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APPLICATION GUIDE

LOGIC MODEL (LOGMOD) STANDARD MAINTENANCE INFORMATION DISPLAY SYSTEM (SMIDS)

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20 ABSTRACT *(Continue on reverse side if necessary and identify by block number)* This document describes the Standard Maintenance Information Display System (SMIDS) and its application to Army systems. The SMIDS approach includes a versatile systems Logic Model related portable, field-use SMIDS. The (LOGMOD) analysis method and a a portable information SMIDS is processor and display device for use as a troubleshooting aid.		

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FOREWORD

This document describes the Logic Model (LOGMOD), the Standard Maintenance Information Display System (SMIDS), and their applications to Army systems. Included are explanations of the underlying LOGMOD/SMIDS concepts, potential benefits, selection of systems, and implementation guidelines. LOGMOD/SMIDS efforts at the Applied Technology Laboratory (ATL) are intended to improve the cost-effectiveness of Army aviation maintenance by providing tools to enhance the maintainability of systems acquired by Army programs.

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INTRODUCTION

PURPOSE

This Guide describes the Logic Model (LOGMOD),* the Standard Maintenance Information Display System (SMIDS), and their applications to Army systems. Included are explanations of the underlying LOGMOD/SMIDS concepts, potential benefits, selection of systems, and implementation guidelines.

LOGMOD and SMIDS are intended to improve the cost-effectiveness of Army aviation maintenance by providing tools with which to enhance the maintainability of systems acquired by Army programs. Affected areas include:

- ▪ Equipment design
  - •• Modularization
  - •• Testability concept and test point location
- Maintenance concept - level of repair
- Supply - sparing levels
- Personnel requirements
  - •• Training
  - •• Experience levels •• Manning levels
- Support equipment •• Special test sets

•• TMDE

*LOGMOD is not a registered trademark of any individual or corporation (Source: U.S. Department of Commerce, Patent and Trademark Office).

PROBLEM STATEMENT

Problem Context

There is a critical need within the Army for more cost-effective maintenance. This need results from the fielding of increasingly sophisticated equipment, the increasing costs of operation and maintenance, and a significant decline in Army aviation maintenance effectiveness.

Defense expenditures have constituted a declining portion of the federal budget, as shown in Figure 1 (Reference 1). Operation and maintenance costs have been soaring, as is shown in Figure 2 (Reference 1). Nevertheless, Army aviation maintenance effectiveness and personnel technical competence have declined significantly since the end of the Vietnam era.[2] Overall, required aircraft maintenance tasks exceed personnel capabilities.[2] The Army has sometimes had to resort to civilian contractor maintenance of aviation systems.

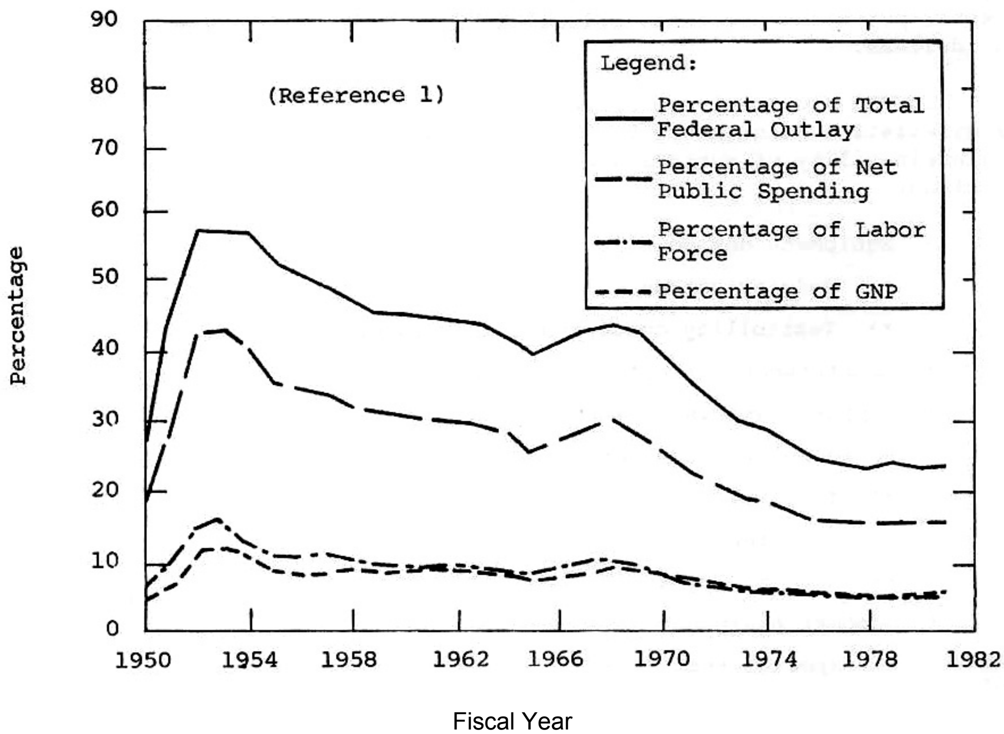

Figure 1. DEFENCE PORTION OF FEDERAL BUDGET

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(1)Department of Defense, *Annual Report FY 1981,* January 1980.
(2)Department of the Army, Chief of staff for Logistics, *Army Aviation Maintenance Career Management Field 677 Study,* October 1980.

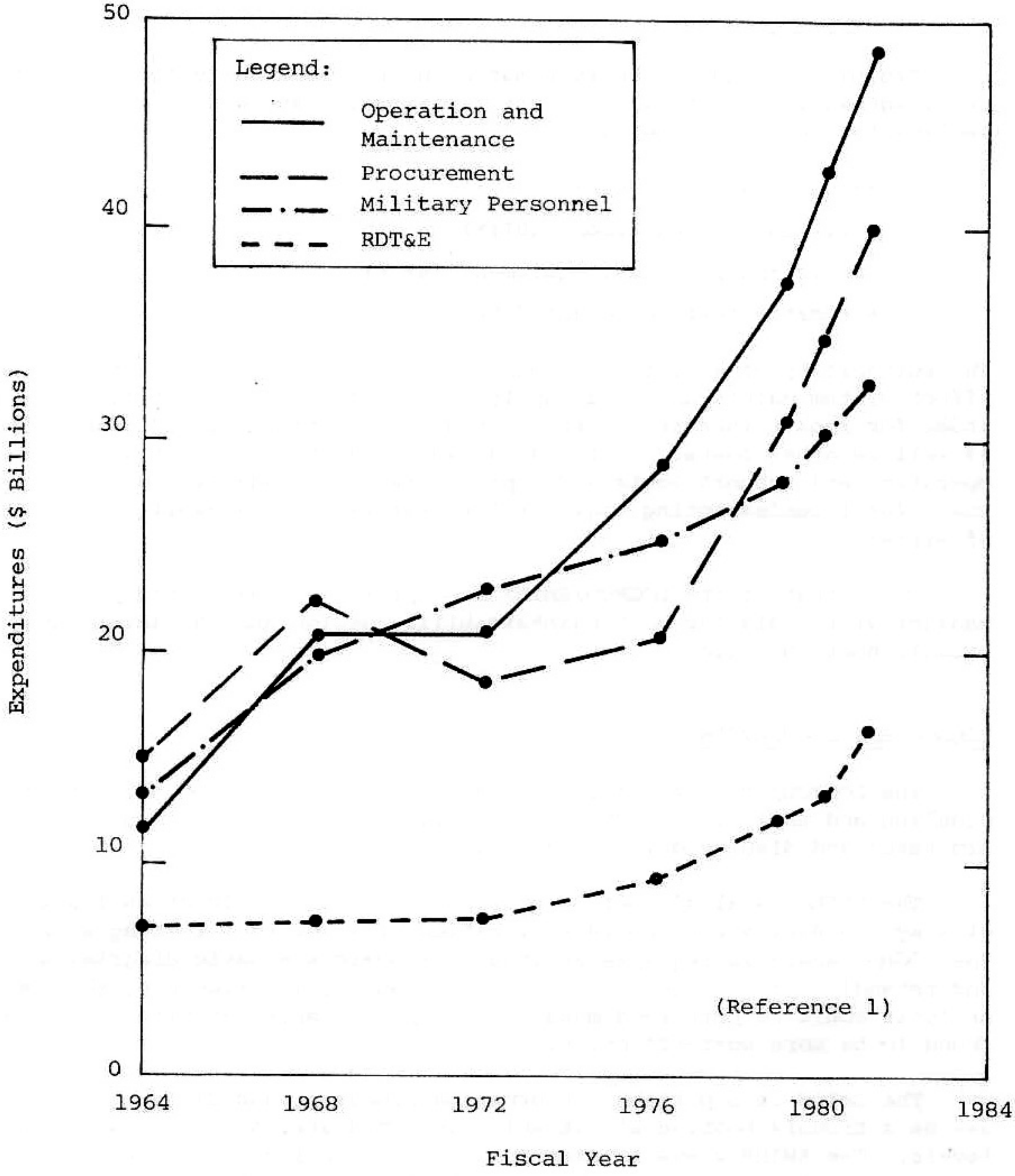

Figure 2. PRINCIPAL DEFENSE EXPENDITURES

The Applied Technology Laboratory (ATL) has been developing several maintenance technologies to improve the cost-effectiveness of Army aviation maintenance. This report describes some of these technologies.

Troubleshooting Logic

Troubleshooting is the systematic checking and analysis used to locate and diagnose equipment malfunctions. The troubleshooting logic may be implemented by the following:

- Manual test procedures
- Built-in test equipment (BITE)
- Special-purpose test equipment (SPTE)
- Automatic test equipment (ATE)

The suitability of a system's troubleshooting logic will significantly affect system maintenance and supply costs. Incorrect identification of items for repair increases costs of spares, maintenance, and transportation, as well as other costs. A program manager must trade potential savings in operating and support costs and improved readiness against the investment costs for troubleshooting logic or for improved maintainability engineering of systems.

The intent of the LOGMOD/SMIDS concept is to provide the program manager with tools for both maintainability design and the development of troubleshooting logic.

LOGMOD/SMIDS OVERVIEW

The LOGMOD/SMIDS approach includes a versatile method of systems logic modeling and analysis (LOGMOD) and a related portable, field-use information processor and display device (SMIDS).

The LOGMOD analysis method provides a systematic functional analysis of a system design and the identification of an optimal testing strategy. The LOGMOD analysis requires as inputs standard schematic diagrams and an understanding of a system's functioning. While, in principle, the LOGMOD analysis could be performed manually, computer implementations have been found to be more cost-effective.

The SMIDS is a portable information processor and display device for use as a troubleshooting aid at unit, intermediate, or depot maintenance levels. The SMIDS visually displays fault-isolation procedures to a maintenance technician as he performs sequential manual tests or observations. System-specific data for the unit under test is contained in software on insertable modules. The SMIDS does not physically attach to the unit under test; the SMIDS is not test, measurement, and diagnostic equipment (TMDE).

BENEFITS

The purpose of the LOGMOD/SMIDS approach is to provide analysis and diagnosis tools for more cost-effective support of Army systems. The degree of benefit depends largely upon a specific program's available alternatives and support constraints. Benefits affect the following:

- Cost
- Support requirements
- Schedule
- Risk
- Mission effectiveness

Cost

The LOGMOD/SMIDS approach results in direct and indirect savings in the following:

- System design evaluation
  - Performance
  - Reliability
  - Maintainability (including testability)
- Systems integration
- Development of troubleshooting logic
- Verification and validation of troubleshooting logic
- System operational testing and evaluation
- Data and publications (initial and updates)
- Training
- Support equipment (development and production)
- Spares
- Maintenance personnel
- Depot (labor, material, transportation)
- Warranty
- System modification

These cost benefits are discussed in the final section of this report.

Support Requirements

As a result of both improved system design for maintainability and better troubleshooting at the unit, intermediate, or depot levels, the LOGMOD/ SMIDS approach is expected to reduce the maintenance, logistics, and training support required by each fielded system.

The LOGMOD/SMIDS approach makes possible quick and accurate trouble-shooting by personnel with lower MOS skills[3]. This reduces unnecessary maintenance, maintenance time, and demand for spares. The payoff is in-creased unit self-sufficiency and reduced need for maintenance assistance teams.

On some programs it may be possible to use the SMIDS for a variety of systems and thereby reduce the makes and models of special test equipment. Thus, the SMIDS can be integrated with other ongoing Army efforts to standardize common items of test, measurement, and diagnostic equipment (TMDE), to increase the availability of TMDE where it is needed, and to reduce the logistic management burden within DARCOM activities.

Since the LOGMOD/SMIDS approach allows troubleshooting to be performed without a detailed knowledge of a system's theory of operation, the use of this approach reduces the training requirements for maintenance technicians. When the SMIDS is used in conjunction with common test equipment, it should reduce the quantity of special test sets with which a technician must be trained. In addition, the SMIDS can be used as a maintenance training aid both before and after technicians are assigned to units.

Schedule

The LOGMOD/SMIDS approach provides scheduling benefits by expediting several development activities, including developmental design reviews, developmental tests, test-set development, development or revision of troubleshooting logic, data and publication development or revision, training activities, and procurement of initial spares.

Risk

Risk is expected to be reduced through increased design confidence resulting from the LOGMOD analysis and through the use of the separately developed SMIDS. Once a system has undergone the LOGMOD review, it is less likely to contain a design defect or a testability problem (see page 20) that would otherwise be discovered at a key decision point in a program and delay the program. In addition, if the SMIDS is used, instead of or in conjunction with automatic test equipment (ATE) or special-purpose test equipment (SPTE), there is less likely to be an impact on the program if problems are encountered with the ATE or SPTE.

Mission Effectiveness

Mission effectiveness will naturally benefit from improved system functional design, increased supportability, and greater system availability.

APPLICATION CRITERIA

The LOGMOD/SMIDS approach may be applied to equipment items, including major systems, individual line-replaceable units (LRUs), or individual shop-replaceable units (SRUs) at any level or combination of levels of maintenance (unit, intermediate, or depot). Equipment resolution may be selected in accordance with the desired maintenance concept.

As a general consideration, LOGMOD/SMIDS applications should be made early in an equipment-acquisition phase. High-payoff applications include equipments with anticipated or actual problems in any of the areas discussed in the Benefits Section.

Prime candidates for the LOGMOD/SMIDS approach are equipments for which there is concern over the sequence and selection of tests for fault isolation, including the use of BITE. Motivation may include system complexity and interrelationships, high spares costs, high failure rates, high maintenance burden, overtaxed supply system, or proliferation of special test equipment.

LOGMOD/SMIDS applications will be easiest where good equipment documentation and functional descriptions are available.

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(3) Air Force Logistics Management Center, *LOGMOD Diagnostics,* Report 760701, 15 October 1978.

no Computer algorithm is proprietary to DETEX Systems;

LOGIC MODEL ANALYSIS

This section discusses the Logic Model (LOGMOD) and its use with SMIDS. LOGMOD is a systematic process of analyzing a system's design and identifying an optimal testing strategy. LOGMOD provides outputs to assist a system designer in identifying test points, selecting locations for built-in test (BIT), developing troubleshooting logic, and verifying and validating troubleshooting logic. LOGMOD has additional applications as an automated problem-analysis tool for existing equipment.

BACKGROUND

The Army became interested in LOGMOD through a series of studies con-ducted by the U.S. Army Air Mobility Research and Development Laboratory, Ames Research Center.[4] These studies were directed toward the development of analytical methods in reliability and maintainability technology. Computer implementations were developed and tested for feasibility[5].

Army LOGMOD efforts are being continued at ATL in conjunction with the development of the SMIDS.

Several DoD evaluations of the LOGMOD approach have been conducted.

An evaluation of LOGMOD's applicability as a measure of testability is being completed in response to a congressional inquiry and in follow-up of a previous evaluation[6] by an inter-service group. The current evaluation is being conducted by the Joint Logistics Commanders Panel on Automatic Testing; interim conclusions indicate that LOGMOD has potential value in early design evaluations .[7]

LOGMOD was evaluated as a troubleshooting aid by the U.S. Air Force. The conclusion was that LOGMOD implemented on a prototype SMIDS provides a workable and effective troubleshooting aid at the intermediate level of maintenance, especially when used by technicians of limited experience.[8] In addition, high user acceptance was anticipated in a fielded troubleshooting device based upon the LOGMOD approach.

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[4]James T. Wong and William L. Andre, *Some Generic Properties of a Logic Model for Analyzing Hardware Maintenance and Design Concepts,* U.S. Army Air Mobility Research and Development Laboratory, symposium presentation on "Applications of Decision Theory to Problems of Diagnosis and Repair," June 1976.

[5]Ralph A. DePaul, Jr., *Maintenance Logic Model Analysis Feasibility Study,* Tait and Associates, November 1974.

[6]Wilton J. Stiegman, *LOGMOD Final Report,* Inter-service Group on Exchange of Technical Manual Technology, U.S. Air Force Deputy Chief of Staff for Logistics, 21 March 1980.

LOGMOD OVERVIEW

Concept

The LOGMOD concept is to represent mathematically the functional design of an item of equipment in such a way that the maintainability characteristics of the equipment can be evaluated and diagnostic procedures developed. In addition, the LOGMOD structure must be capable of being implemented with normally available data and must be amenable to automation.

The key graphical tool in the LOGMOD approach is the maintenance dependency chart (MDC). The principal graphic symbols used in MDCs are shown in Figure 3.

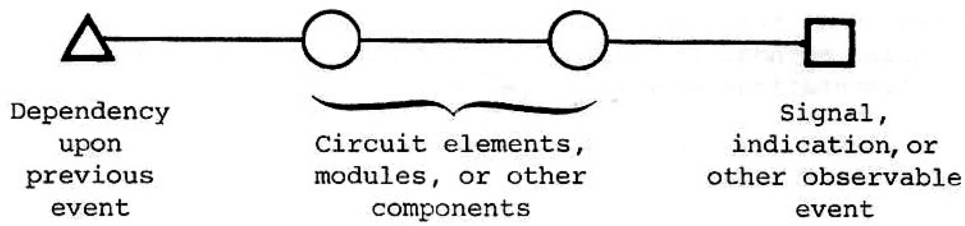

Figure 3. DEPENDENCY STRUCTURE

A square is used to represent a signal, indication, or other observable event; circles are used to represent circuit elements, modules, or other components; triangles are used to show event dependencies. An MDC is a graphic representation of the functional relationships in an equipment. The LOGMOD concept uses the mathematical equivalent of an MDC to model a system's design and to develop troubleshooting strategies. The LOGMOD MDC is pictorially similar to the graphic documentation techniques described in military

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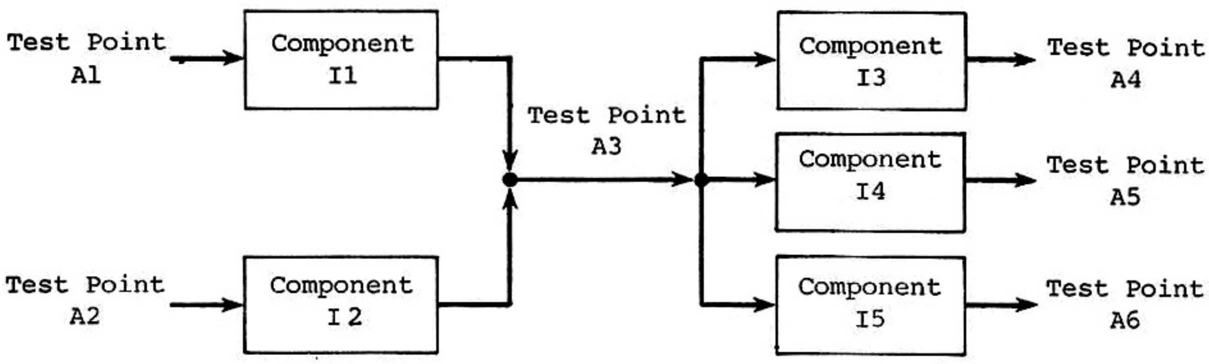
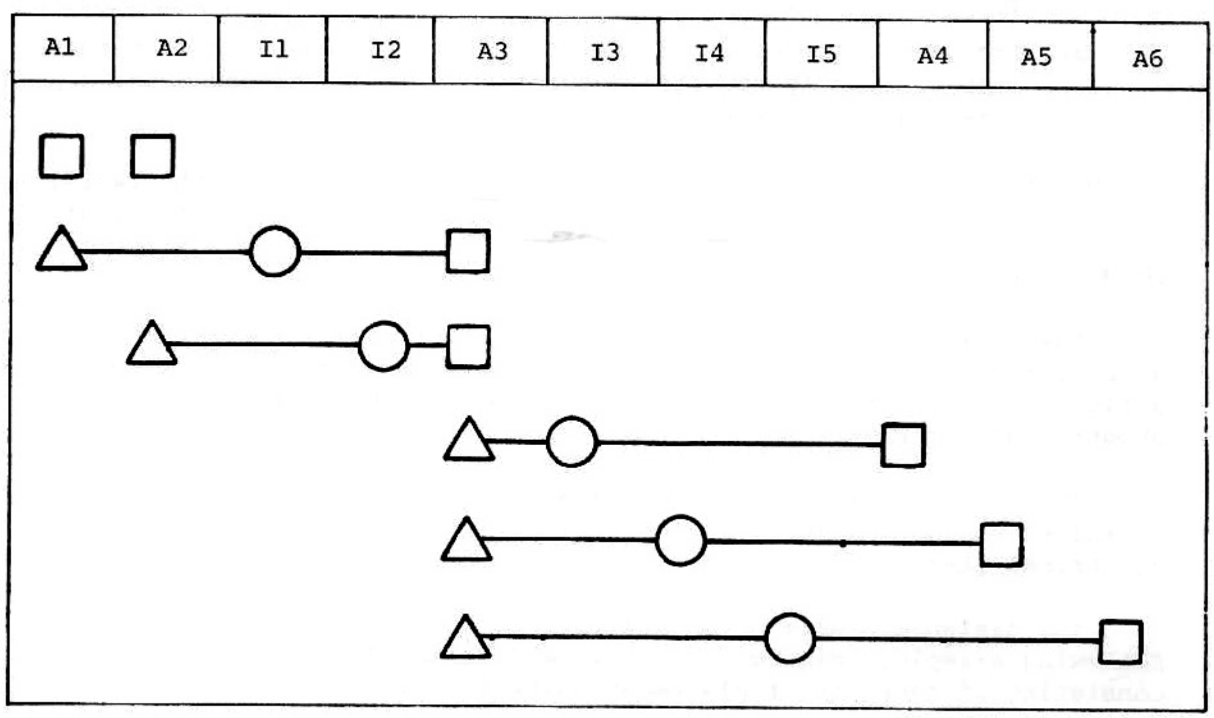
(7)William L. Keiner, *The Assessment of LOGMOD as a Testability Design Tool,* Naval Surface Weapons Center, 31 December 1980.
(8)B. F. Lacy and J. B. Berry, *LOGMOD Diagnostics,* Air Force Logistics Management Center, Project 760701, 15 October 1978.

specification MIL-M-24100 (Reference 9). However, the LOGMOD MDC is related to the development of an optimum testing strategy and is therefore more constrained than the MDC allowed by MIL-M-24100. Figure 4 shows a sample system's block diagram and its equivalent MDC. In this figure, events A4, A5, and A6 are the three outputs of the system. Since they terminate dependency chains, outputs are referred to as terminal events. More detail on the MDC is presented in Reference 9.



Block Diagram



Maintenance Dependency Chart

Figure 4. USE OF THE DEPENDENCY CHART

(9)Military Specification, *Manuals, Technical: Functionally Oriented Maintenance Manuals (FOMM) for Equipment and Systems,* MIL-M-24100B, 2 January 1974.

LOGMOD Fault Isolation

The MDC representation of a system's functional design is a convenient way to compare alternative diagnostic strategies. Tests are made in sequence; results are judged good or bad depending on whether observed measurements or observations are within known specified limits.

The LOGMOD diagnostic strategy uses terminal events to provide a check of an item's performance. Each terminal event is tested. For each terminal event giving a bad test result, the following operations are performed, as illustrated in Figure 5:

1. Begin by testing the event halfway* between the first event (input) and the bad terminal event, considering only events related to this terminal event (see Figure 5, Test 1).

2. Until a test gives a bad result, select the next test by advancing half of the way to the last event on the MDC (see Figure 5, Tests 2 and 3).

3. Once a test gives a bad result, select for the next test the left-most previously unverified event upon which the bad event depends. (See Figure 5, Tests 4 and 5.)

In the example illustrated, once Test 5 has been conducted, the faulty component can be isolated as the only source of the bad results for Test 4.

LOGMOD Design Evaluation

The LOGMOD approach to troubleshooting analysis has been found useful as a system design-evaluation tool allowing review of the functional organization of components and the location of test points for manual trouble-shooting or for BITE.

The LOGMOD analysis approach is applicable to any type of functionally organized equipment, including mechanical, fluid, and analog or digital electrical items.

The design-evaluation capabilities of LOGMOD are illustrated by the following example. Figure 6 is a block diagram of a hypothetical system consisting of four line-replacement units (LRUs). The design engineer for this system is asked to provide test points to allow unit-level maintenance personnel to fault-isolate to a single LRU. As a result of the loops in the functional flow, an MDC cannot be constructed at the LRU level; therefore, fault isolation will not be possible solely on the basis of test-point accessibility at the unit level.

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*Events are counted diagonally by using the squares shown in Figure 5. The terminal event is not included in the count. The first test is selected at the midpoint in the count from left to right. When the count is odd, the first event to the right of the midpoint is chosen.

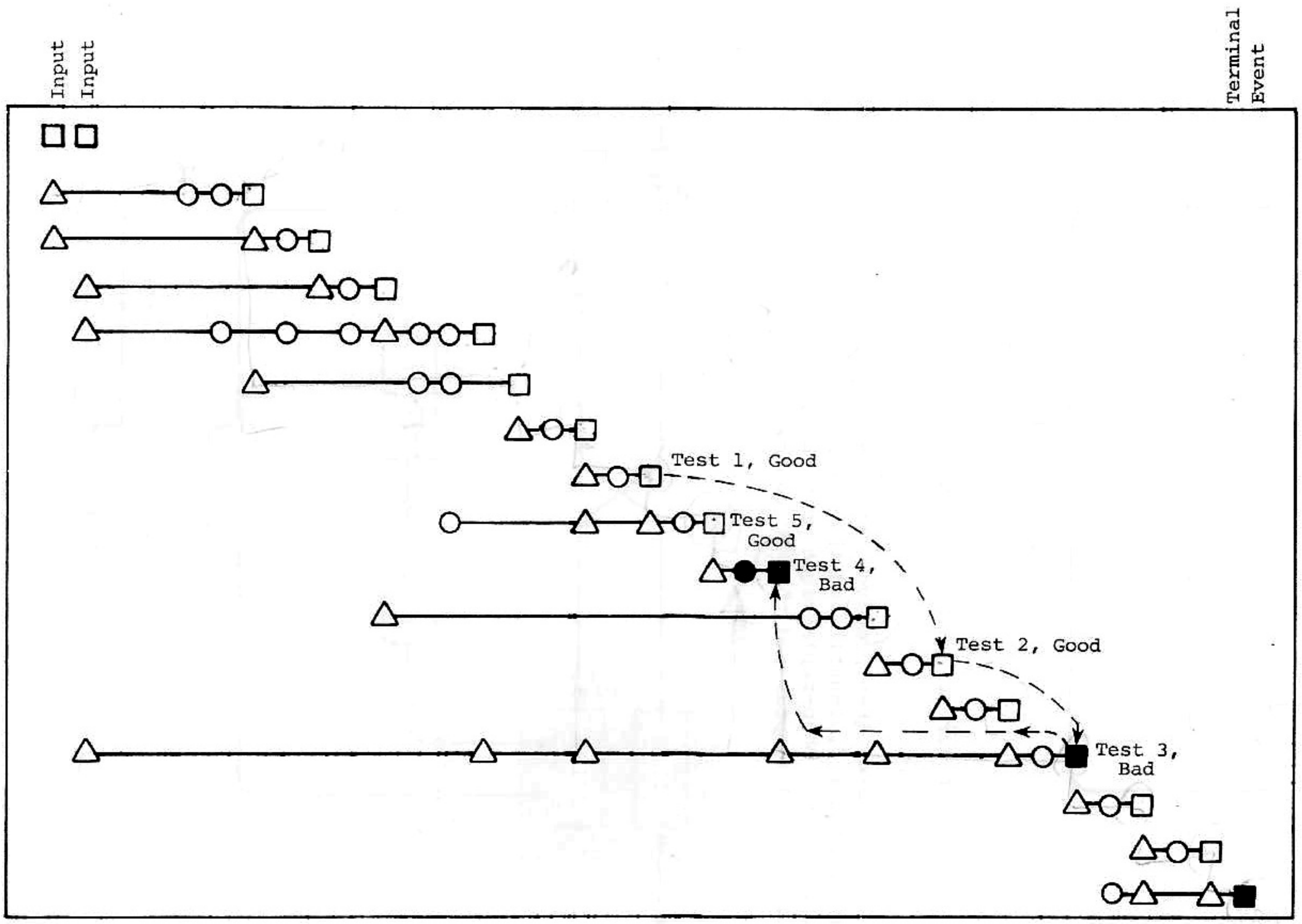

Figure 5. LOGMOD DIAGNOSTIC STRATEGY

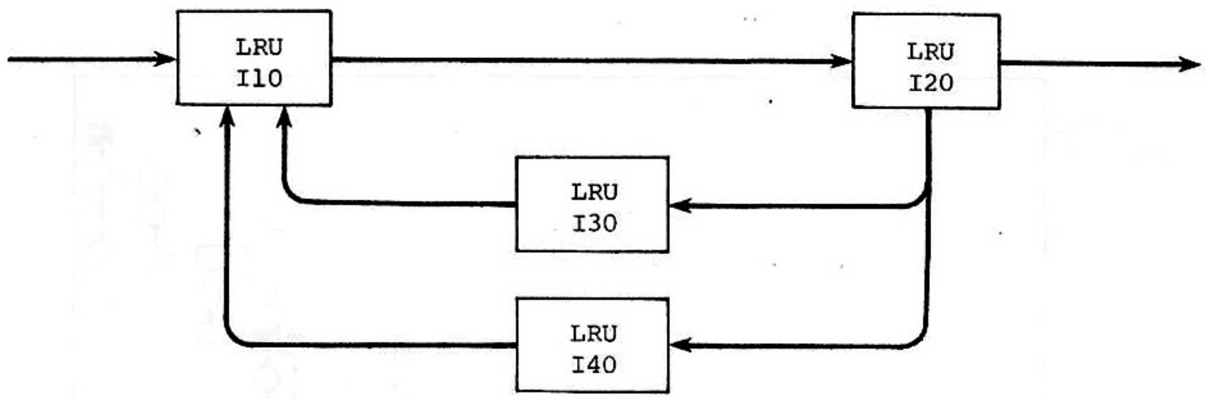

Figure 6. HYPOTHETICAL SYSTEM BLOCK DIAGRAM

The engineer then prepares the more detailed troubleshooting chart shown in Figure 7. Identifying the six potential test points (TPs) illustrated. At the shop-replaceable unit (SRU) level of resolution. The functional loops disappear and the MDC can be constructed as shown in Figure 8

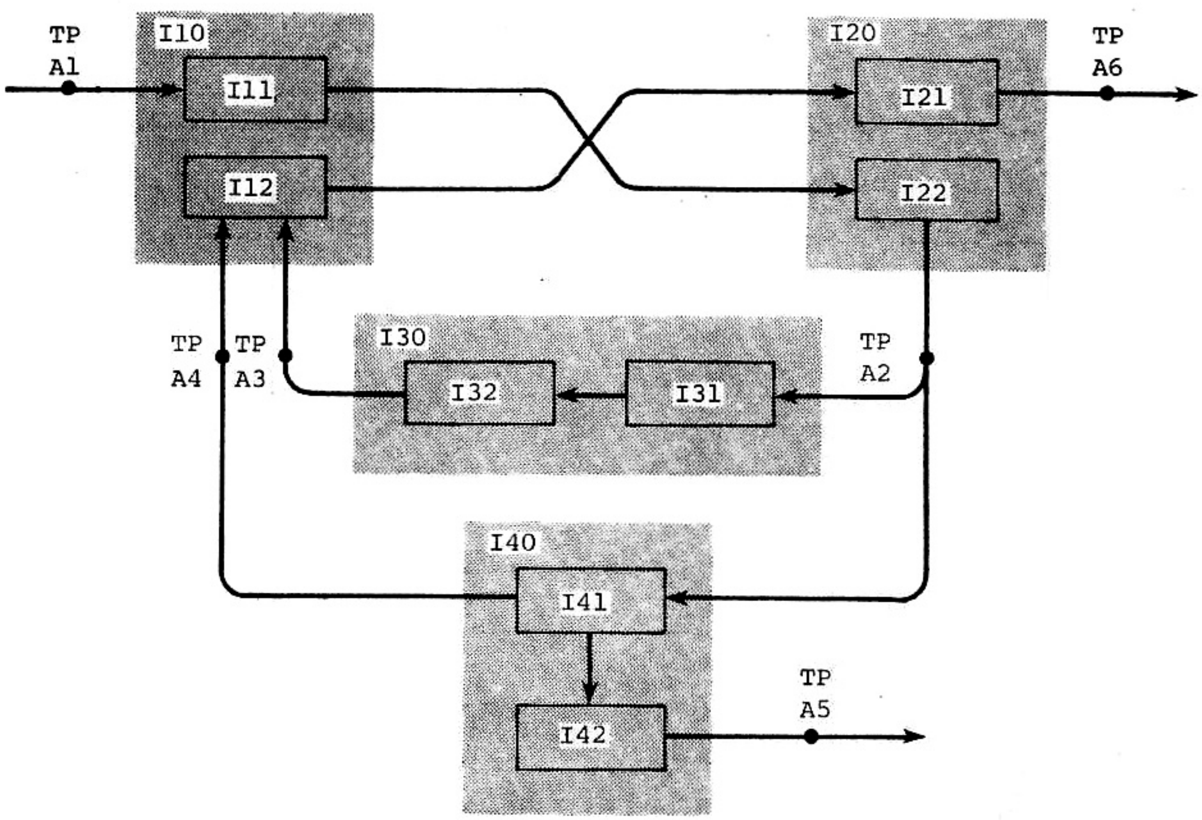

Figure 7. BLOCK DIAGRAM OF THE SRU LEVEL

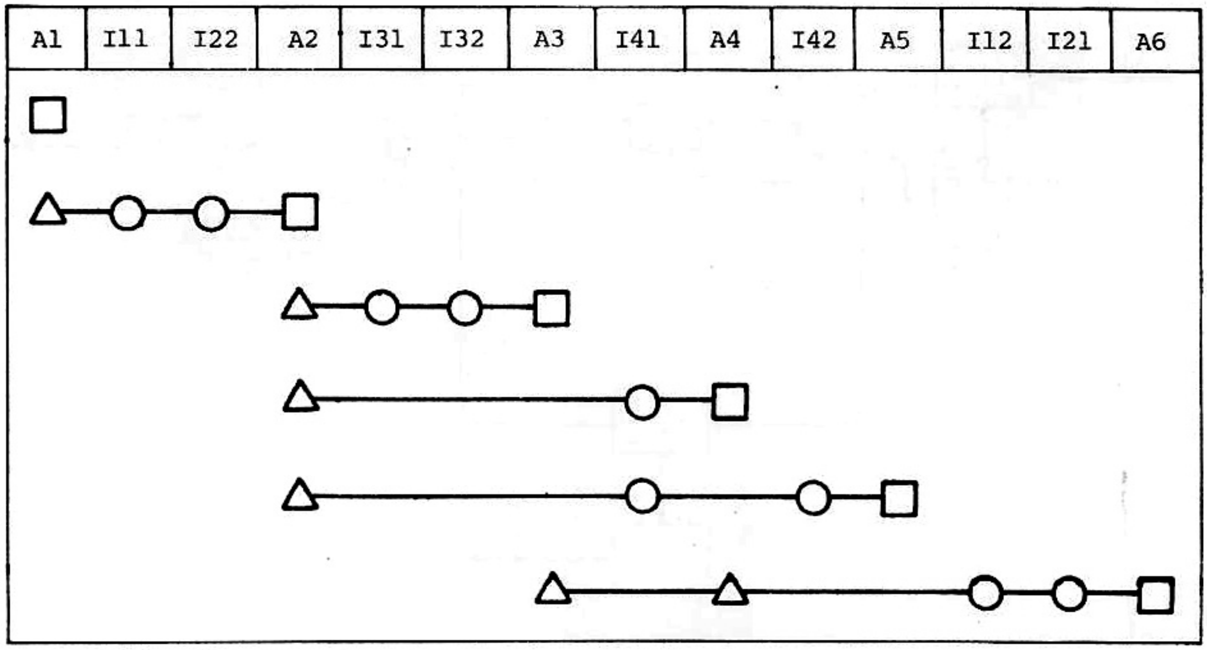

Figure 8. MAINTENANCE DEPENDENCY CHART FOR SYSTEM

The MDC identifies the following possible design improvements for consideration:

1. The SRUs' functional organization is inconsistent with their packaging into LRUs. Figure R shows that SRUs Ill and 122 are functionally linked, as are I12 and I21. A comparison with Figure 7 suggests the exchange of 112 and I22 between LRUs I10 and I20. Figure 9 shows the repackaged system, which is now amenable to fault isolation to the LRU level. Test points are as shown.

2. An SRU is present that may no longer be needed. TPs A5 and A6 are terminal events, but Figure 6 did not show A5 as a system output. Unless TP A5 is one of the desired outputs of the system, SRU I42 may not be needed. Figure 8 indicates that output A6 of the system does not depend upon I42, which may be a carry-over from a previous configuration of the system. (This has happened in many LOGMOD applications.)

The repackaged system can be fault-isolated to the LRU level by using definable test points. Depending on the nature of the system it may be useful to select some of these for built-in test. Other test points (e.g., between Ill and I22 or between I12 and 121) are not necessary and would provide information that was either redundant or not needed for unit-level maintenance.

The foregoing example illustrated the use of the LOGMOD approach for design evaluations. While this hypothetical system was simple enough that the same conclusions could have been made without the use of the LOGMOD approach, many actual systems are so complicated that packaging and test-location improvements may not be discovered during normal design reviews.

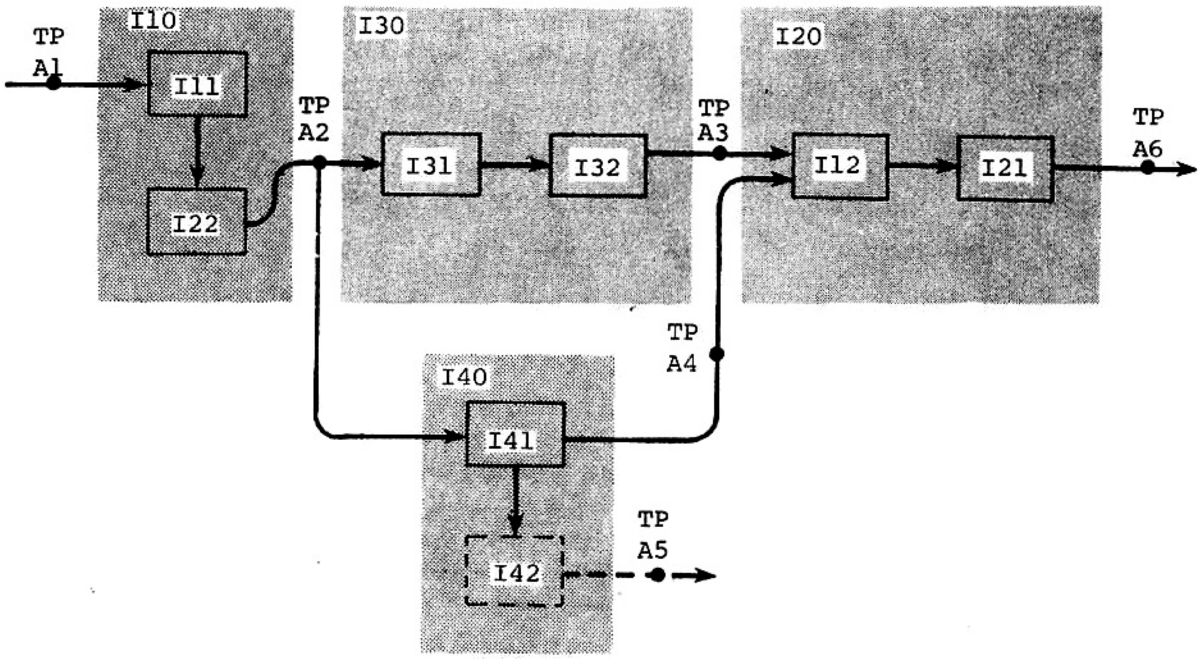

Figure 9. BLOCK DIAGRAM FOR REPACKAGED SYSTEM

For LOGMOD applications on existing equipment items, documentation describing the current equipment configuration will be needed. If such documentation is not available, it will have to be developed during the LOGMOD analysis. The LOGMOD approach provides a systematic evaluation of equipment testability, including test-point adequacy.

LOGMOD IMPLEMENTATIONS

The LOGMOD approach described in the previous section could in principle be manually applied; however, manual approaches can be expected to be time-consuming and costly.

Computer implementations of the LOGMOD approach are currently available from a single commercial vendor, DETEX Systems, Inc., which has applied the LOGMOD approach to equipment items at a variety of levels, including systems, LRUs or their equivalent, and SRUs or their equivalent.

The potential range of LOGMOD applications is suggested by the past and present applications listed in Table 1. The purposes of these applications are:

- To evaluate the LOGMOD concept
- To develop manual troubleshooting logic

Table 1. LOGMOD APPLICATIONS

Item	Sponsor
M-65 Tow Missile Subsystem	U.S. Army Applied Technology Laboratory
M-28 Gun Turret Subsystem,AH-1G	U.S. Army Troop Support and Aviation Materiel Readiness Command, CobraProject
XM-140A Automatic Gun, 30mm	U.S. Army Aviation Research and Development Command
AN/BRD-7 DF Receiver	U.S. Navy Electronic Systems Command
General Noise and Tonal System (GNATS)	U.S. Naval Sea Systems Command
HP3450B Multifunction Meter (ME-482/PU)	U.S. Naval Air Engineering Center
Wavetek 154 Programmable Waveform Generator	U.S. Naval Air Engineering Center
Assembly from Main Display Unit, E-2C*	NAVAIR Engineering Support Office, Naval Air Rework Facility, North Island
Four Assemblies from Inertial Navigation System, RF-4B*	NAVAIR Engineering Support Office, Naval Air Rework Facility, North Island
AN/APN-147(V) Radar Set	U.S. Air Force Logistics Management Center
Wavetek 172B Programmable Signal Source	Sperry Univac Corporation
C-4 Load Station, TRIDENT Missile	Lockheed Corporation
Remotely Piloted Vehicle System	Lockheed Corporation
Airborne Target Simulator	Government of Sweden

Note: Table includes both current and previous LOGMOD applications.
Data Source: DETEX Systems, Inc.
*ATE application.

- To validate test program sets (TPSs) for ATE applications
- To develop new TPSs
- To evaluate a system's design for testability
- To develop troubleshooting logic for implementation on the SMIDS prototype display device

Figure 10 summarizes the inputs needed for the LOGMOD analysis process and the resulting products described in the following paragraphs.

Maintenance Dependency Chart

The LOGMOD analysis generates the MDC by sorting the input list of events and components and generating a graphic printout similar to the examples discussed previously and illustrated by Figures 4, 5, and 8. The MDC shows the functional organization of the system.

Terminal Events List

Events are considered terminal when no other events depend upon them. The set of terminal events is the set of outputs from the equipment being modeled. The LOGMOD analysis produces a list of all terminal events in order to facilitate a review of the equipment design.

Test Frequency Tabulation

The LOGMOD analysis considers all possible system failures in order to generate the relative frequency of use of all designated test points. A sorted list is printed to facilitate review.

Test Strategies for Replaceable Units

The LOGMOD approach analyzes the functional organization of components into replaceable units and their associated fault-isolation strategies. The terminal event that first indicates the presence of a fault is identified, together with the sequence of test events and "good" or "bad" results that would be observed in the isolation of the fault.

Diagnosis Times or Costs

The test times or costs for each replaceable unit are added according to the testing strategies. These are listed to facilitate comparative test-ability evaluations.

List of Related Out-of-Tolerance Events

A list is produced for each replaceable unit, identifying all events that will test "bad" when that replaceable unit contains a fault. This list, together with the MDC and the test strategies for replaceable unit outputs previously discussed, constitutes a verification and validation (V&V) package useful for V&V of the troubleshooting logic.

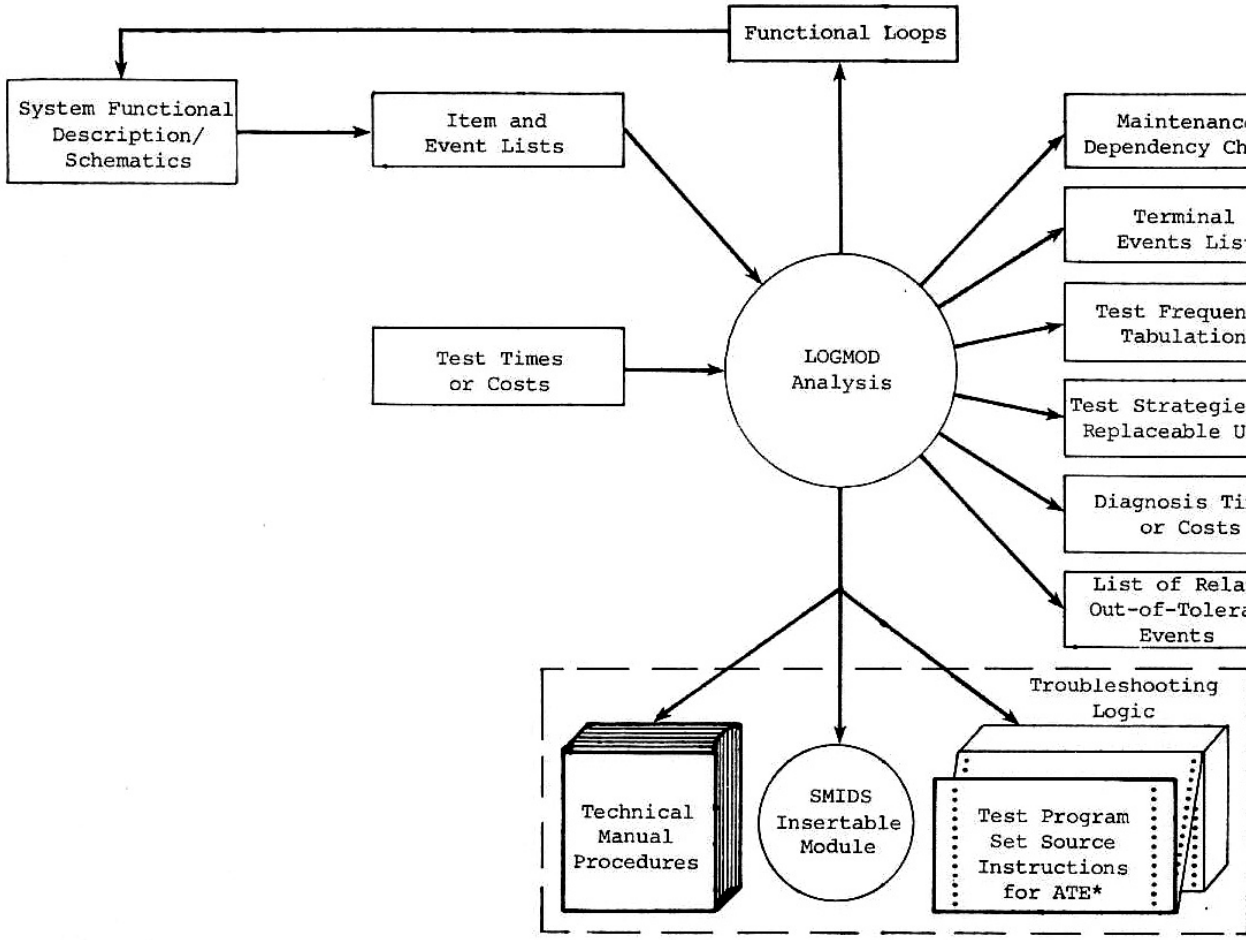

Figure 10. LOGMOD INPUTS AND PRODUCTS

Troubleshooting Logic

The troubleshooting logic output from a LOGMOD analysis may be produced in a variety of forms. When the troubleshooting logic is to be used with the SMIDS, it can be converted to software on insert able modules for SMIDS. Manual troubleshooting steps could be developed by using test procedures from the LOGMOD analysis. The capability to automatically generate test program set source code is currently being developed and evaluated at the NAVAIR Engineering Support Office, Naval Air Rework Facility, North Island (Code 38110).

STEPS IN LOGMOD APPLICATIONS

Table 2 lists the steps necessary for each of three types of LOGMOD applications. It also shows which of these steps would have to be taken in the conventional approach without LOGMOD.

Table 2. LOGMOD APPLICATION STEPS

Steps	LOGMOD Design Review	LOGMOD Development, Verification, or Validation of Troubleshooting Logic	SMIDS Maintenance	Conventional Approach Without LOGMOD
1. Gather equipment documentation	●	●	●	●
2. Analyze equipment functions	●	●	●	●
3. Identify tests and specifications	●	●	●	●
4. Develop item and event lists	●	●	●	
5. Prepare test instructions and fault messages			●	●
6. Conduct LOGMOD analysis	●	●	●	
7. Review functional design and packaging	●	●	●	●
8. Select test points and BIT	●	●	●	●
9. Review test strategies	●	●	●	●
10. Conduct support-equipment analysis		●	●	●
11. Verify and validate troubleshooting logic		●	●	●
12. Prepare SMIDS insertable module			●	
13. Prepare test program set source code if ATE is used		●		●

Step 1: Gather Equipment Documentation

The initial task in any LOGMOD application is to gather technical documentation describing the current design or configuration of the equipment. This documentation should include schematics sufficiently detailed for the replaceable units to be resolved.

Step 2: Analyze Equipment Functions

Documentation is reviewed to identify the functions, component items, and functional logic flow among the component items.

Step 3: Identify Tests and Specifications

In light of the results of Step 2, test points are identified according to the common functioning and grouping of component items. Specification values are then developed to indicate measurable or observable indications of proper functioning. Depending upon the complexity of the equipment, it may be necessary to use some form of computer-aided design (for example, CYBERNET Service's SYSCAP II) in order to define the particular specification values. Such computer-design tools should not be confused with the LOGMOD analysis to be applied in Step 6.

Step 4: Develop Item and Event Lists

The results of Steps 2 and 3 are converted into the lists required as inputs to LOGMOD. These lists identify events (i.e., test points), related component items, and dependency relationships. Step 4 is straightforward and should require a relatively minor additional effort once Steps 2 and 3 have been taken.

Step 5: Prepare Test Instructions and Fault Messages

If troubleshooting logic is being developed, test instructions and fault messages must be prepared for identification of the diagnostic procedures to be followed by a maintenance technician.

The LOGMOD analysis prepares the proper sequencing of messages describing test events and faults. Without LOGMOD, considerably more effort must be expended to prepare fault-trees, diagnostic procedures, or their equivalent.

Step 6: Conduct LOGMOD Analysis

In a computer implementation, the LOGMOD analysis process automatically generates the products discussed above and illustrated in Figure 10. The costs of this step are small in comparison with the costs of the previous five steps, either with or without the LOGMOD approach.

Step 7: Review Functional Design and Packaging

With the maintenance dependency chart and the terminal events list from the LOGMOD analysis, a thorough and systematic design review can be conducted; after this review the design engineer has considerably more confidence in the equipment than he did at Step 3. If design changes are needed, it is easy to update the input data file previously developed in Step 4 and rerun Step 6. The equivalent design review without LOGMOD is likely to require more effort, both initially and after a design revision.

Step 8: Select Test Points and BIT

With the test frequency tabulation and the test strategies for replace-able units from the LOGMOD analysis, the relative usefulness of test points is immediately identified. The design engineer may then systematically select some of the more frequently used events for BIT. Test points that have zero frequency may be eliminated. Without the tools provided by LOGMOD or its equivalent, these same determinations are much more difficult, and there is less confidence in the location of test points and in the BIT.

Step 9: Review Test Strategies

With the test strategies for replaceable units and the diagnosis times or cost outputs from the LOGMOD analysis, test strategies can be systematically reviewed and evaluated.

Step 10: Conduct Support Equipment Analysis

Once test points, BIT, and test strategies are identified, support equipment can be determined by consideration of requirements for tools, test sets, and personnel skills. Whether LOGMOD is used or not, the effort to conduct this analysis is expected to be about the same. With the LOGMOD approach, the SMIDS provides an additional alternative that may lead to lower support costs.

Step 11: Verify and Validate Troubleshooting Logic

With the MDC, the test strategies for replaceable units, and the related out-of-tolerance events list from the LOGMOD analysis, verification and validation (V&V) of troubleshooting logic is systematic and thorough. Without these LOGMOD outputs, V&V of troubleshooting logic (if it is done at all) is likely to depend on guesswork or time-consuming engineering effort.*

Step 12: Prepare SMIDS Insertable Module

The SMIDS information processor and display device assists the maintenance technician in performing the sequence of diagnostic tests. System-specific data for the unit under test is contained in software on insertable modules. The software for these modules is automatically provided, if desired, by the LOGMOD computer analysis.

Step 13: Prepare Test Program Set Source Code

If ATE is used, source code for test program sets (TPS) must be written to implement the troubleshooting logic. Under the LOGMOD approach, it may sometimes be possible to reduce the requirement for ATE through use of the SMIDS. An anticipated future LOGMOD product is the automatic generation of portions of TPS source code for those applications in which ATE is used.

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*ARINC Research survey of AVRADCOM and TSARCOM aviation project offices.

COMPARISON

Figure 11 presents a qualitative comparison of LOGMOD and conventional approaches. Additional efforts are required to apply the LOGMOD approach (principally in steps 4, 6, and 12); in the remaining steps, however, where most of the total effort is required, the LOGMOD approach requires effort comparable to or less than conventional alternatives. Table 3 presents some estimated costs of a full LOGMOD analysis.

Detailed discussions of trade-offs affecting the selection of LOGMOD or alternative approaches are presented in the Application Criteria and Methodology section.

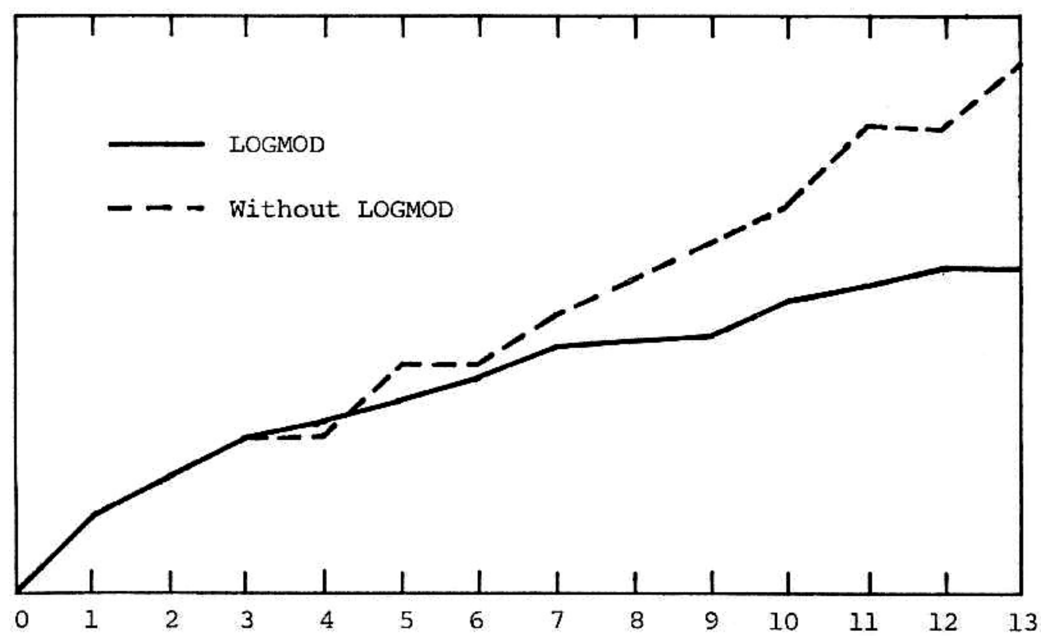

Figure 11. QUALITATIVE COMPARISON OF LOGMOD AND CONVENTIONAL APPROACHES

Table 3. LOGMOD ANALYSIS COST ESTIMATES		
Application Type	Estimate	Source
Full system, modeled to LRU and SRU levels	Number of LRUs x $24,000	DETEX Systems, Inc.
One LRU or box-type item, modeled to SRU level	$18,000 - $40,000	DETEX Systems, Inc., and Naval Air Electronics Center
One SRU modeled to component level	$6,000 - $10,000	DETEX Systems, Inc., and NAVAIR Engineering Support Office, Naval Air Rework Facility, North Island

STANDARD MAINTENANCE INFORMATION DISPLAY SYSTEM

The Standard Maintenance Information Display System (SMIDS) is a portable information processor and display device for use as a troubleshooting aid at unit, intermediate, and depot levels. The SMIDS visually displays fault-isolation procedures to a maintenance technician as he performs a sequence of manual tests or observations. When the technician keys in the result of a test (typically as a "good" or "bad" determination), the SMIDS identifies and displays the next test to be performed in order to locate the faulty component efficiently. When a determination is possible, the search is concluded and the diagnosed fault is identified by a displayed message.

System-specific information for each unit under test is contained in software on individual insertable modules. The SMIDS does not physically attach to the unit under test and therefore should not be considered an item of TMDE.

OVERVIEW

The SMIDS functional design is summarized in Figure 12.

Insertable Module

The insert able module stores data describing the unit under test. These data include the software equivalent of the maintenance dependency chart (MDC) and sets of messages. MDC data are stored as sorted lists of test events and component items from LOGMOD. Messages include test instructions and fault descriptions.

Processing Logic and Internal Storage

The processing logic implements the internally stored LOGMOD diagnostic strategy, which was discussed in the preceding section.

This logic interprets the technician's keyed inputs, selects test events and messages for display, and isolates to the faulty item. SMIDS self-test could also be implemented by this processing logic.

Display

The display presents alphanumeric messages to the maintenance technician, including start-up procedures, test instructions, fault determinations, and error messages.

Keyboard

The keyboard allows the technician to enter test results or other requests to processing logic.

Printer Interface

Where hard copy is required, e.g., for audit-trail purposes, a printer interface provides data at required rates and formats.

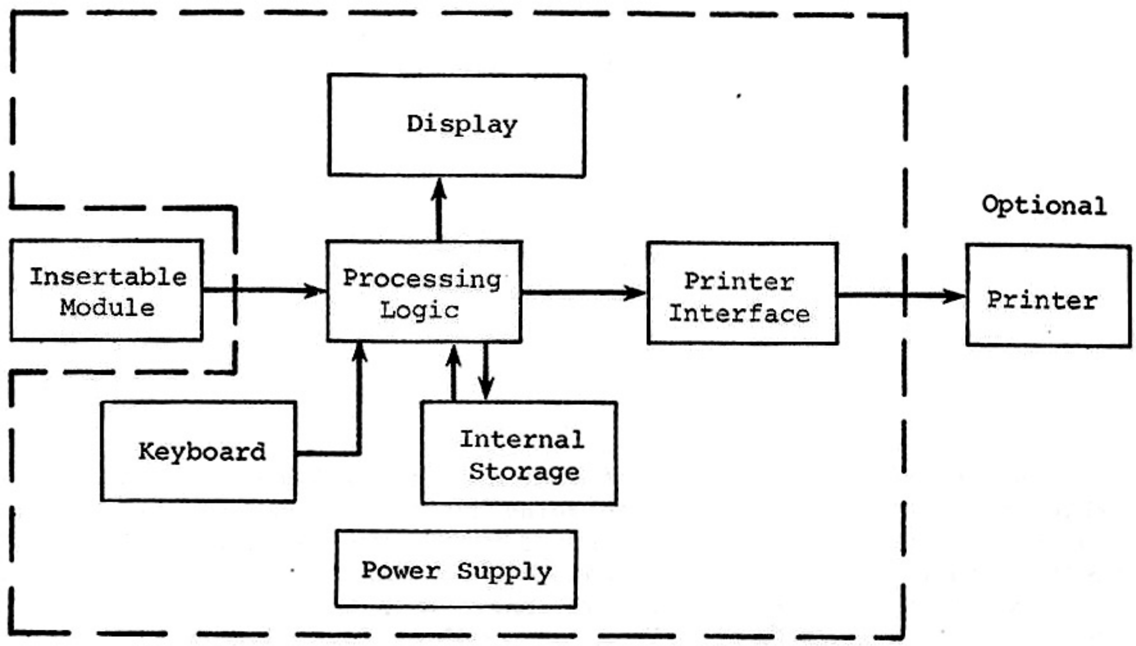

Figure 12. SMIDS FUNCTIONAL OVERVIEW

PROTOTYPE

A SMIDS prototype has been manufactured and sold by DETEX Systems, Inc., under the names "LOGMOD Diagnostic Test Set" and "LOGMOD Maintenance Aid." Figure 13 shows this device. The DETEX Systems, Inc., device uses flexible disc data storage and a 480-character plasma display and operates from 100 to 130 Vac power. This prototype has been in limited use, primarily to test the LOGMOD concept. Since this prototype has not been manufactured in quantity and has not been issued to any military field organization, it was not built to standards for ruggedness, nor is it expected to meet such standards without further development. The use of flexible discs may not be suitable to Army field-maintenance environments that might be encountered at the unit level. Suitable power availability may also be a problem.

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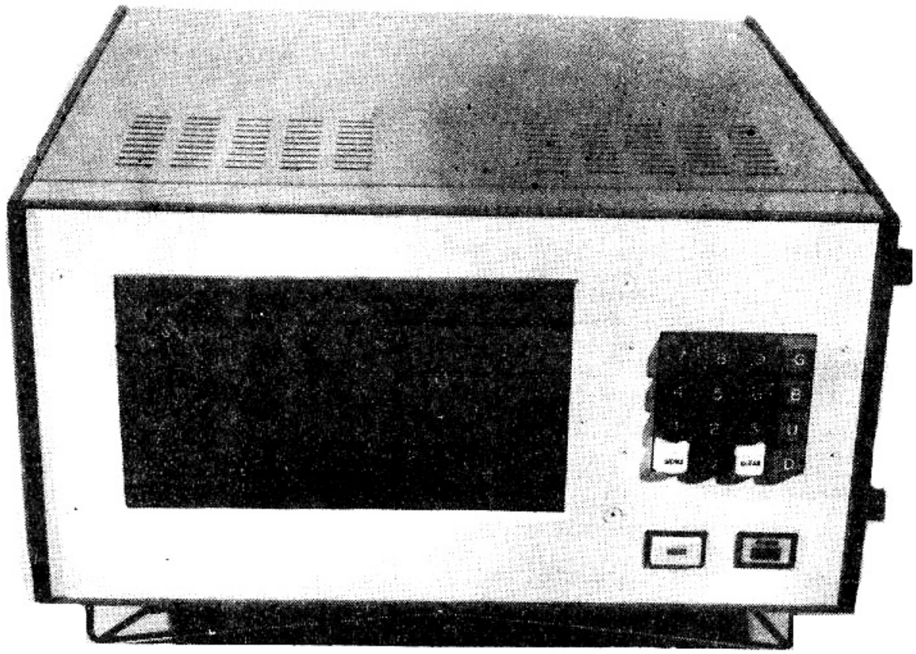
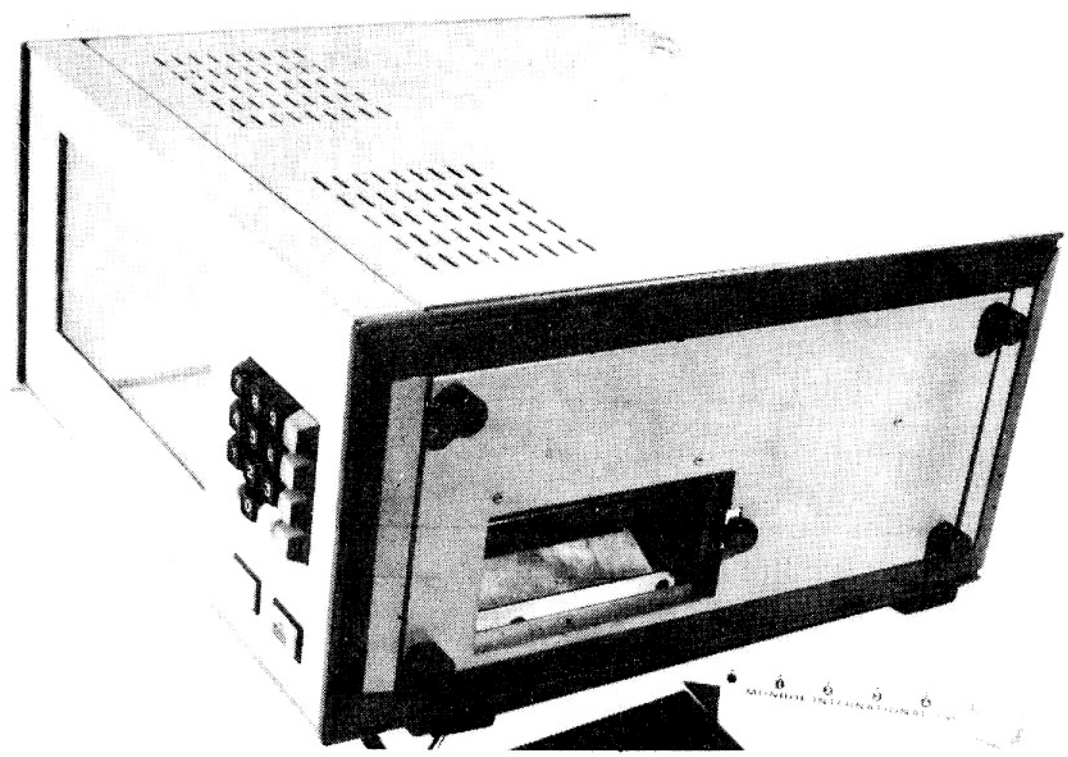
(10)DETEX Systems, Inc., *LOGMOD* Maintenance *Aid, Operator's* Manual.



(a) Front View



(b) side view showing floppy disk and access door

Figure 13. SMIDS PROTOTYPE

STATUS

ATL has been evaluating the prototype SMIDS for several years, with the intent of developing SMIDS as a versatile item of aviation ground sup-port equipment (GSE). Tables 4 and 5 summarize some comparable computing, display, and storage devices and their costs. Currently, ATL is defining the requirements for production SMIDS devices. More than one configuration is under evaluation, since different requirements may exist for unit, inter-mediate, and depot environments. Two issues remain to be resolved:

- To what degree a production SMIDS needs to be ruggedized and MIL-qualified
- Whether a completely new device must be developed or an existing device can be adapted either for the SMIDS or for accessories (e.g., graphic display).

Table 4. COMPUTING AND DISPLAY DEVICES

Device	Relevance	Vendor	Unit Cost
LOGMOD Maintenance Aid	SMIDS prototype	DETEX. Systems, Inc. Villa Park, CA	$20,000
Digital Communications Terminal (DCT) and Fire Control Calculator (FCC)	Militarized, hand-held calculating and display systems	Litton Data Systems Van Nuys, CA	$20,000 to $23,000
MYRIAD/XK Model 440	Rugged, hand-held, programmable, digital logic analyzer	Hy-Tronix Instruments, Inc. Newton, KA	$3,87
HP-41C calculator with custom ROM modules	Off-the-shelf, hand-held, alphanumeric, program-mable calculator with plug-in custom ROMs. Beechcraft A200 Flight Planning Computer	Hewlett-Packard	$300
TI-58/59 calculator with custom ROM modules	U.S. Army Field Artillery Computer Set U.S. Marine Harrier Flight Calculator	Texas Instruments	$400

Table 5. INFORMATION STORAGE DEVICES			
Device	Vendor	Capacity	Unit Cost
Floppy Disc	Numerous (11)	0.1 to 3 megabytes	$200 to $5,400 (drive) $5 (disc)
Memory Disc MD104	Sperry Flight Systems	4 Megabits	(Unavailable)
Bubble Memory FBM-V002	Fijitsu America, Inc.	32 kilobytes	$545(holder And circuit card) $462 (cassette)
HP-41C Custom Modules	Hewlett-Packard	8 kilobytes	$22(module only)

[11] Malcom S. Stiefel, "Maturity Marks Floppy Market," *Mini-Micro Systems,* February 1981, p. 156.

<u>LOGMOD Maintenance Aid</u>

The DETEX Systems LOGMOD Maintenance Aid has served as a SMIDS prototype for many of the initial LOGMOD/SMIDS evaluations. These devices have previously sold for approximately $27,000. Current vendor quotations have decreased to $20,000. A similar device may be suitable for many SMIDS applications at intermediate or depot levels. In a quantity procurement, the cost of this device may decrease further.

<u>Digital Communications Terminal (DCT) and Fire Control Calculator (FCC)</u>

The DCT and the FCC are two of a family of adaptable militarized, hand-held calculating and display systems developed for the Marine Corps by Litton Data Systems for those applications where a militarized SMIDS is required, such as some unit-level environments; it is conceivable that a similar device may be adapted. Unit costs have ranged from $20,000 to $23,000 depending upon the size of the display required.

<u>MYRIAD/XK Model 440</u>

Hy-Tronix Instruments manufactures the MYRIAD/XK Model 440, a rugged hand-held, programmable digital logic analyzer with display and keyboard. This device, selling for $3,875, contains a diagnostic microcomputer with an internal 1.5 megabit library of the characteristics and test procedures for over 10,000 integrated microcircuits. It is conceivable that a similarly rugged production hand-held SMIDS could be made available at a similar cost.

HP-41C with Custom ROMs

Many applications are being made of off-the-shelf programmable calculators using custom plug-in ROM modules. Hewlett-Packard provides custom modules for its HP-41C model calculator, which costs about $200. Up to 32,000 bytes are available with four modules. The cost of custom modules is about $20,000 (nonrecurring) for programming plus $22 per module. The use of such a device for some SMIDS applications cannot be ruled out at this time. One recent application illustrating the capability of this calculator is the Model A200 flight planning computer developed for Beech Aircraft Corporation to automate the entire performance calculation manual for the Beechcraft Model A200 (the military version is designated the C-12).

TI-58/59 with Custom ROMs

Several military applications have been made of Texas Instruments programmable calculators using custom plug-in ROM modules. The Army has procured a version of the TI-59 as the field artillery computer set (NSN 1220-01-082-1646). The Marine Corps has procured a version of the TI-58 as the Harrier VSTOL/REST calculator (NSN 1RM7420-01-052-0641KA) to auto-mate aircraft performance calculations for the AV-8 Harrier.

Conclusion

It is expected that the cost of a production SMIDS will be less than $20,000. Depending upon the application, the cost of a production unit may actually be considerably lower.

APPLICATION CRITERIA AND METHODOLOGY

This section discusses criteria to assist program management personnel in deciding when and where to apply LOGMOD/SMIDS.

Figure 14 illustrates the trade-offs to be considered by each program. Changes in any of the illustrated factors will change the other three. The resolution of these types of trade-offs will vary with the program as a result of differing requirements or life-cycle phase.

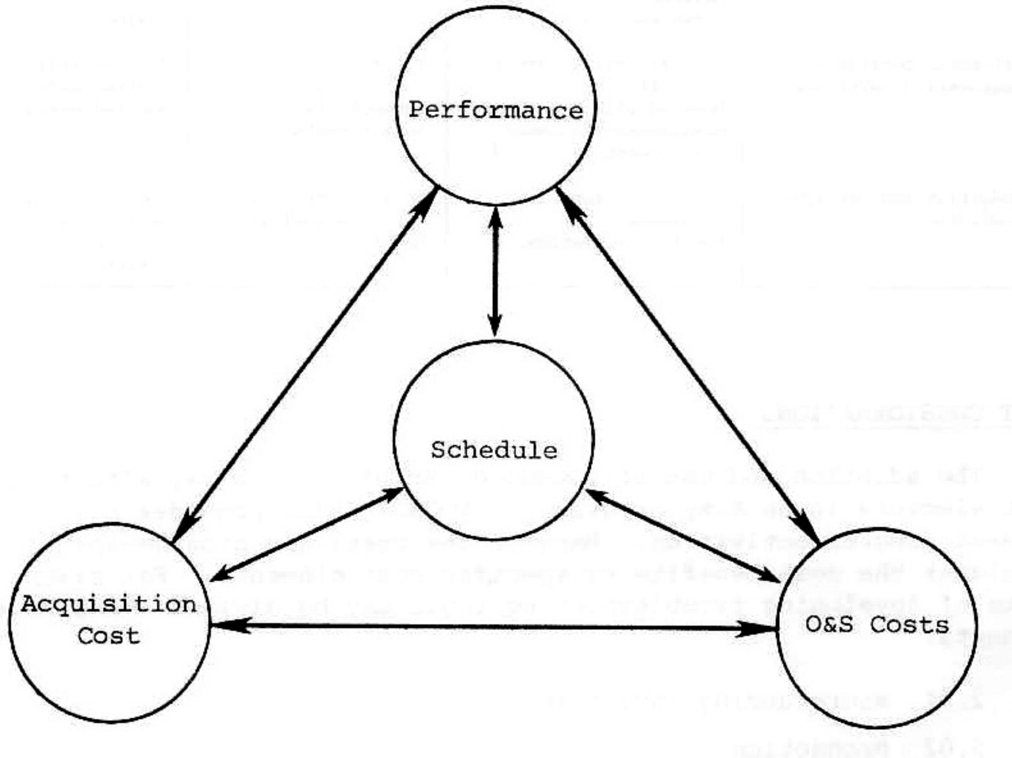


Figure 14. TRADE-OFFS

PROGRAM PLANNING

The thirteen steps of a LOGMOD/SMIDS implementation were summarized in Table 2. LOGMOD/SMIDS applications can be made in a series of sequential stages consistent with the objectives of each life-cycle phase. Table 6 summarizes these applications, together with their relationship to the objectives of each life-cycle phase.

The LOGMOD approach is more efficiently applied during the conceptual phase. Already developed systems will benefit primarily through design improvements needed to correct identified deficiencies.

Table 6. LIFE-CYCLE CONSIDERATION

Phase	Related Milestone	Application	Result
Conceptual (Prototype/Breadboard)	Functional baseline system specification	Conduct Steps 1-7 of LOGMOD analysis	Testability trade-offs Maintainability portions of support estimates
Validation (Advanced Development)	Maintainability program plan Logistic support plan Allocated baseline system specification	Update Steps 1-7 of LOGMOD analysis Conduct Steps 8-11	Maintainability trade-offs, allocations, and model Maintenance concept Design criteria
Full-Scale Development (Engineering Development)	Maintainability demonstration Updated plans Government furnished equipment	Update Steps 1-11 of LOGMOD analysis Conduct Steps 12-13 Obtain SMIDS	Updated trade-offs Updated model Updated design
Production and Deployment (Production)	Design and support changes Problem resolution	Update Steps 1-13 of LOGMOD analysis Obtain SMIDS	Updated design Application of LOGMOD/ SMIDS to fielded systems

COST CONSIDERATIONS

The adoption and use of LOGMOD or SMIDS or both may affect many of the cost elements in an Army program.[12] LOGMOD/SMIDS provides cost benefits in several program activities. Many of the costs are program-specific. Table 7 relates the cost benefits to specific cost elements. For example, the costs of developing troubleshooting logic may be divided among several cost elements:

2.01 Nonrecurring investment

2.02 Production

2.05 Data and publications

2.08 Training

2.11 Support equipment

(12)Headquarters, Department of the Army, *Standards for Presentation and Documentation of Life-Cycle Cost Estimates for Army Material Systems,* DA Pamphlet No. 11-5, May 1976.

Table 7. COST ELEMENTS AFFECTED BY LOGMOD/SMIDS

Phase		Cost Element	Cost Benefit Area: *System Design Evaluation*	*System Integration*	*Development of Troubleshooting Logic*	*V&V of Troubleshooting Logic*	*System OT&E*	*Data and Publications*	*Training*	*Support Equipment*	*Spares*	*Maintenance Personnel*	*Depot*	*Warranty*	*System Modification*
Research and Development	1.01	Development Engineering	●	●	●	●	●			●					●
	1.02	Producibility Engineering and Planning	●	●											
	1.03	Tooling			●		●			●					●
	1.04	Prototype Manufacturing	●	●											
	1.05	Data	●	●				●							
	1.06	System Test and Evaluation	●	●											
	1.07	System or Project Management													
	1.08	Training							●			●			
	1.09	Facilities		●		●			●				●		
	1.10	Other													
Investment	2.01	Nonrecurring Investment	●	●	●	●	●			●			●		
	2.02	Production	●	●	●	●				●					
	2.03	Engineering Changes	●	●			●	●							●
	2.04	System Test and Evaluation	●	●			●								
	2.05	Data and Publications	●	●	●	●		●							●
	2.06	System or Project Management					●	●	●						●
	2.07	Operational Site Activation						●	●	●					
	2.08	Training			●	●		●	●			●			●
	2.09	Initial Spares and Repair Parts								●	●				
	2.10	Transportation								●	●				
	2.11	Peculiar Support Equipment			●	●				●			●		●
Operating and Support	3.01	Military Personnel													
	3.011	Crew Pay and Allowances													
	3.012	Maintenance Pay and Allowances							●			●			
	3.013	Indirect Pay and Allowances							●			●			
	3.014	Permanent Change of Station							●			●			
	3.02	Consumption													
	3.021	Replenishment Spares								●	●				
	3.022	Petroleum, Oil, and Lubricants													
	3.023	Unit Training							●			●			
	3.03	Depot Maintenance													
	3.031	Labor										●	●	●	
	3.032	Materiel											●	●	
	3.033	Transportation										●	●	●	
	3.04	Modifications of Materiel						●							●
	3.05	Other Direct Support Operations													
	3.051	Maintenance, Civilian Labor							●		●	●	●	●	
	3.052	Other													
	3.06	Indirect Support Operations							●	●		●			

Most frequently, Army aviation programs have included the development costs of troubleshooting logic as part of the production cost of either the prime system or its major subsystems, where it is unlikely to noticeably affect the total element cost.

Cost elements whose totals are most likely to be noticeably reduced by use of the LOGMOD/SMIDS approach are:

2.05 Data and publications

2.08 Training

2.09 Initial spares

2.11 Support equipment

3.03 Depot maintenance

3.051 Maintenance, civilian labor

Programs for equipments for which the costs of these elements are significant are candidates for potential cost savings from LOGMOD/SMIDS.

Support equipment options include combinations of the following:

- Manual test procedures
- Built-in test equipment (BITE)
- Special-purpose test equipment (SPTE)
- Automatic test equipment (ATE)

MIL-STD-1591[13] provides criteria for conducting trade-off studies to determine the optimal design for on-board built-in test systems. These criteria include some formulas for estimating the comparative costs of options consisting of various degrees of built-in test.

For LOGMOD/SMIDS and cost evaluation purposes, Figure 15 summarizes the constituent elements of a basic cost methodology.

Figure 16 illustrates the LOGMOD/SMIDS decision process. As indicated in Figure 16, many LOGMOD/SMIDS candidates may be eliminated for preemptive reasons such as:

- Equipment Simplicity. Many primarily mechanical equipment items may consist of a small number of independent components, the diagnosis of which is clear enough without use of modeling.

- Maintenance Concept. The maintenance concept required in an item's operational and organizational concept may limit the requirements for troubleshooting of some items.

- Availability of Test Points on Test Equipment. Many items may not have been originally designed for testability. In some cases suit-able test equipment may not be available.

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(13)Department of Defense, Military Standard, *On-Aircraft, Fault Diagnosis, Subsystems, Analysis/Synthesis of,* MIL-STD-1591, 3 January 1977.

- Existing Logistic System Already in Place. When an existing logistic system is in place, there will generally be costs associated with changing this system, costs that will have to be justified by reductions in support costs.

- Warranty restrictions. Warranty provisions on some equipments may limit the maintenance actions to be performed by the Government. In some cases the contractor may wish to apply the LOGMOD/SMIDS approach for his maintenance.

As shown in Table 1, LOGMOD/SMIDS has been applied to a large variety of systems. However, none of these items has been deployed with SMIDS support. Accordingly, actual cost-reduction data from the use of LOGMOD/SMIDS are not currently available. Therefore, Tables 8 and 9 are provided to summarize cost factors that can be used by program office cost analysts or contractors in evaluating support alternatives.

Operation and support (O&S) costs will be item-and program-dependent. In the absence of directly related program-specific data, O&S costs can be estimated by using the general cost factors in Table 8. These cost factors are based on historical experience and are applicable for the non-LOGMOD/ SMIDS case. For specific cost terms, improvements achievable through the use of LOGMOD/SMIDS may be estimated by considering anticipated reductions in an item's no-fault removal rate. This is illustrated by Figure 17, which can be applied to cost elements proportional to the number of removals. Examples include spares cost and depot maintenance.

$$
\begin{aligned}
\left[\text{Option Cost}\right] = & \left[\begin{matrix}\text{Equipment Development}\\ \text{and Production Cost}\end{matrix}\right] + \left[\begin{matrix}\text{Troubleshooting Logic}\\ \text{Development Cost}\end{matrix}\right] \\
& + \left[\begin{matrix}\text{Support Equipment}\\ \text{Procurement Cost}\end{matrix}\right] + \left[\begin{matrix}\text{Support Equipment}\\ \text{Maintenance Cost}\end{matrix}\right] \\
& + \left[\begin{matrix}\text{Initial Maintenance}\\ \text{Publications Cost}\end{matrix}\right] + \left[\begin{matrix}\text{Revision of Maintenance}\\ \text{Publications Cost}\end{matrix}\right] \\
& + \left[\begin{matrix}\text{Training and Trainer}\\ \text{Cost}\end{matrix}\right] + \left[\begin{matrix}\text{Trainer}\\ \text{Maintenance}\end{matrix}\right] \\
& + \left[\text{Spares Cost}\right] + \left[\text{Personnel Cost}\right] \\
& + \left[\begin{matrix}\text{Maintenance}\\ \text{Man-Hour Cost}\end{matrix}\right] + \left[\begin{matrix}\text{Maintenance}\\ \text{Materiel Cost}\end{matrix}\right] \\
& + \left[\text{Equipment Modification Cost}\right]
\end{aligned}
$$

Figure 15. OPTION COMPARISON EQUATION

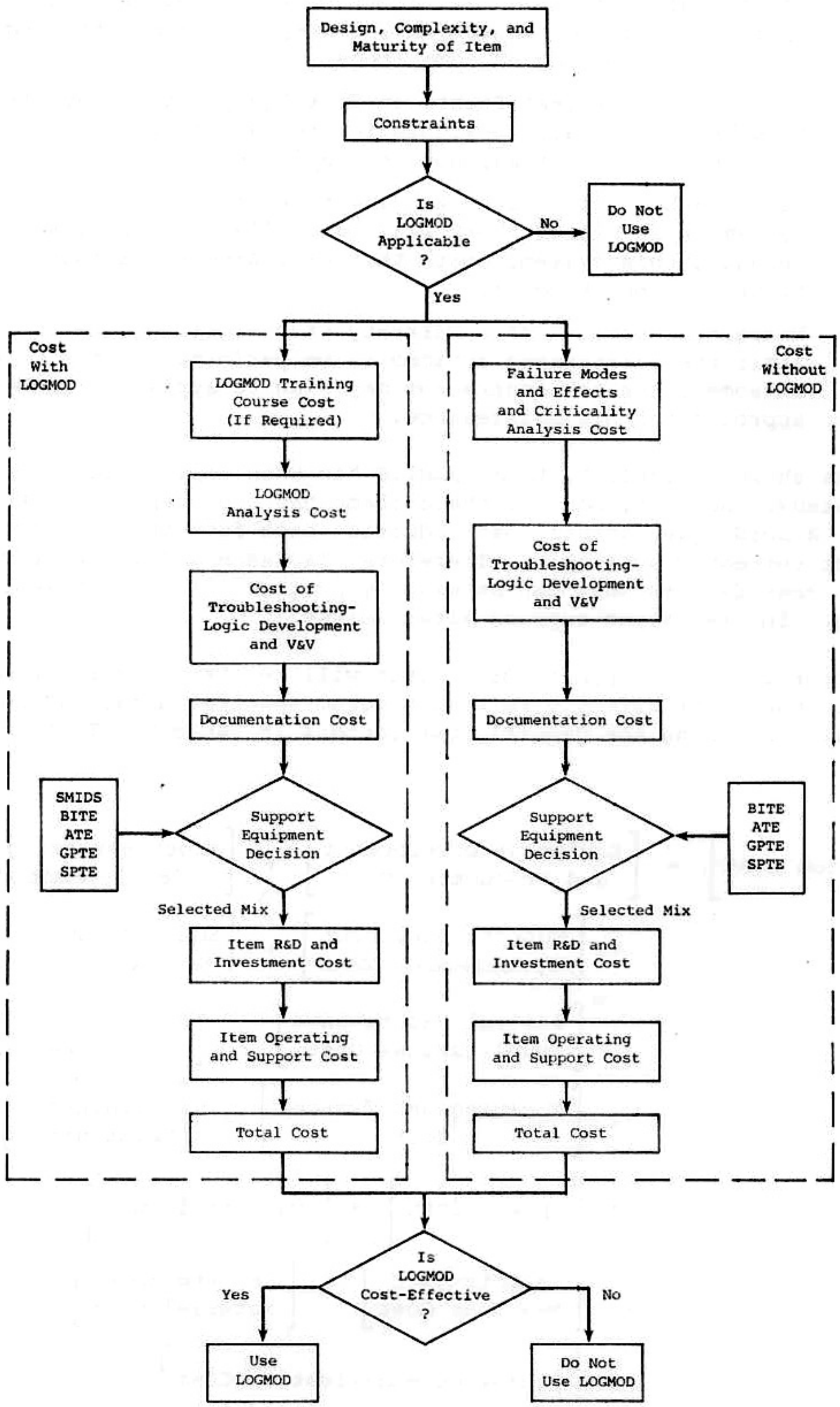

Figure 16. LOGMOD APPLICABILITY DECISION PROCESS

Table 8. COST FACTORS			
Category		Estimate	Source
Engineering Changes		4% of Recurring Production Cost	AVRADCOM Plans and Analysis Directorate (14)
Data		2% of Recurring Production Cost	AVRADCOM Plans and Analysis Directorate
Publications	Standard format	$500 per page*	RADCOM Plans and Analysis Directorate (15)
	Skill Performance Aid (SPA) format	$2,500 - $3,500 per page*	
Test Program Set for ATE	LRU level	$[5]0,000 - $500,000 nonrecurring 1- $5,000 - $50,000 each TPS	ARINC Research Corporation estimate
	SRU level	$12,500 - $50,300 nonrecurring	
Initial Spares and Repair Parts	Airframe	23% of recurring Propulsion cost	Directorate Plans and Analysis
	Propulsion	90% of recurring production cost	
	Communications & Navigation	15% of recurring production. cost	
	Armament	26% of recurring production cost	
	Support Equipment	220 of recurring production cost	
Depot (Avionics Items)	Labor	(Unit Cost 0.0099 + 5215.55	ARINC Research Corporation (16)
		$30.66/Man-Hour	Naval Weapons Engineering Activity'
	Materiel	(Unit Cost) 0.0373 + $20.90	ARINC Research Corporation(17)
		10.8% of unit cost, or $15.21/man-hour	Naval Weapons Engineering Support Activity(17)

(14)U.S. Army AVRADCOM, Directorate for Plans and Analysis, U.S. Army Aircraft Systems Cost, July 1977,
(I5)Discussion with Steve Martinez, Cost Analyst, AVRADCOM.
(I6)'RC-12D Support Alternatives Evaluation, Volume 2, ARINC Research Publication 1761-01-TR-2272, September 19E0, Appendix C.
(17)U.S. Naval Weapons Engineering Support Activity, Naval Air Systems Command Avionics Level of Repair Model, MOD-III Default Data Guide, November 1976.
*Average length has been 150-300 pages per technical manual.

Table 9. LOGMOD/SMIDS COST FACTORS			
Category		Estimate	Source
LOGMOD Analysis	System level	(Number of LRUs) x $24,000	DETEX. Systems, Inc. Naval Air Engineering Center NAVAIR- Engineering Support Office
	LRU level	$18,OO- 540,000	
	SRU level	$6,000- 510,00	
LOGMOD Training Class		$3,6O0 + Travel	DETEX Systems, Inc.
SWISS		5200 - $23,000	See Table 4
SMIDS Insert able Modules		$25 -$400	See Table 5

$$\begin{bmatrix}\text{Cost With}\\ \text{LOGMOD/SMIDS}\end{bmatrix} = \begin{bmatrix}\text{Cost Without}\\ \text{LOGMOD/SMIDS}\end{bmatrix} \times \left\{ \frac{\begin{bmatrix}\text{Failure Rate}\end{bmatrix} + \begin{bmatrix}\text{No-Fault Removal}\\ \text{Rate With LOGMOD/SMIDS}\end{bmatrix}}{\begin{bmatrix}\text{Failure Rate}\end{bmatrix} + \begin{bmatrix}\text{No-Fault Removal}\\ \text{Rate Without LOGMOD/SMIDS}\end{bmatrix}} \right\}$$

Figure 17. COST ELEMENT COMPARISON FORMULA

Many warranties allow vendors to bill the Government for no-fault returns; consequently, improvements in unit-level diagnostics will benefit O&S costs even for warranted items.

The degree to which no-fault returns can be reduced by LOGMOD/SMIDS will depend on both specific equipment characteristics and the program phase in which LOGMOD/SMIDS is applied. This is illustrated by a recent ATL evaluation(18) which found that the current LRU false-removal rate is five times the LRU failure rate; that the use of SMIDS for fault isolation could reduce the LRU false-removal rate to 1.34 times the LRU failure rate; and that if a LOGMOD analysis had been conducted during the initial design phases, the false-removal rate could have been made considerably smaller.

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[18] Ralph A. DePaul, *A Standard Maintenance Information and Display System (SMIDS) Analysis on the M65 TOW Guided Missile System,* DETEX Systems, Inc., November 1980.

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18. Ralph A. DePaul, *A Standard Maintenance Information and Display System (SMIDS) Analysis on the M65 TOW Guided Missile System,* DETEX Systems, Inc., November 1980.

GLOSSARY

ATE	Automatic test equipment
ATL	Applied Technology Laboratory
AVRADCOM	Aviation Research and Development Command
BIT	Built-in test
BITE	Built-in-test equipment
DARCOM	Materiel Development and Readiness Command
DoD	Department of Defense
FOMM	Functionally Oriented Maintenance Manual.
GPTE	General-purpose test equipment
GSE	Ground-support equipment
LOGMOD	Logic Model
LRU	Line-replaceable unit
MDC	Maintenance dependency chart
MOS	Military occupational specialty
NSN	National stock number
OT&E	Operational test and evaluation
ROM	Read only memory
R&M	Reliability and maintainability
SMIDS	Standard Maintenance Information Display System
SPTE	Special-purpose test equipment
SRU	Shop-replaceable unit
TMDE	Test, measurement, and diagnostic equipment
TP	Test paint
TPS	Test program set
TSARCOM	Troop Support and Aviation Materiel Readiness Command
UUT	Unit under test
V&V	Verification and validation