Advancements of Integrated LVC Applied to Tactical Aviation Aircraft Training

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ABSTRACT

Integrated Live, Virtual, Constructive (ILVC) training for tactical aircraft has the ability to greatly enhance range training and increase warfighter readiness while overcoming live range limitations. However, it remains an elusive capability, yet to be implemented on current tactical fighter and command and control aircraft. The issue remains as to how to implement this capability given the multiplicity of technologies to implement ILVC. This paper discusses several approaches to implementing ILVC on-board these platforms.

In 2007, The Boeing Company began an independent Research and Development project entitled 'Project Alpine.' This project, aimed at reducing the risk of providing airborne aircraft with a realistic view of a Live, Virtual, Constructive environment injected into platform sensors, has completed three spiral development phases to date. Project Alpine Spiral 1, based on an air-air combat scenario, was discussed in the 2008 I/ITSEC Best Paper nominee "Integrated Live Virtual Constructive Technologies Applied to Tactical Aviation Training." Our intent was to leverage the largely successful virtual, constructive environments and networks utilized by the Distributed Mission Operations (DMO) training solutions to provide a realistic training context for live training.

This paper presents the follow-on work completed in Spirals 2 & 3 of Project Alpine. We will compare and contrast the different architectures utilized in each spiral and discuss the advancements achieved in Spiral 3. We discuss such topics as architecture implementation, avionics processing, operational flight program and mux bus implications, simulation network data links, information assurance aspects, and lessons learned.

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INTRODUCTION

In 2007, The Boeing Company initiated an Independent Research and Development project to advance the state-of-the-art in Integrated Live, Virtual, Constructive Technologies for Tactical Aircraft Training, entitled Project Alpine. The intent of the project is to build upon the Distributed Mission Operations construct and expand it into the live training domain.

The overall objective of the project is to perform risk reduction on the integration of live platforms with virtual and constructive environments for adoption by the Department of Defense (DoD) and show a dramatic increase in training value. Through the development of network technologies and the integration/maximum reuse of existing assets, the goal was to demonstrate proof-of-concept training capabilities here-to-fore unavailable on platform.

Since the 2007 inception of Project Alpine, Boeing has performed three spiral development efforts, each culminating in a live fly experiment. For all three spirals, an F-15E test platform was utilized. For each spiral, we increase the on-board capability of the F-15E aircraft to interact within a virtual/constructive training domain.

This paper will compare and contrast the Project Alpine Spiral 1 & 2 solution set and outcomes with the designs utilized in Project Alpine Spiral 3. At the conclusion of this paper the reader will have an appreciation for various nuances of integrating the virtual, constructive domain on board live platforms.

ARCHITECTURE

Spiral 1 – The Beginning

The primary engineering development effort performed during Spiral 1 was to develop an architectural framework that would allow us to fuse the virtual/constructive environment with the live environment and present this information on sensor displays on-board the F-15E aircraft. The objective of Spiral 1 was to perform an air-to-air scenario with a fused live, virtual, constructive environment. To accomplish this, we needed to give the aircrew the ability to detect, track, target, and launch against red threat aircraft. The engineering challenges and solutions of spiral 1

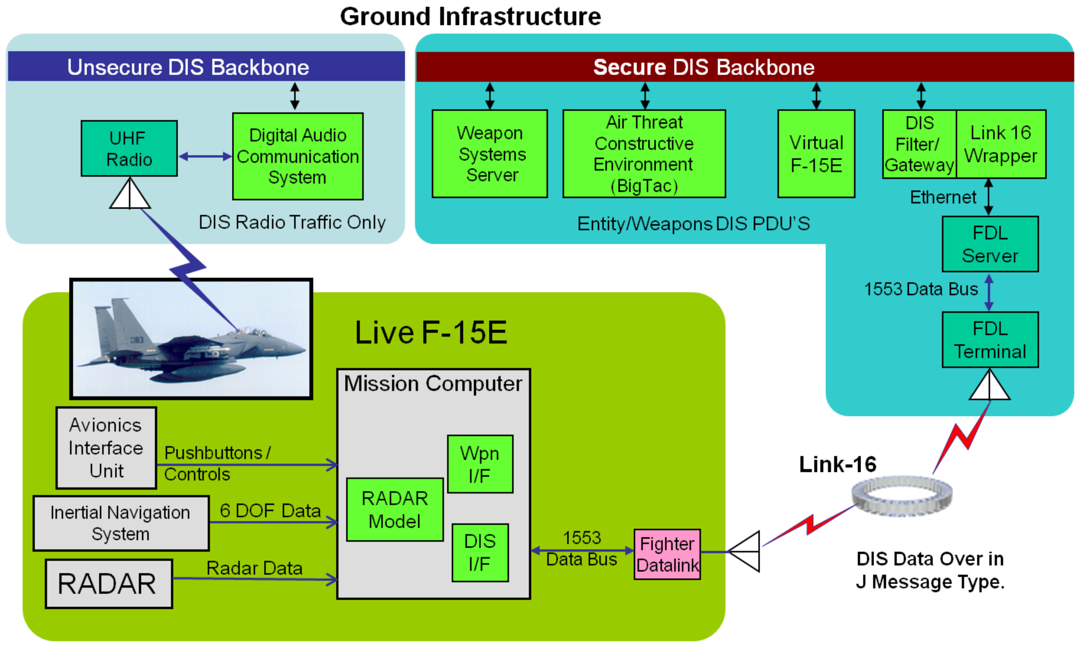


Figure 1 - Spiral 1 Architecture

are presented in the paper entitled "Integrated Live Virtual Constructive Technologies Applied to Tactical Aviation Training."[1] A diagram depicting the architecture assembled for this effort is shown in Figure 1.

As can be seen in the diagram, the ground elements consisted of radio communications equipment, a weapons server, a constructive threat environment, an F-15E Aircrew Training Device (virtual element), a Link 16 Tactical Data Link, and networking components that allowed us to bridge the ground based simulation network (DIS[2] backbone) to and from the aircraft.

The function of the radio equipment allowed the aircrew in the airborne F-15E to communicate with the aircrew flying the F-15E simulator. The F-15E simulator performed the role of a virtual wingman. During the live fly experiment, the live aircraft is placed in training mode to emulate a weapon load out. The Weapons Server role was to fly out virtual weapons launched from the live aircraft in the virtual environment. The Constructive Threat Server (Boeing BigTac™) provided red air threats for the exercise. Lastly, the combination of the TADIL-J[3] data link (Fighter Data Link) and network bridge allowed us to send and receive entity and weapons data to/from the airborne F-15E.

On board the live aircraft, we utilized various avionics equipment to gather: aircrew interactions with the aircraft (buttons /switch activations), position/orientation information (GPS/INS) including velocities and accelerations, and live RADAR parameters. Embedded in the Mission Computer were LVC Algorithms and models that allowed the aircraft to interact with the Virtual / Constructive environment. The air-to-air RADAR model was integrated as a virtual 1553 remote terminal (RT) unit. The LVC Algorithms were activated by the aircrew depressing an LVC mode button placed on the RADAR display page.

The LVC Algorithms included methods to collect and manage DIS data being broadcast from the ground infrastructure, execute a virtual RADAR model, manage message traffic to/from the Link 16 Data Link, and fuse the live, virtual, constructive tracks on both the RADAR and Situation displays. We added additional symbology to represent the virtual/constructive elements and provide cues on the Heads-Up Display. The live RADAR and RADAR model operated simultaneously when in LVC mode such that all three domains were presented to the aircrew.

Spiral 2 – Additional Capability

The objectives of Spiral 2 were twofold: introduce RADAR emissions from the virtual/constructive domain on-board the live aircraft and, increase the mission capability of the live aircraft by adding air-to-ground targeting capability. To accomplish this, we needed to give the aircrew the ability to detect RADAR emissions from both hostile air and ground threats and provide the ability to detect, track, target, and launch against red ground threats.

Spiral 2, in large part, leveraged the framework established in Spiral 1. Figure 2 depicts the additions to the architecture.

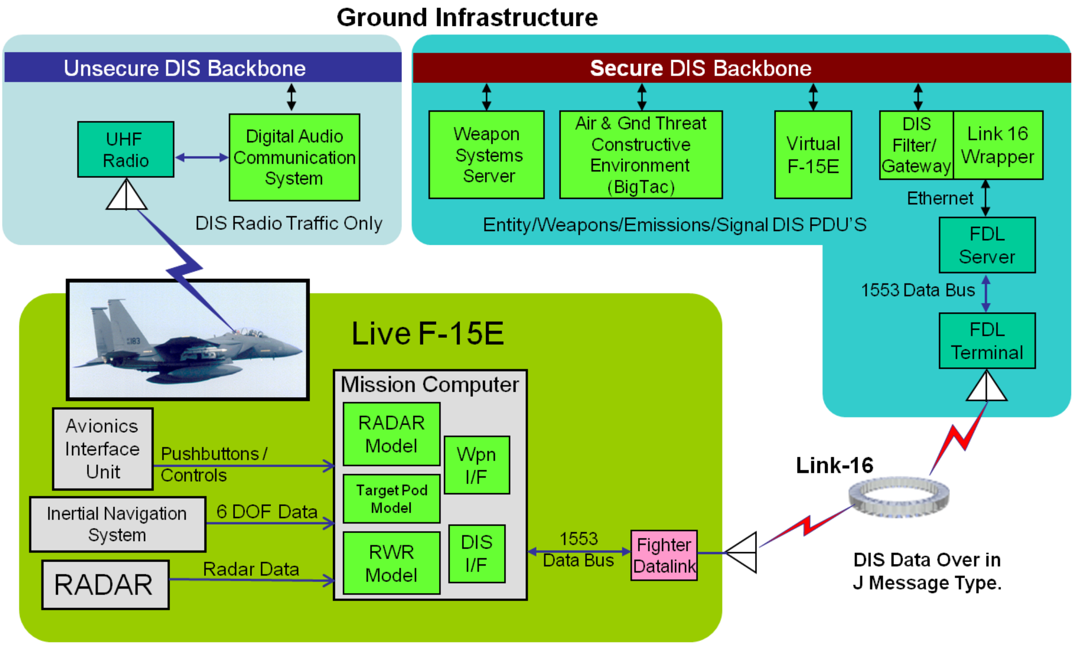


Figure 2 - Spiral 2 Additions to Architecture

As can be seen in this diagram, Spiral 2 included the addition of constructive ground threats, a RADAR Warning Receiver (RWR) model, a Ground Moving Target Indicator model, Targeting Pod model, and air-to-ground weapon models loaded on the Weapons Server. We increased the types of network Protocol Data Units (PDU's) transmitted and received including the Emissions PDU to represent emissions.

The RWR was integrated within the LVC algorithms as a second virtual 1553 remote terminal unit. This gave the aircraft the ability to receive RADAR warnings from the virtual, constructive environment. Although we did not have direct access to emulate RWR tones (required an RWR OFP modification), we did create a unique voice warning cue.

The Ground Moving Target Indicator model provided the aircraft the ability to detect, acquire, and track moving entities broadcast on the DIS network. Special symbology was utilized to identify these tracks to the aircrew. This symbology was correlated and overlaid on top of the air-to-ground RADAR map (reference Figure 3). In order to provide a correlated visual representation of the constructive ground targets on the Infrared Targeting Pod, we also included a symbology overlay fused with the sensor video.

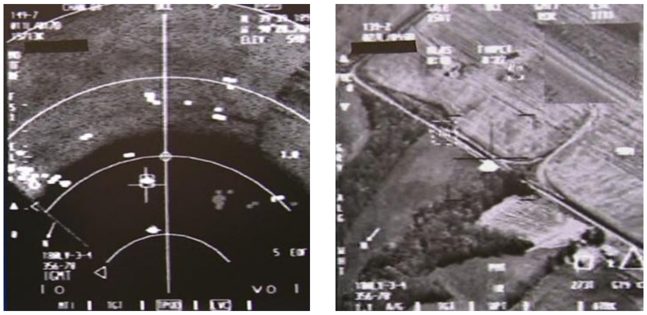


Figure 3 – A/G RADAR and Target Pod Overlays

Additions to the ground-based systems included a new Weapons Server subsystem that included air-to-ground weapons, a ground threat lay down to include advanced surface-to-air threats, and additions to the type of PDU's passed through the network gateway.

As the Spiral 1 Weapons Server was a temporary design, we opted to include a new Weapons Server subsystem designed by the Boeing Weapons System group. This system has the flexibility to simultaneously launch and fly out multiple weapons. In addition to the AIM-120D AMRAAM weapon type we had in Spiral 1, we added a GBU-38 JDAM and a GBU-12 Laser Guided Bomb to perform our strike mission scenarios.

Spiral 3 – Advancements in Architecture

With the advent of completing Spirals 1 & 2, our next hurdle was to increase the complexity of the mission set while developing an architecture that did not rely heavily on the use of the aircraft Mission Computer (to support legacy aircraft) nor dramatically affect the Operational Flight Program. To that end we performed an architecture study across various platforms that yielded several paths forward. The path we chose provided the most flexibility and a relatively short development time yet provided us the ability to increase the capabilities previously added to the live aircraft.

In order to accomplish our goals for this spiral we had to remove software from the Mission Computer added during spirals 1 &2, yet maintain access to the OFP to perform our fusion algorithms. The bulk of the software included sensor models and the network management software. We decided to add an avionics processor (to execute this software) to the existing avionics suite that resided on a 1553 Mux bus which had direct interconnection to the Mission Computer (reference Figure 4). The processor was a commercial off the shelf processor (Thales PENTXM2) that has multiple input/output options, namely Ethernet and 1553.

Utilizing an external processor had the added benefit of allowing us to connect the simulation network to a new data link via Ethernet. We chose to incorporate an Internet Protocol based radio. The Common Range Integrated Instrumentation Program (CRIIS[4]) was in the process of developing a new generation of software programmable radios for range testing purposes. Through permission of the US Government, we were afforded the option to use this new radio for our experiment. This radio has a 2X performance capability over the aforementioned TADIL-J link utilized in Spirals 1 & 2. This radio required the use of a one-pulse-per-second signal derived from an on-board GPS to provide synchronization pulses for synchronization between the airborne and ground based radios. This signal was derived from an external GPS that was also provided by the CRIIS program.

Lastly, with the replacement of the radio from TADIL-J to and IP-Based data link, we had to install a different encryption mechanism. Since we were now using an Ethernet based network, we were able to utilize a COTS High Assurance Internet Protocol Encryption device installed between the radio and the processor. We chose to use a ViaSat KG-250A encryptor as it is a ruggedized encryptor capable of operating in a dynamic flight environment.

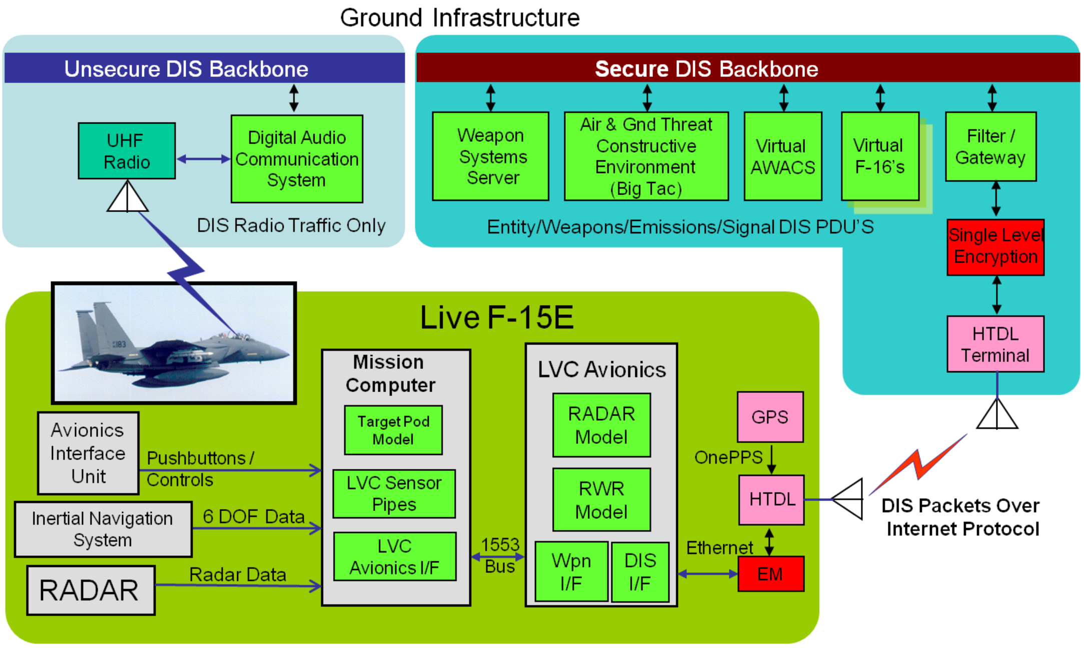


Figure 4 – Spiral 3 Architecture

COMPARISON OF APPROACHES

Spiral 1 tasks included flying a test platform and examining air-to-air functions as well as the fusing of the aircraft's OFP with sensor simulation models. Spiral 2 built upon the successes of Spiral 1 and added air-to-ground capabilities by integrating additional sensor models into the OFP. Spiral 3 off loaded the simulation models onto an external processor and added a separate Ethernet based high bandwidth radio data link. In the following paragraphs we will compare the benefits and differences of the varying approaches.

Physical Architecture

Spiral 1 & 2 required no hardware changes to the F-15E platform, only software modifications. Most of the changes were embedded in the OFP and required software engineering to make the I-LVC sensor models and DIS interface work in parallel with the OFP logic. Spiral 3 introduced a new processor external to the OFP Mission Computer. The new system is dependent on multiple components, namely an avionics processor, an encryptor, and an Ethernet radio.

Spiral 1 & 2 provided great physical benefit, i.e. no additional hardware was required. All the simulation models ran inside the aircraft mission computer and we used the already present TADIL-J^3 data link to communicate with the ground station.

Spiral 3 offered us the ability to operate outside the bounds of the OFP and provided us with our own "sand box". We used a flight certified avionics chassis containing two Thales PENTXM2 processor boards, a DDC Quad 1553 mux card, a 30 GB Solid State Drive, and a 24 port Gigabit Ethernet Switch. We used an Ethernet based software programmable radio to communicate with the DIS network on the ground. Connected between the radio and avionics processor was a single level encryption device. The encryption device ensured that all communication between the F-15E and ground was secure. The use of the TADIL-J^3 data required us to bundle data inside the J16 message format and compress the PDU's due to limited payload size and bandwidth. The new radio had twice the capacity of Link 16 and a programmable payload size which allowed us to transmit and receive uncompressed DIS PDUs.

Spiral 3 required the following additional hardware: shielded Ethernet cabling, mux connections, installation of the avionics processor, installation of the Ethernet radio, installation of the encryption device, and running power leads. Additional time was required to test the new hardware and prepare/certify it for flight. During hardware integration testing we used an external keyboard and monitor connected to the I-LVC avionics processor to verify results. The isolated I-LVC system afforded us the ability to easily modify or swap components, and enhance the hardware as needed.

Software Architecture

The benefits of Spiral 1 & 2 software architecture include the following: full integration with OFP providing unrestricted access to all aircraft resources and communications; shared memory access between the LVC models, DIS Engine, and the aircraft OFP; and control of the interface between the simulation logic and OFP.

Running the LVC models and network interface internal to the aircraft mission computer had its challenges. Scheduling the packing and unpacking of the model messages around the execution of the DIS engine proved to be difficult. Early on in the development, we experienced OFP crashes, large frame overruns, memory allocation issues, and compiler differences. This required unanticipated testing and additional debugging to find and resolve these issues using the AdaMulti debugger.

We had difficulty in Spiral 1 determining the characteristics of passing DIS packets between the ground and the live jet over Link 16. We had to split packets in half in Spiral 1 which increased the risk of lost packets when a message was dropped by the link. Metering the updates with other Link 16 traffic became increasingly difficult as more Link 16 traffic was introduced. We had to send state transition message multiple times to ensure the ground systems would receive it since we did not implement a handshake mechanism due to bandwidth constraints.

In Spiral 2 we increased the compression of the DIS packets so they would fit within the payload of a single link 16 message, but in early testing we had issues in the DIS Engine during decompression in the mission computer and on ground systems.

The benefits of the Spiral 3 architecture include the following: minimal OFP modifications, ease-of-access for making improvements and updates to LVC algorithms and models, and added flexibility to easily scale or tailor LVC software models to support hardware specifications. We maintained interconnectivity with the platform’s OFP over mux bus communication. Using a software interface written for the I-LVC avionics processor, the OFP developer’s implemented mux messages as if the I-LVC processor were another piece of mission equipment. The messages transmitted between the I-LVC avionics processor and OFP contain virtual and constructive entity information as well as information necessary to replicate the aircraft sensors it was simulating. The Spiral 3 configuration offered great flexibility without the ramifications of intermingling with the OFP.

The models and algorithms that were used in Spiral 1 & 2 were reused for Spiral 3 and underwent some modifications to support the new architecture. The simulation software architecture utilized inside the I-LVC avionic processor was designed with Boeing’s Common Simulation Framework (CSF). CSF is a simulation framework which provides executive control, distributed communication, diagnostic tools, and strict well-defined component interface objects.

The LVC models were adapted to the CSF architecture and modified to run as separate 1553 remote terminals. That is, within one avionics processor we had multiple RTs. Spiral 3 improvements allowed ground control to send a Real Time Kill Notification (RTKN) to the live aircraft. Additionally, we added a performance monitor software component into the I-LVC processor which sent all processor performance statistics down to the ground station for displaying, analyzing and storing.

Data Link

During Spiral 1 and 2 exercises, the Link 16 data link supplied the medium for transmitting and receiving data between the ground station and live platform. Link 16 already existed on the live platform and was an obvious low risk choice for the experiments. However, because Link 16 supports approximately 400 bits per message and a single entity PDU can contain over 700 bits, it was necessary to compress the DIS traffic between the ground and live platform.

On the ground station we ran a DIS gateway application to route DIS traffic to and from the live platform’s simulation network. The DIS gateway, called Filtergate, was also used to compress and decompress the data traffic traveling between the air and ground. When compressing the PDU data on the ground, Filtergate would first filter on specific PDUs (entity, emission, etc), remove all unnecessary bits and then route the packets to the live platform.

In the platform we made custom changes to the DIS engine to support the new compressed DIS PDU structure. All DIS traffic on the platform was transmitted and received using the new custom compressed PDU definitions. Because we were using Link-16 we also had to embed the messages in TADIL-J J-messages requiring more logic and additional steps.

During Spiral 3 demonstration we used an IP based Software Programmable radio. This radio supported over 200% more bandwidth than Link 16 permitting us to leave the DIS PDUs uncompressed. We were also able to add additional information embedded in data PDUs. This additional information contained performance statistics captured on the I-LVC avionics processor. The ability to use uncompressed DIS PDU packets allowed us to use standard DIS tools to monitor and debug during integration. Using standard tools lowered our integration overhead costs, reduced startup times, provided us greater flexibility and gave us freedom to use the DIS tool we had the most experience with.

Performance

The primary performance measures captured during all three spirals was the number of entities we were able to publish on the network to the live aircraft. Additional measures included CPU performance, increased functionality, etc.

As previously mentioned, the focus of Spiral 1 and 2 was the implementation of the architecture and infrastructure to fuse the virtual/ constructive environment on board a live platform. Thus entity count was limited to seven entities plus emissions and munitions.

The focus for Spiral 3 was to increase the complexity of the mission scenario. The test scenario consisted of twenty eight entities composed of one live aircraft (F-15E), three virtual aircraft, up to eight red aircraft, and ten surface-to-air sites, all emitting radar signals and firing munitions (reference Figure 5). If necessary the system had the ability to throttle up or down the number of entities active in the constructive environment. We never had to adjust the entity count during the test flight because the data link and I-LVC Processor were able to accommodate the scenario.

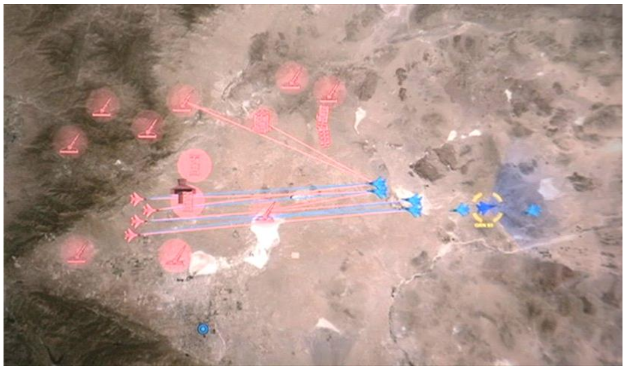


Figure 5 - Spiral 3 Primary Test Scenario

After completing the primary test scenario, network load tests were performed on the I-LVC system. There were multiple scenarios created with varying entity sizes. Each scenario increased the entity count by 150%. Four performance tests were executed during the test flight. Each test ramped up the number entities starting with 150, 250, 300, and finally 500. Figure 6 depicts an example of the network test scenario. We collected data from onboard the platform on CPU usage, memory usage, software model frame rate, and total number of entities reported by the local DIS engine. For each performance test, increases in CPU usage, frame rates, and entity counts occurred. The I-LVC avionics processor maintained the simulation model frame rates and supported the large entity counts.

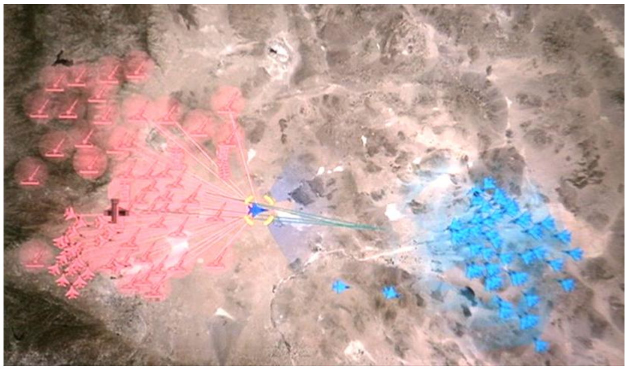


Figure 6 – Spiral 3 High Entity Count Testing

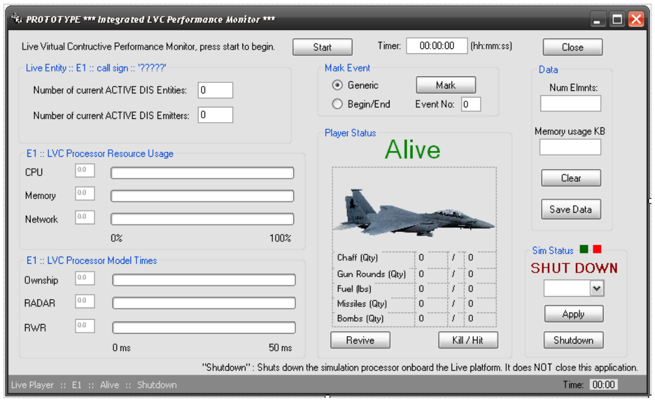
We found that the IP-based data link reached entity counts over 300 before showing signs of bottlenecks and lagging. Shortly after beginning the third performance test of 300 entities, we began to see packets dropped over the data link. Even though there was packet loss, the air crew was still able to acquire, track, and lock onto targets. When the 500 entity test began, dropped packets across the data link were immediately apparent.

Performance Monitoring Tools

The performance monitor component embedded in the I-LVC processor capture how many succinct DIS entities were being received by the live platform. By monitoring the number of DIS entities managed onboard the platform we could determine how the IP-based data link was performing. The performance monitor component also monitored CPU usage, memory usage, simulation network utilization, simulation model frame rates and current status. This information was bundled and sent via DIS Data PDUs to the ground station.

The ground station application, called the Performance Monitor, received the performance data and displayed the information in real-time to the operator. The Performance Monitor acted as an Instructor/Operator Station for the I-LVC system (reference Figure 7). The operator had the ability to save all of the received performance data for statistical analysis which could be used to determine performance concerns and needed improvements.

In addition to receiving data from the airborne aircraft, the Performance Monitor communicated with the I-LVC avionics processor onboard the live aircraft via DIS data PDUs. The application provided a user interface to control and monitor the platform's status (alive or dead) and mode of operation (Reset, Freeze, Run, etc). The operator had the ability to revive the platform and control the simulation status onboard the platform. We also had the ability to remotely shutdown and restart the I-LVC avionics processor if needed.


PROTOTYPE *** Integrated LVC Performance Monitor ***

Live Virtual Contructive Performance Monitor, press start to begin.

Timer: 00:00:00 (hh:mm:ss)

Live Entity :: E1 :: call sign :: '?????'

Number of current ACTIVE DIS Entities: 0

Number of current ACTIVE DIS Emitters: 0

Mark Event: ● Generic ○ Begin/End; Event No: 0

Player Status: Alive

Chaff (Qty)	0	/	0
Gun Rounds (Qty)	0	/	0
Fuel (lbs)	0	/	0
Missiles (Qty)	0	/	0
Bombs (Qty)	0	/	0

E1 :: LVC Processor Resource Usage: CPU 0.0, Memory 0.0, Network 0.0

E1 :: LVC Processor Model Times: Ownship 0.0, RADAR 0.0, RWR 0.0

Sim Status: SHUT DOWN

"Shutdown" : Shuts down the simulation processor onboard the Live platform. It does NOT close this application.

Live Player :: E1 :: Alive :: Shutdown

Time: 00:00

Figure 7 - IOS / Performance Monitor Tool

As an additional feature, we implemented the ability to send a Real Time Kill Notification (RTKN) to the live aircraft. RTKN was generated from the Performance Monitor via an operator button push. When activated, the application sent a message to the platform and a MORT cue was displayed to the crew members on the HUD (head-up-display) and Situation display. In order to clear the cue the aircrew had to acknowledge the MORT cue.

This tool gave us great control over the I-LVC avionics processor to ensure we maximized the training effectiveness without intruding on operations of the crew members.

LESSONS LEARNED

The architecture developed in Spirals 1 & 2 focused on maximum reuse of platform assets. Customer feedback we inferred from the Spiral 2 demonstration included a focus on the use of other data links and an implementation that was independent of platform architecture, both of which we implemented in Spiral 3.

During the Spiral 2 demonstration we learned the true value of integrated LVC. On the third leg of the mission, the live and virtual aircraft were to perform a buddy lase operation on a ground moving target. The virtual aircraft would lase a target and the live aircraft would launch the weapon. The weapon was flown out by the Weapons Server. After the launch of the virtual weapon from the live platform, the weapon went ballistic and did not hit the intended target. After radio communications between the aircrew in the airborne aircraft and the virtual simulated aircraft, it was realized that improper laser codes had been programmed into the weapon. The codes were corrected in flight, and on a subsequent pass, the aircrew destroyed the intended target, all without expending a live weapon.

During the hot wash from the Spiral 3 test flight we captured several lessons learned from the aircrew. Feedback provided two major insights with respect to LVC scenarios. In both spiral 1 and spiral 2, the aircrew in the live aircraft flew with a virtual wingman (i.e. aircrew in a simulator on the ground). In addition, the missions were design such that the live aircraft was immediately engaged in the battle for each leg of the scenario.

Spiral 3's scenario was designed with the virtual aircraft performing a Suppression of Enemy Air Defenses (SEAD) role, thus the live aircraft was flying without a wingman. The aircrew stated that in the previous spirals the scenario required more crew coordination and intensity to the mission due to crew coordination, which was lacking in the spiral 3 scenario. The lesson learned was whether flying with a live or virtual wingman, a two-ship formation provides increased training value for an LVC exercise.

Spiral 3's scenario was designed such that the live aircraft begin at an Initial Point to the east of the battle with the virtual and constructive air-to-air and SEAD roles occurring in advance of the F-15E strike mission. The aircrew stated that there was some benefit to watching virtual and constructive entities battle, but the scenario had the live entity waiting and watching too long. The lesson learned was to engage the live aircraft as soon as possible in the scenario. This has the obvious benefit of maximizing the training value during time-in-air.

Since Spiral 3 was designed as a test flight, we did not have experienced aircrew operating the ground simulations. The lack of experience garnered negative feedback from the aircrew. Additionally, not having the ability to launch chaff/flare from the live aircraft into the virtual/constructive environment reduced the effectiveness of the defensive maneuvers of the live aircraft when engaged by threats.

On the engineering side, we learned several valuable lessons. Prior to the test flight, we learned that we would not be able to use the TADIL-J system at the test site. This was not anticipated or planned for. In the prior flights, we instrumented the ground systems such that we could track the live aircraft from either Precise Position Location Information (PPLI) tracks from Link 16 or DIS entity PDU's regardless of whether the aircraft was in LVC mode (i.e. transmitting DIS entity PDU's) or not. For safety of flight concerns, the aircrew would periodically exit LVC mode to perform far range scans with the aircraft RADAR to delouse the airspace. During the spiral 3 flight, we were not able to track the aircraft when the aircrew exited LVC mode since we did not have the Link 16 track. Since we did not require the aircrew to communicate when LVC mode was exited, it had the appearance of an unknown track loss on the ground systems.

During prior ground tests, we tested for multiple continuous single weapon launches to ensure the ground systems were fully capable. We did not plan for or coordinate prior to flight a preprogrammed multiple weapon launch (i.e. multiple air-to-ground weapons launched with a single pickle depress in the aircraft). Thus, while the aircrew was fully expecting their weapons to destroy a ground threat, the ground systems only captured a single weapon launch and the weapon kills were not as effective.

On the positive side, we learned that by utilizing an IP-based data link we were able to use the DIS protocol directly without compression. This has the benefit of not requiring another network bridge (less integration and reduces an opportunity for data loss). The higher bandwidth of the IP link and the elasticity of the DIS protocol allowed us to achieve far greater entity counts received by the live aircraft than anticipated.

Lastly, our system included a single level of encryption on board the live platform. As previously mentioned we used the ViaSat KG-250A. Due to the mounting location in the aircraft we had to add wiring for a key fill port and Ethernet. One needs to consider the appropriate cable separation, routing, and shielding (Emissions Security) of the secure wiring when planning for secure operations.

FUTURE GROWTH

The culmination of our research has afforded us the opportunity to work with the United States Air Force Research Laboratory to further develop an LVC concept of operations and development roadmap. We will be continuing this research under that effort.

In addition to furthering our work with Ethernet based radios we will be examining the Range Instrumentation Waveform when it becomes available. Because of the inherent modular design and component based hardware of the Spiral 3 architecture we now have flexible test bed to experiment with new technologies on a relevant platform.

Further research is required on the incorporation of additional models into the I-LVC solution set. Of noted importance are aircraft self-defense mechanisms such as chaff, flare, and jamming systems. Additionally, through the use of simulated conditions, I-LVC has the opportunity to offer training on degraded aircraft operations and denied GPS environments while maintaining safety of flight.

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- Boeing F-15 Mission Systems – OFP Development
- Boeing Palmdale ISR – Test Facilities and Virtual Entities
- Boeing Electronic Prototype Integration Labs – Avionics Processor
- Boeing Training Systems & Services – Constructive Threat Server, Networking Utilities and Real-Time Monitoring Tools
- Boeing Advanced Weapons Systems – Weapons Server

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