TELEMETRY SYSTEMS SUSTAINMENT

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ABSTRACT

Tactical training ranges provide an opportunity for all of the armed forces to assess operational readiness. To perform this task the various training ranges have deployed numerous telemetry systems. The current design efforts in place to upgrade the capabilities and unify the ranges under one telemetry system do not address the training ranges' need to maintain their training capability with the legacy systems that have been deployed until the new systems are ready. Two systems that have recently undergone sustainment efforts are the *Player and Event Tracking System* (TAPETS) and the *Large Area Tracking Range* (LATR).

TAPETS is a telemetry system operated by the U.S. Army Operational Test Command. The TAPETS system is comprised of the ground mobile station Standard Range Unit (SRU) and the aircraft Inertial Global Positioning System (GPS) Integration (IGI) Pod. Both systems require a transponder for the wireless communications link.

LATR is an over the horizon telemetry system operated by the U.S. Navy at various test ranges to track ground based, ship based, and airborne participants in training exercises. The LATR system is comprised of Rotary Wing (RW), Fixed Wing (FW) Pods, Fixed Wing Internal (FWI), Ship, and Ground Participant Instrumentation Packages (PIPs) as well as Ground Interrogation Station (GIS) and relay stations. Like the TAPETS system, each of these packages and stations also require a transponder for the wireless communications link.

Both telemetry systems have developed additional capabilities in order to better support and train the Armed Forces, which consequently requires more transponders. In addition, some areas were experiencing failures in their transponders that have been deployed for many years. The available spare components of some systems had been depleted and the sustainment requirements along with the increased demand for assets were beginning to impact the ability of the systems to successfully monitor the training ranges during exercises.

The path to maintaining operational capability chosen for the TAPETS system was a mixed approach that consisted of identifying a depot level repair facility for their transponders and funding the development of new transponder printed circuit boards (PCB's) where obsolescence prevented a sufficient number of repairable units.

In the case of LATR, the decision was made to create new transponders to take advantage of cost effective state-of-the-art RF design and manufacturing processes. The result of this effort is a

new transponder that is operationally indistinguishable from the legacy transponder in all installation environments.

The purpose of this paper is to present two successful system sustainment efforts with different approaches to serve as models for preserving the current level of training range capabilities until the next generation of telemetry systems are deployed. While the two programs illustrated here deal primarily with the transponder components of the systems, these same methods can be applied to the other aspects of legacy telemetry system sustainment efforts.

KEYWORDS

Sustainment, *Player and Event Tracking System* (TAPETS), *Large Area Tracking Range* (LATR), state-of-the-art, RF Communications

INTRODUCTION

Telemetry systems are vital tools to tactical training ranges. The heart of these systems is the wireless communications link that passes data between the observers and the participants. When a failure in the communications link occurs, the participants become invisible to the command and control center resulting in an inability to assess the successfulness of an exercise or provide crucial post exercise training information to the participants. When this critical system component no longer performs in the field or the number of assets to be fielded increases, the effectiveness of the training exercise is undermined. To meet the growing needs of the tactical training ranges, new telemetry systems such as the Tactical Combat Training System (TCTS), Common Range Integrated Instrumentation System (CRIIS), and the Integrated Network Enhanced Telemetry (iNET) are under development or in the preliminary stages of deployment.

While these new systems are in development and initial deployment stages, the tactical training requirements for the ranges are constantly increasing. The deployed systems are approaching or have already exceeded their expected lifecycle. The expanding requirements in conjunction with the aging assets create a dilemma for the ranges while they await the arrival of the replacement systems. The issue manifests itself when the training exercise requirements exceed the number of tracking system assets available due to assets no longer in production or unusable assets awaiting repair.

To address these problems, sustainment efforts are in progress to bridge the gap and maintain the training range's ability to successfully conduct training exercises with the legacy telemetry systems. Recently, two telemetry systems (TAPETS and LATR) have undertaken sustainment efforts that resulted in new state-of-the-art circuit card assembly (CCA) designs that will extend the operational lifetime of each system until their replacement systems are in place.

SUSTAINMENT EFFORTS

The sustainment efforts for both transponder systems will be described in this paper.

TAPETS

The TAPETS system is a time-space-position information (TSPI) system that is used to track multiple participants in real-time and playback modes. The TAPETS system is used by the U.S. Army Operational Test Command to conduct training exercises incorporating fixed winged aircraft and various land-based vehicles. The communications link for the system is incorporated in two units. The Standard Range Unit (SRU) is used in ground based applications. The Inertial Global Positioning System (GPS) Integration (IGI) Pod is attached to aircraft. These units have been fielded for many years and are still vitally important for numerous exercises. Due to the advanced age and extreme operating conditions endured by these units, circuit card assemblies (CCAs) in the SRU and IGI Pod began to fail while the requirement for assets increased for training support.

The transceiver and power amplifier CCAs in the SRU are the critical components that were failing and preventing usable systems from being deployed during exercises. For the IGI Pod, both the transceiver CCA as well as the digital CCA required corrective action to maintain the required number of systems available for exercises. Due to programmatic risks, it was determined to repair and update only one CCA at a time. The risks considered were:

- Operational Environment
- Factor of Component Obsolescence
- Documentation Availability

After weighing the risks, the SRU transceiver CCA was selected first for repair and update. The IGI Pod transceiver CCA was to follow, with the IGI Pod digital CAA to be last.

SRU

The initial phase of the sustainment effort focused on identifying a depot level maintenance provider for the SRU's transceiver CCAs. The depot level maintenance provider was required to repair the non-functional transceiver CCAs that could not be refurbished by range personnel. A depot maintenance provider was identified and a number of transceiver CCAs were repaired and returned to operational status. However the repair process was hampered by limited availability of replacement components and mechanical damage due to age and previous rework to the printed wiring boards (PWBs).

To continue forward with the sustainment effort in order to obtain the required number of CCAs to field all of the SRUs, a second phase was initiated. The second phase of the sustainment effort called for the development of replacement transceiver and power amplifier CCAs. The approach was to create state-of-the-art replacement CCAs that were operationally indistinguishable from the legacy hardware. The freedom to incorporate modern design techniques and components created improvements such as:

- The transceivers no longer required manual tuning to change the operational frequency.
- The external power amplifier CCA was incorporated into the transceiver CCA; therefore eliminating the requirement to sustain two separate CCAs.
- Protection circuitry was added to prevent the power amplifier from damage due to improper operation or antenna load including of go/no go voltage standing wave ratio (VSWR) detection.
- Modern Technology was used that extends the lifetime of the system support.

- Variable RF Output to support integration into various SRU configurations.

These improvements incorporated into the new CCAs not only reduced the cost of the transceiver CCA, but also reduced operational costs in fielding the SRU. Figure 1 shows the NuWaves transceiver with the power amplifier incorporated and the use of on board shielding. Figure 2 depicts NuWaves' redesigned transceiver installed in an SRU chassis.

Figure 1: NuWaves' Transceiver with Incorporated Power Amplifier

Figure 2: NuWaves' Transceiver Installed in an SRU Assembly

IGI POD

Due to the success of the SRU transceiver sustainment effort, a second phase of the TAPETS sustainment effort was conducted to refurbish failing IGI Pods. The situation for the IGI Pod differed from that of the SRU in that the microprocessor (digital) CCAs were failing along with the transceivers. Similar to the SRU, the design documentation was not available for review when the sustainment effort began. Based on the success of the SRU transceiver development, the IGI Pod transceiver was selected to precede the microprocessor CCA in the second TAPETS sustainment effort.

TRANSCEIVER

Unlike the SRU, the legacy transceiver CCA of the IGI Pod was not provided for depot level maintenance. The sustainment effort was dedicated to redesigning new transceiver CCAs. Since the design documentation was unavailable, a functional IGI Pod was provided as a representative model. From this model, the power requirements and digital input/output (I/O) were determined. The information gathered from this model included:

- Transmit Output Power
- Receiver Sensitivity
- I/O Signal Polarities
- Operating Voltage
- Transmit and Receive Current Consumption
- Mechanical Dimensions

This information, along with the knowledge of the RF signal characteristics of the SRU, was used to create the specifications for the new design. Again, the goal of the sustainment effort was to create a transceiver that was form, fit, and functionally equivalent to the legacy design.

Figure 3 and Figure 4 illustrate the new IGI Pod transceiver and the required IGI Pod transponder enclosure.

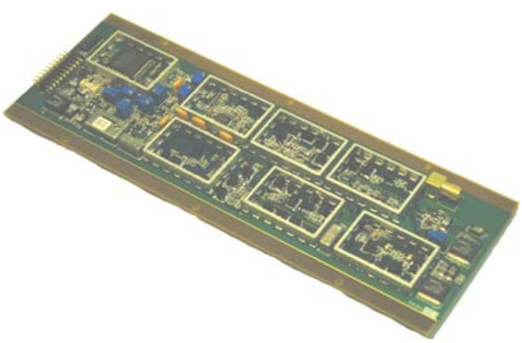

Figure 3: NuWaves' IGI Pod Transceiver CCA

Figure 4: IGI Pod Transponder Assembly

Similar to the SRU transceiver CCA redesign, the IGI Pod transceiver incorporated many improvements that reduced the cost of the CCAs as well as the operational costs associated with the IGI Pod. The successful conclusion of this phase of the system sustainment effort created the opportunity to expand the effort to the IGI Pod's digital CCA.

DIGITAL

The IGI Pod's digital CCA was the third and most challenging of the CCA's to undergo the sustainment effort. The major challenges were due to non-availability of design documentation and the "bussed" nature of digital signal groupings.

The higher risk associated with the digital CCA required an additional step to calculate the risk associated with various approaches to this phase of the TAPETS sustainment effort. The first step for this phase was a technical study and report. The study and subsequent report encompassed many factors to determine a recommended approach for the range to consider. The first step was to research all of the major integrated circuits (ICs) used on the digital CCA. This resulted in the collection of the component data sheets along with availability information. For obsolete components, the research phase also identified and located possible replacement components. Table 1 summarizes the IC search conducted during the study phase.

Item Number	QTY	Part Number	Manufacturer	Possible Replacement Part Number	MFG	Description	Obsolete	Available
1	2	A	MFG A	N/A		Universal Serial Controller	No	Yes
2	2	B	MFG B	RAM2	MFG N	SRAM	Yes	Yes
3	4	C	MFG C	ROM2	MFG N	PEROM	Yes	Yes
4	1	D	MFG D	MP2	MFG O	Microprocessor	No	Yes
5	1	E	MFG E	N/A		Floating-point co-processor	No	Yes
6	1	F	MFG F	N/A		IC, RS-422 Trans.	No	Yes
7	1	G	MFG G	N/A		Xtal, Crystal	No	Yes
8	1	H	MFG H	N/A		DC-DC Converter	No	Yes
9	1	I	MFG I	N/A		Transistor, NPN	No	Yes
10	2	J	MFG J	N/A		Resistor 110 Ohm	No	Yes
11	1	K	MFG J	N/A		Resistor 150 Ohm	No	Yes
12	1	L	MFG K	N/A		IC, Battery Controller	No	Yes
13	2	M	MFG L	AMC3	MFG P	Programmable Flags FIFO	Yes	Yes
14	1	N	MFG L	AMC1	MFG P	TAXI Receiver	Yes	Yes
15	1	O	MFG L	AMC2	MFG P	TAXI Transmitter	Yes	Yes
16	1	P	MFG M	N/A		IC RS-232 Trans.	No	Yes

Table 1: Availability of Components Utilized on the IGI Micro-Controller Circuit Card Assembly

During the part search, it was noted that to maintain operational compatibility with the legacy digital CCA, a new CCA would have to utilize the same EPROMs, microprocessor and coprocessor. These components were required to eliminate the need for software redesign.

The recommendation between repair and build is determined by whether or not the government requires long-term support or only short-term support. The cost for building includes the Non-

Recurring Engineering (NRE) to redesign for delivery of new generation hardware. The NRE cost is high compared to troubleshooting existing units, however, the support for the controller assembly as well as a source of new controllers is attractive. A listing of pros and cons for each scenario is provided in Table 2.

IDENTIFIER	SCENARIO	
	BUILD	REPAIR
NRE	CON	PRO
Recurring Cost in Volume	PRO	CON
Maintainability	PRO	CON
Turn-around Time (Schedule)	CON	PRO
Schematic Generation Required (Gov't Will Own)	PRO	PRO
Risk	CON	PRO
Unlimited Number of Units	PRO	CON
Long Term Support	PRO	CON
Short Term Support	CON	PRO

Table 2: Build vs. Repair Pro/Con Identifier

Due to the small number of digital cards that were failing, the repair option was selected. Because no documentation was available, the first step in developing a support plan for the digital CCA was to create a schematic diagram. Processes to follow transmit or receive signal paths through an RF board are straight forward. Digital circuits do not have as well defined signal flows and are inherently more difficult to capture all of the signal connections. The datasheets collected in the research portion of this sustainment effort were utilized to aid the schematic generation process. The schematic symbols were created from the data sheets and NuWaves' digital hardware design experience was used to create an initial schematic. This schematic was compared to connections on the board and refined to incorporate any discrepancies.

After completion of the schematic, a test station was developed to verify the performance of reworked CCAs. After the CCAs were reworked, tested, and verified in a laboratory setting, on-site integration exposed an issue that could not be replicated in the lab. A short investigation revealed the problem to be interaction between CCA boards and the appropriate corrective action was performed at the range. This action successfully completed the final phase of the TAPETS sustainment effort and returned all of the available assets to active status.

LATR

Similar to the TAPETS system, the LATR system has been fielded for many years and the originally designed operational lifetime has been exceeded. The sustainment effort for the LATR system is an ongoing process led by the NAVAIR Naval Air Training Systems Office.

To maintain a full complement of assets, the ranges identified the need for a second source for depot maintenance for the AN/URY-3A and AN/URY-4 transponder CCAs. These transponders are installed into Rotary Wing (RW), Fixed Wing (FW) Pods, Fixed Wing Internal (FWI), Ship, and Ground Participant Instrumentation Packages (PIPs) as well as Ground Interrogation Station (GIS) and relay stations. Upon successful repairs of numerous transmitter, receiver, and digital CCAs, the opportunity to increase the number of transponders arose. Increasing the total number of transponders was part of the strategy to sustain the LATR system for an expected 10 years. Since LATR's original concept, the test ranges have developed additional capabilities in order to better support and train the Armed Forces, which consequently requires more transponders.

To increase the number of transponders, NuWaves investigated the feasibility of designing and manufacturing the AN/URY-5 transponder. The focus of the investigation was to evaluate design approaches that could be employed to replace obsolete components and manufacture additional, lower cost transponders. As a cost reduction approach, the new transponders were not to be qualified for United States military airborne applications. This plan would allow the AN/URY-5 to replace those AN/URY-3A and AN/URY-4 transponders that were deployed in GIS and relay stations, thus freeing flight qualified assets for installation into PIPs.

During the investigation, four design approaches were considered. These design approaches, summarized in Table 3, used different combinations of design reuse and weighing the risks, costs, CCA compatibility, and maintainability.

			Cost Trend		Form Fit, Backward Compatible with Current Transponders		
Functionally Equivalent Design Approaches for the Emulator		Risk	NRE	RC	Circuit Cards	Mechanical Chassis	10 year Maintainability
Approach 1	Current transponder chassis and circuit cards are duplicated in form and fit.	Very Low	******	$$$$	Yes	Yes	Poor
Approach 2	Design a new chassis and all circuit cards are duplicates in form and fit of the current transponder circuit cards.	Low	****	$$$	Yes	No	Poor
Approach 3	Design a new chassis and circuit cards. Similar logic card design to current transponder for software re-use.	Low	*****	$$	No	No	Good
Approach 4	Design a new Equivalent Unit without re-use for future maintainability. Overall package size, if desirable, could be smaller.	High	********	$$	No	No	Best

Table 3: LATR Transponder Sustainment Effort Options Matrix

Review of the matrix quickly allowed NAVAIR personnel to narrow the recommended design approaches down to two possibilities; Approaches 2 and 3. Each of these approaches had similar levels of risk; however the benefit of the approaches varied between up front NRE cost versus recurring manufacturing costs. This difference meant that the approach selected was largely based on the volume of units required. The advantage to Approach 3 is realized after the quantity of units exceeds 10. That is the point in which the higher NRE and lower recurring cost are equal to the lower NRE and higher recurring cost of Approach 2. Additional units after 10 cost less with Approach 3. After 20 units, the total cost associated with Approach 3 is also less than purchasing 20 AN/URY-4 units. Additional benefits gained by the selection of Approach 3 included higher reliability and more sustainable assets due to the utilization of more modern design techniques and components.

A whitepaper was submitted to NAVAIR and distributed to the ranges. The whitepaper presented this table along with the obsolete component listing and a risk abatement plan. The consensus of the team was to move forward with development of the AN/URY-5 utilizing Approach 3. The first article AN/URY-5 units have been delivered, qualified, site tested, and are fully functional within the LATR system.

Figure 5: Legacy AN/URY-4

Figure 6: NuWaves AN/URY-5

CONCLUSION

Newer, more advanced telemetry systems continue to be developed to provide services aiding in the operational readiness of our armed forces. As these advanced systems are being developed and deployed, sustaining current systems is necessary to preserve training range and operational capabilities.

Many options should be considered when evaluating the approaches the sustainment of telemetry systems including, but not limited to; duration of support requirement, NRE and recurring costs, degree of available technical documentation, risk to operations, technical risk, compatibility with current hardware and software, and future maintainability.

While the sustainment efforts reviewed here are directly related to transponder components, these same principles and methods of determining the optimal approaches apply to other aspects of telemetry system sustainment efforts.

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