

LOGIC MODEL TEST EQUIPMENT
FOR MAINTENANCE AND TRAINING

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Introduction

In 1973 the Army Air Mobility Laboratory Headquarters at Ames Research Center, Moffett Field, California, initiated special research investigations in the area of diagnostics technology. These investigations have developed Logic Model (LOGMOD) concepts for performing a variety of functions related to design, maintenance, and testing. As a result of research investigations conducted both in-house and under contract, the first LOGIC MODEL TEST SET was designed and built during 1976. The capabilities of the Logic Model test set are the principal topics discussed here. The theoretical and mathematical concepts have been addressed in the referenced papers.

The basis or starting point for the project relates to the notion of maintenance dependency charts. The Navy has for several years used these charts as a graphical aid in fault isolating. The mathematical structure underlying this concept was identified and generalized in an abstract setting. From this the logic model basis was formed and expanded to allow any complex hardware design, whether of a mechanical, electromechanical, or electronic nature to be modeled. As a result the logic model techniques can be applied to most military systems in the Army, Navy, and Air Force. The degree of application for a particular system is determined by the degree to which access is available for observing and measuring the set of events which exist in a given design.

The original objective of the project was to develop a design evaluation tool which would provide greater capability for evaluating design concepts from engineering drawings and schematics. In particular, those aspects of hardware design that determined the system requirements for troubleshooting, maintenance, and training as evidenced during the operation phase of equipment life cycle, were the overall driving factors. The logic model analysis techniques which were developed have gone a long way in the direction of providing this capability.

It was found that the very same structure that was used as a design evaluation tool could also be used once hardware was built and fielded to perform troubleshooting and diagnostic functions on the fielded equipment. An attempt was made to design a test set using recent off-the-shelf components that would provide this capability.

The first Logic Model test set was designed and built by December 1976. Since then experience has been gained regarding its use and application. The following observations have been made:

a. The Logic Model test set synthesizes troubleshooting strategies and provides instructions to the test set operator that equal the knowledge of the hardware designers of the equipment under test. The skill level required to operate the Logic Model test set is roughly equivalent to that needed to operate a hand-held calculator that performs arithmetic operations.

b. The time required to fault-isolate malfunctions is reduced greatly, often by at least two orders of magnitude.

c. The ability to fault-isolate is expanded such that any malfunction or combination of malfunctions within equipment can be fault isolated within the design constraints of the equipment.

d. The Logic Model test set requires no design change in the test set itself to fault-isolate different equipment, only a software change is required.

e. The Logic Model test set can be used to simulate actual failures and therefore, provide training experience in fault isolation and trouble-shooting as a training aid.

The following sections address the specific capabilities of the Logic Model test set, establish some comparisons of this test set with automatic test equipment, address cost aspects, the operational requirements, and discuss application areas.

Capabilities

A characteristic of the test set is that it does not require but can admit a physical connection to the equipment under test. For all tests and inspections required by the test set, the man is the link.

A hand-held control keyboard has been designed to allow initial numeric information to be keyed in. Operating in this mode the Logic Model test set performs in what may be considered a semi-automatic mode. There are advantages and disadvantages associated with this.

Some of the advantages are:

- a. The test set becomes a piece of general purpose equipment applicable to many diverse hardware systems.
- b. The human link provides the capability of performing multiple complex tests that could not normally be economically performed by fully automatic test equipment.
- c. No physical connection between the test set and the equipment under test means the test set, if desired, could be located in a spot remote from the unit under test (i.e., field technicians can use the test set by talking to someone at a fixed base operation over the phone).

Some disadvantages may be:

- a. The time to test is dependent on the speed of the technician.
- b. The technician sometimes makes mistakes and can make a wrong decision.

The Logic Model test set can also be designed for use in the ATE mode where no human link is required to perform the troubleshooting sequence. This could be accomplished by appropriate use of test measuring equipment which could translate the measured parameter information into a go-no-go situation. Then the need for the man is eliminated and advantage can be taken of the great reduction in actual test time that can be achieved. No reduction in diagnostic time is achieved since the test set arrives at decisions in a period of time which for all practical purposes is instantaneous. If the Logic Model test set were used in an ATE mode then some of the advantages may be:

- a. The human error probability which can be considered high without the test set and considered low with the test set can be reduced further or effectively eliminated.
- b. The overall time to troubleshoot is reduced to the same magnitude of time as that needed for the test to function (usually fractions of a second).

Some disadvantages may be:

- a. The ATE mode brings the test equipment closer to being special purpose equipment with the automatic sensing aspects being peculiar to the equipment under test.
- b. The hardware cost of the ATE mode can be greater than the semi-automatic mode.
- c. The ATE mode is restricted to relatively simple tests and cannot take advantage of the inherent capability of the human brain to perform complex tasks not economical or feasible for ATE testing.

The economical aspects of using the Logic Model test set in either semi-automatic or fully automatic (ATE) modes show high potential for cost savings.

Within Army aviation one of the highest single causes of maintenance burden is faulty diagnostics. It is not uncommon to find that up to forty percent of returns to depot were unjustified.

The logic model approach will not only effect improvement in the diagnostic batting average, it also will contribute to allowing technicians to perform maintenance and troubleshooting of very sophisticated equipment. This means many things; some of which translate into a strong impact on the training area and improved maintenance capability. Hardware formerly considered too sophisticated to be put in the hands of the user and maintenance man can now be more readily accommodated.

It would be impossible at this time to compute the actual cost savings that this class of testing equipment can achieve in the next few years. However, when taken on a system by system basis, it would not be surprising to find the cost avoidance and savings would not simply be measured in the millions of dollars but could be counted at the billion dollar level.

Operational Requirements for Diagnostics

The Logic Model test set is basically a responsive diagnostic device, which interacts with a person familiar with the simple operational procedures of the Logic Model test set. Conceptually, the test set is a mechanization of the diagnostic concept employing the functional Logic Model of the system under test. The test procedure follows the intrinsic property that a system malfunction can be detected by checking the terminal events of the Logic Model. To do this, no in-depth understanding of the basic Logic Model as well as the testing strategy is required. In fact, the information needed to operate the test set is as follows:

1. Familiarization with the locations of each test point on the system under test.
2. Operation of the appropriate common test equipment, such as an oscilloscope, voltmeter, pressure gauge, etc., required to measure test point parameters.
3. Sufficient training or knowledge to determine whether or not a measured (or observed) quantity is within tolerance.
4. Operation of the Logic Model Test Set.

Here, we have tacitly assumed that each test point in the system under test is accessible for testing purposes. With this stipulation in mind, a quick review of the four requirements stated above reveals that the first three items can be easily mastered without lengthy and intensive training. The remaining requirement is equally simple, as is illustrated by the following sequence for operating the test set.

1. Plug the test set power cord into a 110 volt outlet.
2. Turn on the power switch, located on the front panel of the test set.
3. Open the floppy diskette compartment door, located on the front panel, and insert the prepared floppy diskette containing the appropriate functional Logic Model, and then close the door.
4. Push the reset button, located on the front panel of the tester, and the test set will ask, through the display panels, for the desired Logic Model on the magnetic diskette.
5. To input the requested information key in the identified code through the hand-held keyboard and the display will register the code on the panel. The "C" key on the keyboard is provided to clear any undesired entry. The "." or period key on the keyboard is provided as a command to accept and execute.
6. Now the test set will respond and ask for the numeric code relating to the observed malfunction. Only terminal event malfunctions need be considered.
7. Insert the correct code and push the period key.
8. The test set then computes a strategy and determines the specific test required such that the technician can determine from the result of the test if it was "good" — within the specification, or "bad" — out of tolerance.
9. Key in "G" for good, or "B" for bad, then push the "." key.
10. This interface between the operator and the test set continues as outlined in steps 8 and 9 until the malfunction has been determined. At this point, the test set identifies the defective items.
11. Push the reset button and the test set is ready to continue if other malfunctions exist.

12. To turn off the test set, open the compartment door and remove the floppy diskette, and turn the power switch off.

Although the foregoing operational procedure is an elementary exercise, it demonstrates the simplicity of operation associated with the Logic Model test set.

Applications

To date, several distinctly different but related areas of application have been found. These areas address the following:

1. DESIGN EVALUATION
2. TROUBLESHOOTING/DIAGNOSTICS
3. TRAINING AID
4. MAINTENANCE MANUALS

The design evaluation aspects have already been discussed; however, some specific examples of how the designer can use the logic model are worth mentioning. On a general purpose computer the logic model which identifies all the design functional relationships can be operated upon to compute some very useful statistics. For example, the time to fault-isolate any component in the design can be computed. The utility of each test point or observable can be assessed by identifying the frequency of use of test points. Often many are found redundant and not needed in the design. Characteristics of design very sensitive to the ability to maintain and effect repair can be identified. The requirement for developing Logic Models at the design stage requires the existence of engineering drawings. Technicians or the engineers themselves can formulate the base-line data package from which the Logic Model is generated. Logic Models need not be generated by hand.

The troubleshooting/diagnostics application stems from the product of the design effort. That which was used to develop and evaluate a design becomes exactly the same tool used by the technician to take care of the hardware when it gets to the field. If the design logic is good so will the maintenance logic be good. Classically, the person who designs the hardware is not the one to maintain it. The point to be made is that design for function and design for maintenance should go hand in hand and the logic model techniques provide a basis for effectively doing this.

As a training aid the test set can provide a means for familiarizing the student with what to do and how to go about it for any combination of faulty components. The repair and fault isolation procedure can be simulated on the test set very rapidly and repeatedly. Any combination of failures can be addressed without having to spend time engaged in trying to follow and understand a fault tree. Since the Logic Model is equivalent nominally to a fault tree of size two raised to the n power where n is the number of components in the system, a fault tree for a design with twenty components would have more than a million paths if it were equivalent to the Logic Model test set diagnostics.

The effect of utilizing the Logic Model test set with respect to maintenance manuals is of interest since the need to develop elaborate fault trees or troubleshooting procedures can be reduced significantly if not eliminated altogether. The present experience in formulating a maintenance manual around the Logic Model test set has indicated that a conventional manual as presently used and developed can be reduced in size significantly. This can occur because many of the tasks and rationale contained in the manual can be handled within the test set. Also the level of comprehension required to effect a repair can be greatly reduced, eliminating the need for detailed information and technical statistics.

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