MAJOR ITEM SPECIAL STUDY (MISS),
CH-47A GAS TURBINE ENGINE (T55-L-7C)

Army Aviation Systems Command
St. Louis, Missouri

May 1974
Major Item Special Study (MISS), CH-47A Gas Turbine Engine

Interim; Jan 1964-July 1973

Personnel of the Directorate for Product Assurance
Systems Performance Assessment Division

May 1974

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Approved for public release; distribution unlimited

Major Item Special Study (MISS) reports are performed on DA Form 2410 reportable components. These are time change items and certain condition change items selected because of high cost or need for intensive management. Basically, the MISS reports are concerned with analyzing reported removal data presented in the Major Item Removal Frequency (MIRF) report. The failure modes reported for each removal are examined and grouped into categories which are intended to clarify the intent of the data reporting. From this data, removal distribution can be plotted and an MTR (mean time to removal) can be calculated. The MISS reports then investigate possible cost savings based on total elimination of selected failure modes. These modes are chosen because of the percentage of failures they represent and/or because they appear to be feasible Product Improvement Program (PIP) areas. (U)
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INTERIM REPORT
prepared by the personnel of the
DIRECTORATE FOR PRODUCT ASSURANCE
SYSTEMS PERFORMANCE ASSESSMENT DIVISION

Period Covered by Data
JAN 01, 1964 THRU JULY 01, 1973

Published: MAY 1974

US ARMY AVIATION SYSTEMS COMMAND
St. Louis, MO
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<td>4</td>
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1. INTRODUCTION

The following report is designed to illustrate cost savings which would result from specific efforts in the areas of product improvement in quality and design. For the purpose of this study the cost savings produced in the area of product improvement are based on total elimination of a certain failure mode or modes. Appropriate modes are chosen because of their proportion of the total removals or their proportion in combination with other similar modes. These eliminated removals are then assumed to follow the distribution of the remaining removal modes. The actual cost savings are determined from the increase in the mean time to removal based on the new removal distributions. The data used and methods involved are described in the following paragraphs.

1.1 PURPOSE

The objective of this study is based on several factors. While the specific objective of this report is to identify and quantify possible cost savings through product improvements, the following parameters may also be affected by implementation of the actions proposed in this report.

1.1.1 Mission reliability is increased due to fewer failures.

1.1.2 The maintenance manpower requirements are decreased due to fewer spares replacements.

1.1.3 Product Improvement Program (PIP) Candidates are identified and reflected as potential savings in materiel and manpower.

1.1.4 Aircraft availability is increased due to decreased downtime for replacements.

1.1.5 Spares requirements are reduced due to decreases in the number of replacements.

1.1.6 It is possible to project spares requirements based on removal frequencies, flight hour programs, new vs overhaul replacement policies and the number of aircraft in the inventory.

1.1.7 Problem areas are identified where the state of the art is not satisfying the operational requirements, indicating that R&D efforts are needed for developing new materials and processes.

1.1.8 Problem areas are identified where improvements are needed in operation and maintenance (for example: pilot technique in avoiding striking objects and unnecessary replacements).
1.1.9 Improved reliability standards are established for future similar components.

1.2 SCOPE AND LIMITATIONS

The basic source of data for this study is the Major Item Removal Frequency (MIRF) report of the Reliability and Maintainability Management Improvement Techniques (RAMMIT) system. The data is stratified according to removal modes and flight hour intervals. The data is further examined by specific reasons for removals and redistributions are made with the assumption that selected failure modes can be eliminated entirely through Product Improvement Programs (PIP). While this data is limited to first removals of new items, similar studies may be performed on overhauled items. No attempt is made to develop the means of eliminating failure modes or extending the retirement life interval. This report does show the magnitude of possible benefits to be derived if appropriate actions are taken.

1.3 METHODS

The specific method employed in this study is explained in Section 3. Generally, a cost savings is calculated based on an increase in the mean time to removal by elimination of selected failure modes.

For the purpose of cost calculations, a new Gas Turbine Engine acquisition cost is estimated to be $69,606, while overhaul is estimated to be $20,184 per unit assembly. The manhour cost per replacement is $135.45 based on $10.50 per manhour and the average manhours reported for replace actions.

1.4 APPLICABLE DOCUMENTS

TM 38-750
TB 55-1500-307-25
TB AVN 23-65

Master Data Record T55-L-7C Turbine Engine

Major Item Removal Frequency Report CH-47A Aircraft
2. REMOVALS

DA Form 2410, as applicable to Army Aviation is a six copy form. It is used to provide installation, removal, overhaul, operating time and control information for reportable aircraft components and parts. The components included under the 2410 reporting system, and in this study, are time change items and certain condition change items selected because of high cost or need for intensive management. This study utilizes the removal copy of the 2410 data system, as organized in M1RF to analyze the number of removals with respect to the reported flight hours since new of the component.

The failure modes reported for each removal are examined and divided into categories which are intended to clarify the intent of the data reporting. As the categories are often not as definitive as might be desired, this stratification allows a generalization of the causes of removals to two main categories: failures and non-failures. These are represented graphically in Illustration 1. Note that failures accounted for 40.2% of all removals while non-failures comprised the remainder of 59.8%. The non-failure categories include those that require overhaul and those that do not, as shown in Table 1.

For the purpose of this study there are two types of failures. They are induced failures which include all those removals that resulted from failure not attributable to an actual material defect and material failures which imply a direct discrepancy or deficiency of the quality and/or design of the component. The reported modes for these categories are also displayed in Table 1. Illustration 2 shows that induced failures accounted for 27.5% of all failures, while the remainder of failures, 72.5%, were due to material failures. Of these material failures, 24.1% were due to cracks and 19% were due to leakage as shown in Illustration 3. Table 2 lists the total removals by flight hour interval in each of the categories described above. The intent of this study is to show the effect of the elimination of these removals due to cracks and leakage in the engine assembly. Cracks and leaking failures will be considered as high mode failures in this study.
TABLE 1
CLASSIFICATIONS OF REMOVAL CATEGORIES TO REFLECT INTENT OF REPORTING

**FAILURES**

**MATERIAL FAILURES** (Those removals which indicate a deficiency or discrepancy in the quality and/or design).

- Worn Excessively
- Broken
- Torque Incorrect
- Corroded
- Cracked
- Low Lube Pressure
- Burned
- Leaking
- Metal on Magnetic Plug
- Internal Failure
- Oil Consumption Excessive
- Overheats
- Surged
- Low Power on Thrust
- Bearing Failure

**INDUCED FAILURES** (Those removals which are a result of conditions imposed upon the item for which it was not designed).

- Foreign Object Damage
- Contamination
- Hot Start
- Crash Damage
- Accident Damage
- Chipped

**NON-FAILURES**

**NON-FAILURES REQUIRING OVERHAUL** (Those removals which were not due to a material failure or induced failure, but by the nature of their cause for removal require overhaul).

- No Defect - MWO Compliance
- No Defect - Removed for Scheduled Maintenance

**NON-FAILURES NOT REQUIRING OVERHAUL** (Those removals which were not due to a material or an induced failure and involved no defect).

- Cannibalization
- No Defect
- Component Removed to Facilitate Other Maintenance
ILLUSTRATION 1

TOTAL REMOVALS PER FLIGHT HOUR INTERVAL
CH-47A GAS TURBINE ENGINE (T55-L-7C)
FSN 2840-950-6875  PN 2-000-030-18

FIRST REMOVAL OF NEW ITEMS: 199 TOTAL REMOVALS

59.8%  TOTAL NON-FAILURES
       (REQUIRING OVERHAUL AND NOT
       REQUIRING OVERHAUL)

40.2%  TOTAL FAILURES (INDUCED
       AND MATERIAL FAILURES)

TOTAL REMOVALS

FAILURES

FLIGHT HOUR INTERVAL

0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700
0099 0199 0299 0399 0499 0599 0699 0799 0899 0999 1099 1199 1299 1399 1499 1599 1699
ILLUSTRATION 2
TOTAL FAILURES PER FLIGHT HOUR INTERVAL

CH-47A GAS TURBINE ENGINE (T55-L-7C)
FSN 2840-950-6875 PN 2-000-030-18
FIRST REMOVAL OF NEW ITEMS: 80 TOTAL FAILURES

17.5% \text{INDUCED FAILURES RELATED TO FOREIGN OBJECT DAMAGE}

10.0% \text{OTHER INDUCED FAILURES}

72.5% \text{MATERIAL FAILURES}

FLIGHT HOUR INTERVAL

\begin{tabular}{cccccccccccccccc}
0000 & 0100 & 0200 & 0300 & 0400 & 0500 & 0600 & 0700 & 0800 & 0900 & 1000 & 1100 & 1200 & 1300 & 1400 & 1500 & 1600 & 1700 \\
0099 & 0199 & 0299 & 0399 & 0499 & 0599 & 0699 & 0799 & 0899 & 0999 & 1099 & 1199 & 1299 & 1399 & 1499 & 1599 & 1699 \\
\end{tabular}
ILLUSTRATION 3

TOTAL MATERIAL FAILURES PER FLIGHT HOUR INTERVAL
CH-47A GAS TURBINE ENGINE (T55-L-7C)
FSN 2840-950-6875 PN 2-000-030-18
FIRST REMOVAL OF NEW ITEMS: 58 MATERIAL FAILURES

24.1% MATERIAL FAILURES RELATED TO CRACKS

19.0% MATERIAL FAILURES RELATED TO LEAKAGE

56.9% MATERIAL FAILURES NOT RELATED TO CRACKS AND LEAKAGE

FLIGHT HOUR INTERVAL
### TABLE 2

**FLIGHT HOUR DISTRIBUTION OF TOTAL REMOVALS**

CH-47A GAS TURBINE ENGINE (T55-L-7C)

FSN 2840-950-6875  PN 2-000-030-18

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<tr>
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3. DESIGN AND QUALITY IMPROVEMENT

This chapter illustrates possible cost savings and avoidance based on total elimination of cracks and leaking failures. This assumption necessitates a redistribution of the eliminated failures because all items are eventually removed at TBO, if not sooner, due to other reported removal modes. The redistribution process involved assumes that the eliminated high mode failures would not have failed by any other failure mode prior to the actual failure. After this time (flight hour interval) they are assumed to follow the distribution of the remaining removals. Thus, at each flight hour interval the high mode failures are redistributed according to the remaining distribution (i.e., all other failure or non-failure modes). At each flight hour interval a proportional number of removals is added to all subsequent intervals, and when this process is repeated to TBO, a revised distribution is calculated. Since hand calculations were extensive and laborious, a Fortran computer program was written and used for the redistribution. This distribution is shown in Table 3 which illustrates the breakdown of removals by flight hour interval before and after the eliminated removals are redistributed.

Potential cost savings are based on an increase in mean time to removal (MTR) from the original distribution to the revised distribution. In order to calculate these cost savings an inventory of 187 aircraft flying 49.1 hours per month is assumed for both the original and revised distributions. Each of these distributions is limited to removals that require replacement by a new or overhauled component. Thus, any increase in MTR causes a decrease in the number of replacements and therefore a reduction on the cost of replacements.

Illustration 4 graphically illustrates the increase in mean time to removal after elimination of the high mode failures. The distributions before and after the elimination are shown with shaded areas to show the decrease in the number of early failures due to cracks and leaking failures. The increase in mean time to removal in this study is 15 hours which, based on the 220,360 flight hours per year (187 aircraft x 12 months x 49.1 hours x 2 engines per aircraft), yields an annual decrease of 38 removals.

The cost savings or cost avoidance indicators are on an annual basis as shown in Table 4. The costs represent replacement by new or overhaul parts as well as the manhour cost of removal. The range of savings, then, is from $772,139 (assuming replacement by overhauled items) to $2,650,171 (assuming replacement by new items). These cost indicators do not include the total logistical cost inputs but indicate the significant costs for acquisition versus overhaul of the T55-L-7C Gas Turbine Engine.
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<th>1300</th>
<th>1400</th>
<th>1500</th>
<th>1600</th>
<th>1700</th>
<th>TOTAL</th>
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<td>20</td>
<td>11</td>
<td>12</td>
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</tr>
<tr>
<td>Revised Distribution (After Elimination and Redistribution of cracks and leaking failures)</td>
<td>25</td>
<td>18</td>
<td>5</td>
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<td>6</td>
<td>12</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>87</td>
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</table>

**TABLE 3**

NUMBER OF REMOVALS PER FLIGHT HOUR INTERVAL REQUIRING NEW OR OVERHAULED REPLACEMENT ITEMS

CH-47A GAS TURBINE ENGINE T55-L-7C
FSN 2840-950-6875  PN 2-000-030-18
ILLUSTRATION 4

NUMBER OF REMOVALS PER FLIGHT HOUR INTERVAL BEFORE AND AFTER
REDISTRIBUTION OF CRACKS AND LEAKING FAILURES
CH-47A GAS TURBINE ENGINE T55-L-7C
FSN 2840-950-6875 PN 2-000-030-18

INCREASE IN NUMBER OF
REMOVALS OCCURRING AT
OR NEAR TBO

DECREASE IN NUMBER OF
EARLY REMOVALS BASED ON
ELIMINATION AND REDISTRIBUTION
OF CRACKS AND LEAKING FAILURES

ORIGINAL DISTRIBUTION

REVISED DISTRIBUTION

ORIGINAL MTR = 288
REVISED MTR = 303

FLIGHT HOUR INTERVAL
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CURRENT VALUE</th>
<th>DESIGN AND QUALITY IMPROVED VALUE (CRACKS &amp; LEAKING FAILURES ELIMINATED)</th>
<th>NET ANNUAL CHANGE</th>
</tr>
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<tbody>
<tr>
<td>MEAN TIME TO COMPONENT REMOVAL (HOURS TO FIRST REMOVAL)</td>
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<td>303</td>
<td>15</td>
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<td>TOTAL NUMBER OF ANNUAL REMOVALS</td>
<td>765</td>
<td>727</td>
<td>38</td>
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<td>ANNUAL COMPONENT COST</td>
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<td>NEW ITEMS</td>
<td>$53,248,576</td>
<td>$50,603,552</td>
<td>$2,645,024</td>
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<tr>
<td>O/H ITEMS</td>
<td>$15,440,760</td>
<td>$14,673,768</td>
<td>$766,992</td>
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<tr>
<td>ANNUAL MANHOUR COST</td>
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<tr>
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<td>$103,619</td>
<td>$98,472</td>
<td>$5,147</td>
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<tr>
<td>TOTAL ANNUAL REPLACEMENT COSTS</td>
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<td>NEW ITEMS</td>
<td>$53,352,195</td>
<td>$50,702,024</td>
<td>$2,650,171</td>
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<td>O/H ITEMS</td>
<td>$15,544,379</td>
<td>$14,772,240</td>
<td>$772,139</td>
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NOTE: All the above figures are based on 187 aircraft flying 49.1 hours per month.
4. SUMMARY

Thorough analysis of DA Form 2410 data on the CH-47A Gas Turbine Engine indicates that a problem exists with respect to the number of engines that are failing due to cracks and leakage. The flight hour distribution for all failure and non-failure removals were presented in this report, and the total material failures per flight hour interval were shown, illustrating that proportion which failed due to high mode failures. Approximately 43.1% of all material failures were removed for cracks and leaking failures.

It is readily apparent that this failure mode deserves particular attention. This is the one big problem area that is both well-defined and potentially solvable. The obvious conclusion is that the failure mode should be eliminated. This analysis was not directed toward the development of solutions for high-frequency removal categories, but the identification of them and the potential cost savings to be realized by their elimination. The completed analysis followed this basic tenet.

Assuming the problem could be completely eliminated, the high mode failure distribution was removed from the overall removal distribution. It was then assumed that if the turbine engines had not failed for that reason, they would have survived at least as long as they did, and then be removed according to the remaining removal distribution. This redistribution was performed, thereby creating a theoretical total increase in the Mean Time to Removal (MTR) of 35 flight hours. In effect, this would give 2,805 additional flight hours of operational service for the same number of removals on a fleet of 187 aircraft if the cracks and leaking failure problems were eliminated.

It follows that a higher MTR implies fewer component removals for a given flight hour profile. Using the standard flight hour profile of 2 engines per aircraft x 187 aircraft flying 49.1 hours per month for 12 months, basic comparisons were made in the number of high mode failure removals for the existing removal distribution and the non-high mode failure removal distribution. Cost comparison indicators of the current and theoretically improved Gas Turbine Engine were calculated with the potential cost savings shown. The component costs used were the estimated procurement cost for a new item and the estimated cost for overhaul of the item. Depreciation, storage, shipping, etc., were not considered in development of cost indicators for this analysis. The total potential cost savings revealed in this study may be found in Table 4. The range of savings is from $772,139 to $2,650,171 per year.
The analytical technique just described as having been performed on the CH-47A Gas Turbine Engine (i.e., removal of abnormally high failure modes) can be performed on any 2410 reportable item. As previously stated, no attempt has been made to redesign an item, only to point out its major deficiencies and identify them as candidates for a Product Improvement Program. By improving the removal characteristics of this component with a PIP program, benefits other than the direct cost considerations would be realized. This would include increased availability and mission capability, decreased logistics requirements, and higher reliability of the component and the entire aircraft system. Also, the characteristics of the theoretically improved item can be used as a standard which would give the minimum acceptable reliability characteristics of future generation like items.