CONTRACT: N62462-68-M-
5 SEPTEMBER 1967

PUBLICATION NO. U-4211

REPORT ON THE MECHANIZATION of DDF For

SYSTEM PERFORMANCE MONITORING

FOR THE NAVAL APPLIED SCIENCE LABORATORY

PHILCO

TECHNICAL REPORT ON THE EXPANSION OF
THE DESIGN DISCLOSURE FORMATS TO INCLUDE
A METHOD OF SYSTEM PERFORMANCE
MONITORING INCORPORATING SOME FEATURES
OF "FAULT ISOLATION BY SEMI-AUTOMATIC TECHNIQUES."
BY
Ralph A. De Paul, Jr.

FOREWORD

During the past ten years there has been on increasing awareness on the part of both military and industrial defense institutions concerning the tremendous costs involved in maintaining an arsenal of military machines which, when called upon, could effectively respond to an immediate need. This indicates that support requirements for military hardware will reach some astronomical figure unless a support methodology is initiated which will at least slow down the trend - if not stop it. The area of particular discourse in this report is that of support equipment. By support equipment we mean not only that hardware which operates from a physical sense, but also the ideological means, techniques, and desires which allow the physical machine to complete its mission.

As a starting point for conceptualizing a system which would give the most benefit for a machine, we have begun with the notion of Design Disclosure Formats. As pointed out the references of Appendix I, the Design Disclosure Techniques are most common and natural to a technical approach to disclose what was in the designer's mind when he accomplished his task of designing an operating equipment. After the design is fully disclosed it remains dormant unless a person acts on it. The person is not a specialized machine, and hence, can make certain decisions which the designed machine could not make of its own volition. This act of decision making in testing and performance monitoring has for a time been relegated to computational machines (both analog and digital) with as much intelligence built into the machines as the designer of such test equipment could devise. With the advent of many different terms such as "interface," "time phasing," and "time sharing," the task of designing a universal test and monitoring device became a very challenging one.

The answer to this dilemma, however, lies in our midst in the form of the Design Disclosure Formats (DDF). This type of software describes operating systems, their associated sensing devices, as well as any built-in test/self verification equipment. Lastly, the DDF documentation properly executed can become a powerful troubleshooting tool and a means of determining where tests should be made along with the nature of the test and simple diagnostic strategies. To do this in a manual fashion in all instances becomes a laborious and often repetitious task. With such automatic machines abundantly at our disposal at this rime, it is incumbent upon us to use these automatic devices to the advantage of liberating the technician from, some basic diagnostic strategies, and use him in his more useful role as a decision maker and repairman.

In order that any centralized automatic, semi-automatic or manually operated test device be an asset to the maintenance technician, it mast be capable of being maintained and backed-up by an easily understood analog of the test device. This quality is lacking in most, if not all, of the testing devices either in service, or contemplated for employment in the foreseeable future. Without some basic organizing technique similar to the Logic Model portion of the DDF, it is not an easy task to program a computer to make many different measurements, and report an accurate conclusion regarding the exact malfunctioning equipment.

Since 1965, the Naval Applied Science laboratory has pursued the Design: Disclosure Format as a major advance in systems effectiveness. The recognition of the Design Disclosure Format as a technical information transform has exposed a whole new field of communication; opening the way for the unambiguous exchange of technical information between personnel of widely divergent backgrounds and abilities.

The employment: of Design Disclosure principles by the Aeronutronic Division of Philco-Ford in a current program has accrued many benefits, particularly in the area of Maintainability improvement. During the past year the Chaparral Guided Missile launcher design has been disclosed in the dependency chart format thereafter referred to as Logic Model).

Following are some of the benefits resulting from an early decision to use the Logic Model format throughout the entire program:

1. A single engineering source document of all interdependencies in the system is available to any activity within the Customer's Philco-Ford's organization.

2. Assessment of test equipment requirements and subsequent design has been facilitated.

3. Maintainability evaluation, demonstration, and assessment have been quantitatively recorded and used for comparisons.

4. Logistic tradeoff decisions affecting: Inspection, Test, Service, Adjustment, Alignment Calibration, installation, Replacement, Repair, Overhaul, Rebuild, Recoverability, Essentiality, Special Tools, Stockage, Relative Failure Frequency, Replacement Rate, Percentage of Maintenance at all maintenance levels. Turn Around Time for Repair or Replacement a: all maintenance levels.

Through the process transforming the Chaparral design to Logic Models the revelation of new qualities of the Logic Model began to unfold.

What began to reveal itself were the possibilities which might be realized if support equipment took dictation from prime equipment Logic Models. These discoveries subsequently led to certain speculations relating to the failure of many current support equipments to fulfill design objectives, such as universality, changeability, and flexibility. Pursuit of these ideas has led to a research of the underlying principles of several current systems as an examination of the design philosophies utilized in support equipment development.

I. INTRODUCTION

In the following pages of this report we shall explore current work being accomplished by the Aeronutronic Division of Philco-Ford. This work is an outgrowth of the Design Disclosure Formats and, for this reason, it should be valuable as a barometer indicating what the Formats can accomplish. Next, we shall discuss some general concepts and philosophies of present day automatic and semiautomatic test equipment. Major discussion shall involve both the FIST and VAST approaches to fault isolation devices. The discussions may seem somewhat critical, but the need of a new device can come only from a knowledge of the problem to be solved and an analysis of proposed solutions.

Test equipment design philosophies for complex equipment currently in vogue seem to fall into certain generalized categories:

1. Single purpose test devices designed to suit the characteristics of a certain system or portion thereof.

2. Mufti-system test equipment wherein the basic idea is to automate the utilization of standard test equipment through elaborate computers and patch panels.

3. Self-test or built in lest Equipment capability.

Each of these design philosophies has certain advantages and limitations in their use.

Single purpose test equipment may, very successfully, fulfill the requirements of a given system; however, the sheer bulk of these equipments, cost, and needless duplication of function have weighed heavily against their use.

Limitations of the single purpose test equipment lead to the evolution of the multi-system test equipment philosophy which, in theory, would minimize duplication and reduce the size and cost of test equipment. In practice, however, these systems have evolved into banks of standard test equipment which, by elaborate programming techniques and cross patching, are utilized to perform the required measurements. To date none of these systems have been able to readily accept new equipment for test or even changes to existing systems without major redesign problems. VAST is a system of this type. But these systems have other problems.

The topic of next-generation fault isolation device is a difficult one to cover exhaustively in a report of the diversity attempted here. However, we feel that an excellent approach to this next generation fault isolation device should take the form of theorizing some basic objectives while using proven methodologies as building blocks. These theories will use certain of the Design Disclosure Format techniques as a bona fide basis for making objective hypotheses and point out the evolution of the Logic Model form of the DDF. Typical ultimate and proximate goals shall be depicted in the mechanization of the DDF using proved transform theories of FIST plus some novel innovations.

No hardware system could be considered as feasible without some explanation of the effect of Configuration Management (or control) and the compatibility of the hardware and its software backup. Nor should the concept of System Effectiveness be overlooked in such an analysis. These concepts will be covered, although not to an extent which might be accomplished were the intent of this report one of investigating the conformance of the feasibility of a fault isolation model to some set of standards.

Lastly, we shall include a summary of the main topics of the report and firmly conclude recommendations which we find fit the tenor of what the U.S. Naval Applied Science Laboratory has been advocating for the past four years.

Self-test techniques seem to offer meaningful answers to many of the limitations imposed by most support equipment design philosophies, and FIST has provided much toward defining how this may be accomplished. FIST has shown that transforms can be economically designed which may be used to furnish go/no-go system performance indications. Many FIST objectives are highly desirable, while others become questionable when trade-offs with other important issues are considered. The overall scheme, designed to reduce the maintenance problem, described in FIST reports has immediate appeal as an individual identifies himself with the problems FIST attempts to solve. Perhaps the greatest contribution FIST has made to the support equipment field is the strong case developed for the need and practical use of such things as transforms which can be used in an almost universal sense.

An in depth understanding of the complete maintenance problem, however, becomes a basic requirement to any system offered as a solution to it. The problem is in fact plural, diverse, and subject to change. Any proposed new solution faces these problems. If it is to become more than just another system with restricted application must in itself be diverse, meeting wide-range needs without becoming unwieldy and obviate obsolescence by readily accommodating change such as equipment modifications and introduction of new equipment into inventory.

The application of FIST restricts itself to the following:

1. Prime equipment which has adequate panel space to mount test sockets for connection with the general purpose test set.
2. Equipment where small size and weight are not of major importance.
3. Equipment in the initial design phase or earlier phases.
4. Equipment of modular design.
5. Equipment for which an invariant testing procedure must be followed.

The preceding restrictions would exclude all equipment presently in inventory, all new equipment presently beyond the initial design phase and any future equipment which would have limited panel space, small size and weight restrictions, and non-modular construction.

With the trend toward miniaturization (small size and light weight), panel space will be at a greater premium than at present leaving only a very small cross-section of future equipment design in the category of "FIST-ability."

The requirement to following an invariant testing procedure is at best a compromise; usually resulting from the selection of a single testing routine based on the degree of probable failure from failure mode studies. As such, test routines for exercising less probable failures are rejected. Invariant testing commonly results in a test routine which handles a definite number of different malfunctions in a single manner covering the efficiency spectrum from high on one end to utter failure on the ether end.

Since performance characteristics and functional dependencies are comprehensively declared in Logic Model Charts, they can become the source for testing routines. Rather than an invariant test routine, an invariant procedure is employed for selecting tests. The procedure, in a few simple steps, tailors each test to meet the specific demands of the failure mode. This eliminates the necessity for compromise inherent with a fixed test routine and achieves equal efficiency for isolation of all dynamic failures.

Following these conclusions further, it appears that if the Logic Model reveals the procedures best suited for fault isolation then the transform techniques used in FIST properly applied, will yield an optimum logical method for sampling every diagnostic situation.

Further, the tests may be started at any point in a functional sequence. The DDF becomes the specification for test data and a guide to performing efficient diagnostic strategy. It has been noted in an AIA meeting of the Maintainability Committee, 27 June 1967 in St. Louis, Missouri that several opinions were expressed from industry leaders concerning the VAST system. Excerpt of the minutes of that meeting are summarized below:

> "... the opinion was expressed that no contractor feels that he can oppose the concept but that it may well result in very significant reductions in future support business..
>
> "It was agreed that there will be technical difficulties in meeting the compatibility with VAST for such reasons as:

(1) Each manufacturer of avionics equipment wants to be sure his equipment can be checked and maintained and will have emotional concern with checking and analysis by someone else's universal test set.

(2) Design requirements for compatibility will require much coordination and interface with the VAST system. Each designer will need access to a VAST system because he must be assured of the compatibility by checkouts and tests prior to delivery of his equipment.

(3) Prediction and demonstration of repair times will be difficult.

(4) Work loading for the test equipment may become a problem.

(5) Design penalties in terms of weight and cost may be necessary.

"Further discussion of possible action by the Committee indicated that the industry position in regard to the VAST concept should be generated at a level higher than the committee because of the significant non-technical considerations and effect on future business. Several committee members indicated that their companies were replying to the Navy letter individually, but that the reply was being generated at corporate level."

These excerpts indicate the reluctance of industry to accept a test and checkout system which excludes the prime equipment manufacturer from the support equipment loop. With a different concept the prime equipment manufacturer could become the test equipment manufacturer by reason of his providing the necessary transforms for his equipment.

The transforms may be viewed as special test equipment which is integral to the prime equipment. In this manner he has control of the test equipment: what it will test, and how the tests will be made. In addition, the test equipment (transforms) will be made a part any prime equipment ECP action which may take place subsequent to Initial equipment design. The work loads of the manufacturer's test equipment (transforms) will never be more of a problem than the operation of the prime equipment itself. Workloads at the newly devised equipment will be no problem since it will be time-shared by many equipments. Some novel operations are presently contemplated for such an equipment which will make it absolutely possible for it to immediately respond to an equipment which begins to show signs of a malfunction. The equipment would have built-in diagnostic strategies of unlimited capability. It will not be necessary to proceed through a test sequence which requires the testing of an equipment from a black box standpoint. All tests will be monitored from a functional overview eliminating superfluous stimuli types of devices. Assemblies will be normally tested in the system. The reason for leaving the assemblies in the system is to allow related functional parts to continue to act with other parts. It is no loner permissible for a diagnostician to pretend that a malfunctioning equipment or system has but one Isolated fault, even though an operational check may highlight one particular assembly as not functioning properly. More often than most people would care to admit, there is more than one fault if an equipment/system is ascertained to be malfunctioning.

This fortifies another advantage of such a new monitoring equipment which is probably its greatest. The nature of the equipment would be such that its universal application could assist in the combat readiness of systems/equipment to such a degree that cost considerations for the test equipment would gradually be absorbed into the cost of the prime equipment. This may bring about the evolution of a universal (or nearly universal) set of transforms comparable to present day integrated circuits. The natural result would be the acquisition of both a prime operating equipment and its testing device for a price somewhat nearer the price of the prime operating equipment alone.

By this report, we also acclaim the possibility of using the same testing equipment to predict faults. From the source document of the Logic Model (which, among other data, contains Relative Failure Frequencies), we might well reason to such a possibility.

The wedding of Logic Modeling and FIST philosophies defines-the basic hardware functions necessary to perform the fault isolation task. The basic functions are as follows:

1. Sensing detection of circuit/equipment parameters.

2. Transformation - conversion of circuit parameters This may involve analog to digital conversion but always will involve the comparison with specification.

3. Transmission - Conveyance of circuit performance data from circuit to test equipment.

4. Analysis - Integration of circuit performance information into logic model network to determine the real meaning of failure signals.

As systems vary in complexity it seems unreasonable to assume that a single philosophy of application would be ideal for all systems. It is more reasonable to keep in mind that the four basic functions may all be incorporated in the prime equipment being tested (100% self-test) or all in the test equipment (no self-test). Many types of equipment will fall into the middle ground where sensing and transformation will take place on the equipment, transmission of data will be by wire or other means such as telemetry, and analysis or diagnosis will take place in a test equipment console. It is also not warranted to assume that fault isolation will always be made to the same level. Here, as in the first instance, the type, complexity, and use of the equipment may dictate variations in the application. In all cases, however, the basic principles and functions will remain the same. The same philosophy will function with all systems and types of equipment. Complexity and cost of application will normally vary directly as a function of system complexity and cost.

Some hypothetical illustrations of variations in the application of this basic philosophy may clarify how the potential of this technique may be optimized.

EXAMPLE 1 — System Alfa is a large complex, mobile weapon system containing electronic, electro-mechanical, electro-hydraulic and mechanical systems. Military application involves remote operation for extended periods away from logistic support facilities. Electronic systems are field replaceable at the black box level similarly for mechanical systems.

SOLUTION — System Alfa has integral sensors and transformers. Digital outputs are telemetered to a Logistic support area for all subsystems at the field replaceable level. Direct cable connections provide fault isolation to the lowest level of repair performed at that support facility.

RATIONALE — The proposed solution would use integral sensors and transformers to minimize data transmission time and signal complexity of the telemetry system. Telemetry would enable remote field replacement of black box level subsystems. Cable connections at the analysis station would enable fault isolation to the support level capability (i.e., module replacement).

EXAMPLE 2 — System Bravo is a small Sonar Buoy in which emphasis is placed on low cost, simplicity, light weight and disposability. Units are serviced only at the Logistic (Support Station/carrier).

SOLUTION — System Bravo contains sensors or transformers. Transmission is by plug-in to the test analysis equipment which contains the transforms and sensors necessary to test to the repairable level.

RATIONALE — System use (size, weight, cost, expendability) dictates that absolutely nothing be added to the end item which is not necessary to the direct mission. When this system is in use NO-GO indications are necessary and units are not recovered for repair.

SAMPLE 3 — System Charlie is a complex shipboard Air Search Radar System. There is only one system of this type on each ship and essentially all service performed logistic functions are performed the ship's crew.

SOLUTION — System Charlie has sensors and transforms as an integral part of the system. Transmission is by cable to the test analysis equipment which is located with other test/analysis equipment in an adjacent compartment.

RATIONALE — One-of-a-kind self-supporting systems require what amounts to 100 self-test capability to minimize downtime. Since virtually all of the CIC equipment is maintained by the same personnel (Electronic Fire Control Technicians) and the overall CIC function is mission critical to the ship, it follows that the supporting test/analysis equipment would be grouped for convenient use.

There are other variations to the general application examples given above. All that is intended is to show that the basic philosophy remains unchanged although hardware configuration may differ over a wide spectrum.

The application of Logic Modeling techniques to automated equipment malfunction isolation utilizing FIST type transforms will not only identify that a fault exists, but will express the meaning of that fault in terms of the true system dependency. Ideally, equipment will be designed utilizing the logic model as a basic part of the philosophy of design development. With system dependency recorded in the logic model, the system designer would proceed with the assignment of hardware/functional breakdown. At this point, the designer should consider the maintainability aspects of functional grouping as related to the parameters to be transformed. As systems vary in complexity, it seems unreasonable to assume that a single philosophy of application would be ideal for all systems. In electronic equipments with no reparable modules, the transforms need only examine the module's output, if the module’s output is truly dependent on all of the sub functions of that module.

Malfunctions in many systems today are diagnosed through use of portable test equipment designed to interface with test connectors in the system. Measurements are made of selected functions and an assessment is made regarding the acceptability of the measurement taken compared to a standard for the same function. This process continues either in a manual, semi-automatic, or automatic fashion until a conclusion is reached regarding the localization of the malfunction. The object of this routine is to continue the process of select, measure and evaluate until the source of the malfunction is localized to an authorized replaceable element.

The intelligence of the selection, the rapidity of the measurement, and the conclusions reached upon evaluation, all influence the decree of success in localizing the problem.

The ability of Logic Models to display system performance characteristics so that intelligent interrogation of the system may take place has been proven in systems currently in military inventories.

Design Disclosure Format disciplines have been applied to the Chaparral Guided Missile Launcher (U.S. Army) including the AN/TSM-95 and AN/TSM-96 test equipment; the Hawk Missile System (U.S. Army); the Pershing Missile System (U.S. Army); the Integrated Combat Ship (U.S. Navy); an Acoustic ECCM device (U.S. Navy); and the AN/TPX-28 Interrogator (U.S. Navy). In most of these cases some intelligence was fed back to the prime equipment design, indicating the need for modification of the operating equipment to enable quick and easy isolation of malfunctions.

The question naturally arises concerning the rational use of Logic Model analyses of a system equipment. If it is possible to make certain manual checks or tests, and if it is also possible to conceive of individual fault isolation strategies being developed from a combination of good and bad events, then it may be possible to develop a scheme of an automatic checking of entire systems, operating modes, functions, or groups of component parts of the system.

Aeronutronic has conceived of such an automated analog of the Logic Model. It has been given the name Area Reporting Central (ARC) because of the ability to universally adapt it to many different types of systems (in the broad sense of the term). The basis for ARC is the Logic Modeling methodology converted from a strictly software basis to an active hardware device capable of performing dynamic checks of a system.

This methodology used in choosing the circuits to be monitored or performance checked are derived from the Logic Models of Design Disclosure Formats. This methodology enables the prime equipment or subsystem designer to actually concern himself with checkout as well as performance of the operational equipment. It also gives prime equipment and subsystem contractors the same freedom they now enjoy in determining which tests of the equipment will be performed in the maintenance environment. Due to the fact that the choice is made from Logic Models, the Department of Defense also has the opportunity to observe the practicality of such tests and measurements and can better review the reliability and maintainability features of the contractor's equipment.

Before considering exactly what the configuration of any centralized test station should be, we should make a concerted attempt to determine the effect that such a centralized test station would have on the entire Logistic capability of the system. This affirms the position that, in order to justify a centralized measuring, monitoring, or checkout equipment, the several disciplines inherent in Logistics must be scrutinized for any adverse or helpful side effects.

The prime purpose of the ARC equipment would be to provide the U.S. Navy with a fast and versatile monitoring/checkout device for shipboard systems which can be applied with equal effectiveness to airborne and ground based equipment. The monitoring checkout equipment would be capable of verifying equipment/system performance with the equipment "system under test intact. Assemblies need not be removed but may have them removed if complete functions of the equipment system are not interrupted. Comparisons with other centralized test or monitoring devices to solve the basic problem of centralized testing facilities making maximum use of trained technician time would seem to indicate the ARC to be superior in many respects.

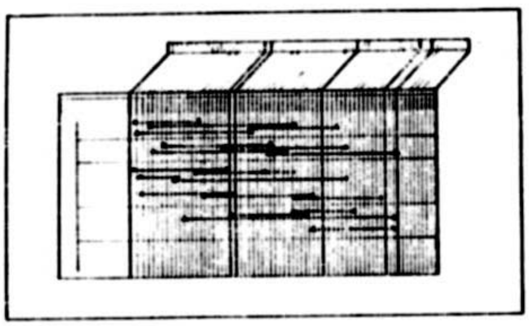
One important feature of ARC is that complete functions of the system under test would be monitored with respect to the actual stimuli in the system rather than artificial stimuli. There is little flexibility in a machine which contains all the stimuli, diagnostic programs. measuring equipment, transformation devices, comparison standards, and readout devices. In a sense this is the act of making decisions for which different devices are much better suited. The interface would be so great that any change in the operational hardware could only be realized in the testing device many months or years after the changed hardware is in use. Still another advantage is the almost exhaustive testing which is automatically available in an instantaneous manner - sequencing and resequencing of tests is virtually eliminated.

II DESCRIPTION OF THE AREA RECORDING CENTRAL (ARC)

The Area Recording Central uses a syntactical structure which is relatively simple and is easily understood by many of the lower skilled technical personnel. Systems other than ARC have only one method or approach to diagnosis. ARC techniques for malfunction diagnoses, though simple, can be applied universally. ARC performance becomes a nucleus of direction - it chooses and directs, rather than remaining a static discipline relegated to only one method of checking.

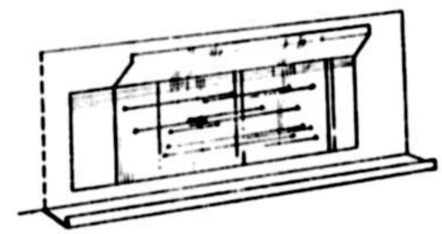
The design techniques used in ARC are microelectronic, using the latest proven state of the art advances known in thin films, chips, and wafers. The understanding required of a manufacturer in making test devices compatible with the system/equipment/component being interrogated could be found only through the use of the medium of the Logic Model. In Figure 1 the evolution of the Logic Model into a test device is illustrated. Detail 1 the illustration shows the basic Logic Model. Detail 2 shows the Logic Model in animated form with a trouble insertion console. Detail 3 depicts the connection a Logic Model type of equipment with a transformation device to the ship's operating systems. And, lastly, Detail 4 display's a remote device connected to the ship's operating equipment through a radio medium.

It appears most desirable at this time to concentrate the efforts of both the U.S. Naval Applied Science Laboratory and Philco-Ford's Aeronutronic Division on the application of the Logic Model to a particular shipboard equipment using Aeronutronic transform techniques and a dynamic form of Logic Model Display.



LOGIC MODEL FROM DESIGN DISCLOSURE FORMAT

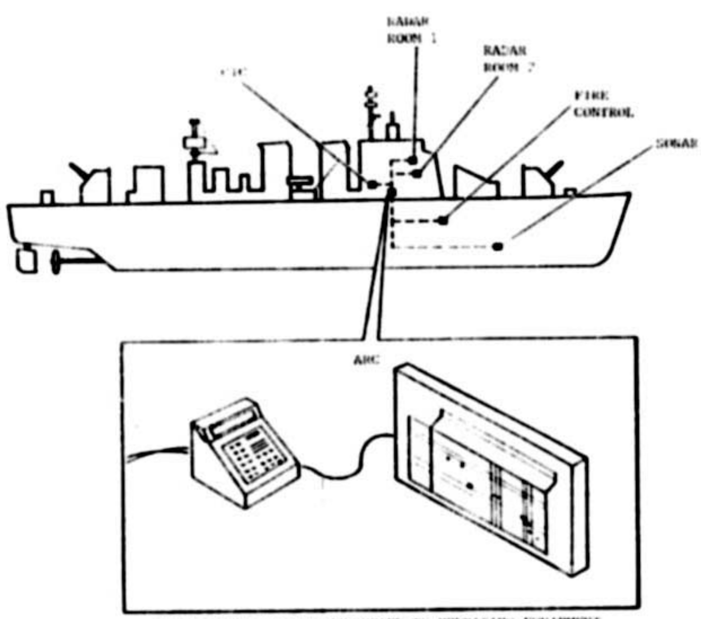
①



DYNAMIC LOGIC MODEL DISPLAY
AND REMOTE TROUBLE INSERTION
CONSOLE

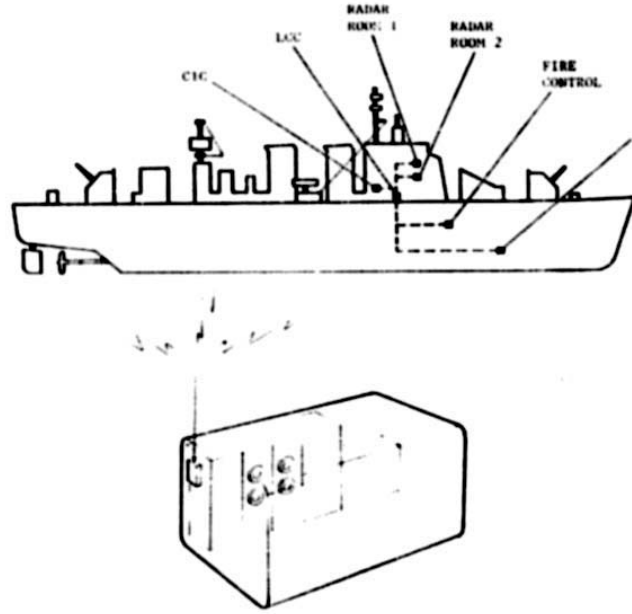
②

③

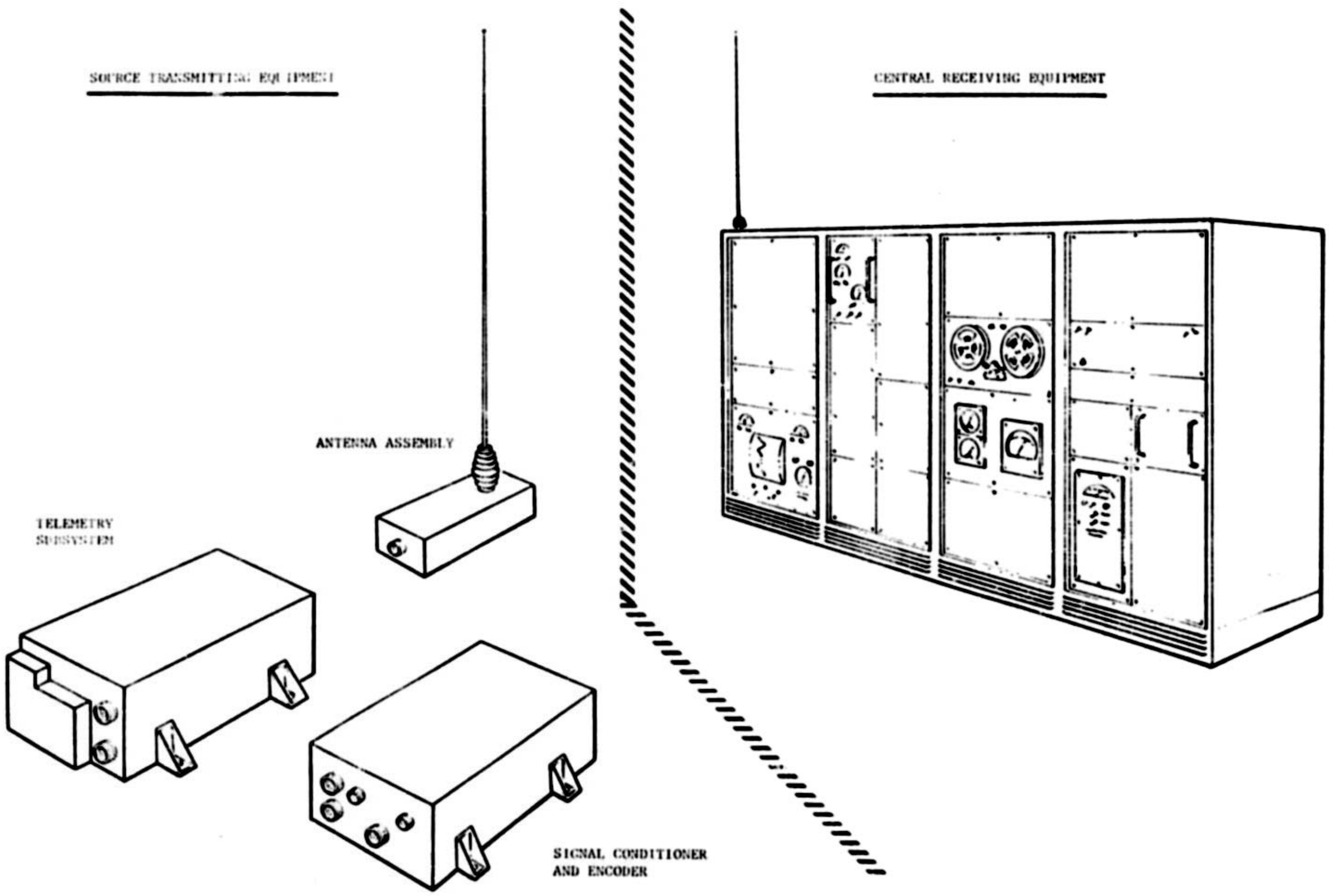


LOGIC MODEL DISPLAY CONNECTED TO OPERATING EQUIPMENT
THROUGH TRANSFORM NETWORK (HARD WIRE HOOK-UP)

④



SHIP-TO-SHORE MONITORING AND ASSESSMENT


SOURCE TRANSMITTING EQUIPMENT
CENTRAL RECEIVING EQUIPMENT
ANTENNA ASSEMBLY
TELEMETRY
SUBSYSTEM
SIGNAL CONDITIONER
AND ENCODER

III. MECHANIZATION OF THE LOGIC MODEL

In the first application of the Logic Model to an automatic fault isolation device, the mechanization is quite straightforward. Transform modules similar to those incorporated in FIST will be used where required. The first application will resemble closely the dynamic Logic Model using an actual equipment for trouble isolation. This application is required to verify the use of particular multiple use transforms and to study the feasibility of using a matrix board for multiple Logic Model displays. Some techniques of providing overlays for basic matrix logic board will have to be perfected. This technology is unique and could be classed in the microelectronic circuit field in which Aeronutronic has been working for some time.

The ultimate goal to provide either a punched or magnetic tape as a replacement for the dynamic Logic Model is under concentrated study by Aeronutronic personnel. The primary benefit of completing this type of task would enable an enormous amount of discrete logic models to be coded on the several different channels of a tape transport.

The initial Logic Model Display form of ARC will perform similar to the purely manual technique of troubleshooting using DDF dependency charts and common test equipment. The difference will mainly be in the substitution of transforms for test equipment and lighted events on the display in lieu of using a grease pencil on the acetate overlay of a dependency chart. Additionally, the operator of the ARC will be able to interrogate the system in considerably more depth than a maintenance technician because the analogs of many signals are available from transform modules, obviating the necessity of having to set-up and use common test equipment. Savings should be realized as a by-product of the ARC in the reduced amount of test equipment required to be available and the companion logistics necessary for them.

Future maintainability parameters will be tabulated more accurately regarding the number of particular kinds of failure, the time increment for isolation, and the return of the system to an operate situation. Part of the reason for the ARC system is to bridge a gap which has existed for some time regarding actual downtimes. By means of the ultimate configuration of ARC, an elapsed time indication can give better visibility to unknown downtime factors and keep equipment manufacturer estimates of maintainability relatively accurate.

The ultimate Area Reporting Central will have the following frame of reference or features:

1. Low power consumption
2. Medium Range (radio signal mode)
3. Minimum space (an approximate ratio of 1 to 8)
4. Choice of displays (mechanical. print-out, lighted status board, video tape, electrostatic print-out)
5. Remote operation
6. Remote read-outs
7. Choice of data measurement (interpreted or non-interpreted)
8. Preventive Maintenance routines
9. Interrogation of Operating systems
10. Modes of operation (Standby/Receive, Interrogate, Automatic Alarm, Hold (for storage and real time communication purposes)
11. Built-in radio-telephone
12. Maintainability and reliability prediction routines
13. Construction - rack and panel
14. Capability of troubleshooting; unattended equipment at a remote site.

Peripheral equipment:

1. Cable runs
2. Telemetry receiver/transmitter (optional)

A number of benefits may be derived from the first development application of the ARC in addition to its use as a centralized isolation/checkout/monitoring device. Some of these benefits are as follows:

1. A computerized scheme for deriving maintainability information from Logic Models may develop because of the special programming required of a matrix display board. It might be reasoned that to accomplish the task of providing one display board with illuminated events for any combination interdependent functional entities would require a programmed control of the matrix board. This programmed control, when fed information on isolation time, measurement time, relative failure frequency, etc., could in a matter seconds, provide accurate M information relative to Availability, as well as mean-time-to-restore (MTTR).

2. Benefits might also result in the form of prediction of turn-around times for all sorts of logistic activities.

3. The transformation portion of the first application could yield a bank of common transforms capable of being provided in microcircuit form and used profusely and inexpensively throughout many different types of operating systems.

4. A Design Status Board might also be a fallout from a study toward development of the first application of ARC. It is conceivable that the customer would be in possession of such a Design Status Board and, by means of the matrix board, be able to overlay the Logic Model for any system or portion of the system and perform his own qualitative assessments which could affect Maintainability, Reliability, Availability, and System Effectiveness.

If such a development program as proposed by the ARC were followed, the beneficial side effects could be as dramatic as the formulation of the basic Logic Model concept itself.

IV. COMPATIBILITY OF SOFTWARE (LOGIC MODEL) TO HARDWARE (AREA REPORTING

After a system or equipment has been designed, an expansion of the original Logic Model represents the complete system broken down to the lowest desired subassembly. With this expanded configuration maintained by means of the Logic Model portion of the DDF, a thorough analysis can be conducted to ensure that all required tests can be performed (sufficient test points etc.) The Logic Model then represents the operation of the system in proper sequence with specifications given for each test point. From this information hardware (transforms for the ARC) can be designed to produce the inputs to the universal ARC monitoring device. The hardware used to transform the system monitoring points is unique only to that particular system, since the ARC monitoring device can be used for any system requiring only simple programming for each different system.

TESTING

The transform hardware will be developed directly from the information on the logic model. Each test will be monitored in the proper sequence indicated on the logic model. Using this method, fault isolation to the black box level in the system becomes a very accurate and time-saving process. In the case of a failure in the transform hardware or the ARC monitoring device, testing of a system in the field can still be performed by using the Logic Model (software) as a test procedure and fault isolator. In addition to being used as a procedure for testing, the Logic Model can also be used to determine the section which has failed in the transform hardware. If test equipment is desired in addition to the ARC hardware, it is obvious that the Logic Model (software) should be used to develop the most efficient hardware.

EFFECTS OF SYSTEM CONFIGURATION CHANGE

When a change is proposed, the affected area on the Logic Model is investigated as to the impact on system performance and maintainability. Using this procedure, all avenues affected by the change can be considered. Once the change has been accepted, the Logic Model is very easily changed to the latest configuration. Then, since the transform hardware and ARC monitoring equipment have been derived and developed directly from the Logic Model, it again is a very simple process to make this hardware compatible to the system change. When a change is proposed on a system that is using conventional techniques for testing and conventional test equipment, the first problem which exists is the lack of ability to examine the total effect on the system performance, maintainability, and reliability. The second problem is the difficult and time consuming procedures which are used to make necessary changes to the test equipment to conform with the system change.

V. ECONOMIC CONSIDERATIONS

The economic advantages of ARC fall into two broad areas: Tangible and intangible. The most obvious and readily discernible advantage of any automatic or semi-automatic fault isolation system is a reduction in equipment down time for repair. In an average fire control system of medium complexity, as much as 5 percent of its useful life is consumed by maintenance. If the dollar value of this equipment is one hundred thousand dollars, it is apparent that less than half of this cost has returned any value to the user. Sixty five thousand dollars worth of system has been inactive during its useful life. When considering a weapon, it is logical to think in terms of combat effectiveness. Thus, the above numbers now show that a given weapon system could be unavailable for combat deployment nearly two thirds of its expected life. Viewed in this light, devoid of confusing statistics, it becomes self evident that even a small improvement in battle readiness would be desirable. The ARC accomplishes this in several ways.

a. Preventive Maintenance. Continuous monitoring of key signals prevents catastrophic (and expensive) failures.

b. Rapid Fault Isolation. Reduces down time for maintenance, thus increasing useful system life.

c. Reduced Stares Requirement. By improving maintainability of system less spare parts are required.

d. Manpower Utilization. Key maintenance personnel are available for other important assignments. In addition, lower skilled personnel may be utilized for fault isolation and black box changing. The aforementioned savings will greatly increase the combat efficiency of any weapon system or improve the effectiveness of any system.

VI. FEATURES OF THE AREA RECORDING CENTRAL

1. Sensor transforms are located in the most convenient and equipment-consistent manner.

2. The operating equipment interrogates the ARC rather than vice versa.

3. A display of the affected logic model of the sequence being monitored is constantly available for view to the ARC operator.

4. The logic modeling base for the test sequence allows event sensing and comparison for more than "mission critical" events. In many instances the different operational phases (cast off, underway, rendezvous, etc.) can give valuable information concerning the modes of operation of the equipment and systems aboard. Some failures may be unique to a particular mode and, therefore, may not be mission critical, while others may affect several modes simultaneously.

5. Adaptation to ARC remote control of operational equipment is a valuable growth potential.

6. Automatic search of events comprising the same relative functional failure frequency of a failed assembly or sub-assembly is possible by means of interrogation of prime equipment from the ARC console.

7. Inventory Control equations will be built into the ARC programs based on logic model data (maintenance factor, percent maintenance, turnaround time, safety factors, criticality, etc.)

8. A single matrix for dynamic display of logic model situations will always be available to ARC operator personnel. This will enable maintenance technicians assigned to repair malfunctions to communicate directly with the ARC operators.

VII. SUMMARY AND RECOMMENDATIONS

We have examined the need for a testing and monitoring equipment with a cross-section of features itemized as follows:

1. Hardware design backed up by software Logic Model.

2. Fault isolation accomplished in modularized as well as non-modularized equipment.

3. Active monitoring equipment/systems.

4. Multiple-fault detection with first ordered fault isolated first.

5. Self organizing and iterations of testing sequences.

6. Retention of selected performance profiles for subsequent use in programs such as fault prediction, mean-repair time, mean isolation time, relative failure frequency, inventory control, and performance effectiveness.

Descriptions have also been given of an Area Reporting Central (ARC) which is within the state of the art of test equipment design. Within the framework of ARC we have shown an evolution from the dependency chart of the Design Disclosure Formats. At the present, Aeronutronic has progressed somewhat beyond the stage of building a dynamic Logic Model and a Remote Trouble Insertion console. We have begun in house studies on transform design with emphasis on the universality of the use of such transforms.

Prior to developing an ultimate ARC configuration with its many sophisticated features, it is recommended that the U.S. Naval Applied Science Laboratory consider a development model of the ARC which is basically represented in Detail 3 of Figure 1 and allows the exercising and evaluation of an ARC model.

This attack is deemed to be most economical for a dollar expenditure and developmental time increment required to produce a working model.

A course of action which would logically be pursued, by means of a development contract is presented as follows:

1. Review wider range of military maintenance problems in depth and isolate root causes for later application of solutions.

2. Intensify transformation of Logic Model to test equipment research.

3. Investigate in greater depth the progress made in answering military maintenance problems presently employed and proposed for the future.

4. Expand present investigations of off-the-shelf equipment which might be suitable for use in ARC.

5. Develop a comprehensive design specification for ARC describing performance characteristics and hardware interfaces.

6. Apply ARC techniques to a mutually agreed upon item of hardware.
    a. Design transforms for test points which might be required.
    b. Select readout system (lighted board, printed tape, ink recorder, CRT, etc.)

7. Develop a computerized scheme for deriving maintainability information from logic models.

8. Perform a study to examine the possibility of using predominantly fault isolation equipment to predict faults.

APPENDIX I

REFERENCE MATERIAL, LOGIC MODEL AND FIST

The following documents on the subject of FIST and Logic Models have been used in compiling material for this report.

LOGIC MODELS

Reports

Design Disclosure Format for Maintainability
"System Performance Effectiveness Program” Lab. Project 9200-72-2, 31 March 1965

Design Disclosure Format General Specification
"System Performance Effectiveness Program" Lab. Project 9200-72-2, Progress Report 1, 4 October 1966

Design Disclosure Formats for Naval Applied Science Laboratory
"Task No. 8: Reliability Formats, 31 May 1965

Specifications

MIL-M- 2400 A (SHIPS)
Manuals, Orders and Other Technical Instructions, for Equipment and Systems, 15 June 1966.

NAVSHIPS 0967-077-5000
Writers Preparation Guide for Symbolic Integrated Maintenance Manuals (SIMM), 10 December 1965

AR-8, AR-9 AR-10 (Naval Air Systems Command)
General Requirements for Versatile Avionic Shop Test System/Avionics Systems Compatibility, I May 1967.

FIST

National Bureau of Standards Reports

NBS Monograph 83
Project FIST - Fault Isolation by Semi-automatic Techniques dated 17 September 1964

NBS 9408
Design Considerations for the Application of the FIST Maintenance. Concept to Electronic Equipment, dated 6 May 1966.

NBS 9409
Design Considerations for a General-Purpose FIST Test Instrument

Other Reports

Project FIST: Fault Isolation by Semi-automatic Techniques (In two parts) IEEE "Spectrum," August and September 1964.