The Merging of Multisource Telemetry Data to Support Over the Horizon Missile Testing

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ABSTRACT

The testing of instrumented missile systems with extended range capabilities present many challenges to existing T&E and training ranges. Providing over-the-horizon (OTH) telemetry data collection and displaying portions of this data in real time for range safety purposes are just a few of many factors required for successful instrumented range support. Techniques typically used for OTH telemetry data collection are to use fixed or portable antennas installed at strategic down-range locations, instrumented relay pods installed on chase aircraft, and instrumented high flying relay aircraft. Multiple data sources from these various locations typically arrive at a central site within a telemetry ground station and must be merged together to determine the best data source for real time and post processing purposes. Before multiple telemetered sources can be merged, the time skews caused by the relay of down-range land and airborne based sources must be taken into account. The time skews are fixed for land based sources, but vary with airborne sources.

Various techniques have been used to remove the time skews associated with multiple telemetered sources. These techniques, which involve both hardware and software applications, have been effective, but are expensive and application and range dependent.

This paper describes the use of a personal computer (PC) based workstation, configured with independent Pulse Code Modulation (PCM) decommutators/bit synchronizers, Inner-Range Instrumentation Group (IRIG) timing, and data merging resident software to perform the data merging task. Current technology now permits multiple PCM decommutators, each built as a separate virtual memory expansion (VME) card, to be installed within a PC based workstation. Each land based or airborne source is connected to a dedicated VME based PCM decommutator/bit synchronizer within the workstation. After the exercise has been completed, data merging software resident within the workstation is run which reads the digitized data from each of the disk files and aligns the data on a bit by bit basis to determine the

optimum merged result. Both time based and event based alignment is performed when merging the multiple sources.This technique has application for current TOMAHAWK exercises performed at the Air Force Development Test Center, Eglin Air Force Base (AFB), Florida and the Naval Air Warfare Center/Weapons Division (NAWC/WD), Point Mugu, California and future TOMAHAWK Baseline Improvement Program (TBIP) testing.

BACKGROUND

In fiscal year (FY) 94, a demonstration was conducted to test the feasibility of relaying near real time TOMAHAWK telemetry data from Eglin AFB to the Naval Warfare Assessment Division (NWAD) during Operational Test Launch (OTL) 163. The purpose of this demonstration was to evaluate the timeliness and effectiveness of using commercial off-the-shelf (COTS) telecommunication and telemetry equipment to electronically distribute actual TOMAHAWK exercise data. The hardware configuration used during this demonstration would baseline a standardized design for implementation during future tests and test sites. Technical details of the OTL-163 demonstration network are documented in the International Telemetering Conference (ITC) 1994 proceedings. Both the telemetry and telecommunications hardware performed successfully during the tests which provided lessons learned on the following technical subjects:

- Optimal data transmission speeds.
- Optimal data compression algorithms.

After the OTL-163 exercise, telemetry data was relayed to NWAD within four hours and a quick-look performance assessment was performed. The analysis results were released to the TOMAHAWK technical community within 24-hours after the exercise.

Having recognized the need for the electronic transfer of telemetry data from both the East Coast test site at Eglin AFB, FL and the West Coast test site at NAWC/WD, Point Mugu, CA to the TOMAHAWK analysis agent at NAWD, Corona, CA, the TOMAHAWK program office has initiated plans to install permanent equipment to support this requirement. This effort is called the TOMAHAWK Performance Assessment Network (TPAN).

OBJECTIVES

The TOMAHAWK performance assessment network objectives are identified as follows:

- Provide the TOMAHAWK technical community with electronic access to digitized telemetry data.
- Reduce time and effort required for post-mission data processing.
- Effect rapid, secure, and low cost data transfers between West/East Coast test sites (NAWC/WD and Eglin AFB) and NWAD.
- Provide expandable network to incorporate new node sites as required (Applied Physics Lab/John Hopkins University, NAWC/China Lake, Hughes, etc.).

APPROACH

Dedicated hardware will be procured to digitize TOMAHAWK telemetry data from multiple sources from either NAWC/WD or Eglin AFB. Application software will be developed to merge data originating from multiple sources (up to four) at each of the range sites immediately after the exercise has been completed. Open system technology and architecture will be used to ensure long term software and configuration flexibility. Commercial off-the-shelf (COTS) technology will be used and the design will be compatible with the common Test and Evaluation Network Architecture (TENA) project goals.

After data originating from multiple sources has been merged, it will be electronically transferred to the NWAD Warfare Assessment Laboratory (WAL) for detailed analysis. Analysis results, merged data, and raw data will then be shared among the TOMAHAWK technical community to further evaluate the exercise results.

BENEFITS

Benefits of the TPAN network are identified as follows:

- Provides electronic connectivity between East/West Coast test sites and the TOMAHAWK technical community for telemetry.
- Also supports administrative and other digital data categories (multimedia, digitized video, etc.).
- Provides remote operation and control of test site portable telemetry hardware from NWAD to minimize operational costs.
- Improves collaboration among the TOMAHAWK technical community.

- Supports rapid test data distribution to improve depth/breadth of analysis and reporting by reducing flight test turnaround times.
- Uses existing integrated logistics support provided for the AEGIS Performance Assessment Network (APAN) and telemetry range sites to minimize life cycle support costs.

TPAN HARDWARE DESIGN

The TPAN data transmission concept, which makes use of Defense Communication Telecommunication Network (DCTN) and switched 56 Kbit/second telecommunication system technologies, is shown in Figure 1. COTS hardware will be used to ensure interoperability between Government and commercial systems and reduce future support costs.

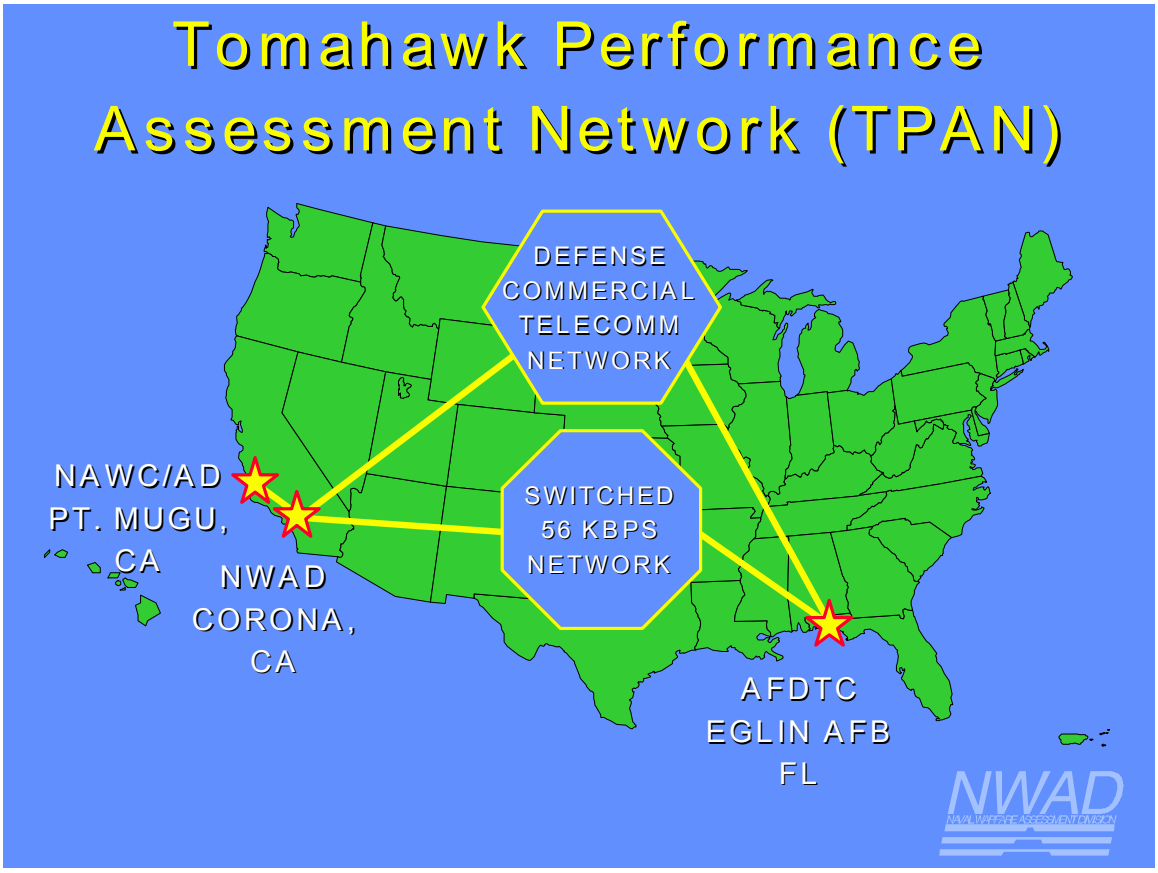

Figure 1 - TPAN Data Transmission Concept

RANGE SITES

Inputs to the systems installed at NAWC/WD and Eglin AFB will consist of NRZ-L data, synchronous NRZ-L clock, and IRIG B/A timing. Provisions for up to four inputs will be provided. Outputs of the range system will consist of encrypted ethernet for connection to DCTN or switched 56 Kbit/second network systems. A block diagram of the Eglin AFB hardware range configuration is shown in Figure 2.

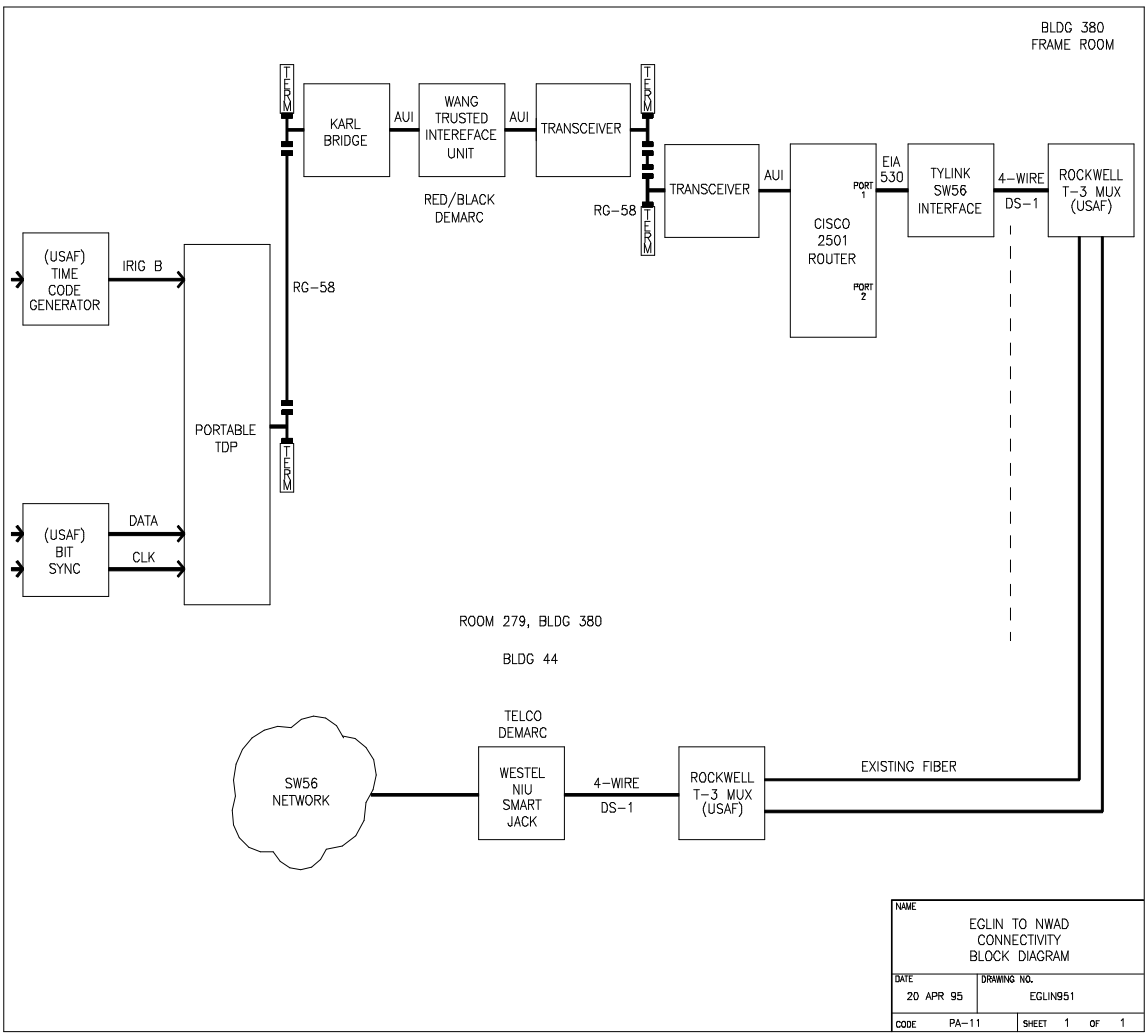

Figure 2 - EGLIN AFB Range Block Diagram.

NWAD SITE

The system will accept both DCTN and switched 56 Kbit/second inputs. The ethernet signal will be decrypted and distributed to the NWAD Warfare Assessment Laboratory. A block diagram of the NWAD configuration is shown in Figure 3.

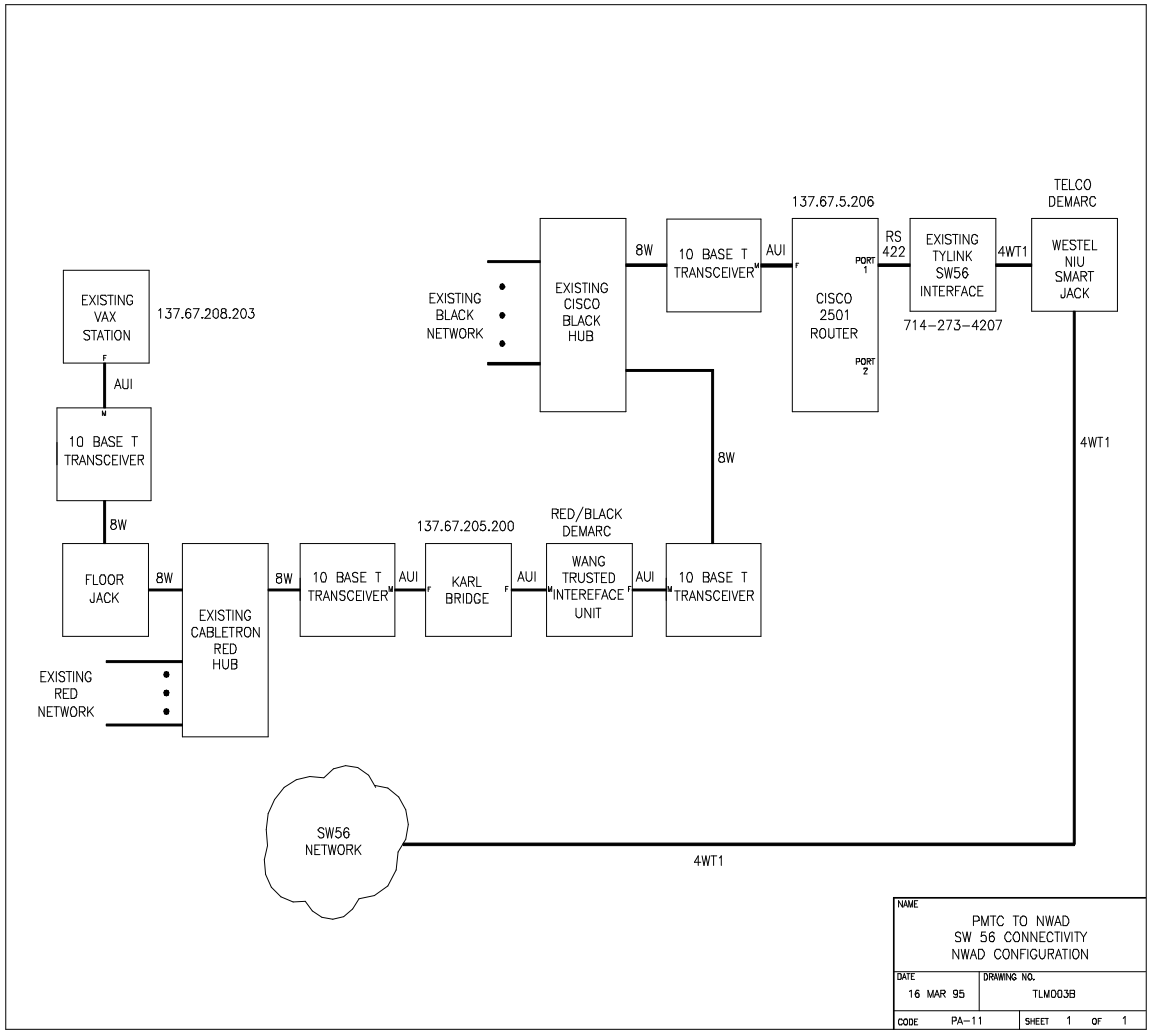

Figure 3 - NWAD Configuration Block Diagram

TECHNICAL COMMUNITY SITES

Hardware which supports the connection of other sites to the TPAN network is shown in Figure 4. This hardware is similar to the equipment shown in Figure 3 and is required for each additional remote TPAN site .

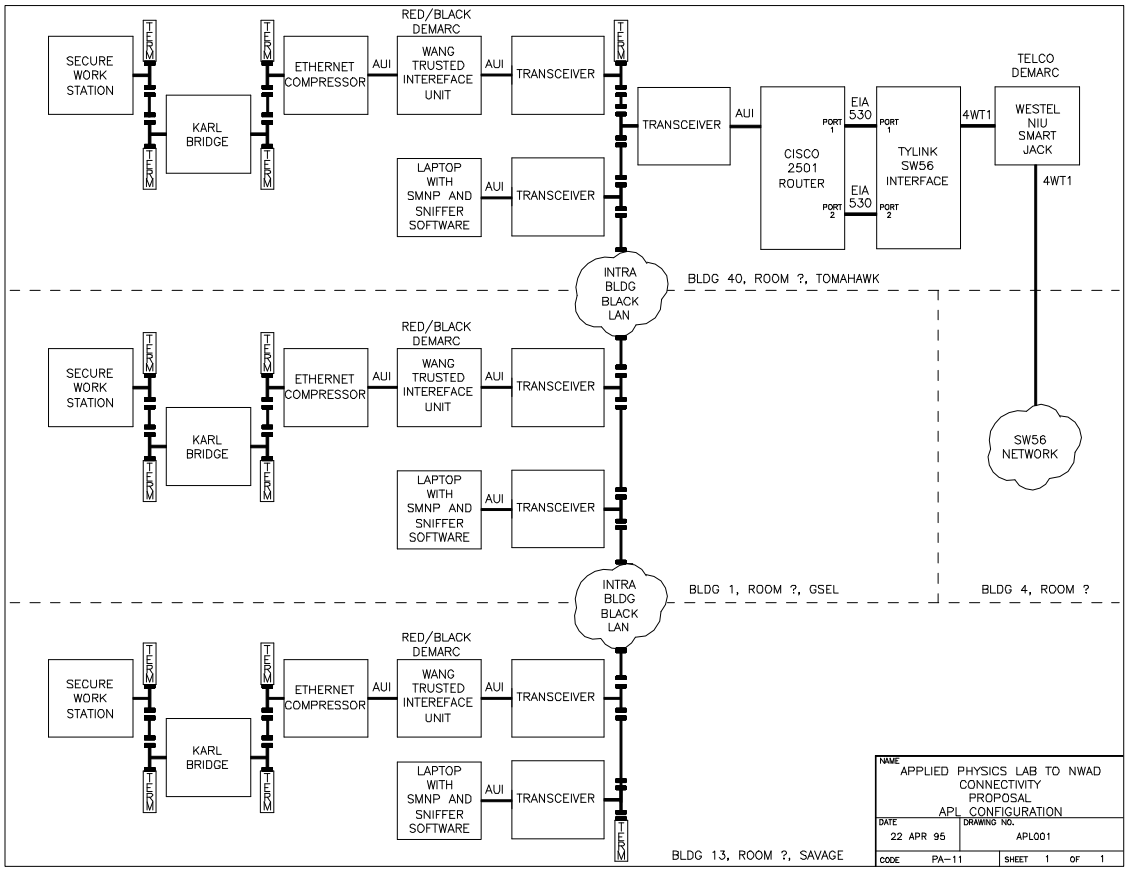

Figure 4 - Additional TPAN Site Block Diagram

MULTIPLE SOURCE DATA MERGING

TPAN workstation hardware installed at each range site will be capable of accepting up to four independent telemetry streams. Data from each of these four streams will be archived to independent disk files within the TPAN workstation. A removable hard disk will be used to satisfy security requirements. After digitizing the exercise data, data from up to four independent files stored on the workstation hard disk will be merged to generate a single file. The merged file will contain the best source data obtained by aligning each input on a bit by bit basis. Both time based and event based alignment will be performed when merging multiple sources.

Each independent data source will be aligned on key known data fields within the telemetry stream, such as the minor frame synchronization pattern, fixed word or bit fields, or any user defined fields. Considering that each input data source can originate from tracking antennas at different sites separated by significant distances, timing base differences can exist between different sources due to microwave transmission delays.

One of the input data sources will be identified for use as the master timing reference. A provision for adding or subtracting an offset amount to the master timing reference will be provided if necessary to correct any master timing reference discrepancies.

After each input source is aligned on the same minor PCM frame, a bit by bit alignment will be maintained using known key data fields (i.e. frame sync pattern, user defined word, etc.) and timing information embedded in each data word. The timing offset for each input source will be calculated and maintained by comparing it with the master timing reference.

Minor time synchronization will be recorded within the identification tag (ID) for each data word when the PCM data is digitized at each range site. Minor time will be embedded at user selectable accuracy from one second to 0.01 milliseconds.

The data quality of each source will be saved in a unique status work on a minor frame basis. The data quality status will be scaled based on how often the PCM frame synchronizer has gone in and out of lock over the last n frames.

Given the data quality status of each source and the previous data quality performance over the last n frames, it is possible to develop a probabilistic relationship between each data source. As the aligned bits from each data source are compared, the most probable result will be determined using: (1) the data quality status performance of each source, and (2) a majority voting of all sources to determine the actual telemetered signal level (i.e. 0 or 1). The merged file will contain the correct number of bits obtained using the most probable combination of all input sources. The merged data file will then be compressed and transferred electronically using the TPAN network.

CONCLUSION

Implementation of the TOMAHAWK performance assessment network represents another step in networking Navy and Air Force test ranges together with the NWAD Warfare Assessment Laboratory and Department of Defense government and commercial facilities. The linking of these sites together brings us yet another step

closer toward having test and training ranges linked together from all services to meet our telemetry challenges of the future.

ACKNOWLEDGMENTS

I would like to acknowledge the creativity, dedication, and hard work of the telecommunication, telemetry, and weapon system engineering branches within NWAD for their contributions in making this network possible. It is through these gifted and talented engineers that we turn our vision of the future into reality.