Addressing ATE Instrument Obsolescence with Form / Fit / Function Compatible Solutions – A Case Study

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***Abstract* — Military - aerospace automated test equipment (ATE) can have very long product life cycles – many times longer than the individual components and instrumentation that comprise the overall test system. When a dedicated test system fails and is not available, there is usually an immediate impact on the military platform's product or products it supports. The resulting impact can be monetary or even worse, the product or system's readiness. With product life cycles being extended, the associated legacy ATE systems are also being pushed into extended service and as they age, downtime and maintenance costs increase. Instrument obsolescence is one of the major reasons for test system downtime. If a system resource fails, it must be repaired or replaced.**

This paper discusses how the use of a form / fit / function instrument replacement solution was employed for replacing pulse and arbitrary waveform function generators that are part of the Hybrid Test Set (HTS) AN/USM-484 test system. The test system is currently employed by multiple services and supports SRU level testing for the F/A-18, AV-8 and H-60 via 600 Test Program Sets (TPSs). The paper details the overall process employed to implement and qualify the instrument replacement solution as well as the benefits associated with employing this replacement strategy.

Keywords—legacy instrumentation, instrument obsolescence, pulse generator, arbitrary waveform generator

I. BACKGROUND

Many projects and programs rely upon test systems that were designed at the beginning of a program for ongoing system support and maintenance. However, as programs are extended beyond their original life cycle, the equipment, including ATE systems, is required to undergo a modernization phase in order to ensure continued support and maintenance of the system and its sub-assemblies. One of the major issues typically addressed by this upgrade phase is equipment obsolescence. Equipment that is no longer in production or supported by the OEM will need to be replaced or a strategy for long-term support needs to be established.

Preserving TPS Investment

Over a test system's life span, significant costs can accrue, beyond the initial cost of the ATE asset. ATE costs start with the initial investment for designing, building and developing Test Program Sets (TPSs). However, after the initial cost of ATE deployment, test system costs will continue to accrue due to the ongoing investment in test programs, fixtures, etc. And over time, the cost of the test programs will become the major investment component, increasing exponentially as additional programs are added to a system (Figure 1).

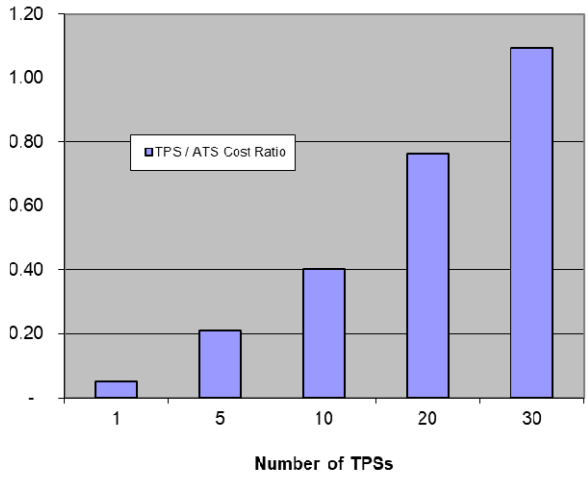

Figure 1: Cost of TPSs Relative to ATE Capital Cost [1]

Additionally, as the ATE matures, maintenance costs will increase due to ageing and obsolescence issues. Consequently, to preserve the investment in the test system and associated test programs, identifying cost-effective replacement solutions for obsolete instrumentation that preserves TPS investment becomes critical.

Instrument Replacement Strategies

There are several strategies for addressing the replacement and maintenance of obsolete instrumentation that is part of a TPS.

- Stockpiling spares - Stockpiling of spare instruments is one way to mitigate system downtime and maintenance issues. The spare instruments may be procured as part of the initial investment, during the ATE's life span or as a life time buy when the notice of end of life is received. With the typical life span for commercial instrumentation being 5-7 years, but with test systems in use for 20 or more years, this strategy is routinely employed by test system maintainers. However, this is only a short-term solution, particularly when dealing with system life cycles of 20+ years since at some point, the spares will be depleted.

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- Ongoing maintenance and repair – Continual repair and maintenance of the obsolete instrument may be an option. However, the problem with this approach is the ever-increasing cost and time to repair as well as obtaining components which may become obsolete. Even if some systems are reserved for cannibalization, the source of instruments and parts will eventually be exhausted – resulting in a short-term solution at best.
- Secondary market instruments – The use of instruments available on the secondary market can be a possible solution. Many test equipment distributors offer used instruments and depending on the age of the instrument (how long it has been out of production), there is a good chance of finding the instrument on the secondary market. However, even if the equipment is in pristine condition, this is still a short term solution to the long term problem of support and maintenance since eventually, this source will be exhausted.
- TPS migration / COTS instrument with adapter - A long-term solution can be the replacement of the obsolete instrument with a new COTS instrument with comparable functionality and performance. However, the replacement instrument's software functionality will not be compatible, requiring a software driver wrapper or adapter in order to mimic the legacy instrument's commands and response characteristics. Identifying a COTS functional replacement instrument should be done with care. The candidate instrument's specification should be scrutinized closely to verify that all the features used in the ATE are compatible, all the levels and ranges are covered, and all required inputs and outputs exist. In addition, comprehensive functionality also needs to include any self-test functionality that the legacy instrument may have offered, since overall compatibility must address not only test program functionality, but also any system / instrument self-test functionality. However, even with the use of a software wrapper that mimics the legacy instrument's functions, this implementation will necessitate reverification and potentially upgrades to all test programs (and system self-test), which can be an extensive effort.
- Hardware adapter or Translation Module Adapter (TMA) - A TMA is a stand-alone unit that connects between the system controller and the replacement instrument which offers comparable functionality to the legacy instrument. The TMA has its own processor and uses two ports: one to communicate with the system controller and one to communicate with the replacement instrument. Special firmware needs to be developed to accept the legacy commands from the controller and translate them to the new instrument's commands. Like its software counterpart, once a hardware adapter is implemented, TPSs should be able to use the new instrument with virtually no changes but unlike the software adapter, the legacy instrument can still be used simply by bypassing the TMA. Hardware adapters face similar obstacles as their software counterparts. There is some risk involved with firmware development and communication response time can create timing issues, necessitating test program revisions and consequently, requiring TPS revalidation.

II. FORM, FIT, FUNCTION (FFF) INSTRUMENT REPLACEMENT – A SUPERIOR SOLUION

All of the instrument replacement strategies detailed above have limitations and can potentially require substantial time and investment for validation and acceptance as compatible replacement solutions. FFF instrument replacement offers a superior solution for replacing out of production, legacy instrumentation. A modern, COTS instrument with an integral communication interface adapter offers a replacement solution that is functionally, electrically, and mechanically equivalent to the legacy instrument, preserving the initial investment in the ATE and associated TPSs. Key features and benefits associated with a FFF solution include:

- Preservation of existing test programs. Great care is taken to replicate the legacy instrument's functionality, allowing system self-test and test programs to execute with no changes – eliminating the time and costs associated with extensive re-verification.
- Flexibility to use either the legacy instrument or replacement instrument with existing test programs.
- Ability to replicate "undocumented" behavior of a legacy instrument – which can be a key feature for performing accurate TPS execution since a TPS may use undocumented instrument functions as a "feature", which requires that the replacement instrument behave in the same manner.

For those applications that involve a large number of active legacy test programs, the use of a FFF replacement solution offers the most cost-effective solution for extending the life cycle of a test system. As shown in the table below, the FFF solution, when compared to all other alternatives, offers key advantages for those users looking to replace legacy instrumentation as well as preserving their investment in ATE and TPS. Figure 2 provides an example of a FFF replacement instrument for a HP 8112 pulse generator.

Replacement Options	Life Cycle Timeframe	Total Cost (Acquisition / Implementation)	Risk
Spares Stockpiling	Short / Medium	Low / Medium	Low
On-going Maintenance	Short	Low / Medium	High
Used Instruments	Short	Low/ Medium	Low / Medium
TPS Migration	Long	High	Med / High
TMA	Long	Med / High	Med / High
FFF Replacement	Long	Low	Low

Comparison of Instrument Replacement Options

Figure 2 - FFF Replacement Instrument for HP 8112

III. UPGRADING THE AN/USM-484 HYBRID TEST SYSTEM WITH FFF INSTRUMENTATION

As the AN/USM-484 Hybrid Test System (HTS) (Figure 3) OEM, Peraton Canada Corp. provides support for multiple international customers. The HTS supports over 600 test program sets and supports SRU level testing for the F/A-18, AV-8 and H-60 aircraft.

Figure 3- AN/USM-484 HTS

The HTS has been in service for over 35 years and with OEM instrumentation obsolete, Peraton was challenged with how best to upgrade the HTS without impacting the hundreds of test programs deployed on this test system. Specifically, the HTS employs (2) Wavetek 859 pulse generators and (3) Wavetek 175 arbitrary waveform generators – instruments that are out of production, obsolete and very difficult if not impossible to maintain. With a large investment in test programs and with multiple instruments installed in each test system, Peraton looked to employ a FFF instrument solution as the most viable and cost effective method for replacing these instruments. As detailed below, the FFF replacement strategy required extensive verification and interaction with the replacement instrument supplier but resulted in a solution that allowed Peraton ensure that the replacement instruments would not impact the hundreds of deployed test programs.

IV. IMPLEMENTING THE FFF INSTRUMENT REPLACEMENT SOLUTION FOR THE AN/USM-484

The initial compatibility testing was performed using instruments loaned to Peraton by Marvin Test Solutions (MTS). The station's self-test was performed to identify deltas in performance and potential compatibility issues. Following the successful proof of concept, pulse and arbitrary waveform generators were procured by Peraton to move forward with the integration process.

In order to establish an accurate baseline prior to integration of the MTS generators, the HTS station's self-test programs were executed and the test results recorded using the five original Wavetek generators. The new instruments were then installed, and the same programs were executed for comparative test results analysis. During the execution of the self-test programs, multiple anomalies and deviations were observed with regard to the integrity, amplitude, or shape of the output waveforms with the new instruments. To rectify these issues, multiple hardware and firmware changes were implemented by MTS based on investigative data provided by Peraton engineering.

Once the MTS instruments were fully integrated for self-test operation, the verification process was repeated on over 100 different avionics test programs. This iterative process led to several firmware revisions in order to completely emulate the original equipment. In total, Peraton engineering expended approximately 2,000 hours to ensure the MTS generators operated as a form, fit, function (FFF) replacement for the legacy instruments.

During the validation phase of the project the following issues associated with the FFF instruments were encountered and rectified.

Wavetek 175 Arbitrary Waveform Generator Replacement with GP1650:

- The output of the generator is fed into a fixed 8x gain amplifier installed in the HTS station. With the replacement generator, significant ringing was observed on the signal. This ringing was not present with the original instrument. Upon investigation, it was determined that the slew rate of the replacement instrument's output amplifier was approximately 160 times faster than the legacy instrument's. Consequently, the output amplifiers in the FFF units were replaced, in order to replicate the legacy instrument's output slew rate.

- The SYNC output from the legacy generator can be programmed to produce a marker pulse at phase positions from 0° to 359°. This function was not clearly defined in the original Wavetek specifications. The programming strings from several TPSs were captured, analyzed and detailed. MTS then updated the instrument's firmware to replicate the legacy instrument's phase programmability.

Wavetek 859 Pulse Generator Replacement with GP1552:

- While conducting regression testing the GP1552 would—on occasion—reset to a quiescent state after receiving a general-purpose interface bus (GPIB) command. Analysis of the problem revealed that invalid waveform commands embedded in the TPS and issued to the GP1552 would reset the instrument to a quiescent state. Conversely, the Wavetek 859 would execute those parts of the command that were valid and ignore invalid commands, while still producing an output signal. This "undocumented feature" of the legacy generator required that each anomaly be investigated, which resulted in the FFF instrument's firmware being updated to replicate these undocumented features.
- The GP1552 employs a software calibration implementation whereas the Wavetek 859 was manually calibrated. Pulse rise and fall time issues were encountered in the 2.5 msec range. Based on the recommendation from Peraton, the MTS engineering team added custom rise and fall calibration factors for the 2.5 msec range which corrected the issue.

Figures 4 and 5 detail the Wavetek 175 and 859 instruments and their respective replacements. Note that the replacement instruments are significantly smaller but are supplied with adapter panels to replicate the size and connections associated with the legacy instruments, thereby maintaining mechanical compatibility.

Figure 4 – Wavetek 175 & GP1650

Figure 5- Wavetek 859 & GP1552

Peraton installed the GP1650 and GP1552 in three Canadian HTS stations in 2017. The increased accuracy and reliability of the instruments has significantly reduced the required HTS maintenance and legacy instrument repair cost. In early 2019, Peraton upgraded two HTS stations for an international customer eliminating several signal integrity issues experienced with the legacy generators. The investment in testing and validating of the FFF replacement solution has provided Peraton's customers with a comprehensive and validated upgrade solution for their automatic test equipment.

V. SUMMARY

The availability of form, fit, function (FFF) replacement instrument solutions offers a viable path for extending the life cycle of automatic test systems and preserving the investment in associated test programs. And for those applications where a significantly large number of active TPSs are involved, the FFF approach offers the only real viable solution. By employing a FFF replacement solution, test system maintainers are able to extend the life cycle of ATE and the associated test program sets as well as improve performance and reliability of both the ATE and the test programs.

References:

[1] "Modernizing Legacy Automated Test Systems for DoD Depots"; Dewey & Carey; Autotestcon 2010

[2] "Addressing the Instrument Obsolescence Problem – Options and Solutions", Manor; Autotestcon 2006