MC-130 EMBEDDED RADAR WARNING SIMULATOR

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ABSTRACT

Air Education and Training Command, Studies and Analysis Squadron (AETC SAS) in conjunction with the 58th Special Operations Wing (58 SOW) at Kirtland AFB, NM, assessed the suitability and effectiveness of using an embedded simulator to stimulate the HC/MC-130P AN/ALR-69 radar-warning receiver (RWR). The AN/ALR-69 is Air Force Special Operation Command's (AFSOC) operationally employed radar warning receiver (RWR), currently installed on AC-130, MC-130, and MH-53 aircraft. It continuously monitors the radar environment to alert the pilot of any hostile or foreign activity that may be taking place. Currently, the only way to effectively train aircrews in the use of the RWR is by scheduling flights at electronic warfare (EW) ranges. Although these ranges provide excellent training, they are expensive, constrained by scheduling considerations, and consume additional flying hours in transit time. Ultimately, this training approach is limited by the scarcity of training opportunities necessary to teach and reinforce learned behaviors.

The 58 SOW, in conjunction with the Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA), has created an on-board system to stimulate the HC/MC-130P AN/ALR-69 RWR with fully correlated and validated threat parametric data. Advances in technology now permit hosting of a transportable, affordable, and credible "electronic combat range in a box" utilizing a commercial-off-the-shelf (COTS) personal computer (PC). In addition to overcoming the cost and inconvenience associated with geographically constrained EW ranges, this solution allows instructors to manipulate the order of battle in support of diverse training scenarios. The ability to regularly engage countermeasures against adversary air defense radar systems during routine training sorties infuses increased realism into the training domain and permits aircrew to "train the way we fight."

The study focused on real-time interactions between aircraft positional data, line of sight (terrain masking) calculations, clutter degradation, and RWR visual/aural cueing to provide accurate threat representation. Additionally, the test confirmed that no permanent aircraft modifications are required and the system installation/removal does not exceed 30 minutes. This paper presents the test and study results and recommendations.

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BACKGROUND

The 58th Special Operations Wing (58 SOW) identified a requirement for enhanced threat signal recognition and tactical maneuver training in response to information provided via the MC/HC-130 AN/ALR-69 radar warning receiver (RWR). During tactical flight operations, the onboard RWR equipment provides visual and aural cueing in response to external electronic stimuli. Currently, the only way to effectively train with the aircraft RWR is to schedule flights at electronic warfare (EW) ranges. Although these ranges provide excellent training, they are very expensive (costing up to several thousand dollars per hour), constrained by scheduling considerations (limited operating hours, flight restrictions, etc.), and consume additional flying hours (travel to and from). Ultimately, this training approach remains limited by the scarcity of training opportunities necessary to teach and reinforce learned behaviors. To mitigate this problem, aircrews require a device that permits them to practice RWR threat signal recognition and perform requisite evasive maneuvers on all tactical training flights.

The 58 SOW, in conjunction with the Air Force Research Laboratory Warfighter Training Research Division (AFRL/HEA), proposed creating an on-board system to stimulate the HC/MC-130P AN/ALR-69 RWR with fully correlated and validated threat parametric data. Advances in technology now permit hosting of a transportable, affordable, and credible "electronic combat range in a box" utilizing commercial-off-the-shelf (COTS) computer components. Because of continuing efforts at the Air Force Research Lab, these simulations already exist and could readily migrate to an aircraft-compatible system. This approach intended to stimulate the AN/ALR-69 RWR without permanently modifying the aircraft, merely disconnecting and stimulating the cockpit's actual azimuth indicators and indicator control unit for specified training sorties. The engineering risk was assessed between none to extremely low as AFRL/HEA had already implemented this RWR simulation into F-16 flight simulators. The requisite radar landmass simulation database already existed at the 58 SOW and merely required a straightforward and relatively simple conversion.

Besides overcoming the cost and inconvenience associated with geographically constrained EW ranges, this solution allows instructors to easily manipulate the order of battle in support of diverse training scenarios, thus promoting part-task training, individualized instruction, and crew resource management training. The ability to regularly practice counter-tactics against adversary air defense radar systems during routine training sorties infuses increased realism into the training domain and permits the aircrew to "train the way we fight". This project was funded through AETC's Education and Training Technology Application Program (ETTAP), which seeks to identify and evaluate innovative technologies for Air Force education and training. AETC SAS serves as the Command's independent assessment body for current and future programs.

MC-130P Combat Shadow

The Combat Shadow flies clandestine or low visibility, single or multi-ship low-level missions intruding politically sensitive or hostile territory to provide air refueling for special operations helicopters. The MC-130P primarily flies missions at night to reduce probability of visual acquisition and intercept by airborne threats.

Secondary missions include airdrop of leaflets, small special operations teams, resupply bundles and combat rubber raiding craft, as well as covert takeoff and landings and in-flight refueling as a receiver.

Figure 1. MC-130P Combat Shadow

The Combat Shadow can fly in the day against a low threat. The crews fly night low-level, air refueling and formation operations using night vision goggles. To enhance the probability of mission success and survivability near populated areas, employment tactics incorporate no external lighting and no communications to avoid radar and weapons detection. (U.S. Air Force, 2003)

Electronic Warfare Training

American military pilots face numerous threats during combat operations, including enemy aircraft, anti-aircraft artillery (AAA) and surface to air missiles (SAMs). Over the last fifteen years, America engaged in conflicts with adversaries fielding older generation, Soviet-built SA-2, SA-3, SA-6, and SA-8 SAMs: the so-called single digit SAMs, designed in the 1960s and 1970s. The newer generations of SAMs, double digit SAMs such as the SA-10, SA-12, SA-15, SA-19, and SA-20, are far more sophisticated and lethal. These have higher power radars that are jam-resistant, and they use faster and longer-range missiles. (Spratt, 2001)

Numerous recent reports, summits, and roadmaps all have articulated EW training shortfalls. An Air Staff-level Integrated Process Team used such terminology as "limited inflight training opportunities for aircrews to employ EW systems" and "EW not a mainstream competency" while recommending "embed EW training at all levels." Taking into account the cost, availability, and impact of utilizing EW ranges as the sole means for training on-board RWR, current MC-130P training guidance requires aircrew to practice against radar-guided threats only once per semi-annual period.

Range Training

One way to better prepare pilots to face these emerging threats is to provide better training; particularly in environments that more closely simulate what they will see in a real combat situation. The United States Air Force currently has portable threat emitters (Figure 1) on many of their air combat training ranges, called miniature multiple threat emitter systems ("Mini-MUTES"). These highly mobile, trailer mounted systems simulate the radiation that would "paint" an aircraft if it were flying into a threat area.

Although the Air Force has committed to upgrade the Mini-MUTES system to meet projected threats (Harris Corporation, 1998), EW range limitations in both training frequency and practical limitations (location, size, and cost) currently prevent aircrew from effectively incorporating RWR training either effectively or routinely. Successful RWR skills prove difficult to master and extremely perishable in nature. The current inability to habitually exercise such skills manifests itself in marginal aircrew proficiency relative to RWR counter-tactics.

In an effort to overcome the limitations of range training, efforts have been made to implement rangeless air combat training systems (ACTS). When typhoons severely damaged tracking towers used by the Kadena Airbase air combat training range, the U.S. Air Force selected Cubic Defense Systems to develop a new system that would preclude the need for ground towers. The Air Combat Training - Rangeless (ACT-R) system combined aircraft data links and Global Positioning System data to track and record aircraft maneuvers (Panarisi, 2001). However, current rangeless ACTS focus on air-to-air tactical combat training and do not provide an electronic threat environment robust enough for MC-130 training (Testa, 2002).

Figure 2. VPQ-1 Tactical Range Threat Generator

As American cities expand, training ranges find themselves constrained by urban growth. Ranges located in areas once considered remote are now feeling the encroachment pressures. As outlined by the U.S. General Accounting Office (2002), military training ranges face several challenges stemming from encroachment. These include the application of environmental statutes, competition for radio frequency spectrum, and competition for airspace. These threats can be mitigated using embedded training systems.

A key financial benefit of an embedded EW trainer is the cost avoidance achieved by reducing the need for EW range assets. Mission effectiveness and training is enhanced by not being constrained to operate against range assets whose locations never change and where the electronic order of battle (EOB) is always a known entity.

To accomplish this same training on actual EW ranges every sortie proves difficult due to cost and flying hour constraints. Consider the expense to routinely incorporate EW training based on a squadron of four MC-130Ps, provided 1500 flying hours per year. This equates into approximately 300 sorties annually. Adding one hour of flight time to and from a nearby range translates into 300 training hours at a cost of roughly $960,000 ($3200 per flying hour). Additionally, corresponding range costs potentially add a significant expense, depending on particular range and range capabilities utilized.

Embedded Training

Embedded simulation provides crews the ability to interact with computer-generated objects and inputs (both friendly and adversary) using the controls, sensors and subsystems of a weapon system, at any location and at any time. Employing on-board electronic combat simulation can improve training efficiency while simultaneously realizing significant cost savings and optimum use of limited resources.

As early as 1987, the U.S. Army established embedded training as the preferred method for training device strategies (Embedded simulation, n.d.). The U.S. Army has put embedded training technology to work in its Bradley A3 Virtual Range Demonstrator (Bernard, 2001). Operators and commanders can train while actually in the vehicle using an onboard simulator that displays a variety of computer-simulated battlefield scenarios. Because the software is embedded in the vehicle, crewmembers can take advantage of non-combat situations for training, increasing their readiness levels and reducing the unit's demand for training ranges.

While embedded training has also been tested with the M1A2 Abrams System Enhancement Package (SEP) main battle tank, the Army is planning for long-term embedded training in its Future Combat Systems (FCS) program. FCS sets top-level requirements for distributed and embedded training. The Army Chief of Staff has mandated a 96-hour response time for a combat-capable brigade (U.S. Army, 2002). To meet this requirement, FCS units will engage in mission rehearsal and focused training while en-route (Army Training Support Division, 2002). Key to this effort is the Inter-Vehicle Embedded Simulation Technology (INVEST) initiative (Hart, Green, Dolezal, Lowe, 2002), which showed that the availability of onboard simulation could enhance operational capabilities such as situational awareness and mission planning (Hart, et. al.). The U.S. Army Simulation, Training and Instrumentation Command (STRICOM) has also sponsored the development of an augmented reality embedded training system for its Objective Force Warrior initiative (Kirkley, Kirkley, Borland, Waite, Dumanoir, Garrity & Witmer, 2002).

With regard to U.S. Air Force training, the October 2000 AETC EW Roadmap states "…it is clear that a solid foundation in EW is critical to future success on the battlefield. AETC must take leadership and expand its role in this arena. Today's EW plays a vital role in the AF's war fighting capability." Failure to field an embedded EW training capability potentially impacts the combat readiness of the United States Air Force.

APPROACH

The approach for the embedded EW simulation is based on a series of tasks designed to provide immediate improvements and support future upgrades to the simulation. The strategy incorporates an extremely low risk implementation while ensuring a significant training improvement at minimum cost. The design option leverages commercially available software solutions and considers reliability, maintenance, and commonality with current aircraft systems. This study divided the process into four distinct tasks:

1. Convert actual AN/ALR-69 Operational Flight Plan (OFP) software from Assembly and Jovial to C code.

2. Provide a digital radar landmass simulation to affect terrain-masking parametrics, e.g., line of sight and terrain clutter calculations. AFRL utilized Level 1 DTED directly from NIMA sources.

3. Provide an aircraft-compatible portable computer with at least two Versa Module Europa (VME) chassis and sufficient capacity to run the ALR-69 and radar simulations in real-time. Once the appropriate platform is identified, it must then be certified for on-aircraft use such that it does not detrimentally affect any aircraft system or power supply.

4. Provide aircraft positional data to the simulation system from the aircraft's Self-Contained Navigation System (SCNS). The solution required certification to ensure no corruption to aircraft navigation systems.

IEWS On-Board Simulator

The Imbedded Electronic Warfare System (IEWS) was designed to interface with the AN/ALR-69 signal processor through the MIL-STD-1553 EW data bus, creating an on-board simulation of threat parametric data. Some of the threat emitters that the IEWS can generate include anti-aircraft batteries, surface-to-air missiles, search radars, and fighter aircraft. Aircraft airspeed, altitude, and position data are fed into the IEWS from the MIL-STD-1553 NAV bus, allowing the simulator to provide the AN/ALR-69 azimuth indicator and indicator control unit fully correlated threat data. ("Next generation threat system," 2003)

In its role as an EW trainer, the IEWS does not affect the operational use of Air Force Special Operations Command (AFSOC) aircraft. The operational concept allows EW training without the need for an EW range. The aircrew can fly a training program that includes threat emitters designed specifically for a particular training mission. The program can be started at any time during the training mission. As the aircraft flies within range of the simulated threat emitters, the aircrews see threat emitter symbology on the AN/ALR-69 azimuth indicator and hear aural tones on the aircraft intercom system. The aircrews then employ evasive maneuvers to either avoid or escape detection.

The IEWS software runs on Microsoft's Windows operating system. A Unix-based system would have required technical knowledge beyond what aircrews possess, while Windows provides a user-friendly environment.

Figure 3. IEWS hardware and equipment rack

The IEWS project was initiated through AETC's ETTAP in May 2001. The final cost for a single IEWS was approximately $53,000, and to provide backup capability and increase the opportunity for use on available training sorties, ETTAP funded two systems. It was not designed to reduce flying hours. It was however, intended to maximize the utility of every available flying hour by providing the ability to conduct RWR training and basic defensive tactics training during any type of mission, at any phase of the mission. It was hypothesized that on-board, embedded RWR simulation would improve both training and real-world mission effectiveness by enhancing aircrew threat signal recognition, coordinated crew response, and defensive tactics.

METHODS

Both HC/MC-130P permanent party aircrew (continuation training) and students (mission qualification/instructor upgrade/aircraft commander upgrade) utilized the onboard electronic warfare simulation during tactical training sorties. Once installed, operators could elect to leave the system onboard the aircraft assuming real-world requirements do not necessitate use of the RWR (i.e., the aircraft remains dedicated to training sorties). Otherwise, an estimated 30 minutes of maintenance personnel time was required to return the aircraft to its original configuration.

The system was tested onboard an MC-130P over 12 sorties and passed flight-safety checkout sorties prior to flying electronic warfare tactical training missions. These missions ranged from low to high threat scenarios. The embedded system simulated aircraft sensor arrays to indicate threats from anti-aircraft artillery, surface-to-air missile, and fighter aircraft.

System testing was carried out by personnel from AFRL and the 18th Flight Test Squadron (18 FLTS) in two phases. First, an electromagnetic interference (EMI) evaluation of the prototype IEWS was carried out at Kirtland AFB, NM, from 5-12 September 2002. The second phase involved flight testing at Kirtland AFB from 22-25 October, 2002. (18th Flight Test Squadron, 2003)

Phase I

EMI evaluations were conducted on a static aircraft while the IEWS was active. The intent was to determine if any interference occurred either to the aircraft or to the IEWS. After ground testing revealed no interference, in-flight systems were evaluated during a 45-minute test flight. Neither aircraft systems nor IEWS experienced EMI.

Phase II
Following the EMI evaluation, aircrews from the 58 SOW flew standard training routes across varied terrain. AFRL engineers operated the IEWS, simulating various threat emitters along the route. During the flight, simulated threat emitters along the route were displayed on the AN/ALR-69 azimuth indicator when in range, and aural tones were produced. Crews used standard tactics to avoid or reduce threat emitter detection. The test team was able to inject spontaneous threat events during the flight, depending on the training profile. During flight testing, a variety of onboard instrumentation was used to record data, including a PC-based 1553B bus analyzer, video recorders, global positioning system recorder, video scan converter, and video time inserter. All data was time-tagged and correlated. In total, approximately 5 hours of flight time was devoted to testing.

RESULTS

System effectiveness was evaluated based on the following two critical operational issues:

1. Determine if the AN/ALR-69 IEWS has the potential to enhance MC-130P electronic warfare training.

2. Determine if the AN/ALR-69 IEWS is potentially suitable for use by MC-130P aircrew.

Training Enhancement

The IEWS met three out of three criteria to determine its potential to enhance MC-130P EW training.

1. It was able to generate the correct symbology and provide appropriate audio cues for all programmed threats, exceeding the 80% threshold set by the testers. The fidelity of the IEWS cues was actually judged "too accurate" for some emitters and the audio cues "too crisp" as compared to actual AN/ALR-69 threat emitter audio.

2. The IEWS incorporated all aircraft maneuvers into the simulation, including changes in altitude, heading, and speed. Consequently, aircrews were able to use terrain-masking maneuvers to avoid detection and break the lock of the simulated threat emitters.

3. Threats were displayed in the proper quadrants of the AN/ALR-69 azimuth indicator, with no direction finding errors noted during the evaluation.

Figure 4. MC-130 IEWS system development and test team

Suitability

In terms of usage, the IEWS was found to be potentially suitable for use by MC-130P aircrews. However, due to operational issues, one of the two measures of suitability was not assessed.

The ability of users to use the IEWS was unresolved. Due to aircrew scheduling sensitivities, the test team did not collect a sufficient number of surveys to assess the criteria. However, six test team members and two aircrew members used the IEWS and determined that it met the following three usability criteria:

1. The IEWS required minimal training and was used throughout the mission planning process. For example, the IEWS can show preplanned EW training routes, review terrain altitudes, review threat locations, review avoidance procedures, and plan for potential deviations, e.g., weather and in-flight emergencies.

2. Modifying IEWS scenarios was categorized as "very easy" by the test team. Adding new threats to the route was accomplished via on-screen drop-down menus, and existing threats were rapidly relocated using drag-and-drop functionality. Modifications were easily accomplished while flying the actual training mission.

3. The threshold for system stability was 70% operational uptime. During the first mission, the IEWS "locked up" several times, requiring the system to be rebooted. However, AFRL determined the cause to be a subroutine failure in the audio signal software produced by flaws in the underlying Windows operating system. As with most general-purpose products, Windows creates a significant challenge for developers of real-time embedded applications (Drabik, 1998).

Once this error was corrected, no subsequent system failures were observed over the following five missions. The software was operational for 83% of the test.

Safety of flight was always the primary consideration. In order to isolate any possibility of writing to the Nav bus, the testers used two 1553 interface cards. One card pulled navigational data with no write capability. The other card was used to transmit the simulated pulses into the 1553 EW bus. Simply unplugging the RWR processors while extracting aircraft positional data from the Military Standard (MIL STD) 1553 data bus posed no hazard to flight.

DISCUSSION

During the IEWS evaluation, the test team observed that crew coordination between pilot, co-pilot, navigator, and flight engineer "increased substantially" during IEWS training missions.

Based on observations of approximately 25 training flights, it was found that further use of the IEWS may allow aircrews to improve their understanding of integrated air defense systems and related threats, while understanding limitations of the onboard RWR, particularly concerning ambiguous indications. Evaluators also observed that use of the IEWS led to improved situational awareness. In response to IEWS-generated threats, aircrews implemented evasive maneuvers and maximized communication to increase awareness of critical elements such as aircraft altitude, airspeed, relative bearing to the threat, and the location of terrain that most likely would mask the aircraft from the threat.

With the IEWS recommended for wider use, C-130 EW training plans must be consulted when considering fielding the system. An EW bus with consolidated display and embedded training mode with record capability for the AC/MC-130s is included in the C-130 Avionics Modernization Program/Common Avionics Architecture for Penetration (AMP/CAAP). With the planned USSOCOM acceleration, the first Talons should be fielded by the end of FY 08. Based on this favorable evaluation, the IEWS could serve as a suitable interim solution until C-130 AMP/CAAP modifications are fielded.

The IEWS demonstrated an ability to provide training with a degree of realism and flexibility not available on the EW training range. Evaluators cited the system's reliability and ease of use, noting an improvement in crew resource management skills as an ancillary benefit. The IEWS is a robust, embedded training device and is ready for operation use.

In addition to improved HC/MC-130 training, the system could be used during mission planning and rehearsal with any platform facing an EW threat.

REFERENCES

18th Flight Test Squadron. (2003). *Operational Utility Evaluation (OUE) of the AN/ALR-69 Imbedded Electronic Warfare System* (AFSOC Project 02-028). Hurlburt Field, FL: Author.

Army Training Support Division. (2002, July 5). *Future Combat System Embedded Training* (Training Support Assistance and Integration Directorate White Paper). Retrieved April 22, 2003, from http://www.atsc.army.mil/tsaid/documents/ 2002-06-6%20ET%20White%20Paper%20v7.0.doc

Bernard, J. R. & Alban, A. M. (2001). Embedded training solution for the Bradley Fighting Vehicle (BFV) A3 (United Defense, L.P.). Retrieved April 18, 2003, from http://www.uniteddefense.com/ cap/embedtrain.htm

Drabik, J. (1998). *Windows NT & Real-Time Applications: Solution, or Problem?* International Alliance for Compatible Technology. Retrieved June 26, 2003, from http://pages.cthome.net/iact/ features/24x7reports/iact-24x7-NTreal.html

Embedded simulation. (n.d.). ETS News. Retrieved June 2, 2003, from http://www.ets-news.com/embeddedsim.htm

Harris Corporation. (1998). *U.S. Air Force awards Harris Corporation $49 million electronic warfare contract*. Press Release, August 10. Retrieved May 2, 2003, fromhttp://www.harris.com/view_press release.asp?act=lookup&pr_id=747

Hart, J., Green, G., Dolezal, M., & Lowe, V. (2002). *Embedded training technology development – progress to date and lessons learned in getting there*. Proceedings of the 23rd Army Sciences Conference, USA. Retrieved April 22, 2003, from http:// www.asc2002.com/summaries/m/MP-10.pdf

Kirkley, S., Kirkley, J., Borland, C., Waite, T., Dumanoir, P., Garrity, P., & Witmer, B. (2002). *Embedded training with mobile augmented reality*. Proceedings of the 23rd Army Sciences Conference, USA. Retrieved April 22, 2003, from http:// www.asc2002.com/summaries/m/MP-04.pdf

McGuire, M. (2000). *AN/ALR-69 On-board electronic warfare simulation* (Education and Training Technology Applications Program Project Proposal Long Form).

Next generation threat system. (2003, Winter). *Fight's On!, 2*, 3.

Panarisi, M. T. (2001). A *comparative analysis of internal and external solutions to provide air combat maneuvering instrumentation functionality*. Master's thesis, Air University, School of Advanced Airpower Studies, Maxwell AFB, AL.

Spratt, J. M. (2001). *Improving electronic warfare training for America's pilots* (Issue Brief #9). Electronic Warfare Working Group. Retrieved April 29, 2003, from http://www.house.gov/pitts/initiatives/ew/010629ew-brief-9.htm

Testa, J. E. (2002). *Brining back interoperability to Air Force combat training ranges.* Proceedings of the Interservice/Industry Training, Simulation and Education Conference, *24*, 321-329.

U.S. Air Force. (April, 2003). *MC-130P Combat Shadow Fact Sheet*. Retrieved May 13, 2003, from http://www.af.mil/news/factsheets/MC_130P_Combat_Shadow.html

U.S. Army. (2002). *Unit movement operations* (US Army Field Manual 4-01.011). US Army Combined Arms Support Command: Fort Lee, VA.

U.S. General Accounting Office. (2002). *DOD needs a comprehensive plan to manage encroachment on training ranges.* (Testimony before the Committee on Government Reform, House of Representatives). Washington, DC: Author.

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