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FINAL REPORT

FOR

LOGIC MODEL DIAGNOSTIC PROGRAMS AND PROCEDURES

FOR USE ON

AH-1 HELICOPTER

M28A1 ARMAMENT SUBSYSTEM

30 SEPTEMBER 1978

Prepared For U.S. Army Research and Technology Laboratory NASA-Ames Research Center Moffett Field, California 94035

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EXECUTIVE SUMMARY

Complex modern equipment and rapid personnel turnover have aggravated maintenance problems and cost. A new computer based logic modeling technique develops functional mathematical models which are transcribed on inexpensive magnetic discs for use at all maintenance levels. These discs are used with a universal lightweight portable test set to communicate in plain English the test and diagnostic strategy to the operator. Operation of the test set requires virtually no training. The LOGMOD Diagnostic Test Set, the appropriate disc, the operator, and common test equipment are all that is required for use with any system.

Those unfamiliar with logic modeling and the background of the LOGMOD System should refer to the following:

Naval Underwater Systems Center, New London Laboratory Technical Memorandum Number RA44-36-76 of 19 February 1976, entitled "Computer Generated Maintenance Logic Diagram (MLD): A New Approach to System Support', prepared by Alexander C. Vasiloff.

Final Report for LOGMOD Diagnostic Test Set and Demonstrator of June 1977 prepared by DETEX Systems, Inc., for the U. S. Army Air Mobility Research & Development Laboratory, Moffett Field, California. Contract NAS2-9319.

INTRODUCTION

The objective of this contract was to apply the LOGMOD concept to an actual army helicopter subsystem and demonstrate that this concept can be adapted to existing equipment, personnel, organization, and maintenance philosophies and achieve significant improvements in acceptance testing and fault isolation with minimal training.

The AH-1 helicopter's M28A1 Armament Subsystem was selected because it has known maintenance characteristics and is sufficiently complex to demonstrate that the LOGMOD system can handle the electrical, electronic, optical, mechanical, and hydraulic components that are typical of helicopter systems in general.

Tests were run at Fort Ord, California and at Fort Irwin, California on actual aircraft with actual problems. It was convincingly demonstrated that the LOGMOD concept was viable and well received by the Army user personnel having direct day-to-day M28 maintenance responsibilities. These people were impressed by the capability, simplicity, speed and accuracy of the LOGMOD Test Set when used by them. These are real people using real equipment under real conditions with little or no training or contractor assistance.

1.0 DEFINITION OF THE ANALYSIS TASK

The system selected for analysis under this contract was the M28A1 Helicopter Armament Subsystem (less the guns and feed system). This system consists of the pilot's and gunner's control panels and sights, the turret and weapons controllers and the Electronics Components Assembly (ECA). Together this system utilizes electrical, electronic, electro-mechanical, optical, mechanical, and hydraulic components to position and control the turret mounted guns of the Cobra Helicopter. As a subject for demonstrating the capabilities of the LOGMOD concept, the M28 system was challenging, satisfying and frustrating.

The complexity and diversity of components and mechanisms made the system a satisfying and challenging choice for analysis and demonstration. Inflexible test equipment and inadequate technical data provided both frustration and challenge.

The goal of the logic modeling analysis was to provide test and diagnostic capability for Aviation Organizational Maintenance (AVON) and Aviation Inter-mediate Maintenance (AVIM) levels within the present context of Maintenance Allocation and available equipment augmented only by the LOGMOD Diagnostic Test Set. The original concept was to make use of the organizational and intermediate level test sets in conjunction with the LOGMOD system; however, early in the analysis it became evident that the two existing test sets were unsuited for use in combination with the LOGMOD. The existing AVON and AVIM Test Sets were not designed to perform system tests nor were adequate test points available on the system as it is normally installed on aircraft or on the AVIM test stand. AVOM/AVIM Test Set operation requires testing each subassembly as an isolated unit. Each "black box" is tested in a fixed test sequence. The ECA circuit cards may be tested in any order but there is a fixed test sequence for each card. Consideration was given to alternate methods for providing access to the necessary system level test points with which the LOGMOD system would be unable to operate efficiently. Quite by coincidence, it appears, most of the essential test points were available at two internal ECA connectors (A1J2 and A1J3). To gain access to these connectors on the aircraft, it is necessary to remove an access panel and detach the ECA from the mounting bulkhead. Removing the ECA top cover then exposes the necessary connectors. The multiplicity of test points available at A1J2 and A1J3 augmented the few available at ECA test connector A1J1 and Turret test connector A3J5 to such an extent that only a small number of other test points were really needed. Fortunately, almost all test point measurements were simple voltages so the only on-aircraft test instrument necessary is a volt-ohm-millimeter (VOM) such as the PSM-6.

At AVIM the VOM is supplemented by the AVIM test set which is only used to confirm "bad card" diagnoses or to adjust a "bad card" to bring it into specification. The contractor was unable to obtain specification data for any of the test points where other than straight forward voltages are available. No data was available for example, for the test points at test connectors A1J1 and A3J5! Mr. Billings of Rock Island Arsenal went to considerable trouble to locate these data and concluded that none was furnished to the Army by the manufacturer. These data could probably be determined empirically, but contract milestones prohibited the contractor from obtaining the data in a timely manner without considerable additional cost to the contract. If the complete specification data is subsequently obtained, it could easily be inserted into the existing disc programs. The mechanical portions of the M28 system were easily modeled in great detail. This was done on an informal basis as part of the "learning" Process, but the details were not included on the discs because of the maintenance allocation and because most of the events are unobservable. While still somewhat incomplete in certain areas as indicated above, a remarkable amount of analyses was completed in a relatively short time with impressive results.

The LOGMOD Diagnostic Test Set and discs offer a new, quick, and accurate means of checking out the M28 system and identification of defective Line Replaceable of Shop Replaceable units. Application of these modeling techniques during the design phase would have resulted in "knowing" which test points were needed so they could be incorporated into the design.

2.0 PROGRAM SCHEDULE AND MILESTONES

The program schedule for this contract was defined during a start of Work meeting in May, 1977. This meeting set up a program of contractor analysis assisted by M28 experienced Army personnel with interspersed in-process reviews and evaluations. Following the meeting DETEX personnel went to Fort Ord, California to examine the M28 system installation and to become familiar with the system maintenance environment. June, 1978 was spent on analysis of the system for organizational maintenance, concentrating on identifying the defective Line Replaceable Units (LRUs). At the end of June a meeting was held at Fort Ord for an In-Process Review. Analysis continued through July and on July 25 and 26 an evaluation of the discs prepared for organizational maintenance was conducted at Fort Ord. The LOGMOD Diagnostic Test Set and discs were used to acceptance test and troubleshoot M28 Systems on helicopters. Several aircraft were utilized by the evaluation team. The first tests were run with DETEX personnel assisted by Fort Ord military personnel. Later tests were performed by Army personnel with little or no contractor assistance as it was little needed. During the remainder of July comments from the evaluation were incorporated into the LRU discs. August and part of September were devoted to expanding the organizational level analysis to cover the Intermediate level and to prepare discs that included Shop Replaceable Unit (SRU) level analysis.

Evaluation of the SRU level discs were conducted on aircraft at Fort Ord on 31 August and at Fort Irwin during the weeks ending 23 and 30 September. The Fort Irwin evaluation was conducted in conjunction with gunnery practice by Fort Ord based Cobra Troops. Comments from these evaluations were incorporated into the disc programs during the balance of September.

3.0 RESULTS OF ANALYSIS AS APPLIED TO M28 SYSTEM

As the analysis of the M28 system progressed it became apparent that a new approach to system modeling was evolving. The final product was unique in that the model was no longer a strictly conventional logic model in the sense of the MIL-M-2400 Maintenance Dependency Chart nor mathematically pure in an analytical sense.

What evolved was an overall model that was broken into steps in which operating conditions were progressively changed or exercised in a logic dependency order. These steps form a checklist which progresses from non-operational observations through an orderly sequence of operational observations. Underlying this progression are ever deeper penetrations into the system's logic structure. Each step successively confirms additional aspects of equipment operation so that the successful completion of the checklist gives a high confidence level acceptance inspection.

The order of events is scientifically chosen so that once an item, or aspect of equipment operation is determined to be good, this aspect is dynamically removed from the diagnostic model. This model reduction or "stripping" process yields a dramatic reduction in diagnostic steps (and time) when a failed event is observed. This reduction is so effective that the number of steps required to fault isolate to the appropriate level after failing a checklist step is less than four for substantially all failures with a high proportion of zero or one step diagnoses.

Since any given operational step may only verify an aspect of a circuit or mechanism's operation, several steps may be required to confirm total operability of that item. The result of this is a more complex model structure and more emphasis on the logic analyst's complete understanding of equipment function, but this certainly is a worthwhile tradeoff.

Properly trained logic modeling analysts have long recognized different aspects of a given item’s functioning. A good example of this are the hydraulic solenoid valves in the M28 system. These valves change the direction of turret rotation or stop rotation. A piston within the valve closes all fluid ports in the center or balanced signal position (voltage A = voltage B). When voltage A > voltage B, the valve moves to one side exposing one set of outlet and return ports. When voltage A < voltage B, the valve moves to the opposite side exposing the ports reversing the direction of flow in the hydraulic system. Skilled analysts recognize that this valve has several failure modes or functional aspects. It may not initially be in the "off" position. It may not move in one direction or the other or it may not return to "off" after moving in one direction or the other. In computer modeling each of these functions is considered to be a unique "item". The electrical/electronic equivalents of this example are easily recognized. What may easily be overlooked are the aspects of function when an item is used in apparently the same way but under somewhat different conditions. Examples of these are different conditions of loading on a gear train or differing signal levels, polarities, or frequencies in an amplifier. The modeling rule that once an item is proven good, it remains good and is used in the computer algorithm to strip out the good events (and items) leaving only the bad or unproven events. Because of this, the equipment analyst must constantly question whether a good event really proves the items on which it depends are "good" or whether it merely proves that the items were not "bad" in some manner that would cause that particular event to be bad. As the M28 system analysis progressed and the analysts understanding of the system became more complete, they recognized more and more "aspects" of the systems function and expanded the modeling to encompass those aspects. This is critically important in "checklist" models as when each "step" is completed its events (and items) are no longer considered in the diagnostic subroutines for subsequent steps. Premature modeling reduction or stripping would cause erroneous diagnoses. This is avoided by what amounts to duplicating the events and items in each applicable "step" until they are "proven" to an acceptable confidence level. This technique promises to be invaluable when applied to digital circuits where all possible combinations may be impossible to verify because of the sheer magnitude of these combinations.

4.0 RESULTS OF EVALUATIONS

The evaluations conducted of Fort Ord and Fort and Irwin originated with an AVRACCOM request that the people at Fort Ord assist in evaluating the feasibility of using the LOGMOD concept for field maintenance of the Cobra mounted M28 system. The direct involvement of user personnel gives extra credibility to the results of the evaluations because the type of personnel participating in the evaluation are exactly the same as those in the field not a laboratory simulation of them. The evaluations proved that:

1. Complicated systems comprised of diverse types of mechanisms can be modified exactly as they function together regardless of their complex interrelationships.
2. The knowledge and experience of experts such as Messes, Billings, and Kelly can be preserved and made available for use by less experienced people when that knowledge is incorporated into the LOGMOD analysis.
3. First enlistment personnel are able to operate the test set with only a few minutes instruction.
4. Personnel of all ranks and levels of expertise are highly motivated because of their success in solving problems when using the Test Set. All reactions were favorable.
5. The LOGMOD concept is reliable in and fully compatible with the existing maintenance environment.
6. There is no essential reason for the test set to be located at or near the aircraft. It was used remotely at Fort Ord and data was communicated via aircraft's intercom. At Fort Irwin communication was by radio. The Test Set and operator were located in a Direct Support van.
7. The laboratory model Test Set was fully operable under the field conditions experienced.
8. The LOGMOD method eliminates inaccurate diagnoses and dramatically reduces diagnosis time.

The checklist portion of the disc programs is identical in both the AVIM and AVON versions. Since both the organizational and intermediate people are operating from the same checklist with the same step numbering system they can communicate the precise nature of the failure. AVOM personnel simply record the step number of the failed event on the paperwork which accompanies the LRU to the AVIM shop. At AVIM the LRU fault isolation can proceed from that step to isolate to the SRU. Most of the time even this won't be required as the AVOM model will have already defined the required maintenance action. This same principle would operate between AVIM and depot producing the same exactness of communication while eliminating false returns.

Times to run the checklist for systems having no malfunctions will vary from about 20 minutes for a first time operator and then down to about 5 minutes when they have a little experience. These times do not, of course, include aircraft turnaround, turn up, and shutdown times or the normal "inefficiency" factors.

When a malfunction is detected during the performance of the checklist the additional time required to diagnose the problem is primarily a function of that required to remove the aircraft access panel, loosen the Electronic Components Assembly, and remove the cover to get to the essential test points. Actual test time is only a couple of minutes.

During the evaluation in August, four aircraft with four malfunctioning turrets were correctly diagnosed during an eight hour period divided between two working days. When the NCO in charge was questioned by a superior as to how long it would have taken to obtain the same result with conventional methods the NCO replied "twenty-four hours". Thus the same people under otherwise identical conditions experienced a three-fold reduction in maintenance time!

Because of the checkouts in August at Fort Ord there were only two malfunctions encountered at Fort Irwin. Both of these problems were correctly identified by the Test Set. Of these problems one was incorrectly diagnosed by conventional methods after four hours and correctly identified by the Test Set in one-half hour.

One of the most important conclusions from the evaluations is that the analysis for the LOGMOD method would be most effective if performed during the design cycle so that designed in maintenance characteristics may be improved and system logic optimized.

5.0 ORGANIZATIONS AND KEY PERSONNEL

INVOLVED IN PROGRAM

U.S. Army Research and Technology Laboratory

Dr. Richard Carlson, Director
William Andre, Technical Monitor
Dr. James Wong, Technical Monitor

Cobra Program Office

Major Bruce Gardner
Captain Donald Cilly

ARMCOM

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AVRADCOM Training School

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Fort Ord

General Kerwin, Commanding Officer
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Colonel Robinson, CO 2/10 Cavalry
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