Electronic Warfare Rangeless Embedded Training
A Cost Effective Training Approach

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ABSTRACT

US military aircraft are continuously being updated with the latest advances in modern weaponry and electronic warfare (EW) systems are no exception to this trend. While enhancing ownship threat avoidance and detection capabilities, these advances in weaponry place significant demands upon service men and women to adequately train with these new systems to maximize their battlefield effectiveness. On-going efforts are underway to enhance EW training on several US Air Force aircraft. These enhancements provide closed-loop simulations of air-defense environments creating realistic in-flight combat training for the aircrew. This training capability is an integral part of the aircraft integrated processor operational flight program (OFP), which allows for 'on-demand' training facilitating an in-route mission rehearsal. This capability also removes the requirement to schedule expensive time on training ranges or can be used in conjunction with traditional range training to supplement the training environment.

This paper will present an overview of an EW Embedded Training System including: the embedded training architecture, an instructor toolset for configuring training scenarios consisting of threat laydowns and air defense behaviors, and a training mission playback capability to support instructor scoring. Additionally, this paper will summarize results from these ongoing efforts.

ABOUT THE AUTHORS

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INTRODUCTION

Today's US military is continuously being supplemented with the latest advances in modern weaponry and the electronic warfare (EW) community is no exception to this trend. These advances in weaponry place significant demands upon service men and women for adequate training to maximize their use in the battlefield. Upgrades, as well as new weaponry, demand that training be a never-ending process. However, the services are constrained by limited funding and range training assets. Coupled with the demands for service men and women to be ready to fight at a moment's notice, asset limitations have greatly restricted the level of training available. Several efforts are currently underway to enhance the EW training on Air Force Special Operations Command (AFSOC) aircraft using on-board, "rangeless" EW training. On-board EW training provides closed-loop simulations of air-defense environments for realistic in-flight combat training of aircrews. The training capability will be an integral part of the aircraft integrated processor operational flight program (OFP), allowing training to be accomplished any time the crew is in the air providing a low-cost training alternative.

Traditionally, when independent trainers are used, separate development efforts are required to upgrade the training simulator with the latest system upgrades. Often, the trainer has lower priority which means it quickly becomes out of date when compared with the fielded system. By integrating the training function into the OFP, trainer upgrades coincide with system upgrade releases.

On-board training capability can be used to augment range training and testing by increasing the density of a threat environment or adding assets to the training scenario. Some inherent limitations of ground-based emitters associated with range training include: radio frequency (RF) emitters are needed to track the aircraft in-flight, a scenario beyond one to two emitters becomes overly expensive, emitter power levels are subject to Federal Communications Commission (FCC) controls unless the system is on a national range, and training flexibility is limited since most ranges have threat simulators installed in fixed locations.

Previous onboard EW trainers have been developed to inject RF emissions from an aircraft installed emitter. These programs required extensive aircraft integration, required complex custom hardware, and thus are likely to be too costly for implementation across an aircraft fleet.

The embedded training approach presented herein does not restrict training to geographical areas, and requires no unique aircraft hardware. In-flight training can occur anytime and anywhere (e.g., in-route to "hot" spots or to a training range). Training scenario complexity is not limited to the available number of real or simulated threat systems and it can be used to augment range training.

EW TRAINING OVERVIEW

The Necessity for EW Training

'American military pilots face numerous threats during combat operations, including enemy aircraft, anti-aircraft artillery (AAA) and surface to air missiles (SAMs). While our forces preformed extremely well in both the Gulf War and in Kosovo, we should not be lulled into a false sense of security. We cannot assume that flying over enemy territory is safe or that the current level of performance will exist in perpetuity.' (Spratt, 2001) The need for EW training is always present whether it is general tactics training or mission specific training. Today EW training takes place in the aircraft on an outdoor training range or using a 'cockpit simulator'; both of these training methods are effective and have their advantages and disadvantages.

Training on a Simulator

Simulator-based training provides the core capability for providing aircrew proficiency in basic system operation, inter-crew coordination, and weapon systems deployment. Simulator-based training takes on several forms. Use of a part-task trainer is widely used to train a member of the aircrew or maintenance staff on a particular task associated with the aircraft. A part-task trainer is sometimes used to provide training on basic electronic warfare system aircrew interactions. Weapon systems trainers are required for each major Department of Defense (DoD) weapon system and provide a more comprehensive and integrated approach to training. Many weapon systems trainers provide simulation of threat engagements. These vary in levels of fidelity, but all serve to indoctrinate the aircrew in threat engagement tactics. More recently, weapon systems trainers are being used and enhanced to support mission rehearsal functions. Ground-based training provides a solid training foundation prior to in-flight training.

Training on a Outdoor Range

Training in the air provides the ability to experience the in-flight integrated environment. A typical training scenario could include flying a preplanned route to a restricted flight area such as an outdoor training range equipped with a multiple emitter threat system (MUTES), single emitters, real threat systems, or a bombing range. This type of training can be gradual in terms of integration. Specifically, trainees may first start out in the air, acclimating to the in-flight environment; then, Airborne Warning and Control System (AWACS) radio traffic can then be added slightly increasing the training intensity; and as a last step training over a range equipped with threats would be added. This gradual approach to training provides an enormous benefit. Adding on-board threat simulations prior to flying over a training range facilitates the gradual approach to training EW systems operators, and provides a cost effective means of allowing trainees to increase their training intensity. Augmenting outdoor range training with on-board training provides the experience needed to operate the EW system before flying over training range threats. The key to the on-board simulation of threats is the ability to provide a closed-loop simulation providing real-time feedback to the trainee in terms of countermeasures effectiveness.

Background - Integrated EW Suites

One evolutionary change that is occurring in combat systems is the integration of individual EW systems on an aircraft to address the need for an integrated view of the threat environment. The control of individual EW systems is being merged into an aircraft integrated processor OFP creating an integrated defensive avionics suite with an integrated display and response management. These integration efforts leverage the MIL-STD-1553 bus structure present on many EW systems. Functionally, the integrated system collects and correlates the reported individual EW system information and forms a comprehensive view of the actual threat environment. Integrated displays, which reflect the full spectrum of EW systems present on the platform, provide enhanced situational awareness to the operator. These systems also reduce crew workload by facilitating coordinated responses such as jamming, expendables, and flight maneuvers. This level of integration is unique in that the integrated OFP provides enhanced operator visibility into the EW threat environment, including multi-spectral behavior, and can be key to understanding a threat's intent.

Several individual EW systems such as the AN/ALR-69 (Class IV) radar warning receiver (RWR) and AN/ALE-47 countermeasures dispensing system (CMDS) provide an embedded training capability within their individual OFPs. These standalone systems allow training to be provided through direct interaction with the actual system. For example, the ALR-69 RWR supports embedded training through the use of an On-Board Electronic Warfare Simulator (OBEWS) interface to the OFP. The OBEWS interface allows a MIL-STD-1553 source to send emitter information (pseudo threats) to the ALR-69 and record information from the ALR-69. The pseudo threats are subsequently entered into the Emitter Track File. The ALR-69 responds to pseudo threats with the appropriate display enhancements, such as a new threat symbol on the azimuth indicator at the appropriate location, using the same techniques as those for threats received through the RF sensor inputs. Appropriate audio cues augment the ALR-69 RWR representation to the operator. Although the audio is synthetic, for most threats it is difficult to differentiate from RF generated audio. The response of the system to a real RF threat versus a pseudo embedded training threat is virtually indistinguishable to the operator.

Although the individual systems provide effective training, one key element is missing. Real threat environments involve complex multi-spectral threats which are not limited to just those identified by a single EW system. For example, a threat might rely on a RF tracking radar but also be detected by the on-board electro-optical missile warning system. Training which is limited to a single mode cannot adequately represent the threat environment and falls short of fulfilling EW training requirements.

The approach proposed herein leverages integrated defensive avionics suites by utilizing the aircraft integrated processor OFP to host the EW training software. The EW training software will generate pseudo threat representations to stimulate the various

EW systems present on the platform, provide a closed-loop training environment with real-time trainee feedback, and simulate EW systems which do not support embedded training.

THE SOLUTION
INTEGRATED EMBEDDED EW TRAINING

In order to provide an effective EW training environment for an operator or aircrew, the simulated training engagement must accurately reflect the behavior of a real threat environment. The aircrew should not be able to differentiate a real threat engagement from a training engagement. This functionality requires that training simulations provide full-spectrum closed-loop representations of threat behaviors which respond appropriately to the actions of the trainee. The following sections outline an approach for providing such an electronic warfare training environment.

The integrated embedded EW training capability is accomplished in three phases as illustrated in Figure 1: 1) Mission Planning, 2) In-flight Training, and 3) Mission Playback. These three phases are discussed in detail in the following sections.

Mission Planning

The mission planning phase utilizes an application referred to as the Training Mission Data Management System (TMDMS) which runs on a personal computer (PC). TMDMS allows a trainer to construct a set of scenario files which define the training boundary and the EW environment to be simulated during the training mission. Defining the training scenario requires four categories of information: threat specific data parameters, threat operational behaviors, EW subsystem-specific behavior, and the training threat laydown.

Threat specific data are the unique parameters that are used to construct a pseudo-threat during the training simulation. These include operating frequency, pulse repetition interval, threat antenna height, transmit power, and scan characteristics. The parameters are used during the actual training mission to produce a realistic representation of the threat for each EW system on the training platform. It is important that the parametric representation for these threats be consistent across all the EW systems in the integrated platform in order to facilitate an accurate representation of the real threat. Consistent parametric data is critical to realistic display and auditory responses since these parameters are often used directly on displays or to generate audio tones. To properly exercise the threat correlation

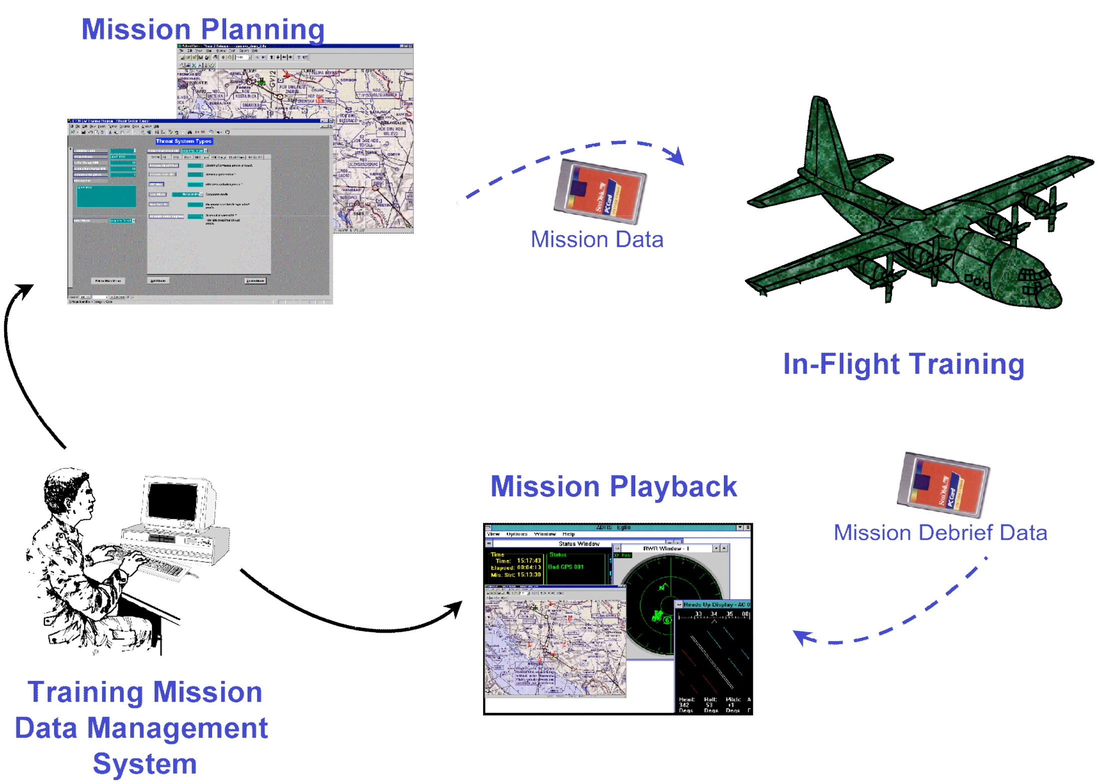

Figure 1. Embedded Training Process Flow Diagram.

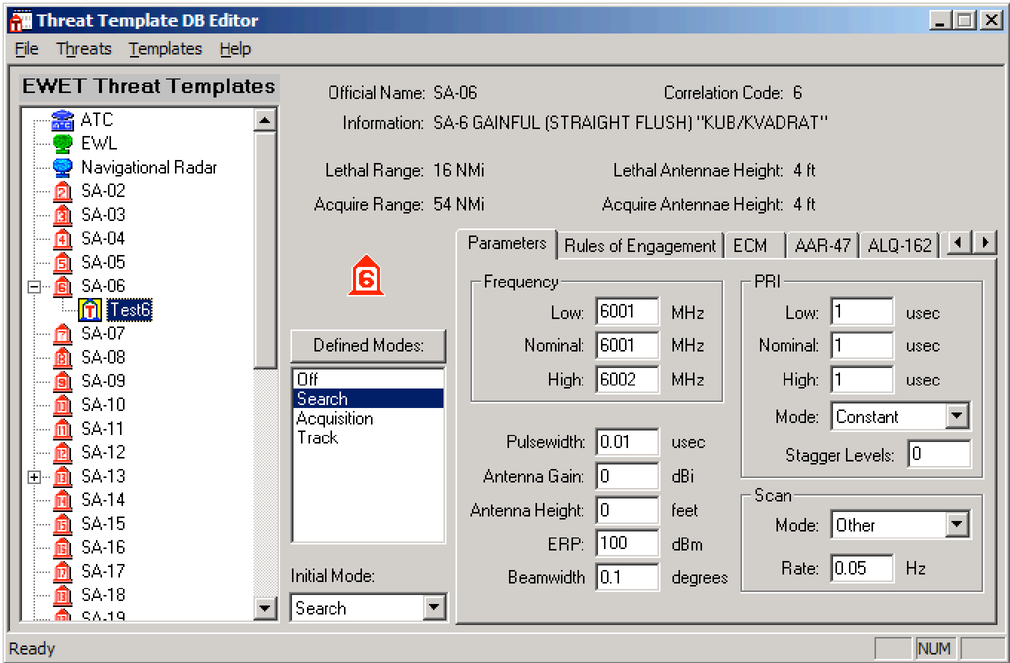

Figure 2. Example Threat Parameters Entry Screen.

procedures commonly implemented in integrated defensive suites, it is also necessary to have consistent threat parametric data. Figure 2 provides an example input screen for building a threat database with user-defined threat parameters.

The second data category is the threat operational behaviors. Threat operational behaviors are parametric representations of how the threat behaves from a tactical level. Figure 3 provides an example screen for configuring threat operational behavior characteristics. This level of specification allows the full spectrum of

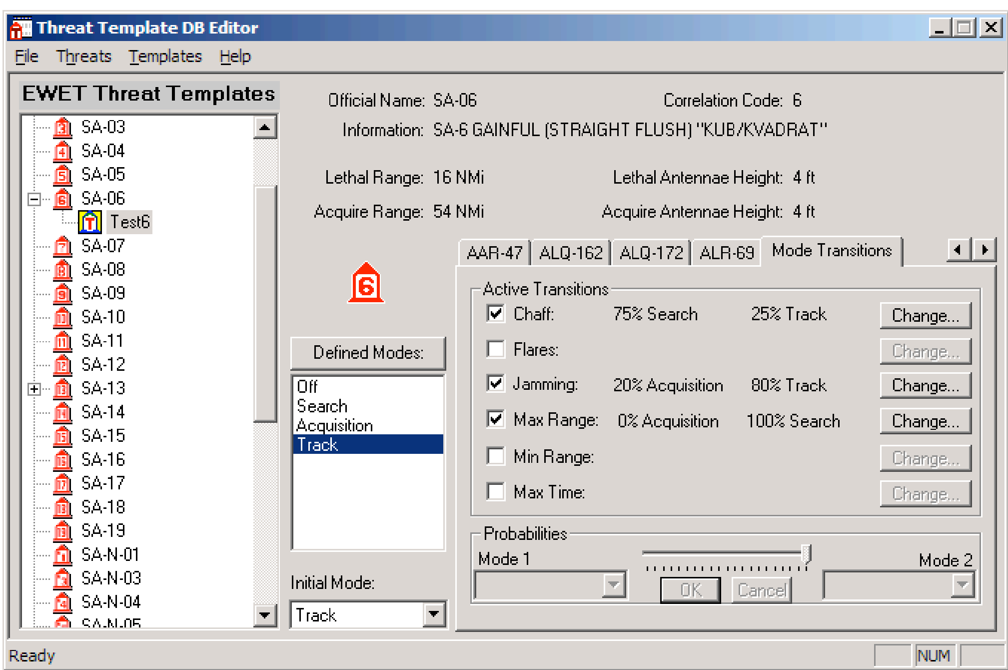

Figure 3. Example Threat Behavior Entry Screen.

enemy tactics and training levels from highly trained well-integrated air defenses to the less predictable behaviors of a poorly trained operator to be represented. The TMDMS allows the user to create several different templates for a single threat system with each template representing different classes of operational behavior. Each template is directly linked to the specific threat parameters discussed in the previous category but differentiates its behavior from a tactical perspective. For example, one template may define Threat System A as a well-trained radar operator. In this case, the on-board jammer may be expected to perform poorly as the operator is expected to be able to recognize various cues to allow him to identify a true target. As shown in Figure 3, this could be represented with only a 20% likelihood that the jammer could drive the radar out of target tracking mode. Similarly, a second template could be defined which represents a poorly-trained operator. In this case, the jamming may be expected to be highly effective in which case the probability of transitioning out of track mode might be set to 90%. The ability to parameterize threat behavior is a key component of the training methodology described in this paper. Additionally, the flexibility afforded by defining templates of different behaviors provides for mission specific EW training in addition to generic platform EW training.

The third category of threat information is the EW system-specific behaviors. Generally, this information is expected to be minimal but provides the flexibility for defining EW system-unique behaviors that are keyed to each threat system. This degree of flexibility is critical to realistic training for the operator. For example, if the RWR requires some time to resolve a threat due to some factor such as additional parameter measurement or additional processing, then the system may indicate an ambiguity whereby the display might oscillate (mipple) between two symbols for some period of time prior to resolving the ambiguity. This feature is provided in the TMDMS by unique entry screens for each of the EW systems on a given platform. An example is provided in Figure 4 where the ALR-69 RWR will mipple between a symbol 3 and symbol 4 for 10 seconds prior to resolving to symbol 4. While appearing minor, these qualities are important in providing a realistic training environment.

The fourth and last category of information required during mission planning is the actual threat laydown. Specifying the threat laydown involves defining a training area and placing instances of specific threat templates within this geographic training environment. Specifically, the individual who is designing the training scenario will want to locate three classes of scenario information: 1) threat placement, 2) planned

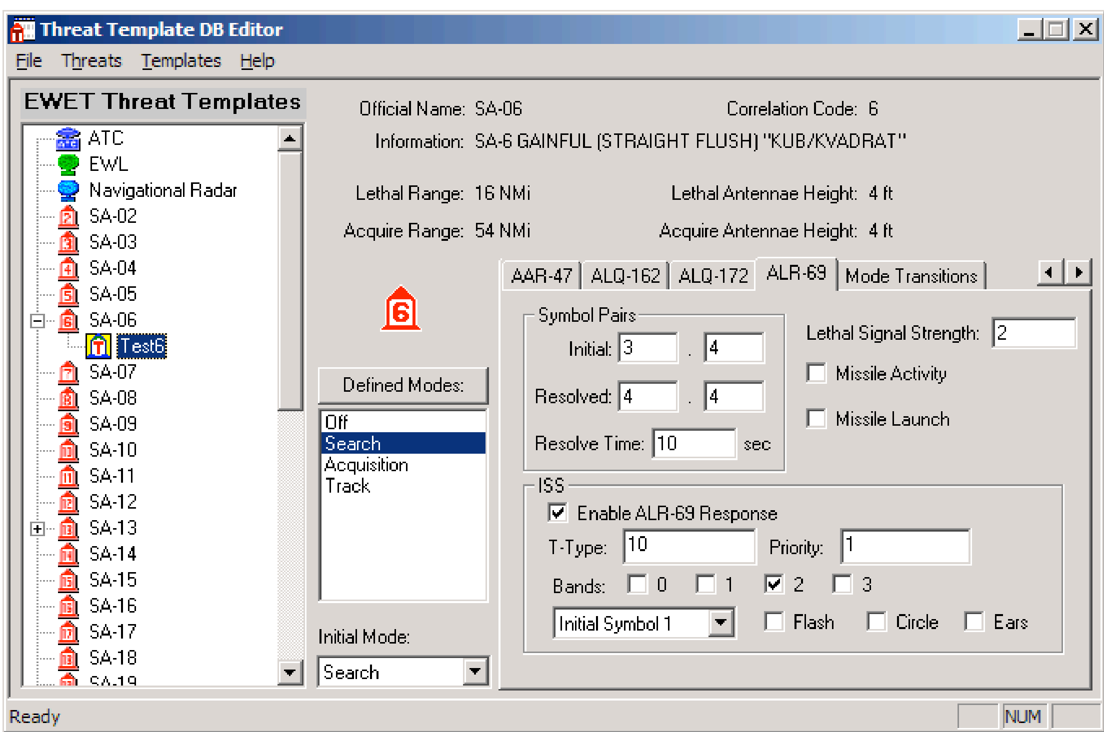

Figure 4. EW Subsystem-Specifc Behaviors.

flight profile, and 3) training boundary. The TMDMS integrates with the Portable Flight Planning Software (PFPS) FalconView mission planner to facilitate ease in geographical laydown of threat locations. Figure 5 provides an example using FalconView. In the example, four threats have been placed on the map: two "threat 2's", a "threat 6", and a "threat 10". The detection and engagement rings as well as effects of terrain masking for these threats are added using FalconView. Further, Figure 5 illustrates a preplanned flight profile and a training boundary defined by the polygon around the geographic training area. The training boundary serves to define the region within which the simulated training threats will be enabled; outside the training boundary, simulated training threats will not stimulate the EW systems. The planned flight profile only serves to facilitate threat laydown. The training threats react to the actual location of the aircraft as provided by on-board navigation data, not the planned flight profile; this will be discussed further in the next section.

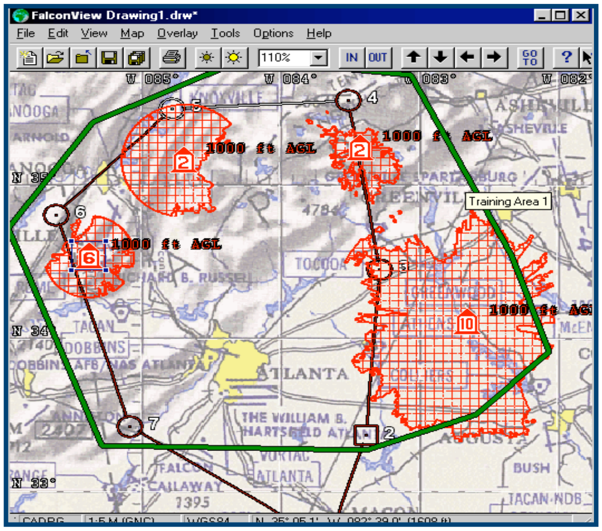

Figure 5. Threat Scenario Laydown.

Execution of the in-flight training mission is controlled by a mission data file. The final step in pre-mission planning is to build the training mission data file. TMDMS merges the training threat parameters (both parametric and operational behavior), EW system unique characteristics, and the training threat scenario laydown, into a single mission data file.

In-flight Training

The second phase of the embedded training methodology is execution of the OFP EW training algorithms during in-flight training. The training algorithms utilize the mission data file produced during the mission-planning phase to derive the pseudo threat stimulations. The OFP monitors the navigational data (including aircraft location, attitude, and maneuvers) as well as on-board systems responses (jamming status, expendable dispenses) in order to exercise the threat simulations in accordance with the predefined training scenario. The training algorithms inject pseudo threat messages into the various EW systems. For example, for those systems which support an internal embedded training capability such as the ALR-69 RWR, the pseudo threats are forwarded to the RWR through its OBEWS interface. Those EW systems which do not support an embedded training mode are disabled during training and the training algorithms simulate these EW systems. Training for off-board threats is handled by simulating tactical ELINT messages.

When generating threat messages, factors such as aircraft location, attitude, distance to the simulated threat, and terrain are all taken into account. This provides a realistic training environment through the use of a closed loop simulation. Operator response through deployment of on-board protection measures such as jamming, chaff and flare dispenses, and maneuvers are monitored in real-time and fed back into the algorithms in order to implement the threat behaviors defined in the training mission data file. Mission debrief data is also recorded during the training mission which can be used to support post mission scoring and replay.

As an interim solution to an immediate need for EW training and mission rehearsal on the AFSOC MH-53M Pave Low platform, a rugged PC was utilized to host the EW training algorithms. The PC is interfaced to the EW suite via MIL-STD-1553 busses. This provides the capability for training mission planning, execution and playback in a single low-cost package.

Mission Playback

The final phase provides for post-training analysis using mission playback capabilities. This is supported by recording a mission debrief data file during the training mission for use by the playback and analysis application. The TMDMS mission playback application provides access to simulations of the various on-board displays including the RWR azimuth indicator, integrated tactical map display, EW systems status pages, and navigational displays. Figure 6 provides an example of the types of playback displays that would be present. The playback displays may be used by the trainee to review training mission actions or by the trainer to support feedback and scoring.

One unique feature supported by the playback application is the ability to switch between manual and automatic display modes. During a training exercise, the trainee may have a multi-function display with the choice of several different displays in which to view the threat environment. During playback, the automatic display mode shows the display selected by the trainee during the training mission. Manual mode allows the trainer to override the trainee-selected displays and view any of the available threat environment displays. This is useful for instructing operator trainees on which view is best for a given environment or situation.

The mission playback application also seamlessly integrates into the FalconView map display providing a view of the actual flight path along with the threat laydown. This view can be compared to the trainee's EW displays during playback providing a comprehensive view of the training session.

SUMMARY

The embedded training system described in this paper focuses on providing a realistic training environment with closed-loop simulations providing immediate feedback to support aircrew training. It has a time-sensitive component in that it eliminates the development delay commonly associated with training simulators which are independent of the air platforms. It has inherent flexibility in being able to support 'training anytime, anywhere' with minimal infrastructure support. In addition, the presented approach can co-exist with and supplement traditional training capabilities available on outdoor training ranges.

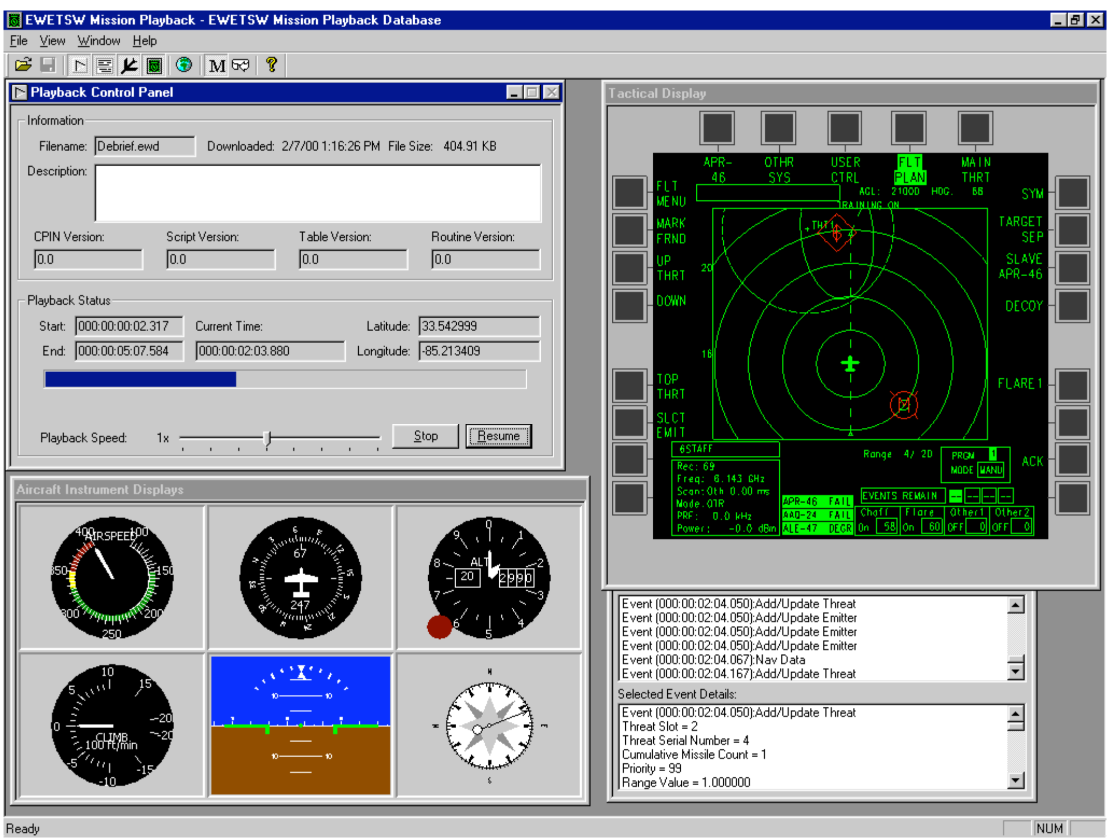

Figure 6. Example Mission Playback Control Screen.

This highly effective training approach was successfully used as a component of the Air Force's C-130 WIRED demonstration program. It will be fielded as a capability in the Air Force's C-130 AMP and MH-53 M-Commonality programs. Further, IADS (Integrated Air Defense Systems) functionality and the simulation of airborne interceptors and mobile threats are significant enhancements under consideration for inclusion in these Air Force releases.

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