

Integrating Distributed Virtual Command and Control Platforms into Live Training

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ABSTRACT

As the United States Air Force's budget continues to shrink, so does the budget for live fly training. This drives aircrews to increase their usage of virtual trainers. These reduced budget constraints will directly impact live training ranges such as the Pacific Air Force's (PACAF) Joint Pacific Alaska Range Complex (JPARC) ability to fund live aircraft participation in joint exercises such as Red Flag-Alaska and Northern Edge. One approach to reduce live exercise costs is to provide critical Command and Control (C2) platforms such as E-3, E-8, and RC-135V/W as virtual assets.

The JPARC has taken this approach and has integrated the Combat Air Force Distributed Mission Operations (CAF DMO) E-3 and E-8C mission training centers to support live training exercises. The integration of these virtual C2 platforms required the merging of two disparate training architectures, the CAF DMO Virtual-Constructive solution and the JPARC's live range solution. A primary difference among these architectures is the standards each are based on. CAF DMO implements the Distributed Interactive Simulation (DIS) standard while the JPARC implements the Test and Training Enabling Architecture (TENA). The merging of TENA and DIS architectures has resulted in significant challenges. (1) How to accurately model live airspace in the DIS domain with multiple live aircraft data sources, (2) live-to-virtual and virtual-to-live radio communications, (3) tactical data links, and (4) inconsistencies of live data. These challenges proved vital to accurately representing the live battlespace for C2 assets.

To overcome the difficulties of merging two disparate architectures with individually unique standards, the JPARC utilized a progressive solution that enabled bi-directional information to be accurately exchanged, formatted, and processed between TENA and DIS architectures. Our paper will discuss this solution and lessons learned during the integration of virtual C2 platforms into live fly exercises.

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Background

As stated in the recent CY14 Air Combat Command (ACC) LVC Innovation Summit, “Future training demands reliance on integrated LVC”. The Live, Virtual, Constructive (LVC) concept has been in development for many years yet few concrete implementations have been developed and the vision has had trouble crystallizing. There are many factors contributing to this dilemma. Cost and integration interoperability challenges have been primary challenges that have thus far prevented LVC from playing a bigger role in training.

Standards based training architectures have been a positive step towards addressing both the cost and integration challenge associated with on-demand LVC operational training. Combat Air Force Distributed Mission Operations (CAF DMO) and Mobility Air Forces Distributed Mission Operations are current examples of standards based VC training architectures utilized by the Air Force. Live range training architectures implement a myriad of protocols from native data formats, to the Test and Training Enabling Architecture (TENA), and even M&S protocols to include Distributed Interactive Simulation (DIS).

In 2005, ACC tasked Northrop Grumman to implement and demonstrate a DMO LVC training capability by integrating our existing standards based CAF DMO training capabilities with select training ranges. The primary focus of this effort was the architecture reuse to achieve interoperable solutions for LVC radio communications, tactical data links, entity state, and weapons engagement. This effort culminated in capability demonstrations at both Elmendorf and Eielson AFB, with an operational demonstration at Tyndall AFB. These demonstrations validated the potential and cost effectiveness of standards based architectures in achieving LVC training objectives. This work has evolved into fully integrated, on-demand training solution which leverages both the CAF DMO and Joint Pacific Alaska Range Complex (JPARC) training architectures. This paper discusses the Command and Control (C2) aspects of this LVC training capability.

Joint Pacific Alaska Range Complex

The JPARC encompasses airspace in excess of 66,000 square miles and includes over 1.4 million acres of land. The JPARC architecture facilitates multi-platform, multi-service combat operations exercises which correspond to participating unit’s operational capabilities and tailored to their training objectives. Red Flag-Alaska is the premier PACAF sponsored exercise which supports 60-90 aircraft and up to 2000 personnel in live training on the JPARC split between Eielson AFB and Joint Base Elmendorf Richardson (JBER). The exercise provides a realistic integrated air defense system by including Early Warning (EW)/Ground Control Intercept (GCI) with C2 links, Anti-Aircraft Artillery (AAA), Surface to Air Missiles (SAMs), and aggressor-trained air-to-air threats.

Another live training exercise includes Pacific Command’s (PACOM) sponsored Northern Edge, which is hosted by JPARC and is a joint training exercise designed to practice operations, techniques, and procedures; with a main focus on enhancing inter-service interoperability. Over 9,000 participants from all services, including active duty reserve and National Guard units are involved. Participants focus on sharpening their skills by practicing operations, techniques, and procedures. This joint training event provides real world proficiency in detection and tracking of units at sea, in air, and land.

The JPARC architecture consists of two enclaves: classified and unclassified. It also includes a Secret and Below Interoperability (SABI) Certified and Accredited (C&A) PL4 Cross Domain Solution (CDS) and connects the two enclaves seamlessly and in near-real time. Use of cross domain solutions in this training architecture maximizes training benefits for the training audience by achieving an integrated battlespace between training systems at multiple classification levels.

Combat Air Force Distributed Mission Operations

CAF DMO has revolutionized training for the United States Air Force (USAF) by providing training to USAF warfighters in a variety of team combat skills. This training is accomplished through use of Mission Training Centers (MTCs) and high-fidelity, man-in-the-loop, virtual trainers. These training centers utilize training aides such as Computer Generated Forces (CGFs) and threat instructor stations to achieve the required training environment.

The geographically separated CAF DMO MTCs provide both inter-team and intra-team composite force training for warfighters. This enables the warfighter the capability to train as a team and improve individual skill proficiencies. The objective is to train them on mission essential competencies necessary for combat readiness.

RED FLAG-Alaska

RED FLAG-Alaska (RF-A) is a Pacific Air Forces-sponsored, Joint National Training Capability accredited exercise. Initiated in 1976 as COPE THUNDER, RF-A provides aircrews their first taste of warfare and increases their chances of survival in combat environments. RF-A executes a premier tactical joint air combat exercise designed to replicate the stress a warfighter might face during their first ten combat missions.

RF-A participants are organized into aggressor “red”, coalition “blue”, and neutral “white” forces. The red forces utilize defensive counter-air tactics directed by ground-control intercept sites. Range threat emitters simulate SAM and Anti-Aircraft Artillery (AAA) providing valuable surface-to-air training. The blue force includes a variety of U.S. and coalition units. The force includes air-to-air fighters, surface air defense forces, simulating threats from hostile nations.

Integration of Virtual E-3 – Airborne Warning and Control System

PACAF and the JPARC chose virtual Command and Control (C2) platforms and specifically the AWACS MTC at Joint Base Elmendorf Richardson (JBER) as the first virtual CAF DMO platform to integrate on the range. This was due to its proximity to the range and the ability to directly connect the range, over an existing network connection, to the simulator if necessary. Feedback from pilots and operators in early ACC LVC efforts indicated that this C2 platform would be of a great benefit if it could be provided by a virtual aircraft. This would ensure that an AWACS could always support and would not be plagued with weather or mechanical failures as the live JBER AWACS can suffer from.

The AWACS MTC at JBER should be able to perform the same function as if a live AWACS from JBER was flying the mission. This means that the AWACS’ simulated radar should be able to see a very similar air picture, if not the same, as the real AWACS radar and AWACS controllers. Moreover, the AWACS simulator should have the ability to control live aircraft in the same manner. The live aircraft information that the JPARC receives must be provided to the simulator in a format that the AWACS MTC can process. This topic has been the main focus of the current integration work and the focus of this paper. To date, there have been over twenty test missions between virtual C2 and live aircraft spanning over forty hours of flight time. The live aircraft that has been used for testing has been the E-3 from JBER. This aircraft has participated in all of our integration events due to its availability and ability to loiter in the JPARC airspace for long periods of time. During this time, we have tested the fidelity of live aircraft positions on the virtual AWACS radar, tactical data links, Identification, Friend or Foe (IFF), and radio communications. This paper will focus on the integration challenges and lessons learned during these integration efforts.

Air Combat Maneuvering Instrumentation Pods

The JPARC, like many other tactical training ranges, utilizes Air Combat Maneuvering Instrumentation (ACMI) pods as a means to provide Time Space Position Information (TSPI) data for live aircraft. These instrumented pods provide location, velocity, acceleration, callsign, and aircraft type, data that is critical for both live and virtual participants. Currently the JPARC utilizes the P4 and P5 ACMI pods to provide this information for daily training on the range.

Live systems on the range, such as Individual Combat Aircrew Display System (ICADS), 9C2, and Adaptable Range Exercise System (ARES), utilize the ACMI data to provide playback for debrief, data fusion, and Common Operating Picture (COP) capabilities on the range. These capabilities and systems are critical in order to conduct positive live training at the JPARC and other open-air training ranges.

The JPARC converts the TSPI data from ACMI pods into TENA Platform and PlatformDetails Stateful Distributed Objects (SDO). The JPARC currently utilizes TENA version 6.0.1. These SDOs are utilized by both live range systems as well as virtual participants, by way of the DMO LVC Portal, to provide aircraft position information. These two SDO's jointly provide data such as aircraft TSPI, velocity, acceleration, aircraft type, affiliation, and callsign that the DMO LVC Portal subscribes to and converts into DIS entity State Protocol Data Units (PDU). These converted DIS PDUs will represent the live aircraft inside of the DMO virtual battlespace.

ACMI Live-to-Virtual Integration

The integration of live aircraft into the DMO virtual battlespace required the integration of the ACMI data on the JPARC with the virtual AWACS. This integration required the TENA SDOs to be translated into DIS entity state PDUs. Marsden [1] *et. al.* describe the challenges with the original integration of the P4 pods with regard to inaccurate velocity and acceleration information. This challenge is still persistent today even with the current P5 implementation. As such, the DMO LVC Portal still is required to smooth the trajectory of the aircraft.

The smoothing of the instrumented aircraft trajectory is still not the ideal solution and has not yet been addressed. This is still considered future work and has not caused significant issues during integration events between virtual C2 platforms and live aircraft to date. One issue that has consistently caused challenges is the loss of data from the ACMI instrumented aircraft. This is often caused by Line Of Sight (LOS) issues between the pod and ground tracking station on the range. This loss of data causes the virtual simulations to lose updates for up to several seconds at a time. This has been observed in numerous test events and is dependent upon the area of the range the aircraft is flying. The impact of such a loss is that the virtual simulations continue to dead reckon the position in a smooth trajectory. Once the updates are received again, it causes the aircraft to snap to the correct position. This issue can sometimes cause a rubber band effect where this snapping happens quite frequently. Fortunately, the range has very good radar coverage and the radar tracks of these aircraft can help minimize this effect, but cannot remove it entirely due to the relatively slow refresh rate of the radars. The solution to this problem would be through the combined use of fused tracks and ACMI sources.

Another issue observed during the integration was that certain fields such as callsign or entity type information were often incorrectly entered for a particular pod or can be changed dynamically. This causes confusion when a virtual C2 attempts to identify or address a particular aircraft and causes an inconsistency between the virtual battlespace and what is really flying on the range. This issue has typically been overcome by an operator on the ground making the correction, though it is made during the event and after battlespace inconsistencies have already been identified. This issue has been a nuisance during our testing, but will have a negative impact to training during real live exercises such as RF-A.

The last issue is the inability to add virtual C2 into the playback of the ICADS system. Currently ICADS, at JPARC, can only playback live aircraft as part of the post mission debrief. This current limitation has been less of an impact for the virtual C2, but will have to be addressed as future work as virtual fast flyers, such as the CAF DMO F-16CM, are being integrated on the JPARC. To date this has not impacted any testing on the range, but this will be addressed in the future and is considered future work. Figure 1 provides the flow of TSPI data between Live and Virtual training participants.

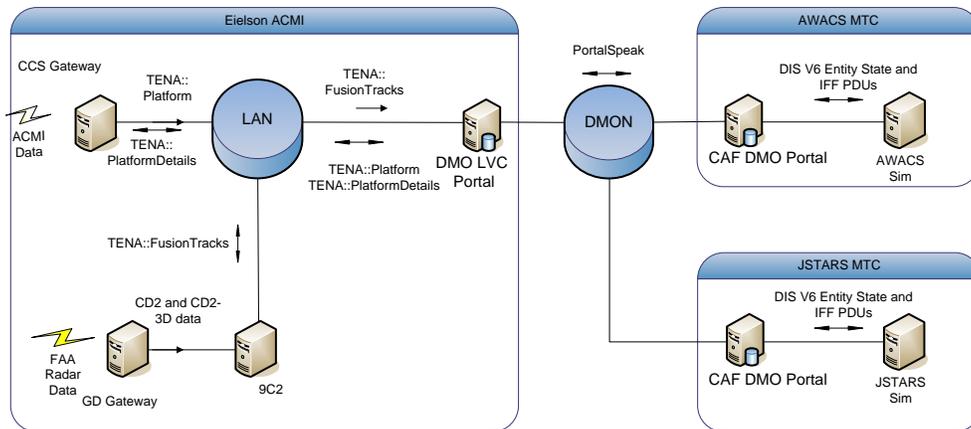


Figure 1. Live-to-Virtual TSPI Data Flow

Radar Tracks

The integration of live aircraft into the DMO virtual battlespace also required the integration of JPARC radar information. This information is important because not all aircraft on the range carry an instrumented training pod. This is certainly true for all non-military and certain military aircraft flying in the airspace. This information is necessary for the virtual AWACS. Radar information is provided to the JPARC by the FAA and range military radars. This information is fed to the necessary gateway and ultimately to the range's aircraft position correlation software, 9C2.

Marsden *et. al.* described the early challenges with two sources of track data; 1) ACMI pods, 2) radar tracks from the 9C2. During that initial integration, the 9C2 system was unable to effectively correlate the radar and ACMI source data into a single coherent fused track source. This led to duplicate aircraft in the virtual DIS battlespace, one from the ACMI pod and another from the radar. This issue was less of an impact to live range systems which could just filter out the TENA data received from the 9C2 system if necessary. This correlation issue was resolved with a software update to the 9C2 and has been correctly correlating ACMI and radar sources of data into a single fused track object. This fused track object is published by way of TENA FusionTrack SDOs and was introduced in TENA version 6.0 and contains information regarding the source or sources of data that the track originates from, as well as most data found in TENA Platform SDOs. It can contain source information from radars, ACMI pods, or Link16 air tracks. The JPARC currently utilizes this version of the 9C2 software and utilizes the FusionTrack SDO as a primary means of aircraft location.

Though the duplicate aircraft issue due to the 9C2 correlator was fixed, integration challenges were still encountered. One such challenge was due to ACMI pod data dropping in and out due to LOS issues. When this occurs, the FusionTrack object can only rely on radar or Link16 location data, and as such, removes the ACMI pod as a source. When this occurs the DMO LVC Portal has to determine that the ACMI track source is no longer being received. In turn, the radar or Link16 data now becomes the location source. This is necessary due to the DMO LVC Portal having a preference for ACMI track sources due to its 100ms update rate. FusionTracks provide a much slower refresh rate from the 9C2 system and live systems lack proper utilization of dead reckoning. This requires the DMO LVC Portal to keep track of all of the FusionTracks that also have ACMI pods and determine when to best utilize the radar or Link16 as the appropriate data source. Once this event is detected the DMO LVC Portal will utilize the FusionTrack objects as the track source until the ACMI data becomes available. For those aircraft that lack an ACMI instrumented pod, the FusionTrack object is always used. This is also true for commercial aircraft as well.

Another challenge encountered was incorrect or unavailable IFF data from the FusionTrack objects. During training events, all aircraft participants are assigned IFF codes that are programmed on the ground. These codes are then utilized to associate a particular IFF code to an individual aircraft type and callsign. If these codes are not keyed in correctly, the fusion system cannot associate the erroneously keyed IFF to the correct aircraft and as such appears to be an unknown aircraft. This often does not get noticed until the exercise or test has already begun and a ground operator calls out over the radio to determine the error. This error is corrected via the fusion system software. We

observed this occurrence for aircraft that could not be instrumented with ACMI pods. Moreover, aircraft could not be identified until an operator manually keyed in the correct IFF information. This resulted in additional unknown aircrafts flying around the JPARC airspace and also in the DMO virtual battlespace. Once this error was corrected, the aircraft was able to be correctly correlated and then passed to the DMO virtual battlespace. This issue is more problematic when the IFF code is incorrectly keyed in an aircraft that also has an ACMI pod. This keeps the 9C2 system from correctly correlating the ACMI pod and radar source and causes duplicate entities in the live and DMO virtual battlespace. This issue was encountered on multiple integration events and had to be addressed each time. This issue was corrected by calling the 9C2 operators to address the issue and correct the IFF code. Once this code was corrected, the 9C2 system was able to correctly correlate the track. During our integration events, this issue was the biggest cause of virtual and live battlespace inconsistencies and will need to be addressed in the near term.

Tactical Data Links – Link16

Tactical Data Link is a communication system of combining the battlefield command center, combat forces and weapons platforms, which processes, exchanges and distributes information with wireless network communication and application protocols. It can exchange tactical data among the airborne, land and naval vessels, thereby maximize the fighting effectiveness [2]. The exchange of tactical data links between live and virtual players transcends several interfaces before reaching its final destination. Moreover, messages undergo a translation process prior to reaching their final destination.

Live aircraft at the JPARC primarily utilize the Joint Tactical Information Distribution System (JTIDS) as their data link message type. When a JTIDS message is forwarded from a live aircraft to a virtual E-3 AWACS platform, its first destination is the Joint-Range Extension (JRE). The JRE is a tactical data link terminal composed of hardware and software components that receives information in the form of a tactical data link. Once the information is received, it's immediately forwarded to the Gateway Manager beyond the line of sight. The Gateway Manager provides the end user with a full scope of situational awareness. It provides connectivity status between itself and remote computers, message filtering, tracking, and trafficking of virtually all tactical communications in real-time. As the JTIDS messages exits the Gateway Manager, its next destination is the DMO LVC Portal. The DMO LVC Portal serves as a translator for foreign protocols (e.g., DIS, HLA). The JTIDS message now makes its way to the Distributed Mission Operations Network (DMON). The DMON connects more than 50 global sites to provide daily collaborative team training for air combat missions. Prior to the JTIDS message reaching its final destination, it must cross the CAF DMO Portal. Similar to the DMO LVC Portal, the CAF Portal is a DIS translator for foreign protocols. In this case, the information being received by the CAF Portal is TENA based. In turn, the CAF Portal translates the TENA protocol to DIS and sends it off to the virtual E-3 AWACS participant for deliverance. Figure 2 provides the Live-to-Virtual Link 16 Data Flow on the JPARC.

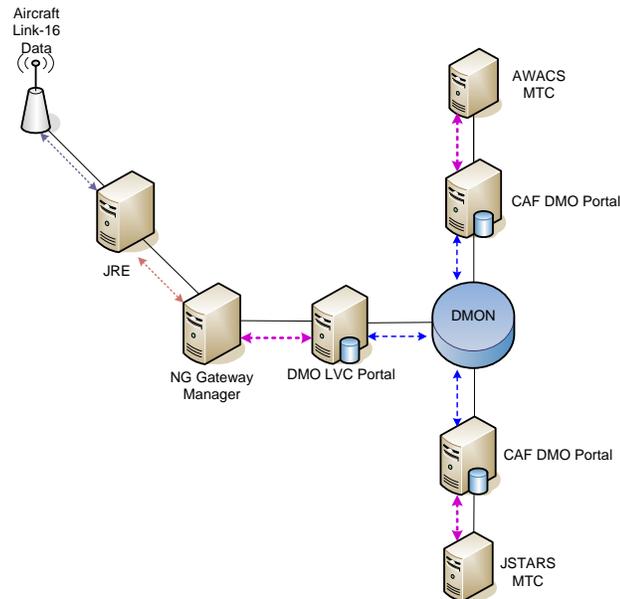


Figure 2. Live-to-Virtual Link16 Data Flow

Several issues were encountered when trying to establish Link 16 connectivity between live and virtual aircraft. (1) Encryption lockout. JRE personnel could not access Link 16 encryption. Encryption codes for the JRE expire on a regular interval. Prior to testing, JRE personnel did not receive a new set of encryption keys to replace the expiring set. (2) JRE hardware and software issues. The JPARC encompasses over 66,000 square miles of potential training space. Many of the assets used to forward data from one terminal to another are located in remote locations. Some locations can only be reached via a helicopter. During times of severe weather, temperatures can reach in excess of 40 degrees below zero. Considering the time to reach these remote locations, and factoring in freezing temperatures; it may take days before anyone can get onsite to assess the equipment. More often than not, the JRE simply needs to be restarted to fix an issue. The software issues we faced revolved around a software mismatch at a remote site that required a hard drive swap. (3) Non connectivity between live aircraft and the JRE. During testing, virtual and constructive participants were successful in sending Tactical Digital Information Link (TADIL) J messages to the JRE. Virtual and constructive participants were also able to send TADIL-J messages to one another. However, the JRE could not establish a connection to the live aircraft. This issue caused the TADIL-J messages originating from the virtual AWACS to not be received by the live JBER AWACS.

Radio Communications

The JPARC utilizes a TENA Live Simulation Communication Interface (LSCI) to bridge live to virtual radio communication between training participants and platforms. The LSCI uses Session Initiation Protocol (SIP) to set up digital audio paths with the Denro communication system. The LSCI converts the digital audio to TENA voice objects which interface directly to the SimShield. The SimShield is a fixed format data guard that protects information between systems operating at different security levels and or classifications. The JPARC previously used the Virtual Tactical Bridge (VTB) as a LVC radio bridge. The VTB used analog audio which was converted to DIS simulation protocol. The VTB required a separate network guard between the high and low networks. Figure 3 provides a conceptual view of how bi-directional communication is established between virtual and live platforms.

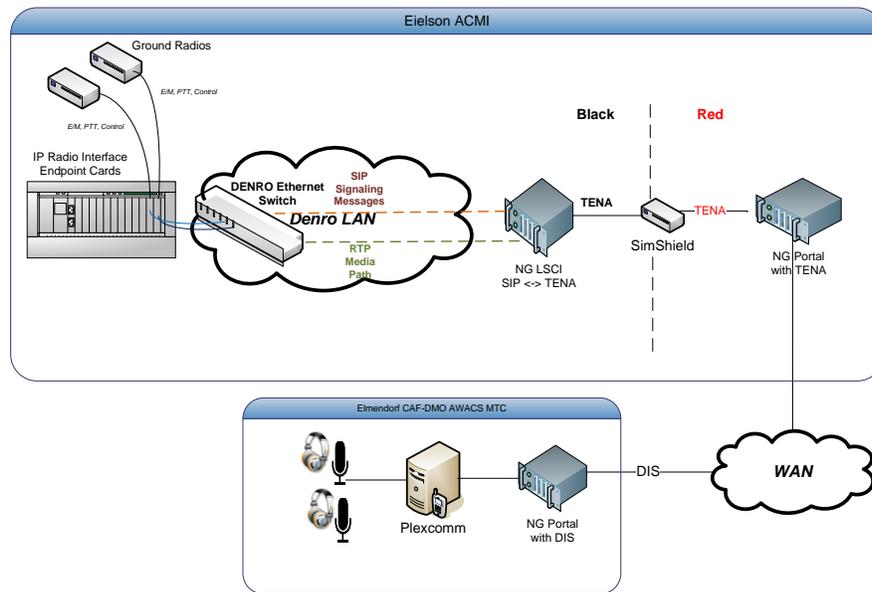


Figure 3. Radio Bridge Concept

Several issues were encountered when trying to establish radio communications between live and virtual platforms. (1) Live Radios. Denro interface cards were not up to date with the latest firmware. It was discovered during testing, that some ground based radios worked with the LSCI while others didn't. Updating the firmware required power cycling each radio at its remote site. (2) Denro Real-Time Transport Protocol (RTP) silence insertion caused audio distortion from the live to virtual radios. During testing, the virtual platform produced clear radio communications to the live aircraft. However, the virtual platform reported that live communications were choppy. This was caused by the Transmitter transmit state toggling between transmitting and not transmitting. The Denro radio interface card places silence insertion in the RTP stream whenever there was a pause in speaking. This was unacceptable because multiple transmitter PDUs are sent, causing audio cutout and distortion. A modification to the LSCI code was made to address the issue. (3) Frequency Deviation. During testing it was discovered that certain frequencies would not allow for radio communications between live and virtual assets. It was discovered that the LSCI did not allow enough frequency deviation for frequencies of six significant digits. Frequencies of five or less significant digits worked as expected. An update to the LSCI code was made to allow radio frequencies to support up to six significant digits.

Integration of E-8C - Joint Surveillance and Target Attack Radar System

Once the E-3C integration reached maturity, PACAF and JPARC chose to integrate an additional virtual C2 platform, the E-8C Joint Surveillance Target Attack Radar System (JSTARS) MTC. This high demand low density platform is often difficult for live exercises to obtain and was a perfect next step for LVC integration on the JPARC. This asset could provide key ground situational awareness for both live instrumented ground vehicles as well as injected virtual and constructive ground entities. Since the JPARC rarely gets this platform the objective was to enable the JSTARS to provide additional C2 fidelity to RF-A exercises by providing situational awareness of what is on the ground by way of Link16. The virtual JSTARS should be able to detect, through live instrumented ground vehicles and necessary gateways, the movement of friendly and hostile vehicle and troop movements and also inject additional virtual/constructive entities to enrich the battlespace with additional vehicles and ground troops as necessary. The JSTARS MTC would utilize the same approaches to integration as the AWACS. The lessons learned with tactical data links and radio communications interoperability would directly apply to the JSTARS MTC integration and thus reduced the risk and effort for integration. This is possible due to the CAF DMO and its standards based approach to distributed training. This means that both the AWACS and JSTARS MTCs follow the same set of interoperability standards, ensuring DIS data consistency over the DMON Wide Area Network (WAN) and thus reduces the risk of integration of additional CAF DMO platforms at the JPARC.

The integration of the JSTARS took place at the JPARC and utilized the Melbourne JSTARS site via the JPARC's DMON connection. The testing utilized over 10 individual test events between the JPARC live systems, live AWACS, and Melbourne JSTARS. These test events verified tactical data link, radio communications, and live battlespace consistency interoperability between the JPARC's live environment and CAF DMO virtual JSTARS. The integration effort demonstrated efficiencies of a standards based approach to integration as well as additional challenges not observed during the integration of the virtual AWACS. These challenges were not the result of TENA and DIS interoperability challenges, but was related to JPARC system malfunctioning. The systems that affected this integration were the ATREP and JRE systems.

Ground Entities

The integration of the virtual JSTARS on the JPARC required the integration of live instrumented ground vehicles and dismounted soldiers. These vehicles and dismounted soldiers would be fitted with Initial – Homestation Instrumentation Training System (I-HITS) and is responsible for providing the TSPI and type of entity on the JPARC to the DMO simulated battlespace. The I-HITS system, on the JPARC, does not natively support providing this information in the DIS format. The JPARC utilizes the TENA architecture, and as such, requires all systems to publish this data in TENA. On the JPARC, the system responsible for publishing the instrumented ground data in TENA is the Alaska Training Range Evolution Plan (ATREP).

The integration with the ATREP system provided a new set of challenges. The ATREP system had previously been installed and tested while the JPARC supported TENA version 5.2.2. When the JSTARS integration took place, the JPARC had migrated to TENA version 6.0.1. When the ATREP system was started, it could not successfully join the TENA version 6.0.1 execution. This challenge did not allow us to directly receive instrumented ground data from the JPARC ATREP system. This prevented us from passing live instrumented ground vehicle data to the DMO simulated battlespace. This issue has plagued our efforts to date and is still an issue being resolved on the range.

Because we could not get live ATREP data from the range, we integrated with recordings from the ATREP system provided by the ATREP Army program office. This recording allowed us to utilize TENA playback tools to publish ATREP formatted TENA Platform and PlatformDetails SDO's into the JSTARS DMO simulated battlespace. The fact that the ATREP system, live instrumented vehicles on the JPARC, and CAF DMO MTC integration at JPARC has not been completed has not stopped PACAF from considering the integration ready for RF-A exercises. The benefit for injecting constructive entities and Link16 has led PACAF to consider the ATREP integration future work and will be continued once the ATREP system issues have been resolved.

Though live JPARC instrumented ground vehicles cannot yet be detected by a virtual JSTARS, other uses of the JSTARS have proven useful for JPARC exercises. The JSTARS can easily augment the live battlespace by injecting constructive ground enemy ground vehicles and troops. This allows the JSTARS to publish Link16 ground tracks for constructive entities on the JPARC's Link16 network. This allows the strikers and bombers to see a much more target rich environment giving the mission additional fidelity and realism.

Standards Based Approach to DMO LVC Integration

Lessons learned during the integration of disparate CAF DMO simulators and their need for a set of standards directly applied to the integration of simulators with live ranges. The need to standardize how live systems interact with a DMO virtual battlespace was identified early in the integration of the AWACS MTC. The challenges observed with the early TENA protocol translation to DIS and numerous battlespace inconsistencies demonstrated the need to define how the TENA protocol would be translated to and from DIS or HLA. Issues such as what data should be available, as well as how it should be represented, such as aircraft representations, radar emissions, munitions, expendables, network connectivity, security and Information Assurance, had to be developed and documented to ensure repeatable interoperability. This was not only important for AWACS integration, but for each simulator that would be integrated with the JPARC.

The approach to the integration of live range systems with CAF DMO virtual simulators was performed incrementally. Each increment would require the integration of key operational capabilities necessary to represent live entities in a DMO virtual battlespace. These operational capabilities consisted of aircraft TSPI and appearance,

IFF, tactical data links, radio communications, radar emissions, weapon engagements, electronic warfare, and expendables. The approach was to integrate each capability and develop standards to capture lessons learned and guidelines for future integration efforts. This would allow each subsequent CAF DMO MTC integration effort to utilize the capability previously integrated and thus the standards as well. If changes are identified that affect a standard then the affected standard can be updated with lessons learned.

The AWACS integration would allow us to integrate aircraft representation, IFF, tactical data links, and radio communications operational capabilities. The integration of these initial operational capabilities would enable the first implementation of a TENA and DIS interoperability, network, security, and event control standards. These standards would build upon the lessons learned and define how TENA and DIS shall be translated back and forth, LVC event execution, and network and information assurance requirements to connect to the DMON. These four topics were the first set of standards developed and are utilized today not only at the JPARC, but at the Polygone range in Germany.

JSTARS integration was the next platform to be integrated and demonstrated that the standards based approach to integration can greatly reduce the risk and complications of LVC integration. JSTARS integration was able to build on the tactical data links and radio communications work done during virtual AWACS integration. This meant there was no additional work required to integrate these two capabilities. This was due to both CAF DMO platforms following the same set of DMO standards that ensures the compatibility. The idea for CAF DMO and also our approach to integrating with CAF simulators is that if you can integrate one of the operational capabilities for one CAF DMO platform, then there is a good probability that it will work without significant integration effort. If each CAF DMO platform is standards compliant in radio communications and tactical data links, then once one platform has been integrated, such as AWACS, all others should work very similarly. This was confirmed with the integration of JSTARS and RC-135V/W.

Integration of RC-135V/W

The integration of the RC-135V/W is in progress and is considered future work. Though the integration of the virtual RC-135V/W is incomplete, it has also benefited from our standards based approach to LVC integration. The integration has been able to build upon the standards and operational capabilities integrated during AWACS, JSTARS, and F-16CM integration. Radio communications and tactical data links integration have been identical to integration efforts for AWACS and JSTARS allowing the focus of integration to center on radar emissions interoperability.

The ability for the virtual RC-135V/W to receive radar emissions data from live JPARC threats has been tested and the interoperability has been evaluated. These tests utilized JPARC's DMON connection to allow the Offutt RC-135V/W simulator to receive and process JPARC radar emissions data from numerous JPARC threats. This required the live TENA based emissions data, TENA RadarSystem SDOs, to be translated into DIS electromagnetic emissions PDUs. These DIS electromagnetic emissions PDUs would have to be CAF DMO compliant in order to be correctly processed by the RC-135V/W simulator. The results of the testing have been very promising with very few issues identified to date and believe that this platform may be ready to support Red Flag exercises in the near term.

Conclusions

A standards based LVC integration solution with operational capabilities for PACAF was demonstrated between the JPARC and CAF DMO AWACS, JSTARS, and RC-135V/W MTCs. This paper demonstrates significant progress in a standards-based DMO LVC integration at the JPARC and how this approach reduces the time and risk for integrating additional CAF DMO MTCs on the JPARC. Lessons learned and challenges encountered while integrating operational capabilities, enabling live JPARC systems and CAF DMO C2 MTC interoperability, such as Aircraft TSPI and battlespace representation, tactical data links, radio communications, IFF, and radar emissions were presented. Finally the current status and future integration work between the JPARC and CAF DMO RC-135V/W MTC has been discussed and provided additional evidence of the benefits of standards based DMO LVC integration.

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