ATE Technology Trends

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ABSTRACT

Automatic Test Equipment technology has evolved considerably over the years, matching the diagnostic test requirements of advancing avionics. This evolution has been fueled by significant developments in computing, software and instrumentation technology. It is important to recognize the characteristics of avionics and ATE that have driven this evolution in order to postulate ATE technology trends for the future.

Avionics evolution to well-partitioned, modular, bus-oriented architectures has demanded ATE that is capable of dealing with bus test techniques, built-in test analysis and system emulation. Avionics use of digital electronics technologies has required ATE to accommodate Automatic Test Pattern Generation test approaches. Avionics are on the move again with the line replaceable module (LRM) soon to appear in both commercial and military aircraft.

ATE control has evolved from dedicated sequencers, to mini-computers and now to personal computers. Computer systems are more powerful in processing and memory capabilities than ever. ATE software has moved to use commercial operating systems and standard languages. ATLAS remains the internationally recognized test program language for military and commercial airline support, but new initiatives to adopt an Ada Based Environment for Test (ABET) seems to be gathering steam. Test documentation has an interesting future, moving from paper to hypermedia.

ATE instrumentation has moved from unique designs to standard rack-based instruments, and are now being re-tooled into instrument-on-a-card form factors. The VXI and MMS standards are having as profound effect on instrumentation as the IEEE-488 bus did in the 1970's.

This paper explores current state-of-the-art ATE hardware and software. It focuses on trends in test technology and their effect on future ATE. The paper addresses specific application areas with potential for international industrial involvement.

INTRODUCTION

It is interesting to take a step back and take a look at the big picture sometimes. If we take a wide angle shot at Automatic Test Equipment and avionics history, some truly amazing technology trends become apparent. Several of these trends actually repeat over the long term. Others indicate a unique and elegant departure from tradition, and may mark a new direction for ATE technology in the future.

ATE - THE EARLY YEARS

Electronics & Space Corp. has been at the forefront of ATE development since the mid-1950's, when semi-automatic and manual test of avionics began in a major way. This started with dedicated test stands for all sorts of electrical and electo-mechanical systems. It was driven by increasing sophistication in electrical systems on military aircraft, such as the B-58.

The 1960's saw more and more dedicated test systems, but trends toward automation in testing were clear. The USAF embarked on a major program called General Purpose Automatic Test System (GPATS), aimed at providing a universal ATE for a variety of avionics LRUs and SRUs. GPATS was the crowning achievement in automation of testing in its time. It consisted of up to 20 racks of test instruments, all individually custom designed. Instruments were controlled via peculiar busses, and sequenced by punched tape instructions. GPATS pioneered the building block approach to ATE, and was the first instance of Test Requirements Documents to document avionics test parameters. A high level language called PLACE was used to write some Test Program Sets in much the same way ATLAS is used today, but most were written in a machine code.

The U.S. Navy initiated its own ATE development called Versatile Avionics System Tester (VAST). It had no commonality with GPATS, but used a similar building block approach for its uniquely designed test resources. It was able to take advantage of one of the initial mini-computers as a controller, so had a more robust TPS language called VITAL. Avionics began to have more digital electronics, so VAST was made to support the first Automatic Test Pattern Generators (ATPG) as a way to implement this testing. Both GPATS and VAST are still used to this date for support of avionics in the USAF and Navy.

The commercial airlines were also using semi-automatic testing for their avionics in the 60's. Like the USAF and the U.S. Navy, they saw a need to standardize testing procedures that they received from a variety of suppliers. In 1966, the airline's standards organization, ARINC, coordinated the first draft of the Automatic Test Language for Avionics Systems (ATLAS) standard, ARINC-416. This was developed as a set of standard syntax for writing test procedures that would be equally readable by avionics maintenance people and ATE systems.

EXPLOSIVE GROWTH OF ATE SYSTEMS

The introduction of several commercial mini-computers in the late 1960's gave way to an explosion of mini-computer based ATE systems in the 1970's. Most of this ATE employed commercial test instrumentation that had been developed by instrument suppliers for laboratory use. Instruments were controlled by all sorts of electronic bus schemes, usually based on binary coded decimal (BCD) commands. The late 70's saw the emergence of the Hewlett Packard Interface Bus (HPIB) as a quasi-standard for instrument interfacing. A strategy developed to promote this as an IEEE standard (488), which led to industry wide acceptance of this bus for instrument control to this day. Interfacing to this bus hardware in the late 70's was a challenge, requiring significant design and integration efforts.

Changes in LRU technologies also began to appear in the 1970's. LRUs became significantly more complex, as avionics suppliers were asked to push the limits of their respective technologies. As the enabling technologies in integrated circuits arrived, LRUs adopted more digital control, memory and processing capability. LRU control and communication in an integrated avionics sub-system was implemented with MIL-STD-1553 or ARINC-429 bus schemes. Initial designs exhibited high failure rates, poor built-in test (BIT), high cost and high re-test OK (RTOK) rates. As the 70's proceeded, designs exhibited better partitioning of internal LRU functions to allow for more effective ATE testability. Military ATE pushed the limits of available computing, software and instrumentation technology. Fully automatic test systems tested everything from DC to light, pneumatics to jet engines. The model of ATE architecture employed was basically the same in all cases, using a mini-computer controller for instruments interfaced to a Unit Under Test (UUT) through an electro-mechanical interface sub-system. Some innovations were made in this period to explore technologies for universal pin electronics, dual port testing, and various human interface alternatives.

The ATE of the early 1970's used a variety of test programming languages, including Basic, OPAL, ELAN, and many dialects of ATLAS. The proliferation of test languages in military ATE led the U.S. DOD to adopt the ATLAS language as its single, approved, test language in the mid-70s. The IEEE took over management of the ATLAS standard from ARINC, and formalized it into the IEEE-416 Standard. The Ministries of Defense for five nations felt a need to limit redundancies and ambiguities in this standard by issuing the IEEE-716 Common ATLAS Standard as a subset of the 416 standard.

THE SECOND STANDARDIZATION OF ATE

In the late 70's and early 80's, the three services in the U.S. recognized the logistics nightmares, and operational costs, imposed by the proliferation of ATE hardware, software and Test Program Sets (TPSs). Each service tried to limit the introduction of new forms of ATE to their inventory. The Army limited applications to the AN/USM-410 EQUATE and USM-465 testers. The Navy, similarly, identified the "Family of ATE" in their inventory for any test applications.

MODULAR AUTOMATIC TEST EQUIPMENT

The USAF initiated a broad and ambitious Modular Automatic Test Equipment (MATE) standardization program, aimed at defining a set of standards and guidelines for all USAF ATE systems. This effort developed many significant ATE related standards that are used beyond the USAF, including: the refinement of the IEEE-716 ATLAS standard; the definition and implementation of the Control Interface Intermediate Language (CIIL), which finally set standards for data protocol on the IEEE-488 bus controlling instruments; UUT interface connection and interface test adapter standards; TPS standards for coding, design and documentation; operator interface standards; standard ATE control and support software; and standard computer architecture. Through the 80's, the USAF implemented over 250 MATE test systems and thousands of TPS applications. This sparked intense industry participation in these MATE programs, evidenced by typical participation by over 250 representatives at most MATE User Group meetings, which were held every 6 months. Instrument suppliers and ATE integrators participated aggressively to assure their instruments and ATE systems complied with MATE requirements. MATE achieved overwhelming success in taming TPS development, integration and maintenance issues. TPS businesses were spawned by both industry and military Air Logistics Centers to accommodate test support application development on these standard MATE systems.

The USAF became frustrated in the late 1980's when it found the MATE standards too restrictive to accommodate portable ATE systems. MATE standards were build around a model of ATE systems that employed rack-based instrumentation and interface connection hardware that limited downsizing. Industries' MATE User Group responded with an intensive effort to define changes to the MATE guides to allow use of instrument on a card technology in place of rack-based instrumentation. This initiative was adopted by an industry consortium and the IEEE, which has resulted in the IEEE-1155 VXI instrument on a card standard. This effort has virtually re-shaped the instrument industry's focus in the 1990's, with every instrument manufacturer endorsing the VXI standard, and offering compliant instrument modules.

While VXI accommodates analog and digital frequency instrumentation needs, RF and microwave test resources demanded unique requirements. Hewlett Packard responded with the definition of the Modular Measurement System (MMS) for such modular RF and microwave instruments, such as spectrum analyzers, waveform digitizers, power meters, RF synthesizers, etc. As they had done with the HPIB in the 1970's, HP made the MMS an open, non-proprietary architecture to encourage its adoption as a standard used throughout industry. While this has not reached the acceptance levels that VXI has, it is recognized as the most robust modular microwave implementation system available in the early 1990's.

INTERMEDIATE FAMILY OF TEST EQUIPMENT

Just after the USAF initiated the MATE program in the early 80's, the Army started their ATE standardization program, originally as DS-ATSS, then ATSS, and finally IFTE (Intermediate Family of Test Equipment). The Army's special constraints of operating the ATE in an S280 shelter made this ATE adhere to some unique and demanding environmental and operational requirements, which may be the reason it has taken 10 years to get IFTE to operational test status. While this ATE uses instrument on a card technology to achieve downsizing, its implementation pre-dates the development of VXI, and uses an early implementation of some MMS instrumentation. IFTE implemented several new operator interface technologies, including voice synthesis, color graphics and on-line video disk documentation. IFTE also developed a unique UUT interface to the ATE, aimed at improving interconnection reliability, although no other ATE is likely to use this unique contractor's approach.

The S280 version of IFTE was defined to have three siblings: a commercial equipment equivalent (CEE) of the S280 version for TPS development, an Electro-optics Test Augmentation, and a Contact Test Set (CTS). While the CEE is developed, the EO augmentation is yet to be defined. The CTS went through three iterations and two contractors before the Army was confident the design was acceptable, although it will not be fielded until the mid-90's. These CTS iterations were typical of the test industries' pursuit to implement Artificial Intelligence Expert System technology into ATE in the late 1980's. While incorporating an Expert Diagnostics System into ATE was easily accomplished, it proved very difficult to gather and machine the expert's intelligence needed to make these systems work.

CONSOLIDATED AUTOMATED SUPPORT SYSTEM

On the heels of the USAF MATE and Army IFTE developments, the Navy embarked on the most agressive ATE standardization project to develop a replacement for all U.S. Navy Aircraft Carrier and shore based ATE. This Consolidated Automated Support System (CASS) was primarily driven by the needs of the Carrier based test requirements of the Naval Air Command, so a suite of six, rack-based, mainframe ATE stations developed out of these efforts, and are now in limited initial production.

Two portable ATE variants were planned, however, the CASS Organizational Level Tester (COLTS) was terminated, and the CASS Portable Test System (CPTS) design is languishing in requirements confusion. The mainframe CASS employs a unique architecture and software system. While it uses instrument on a card technology, its design pre-dated VXI standards, and so uses unique designs and bus architectures. Interfaces to instrument assets departs from the traditional use of the IEEE-488 bus, using an Ethernet bus instead.

LRU TECHNOLOGY ADVANCES

Through the 1980's, LRU designs have focused on combining functions; shrinking size, weight, and power; and are evolving toward integrated avionics suites. Discrete LRUs communicate interactively on better isolated MIL-STD-1773, or STANAG-3510 fiber-optic buses. Significant improvements and flexibility in LRU performance have been made possible through unprecedented advancements in digital processor and memory technology. This has allowed implementation of improved BIT, without suffering LRU size, weight or power compromises. The Mean Time Between Failure (MTBF) of avionics has been steadily improving, with some LRUs achieving over 2,000 hours MTBF. This changing LRU profile is re-shaping the definition of some LRU maintenance requirements, and the corresponding ATE needs. Only LRUs that have been determined to be mission critical require support at the intermediate level of maintenance. The rest of the LRUs employ a two-level maintenance strategy.

For some aircraft, this has resulted in significantly downsizing the ATE requirements. Such ATE requirements were implemented in the late 1980's and early 1990's for the AV-8B, GR-MK-5, F-15E and MC-130 mission critical LRU support. Rugged, portable ATE was developed employing a fresh, functional testing approach to testing LRUs, taking advantage of the distributed processing architecture possible with micro-processor computing technology. This Functional ATE departed from the traditional, parametric test techniques used in virtually all previous ATE systems. Functional testing puts the LRU in the electrical signal environment, that the LRU sees in the aircraft, while its performance is evaluated and failures diagnosed. Distributed processing in this ATE has reduced the test times for complex LRUs from several hours to under 30 minutes.

NEW AGE ATE TECHNOLOGIES EMERGE

Computing power of personal/desktop computers in the 1990's is changing the way we look at ATE controllers. Processing power, disk capacity, memory, and peripherals have all increased in capability, capacity and standard interfaces. Operating software on these machines has been honed by an incredible commercial user community, far beyond the maturation achieved by any mini-computer used previously in ATE. Operator interfaces today are dominated by user-friendly, graphic, windows-oriented displays, and interactive mouse, track-ball or touch screen input devices. Integrators of these technologies are creatively applying them to related test domains. Interactive video disk based training systems utilize the same desktop computer system in the ATE to provide an on-demand, user-paced training package for operators and maintainers of complex avionics. These systems employ full motion video and audio integrated in a hypermedia presentation system to give a powerful and directed display of information appropriate to the needs of the operator. Portable Maintenance Aids (PMAs) with such hypermedia systems employ the latest in rugged, portable computing technology. PMAs use CD ROM and touch-sensitive LCD screens for storaging and displaying electrical or mechanical diagnostic and repair information, on-site.

The ATLAS language is being both challenged and defended in the early 1990's. Commercial, windows-oriented software programming packages, like OCTS, LabView/LabWindows, and HP's Visual Engineering Environment (VEE), are focused on improving certain aspects of programming instrumentation in an ATE or desktop lab environment. The USAF has embraced an industry initiative to foster the use of the Ada Language for test programs. A task has been given to the IEEE SCC 20 ATLAS Committee to define a standard for an Ada Based Environment for Test (ABET). Even though no ATE systems or TPSs have been developed for ABET, the USAF has given direction that all future ATE will comply with this emerging standard. Needless to say, industry is responding to assist in the ABET definition, but compliant ATE is probably several years off.

The ATLAS language is still the primary military and commercial ATE TPS language. It is being supported by system integrators, as well as commercial software suppliers. Several commercial software houses offer full ATLAS support packages on a variety of computing platforms. System integrators are using these packages, or their own, to configure ATE systems for small to large scale applications.

The commercial airlines have once again decided to confront proliferation of ATE and test languages. In the late 80's, they tasked the ARINC organization to develop the Standard Module Avionics Repair and Test (SMART) system to help that industry standardize on ATE that is eventually provided to airline maintenance organizations for support of avionics. This effort has produced a standard control and support software for the airline version of ATLAS (now back under the control of ARINC as the ARINC 626 Specification), that is targeted to several different computing platforms. While the airlines and ARINC developed this software, airline and avionics suppliers are reluctant to require this in their ATE.

As part of this effort, the airline community has defined a standard ATE TPS interface, documented with the ARINC-608A Specification. Instrument suppliers have machined this specification into compliant products, which are just now showing up in prototype ATE systems. This interface may offer an internationally accepted ATE interface for TPSs in the future, for both commercial and military ATE systems.

VXI and MMS based instrumentation are just now emerging in deliverable ATE systems. They appear to be the instrument of choice for most automated test requirements. The instrumentation industry has invested significantly in this technology as the logical evolution of their rack based armada of test and measurement devices. While the late 80's saw the introduction of the initial VXI and MMS modules, these were naturally limited to the very basic of measurement needs. These were typified by VXI card racks, controllers, multimeters, counters, A/D, D/A and switching modules. The early 1990's have seen far more complex instrumentation converted to VXI, including function/pulse generators, digitizers, digital word generators, etc. MMS modules are now available to provide RF synthesis, more comprehensive spectrum analysis, and even microwave transition analysis. These advances demonstrate the maturity and acceptance level of these technologies. VXI and MMS are having as profound an effect on ATE in the 1990's as the IEEE-488 bus did in the late 70's.

However, most new ATE systems are definitely not ignoring the IEEE-488 based instrument world, since there are still many important instrument technologies that are not now, and may never be converted, or compatible with VXI or MMS. IEEE and industry have responded to the data interface protocol issues that the USAF MATE program addressed with their CIIL standard. Instrument supplier agreements are focused on the adoption of the Standard Control Protocol Interface (SCPI) definition, as the industry replacement for CIIL. This is an important step in standardizing the data protocol on the 488 bus.

AVIONICS TECHNOLOGY CONTINUES...

Avionics are taking yet another turn at evolution in the 1990's. Both military and commercial avionics systems are being integrated to unprecedented levels. U. S. military and commercial aircraft manufacturers have ambitious plans for new aircraft that modularize avionics LRUs into an integrated avionics rack, populated with Line Replaceable Modules (LRMs), rather than discrete LRUs. Processing functions are centralized to manage the needs of several LRMs. LRMs become coordination points for sensor and emitter functions. LRMs communicate over a very high speed backplane, rather than serial buses. Integrated testability is being built into the design of these types of systems using advanced boundary scan testing techniques. SRU integration is reaching such levels that traditional methods of digital testing using ATPG techniques will need significant advances to keep pace.

While this level of avionics integration is significant, its application is a long and expensive process that will be primarily limited to specific new aircraft platforms. Nevertheless, it is a trend to be watched for its impact on ATE.

SUMMARY

Technology trends in ATE have largely been driven by computing, instrument and switching sub-system evolution. There are certainly some significant advances that enabled ATE to move forward at a much more rapid pace. These include: the mini-computer and its evolution to the micro-processors and the personal/desktop computer; the ATLAS test language; lab based instruments; the IEEE-488 bus as an architectural backplane for ATE and its integration into commercially available instruments; the standardization efforts of the MATE, CASS, IFTE and SMART programs; and the emergence of functional test approaches in portable ATE which led to the VXI and MMS instrument standards.

As we move further into the 1990's, avionics will continue to demand the very best performance of ATE systems. It will be interesting to see how the latest technologies in computers and software, modular VXI and MMS instrumentation, and functional test techniques will evolve to address these requirements.

Biography - Mr. Gooding is the Director for New Program Development for the Automatic Test Equipment Product Line of Electronics & Space Corp. He has been responsible for engineering design, engineering management, program management and business development for many military and commercial ATE systems and TPSs over the last 21 years. He received his B.S. Degree in Electrical Engineering from the University of Illinois in 1971.