Networked Electronic Warfare Training System (NEWTS)

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ABSTRACT

Several efforts are currently underway to enhance electronic warfare (EW) training on Air Force 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 can be an integral part of the aircraft operational flight program (OFP) or can be an external simulator carried onto the aircraft. An emerging requirement for embedded EW training is in support of live, virtual, constructive (LVC) threat simulations in multi-element training exercises like Red Flag. The LVC experience requires coordination of multiple air and ground threat systems with multiple aircraft "players" where some are simulated and some are real. This concept allows training against denser, more realistic threat arrays than are typically available on most live-fly EW ranges.

This paper provides highlights of an investigation conducted to support a low-cost EW training system that meets current and future requirements of a ground-based threat simulation tool that can stimulate the aircraft EW subsystems and monitor aircraft and operator responses over existing aircraft data links. The investigation identified system architectures for an off-board training system that required minimum changes to the aircraft OFP while providing a centralized threat simulation for multiple aircraft in training exercises without the need for expensive training ranges or flight equipment. A primary feature of this concept is a ground-based threat simulator based on the Air Force Research Lab (AFRL) Experimental Common Immersive Theater Environment (XCITE) simulation environment and the Georgia Tech Research Institute (GTRI) on-board embedded training system the Virtual Electronic Combat Training System (VECTS). The concept links the XCITE training simulation system across existing aircraft data links to the VECTS requiring minimal changes to existing aircraft systems and software.

ABOUT THE AUTHORS

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CURRENT EW TRAINING TRENDS

There are currently three methods used to provide Radar Warning Receiver (RWR) in-flight training. The first method, typically used only in multi-crew aircraft, uses ‘flash cards’ or ‘hand-signals’ to indicate a threat event in lieu of flying over a real threat ranges. The use of flash cards is low-cost, but it does not provide the aircrew with training on the use of the RWR controls or threat indications, symbology, or audio tones/alerts. The second method is range based threat training using emitters that stimulate RWR gear with transmit only signals. These systems typically track the target aircraft via IFF and cannot model a full radar guided surface to air missile system. The third method is to fly against actual radar systems, typically only available on major training ranges. On these ranges, Air Combat Maneuvering Instrumentation (ACMI) ranges provides RWR training and a debrief capability against real threats or ground-based threat simulators. This is accomplished by mounting a pod on an aircraft wing station, which uses a constant link to a number of global positioning satellites or transponds with ground telemetry stations to sense a change in aircraft direction or attitude and then transmits the aircraft position data to an instrumented range. The range contains a ground station which receives the instrumented range data and uses a recording device to record the aircraft position and flight simulation software is used to track the aircraft's flight path in real-time. Ground-based threat systems or simulators are located on the range and used to stimulate the on-aircraft RWR. The threat systems can be instrumented allowing the threat system behavior to be transmitted to the ground station for recording. Post-flight the ground station is equipped with the ability to provide immediate aircrew debriefing. This solution is a vast improvement, but is limited in terms of airspace. More significant limitations include availability of current threat systems, mobility of the threats, and density of the threat environment, all critical factors in developing a relevant and realistic training environment.

Pods have now been developed which record and store the aircraft data directly in a data recording device located in the pod. This advancement has allowed the training area to be expanded beyond an instrumented training range. At the end of the training mission, the recording device can be removed from the pod, and the data can be used to create a three dimensional replay of the aircraft flight path. Post-mission replay is useful in helping pilots debrief lessons learned and recognize mistakes they may have made during a training mission. New pods are now being developed with long-range data link capability which will allow real-time viewing of the aircraft's flight path at the ground station. More important, these pods are introducing the concept of rangeless training through the use of real-time weapons simulations and real-time kill notification providing a limited improvement to RWR training. The limitations in this approach stem from the lack of access to the on-aircraft electronic countermeasures (ECM). The feedback loop can only provide real-time assessment based on aircrew initiated maneuvers not the aircrew’s use of the ECM suite which is the essence of EW training. Other drawbacks to the pod training system include cost of the pod system, pod maintenance costs, and lack of availability of ACMI pods on some aircraft.

An embedded training system which is developed as part of the aircraft operational flight program (OFP) can connect the datalinks between podded (or even tactical datalink connected systems) with the actual aircraft EW suites and radar warning systems, closing the gap for fully interactive, live, virtual, constructive (LVC) EW training. The embedded training system has access to the aircraft position data using the on-board inertial navigation system (INS) with access to pilot initiated ECM. The real-time access to ECM data allows the probability of kill (P(k)) analysis to evaluate the use of all evasive tactics available to the pilot. Additionally, the updates to the training software can be made using the normal OFP update cycle. This provides a development and test cost savings and allows the training system features to keep pace with the aircraft system updates. Drawbacks to this solution include the long lead-times for OFP updates and the proliferation of outdated embedded processors. Although, embedded processors are being employed in newer aircraft, many aircraft do not have embedded processors that would support the processing capacity needed to execute a real-time missile flyout simulation and resulting P(k) analysis.

Embedded Training Systems

Several efforts are currently underway to enhance electronic warfare (EW) training on Air Force 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 Virtual Electronic Combat Training System (VECTS) developed by the Georgia Tech Research Institute (GTRI) and the Imbedded Electronic Warfare System (IEWS) developed by the Air Force Research laboratory are examples of low-cost embedded training solutions. The VECTS or IEWS training capabilities are an external simulator carried onto the aircraft typically connected to the EW suite via the 1553 aircraft bus. With modifications, they can be an integral part of the aircraft OFP. This on-board system allows training to be accomplished any time the crew is in the air (with or without instructors), providing a low-cost training alternative.

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. For "mission rehearsal" level realism, 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 training simulations must directly interface with the operator controls and displays as well as on-board aircraft systems to provide visually accurate threat display indications, threat interactions coupled to aircraft position, and appropriate threat response to aircraft countermeasures (CM) and maneuvers. Thus the training system must provide accurate threat simulation and must monitor aircraft and aircrew actions.

Several individual EW subsystems such as RWRs, missile warning systems (MWS), and countermeasures dispensing systems (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. Embedded EW training systems can directly stimulate the training modes of these radar and infrared/laser missile warning systems to exercise the actual aircraft controls and displays. The resulting system provides accurate simulation of threats within a commercial portable computer based platform and embedded processors.

Although embedded EW training solutions have been demonstrated to provide an accurate training experience, there are problems that limit widespread use. Standalone computer-based trainers require additional equipment to be carried onto the aircraft unless the training threat simulations are embedded into a component of the aircraft OFP. Designing additional training modes into the OFP requires the expense of flight software changes and an associated flight test program. A carry-on system, even if hosted on a portable laptop computer, may not meet volume and weight constraints of a small fighter aircraft.

Existing EW trainers operate from scripted threat types and locations either planned ahead of the training mission or inserted into the simulation computer in real time by an instructor. Preplanned threat laydowns do not always provide the flexibility needed for the overall training experience, especially for fighter aircraft requiring dynamic, reactive training. There is a need to adjust the training experience when the training locations are not accessible, and it is useful to allow new threats in the simulation to vary the experience or allow the operator additional tries. Allowing an instructor to change the threat laydown in flight is effective, but only for large aircraft that can support a human instructor on-board. Thus for small aircraft, there is a need to get new threat types and locations into the simulation from an off-board data source.

Live-Virtual-Constructive EW Training

A further emerging requirement for embedded EW training is in support of live and virtual constructive (LVC) threat simulations as well as range-based emitters in a multi-element training exercise as depicted in Figure 1. The LVC experience requires coordination of multiple air and ground threat systems with multiple aircraft "players" where some are simulated and some are real. Virtual threat types and

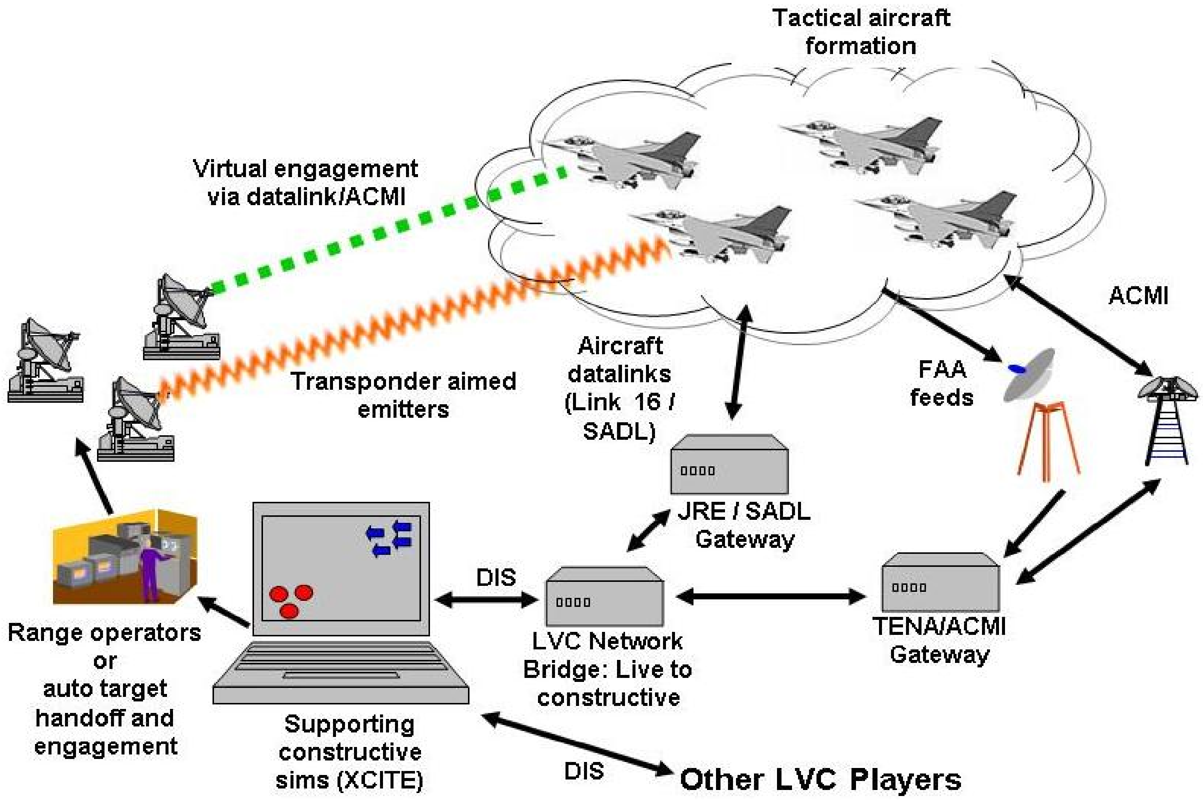

Figure 1: LVC EW Training

locations need to be broadcast to all real aircraft in the exercise, and each of these aircraft need to respond individually to the simulated threat. This implies both an off-board simulation of the virtual threats and an on-board simulation of threat indications and responses based on each real aircraft's capabilities and subsystems. Furthermore, all of the real aircraft need to determine if they survived or were killed by the virtual threat, and must broadcast this information to the other players in the exercise. This type of integrated threat array also allows modeling of realistic Integrated Enemy Air Defenses (IADS) in the training environment

Networked EW Training Environment

To provide relevant EW training the threat environment should not only be a high-fidelity physics based model, but also should model emerging threats as well as existing threat systems. The environment should be able to add or delete threats easily providing a dense, reactive environment when needed. The list below further highlights the requirements identified for the training environment:

1. Threat simulation with physics-based interactions executing in real-time
2. High fidelity radar, ECM, jammer simulations
3. Physics based interactions – radar detection, radio frequency clutter, line of sight, occulting, IR background
4. Real-time missile flyouts and P(k) analysis
5. Increased threat density and variety of threats including mobile threats
6. Support Integrated Air Defense System (IADS) operations
7. Common, cross platform data and mission planning tools at the ground station
8. Database driven for security and rapid mission updates using "validated" data sources
9. Robust and data dense debriefing capabilities
10. Easy to operate with manageable, realistic scenarios

THE NEWTS CONCEPT

NEWTS Architecture

The NEWTS architecture consists of three major components, the NEWTS ground station, the radio data link, and the aircraft training system software. Each of these components leverages existing hardware or software systems, allowing for a low-cost and rapid development effort. The ground station is based on the Air Force Research Lab (AFRL) Experimental Common Immersive Theater Environment (XCITE) simulation. XCITE has a simulated EC training environment which supports generation of ground-based training threats and off-board threat reports. It also supports the Distributed Interface Simulation (DIS) protocol interface for linking additional simulations to create a complex realistic training scenario. The GTRI VECTS software provides the on-aircraft embedded platform to process the simulated training environment and stimulate the aircraft EW and data link displays. VECTS also monitors the real-time pilot initiated tactics during the training mission and transfers the data back to the ground station. The radio data link serves as the transmission medium to connect the ground station to the live aircraft. The data link transfers the simulated training environment from the ground station to the aircraft and transfers live aircraft data to the ground station. The study identified standard tactical message formats that could be used to transfer the simulation data, which could potentially be provided by any existing tactical data link. The components of the NEWTS are depicted in Figure 2 and further defined in the subsections that follow.

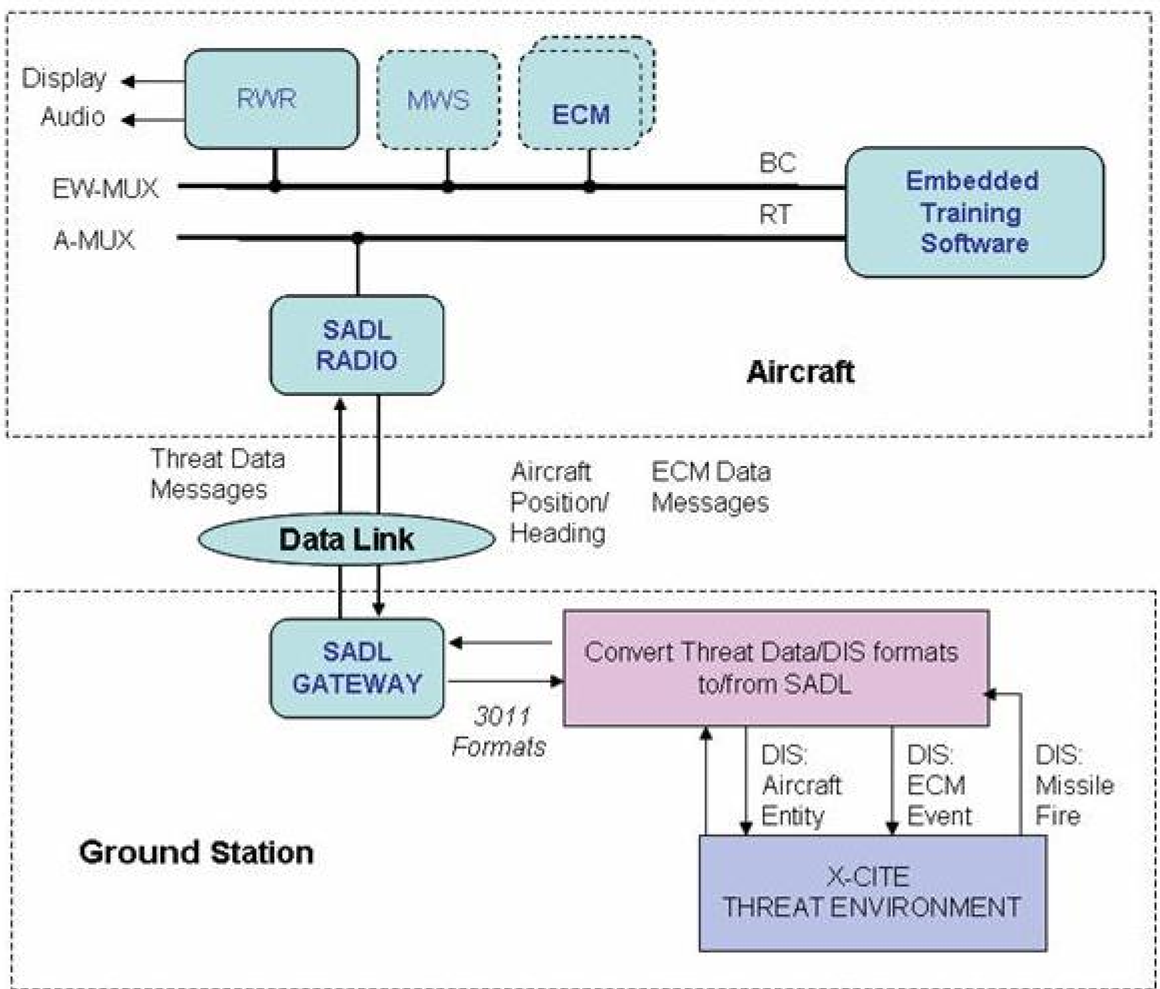

Figure 2: NEWTS Architecture

XCITE Threat Environment

XCITE is a high fidelity threat radar and ECM simulation for aircrew training systems. It is used in a number of existing training systems and provides a standard environment for simulation of threat engagements in high fidelity Distributed Mission Operations (DMO) systems like fighter Mission Training Centers. XCITE provides a set of threat radar and environment models that accurately represent radio frequency (RF) emitter characteristics to an aircraft sensor. As a full threat system environment, XCITE also models infrared (IR) and electro-optically (EO) guided weapons such as Man Portable Air Defense Systems (MANPADS) that can engage the aircraft without radar signals. The XCITE threat models include command and control functions and weapons fly-out models to realistically simulate a threat engagement against a simulated or live aircraft in a training environment. XCITE threat models respond correctly to different types of aircraft ECM systems to simulate aircrew response actions. XCITE also provides a mission environment that models other aircraft, command and control systems, and intelligence information. The XCITE operator station supports flexible training control; including dynamic control of threat positions, addition and removal of threat entities, and provides the ability for the instructor to control the threat operation.

XCITE is built on the Department of Defense High Level Architecture (HLA) with standard DIS communications protocols between simulation entities. Simulations can be added to the overall XCITE environment by utilizing existing DIS interfaces and adding new threat or aircraft functions. When possible, actual aircraft software is used to model the aircraft systems for training to provide realistic interaction with the aircrew.
VECTS Embedded Training Software

VECTS

VECTS is a low-cost, rangeless threat recognition training system which significantly improves training through direct integration with the operator controls, displays, and on-board aircraft systems. It provides visually accurate threat display indications and threat interactions based on aircraft position, appropriate threat response to aircraft ECM, and maneuvers. The VECTS RWR training directly uses the EW subsystem training interfaces when available. The VECTS training algorithms have been hosted on laptops and in the embedded processor of the controller. The VECTS solution leverages the existing pilot interfaces to the EW subsystems to enable and disable the training mode. VECTS also leverages MIL-STD-1553 connections to the EW subsystems to inject simulated training threats and to monitor the subsystem operation for tactics employment. It also monitors the aircraft state data to determine aircraft position and calculate threat occulting.

On-aircraft EW defensive systems are being integrated and centrally controlled by an EW suite controller, which provides the pilot vehicle interface (PVI) to the on-board defensive systems. The controller is an embedded computer system which provides real-time control of operation, mode selection, and management of the individual EW systems. The controller is the bus controller on the MIL-STD-1553B EW multiplex bus and provides a direct link to the EW systems such as the RWR, MWS/LWS, jammer, Decoy, and CMDS. The controller is typically connected to the aircraft mission processor through the MIL-STD-1553B Avionics (A) multiplex or mission bus. The mission processor provides the connection to the aircraft Embedded Global Positioning System/Inertial Navigation System (GPS/INS) and radio data link.

Situational Awareness Data Link

The radio data link used to define the NEWTS is the Situational Awareness Data Link (SADL). SADL is a low-cost tactical radio designed to integrate close air support aircraft with the digital ground battlefield using the Army's Enhanced Position Location Reporting System (EPLRS) radio. Aircraft equipped with these radios can create air-to-air networks as well as communicate with EPLRS ground networks. The SADL radio typically integrates with other aircraft avionics systems over MIL-STD-1553 or Ethernet standard data buses. SADL equipped aircraft can share their position data as well as threat and target locations over the data link. SADL implements a flexible protocol allowing transmission of multiple message formats including EPLRS text, images, and Variable Message Format (VMF). Using SADL Gateway software, the radio can also transmit and receive Link-16 Joint Tactical Digital Information Link (TADIL-J) messages.

NEWTS CAPABILITIES

A NEWTS architecture that provides a full closed-loop EW training function is possible. This architecture can likely be implemented with minimal

OFP changes. In fact, a near-term flight demonstration appears to be possible with only minimal change to existing aircraft software. The heart of the NEWTS architecture is a ground station that contains the XCITE simulation and additional software that manages the message transfers across the data link. The ground station software establishes a simulation entity that represents the current state of the live aircraft and converts the current state of the threat environment into a format that can be processed by the VECTS software on the aircraft.

The XCITE simulation will recognize the live training aircraft entity and will maintain accurate aircraft position using position updates provided over the data link and its own dead reckoning algorithms. XCITE's ability to use standard DIS communications protocols between simulation entities will be used to provide a theater training environment adding other aircraft or threat systems to the training scenario. The DIS messages passed to and from the actual aircraft (threat updates, Link-16 reports, ECM data, and aircraft position) will retain their native format until converted for transfer over the data link.

To stimulate the aircraft EW embedded training using VECTS, the threat entities and states provided in XCITE will be used to provide threat positions and state over the data link. The aircraft VECTS software simulation will be used to create the RWR and MWS indications based on the XCITE generated threat positions and states. Alternatively, a detailed sensor subsystem model in XCITE can be used to stimulate the actual aircraft displays directly.

For full closed loop training, the VECTS software on the aircraft will provide countermeasure dispenses, ECM activity, and aircraft maneuver data back to XCITE over the data link. XCITE will accurately simulate the threat/emitter response to the countermeasure event and return the updated threat entity state to the aircraft.

The XCITE Simulation will be able to accurately simulate threat situational awareness messages to the training aircraft based on its simulation of both C2 and other aircraft entities. These can be sent to the training aircraft using standard TADIL-J or VMF messages. The method for generating these messages will be based on the individual training aircraft type (for example C2 data would include SADL Gateway messages and SADL fighter to fighter net messages).

The NEWTS Ground Station can be hosted on commercial portable computers and extended within the architecture of the training environment to simulate different components of the environment and aircraft subsystems.

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NEWTS DEMONSTRATION PLAN

The authors are currently developing a demonstration system can be used to evaluate the capabilities and performance of XCITE as an RF training threat environment. The XCITE software will execute in a PC located in the NEWTS ground station and will stimulate the RWR display on the aircraft. A SADL radio will be used to transmit the training threats from XCITE to the aircraft and to transmit the aircraft position data to XCITE. The demonstration will use the existing SADL message set and will leverage the VECTS embedded training software.

The primary areas of concern for implementation of the NEWTS architecture are the potential scope of software changes required and the ability of the SADL data link to support the message rates and latencies required for closed loop simulation. The use of the VECTS software baseline as the primary software interface to the NEWTS ground station is expected to mitigate the software risk, as VECTS currently interfaces to all of the data sources identified for the NEWTS extended architecture. The software changes required to implement the SADL training message within the selected aircraft MULTIPLEX bus interface will need to be identified and estimated.

The demonstration system will be used to determine the effectiveness of transmitting training data to and from an aircraft in real-time over a data link network. It will provide a system in which the latencies associated with the radio transmissions can be studied to allow further refinement of the ultimate closed-loop simulation system architecture. It will also provide a capability that can rapidly transition to a flight test program.

The demonstration system will provide a test-bed for defining the set of training messages needed for the full closed-loop simulation over a data link. This can serve as a basis for working with standards bodies to incorporate a EW training message set into existing tactical message standards and aircraft interface

SUMMARY AND CONCLUSIONS

A concept for a Networked EW Training System was presented. Based on the concept development, the approach appears feasible. In fact, a near-term flight demonstration appears to be possible with only minimal change to existing aircraft software. Demonstrations are planned to investigate the performance of the concept in a representative aircraft environment.

The NEWTS architecture was designed to make extensive use of exiting Government funded system software to provide a low-cost but effective training capability. The XCITE high fidelity networked EW training environment for distributed mission operations will be utilized in a closed-loop training environment. The VECTS software will be leveraged to provide the interface to the on-board EW systems for threat stimulation and monitoring aircrew tactical responses. The SADL gateway software will be leveraged to provide transmission of the training messages over the data link.

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