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USAAMRDL TECHNICAL REPORT 72-11A

IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES

VOLUME I

INTRODUCTION, ANALYSIS, AND SUMMARY

By

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April 1972

EUSTIS DIRECTORATE

U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY

FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-71-C-0051

AMERICAN POWER JET COMPANY

RIDGEFIELD, NEW JERSEY

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This report was prepared by the American Power Jet Company under the terms of Contract DAAJ02-71-C-0051. It presents a discussion and ranking of reliability and maintainability (R&M) problems that have been encountered during the periods of ownership of the UH-1, AH-1, OH-6, OH-58, CH-47, and CH-54 aircraft by the U.S. Army. Included in the report is a listing of remedial actions directed toward certain of the R&M problems; where data existed, an assessment of the corrective action impact is determined. The contractor relied heavily on qualitative information that was gathered through numerous interviews with Army maintenance and aircraft prime contractor personnel. The basically subjective problem statements developed from these interviews were subsequently quantified to the maximum extent permitted by available data.

This report is considered to provide a reasonable insight into the many R&M problems that have been and continue to be experienced by Army aircraft. The lack of quantified data, however, precludes an exact ranking of problem areas; consequently, the reader is cautioned regarding the apparent severity of any specifically identified problem. Results of this contract are being integrated with other R&M problem identification efforts at the Eustis Directorate to establish research and development programs to improve the R&M characteristics of future Army aircraft systems.

Major Robert A. Mangum served as project engineer for this effort.

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IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES

Volume I
Introduction, Analysis, and Summary

American Power Jet Company Report 670-2

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ABSTRACT

This report presents the results of a study and analysis of reliability and maintainability (R&M) problems encountered by the Army's current generation of utility, attack, training, observation, and cargo helicopters.

Problem identification is based on an extensive series of interviews with personnel who have had long experience in operating, supporting, and maintaining these helicopters in Vietnam, in CONUS training bases, and in other missions and deployments. Interviews were conducted at eleven Army commands, activities and offices and at the prime manufacturers' plants (Bell Helicopter Company; the Boeing Company, Vertol Division; Sikorsky Aircraft, Division of United Aircraft Corporation; and Hughes Tool Company, Aircraft Division). Problem validation, expansion, and quantification are based on a large volume of publications and statistical data describing various aspects of reliability and maintainability problems identified.

A standard format provides a description of each problem, its cause, its duration, and its impact on safety, maintenance workload, and aircraft availability. Mission and deployment effects on each maintainability and reliability problem are specified, and remedial actions taken or in process to correct the problems are described.

Problems are grouped by helicopter type and within each type by functional group. Additionally, an analysis is made of problems common to two or more types, as a basis for development programs and product improvement. Problem rankings, in terms of their severity, are provided for each helicopter type in the three major impact areas of safety, maintenance workload, and availability.

FOREWORD

Because of its length, this final report on the Identification and Analysis of Army Helicopter Reliability and Maintainability Problems is presented in four volumes:

Volume I, "Introduction, Analysis, and Summary," contains:

1. A discussion of the study objectives, scope and the APJ approach.

2. A statement of the analysis considerations and an analysis of problems common to two or more helicopter types.

3. A detailed discussion of the standard format used in presenting the analysis of individual problems, a discussion of the data used and their adequacy, and definitions of the failure rate terms and measures used in problem analysis.

4. A ranking of the problems in terms of the severity of their impact on the major elements of safety, maintenance workload and aircraft availability.

Discussions of individual reliability and maintainability problems are presented in:

Volume II -"Utility, Attack and Training Helicopters (UH-1, AH-1, TH-1)"

Volume III -"Cargo Helicopters (CH-47, CH-54)"

Volume IV -"Light Observation Helicopters (OH-6, OH-58)"

They are presented in the standard format and form the basis for the analyses described in Volume I.

The work reported herein was done under the authority of DA Task 1F162205A11903.

Preparation of this report and the data acquisition and analysis on which it is based were accomplished by the APJ Project Team of Manley W. Clark, William K. Krauss and James M. Ciccotti, under the supervision of George Chernowitz. Grateful acknowledgement is made to the U.S. Army Air Mobility Research and Development Laboratory for its support, and particularly to Major Robert Mangum, the Contracting Officer's Technical Representative, for his cooperation and assistance throughout the project. Acknowledgement is also made of the assistance rendered by Army agencies and field activities and by manufacturers of the helicopters studied. The time spent by representatives of these activities and the records and reports made available by them were a major contribution to our work.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

INTRODUCTION

STUDY OBJECTIVES

The objectives of this study are to identify, describe, and quantify reliability and maintainability problems and deficiencies of the current generation of Army helicopters. Results of the study will pinpoint major areas of effort required in research, development and procurement of new helicopter systems by specifying current areas of weakness which affect safety, maintenance workload, and aircraft availability and by establishing, through a ranking, the relative seriousness of problems in each of these three areas.

The purpose of this report is to present results of the study covering analyses of the AH-1, TH-1, UH-1, CH-47, CH-54, OH-6 and OH-58 helicopters by type, model, and series.

SCOPE

The study encompasses both current problems and those which have occurred earlier in the life history of the helicopters under study, even though earlier problems may have been resolved. In general, analyses cover approximately a four-year span from early 1967 through mid-1971. In some cases, where data were available, longer periods of time have been included for portions of the analyses.

Analyses involve identification of problems and, for each problem, a description of the particular failure or malfunction which caused the problem, and a statement of the cause of the failure. The period during which the problem occurred is also stated, to the extent such identification is possible. Failure data related to the part or component affected by the problem is given, and mission and deployment factors associated with the failures are shown.

Additionally, a discussion of remedial actions taken or in process is provided for each problem, and where possible, the effect of remedial action on the problem is shown. In most cases, however, the long lead time associated with remedial actions precludes determination of the effect of the action on the problem. This subject is treated fully in the discussion of analysis logic and format.

Finally, the impact of each problem on helicopter safety, maintenance workload, and availability is provided. Within each category and for each helicopter type, model, series (TMS), problems are ranked in order of the severity. Safety rankings are based on the number and seriousness of mishaps attributed to failures of the particular part or component studied. Maintenance workload and availability rankings are based on the frequency of failure and maintenance manhours required for corrective action, and the frequency of failure and aircraft downtime resulting from failure.

Missions and deployments covered in the study include aircraft assigned to CONUS both in training bases and other CONUS activities, to Vietnam in combat and other missions, and to other activities worldwide using Army aircraft. Thus, problems analyzed are looked at on a fleet-wide basis as well as in relation to the particular environment and mission in which they operate.

All problems are also looked at from the standpoint both of the individual aircraft TMS against which the problem is identified and across the fleet as a whole. Many of the problems related to reliability and maintainability are common to helicopter TMS's across the fleet. These common problems are identified, summarized and discussed fully later in the text.

APPROACH

A considerable amount of work has been done and a large body of literature produced in the field of aircraft reliability and maintainability. In general, reliability and maintainability problems have been approached from one of two standpoints:

1. A statistical analysis of aircraft operating experience used as a basis for identifying those components or parts which fail most frequently. This approach involves the accumulation and analysis of

large volumes of statistical data (such as TAMMS, USABAAR Mishap Data, etc.). It is costly and time consuming, as statistical data become available only after events have occurred. The period of time necessary to secure an adequate data base for valid statistical inferences may be lengthy. In such cases, results will reflect conditions as they were at the time of occurrence, but not necessarily as they are at the time the analysis is completed. When completed, however, it does achieve its objective of identifying the particular parts or components shown during the period analyzed as most likely to fail. It does not normally identify the cause of failure, although symptoms may be provided.

2. Engineering tests and detail engineering design analyses of specific problems which have been identified by other means. This method normally involves laboratory tests and other tests which identify the particular metallurgical or other weaknesses which led to failure, and permits allocation of reliability through the relationship of reliability rates for interacting parts to each other. It is costly, and effort must be pinpointed to specific problems of specific parts and components to be useful.

Therefore, a third and very direct approach was used for problem identification in this study. It consisted of visiting and talking to a large number of people who had operated, maintained and supported the helicopters over a long period of time. It was felt that interviews with people of this type at various levels of operation and who had been involved in maintenance and support of the helicopters over a sufficient period of time under various operating conditions (Vietnam, CONUS training bases, National Maintenance Point, National Inventory Control Point, Depot, etc.) would present a cross section of experience which would serve to identify all major problems which had occurred over the life cycle of the aircraft. Our results, from using this approach, have shown this to be true. It has the advantages of providing identification in a short response time after the problem occurs, and pinpoints problems to the specific failures which occurred. Cross-checking of the results of the many interviews conducted during the study with other documents relating to these same helicopters has shown that, in fact, all major problems were identified by means of the interviews.

Identified problems have been validated and quantified through the use of a large volume of other data sources (these are discussed below under the heading, "Data Sources"). Additionally, APJ experience in previous studies of aircraft maintenance, logistic support, availability, safety, reliability and maintainability provided a valuable input to the report. Our data bank, resulting from studies of these same aircraft in Vietnam combat operations, at the Army Aviation Center training activities, operations of the Floating Aircraft Maintenance Facility in Vietnam, and of the 11th Air Assault Division in CONUS during its test, provided valuable inputs to this study. Experience gained by APJ personnel in these studies also provided background and experience essential to an understanding of the problems.

This approach has resulted in a summary of each of the major problems related to the aircraft TMS included in the study and, additionally, identification of major R&M problems which cut across all elements of the fleet. Thus, both a "horizontal" (across aircraft) and a "vertical" (across aircraft/functional system) examination of the problems analyzed are provided. Personnel and activities involved in follow-on development of aircraft with mission requirements similar to those studied will have available to them a compendium of the problems which have affected current aircraft of a similar type and with similar missions. Personnel and activities involved in the overall improvement of helicopters and helicopter reliability or in improvements in specific areas common to all helicopters (i.e., hardware, hydraulic systems, avionics, etc.) will have available analyses of the particular problems related to their areas of interest which are found to be common to all helicopters in the fleet.

DATA SOURCES

As noted above, the primary sources of data, particularly as related to problem identification, are the interviews conducted at the beginning of the study. Visits were made to the Aviation Center, Ft. Rucker; Hunter Army Airfield; the

USAAMRDL, Eustis Directorate, Ft. Eustis; USARADMAC, Corpus Christi; USABAAR, Ft. Rucker; U.S. Army Aviation Test Board, Ft. Rucker; USAAVSCOM, St. Louis; applicable project managers, St. Louis; Bell Helicopter Company, Ft. Worth; Sikorsky Aircraft, Division of United Aircraft Corp., Stratford, Conn.; Hughes Tool Company, Aircraft Division, Culver City, Cal.; Boeing Company, Vertol Division, Phila., Pa.; and New Cumberland Army Depot, New Cumberland, Pa. At each visit, personnel associated with operation, support, or maintenance of the helicopter TMS's under study were interviewed, and data in the form of records, reports and other publications applicable to the study were obtained.

Lists of the data sources used in analyses of the reliability and maintainability problems associated with each TMS are contained in Volumes II, III, and IV. To avoid lengthy repetition of these references, they have been numbered and will be referred to by number in the discussions of individual problems provided in each volume.

FLEETWIDE RELIABILITY AND MAINTAINABILITY CONSIDERATIONS - RELATIVE PROBLEM IMPACTS

GENERAL

Volumes II, III, and IV of this report identify a series of problems related to the current generation of Army helicopters and more specifically, to the parts, components and assemblies of the major functional groups which make up these helicopters. In the process of identifying and analyzing these various problems, it became apparent that many of the problems were common to more than one helicopter type.

These common problems are discussed in this section. The discussion is provided primarily to support research and development efforts leading toward overall improvements in future Army helicopters. A knowledge and understanding of the current problems which affect the fleet generally serve as a basis for concentration of effort in the most productive areas.

PROBLEM ANALYSIS CONSIDERATIONS

R&M is always in a trade-off position with the elements of cost and performance. In a situation where cost limitations are placed on helicopter procurement programs, R&M improvements generally can be obtained only at some sacrifice of performance. Such improvements frequently add weight to the aircraft, may affect power output, and generally reduce the capability of the manufacturer to produce a high-performance aircraft with improved R&M characteristics within a cost ceiling. Conversely, improvements in R&M are frequently costly, and if performance characteristics must be maintained, these improvements can be achieved only at additional cost for procurement.

For this reason, effort in the field of R&M has been concentrated largely on the high dollar value (primarily dynamic) components which have major safety, cost, maintenance workload, and aircraft availability implications. Much less effort has been devoted to other areas of the helicopter where many of the common problems discussed in this chapter are found. In general, the problems in these areas do not individually present large problems in safety, maintenance, availability, or cost. In total, however, they do present a significant maintenance workload which can, of course, be converted to cost and aircraft downtime. Perhaps even more important, this workload can also be converted to personnel requirements (skills and numbers) which may present an even larger problem than cost.

It is interesting to note that the sacrifice of reliability and maintainability for performance in initial procurement frequently does not resolve the trade-off problem. Most Army helicopters, as soon as delivered, undergo a continuing series of modifications (based on engineering change proposals and modification work orders), many of which are necessary to correct the reliability and maintainability problems not resolved in the initial procurement. The modifications in general are more costly than the same action would have been had it been taken in initial procurement, and frequently result in some sacrifice of performance. APJ studies have shown that the cost of modification can, over a few years, represent an appreciable percentage of the total cost of the aircraft itself. Additionally, modifications requiring field retrofit present a considerable demand for manpower and manpower skills at all levels of maintenance. For example, in the course of this study, it was determined that the application of all authorized modification work orders to one CH-47A helicopter would require over 7000 manhours.

Consequently, the true relationship between performance, R&M, and cost for all functional groups should be thoroughly explored when making trade-off analyses. The trade-off which defers the introduction of R&M characteristics in the hope that they will not be needed is not really a trade-off at all. While it is recognized that all potential R&M problems can not be identified during development and frequently even during test, a history of past experience and the failures which have been common to past helicopter development and operations should be of assistance in making the trade-off analyses best for future aircraft development and procurement.

EFFECTS OF ENVIRONMENTAL STRESSES ON R&M

Almost all helicopter reliability and maintainability problems result from the inability of the design and material used in the helicopter to withstand the environmental stresses to which the helicopter is subjected. These stresses vary considerably depending on the mission and deployment factors relating to the helicopter. Major examples, of course, are helicopters used for training, in combat, or for normal peacetime missions. While in theory all helicopters are procured with the objective of having a reliable vehicle safe for combat missions, in fact until Vietnam operations there was very little combat experience available related to helicopter operations. Thus, many of the current generation of helicopter TMS's were developed without combat experience input as a guide in development for R&M. Additionally, many of the types of helicopters in the current fleet were not "developed" helicopters under DOD long-range development programs but rather "off the shelf" procurements of helicopters designed by a manufacturer for commercial use and reconfigured to meet Army specifications. Consequently, many helicopters which operate satisfactorily in a CONUS environment encounter problems when placed in a combat or training environment.

The primary operational stresses are well known. They include vibration, shock, and acceleration. These are escalated in combat operations when the aircraft is often flown under overgross conditions, is overtorqued, or is subjected to the stresses resulting from serving as a weapons vehicle. Vibration, shock, and blast from the weapons increase markedly the effects of the normal vibration resulting from operation of the helicopter itself. Training programs produce increased usage of many parts (cowls are opened and closed much more frequently; doors, hinges, and latches receive more wear), and practice landings and autorotations produce stresses on landing gear and other airframe components not normally encountered in other environments.

A high percentage of all the material and design inadequacies discussed below can be traced to the effect of these operational environmental stresses and the inadequacy of the material to meet them.

Natural environmental stresses also affect reliability and, in the case of the current helicopter fleet, have been particularly severe for aircraft operating in Vietnam. A primary contributor to R&M problems in Vietnam is sand and dust, common to that area. Additionally, humidity, water, atmospheric salts, and other pollutants and heat also play a part in the capability of material to withstand the natural environment in which it is operated.

It is apparent, therefore, that careful consideration must be given to the operating environment and the natural environment in which helicopters may be used. Satisfactory reliability and maintainability can only be attained when the design and materials used can withstand these stresses.

COMMON MATERIAL AND DESIGN INADEQUACIES

Following is a brief discussion of the major material and design inadequacies which have been identified in this study and which are common to more than one helicopter TMS.

Fasteners and Rivets

Reference Problems UH-1 01-5; AH-1G 01-8, 01-1, 01-4, 01-5, 01-9; CH-47 01-1; OH-6 01-5; OH-58 01-3.

Fasteners and rivets fail with high frequency in most areas of the aircraft where they are used. Individual failures do not normally present major maintenance workload or aircraft availability problems. In total, they represent a considerable maintenance manhour demand and aircraft downtime. Most failures do not present immediate safety problems, although in some critical areas they may. Cases of ingestion of fasteners through the engine have produced engine malfunctions and failures.

Many failures result from vibration or the effects of torsion which exceed the capability of the material. Improper installation of the fasteners by maintenance personnel also accounts for a significant number of failures. Forcing the fastener to close when misaligned is a common maintenance error.

Maintainability would be improved by a fastener which would eliminate this possibility. Improved reliability would reduce maintenance workload and aircraft downtime.

Seals, O-Rings, Preformed Packing

Reference Problems UH-1 04-3, 04-4, 04-5, 04-6, 06-1; AH-1G 01-1, 04-2, 04-4, 04-5, 06-2, 06-3; CH-47 04-5, 06-1; CH-54 04-3, 04-8, 04-10, 04-11, 06-2, 06-4, 18-1; OH-6 04-1, 04-3; OH-58 04-2.

The failure of seals and O-rings is a continuing problem. Most failures result in leaking of oil and hydraulic fluid. In some instances, failure permits entrance of sand, dirt, dust, water, and other contaminants into areas where activity of these foreign elements produces damage. Seal failures are a major source of bearing problems and are primary contributors to problems in the hydraulic system, in the flight control system, in the oil system installation, and in rotor and transmission systems. Additionally, hydraulic fluid and oil seepage accelerates corrosion and causes shorts in electrical circuits.

Failures do not normally present safety hazards in terms of serious accidents. However, as noted in the many problems referenced above, frequency of failure is high and maintenance workload is correspondingly heavy. Failures result primarily from the inability of the material to withstand the pressures and wear to which they are subjected.

Hydraulic System Components

Reference Problems UH-1 06-1; AH-1G 06-1, 06-2, 06-3; CH-47 06-1; CH-54 06-1, 06-2, 06-3, 06-4; OH-58 11-1.

Failures in the hydraulic systems of utility, attack, and cargo helicopters present serious reliability and maintainability problems. Failures are common to most parts and components of the systems. Valves, servos, and pumps fail and malfunction, frequently from internal failures and, as noted above, are also subject to frequent seal failures. Hoses and tubes are chafed, burst and cracked. Connections leak and fittings crack and break.

Failures of hydraulic components in the flight control system can cause serious safety problems. Other failures normally do not result in major mishaps but cause more precautionary landings than any other category of failures. Maintenance workload and aircraft downtime factors are difficult to establish for most parts and components of the hydraulic system. However, the Ft. Rucker maintenance activity estimates that from 8% to 15% of their total maintenance workload for the UH-1, CH-47 and CH-54 helicopters is required for hydraulic system repairs and replacements.

As noted in the discussion of seal failures above, hydraulic fluid from leaking hoses, tubes and connections may accelerate corrosion, contaminate bearing surfaces, and produce shorts in electrical circuits.

Failures result from the inability of the materials in the system to withstand the pressure and other stresses to which they are subjected. Some of the more specific causes of failure are inability of components to withstand surges above the rated pressure for the system, vibration, improper routing of lines in design, and improper securing of lines in maintenance.

<u>Doors, Access Panels, Work Platforms and Attaching Hardware</u>

> Reference Problems UH-1 01-3, 01-4; AH-1G 01-4, 01-6, 01-7; CH-47 01-1, 01-3, 01-4, 01-5; OH-6 01-4; OH-58 01-1, 01-2.

Failures of these parts and components are frequent and common to most helicopter types. There are many modes of failure, including malfunction and failure of latches, hinges and handles, breaking and cracking of door posts and attaching fittings, and failure of door stops and ejection mechanisms.

Failures result from inadequacy of material and design to meet stresses resulting from vibration, torsion and normal usage. Maintenance errors, particularly incorrect installation, improper adjustment, the use of force to close doors and panels, and standing and walking on areas not designated as steps or walkways, have all been cited as contributing to failures.

Flying with doors open has also caused failures and malfunctions.

Failures of these components can present a serious safety problem. Instances of doors, panels and work platforms leaving the aircraft in flight and striking the main or tail rotor system have occurred. Most failures, however, do not present immediate safety problems.

Correction of most individual failures does not ordinarily present serious maintenance nor aircraft downtime problems. The high frequency of failure, however, results in high maintenance workload and aircraft downtime.

Windshields, Windows and Other Transparent Panels

Reference Problems UH-1 01-2, 01-3; AH-1 01-3; CH-47 01-2; OH-6 01-2.

Windshield failures result from the use of transparent plastic materials which become scratched and crazed from abrasion, crack and break, or melt and delaminate from rain removal and defrosting unit operations. Windows craze, crack, and break. Operation of windshield wipers, dropping of tools on panels, and standing or walking on panels also contribute to failures. Failures have not resulted in serious safety problems. The rate of failure and manhour requirements to repair any one windshield, window or panel are generally not excessive. However, the number of such components on helicopters produces, in total, a high workload and aircraft downtime requirement.

Plastic and Fiberglass Components

Reference Problems AH-1 01-4, 01-5, 02-2, 12-1; CH-47 01-3; OH-6 01-3.

Components made of plastic and fiberglass (excluding windshields and windows, discussed separately) are used in many helicopter subsystems. Most fairings are constructed of these materials, and they are widely used for ventilation system ducting. Failures of these components consist primarily of cracking and breaking, particularly at and around attaching points. Causes of failure are vibration, torsion and, in the case of landing gear fairings, use of fairings as a step by pilots and maintenance personnel.

Failures normally do not present safety problems. Manhour and aircraft downtime requirements vary considerably, depending on the affected parts and components. In total, however, failures of these items produce sizeable maintenance workload and downtime factors.

Landing Gear (Skid Type)

Reference Problems UH-1 02-1; AH-1 02-1, 02-2; OH-6 02-1, 02-2, 02-3.

Failures and malfunctions of many skid type landing gear components have produced problems. Some components most subject to high failure rates have been dampers, skid shoes and tubes, cross tubes, and struts. Common modes of failure are cracking, breaking, bending, wearing and collapsing.

Failures result primarily from hard landings and landing on rough terrain. The problem is most severe at the Army Aviation Center where practice autorotations and practice landings produce a high rate of wear. However, failures also produce less severe problems in other areas of operation.

Landing gear failures have not caused safety problems, and failures of individual components can be corrected with few manhours and minimum aircraft downtime. However, the frequency of failure, particularly at Ft. Rucker, imposes a heavy maintenance workload and high downtime factors.

Rotor Blades

Reference Problems UH-1 04-2; AH-1 04-3; CH-47 04-1; CH-54 04-1; OH-6 04-4.

Main rotor blade failures are categorized as inherent and external. Inherent failures are those that result from conditions which the blade is designed to meet, e.g., bonding failures, delamination, and corrosion. External failures account for 50% or more of all blade failures on Army helicopters.

There is no marked difference in failure rates from inherent and external causes. In both cases, failures occur on the average well before the allowable operating time. Causes of inherent failures vary somewhat from aircraft to aircraft, but some of the major causes are erosion and abrasion, bonding separation, delamination, and excessive wear. Combat and crash damage account for a high percentage of failures from external causes.

Rotor blade failures have not presented serious safety problems. Maintenance workload and aircraft downtime requirements vary. For some helicopters, replacement is authorized at organizational level and for others at the direct support level. The size and number of blades per helicopter also affect these factors. In general, the frequency of failure establishes high workload and downtime factors in this area of support.

Tail Rotor System

Reference Problems UH-1 04-1; AH-1G 04-1, 04-2, 11-1; CH-54 04-2, 04-11, OH-6 04-2; OH-58 04-1, 04-3.

The tail rotor system on all aircraft so equipped has presented reliability problems which have seriously affected safety, maintenance workload, and aircraft availability. There are many areas of failure including bearings, blades, quills, and seals. Malfunctions and failures of the hub are common. Causes of failure include spalling and pitting of bearings, bonding separation and cracking of rotor blades, and corrosion, bending, wearing, cracking and breaking of other components and parts. Vibration is a major primary source of many of the tail rotor failures.

Tail rotor system failures present serious safety problems, often causing the total loss of the helicopter or a major mishap. The frequency of malfunctions and failures of various parts and components of the tail rotor system also produces high maintenance workload requirements and aircraft downtime.

Bearings

Reference Problems UH-1 04-1, 04-4, 04-8, 04-9, 04-10; AH-1G 04-1, 04-4; CH-47 04-3, 04-6; CH-54 04-7, 04-10, 04-11, 18-1; OH-6 04-3, 04-5; OH-58 04-1, 04-3.

Bearing failures have been a continuing problem on all helicopter types. Main and tail rotor installations have been most seriously affected. Many failures result from foreign material contaminating the bearing surfaces. Sand, dirt, hydraulic fluid, oil, and water are common sources of contamination. The polytetrafluoroethylene (PTFE)* bearing has been particularly susceptible to failure from these sources. When contamination occurs, the PTFE lining flakes off and metal-to-metal contact results. Spalling, pitting, corrosion, and excessive wear are typical modes of failure.

While bearing failures can produce serious safety conditions, particularly when tail rotor, main rotor or transmission systems are involved, most incipient failures are detected before they cause major mishaps. Maintenance workload from bearing failures occurs often at more than one level of maintenance. Most repairs are accomplished at direct support or higher levels, and many only at depot level. In these cases, repair of the aircraft involves replacement of the assembly in which the bearing is located, with subsequent repair of the bearing itself at another level. Aircraft downtime is generally related to assembly rather than bearing replacement. The extent and frequency of bearing failures described in the problems referenced above indicate the seriousness of their impact on maintenance workload and downtime.

Automatic Stabilization and Flight Control Systems

Reference Problems AH-1 09-1, 11-2; CH-47 19-1; CH-54 06-3

The systems used on the AH-1 (SCAS), CH-47 (SAS), and CH-54 (AFCS) are similar to the extent that they combine electronic and hydraulic components into a single system. Failures occur in both areas. Transducers and transmitters fail and malfunction. As noted in the discussion of hydraulic systems, hydraulic components are subject to a high rate of failure and malfunction, including those components in the stabilization and flight control systems. Causes of electronic component failures are not well defined, as most corrective action below depot level is component replacement rather than repair. Causes of hydraulic component failures have been discussed.

* Teflon TFE, the trade name of E.I. DuPont de Nemours Co., Inc. for polytetrafluoroethylene, is widely used as a generic term for PTFE.

Failures in these systems do not ordinarily present serious safety problems, as the systems can be overridden or turned off by the pilot. However, the rate of precautionary landings is high. Maintenance workload and aircraft downtime requirements for replacement of individual components are low. Troubleshooting to identify the source of the problem is frequently time consuming.

RANKING

The various problems discussed in Volumes II, III, and IV have varying impacts on the major elements of safety, maintenance workload, and aircraft availability. Many problems which have relatively severe impact on maintenance workload and aircraft availability have little or no effect on safety. Conversely, some problems may have a measurable impact on safety and yet produce little effect on maintenance workload and aircraft availability.

Because of these differences, it was determined that three categories for ranking would be used to cover the three major areas of safety, maintenance workload, and aircraft availability. Rankings are shown below. It will be noted that there is a close correlation between maintenance workload and aircraft availability as availability is, for the most part, closely related to the maintenance workload involved in corrective action. In general, safety rankings are based on the frequency and severity of mishaps as reported by USABAAR, with severity being the primary ranking factor. However, less severe mishaps are also given a high level of consideration in ranking if they occur with sufficient frequency. A forced landing or precautionary landing could well have been a major mishap if the pilot had not had the skill (and perhaps, good fortune) to land the aircraft before a major mishap occurred.

Ranking of problems related to maintenance workload is essentially based on the frequency of failure and the manhour load imposed on the maintenance structure for repairs and replacements. Availability rankings also are based on the same considerations, i.e., frequency of failure and downtime required for corrective action.

It is obviously impossible to assign a specific numerical ranking to each individual problem. The degree of definition required for this is not present, and such rankings would be of little practical value in any event. Therefore, five categories have been assigned to define the impact of the problem on the three major areas noted. These are:

1. Very high

2. High

3. Medium

4. Low

5. Very low or none

It must be recognized that any ranking system involves subjective evaluations, to some degree. To the extent possible, we have used the data contained in the discussions as the basis for ranking. However, particularly in the area of safety, some judgement must be introduced. In these cases, we have used our background and experience in the field of aviation analyses of safety, reliability, maintainability, maintenance and logistics support of Army helicopters over the past twelve years in making such judgements.

Rankings are provided in Tables I through XVIII.

TABLE I. UH-1 PROBLEM RANKING - SAFETY FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Dampers					X
01-2	Windshield					X
01-3	Doors/Hardware			X		
01-4	Bonded Panels				X	
01-5	Fasteners			X		
01-6	Structural		X			
02-1	Landing Gear					X
04-1	Tail Rotor	X				
04-2	M/R Blades				X	
04-3	Radius Ring/Seals				X	
04-4	M/R Grip				X	
04-5	Input Quill				X	
04-6	Stabilizer Assembly					X
04-7	Short Shaft		X			
04-8	Swashplate					X
04-9	Lever Assembly					X
04-10	Scissors & Sleeve					X
06-1	Hydraulics		X			
08-1	Instruments					X
09-1	Lights/Bulbs					X

TABLE II. UH-1 PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Dampers				X	
01-2	Windshield				X	
01-3	Doors/Hardware		X			
01-4	Bonded Panels	X				
01-5	Fasteners				X	
01-6	Structural		X			
02-1	Landing Gear			X		
04-1	Tail Rotor		X			
04-2	M/R Blades		X			
04-3	Radius Ring/Seals			X		
04-4	M/R Grip	X				
04-5	Input Quill			X		
04-6	Stabilizer Assembly				X	
04-7	Short Shaft			X		
04-8	Swashplate		X			
04-9	Lever Assembly				X	
04-10	Scissors & Sleeve				X	
06-1	Hydraulics		X			
08-1	Instruments					X
09-1	Lights/Bulbs					X

TABLE III. UH-1 PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Dampers				X	
01-2	Windshield			X		
01-3	Doors/Hardware			X		
01-4	Bonded Panels	X				
01-5	Fasteners					X
01-6	Structural	X				
02-1	Landing Gear			X		
04-1	Tail Rotor		X			
04-2	M/R Blades		X			
04-3	Radius Ring/Seals			X		
04-4	M/R Grip		X			
04-5	Input Quill			X		
04-6	Stabilizer Assembly				X	
04-7	Short Shaft			X		
04-8	Swashplate		X			
04-9	Lever Assembly				X	
04-10	Scissors & Sleeve				X	
06-1	Hydraulics		X			
08-1	Instruments					X
09-1	Lights/Bulbs					X

TABLE IV. AH-1G PROBLEM RANKING - SAFETY FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Damper					X
01-2	Air Inlet Filter					X
01-3	Window Panel					X
01-4	Access Doors & Panels					X
01-5	42° Gearbox Cover					X
01-6	Canopy, Doors				X	
01-7	Bonded Panels					X
01-8	Fasteners and Rivets				X	
02-1	Landing Gear			X		
02-2	Cross Tube Fairing					X
04-1	Tail Rotor Assembly	X				
04-2	90° Gearbox		X			
04-3	Main Rotor Blade					X
04-4	Main Rotor Hub Bearing					X
04-5	Xmsn. Input Quill				X	
06-1	Valves				X	
06-2	Servo Cylinder					X
06-3	Hydraulic Components		X			
08-1	Attitude Indicator					X
08-2	Fuel Quantity Ind.					X
08-3	Airspeed Indicator					X
08-4	Radio Magnetic Ind.					X
09-1	Inverters					X
09-2	Lights					X
11-1	Tail Rotor Cable					X
11-2	SCAS			X		
12-1	Air Distribution			X		
19-1	AN/ARC-54 Radio					X
19-2	Impedance Network					X
30-1	XM-28 Turret				X	
30-2	External Stores Ejector Rack					X

TABLE V. AH-1G PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Damper			X		
01-2	Air Inlet Filter					X
01-3	Window Panel			X		
01-4	Access Doors & Panels					X
01-5	42° Gearbox Cover				X	
01-6	Canopy, Doors			X		
01-7	Bonded Panels					X
01-8	Fasteners and Rivets			X		
02-1	Landing Gear			X		
02-2	Cross Tube Fairing		X			
04-1	Tail Rotor Assembly		X			
04-2	90° Gearbox		X			
04-3	Main Rotor Blade		X			
04-4	Main Rotor Hub Bearing	X				
04-5	Xmsn. Input Quill	X				
06-1	Valves				X	
06-2	Servo Cylinder					X
06-3	Hydraulic Components		X			
08-1	Attitude Indicator			X		
08-2	Fuel Quantity Ind.				X	
08-3	Airspeed Indicator				X	
08-4	Radio Magnetic Ind.				X	
09-1	Inverters			X		
09-2	Lights				X	
11-1	Tail Rotor Cable		X			
11-2	SCAS			X		
12-1	Air Distribution			X		
19-1	AN/ARC-54 Radio		X			
19-2	Impedance Network				X	
30-1	XM-28 Turret	X				
30-2	External Stores Ejector Rack					X

TABLE VI. AH-1G PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Prob. No.	Short Title	Very High	High	Med.	Low	Very Low
01-1	Pylon Damper			X		
01-2	Air Inlet Filter					X
01-3	Window Panel			X		
01-4	Access Doors & Panels					X
01-5	42° Gearbox Cover				X	
01-6	Canopy, Doors			X		
01-7	Bonded Panels					X
01-8	Fasteners and Rivets					X
02-1	Landing Gear			X		
02-2	Cross Tube Fairing		X			
04-1	Tail Rotor Assembly			X		
04-2	90° Gearbox		X			
04-3	Main Rotor Blade		X			
04-4	Main Rotor Hub Bearing	X				
04-5	Xmsn. Input Quill	X				
06-1	Valves				X	
06-2	Servo Cylinder					X
06-3	Hydraulic Components		X			
08-1	Attitude Indicator			X		
08-2	Fuel Quantity Ind.			X		
08-3	Airspeed Indicator				X	
08-4	Radio Magnetic Ind.				X	
09-1	Inverters			X		
09-2	Lights				X	
11-1	Tail Rotor Cable		X			
11-2	SCAS			X		
12-1	Air Distribution			X		
19-1	AN/ARC-54 Radio		X			
19-2	Impedance Network			X		
30-1	XM-28 Turret	X				
30-2	External Stores Ejector Rack					X

TABLE VII. CH-47 PROBLEM RANKING - SAFETY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Fasteners/Rivets				X	
01-2	Windshield					X
01-3	Tunnel Cover/Fiber-glass			X		
01-4	Doors/ Work Platforms			X		
01-5	Cargo Door/Ramp Hinge					X
01-6	Structures/Bulkheads					X
01-7	Engine Mount Fitting					X
01-8	Floor Beam Assembly					X
04-1	Rotor Blades		X			
04-2	Oil Tank					X
04-3	Synchronized Drive Shaft				X	
04-4	Oil Pressure Trans-ducer			X		
04-5	Pitch Varying Housing Seal					X
04-6	Bearings				X	
06-1	Hydraulics		X			
09-1	Voltage Regulator/ Panels					X
19-1	SAS/SAS Components				X	
19-2	AN/ARC-54 Rec-Trans					X

TABLE VIII. CH-47 PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Fasteners/Rivets				X	
01-2	Windshield				X	
01-3	Tunnel Cover/Fiber-glass	X				
01-4	Doors/ Work Platforms		X			
01-5	Cargo Door/Ramp Hinge				X	
01-6	Structures/Bulkheads			X		
01-7	Engine Mount Fitting			X		
01-8	Floor Beam Assembly		X			
04-1	Rotor Blades		X			
04-2	Oil Tank					X
04-3	Synchronized Drive Shaft		X			
04-4	Oil Pressure Trans-ducer					X
04-5	Pitch Varying Housing Seal			X		
04-6	Bearings	X				
06-1	Hydraulics	X				
09-1	Voltage Regulator/ Panels					X
19-1	SAS/SAS Components				X	
19-2	AN/ARC-54 Rec-Trans					X

TABLE IX. CH-47 PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Fasteners/Rivets				X	
01-2	Windshield				X	
01-3	Tunnel Cover/Fiber-glass	X				
01-4	Doors/ Work Platforms	X				
01-5	Cargo Door/Ramp Hinge				X	
01-6	Structures/Bulkheads			X		
01-7	Engine Mount Fitting			X		
01-8	Floor Beam Assembly		X			
04-1	Rotor Blades			X		
04-2	Oil Tank					X
04-3	Synchronized Drive Shaft		X			
04-4	Oil Pressure Trans-ducer					X
04-5	Pitch Varying Housing Seal				X	
04-6	Bearings	X				
06-1	Hydraulics	X				
09-1	Voltage Regulator/ Panels					X
19-1	SAS/SAS Components			X		
19-2	AN/ARC-54 Rec-Trans					X

TABLE X. CH-54 PROBLEM RANKING - SAFETY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
04-1	Main Rotor Blades				X	
04-2	Tail Rotor Blades				X	
04-3	Rotor Brake Seal Assy					X
04-4	Rotor Brake Support Assy					X
04-5	Brake Disc				X	
04-6	Brake Pucks					X
04-7	Oil Cooler Assy					X
04-8	Carbon Seals				X	
04-9	Main Gearbox		X			
04-10	Viscous Dampers					X
04-11	T/R Head Assy		X			
04-12	Generators				X	
06-1	Hoist Pump			X		
06-2	Manifold & Housing Assy					X
06-3	AFCS Servo Assy				X	
06-4	Hydraulics			X		
17-1	Limit Safety Switch			X		
18-1	APP Clutch/Adapter Assy					X
19-1	AFCS/AFCS Components				X	

TABLE XI. CH-54 PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
04-1	Main Rotor Blades	X				
04-2	Tail Rotor Blades			X		
04-3	Rotor Brake Seal Assy			X		
04-4	Rotor Brake Support Assy				X	
04-5	Brake Disc				X	
04-6	Brake Pucks			X		
04-7	Oil Cooler Assy		X			
04-8	Carbon Seals		X			
04-9	Main Gearbox			X		
04-10	Viscous Dampers			X		
04-11	T/R Head Assy			X		
04-12	Generators				X	
06-1	Hoist Pump			X		
06-2	Manifold & Housing Assy		X			
06-3	AFCS Servo Assy		X			
06-4	Hydraulics	X				
17-1	Limit Safety Switch				X	
18-1	APP Clutch/Adapter Assy		X			
19-1	AFCS/AFCS Components			X		

TABLE XII. CH-54 PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
04-1	Main Rotor Blades		X			
04-2	Tail Rotor Blades			X		
04-3	Rotor Brake Seal Assy			X		
04-4	Rotor Brake Support Assy				X	
04-5	Brake Disc					X
04-6	Brake Pucks			X		
04-7	Oil Cooler Assy			X		
04-8	Carbon Seals		X			
04-9	Main Gearbox			X		
04-10	Viscous Dampers		X			
04-11	T/R Head Assy			X		
04-12	Generators				X	
06-1	Hoist Pump			X		
06-2	Manifold & Housing Assy		X			
06-3	AFCS Servo Assy			X		
06-4	Hydraulics	X				
17-1	Limit Safety Switch				X	
18-1	APP Clutch/Adapter Assy			X		
19-1	AFCS/AFCS Components			X		

TABLE XIII. OH-6A PROBLEM RANKING - SAFETY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Horizontal Stabilizer				X	
01-2	Windshield					X
01-3	Polycarbonate Components					X
01-4	Cabin & Access Doors/ Hardware			X		
01-5	Rivets				X	
02-1	Landing Gear Skid/ Strut					X
02-2	Landing Gear Damper					X
02-3	Landing Gear Fairing Assy					X
04-1	T/R Drive System	X				
04-2	T/R Hub & Blade	X				
04-3	Main Transmission		X			
04-4	Main Rotor Blade			X		
04-5	Bearings			X		
09-1	Battery			X		

TABLE XIV. OH-6A PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS						
Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Horizontal Stabilizer			X		
01-2	Windshield			X		
01-3	Polycarbonate Components			X		
01-4	Cabin & Access Doors/ Hardware	X				
01-5	Rivets			X		
02-1	Landing Gear Skid/ Strut		X			
02-2	Landing Gear Damper				X	
02-3	Landing Gear Fairing Assy		X			
04-1	T/R Drive System			X		
04-2	T/R Hub & Blade			X		
04-3	Main Transmission			X		
04-4	Main Rotor Blade				X	
04-5	Bearings		X			
09-1	Battery					X

TABLE XV. OH-6A PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Horizontal Stabilizer				X	
01-2	Windshield		X			
01-3	Polycarbonate Components		X			
01-4	Cabin & Access Doors/ Hardware	X				
01-5	Rivets				X	
02-1	Landing Gear Skid/ Strut		X			
02-2	Landing Gear Damper		X			
02-3	Landing Gear Fairing Assy			X		
04-1	T/R Drive System			X		
04-2	T/R Hub & Blade			X		
04-3	Main Transmission			X		
04-4	Main Rotor Blade				X	
04-5	Bearings			X		
09-1	Battery					X

TABLE XVI. OH-58A PROBLEM RANKING - SAFETY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Armor Side Panel				X	
01-2	Doors/Latches					X
01-3	Fasteners/Rivets					X
04-1	T/R Drive Shaft				X	
04-2	Short Shaft					X
04-3	Tail Rotor Hub				X	
11-1	Flight Control Actuator					X

TABLE XVII. OH-58A PROBLEM RANKING - MAINTENANCE WORKLOAD FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Armor Side Panel					X
01-2	Doors/Latches			X		
01-3	Fasteners/Rivets			X		
04-1	T/R Drive Shaft			X		
04-2	Short Shaft			X		
04-3	Tail Rotor Hub				X	
11-1	Flight Control Actuator				X	

TABLE XVIII. OH-58A PROBLEM RANKING - AIRCRAFT AVAILABILITY FACTORS

Problem Number	Short Title	Very High	High	Med.	Low	Very Low
01-1	Armor Side Panel					X
01-2	Doors/Latches			X		
01-3	Fasteners/Rivets			X		
04-1	T/R Drive Shaft			X		
04-2	Short Shaft				X	
04-3	Tail Rotor Hub				X	
11-1	Flight Control Actuator				X	

ANALYSIS LOGIC AND FORMAT

GENERAL

Reliability and maintainability problems related to the six helicopter TMS's included in this study are presented in Volumes II, III, and IV. Problems for each TMS have been organized by functional group shown in the prefix to each problem number. Functional Group 03 (power plant) is not within the scope of this study and thus is not covered.

All problems are identified to the helicopter series to the extent that such identification could be made. The AH-1G and TH-1G are identical in every respect with the exception of the installations made to convert the gunner's position to an instructor's position. (The changes provided by MWOs 30-6 and 30-7 consisted only of installing a flight control boost system and an instructor instrument system.) Therefore, all problems identified as AH-1G in Volume II also apply to the TH-1G, and information based on Hunter Army Airfield experience is applicable to the TH-1G used there. In only one instance was a problem related solely to the TH-1G, and that problem has been so identified.

The number of problems identified to any helicopter TMS is related, to some extent, to its exposure in terms of the numbers of the TMS in operation, and particularly to the length of time the TMS has operated. Relatively few problems have been identified to the OH-58A helicopter, and it is probable that its relatively short time in operation contributes to this situation. Several of the structural problems discussed in this report occur only after a fairly extended period of operation. Other failures cannot be considered problems until sufficient hours of operation have been accrued to show trends and patterns. Therefore, this report does not attempt to evaluate the comparative reliability and maintainability of the helicopter TMS's analyzed, but only to analyze problems which have occurred during their life cycle to the time of the study.

A standard format has been used for problem discussion. Following is a brief description of the major headings and certain background information which will assist in reviewing and understanding the problems set forth in the respective volumes.

PROBLEM DESCRIPTION

This section contains the data which serve to identify the problem in terms of: (a) the particular components affected, giving part identification and aircraft series affected; (b) a description of the failure; (c) causes of failure; (d) the period in the life cycle of the helicopter when it occurred, and the duration of the problem; (e) the mean time between failures, mean time to removal, or other data which will indicate the severity of the problem; and (f) a statement of the particular missions or deployments most affected by the problem.

Component Identification and Description of Failure

Problems were identified primarily based on discussions by APJ representatives (accompanied and assisted by USAAMRDL representatives) with personnel at various Army and contractor activities familiar with the problems of operating and maintaining the helicopters under study. The approach is discussed in the Introduction to this report. These interviews, supplemented by extensive review of other data, including EIR Digests, ECP and MWO descriptions, Project Manager records and reports, prime contractor records, U.S. Army Aviation Test Board reports, and USABAAR Accident Data Summaries, were principal validating sources. Part numbers are used exclusively in all discussions, as part number identification generally is more complete than Federal Stock Number identification in technical manuals.

Cause of Failure

As noted earlier, the discussion of cause of failure is not based on engineering analysis of actual failed components. Essentially, it is based on the information obtained from the data sources listed above. It should be noted that many personnel interviewed had theories regarding the cause of failures for problems which they discussed. In a great many cases, however, these were purely personal opinions and not substantiated by actual analysis or tests. Causes of failure shown in this report do not ordinarily reflect these opinions. If they are included in the discussion, they are identified as such.

Period and Duration of Problem

The discussions generally show the earliest recorded date at which the problem appears in the data available. It is probable that a number of the problems actually existed prior to the date shown, but data were not available for these early periods to determine the specific date at which the problem first became known. The problem of identifying the date of occurrence of problems for later helicopters such as the AH-1G, OH-6 and OH-58 is not as great as helicopters which have been operating in the Army fleet for several years. The duration of the problem is also exceedingly difficult to determine precisely. While remedial actions may have been taken to correct the problem, as noted below, the effect of the remedial action in resolving the problem is generally exceedingly difficult to establish. Reasons for this are discussed below under Remedial Actions.

Failure Rate Data

Three terms are used to describe failure rates in this report. The terms are generally used as presented in the source documents from which failure rates were obtained or have been selected as the most precise definition of failure rates derived from source documents by APJ. The terms are:

1. Mean Time Between Failures (MTBF). The ratio of the operating time to the number of observed failures. It is taken directly from R&M reports produced by Bell Helicopter Company; Boeing Company, Vertol Division; Sikorsky Aircraft, Division of United Aircraft Corp.; related to UH-1, AH-1, CH-47, and CH-54 helicopters and helicopter components respectively. Where only one of a component is used on a helicopter, the component MTBF is also a measure of the frequency with which the helicopter will require maintenance to correct the component failure. Where more than one component of a type is used on a helicopter, component MTBF is computed by multiplying the MTBF derived from the ratio of aircraft flying time to observed failures by the number of component applications per helicopter.

2. Mean Time to Removal (abbreviated as MTR to distinguish it from MTTR - Mean Time to Repair). The average operating time on components removed from the aircraft since last installed. MTR rates in the report are:

   a. Taken directly from Bell Helicopter Company and Boeing-Vertol R&M reports (called Average Time to Removal by Boeing-Vertol)
   b. Derived by APJ from Hughes Tool Company Report 1C, which lists component removals and component operating hours at removal
   c. Derived by APJ from USAAVSCOM Major Item Removal Frequency Reports (MIRF). These reports show number of component removals and average time since installation. Mean time to removal measurements used in this report are based on removals for failures only. Removals for time change, to facilitate other maintenance, and other non-failure causes are excluded from computations.

3. Mean Time Between Replacement (MTBR). The ratio of aircraft operating time to the number of demands made on the supply system for a component. This term is restricted to failure rates derived by APJ from data obtained at the Aviation Center, Ft. Rucker.

   A list of demands against the supply system for a one-year period ending 30 April 1971 was obtained from the Aviation Center Maintenance Activity. Flying times for aircraft assigned to the Center over the same time period were extracted from the Army Aircraft Inventory and Flying Time Report (RCS,AMCMR-123). On the assumption that a demand against the supply system for a component represented the failure of a similar component on the aircraft, the ratio of flying times to demands is designated as the MTBR. This measurement reflects only failures corrected by replacement and excludes any corrections by repair. For this reason, the MTBR is often greater than the MTBF which considers all failures.

Mission and Deployment Factors

An attempt has been made to determine the effect of mission assignment and geographic deployment on the problems discussed. While many problems are common to all missions and deployments, in some cases there is a clear difference between the problem severity in combat missions in Vietnam and that in training missions in CONUS and other aircraft missions. These differences are identified in the discussions where they occurred.

PROBLEM IMPACT

The impact of each problem on three major areas related to helicopter operations and support is analyzed: safety, maintenance workload, and aircraft availability.

Safety Factors

Safety factors are based almost exclusively on data provided by USABAAR in the form of a listing of mishaps covering the period 1 January 1967 through 31 March 1971. Mishaps are classified as:

1. Total loss
2. Major
3. Minor
4. Incident
5. Forced landing
6. Precautionary landing

The data distinguish between mishaps resulting from material failures and malfunctions and those resulting from maintenance errors. However, in many instances, USABAAR is not able to determine, from the reports received, the cause of the mishap to that degree of refinement. Thus, it is probable that a complete investigation of every mishap reported over the period might result in a higher number charged to maintenance error and fewer to material malfunction than shown. It is important to note that the data provided exclude mishaps resulting from combat operations.

Maintenance Workload Factors

Maintenance workload factors are shown based on the particular action required to correct the condition resulting from the problem -- normally replace or repair. For each action, the manhours required to accomplish corrective action and the level of maintenance at which the action is authorized are provided. These factors are based primarily on APJ studies of helicopter maintenance, including particularly the studies which produced the APJ Flat Rate Manual series and on estimates obtained from maintenance personnel during field visits. In a few instances, manhour data are available in the USAAVSCOM Reportable Items Action Data Sort Reports, the USAAVSCOM Aircraft Component Time Since Installation or New Reports, and in helicopter manufacturer reliability reports. Validation from these sources, however, was limited by the relatively few components on which such data were provided in these reports.

Aircraft Availability Factors

Aircraft availability factors are primarily based on maintenance workload factors, with consideration given to the size of the crew which would normally be applied to the corrective action. It will be noted that the aircraft downtime factor normally exceeds the maintenance workload factors shown. APJ studies of manhour utilization at Army maintenance activities, over a considerable number of years, have shown that direct productive maintenance (wrench turning) on the aircraft represents only a portion of the total manhours spent in the work area. Activities such as setup, parts chasing, moving aircraft within the work area, quality control inspection, and other nondirect productive activities occupy a considerable amount of time during the work day. Therefore, aircraft availability factors have been adjusted to reflect this differential.

REMEDIAL ACTIONS

The final major section of the discussion deals with the remedial actions taken or in process to correct failure. The discussion of remedial actions is based on review of a considerable number of data sources. Some primary sources have been ECP and MWO lists and descriptions, EIR Digest items, technical bulletins, records and reports of helicopter manufacturers, technical manuals in the -20P, -34P, and -35P series (which identify obsolete and replacement part numbers as well as MWO application data), and discussions with Project Managers and USAAVSCOM and field activity personnel.

The effect of remedial action on the problem has, in most cases, been exceedingly difficult to determine. The lead time from identification of a problem to actual application of remedial action is frequently long. Following are some of the types of actions which are taken:

1. Corrective action only on production aircraft with no provision for other aircraft in the fleet. In these cases, only a portion of the fleet receives the corrective action and other fleet elements will continue to have the problem.

2. Installation of corrective action on production aircraft, plus retrofit of the fleet. Most actions of this sort start with an Engineering Change Proposal submission. Approval authorizes modification of production aircraft and production of retrofit kit and installation instructions by the prime manufacturer. The instructions are normally issued by the Army in the form of a Modification Work Order when the kits are available for issue. The time from submission of an ECP by the manufacturer until approval is often several months. Time from approval of the ECP to issuance of the MWO is frequently a year or more. The time from issuance of the MWO until

installation of the remedial action on fleet aircraft additionally takes some period of time, depending on the urgency of the MWO. In some cases, the MWO is never installed on some aircraft to which it applies. After remedial action has been applied, it is necessary that sufficient experience (flying hours) be accumulated to provide a sound statistical base before evaluation of the "before and after" failure factors can be made. In the case of newer helicopters, they generally have not been in the system long enough to permit this type of evaluation. In the case of older aircraft, identifying the particular aircraft to which remedial action has been applied and securing the necessary before and after data for these particular aircraft present a problem well beyond the scope of this study.

3. Actions resulting from EIR Digest instructions and prime manufacturer service memoranda to the field. The actual application of corrective action to specific aircraft in the field is almost impossible to determine. Therefore, in these cases too, the effect of the corrective action generally cannot be determined.

4. Parts replacement through USAAVSCOM engineering and procurement actions. Frequently, parts are replaced with improved types of the same parts or parts from other vendors. The determination of which aircraft received these parts is impossible to establish from available data. Frequently, an existing part or component is put in a "use until exhausted" category, or the user is told to use the old part until failure and then requisition the new number. Therefore, it is not possible to determine, in these cases, the effect of the new part on the problem.

In those cases where remedial action can be clearly seen to have, or not to have, resolved the problem, it has been indicated.

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13. ABSTRACT

This report presents the results of a study and analysis of reliability and maintainability (R&M) problems encountered by the Army's current generation of utility, attack, training, observation, and cargo helicopters.

Problem identification is based on an extensive series of interviews with personnel who have had long experience in operating, supporting, and maintaining these helicopters in Vietnam, in CONUS training bases, and in other missions and deployments. Interviews were conducted at eleven Army commands, activities and offices and at the prime manufacturers' plants (Bell Helicopter Company; the Boeing Company, Vertol Division; Sikorsky Aircraft, Division of United Aircraft Corporation; and Hughes Tool Company, Aircraft Division). Problem validation, expansion, and quantification are based on a large volume of publications and statistical data describing various aspects of reliability and maintainability problems identified.

A standard format provides a description of each problem, its cause, its duration, and its impact on safety, maintenance workload, and aircraft availability. Mission and deployment effects on each maintainability and reliability problem are specified, and remedial actions taken or in process to correct the problems are described.

Problems are grouped by helicopter type and within each type by functional group. Additionally, an analysis is made of problems common to two or more types, as a basis for development programs and product improvement. Problem rankings, in terms of their severity, are provided for each helicopter type in the three major impact areas of safety, maintenance workload, and availability.

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	ROLE	WT	ROLE	WT	ROLE	WT
Component failure						
Failure modes						
Failure rates						
Safety factors						
Component maintenance workload						
Aircraft availability						
Aircraft reliability						
Aircraft maintenance						
Remedial actions						
AH-1						
UH-1						
TH-1						
CH-47						
CH-54						
OH-6						
OH-58						

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