AIRWORTHINESS AND FLIGHT CHARACTERISTICS (A&FC) TEST OF THE EH-1X/ EH-1H HELICOPTER CONFIGURATIONS

GARY T. DOWNS
LTC, AV
PROJECT OFFICER/ PILOT

JAMES M. ADKINS
CW4, AVN
PROJECT PILOT

JOHN I. NAGATA
PROJECT ENGINEER

JACK L. KIMBERLY
CPT, AV
PROJECT ENGINEER

JEFFREY L. LINEHAN
PROJECT ENGINEER

RICHARD T. SAVAGE
CPT, AV
PROJECT ENGINEER

JANUARY 1984
FINAL REPORT

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

84 08 03 015
DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.
DISCLAIMER NOTICE

The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed. Do not return it to the originator.

TRADE NAMES

The use of trade names in this report does not constitute an official endorsement or approval of the use of the commercial hardware and software.
The US Army Aviation Engineering Flight Activity conducted level flight performance tests of five EH-1X/EH-1H helicopter configurations to determine the change in drag characteristics with the addition of external mission equipment to the standard UH-1H helicopter configuration. Comparison of data from a baseline test configuration with previously published UH-1H and YUH-1H data indicated approximately 8.0 ft² increase in equivalent flat plate area which was attributed to the external mission antennas, low reflective infrared/optical
paint, and heat suppression kit with vertical exhaust ejector. Installation
of the M-130 chaff/flare dispensers resulted in a further increase in equivalent
flat plate area of 5.0 ft². Replacing the vertical exhaust ejector with the hot
metal plus plume infrared suppressor, including the ALQ-144 countermeasures
jammer resulted in a reduction in equivalent flat plate area of 1.5 ft². Install-
ation of the direction finding antennas resulted in no measurable increase in
drag. Addition of all external mission equipment and the hot metal plus plume
exhaust resulted in a total increased equivalent flat plate area of approximately
11.5 ft² from the standard UH-1H helicopter.
SUBJECT: Directorate for Engineering Position of the Final Report of USAAEFA Project No. 82-13, Airworthiness and Flight Characteristics (A&FC) Test of the EH-IX/EH-1H Helicopter Configurations

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. The report provides excellent documentation of the delta drag characteristics and direction finding (DF) antenna temperature survey of both the EH-IX and EH-1H helicopter configuration as compared to the UH-1H helicopter. Also noteworthy is the excellent extensive photographic and written documentation of the external configurations of the EH-IX and EH-1H helicopters for future reference.

2. This Directorate agrees with the Conclusions and Recommendation stated in the report. The A&FC performance data will be used to update the EH-IX and EH-1H Operator's Manuals.

FOR THE COMMANDER:

[Signature]

RONALD E. GORMONT
Acting Director of Engineering
# TABLE OF CONTENTS

## INTRODUCTION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>1</td>
</tr>
<tr>
<td>Test Objective</td>
<td>1</td>
</tr>
<tr>
<td>Description</td>
<td>1</td>
</tr>
<tr>
<td>Test Scope</td>
<td>2</td>
</tr>
<tr>
<td>Test Methodology</td>
<td>2</td>
</tr>
</tbody>
</table>

## RESULTS AND DISCUSSION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>4</td>
</tr>
<tr>
<td>Level Flight Performance</td>
<td>4</td>
</tr>
<tr>
<td>Configuration Variation</td>
<td>4</td>
</tr>
<tr>
<td>Temperature Survey</td>
<td>6</td>
</tr>
</tbody>
</table>

## CONCLUSIONS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conclusions</td>
<td>9</td>
</tr>
</tbody>
</table>

## RECOMMENDATION

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendation</td>
<td>10</td>
</tr>
</tbody>
</table>

## APPENDIXES

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. References</td>
<td>11</td>
</tr>
<tr>
<td>B. Description</td>
<td>12</td>
</tr>
<tr>
<td>C. Test Instrumentation</td>
<td>40</td>
</tr>
<tr>
<td>D. Test Techniques and Data Analysis Methods</td>
<td>45</td>
</tr>
<tr>
<td>E. Test Data</td>
<td>49</td>
</tr>
</tbody>
</table>

## DISTRIBUTION
INTRODUCTION

BACKGROUND

1. The EH-1X and EH-1H helicopters are special Quick Fix electronic mission aircraft developed under management of the Special Electronic Mission Aircraft Product Manager. Both aircraft are equipped with the AN/TLQ-17A electronics countermeasures (ECM) jammer while the EH-1X is further equipped with direction finding (DF) equipment developed by the Electronic Systems Laboratory (ESL), a division of TRW Defense Systems Group, TRW Inc., Sunnyvale, California. The US Army Aviation Engineering Flight Activity (USAAEFA) conducted a qualitative flight evaluation of the EH-1X (ref 1, app A) on 18 November 1981. The US Army Research and Development Command (AVRADCOM) requested USAAEFA to conduct a limited airworthiness and flight characteristics (A&FC) test (ref 2, app A) prior to final US Army acceptance of the aircraft from ESL and their issuance to using units. A test plan for the A&FC (ref 3, app A) was submitted in January 1983 and approved by AVRADCOM on 4 March 1983.

TEST OBJECTIVE

2. The objective of this limited A&FC was to conduct level flight performance testing to determine the drag characteristics of the EH-1X/EH-1H helicopter configurations for use in updating the operator's manual (ref 4, app A) for performance planning.

DESCRIPTION

3. The test aircraft (S/N 69-15920) was a production UH-1H aircraft modified to the Quick Fix II configuration (EH-1X) by the installation of the external antennas, low reflective infrared (IR)/optical paint, heat suppression kit, the M-130 Aircraft General Purpose Dispensing System (AGPDS), the hot metal plus plume (HMPP) IR suppressor, and the ALQ-144 countermeasures (IRCM) jammer. The aircraft was powered by an AVCO Lycoming T53-L-13B engine which was transmission limited to 1100 shaft horsepower (shp). The main transmission mounted generator was replaced by a 30 kilovolt-ampere alternator to provide the electrical power required by the installed mission equipment. Internal mission equipment and equipment racks were not installed. A detailed description of the test aircraft is presented in appendix B and the operator's manual as amended by a draft change (ref 5, app A).
TEST SCOPE

4. The A&FC was conducted at Edwards AFB, California (2302 ft MSL) during the period 26 July to 19 September 1983. A total of 21 test flights were flown resulting in 19.5 productive flight hours. Five different configurations were evaluated as described in the Results and Discussion section. These various configurations were obtained by adding or removing the DF antennas, AGPDS, and HMPP IR suppressor/IRCM jammer. Flight restrictions contained in the airworthiness release (ref 6, app A) and the operator's manual were observed during this evaluation. Level flight performance tests were conducted using the constant weight to pressure ratio (W/\delta) and a constant main rotor speed to temperature ratio (N_R/\theta) of 324 rpm. The thrust coefficient (C_T) range was from 31 to 40 \times 10^{-4}. All flights were flown at zero sideslip. Test conditions are shown in table 1. A limited temperature survey of the DF antennas was also conducted after installation of the HMPP IR suppressor.

TEST METHODOLOGY

5. Established level flight test techniques and data reduction procedures (ref 7, app A) were used. The temperature survey on the DF antennas was conducted utilizing temperature sensitive tapes. Test instrumentation consisted of calibrated cockpit gauges and data were hand recorded. A detailed listing of test instrumentation is contained in appendix C. Test techniques and data analysis methods are described in appendix D.
### Table 1. Level Flight Test Conditions

<table>
<thead>
<tr>
<th>Configuration(^2) (Configuration No.)</th>
<th>Average Longitudinal Center of Gravity (FS)</th>
<th>Average Gross Weight (lb)</th>
<th>Average Density Altitude (ft)</th>
<th>Average OAT (°C)</th>
<th>Average(^3) Rotor Speed (rpm)</th>
<th>Average Thrust Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH-1X(1)</td>
<td>135.2</td>
<td>7480</td>
<td>6610</td>
<td>24.0</td>
<td>329</td>
<td>0.003100</td>
</tr>
<tr>
<td></td>
<td>135.3</td>
<td>8390</td>
<td>6640</td>
<td>21.0</td>
<td>327</td>
<td>0.003523</td>
</tr>
<tr>
<td></td>
<td>135.9</td>
<td>8320</td>
<td>10,540</td>
<td>15.0</td>
<td>324</td>
<td>0.004018</td>
</tr>
<tr>
<td>EH-1X(2)</td>
<td>136.4</td>
<td>7550</td>
<td>5850</td>
<td>20.0</td>
<td>326</td>
<td>0.003114</td>
</tr>
<tr>
<td></td>
<td>136.3</td>
<td>8380</td>
<td>6130</td>
<td>17.5</td>
<td>326</td>
<td>0.003486</td>
</tr>
<tr>
<td></td>
<td>136.3</td>
<td>8340</td>
<td>10,100</td>
<td>12.5</td>
<td>323</td>
<td>0.003996</td>
</tr>
<tr>
<td>EH-1X(3)</td>
<td>135.2</td>
<td>7690</td>
<td>5710</td>
<td>24.0</td>
<td>329</td>
<td>0.003101</td>
</tr>
<tr>
<td></td>
<td>135.3</td>
<td>8040</td>
<td>8050</td>
<td>23.0</td>
<td>328</td>
<td>0.003505</td>
</tr>
<tr>
<td></td>
<td>135.9</td>
<td>8300</td>
<td>10,440</td>
<td>15.0</td>
<td>324</td>
<td>0.003995</td>
</tr>
<tr>
<td>EH-1H(4)</td>
<td>135.8</td>
<td>7380</td>
<td>6930</td>
<td>23.0</td>
<td>329</td>
<td>0.003089</td>
</tr>
<tr>
<td></td>
<td>135.9</td>
<td>7950</td>
<td>8520</td>
<td>23.5</td>
<td>329</td>
<td>0.003495</td>
</tr>
<tr>
<td></td>
<td>135.9</td>
<td>8300</td>
<td>10,720</td>
<td>16.5</td>
<td>326</td>
<td>0.003981</td>
</tr>
<tr>
<td>EH-1H(5)</td>
<td>135.7</td>
<td>7590</td>
<td>6090</td>
<td>22.5</td>
<td>329</td>
<td>0.003096</td>
</tr>
<tr>
<td></td>
<td>135.8</td>
<td>8140</td>
<td>7330</td>
<td>19.5</td>
<td>327</td>
<td>0.003492</td>
</tr>
<tr>
<td></td>
<td>136.4</td>
<td>8230</td>
<td>10,250</td>
<td>11.0</td>
<td>322</td>
<td>0.003987</td>
</tr>
</tbody>
</table>

**NOTES:**

1. All configurations were flown at mid lateral cg, zero sideslip, and with the ECM jammer antenna extended.
2. Configurations presented in table 2.
3. Average referred main rotor speed \(N_R/\sqrt{\delta}\) was 324 rpm.
RESULTS AND DISCUSSION

GENERAL

6. Level flight performance tests were conducted to determine the drag characteristics of the EH-1X/EH-1H helicopter configurations for inclusion in the operator's manual. Comparison of data from the EH-1X(1) baseline configuration with previously published UH-1H and YUH-1H data indicated approximately 8.0 ft² increase in equivalent flat plate area ($F_e$) which was attributed to external mission antennas, low reflective IR/optical paint, and heat suppression kit with vertical exhaust ejector. Other significant results were a 5.0 ft² drag increase for the M-130 AGPDS installation and 1.5 ft² drag decrease for the HMPF IR suppressor installation. No measurable drag increase was observed with addition of the DF antennas. Installation of all external mission equipment and HMPF IR Suppressor resulted in a total $F_e$ increase of approximately 11.5 ft² from the standard UH-1H configuration. A limited temperature survey with HMPF IR suppressor installed indicated that temperatures were within limits at the conditions tested, both internally and externally, on all four DF antennas.

LEVEL FLIGHT PERFORMANCE

General

7. Level flight performance tests were conducted to determine the power required for level flight in the five configurations shown in table 2. The thrust coefficient ($C_T$) range was from 31 to $40 \times 10^{-4}$. The constant referred rotor speed constant gross weight to pressure ratio technique was used to maintain a constant $C_T$. The EH-1X(1) was used as a baseline configuration for comparison since the test aircraft could not be configured to the UH-1H configuration. EH-1X(1) level flight performance data was compared with previously published UH-1H and YUH-1H data to determine the change in $F_e$ with the addition of external mission equipment to the UH-1H configuration. All other configurations were compared to the EH-1X(1) baseline data. A summary of change in $F_e$ for the various configurations is presented in table 2.

Configuration Variation

8. The EH-1X(1) configuration was used as the baseline configuration for all $F_e$ comparisons for this report. Level flight performance data for this configuration are presented in figures 1 through 5, appendix E. EH-1X(1) level flight performance data was compared with previously published UH-1H data obtained on aircraft S/N 69-15532 (ref 8, app A). This comparison (fig. 6,
Table 2. Test Configurations and Results

<table>
<thead>
<tr>
<th>Configuration(^1) (Configuration No.)</th>
<th>HMPP Suppressor/IRCM Jammer</th>
<th>M-130 AGPDS</th>
<th>DF Antennas</th>
<th>ECM Jammer Antenna</th>
<th>( \Delta P_e )(^2) ( \text{from} ) Baseline EH-1X(1)</th>
<th>( \Delta P_e )(^2), 3 ( \text{from} ) Standard UH-1H</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH-1X(1) Baseline</td>
<td>OFF(^4)</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
<td>0</td>
<td>8.0</td>
</tr>
<tr>
<td>EH-1X(2)</td>
<td>OFF(^4)</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>5.0</td>
<td>13.0</td>
</tr>
<tr>
<td>EH-1X(3)</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>3.5</td>
<td>11.5</td>
</tr>
<tr>
<td>EH-1H(4)</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>3.5</td>
<td>11.5</td>
</tr>
<tr>
<td>EH-1H(5)</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
<td>-1.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

NOTES:

\(^1\)All EH-1X/EH-1H configurations included external mission antennas described in appendix B, low reflective IR/optical paint, and heat suppression kit.

\(^2\)\( \Delta P_e \) = change in equivalent flat area

\(^3\)EH-1X(1) level flight performance data was compared to UH-1H data presented in ref 8, app A at 

\[ C_T = 0.00367 \] to determine the \( \Delta P_e \) resulting from the addition of external mission equipment.

All other configurations were then compared with the EH-1X(1) baseline data.

\(^4\)Flown with vertical exhaust ejector
app E) indicates that addition of external mission antennas, low reflective IR/optical paint, and the heat suppression kit with vertical exhaust ejector resulted in a $F_e$ increase of approximately 8.0 ft$^2$ from the UH-1H configuration. An additional comparison of the EH-IX(1) data with previously published data on a YUH-1H (ref 9, app A) verified this increase in $F_e$.

9. Level flight performance data for the EH-IX(2) configuration are presented in figures 7 through 9, appendix E. Comparison with the EH-IX(1) configuration indicates an $F_e$ increase of 5.0 ft$^2$ attributed to the M-130 AGPDS installation. The EH-IX(2) which features the addition of all Quick Fix II external mission equipment with vertical exhaust ejector shows a total $F_e$ increase of approximately 13.0 ft$^2$ from the UH-1H.

10. Level flight performance data for the EH-IX(3) and EH-1H(4) configurations are presented in figures 10 through 15, appendix E. Comparison of both these configurations with the EH-IX(1) indicates an $F_e$ increase of 3.5 ft$^2$ with a 5.0 ft$^2$ increase attributed to the M-130 AGPDS and a 1.5 ft$^2$ decrease attributed to the HMPP IR suppressor/IRCM jammer installation. This comparison indicated that the DF antennas contributed no measurable drag increase since the only difference between the EH-IX(3) and the EH-1H(4) was the DF antenna installation. The EH-IX(3) configuration represents the Quick Fix II mission configuration (EH-IX) in that all external mission equipment is installed and results in a total $F_e$ increase of approximately 11.5 ft$^2$ from the UH-1H.

11. Level flight performance data for the EH-1H(5) configuration are presented in figures 16 through 18, appendix E. Comparison with the EH-IX(1) configuration indicates an $F_e$ decrease of 1.5 ft$^2$ which verifies the drag decrease caused by substitution of the HMPP IR suppressor/IRCM jammer for the vertical exhaust ejector of the UH-1H heat suppressor kit. This comparison also verifies that the DF antennas contributed no measurable drag increase. The EH-1H(5) shows a total $F_e$ increase of approximately 6.5 ft$^2$ from the UH-1H.

TEMPERATURE SURVEY

12. A temperature survey was conducted prior to initial performance testing on the EH-IX(3) after installation of the HMPP IR Suppressor/IRCM Jammer. Temperature sensitive tapes were applied internally and externally to the DF antennas as shown in photo 1. The maximum allowable limits for the temperature survey...
were 121°C internally and 149°C externally. The temperatures were sampled during in-ground effect (IGE) and out-of-ground effect (OGE) hover at maximum continuous power. Hover time was limited to 30 minutes for both IGE and OGE tests. Temperature survey results are presented in tables 3 and 4. Observed temperatures, both internally and externally, did not exceed maximum allowable limits.

Table 3. Temperature Survey Results IGE (30 Minutes)

<table>
<thead>
<tr>
<th>Antenna Number</th>
<th>External (°C)</th>
<th>Internal (°C)</th>
<th>OAT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;93</td>
<td>107</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>&lt;93</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>121</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&lt;93</td>
<td>107</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Temperature Survey Results OGE (30 Minutes)

<table>
<thead>
<tr>
<th>Antenna Number</th>
<th>External</th>
<th>Internal (°C)</th>
<th>OAT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>107</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Not Recorded</td>
<td>&lt;93</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Not Recorded</td>
<td>&lt;107</td>
<td></td>
</tr>
</tbody>
</table>
Temperature sensitive tape attached to DF antennas at this location (internally and externally)

Photo 1. DF Antennas.
CONCLUSIONS

13. Modification of the UH-1H configuration by addition of the external mission antennas, low reflective IR/optical paint, and heat suppression kit with vertical exhaust ejector resulted in an $F_e$ increase of approximately 8.0 ft$^2$ (para 8).

14. Based on the A&FC flight tests of the EH-1H/ER-1X, installation of the M-130 AGPDS resulted in an $F_e$ increase of 5.0 ft$^2$ (para 9).

15. Substitution of the HMPP IR suppressor/IRCM jammer for the vertical exhaust ejector of the UH-1H heat suppressor kit resulted in an $F_e$ decrease of 1.5 ft$^2$ (paras 10 and 11).

16. Installation of DF antennas resulted in no measureable drag increase (paras 10 and 11).

17. Addition of all Quick Fix II external mission equipment with the vertical exhaust ejector resulted in an $F_e$ increase of approximately 13.0 ft$^2$ from the UH-1H configuration (para 9).

18. Addition of all Quick Fix II external mission equipment with HMPP IR suppressor/IRCM jammer (EH-1X) resulted in an increase $F_e$ of approximately 11.5 ft$^2$ from the UH-1H configuration (para 10).

19. Observed temperatures on the DF antennas, both internally and externally, did not exceed maximum allowable limits when the HMPP IR suppressor/IRCM jammer was installed (para 12).
RECOMMENDATION

20. Include the flight test data from this A&FC report in the operator's manual for the EH-1H/EH-1X.
APPENDIX A. REFERENCES


APPENDIX B. DESCRIPTION

GENERAL

1. The EH-1X test aircraft (photo 1) was a production UH-1H helicopter modified to a Quick Fix II configuration. Significant features included Quick Fix external mission antennas, low reflective infrared (IR)/optical paint, and heat suppression kit with the vertical exhaust ejector replaced by a hot metal plus plume (HMPP) IR suppressor with the AN/ALQ-144 (IRCM) jammer (photos 2 and 3). The EH-1X electrical system utilized the engine driven starter-generator as the main DC power source. A 30 kilovolt-ampere alternator driven by the main transmission supplied the AC power for the mission equipment. A converter (transformer-rectifier) unit provided mission DC power and emergency DC power for aircraft systems in the event of a main generator failure. Principle dimensions and features of the EH-1X are presented in the operator's manual (ref 4, app A) as amended by draft change source data (ref 5, app A).

EH-1X/EH-1H EXTERNAL CONFIGURATIONS

2. Five different configurations were obtained by adding or removing the M-130 AGPDS, HMPP IR suppressor/IRCM jammer, and DF antennas. All configurations included the low reflective/IR optical paint, heat suppression kit (with either vertical ejector or HMPP), and ECM antenna (photos 4 and 5). The various configurations are shown in table 1 and described below.

   a. The baseline EH-1X(1) configuration featured the standard heat suppression kit with vertical exhaust ejector (photos 6 and 7) and DF antennas. The EH-1X(2) configuration (photos 8 through 12) was similar to the EH-1X(1) configuration with the M-130 AGPDS (photos 13 and 14) installed.

   b. The EH-1X(3) configuration (photos 15 and 16) had the M-130 AGPDS, DF antennas, and vertical ejector replaced with the HMPP IR suppressor/IRCM jammer.

   c. The EH-1H(4) was similar to the EH-1X(3) configuration except the DF antennas (photo 17) were removed. The antenna attaching points were covered with metal plates.

   d. The EH-1H(5) configuration was the same as the EH-1H (4) configuration except the M-130 AGPDS were removed. The aircraft hard points for mounting the M-130 AGPDS are shown in photo 18.

Miscellaneous mission antennas installed on all configurations tested are shown in photos 19 through 21. A complete list of external equipment mounted on the EH-1X(3) is shown in table 2.
Table 1. Aircraft Configuration

<table>
<thead>
<tr>
<th>Configuration (Configuration No.)</th>
<th>HMFP Suppressor/IRCM Jammer</th>
<th>M-130 AGPDS</th>
<th>DF(^4) Antennas</th>
<th>ECM Jammer Antenna (^5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH-1X(1)</td>
<td>OFF (^6)</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>EH-1X(2)</td>
<td>OFF (^6)</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>EH-1X(3)</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>EH-1H(4)</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
</tr>
<tr>
<td>EH-1H(5)</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>

**NOTES:**

1. All configurations included low reflective infrared/optical paint, heat suppression kit, and ECM antenna.
2. AN/ALQ-144 IRCM Jammer (photos 2 and 3)
3. Flare/Chaff Dispensers (photos 13 and 14)
4. Tail boom mounted dipole antennas (photo 12)
5. AN/TLQ-17A antenna (photos 4 and 5)
6. Flown with vertical exhaust ejector (photo 6)
<table>
<thead>
<tr>
<th>Part</th>
<th>Identifying Photographs</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFSS Suppressor/Jammer (AM/ALP-166)</td>
<td>2 and 3</td>
<td>Exhaust ejector and modified aft engine cowl</td>
</tr>
<tr>
<td>Radar Warning Antennas APR-39</td>
<td>9</td>
<td>Left and right nose mounted</td>
</tr>
<tr>
<td>RHJ Homing Antenna (PM 10-120)</td>
<td>9 and 10</td>
<td>Left and right side mounted</td>
</tr>
<tr>
<td>ECH Jammer Antenna (AM/TLQ-17A)</td>
<td>4, 5 and 11</td>
<td>Bottom aft tailboom (retractable)</td>
</tr>
<tr>
<td>BITN Antenna</td>
<td>11</td>
<td>Bottom side tailboom</td>
</tr>
<tr>
<td>DF Antennas</td>
<td>12 and 17</td>
<td>Left and right side tailboom</td>
</tr>
<tr>
<td>Radar Warning Antennas APR-39</td>
<td>12</td>
<td>Rear tailboom</td>
</tr>
<tr>
<td>Chaff Dispenser (N-130)</td>
<td>12 and 13</td>
<td>Left side</td>
</tr>
<tr>
<td>Flare Dispenser (N-130)</td>
<td>12 and 14</td>
<td>Right side</td>
</tr>
<tr>
<td>Standard Heat Suppression Kit</td>
<td>6 and 7</td>
<td>Exhaust ejector, engine cowling heat shield, and oil cooler heat shield</td>
</tr>
<tr>
<td>VOR Antennas¹</td>
<td>AS 1304/ARN</td>
<td>6</td>
</tr>
<tr>
<td>Radar Altimeter Antennas APR 209</td>
<td>19</td>
<td>Front bottom side</td>
</tr>
<tr>
<td>IFF Antennas¹</td>
<td>AS-864/APR</td>
<td>19</td>
</tr>
<tr>
<td>TACO G1169 Antenna</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Radar Warning Antenna AS 2890/APR 39</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Marker Beacon Antenna¹</td>
<td>AT 64A/ARN</td>
<td>19</td>
</tr>
<tr>
<td>TACO G1169 Antenna</td>
<td>20</td>
<td>Aft bottom center</td>
</tr>
<tr>
<td>TACAN antenna AS-741</td>
<td>20</td>
<td>Aft bottom left</td>
</tr>
<tr>
<td>VHF/PK Antennas¹</td>
<td>AS 4070/ABC</td>
<td>21</td>
</tr>
<tr>
<td>UHF/PK Antennas¹</td>
<td>AS 1108/ABC</td>
<td>21</td>
</tr>
<tr>
<td>TACAN Antenna AS-741</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>ADF Sense Antenna¹</td>
<td>203-075-325-1</td>
<td>21</td>
</tr>
</tbody>
</table>

NOTE:  
¹Standard EH-1H external equipment
3. The UH-1H aircraft, US Army S/N 69-15532 (photo 22), was a production UH-1H aircraft with gloss lacquer paint and a standard engine exhaust assembly. The cargo hook was removed and the main generator driven off the transmission provided D.C. electrical power. The standby generator driven off the engine provided emergency electrical power in the event of main generator failure. A list of the external mounted equipment on the UH-1H aircraft is presented in table 3. External equipment is also identified in photos 22 and 23. Further descriptive material is presented in reference 4, appendix A.
<table>
<thead>
<tr>
<th>Part</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM Antenna&lt;sub&gt;1&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>AS 1703/ARC</td>
<td>Upper tailboom pylon</td>
</tr>
<tr>
<td>VOR Antennas&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>AS 1304/ARN</td>
<td>Left and right side aft</td>
</tr>
<tr>
<td>Strobe beacon</td>
<td>tailboom</td>
</tr>
<tr>
<td>Anti Collision light&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>OAT probe&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Forward bottom center</td>
</tr>
<tr>
<td>DME Antenna&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Forward bottom left</td>
</tr>
<tr>
<td>IFF Antenna&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>(AT-884/APX)</td>
<td>Forward bottom center</td>
</tr>
<tr>
<td>Marker Beacon Antenna&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>AT-64A/ARN</td>
<td></td>
</tr>
<tr>
<td>UHF/VHF Antenna&lt;sub&gt;2&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>(AT-1108/ARC)</td>
<td></td>
</tr>
<tr>
<td>ADF Sense Antenna&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Roof mounted</td>
</tr>
<tr>
<td>205-075-325-1</td>
<td></td>
</tr>
<tr>
<td>FM Homing Antenna&lt;sub&gt;1&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>AS-1922/ARC</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

1 Not installed on EH-1X
2 Standard UH-1H external equipment
Photo 2. HMP/IR Suppressor, Right Rear Quartering View
Photo 4. ECM Jammer Antenna (AN/TLQ-71A)
Photo 5. ECM Jammer Antenna (Extended Position)
Photo 10. EH-1X(2) Front View
Photo 11. EH-1X(2) Aft Left Quartering view
Photo 12. EH-IX(2) Rear View
Photo 14. AGPDS (M-130) Flare Dispenser
Photo 1R. ACADS (N-130) Mounting Hard Points

H-130 ACADS Electrical Connecting Point
Photo 19. ER-1X Bottom-Front View
APPENDIX C. TEST INSTRUMENTATION

1. All instrumentation was calibrated and installed prior to commencing the test program. The engine test cell calibration is shown in figure 1. All quantitative data obtained during the flight test program were derived from special instrumentation. An instrumentation boom (photo 1) with a swiveling pitot-static tube was mounted on and extended 92 inches forward from the nose of the aircraft. The boom provided airspeed, altitude, free air temperature, and sideslip information. Instrument boom airspeed calibration is presented in figure 2. Engine torque was measured with a differential pressure transducer. A detailed tabulation of calibrated instrumentation, equipment and recorded data is listed below. Cockpit test instrumentation is shown in photo 2.

Pilot Station

Airspeed indicator (boom system)
Altitude indicator (boom system)
Sideslip Indicator (boom system)

Copilot Station

Airspeed indicator (boom system)
Altitude indicator (boom system)
Rotor speed indicator
Torque indicator
Free air temperature indicator (boom system)
Fuel counter (calibrated gauge with flow transducer)

Hand Recorded Data

Airspeed
Altitude
Fuel used
Free air temperature
Rotor speed
Engine torque pressure
NOTE: CURVE BASED ON DATA OBTAINED FROM CORPUS CHRISTI ARMY DEPOT TEST CELL NO. 9 DATED 6 FEB 81

EQUATION OF LINE:
TORQUE, FT-LB = 18.08 + 19.08 x PRESSURE, PSI

Differential, Torsionmeter Pressure (PSI)
APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Conventional level flight performance test techniques were used to conduct this evaluation. To achieve a constant thrust coefficient ($C_T$) throughout each test, a constant referred gross weight (the ratio of gross weight to pressure ratio, $W/\delta$) and referred rotor speed (the ratio of rotor speed to square root of temperature ratio, $N_R/\sqrt{\delta}$) were maintained. A constant $W/\delta$ was maintained by increasing pressure altitude as the aircraft gross weight decreased due to fuel burnoff. Rotor speed was also varied to maintain a constant $N_R/\sqrt{\delta}$ as the ambient temperature varied. All tests were conducted in non-turbulent conditions to preclude atmospheric disturbances influencing the results. All tests were conducted with the ECM jammer antenna extended. Fifteen second records were taken manually at the mid point of approximately 1 minute stabilized data points.

2. Three values of $C_T$ were flown for five different configurations. The results of the level flight tests were converted to nondimensional form and plotted as power coefficient ($C_p$) versus $C_T$ and constant airspeed ratio ($\mu$). This plot defined the level flight performance for all gross weights, density altitudes, and airspeeds throughout the $C_T$ range tested for the baseline configuration (EH-IX(1)).

WEIGHT AND BALANCE

3. The aircraft empty weight (including full oil and trapped fuel) and longitudinal center of gravity (cg) location were determined with a portable electronic weighing kit. Two complete weighings were conducted, one prior to the start of the test in the EH-IX(2) configuration, the other following the installation of the HMPP IR suppressor/IRCM jammer in the EH-IX(3) configuration.

4. A manometer-type external sight gauge was calibrated and used to determine fuel volume. Fuel specific gravity was measured with a hydrometer. The fuel loading for each test flight was determined both prior to engine start and following engine shutdown. Fuel used in flight was recorded manually from a test fuel used system and compared with the pre and post flight sight gauge readings. Fuel cg versus fuel volume contained in the fuel cell (208.5 gallon capacity) had been previously determined. This calibration was used to calculate aircraft cg for each test point. Aircraft engine start gross weight and cg were also controlled by ballast installed in the aircraft.
Level Flight Performance

5. The level flight performance data were generalized by the following nondimensional coefficients:

a. Coefficient of power (Cp):

\[ Cp = \frac{\text{SHP (550)}}{\rho A(\Omega R)^3} \] (1)

b. Coefficient of thrust (CT):

\[ CT = \frac{\text{Thrust}}{\rho A(\Omega R)^2} \] (2)

c. Advance ratio (\(\mu\)):

\[ \mu = \frac{(1.68781)\nu_T}{\Omega R} \] (3)

d. Advancing blade tip Mach number (\(M_{\text{tip}}\)):

\[ M_{\text{tip}} = \frac{(1.68781)\nu_T + (\Omega R)}{a} \] (4)

where:

- SHP = Engine output shaft horsepower
- 550 = Conversion factor (ft-lb/sec/SHP)
- \(\rho\) = Air density (slug/ft\(^3\))
- A = Main rotor disc area (ft\(^2\)) = 1809.5
- \(\Omega\) = Main rotor angular velocity (radians/sec = 33.93 at 324 RPM)
- R = Main rotor radius (ft) = 24.0
- Thrust = Gross weight (lb) during free flight in which there is no acceleration component in the vertical direction.
- 1.68781 = Conversion factor (ft/sec/knot)
- \(\nu_T\) = True airspeed (knot) = (calibrated airspeed/\(\sqrt{\sigma}\))
- \(\sigma\) = Density ratio = \(\rho/\rho_o = \delta/\theta\)
- \(\rho_o\) = Air density at sea level standard day (slug/ft\(^3\)) = 0.002376892
\[ \delta = [1 - (6.875586 \times 10^{-6}) H_p] \times 255863 \]
\[ H_p = \text{Pressure altitude (ft)} \]
\[ \delta = (T + 273.15)/288.15 \]
\[ T = \text{ambient air temperature (°C)} \]
\[ a = \text{Speed of sound (ft/sec)} = 1116.45/\delta \]

For normal operating rotor speed of 324 rpm the following constants were used:

\[ A = 1809.5 \text{ ft}^2 \]
\[ \Omega = 814.30 \text{ ft/sec} \]
\[ A(\Omega)^2 = 1.199851385 \times 10^9 \text{ ft}^4/\text{sec}^2 \]
\[ A(\Omega)^3 = 9.770389825 \times 10^{11} \text{ ft}^5/\text{sec}^3 \]

Test day (measured) level flight power was corrected to average flight conditions for each set of speed power data by assuming the test day dimensionless parameters \( C_p, C_T, \) and \( \mu \) are identical to \( C_{p avg}, C_{T avg}, \) and \( \mu_{avg} \) respectively.

From equation 1, the following relationship can be derived:

\[ \text{SHP}_{avg} = (0.12414) (C_{p_T}) (\sigma_{avg}) (N_{R_{avg}})^3 \quad (5) \]

where:

\[ N_R = \text{rotor speed (rpm)} \]
\[ \text{subscript avg} = \text{average over each set of speed power data} \]

**Shaft Horsepower Required**

6. The engine output shaft torque was determined from the engine manufacturer's torque system. The relationship of measured torque pressure (PSI) to engine output shaft torque (ft-lb) was determined from the engine test cell calibration shown in figure 1, appendix C. The output shp was determined from the engine output shaft torque and rotational speed by the equation below.

\[ \text{SHP} = \frac{2\pi \times N_p \times Q}{33,000} \quad (6) \]
where:

\[ N_p = \text{Engine output shaft rotational speed (rpm)} \]
\[ Q = \text{Engine output shaft torque (ft-lb)} \]
\[ 33,000 = \text{Conversion factor (ft-lb/min/SHP)} \]

Airspeed Calibration

7. The boom pitot-static system was calibrated by using the trailing bomb method to determine the airspeed position error, presented in figure 2, appendix C. Calibrated airspeed \( V_{cal} \) was obtained by correcting the bomb indicated airspeed \( V_i \) using instrument \( \Delta V_{ic} \) and position \( \Delta V_{pc} \) error corrections.

\[ V_{cal} = V_{i\text{bomb}} + \Delta V_{i\text{bomb}} + \Delta V_{p\text{c\text{bomb}}} \quad (7) \]

The airspeed position error (correction to be added) was determined by:

\[ \Delta V_{p\text{c\text{boom}}} = V_{cal} - (V_{i\text{boom}} + \Delta V_{i\text{c\text{boom}}} ) \quad (8) \]

Drag

8. The following relationships were used to compute differential drag in terms of a change in equivalent flat plate area \( \Delta F_e \).

\[ \Delta F_e = 2A \frac{\Delta C_p}{u^3} = \frac{(228.782)(\Delta SHP)}{\rho V_T^3} \quad (9) \]

where:

\[ \Delta C_p = \text{differential power coefficient (based on engine power)} \]
\[ \Delta SHP = \text{Differential output shaft horsepower} \]

NOTE: No corrections were made for airspeed boom drag.
APPENDIX E. TEST DATA

INDEX

<table>
<thead>
<tr>
<th>Figure</th>
<th>Figure Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level Flight Performance</td>
<td></td>
</tr>
<tr>
<td>EH-1X(1)</td>
<td>1 through 5</td>
</tr>
<tr>
<td>Comparison EH-1X(1) and UH-1H</td>
<td>6</td>
</tr>
<tr>
<td>EH-1X(2)</td>
<td>7 through 9</td>
</tr>
<tr>
<td>EH-1X(3)</td>
<td>10 through 12</td>
</tr>
<tr>
<td>EH-1H(4)</td>
<td>13 through 15</td>
</tr>
<tr>
<td>EH-1H(5)</td>
<td>16 through 18</td>
</tr>
</tbody>
</table>

49
FIGURE 1

MONODIMENSIONAL LEVEL FLIGHT PERFORMANCE

EM-114 USA S/N 69-15300
CONFIGNATION EM-47(1)

COEFFICIENT OF THRUST, $C_T \times 10^3$
FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
EH-IX USA S/N 69-15920
CONFIGURATION EH-IX(1)

COEFFICIENT OF POWER, CP x 10^7

μ = 0.10 TO 0.24

μ = 0.24

μ = 0.22

μ = 0.20

μ = 0.18

μ = 0.16

μ = 0.14

μ = 0.12

COEFFICIENT OF THRUST, CT x 10^5

30 32 34 36 38 40 42
<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG. CG LOCATION (FT)</th>
<th>AVG DENSITY ALTITUDE (FT)</th>
<th>AVG OAT (° C)</th>
<th>AVG ROTOR SPEED (RPM)</th>
<th>AVG CT</th>
<th>AIRCRAFT CONFIG.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7400</td>
<td>135.2</td>
<td>6510</td>
<td>24.0</td>
<td>329</td>
<td>31.00</td>
<td>EH-1X(1)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Figure 3**

Level Flight Performance

Engine shaft horsepower (SHP)

Curve derived from Figs. 1 and 2

True Airspeed (KNOTS)
### FIGURE 4
**LEVEL FLIGHT PERFORMANCE**

**CH-54 USA** S/N 69-15926 T53-L-13B 43204999

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG CG (FS)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG DAT (° C)</th>
<th>AVG Rotor RPM</th>
<th>AVG CT</th>
<th>A/C CONFIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8390</td>
<td>135.3</td>
<td>6540</td>
<td>21.0</td>
<td>327</td>
<td>38.28</td>
<td>CH-54(1)</td>
</tr>
</tbody>
</table>

**Engine Short Horsepower (SHP)**

**TRUE AIRSPEED (KNOTS)**

**Curve Derived from Figs. 1 and 2**
FIGURE 6
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
EH-1X(1) VERSUS UH-1H
C\( \tau \) = 0.603167
### Figure 7

**Level Flight Performance**

**EH-1X USA 5/N 69-15920 T53-L-136 2E2O60S6**

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG. CG LOCATION (FS)</th>
<th>AVG ALTITUDE (FT)</th>
<th>OAT (°C)</th>
<th>AVG ROTOR Speed (RPM) x 10^6</th>
<th>AVG CY CONFIG.</th>
<th>AIRPLANE FLIGHT CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8750</td>
<td>156.4</td>
<td>5850</td>
<td>20.0</td>
<td>326</td>
<td>31.14</td>
<td>E-1X[G]</td>
</tr>
</tbody>
</table>

*Curve derived from dashed line with $\Delta f e = 5.0$ ft² incorporated*

*Dashed line derived from Figs. 1 and 2*

*True Airspeed (Knots)*
FIGURE 9
LEVEL FLIGHT PERFORMANCE
EH-1X QSA 5/N 69-15920 T53-L-136 LE208250

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG. CG LOCATION (FT)</th>
<th>AVG DENSITY (p) AT ALTITUDE (FT)</th>
<th>AVG OAT (°F)</th>
<th>AVG Rotor Speed (RPM)</th>
<th>AVG Cy</th>
<th>AVG AIRCRAFT CONFIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8340</td>
<td>136.3</td>
<td>10,100</td>
<td>12.5</td>
<td>323</td>
<td>39.95</td>
<td>EH-1X(2)</td>
</tr>
</tbody>
</table>

CURVE DERIVED FROM DASHED LINE WITH
ΔF = 5.0 FT² INCORPORATED

DASHED LINE DERIVED FROM FIGS. 1 AND 2

TRUE AIRSPEED (KNOTS)
LEVEL FLIGHT PERFORMANCE
EH-1X USA S/N 69-15920 T53-L-13B 1E20B58

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LB)</th>
<th>AVG LONG. CG LOCATION (FO)</th>
<th>AVG DENSITY (FT)</th>
<th>AVG ALTITUDE (° C)</th>
<th>AVG SPEED (RPM)</th>
<th>AVG CT</th>
<th>AIRCRAFT CONFIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7690</td>
<td>135.2</td>
<td>5710</td>
<td>24.0</td>
<td>329</td>
<td>31.01</td>
<td>1.0</td>
</tr>
</tbody>
</table>

CURVE DERIVED FROM DASHED LINE WITH ΔF₀ = 3.5 FT² INCORPORATED

DASHED LINE DERIVED FROM FIGS. 1 AND 2

TRUE AIRSPEED (KNOTS)
FIGURE IX
LEVEL FLIGHT PERFORMANCE
EX-IX USA 57X-69-15920 T53-E-15B L129626

<table>
<thead>
<tr>
<th>AVG GROSS WEIGHT (LL)</th>
<th>AVG LONG. CG LOCATION (FS)</th>
<th>AVG DENSITY ALTITUDE (FT)</th>
<th>AVG OAT</th>
<th>AVG SPEED (KTS)</th>
<th>AVG THRUST</th>
<th>AERODYNAMIC CONFIG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,300</td>
<td>155.9</td>
<td>10,720</td>
<td>16.5</td>
<td>226</td>
<td>35.61</td>
<td>-10°</td>
</tr>
</tbody>
</table>

CURVE DERIVED FROM
DASHED LINE WITH
ΔF_a = 3.5 FT², INCORPORATED

DASHED LINE DERIVED
FROM FIGS. 1 AND 2

TRUE AIRSPEED (KNOTS)
DISTRIBUTION

Deputy Chief of Staff for Logistics (DALO-SMM, DALO-AV) 2
Deputy Chief of Staff Operations (DAMO-RO) 1
Deputy Chief of Staff for Personnel (DAPE-HRS) 1
Deputy Chief of Staff for Research Development and Acquisition (DAMA-PPM-T, DAMA-RA, DAMA-WSA) 3
Comptroller of the Army (DACA-EA) 1
US Army Training and Doctrine Command (ATTG-U, ATCD-T, ATCD-ET, ATCD-B) 4
US Army Test and Evaluation Command (DRSTE-CT-A, DRSTE-TO-O) 2
US Army Logistics Evaluation Agency (DALO-LEI) 1
US Army Materiel Systems Analysis Agency (DRXSY-R, DRXSY-MP) 2
US Army Operational Test and Evaluation Agency (CSTE-POD) 1
US Army Armor Center (ATZK-CD-TE) 1
US Army Aviation Center (ATZO-D-T, ATZO-TSM-A, ATZO-TSM-S, ATZO-TSM-U) 4
US Army Combined Arms Center (ATZLCA-DM) 1
US Army Safety Center (IGAR-TA, IGAR-Library) 2
US Army Research and Technology Laboratories (AVSCOM)
(SAVDL-AS, SAVDL-POM (Library)) 2

US Army Research and Technology Laboratories/Applied Technology Laboratory (SAVDL-ATL-D, SAVDL-Library) 2

US Army Research and Technology Laboratories/Aeromechanics Laboratory (AVSCOM) (SAVDL-AL-D) 2

US Army Research and Technology Laboratories/Propulsion Laboratory (AVSCOM) (SAVDL-PL-D) 1

Defense Technical Information Center (DDR) 12

US Military Academy, Department of Mechanics
(Aero Group Director) 1

MTMC-TEA (MTT-TRC) 1

ASD/AFXT 1

US Naval Post Graduate School, Department Aero Engineering 1
(Professor Donald Layton)