It is the responsibility of management to see that all program levels are educated in the usefulness of maintainability design techniques and to assure that this education is undertaken by a maintainability specialist.

Like any management technique, its communication system can make it work or cause it to fail. We must specify the type and amount of communication that is required for the Maintainability Manager to effectively perform his job.

I have mentioned a few examples of the lack of maintainability, shown the relationship of the maintenance cycle to the design control, pointed to the responsibilities of management to the maintainability program, shown the precentage rate of availability as it stands today with respect to where it should be, revealed the Department of Defense's request for corollary action, and made an appeal for your concern and assistance in attaining our mutual goals.

We do not claim to have all the answers nor do we profess to be the authority on Maintainability, however we do intend to reach our goal.

AUTOMATIC BUILT-IN TEST EQUIPMENT FOR TRAINING DEVICES

Mr. Lyman A. Whalen
Aerospace Engineer

Automation of electronic test, checkout and support equipment has grown over the past few years until it now represents a substantial nationwide effort.

Very often in the past, little thought and time were devoted to the design of support and checkout equipment. It is now evident that the same consideration should be given to the design of a test equipment system as we give to the design of a weapon system. This requires a thorough analysis of the mission of the test system and its environment. It also means making trade-offs between the constraints of cost, time, operator skill levels, accuracy, repeatibility, and user confidence to arrive at an optimum test system.

The alternative to the test system approach would be to solve each of the test equipment design problems independently, considering only the immediate requirements of the equipment under test.

One solution to the test system problem would be the utilization of Automatic Built-In Test Equipment. Such equipment can be used for fault detection, fault isolation, and continuous performance monitoring. Automatic Built-In Test Equipment has been used for aircraft and aerospace applications for quite some time, giving us extensive background information to draw upon.

Our primary goal is to achieve the maximum availability for our training devices. Availability may be expressed simply as:

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

It can be seen from this expression that availability can be increased by increasing the Mean Time Between Failures (MTBF) or by decreasing the Mean-Time-To-Repair (MTTR). Mil Standard 778 defines MTTR as: "A mathematical mean of the summation of active repair times during a given period of time divided by the total number of malfunctions during the same time interval." Experience at NTDC shows that fault isolation comprises approximately 75% of the active repair time for a given malfunction. Because of this, our efforts are directed to reducing MTTR by minimizing the fault isolation time. This may be done by effective utilization of more advance test systems.

Let's look at some of the advantages of using Automatic Built-In Test Equipment:

ADVANTAGES:

a. Availability - It is available when needed, since in all probability, it is integral to the training device.

b. Conserve Manpower- We can conserve skilled manpower, since it presents no problem of selection to the unskilled maintenance man.

c. Specialization - It can be specialized for the particular measurement data required. This may result in a reduction in testing time and enable us to check out complete systems or subsytems rather than individual segments.

d. Objective Standards - By using objective standards rather than judgements to determine operational readiness, one is able to establish uniform, controlled, and reliable checkout procedures.

e. Simplified Controls - The simplest of controls may be used; elaborate set-up procedures are not required.

f. Simplified Handling - It need not be transported, and if necessary, may be larger and heavier than portable test equipment; in addition, no special storage facilities are required.

DISADVANTAGES: There are, of course, certain disadvantages:

a. Automatic Built-In Test Equipment can be used only with one training device, and it is not portable.

b. The circuitry for the test system may have to be more complex than that of portable test equipment, since its wiring must interact with the wiring of the prime equipment.

c. Calibration and modification may be more difficult than for portable test equipment.

d. It increases the magnitude and duration of the development effort.

An automatic checkout and monitoring system can be used to perform calibration and dynamic testing, first-level diagnostic testing, final diagnostic testing, and continuous performance monitoring. There is no guesswork on the part of the maintenance man. Certain assemblies may require this technique at the assembly level only. Further isolation would then be accomplished manually. An allocation of maintenance tasks between automatic and manual test equipment may be accomplished based on crew workloads and the equipment failure rate.

A representative automatic test system built around a programmer comparator might contain the following:

a. An operator's console, including control and display devices to present the evaluation of the tests to the operator.

b. Programming equipment that provides coordinated and precise control of the test equipment and the unit under test by using prepunched or magnetic tape.

c. A stimulation control unit that provides signals to be injected into the unit under test.

d. An adapter unit that is the link between the tester and the unit under test and provides the required interfaces.

e. A test point switching unit that selects test points determined by the programmer and routes the signals to the test evaluator.

f. A comparator that accepts the information from the test points as ordered by the programmer and determines if the selected test results are within permitted tolerance.

g. A measurement unit which provides a standard for the comparator.

Depending upon the encoded instructions and the results of the comparison, the test system may proceed to the next test, stop and allow the operator to make the next decision, or automatically search to a desired sub-routine for further evaluation of the malfunction.

Although the normal mode of operation would be automatic, it is desirable that the test system be capable of manual operation so that specific checkpoints may be re-run at the operator's discretion. Manual controls are also useful for line by line monitoring of a program tape routine or for the insertion of a subroutine by the operator.

Automatic program control is provided by an electronic network of logic and memory circuits. These circuits are designed to control various operational elements to accomplish the test sequences automatically. The basic functions of automatic program control are as follows:

a. Selection of the proper stimuli control channels to be applied to the system under test.

b. Selection of the measurement channels for connection to the test points in the system under evaluation.

c. Direction of appropriate measurement and evaluation devices as to the type and range of the measurement to be made on the selected test point.

d. Introduction of time delays as required for proper functioning of the system under test.

e. Storage of the upper and lower tolerance limits.

f. Regulation of the program continuation based on the results of the evaluation or upon other program conditions, as directed by the tape.

g. Actuation of the visual and printed readout devices to indicate test results and test status.

During the preliminary analysis phase of the prime equipment design, we must decide what type of test system will be used. By the system and subsystem development stage, this decision should be firm.

Some of the factors to be considered in making this decision include: the mission and operational characteristics of the equipment; the anticipated reliability; the maintenance structure; equipments and personnel available to the using command; the operational environment; logistical support requirements; development time; and cost. Economics plays an important role in the selection of a particular type of test system. Before we can select or design a test system, we must evaluate what kind of test system is capable of doing the job for the least amount of money.

Test specifications of the equipment under test are the prime source of information in understanding the system. These specifications are based on design acceptance tests performed with general purpose manual equipment by skilled personnel. They provide signal parameters and tolerances usually not available from any other source. The danger here is that these specifications might be considered as more than sources of information, and that the test system designer may be trapped into automating manual procedures.

So far we have looked at the background concerning Automatic Built-In Test Equipment, at the advantages and disadvantages, some of the operational characteristics and design considerations. Now let us discuss what has been done with test equipment in the field of training devices, and what is in store for the future.

Various types of special check-out equipment have already been designed and manufactured to assist in the maintenance of specific pieces of operational hardware. This checkout equipment, while falling short of the requirements for Automatic Built-in Test Equipment which we have discussed, nevertheless represents an initial step toward the ultimate goal. Typical of the equipments already developed are:

a. A Diagnostic Test Set procured as part of Device 2F65, E-2A Weapon System Trainer.

b. Printed Circuit Card Test Unit used in conjunction with Device 21A39, Fleet Ballistic Missile Submarine Attack Center Trainer.

The Diagnostic Test Set for Device 2F65 is designed to perform two major functions related to the AN/ASA-27 Computer Indicator Group which is the heart of the device. First, it provides continuous monitoring of the alarm flip-flops which are an integral part of the AN/ASA-27. This means that maintenance personnel can be immediately aware of a failure in one of the major subsystems of the Computer Indicator. Secondly, the test set provides external signals and program controls to assist in further isolating a subsystem failure. In many cases when utilized by a highly proficient operator, the test set is able to isolate failures down to a replaceable unit within a subsystem.

It must be emphasized that while this is to some extent an "on-line" tester, it is definitely limited by the high degree of operator proficiency required in order to analyze the indications received from it.

A Printed Circuit Card Test Unit was procured by the Government as part of Device 21A39. This "off-line" tester is designed to provide power and signal inputs to check-out and troubleshoot the various types of printed circuit cards employed in the device. This test unit requires manual programming in order to provide proper voltages and signals to the particular card under test. The associated test equipment together with other external equipment is used to check the various components on the card.

The primary shortcoming of this type of tester is obvious. While it is useful for repairing faulty cards, it is an "off-line" unit and does not contribute directly to device availability.

The door to advancement for incorporation of Automatic Built-In Test Equipment into the Navy's training devices is wide open. At least one of our major airline companies has partially achieved this goal for its flight simulators. United Airlines has incorporated a Voltage Data Logging System into some of its large analog flight simulators. This test equipment is automated, but it is not built into the prime equipment.

This "scanner" sequentially reads and prints out the magnitude of 120 test voltages to three-place accuracy in just three minutes. When the flight simulators were analyzed to determine the best utilization of the "scanner" for performing an optimum maintenance evaluation, over 1500 possible test points were found. This was obviously an excessive number of points to check. A detailed evaluation was conducted which narrowed the selection to the most significant 750 test points. These 750 test points were broken down into smaller groups since the "scanner" is limited to reading 120 test points at a time. In order to arrange the test points in convenient groups, the analog circuits in the flight simulators were divided into the following major subsystems:

Longitudinal flight equations; Lateral flight equations; Engine performance; Control loading; Navigational aids; and Miscellaneous systems.

Even this limited group of major subsystems is difficult to analyze. Part of the overall scheme was to simplify drawings to make the job of locating test points easier. Drawings were developed for the purpose of analyzing systems rather than specific circuits. Details in the original drawings were omitted in order to reduce the drawings to a convenient working size.

The readings obtained with the "scanner" are printed out on a paper tape which can be checked against another tape containing the operational voltage limits for each test point. By analyzing the out-of-tolerance voltages one can localize the trouble to a particular portion of the system. In addition, the voltage at any particular test point can be visually read out on the built-in digital voltmeter.

The United Airlines' Voltage Data Logging System is an adequate piece of "automatic check-out equipment," but it does not meet the requirements of Automatic Built-In Test Equipment. It has the advantage of automatic test point selection, and low-skill level personnel may be utilized to operate it; however, this test system has limitations. In order to perform tests properly and to obtain the correct measurements, the initial conditions must be locked into the simulation equipment prior to starting the scanning operation. This means that the system under test must be in a static condition when tests are made. The result is that continual on-line performance monitoring is not possible. This test system is limited to voltage measurements. Ideally, several other types of measurements are necessary to evaluate system performance.

Even though this particular test system does not meet all our requirements, the maintenance troubleshooting technique developed utilizing this "scanner" has become so effective for anticipating analog component malfunctions that the number of operational discrepancy reports has been reduced by as much as ninety percent.

This is only the beginning. With advancements in the state-of-the-art, new techniques are constantly being developed for answering the question of on-line testing. Methods of programming are widely varied to adapt to almost any situation. New modularized magnetic core memories can be expanded to suit any requirement we might have for a training device test system.

More effective test systems can be expressed in actual savings to the Government.

a. First, an effective test system will enable us to have a more efficient maintenance program and will result in a long-range increase in availability.

b. Actual dollar savings can be exemplified. If we assume that it costs an average of $100 per hour to operate a complex training device, based on a device utilization time of 60 hours per week, we can save over $5000 per year per unit by reducing the maintenance time per unit by just one man-minute per utilization hour - certainly a significant savings.

c. Automation of test equipment will result in a direct reduction in personnel to operate the equipment. It takes the Navy over two years to completely train skilled technicians (TD's) to the point that they are qualified to maintain complex training devices. This amounts to an investment of approximately $75,000 per man, and there is no guarantee that the man will remain in the Navy beyond his original enlistment.

d. Because of test equipment automation, especially in areas where results must be evaluated and decisions must be made, it is possible to use lower skill level personnel for on-line maintenance. This frees the higher skill levels for specialized off-line maintenance.

e. As a by-product savings, we have better student motivation. Indirectly, by increasing the availability of the training device, we have less down time, and can keep the student motivated by having the equipment in an operational status a maximum amount of the time.

We must never lose sight of the end objective of keeping the prime equipment operational and available for its intended use at any time. Automation of test equipment should be considered as a valuable, necessary tool to get the job done. At no time should it be considered for the sake of automation alone, without considering its full impact on the prime equipment. We must be the masters of automation, not the slaves to it, and mastery of automation begins in the designers' approach to the problem.

3M MAINTENANCE DATA SYSTEM AND AUGMENTED SUPPORT

Mr. R. N. Underwood
Head, Field Service Support Division

A new term which is gaining greater emphasis at NTDC is 3M, Maintenance and Material Management, on overall support management. The Maintenance Data Collection System, which I will discuss first, is one very important element of the 3M system. One which provides us with essential feedback for key management decisions concerning training device procurement, reliability, and support. My discussion is not only intended to acquaint you with the Maintenance Data Collection System, but also to convey our extreme interest in you as contractors and military, playing your respective roles in support of the goals of this system. Simply stated, the Maintenance Data Collection System (MDCS) is an efficient information system for reporting maintenance actions during the reliability test and augmented support phases of a training device contract. The Maintenance Data Collection System, which embodies many exciting advantages of modern reporting methods, has projected training device development and support programs into the age of automatic data processing (ADP). Reporting under the Maintenance Data Collection System begins initially at the manufacturer's plant during the Reliability Test Phase and continues on through the on-site Augmented Support Period. Reporting ends when the contractor support period is terminated. A single, uncomplicated, Maintenance Action Form is used to convey maintenance actions back to a central processing location from which many data products are available such as: raw tabulated data, reliability data, maintainability data, historical records of failures encountered, and numerous other possible data products.

Whenever an equipment failure is identified it is reported on the Maintenance Action Form in sufficient detail to permit correlation of the maintenance and material picture. With each successive report, failure rates gradually emerge. Typical data elements, are reported on the Maintenance Action Form. All maintenance and support actions will be reported during the period of interest. The first four listed elements are simple format elements. However, following elements such as "when discovered", "type maintenance:","action taken", etc., become more descriptive of the maintenance problem. The contractor has a prime responsibility for developing the "Work Unit Code" and several other codes for the system.

The Work Unit Code Manual is prepared by the contractor as a deliverable item under the contract. This manual contains the necessary alpha-numeric identification codes for entry on the Maintenance Action Form to accommodate automatic data processing.