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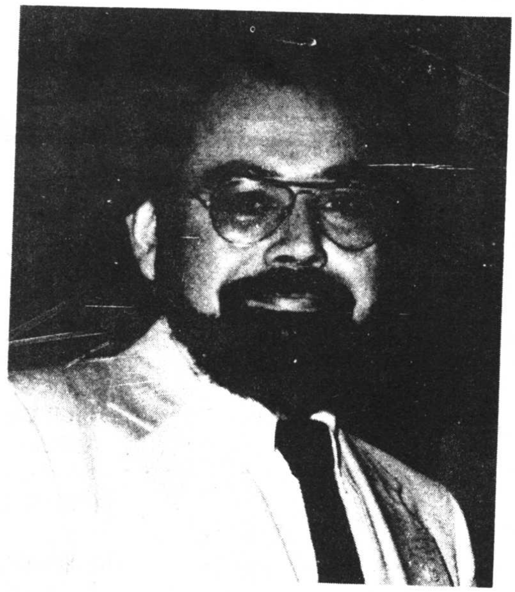

GREETINGS FROM THE CHAIRMAN

When we began planning this year's AUTOTESTCON, Orwell's book, "1984," motivated in part the conference theme "Predictions, Realities and Goals." The Automatic Testing Community has for the past decade been making predictions concerning what ATE would and could be made to do. A moment of introspection concerning these predictions and how well they have been achieved is proper, as well as looking at and assessing new predictions currently being promulgated. The accuracy of predictions must be viewed in terms of what currently exists. Thus, the conference takes a realistic look at where we are today in ATE. Finally, where are we going, what can we really attain, what must be avoided and how can we optimally achieve the attainable.

On behalf of the Instrumentation and Measurement Society, the Aerospace and Electronic Systems Society and the Washington Section of the Institute of Electrical and Electronic Engineers, I welcome you to AUTOTESTCON '84. The AUTOTESTCON '84 program, environment and people provide all of us with an opportunity to learn, contribute and grow.

Michael D. Myles

AUTOTESTCON '84

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MAN OF THE YEAR

Born in Rhode Island, Patrick M. Toscano, attended elementary and secondary schools in Westerly, Rhode Island. Later he served as an Electronics Technician Mate 1/C during World War II with the Navy's 7th fleet, Repair Unit #1, in the Pacific Theater. Selected from fleet competition for NROTC V-12, he attended Ohio State University at the close of World War II. He then went on to earn his BS and MS degrees in Electrical Engineering from the Universities of Rhode Island and Drexel respectively.

Mr. Toscano has been a practicing engineer with RCA since 1950, both as an individual contributor and as a Manager of Engineering groups and projects.

His broad based Service company maintenance experience, coupled with hardware design and management experience have made him an all around contributor to the ATE field.

His early work included fire control, television and communication systems. Later he supervised a group of engineers responsible for the design of advanced data conversion equipment for use in a data link for century series aircraft.

From 1960, he headed various groups of engineers involved in Automatic Test Equipment design, specializing in computer control systems and custom peripheral equipment. The systems for which he was responsible included Multipurpose Test Equipment (MTE), Depot Installed Maintenance Automatic Test Equipment (DIMATE), Land Combat Support System (LCSS) and Equate.

Beginning in 1963, he held responsibility for ATE software involving several engineering groups engaged in test program set development.

In 1974, he was chairman and organizer of a six session IEEE sponsored Colloquium, entitled "Software for the Engineer" presented in Lexington, Massachusetts, and attracting several engineers throughout the New England area.

In 1976, he became active in the program management of several ATE programs with RCA. Amongst these programs were Equate's AN/USM-410 and the AWACS AN/GSM-285.

Currently he is active as a Program Manager on US Army APACHE AH64A ATE contracts.

Mr. Toscano is a Senior Member of the IEEE and has actively participated in Professional Groups in Engineering Management, Information Theory and Electronic Computers. He has published technical papers in several engineering specialties but most recently in ATE related subjects.

He is a registered professional engineer in Massachusetts and belongs to the AIAA, as well as the Association of Old Crows Patriot's Roost.

He is widely known in the ATE community, having interfaced with fellow engineers in industry, as well as in the tri-services over his 34 year tenure with RCA.

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ATE STANDARDISATION IN A LARGE AEROSPACE COMPANY

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ABSTRACT

The Dynamics Group of British Aerospace produces numerous high technology weapon system products which are in use with all branches of the Armed Services. The Group is comprised of a number of independently accountable, geographically divorced Divisions. This paper describes the formulation and implementation of a Group Test Policy, the approaches to standardisation, and the advantages gained over a three year period.

INTRODUCTION

British Aerospace Dynamics Group is a major U.K. supplier of Guided Weapon Systems and associated high technology products. The Group employs some 23,000 people in six main Divisions spread throughout Britain.

Whilst each Division is independently accountable and has specific project management responsibilities, the diversity of skills and facilities required to contribute to high technology products makes interoperability an important consideration. Similarly, the crucial need for high reliability and availability of weapon systems dictates extensive testing, and the associated costs must be continuously and critically examined. A common test policy implemented throughout the Group was seen as a major contributor to Company strategy in the areas of interoperability and effectivity.

In 1981 a Group Test Policy Committee was established, with a mandate to formulate and implement a common approach to all test aspects of new weapon system developments. There were considerable obstacles to the achievement of a common test policy, such as large capital investments in existing facilities, differing Divisional operating procedures, and so on. However, in three years many changes have been made which contribute to the common test policy goal, and this paper deals specifically with the techniques now adopted throughout the Group for the test of printed circuit assemblies and electronic line replaceable units (L.R.U.).

OBJECTIVES

The Group Test Policy Committee initially defined a number of objectives which would form the basis of a policy. These objectives would not necessarily be identically implemented by each Division, but would lead to sufficient commonality to satisfy the interoperability criteria. Amongst the most significant of these objectives were:

i. To establish common testability criteria to be applied to all new products.

ii. To define common design rules reflecting these criteria for incorporation within relevant Divisional handbooks, standards and procedures.

iii. To define common test philosophies to be applied to each level of asssembly e.g. components, bare boards, populated boards, L.R.U. etc.

iv. For new investment, to adopt a common standard for major test facilities.

v. To establish a direct relationship between development, factory and field test facilities, with maximum commonality, particularly of software.

vi. To optimise the use of built-in-test and built-in-test equipment in the factory and field environments.

Against this background, the methods used by each Division for the test of printed circuit assemblies and electronic L.R.Us were assessed, and revised common policies formulated.

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TEST OF PRINTED CIRCUIT ASSEMBLIES

In establishing a test policy for printed circuit assemblies it became evident that two different categories of assembly existed. Missile flight equipment generally contained a relatively small number of different assemblies, was produced in high volume, and was subject to a relatively low modification rate. Ground Equipment, however, contained a large number of different assemblies, was produced in low volume, and was subject to a much higher rate of modification.

The test approach generally in use was to subject the assemblies to functional test, using either general purpose ATE of various types or special-to-type automatic/semi-automatic test sets. In some instances in-circuit testing was being used in an automatic inspection role to eliminate manufacturing defects.

In examining the effectiveness of this approach a number of factors emerged:

i. The cost of producing functional test programs for general purpose ATE was high in terms of both cost and skilled engineering resource, and was constantly rising.

ii. Diagnostic programs were even more expensive to produce, and were often inadequate.

iii. In-circuit testing, even using the passive and static techniques then available, was very cost effective. However, the use of different machines for in-circuit and functional test made programming and fixturing costs higher than necessary.

iv. Apart from the cost, the time to produce and modify test program sets was too long, causing the test resource to lag behind production requirements. Similarly development model testing was largely by "knife and fork" techniques, since production equipment and procedures lacked the flexibility and speed of response to new/modified designs necessary to assist with this stage of testing.

The proposed solution was to adopt a combinational approach, in which the facilities to perform in-circuit component test and functional test from the edge connector were combined in one suite of equipment. This approach would enable testing to be optimised to the particular requirement, for example functional testing coupled with in-circuit diagnostics, in-circuit testing followed by functional test, functional testing of complex sub-sections in conjunction with in-circuit testing and so on.

For the policy to show significant advantages a number of criteria had to be satisfied. These included:

i. The chosen equipment had to provide the resources for in-circuit component test and hybrid functional test in a modular fashion, thus allowing the equipment to be economically configured to the requirements of a particular project, but enabling quick enhancement to meet a new requirement without any loss of integrity.

ii. The equipment had to provide the ability to perform dynamic in-circuit testing of complex digital devices.

iii. Since much of the data necessary to produce the test program resided in either computer aided drawing or computer aided design data bases, the equipment should be capable of interface with these facilities.

iv. The application software language and associated tools should help to make programming as simple as possible.

The CAD Interface

The generation of an in-circuit test program generally follows a standard pattern. The topography of the board under test is entered into the ATE in terms of component description and interconnection data, often in response to menu instructions. This is a low skilled, but time consuming task, perhaps taking two days for an average board. An automatic test program generator, (ATPG), then uses this data to assemble the test program from a series of device models held in libraries. These models are essentially functional test programs in their own right, and are either provided by the ATE manufacturer as part of a standard library or written by the test programmer. The ATPG modifies standard device models to suit the particular circuit configuration, applies automatic guarding algorithms etc., and outputs a test program and fixture wiring information.

Within the Dynamics Group, certain common computer aided design and drawing systems had, or were being, established. Similarly site communications networks based on broad band systems and local area networks were also being implemented.

From the beginning the combinational test equipment was therefore made an integral part of the Computer Aided Engineering network. The computer aided drawing data base was accessed to provide the component and net list information necessary, and this was processed to provide the correct file format for down loading to the ATPG. Additionally most new designs incorporate custom or semi-custom devices, designed using simulators such as Hi-Lo and Tegas. Part of the design process is theoretical evaluation using test programs generated with the aid of these simulators. By providing suitable post processors, the programs could be automatically converted to device models suitable for use by the in-circuit test equipment, and indeed the provision of such models is now a procedural requirement of the design process.

Standardising on the test equipment has the added advantage that the prime equipment designer is aware of the performance of the equipment which will be used to test his design, and can therefore ensure that problems such as timing conflicts between the requirements of his test program and the capability of the test equipment are avoided.

Finally the physical layout information resident in the computer aided drawing data base can be used to optimise probe placement and to generate a drill tape for the manufacture of the bed-of-nails interface.

By placing the test equipment on the site communications network, other advantages such as central program storage and the associated configuration control, access to the central defect data bank for defect data recording and analysis etc., are also gained.

The result of making the test equipment an integral part of the CAE system from the outset has been that the in-circuit portion of the test program, and the fixture manufacturing information, is now generated largely automatically, with consequent reductions in costs and timescales.

Other Changes

In addition to the test equipment itself, other significant changes were necessary to ensure the maximum cost effectiveness of this method of testing. Firstly, it was apparent that little could be achieved in reducing the cost of fixturing whilst board sizes, component layout, connectors etc, had no standardisation. The constraints of missile flight equipment in terms of space envelope and profile, component density etc., meant little could be achieved in this area. However, since these were the high volume/low modification assemblies, the cost of special fixturing was easily justified.

For ground equipment, however, the adoption of a common standard would significantly reduce the test cost. The result has been that new product designs are now based on the eurocard standard, and that components (or at least the associated test points), are placed on a standard grid matrix, with the test points arranged on a 0.05 inch matrix for boards up to 100 x 160 mm (single eurocard) and on a 0.1 inch matrix for boards up to 160 x 233.4 mm (double eurocard).

For ground equipment the double eurocard is now the normal standard, and this has enabled the adoption of a universal fixturing technique incorporating compliantly mounted, steerable pins. The only part of the fixture which is therefore unique to the board under test is the steering plate. This approach has not only dramatically reduced the cost of fixtures, but has contributed to the feasibility of deploying combinational equipment in a field test vehicle, since the volume necessary to store the fixture in so considerably reduced.

To gain maximum benefit from combinational testing, the amount of functional testing performed must be reduced to a minimum, since functional programming remains the engineeringly intensive activity. This can be achieved provided that the information gained by dynamic component measurement is considered when assessing the overall performance requirement, and the amount of functional testing reduced accordingly. However, customer requirement dictated that interchangeability was ensured by full functional performance demonstration from the edge connector, and this was reflected in the format and content of test specifications prepared to the accepted standards.

Considerable negotiation was necessary with customer authorities in order that the full benefits of combinational testing could be realised. Technological evidence as to the safety of back driving techniques, methods of ensuring integrity of device models and many other criteria had to be satisfied before the technique was endorsed and a new format of test specification, which whilst still test equipment independent was no longer test method independent, was accepted. The specification format now accepted comprises three parts. Part one defines the interchangeability requirements which have to be satisfied, in terms such as defined transfer functions. Part two has three sections, a network listing, a listing of device model specifications against which the individual components will be in-circuit tested, and a statement of any necessary functional test parameters. It is, however, the combination of the individual device tests, and the 'end to end' functional tests, which together demonstrate the interchangeability criteria specified. For completeness, part three then defines in-process conditioning requirements.

The advantages gained from the adoption of combinational test and the associated design rule changes have been significant. The cost of producing test program sets has been reduced to an average 25% of its previous level. Perhaps just as important, due to the largely automatic nature of the process, the dynamic in-circuit test program and fixture can be produced and evaluated very quickly (typically 2 to 3 weeks), thus making the provision of a test package in the timescale required by development a viable proposition. Thus a design engineer can now be provided with not just a manufactured prototype board, but one that has been tested to a high level of confidence.

The impact on production has been equally significant. Delays in the production process caused by the late availability of test program sets have been largely eliminated, and the use of a common standard of equipment has reduced logistic and maintenance problems, whilst giving production managers flexibility in dealing with peak workloads and equipment failures. The accuracy achieved in fault diagnosis is also considerably improved, leading to less time in the rework cycle, improved throughput, and less scrap.

There are, of course, some areas of difficulty. The increasing use of ceramic substrates and leadless components complicates the electrical interface. Also, whilst ground equipment boards are no longer conformally coated, solder resist only being used, the same is not true for flight equipment where the physical properties resulting from conformal coating are still required. For this type of board, final test must still be fully functional from the edge connector.

Few tools exist to assist with the analysis of circuit designs to ensure that back driving does not stress components beyond the levels established by the technology authorities, thus placing considerable responsibility on the testability review panel. Finally the proprietary nature of some component design information may make the generation of a completely comprehensive model difficult, although this problem is usually avoidable in military equipment designs.

We would not be so rash as to suggest that this policy provides the most effective solution to board test under all circumstances. Other techniques, such as in-circuit emulation, obviously have a place, and where the technology, design or manufacturing volume becomes a dominant factor, deviation from the standard policy is considered. However, in the vast majority of cases the policy can be shown to have considerable benefits which may be reflected in a lower final product cost.

TESTING OF ELECTRONIC L.R.U.

Policy

As with printed circuit assemblies, an initial appraisal was made of the test methods in general use, their weaknesses, and what could be achieved in terms of a common approach to provide an optimum solution. The major factors highlighted by this apraisal were:

i. Technology Changes

The general level of technology appearing in new weapon systems was very different to that contained within currently fielded equipment. Older systems generally contained a high proportion of analogue electronics, were based on point-to-point wiring, incorporated LSI/MSI digital signal processing and relied on visible optics. New systems are processor based, incorporate standard busses, are reconfigurable by alteration of processor memory contents, include a large amount of built-in-test equipment (BITE) and often utilise thermal imaging techniques. Thus the modern L.R.U. falls into one of three categories:

(a) Processor based, and therefore containing local intelligence.

(b) Bus structured, and therefore whilst not containing its own processor, intended to communicate with a processor in another part of the system.

(c) Conventional, i.e. neither processor based or bus structured. This last category of L.R.U., now in the minority, was the only one really suited for test by conventional functional ATE, which was the primary method in general use.

To test the other categories of L.R.U. by conventional means generally entailed inhibiting the internal processor of the unit and taking over its bus functions. The disadvantages of this approach were that interfacing to the bus required complex pin electronics, high test speeds were required at the bus, test programs were long and complex and the overall test sequences were slow compared with the actual execution of the test patterns.

If, instead of implementing the tests from an external equipment, the intelligence within the unit could be exploited by loading test routines and executing them within the unit itself, then these disadvantages could be eliminated. This move of intelligence from the test equipment to the unit under test would have significant impact on the design of both the test equipment and the application program language. In effect the L.R.U. would contain the test program sequence, and all that would be required is relatively "dumb" instrumentation. This is obviously an over simplification, and in practice there must be a balance of intelligence between the test system and the unit under test. In order that each part of this new distributed test system may be aware of what the other half is doing, communication channels need to be established.

Such a concept not only impacts on the test hardware required, but demands a test language with facilities to describe communications protocols, file handling capability, etc.

Equally the designer of the BITE would need to consider its role in other than its primary operational mode. In general for operational purposes BITE sensors are required to give go/no go decisions only, such that the operational software may cause the system to enter a regressionary mode or initiate some other action. Provided the primary software contained the necessary "hooks", test software could access and calibrate the BITE sensors, enabling them to be used as part of the test and fault diagnosis strategy.

ii. Factory/Field Compatibility

It was immediately evident that no real commonality existed between the testing carried out in the development laboratory, in the factory production test environment, or in field deployed test and repair facilities. With regard to factory and field in particular, essentially the same task of providing a test program set was being performed twice, quite independently, in the factory normally using commercial general purpose functional ATE, and in the field using ruggedised military standard ATE configured to the requirements of a particular weapon system.

There were, perhaps, understandable reasons for this situation. On a technical front, in the factory the build of a unit might be in stages, with testing performed at various levels of assembly. This process could be regarded as "bottom up", wherein the test time would be reasonably constant for every assembly. In the field, the opportunity to stage build does not exist. The requirement is to identify the failed component in the shortest possible time with the least disturbance to the rest of the assembly, or what could be considered "top down". Contract phasing, whereby the requirement for field test facilities was the subject of quite separate contracts from production (and hence the production test facilities) was another problem, as were considerations such as relative skill levels, documentation standards and so on.

Perhaps the most significant reason, however, was that a weapon system is usually the product of a number of companies acting in sub-contractor or co-contractor roles. Thus, whilst the field facility addressed the test requirements of the entire weapon system, the factory facilities used by the various contractors would be subject to their individual Company policies and the test envelope of their particular sub-system.

It was obvious however, that if factory/field compatibility could be achieved then considerable benefits would accrue. The fact that test software was developed only once for both environments would lead to considerable cost reductions, field software would be available earlier and there would be direct correlation between field and factory results, easing defect investigations and readily providing trend data. Cost reduction and earlier software availability was, of course, equally applicable to modifications as to initial release. Secondary benefits, such as the better utilisation of engineering resources, were also accrued.

Returning to the development environment, again there was no direct relationship between this and subsequent echelons of test, other than that the Performance Test Specifications were a product of the development process. In the past, where development testing had been largely hardware oriented, using conventional test instruments, this was not too important. With the current generation of L.R.U., however, much of the development testing was by means of specially written software, and again some carry forward of this software into production would be beneficial.

Taking together, then, the effects of the changing technology of the units to be tested, and the obvious benefits to be gained from a direct relationship between development, factory and field testing, the general requirements for a new type of test facility emerged. These were:

i. The test equipment should be simpler

than conventional ATE, this being achieved by fully exploiting the L.R.U. technology of processors, standard busses, built-in-test equipment, etc.

ii. The equipment should be fully modular, such that factory facilities suitable for a given sub-system could be reconfigured into one overall field facility, or a role change could be readily effected.

iii. The software should be largely hardware independent to protect against obsolescence.

iv. The equipment should be suitable for different project applications.

v. The equipment should meet the requirements of both development and production test by combining the power of a structured high level computer language with the facilities of a test language familiar to a test engineer.

vi. Factory/Field compatibility should be considered from the outset, such that the design considered both the "soft" factory environment and the rugged mobile field environment with minimal compromises.

Against these general requirements the design of an L.R.U. tester, now deployed as standard equipment throughout the Dynamics Group, proceeded.

L.R.U. Tester Concepts

The tester, shown diagramatically in figure 1, may be considered as consisting of three tiers, between which communication is across defined standard interfaces.

At the top level is the CORE which is common to all projects and contains the test controller, peripherals, communications ports, standard instruments and synchronisation facilities. At the next level are those items common to a

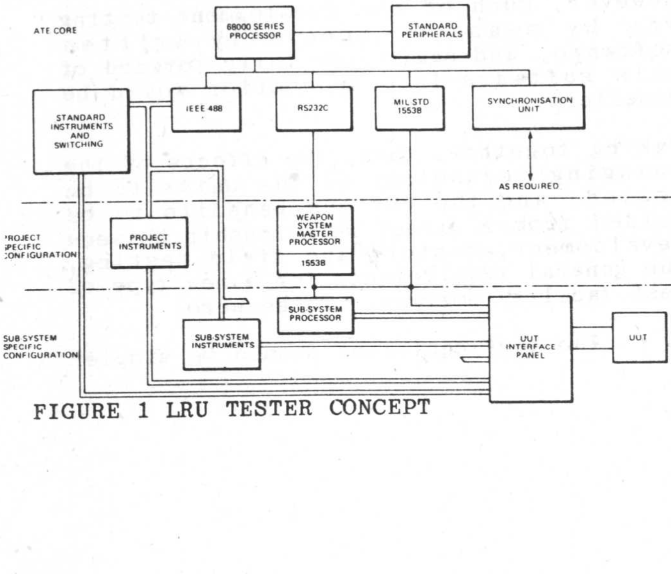

FIGURE 1 LRU TESTER CONCEPT

total project. The content of this level is variable but at a minimum will contain the weapon system peculiar master processor, which provides the natural environment for the enhanced BITE software. Normally, common items such as system power supplies reside at this level. At the final level are the sub-system specific items, comprising any necessary special instruments such as video pattern generators and signal analysers, digital/synchro/digital converters, RF instruments and IR equipment such as variable temperature targets. This final level also contains the interface with the unit under test.

The equipment includes a minimum compliment of switching, that mandatorily required for safety purposes such as power supply isolation and a small instrument routing module. In general, however, the type of L.R.U. to be tested does not demand the large switching matrices found in conventional ATE, since most testing is via the data highways.

CORE Configuration

The CORE controller is based on Motorola 68000 Series microprocessors. These processors provide suitable architecture, memory size and speed, and represent low cost industry standard devices. A long life cycle could be expected due to the large user base and the device family is generally upward compatible. The controller provides a number of standard interfaces including the IEEE 488 bus for instrument control, RS 232C and SASI interfaces and, in particular, MIL-STD 1553B interfaces.

The MIL-STD 1553B interface has been designed with a high degree of comprehensiveness to enable both test and communication functions to be performed, since this bus represents the primary data highway in the majority of modern weapon systems. The interface provides bus control (with error generation), multi-remote terminal simulation and full bus monitoring facilities.

The controller also includes synchronisation facilities such that events may be synchronised either by software command or in response to external triggers.

Completing the CORE are the normal peripherals of terminal, keyboard, printer, floppy and Winchester disks, all of which may be chosen to suit the particular operating environment, a small range of standard instruments (e.g. DMM, Timer/Counter etc.), and an instrument routing module which may be expanded as required.

The Test Language

In considering the test language, the differing requirements of development and factory/field environments had to be satisfied. The development engineer, in addition to controlling test resources, may need to perform complex processing tasks, whereas the test engineer needs to address test resources in terms with which he is familiar.

The result of these considerations was the design of a Standard Language for Instrument Control (SLIC). SLIC is a high level test language which, although it is resource dependent, is closely aligned with IEEE ATLAS statements. It also has the full power of a structured general purpose language.

The current implementation of SLIC uses ISO Pascal as the underlying, or carrier, high level language. The International Standards Organisation definition of Pascal is a very basic and restricted form of the language, conforming to the original definition in most respects, and the vast majority of Pascal compilers will compile ISO Pascal/SLIC programs without modification. SLIC is grafted onto the existing language by including in the sub-program library of the language a series of new procedures, the SLIC procedures. A test program consists, therefore, of a Pascal program with the SLIC statements appearing as calls to these procedures.

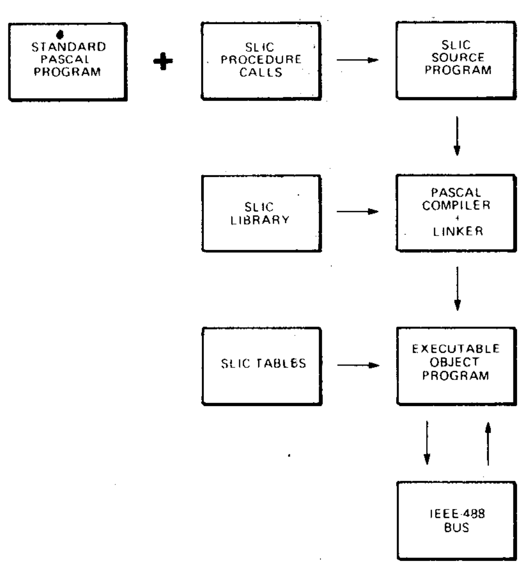

FIGURE 2 PASCAL AND THE STANDARD LANGUAGE FOR INSTRUMENT CONTROL

At execution time, these procedure calls invoke a runtime package, also written in the carrier language, which causes test resources to be controlled, usually but not always, via the IEEE 488 bus.

An important design aim and feature of SLIC is the reduction of problems caused by the obsolscence of the components of an automatic test system. SLIC does not contain the particular commands for resources used in an ATE, but translates from the statements to the instrument commands by means of tables which are held in source form in memory or on disk. It is therefore possible to alter the resource performing a particular function by preparing a new instrument table, a relatively trivial task. Use of SLIC thus allows resources of the same generic type to be changed when required without modification or recompilation of the test program. The general elements of a Pascal/SLIC program are shown in Figure 2.

The names and functions of SLIC verbs, nouns and noun modifiers have been chosen to give a close correspondence between SLIC and IEEE ATLAS. The production of an ATLAS to SLIC translator is therefore facilitated, allowing the industry standard specification language to be closely coupled with a flexible and powerful machine dependent language.

The availability of standard high level language resources makes SLIC especially suitable for use in development applications. Testing can thus be made consistent and synergistic throughout the life cycle of the product, from development through production, to field repair.

The Operating System

Application test programs are prepared and executed under a version of UNIX. UNIX was chosen for the facilities offered, the fact that it represents an industry standard operating system and is commercially available at a low cost. In the particular implementation chosen real time features are available sufficient for instrument control via the IEEE 488 bus. For more demanding operations an alternative real time operating system is available.

Sub-Contractor Involvement

As previously stated, for a common factory/field policy to show maximum benefit, all contractors involved in the production of weapon system components must follow the same policy. For this to be achieved the policy must be both technically and commercially attractive.