VIDEO BUS INTEGRATED TELEMETRY SYSTEM

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ABSTRACT

Yuma Proving Ground (YPG) personnel developed the Video Bus Integrated Telemetry System (VBITS) for air delivery testing at YPG. The system consists of a common rack for mounting both video and telemetry equipment, which makes installation easier and more time efficient. Prior to the one-rack concept, the video, TSPI, and telemetry were all installed as separate entities competing for space, power, and time. Requirements to downlink High-Definition (HD) video from the aircraft prompted research into technological improvements in transmitters, on-board encoders, and recorders. These advances allowed the integration of video, analog sensors, and aircraft bus data into a single telemetry stream. Future advancements will include combining multiple HD video sources in a single downlink.

KEYWORDS

1. Chapter 10
2. Ethernet
3. Wireless
4. User Datagram Protocol (UDP)
5. High Definition (HD)

INTRODUCTION

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 2013, YPG fired over 400,000 rounds of artillery, mortar, missile and small arms munitions, flew over 2,800 aircraft sorties, drove over 145,000 test miles, and conducted over 2,100 airdrops. These numbers more than double when events conducted in support of training are included. For the last 3 years, YPG was the busiest Army proving ground.
The Aviation Systems and Electronic Test Division at YPG is responsible for testing of aviation 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.

YPG has been testing air delivery systems since the early 1950’s and is the Army’s sole development tester for air delivery systems. Throughout the years, many different types of technologies were developed to meet the Army’s wide-ranging requirements for both personnel and cargo air delivery systems. Although there is no question that anything airdropped from an aircraft will eventually hit the ground, there are many complex interactions involved that can and will impact the performance of all systems designed to execute this simple sounding act. As a result, there is an increasing demand for air delivery instrumentation regardless of the type of system being tested.

One of the earliest requests for aircraft instrumentation was for video footage of the load as it exited from the aircraft. This video coverage augments the ground and airborne cameras used to document all the phases of an air delivery trial. To address this requirement, YPG’s Optics group developed an “on-board” video pallet that used standard definition video cameras and recorders. Requests for an independent TSPI source and the recording of the aircraft’s MIL-STD-1553 bus and other analog data signals available on the aircraft followed. To address these requests, two other YPG groups provided their own “on-board” pallets to support each of these requirements. After years of air delivery testing, it became clear that even though the types of systems being tested and the aircraft used could vary greatly, these three instrumentation types were common to most.

Until recently, efforts to instrument a particular test aircraft were handled independently by three different groups, which were each responsible for either video, TSPI, or signals. Figure 1 shows an example of past instrumentation efforts. Although this approach was effective, the net result was that all instrumentation efforts were custom jobs with little or no direct carry over to a follow-on test, i.e. effective but inefficient.

![Figure 1. Legacy Instrumentation Pallet](image_url)
In order to better address the need for instrumentation for air delivery testing, YPG personnel developed the VBITS to consolidate all the instrumentation used on the aircraft into a common package that could be installed in a time efficient manner on a variety of aircraft types. The VBITS effort also included upgrades to HD video, a HD capable telemetry down link, and the process and procedures needed to standardize efforts.

**TEST ITEM BACKGROUND**

YPG’s VBITS was an effort to develop a common instrumentation package for use on cargo aircraft during air delivery testing. Controlled flexibility was the key design goal. This goal was driven by the need to balance support to an expansive air delivery mission, multiple aircraft types, emerging instrumentation requirements versus a long and involved airworthiness approval process, and the need for standard processes and procedures.

The great versatility and flexibility that is provided by recording data in a IRIG 106 Chapter 10 Digital Recording Standard file made it the obvious choice for any recorder selected. It takes signals from multiple data sources and records them in a Chapter 10 file. That data can be analyzed post-mission or viewed real-time in a Mission Control room. One operator is all that is required to operate the system in flight. Figure 2 illustrates the basic functions of VBITS.

![Figure 2. VBITS Basic Functions](image)

The VBITS pallet can record up to eight HD video streams, four aircraft 1553 dual-redundant data busses, two audio channels, eight analog sensor inputs, and one TSPI channel. Any of the data recorded can also be transmitted to the ground for real-time display in mission control. The system is designed so only the capabilities required for the mission need to be powered on and functional. It is also expandable to accommodate future requirements that have yet to be defined. All major equipment is permanently installed on a removable instrumentation rack.
EQUIPMENT

The VBITS rack has equipment from three different organizational groups that each individually support airdrop testing at YPG. Figure 3 shows a Block Diagram of the equipment on the VBITS rack. One group records TSPI information using GPS as a source and their TSPI recorder; another is responsible for recording on-board video from multiple stationary cameras in the cargo bay; and, a third records aircraft 1553 bus information, analog sensors, and transmits that data, plus video, to the ground. This streamlined package combines most equipment onto one pallet for simple installation and removal. The only equipment that is separate from the pallet are cables, cameras and antennas. Previously, each group installed their own equipment independently and then interfaced hardware together once on the aircraft, so installing the VBITS rack reduces installation labor time.

Figure 3. VBITS Block Diagram

The core component of the VBITS system is the Chapter 10 compliant instrumentation recorder. The recorder accepts multiple video signals, Pulse Code Modulation (PCM), 1553 bus information, GPS information, analog signals, Ethernet data, and audio. The recorder has the capability to produce a transmittable signal comprised of any mix of input signals captured by the recorder a groundbreaking Telemetry™ Downlink module. The TM Downlink module outputs data in an IRIG Chapter 4, fixed bit rate, Class II PCM stream that is compatible with existing transmitters, receivers, and telemetry front ends. Up to three independent streams of data can be transmitted to the ground simultaneously.
The rack has MIL-STD-1553 bus couplers, which utilizes transformer-coupling to connect to the aircraft’s avionics data busses. Four dual-redundant busses can be supported. A telemetry transmitter is also on the rack with a 50-50 Radio Frequency (RF) splitter to feed two antennas. The antennas are mounted inside the aircraft on opposite sides to provide the best RF coverage to the ground. The rack has an HD Video monitor so the operator can see camera outputs real-time. It also has an HD video time inserter to insert IRIG B time onto the video.

The VBITS rack has input/output provisions for connecting cables to all external components (cameras, antennas, 1553 bus connections, sensors, etc.). Power conditioning is also built into the pallet to protect the equipment and for quick shutoff in case of emergency in the aircraft. Figure 4 shows a populated VBITS rack.

![Figure 4. VBITS Rack](image)

A TM Ground Station is required to receive the transmitted signal from the aircraft. On the ground, a special module is required to unwrap and reconstruct the data from the TM downlink module into its native format for display and processing. It is also capable of producing Chapter 10 UDP packets, which allows distribution of live streaming data over the network. Since the data is recorded in Chapter 10 format, several standard software tools are available to analyze and extract data products from the file post-flight. Software also exists that is capable of ingesting the UDP streaming data for real-time display.
AIRWORTHINESS

Before flying the VBITS system, it underwent airworthiness analysis. Specification sheets for all vendor hardware were packaged together. Next, YPG utilized in-house engineering assets to perform an initial analysis. Mechanical engineers completed a stress analysis on the structure of the rack along with any physical connections between the rack and the equipment. This involved a finite element analysis (FEA) utilizing a crash load rating of 4.5 gravity force, along with mounting requirements that would be seen in cargo aircrafts. This ensured that even during a crash, neither the rack nor the components would represent a risk to flight personnel or damage the airframe. Figure 5 shows an exaggerated deflection and stress shown utilizing the crash loads. A safety factor of nearly 2 was calculated.

![Figure 5. Rack Deflection and Stress](image)

The VBITS rack also had a full suite of electromagnetic interference and compatibility (EMI/EMC) tests run on it. Figure 6 shows the rack in an anechoic chamber during one of those tests. Two trips were made to the test facility with YPG personnel accompanying the rack to operate the equipment and observe the EMI/EMC testing. Airworthiness approval has been granted for C-17 and C-130 aircraft, which support 99% of airdrop testing at YPG. YPG will seek airworthiness approval from other aircraft platforms, as needed.
All VBITS hardware is temporarily installed on the aircraft—nothing is permanently attached to the aircraft. Equipment is strapped down or secured in place to support testing and is simply removed after the mission is complete.

**SYSTEM BENEFITS**

The VBITS pallet has many physical benefits designed into it. The rack was designed to be easily mounted in a military cargo aircraft; it has multiple tie-down points and a compact design to save time and space when installing it. The connector panel was designed to have all possible input and output connections in one central place, but is still configurable for each mission. The power control panel was designed for a single operator to easily power up and configure the VBITS pallet for the capabilities the mission required. Even the power supply was chosen for its ability to use a wide range of inputs. The power supply can be powered by 47-500 Hz, 85-265 VAC, and single to three phase power source, making it a universal fit for all military aircraft. The only aircraft-specific component required to power the VBITS pallet is a power cable with the appropriate connection.

The VBITS platform is independent of the aircraft it is designed to fly on, making it very versatile. Although physical camera location and 1553 busses vary on different aircraft, VBITS can support them all. VBITS was designed to support a maximum level effort, but if fewer channels are required, then they can be easily disabled or not used. Ultimately, this also leads to a common data format independent of the aircraft, which simplifies the data reduction process.

One of the biggest benefits is that all data is recorded in a Chapter 10 format. YPG Test Officers want to take advantage of all the capabilities that Chapter 10 can offer for their data analysis. Having a Chapter 10 file allows the Test Officer to use any suite of Chapter 10 software to view the airborne data synchronized with other ground-based data sources.
Other benefits to YPG are that all VBITS hardware is compatible with other Aviation test efforts at YPG for commonality and the system is well documented for airworthiness approvals and operational procedures.

FUTURE ENHANCEMENTS

YPG is not currently utilizing all of the capabilities of the system. Audio from the aircraft intercom system (ICS) is desirable in the mission control real-time to provide better situational awareness to the Test Officer. Although this function is referenced in some documentation, it has yet to be implemented. The plan is to use the TM Downlink module to send ICS audio to the mission room. YPG is working with a vendor to develop software that will extract the 1553 bus traffic from the UDP data stream to drive displays in the mission room. The instrumentation recorder already has this capability, but the ground station for the TM Downlink card does not. YPG currently uses a PCM encoder to perform this function, but wants to eliminate that piece of hardware to save on equipment maintenance costs, simplify the configuration, and save space on the pallet.

YPG is also integrating newer Shaped Offset Quadrature Phase-Shift Keying (SOQPSK) transmitters into the VBITS rack. They are more spectrally efficient than legacy PCM/FM transmitters, and they will be able to push more data with less bandwidth. This is especially important since VBITS has the capability to downlink multiple HD video channels along with 1553 and sensor data, which takes up a lot of bandwidth.

Another future enhancement is VBITS Lite, which is a smaller version of VBITS that is on a smaller rack. It will have most of the same capabilities of VBITS, but in fewer quantity and a smaller footprint. This package will be ideal for smaller airframes where space is limited or for safari trips when less instrumentation is required.

CONCLUSION

This approach worked so well that customer’s demand has increased so much that YPG has already begun to expand both the number of VBITS systems and the amount of data collected. Notably, an air delivery test was the first test to transmit and display HD video in mission control at YPG. This capability has already been used on other aviation test programs at YPG. 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 parts of this cutting edge solution. This has also expanded into creating several additional variants into smaller packaging and different configurations for use in different airframes.
REFERENCES

