USING CHAPTER 10 USER DATAGRAM PROTOCOL (UDP) STREAMING AND ETHERNET TECHNOLOGIES TO SUPPORT GROUND-BASED AIRCRAFT TESTING

Michael Diehl, Steven Kuipers, Jason Swain, and Tab Wilcox
Air Combat Systems Directorate, U.S. Army Yuma Proving Ground, Yuma, AZ 85367

ABSTRACT

During a recent U.S. Army Yuma Proving Ground (YPG) ground test, an unexpected change in test location resulted in the implementation of an innovative ad hoc network solution to complete the planned test matrix. The original plan was to use an aircraft ground test facility; however, safety requirements resulted in the aircraft being placed 50 meters away from the facility. This distance was too great to use the existing connections; consequently, data collection and analysis were adversely affected until this time expedient solution was implemented.

KEYWORDS

1. Chapter 10
2. Ethernet
3. Wireless
4. User Datagram Protocol (UDP)

INTRODUCTION

Recent testing at the U.S. Army's Yuma Proving Ground (YPG) required a unique set-up to safely and efficiently conduct an aircraft ground test. Testing involved the evaluation of an aircraft's non-eye safe laser designator to assess its functionality and performance after a recent upgrade. Ultimately, an ad hoc network approach had to be implemented to complete the ground test portion. This approach worked so well that YPG has already begun to expand its ground test capability based on this methodology for use in the future. Not to be understated was the capabilities provided by the use of IRIG 106 Chapter 10 and Telemetry Attributes Transfer Standard (TMATS), which were key elements of this timely solution.

ABOUT YPG

YPG is a subordinate command of the Army Test and Evaluation Command and is one of the largest military installations in the world. Located in southwestern Arizona, it encompasses

1,308 square miles. YPG personnel conduct tests on nearly every weapon system or piece of military equipment in the ground combat arsenal. With a mission to provide premier test services to the U.S. Government and her allies, YPG conducts, reports, and supports developmental tests, experiments, production tests, integrated developmental/operational tests, as well as provides training support. In 2011, YPG fired over 384,000 artillery, mortar, and missile rounds, more than 415,000 miles were driven on military vehicles, over 1,900 airdrops were conducted, and over 2,100 aircraft sorties were flown. These numbers more than double when events conducted in support of training are counted. YPG was the busiest Army proving ground in 2011 and again in 2012.

The Aviation Systems and Electronic Test Division at YPG is responsible for testing of aviation ballistic weapons and missiles, unmanned aerial systems, aircraft systems, precision guided and unguided air delivered systems, personnel parachutes, sensors and surveillance systems, and electronic warfare systems. As a developmental test activity, the goal is to help the developer field their systems and provide the Soldier with the safest, most lethal equipment. Instrumentation is a critical part of meeting this goal, and is used to either capture the reported information from the item under test or capture the "true" performance of the system. In either case, it is critical that the instrumentation accurately capture the necessary data.

Three YPG facilities were used during this test. The first was the Cibola aircraft test range. Established in 1971 specifically to test the Army's armed helicopters, it has been continually improved since then to meet the needs of modern test and evaluation. This heavily instrumented open air test range is where all the flight testing for this laser designator evaluation was performed.

The second facility utilized was the Laguna Army Airfield (LAAF). LAAF is a fully functional airfield located on YPG featuring two runways 6,000 feet in length, multiple hangars, and the Air Delivery test facility. The facility utilized was the Weapons System Test Integration Lab (WSTIL) ground test facility co-located in a hangar at the LAAF. The WSTIL was specifically designed to support ground testing of armed aircraft, such as the one involved in this test.

TEST ITEM BACKGROUND

For this effort, YPG was tasked to evaluate the laser designator as the item under test. Laser designators have been utilized by the Army for decades and are a key component for precision weapons delivery. The test item was a component of an electro-optical/infrared sensor system that was part of the aircraft's mission equipment used for surveillance, reconnaissance, and targeting. This sensor system had been in use for decades, and the new laser designator was designed to be a modern replacement for the original component. The test item had to have identical form, fit, and function. This was especially critical because the fielding of this new laser designator was to be spread out over several years based on the attrition of the legacy laser units. As the legacy units failed, they would be replaced with the new laser designators; consequently, identical form, fit, and functionality was essential since a mixture of old and new units would be in operation concurrently for many years.

This particular laser designator was essentially a modern replacement for an item that was designed in the 1980s, so ensuring form, fit, and functionality was not a trivial task. Since its original design, there have been tremendous advancements in the field of electronics, lasers, and manufacturing so the challenge was not the technology but rather the seamless integration into the aircraft.

Much had changed on the aircraft in the decades since the sensor system was first integrated onto the aircraft, so ensuring proper interface was one of the most challenging aspects of the entire development effort. When the sensor system was originally designed, it was done in conjunction with the aircraft development. The process included an integrated team comprised of engineers from the sensor developer, aircraft manufacturer, and other groups. The large integrated team had a considerable amount of pooled experience that could be devoted to complex integration issues. When this single laser was upgraded decades later, the level of integration experience was considerably less.

Finally, validating a new non-eye-safe laser design can be challenging for the manufacturer because of the operational hazards. When utilized tactically, they are used to designate targets at distances measured in miles but manufacturers can only test their lasers at very short ranges (tens of meters) in a controlled laboratory environments. These factors often leave many integration items untested by the manufacturer prior to field testing.

TEST DESIGN

Many things were considered by the YPG team when designing this test. A test of a laser designator should ideally be conducted in open air, at long range, and in a variety of conditions because this best replicates the conditions that the system would be employed in. As designed, this test would have both ground and flight test phases. This is a common approach to reduce test costs associated with flight testing. Our customer was an aircraft program manager and he was constantly balancing cost and schedule impacts while developing this product. YPG worked to develop the best mix of ground and flight testing that minimized cost and schedule while gathering enough data for a thorough evaluation. Flight testing would be conducted on the Cibola range to assess long ranges and the ground testing out to 1,500 meters at LAAF.

The YPG team focused on testing the functionality since the preliminary form and fit evaluation was completed prior to the aircraft's arrival at YPG. The plan was to test functionality in two main areas: performance and integration. The performance of the laser would be tested in areas such as duty cycle, beam divergence, stability, and accuracy. To test the laser performance, approximately twenty different test scenarios with repetitions were planned. If executed and instrumented correctly, these trials would provide enough information to assess the various areas of performance with a high degree of accuracy. Most of these test scenarios had to be completed while the aircraft was in flight due to the distance specified for the trials, as well as the need to evaluate performance with real-world aerodynamic and environmental effects present. For example, the vibrations associated with an aircraft in flight had to be included when evaluating laser spot stability.

Integration, on the other hand, required testing to verify thousands of possible mode/switch combinations that could result as the aircrew utilized the sensor system. During the time of the original development, the ability to effectively segment software modules was not possible; consequently, the test design had to also verify functionality of the various other sensor system components. Furthermore, the sensor system interacted with other subsystem on the aircraft as well. For example, to determine the geographic location of a target the crew would use the sensor system. The process required use of the laser designator and a transfer of data between the sensor system and the navigation systems. These external data exchanges would also need to be verified to validate the integration. Consequently, interface testing, even when using appropriate statistical analysis techniques, required hundreds of iterations to be performed to gain the necessary confidence that the laser designator has indeed been successfully integrated. For the sake of cost and efficiency, the plan was to maximize the ground test trials for interface verification.

TEST EXECUTION

This paper focuses on the ground test portion of the evaluation; however, it was the flight testing portion that required the aircraft to be instrumented. This instrumentation suite was ultimately used during the ground test and developed by YPG to record aircraft data onboard while also transmitting a key subset of this data real-time to the Mission Control facility. Telemetered data includes pilot and co-pilot display video, MIL-STD-1553 parameters, intercom system audio, and independent time space-position information, which allowed real-time analysis as well as command and control to be done during flight testing.

The first order of business to attend to after the aircraft arrived at YPG was to install/check out the flight test instrumentation package. Once accomplished, the preparation to start the ground testing began. The plan was to utilize the WSTIL and its Test Control Center (TCC). The TCC would be the “mission control” during the ground test, allowing the WSTIL extensive capabilities to monitor, document, and analyze the results to be utilized during this test. The WSTIL made the mission easier to support logistically, since there was ample space for people to gather and monitor data as the ground test was being conducted. More benefit is realized during the analysis/reporting phases of testing, where collaboration and organization of information produced better products faster.

THE PROBLEM

The ground test plan called for extensive non-eye safe laser trials to be conducted at the LAAF. This type of test has been done for many years, and standard operating procedures are in place that allows this to be conducted safely. Based on the desired test conditions and the current airfield activities, the test aircraft had to be located approximately 50 meters in front of the hangar that housed the WSTIL for safe operations.

This aircraft location was not an issue for executing all the planned ground test trials; however, data collection, situational awareness, and data reduction were negatively affected. The aircraft only has two crew stations, both of which are used to conduct the test matrix, leaving no space for support personnel. A Test Officer is on-site conducting the test; a data collector documents the events and different mode combinations for the Test Officer; and a ground safety officer is also required and is in constant communication with aircraft and airfield tower. These individuals, and any other required personnel, had to stand around the aircraft and look into the cockpit as crew members executed each test point. This was cumbersome for support personnel and placed them inside the hazard region of the laser designator during test execution.

The WSTIL was not viable due to the distance to the aircraft. When the WSTIL was designed, two of the assumptions were that the test aircraft would be co-located in the same hangar and the test aircraft would not need any additional instrumentation to be connected to the WSTIL. Simply stated, the interfaces from the aircraft to the WSTIL (MIL-STD-1553, Video, Audio, etc.), were to be directly wired in their native format. These native formats would not support transmission at the distance required for this particular test. Utilizing the aircraft's on-board telemetry package would require setting up a telemetry ground station in the WSTIL, which was not realistic or cost-effective. So although the benefits of utilizing the WSTIL were in sight, a simple time expedient solution was required to successfully complete the test.

THE SOLUTION

As is often the case, necessity is the mother of invention. As the test team collaborated and brainstormed options to utilize existing wired WSTIL interfaces, a solution began to evolve. One team member recalled that when the hangar and WSTIL were built, power and Ethernet lines were routed to several locations on the tarmac with one drop at the physical aircraft test location. With a small network switch change and adding a couple extension cables, the Ethernet connection could be routed into the WSTIL. But how could the test team quickly get all the necessary data (video, bus parameters, etc.) on a single Ethernet connection? Another team member realized that the IRIG 106 Chapter 10 recorder installed on the aircraft as part of the instrumentation package had the capability to produce an Ethernet data stream composed of any data being sent to the recorder. Although the recorder already had the capability, this was a new application at YPG.

The recorder could be setup in broadcast mode and output a UDP stream that multiplexed multiple types of data together. For this test, two 1553 data streams, two standard definition video streams, and an audio stream were in the UDP stream. The only new hardware that had to be added was a new interface cable for the recorder. The Removable Memory Module for the recorder was setup with a static IP and net mask. As soon as the recorder was powered up, the recorder started sending packets on that address. Any information sent to the recorder was present in the UDP stream. Ethernet stream had the added bonus of already being in a Chapter 10 compatible format for data display purposes.

The WSTIL had a considerable amount of Chapter 10 display capability and could easy record the Chapter 10 stream. The WSTIL had previously been used extensively for post-flight analysis utilizing Chapter 10 files recorded during flight testing, which made it a straightforward task to have those tools available for this ground test. The output of the recorder was hard wired into a network switch in the WSTIL, which allowed multiple users to subscribe to the stream and view information.

The Test Officer selected the 1553 bus parameters to monitor the appropriate receive and transmit messages in order to determine if a command transmitted to a remote terminal on the aircraft 1553 bus was correctly interpreted by the receiving remote terminal. For example, when the sensor is commanded to point to a particular angle, the Test Officer can determine if the sensor moved to the correct angle. Those bus parameters were added to the recorder's TMATS setup file. Chapter 10 Software in the WSTIL displayed Pilot and Co-Pilot video, Integrated Communication System (ICS), and the 1553 bus parameters during the mission. The video and audio were used for situational awareness. The key 1553 parameters were used by the data collectors to ensure the aircraft was in the proper configuration for a particular test point, taking that burden away from the Test Officer. This allowed for more accurate data collection and fewer repeated events due to improper configuration.

The next significant improvement to the ground test was the realization that the laser test set could be run remotely. One of the key capabilities of a laser designator is its ability to lase at different rates. The different rates are used to sort out the battlefield and allow multiple precision weapons to be utilized at once. Consequently, one of the primary objectives of the ground test was to verify the new laser designator was capable of producing the hundreds of different rates. In order to verify that the test item was indeed performing correctly, a PC based laser test set was utilized. The test set used a laser sensor to verify the desired rate was achieved, but also required an operator to be in close proximity of the laser termination point. This meant the operator's workstation had to be located within the surface danger zone of the laser designator. Although proper personal protective equipment was available to the operator, the safety requirement is to remove all personnel from the hazard area if possible.

Furthermore, logistics involved numerous back and forth radio calls to coordinate the test matrix and collect the necessary data. The solution was to relocate the laser designator operator into the WSTIL with the other support personnel. Point-to-point wireless radios were used to connect to the laser test set. These radios operated in the 5.4 GHz band, which would not interfere with other tests using normal telemetry frequencies. The radios were stand alone and had been used at YPG before, so they already had the necessary approvals to operate. The radios connect using Ethernet technology, but for this setup, only the radio test set and computer controller were on the network. The laser test set and one radio were out in the open and located about one kilometer away from the WSTIL hanger. The second radio was outside the hanger door and connected to the WSTIL with an Ethernet cable. The radio frequency (RF) modem was connected to the network switch, which allowed a remote desktop connection from any computer in the WSTIL.

Once an RF connection was established with the laser test set, the Windows remote desktop application was used to display the laser test information on a computer in the WSTIL. This computer was collocated with the computer that was displaying the aircraft information. Consolidating the test team in one place had the added benefit of them being able to analyze aircraft operational information and data from the laser test set together; this made test operations more effective and efficient.

This test also showed that a hard-wired connection was not required for the Chapter 10 UDP data stream. An RF radio similar to one used for the laser test set could be used instead, increasing flexibility since the aircraft could be located anywhere around LAAF. Future plans include setting up an RF radio at the test aircraft, sending the Chapter 10 UDP Ethernet stream out of the recorder into the WSTIL, and then routing the stream onto the network. Real-time streaming data would be available for Test Officers to view from their desks. The Chapter 10 recorders in the WSTIL have the ability to be remotely controlled and can playback test data for Test Officers as well. Additionally, since data is being recorded on a dedicated server, multiple users could access the data at the same time without adversely affecting the stream coming from the aircraft. The server also has a video control panel that allows any video coming into the WSTIL to be displayed on large display monitors.

CONCLUSION

The test was a success. Existing hardware was used to expand capabilities to the benefit of the mission. Although Ethernet is not a new technology, its application for remotely controlling laser test sets had not previously been considered. For YPG, the focus of Chapter 10 had always been recording and reproducing data, not real-time display. The Chapter 10 UDP output has many potential real-time uses beyond this mission that YPG is just starting to explore.

The customer was very satisfied with the support they received. By remotely controlling the laser test set, the potential for injury to the laser designator operator was eliminated; the data collectors were able to see and hear everything that was going on in the cockpit without standing adjacent to the aircraft; and test execution was improved. This resulted in more accurate data being collected in a shorter period of time. Moreover, YPG expanded current capabilities utilizing existing hardware.

REFERENCE

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