A COTS AND STANDARDS BASED SOLUTION TO WEAPONS SYSTEM INTEGRATION

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ABSTRACT

The Weapons System Test and Integration Laboratory (WSTIL) at the U.S. Army Yuma Proving Ground (YPG) will provide a new capability for ground based testing in this arena. Current and near term YPG scheduled test programs will benefit tremendously from this enhanced ground test capability provided by the Weapons STIL. The Weapons STIL's design goals center on the implementation of an automated mechanism for testing the weapon systems and sensors that are currently the responsibility of the YPG facility. To meet the Army's weapons test needs the Weapons STIL incorporates various levels of digital stimulation, human-in-the-loop, hardware-in-the-loop, and installed system test facility (ISTF) techniques to maximize ground testing in order to focus and optimize subsequent open air flight testing.

This paper describes this work in progress.

KEY WORDS

Standards, TMATS, Test and Evaluation, Weapons System, Ground Testing, Installed System Testing

INTRODUCTION

Over many years of testing weapon systems, lessons learned have shown that system problems are less costly to correct if discovered during ground test in both developmental and operational test and evaluation rather than in flight-test. Several factors contribute to this; the largest of which is the cost of range and test assets per flying hour. A ground test program with many test points is less costly to accomplish than an equivalent flight test program for both weapons platforms and their associated systems. An appropriately planned and implemented set of ground test activities may not reduce the number of test flights, but will provide an opportunity to ensure scheduled flight missions to be performed in a more efficient and cost effective manner.

The ongoing Global War on Terror (GWOT) places an urgent need on the Army to rapidly field new weapon systems and improvements to existing weapons and deploy to the warfighter. This need makes the timely development of the Weapons System Test and Integration Laboratory (WSTIL) critical. The YPG Weapons STIL will provide a capability which currently does not exist. Current and near term YPG scheduled test programs will benefit tremendously from this enhanced ground test capability.

The Weapon STIL's design goals center on the implementation of an automated mechanism for testing the weapons system and associated sensors that are currently the responsibility of the Army YPG facility. One of the primary focuses of the Weapons STIL design is to provide as much automation as possible in the testing process to minimize operational intervention, expedite testing, provide a repeatable environment for testing, and prepare report outputs in an easy to integrate and implement format.

The high level design goals of the Weapons STIL are defined as follows:

1. To test and identify problems associated with the integration of air-platform weapon systems with other onboard aviation systems.
2. To test the implementation of corrective actions.
3. To provide a value added capability for the Army's Weapons Test and Integration mission.
4. To provide test information in "real-time" to and from the air-platform systems through a Test Control Center (TCC).
5. To maximize the use of commercially available hardware and software (COTS) as well as Government and Industry standards around a network centric implementation allowing for a secure and flexible system architecture.

The Weapons STIL provides unique test capabilities, the most important of which includes:

- Evaluating the performance, response, and sensitivities of software algorithms by precise control of avionics processor inputs and automated analysis of outputs.

- Investigating weapons/avionics integration anomalies by recreating basic operational conditions/scenarios until all the cause and effect relationships are thoroughly understood and next-test-phase/flight decisions can be made.
- Regression testing of new software changes to ensure that undesired impacts did not occur to functions that have been previously evaluated.

- Integration testing to verify interface documentation, degraded operation, and self-test adequacy.
- Avionics sensor integration to include radio frequency (RF), electro-optic (EO), infrared (IR), and electromagnetic support measures (ESM).
- Ensure test "repeatability" is achieved to allow for adequate regression testing insuring that the identical test is run.

WEAPONS SYSTEM TEST AND INTEGRATION LABORATORY (WSTIL)

The Weapons STIL development team consists of the system engineering and integrator (Spiral Technology, Inc.), local YPG program management and facility coordination (TRAX International, Inc.), the end user organization (Aviation and Air Delivery Systems Division, Aviation Branch, U.S. Army Yuma Proving Ground), with overall project management from Project Manager for Instrumentation, Targets, and Threat Simulators (PM-ITTS).

Requirements gathering and design documents and reviews have been generated which include:

- Test Capabilities and Requirements Document (TCRD)
- Integrated Master Schedule (IMS)
- System Engineering Management Plan (SEMP)
- System Specification (SS)
- System/Subsystem Design Description (SSDD)
- Miscellaneous other Documentation
- Post Award Conference (PAC)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Test Readiness Reviews (TRR)
- In Process Reviews (IPR)

The table below presents the three (3) Key Performance Parameters (KPP) which were a guide to the development team.

Characteristic	Key Performance Parameter	Development Threshold	Objective
Networked	**KPP 1**	**Major components will be capable of a network interface.**	**Net-ready. System capable of participating in distributed testing over the Defense Research and Engineering Network (DREN).**
Repeatable	**KPP 2**	**Improve accuracy, efficiency and repeatability of test conditions through employment of computer-controlled, scripted scenarios.**	**Threshold = Objective**
Adaptable	**KPP 3**	**Reconfigurable to support performance assessments of at least two manned and/or unmanned platforms in a controlled environment.**	**Reconfigurable to support performance assessments of a broad range of aircraft (manned and unmanned platforms) and missions in a controlled environment.**

As a logical outgrowth of satisfying these KPPs and from close communications with the user community, the Weapons STIL development team incorporated several concepts into the design of the Weapons STIL. These include:

1. As a result of implementing KPP-1, the decision was made to utilize the Weapons STIL Secure Network to provide the control interface to the various test equipment required to support testing. As an example, to simplify the interfaces for the Weapons STIL configuration, the development team chose to control all devices through "Ethernet" even if this is not available on each device. This can be accomplished by providing an "Ethernet to/from IEEE 488" converter as well as an "Ethernet to/from RS-232" converter.

2. As a result of implementing KPP-2, the decision was made to implement the Weapons STIL utilizing, where feasible, both industry and Government standards to insure compatibility with existing systems and also utilize, as much as possible, commercial-off-the-shelf (COTS) components to integrate the Weapons STIL capability. An example of this standardization approach is seen in the selection of the Telemetry Attributes Transfer Standard (TMATS) as the foundation of the mission configuration component of the Weapons STIL implementation.

3. By implementing the Weapons STIL mission configuration data system around the TMATS, the Development Team chose to build around a Government supported standard that has been in use since 1993. Further, by requiring that this standard be adhered to by the major data acquisition and processing components of the Weapons STIL design further supports long range planning and technology refreshes.

4. To satisfy the requirements driven by KPP-3, the Development Team chose to implement the Weapons STIL in a redundant mode. Considering the possibility of two (2) completely independent test activities being performed in the Weapons STIL facility, each of which may have proprietary or competition sensitive data they would not be willing to share with others, it was important NOT to mix data acquisition and/or data storage between the two missions. This drove the decision to acquire two (2) data acquisition and archive/retrieval subsystems to be placed in the Weapons STIL.

5. To further provide the maximum amount of operational flexibility of the Weapons STIL system, the Design Team chose to acquire and implement a Digital Matrix Switch allowing the Weapons STIL operations personnel to select which data is routed to each of the data acquisition and archive/retrieval subsystems from a computer interface.

6. As the foundation of the Weapons STIL, the Local Area Network (LAN) is implemented utilizing the Common Identification Standard for Federal and Contractor employees and is Federal Information Processing Standards (FIPS) 140-2 compliant. It is designed to be available to at least 48 test engineers from outside the Weapons STIL complex using a 2-Factor Authentication process, and be available to the test engineers from within the Weapons STIL complex.

Figure 1 represents a logical view of the Weapons STIL's Operational Concept. The large circle in this view represents the Weapons STIL private secure LAN which consists of a Gigabit backbone and contains all of the necessary security components to protect it from intrusion from the outside world. This basic infrastructure is critical to the operation of the Weapons STIL in that it carries most of the information between the different components (subsystems) which make up the Weapons STIL architecture including:

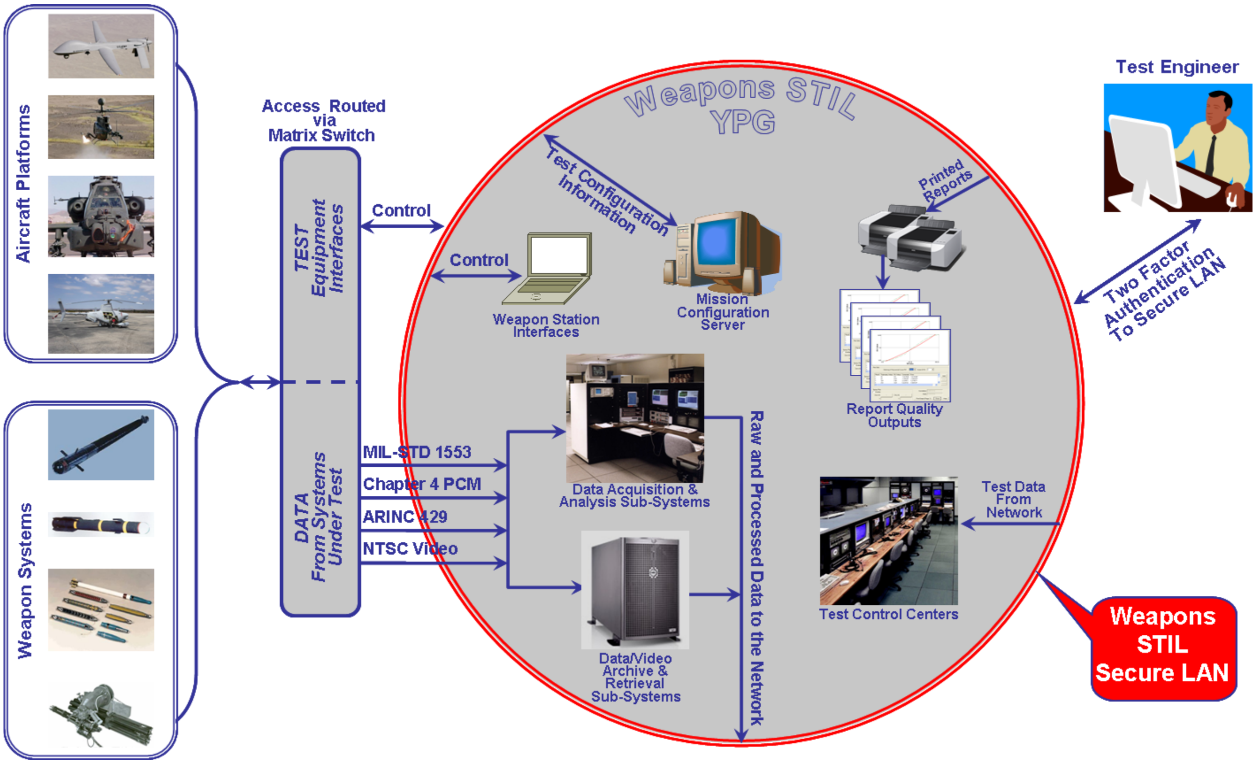

Figure 1 – Weapons STIL Concept of Operation Flow

Aircraft and Weapons Interfaces: The aircraft and weapon systems under test integrate to the Weapons STIL via a set of standard data interfaces including, MIL-STD-1553 Busses, ARINC 429 Busses, Inter-Range Instrumentation Group (IRIG) Chapter 4 PCM, National Television System Committee (NTSC) and Digital Video.

LAN Infrastructure: The Weapons STIL's Secure Private LAN is built on a Gigabit Ethernet backbone allowing for the transfer of all of the information necessary to support the various test missions. Each of the design components of the Weapons STIL is directly connected to this LAN for ease of communications between subsystems.

DREN Interface (Objective): Not in this version of Weapons STIL Implementation however, the Weapons STIL is designed to support a future interface to the Defense Research and Engineering Network (DREN).

Test Engineer Interface: The Test Engineer Interface is designed to allow any of the authorized test engineer's access to test data during and/or after a mission over a secure interface to the Weapons STIL network.

Mission Configuration Server: The Mission Configuration Server is located in the Data Analysis Center and represents the heart of the centralized configuration definitions for any of the test missions to be accomplished utilizing the Weapons STIL. This includes format definitions of the aircraft/weapons data sources, measurement definitions of the data to be utilized for testing, calibration definitions (as appropriate) for each of these measurements, and initial condition definitions for the Weapons STIL test equipment.

Data Acquisition and Analysis Sub-Systems: The Data Acquisition and Analysis Sub-Systems (one for each of the two test bays) are responsible for gathering, processing, and distributing pertinent mission data in real-time and post real-time.

Data/Video Archive and Retrieval Sub-Systems: The Data/Video Archive and Retrieval Sub-Systems (one for each of the two test bays) are responsible for capturing the data associated with each test and providing it to the test engineers for post test analysis and report preparation

Test Control Centers: The Test Control Centers (one for each of the two test bays) have five (5) display stations at which the test engineers can observe the test in real-time and/or play back mode. Data is presented in tabular or graphic displays (i.e. time history plots, parameter versus parameter plots, bar graphs, pie charts, discreet displays, etc.).

Weapons Station Interfaces: The Weapons Station Interfaces (one for each of the two test bays) is responsible for the initial configuration of the test equipment included in this active test as well as dynamic control and monitoring of this test equipment during the execution of the test.

Post Test Analysis (Report Quality Outputs): The Post Test Analysis component of the Weapons STIL consists of a set of COTS software which interfaces to the data/video archive system and provides its user with a significant amount of "data mining" and report generation capabilities.

Physical Accommodations for the Weapons STIL

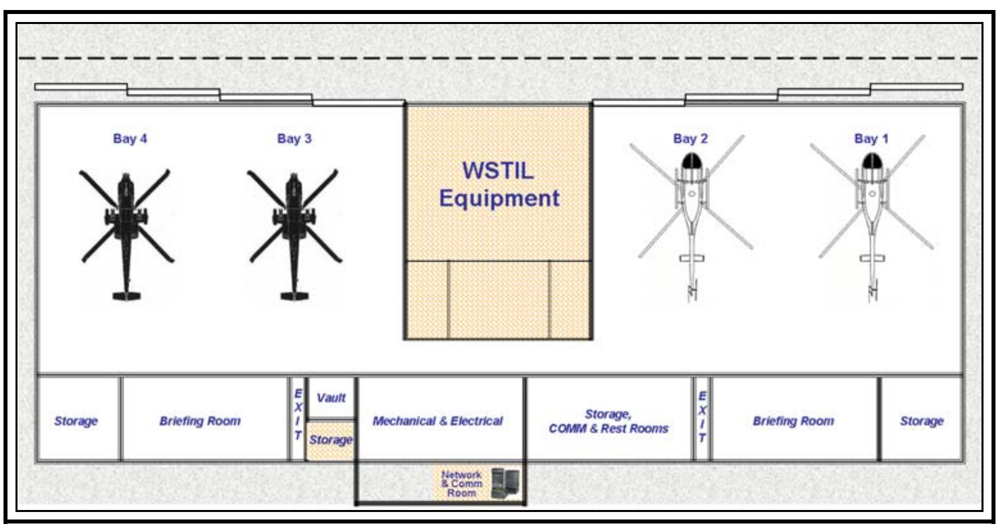

Figure 2 – Weapons STIL Hangar Layout

In an effort to develop a functional ground test capability that satisfies the overall testing goals for the Weapons STIL, YPG is providing an existing facility to house these systems which is depicted in Figure 2. This on-site hangar/test facility is a single-story building with hangars at either end. The hangars are separated by six engineering/technical and management support areas. Utilizing Simulated Avionics combined with real aircraft Hardware-in-the-Loop, Instrumentation Busses, High-Speed Networks, and Open Architecture hardware and software, these ground-based avionics and weapons test stations will provide extensive and flexible capabilities in the area of basic mission simulation, training and developmental avionics testing.

When designing the architecture for the Weapons STIL, several major system design drivers were considered by the design team.

1. Where Data Exchange was Important:
    a. Compatibility with other Army Data Systems
2. Ability to Import Configuration Data from Airframe and Weapon System Manufacturers.
3. Maximum Utilization of Commercially available Components.
4. Interface these COTS Components utilizing Government and Industry Standards.
5. Provide as much Automation as possible to what is currently a manual testing process.
    a. Provide Information to the Test Engineers in an electronic form for ease of access and review.
    b. Provide for Ground Station Equipment Setup from Standards Based Data Files retrievable from a Server Disc Storage.
6. Insure Operations Personnel are involved in the Design Process.

Figure 3 represents the Weapons STIL from a functional perspective. It shows the primary components of the Weapons STIL and how they are linked together to provide the testing required by the Test Engineers. The primary components of this test architecture are represented along with their interfaces to other components in the system. These primary hardware and software components include:

- The Systems Under Test (SUTs) which include multiple aircraft types (e.g. Helicopter, Unmanned Aircraft System, etc.) and/or Weapon Systems (e.g. Missile, Rocket, Gun, etc.)
- The Weapons STIL Secure LAN.
- The Weapons STIL Data Acquisition and Analysis Subsystem(s).
- The Weapons STIL Mission Configuration Setup Subsystem
- The Weapons STIL Test Control Center(s).
- Test Engineer Interface from outside the Weapons STIL.
- The Weapons STIL Test/Video Data Recording and Archive Subsystem(s)
- The Weapons STIL Weapons Station Interface(s).
- The Weapons STIL Post Test Analysis

Utilizing the Functional Block Diagram of the Weapons STIL Architecture presented in Figure 3, the following paragraphs follow the typical test data process through these components at a functional level.

Begin with Data coming from a System Under Test (Aircraft and/or Weapon) residing in one of the four (4) Test Bays. This data includes a combination of PCM data, MIL-STD 1553 Buss Data, ARINC-429 Buss Data, Video data, and IRIG time code data.

All of this data is directly cabled from the Aircraft into a Matrix Switch which resides in the Data Analysis Center where it is switched (by the Mission Configuration Server) to the appropriate Data Acquisition Subsystem (1 or 2) being used for the current test. This routing information will also be controlled by the Mission Configuration Server as defined by the Test Engineer performing the test.

The Mission Configuration Server also contains detailed information including 1553 Buss Messages and Data definitions, PCM Format definitions, Measurement information including bit size, data type, bit weightings, Engineering Units Conversion Algorithms, and other detailed data information including routing information to the Data Archive and Retrieval subsystem.

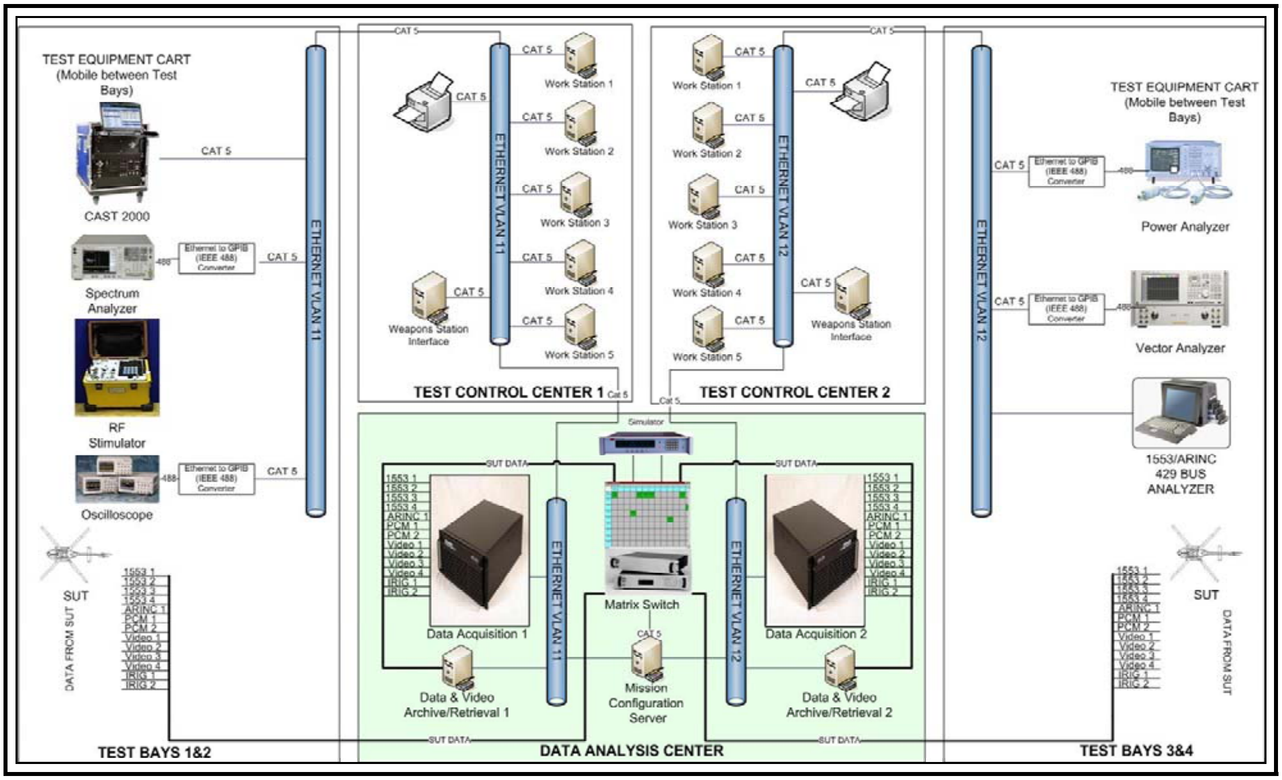

Figure 3 – Weapons STIL Functional Block Diagram

Decommutation of encoded PCM Data is processed creating real-time concatenation of parameters, derivation of raw parameters, parsing of discrete bits from parameters, and application of Engineering Unit conversions. This is accomplished by the Data Acquisition Subsystem component and it is then sent to the network making it available to the other Weapons STIL Components for archiving, processing, and display purposes.

Data from the Data Acquisition subsystem is presented to the appropriate Test Control Center (TCC) and the Data & Video Archive and retrieval Subsystem. Work stations in the TCC receive the data via the network to which they are attached. These Work Stations can run any applications desired by the engineer to display the particular data of interest. This Data will also be recorded by the Data & Video Archive/Retrieval Subsystem.

The Weapons Station Interface in each of the TCCs is used to configure and control the test equipment in the test bays. Data on the 1553 and ARINC Busses can be manipulated and sent back to the system under test using the Buss Analyzer. This is then verified by the Engineer at the Work Station in the TCC via the data path from the SUT. The RF Stimulator can be configured to emulate ground RF Systems providing the SUT with signals that emulate flight conditions for the aircraft while it is still on the ground. The Test Equipment Configurations will be stored on (and can be recalled from) the Mission Configuration Server.

In a Post Test Analysis mode of operation the data that was recorded on the Data & Video Archive/Retrieval Subsystem can be played back though the system to review the test after completion and/or many days or weeks later.

Mission Configuration Management:

In support of Mission Configuration the Weapons STIL utilizes the TMATS and the interface to the necessary Data Acquisition System being used in the Weapons STIL. In most cases the required information can come from the airframe or weapon manufacturer in some electronic form. The Weapons STIL Development Team is using the IRIG 106-09 Chapter 9 TMATS as the format in which to collect and store this information.

TMATS is used as the foundation for the Mission Configuration Management System internal structure. This project oriented system software architecture allows its user to structure a file system that best suits his/her needs for tracking mission test configurations on a centralized file server which resides in the Data Analysis Center and then distribute this information over the LAN to the appropriate Data Acquisition Subsystem and associated hardware items included in the test environment.

The current hierarchy of the file structure (depicted in the Figure 4) for Projects stored by this system on the Mission Configuration Server includes:

Project: This is a user defined name, and generally refers to the type or name of vehicle under test.

Operation Type: This is a user defined field, and is used to further define the conditions under which the test took place.

Operation Number: A unique number that can be assigned by the user. Generally, this would be a number that increments, and could be used to identify the test.

Revision Number: This is a number that is automatically incremented whenever changes are made to system formats and/or the measurements defined within those streams are changed.

Date: A unique date, in a pre-defined format. This field is used to identify the date on which the test occurred.

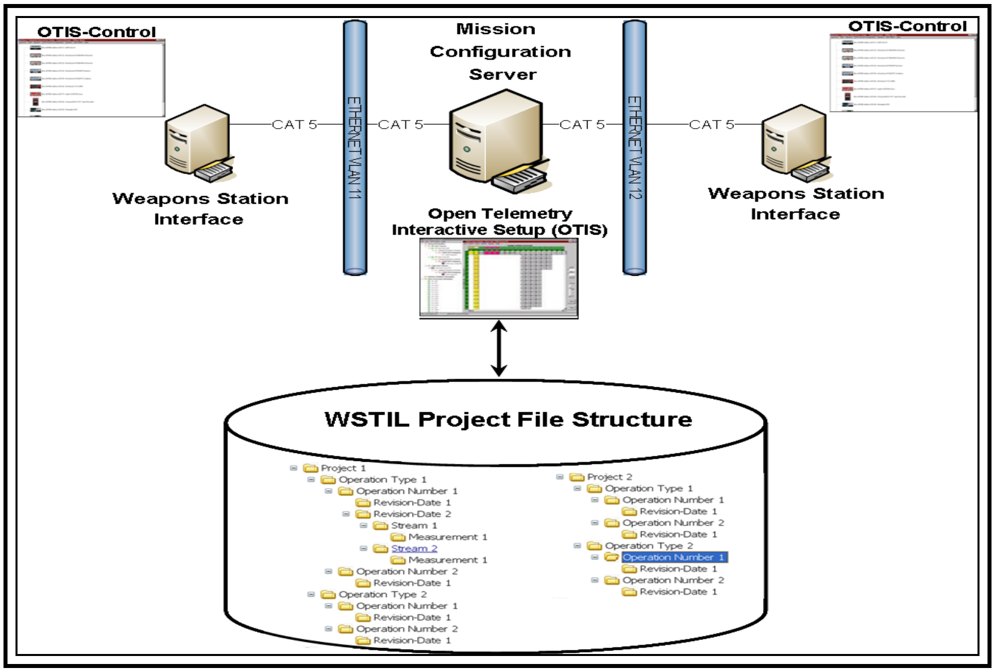

Figure 4 – Weapons STIL Mission Configuration Management

By far, the largest portion of the mission configuration for a test to be performed in the Weapons STIL consists of the definition of all measurements to be utilized and the associated processing required for each, such as Engineering Units Conversion and/or Derived Parameter Calculations. Figure 5 represents the general process flow to prepare for the execution of a Weapons STIL test.

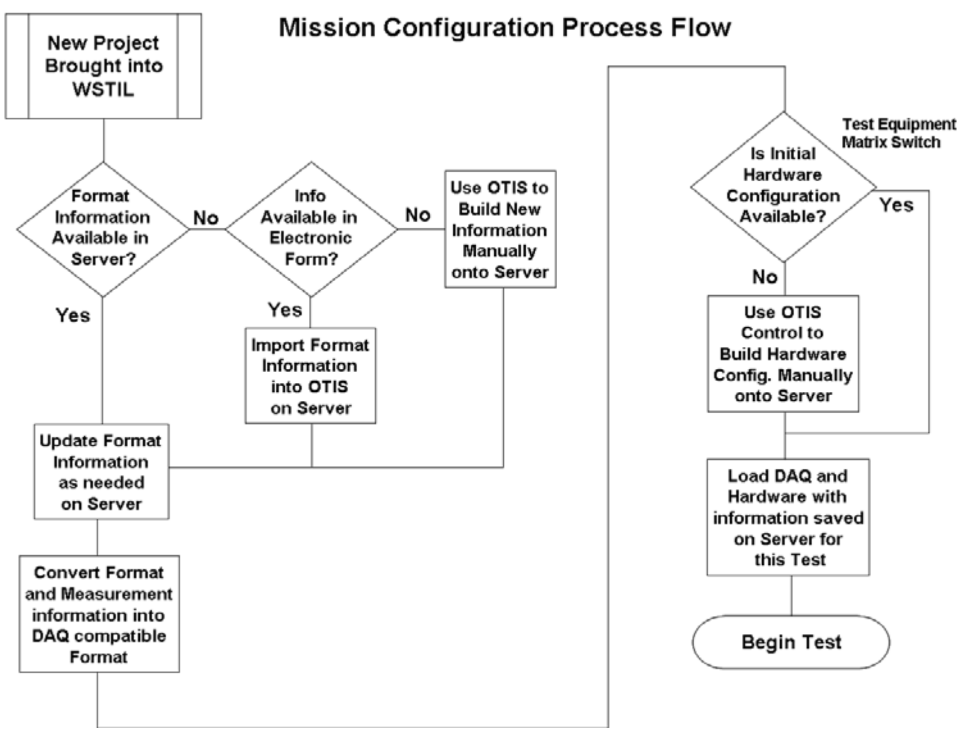

Figure 5 – Mission Configuration Process Flow

As presented in this process there are two (2) primary sources of information required by the test engineer to prepare for the execution of a test using the Weapons STIL. These consist of:

1. Data source formats and the associated measurement information necessary to collect, process, and present in the TCC the information gathered as results from the test. This information is collected and stored in the (IRIG-106) Chapter 9 TMATS format.
2. Configuration of the hardware (data distribution via the Matrix Switch) and the initial setup of the test equipment to be utilized in the test execution.

Information Routing using the Matrix Switch

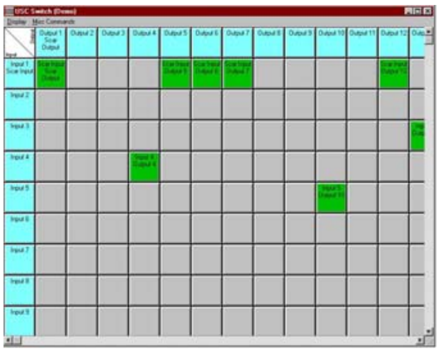

Figure 6 – Matrix Switch

The matrix switch is configured using a display similar to the one presented in Figure 6.

In this representation, Inputs are presented on the Left Hand side of the display and Outputs are presented on the Top of the display.

Therefore, a connection between an input and an output is represented by a colored box at the intersection of the row and column. This configuration is saved on the Mission Configuration Server for this mission/test.

The Test Control Centers

Figure 7 – Weapons STIL Test Control Center

As shown in Figure 7, the Weapons STIL Test Control Centers consist of the data presentation and control capabilities necessary to conduct a mission. There is a TCC for each half of the Weapons STIL complex so that two (2) missions can be performed simultaneously. Each TCC consists of:

- 5 – Test Engineer Work-stations
- 1 – Weapon Station Inter-face for control of Test Equipment for the test.
- 1 - High Speed printer
- Network interfaces to the Data Analysis Center

Data Analysis Center

Figure 8 – Data Analysis Center

The Data Analysis Center shown in Figure 8 is the core of the Weapons STIL system support. It consists of three (3) racks of equipment consisting of:

- Data Acquisition System for TCC 1
  - Data Acquisition Hardware
  - Data Archive Hardware
  - Data/Video Retrieval Server
  - Data Routed from Test Bay 1&2
- Data Acquisition System for TCC 2
  - Data Acquisition Hardware
  - Data Archive Hardware
  - Data/Video Retrieval Server
  - Data Routed from Test Bay 3&4
- Centralized Support for:
  - Mission Configuration Server
  - Matrix Switch
  - PCM Simulator
  - Data Analysis/Access Tools

Test Equipment to be used in the Weapons STIL

A variety of test equipment has been acquired and interfaced into the Weapons STIL to expedite the various tests that are required to support weapons integration. The following is a brief description of this equipment.

GPS Simulator

Provide Global Positioning System (GPS) RF simulation and/or timing source to SUT. The CAST-2000 used by the Weapons STIL offers the ability to stimulate GPS systems installed on test vehicles. The CAST-2000 produces real-time radio frequency (RF) signals representing a simulated GPS environment to stimulate GPS receiver equipment.

RF Stimulator

The RF Stimulator can be configured to emulate ground RF System providing the SUT with signals that emulate flight conditions for the aircraft while it is still on the ground. Individual Signals and Connections can be verified at Test Setup time by the Technicians and Engineers in the Test Bay via other test equipment in the Test Bay.

High-Performance Spectrum Analyzer

A Precision Spectrum Analyzer which fully supports a majority of Sensor-related testing. It supports millimeter wave, phase noise measurements, spur searches and modulation analysis and offers flexible, high-performance characteristics.

Buss Analyzer

This piece of test equipment functions as a Buss Analyzer, allowing for Data Display, Error/Data Logging and Analysis, Simulation, Playback of Data, it can also act as a Buss Controller, with the ability to put data on the buss and directing other components to act upon the simulated buss traffic. As a Remote Terminal (R/T) on the buss, this device allows the engineer to convert the raw data to engineering units and display it on a series of gauges, fault indicators, and charts, much like the indicators found in the cockpit or instrument panel.

Pulse Code Modulation (PCM) Data Simulator

An independent PCM simulator provides a data frame filled with a background pattern over which unique data words may be superimposed. A sub-frame may also be added to the format and unique words placed anywhere within the frame/sub-frame matrix. The unique words may also be distributed throughout the frame and/or sub-frames in a super commutated structure.

Other test equipment includes:

- Oscilloscope and DMM
- Peak Power Analyzer
- Network Analyzer
- RF Generator
- Attenuator Set
- Low-Loss RF Cables (Various) TNC
- Low-Noise Amplifier (300Mhz - 3Ghz)
- Avg Power Meter (Boonton 4300 or Equiv)
- RF Couplers
- Variable Attenuator
- Low Noise Amplifier (30Mhz - 400Mhz)
- Low Noise Amplifier (300Mhz - 3Ghz)
- Low Noise Amplifier (2Ghz - 20Ghz)
- Low Noise Amp (1W - 10dbm)
- Avg Power Meter (Boonton 4300 or Equiv)
- Attenuator Set
- Color Printer
- Miscellaneous (adapters, supplies, CDs, etc.)

CONCLUSION

Development began on the Weapons STIL concept in late calendar 2007. Requirements gathering and conceptual design was completed by mid calendar 2008 with a Critical Design Review occurring late July of that year.

The table below represents the relevant milestones in the development phase of this program.

Weapon STIL	2007		2008				2009				2010
Spiral Implementation	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Initial Planning Phase			PAC								
Requirements Gathering & Design				PDR	CDR	IOC1					
Implement and Install at 2882										IOC2	FOC

At the time of this writing, approximately 95% of all materials and equipment have been acquired and being integrated into the system. The Test Control Centers have been configured and are operational. The Mission Configuration Server has been configured and is operational. The Data Acquisition systems have been installed and are operational as well as data distribution to the Test Control Centers. All of the major test equipment has been acquired and delivered and that which will be remotely controlled has been integrated.

Major items remaining to be accomplished center around the Data Archival and Retrieval hardware and software and the final test cases which will demonstrate the capabilities of the Weapons STIL and how it will satisfy the requirements set out in the requirements gathering process.

At ITC/USA 2010, we will present the final status of this program and the lessons learned during this development process.

REFERENCES

[1] "Telemetry Standards", IRIG Standard 106, April 2009, Secretariat, Range Commanders Council, U.S. Army White Sands Missile Range. https://wsmrc2vger.wsmr.army.mil/rcc/

[2] "The Role of Standards in Flight Testing", The ITEA Journal of Test and Evaluation, September/October 1998, Volume 19, Number 3, Page 52.

[3] "The Telemetry Attributes Transfer Standard (TMATS): Reducing the Cost of Flight Test", presented at the European Telemetry Conference with Exhibition, 2002

NOMENCLATURE

CDR	Critical Design Review
COTS	Commercial Off The Shelf
DREN	Defense Research and Engineering Network
EO	Electro-Optic
ESM	Electromagnetic Support Measures
FIPS	Federal Information Processing Standards
GPS	Global Positioning System
GWOT	Global War on Terror
IMS	Integrated Master Schedule
IPR	In Process Reviews
IR	InfraRed
ISTF	Installed System Test Facility
ITEA	International Test and Evaluation Association
KPP	Key Performance Parameters
LAN	Local Area Network
PAC	Post Award Conference
PCM	Pulse Code Modulation
PDR	Preliminary Design Review
R/T	Remote Terminal
RCC	Range Commander’s Council
RF	Radio Frequency
SEMP	System Engineering Management Plan
SS	System Specification
SSDD	System/Subsystem Design Document
SUT	System Under Test
TCC	Test Control Center
TCRD	Test Capability Requirements Document
TG	Telemetry Group
TMATS	Telemetry Attributes Transfer Standard
TRR	Test Readiness Reviews
WSTIL	Weapons System Test and Integration Laboratory
YPG	Yuma Proving Grounds
YTC	Yuma Test Center