TEST AND TRAINING ACTIVITIES IN THE SYNTHETIC BATTLEFIELD

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ABSTRACT

The U.S. Air Force has developed GPS-based instrumentation systems to support both test and training activities. In support of recent large-scale exercises, interfaces were developed to employ existing test and training assets in a synthetic battlefield. The writers propose exploration of similar approaches to overcome the challenge of developing a common approach to test and training instrumentation.

KEY WORDS

Distributed Interactive Simulation, Global Positioning System, range instrumentation, test, training

INTRODUCTION

The U.S. Air Force develops and procures instrumentation systems for airborne testing and for air combat training. These two procurement activities have traditionally been segmented efforts, both conducted at Eglin Air Force Base, FL. Acquisition of test instrumentation was managed by the Range Applications Joint Program Office (RAJPO), while acquisition of training instrumentation was managed by the Air Combat Training System (ACTS) Program Office. This division of responsibilities was historically based upon differences in requirements and instrumentation technology.

Test and evaluation (T&E) instrumentation users required very high accuracy time space position information (TSPI), for a few aircraft, in a highly controlled environment, with robust engineering analysis capability. Historically, these TSPI requirements were met by using noncooperative instrumentation such as laser trackers, cine-theodolites, and radars. Unfortunately, these noncooperative sensors did not provide attitude and orientation data, they had constrained geographic coverage, and limited the number of simultaneous participants. Further, the large number of sensors required by these traditional systems invariably led to instrumentation and timing errors, as well as staggering infrastructure costs. During the 1980s, the search for more suitable T&E instrumentation eventually drove the use of costly GPS-based tracking systems, with computationally complex analytical software.

In contrast, training instrumentation users required much lower accuracy TSPI, but for much greater numbers of aircraft, in a relatively uncontrolled environment. Additional training requirements included real-time control, interaction with weapon simulations, and highly graphical post-mission debriefing. The TSPI requirements were easily met by multilateration tracking systems, but required more visually attractive, user-friendly software.

In recent years, technological advances have blurred the lines between test and training instrumentation. GPS technology has become so cost effective that training system users can now afford to procure it in the large numbers required. Also, sophisticated computer visualization systems have become less expensive, and therefore test instrumentation users have come to rely upon more complex graphical presentations. Further, many aircraft weapons bus interface modules, previously only of use to the training community, are finding use in T&E data collection and analysis.

These increasing similarities, combined with increasing pressure on military acquisition budgets, has raised interest in developing compatible test and training instrumentation systems. Several tri-service, flag-level organizations have endorsed the development of standards to ensure as much commonality as possible between test and training instrumentation systems. In response to these developments the RAJPO and the ACTS Program Office were combined into a single "Range Instrumentation Systems Program Office" (RISPO). To date, this effort has not yielded any substantive plan to integrate test and training instrumentation. However, both test and training instrumentation systems have recently played important roles in DoD exercises creating a synthetic battlefield. Applying the lessons learned from these exercises, this paper illustrates a systems approach for integrating test and training instrumentation.

TEST RANGE INSTRUMENTATION

The RAJPO High Dynamic Instrumentation System (HDIS) depicted in Figure 1, provides support to high activity airborne testing. The Range Pod Subsystem (RPSS) is the system's airborne component. It is based upon a multi-channel, P(Y)-code, dual-frequency GPS receiver that was designed and optimized for test instrumentation. A 17-state Kalman filter tightly couples the GPS receiver with a strapdown inertial navigation system (INS). This combination improves high-dynamic (up to 9 g) performance, maintains a precise TSPI solution during satellite blockage, and accelerates reacquisition if aircraft maneuvers interrupt the GPS tracking. Satellite tracking during aircraft maneuvers is further enhanced through the use of dual (top/bottom high-speed multiplex) antennas to maintain satellite signal tracking during banked turns, while minimizing platform or ground-induced multipath errors.

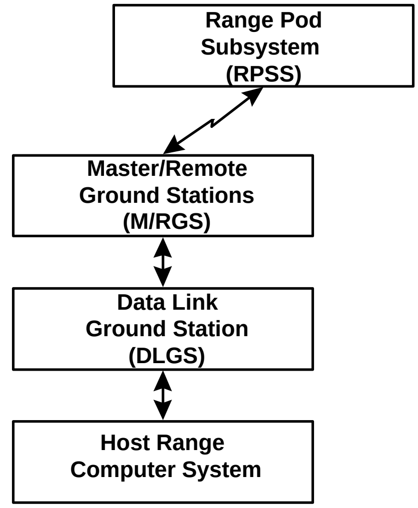

Figure 1: HDIS

The RPSS can be configured in a plate-mounted set for carriage inside an aircraft, or mounted in an AIM-9 style pod for external aircraft carriage. The pod-mounted set is designed to be easily installed on any tactical aircraft without requiring any software or hardware modifications. The RPSS provides a standard interface with the host aircraft 1553B weapons data bus to accommodate collection and formatting of platform activity and performance data. All TSPI and platform data may be recorded via an on-board PCMCIA flash memory card recorder.

At each participating test range, the Data Link Ground Station (DLGS) can communicate with as many as 250 airborne RPSSs through a high-capacity (up to 10 Hz) data link with a range of up to 150 nautical miles. This range can be extended, either through the use of Master/Remote Ground Stations (M/RGS), or through the RPSS's inherent airborne relay capability. Using GPS pseudorange corrections, this system is capable of real-time position accuracies exceeding 4 ft horizontal and 6 ft vertical. The system is also capable of velocity accuracies exceeding 0.7 ft/sec horizontal and vertical, as well as attitude accuracies of 0.3 degree pitch/yaw and 0.5 degree roll. There are currently ten tri-service T&E ranges across the continental U.S. using the HDIS system, with over 300 RPSS in use or in production.

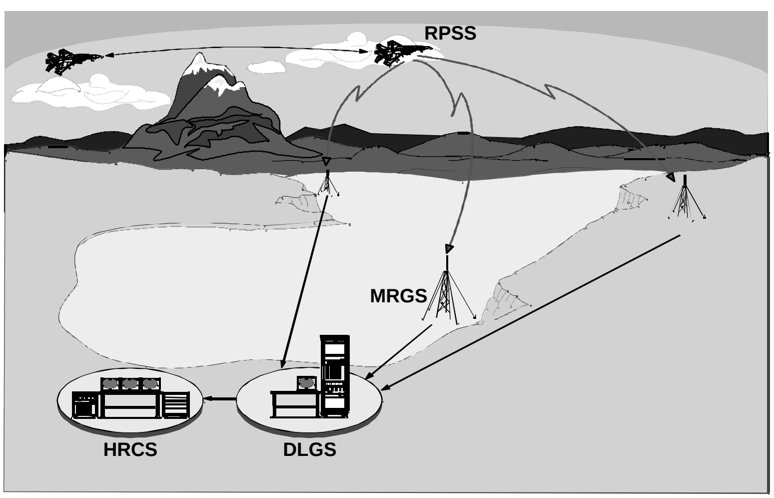

Figure 2: RAJPO Test Range High Dynamic Instrumentation

TRAINING RANGE INSTRUMENTATION

A variety of air combat training range instrumentation systems are in use by U.S. military forces, including the Tactical Aircrew Combat Training System (TACTS) developed by the US Navy, the Air Combat Training System (ACMI) and the Measurement and Debriefing System (MDS) in use at many Air Force Bases. All of these system fall into the category of Air Combat Training Systems (ACTS), and all have a standard architecture that is similar to that of test instrumentation systems (see figure 3).

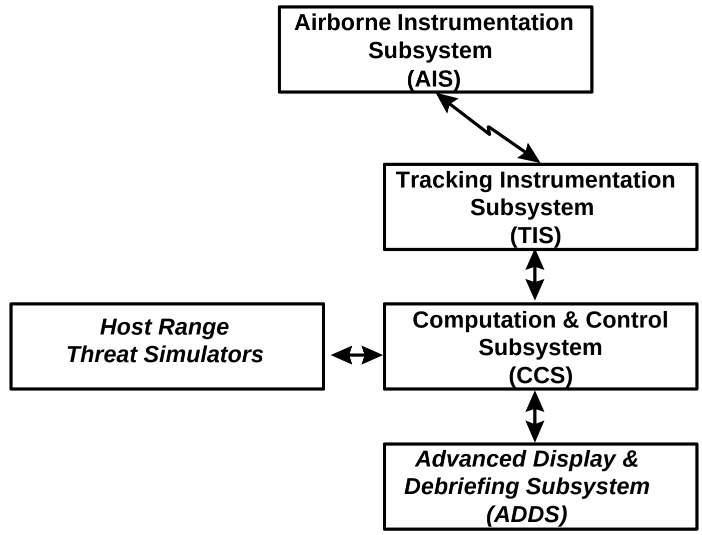

Figure 3: ACTS Architecture

The airborne component of these systems is the Airborne Instrumentation Subsystem (AIS). It is mounted in an AIM-9 style pod almost identical to those used for the RPSS. Older versions of the AIS are quite different from the RPSS, relying upon a multilateration transceiver that performs the communications function, as well as providing the ranging measurements to ground based Tracking Instrumentation Subsystems (TISs) located at surveyed locations. This transceiver operates in conjunction with an INS and an Air Data Computer. The data from these sensors is transmitted via the TISs to the ground-based Computation & Control Subsystem (CCS) where the TSPI solution is computed. This TSPI solution requires ranging measurements from a minimum of four TISs (see figure 4). The size of the range and the area of coverage are dictated by the location of the TISs, and the ability to communicate with TISs having adequate geometric separation for a multilateration solution. Although these older pods provide a robust interface with the host-aircraft weapon bus, no on-board recording was possible. The newer versions of the AIS are similar to the RPSS, with a GPS/INS TSPI source, and on-board recording capability.

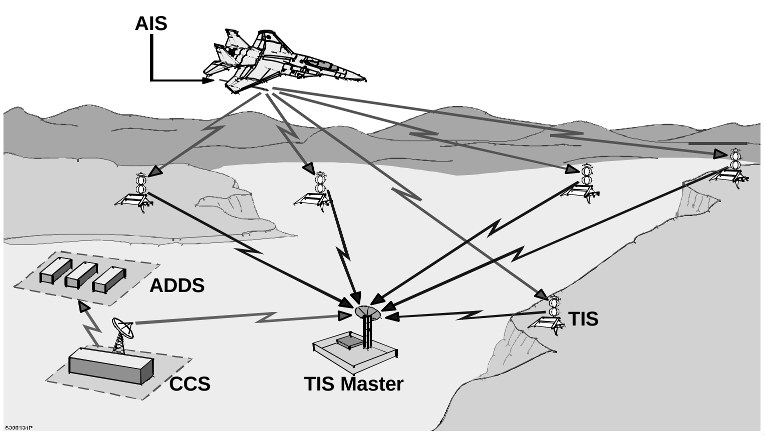

Figure 4: ACTS Multilateration Instrumentation

The data link used by older versions of this system supported air-to-air combat training in a four-on-four scenario at medium-to-high altitudes. In response to changing technology and evolving missions and tactics, the ACTS data link was upgraded to provide support for up to 36 simultaneous high activity aircraft (HAA). Other upgrades have integrated advanced display and debriefing subsystems (ADDS), more powerful CCSs, and ground threat systems. The most recent system development has been a move toward use of GPS as the primary TSPI sensor. This enhancement provides accurate tracking during low-level flight, unconstrained geographic coverage, and precise TSPI to support no-drop bomb scoring, missile flyout simulations, and steering of computerized threat simulators.

Further changes in missions and tactics have recently led to additional system capability updates. The most recent advances in ACTS have been the Nellis ACTS (NACTS), and the Kadena Interim Training System (KITS). NACTS will support up to 100 HAA, consisting of a combination of traditional multilateration-based AIS and newer GPS-based AIS. KITS, also a GPS-based system, uses a unique air-to-air data link and on-board recorder to provide ACTS-like capability without the any ground-infrastructure or real-time communication with a control element. There are currently over a dozen ACTS ranges around the world, with more than 1000 AIS in use.

INTEGRATION OF TEST AND TRAINING RANGE INSTRUMENTATION

Clearly, the architectures of test and training range airborne instrumentation are very similar. Both now rely upon integrated GPS/INS units for TSPI, and integrate host-aircraft weapons bus data with TSPI in the message downlink. Both may use on-board recording systems to support post-mission debriefing. Further, both systems meet similar requirements for physical and electromagnetic environment, flight envelope, and aircraft interface, and are compatible with AIM-9 captive carriage mounts, AIM-9/AIM-120 connectors, MIL-STD 1553 Data Bus, and MIL-STD-1760 hardware and software.

There have been several different studies performed to determine the feasability of integrating test and training range instrumentation. Each study has similarly concluded that the data link incompatibility is the primary obstacle to integration. Table 1 summarizes the operating characteristics of test and training data links presently in use. The RAJPO DLS operates in the 1350-1400 MHz and 1429-1435 MHz ranges. By comparison, the ACTS data link operates in the 1778-1840 MHz range. Beyond the differences in transmission frequencies, the data link architecture, modulations, data rates, transmission range and power are also substantially different.

Characteristic	Multilateration ACTS	NACTS	RAJPO
Frequency	1778-1840 MHz Full Duplex FSK and Phase Modulated RF Communication & Ranging Signals	1778-1840 MHz Software Switchable to ACTS Full Duplex and FSK Ranging Signal Compatible	1350-1400 & 1429-1435 MHz 8 to 10 separate/simultaneous communication nets may operate within line-of-sight
Power	12 W	12 W	65 W
Range	60 nmi air-to-ground phase-locked loop	60 nmi air-to-ground	100 nmi extended by up to 5 air-to-air /air-to-ground relays
Ground Stations	Surveyed Multilateration Towers	Surveyed Multilateration Towers with GPS Overlay	Unsurveyed GPS Range Transceivers
Data Slot/Second	40	100	330
Capacity	198.4 kbps uplink and downlink	198.4 kbps uplink and downlink	243 kbps uplink and downlink
Update Rate	36 HAA @ 2.5 Hz	100 HAA @ 2.5 Hz	25 HAA @ 10 Hz 250 LAA @ 1 Hz
Message	76 16-bit words	125 16-bit words	43 16-bit words
Processor	Analog	Digital 80186	Digital 80186
Reliability	97% with > 1 TIS within 40 nmi 95% with 1 TIS within 40 nmi	97%	99% with 2 or more M/RGS 90% with only 1 M/RGS

Table 1: Datalink Comparison

Analyses have indicated that it is feasible to develop a multi-mode data link. However, the estimated cost of developing such a system is as prohibitive as the cost of completely replacing one or the other data links. Clearly, integrating test and training instrumentation systems in the RF spectrum does not appear practical. Admittedly, failure to achieve RF compatibility mandates fielding redundant Ground Communications Infrastructure, but at many locations (i.e., Nellis AFB and Hill AFB) this redundant infrastructure already exists.

The basic weakness of previous studies was the lack of a systematic approach for obtaining a common test and training architecture. A more promising method would be to view all test and training ranges as a single, complex system with four basic components:

- Airborne Instrumentation
- Ground Communication Infrastructure
- Computation and Control
- Display

These subsystems are common to both test and training. Interfacing at this level offers the potential for integrating across test and training instrumentation by establishing, tracking and controlling external interfaces. This affords subsystem developers maximum flexibility to incorporate new technological advances without impacting other subsystems. Funding can be applied to component phases as it becomes available, even though enough funding may not be available to upgrade the entire “system”.

Standardizing on GPS as the primary TSPI source has been a significant step toward test and training range interoperability. However, to truly implement a systems approach toward integration of test and training, an standard subsystem data interchange format must be selected. This standard must address the need to pass data on many individual participants in a timely, and bandwidth-efficient manner. Further, this standard must be based upon an open architecture which can grow and adapt to evolving user requirements. Although the test and training range communities have made very little progress toward development of such a standard, the Modeling & Simulation (M&S) community has made significant progress in this direction with the development of the Distributed Interactive Simulation (DIS) and High Level Architecture (HLA) standards. These standards have been successfully adapted for use with range instrumentation, and could be the basis for future integration between test and training instrumentation.

INTEGRATION THROUGH SIMULATION PROTOCOLS AND ARCHITECTURES

In 1995, the RAJPO launched a project to integrate live, instrumented aircraft in real-time with virtual and constructive simulations. This involved the addition of two components to the standard system architecture (see figure 5). The first component was an interface unit designated as the Live Entity Broker (LEB). This unit accepts raw TSPI data from the RAJPO DLGS, performs detection and filling of data dropouts, converts the TSPI to DIS Protocol Data Units, and applies standard DIS dead-reckoning algorithms. The second component was a computer display that permitted simultaneous visualization of live and simulated participants in a single synthetic environment. This tool was designated as the Live Entity VisualizeR (LEVR).

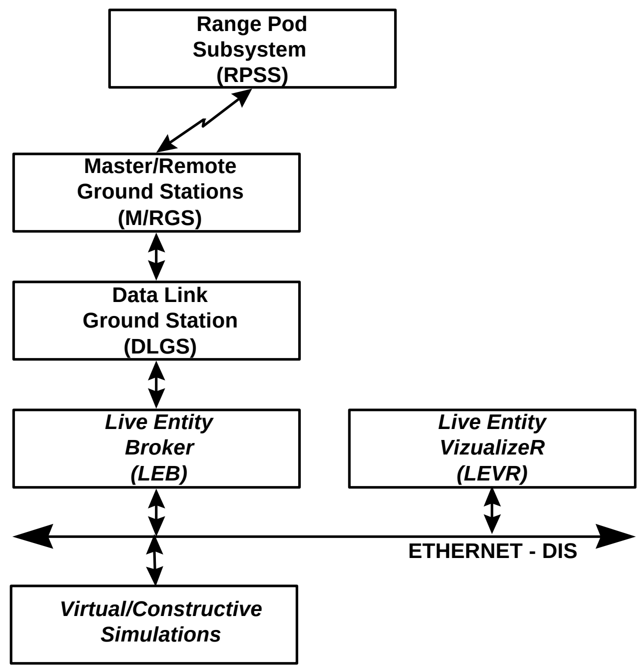

Figure 5: DIS-Compatible Test Instrumentation Architecture

This project successfully integrated test range instrumentation with a variety of virtual and constructive simulators. However, an additional benefit of this project was the realization that the unique data collected by the test range instrumentation could be converted to an interservice, international, IEEE-balloted standard widely accepted by commercial industry. This conversion was accomplished in an economical, timely, and transparent fashion.

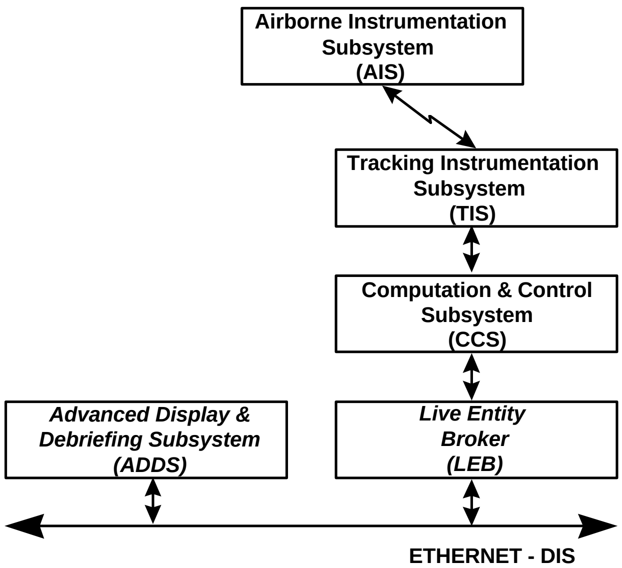

Figure 6 DIS-Compatible Training Instrumentation Architecture

Using DIS to communicate between the computation and control component of this system (the DLGS) and the display component of this system (the LEVR) brought about the realization that this protocol could be used to communicate between computation and control component of this system, and the display component of the training instrumentation system (the ADDS) or vice-versa. In figure 6, a modification to the standard training instrumentation system architecture is proposed. This new architecture uses the DIS protocols in a similar fashion to their implementation by the RAJPO in the test system architecture. This modification adopts a standard interface that could permit the exchange of data between test and training instrumentation systems. Most of the necessary components for this data exchange are already in place. The test community uses the RAJPO system, with it's basic DIS interface. The training community has not yet standardized on a DIS-compliant interface, but has made several steps in the right direction, including the DIS-compliant Advance Display and Debriefing System (HDDS) developed for the Project HyDy, and the DIS-Integrator developed to support the All Service Combat Identification Evaluation Team. Completing these initial developments could yield a fully integrated system, allowing the optimal mixture of test and training assets to support any given exercise (see figure 7).

CONCLUSION

GPS increasingly provides a common TSPI source to both the test and training communities. Most of the test ranges currently use GPS as their primary TSPI source. As the remaining test ranges become more familiar with the GPS-based assets they are receiving, GPS-based TSPI will be the basis for all developmental and operational testing.

The training range community is changing to GPS-based TSPI. The problems in the training community are somewhat different from the test community, as a result of the massive infrastructure that is in place, the dissimilarity between many of these training systems. On a selected basis, some of the training ranges are making the switch over to GPS. Some ranges are requiring that they be able to accommodate the older multilateration-based TSPI as well as GPS. They are solving the problems of incompatibility by carefully scheduling missions and pod assignments.

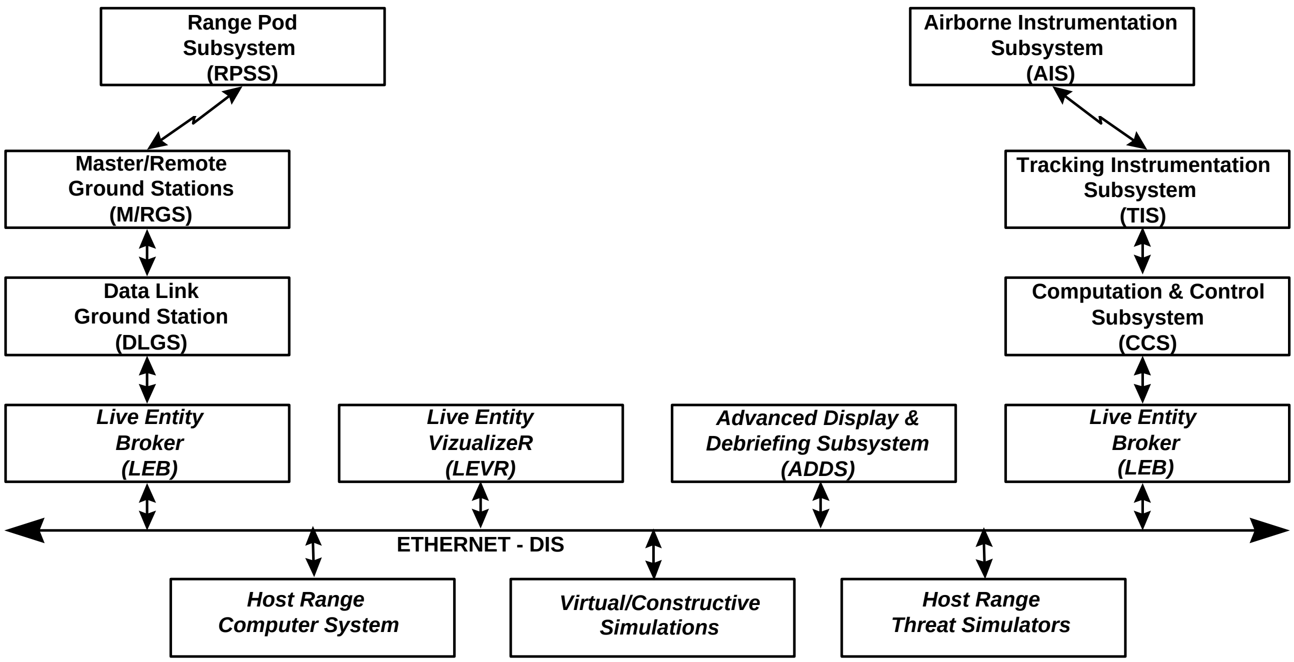

Figure 7: Integrated Test and Training Instrumentation Architecture

When one considers the incompatibility between training ranges, the idea of an integrated test and training capability seems overwhelming. This has been the case as we try to solve the problems of integration by recommending a common data link architecture, or multi-mode transceiver. This paper recommends that we look at the two systems as four distinct subsystems, and solve the problem as a subsystem interface problem.

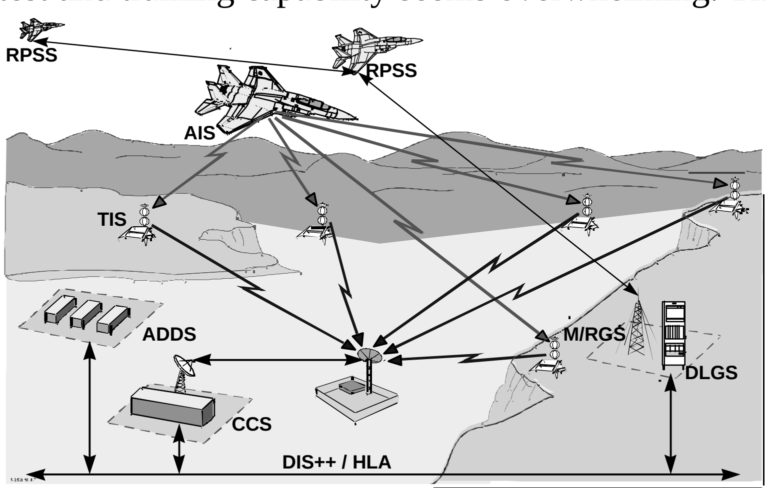

Figure 8: Integrated Test and Training Instrumentation Architecture

By pursuing a solution on how the RAJPO GPS test system assets can operate in a DIS-supported synthetic battlefield, we were required to develop interfaces at the subsystem level in order to transfer the real-time data into the synthetic battlefield. When asked to bring the ACTS assets into this battlefield, the disciplines described above permitted us to develop subsystem interfaces to we the test and training system assets into the virtual battlefield.

These experiences should be the basis of future planning for integrated test and training systems. Commonality in hardware will follow once the benefits of a common system are in place.