Standard and special shop TOE authorized tools and unauthorized tools.
5.	Test Equipment	Standard and special TOE authorized and unauthorized, including diagnostics equipment.
6.	Troubleshooting Procedures	Procedures used to determine corrective action, including trial and error and tables provided in maintenance manuals.
7.	Standard Procedures	Maintenance policy and shop or company procedures as they affect work performance.
8.	Job Evaluation	Maintenance personnel attitude work environment, and supervision.
9.	Design	Structural and mechanical design assembly of the helicopter.
10.	Maintenance Manuals	Technical maintenance, parts supply, and procedures handbooks and inspection checklists.

TABLE 4. RELATING QUESTIONS TO ATTRIBUTES

	Attribute	Questions Designed To Assess Attribute	No. of Questions per Attribute
1.	Experience	1, 2, 3	3
2.	Training	4, 12, 33, 38	4
3.	Supply	17, 21, 22, 23, 24, 25, 27, 28, 33, 50	10
4.	Tools	6, 7, 17, 33, 35, 41	6
5.	Test Equipment	13, 20, 33, 44, 50	5
6.	Troubleshooting Procedures	8, 9, 11, 14, 15, 18 19, 29, 36, 42, 48, 49	12
7.	Standard Procedures	10, 12, 13, 16, 26, 27, 30, 31, 37	9
8.	Job Evaluation	17, 32, 33	3
9.	Design	9, 34, 40, 41, 43, 45, 46, 47, 49, 50	10
10.	Maintenance	5, 15, 17, 33, 39	5

The final questionnaire, pages 11-23, consisted of 50 questions, 39 of which were generalized so as to not reflect a particular helicopter type or model. Eleven were specialized and related to the UH-1H and CH-47C helicopters.

REPETITIVE MAINTENANCE ACTION DATA COLLECTION

U. S. Army operational maintenance records were searched and analyzed to identify repetitive maintenance actions and to determine the causes and severity of these actions. The Army Maintenance Management System (TAMMS), in conjunction with the Army Equipment Record System (TAERS), was used to provide the required information on procedures. The Aircraft Inspection and Maintenance Record, DA Form 2408-13, was used to provide data on maintenance and service of Army aircraft. This form records:

- detected faults and action taken to correct them
- aircraft flying hours
- maintenance and servicing actions
- status of aircraft

This form is completed daily when the aircraft is operational. The pilot or his designee (crew chief/flight engineer) completes the form, recording data as necessary. Immediately upon discovery of a fault or upon removal of a part or accessory, the individual makes an appropriate entry on the first open line of the current DA Form 2408-13. The pilot must initial all fault-recorded entries and actions prior to flight.

This DA Form 2408-13 recording procedure provided the necessary information to identify repetitive maintenance actions for a representative six-month period on both UH-1H and CH-47C helicopters. Data for identifying CH-54B repetitive maintenance actions was taken from the Operational Reliability Maintainability Engineering (ORME) program.

INCORRECT DIAGNOSIS DATA COLLECTION

The objective of this effort was to collect data on component removals at the operational maintenance level and to compare them with repair/overhaul information from depots. From these data, it could be determined whether components had been removed and sent to overhaul without proper reason. Incorrect diagnosis of part failure in the field could then be traced to the repair/overhaul facility by comparing the reason-for-failure found during disassembly and inspection with that recorded upon removal of the component from the aircraft. To do this, it was necessary to search Army maintenance records to find whether a means existed for tracking a part from operational maintenance level to depot. It was found that the Army Maintenance Management System (TAMMS) and the Army Equipment Record System (TAERS) use Component Removal and Repair and Overhaul Record, DA Form 2410, to track repairable components. The DA Form 2410 is prepared by the using organization when the unserviceable component is removed from the aircraft. At this time, a failure code is recorded in block 18 of the multi-copy form. The record is then shipped with the component to the depot or repair facility. The reverse side of copy 5 is then used by the depot to record parts replaced and the failure code.

It was expected that analysis of the DA Form 2410 records, including field and depot inputs for a six-month period for several UH-1H and CH-47C helicopters, would provide data to determine the extent of incorrect diagnosis as a cause of ineffective maintenance. However, after reviewing six months of DA Form 2410 field data and upon visiting the depots, it was found that the depots did not use the DA Form 2410 consistently. Discussion with depot personnel revealed that activities such as depots that employ an assembly-line production method of overhaul have an option of waiving the use of copy 5 for an alternative method of reporting if approved by the U. S. Army Materiel Command. As a result, the data were incomplete. This subject is discussed further in the section of this report entitled "INCORRECT DIAGNOSTIC DATA."

QUESTIONNAIRE ANALYSIS

Of over 940 questionnaires distributed to maintenance personnel at six major U. S. Army bases flying large complements of UH-1H and CH-47C helicopters, 551 completed questionnaires were returned and statistically analyzed to identify the causes of maintenance inefficiency. The results of the analysis are categorized in five major Army management attributes, shown in Table 5. These attributes are shown with the related basic attributes of Table 3.

TABLE 5. COMPARISON OF ATTRIBUTES

	Army Management Attribute	Basic Attributes (from Table 3)
1.	Environment	Experience, Job Evaluation
2.	Resource	Training, Tools, Maintenance Manuals
3.	Diagnostics	Troubleshooting and Standard Procedures, Test Equipment
4.	Applications	Design
5.	Logistics	Supply

Each question was analyzed with respect to its related attribute. Statistical correlation among questions provided further insight into their relationships with the basic attributes. To derive the maximum information from these questions, statistical credibility of relationships between answers to various questions was established. A chi-square (χ^2) approach is used in accomplishing these evaluations. A χ^2 test of goodness of fit is a commonly used method of testing normality. A χ^2 test compares a set of sample frequencies with a set of frequencies that would be expected on the basis of some hypothesis. If the two sets compare well, the hypothesis is accepted; if they compare badly, the hypothesis is rejected. Since the distribution on which the decision to accept or reject is based on the χ^2 distribution, the test is called a χ^2 test.

The questions involve the following types of responses:

- (a) yes/no
- (b) multiple choice where answer categories are mutually exclusive
- (c) multiple choice with more than one answer permitted

(d) quantitative answers
(e) multiple choice with more than one answer solicited and ranked
(f) multiple essay answers (did not require statistical analysis)
(g) multiple choice from a matrix of categories (did not require statistical analysis).

Table 6 lists the relationships among questions and the number of statistical evaluations performed.

TABLE 6. RELATIONSHIPS DETERMINED

	Relationships	Number Processed
1.	(a) vs (a)	34
2.	(a) vs (b)	14
3.	(a) vs (c)	24
4.	(a) vs (e)	24
5.	(b) vs (b)	4
6.	(b) vs (c)	14
7.	(c) vs (c)	2
8.	(c) vs (e)	4

In applying the χ^2 test[1] of correlation between questions, a level of significance of 0.002 was used (that is, a chance of two incorrect answers in 1000). Based on the assigned level of significance and the degrees of freedom manifested by the specific example, a critical value can be read from standard χ^2 tables such that the following conclusion may be drawn. If the computed χ^2 statistic exceeds the critical χ^2 value, there exists sufficient statistical evidence that the answers to the two questions studied are related.

An example of the χ^2 statistical procedure is given to show the rationale for relationships and to observe whether data from UH-1H (MOS 67N) and CH-47C (MOS 67U) maintenance personnel yield different results.

Example: Is there a relationship between the answers to Q7 and Q35? Question 7: Are there shop tools

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[1]Dixon and Massey, Introduction to Statistical Analysis, New York, McGraw-Hill, 1957, pp. 221 - 226.

you need that are not TOE authorized? Question 35: Is lack of special tools an important cause of repeated maintenance actions?

Use all UH-1H (MOS 67N) and CH-47C (MOS 67U) population in a 2 x 2 arrangement of data, that is, Q7 yes/no vs Q35 yes/no, and perform analysis as shown in Table 7.

TABLE 7. QUESTION 7/35 RELATIONSHIP

	Total UH-1H and CH-47C		
	Q7 Yes	Q7 No	
Q35 Yes	(a) 212	(b) 55	(a+b) 267
Q35 No	(c) 83	(d) 39	(c+d) 122
	(a+c) 295	(b+d) 94	(N) 389 a+b+c+d = N

then $\chi^2 = \frac{(|ad - bc| - 1/2N)^2 N}{(a+c)(b+d)(a+b)(c+d)}$ = or

$$\chi^2 = \frac{(|212x39 - 55x83| - 1/2\ 389)^2\ 389}{(212+83)(55+39)(212+55)(83+39)} = 5.3$$

This value is compared with the critical $\chi^2_{1-\alpha}$ value

for 1 degree of freedom, that is, (no. of rows - 1) (no. of columns - 1) = (2-1) (2-1) = 1.

The $\chi^2_{1-.002} = \chi^2_{.998} = 9.4$, and the 5.3 does not exceed this value, indicating that the answers to the two questions are independent, that is, not related.

A further example of the χ^2 test and the interpretation of test results is as follows:

Are the answers to the above questions dependent on whether UH-1H (MOS 67N) or CH-47C (MOS 67U) mechanics are being questioned?

Compare all "yes" data of Q7. Note that we could have chosen the "no" data instead, but the "yes" data give a larger sample size. Also note that since the "no's" to Q7 are precisely dependent on the preparation of "yes's" to Q7 for each aircraft mechanic type, any effects run in the "yes" populations also will exist in the "no's". Perform analysis as shown in Table 8.

TABLE 8. QUESTION 35 VS HELICOPTER MODEL

Q35 (given Q7 = yes)

	Y	N	
CH-47C	(a) 63	(b) 27	(a+b) 90
UH-1H	(c) 149	(d) 56	(c+d) 205
	212 a+c	83 b+d	295

$$\chi^2 = \frac{(|63x56-27x149| - 1/2\ 295)^2\ 295}{(212)\ (83)\ (90)\ (205)} = 0.11$$

A χ^2 value of 9.4 vs 0.11 for the question shows that tne responses of the UH-1H (MOS 67N) and CH-47C (MOS 67U) are not related.

From these two examples, the conclusion can be reached that there is a need for shop tools that are not TOE authorized, and the lack of special tools causes repeat maintenance actions. In this example, there was no indication of a dependency between the two personnel categories.

Care must be taken in the use of the statistical method to account for the size of the data sample. Populations of less than 100 significantly reduce confidence in the results of the test. Therefore, tests on specific question relationships for which the population was less than 100 are viewed as having a low level of statistical confidence.

Multiple-choice questions that solicited more than one answer ranked according to the respondents' preferences are analyzed by a weighting procedure. This places the greatest emphasis on the areas the respondents felt strongest about. The questions are analyzed using the first three choices. For each question a ranking is determined by using the following methodology:

$$\left[(W_{F1}\ XN_{1I}) + (W_{F2}\ XN_{2I}) + (W_{F3}\ XN_{3I})\right] / (W_{F1} + W_{F2} + W_{F3}) = R_I$$

where $W_{F1} = 4$, $W_{F2} = 2$, $W_{F3} = 1$
N_{1I} = number of respondents selecting answer I as their first choice

N_{2I} = number of respondents answering I as their second choice

N_{3I} = number of respondents answering I as their third choice

R_I = ranking for Question I.

This standard statistical procedure of weighting each choice with the weighting factor being arbitrarly chosen to place the emphasis on the first choice was used to rank the responses to the ranking questions. The rankings are normalized by dividing by 7 ($W_{F1} + W_{F2} + W_{F3}$) to permit comparison of the answers.

The following sections describe the findings of the questionnaire survey. (1) Respondents provides information relative to the population of maintenance personnel who completed the questionnaire. Data on MOS, years experience, maintenance level (Org. vs DS), etc., of respondents is contained in this section (pages 36-39). (2) Environment relates the attitude of the mechanics and their job evaluation. Answers to questions that are job related and Army maintenance environment related were recorded in this section (pages 40-42). (3) Resources evaluates the responses to questions that related to training, tools, and maintenance manuals and the influence on repetitive maintenance actions. The responses showing percentages of school-trained personnel and the problems in using maintenance manuals, tool requirements, etc., are contained in this section (pages 43-53). (4) Diagnostics evaluates the results of the question responses to troubleshooting, standard procedures, and test equipment and how these attributes affect maintenance effectiveness. Data are presented showing the responses to questions relating to application of procedures, lack of procedures, parts replaced because of poor procedure, etc., in this section (pages 53-60). (5) Applications discusses the results of the findings relating to how aircraft design affects maintenance operations. Data on the location of parts, the application of trial-and-error procedures, the effect of reported vibration as a maintenance action, etc., are contained in this section (pages 61-76). (6) Logistics evaluates the effect of supply in providing spare parts in sufficient quantity and quality to prevent repetitive maintenance actions. Data included in this section (pages 76-85) show the respondents' experience in obtaining defective and wrong parts through supply, samples of serviceable parts returned to supply as unserviceable, etc.

Questions are first analyzed independently in order of importance and not necessarily in numerical order. Question correlation analysis follows the independent question analysis in each section.

RESPONDENTS

The questionnaire survey was conducted at six bases where large complements of UH-1H and CH-47C helicopters are operationally deployed. The number and type of personnel by Military Occupational Speciality (MOS) codes that participated in the survey and the bases surveyed are shown in Table 9. All analysis was conducted using only the populations of MOS 67N(UH-1H) and MOS 67U(CH-47C) personnel. Other MOS categories that provide specialty skill maintenance support were surveyed, but their sample sizes were too small to have statistical significance. Table 10 shows personnel by MOS and number who participated.

TABLE 9. PERSONNEL SURVEYED CLASSIFIED BY BASE

	Fort Hood	Fort Lewis	Fort Bragg	Fort Campbell	Fort Carson	Fort Riley
MOS 67N (UH-1H)	67	64	54	55	9	23
MOS 67U (CH-47C)	30	20	19	20	30	2
Total	97	84	73	75	39	25

TABLE 10. PERSONNEL SURVEYED CLASSIFIED BY MOS

MOS	Skill	Quantity
67N	UH-1H Helicopter Repairman	283
67U	CH-47C Helicopter Repairman	124
67W through 67Z	Technical Inspector/Supervisor	52
68A through 68G	Component Repairman	39
35K through 35P	Avionics Repairman	29
45J	Armament Repairman	6

The personnel were grouped in experience levels related to time assigned to an MOS. The experience groups chosen were: 0 to 2 years, 3 to 5 years, 6 to 10 years, and over 10 years. The over-10-year group included only 8 respondents. This sample was, therefore, disregarded in the analyses. The distribution of personnel by experience and MOS is shown in Figure 1. Only the MOS 67N (UH-1H) and MOS 67U (CH-47C) personnel are shown. Figure 3 provides the distribution of personnel from the bases by experience levels.

The assignment of the responding personnel to organizational or direct support maintenane levels is shown in Figure 2. Of

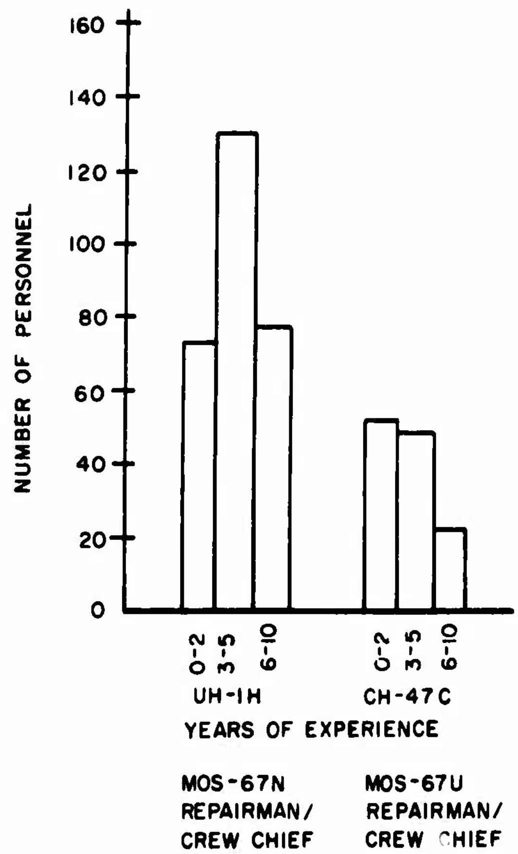

Figure 1. Experience Distribution, UH-1H and CH-47C

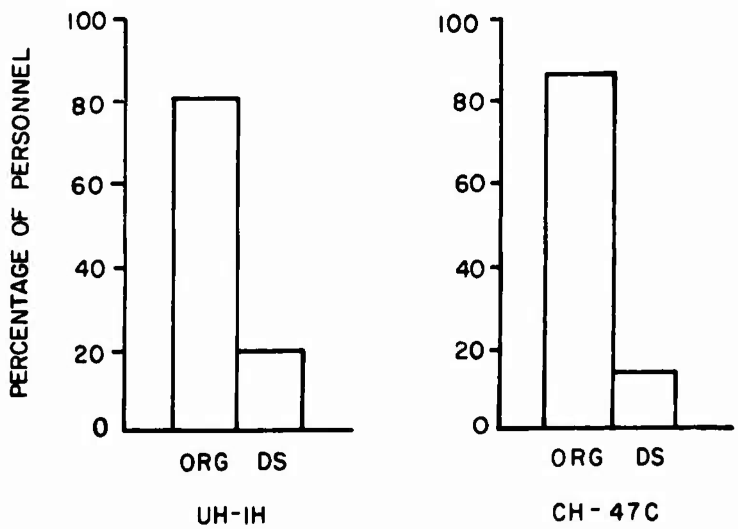

Figure 2. Organizational vs Direct Support Assignment Distribution

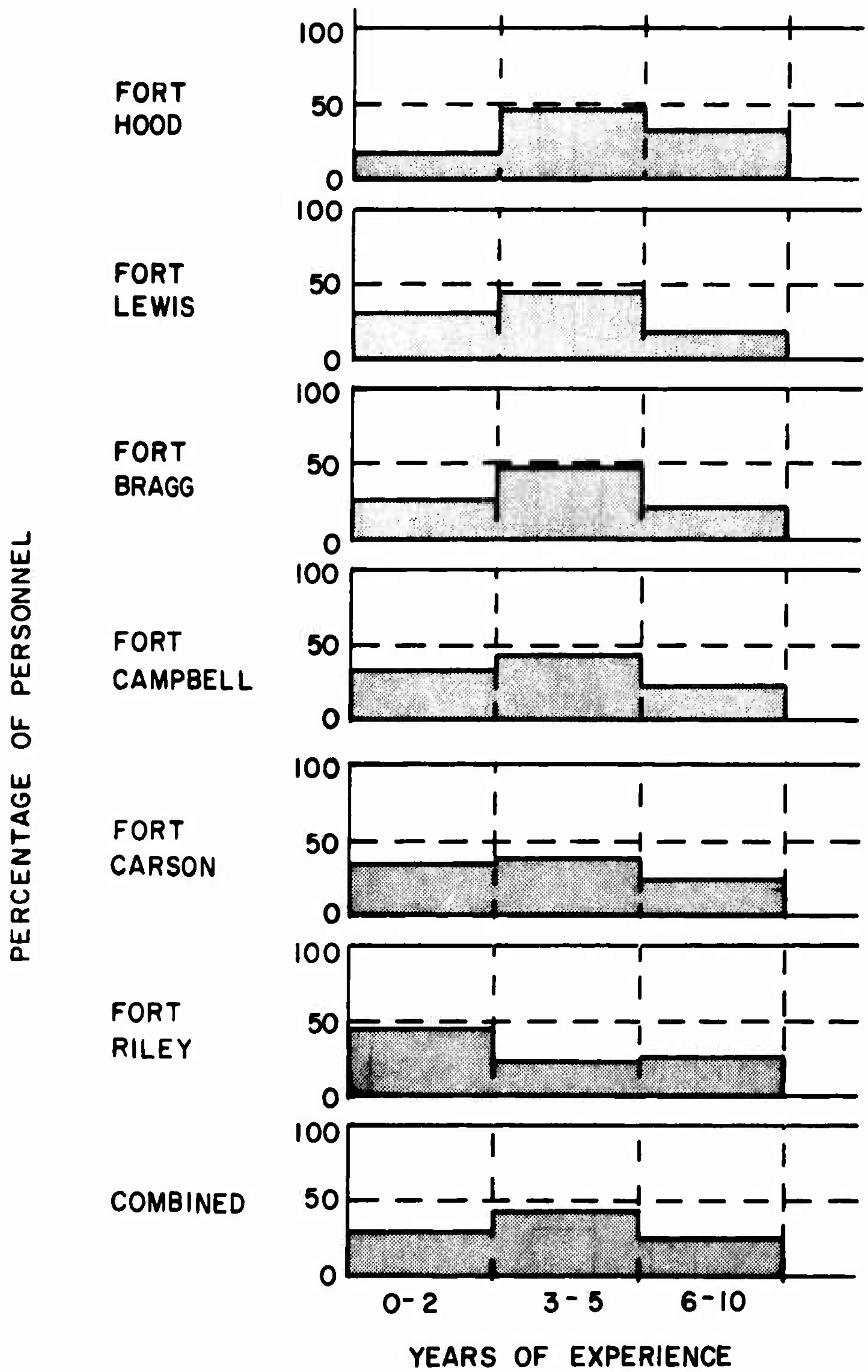

Figure 3. Experience Distribution by Base

the two maintenance levels, 83% of the two MOS skills were assigned to organizational maintenance.

To examine the experience of the mechanics, it was important to identify the systems of the aircraft they worked on. Even though they indicated that they worked on a particular system, they may not have been trained in that skill. Helicopter mechanics assigned to a helicopter model are expected to be generalists and, therefore, work on most mechanical systems. Some tend to work only on those systems they feel proficient in. Others work on all systems. Figure 4 shows experience by system. These data show that flight controls, rotor systems, power trains, and hydraulics are the systems in which the greatest experience is concentrated. (These personnel have experience in more than one system; therefore, percentage of personnel in Figure 4 exceeds 100.) The other five systems are supported by the individual system skilled specialist.

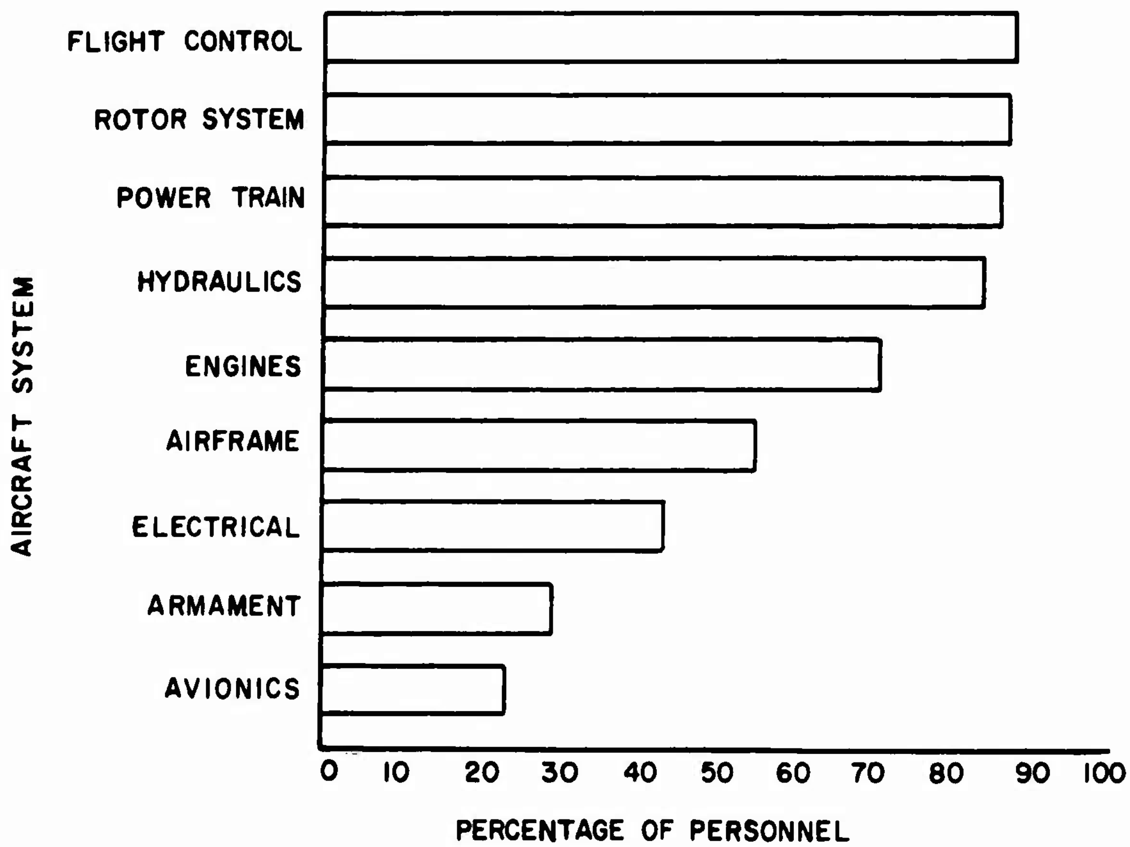

Figure 4. Maintenance Personnel System Experience, UH-1H and CH-47C

ENVIRONMENT

The environment attribute includes the physical conditions within which the maintenance personnel perform their work and the attitudes of the mechanic relative to his job and the maintenance operation.

The attitude of the respondents indicated that extra duties and the lack of tools and spare parts bothered them most in their everyday job. Spare parts was the predominate area of maintenance that the respondents revealed as needing improvement the most. The lack of parts tends to lead to alternate courses of action, such as postponing maintenance or carrying the action on the DA Form -13 as a "carried forward" for several days. Substitute parts are sometimes used. The aircraft are flown, awaiting parts, with less than full operational capability.

The mechanic is considered to have a specific skill, either from school or on-the-job training. He objects to being used to perform other duties not related to his skill. These other duties are military related. When extra duties are performed, the mechanic may not be as efficient and effective in performing maintenance because of fatigue.

Q17. What is it about your job that bugs you most? This question was intended to gain personal attitude response. The respondents stated that extra duty was what bothered them most, as shown in Table 11.

TABLE 11. UH-1H(67N) AND CH-47C(67U) COMBINED RESPONDENT REACTION TO JOB BY PERCENTAGE OF RESPONSE

Attitude Reaction	UH-1H(67N) Percentage Response	CH-47C(67U) Percentage Response	Combined Percentage Response
Extra duties	20	22	21
Lack of tools	21	20	20
Lack of spare parts	20	20	20
Lack of manuals	15	8	13
Not allowed to do capable work	10	8	10
Supervision	7	12	8
Paperwork	6	7	7
Nothing	1	3	2

Further analysis in Table 12 shows the percentage of respondents by type of aircraft and years of experience.

TABLE 12. UH-1H(67N) AND CH-47C(67U) RESPONDENT REACTION TO JOB BY PERCENTAGE RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Attitude Reaction	0-2	3-5	6-10	0-2	3-5	6-10
Extra duties	21	20	18	24	18	25
Lack of tools	20	20	24	22	21	15
Lack of spare parts	16	21	21	13	22	27
Lack of manuals	14	15	16	8	8	8
Not allowed to do capable work	10	11	11	9	7	10
Supervision	8	7	6	14	15	2
Paperwork	9	5	4	4	7	10
Nothing	2	1	2	4	3	2

The respondents to this question, being from different military bases, may have had different attitudes, and because of this their responses may have been different. To test for dependency the χ^2 test was applied, with the result being that there was no dependency between bases indicated. The χ^2 calculated value, 51.3, was below the critical χ^2 value, 78.1, for the 99.8% level of significance, indicating that the respondents' answers from each base were independent.

Q33. What areas related to Army maintenance could be improved? This question was directed to the respondent to elicit his attitude on a less personal basis than Q17. The results were ranked by the procedure given in the Questionnaire Analysis section and are shown in Table 13 for the UH-1H(67N) and Table 14 for the CH-47C(67U) respondents. Spare parts supply ranked first for all respondents. Work environment was more important to the UH-1H(67N) than the CH-47C(67U) respondents. Perhaps this is because the UH-1H is more mobile and requires less maintenance support. Therefore, many of the maintenance actions are performed outdoors without maintenance stands and other support equipment. Technical supervision and aircraft complexity were ranked by all respondents as affecting them the least. This indicates that the mechanics have the capability to handle complex aircraft and are not disturbed by their supervision.

TABLE 13. UH-1H(67N) IMPROVEMENT IN MAINTENANCE NEEDED RANKED BY YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Parts Supply	17	17	20	17
2	Tech Manuals	14	18	20	17
3	Work Environment	17	17	18	16
4	Training	20	16	11	15
5	Test Equipment	12	11	8	15
6	Special Tools	12	15	15	14
7	Technical Supervision	7	4	7	5
8	Aircraft Too Complicated	0	2	0	1

TABLE 14. CH-47C(67U) IMPROVEMENT IN MAINTENANCE NEEDED RANKED BY YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Parts Supply	20	24	25	22
2	Special Tools	18	19	17	18
3	Training	14	15	18	15
4	Test Equipment	14	11	16	13
5	Work Environment	12	14	13	13
6	Tech Manuals	7	11	9	9
7	Technical Supervision	12	5	3	7
8	Aircraft Too Complicated	2	1	0	1

The respondents of Q33, being from different military bases, may have had different attitudes, resulting in responses that reflected those attitudes. Possibly the base location did not matter and the respondents appraised the maintenance problems all the same. To test if there was a tendency for the respondents to be independent or dependent in their answers, a χ^2 test was applied, comparing the military base response with the possible answers to the question. The results were that the χ^2 test value calculated, 62.8, was less than the critical χ^2 value, 78.1, for the 99.8% level of significance, indicating the respondents' answers were independent of the base in which they were located. From this indicated independence, it appears that the questionnaire as it relates to this question was not biased by base location.

By observation, the respondents' reactions to Q17 and Q33 lack similarity, except for spare parts being high on the lists in both question analyses. Those respondents that checked Q17 for lack of spare parts, gave spare parts first ranking in Q33.

RESOURCES

The resources attribute of a maintenance organization consist of trained and skilled mechanics, technical maintenance manuals, tools and special tools. The analysis of the questionnaire shows that shop tools both authorized and not authorized in the TOE are needed to support maintenance operations. Indications are that special tools beyond those presently used should be added to assist maintenance. Troubleshooting tables in the maintenance manuals were found to be adequate; however, improvement in updating is desirable. Maintenance manuals are needed in larger quantities to make them available to all personnel. Additional training in the use of diagnostics was indicated. A large percentage of the MOS assigned maintenance personnel are school trained. The following analysis of question responses from the questionnaire shows the need for improvements in tool support, technical maintenance manuals and training.

Q4. Were you school trained in the MOS in which you are assigned? The larger percentage of respondents were school trained as shown in Table 15. More CH-47C(67U) mechanics were trained in their assigned MOS than the UH-1H(67N) mechanics.

TABLE 15. DISTRIBUTION OF RESPONDENTS SCHOOL TRAINED IN ASSIGNED MOS BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
School Trained	0-2	3-5	6-10	0-2	3-5	6-10
Yes	57.74	69.69	71.62	85.71	69.38	90.47
No	42.26	30.31	28.38	14.29	30.62	9.53

From this analysis it appears that a large percentage of maintenance personnel are trained in their assigned skills. This indicates that lack of training is not a cause of maintenance inefficiency, if the training is adequate.

Q38. Did school training cover the use of diagnostic equipment for troubleshooting? The responses as shown in Table 16 indicate that only approximately 50% were school trained in the use of diagnostic equipment. In personal interviews with mechanics and from notations made by respondents, the training on the use of diagnostic equipment was considered to have been inadequate.

TABLE 16. DISTRIBUTION OF RESPONDENTS SCHOOL TRAINED IN DIAGNOSTIC EQUIPMENT BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
School Trained	0-2	3-5	6-10	0-2	3-5	6-10
Yes	38.02	51.51	54.05	46.93	36.73	52.38
No	61.98	48.49	45.95	53.07	63.27	47.62

The training in how to use diagonistic equipment is important, and periodic updating of this training would benefit the maintenance operation. As new diagnostics are used in the field, training on such equipment should be scheduled. In updating maintenance manuals, the latest in diagnostics should be included.

Q12. Are recoverable parts frequently sent out for repair because trained personnel are not available? The UH-1H(67N) and CH-47C(67U) respondents strongly indicated that parts are frequently sent out for repair because trained personnel are not available. It is possible that the type of trained personnel needed to repair a part is not usually assigned to that unit level. Repairs that require skills beyond those usually assigned must be performed elsewhere. However, there can be conditions where authorized skill level personnal are not assigned and therefore are not available to perform maintenance actions that require that skill. Maintenance actions that can be successfully performed at the unit level should be supported by skilled personnel, tools and technical manuals.

Q5. Do you think the troubleshooting tables in the maintenance manuals are adequate for your work? The UH-1H(67N) and CH-47C(67U) respondents indicated, as shown in Table 17, that maintenance manuals are adequate.

TABLE 17. DISTRIBUTION OF RESPONDENTS RELATING TO TROUBLE-SHOOTING TABLES BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Adequate Tables	0-2	3-5	6-10	0-2	3-5	6-10
Yes	69.01	63.63	62.18	81.63	59.18	66.66
No	30.99	36.37	37.82	18.37	40.82	33.34

The more experienced respondents were not as strong in their convictions perhaps because they are less dependent on troubleshooting tables, except when they face a problem they have not experienced. At that time, tables are found to be of little value because they do not go beyond the mechanic's own experience. As new problems are identified, new troubleshooting procedures are developed. When technical manuals are revised, the troubleshooting tables should be updated with latest procedures.

Q39. What problems do you have in using maintenance manuals? Table 18 and Table 19 show the UH-1H(67N) and CH-47C(67U) respondents' results as ranked by the ranking procedure defined in the Questionnaire Analysis section. The UH-1H(67N) respondents felt that their greatest problem was that there are not enough manuals. This indicates that the user, the crew chief or mechanic, does not have ready access to maintenance manuals. Many aviation units maintain a reference file of technical manuals under the cognizance of the technical inspector. Sometimes this can restrict and discourage the use of manuals by the mechanics who need them. The CH-47C(67U) respondents felt that their problem was primarily that manuals are not up to date. By the time periodic revisions to manuals are distributed to the field, they are sometimes already obsolete. The rankings show that poor troubleshooting tables are not considered to be a major problem. This agrees with the analysis of Q5, where troubleshooting tables were assessed as being adequate.

TABLE 18. UH-1H(67N) RANKING DISTRIBUTION OF PROBLEMS USING MAINTENANCE MANUALS VERSUS YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Not Enough Manuals	24	26	25	23
2	Pages Fall Out	21	22	24	23
3	Not up to Date	20	20	26	22
4	Instruction Not Clear	19	16	10	15
5	Poor Troubleshooting Tables	9	9	7	9
6	Changes Are Not Correct	6	6	8	8

TABLE 19. CH-47C(67U) RANKING DISTRIBUTION OF PROBLEM USING MAINTENANCE MANUALS VERSUS YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Not up to Date	23	25	21	23
2	Not Enough Manuals	18	25	16	21
3	Pages Fall Out	28	15	12	20
4	Instruction Not Clear	16	15	15	16
5	Poor Troubleshooting Tables	8	12	23	12
6	Changes Are Not Correct	8	8	14	9

Q44. What additional test equipment would be of value to you? The UH-1H(67N) respondent indicated the need for additional test equipment as shown in Table 20.

TABLE 20. DISTRIBUTION OF UH-1H(67N) RESPONDENTS, TEST EQUIPMENT NEEDED BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Test Equipment	Years Experience 0-2	3-5	6-10
Vibration meter	30	25	23
Hydraulic mule	21	22	23
Fuel probe tester	16	19	19
Thermocouple probe tester	11	12	13
Frequency meter	11	11	10
Temperature gage tester	10	11	12

The vibration meter is necessary to isolate components causing vibration problems, thus reducing repetitive maintenance actions. The other test equipment will provide the capability to test components prior to their being classed as defective and, in turn, will improve maintenance effectiveness.

Q7. Are there shop tools you need that are not TOE authorized? The respondents strongly indicated, as shown in Table 21, that there are tools needed that are not TOE authorized.

TABLE 21. DISTRIBUTION OF RESPONDENTS RELATING TO TOE AUTHORIZED TOOLS BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Need Tools	0-2	3-5	6-10	0-2	3-5	6-10
Yes	67.60	73.48	79.72	71.42	83.67	71.42
No	32.40	26.52	20.28	28.58	16.33	28.58

Tools that are not authorized, such as a vibration meter, can improve maintenance effectiveness. The need for a vibration meter has been expressed in the analysis of Q20. Additional tools needed are listed in the analysis of Q44. Mechanics, many times, make tools or modify standard tools to aid in performing a specific maintenance task. When a tool is developed this way, it should be evaluated; and, if found to be of value, it should be authorized and defined in the maintenance manual with instruction on how to manufacture it locally.

Q6. Do you have all shop tools listed in your TOE? A high percentage of respondents, as shown in Table 22, indicated that they do not have all authorized listed shop tools. When a tool is needed and not available, either the maintenance action is delayed or alternate actions take place. The use of the wrong tool can damage parts and sometimes endanger the safety of personnel.

TABLE 22. DISTRIBUTION OF RESPONDENTS RELATING TO NEED FOR SHOP TOOLS BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Have All Tools	0-2	3-5	6-10	0-2	3-5	6-10
Yes	21.12	25.75	28.37	20.40	8.16	14.28
No	78.88	74.25	71.63	79.60	91.84	85.72

Shop tools include both standard and special tools. Standard tools are sometimes difficult to control and become lost. Special tools which are used on an irregular basis are controlled. When tools are lost or broken, they are not readily replaced. Therefore, the supply of tools should have high priority.

Q35. Is the lack of special tools an important cause of repeated maintenance actions? Respondents have indicated that the lack of special tools is an important cause of repeated maintenance actions, as shown in Table 23.

TABLE 23. DISTRIBUTION OF RESPONDENTS RELATING TO SPECIAL TOOL REQUIREMENTS BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Special Tools Required	0-2	3-5	6-10	0-2	3-5	6-10
Yes	59.15	66.66	72.97	55.10	81.63	61.90
No	40.85	33.34	27.03	44.90	18.37	38.10

Many maintenance tasks can not be performed efficiently without the use of special tools. Lack of access to a part may require a tool to aid in the part removal or adjustment. A complete supply of authorized special tools should be maintained to insure that the mechanic will be fully equipped. Time lost in finding alternate sources for tools or by the improper use of tools reduces maintenance efficiency.

Q20. Do you have a vibration meter available for your use? Respondents indicated, as shown in Table 24, that they do not have a vibration meter. The need for a meter is expressed in the analysis of Q44. A recently completed USAAMRDL report[2] relating to inspection aids recommended the use of vibration meters in solving rotor and other vibration-related problems.

TABLE 24. DISTRIBUTION OF RESPONDENTS RELATING TO VIBRATION METER AVAILABILITY BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Have Vibration Meter	Years Experience UH-1H(67N) 0-2	3-5	6-10	CH-47C(67U) 0-2	3-5	6-10
Yes	28.16	29.54	22.97	38.77	46.93	52.38
No	71.84	70.46	77.03	61.23	53.07	47.62

From personal interviews it was found that personnel who thought they had a vibration meter available admitted they did not know how to use one. Vibration meters should be provided as a special tool or test equipment, and mechanics should be trained to use them.

Q13. Is test equipment used to check out removed parts to determine if they are serviceable before turning them in to supply? The UH-1H(67N) and CH-47C(67U) respondents agreed that test equipment is not used to check out parts for serviceability. Test equipment, along with the training and maintenance manual as to its application, can increase the efficiency of a maintenance operation by keeping parts from being replaced arbitrarily. School training on aircraft systems should include the application of test equipment and special tools.

Q33. What areas related to Army maintenance could be improved? The responses to this question were ranked by the procedure defined in the Questionnaire Analysis section; Tables 13 and 14, shown in the Environment section, indicated that parts supply was the first choice as to what can be improved in Army maintenance. The UH-1H(67N) respondents felt that technical manuals ranked second, training forth, and special tools sixth out of eight selections. This ranking shows that technical manuals and training are important to maintenance effectiveness. Perhaps the UH-1H(67N) respondents are affected more by lack of manuals than the CH-47C(67U) respondents, who felt special tools were second in importance. The CH-47C, a more complex aircraft, is expected to require more special tools than the UH-1H. Therefore, the need for this kind of support is more apparent. Training on both aircraft types is of high importance. Even with the large percentage of respondents school trained (Q4 analysis), they felt that more training is needed.

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[2]"Investigation of Inspection Aids", USAAMRDL-TR-74-44, Eustis Directorate, USAAMRDL, Fort Eustis, Virginia, July 1974, pp 134-138 and 157-165.

The responses to certain questions relating to the Resources attribute were considered to have possible significant correlation. To determine if the answers to these questions were independent or depended on one another, the χ^2 test was applied with the results shown in Table 25. Those questions showing dependence on one another are further analyzed. Also, questions that were expected to show correlation but could not be χ^2 tested are analyzed.

TABLE 25. RESOURCES QUESTIONS TESTED FOR DEPENDENCY

Question Combination	χ^2 test (%) (Calculated)	χ^2 (99.8%)	Dependence
4/5	0.1	9.4	No
4/12	1.0	9.4	No
4/13	2.1	9.4	No
4/20	.1	9.4	No
4/33	Q33 ranked for both answers to Q4		
4/38	8.6	9.4	No
38/13	4.9	9.4	No
38/20	0.7	9.4	No
38/33	Q33 ranked for yes answer to Q38		
12/13	6.5	9.4	No
5/33	Q33 ranked for yes answer to Q5		
5/39	Q39 ranked for no answers to Q5		
13/44	5.2	18.8	No
6/7	26.7	9.4	Yes
7/33	Q33 ranked for yes answer to Q7		
7/35	5.3	9.4	No
6/33	Q33 ranked for no answers to Q6		
6/35	0.1	9.4	No
6/37	0.1	9.4	No
6/20	0.5	9.4	No

Q4/Q33. The analysis of Q33 showed the areas of Army maintenance that could be improved. The difference in ranking the responses to Q33 by those that answered Q4 as Yes (they were trained) and as No (they were not trained) is shown in Table 26.

TABLE 26. WHERE TO IMPROVE MAINTENANCE RELATIVE TO TRAINING

Rank	Trained	Not Trained
1	Parts supply	Training
2	Technical manuals	Parts supply
3	Special tools	Work environment
4	Work environment	Special tools
5	Training	Technical manuals
6	Test equipment	Test equipment
7	Technical supervision	Technical supervision
8	Aircraft complexity	Aircraft complexity

The most revealing result of this analysis is that the untrained placed training first as to where improvement is needed, showing correlation between answers to Q4 and Q33. Technical manuals are less important to the untrained than to the trained respondents perhaps because the untrained use the manual less and therefore do not know that it needs to be improved. The last ranking, aircraft complexity, shows that complexity does not appear to be a problem with the respondents.

Q38/Q33. The analysis of Q33 showed the areas of Army maintenance that could be improved. The analysis of Q38 related to school training in diagnostic equipment. The relationship between these two questions is that the respondents to Q38 who were school trained ranked test equipment, training, and special tools high. Table 17 shows the result of testing Q33, given that Q38 was answered Yes.

TABLE 27. WHERE TO IMPROVE MAINTENANCE RELATIVE TO DIAGNOSTICS TRAINING

Rank	Area of Improvement
1	Parts supply
2	Work environment
3	Technical manuals
4	Special tools
5	Training
6	Test equipment
7	Tecnnical supervision
8	Aircraft complexity

Technical manuals, tools, training and test equipment were not the top choices of the respondents, showing that their concern for resources was not as great as it was for logistics and environment.

Q5/Q33. The analysis of Q5 showed that respondents felt troubleshooting tables were adequate. The analysis of Q33 showed the areas of Army maintenance that can be improved, one of which is technical manuals. By ranking the answers to Q33 of the respondents who answered Q5 as yes, a correlation of answers may be found between the two questions. Table 28 shows the results of the ranking of Q33, given that Q5 was answered Yes.

TABLE 28. WHERE TO IMPROVE MAINTENANCE RELATIVE TO TROUBLESHOOTING TABLES

Rank	Area of Improvement
1	Special tools
2	Parts supply
3	Training
4	Work environment
5	Technical manuals
6	Test equipment
7	Technical supervision
8	Aircraft complexity

This shows that those who felt that troubleshooting tables were adequate also felt that technical manuals was not the most important area to be improved in Army maintenance.

Q5/Q39. The results of the analysis of Q5 indicated that troubleshooting tables in the maintenance manuals are adequate. The analysis of Q39 showed the problems related to maintenance manuals. If the respondents to Q5 felt that troubleshooting tables were not adequate, would these same respondents rank poor troubleshooting tables as a primary problem? Table 29 shows Q39 ranked for the negative respondents to Q5.

TABLE 29. WHERE TO IMPROVE MAINTENANCE MANUALS RELATIVE TO TROUBLESHOOTING TABLES

Rank	Maintenance Manual Problem
1	Not enough manuals
2	Not up to date
3	Pages fall out
4	Instruction not clear
5	Poor troubleshooting tables
6	Changes are not correct

There is little sign of correlation between the answers to Q5 and Q39. Aparently the respondents to Q5 who said that troubleshooting tables were inadequate, felt tnat the other problems listed in Q39 were more significant.

Q6/Q7. Are the answers to Q7 from the UH-1H(67N) and CH-47C (67U) respondents dependent on the answers to Q6? The results of the χ^2 test indicated a strong dependency between the answers to the two questions. The questions are similar in that they relate to tools. It appears that the respondents do not have all the shop tools they are TOE authorized and need shop tools that are not TOE authorized. There is strong evidence that tools are needed and maintenance effectiveness may be affected by it. Inventories of tools should be examined and missing tools replaced. New tools should be supplied where necessary.

Q7/Q33. The analysis of Q7 revealed that the respondents felt shop tools that are not TOE authorized are needed. The analysis of Q33 shows what areas of Army maintenance need improvement. By ranking the responses to Q33 of those respondents who answered Q7a Yes, it may be determined if the same respondents who felt that shop tools are needed also felt that special tools and test equipment are the most important maintenance improvement areas. Table 30 shows the results of this analysis to be that special tools ranked as the second most important area needing improvement. Respondents who felt that shop tools that are not TOE authorized are needed also felt that special tools support needs to be improved.

TABLE 30. WHERE TO IMPROVE MAINTENANCE RELATIVE TO SHOP TOOLS

Rank	Area of Improvement
1	Parts supply
2	Special tools
3	Training
4	Work environment
5	Technical manuals
6	Test equipment
7	Technical supervision
8	Aircraft complexity

Q6/Q33. The analysis of Q6 showed that all shop tools listed in the TOE are not available. The analysis of Q33 ranked areas of improvement in Army maintenance. By analyzing the responses to Q33 of those respondents who answered Q6 as negative, a correlation may be revealed, in that their answers may rank special tools or test equipment as a most important area of maintenance support needing improvement. Table 31 shows the results of the ranking of Q33, given that the answers to Q6 were No. Special tools again, as in the analysis of Q6/Q33, ranked the second highest area needing improvement. The lack of necessary tools delays maintenance actions, causing the mechanics to use less desirable alternative procedures in performing maintenance actions.

TABLE 31. WHERE TO IMPROVE MAINTENANCE RELATIVE TO AVAILABILITY OF AUTHORIZED SHOP TOOLS

Rank	Area of Improvement
1	Parts supply
2	Special tools
3	Training
4	Technical manuals
5	Work environment
6	Test equipment
7	Technical supervision
8	Aircraft complexity

DIAGNOSTICS

The use of test equipment, troubleshooting and standard procedures constitutes the diagnostics application in the support of a helicopter in the Army operational environment. To do a proper job, test equipment must be adequate and available. The mechanic must know how to use the equipment and he must use it. Standard troubleshooting procedures can be effective if they are inclusive, well defined and utilized by the mechanic. Standard maintenance procedures provide direction and control of maintenance operations.

The number of times trial-and-error is used for troubleshooting is excessive. To reduce the dependency on this procedure, troubleshooting tables in the maintenance manuals should be improved, test equipment such as the vibration meter should be provided, and standard procedures should be revised to discourage the use of trial-and-error. Test flights before periodic inspections may reduce repetitive maintenance actions by finding problems that can be corrected during the inspection period.

Procedures for determining excessive leakage in gearboxes, pumps, and servos need to be developed. Those procedures can be used effectively in the field to take the guesswork out of parts replacement. Test equipment to assist quality checks of components repaired in the field would reduce maintenance actions.

Q14. When you perform corrective maintenance, how often does the first fix fail to work? The UH-1H(67N) and CH-47C(67U) respondents indicated that the first fix failed to work less than 10% of the time. The CH-47C respondents with more experience, 6-10 years, indicated by a response of 38% that a first fix failed to work less than 50% of the time. Less than 10% of all respondents indicated that a first fix failed to work over 50% of the time. This shows that the mechanic, in his opinion, usually performs the maintenance action correctly the first time. The analysis of this question did not reveal any significant factor that could be directly related to diagnostics. The causes for first fixes failing to work may include the lack or improper use of diagnostic equipment, troubleshooting tables or procedures.

Q36. What percentage of the time is trial-and-error used to correct a maintenance problem? The respondents, as shown in Table 32, varied in their responses. The more experienced respondents on the more complex aircraft show trial-and-error being used extensively as a maintenance procedure.

The unrestricted use of this procedure results in repetitive maintenance actions, excessive use of spare parts as indicated by the responses to Q18 in the Applications section of this report, and poor utilization of manpower. Standard procedures and systemized troubleshooting procedures with the use of test equipment can provide more effective maintenance.

TABLE 32. USE OF TRIAL-AND-ERROR MAINTENANCE PROCEDURES BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Percentage of Time Trial-and-Error Is Used	Years Experience UH-1H(67N) 0-2	3-5	6-10	CH-47C(67U) 0-2	3-5	6-10
0%-30%	56	55	59	52	37	35
31%-50%	33	36	34	35	43	60
51%-100%	11	9	7	12	20	5

Q8. Trial-and-error is used to troubleshoot a maintenance problem because: it is an easy way to correct the problem, it is fast, the mechanic lacks experience, or the technical manual covers only obvious causes of a particular problem. Which option is most representative of the maintenance procedure in your unit? The UH-1H(67N) and CH-47C(67U) respondents indicated that the reason trial-and-error is used to troubleshoot is that it is an easy way to correct the problem. The second choice of all respondents was that the technical manual covers only obvious causes. This shows that the mechanic's action lacks direction. He may be inexperienced, inadequately trained or unsupervised. The arbitrary use of trial-and-error procedure for troubleshooting a problem by the mechanic without the use of the diagnostics available to him is inefficient and is represented by the repetitive maintenance actions it generates.

Q15. Where do you go to get troubleshooting assistance for maintenance problems? Of the six choices listed, the UH-1H(67N) and CH-47C(67U) respondents indicated that they go to technical manuals first and rely on their own judgement secondly.

Results of the ranking are shown in Table 33 for the UH-1H(67N) respondents and in Table 34 for the CH-47C(67U) respondents. The conclusion is that the mechanic uses the technical manual or relies on his own judgement before going to someone else for assistance. With complete, concise troubleshooting procedures in the technical manuals, the mechanic will use them to troubleshoot a maintenance problem.

TABLE 33. UH-1H RANKING OF WHERE TO GET TROUBLESHOOTING ASSISTANCE BY YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Use technical manuals	39	42	43	42
2	Rely on knowledge and experience	16	18	23	19
3	Go to fellow mechanic	21	14	7	14
4	Go to tech. inspector	14	11	14	12
5	Go to maint. supervisor	8	11	12	10
6	Go to maint. officer	1	4	1	3

TABLE 34. CH-47C RANKING OF WHERE TO GET TROUBLESHOOTING ASSISTANCE BY YEARS EXPERIENCE

Rank	Choice	Years Experience 0-2	3-5	6-10	All
1	Use technical manuals	32	34	47	36
2	Rely on knowledge and experience	21	29	27	25
3	Go to fellow mechanic	22	18	16	20
4	Go to maint. supervisor	14	8	5	9
5	Go to tech. inspector	10	10	5	9
6	Go to maint. officer	1	2	0	1

Q11. Excessive leakage from gearboxes, pumps, and servos is determined by: observing sight gage, collecting fluid in container, counting drops (static), counting drops while operating, wiping part and watching for seepage that cannot be measured, and/or guessing that the leakage is excessive. Table 35 and Table 36 show the distribution of the responses from the UH-1H(67N) and CH-47C(67U), respectively. The respondents for the UH-1H(67N) and CH-47C(67U) indicated that observing the sight gage was the way to determine excessive gearbox leakage. For pumps, the procedure by all respondents except the more experienced CH-47C(67U), 6-10 year respondents was to wipe the part and check for seepage. The CH-47C(67U), 6-10 year experience respondents selected the procedure of counting drops while the part is operating. For servos, the UH-1H(67N) respondents chose wiping the part and watching for seepage as the procedure to use; the more experienced felt that counting drops while the part is operating was the better procedure. The CH-47C(67U) respondents varied in their choice of procedures relative to servos. The lesser experienced selected wiping the part and looking for seepage. Those with 3-5 years experience indicated that counting drops in the static mode was the best procedure, while those with 6-10 years experience considered counting drops with the part operating as the procedure to follow. Variation in response to this question was expected because clear definition as to what constitutes leakage and how to measure it is lacking in the maintenance manuals. Mechanics are allowed to identify leakage in their own way and to replace parts accordingly without any accurate method of determining if leakage is excessive. Better troubleshooting procedures should be provided to include methods for measuring leakage of dynamic components such as gearboxes, pumps, and servos. Test equipment may be necessary to test parts for leakage on or off the aircraft. Standard procedure should be such that parts removed for leakage or suspected of excessive leakage must be inspected and tested prior to replacement.

TABLE 35. UH-1H DISTRIBUTION OF DETERMINATION OF EXCESSIVE LEAKAGE BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience		
	0-2	3-5	6-10
Determine leakage by:			
Gearboxes			
observing gage	39	39	34
collecting fluid	4	4	5
counting drops (static)	11	9	11
counting drops (dynamic)	12	10	13
wipe and watch for seepage	25	30	26
cannot be measured	3	1	2
guessing leakage is excessive	6	7	10
Pumps			
observing gage	5	6	1
collecting fluid	8	9	8
counting drops (static)	18	19	20
counting drops (dynamic)	24	24	26
wipe and watch for seepage	28	32	32
cannot be measured	8	5	4
guessing leakage is excessive	9	6	9
Servos			
observing gage	3	4	1
collecting fluid	6	3	5
counting drops (static)	19	24	21
counting drops (dynamic)	21	29	32
wipe and watch for seepage	34	32	26
cannot be measured	7	3	4
guessing leakage is excessive	10	5	10

TABLE 36. CH-47C DISTRIBUTION OF DETERMINATION OF EXCESSIVE LEAKAGE BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience 0-2	3-5	6-10
Determine leakage by:			
Gearboxes			
observing sight gage	36	27	45
collecting fluid	3	7	0
counting drops (static)	16	13	10
counting drops (dynamic)	7	13	21
wipe and watch for seepage	25	28	14
cannot be measured	4	5	0
guessing leakage is excessive	10	7	10
Pumps			
observing gage	4	0	3
collecting fluid	8	5	6
counting drops (static)	17	24	19
counting drops (dynamic)	23	28	39
wipe and watch for seepage	32	32	22
cannot be measured	8	3	6
guessing leakage is excessive	7	7	6
Servos			
observing gage	7	4	0
collecting fluid	10	9	5
counting drops (static)	18	29	23
counting drops (dynamic)	18	27	41
wipe and watch for seepage	34	24	23
cannot be measured	4	1	0
guessing leakage is excessive	8	6	8

Q26. Who usually decides that a major component is defective and requires replacement? The UH-1H(67N) and CH-47C(67U) respondents unanimously agreed that the technical inspector decides if a major component requires replacement. The technical inspector is usually the best trained, experienced, and technically capable man in the unit. He is familiar with aircraft system function and procedures. Major components are usually costly and require extensive man-hours to replace. Test equipment and inspection procedures that assist the technical inspector in making his decisions benefit the maintenance operation and improve efficiency.

Q9. Which of the following gripes are hardest for you to diagnose on the first try? Table 37 and Table 38 give the rank by percentage response and years experience of the problems hardest to diagnose and reveal that the less experienced UH-1H (67N) personnel indicated that electrical problems are hardest to diagnose on the first try. Perhaps electrical test equipment is needed to assist them in troubleshooting. The respondents who felt that vibration was the most difficult problem to diagnose may need the vibration meter as discussed in the Resources section, Q20 analysis. Adequate test equipment and troubleshooting procedures can aid in the diagnosis of maintenance problems and can reduce the use of trial-and-error to find the answer.

TABLE 37. UH-1H PROBLEMS HARDEST TO DIAGNOSE BY YEARS EXPERIENCE

Rank (by % Response)	Years Experience 0-2	3-5	6-10
1	Electrical	Electrical	Vibration
2	Vibration	Vibration	Electrical
3	Avionics	Avionics	Avionics
4	Hydraulic	Rotor system	Fuel system
5	Engine	Engine	Rotor system
6	Flight control	Flight control	Flight control
7	Rotor system	Fuel system	Hydraulics
8	Fuel system	Hydraulics	Engine

TABLE 38. CH-47C PROBLEMS HARDEST TO DIAGNOSE BY YEARS EXPERIENCE

Rank (by % Response)	Years Experience 0-2	3-5	6-10
1	Vibrations	Vibrations	Vibrations
2	Electrical	Electrical	Electrical
3	Avionics	Avionics	Avionics
4	Engine	Engine	Engine
5	Flight controls	Hydraulics	Flt.controls/ Hyd./Fuel sys.
6	Hydraulics	Fuel system	
7	Fuel sys/Rotor system	Flight controls	
8		Rotor system	

Q50. Repeat maintenance actions on the P-SAS are caused by: difficult adjustment, high single component failure rate, availability of parts, lack of test equipment or lack of training. Which is the most important?

The CH-47C(67U) mechanics, to which this question was directed, responded by indicating that the lack of training was the primary cause of repetitive maintenance actions on the pilot's stability augmentation system (P-SAS), except for the 6-10 year experienced respondents, who felt that the lack of test equipment was most important. The two most important reasons for repetitive maintenance actions on P-SAS are the lack of training and test equipment. Proper test equipment provided to maintenance personnel and the proper training in its use could reduce the repetitive maintenance actions on the P-SAS system.

Q41. Several attempts are necessary to properly adjust cyclic stick rigging because of: the lack of proper tools, too many adjustment points, or the location of adjustment points. Table 52 in the Applications section, Q41 analysis, shows the location of adjustment points as the cause of repeated maintenance actions relative to properly adjusting the cyclic stick rigging. The use of special equipment (rigging pins to hold the controls in a fixed position) can reduce the number of actions necessary to rig a control system.

Q49. What is the cause when repairs on flight boost accumulators are not successful? The reason given by the CH-47C(67U) respondents was that the part is not bench or submerge tested after seals are replaced in the field. A simple procedure for submerge testing a part of this type could prevent it from being installed on an aircraft when it is still defective. Quality inspection after parts are disassembled and reassembled in the field is important. If parts can be repaired in the field, they can also be inspected there. In some cases new test equipment may be required.

Q37. Do you think that a maintenance test flight before each Periodic Inspection would reduce the number of repeated maintenance actions required after Periodic Inspection? The response to this question was positive as shown in Table 39.

TABLE 39. DISTRIBUTION OF PREFERENCE FOR TEST FLIGHT BEFORE PERIODIC INSPECTION BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Test Flight	0-2	3-5	6-10	0-2	3-5	6-10
Yes	61.97	60.60	68.91	65.30	65.30	47.61
No	38.03	39.40	31.09	34.70	34.70	52.39

Only the most experienced CH-47C(67U) respondents indicated a difference in opinion. Perhaps they felt that they know their aircraft and that a test flight would not serve any purpose.

Generally, a test flight performed by a qualified maintenance test pilot can provide the opportunity to test aircraft systems which may not be used regularly. This may serve as an opportunity to use a vibration meter to check for or isolate a reported vibration problem so that it can be corrected during periodic inspection. A pre-periodic inspection test flight as a standard procedure can define maintenance actions and improve maintenance efficiency.

Q32. In general, how accurate is the flight crew -13 write-up? The UH-1H(67N) and CH-47C(67U) respondents indicated from the choices of poor, fair, or good that the DA Form -13 write-up by the flight crew is generally fair, as shown in Table 40. Since most respondents were reporting on themselves, the results of the response were not unexpected. Even so, the larger percentage of the respondents indicate that the write-ups are less than good, showing the need for improvement. Changes in procedures and possibly the use of a standard dictionary of terms for the mechanics to identify a problem could improve the DA Form -13 write-up and reduce confusion in trying to identify maintenance problems.

TABLE 40. DISTRIBUTION OF QUALITY OF FLIGHT CREW WRITE-UP ON DA FORM -13 BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Accuracy	0-2	3-5	6-10	0-2	3-5	6-10
Poor	13	11	23	6	20	4
Fair	51	50	49	60	46	48
Good	36	39	28	34	34	48

The responses to certain questions relating to the diagnostics attribute were considered to have possible significant correlations. To determine if the answers to these questions were independent of or dependent on one another, the χ^2 test was applied, with the results shown in Table 41. Those questions showing dependence on one another are further analyzed.

TABLE 41. DIAGNOSTICS QUESTIONS TEST FOR DEPENDENCE

Question Combination	χ^2 test (%) (Calculated)	χ^2 (99.8%)	Dependence
14/8	4.1	16.9	No
14/36	13.7	16.9	No
36/8	24.2	16.9	Yes
32/36	2.0	10.9	No
15/26	Respondent Data Compared for Correlation		
37/8	3.53	14.8	No
37/36	5.27	12.5	No

Q36/Q8. Are the answers to Q8 from the respondents who answered Q36 dependent on the answers to Q35? The results of the χ^2 test indicate a dependence between the answers to the two questions. These questions have multiple choice answers. The analysis of Q36 was that the trial-and-error procedure is used extensively. For Q8 the respondents indicate that the primary reason for using trial-and-error is that it is an easy way to correct the problem. The comparison shows that those who think the trial-and-error troubleshooting procedure is used extensively also think that it is used because it is easy.

APPLICATIONS

Applications means the design of the helicopter and its supporting equipment in the Army environment that significantly affect the methods and procedures applied to maintain and support that helicopter in its operation. The complexity of a system and the location and size of a part can cause incorrect diagnosis and repetitive maintenance actions. The trial-and-error method of troubleshooting a maintenance problem is common practice on UH-1H and CH-47C helicopters as much as 50% of the time. The location and accessibility of a part on the aircraft can be important contributing causes of repetitive maintenance actions. The questionnaire data indicates that over 50% of the respondents felt inaccessibility was a problem.

A total of 17 questions of the questionnaire relate to the Applications attribute. The results of the analyses of these questions and 12 correlations between questions are as follows:

Q36. What percentage of the time is trial-and-error used to correct a maintenance problem? The UH-1H(67N) respondents indicated that trial-and-error is used from 0% to 30% of the time to correct a problem. The CH-47C(67U) respondents of the 0-2 year experience category agreed with the UH-1H(67N) respondents. However, the CH-47C(67U) respondents with from 3-10 years experience indicated that trial-and-error is used 30% to 50% of the time. The more experienced mechanic on the larger, more complex helicopter confirmed that trial-and-error is used extensively to correct maintenance problems. The impact of this procedure in causing repetitive maintenance actions is significant. Future system and component design should incorporate more extensive use of simple fault-isolation features to determine the cause of a problem and to reduce the tendency to use trial-and-error as a procedure.

Q26. Who usually decides that a major component is defective and requires replacement? The UH-1H(67N) and CH-47C(67U) respondents unanimously agreed that the technical inspector decides if a major component requires replacement. The technical inspector is usually the best trained and experienced man in the unit. He is familiar with system function and is most capable of making the decision. This decision is dependent on his ability to understand the design and component function of the part in question. His limitations are sometimes caused by the lack of current training, test equipment and diagnostic aids to help him in his decision. The results of the analysis of Q33 in the Environment Section of this report indicate that current helicopters are not too complicated, indicating that complexity of design is not a problem.

Q34. Is the location of a part on the aircraft an important cause of repeated maintenance actions? Table 42 shows that it is. This shows the importance in design for considering location and accessibility of components that may cause recurring maintenance actions. Parts that are susceptible to failure, wear-out, and short-term replacement, or require periodic inspections and/or adjustments, should be designed and installed in locations with adequate access to provide the required maintainability.

TABLE 42. DISTRIBUTION OF PART-LOCATION-CAUSED MAINTENANCE ACTIONS BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

	Years Experience					
	UH-1H(67N)			CH-47C(67U)		
Part Is Accessible	0-2	3-5	6-10	0-2	3-5	6-10
Yes	60.56	71.21	66.21	61.22	75.51	52.38
No	39.44	28.79	33.79	38.78	24.49	47.62

Q19. When an unusual vibration occurs: you identify the cause of the vibration(s) by a serviceability check or a replacement of component(s), or you let someone else make the decision. The respondents all agreed that the serviceability check was the predominate method used to identify the cause of vibrations. However, over 30% of the UH-1H(67N) respondents with 0-2 years experience indicated that they let someone else make the decision.

Over 33% of CH-47C(67U) respondents indicated that they replace components to identify the cause of vibration. The need to replace components to solve vibration problems is sometimes caused by the location and inaccessibility of the component. The part that is most accessible is replaced first in hopes that it caused the vibration. This is judged to be one of the primary causes of repetitive maintenance actions. Methods for isolating vibration causes to specified components are needed to reduce the use of trial-and-error.

Q18. List maintenance tasks that have caused more than one part to be replaced before the right part was identified. (Put parts in order of removal, the last one being the one that solved the problem.) Lists of parts replaced and the maintenance actions or symptoms causing the replacement are given in Table 43 for the UH-1H and in Table 44 for the CH-47C, as extracted from the respondent questionnaires. Although these lists show the extensive use of trial-and-error in resolving a maintenance problem and the inference of repetitive maintenance action, the question and response do not relate directly to the Applications attribute. From some maintenance actions and parts replaced, it could be implied that parts would not have been replaced if the parts causing the problem could have been isolated from the system and tested. System design to provide this capability would be beneficial. An example of this might be a component in the hydraulic system such as a pump or servo. By isolating the component and testing it, or by running the system without it, the problem could be corrected without further parts replacement.

TABLE 43. UH-1H MAINTENANCE ACTION AND SEQUENTIAL PART REPLACEMENT LIST

Maintenance Action or Symptom	Replaced Part A	Replaced Part B	Replaced Part C
N_1 Tachometer inoperative	Tachometer	Tachometer	Repaired cannon plug
Dual tachometer inoperative, no throttle center	Governor, overspeed	Fuel control	
Creeping pedals	Tail rotor servo	Tail rotor servo	Adjust balance spring
Adjusted trim tabs	Blades	Rotor head	
Short shaft	Seal	Seal	Shaft
Change mast dust boot	Remove rotor head	Dampers	Scissors assy
Worn scissor lever	Shims	Bearings	Lever
Noise on shutdown	Swashplate assy	Main rotor mast	Hyd. pump
Transmission filter	Gaskets	Filter	Housing
Radio/Transmitter unit	Control head	Wiring	
Radio	Control head	Radio	Cannon plug
Avionics	Control	Wire	
Electrical short	Control	Circuit breaker	Mike cord
Navigation system	Radio magnetic indicator	J-2 compass	
Change fuel control	Fuel control	Overspeed governor	Bleed band actuator
Loss of rotor rpm	Fuel control	Overspeed governor	
Engine rpm fluctuates	Governor	Fuel control	Tach generator
Engine surge	Fuel control	Fuel control	Adjust bleed band
Fuel control	Overspeed governor	Fuel control	Fuel control

TABLE 43. UH-1H MAINTENANCE ACTION AND SEQUENTIAL PART REPLACEMENT LIST (Continued)

Maintenance Action or Symptom	Replaced Part A	Replaced Part B	Replaced Part C
Fluctuating N_1	Check valve	Governor	N_1 gage
N_1 speed calibration	Indicator	Linear actuator	Adjust stop
N_1 actuator	N_1 actuator	Control Pr.	
Engine high temp	Gage	Sensing unit	Oil cooler
Flight idle	Switch	Wire	Solenoid
Fuel system	Overspeed governor	Fuel control	
Transmission oil pr.	Gage	Pr. transmitter	Relief valve
Transmission oil pr.	Gage	Pr. transmitter	Wire
Transmission hot oil light	Temp transmitter	Caution panel	Cannon plug
Pilot attitude indicator	Indicator	Gyro	
Cyclic stick	Cyclic stick	Bellcrank	Control rod
Cyclic binding	Force gradient spring	Bellcrank	Cyclic stick
Compressor stall	90° gearbox	Drive shaft	Engine
Suspected compressor stall	Fuel control	Rig bleed band	
Hydraulics	Check valve	Servo	Irreversible valve
Hyd. servo	Irreversible valve	Pr. valve	
Servo	Servo	Irreversible valve	Seals
Collective stiff	Adjust friction	Power control	Servo
Hydraulics	Check valve	Servo	Pump
Hyd. feedback	Servo	Pump	Transmission
Binding cyclic	Force gradient	Mag. brake	Bearing
Hyd. leak collective servo	Lub. bearing	Servo	Repositioned cable
Hyd. failure	Pump	Check valve	Bypass valve
Caution light	Caution panel	Pr. switch	Wiring
Fuel pump light	Circuit breaker	Pump	Light
Fuel pr. switch	Switch	Pump	Fitting
No fuel pressure	Pump	Pump	Mech sending unit
No fuel pressure	Pump	Circuit breaker	Wire

TABLE 43. UH-1H MAINTENANCE ACTION AND SEQUENTIAL PART REPLACEMENT LIST (Continued)

Maintenance Action or Symptom	Replaced Part A	Replaced Part B	Replaced Part C
Magnetic brakes	Fore and aft brake	Adjust force trim	Lateral brake
Transmission damper	Damper set	Damper set	Damper set
Binding throttle	Torque tube	Torque tube	Flt idle stop pad
Vibration	Hub	Blades	Stabilizer bar
Vibration	Hub	Blades	Damper mount
Vertical vibration	Blades	Hub	Mast
Lateral vibration	Blades	Hub	Swashplate
High-freq. vibration	Bearings	Couplings	Shaft
Vibration	Gearbox	Tail rotor	Drive shaft
Tail rotor vibration	Oil cooler bearing	Drive shaft bearing	Short shaft
High-freq. vibration	Oil cooler	Tail rotor	Drive shaft
Vibrations	Shafts	Gearboxes	
Cyclic vibration	Transmission	Pump	Servo
High-freq. vibration	Tail rotor	Gearbox	Tail boom
Generator surge	Voltage regulator	Circuit breaker	Generator
Main generator voltage	Generator	Reverse current relay	Voltage regulator
No output, generator light	Generator	Light	Circuit breaker

TABLE 44. CH-47C MAINTENANCE ACTION AND SEQUENTIAL PART REPLACEMENT LIST

Maintenance Action or Symptom	Replaced Part A	Replaced Part B	Replaced Part C
Engine vibration	Drive shaft	Engine transmission	Gearbox
Utility system hyd.	Pump	Generator	Aft transmission
Flight boost does not pressurize	Manifold	Pump	
Utility hyd. system pr.	Hyd. reservoir	Check valve	Relief valve
Flight boost leaking	Line	Fitting	Pump
SAS dangerous	SAS boxes	SAS links	Wire in cannon plug shorted

TABLE 44. CH-47C MAINTENANCE ACTION AND SEQUENTIAL PART REPLACEMENT LIST (Continued)

Maintenance Action or Symptom	Replaced Part A	Replaced Part B	Replaced Part C
Fuel boost pump	Wires	Pump	Valve
N_1 engine gage fluctuates	N_1 actuator	Control box	Droop eliminator
Ramp extention	Selector valve	Sequence valve	
Creeping ramp	Sequence valve	Ramp control	Manual override
Stiff cyclic	Magnetic brake	Bellcrank	Uniball
High-freq. vibration	Engine drive shaft	Engine drive shaft	Gearbox
High-freq. vibration	Aft transmission	Several parts	Hyd. pump
High-freq. vibration	Engine drive shaft	Pumps	Hyd. manifold
High-freq. vibration	Engine drive shaft	Quill shaft	Lord mount
High-freq. vibration	Engine	Nose gearbox	C-gearbox
High-freq. vibration	Engine drive shaft	C-gearbox	Cooler fan
Intercom inoperative	Radio	Control head	Cannon plug
APU	Fuel control	Speed switch	APU
APU does not start	90% speed switch	Relay box	Hour meter
APU comes on line	Starter fuel switch	Manifold switch	Igniter
APU	Spark plug	Exciter	
APU on line	Accessory gearbox motor	Valve	
AGB back on line	Pump	Control box	Manifold
AGB drags	Check valves	APU	Aft transmission
Broken stud, aft transmission	Stud	Transmission	
Combining gearbox	Sync. shaft	Mount bolts	
Generator	Generator	Generator	Shorted wire
Brake pucks	Bearing seal	Bearing	Wheel
Accumulator leaking	"O" ring	pr. gage	Accumulator
VGI inoperative	Gyro	Indicator	
Vibration	Engine transmission	Quill shaft	Drive shaft

Q11. Excessive leakage from gearboxes, pumps, and servos is determined by: observing sight gage, collecting fluid in container, counting drops (static), counting drops while operating, wiping part and watching for seepage that cannot be measured, and/or guessing that the leakage is excessive.

Tables 35 and 36 in the Diagnotics section of this report, where Q11 is further analyzed, show the distribution of how the respondents felt about each type of component. For gearboxes, the procedure of observing the sight gage was predominate. Sight gages should be designed so that they can be easily seen and adequate to be used as a measure for leakage if necessary. Either the pumps are wiped off and checked for seepage, or the part is observed while operating. This procedure is a difficult way to determine excessive leakage if the leakage rate is marginal. For servos, the procedure varied depending on the experience of the mechanic. Components that leak should be designed to provide a reasonable operating life without excessive leakage by the application of good seal design and should operate with fluid pressures that do not overstress the component.

Q37. Do you think that a maintenance test flight before each Periodic Inspection would reduce the number of repeated maintenance action(s) required after Periodic Inspection? The UH-1H(67N) respondents indicated that a maintenance test flight prior to a Periodic Inspection would reduce repetitive maintenance actions. The CH-47C(67U) respondents with 0-5 years experience indicated that a test flight would be beneficial. The CH-47C(67U) respondents with 6-10 year experience indicated a mixed attitude toward the advantages of a maintenance test flight. This question does not relate to applications directly and is discussed further in the Diagnostics section of this report.

Q16. Do you feel that you would perform better maintenance if you were permitted to disassemble repairable components to find out what caused a failure? As shown in Table 45, the respondents indicated they would perform better maintenance if permitted to disassemble repairable components. Perhaps it is necessary to design more components so that they can be disassembled and the failure isolated readily by maintenance personnel. Components that are modularized, where the mechanic replaces modules, can reduce downtime and improve maintenance efficiency.

TABLE 45. DISTRIBUTION OF RESPONDENTS WHO PERFORM BETTER MAINTENANCE BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Better Maintenance	UH-1H(67N) 0-2	UH-1H(67N) 3-5	UH-1H(67N) 6-10	CH-47C(67U) 0-2	CH-47C(67U) 3-5	CH-47C(67U) 6-10
Yes	71.83	78.78	74.52	61.22	25.51	52.38
No	28.17	21.22	25.68	38.78	24.49	47.62

(Column groups are under the heading "Years Experience".)

Q47. Excessive vibration is reported as a -13 write-up: after every flight, once every 2 flights, 4 flights, 10 flights or 25 flights. This question, directed to CH-47C(67U) respondents, was answered differently dependent on experience, as shown in Table 46. The less-experienced mechanics indicated a greater tendency to reporting excessive vibration after every flight, and the most experienced tended to indicate an excessive vibration write-up every 25 flights. The conclusion is that excessive vibration write-ups in the DA Form -13 result in recurring maintenance actions. Future designs should be such that vibration can be isolated within the component or system causing the problem. The use of diagnostics perhaps designed into the component could assist in identifying the source of excessive vibration.

TABLE 46. DISTRIBUTION OF REPORTED EXCESSIVE VIBRATION, CH-47C, BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

CH-47C(67U)	Number of Flights				
Years Experience	1	2	4	10	25
0-2	47	50	22	24	23
3-5	36	50	44	28	23
6-10	17	0	34	48	54

Q45. Which of the following repairs on the CH-47C are the most difficult to make successfully on the first attempt? Ten repairs were listed for this CH-47C related question. The results of CH-47C(67U) respondent selection are shown in Table 47 with the repairs ranked in accordance with the ranking procedure defined in the Questionnaire Analysis section. Tracking blades, the most difficult repair to complete successfully on the first attempt, may be difficult because of the tracking procedure and complexity in tracking two sets of blades, one of which can influence the track of the other. Safetying the aft transmission oil filter and rigging flight controls, the second and third ranked selections, are difficult because of inacessibility of the components. The design of such systems should take into account the location of components and reduced adjustment requirements.

TABLE 47. CH-47C REPAIRS MOST DIFFICULT TO ACCOMPLISH IN FIRST ATTEMPT

Rank	Repair Action	Years Experience			
		0-2	3-5	6-10	All
1	Tracking blades	20	37	31	31
2	Safetying aft trans oil filter	23	12	21	17

TABLE 47. CH-47C REPAIRS MOST DIFFICULT TO ACCOMPLISH IN FIRST ATTEMPT (Continued)

Rank	Repair Action	Years Experience 0-2	3-5	6-10	All
3	Rig flight controls	17	10	14	13
4	Adjust stability augmentation system	8	12	7	10
5	Electrical repair	12	6	7	8
6	Adjust N_1 actuator	9	6	4	6
7	Adjust engine control	5	6	6	5
8	APU repair	3	5	6	5
9	Generator repair	2	4	1	3
10	Engine tach. gen. repair	2	2	3	2

Q50. Repeat maintenance actions on the P-SAS are caused by: difficult adjustment, high failure rate for one component, availability of parts, lack of test equipment, or lack of training. Which of these is predominate? Table 48 shows the results by experience of CH-47C(67U) respondents. The lack of training followed by, or in combination with, the lack of test equipment was the predominate reason given for causing repetitive maintenance actions on the P-SAS system.

TABLE 48. CH-47C DISTRIBUTION OF CAUSES FOR REPETITIVE MAINTENANCE ACTIONS ON P-SAS, BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Cause of Maintenance Action	Years Experience 0-2	3-5	6-10
Lack of training	43	39	33
Lack of test equipment	23	25	36
Difficult adjustment	18	14	14
Availability of parts	11	9	8
High failure rate for one component	5	12	8

Difficulty in adjusting P-SAS, as brought out in the analysis of Q45, is the only indication that design might be partially responsible for repetitive maintenance actions. When adjustments are necessary, the system should be designed for access. When possible, parts should be designed so as not to require adjustment.

Q48. Which of the following most commonly cause a high-frequency vibration and require maintenance action? The 13 parts were ranked by the procedure described in the Questionnaire Analysis section and are shown in Table 49. The components in the dynamic drive train systems, such as shafts and gearboxes, should be designed so that the component causing a vibration can be readily identified. Diagnostic aids and vibration-sensing equipment as discussed in the analysis of Q20 in the Resources section can reduce the tendency for high-frequency vibration maintenance problems to become repetitive.

TABLE 49. CH-47C PARTS CAUSING HIGH-FREQUENCY VIBRATION, RANKED BY YEARS EXPERIENCE

Rank	Part Causing Vibration	Years Experience 0-2	3-5	6-10	All
1	Engine drive shafts	28	19	22	23
2	Cooler fan motor	8	13	11	11
3	Hanger bearings	10	10	8	10
4	Engine 90° gearbox	7	7	14	9
5	Forward rotor	9	9	4	8
6	Hydraulic pumps	5	9	9	7
7	Aft syncronizer shaft	9	5	6	7
8	Engine mounts	4	8	8	6
9	Forward syncronizer shaft	9	4	2	6
10	Aft rotor	5	8	4	6
11	Combining gearbox	2	6	9	5
12	Aft transmission	4	3	0	3
13	Forward transmission	0	0	2	1

Q46. What percentage of the maintenance actions on landing gear power steering fail to work the first time? The CH-47C(67U) respondents indicated that the maintenance actions on landing gear power steering failed to work less than 25% of the time. This question lacked adequate definition to find out how often repair of the landing gear power steering failed to work. As an arbitrary value, if the repairs failed to work 10% of the time, it would be too high. The reason that repairs fail to solve the problem is important. If it is poor design, then corrective action is warranted. If it is the lack of training, tools, or test equipment, then better support should be implemented.

Q49. What is the cause of unsuccessful repairs on flight boost accumulators? The CH-47C(67U) respondents indicated that repairs on flight boost accumulators are not successful because the part is not bench or submerge tested after seals are replaced in the field. A component designed to be repaired in the field should also be designed so that testing is not necessary or is a simple procedure not requiring extensive test equipment.

Q43. Which of the following items are hardest to troubleshoot? Of the 12 parts listed, the UH-1H(67N) respondents indicated that the engine was the hardest part to troubleshoot. Table 50 shows the ranking as performed by the procedure described in the Questionnaire Analysis section. The engine on the UH-1H ranked first and is one of the more complex systems. Access to engine accessories and components is a design responsibility. The second- and third-ranked items, fuel probe and transmission damper mount bearings, are inaccessible, showing the need for design consideration. Accessibility and system complexity are the major causes of difficulty in troubleshooting a problem.

TABLE 50. UH-1H PARTS HARDEST TO TROUBLESHOOT
RANKED BY YEARS EXPERIENCE

Rank	Part	Years Experience 0-2	3-5	6-10	All
1	Engine	24	21	20	21
2	Fuel Probes	10	18	18	15
3	Transmission Damper Mount Bearings	7	11	14	10
4	Irreversible Valves	7	9	15	10
5	Flux Valve on RMI	13	9	7	9
6	Fore and Aft Force Gradient Spring	9	12	6	9
7	Starter Generator	9	8	6	7
8	Collective Servo	7	1	4	6
9	Inverters	7	4	5	5
10	Cyclic Torque Tube	4	5	1	4
11	Oil Cooler	2	3	2	2
12	Main Transmission Oil Filter	1	0	1	1

Q40. Which of the following repairs on the UH-1H are the most difficult to make successfully on the first attempt? As shown in Table 51, the UH-1H(67N) respondents selected tracking of the main rotor as the repair most difficult to complete on the first attempt. The analysis of Q45 for the CH-47C revealed the same conclusion by the CH-47C(67U) respondents. The tracking of the UG-1H rotor is a repetitive action because adjustments must be made to control rods and hub assembly, followed by a check of the blade track to determine if the adjustment was correct. Simple tracking procedures and rotor design to reduce the need to track could reduce the impact of this problem. Shimming the synchronized elevator and adjustment of the linear actuator, the second and third respondent choices, are affected by inaccessibility and the need for adjustment. Component design should take into account the need for accessibility if adjustments are necessary.

TABLE 51. UH-1H REPAIRS MOST DIFFICULT TO ACCOMPLISH ON FIRST ATTEMPT, RANKED BY YEARS EXPERIENCE

Rank	Repair Action	Years Experience 0-2	3-5	6-10	All
1	Tracking main rotor	27	26	27	26
2	Shimming synchronizer elevator	13	17	20	17
3	Adjust linear actuator	14	18	16	16
4	Rig tail rotor	19	15	16	16
5	Adjust engine throttle linkage	14	12	13	12
6	Hydraulic problem	8	9	6	8
7	Replace rear damper mounts	5	5	4	5

Q41. Several attempts are necessary to properly adjust cyclic stick rigging because of: lack of proper tools, too many adjustment points, or location of adjustment points. The UH-1H(67N) respondents, as indicated in Table 52, said that the location of adjustment points necessitated several attempts to properly adjust cyclic stick rigging on the UH-1H helicopter. It is noted that as the mechanic's experience increased, too many adjustment points and the lack of proper tools were also important. The location and number of adjustment points can both be controlled by design. Consideration of the frequency of adjustment and simplification of the task during design and integration into the higher level system aid in reducing repetitive maintenance actions and improving maintenance efficiency.

TABLE 52. DISTRIBUTION OF CYCLIC STICK ADJUSTMENT PROBLEM BY PERCENTAGE OF RESPONSE AND YEARS EXPERIENCE

Reasons for Adjustment Problem	Years Experience 0-2	3-5	6-10
Location of adjustment points	36	41	38
Too many adjustment points	43	31	36
Lack of proper tools	21	28	26

The responses to certain questions relating to the applications attribute were considered to have possible significant correlations. To determine if the answers to these questions were independent of or dependent on one another, the χ^2 test was applied, with the results shown in Table 53. Those questions showing dependence on one another are further analyzed.

TABLE 53. APPLICATIONS QUESTIONS TESTED FOR DEPENDENCE

Question Combination	χ^2 test (%) (Calculated value)	χ^2 (99.8%) (Critical value)	Dependence
16/36	3.3	12.5	No
36/19	11.1	16.9	No
36/26	11.4	20.7	No
34/36	5.9	12.5	No
36/47	32.4	20.7	Yes
34/19	1.8	12.5	No
34/40	*Q40 ranked for Yes answers to Q34		Yes
34/41	0.1	12.5	No
34/43	*Q43 ranked for Yes answers to Q34		Yes
34/45	*Q45 ranked for Yes answers to Q34		Yes
34/48	*Q48 ranked for Yes answers to Q34		Yes
34/50	4.7	16.9	No

* Questions that were correlated but did not contain the elements for the χ^2 test were evaluated by stating a hypothesis and ranking the responses to the second question.

Q36/Q47. Are the answers to Q47 from the CH-47C(67U) dependent on the answers to Q36. The results of the χ^2 test indicate a relatively strong dependence among the answers to the two questions. Those personnel who thought that trial-and-error is used to correct maintenance problems also felt that excessive vibration was a common write-up. It can be concluded that vibration write-ups are a common cause for using trial-and-error as a procedure for correcting a maintenance problem. Vibrations are caused by a dynamic imbalance in a component and are sometimes transmitted to other parts of a drive train. The effect of vibration can be reduced by using diagnostics in the design, by the use of special test equipment (vibration meter as discussed in the analysis of Q20 of Resources section), and by providing adequate vibration isolation mounting of components.

Q34/Q40. The analysis of Q40 first ranked which repairs are most difficult on the first attempt as identified by all UH-1H (67N) respondents. The importance of the answers to Q34 in relation to Q40 is most valid if the answer to Q34 is Yes. Therefore, the ranking of answers to Q40 given that Q34 is Yes provides a listing of those repairs most difficult to make on the first attempt by only those personnel who think that the location of a part on the aircraft is important. Table 54 shows this ranking. All yes respondents to Q34 ranked the linear actuator as a more difficult repair than rigging the tail rotor. This was in reverse order to the UH-1H(67N) yes respondents.

TABLE 54. UH-1H REPAIRS MOST DIFFICULT TO COMPLETE ON FIRST ATTEMPT

Rank	Repair Action
1	Track main rotor
2	Shim synchronizer elevator
3	Rig tail rotor
4	Adjust linear actuator
5	Adjust engine throttle linkage
6	Hydraulic problem
7	Replace rear damper mounts

Future designs should avoid the need for adjustments, as they cause repeat maintenance actions for most of these repairs.

Q34/Q43. The analysis of Q43 first listed parts hardest to troubleshoot as identified by all UH-1H(67N) respondents. Q34 is most important in relation to Q43 if the answer to Q34 is yes. Therefore, the ranking of answers to Q43, given that Q34 is yes, provides Table 55, which gives those parts so located on the aircraft that they are hardest to troubleshoot. There is only slight variation in the list shown in Table 50 for the Q43 analysis and Table 55, indicating that the yes respondents to Q34 felt that the same parts were hardest to troubleshoot as the UH-1H(67N) respondents to Q34 felt. This conclusion only confirms the need for design consideration in the placement of parts within the airframe or system so that maintenance actions can be performed efficiently.

TABLE 55. UH-1H PARTS HARDEST TO TROUBLESHOOT

Rank	Part
1	Engine
2	Fuel probes
3	Flux valve on RMI
4	Fore and aft force gradient spring
5	Transmission damper mount bearings
6	Irreversible valves
7	Starter generator
8	Inverters
9	Collective servo
10	Cyclic torque tube
11	Oil cooler
12	Main transmission oil filter

Q34/Q45. The analysis of Q45 first ranked which repairs on the CH-47C are most difficult on the first attempt as identified by all CH-47C(67U) respondents. Q34 is most important in relation to Q46 if the answer to Q34 is yes. The ranking of answers to Q45, given that Q34 is yes, provides Table 56. This ranking of difficult repairs is by respondents who think the location of a part on the aircraft is an important cause of repetitive maintenance actions. The location of a part relative to its repair frequency is important in reducing repetitive maintenance and improving maintaining efficiency.

TABLE 56. CH-47C REPAIRS MOST DIFFICULT TO COMPLETE ON FIRST ATTEMPT

Rank	Repair Action
1	Track blades
2	Safety aft trans. oil filter
3	Rig flight control
4	Adjust stability augmentation system
5	Adjust N_1 actuator
6	Adjust engine controls
7	APU repair
8	Electrical repair
9	Generator repair
10	Engine tach generator repair

Q34/Q48. The analysis of Q48 first listed parts hardest to troubleshoot as identified by all CH-47C(67U) respondents. Q34 is most important in relation to Q48 if the answer to Q34 is yes. The ranking of answers to Q48, given Q34 is yes, is shown in Table 57. Those parts that most commonly cause a high frequency vibration are identified with the location on the aircraft as being an important cause of repetitive maintenance action. This confirms that maintenance personnel are aware that the location of a part is important and that future designs should place parts that require maintenance in accessible locations.

TABLE 57. CH-47C PARTS CAUSING HIGH-FREQUENCY VIBRATIONS

Rank	Part
1	Engine drive shafts
2	Cooler fan motor
3	Hanger bearings
4	Aft rotor
5	Forward rotor
6	Engine 90° gearbox
7	Hydraulic pumps
8	Aft synchronizer shaft
9	Forward synchronizer shaft

TABLE 57. CH-47C PARTS CAUSING HIGH-FREQUENCY VIBRATIONS (Cont'd)

Rank	Part
10	Engine mounts
11	Combining gearbox
12	Aft transmission
13	Forward transmission

LOGISTICS

Spare parts supply is that part of logistics that most affects repetitive maintenance. Parts that are not available when needed cause part substitution, delay, and cannibalization, resulting in repetitive maintenance actions. Based on analysis of the questionnaire, defective parts are issued thru supply channels at a rate of 8 or more per year to each mechanic who requisitions parts. Primary causes of these parts' contaminating the supply system were identified as ordering by incorrect Federal stock number and the improper service check of a part before being issued. Types of parts affected by these actions include major components and nonrecoverable items. Transmissions, rotors, servos, actuators, bearings, seals, and light bulbs are examples of parts issued which were incorrectly identified or defective, thus affecting maintenance efficiency. Maintenance procedures that reduce the need for the return, replacement, repair or shipment of parts reduce the supply burden and improve the efficiency of logistics support.

A total of 14 questions from the questionnaire were logistics related. The results of the analyses of these questions and 20 correlations between questions follow:

Q21. How many defective parts have been issued from supply in the past year? The average mean number of defective parts issued per year per mechanic reported was 8 based on the combined UH-1H (67N) and CH-47C (67U) mechanics' questionnaire response. Table 58 shows the mean number of defective spare parts issued to UH-1H (67N) and CH-47C (67U) mechanics by experience for a 1-year period. The UH-1H (67N) less-experienced men appeared to have obtained more defective parts than others. The data showed that the less-experienced men on the CH-47C(67U) received fewer defective parts than all others. This may be attributed to their not being in the position of responsibility where they would be requisitioning parts. The CH-47C, being a more complex helicopter than the UH-1H, has more than one mechanic assigned to it. The more experienced man is usually the one in charge and would be more apt to have parts issued to himself. The UH-1H usually has one man assigned to it and whatever his experience level is, he requisitions the parts he needs.

TABLE 58. DEFECTIVE SPARE PARTS ISSUED PER MECHANIC PER YEAR

Aircraft (MOS)	0-2	3-5	6-10	Total Mean
	Years Experience			
UH-1H(67N)	19.85	5.07	5.43	8.95
CH-47C(67U)	2.16	5.95	5.82	4.37
Combined Mean	12.63	5.36	5.52	7.58

Q22. What are the reasons for defective parts being issued from supply? The primary reason given by both the UH-1H(67N) and CH-47C(67U) mechanics was improper service check before issuing a part. This could indicate that supply personnel do not check the part number against the part record card and do not examine or test the part prior to issue. The second choice picked by both type mechanics was poor quality control. This may mean quality control at manufacturing thru overhaul or during shelf life storage.

Q23. How many wrong parts have you been issued in the past year? The average number of parts reported by the combined UH-1H(67N) and CH-47C(67U) mechanics was not as clearly defined as in question 21. The results of the respondents' actions, as shown in Table 59, in both UH-1H(67N) and CH-47C(67U) categories indicate that the more experienced and perceptive mechanic tends to make fewer errors in ordering parts and recognizes the correct part more often. The less experienced personnel are more prone to error. The higher number of wrong parts reported by these mechanics tends to substantiate this conclusion.

TABLE 59. WRONG SPARE PARTS ISSUED PER MECHANIC PER YEAR

Aircraft (MOS)	0-2	3-5	6-10	Total Mean
	Years Experience			
UH-1H(67N)	187.50	103.40	4.27	98.47
CH-47C(67U)	1.87	5.85	4.50	3.97
Combined Mean	111.70	76.99	4.32	55.95

Q24. What are the reasons for wrong parts being issued from supply? The primary response given by both the UH-1H(67N) and CH-47C(67U) mechanics was wrong Federal stock number (FSN) ordered. This is caused by the mechanic who orders the part initially and may be due to his carelessness in specifying the correct number or because the parts manual is difficult for him to understand. The supply clerk may be contributing to the problem by not checking the part number on the requisition form with the supply catalogue. He may not compare the part number requested with the actual number on the part at the time of issue. These assessments are supported by the response to the second and third choice answers of this question, which were: wrong FSN supplied and TM not clear. Both of these answers subjectively indicate that consideration should be given to improving supply manuals and the methods used in ordering and issuing parts.

Q25. Examples of wrong parts from supply having been installed on the aircraft include __________, __________. (Question as stated in the questionnaire.) The UH-1H(67N) mechanics reported 51 various wrong parts as having been issued. The CH-47C(67U) mechanics reported 26 various wrong parts issued. A listing of the parts reported is given in Table 60.

TABLE 60. WRONG PARTS ISSUED FROM SUPPLY

UH-1H

Part	Part	Part
Servo	Sync elevator	T/R sprocket
"O" rings	Pitch horn	Rotor blade
Bell cranks	Transmission lift link	Sencing units
T/R pitch link	Hyd filters	Seals
T/R crosshead	Mag. brake	Eye bolt
T/R pitch link bearing	Regulators	Fuel cap
Transmissions	Intermediate kit	Fuel pump
Tail light bracket	Valve, irreversible	Soundproofing
Skid shoe	Hyd pumps	Spring lever
Fuel control	Hinges	Cargo hook mirror
Reverse relays	Jump doors	Compressor blades
Hyd. dampers	Bearings	Glare shield
Cross tubes	Mixing valve	Chip detector
Hyd fittings	Fuel solenoid	Lamps
Seat covers	Oil filters	Rotating beacon
Scissors/sleeve	Gages	Push-pull tubes
Transponder	Actuators	Pylon mounts

CH-47C

Part	Part	Part
Control panel	Hardware	Servo cylinders
Master caution panel	Instruments	Blade damper
Engine drive shaft	Push-pull tubes	Drive shaft
Mag. brakes	Bushings	Soundproofing
N. actuator	Nuts	Engine covers
Hyd pumps	Lines	Rod and bearings
MLG brake	"O" ring	Fuel caps
Actuator, pivot	Speed trim	Bolts
	APU control	Clamps

Q29. What percentage of the time are parts condemned as defective when actually they were serviceable? The responses were intended to provide insight as to the severity of this condition. Response indicated that more than 10% of the serviceable parts are condemned and burden the supply operation. This was reported by 30% to 52% of all respondents. A response indicating that over 10% of all parts are condemned when they are actually serviceable clearly indicates that procedures to correct this condition are warranted. Improvements in the other attributes such as resources and diagnostics could help to further reduce the severity of this problem.

Q27. As the result of trial-and-error troubleshooting, serviceable parts are turned into supply as unserviceable. Why does this happen? The least experienced mechanics on the UH-1H(67N) and CH-47C(67U) strongly indicated that their reason for turning a serviceable part into supply as unserviceable was that they were afraid the part was contaminated from being used in troubleshooting. The more experienced mechanics were less specific as to reason for this condition. Two predominant causes they indicated were: (1) "no way of accounting for an extra part" and (2) "it was easier to do it that way". The intent of this question was first to see if the assumption that the condition existed was valid, and second to see if the proposed reasons were accurate. It appears that the assumption was valid from the high respondent participation and that the reasons were correct. This is a maintenance practice which should be avoided by use of better diagnostic procedures.

Q28. What serviceable part(s) have you seen turned in to supply as unserviceable (in the past year)? As shown in Table 61 the UH-1H(67N) mechanics reported 57 various parts and the reason for being turned into supply as unserviceable. The CH-47C(67U) mechanics reported 19 parts as listed in Table 62.

TABLE 61. UH-1H PARTS RETURNED TO SUPPLY AND REASON FOR UNSERVICEABILITY

Part	Reason	Part	Reason
Engine oil radiator	Possible metal particles	Attitude indicator	Broken
Oil cooler	Outdated		Inoperative
Overspeed governor(s)	Inoperative because we had a new one		Unreliable
		Altimeter	Adjustment
Force gradient(s)	Electrical short	Pressure gage	Faulty reading
	binding in flt. control	Oil gage	Inoperative
Deicing valve	Failed in open position	Oil temp sending unit	Bad oil cooler

TABLE 61. UH-1H PARTS RETURNED TO SUPPLY AND REASON FOR UNSERVICEABILITY (Continued)

Part	Reason	Part	Reason
Battery	Overcharging	Engine temp gage	Bad oil cooler
Trunnion(s)	Poor quality excessive play	Cyclic lockout valve	Maint. supv. decision
Actuator(s)	No DA Form 2410 binding sticks occasionally	Hyd. pr. switch(s)	Caution light inoperative
Inverter	Excessive noise	Irreversible valve(s)	Leaking Defective cylcic stick Pilot valve
Tach. generator(s)	Adjust fluctuation		
Torque meter	Broken glass	42° Gearbox	Seals
Torque gage	Inoperative	Boost pump	Internal failure
Torque pr. transmitter	Gage fluctuates	Pitch change link(s)	Too much play Worn, but not out of tolerance
Voltage regulator(s)	No output Would not regulate		
		Magnetic brake(s)	Binding said to be sticking
Main rotor damper(s)	Bearing worn	Fuel control(s)	Adjust. wrong at factory Troubleshooting Leaking Wrong series Engine surge Throttle arm tight
Rotating beacon(s)	Motor sticks Will not rotate		
Landing light	Open circuit breaker broken		
		Transmission	Dropped
Generator(s)	Burned out Brushes not installed properly	Hydraulic pump(s)	Binding controls Misdiagnosis Wrong pr. setting No new type fittings seals Seeping Noisy Internal failure
Main rotor blade(s)	Internal defect No paperwork Different weight Leading edge - not enough protection Leading edge - strip bubbling. Separation, void	Rod end bearing(s)	Worn (within limits) Too much play
		Mixing lever bearing	Could not see snap ring
		Servo(s)	Leak

TABLE 61. UH-1H PARTS RETURNED TO SUPPLY AND REASON FOR UNSERVICEABILITY (Continued)

Part	Reason	Part	Reason
Tail rotor blade(s)	Leading edge - not enough protection	Servo(s)	Contaminated
Skid shoe(s)	Made from wrong metal		Slipring mark not on retaining ring
	Extra part		Feedback
Main rotor hub(s)	Found on airfield		Internal binding
	Seeping		No irreversible valve
	Seals deteriorated. Vibration		Supervision said to replace it
	Could not balance		No paperwork
90° Gearbox(s)	Contaminated	Lift links	Unserviceable
	No paperwork	M/R universal	Axial play
	Seals - leak	APU pump	Worn shaft
		Swashplate	Packed incorrectly
Drive shaft(s)	Tech-insp.fault	Sync elevator	Worn excessively
	Worn excessively	Cargo door	Door sprung
	Rubber torn	Fuel pr. switch	
Relays	Used for troubleshooting	Engine mounts	Worn bearings
Cowling	Chafed		
Tail rotor hub	Bearing worn		
Engine	Overtemp. on gauge		
	Bearing leaking		
Master caution panel	No test equipment		

TABLE 62. CH-47C PARTS RETURNED TO SUPPLY AND REASON FOR UNSERVICEABILITY

Part	Reason	Part	Reason
Magnetic brake	Sticking	SAS link	Could not adjust
Tach. generator	Not accountable		
Rotor tach	Pin in shaft broken	"C" box(s)	Suspected causing vibration
Hyd fitting	Not authorized		
Actuator(s)	Leaking unknown	Sync shaft	Suspected causing

TABLE 62. CH-47C PARTS RETURNED TO SUPPLY AND REASON FOR UNSERVICEABILITY (Continued)

Part	Reason	Part	Reason
	No DA Form 2410		vibration
	Burned out	Damper(s)	Dead spot in lead/lag
SAS filter	Leaking		Contamination
	No "O" ring in filter element	Oil pr. indicator	Fluctuating
Magnetic compass	Did not swing		
Pump(s)	Leaking	Drive shaft	Vibration
	Wrong FSN	Valve(s)	Leaking
	Installed incorrectly		Creeping ramp
		Seat	Dirty
Accumulator(s)	Internal failure suspected		
	Leaking		
Ramp control	Creeping ramp		
	Internal failure		
Cooler fan	Seeping		

Q30. After removal, is a suspected failed part again checked before being sent out of your unit for analysis and repair? The respondents' yes and no answers were nearly equal in number with only a slightly higher percentage saying that parts are not checked again before being sent out for analysis and repair. This response is inconclusive and does not clearly define a logistics problem.

Q31. When a nonrepairable part has failed, do you attempt to find out why it failed? The UH-1H(67N) respondents were more affirmative (64%) than the CH-47C(67U) respondents (53%) as to their attempt to find out why a nonrepairable part failed. This could be because the UH-1H helicopter is less complex than the CH-47C. Because of this, the UH-1H(67N) mechanics may be more inclined to see if they can learn something from the failed part that will help them keep their helicopters flyable more of the time. The UH-1H maintenance personnel and aircraft are often dispersed from their support activities and have to be more self supporting. The results of this question do not signify a strong trend. It is suspected that only the more curious and motivated mechanics on both helicopter types try to find out why parts fail. If the reason for failure were determined and corrective action taken, the supply system could be improved by the purging of unreliable parts and the supplying of more reliable parts.

Q10. Before a repairable part is sent out of your unit for analysis and repair, it is: operationally tested to see if it is unserviceable, packaged and shipped without further checking, bench tested, or checked by the technical inspector. Respondents reported that the part is checked by a technical inspector prior to being sent out of the unit for analysis and repair. This is a standard operational procedure in most aviation units. The technical inspector's check is usually that of visual static inspection and a review of the DA Form 2410 record. Effect on the supply system operation is not measurable from the results of this question analysis. If procedures were changed and if parts could be operationally tested at the unit level, some parts would not require repair and the burden on the supply system to replace the parts would be reduced.

Q12. Are recoverable parts frequently sent out for repair because trained personnel are not available? Over 70% of all respondents said yes to this question. This means that if trained personnel were available to perform repairs at the unit level, the supply burden would be reduced.

Q13. Is test equipment used to check out removed parts to determine if they are serviceable before they are turned into supply? Over 65% of all respondents reported no to this question. If test equipment were available and used to check out parts prior to seeking replacement parts, the supply system support requirement would be reduced.

Q42. Several replacements of a main rotor head to correct 1-to-1 vibration are common maintenance requirements, yes or no? This question was directed to UH-1H(67N) respondents only. Over 16% of those responding indicated that replacement of rotor heads was a procedure used to troubleshoot a 1-to-1 vibration problem. The effect of this procedure on the supply system is to aggravate the supply burden for delivery of rotor heads. It was not established from the response to this question that this was a common practice, but it confirmed that the procedure is used.

The responses to certain questions relating to the logistics attribute were considered to have possible significant correlations. To determine if the answers to these questions were independent of or dependent on one another, the χ^2 test was applied, with the results shown in Table 63. Those questions showing dependence on one another are further analyzed. If the value arrived at in performing the χ^2 test is greater than the χ^2 value for 99.8% significance, there is an indication that the answers to the first question have a correlation with the answers to the second question.

TABLE 63. LOGISTICS QUESTIONS TESTED FOR DEPENDENCE

Question Combination	χ^2 Test (%) (Calculated)	χ^2 (99.8%) (Critical value)	Dependence
29/10	3.4	20.7	No
12/29	14.7	12.5	Yes
29/27	11.7	20.7	No
13/29	16.8	12.6	Yes
30/29	7.0	12.5	No
31/29	1.1	12.5	No
13/10	27.3	14.8	Yes
12/13	6.6	9.4	No
13/27	6.3	14.8	No
13/30	37.3	9.4	Yes
27/10	6.8	26.1	No
12/27	11.8	14.8	No
30/27	3.8	14.8	No
30/10	16.1	14.8	Yes
30/12	0.9	9.4	No
30/31	17.7	9.4	Yes
31/10	3.4	14.8	No
31/12	0.1	9.4	No
31/13	0.1	9.4	No
12/10	15.0	14.8	Yes

Q12/Q29. Are the answers to Q29 from the respondents who answered Q12 independent of or dependent on the answers to Q12? The results of the χ^2 test indicate that there is a correlation between the answers to the two questions. From this result it is concluded that the same personnel who felt that recoverable parts are sent out for repair because trained personnel were not available also felt that parts are condemned which actually are serviceable. In these responses the supply system is affected by the unnecessary movement of parts. Corrective procedures to reduce the conditions identified in the two questions would improve supply support.

Q13/Q29. Are the answers to Q29 from the respondents who answered Q13 dependent on the answers to Q13? The results of the χ^2 test show a correlation between the responses to both questions. It is concluded that those who said that test equipment is not used to check out removed parts felt also that parts are condemned when they are actually serviceable. Reduced burden on the supply system could result from corrective action to reduce movement of parts because of the conditions identified in the two questions.

Q13/Q30. Are the answers to Q30 from the respondents who answered Q13 dependent on the answers to Q13? The results of the χ^2 test indicate a correlation between the responses. It is concluded that those respondents who said that test equipment is not used to check out removed parts also felt that testing of repairable parts is important. By testing parts prior to their being sent out for repair, fewer parts would be placed in the supply system and fewer replacement parts would be necessary.

Q30/Q10. Are the answer to Q10 from the respondents who answered Q30 dependent on the answers to Q30? The results of the χ^2 test show a correlation between the responses. This correlation verifies that those that responded to Q30 in the affirmative demonstrated their action by identifying the type of check performed in responding to Q10.

Q30/Q31. Are the answers to Q31 from the respondents who answered Q30 dependent on the answers to Q30? The results of the χ^2 test show a correlation between the responses. Those respondents who said suspected parts are checked before being sent out for repair also attempt to determine why nonrepairable parts fail. Both conditions help to unburden the supply system.

Q12/Q10. Are the answers to Q10 from the respondents who answered Q12 dependent on the answers to Q12. The results of the χ^2 test show a correlation between the responses. It is concluded that the respondents who said that recoverable parts are sent out for repair because trained personnel are not available also identified the type of testing used to check a part before it is sent out for repair. This indicates that parts are frequently sent out for repair because trained personnel are not available. The additional parts generated from this action burden the supply system and increase work load.

ATTRIBUTE/QUESTION CROSS-REFERENCE LISTS

The following list shows the questions by numbers identified with the attribute and the order in which they are analyzed.

Environment	Resources	Diagnotics	Applications	Logistics
Q17	Q4	Q14	Q36	Q21
Q33	Q32	Q36	Q26	Q22
	Q12	Q 8	Q34	Q23
	Q 5	Q15	Q19	Q24
	Q37	Q11	Q18	Q25
	Q44	Q26	Q11	Q29
	Q 7	Q 9	Q37	Q13
	Q 6	Q50	Q16	Q27
	Q35	Q41	Q47	Q28
	Q20	Q49	Q45	Q30
	Q13	Q37	Q50	Q31
	Q33	Q32	Q48	Q10
			Q46	Q12
			Q49	Q42
			Q43	
			Q40	
			Q41	

The following list shows the questions on which analyses were performed for correlation as identified by attribute and the order in which the analysis was performed. Those question combinations that show correlation are identified by an asterisk.

Environment	Resources	Diagnostics	Applications	Logistics
Q17/Q33	Q4/Q5	Q4/Q8	Q16/Q36	Q29/Q10
	Q4/Q12	Q14/Q36	Q36/Q19	Q12/Q29*
	Q4/Q13	Q36/Q8*	Q36/Q26	Q29/Q27
	Q4/Q20	Q32/Q36	Q34/Q36	Q13/Q29*
	Q4/Q33*	Q15/Q26	Q36/Q47*	Q30/Q29
	Q4/Q38	Q37/Q8	Q34/Q19	Q31/Q29
	Q38/Q13	Q37/Q36	Q34/Q40*	Q13/Q10*
	Q38/Q20		Q34/Q41	Q12/Q13
	Q38/Q33*		Q34/Q43*	Q13/Q27
	Q12/Q13		Q34/Q45*	Q13/Q30*
	Q5/Q33*		Q34/Q48*	Q27/Q10
	Q5/Q39*		Q34/Q5	Q12/Q27
	Q13/Q44			Q30/Q27
	Q6/Q7*			Q30/Q10*
	Q7/Q33*			Q30/Q12
	Q7/Q35			Q30/Q31*
	Q6/Q33*			Q31/Q10
	Q6/Q35			Q31/Q12
	Q6/Q38			Q31/Q13
	Q6/Q20			Q12/Q10*

REPETITIVE MAINTENANCE ACTION

DATA ANALYSIS

Over 5,000 U. S. Army aircraft inspection and maintenance records, DA Form 2408-13, covering a 6-month period, were analyzed to assess:

1. causes of repetitive maintenance action,
2. types of prevalent repetitive maintenance, and
3. subsystems or parts causing repetitive maintenance.

For completeness, 8,500 flight hours covering a 30-month period of Operational Reliability Maintainability Engineering (ORME) program data gathered under U. S. Army Contract DAAJ01-71-C-0441 were analyzed to assess repetitive maintenance on CH-54B helicopters.

The analyses revealed a total of 1,295 repetitive maintenance actions distributed by helicopter model. These actions were compared with aircraft utilization rates provided by the Eustis Directorate, AMRDL, as reported in Army Aircraft Inventory, Stations and Flying Time Report, DA Form 1352. The results are shown in Table 64.

TABLE 64. REPETITIVE MAINTENANCE ACTION RATE

Helicopter Model	Utilization Rate per Month (hr)	Number of Aircraft	Number of Months	Total Hours	Number Repeat Action	Actions per Flt Hr
UH-1H	17.3	25	6	2595	601	0.231
CH-47C	8.0	21	6	1008	324	0.322
CH-54B	8.5	21	30	5418	370	0.068

As can be seen, actions per flight hour are highest on the CH-47C, possibly because it is more complex than the UH-1H. The differences in actions per flight hour of the UH-1H, CH-47C, and CH-54B may partly be attributable to the differences in data bases, as discussed subsequently in this section.

Further insight is provided by Figure 5, which shows the causes of maintenance actions by the attributes discussed earlier in this report. Figure 5 shows the prime cause of repetitive maintenance by model, as given in Table 65.

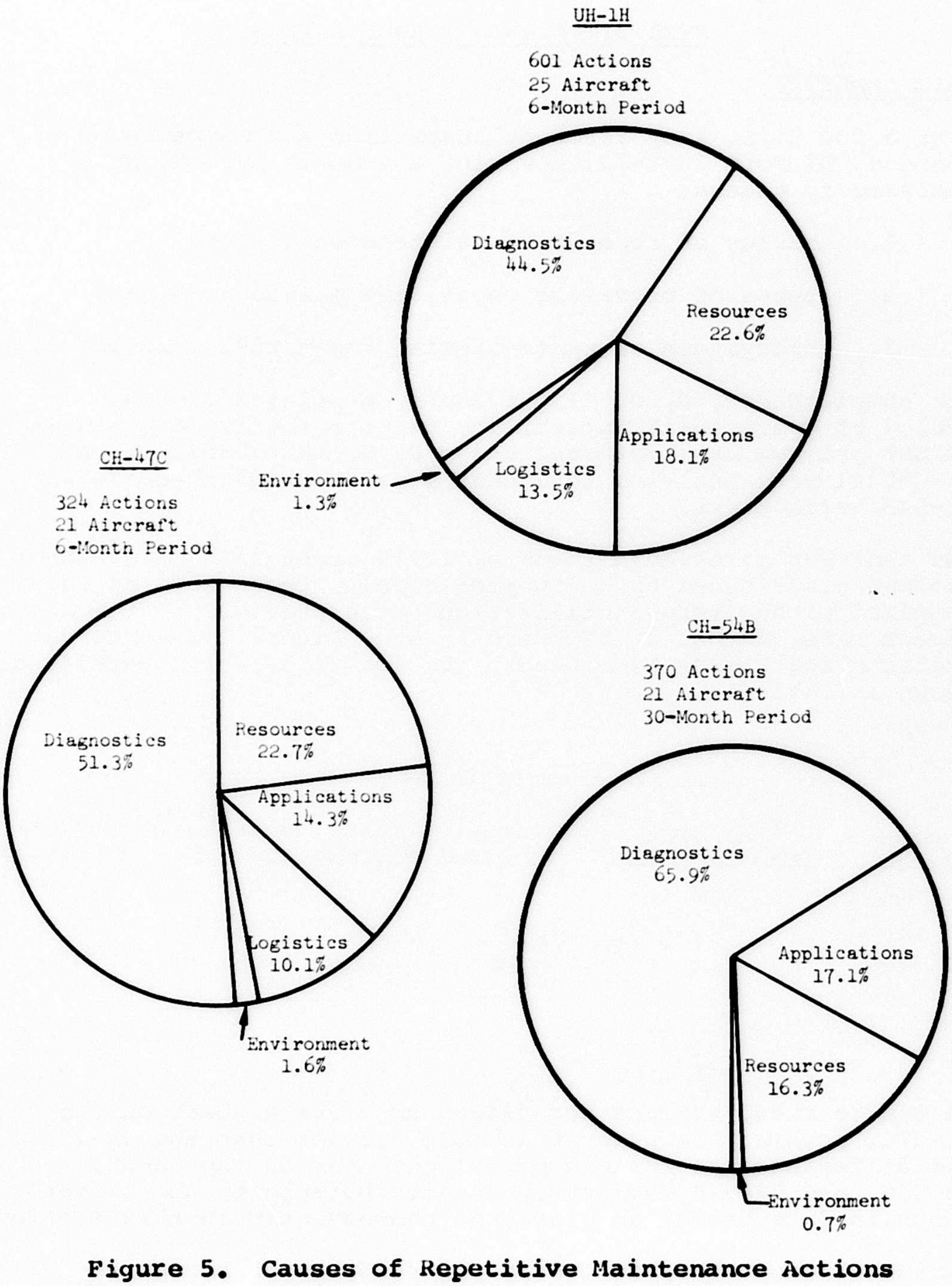

Figure 5. Causes of Repetitive Maintenance Actions by Attribute.*

*** See Table 5 for the definitions of these attributes.**

TABLE 65. CAUSES OF REPETITIVE MAINTENANCE

Model	Prime Cause	Secondary Cause	Percentage of Actions per A/C Prime Cause	Percentage of Actions per A/C Secondary Cause
UH-1H	Diagnostics	Resources	44.5	22.6
CH-47C	Diagnostics	Resources	51.3	22.6
CH-54B	Diagnostics	Applications	65.9	17.1

DISCUSSION

Diagnostics is the highest ranked cause of repetitive maintenance. It includes the use of test equipment, troubleshooting, and standard maintenance practices. Indications are that repetitive maintenance can be reduced markedly by improving the diagnostics of the aircraft systems studied. Troubleshooting by trial-and-error, when it involves dynamic components, can be costly in lost aircraft availability and high material usage. Vibration is a significant symptom that leads to multiple replacement of such components as rotors and blades. In these cases, the use of a vibration meter, which is a diagnostic tool, could alleviate the problem. In the questionnaire analysis section under Diagnostics, it is noted that 66% of the maintenance personnel interviewed did not have access to the use of a vibration meter. A follow-on investigation is recommended to identify specific diagnostic equipment and changes in maintenance procedures to improve Army diagnostics cost effectively.

Resources include training, tools, and maintenance manuals. Resources are the secondary cause of repetitive maintenance on the UH-1H and CH-47C. Based on the number of maintenance actions associated with instrument and sensing units, it appears that tools listed in the TOE may not be available or tools may not be listed in the TOE and therefore are not available. For example, there may be a need for temperature/pressure gage testers to isolate instrumentation equipment so that it does not cause a maintenance action when a mechanic is examining temperature or pressure discrepancies in a gearbox. Gearboxes have been replaced when only a gage or probe sensor unit was at fault. If they are the faulty parts, gages and sensing units are easier and less costly to replace than gearboxes. This indication is reinforced by the responses received in the questionnaire survey.

Mechanics who were interviewed felt that maintenance manuals sometimes were not as readily available as they should be. They also indicated that the troubleshooting procedures in the manuals were sometimes incomplete or covered only the obvious problems. A logical inference from these comments is that the mechanic attempts to solve a problem by trial-and-error. When the mechanic is experienced, this may actually facilitate solution of the problem. In many cases, however, the mechanic may not have the required experience, and the result is excessive repetitive maintenance. A significant reduction in repetitive maintenance could be achieved by assuring ready availability of the manuals and by having more comprehensive troubleshooting tables. One way to improve troubleshooting tables would be to solicit from experienced mechanics procedures that have proved to be successful and then adding these to the tables. More extensive training in troubleshooting might also help.

Analysis of ORME program data showed that the secondary cause of repetitive maintenance on the CH-54B is applications (17.1%), with resources (16.3%) a close third cause. It is suspected that the use of ORME data may have caused an unanticipated bias in the analysis, as compared with the UH-1H applications (18.1%) and CH-47C applications (14.3%), for which DA From 2408-13 was used as the data source. DA Form 2408-13 is oriented toward showing maintenance support problems. ORME reports are oriented toward showing design problems that can be eliminated cost-effectively by product improvement. This may have been the prime reason for the reversal of ranking of applications and resources on the CH-54B.

On all three aircraft models, there is little doubt that product improvement to facilitate maintainability can reduce repetitive maintenance.

Analysis of DA Form 2408-13 required considerable care and judgement. Entries relating to the same problem often used different terminology, abbreviated description, and different assessment of the problem by different personnel. Entries were sometimes illegible. The response to question No. 32 ("In general, how accurate is the flight crew -13 write-up?") was a choice of poor, fair, or good. Of the respondents, 70% felt that entries on the DA Form 2408-13 were less than good as shown in Table 40, Diagnostics section. Many of these same respondents fill out the DA Form 2408-13 as part of their assigned jobs as crew chief or flight engineer. This suggests the possible need for better training, motivation of personnel filling out the form, or a change in the form to simplify the procedure.

Special care was taken to sort out a large number of "carried forward" entries from DA Form 2408-13 where the problem was not repetitive maintenance, but possibly a logistics problem or local maintenance procedure that allows maintenance actions to be delayed daily until a scheduled inspection period.

The following sections divided by helicopter model provide further insight into the subsystems and parts that cause repetitive maintenance.

UH-1H REPETITIVE MAINTENANCE ACTION DATA ANALYSIS

Aircraft inspection and maintenance records, DA Form 2408-13, encompassing 6 months of data on 25 UH-1H helicopters from three typical operational sites were reviewed intensively to sift out repetitive maintenance actions. The total number was 601. Of the 49 subsystems and parts identified, as listed in Appendix A, Table A1, the ten parts having the highest number of repetitive maintenance actions per aircraft were analyzed relative to causes of repetitive actions. They are ranked in Table 66, showing the average action per aircraft and the maintenance attribute considered to be the prime cause of the action.

The attributes found to be most predominant in causing repetitive maintenance are diagnotic, resources, and logistics.

TABLE 66. CAUSES OF REPETITIVE MAINTENANCE ACTIONS, UH-1H (6 MONTHS DATA)

Rank	Repeat Maintenance Action	Average No. Actions per Aircraft	Prime Cause(s) Attribute
1	Attitude Indicator	11.5	Logistics
2	Engine Oil Temperature	11.0	Diagnostics/ Resources
3	ADF	8.5	Logistics
4	Rotor Vibration	8.3	Diagnostics
5	Engine RPM Governor Switch	7.8	Diagnostic/ Resources
6	Transponder, IFF	7.3	Diagnostics/ Resources
7	42° Gearbox Seal	6.7	Resources/ Applications
8	UHF/FM Radio	6.6	Diagnostics/ Logistics
9	Generators	6.4	Diagnostics/ Resources
10	Pitch Control Link	5.5	Diagnostics/ Applications

Maintenance actions recorded from the DA Form 2408-13 entries include those "carried forward" entries considered to be significant for showing the effect of such action relative to the entire repetitive maintenance analysis. The "carried forward" entries reflect one of two possible causes for lack of maintenance effectiveness. The first possible reason for this procedure is that logistics support is not providing replacement parts and the aircraft can remain operational meanwhile. The other conclusion reached with regard to this condition is that it has become a localized maintenance procedure to delay maintenance actions until the aircraft is "down" or grounded for a scheduled inspection period. This localized procedure may be caused by a lack of trained personnel, heavy flying schedule, or poor supervision.

The pilot/copilot VGI attitude indicator was found to have the highest repetitive maintenance action. This instrument provides pitch and roll information to the flight crew. The aircraft is flight limited to VFR when the indicator is inoperative. Because UH-1H operation is mostly VFR, failure of the attitude indication was not operationally significant. Of the repetitive actions recorded from DA Form 2408-13 entries, 79% were "carried forward." This is a strong indication that the replacement part was not available and that logistics was responsible for the delay in performing corrective action. The maintenance action to replace an attitude indicator is simple and would normally have been performed if parts had been available.

The engine oil temperature indicating system, ranking second in repetitive maintenance action entries in the DA Form 2408-13, reflected a noticeable use of trial-and-error in troubleshooting the system. As an example, the following entries are repeated:

Aircraft Flight Time	Indication	Action
2532.1	engine oil temperature reads 93°	replaced oil line, replaced kinked line to reservoir
2557.6	engine oil temperature 97°C at 94% and 22 lb torque	carried forward
2559.5	engine oil temperature 97°C at 94% and 22 lb torque	flushed cooler, replaced gage
2562.5	engine oil temperature 90° - 93° for 1 hr 25 min, then 95° for 5 min	carried forward

Aircraft Flight Time	Indication	Action
2565.3	engine oil temperature 90° - 93° for 1 hr 25 min, then 95° for 5 min	replaced cooler, temperature bulb, thermo-relief valve, oil cooler fan assembly, engine oil pump; removed and reinstalled engine oil filter

This problem continued for over 33 flight hours and two months of operation. With the trial-and-error method used to correct the problem, the cause remained unknown. The primary reason for using trial-and-error may be inadequate diagnostics and resources support. Better trained mechanics with improved troubleshooting tables in the maintenance manuals may reduce the use of trial-and-error, and fewer repetitive maintenance actions of this kind may occur.

The ADF radio navigation system ranked third in repetitive maintenance actions, with 76% of the entries from DA Form 2408-13 records being "carried forward." This strongly indicated a logistics problem. Little maintenance can be performed at organizational level other than replacement of the component. Failure modes were not clearly described. Capability for testing avionics components at organizational level is limited by currently available test equipment and availability of trained personnel.

The forth-ranked system was the main rotor and vibration. Diagnostics was indicated as the attribute most responsible for this condition. Trial-and-error was used in attempts to correct the problem. Main rotor blades are usually tracked first, followed by replacement of a worn control rod bearing or scissors that needed shimming. Pylon and transmission mounts were also considered by the mechanic as possible causes of the problem. Here is a condition in which the amount of vibration experienced is reported as excessive by the operating pilot and found to be normal by the maintenance test pilot. A difference of opinion results in repetitive maintenance actions. More important, perhaps, is the fact that a vibration meter, which is considered to be diagnostic equipment, is not generally employed to determine severity of vibration or its source. When maintenance personnel were interviewed, in response to Question No. 20 ("Do you have a vibration meter available for your use?"), 27% answered "No". Question No. 44 asked, "What additional test equipment would be of value to you?" Of six different pieces of test equipment listed, the vibration meter received the highest percentage response.

Training in how to use test equipment, for example, the vibration meter, and more definitive troubleshooting procedures would reduce repetitive maintenance actions on the rotor system.

The engine RPM governor/switch ranked fifth in repeat actions, and the causes appeared to be diagnostics and resources. Corrective action appears to be a series of adjustments and readjustments to correct such DA Form 2408-13 entries as "RPM too high" or "RPM low." This may be a case in which the pilot reporting the problem and the maintenance test pilot differ in their reaction as to what constitutes an out-of-limit RPM control. It appears that additional training, better defined limits or tolerances on RPM adjustments, or an improved RPM control system to reduce the need for constant adjustment would reduce repetitive maintenance actions.

The transponder, APX-72, ranked sixth in repetitive actions per aircraft. The entries taken from DA Form 2408-13 records indicate the need for training and diagnostic aids in troubleshooting the system. Repetitive actions of resetting the circuit breaker and replacement of parts without correcting the problem or isolating the cause show the mechanic's need for more information on how the system works and how to repair it.

The 42° gearbox input seal ranked seventh. The seal protects the intermediate gearbox from fluid loss in static and dynamic conditions. The cause of repeat actions can be related to resources and applications. Seals are replaced and then reported on the following flight as leaking again, indicating possibly incorrect installation procedure or incorrect seal. Improved training, proper tools, and more complete instructions on how to replace seals would improve this condition and reduce repetitive actions. When seals are not available, the problem is "carried forward" until the part is supplied. Improvement in logistics support would also assist in reducing repetitive actions.

The eighth-ranked component on the UH-1H was the VHF/FM radio. The causes for these repetitive actions appear to be related to diagnostics and logistics. When the UHF/FM radio was reported as a problem, one of the components was replaced, or the write-up was "carried forward" until replacement parts were obtained. Troubleshooting of avionics equipment at organizational level is not authorized or technically supported. Therefore, there is little choice to replace parts as necessary to keep the system operational. If this is the maintenance policy, then adequate logistic support should be provided to reduce repetitive actions that are otherwise performed.

The main/standby generators were ranked to have the ninth highest repetitive action. The entries recorded from DA Form 2408-13 records show voltage out of adjustment to be the primary complaint. Readjustments are repeated every few flight hours. From this, it appears that the voltage readings by flight crew and maintenance personnel are interpreted differently. Correct readings should be defined and clearly prescribed in the maintenance manuals. Test equipment or procedures should be established for adjusting the voltage. A system that would not require periodic adjustment to maintain critical limits would also reduce repetitive actions.

The pitch control link ranked as tenth in repetitive maintenance actions. Bearing wear was the predominant write-up. The reasons for repetitive actions were classed as diagnostics and applications. The reason for assigning the diagnostics attribute was the replacement policy for trunnion bearings without a way of measuring wear or bearing play as a criterion for replacement. The application attribute is related to finding a bearing design that would reduce wear and the requirement for replacement.

The remaining parts that cause repetitive actions have ties to the basic attributes similar to those discussed in the above analyses.

CH-47C REPETITIVE MAINTENANCE ACTION DATA ANALYSIS

Six months of aircraft inspection and maintenance records, DA Form 2408-13, on 21 CH-47C helicopters from three typical operational sites were reviewed to obtain representative repetitive maintenance action data. It was found that 324 repetitive actions were recorded, and 47 different parts or systems were found to be related to repetitive maintenance actions. The entire list is presented in Appendix A, Table A2, The ten parts having the highest number of maintenance actions per aircraft are analyzed relative to causes for repeat actions. They are ranked in Table 67, showing the primary attribute considered to be the cause of these actions.

The attributes found most predominant as shown in Figure 5 are diagnostics, resources, and logistics.

TABLE 67. CAUSES OF REPETITIVE MAINTENANCE ACTIONS, CH-47C (6 MONTHS DATA)

Rank	Repeat Maintenance Action	Average No. Actions per Aircraft	Prime Cause(s) Attribute
1	Fuel-Low Light	11.0	Diagnostics/ Logistics
2	Check Valve	9.0	Diagnostics/ Logistics
3	High-Frequency Vibration	8.3	Resources/ Diagnostics
4	Speed Trim	8.0	Resources/ Diagnostics
5	Transmission Oil Pressure Light	7.0	Resources/ Diagnostics
6	Pilot-Stability Augmentation System	6.5	Resources/ Diagnostics
7	Lateral Vibration	5.7	Diagnostics
8	Attitude Indicator	5.2	Diagnostics/ Logistics
9	APP Mount	5.0	Logistics
10	Transponder	5.0	Diagnostics/ Logistics

These maintenance actions, as recorded from DA Form 2408-13 entries, include those "carried forward" entries considered to be significant for the purpose of showing their effect relative to the whole repetitive maintenance action analysis.

The fuel-low warning light caused the highest number of repetitive maintenance actions per aircraft. The causes of these actions were assessed to be diagnostics and logistics. The diagnostics attribute was designated as the cause of these actions on the basis of the DA Form 2408-13 entries. For example, consider the following: it took 5 flight hours after the initial entry in the DA Form 2408-13 to confirm the problem, and another 25 flight hours taking no corrective action except to "carry forward" until a fuel probe was replaced; even then, the fuel probe replacement did not correct the discrepancy. Delay in obtaining a fuel probe was probably caused by logistics. In this case, lack of replacement parts would explain the "carried forward" entries. When the probe replacement did not resolve the problem, the action again was a trial-and-error troubleshooting procedure that was ineffective. From this example, it appears that availability of logical procedures in checking out a system would reduce the number of repetitive maintenance actions.

A check valve in the combining gearbox was ranked as having the second highest repetitive maintenance action. The attributes considered to cause this were diagnostics and logistics. The DA Form 2408-13 entries reported a bad check valve followed by "carried forward" entries without a corrective action. This was a condition that did not require corrective action, or a replacement part was not available, or corrective action was too difficult to perform except during periodic inspections. The condition in this example was entered on the DA Form 2408-13 record nine times in 37 operational flight hours. "Carried forward" entries generally signify a logistics problem awaiting parts, but it appears that in this example a localized maintenance policy was being exercised to delay maintenance until a scheduled inspection period. If this is true, then standard maintenance procedures as described in TM 38-750, Technical Manual for the Army Maintenance Management System (TAMMS), would justify transferring the entry from the DA Form 2408-13, Daily Flight Record, to the DA Form 2408-14, Uncorrected Fault Record. This action defers maintenance until a scheduled periodic inspection and allows the write-up to be removed from the DA Form 2408-13 record as a daily entry. All this does not correct the discrepancy. It is emphasized primarily to show the ineffecient procedure of excessive record-keeping. If the check valve is inaccessible and has a high replacement or repair rate, then the applications attribute relative to design action would be applicable.

The third highest repetitive action was defined as high-frequency vibration. The reason for this action being identified as a symptom rather than a part or system is that several parts and systems in the CH-47C actually generate high-frequency vibrations when a discrepancy occurs within the component or system. The attributes considered to cause repetitive actions were resources and diagnostics. Based on the DA Form 2408-13 entries, there appeared to be no orderly procedure for determining which system caused the high-frequency vibration. Trial-and-error troubleshooting was attemped, first in trying to find the problem in one system by the replacement of parts, and then going on to another area on the helicopter and trying the same approach again. Meanwhile, the aircraft continued to build flight hours. The use of a vibration meter for diagnostics could substantially reduce repetitive maintenance actions and prevent high utilization of parts. Along with the vibration meter, there should be instructions and maintenance manuals with troubleshooting procedures.

The fourth repetitive action part is the speed trim. This system reduces angle of attack of the fuselage relative to the airstream as forward airspeed is increased and reduces rotor blade flapping. The causes of repetitive actions in the system were related to resources and diagnostics. As an example, the DA Form 2408-13 record entries that were reviewed showed the following events as they occurred:

Aircraft Flight Time (Hours)	Indication	Action
156.8	Aft speed trim indicator fluctuates 80% of seal - all speeds	Replaced Indicator
159.7	Fluctuates and activates motors	Disconnected at cannon plug
162.2	Fluctuates in manual and auto modes	Carried forward
163.4	Fluctuates intermittently	Disconnected trim actuator
168.6	Aft speed trim plug disconnected	Connected cannon plug
171.1	Aft speed trim fluctuates intermittently	Carried forward
173.6	Aft speed trim fluctuates intermittently	Carried forward
177.0	Aft speed trim fluctuates	Transferred to DA Form 2408-14 Delayed Maintenance Form

This example shows inconsistency in the procedure used to attempt to correct the problem. It was possible that the mechanic was not trained to work on the trim system and was avoiding the problem the best way he could until the problem was deferred to the next periodic inspection. The problem could have been in the wiring in the cannon plug, but there was no indication that this mode of failure was examined. Tools to perform repairs to cannon plugs may not have been available, or an electrician specialist may not have been assigned at the time. Trained personnel with experience, tools, troubleshooting procedure, and suitable test equipment could have reduced this type of repetitive maintenance action.

The transmission oil pressure light was ranked fifth in number of repetitive maintenance actions. Inoperability of this warning light system prevents important information from being transmitted to the pilot. It could result in a safety-of-flight problem. Even so, it was "carried forward" until, after 10 flight hours, it was checked and found to be operational. After 20 hours of further operation, it was again written up, checked, and found to be operational. Even the simple procedure of replacing a light bulb to determine if the bulb itself was intermittent was not attempted. This indicates lack of experience or training in proper troubleshooting. It is possible that the supervision or local maintenance policy prevented corrective action from being exercised. Repetitive actions of this type could be reduced if proper procedures, training, and supervision were applied.

The P-SAS, stability augmentation system, was ranked sixth in repetitive actions. Indications are that this was the result of weaknesses in resources, diagnostics, and applications. The DA Form 2408-13 record showed that corrective action was trial-and-error. Discussions with mechanics indicated that they were experiencing difficulty in adjusting the P-SAS and having the adjustment hold. Mechanics' answers to Question No. 50 ("Repeat maintenance actions on the P-SAS are caused by: (a) adjustment is difficult, (b) one component has high failure rate, (c) availability of parts, (d) lack of test equipment, and (e) lack of training") indicated that: 44% felt that lack of training was the cause of repeat actions, 31% claimed lack of test equipment, and 17% said adjustment was difficult. Better training, test equipment, and improved design to eliminate or facilitate adjustment would reduce repetitive maintenance actions on P-SAS.

The seventh highest ranked action/part was lateral vibration in the rotor systems. The cause of these actions appears to be related to diagnostics. An example follows of how a discrepancy of this type is processed:

Aircraft Flight Hours	Indications From DA Form 2408-13	Action Taken
1295.9	1 to 1 lateral vibration	phased blades
1300.0	1 to 1 lateral vibration	replaced blades forward yellow and red
1300.0	1 to 1 lateral vibration	rephased main and aft blades
1300.0	forward damper has internal noise	replaced forward damper
1309.0	lateral vibration at low speed	flight checked OK

Aircraft Flight Hours	Indications From DA Form 2408-13	Action Taken

At the same time, but with separate entries in the DA Form 2408-13,

1284.0	vertical bounce at 150 Kn	checked OK
1300.0	1 to 1 vertical vibration aft head	adjusted aft yellow blade up 3 clicks green blade down 2 clicks
1309.8	1 to 1 vertical at 150 Kn	tracked blades

It appears that the problem may not have been solved by the procedures used in the attempt to correct it. There was nothing to indicate the use of diagnostic tools, such as a vibration meter, to isolate location or cause of vibration. The entire attempt to correct the problem was trial-and-error. As determined in the analysis of the questionnaire, the vibration meter is apparently not being used. Its addition to the TOE equipment list and proper training in its use could significantly reduce repetitive maintenance actions on most dynamic systems.

The pilot/copilot VGI attitude indicator was ranked eighth highest in repetitive actions. Causes for the repetitive actions were diagnostics and logistics. Indiscriminate replacement of parts was common practice to correct this discrepancy. On one aircraft, the corrective action was "carried forward" until part replacement was completed, indicating logistic support needs. The aircraft remained in flight status with a discrepancy in the VGI system. The only constraint is that it was restricted to VFR flight only. Most flying is VFR, so this places a low priority on correcting the problem in the VGI system.

The APP mount was ranked ninth in repetitive actions. The cause of this action was logistics. The corrective action was carried forward until the mount assembly was replaced. Approximately 9 hours of flight time was recorded between the initial DA Form 2408-13 entry and the corrective action. After an additional 12 hours of operation, structural repair of the mounting bracket was required. There is the possibility that the delay may have been a contributing factor in mount wear. Early corrective action of any discrepancy can reduce repetitive actions.

The transponder IFF was the tenth-ranked repetitive action. Indications are that actions were caused by trial-and-error troubleshooting and possible delay in obtaining replacement parts. Repairs were attempted, but were apparently unsuccessful. This may have been done while waiting for a part in an attempt to keep the system operational. Improved diagnostics by better troubleshooting procedures and logistics support would reduce these repetitive actions.

CH-54B REPETITIVE MAINTENANCE ACTION DATA ANALYSIS

Data for the repetitive action analysis of CH-54B helicopters were taken from 30 months of operational data when 21 aircraft flew a total of 8500 hours. These data were derived from the ORME conducted for U. S. Army AVSCOM under Contract DAAJ01-71-C-0641 as a product improvement program. The repetitive actions totaled 370. Of the 55 parts and subsystems listed in Appendix A, Table A3, the ten parts having the highest number of maintenance actions per aircraft were analyzed relative to the causes of repeat actions. These ten parts are ranked in Table 68, showing the average action per aircraft and the maintenance attributes considered to be the prime cause of repetitive actions. Predominant cause attributes were diagnostics, applications, and resources.

TABLE 68. CAUSES OF REPETITIVE MAINTENANCE ACTIONS, CH-54B (30 MONTHS DATA)

Rank	Maintenance Action	Average No. Actions per Aircraft	Prime Cause(s) Attribute
1	Engine Exhaust Duct	9.0	Applications
2	Tail Pipe Assembly	7.8	Applications
3	Speed Actuator	7.0	Diagnostics/ Resources
4	AFCS Control Panel	6.0	Resources/ Diagnostics
5	AFCS Amplifier	5.7	Resources/ Diagnostics
6	Main Rotor Head	5.3	Resources/ Diagnostics
7	Fuel Filter Element	5.0	Diagnostics
8	Main Gearbox	4.7	Diagnostics
9	APP Clutch	4.2	Diagnostics/ Applications
10	Blower	4.0	Diagnostics

These repeat maintenance actions were extracted by a computer program that listed each aircraft by serial number and sorted all actions by calendar date. The ranking of attributes using the ORME data differs from the DA Form 2408-13 data used to evaluate the UH-1H and CH-47C. The CH-54B program was a product improvement program primarily intended to recognize design discrepancies and implement corrective action by Engineering Change Proposals (ECP). The data obtained from the Daily Flight Records, DA Form 2408-13, provided daily information on all actions relating to maintenance. As a result of this difference in data source and intent, the CH-54B repetitive action analysis is biased to show a larger percentage of applications as the prime cause than would have been the case had DA Form 2408-13 data been used.

The engine exhaust duct, a powerplant vendor part, was ranked as causing the highest repetitive action per aircraft part in the CH-54B. Applications is the prime cause of this. The duct would crack, be repaired, then crack again until replacement was necessary. Subsequently, a redesigned duct was provided by the vendor as an ECP action to solve the problem.

The second highest repetitive maintenance action part was the engine tail pipe assembly. The tail pipe has been a source of repeated maintenance action because of cracking and loss of attachment bolts. Applications is considered to be the cause of these actions. A continuing effort to improve the design of this component has been under way for some time. The manufacturer is currently evaluating the use of damping materials and techniques to improve tail pipe reliability. A temperature survey is being performed, to be followed by laboratory testing and field evaluation of a modified tail pipe.

The speed actuator, a rotary electric actuator that operates N_2 engine speed trim controls, is ranked third in repetitive actions. The causes of these actions are related to diagnostics and resources. Trial-and-error troubleshooting procedures in the field were indicated. Difficulty was reported in following rigging instructions from the maintenance manuals. As an example, five actuators were replaced in seven maintenance actions. Adjustments in rigging accounted for the remaining actions. Revised rigging instructions and changes in control limits have reduced repetitive actions in this system.

The AFCS control panel ranked fourth. These repetitive actions can be reduced by better training and improvement in manuals and troubleshooting. Analysis of the repetitive actions showed that the problem was not resolved after six separate maintenance actions, including replacement of five control panels. The problem was reported as internal and switch failures. There is a need for diagnostics for this type of equipment on the aircraft to avoid replacement of major components for minor problems. Test equipment and training can reduce these repetitive actions and save components.

The fifth-ranked repetitive action listed was the AFCS amplifier. The discrepancy actions on this assembly were similar to those with the AFCS control panel. The entire amplifier was replaced as often as was a subassembly. Difficulty in identifying the cause of failure is the result of the lack of diagnostic support equipment and adequately trained maintenance personnel. Improvement in troubleshooting procedures, coupled with test equipment and training, would reduce these repetitive actions.

The main rotor ranked sixth for repetitive actions relative to retorquing of the rotor head nut securing the head assembly to the transmission drive shaft. Problems reported indicated that when this nut was torqued according to maintenance manual instructions, the torque would not be retained. This condition occurred primarily in arctic environments. The solution was to revise the torquing procedure in the maintenance manual. Additional problems included replacement of the rotor head assembly because of seal leakage. It was found that neither the seals nor the special tools required were available in many cases. Better logistics, resources, and diagnostics would help prevent these repetitive actions.

The fuel filter element is ranked seventh in causing repetitive actions. The filter problem is related to the diagnostic attribute. The filter collects contamination from the fuel system and provides a signal when it is obstructed and must bypass fuel. The repetitive actions taken were to replace the filter on an average of every 10 hours for 50 hours of aircraft operation. There was no indication of the fuel systems having been checked for the cause of contamination. Contamination that continues that long would normally warrant further investigation. Better diagnostic procedures in dealing with a problem of this type should be a consideration in reducing repetitive actions.

The main gearbox was ranked eighth in repetitive actions. Most of the reported actions related to the chip detector finding metal particles. In one case, metal chips were found after a gearbox replacement, indicating that the oil system, that is, the cooler and line, may not have been cleaned properly prior to the installation of a replacement gearbox after an internal failure. Better maintenance procedures and experience in determining acceptable limits of contamination would reduce repetitive actions and, perhaps, save gearboxes.

The ninth-ranked repetitive action component was the APP clutch. Two problems were reported relative to the clutch. One was seal leakage, which was an applications attribute problem subsequently resolved by design improvement. The second was clutch shoe adjustment, which would be expected to be an infrequent repetitive action. As the clutch shoes wear from normal usage, adjustment is necessary. However, unusually high wear rate and repeated shoe adjustment indicate the need for design improvement.

The transmission oil cooler blower ranked tenth in repetitive actions, primarily due to vibration. The recorded corrective action was replacement of the woodruff key and repair of housing by riveting. It appears that the normal maintenance procedure is to correct the immediate problem without following through to eliminate the cause. Repetitive actions occur from this procedure, because the work is not completed after the first action. Chronic problems continue to be reported in a system in which the fix is only partially completed. Repetitive actions can be reduced significantly if maintenance actions are performed to eliminate the prime cause.

INCORRECT DIAGNOSTIC DATA

COLLECTION AND ANALYSIS

A field and depot survey was made to collect and compare operational field component removal history with depot overhaul and inspection data. Evidence of incorrect field diagnosis could be established in cases where the depot inspection did not confirm the field diagnosis. Three typical UH-1H and CH-47C operational bases were visited, and their data from six months' previous Component Removal and Repair/Overhaul Records, DA Form 2410, were reviewed. Two typical U. S. Army depots were visited to track the same components removed in the field to the depots and to determine if the failure codes assigned at the field level agreed with the depot overhaul analysis.

The survey reviewed 271 DA Form 2410 records. From these records, 205 components with assigned failure codes were identified. However, the records at the depot for these components failed to identify any failure codes. It was discovered that the primary reason for this was that the depot does not use the DA Form 2410 to list results of teardown inspections. Based on TM 38-750, the Army Maintenance Management System (TAMM) Manual, DA Form 2410 is a multicopy form that is to be used to record parts replacement and failure codes during overhaul or repair. However, the depots are not required to use DA Form 2410 if they use assembly-line production methods for overhaul. Only man-hours and parts-required lists are necessary. At the depots, it was learned that few teardown inspections are made to identify the cause of failure. Detailed disassembly and inspections are normally done only when components are returned after accidents or by special request. Another possible reason for lack of depot follow-up on reason for field removal is that there appears to be a lag of 6 months to 2 years between the time when parts are removed from the aircraft and when they are processed through the overhaul system.

As an alternative data source, a special computer run was obtained from the RAMMIT (Reliability and Maintainability Management Improvement Techniques System) program. This computer run contained a listing of parts from UH-1H and CH-47C helicopters from the same bases being surveyed. These data proved to be of no help, since records of components listed in the computer runs could not be found at the depots.

As a result of these difficulties, the survey to measure incorrect diagnosis as a cause of excessive maintenance could not be completed. However, some insight was provided by personal interview of depot personnel, who estimated that 15% to 25% of transmissions going through overhaul are found to have no defects or malfunctions. The following sections describe the data obtained from the operational bases and depots.

OPERATIONAL DATA FOR INCORRECT DIAGNOSIS ANALYSIS

Component Removal and Repair/Overhaul Records, DA Form 2410, were surveyed for a six-month period on UH-1H and CH-47C helicopters at three typical U. S. Army operational bases. Of the data surveyed, only 76% of the components had been assigned failure codes, as shown in Table 69.

TABLE 69. COMPONENT RECORDS SURVEYED WITH/WITHOUT FAILURE CODES

Aircraft Type	No. of 2410 Records	No. With Failure Codes	No. Without Failure Codes	Percentage Failure Codes
UH-1H	135	82	53	61
CH-47C	136	123	13	90
Total	271	205	66	

It is noted that failure codes were identified more often on CH-47C helicopter components.

Table 70 lists the UH-1H components surveyed.

Table 71 lists the CH-47C components surveyed.

The components listed include those parts identified in TB 55-1500-307-25, Aircraft Components Requiring Maintenance Management and Historical Data, as being controlled parts for overhaul and repair.

DEPOT EXPERIENCE

Two U. S. Army depot facilities were visited to obtain DA Form 2410 depot overhaul, repair teardown, and inspection verification field failure codes. It was found that the depots did not use the DA Form 2410 record copy 5 for recording part replacement or for identifying failure codes. The procedures used at depot are internal shop work control forms for components processing. All file records are retained active for 90 days after a component is processed for either overhaul or repair. The records are stored for 2 years and then discarded. Almost none of the components processed by the depots go through a teardown inspection for cause of failure or reason for removal. Only engines and specially identified components from accidents are subjected to detailed teardown inspections. As a result, it was not possible to compare failure codes from field organizations with depot data.

TABLE 70. INCORRECT DIAGNOSIS COMPONENT LIST, UH-1H

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Main Rotor Head	204-012-101-5	1615-833-1556	ADA-1458	020	worn excessively
			ADA-4500	910	chipped
			ABG-3107	381	leaking
			ADA-0177	381	leaking
	540-011-101-5		AAH-1433	710	bearing failure
			A29-7255	799	no defect
			A29-0751	799	no defect
			A29-6228	-	
			ADA-4523	-	
			ABG-2215	170	corroded
			ABG-9101	020	worn excessively
			ABG-5387	135	binding
Swash Plate and Support	204-011-400-11	1615-060-1062	J19-1190	710	bearing failure
			019-1700	710	bearing failure
	204-011-400-118		J119-7535	020	worn excessively
		1615-060-1o	J119-6253	020	worn excessively
Main Rotor Damper	204-010-937-7	1615-737-6566	1512	381	leaking
	204-010-937-5		A-4111	230	dirty
			R19-1845	230	dirty
		1615-135-2548	E19-717	230	dirty
			A2-8605		changed
			4879	-	no code
			A2-4423	-	no code
			A-18141	-	no code
			A2-8605	-	changed
			A2-4801	-	changed
			A-6449	-	changed
			A2-5953	-	changed
			A2-6614	-	changed

TABLE 70. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Irreversible Valve	204-076-055-1	1650-130-5964	51659	590	bounce time, excessive
			46689	381	leaking
			12182	381	leaking
			28892A	-	
			25926	-	
			46255	920	not determined
Servo Cylinder	205-076-038-7		61257	381 & 020	leaking/worn excessively
			59985	381	leaking
			1522	020	worn excessively
	205-076-038-7		59942	-	
	205-076-038-7		22634	381	leaking
	205-076-038-7		8687A	381	leaking
	205-076-038-7		62513	381	leaking
	205-076-0387		5000	374	internal failure
	205-076-038-7		16967	381	leaking
	205-076-052-9		54317	020	worn excessively
			822304	-	
			822308	-	
			869362	-	
			822269	-	
			869288	-	
			60312	135	binding
Collective Lever	204-011-438-1	1615-830-9754	MD11-6803	020	worn excessively
			MD1-8601	-	changed
Inverter		6125-865-9683	1098	374	internal failure
			15547	-	
Reverse Current Relay	A700A	2925-555-5349	JK-42859	374	internal failure
			T-86977	-	
Starter Generator	30E20-61-A	2925-927-9483	4750	374	internal failure
			3180	-	
			4177	-	

TABLE 70. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Main Rotor Damper			A2-4801	-	changed
			B-1269	-	changed
			A-3266	190	cracked
Main Rotor Blade	204-011-250-5		T2-11243	020	worn excessively
			TBA-0737	020	worn excessively
			A2-14518	910	chipped
			IBA-2453	670	unbalanced
Tail Rotor Blade	204-011-702-15		A3-14518	799	no defect
			A3-72430	799	no defect
			A3-61729	-	changed
Tail Rotor Hub	204-011-801-9		HD-29916	-	changed
			A29-7255	799	no defect
			A29-07521	799	no defect
			A29-6228	-	
			GR29-3387	-	
			A29-6104	-	
Tail Rotor Drive Shaft and Hanger Bearing	204-040-600-9	1615-832-8951	A20-19494	381	leaking
			A20-9930	-	
			A20-43196	381	leaking
			A20-32637	020	worn excessively
			A20-3232	020	worn excessively
			A20-49763	020	worn excessively
			A20-51396	020	worn excessively
			A20-64097	171	burred
			A20-20894	-	changed
			A20-34993	-	changed
			A20-40255	-	changed
			A20-3886	-	changed

TABLE 70. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Elevator	205-030-856		GGBO-4422	190	cracked
			ZEP-7820	020	worn excessively
			ZBO-05518	-	
			GGBF-4435	020	worn excessively
			ZBP-3492	020	worn excessively
Gearbox 42°	204-040-003-37		A13-2001	231	elongated
			A15-1075	-	
Gearbox 90°	204-040-012-13		B13-6198	381	leaking
			B13-7610	-	
			B13-3672	-	changed
			B12-1481A	-	
			BBC-973	-	changed
			ABC-10370	-	changed
			A13-1208	374	internal failure
			B13-6165	381	leaking
Horn Assembly	205-001-914-1		CAS-LC-215	020	worn excessively
Overspeed			672AM 7439	-	Engine S.N. LE-22100
			642AN 71301	-	
Generator (Spare)			903	-	
Input Quill			Q12-0845	-	

TABLE 71. INCORRECT DIAGNOSIS COMPONENT LIST, CH-47C

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Engine	2-001-020-05	2840-428-6382	LE-19118	334/167	temperatrue incorrect/ torque incorrect (test engine)
			LE-19612	910	chipped
			LE-19406	374	internal failure
		2840-937-0480	LE-01129B	690	vibration excessive
			LE-04228B	190	cracked
			LE-04345B	920	not determined
			LE-03342	920	not determined
			LE-04946B	381	leaking
			LE-03205	-	
			LE-04415B	-	
			LE-04946B	-	
			LE-01116B	804	no defect
			LE-01076B	916	impending failure, SOAP
			LE-03253	317	hot start
			LE-03315	381	leaking
Fuel Control	717717-L15	2915-936-8547	57674	799	no defect
			61221	799	no defect
			46645	374	internal failure
			59536	-	
			49399	374	internal failure
			44911	374	internal failure
			58798	916	impending failure, SOAP
			43298	920	not determined
Fuel Control & Inlet Guide	2-161-450-08	2915-431-3648	LE-19382	317	hot start
			LE-196376	537	low

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Engine Drive Shaft	114D3246-2	1615-074-9937	A504	190	cracked
Sync. Drive Shaft	114D3070-6	1615-872-1212	A-348	799	no defect
			A-1481	690	vibration excessive
			A-519	920	not determined
			A-1649	690	vibration excessive
		1615-872-1213	A-8968	690	vibraton excessive
			A-8942	920	not determined
			A-3725	780	bent
Combining Transmission	114D5200-2	1615-176-2628	A-8750	799	no defect
			A-81268	610	shorted to frame
			A-8780	127	adjustment improper
			A-8937	381	leaking
Engine Transmission	114D6200-1	1615-016-0817	A11-1683	690	vibration excessive
	114D6200-2	1615-179-6307	A11-1848	690	vibration excessive
	114D6200-3	1615-079-1007	A11-2168	920	not determined
	114D6200-4	1615-079-1007	A11-1704	381	leaking
Forward Transmission	114D1200-17	1615-092-4661	A-7-811(L-11)	372	metal on magnetic plug
		1615-103-0002	A-7-1213	020	worn excessively
		1615-407-2823	A-12[illegible]7	020	worn excessively
		1615-407-2823	A-7-1304	-	
		1615-407-2823	A-7-1207	-	
Aft Transmission	114D2200-9	1615-092-4666	A-9-835	372	metal on magnetic plug
Transmission		1615-781-6613	A11-2383	381	leaking

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Swash Plate	114R3505-12	1615-106-7911	A84-7911	381	leaking
	114C5115-26	1680-117-9484	49-1064	717	no such code
Damper	114H6800-3	1650-221-9462	UR-915	645	spurious
			UR-563	383	lock on malfunction
			UR-103	374	internal failure
			VY-1851	-	
			UR-899	-	
			VY-2036	-	
			VY-2543	-	
			VY-2472	-	
Actuator Dual Pivot		1650-922-5831	UR-378A	381	leaking
Actuator, N_1	114P3206-3	2995-159-9002	7108131	374	internal failure
			7008113	374	internal failure
	114P3206-2	2995-459-4039	7012193	135	binding
			7012165	680	unstable
Actuator, N_2	114P3205-2	2995-420-5226	1849	650	sticky
			1166	374	internal failure
Actuator, Linear	114CS-114-26	1680-117-9484	49-1064	717	no such code
		1680-443-1138	165	920	not determined
Actuator, D.C.P.	114CS-100-25	1680-443-1137	264	900	EIR burned
		1680-443-1183	493	196	shorted
		1680-443-1183	129	645	spurious
Actuator, FWD Swivel		1650-179-4264	UR-543A	381	leaking
			VY-2299	381	leaking

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Rotor Head		1615-871-7300	A-5-1267	464	overspeed
			A-4-607	464	overspeed
			A-5-1231	381	leaking
			A-5-1113	717	no such code
		1615-871-7303	A-4-924	381	leaking
Damper	114H 6800-3	1615-221-9462	UR-1042	020	worn excessively
			UR-313	710	bearing failure
			VY-1433	008	noisy
			UR-208	710	bearing failure
			VY-2047	381	leaking
			VY-2125	381	leaking
			VY-2567	381	leaking
			VY-2124	381	leaking
			VY-2137	381	leaking
			VY-2157	381	leaking
			VY-1851	374	internal failure
			UR-899	374	internal failure
			UR-512	374	internal failure
			UR-1202	374	internal failure
			UR-1208	374	internal failure
			VY-1994	374	internal failure
			UR-1070	374	internal failure
			UR-151	374	internal failure
			UR-1216	374	internal failure
			UR-1223	374	internal failure
			UR-406	690	vibration excessive
Engine Drive Shaft	114D3247-1	1615-074-9931	A4814	690	vibration excessive
			A3716	670	unbalanced
			A4829	690	vibration excessive
			A-3050	690	vibration excessive

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Drive Shaft	205-040-004-3	1615-068-6635	A20-6758	381	leaking
			A20-10436	108	broken safety wire or key
			A20-09861	116	cut
			A20-50046	020	worn excessively
Engine	1-000-060-10		LE-22417	916	impending failure, SOAP
			LE-20061	800	no defect
			LE-18127	-	
			LE-14396	-	
			LE-14689	-	changed
			LE-21157	-	changed
			LE-15459	-	changed
			LE-15087	381	leaking
			LE-14838	381	leaking
Fuel Control	84200-AS	2915-781-7917	12A5 10854	561	unable to adjust limits
			682A 55716	020	worn excessively
			672A 52609	-	changed
			662A 591	374	internal failure
Damper, Stabilizer	CSC-520-4		A2-3932	-	flight abort
			A2-2103	308	oil contamination
			A2-2128	308	oil contamination
			A-19665	274	timing off
Damper	S6T-520-6		B-10423	374	internal failure
			R19-5374	308	oil contamination
			B-6624	817	total impedence - low
			B-9144	561	unable to adjust limits
			A-28390	561	unable to adjust limits
			a-411	230	dirty

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Drive Arm	114R3434-5	1615-764-8688	RX-225 UT-105	710 020	bearing failure worn excessively
Vibration Absorber	114S2971-86	1560-245-5336	VE-0258	650	sticky
Voltage Regulator	114E5249-13	1680-181-4303	1776-B 2330-D	255 900	no output burned
Adapter, Fwd		1615-937-7666	A-3217	690/020	vibration excessive worn excessively
Adapter, Aft Trans. Sync.		1650-021-2701	A-441	031	alignment improper
Blade		1615-179-0818 1650-176-2106	A-1-432 A-1-1574 672	621 717 020	winding shorted no such code worn excessively
Liner		2840-470-4420	819	190	cracked
Pump, Scav.		4320-998-6611	B-1563	020	worn excessively
Servo		1615-442-6214	UA-845A	381	leaking
Speed Trim		1680-117-9484	10-1730	790	galled
Pitch Change Link		1615-071-4522	A-4830	-	

TABLE 71. (CONTINUED)

Nomenclature	Part Number	Fed. Stock Number	Serial Number	Failure Code	Failure Code Description
Actuator, Elec. Mech.		1680-103-0029	98-447	196	leaking
			88-465	381	shorted
Actuator		1650-105-6258	VY-10373A	381	leaking
Actuator, Fwd Pivoting	114H-6700-3	1650-442-6217	VY-1733	821	no such code
			UR-988A	020	worn excessively
			VY-2052	320	high voltage breakdown
			UR-471A	381	leaking
Actuator, Boost		1650-167-8141	UV-7435A	381	leaking
			UV-10290A	381	leaking
Actuator, Aft Pivot	114H-6600-12	1650-442-6219	UR-377A	730	loose
		1650-865-7967	VY-2003	381	leaking
Vertical Shaft, Aft	114D3250-1	1615-019-5174	A-839	803	no defect removed for time change
Drive Shaft		1520-990-2491	A-3358	020	worn excessively
Control Box, N_1	114ES283-1	2995-150-5915	7010190	037	fluctuates - unstable
	114ES283-1	2995-150-5915	700952	037	fluctuates - unstable
Generator	31161-001	6115-111-6828	476	255	no output
			515	255	no output
			-	920	not determined
			411	920	not determined

Interviews with depot personnel indicated that 15% to 25% of transmissions are processed and found to contain no defects. Components are repaired and overhauled in batch lots on a semi-assembly line basis. This part of the study was inconclusive in identifying incorrect field diagnosis of components as being a prime cause of maintenance inefficiency.

RAMMIT DATA

Raw TAMMS/TAERS data were requested on aircraft components from the bases being surveyed to assure that time lag between component removal and overhaul would not preclude depot analysis.

In response, a printout of Chronological Analysis of Selected Items Record data was provided. The components listed from the computer printouts are shown in Table 72.

TABLE 72. COMPONENT LIST FROM CASIR DATA

Component	FSN	Quantity	Aircraft
Transmission, Comb.	16150552961	29	CH-47C
Swash Plate, Control	16151795918	1	CH-47C
Shaft Assy, Syncro	16158166954	4	CH-47C
Blade, Rotor Wing, Aft	16151790817	34	CH-47C
Transmission, Forward	16150893949	9	CH-47C
Transmission, Forward	16151116806	24	CH-47C
Quill Assy	15608296845	29	UH-1H
Horn Assy, Elevator	15609667517	33	UH-1H
Elevator Assy	15609963905	6	UH-1H

The computer printout to cover these listed components totaled 10,721 pages, or approximately 63 pages for each component. The data were of limited value, since none of the components reported in the CASIR was found listed on the DA Form 2410 surveyed at any of the bases or depots visited. The CASIR data represented an earlier time frame, but the field survey data were more current. No conclusions could be reached from this data source.

CONCLUSIONS

Repetitive maintenance actions are significant. Repetitive actions were found to occur at a rate of 0.32 per flight hour.

Individual repetitive maintenance actions were identified. The causes for these actions were described by attribute.

Diagnostics, including test equipment, troubleshooting, and standard maintenance practices, were identified as causing over 50% of all repetitive maintenance actions.

Incorrect diagnosis of components removed from the aircraft in the field and forwarded to the depot for overhaul and repair could not be confirmed. Depot procedures did not provide appropriate records to track components adequately.

Test equipment is not being used to troubleshoot maintenance problems. Troubleshooting procedures are incomplete.

Flight crew write-ups are not clear, consistent, or traceable enough for maintenance crews to respond efficiently with the proper repairs.

Troubleshooting procedures in maintenance manuals are incomplete. Only expected problems are covered, thus leaving remaining problems to be resolved by trial-and-error procedures that are costly and time-consuming.

Mechanics are frustrated as a result of being trained in a skill and then not being allowed to use their skill in performing the maintenance actions for which they are qualified.

Trial-and-error troubleshooting methods are used up to 50% of the time in resolving a maintenance problem.

The lack of spare parts causes repairs to be delayed and repetitive maintenance actions.

Test flight prior to periodic inspection can reduce repetitive maintenance by testing all aircraft systems for correct operation. Discrepancies found can be corrected during the inspections.

RECOMMENDATIONS

Training in the accurate application and utilization of test equipment should be improved.

A vibration meter, such as that identified in USAAMRDL-TR-74-44, "Investigation of Inspection Aids," as a diagnostic reed vibration instrument, should be added to the Table of Organization and Equipment (TOE) test equipment list for all helicopter companies. If the instrument is presently a part of the standard test equipment, it should be used. If training on the use of this instrument is necessary, it should be conducted.

Standard maintenance procedures should be clear and enforced to be effective and to provide control in maintenance operations.

Spare parts support should provide needed parts as required to reduce aircraft down time, cannibalization, and marginally operational aircraft.

Flight crew write-ups should be standardized to aid in communicating problems to the ground crew. A program is suggested to develop a standard list and code to provide clear and succinct terms for transmitting flight crew complaints to ground crew mechanics.

Maintenance manuals should be revised to provide improved and expanded troubleshooting procedures. As an aircraft matures in its operational environment, new problems occur that are not covered in maintenance manuals. Procedures for troubleshooting are developed and used by personnel in the field. These should be reported, recognized, and distributed Army-wide for maximum efficiency. New and expanded procedures to include the maximum use of test equipment should be provided to maintenance personnel on a timely basis by maintenance manual revisions.

Overhaul and repair procedures at depots should be revised to identify the cause of failure of major components, thus reducing costs by implementing design changes that improve operational life. If components are being overhauled and repaired unnecessarily, these procedures should identify the extent to which this is being done. From this information, field procedures could be improved to prevent the unnecessary, no-defect removal and overhaul of costly components.

Test flight by a qualified maintenance pilot should be performed prior to periodic inspection of an aircraft so that all systems can be tested to be operational and corrective action taken during the inspection.

APPENDIX A

REPETITIVE FAULT-ACTION INCIDENT RECORDS

This appendix provides:

(1) aircraft serial numbers
(2) parts/system listing
(3) number of actions
(4) number of aircraft
(5) actions per aircraft

from DA Form 2408-13 records on:

a. UH-1H helicopters, Table A1
b. CH-47C helicopters, Table A2

and from Operations Reliability Maintainability Engineering Program data files on:

c. CH-54B helicopter, Table A3

TABLE A1. REPETITIVE FAULT-ACTION INCIDENTS RECORDED FROM 2408-13 FORMS

UH-1H

PART / SYSTEM \ A/C SERIAL NO	66-16017	68-15380	68-16179	66-16005	67-17835	70-16492	65-9603	65-9688	65-9789	65-9755	65-9600	64-13592	63-8824	63-8828	67-17848	70-16468	67-17421	68-15402	66-17130	66-16674	65-10125	66-16579	66-16653	69-15315	70-16470	CF		TOTAL ACTIONS	NO OF AIRCRAFT	ACTION/A/C
SCISSORS (PIVOT BOLT)	2																					2			2			6	3	2.0
ROTOR RPM-ADJUSTMENT	3				3	3	2	4					5													10		20	6	3.3
GENERATORS-MAIN/STANDLY	11		14		4		2			4			12	7				2				2				21		58	9	6.4
TAIL ROTOR CONTROL	4					5			2				8							5						10		24	5	4.8
ROTOR VIBRATION (BOUNCE)	4		7	8		4		4			4		25	8			11									36		75	9	8.3
COLLECTIVE CONTROL		2	6	4	4																					1		16	4	4.0
MAIN ROTOR GRIP SEAL (LEAKING)		2		2		2		3																2		3		11	5	2.2
90° GEARBOX SEAL (LEAKING)		3		3				2							2											4		10	4	2.5
ENGINE-OIL LEAK		2																		2					2			6	3	2.0
42° GEARBOX SEAL (LEAKING)			4	6								9											8			12		27	4	6.7
MAIN GEARBOX SEAL (LEAKING)			5	2													4									1		11	3	3.7
N_2 TACH GEN. SEAL (LEAKING)			2	3		3																				1		8	3	2.7
EGT SYSTEMS			6																			3						9	2	4.5
FUEL PRESSURE GAGE (FLUCTUATES)			2																									2	1	2.0
INVERTER-VOLTAGE				2	4				3																	1		9	3	3.0
ENGINE THROTTLE-CUSHION					2		2					6														6		10	3	3.3
FUEL PUMP LIGHT					2																							2	1	2.0
RPM-TACH GEN GOVERNOR/SWITCH				7	3	2	2	4	5	4	8		23	23					5							47		86	11	7.8
VIBRATION-HIGH FREQUENCY					3																							3	1	3.0
FUEL LEAK					2																					1		2	1	2.0
INTERCOM. SW. (CYCLIC)				2																								2	1	2.0
ENGINE TORQUE				2																								2	1	2.0
MAIN GEARBOX OIL PRESSURE				5														5								1		10	2	5.0
N_1 TACH GEN. SEAL (LEAKING)				2																								2	1	2.0
CYCLIC CONTROL-RIGGING						10												4		2	2					4		18	4	4.2

TABLE A1 - Concluded

PART/SYSTEM	66-16017	68-15380	68-16179	66-16005	67-17835	70-16492	65-9603	65-9688	65-9789	65-9755	65-9600	64-13592	63-8824	63-8828	67-17848	70-16468	67-17421	68-15402	66-17130	66-16674	65-10125	66-16579	66-16653	69-15315	70-16470	CF		TOTAL ACTIONS	NO. OF AIRCRAFT	ACTION/A/C
BATTERY-OVERVOLTAGE						2																						2	1	2.0
MAIN GEARBOX—OIL LIGHT						3						7														6		10	2	5.0
ATTITUDE INDICATOR							3							20												19		23	2	11.5
UHF/FM RADIO							5	4			12	9											3			13		33	5	66
PITCH CONTROL LINK							3							8												8		11	2	55
MAIN GEARBOX OIL PRESSURE GAGE							4																			1		4	1	40
TRANSPONDER-IFF							5				8		9													10		22	3	7.3
A/C PHASING							2																			1		2	1	2.0
VOR							2																					2	1	2.0
RADIO MAGNETIC IND.								3																		1		3	1	30
LINEAR ACTUATION								2	2				2													1		6	3	2.0
TAIL ROTOR SERVO										2																1		2	1	2.0
MAIN ROTOR DAMPER												2														1		2	1	2.0
ADF												5		12												13		17	2	8.5
HYDRAULIC TEST RECEPTACLE												2									2					1		4	2	2.0
MASTER CAUTION PANEL														2												1		2	1	2.0
FUEL PUMP															2													2	1	2.0
TAIL ROTOR CHIP DETECTOR															2													2	1	2.0
HYDRAULIC LINE																2												2	1	2.0
BLEED AIR VALVE																	3									1		3	1	3.1
ENGINE OIL TEMP																				11						2		11	1	11.0
ENGINE OIL PRESSURE GAGE																					2							2	1	2.0
C-1611 CONTROL																							2					2	1	2.0
IRREVERSIBLE VALVE																							3					3	1	3.0

TABLE A2. REPETITIVE FAULT-ACTION INCIDENTS RECORDED FROM 2408-13 FORMS CH-47C

PART / SYSTEM \ A/C SERIAL NO	70-15011	68-16004	68-16005	68-15834	68-15831	68-16018	68-15832	69-17117	68-16015	68-16003	68-15844	70-15815	68-16024	68-16021	70-15016	70-15015	70-15014	70-15004	70-15033	70-15023	71-20945	CF	TOTAL ACTIONS	NO OF AIRCRAFT	ACTION/A/C
ENGINE CHIP DETECTOR	8		3		3																		14	3	4.7
GENERATOR	3	4	3																				10	3	3.3
HIGH-FREQUENCY VIBRATION	13	7																			5		25	3	8.3
3-1 VIBRATION	3		2											7									12	3	4.0
LATERAL VIBRATION	10		4	3								7			6			4					34	6	5.7
ENGINE CONDITION LEVER	3																						3	1	3.0
FUEL LEAKS	2		2																				4	2	2.0
VGI	2				11												3		4				21	4	5.2
NO. 2 ENGINE FIRE DETECTOR	4																						4	1	4.0
VERTICAL HINGE PIN LEAK		2																					2	1	2.0
ENGINE OIL LEAK		4	2																				6	2	3.0
CARGO HOOK PRE-CHARGE		4				2										2	5						13	4	3.2
NO. 1 FLIGHT BOOST LINE		2																					2	1	2.0
NO. 1 ENGINE		3																					3	1	3.0
NO 2 ENGINE TORQUE SYSTEM		3				2																	5	2	2.5
UTILITY HYDRAULIC SP COOLER		7	2		2					2													13	4	3.2
TRANSMISSION OIL PRESSURE			2																				2	1	2.0
ENGINE FUEL LEAK			2										4	2									8	3	2.7
FUEL LOW LIGHT				11																			11	1	11.0
CHECK VALVE				9																			9	1	9.0
P-SAS				6									5			13		2					26	4	6.5
APP MOUNT					5																		5	1	5.0
FLIGHT BOOST ACCUMULATOR					5				2												6		13	3	4.3
TRANS OIL PRESSURE LIGHT					7																		7	1	7.0
TRANSPONDER					5																		5	1	5.0

TABLE A2 – Concluded

PART SYSTEM	70-15011	68-16004	68-16005	68-15834	68-15831	68-16018	68-15832	69-17117	68-16015	68-16003	68-15844	70-15815	68-16024	68-16021	70-15016	70-15015	70-15014	70-15004	70-15033	70-15023	71-20945	TOTAL ACTIONS	NO OF AIRCRAFT	ACTION/A/C
PITCH VARYING HOUSING							2															2	1	2.0
NO 1 ENGINE TACH GEN						2																2	1	2.0
AFT SPEED TRIM										5												5	1	5.0
CYCLIC DCP										5												5	1	5.0
BOOST PUMPS										2								3				5	2	2.5
F.M. RADIO											3							3				6	2	3.0
N_1 ACTUATOR											3											3	1	3.0
N_1 CAUTION LIGHT											2											2	1	2.0
THRUST BRAKE														2								2	1	2.0
EXHAUST GAS TEMP														2								2	1	2.0
FWD TRANSMISSION															2							2	1	2.0
PARKING BRAKE																5						5	1	5.0
ENGINE OIL TEMPERATURE																3						3	1	3.0
RADIO MAGNETIC IND.																	4					4	1	4.0
ENGINE START MOTOR																	3					3	1	3.0
SWIVEL ASSEMBLY LEAKING																		2				2	1	2.0
VOR																			2			2	1	2.0
ENGINE OIL PRESSURE																			3			3	1	3.0
POWER STEERING																				2		2	1	2.0
SPEED TRIM																					8	8	1	8.0

TABLE A3. REPETITIVE FAULT-ACTION INCIDENTS RECORDED FROM ORME PROGRAM RECORDS CH-54B

PART/SYSTEM \ A/C SERIAL NO.	18470	18471	18472	18473	18474	18475	18476	18477	18478	18479	18480	18482	18483	18484	18485	18486	18487	18488	18489	18490	TOTAL ACTIONS	NO. OF A/C	ACTION/A/C
APP CLUTCH	2	6	3	5		6			7			5	2	6	3	3		2			50	12	4.2
DECOUPLER		2																			2	1	2.0
TAIL PIPE			2						6			8		9		14					39	5	7.8
MAIN ROTOR DAMPER			2					5													7	2	3.5
MAIN ROTOR HEAD					6							5	6	4							21	4	5.3
MAIN GEARBOX						7		4								3					14	3	4.7
UTILITY PUMP															2						2	1	2.0
HOIST PUMP						3									6	2					11	3	3.7
FUEL CONTROL		2												1	3						6	3	2.0
STARTER, APP			3											3			4				10	3	3.3
SPEED ACTUATOR															7						7	1	7.0
TORQUE INDICATOR															2	6		2			10	3	3.3
IGNITION UNIT	2																				2	1	2.0
ANTICOLLISION LIGHT		2					2	2	4	5	5		4	4							28	8	3.5
MRH SHIM				2																	2	1	2.0
OIL COVER					2	5		2				3	2								14	5	2.8
BATTERY					2																2	1	2.0
IGNITION PLUG	1				3																4	2	2.0
BLOWER						4															4	1	4.0
LOAD LEVEL ACTUATOR								2													2	1	2.0
RADIO RECEIVER/ARN-82									2												2	1	2.0
RECEIVER/TRANS, ARC-131									2	3											5	2	2.5
RECEIVER/TRANS, ARC-134									2	3											5	2	2.5
RECEIVER/TRANS, ARC-51BX										2											2	1	2.0
RECEIVER/TRANS, ARN-83										2									2		4	2	2.0
FUEL VALVE										2											2	1	2.0
AFCS AMPLIFIER											8			7			2				17	3	5.7

TABLE A3 - Concluded

PART/SYSTEM	18470	18471	18472	18473	18474	18475	18476	18477	18478	18479	18480	18482	18483	18484	18485	18486	18487	18488	18489	18490	TOTAL ACTIONS	NO OF A/C	ACTION/A/C
AFCS CONTROL PANEL											6										6	1	60
ENGINE EXHAUST DUCT												9									9	1	90
ENGINE												1	4	2						2	9	4	22
FUEL FILTER														5							5	1	50
TURBINE CASE												3		4							7	2	35
TACH./GEN															2						2	1	20
HOIST PANEL															2						2	1	20
HOIST INDICATOR															2						2	1	20
SPEED SWITCH, APP															2						2	1	20
BLEED VALVE, HYD															2						2	1	20
START SOLENOID			2																		2	1	20
FILTER					2																2	1	20
SENSE SWITCH								4													4	1	40
WORK PLATFORM					4																4	1	40
FIRE DETECTOR														2							2	1	20
FIRE DETECTOR AMP														2							2	1	20
PRESSURE SWITCH															2						2	1	20
PRESSURE TRANSMITTER																2					2	1	20
AFCS SERVO																2					2	1	20
RELAY																2					2	1	20
ROTOR BRAKE PKG																2	2				4	2	20
PITCH MODULE																2					2	1	20
ACCUMULATOR																	2				2	1	20
RMI AMP																	2				2	1	20
ANTENNA																			2		2	1	20
HOIST MANIFOLD																				2	2	1	20

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