Advances in Avionics Testing to Improve Aircraft Readiness and Mission Reliability

William A. Ross
NAVAIRSYSCOM PMA-260D
Naval Air Systems Command
47123 Buse Road, Unit IPT, Suite 349
Patuxent River, Maryland 20670
United States of America

william.ross@navy.mil

1.0 BACKGROUND

In the early 1960s, the US Department of Defense (DoD) first defined three levels of repair: depot, intermediate, and organizational. Generally, on-system repairs and maintenance are a function of organizational level units and off-system repairs are generally performed by intermediate levels of maintenance. Intermediate-level maintenance also includes automatic and manual testing, printed circuit board repair, and fabrication or manufacture of some components. Depots perform major overhaul and complete rebuilding of parts. In practice, depot and intermediate repairs for avionics systems are often equivalent since both levels of maintenance use the same or similar testers and test programs.

The single largest problem facing automatic testing in DoD is the proliferation of automatic test equipment that occurred from the 1960s to the 1990s. Typically each new weapon system would develop and field its own set of testers. This led to a situation where there are over 400 different test systems in use across DoD. This proliferation problem led to implementation of DoD-wide Automatic Test Systems (ATS) policy.

The DoD ATS policy states that:

> "To minimize the life cycle cost of providing automatic test systems for weapon systems support at DoD field, depot, and manufacturing operations, and to promote joint service automatic test systems interoperability, Program Managers shall use approved DoD ATS Families as the preferred choice to satisfy automatic testing support requirements. Commercial-off-the-Shelf (COTS) solutions that comply with the DoD ATS Technical Architecture should only be used if the Milestone Decision Authority concurs that an approved DoD ATS Family will not satisfy the requirement. Automatic Test System selection shall be based on a cost and benefit analysis over the system life cycle."

The policy lists the approved DoD ATS Families (Navy's Consolidated Automated Support System (CASS), Army's Integrated Family of Test Equipment (IFTE), the USMC's Marine Corps Automatic Test Equipment Systems (MCATES) and the US Air Force/Navy Joint Service Electronic Combat Systems Tester (JSECST)).

Also, four goals have been established to guide DoD's way forward as it modernized its ATS:

- To reduce the total acquisition and support costs of DoD ATS.
- To improve the inter- and intra-operability of the Services' ATS functions.
- To reduce logistics footprint.
- To improve the quality of test.

Joint Service teams are working with industry to define needed interface standards (see Figure 1 below) that will help us meet our four "goals" and to develop and implement next generation test technologies. As legacy testers are modernized and the DoD moves to the next generation test systems, the number of tester types will be greatly reduced while inserting or selecting technologies which will make our systems cheaper, faster, scalable, interoperable, more capable, smaller and more mobile.

2.0 ATS ARCHITECTURE FRAMEWORK

Architecture requirements for all DoD systems, including ATSs, are detailed in the Defense Information Technology Standards and Profile Registry (DISR), the replacement for the DoD Joint Technical Architecture. The DoD ATS Framework, Figure 1 below, is a mandatory requirement for all DoD ATS acquisitions and contains the Key Elements and associated specifications and standards that form the open architecture approach for DoD ATSs. The ATS Framework currently comprises 24 key elements in various stages of maturity, and will continue to evolve as test technology evolves. A Joint Services Framework Working Group has been established to continually assess the framework and to work with industry and standards bodies to develop and demonstrate the remaining undefined specifications and standards to satisfy ATS Framework requirements.

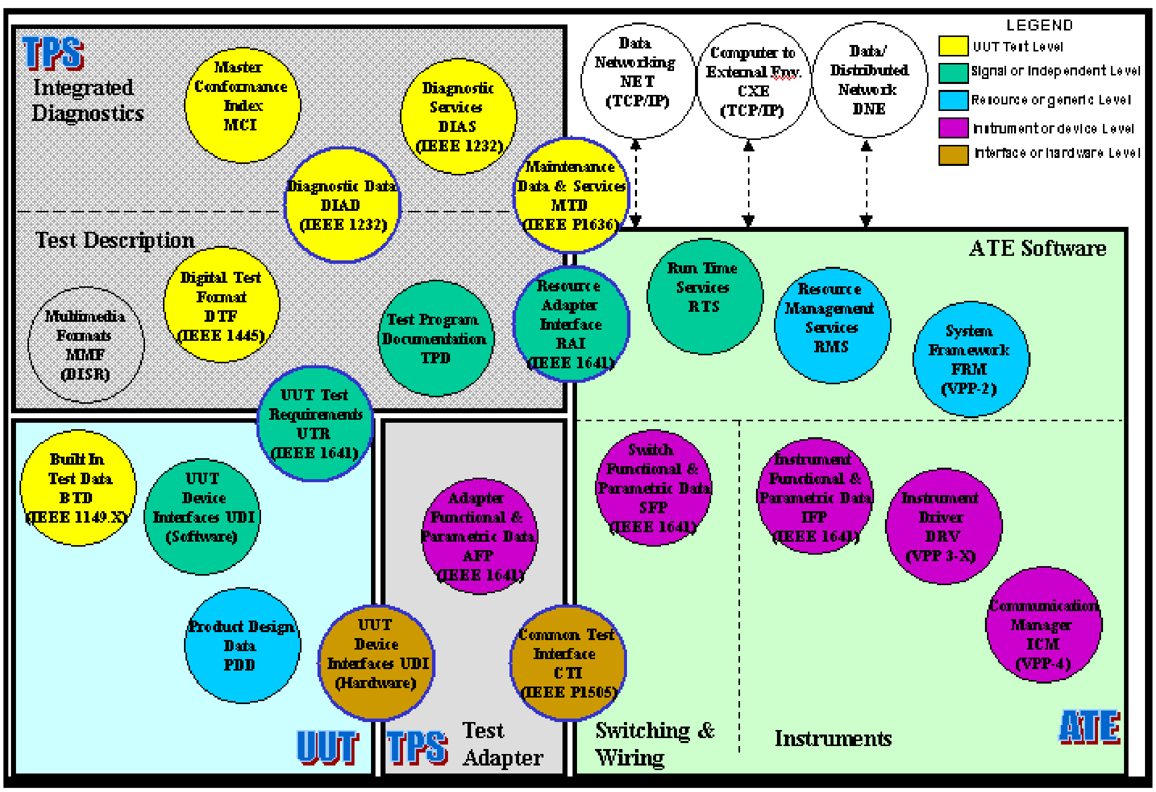

Figure 1 – The DoD ATS Framework.

3.0 TEST TECHNOLOGY DEVELOPMENT

DoD's ATS strategy is to jointly develop and insert test technology while leveraging the Research and Development efforts of the Services, industry and coalition nation partners. The Services work closely with industry through many organizations and consortia. The Joint Service Next Generation Test Technology (NxTest) Team periodically holds test technology reviews with industry, and has developed close working relationships with the ATS leadership in coalition partner countries.

There are two reasons for developing test technologies: (1) to add capability to our test systems to meet emerging weapon system test requirements (the technologies must be four times as accurate as the weapon system component being tested), and (2) to replace existing test capability to address obsolescence, improve quality of test, improve through-put, satisfy new operational needs and provide scalable, mobile and smaller testers.

Following are some of these emerging hardware and software technologies being demonstrated and, in some cases, implemented by the Services in DoD. These technologies offer unprecedented opportunities for improvement in warfighter support throughout DoD including improved aircraft readiness and mission reliability.

3.1 Advanced Synthetic Instruments

Test and measurement requirements have been traditionally satisfied with a suite of test instrumentation that required a single test instrument for each type of test to be performed on any electrical/electronic signal. Present day commercial technology allows a signal to be converted into a digital representation that can subsequently be analyzed using high-speed digital signal processing (DSP) techniques to verify the signal's characteristics. This approach to signal characterization is known as synthetic instrumentation, which can be thought of as "software instruments". As a result of implementing Synthetic Instruments, it is now possible to satisfy the signal's measurement requirements with one synthetic instrument thereby eliminating the need for numerous, dedicated, single-function measurement instruments. Synthetic Instruments based test systems will facilitate the introduction of new test capabilities via software modification verses the introduction of peculiar new hardware and software. Synthetic Instruments will also allow for scalable systems capable of supporting all levels of maintenance.

Synthetic Instruments eliminate redundant Automatic Test Equipment (ATE) overhead, hardware, and ATE functionality, and create needed instruments/functions via software. For example, the CASS Modernization Program may replace at least 12 existing separate RF stimulus & measurement instruments with a small Synthetic Instrument package.

Synthetic Instrument demonstration programs are currently underway. The expected benefits include at least a 65% decrease in hardware (and associated support costs) and footprint.

3.2 Programmable Serial Bus Test

Current test systems require a separate test instrument card for each bus type used by avionics systems. We are working with industry that has developed a synthetic Bus Test Instrument (BTI) capable of assuming a wide range of serial bus protocols required in military and aerospace test environments. The BTI possesses built-in "morph-ability" to assume the bus protocol language of serial communications buses used in operational or factory environments. Because it is able to both emulate and test serial buses, it eliminates the need for a broad range of individual, protocol-specific test instruments.

Each BTI has four independent bus modules that support MIL-STD-1553, MIL-STD-1773, TIA/EIA-RS-232, TIA/EIA-RS-422, TIA/EIA-RS-485, H009, ARINC 429, and more. With an innovative load-and-forget programming environment, native support for popular buses, and the flexibility to emulate custom buses or variations of standard buses, each of the four bus modules (channels) provides the option to emulate a wide variety of serial bus communications and test those protocols, at any time.

The expected benefits are a reduction in footprint (5 or more cards are replaced by 1 card) and higher quality tests with increased capability.

3.3 Reusing Diagnostic Data

Emerging software technologies based on a Windows-based operating system and a browser-based test program set (TPS) developer interface using eXtensible Markup Language (XML) technologies will have many benefits, not the least of which is facilitating reuse of diagnostics data. The Automatic Test Markup Language (ATML), a subset of XML developed by industry and DoD for test software development, will facilitate improved integrated diagnostics. Standardized XML File Structures, Schemas and Tags will be utilized in a .NET environment as interface control standards between weapon system platforms and maintenance systems for high fidelity interoperability and to pass diagnostics data both up- and down-line.

The new environment will also provide the ability to develop Knowledge-Based TPSs using Test Requirements Modeling. These significant software advances open the door to dynamic test strategies to make use of platform maintenance information to direct the flow of activity during TPS execution. Directed TPSs will reduce the time to repair by sending the test software to the most likely cause of the failure instead of performing a full end-to-end run. Test strategies can be revised on the fly based on historic and real-time maintenance data.

“Smart” TPS concepts are being developed for improved test program performance. These use weapon system platform Built-in-Test (BIT) data to direct a start point in a test program based on this BIT data and yield a 25% runtime savings. Historical maintenance data captured automatically is reused to improve diagnostics decisions and to reduce fault isolation ambiguity. The Smart TPS project is currently being demonstrated at Naval Air Station Lemoore, California on the F/A-18 APG73 Radar Receiver and Super Hornet Flight Control Computer. Results to date have been promising, and plans are underway to expand Smart TPS to other weapon systems including V-22 and H-60S. The F/A-18 platform has also implemented Smart TPS with Raytheon to support a commercial repair contract for the ALR-67 weapon system.

3.4 Multi Analog Capability (MAC)

The MAC Instrument Subsystem is the technological breakthrough that is allowing traditional ATE to perform as functional testers. A single C-size VXI card provides 32 channels with 6 test instruments behind each test pin. Each of these 32 independent channels can function simultaneously as one of six instruments: function generator, arbitrary waveform generator, digitizer, digital multimeter, limit detector, and timer counter. Additionally, each channel can share triggering with every other channel. This capability is being introduced into DoD testers with the first application being several F/A-18 units formerly tested on the Intermediate Avionics Test Set which are being rehosted to the Navy’s CASS. The functional test requirement would previously have been impossible to satisfy since CASS is a serial parametric tester. However, with three MAC cards installed, CASS now has 576 instruments that can all be used simultaneously making CASS capable of parallel, functional test.

Although the MAC provides tremendous improvement in parallel processing capability, the traditional analog instruments cannot be 100% replaced as the current MAC has only 80% range and accuracy of the traditional instruments. An enhanced MAC version that sacrifices pin count for greater range and accuracy has been developed to replace the current MAC.

The demonstrated benefits include a significant reduction in some test program runtimes and a real-time functional test which will yield higher quality diagnostics and improved test verticality.

3.5 High Density Analog Instrument

The High Density Analog Instrument provides a parallel stimulus and measurement capability for high-speed functional and operational analog testing. It has eight single-ended system-per-pin channels, including up to sixteen 200 MHz universal timers, 50 M Sample/second 12-bit digitizers and 50 MHz 12-bit arbitrary waveform generators. It also includes a 6.5-digit digital multimeter and a 2-channel 500 MHz digital sampling oscilloscope. The High Density Analog Instrument accurately emulates complete system-level operation of the traditional test instruments.

Since this single card can completely replace several traditional instruments on a card, the expected benefits are significantly reduced test times (parallel testing) and reduced footprint.

3.6 Common Tester Interface (CIT)

An Industry/Government Working Group is developing a common standard pin map for the physical mating of the interface device to the automatic tester. Specification requirements include scalability, frequency coverage from DC to light, cost, reliability, etc. An IEEE standard P1505 is in process.

The key benefit of implementing the CTI is that it for the first time could provide a standard test system interface to help effect interoperability across DoD testers. The CTI is scalable, allowing a smaller interface on smaller systems while allowing the smaller test system's test program adapter to interface with a larger test system using CTI.

4.0 SYSTEM-LEVEL DEMONSTRATION

The Agile Rapid Global Combat Support (ARGCS) Advance Concept Technology Demonstration project is demonstrating most of the test technologies discussed above in a combat support system that will provide electronic systems support at all levels of maintenance. ARGCS can be used to test, troubleshoot, and repair a wide range of digital, radio frequency, analog, and electro-mechanical units. The concept is a DoD-common core system using common control and support software with complementing/augmenting power, and stimulus and measurement hardware as necessary to meet specific test and diagnostics requirements. Integrated diagnostic feedback capability will be included so that diagnostic data captured during the maintenance cycle can be reused.

Reconfigurable and scalable, ARGCS will be easily and quickly deployable worldwide with reduced airlift and logistics footprint requirements. A key performance parameter will be interoperability among weapon systems of not only the US Services but also those weapon systems used in coalition partner nations.

At the completion of the ARGCS development effort, the system will be evaluated starting in April 2007 as part of the Joint Military User Assessment and the End User Evaluation.

5.0 AN EXAMPLE: THE US NAVY STORY

The Consolidated Automated Support System (CASS), the Navy's standard automatic test systems family, is being fielded to replace over 30 legacy automatic testers. Analysis shows that CASS will bring a reduction in Total Ownership Costs of $3.8 billion. To date, CASS has fielded over 600 mainframe testers and will ultimately support almost 3,000 Navy and Marine Corps avionics and electronics units. The CASS program was initiated in the early 1980s in response to many problems with automatic testing identified by a special study team chartered by the Secretary of the Navy. The actual design of CASS dates from the mid- to late-1980s. The initial CASS stations were ordered in 1990 and CASS entered the fleet in 1994. The last of the 613 production Mainframe CASS stations was ordered in 2002 and delivered in December 2003. The initial CASS stations are 15 years old. Modernization of the early CASS stations is driven by several factors including instrument age and associated obsolescence, condition of the station infrastructure (rails, wiring, etc), inflexibility of the architecture, and emerging test requirements that cannot be economically satisfied by the current CASS station configurations.

Goals of the CASS Modernization Program, called eCASS, include incorporating the test technologies needed to satisfy weapon system testing and operational requirements, implementing a modern open architecture based on the DoD ATS Architecture Framework to facilitate future upgrades, ensuring that test programs are fully transportable, providing for interoperability with other Services, and reducing ownership and obsolescence costs. The Navy's vision for eCASS is that it will have a much smaller footprint with more test capability; have faster run times; implement multi-lingual test environments; facilitate factory-to-field use of test software; be interoperable with other Services' ATE; be more scalable to needs; reduce acquisition and support costs; implement the "Smarter" diagnostics concepts; provide faster and better diagnostics; and reduce the "no fault found" rate.

6.0 IMPACT OF THE TEST TECHNOLOGY DEVELOPMENTS ON WEAPON SYSTEM READINESS

In addition to satisfying DoD's four main ATS goals (reducing ownership costs, facilitating interoperability, reducing footprint, and improving the quality of test), the test technologies discussed in this paper improve weapon system readiness by reducing the turn-around time for off-system repairs. Mission reliability will be improved because the new test technologies will enable the next generation testers to provide a more thorough verification of system readiness. Since many test instruments will be replaced by a few synthetic instruments, the new testers will be smaller and have fewer test assets. This will lower acquisition and support costs and reduce logistics footprint, enabling the systems to be more easily be transported where needed world-wide.