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Automatic Testing in the United States Air Force

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Abstract

The need for standardized Automatic Testing Equipment in the United States Department of Defense has brought about new policies and procedures within entities like the United States Air Force. The diversity and lifespan of systems such as jets, missiles, drones, and other electronics have brought on the need for a new system known as the Versatile Depot Automatic Test Station, or VDATS. The VDATS handles the automatic testing of replaceable digital circuits from different systems. I was introduced to this system firsthand during my time as an intern at Tinker AFB, Oklahoma. This new standardized approach to testing a diverse base of mission-critical systems has impacted the Air Force in a number of positive ways, and allows for a future of focused development and maintenance.

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I. Introduction

In every tech-related industry, the rapid development of computing power and complexity requires an equally fast advancement of innovative testing measures. For digital circuits, Automatic Testing Equipment (ATE) is essential to maintain the consistent and dependable functionality that companies and organizations tirelessly work for. New technology brings new challenges, especially when these challenges are scaled greatly for huge organizations like the Department of Defense (DoD). Entities within the DoD-including the United States Air Force-face unique hurdles on the race to ensure dependability and efficiency in war-fighting efforts. However, the Air Force is taking is taking the right steps to combat these new challenges with the introduction of powerful new testing systems. The Air Force has answered with the Versatile Depot Automatic Testing Station (VDATS), which is currently utilized by various depot maintenance centers such as the 76th Software Maintenance Group at the Oklahoma City Air Logistics Complex. The standardization of these testing systems will impact the Air Force for years to come, as the battle for war-fighting dominance demands readiness from the country's cutting-edge systems.

II. Air Force Testing Challenges

A. Diversity of Systems

The Air Force has an enormously wide range of aircraft with an average age of 23 years. [1] The age of aircraft that needs to be tested and maintained ranges from brand new with the F-35 Lightning II, to over 50 years old with the B-52 Stratofortress, introduced in 1955. This is a wildly eclectic group of technology that needs to be tested constantly for mission-critical capabilities needed for war-fighting. Put simply, the Air Force is responsible for keeping 50 year-old technology fully functionally while simultaneously maintaining cutting edge systems. The F-35 consists of over 8 million lines of software code. This is over four times as much code as the next most recent fighter jet, the F-22 Raptor, alluding to the exponential increase of computers involved in future aircraft [11]. Furthermore, planes make up just one portion of the weapon systems and tools that need to be maintained. The USAF has bombs, missiles, spacecraft, and other mission equipment that utilizes digital systems, such as the Joint Direct Attack Munition (JDAM), an air-to-ground smart-guiding system for bombs. To display the diversity and quantity of Air Force technology, a list of systems that currently require testing can be seen in Figure 1 [6]. Having automatic testing equipment is pertinent in the rapidly advancing defense industry as DoD leaders need to decide which advances can and should be integrated into Test Program Set (TPS) management activities, which will be explained in this paper.

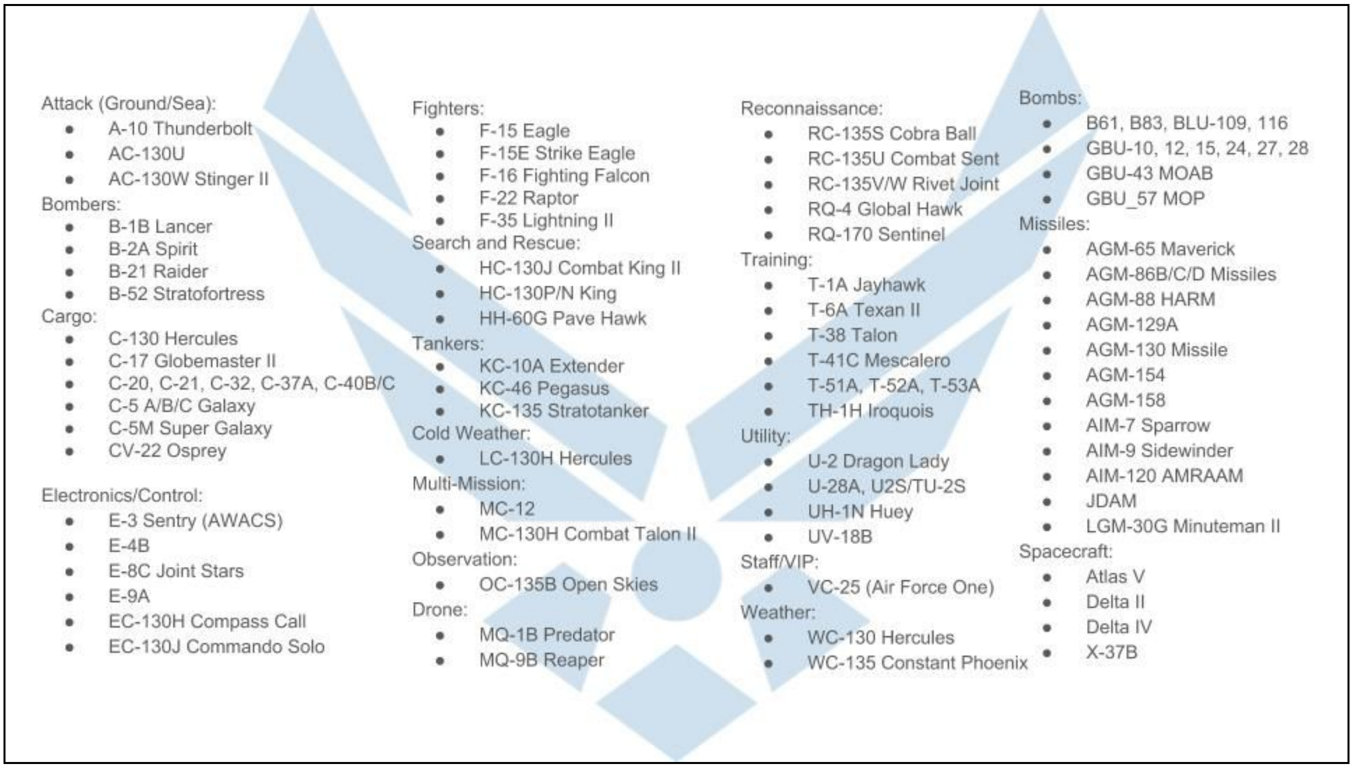

Figure 1: Diversity of systems [6]

B. Multiple Owners

Quite often, multiple AF entities hold responsibility for the same TPS. Specifically, owners of the ATE Software are responsible for maintaining useful testability, while the System Program Office, or SPO, owns the actual weapons system that is being tested. These separate groups must be able to cooperate to do anything correctly. This means that the ATE owners need to communicate with a plethora of SPOs. There are over 20,000 TPSs throughout the Air Force supporting weapon systems and testing systems developed over decades.

C. Lifespan of Systems

In the US Government, most products have a much longer life cycle than their industry counterparts. For example, the B-52, which first flew in 1954, is expected to remain in use until 2040 [6]. In private industry, potential profit drives the addition of new projects and technology. Conversely, in the public sector, funds are allocated for each project meaning a longer life cycle is almost always more cost-effective. Additionally, government standards and procedures typically add time to this process and contracts and completion requirements provide very little flexibility. To further increase the challenge, reverse engineering is often required due to a lack of data on older weapon systems. Older, unused languages that were standard in the past now exist as an obstacle to modern engineers. Any time spent struggling with older systems is even more lost time on the development cycle.

D. Dangers of Non-Standard ATE

All of these factors affect how smoothly systems can be tested and maintained. Therefore, having the appropriate ATE for every system and subsystem is a near-impossible task unless very disciplined measures are taken. In the past, weapon system managers acquired and maintained their own testers. This created a redundant inventory of testers as a large portion of ATE shared similar functionality. Maintaining a collection of non-standard ATE costs billions of dollars and ultimately impacts the support of the warfighter in a negative way. Creating standardized ATE has been attempted before, but these efforts ultimately failed due to a lack of industry conformity.

III. New Policy

Presently, the USAF has adopted a new policy as part of an effort to ensure DoD objectives for ATS modernization. This is known as the ATS Architecture Framework Standards brought forth by the ATS Management Board (AMB) Executive Director [2]. The AMB-whose purpose is to discuss and solve DoD ATS problems-consists of Colonels, Navy Captains, Captains, or civilian equivalents from each branch of service [2]. Some of the changes made include a minimization of system-unique ATS without compromising existing requirements, a compliance with standardization policy, and a use of equipment to fullest extent to promote commonality and interoperability. Another large part of this policy includes the large-scale attempt to use industry products and standards in order to mitigate many of the previously stated disadvantages. For standardization to occur properly, all DoD organizations must be familiar with these policies. This requires a major effort in order to shift the organizational culture and attitude towards testing. On a small scale, past testing efforts may seem completely functional and simple, especially for an experienced operator. From this point-of-view, the need for change might seem pointless and likely to lead to new problems. In reality, only those with a large-scale perspective can clearly see the significant problems with an non-standard, non-modular inventory. This concept must be properly communicated down the line to ensure a team effort in improving the testing and maintenance of the Air Force and other DoD entities, ultimately helping the war fighter succeed.

IV. VDATS

With these policies in place, the Air Force answered. In 2000, the initial concept and design began for the Versatile Depot Automatic Test Station (VDATS), shown in Figure 2. Currently, the VDATS is the first choice for AF depot level ATS needs [4]. This test station is completely organic, meaning the Air Force has complete control over the development, maintenance, and support of the system and it can be tailored to the testing requirements of AF users. It was designed to be modular, allowing for expansion and substitution of devices and instruments. Currently, depots are continuously purchasing VDATS, which essentially provides a standard interface to protect TPS development investments [4]. The VDATS has a uniformed, controlled API which permits any needed system configuration changes. The System Integration Lab, or SIL, located at Robins Air Force Base in Warner Robins, GA is responsible for managing all of VDATS software capabilities [5].

Figure 2: VDATS setup [3]

A. Software

The VDATS system software is uniform across all stations, using a standard software language, interface, and API. This allows for flexible configurations without impacting the actual TPS, due to its isolation from the actual instruments. [4] The core Test Program Sets for each VDATS station include the Digital/Analog (DA) Self-Test, DA Calibration, Radio Frequency Self-Test, and RF Calibration. The calibration tools included in the station certify that operation is within VDATS specifications. This is performed by applying a known stimulus and then measuring the results of the stimulus. The measured stimulus is then compared to the expected value, which ensures consistent measurements across all of the various future tests. Additionally, transportability is maintained because calibration can occur at any location with normal shop conditions [5]. When the engineer moves on to testing other components, the software guides the operator through the necessary steps and allows the operator to write, manage, and adjust the self-test to correspond to the relevant TPS needs. The software is based on ANSI C programming language in a LabWindows/CVI environment.

B. Hardware

The VDATS hardware consists of portable instrument cases containing an assortment of instruments displayed in Figure 3. General Purpose Interface Bus (GPIB) Communication Links are used to connect the Test Module Adapter, or TMA, to the instruments. The TMA is responsible for isolating the software and hardware between the Calibration TPS and the PATEC core standards [5]. The PATEC, or Portable Automatic Test Equipment Calibrator, is managed by the Air Force Metrology and Calibration Program, or AFMETCAL. The PA-1 rack is designed by the SIL Team, and contains only one computer-controlled instrument, the DC Electronic Load.

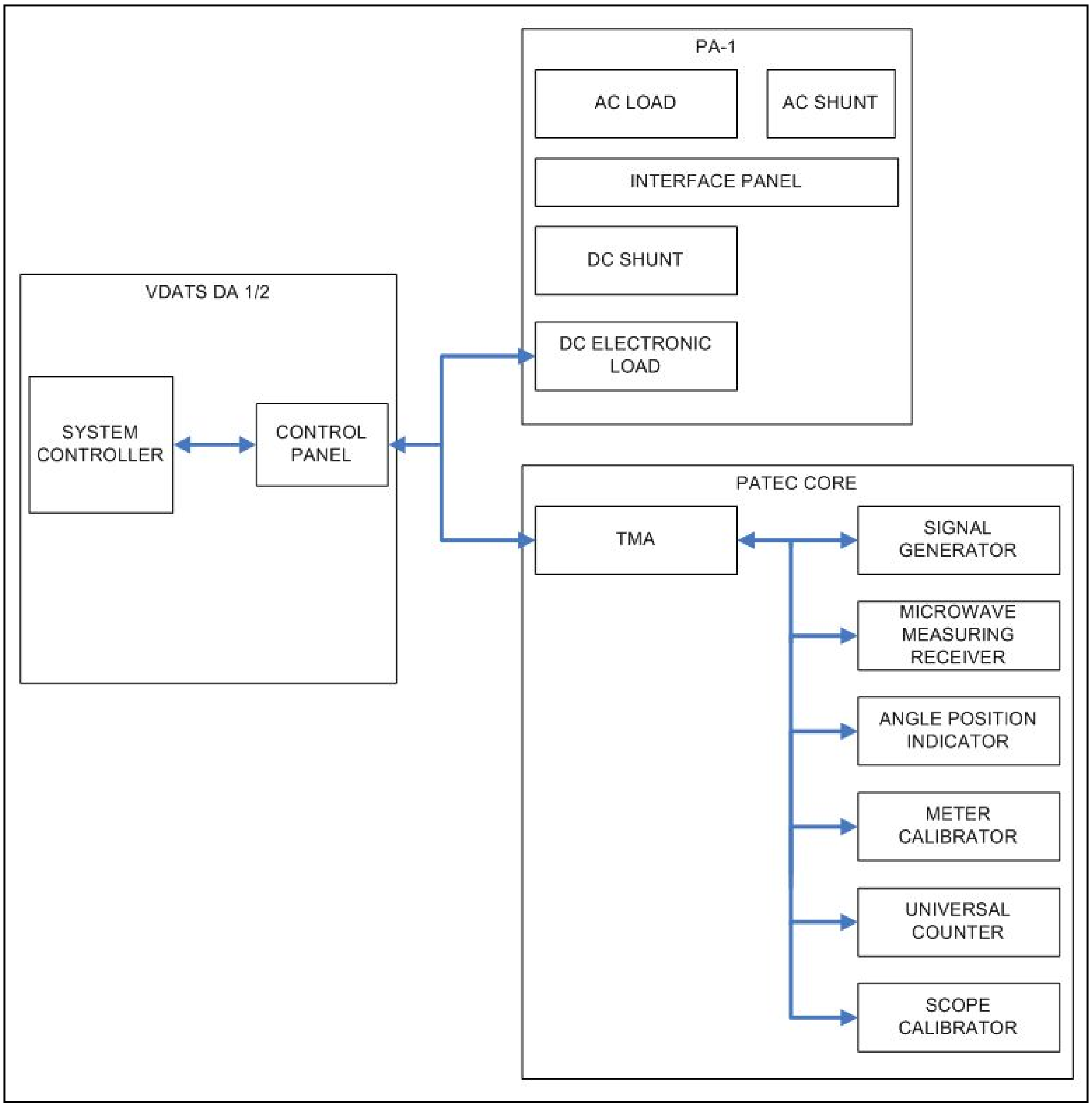

Figure 3: PATEC Core and PA-1 Instruments with GPIB link ot VDATS [5]

Using a test adapter interface, the engineer would hook up a Line-Replaceable Unit (LRU) and perform the various tests to search for hardware issues, such as a fault. An LRU is sometimes referred to as a “black box” and can be removed from the aircraft and replaced in the field. This way, the aircraft remains fully functional while the defective LRU is brought to the lab for testing. However, not all testing ensues as a result of an an observable issue. Scheduled maintenance occurs on each unit to maintain quality and retain mission-ready status at all times.

Figure 4: TPS Engineer at VDATS station [10]

Within each LRU are Shop-Replaceable Units, or SRUs. These are sections of the LRU that can be replaced “in-shop” by a technician if that particular SRU is the cause for malfunction. This increases the modularity of the testing process additionally, as an SRU can be replaced, making the LRU fully functional. At that point, the SRU can be tested further to find the exact repair needed, and a shop technician can carry out the task.

V. Impact of Standard ATS

The push for improved ATE will undoubtedly leave a positive impact for decades. First, the impact of improved testability will lead to cheaper, simpler, and more efficient maintenance. Operators will become more versatile and test points of Line Replaceable Units, (LRU) and Shop Replaceable Units (SRU) will be easier to access. This will reduce testing times and improve diagnostics. Additionally, a system designed for testability can require a TPS that is immensely less expensive opposed to a system that is not properly designed for ease of test. These testable systems will be far easier to control and observe. In addition to testability, the impact of ATS standardization will bring easier maintenance, transportation, and adaptability of ATE. This will also simplify the transition from contractor design of a system to organic Air Force maintenance [10]. Additional workload can be pursued due to the possibility of expanding tester configurations in the future. Most of all, ATS standardization brings a significantly lower cost.

VI. 76th Software Maintenance Group

The 76th Software Maintenance Group (76th SMXG) is one of the several groups that make up the Oklahoma City Air Logistics Complex (OC-ALC) at Tinker Air Force Base, Oklahoma. The OC-ALC is one of the largest units in the Air Force Material Command, employing over 9,800 civilian and military professionals [8]. The 76th SMXG is made up of several squadrons that serve many software and hardware maintenance and development functions, including the 556th Software Maintenance Squadron (556th SMXS). The 556th is responsible for most of the digital testing that occurs within the 76th, especially for the highly-classified B-2 Spirit stealth bomber. In the testing lab, rows of VDATS setups are operated by TPS Engineers to solve issues and test equipment for mission readiness. Engineers are responsible for setting up the test, determining the right test adapters for the specific Line-Replaceable Unit, and ultimately finding needed repairs. A TPS Engineering job for the 556th has actually turned out to be a good entry-level job for many software or hardware engineers, and many new engineers are hired for that specific purpose, however many experienced engineers remain in TPS for years, enjoying the rewarding nature of the job and focusing on the more advanced projects. This is a firsthand account as the result of a two-year internship as a civilian engineer with the 76th SMXG.

VII. Future Work

The Air Force will continue to consolidate testing equipment to the new standard and reap the economic rewards. Due to the organic nature of the new ATE within the Air Force testing labs, future modifications and adaptations will be welcomed for the testing of cutting-edge defense systems.

As for my career, I will continue working for the Air Force in a different capacity after graduation. Instead of staying with Tinker AFB and the 76th SMXG, I will work as a Computer Engineer with the 96th Range Control Squadron within the 96th Test Wing at Eglin Air Force Base, Florida. I will contribute to the real-time testing efforts of newly developed aircraft and weapons as flight tests are administered at the Eglin Test and Training Range. I will be introduced to a new and exciting side of Air Force testing, and I will also be provided the opportunity to continue my learning, research, and leadership skills with a Master of Science in Computer Engineering in the Fall 2019. This will begin after one full year of work with the 96th.

VIII. Conclusions

As the need for ATE grows in all hardware industries, the Air Force is working toward solutions for complex challenges, both old and new. The VDATS will be utilized as the Air Force standard to ensure quality and efficiency in system testing. After all, the cutting-edge technology within the USAF is useless without the ability to test.

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