

RANGE-VIDEO NETWORK (RNET)

Alfredo Berard, Chief Scientist

846 TSS

Eglin AFB, FL USA

Mark Buckley, Software Engineer

JDA Systems Inc

Eglin AFB, FL USA

John Roach, Vice President, Network Products Division

Teletronics Technology Corporation

Newtown, PA USA

ABSTRACT

The deployment of network-based airborne instrumentation systems is leading to cost-efficient replacement of legacy instrumentation systems. One application of airborne data acquisition that has been developed and maintained separately from traditional avionics and orange-wire data acquisition systems is high-speed camera packages. The development of network-based instrumentation systems has led to an opportunity to unify these two previously distinct airborne data acquisition activities. This paper describes the range-video network-based instrumentation system (rNET) being implemented by the 46th Test Wing, 846th Test Support Squadron at Eglin Air Force Base, FL to replace the existing Airborne Separation Video System (ASVS).

Keywords

Instrumentation, High-Speed Cameras, Networking, Video

INTRODUCTION

In the late 90's the Central Test and Evaluation Investment Program (CTEIP) funded the Airborne Separation Video System (ASVS) and its goal was to utilize digital imaging cameras as a replacement for the existing 400 frames per second (fps) film cameras used in an airborne environment. Although there were many different Major Range Test Base Facilities (MRTFB) requirements, a specification was written and funding was allocated for the development and procurement of an ASVS system. The goal of this CTEIP task was to standardize digital image collection, storage, and evaluation. The ASVS was comprised of electronically-shuttered, high-speed, high-resolution digital imaging cameras, a high-density digital data storage device and associated electronics. Although the ASVS program yielded components that are in use today, the hardware components were built to a specification that was proprietary to the manufacturer.

Hardware in use today cannot be replaced with commercial equivalent products since the interfaces, command and control are proprietary. Even if the specification and intellectual property was made available, an outdated defacto standard would be created with outdated technology.

The existing ASVS is the only airborne-qualified high-speed digital imaging system used for weapons separation testing. The ASVS architecture provides for control, timing, and synchronization of up to 32 cameras. Each camera contains up to 5 seconds of volatile storage and the data is sequentially transferred from the camera to a local storage unit. The ASVS uses HOTLink™ PHY chips manufactured by Cypress Semiconductor. The HOTLink transmitters use IBM 8b/10b bit encoding which is DC-balanced and run-length-limited to permit clock reconstruction at the receiver. The ASVS system transmits video data at 160 Mb/s. The 8b/10b encoding produces a binary symbol rate of 200 M code-bits per second, which is the maximum rate specified for the Cypress HOTLink transceiver chips (CY7C924ADX) and has proven to be one of the limiting performance factors of the system. By necessity, aircraft installations require multiple disconnects as wiring is routed through many different compartment bays. Since ASVS cameras are daisy-chained, data is sequentially retrieved utilizing the same HOTLink wiring which often leads to loss of data collected due to wiring and/or impedance mismatch.

A more significant limitation with the existing system is the lack of utilization of standards leading to a proprietary solution and barrier to entry for camera manufacturers. The ASVS is disk-based and its data format and command and control does not adhere to any known standard. The files generated are non-standard Tagged Image File Format (TIFF) images as metadata is inserted in the TIFF headers providing for auxiliary data such as timing information. The original ASVS provided hard drives for storage; however these drives have recently been replaced with solid-state drives in order to improve performance.

A NEW APPROACH TO AN OLD REQUIREMENT

Using experience gained from over ten different aircraft installations (F15, A-10, F16, PODS), a new system is being implemented by the 846th Test Support Squadron that is based on commercial and RCC standards. The key objective of the approach is to implement component interoperability for airborne video systems driven by open standards. For example, one requirement is that high-speed cameras from different manufacturers be utilized in the same network and use the existing IRIG 106 Chapter 10 Recording Standard. The result is expected to create procurement leverage for the customer, based on multiple vendor support and DOD-wide data interoperability. The infrastructure of range-video network would be based on existing airborne network hardware that is already in use in various commercial and DOD programs. Within the 846th TSS/TSI, our approach would leverage existing Joint Range Instrumentation Pod (JRIP) technologies for a generic non-intrusive instrumentation package. The goal is to adopt a system such that it can provide for network-based cameras that can still be backwards-compatible (in form and fit) with the existing legacy ASVS.

Existing F15E 846 TSS camera instrumentation consists of ten cameras (Figure 1). Three cameras each are installed in wing tip pylons (Stations 1 and Station 9), one camera each on

weapon pylons 2 and 8, and two cameras installed on engine bay mounts. Data is sequentially downloaded from each camera to the ASVS Mission System Controller hard drive.



Figure 1: F-15 Camera Installation

The Airborne Separation Video System (ASVS) will be replaced with the high-speed camera component (rNET) of the Eglin Network Instrumentation System (eNET). The RANGE-VIDEO NETWORK (rNET) establishes and promotes implementation of network-aware devices (i.e. switches, cameras, recorders) in an airborne platform. The same wiring that is utilized for ASV cameras will be utilized for rNET. Equivalent to the existing ASVS system, ten (10) cameras will be installed. A total of three network switches will be utilized to create a local eNET video network on the aircraft. A high-level network diagram of the rNET system is shown in Figure 2.

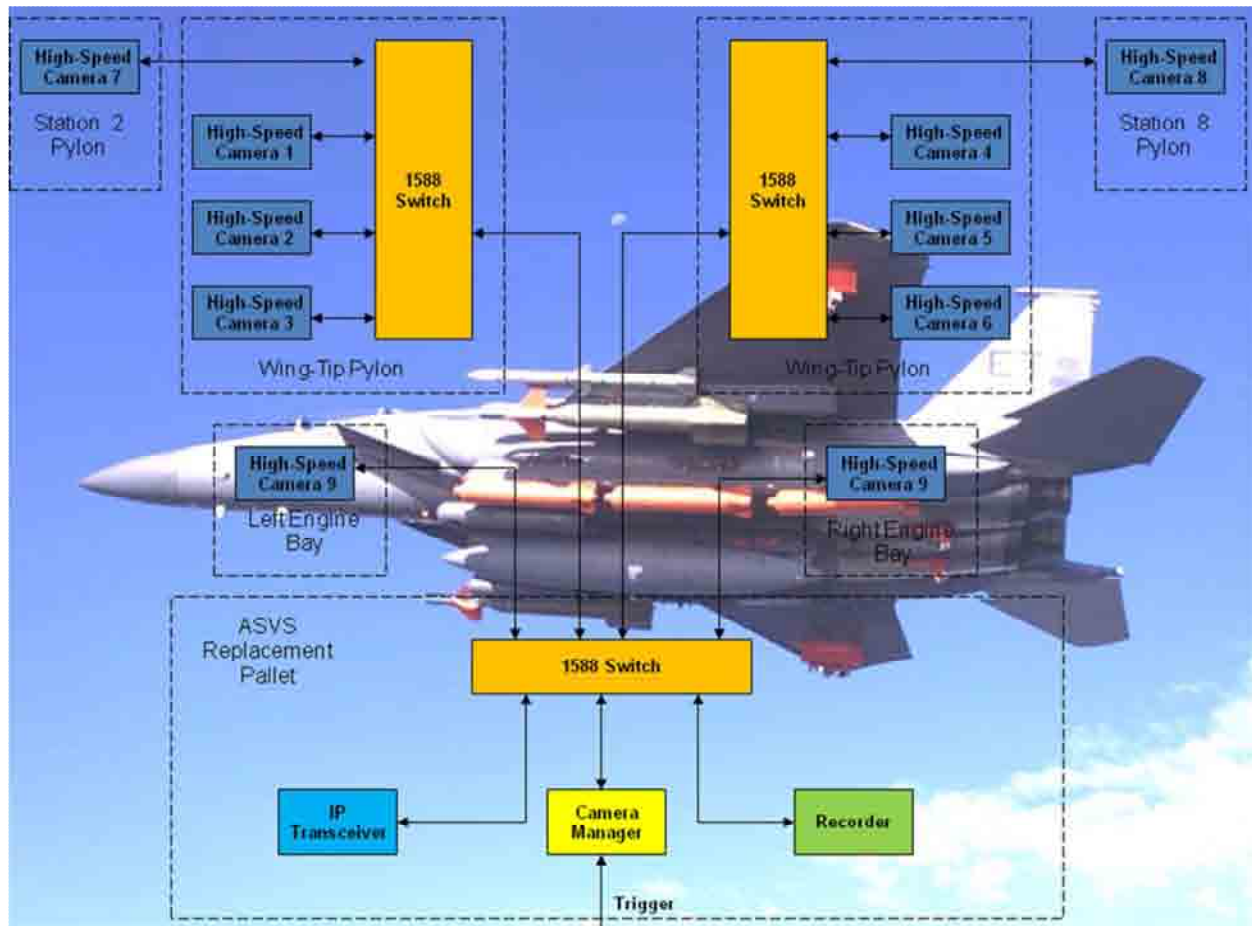


Figure 2: rNET Architecture

The existing wing tip pylons are modified internally with a 5-port Ethernet switch (P/N: NSW-5FT-TG-1) from Teletronics Inc. The first three ports of the switch are dedicated to external cameras, the fourth port is used to interface to the adjacent pylon and the fifth port provides connectivity back to an 8-port switch (P/N: NSW-8GT-TG-D-1). A cable disconnect allows for the ASVS cameras to be installed and the network switch to be bypassed. Critical to the design is maintaining backwards compatibility with mechanical mounts of legacy ASV installations (Figure 3).

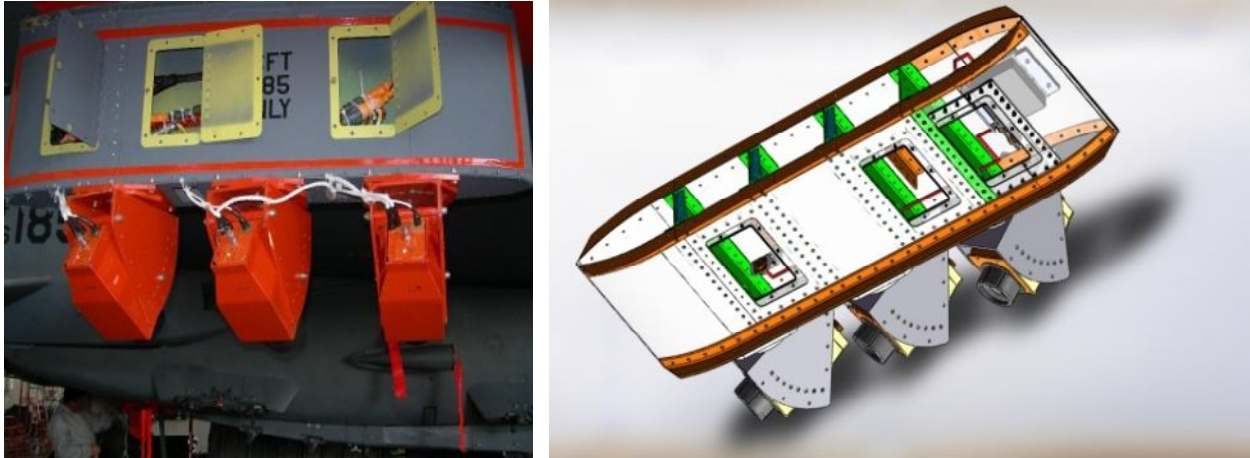


Figure 3: ASV Installation

Inside the aircraft, a pallet will replace the existing ASVS controller and will contain the installed network components. Since the same Gigabit Ethernet (GigE) wiring is utilized, the ASV system can be quickly replaced. Installed in the ASVS replacement pallet is an IP transceiver, camera manager, IRIG 106 Chapter 10 solid-state recorder, and an 8-port switch. The IP transceiver provides IEEE 1588 time to all the network components and provides command and control from the ground over an 802.11a link. The use of bi-directional connectivity allows for real-time mission configuration and data analysis, a capability never realized by ASVS. Additionally, aircraft interface and camera management is provided by the camera manager. The camera manager interfaces to the instrumentation control system, provides NTSC real-time video preview from any camera, and monitors the weapons release and manual run inputs. Data from the cameras is stored IAW IRIG 106 Chapter 10 on either the local or remote media storage.

Vital to the design is the physical layer that provides connectivity for either the legacy ASVS system or a new network-based camera system. Connectivity between cameras and network switches is accomplished utilizing Gigabit Ethernet (GigE), 8 conductor cable from Thermax (MaxFlight Gigabit Plus). The Thermax MaxFlight Gigabit Plus cable inner conductor pairs are utilized as illustrated in Figure 4 to allow for implementation of both ASVS and rNET components.

| CONDUCTOR PAIR | ASV SYSTEM |
|----------------|------------|
| P1 | HL VIDEO |
| P2 | SYNC |
| P3 | TRIGGER |
| P4 | RS-485 |

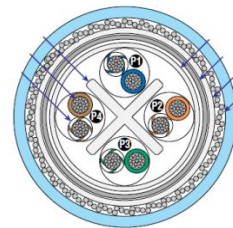


Figure 4: rNET Cable Wiring

Two different types of cameras are utilized in the same system. One camera (nHSC-20 series) is a smaller reduced function device while the second camera (nHSC-30 series) is a larger variant with built-in 1588 support and an on-board recorder. One requirement is for the rNET camera enclosure to be a form fit and functional mechanical replacement for existing 846 TSS ASVS cameras. The approach taken by Mr. Mathew Cooper, lead 846th TSS mechanical engineer, was to create a design for an adapter plate allowing for backwards compatibility with existing 846 TSS cameras. The existing design by Mr. Cooper, henceforth known as "*The Cooper Shell*", is currently being standardized allowing for any standard camera to be installed as illustrated in Figure 5.

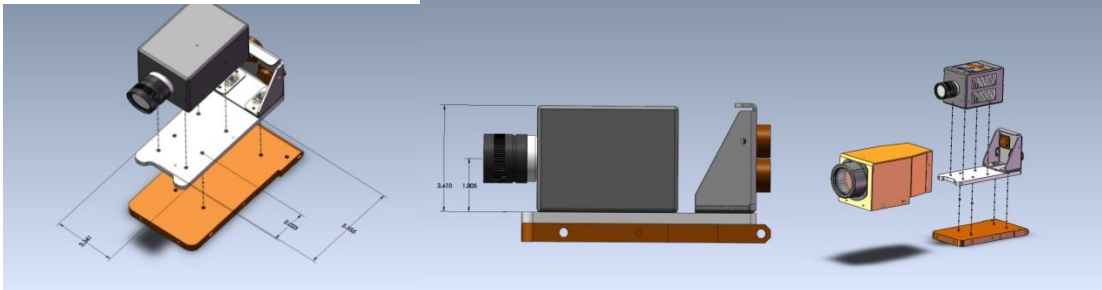


Figure 5: The Cooper Shell

REAL-TIME FULL DUPLEX COMMAND, CONTROL AND DATA

The flexibility and capability achieved in creating a network-based range video system is truly realized through the incorporation of the IP transceiver to interconnect the airborne instrumentation system with the ground network. The nXCVR-2130A transceiver is designed to act as a wireless router for communicating IP packets between the airborne high-speed camera system and the ground network infrastructure. The transceiver uses a Time Division Multiple Access (TDMA) based Media Access Control (MAC) address layer to provide guaranteed bandwidth and Quality of Service (QOS) assignments (that can be dynamically allocated when multiple aircraft are in the air) to control and status protocols flowing to and from the ground. The transmitter power and modulation is automatically controlled based on measurements received from remote transceivers regarding Received Signal Strength Indicator (RSSI) and Link Quality Indicator (LQI). Supported bit rates range from 6 to 36 megabits/sec depending upon received signal strength and interference.

Communicating with the camera manager from the ground, individual cameras can be managed, allowing for preview of the current image, adjustments to exposure, color, and illumination, and field of view can all be made in real-time during the actual flight plan. Status from the airborne system can be accessed using commercial network standardized Simple Network Management Protocol (SNMP) queries, and real-time displays used to convey this information to the operators on the ground. Once a triggered event has been captured by the camera system, individual cameras can be queried and frames downloaded to the ground for review and analysis. Events can be repeated if feasible, or changes to operating parameters can be made if environmental conditions change.

rNET GROUND SOFTWARE SUPPORT

As with all airborne instrumentation systems rNET requires ground support software. This software will be operated by technicians, engineers, systems operators, and analysts. Therefore, the critical architectural requirements are disciplined implementations, tight integration of the main requirements and ease of use by all different levels of operators. The main requirement areas consist of:

1. Configuration Management of rNET Devices:

- Network Topologies (test articles, network devices, data parameters)
- Recorder Configurations and Settings
- Camera Configurations and Settings

2. Pre-Flight Checkout of rNET ASVS:

- Field of View/Region of Interest and Bore Sighting
- Triggering and Capture
- Image Capture Quality
- End-to-End Systems Go/No-Go

3. In-Flight Command & Control of rNET ASVS Components and Real-Time Data Display:

- Camera Command and Control
- Image Sampling and Real-Time Video Displays
- Test Platform Mission and Instrumentation Data Displays (2D/3D Flight-TSPI, Time History, CVT, Discrete's)
- Test Point Objectives Go/No-Go's

4. Post-Flight Playback and Processing of Recorded rNET Data:

- Raw Data Archivals and Management
- Time and Event-Based Exports
- Data, Image and Video Conversions
- Export and Conversion Data Management

As a networked-based system all of these software functions can take place on different host computers on the network, each having its own function and operator, or one or two host computers that combine functions under a single operator. The same software components and functions that a pre-flight technician used on the flight line can be used by an engineer during the test to make adjustments to the system. The same software components and functions that a test engineer or analyst uses to view the data can be used by the pre-flight technician during systems setup.

Configuration Management of rNET Devices:

One of the key ground support elements of the rNET software is standards-based configuration management and network device setup. Multiple network topologies must be assembled and verified by operators. This includes linking in avionics bus and telemetry parameters from other network instrumentation systems, providing a single integrated configuration management environment for the highest level of fidelity of test documentation, data playback and processing. These network topology configurations and settings are then used in pre-flight checkouts, real-time command, control and display, and post-flight playback and processing across the network.

Pre-Flight Checkout of rNET ASVS:

Once network topologies have been produced and verified for the test articles, network devices and data parameters lab and pre-flight checkouts of the systems must be accomplished. Because these are Ethernet-based systems, flight line checkout is as simple as taking a laptop to the test article(s) and connecting a network cable to the laptop network adapter and an rNET switch. No special or proprietary interfaces or cards are required. Checkout of other Ethernet-based instrumentation systems such as avionics buses and telemetry will be conducted along with checkout of the ASVS. Ensuring camera image capture and camera alignments with regions of interest (ROI) are critical. In real practice, settings made on the ground often change due to environmental or flight dynamics during the test. Key to the rNET software is the ability to fine tune camera systems and data systems in-flight, using the same software functions as ground setup/checkout. This ensures no or minimal loss of data and also ensures the quality of that data.

In-Flight Command and Control of rNET ASVS Components and Real-Time Data Display:

Aside from the full duplex command and control capabilities that rNET now provides, another area that will gain new capability with rNET is the merging of test platform data (aircraft and armament parameters) with separation video and imagery.

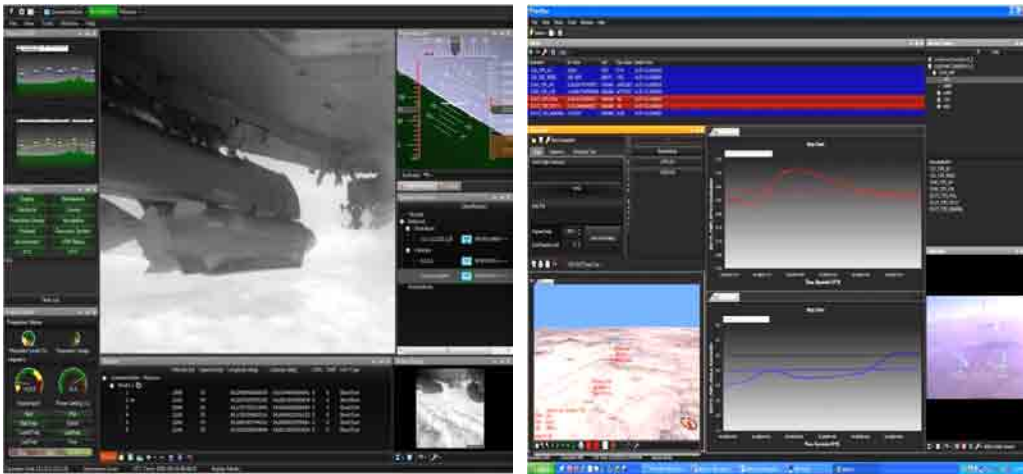


Figure 6: Software Control System

This will provide a single integrated environment for in-test and post-test displays and analysis. Time aligned and synchronized aircraft 2D and 3D situational awareness displays, avionics bus

data, telemetry parameters, ASVS video snapshots and frame imagery will now be available on the range network at multiple PC stations (Figure 6).

Post-Flight Playback and Processing of Recorded rNET Data:

The last function of rNET integrated ground support software is post-test data playback and processing. Based on the leveraging of IRIG 106 Chapter 10 digital recorded standard for the capture of rNET data, integrated high-fidelity playback will now be possible. With embedded setup records, indexing and events automated playback configuration without any external meta-data files can be accomplished. All test article and test platform data will be automatically time aligned and synchronized to ASVS imagery. Ground telemetry site-recorded data in Chapter 10 format can also be played back simultaneously, or data from chase aircraft can provide complete test environment visualization, with all data 100% time aligned to 1/10 of a microsecond.

With the use of open data format standards, post-test archival to preserve the original data and the following subsequent export product extraction can take place in the very same data display environment that was used during the test. Also, with test data parameter information embedded within the Chapter 10 setup records, an analyst can select the data to be displayed along with the ASVS imagery. Many new digital imagery manipulation technologies can be applied or format conversation to legacy display software requirements can be made.

rNET GROUND SUPPORT SOFTWARE ARCHITECTURE

The main approach of rNET ground support software is to keep required functions scoped and focused, and to use integrated communications and service-based end-point transport architectures for data movement, which ensures maximum stability in a flexible environment. The old adage that “software that tries to do everything never does anything very well” can prove to be true, so disciplined adherence to core functionality is paramount. “Nice to haves” or out-of-scope features are not implemented.

The main architectural component of rNET ground support software is SMARTS - Services for Multiple-Access and Real-Time Software. This provides a reusable software framework for the access, transport, processing, presentation and distribution of test and mission data that is compliant with Inter Range Instrumentation Group (IRIG) and industry standards (see Figure 7).

Using SMARTS, the rNET ground support software is packaged as interoperable services and exposed to service consumers within the application and its utilities. The use of a Federated Data Structure (FDS) transparently integrates multiple autonomous raw data measurements (MIL-STD-1553, PCM, imagery, analog, etc) into a single (virtual) data structure. SMARTS uses the FDS internally to assemble products or externally as a data producer service. This service provides common time-tagged data from multiple sources and formats to the consumer as a single source and format.

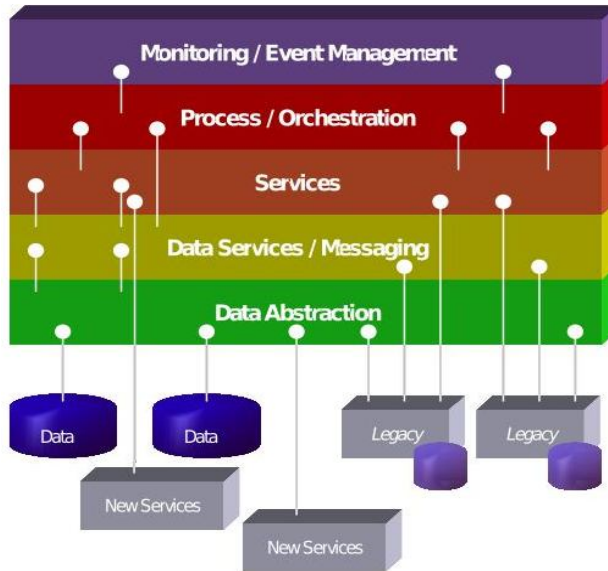


Figure 7: SMARTS Architecture

CONCLUSION

The 846 TSS mission is to provide airborne instrumentation and mission support for test and evaluation. In support of that mission the rNET implementation offers a unique opportunity to validate network implementation and replace proprietary systems with the use of industry and RCC standards.

Along with many new hardware and technology innovations, as well as the move to an interoperable standards-based system, totally new software architectures and bottom-up development are being implemented. This removes the inefficiencies normally encountered when new approaches and requirements are added to older software programs which end up in layered and disjointed code base. The result is less than ideal software execution that causes problems in overall operations for the life of the system. The rNET program is providing an environment of new innovation in software development which will provide dividends to end users and make implementations of future requirements faster and most cost effective.

Several aircraft modifications are planned to replace failing legacy ASVS systems in the fall of 2010 and ground support software development has been underway since January of 2010. Initial rNET system demonstration is planned for the fall of 2010 with an overall goal to modify all legacy ASVS systems and to use new non-intrusive “pod based” ASV or instrumentation solutions for non test-coded aircraft.