APPLYING GPS TO TRAINING SYSTEMS

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ABSTRACT

The United States military has long recognized the need to provide realistic training for its personnel. Improving the effectiveness of battle simulations requires accurate scoring, large engagement areas and numerous participants. The Global Positioning System (GPS), with its accurate position, velocity and time information, will significantly enhance the capability of range instrumentation systems to support field training exercises. GPS provides a precise real-time navigation solution that improves weapons simulation accuracy and simplifies participant pairing at all altitudes. GPS is a worldwide, common grid system and, as such, inherently covers large areas with a minimum of instrumentation hardware. Position location is performed with GPS at each participant. Therefore, the number of participants is limited only by the data communication from the control center. This paper discusses the application of GPS to three (3) field training types: (1) Air Combat, (2) Land Armor Engagements, and (3) War at Sea.

AIR COMBAT TRAINING

The Order of Battle of any potential adversary indicates that all tactical fighter aircrews projecting offensive missions into a hostile theater will be largely outnumbered. In these scenarios, the probability of encountering a complex Integrated Air Defense System (IADS) and multi-bogey environment is very high. As an example, the primary challenge confronting United States Air Forces in Europe with the Air Combat Arena is Command and Control (C²) and related countermeasures. The growing airborne and electronic combat threat necessitates a continuing drive to upgrade our C² capability while expanding our ability to neutralize that of our potential enemies.

Training is a particularly interesting avenue among those being followed to combat the airborne and electronic warfare threat facing today’s fighter aircrews. With appropriate realistic training, U.S. forces can significantly offset the enemy’s capability. Concurrently,
development of ECM equipment that identifies, deceives and negates the electronic threat must continue unrestricted. Preparing for the realities of potential wartime demands require more realistic training.

Today’s TAF aircrews use the building-block approach to air combat training. Units have their own backyard ranges for local training, building up qualifications and maintaining currency in the skills needed to fight as an effective force. Composite force exercises involving low altitude interdiction missions (less than 500 feet AGL), and dissimilar air combat engagements culminating on instrumented tactical ranges with tactical targets, put the final polish on TAF units’ skills.

PRESENT TRAINING REQUIREMENTS

Training requirements necessitate instrumenting and depicting adversaries and threats realistically. That means ensuring all targets on the range are accurate representations of potential enemies. Authentic duplication and emulation of an actual ground combat environment (ground-controlled radars, surface-to-air missiles, anti-aircraft artillery including visual and aural cues, communication deception, deception transmitters and electronic jammers) provide tactical aircrews with a realistic mission scenario. The effectiveness of simulated weapon delivery while aggressively engaged in evasive maneuvers and countermeasures against these air and ground threats is accurately measured through instruments. Weapon scoring and casualty assessment is determined either in real-time or through post-flight analysis of aircrew performance data. Ultimately, the accumulated results influence future requirements in improved weapon technology and tactics development.

FUTURE TRAINING REQUIREMENTS

Existing and future Air Combat Range Training systems are becoming as sophisticated as the aircraft and weapon systems they support. The tactical air training requirements for today’s and tomorrow’s air forces demand it. Present day range instrumentation system capabilities limited by inherent accuracy problems determine the inter-aircraft and air-to-ground parameters. Accurate position, velocity, acceleration and attitude is required to analyze simulated missile firing and weapon releases in a dynamic air combat environment and aircrew tactical performance.

Modern range support requirements for aircrews involved in air-to-air, air-to-ground and ground-to-air weapons training include the target system, missile and target flight termination systems, land independent time space information (TSPI), telemetry (TM), frequency protection/allocation, communications, data handling, range safety and casualty assessment. Accurate TSPI data must be collected to provide missile end game data.
required for PK determination. Different air-to-air phases require various TSPI accuracies (i.e., launch, midcourse and end-game).

The most natural next step is to integrate aircraft ECM and IR countermeasure capabilities into the total range instrumentation system. The requirement exists to uplink digitally computed radar data together with emulated radio frequency (RF) signals to the aircraft’s RWR and have it respond realistically. An appropriate downlink or recording medium of threat data, switchology and pilot response for real-time presentation and post-exercise playback is desirable. The necessary instrumentation interfaces to the aircraft should be transparent to its combat configuration.

**TRAINING RANGE CAPABILITIES**

Major combat exercises are conducted routinely by the United States and allied forces throughout the world. To meet these demanding future training requirements, an improved range technology must be developed. A comparison of present and future training capabilities is shown in Table 1. The system must be adaptable to fit the composition of all TAF wings as well as the circumstances of the group’s operations. As the scenarios become more complex, the greater number of participants involved in multiple air-to-air and air-to-ground engagements simultaneously will require improved tracking accuracies over training areas unrestricted in size or location. All actions taken by the participants will be recorded so the post-exercise debriefing can evaluate the performance and effectiveness of each player and each unit individually. The ultimate goal is being ready for combat-ready in a sense that “you fight the way you train.”

**PRESENT AIR COMBAT TRAINING RANGES**

The existing air combat training ranges provide position location, attitude and data communication between the aircraft and range control center. These functions are typically implemented by four (4) subsystems: (1) Airborne Instrumentation Subsystem (AIS), (2) Tracking and Communication Subsystem (TCS), (3) Control and Computational Subsystem (CCS), and (4) Display and Debriefing Subsystem (DDS). These subsystems are shown in Figure 1. Two (2) separate operations are supported: real-time training feedback to aircrews and post-flight debriefing of the aircrews by the range training officer.
The AIS provides the tracking and communication interface between aircraft and ground. The AIS is housed in an AIM-9 missile type pod that mounts on existing wing station weapon adapters. The transponder provides a digital and range data link to the ground. A digital interface unit collects the status and firing data, collects MIL-STD-1553 multiplex bus data from the aircraft and instruments the aircraft for “state vector tracking” (position, velocity, acceleration, and attitude).

The TCS consists of central station electronics and unmanned remote tracking units. The central station schedules collection of ranging and digital data, provides system timing and communicates data to the CCS. The remote tracking units can be fixed as mobile land units or placed on buoys for over-water installations. They collect ranging information and digital data from the AIS pod and relay it to the central station. Their remote capability permits coverage of areas up to 100 x 100 square miles.

The CCS is a centralized computer complex that processes the tracking and digital data. It uses a Kalman filter to determine the aircraft’s position, velocity, acceleration, and attitude. This information, when combined with pilot weapon firing signals, is used to simulate missile flyouts and their scoring between opposing aircraft.

The DDS supports both the real-time control and the post flight debriefing of the air-to-air exercise. The hardware consists of consoles and large screen displays that present aircraft and missile flight paths of all aircraft, pilot views through the wind screen, and aircraft performance data. The Range Training Officer (RTO) uses these displays to monitor the
exercise in progress and offer feedback to the aircrew. All data is recorded in real-time so that, upon return to base, the aircrews can replay the exercise with the RTO to improve their air combat performance.

Adding GPS to an air combat system requires changes to the existing AIS, TCS, and CCS designs.

**GPS - ACMI IMPLEMENTATION**

Augmenting Air Combat Maneuvering Instrumentation (ACMI) training with GPS navigation causes major changes to the AIS design. The TCS and CCS are modified and simplified. Two AIS implementations are shown in Figure 2. The first is an ACMI pod configuration. A GPS receiver and antenna are added to the pod. This requires combining the GPS and data communication antenna in the nose of the pod. The GPS receiver range data must be combined with the inertial data. This will be done with a multistate Kalman filter. The accurate GPS position and velocity data will aid the standard Inertial Reference Unit (IRU), reducing bias and drift errors.

The second implementation uses the aircraft operational GPS receiver and inertial system. In the early 1990s, a significant number of aircraft will have operational GPS receivers. When available, the ACMI AIS will be a simple digital interface and digital data communication link. The digital interface will collect the GPS-aided inertial data from the aircraft’s digital multiplex bus and provide it to the ACMI hardware. The use of operational GPS hardware will significantly reduce the complexity and cost of the unique AIS hardware.

With the availability of GPS, the TCS became a digital data communication relay network. The measurement and collection of ranging data is no longer required. The digital data to be relayed is GPS-aided position, velocity, and attitude, and weapon firing events.

The CCS computational load is reduced since GPS permits the navigation and attitude solution to be accomplished on-board the aircraft. This eliminates the need for a Kalman filter for each aircraft flying on the ACMI training range. The CCS must be provided with a GPS reference receiver to remove GPS bias errors. This technique, known as differential GPS, significantly improves the absolute position accuracy. It is accomplished by placing a GPS receiver at a known location near the range and developing either range measurement or position corrections for all visible GPS satellite signals. These corrections can then be used to reduce the absolute aircraft position error. Reference 1 discusses the differential GPS technique.
VALUE OF GPS TO AIR COMBAT TRAINING

The world-wide availability of GPS will completely alter the concept of aircrew training. The availability of accurate position information at all altitudes eliminates the need for instrumenting large land areas for active aircraft tracking. Only real-time interaction by the RTO, with the aircrew and weapon simulation scoring, requires data communication with the aircraft.

If real-time interaction is not required, land-independent air combat training is possible. This concept utilizes a recorder on-board the aircraft which stores position, velocity, attitude, and weapon firing information during the engagement. When the aircraft lands, the recorders are removed, stored, processed, and synchronized for replay to the aircrews; for position training feedback. This approach requires no ground-based instrumentation and can be used wherever air clearance is approved, including at sea.

When real-time interaction with the training officer is necessary, some ground instrumentation is required for digital data communications. This permits real-time updating of the training officer’s displays. The amount of ground instrumentation is reduced by approximately one-third (1/3) because only data communication links are required. The use of GPS eliminates the need for multilateration ranging measurements. This will result in larger range areas and more aircraft participating in the exercise than presently possible with existing ACMI designs.

The navigation and inertial update accuracy is more than adequate for ACMI training. The typical GPS accuracies quoted are fifteen (15) meters absolute with respect to the earth coordinate system. However, for air-to-air combat with all aircraft using GPS, the measurement accuracy becomes a relative value between aircraft. The typical method to improve relative navigational accuracy is to use a differential measuring receiver that eliminates bias errors. In GPS this is accomplished by placing a GPS reference receiver at a known location. The receiver then measures ranges to all GPS satellites and generates range errors using its location. These range errors become range measurement corrections for any other GPS receiver. These corrections will reduce the GPS navigation accuracy to two (2) to four (4) meters. This is more than adequate for air-to-air training exercises. It is also sufficient for most air-to-ground training, such as no-drop bomb scoring and anti-radiation missile simulations.

USING GPS IN OTHER TRAINING

The Army and Navy have significant training requirements on land and at sea. The Army performs Land Armor Training at the National Training Center at Fort Irwin, California. This training is force-on-force, with up to five hundred (500) participants in an individual
exercise. GPS will improve this training by improving the position location coverage, increasing the accuracy of the real-time casualty assessment and simplifying the addition of close air support to the training scenarios.

The Navy has been using the concept of a Mobile Sea Range to improve the quality of the participant data in at-sea training exercises. The present concept is to instrument participants with range measuring and data communication transponders. The resulting information collected by a control center is processed, provided for display to training officers, and used for post-test debriefing. The addition of GPS will allow larger areas for fleet-on-fleet training, and will allow increased digital data communication from participants to the control center.

REFERENCES

FIGURE 1. The Four Basic Range Subsystems
FIGURE 2. ACMI Implementation for Aircraft Using GPS