Implementing Integrated LVC for Naval Aviation Training

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ABSTRACT

Integrated Live Virtual Constructive (I-LVC) training for tactical aircraft can produce tradeoffs and efficiencies in the aviation fiscal (flight hour) accounts while generating warfighter readiness. Although fielding the capability remains somewhat elusive, significant progress has been made towards implementation on current tactical fighter and command and control platforms. This paper discusses migrating I-LVC to various Naval Aviation platforms and the multiple challenges associated with implementation.

In 2007, The Boeing Company began an independent Research and Development project entitled 'Project Alpine' aimed at reducing the risk of introducing LVC capability into a tactical platform. To date, Project Alpine has demonstrated the capability to perform air-to-air intercepts between live friendly aircraft and sophisticated ground-based virtual and constructive hostile aircraft, ground moving targets and surface-to-air threats. In 2010, this effort transitioned into a contracted effort with the United States Air Force (USAF) for a program entitled 'LVC Pilot Program (LVCPP).' LVCPP includes three live flight demonstrations with increasing complexity and integration of LVC assets for the purpose of developing an LVC Concept of Operations (CONOPS) and roadmap for the USAF. Phase 2 of the program introduces LVC capability onto the F/A-18E/F platform.

This paper will build upon the approaches discussed in the 2010 I/ITSEC paper, "Advancements of Integrated LVC Applied for Tactical Aviation Aircraft Training", analyze the work completed in Project Alpine / LVC Pilot Program and offer a potential U.S Navy implementation of I-LVC on-board various Navy platforms. We address such topics as Training & Readiness, appropriate combination of LVC components, platform impacts, scalability, and requirements. Additionally, we will address how readiness can be improved and the potential savings to be gained in certain mission areas such as Anti-Air-Warfare; Strike Warfare; and Electronic Warfare with credible and relevant I-LVC technology.

ABOUT THE AUTHORS

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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 (I-LVC) Technologies for Tactical Aircraft Training, entitled Project Alpine. The intent of the project was to build upon the systems and protocols already in place for the distributed training construct and expand it into the live training domain to generate readiness while creating fiscal efficiencies to address flying hour budget reductions. From 2007 to 2009 we demonstrated the capability to perform air-to-air intercepts between a live F-15E aircraft and sophisticated ground-based virtual and constructive hostile aircraft, ground moving targets and surface-to-air threats.

As a result of the successes garnered from the work on the F-15E Strike Eagle, in 2008 we formulated an approach to implement LVC capability on the F/A-18 E/F Super Hornet. This paper captures our work to date on the Super Hornet and associated airborne and ground systems to support an LVC capability for the Naval Aviation. It captures supporting significant writings and directives to support a Naval I-LVC capability. Lastly, it depicts benefits of I-LVC Naval aviation, potential cost efficiencies, and supporting readiness generation.

ENVISIONED FUTURE NAVY ILVC TRAINING REQUIREMENTS

Overarching I-LVC Requirements

In reviewing the hierarchy of strategic guidance from the National Military Strategy and Quadrennial Defense Review to various Joint publications through to Military Training Policy there is a logical flow down from top level training to training specifically supported by I-LVC. Department of Defense (DoD) Directive 1322.18 issued in 2009 has numerous references to I-LVC training. For example, the Directive states: "The Military Departments shall develop and field system interfaces to enable integrated LVC training to stimulate sensors and/or represent synthetic entities and to provide after-action review for the training audience" and also directs the Chairman of the Joint Staff to "develop and maintain open, net-centric, interoperable standards and protocols for LVC joint training systems".

Looking further at the Deputy Under Secretary Readiness and Training's Strategic Plan for Transforming DoD Training, the document discusses the implications for the Training Transformation Program derived from the 2006 DoD Quadrennial Defense Review Report imperative and the DoD Strategic Planning as well as the results of the 2005 Training Transformation (T2) assessments. More specifically is states to "continue building the live, virtual, and constructive (LVC) integrated and distributed joint training environment for export on a global scale and replicate the operational environment to the greatest extent possible. Integrate joint and service virtual and constructive simulation, opposing force capabilities, and range instrumentation".

Finally, the Training Transformation Implementation Plan has direct references to embedded training and LVC, such as; the "department policy defines embedded training as the capabilities built into, strapped onto, or plugged into operational materiel systems to train, sustain, and enhance individual and crew skill proficiencies necessary to operate and maintain the equipment. The policy requires embedded training to function through a joint architecture using common standards with integrated live, virtual, and constructive training systems."

Service Level Requirements

It is envisioned the future I-LVC related training requirements will be defined by the appropriate Joint Capability Integration Development System or JCIDS documents such as an Initial Capability Document (ICD), Capability Development Document (CDD), and Capability Production Document (CPD). The U.S. Air Force is moving forward with developing the ICD titled, Integrating Architecture for Air & Space Live, Virtual, Constructive Environments (IA-ASLVCE) which will began to lay the foundation for the Joint I-LVC requirement[1]. In addition, the U.S. Navy is pursuing the analysis to understand the training benefit and cost efficiencies derived from integrating live, virtual and

constructive technologies. Once proven, the Navy plans to invest in technologies, information assurance, encryption and concept development necessary to support enhanced live training via constructive simulation[2]. As the I-LVC requirement definition at the service level continues, it is now technologically realistic to envision fielding a basic unit level I-LVC aviation training capability in the 2015 timeframe or sooner.
The right mix of I-LVC training can produce the right amount of War-fighter readiness and also meet the DoD's enduring 'requirement' to generate fiscal efficiencies.

Requirements Scalability

While specific requirement analysis continues, based on our extensive experience gained from multiple I-LVC related efforts and various discussions with aviation as well as other service professionals, it will be necessary to provide an I-LVC capability that:

- Accommodates mission planning and rehearsal
- Supports all areas of the kill chain
- Provides multi dimensional tactically relevant Opposing Forces (OPFOR) with realistic targets for constructive weapons delivery
- Has the ability to accurately re-construct the mission with high quality ground truth feedback
- Is completely interoperable with multiple tactical platforms and communication networks
- Scalable from a basic unit level capability to a complex integrated Air Wing and Battle Group training capability
- Potentially deployable to support Carrier based training and readiness generation while deployed

ADVANCEMENTS IN ILVC ARCHITECTURE

F/A-18 OFP Implementation

Dating back to the architecture developed for the F-15E Strike Eagle in 2008, we began the instrumentation of the F/A-18 E/F Super Hornet in 2011. Similar to the Strike Eagle, the Super Hornet architecture takes the same approach of injecting threat tracks into the aircraft master track list through sensor models that are embedded in the OFP. The sensor models include an APG-79 RADAR model and an ALR-67(V)3 RADAR Warning Receiver model. The models are stimulated via DIS protocol simulation data that is received via a data link. The Pilot Vehicle Interface (PVI) collects aircrew control inputs to command the sensor models. The Airframe Collector gathers airframe, sensor, and weapon information to transmit to the simulation network so that the virtual-constructive environment is live-aircraft aware. The LVC Translator has the function of throttling Airframe Collector information so as not to exceed the bandwidth of the data link as well as reconstructing data link messages into the proper simulation format

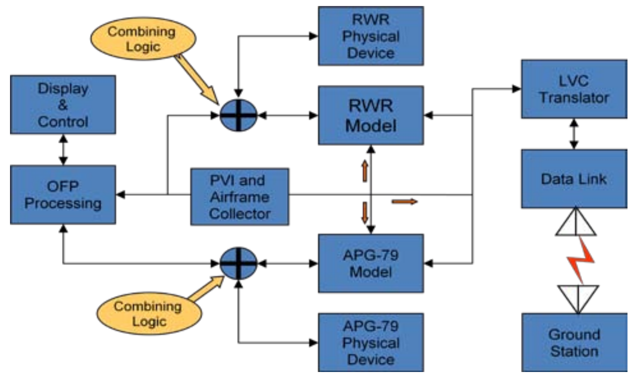

Figure 1 - F/A-18E/F Processing Logic

The resultant aircraft displays presented to the aircrew during an LVC exercise provide an authentic, realistic training scenario as would be replicated by a live-on-live scenario (ref. Figure 2).

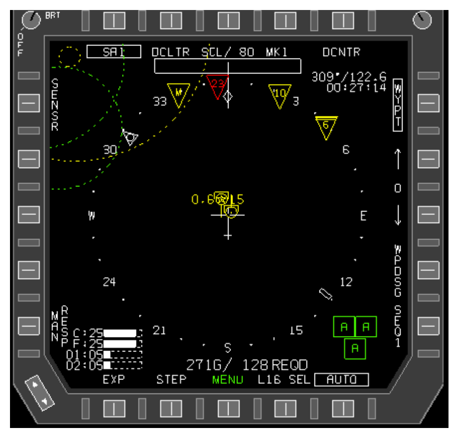

Figure 2 - F/A-18 Situation Display with LVC Tracks

LVC Processing Cluster

In 2009 we performed an LVC Test Flight with an LVC Processor embedded with the F-15E. As referenced in our previous IITSEC Paper entitled "Advancements of Integrated LVC Applied to Tactical Aviation Aircraft Training"[3], the goal was to remove the reliance upon the Mission Computer for a vast majority of the LVC processing algorithms. The remaining problem we had to solve was how to implement an approach that minimized changes to Aircraft wiring and avionics hardware. We performed a trade study to assess various architectural approaches and provide maximum flexibility/ commonality among platforms. As shown in Figure 3, we chose an approach that relocated the LVC processing function out-board of the aircraft. The approach could utilize existing Military Standard MIL-STD buses, thus providing a common interface for data and power. The LVC Processor could be mounted in a simulated weapon store and take advantage of the additional space for a new data link and encryption combination.

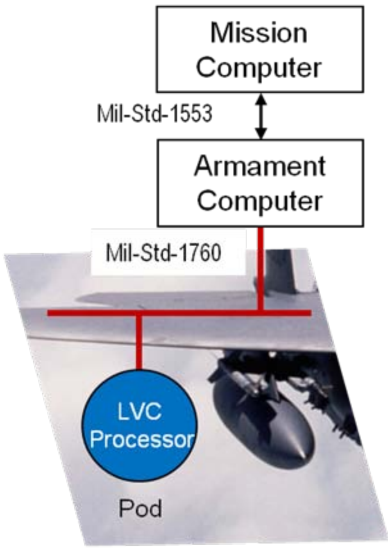

Figure 3 - External Processing Configuration

To that end, we chose the P5 Combat Training System/Tactical Combat Training System (P5 CTS/TCTS) as the preferred approach to begin development of a high capacity processing cluster that could perform complex calculations and run high fidelity simulations in real-time. P5 CTS/TCTS is a joint program maintained by the USAF Eglin Armament Center that supports live air combat training for both the US Air Force and US Navy. We began a collaborative research and development effort with DRS Training and Control Systems, the P5 CTS/TCTS Airborne System original equipment manufacturer, to implement the design. The P5 system placed restraints on the design that required us to shrink our 2009 LVC Processor to match the form and fit of their airborne instrumentation package. The results of the design can be seen in Figure 4. The benefits to this approach are that the P5 system was designed for airborne training and already contained a majority of the additional functions/subsystems needed for LVC operations.

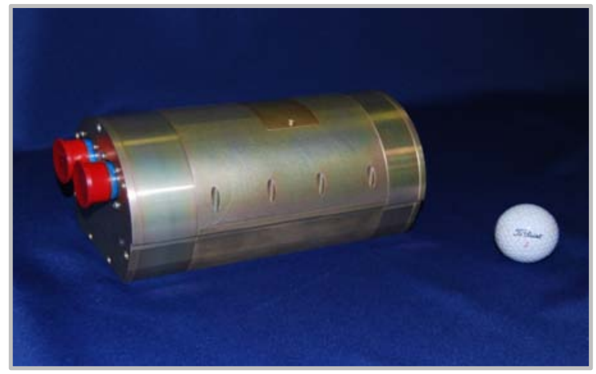

Figure 4 - Small Form Factor LVC Processor

The Small Form Factor LVC Processor is approximately 4 inches in diameter and 8 inches in length. It weighs approximately 6 pounds and is ruggedized for military environments. It is a six processor enclave with, with one processor allocated to aircraft bus messaging, and the remainder processing elements available for LVC models and network management. The system design affords the flexibility to swap out the aircraft interface such that if a modern interface is desired, such as Fibre Channel, it can be accommodated.

To date, we have ported all LVC software to the processor enclave and have modified the F-15E OFP to interface with the processor embedded in the P5. We have tested the system in a full up configuration with the P5 pod in a laboratory environment connected to the F-15E avionics bench (ref. Figure 5) replicating our previous test experiments from 2009. The system was stimulated by the LVC ground station providing the virtual/constructive environment through the P5 data link, communicating over Radio Frequency to the processor.

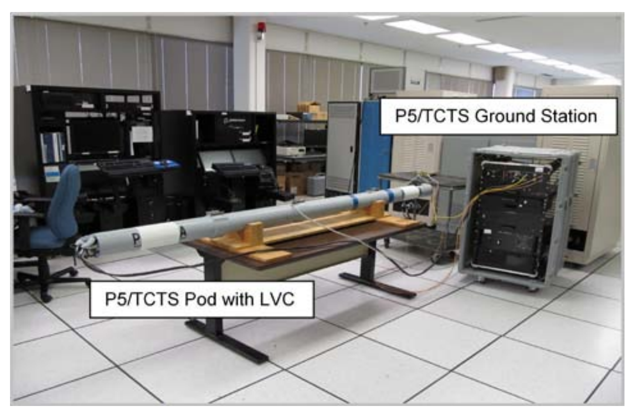

Figure 5 - P5 CTS/TCTS Instrumentation System Lab Testing

The test scenario used for our experiments pitted the I-LVC instrumented F-15E, against three waves of four SU-27 red air aggressors and two SA-6 Surface-to-Air Missile (SAM) sites. The F-15E was placed on a strike mission with a final objective of an air to ground attack on a stationary enemy ground site (a hanger). For these tests a variety of DIS PDU packets were transmitted between the live platform and to the LVC ground station including entity state, emission, fire, designator, and data PDU's. Transmission rates were 3 Hz.

The existing P5 Data link proved to be sufficient to transfer enough data to support a high fidelity 1 v 12 exercise, however, data link bandwidth was identified as the overall system data flow choke point. Data link slot assignments for live players had to be converted to slots assignments for LVC ground station transmissions to the live players, creating additional limitations on the number of live players. All said, the test successfully demonstrated the ability to merge multiple operating environments, from different live aircraft, into the same I-LVC simulation training environment.

LVC Ground Systems Advancements

The LVC Ground Station (ref. Figure 6) is designed as an open architecture system, taking advantage of the Distributed Interaction Simulation protocol as the backbone for communications. The main systems it includes are an Exercise Control subsystem, a constructive environment forces generator, a weapons server to fly out simulated weapons fired from live platforms, a network gateway for the live platform connectivity, and a GPS receiver for time synchronization. After visiting various range locations, it became apparent that facility space is at a premium. To address the facility space limitations and to minimize man-power requirements, we designed the ground station for single user operations. We have also implemented a Real-Time Kill Notification function designed to notify the live aircraft aircrew when their platform has been virtually destroyed.

Figure 6 - LVC Ground Station

In our current instantiation of LVC, terrain elevation data is not stored on the aircraft to minimize processing, memory and data storage needs. Thus the airborne sensor models are not terrain aware. An issue exists that the sensor models can see, target, and shoot through real terrain that the live aircraft may be flying over. To solve this limitation, we created an Occlusion Server process that runs on the LVC ground station. The Occlusion Server monitors positions of all entities in the LVC environment and reports obscuration information to the live platforms when an opposing entity is obscured through line-of-sight. The aircraft sensor models have now been modified to utilize this information and not detect opposing forces per sensor model rules.

An additional new feature to the LVC ground station architecture is a Role Player Station. The function of the role player station is to introduce the human element in the LVC environment. It can either be a virtual red or blue player or assume the role of a red or blue constructive player. It provides a network appropriate signature such that it appears like a real threat to the aircraft sensor models and can launch the same weapon models utilized by the Weapons Server. Again, to meet a concern of facility space constraints, we chose to go with a minimal footprint system of a laptop with stick and throttle. It is based on a commercial simulation product that can be configured to support a variety of platforms. As shown in Figure 7, it is configured to be a SU-27.

Figure 7 - Role Player Station

Lastly, we have also included a virtual Airborne Early Warning and Control System (AWACS) surrogate on the LVC Ground Station network to provide the Command and Control element. The Surrogate runs the actual AWACS mission software providing an authentic Command and Control (C2) node.

APPLICATION TO NAVY ILVC

Tactical Combat Training System applied to I-LVC

The United States Navy currently utilizes the Tactical Combat Training System (TCTS) as the live training system for tactical aircraft such as the F/A-18 E/F Super Hornet. The TCTS is fielded at various Naval Stations both CONUS and abroad. It provides the ability for live-on-live training including embedded weapons simulations and live event monitoring.[4] As mentioned previously, the airborne instrumentation element of TCTS houses a majority of the subsystems needed for I-LVC functionality.

One of the major concerns expressed by various tactical platform customers is the need to modify the platform Operational Flight Program to implement I-LVC. The development cycle for OFP updates takes several years and is costly. Through the development of the LVC Processor, we have taken an approach that minimizes the relation between the OFP and LVC software. Instead of embedding the LVC software (aircraft sensor models and LVC network interfaces) in the OFP, it now resides in the LVC Processor avionics. Ideally, the aircraft OFP would be modified once to provide the communications interface to the LVC processor. This approach expedites software release cycles for the LVC instrumentation and minimizes OFP impacts/development costs. Given the US Navy already has TCTS in inventory; one approach would be to modify the TCTS to include LVC capability in a similar form as to what has been developed through internal research. The missing element provided by previous experiments is the necessary encryption required for secure LVC operations. A compatible encryption device would need to be added to both the airborne and ground data links.

While we were capable of demonstrating a unit level I-LVC environment utilizing the existing TCTS data link, to meet future training needs, it is envisioned that a high data rate capacity data link will be required. Ideally this would be an IP-based data link with extended range capability developed as a form fit function replacement for the existing TCTS data link. This would allow for LVC capability to be added to the existing system in the near future and grow to take advantage of the high bandwidth when available.

Command and Control Element

An additional element that requires consideration is the inclusion of the command and control element for fighter coordination. The US Navy currently uses the E-2 Hawkeye for its tactical aircraft battle management command and control.[5] Two options to consider for I-LVC training are the incorporation of LVC capability on board the Hawkeye, or the inclusion of a network ready ground-based Hawkeye simulation system (virtual Hawkeye).

To incorporate LVC capability on-board the Hawkeye, there would need to be a means to inject simulation entity data (virtual/constructive data) into a RADAR and/or Electronic Surveillance simulation that would be resident on the platform. The simulation could be activated in a live training mode of the aircraft. The models would replicate the functions of the actual aircraft sensors, detecting and tracking red and blue forces within a scenario. Operators would perform the standard tasking to strike aircraft. This would be the same simulation data present on the LVC network that is sent to strike aircraft.

Conversely, similar to the installation at Nellis Air Force Base which includes a virtual AWACS, a virtual Hawkeye could be considered. It would be resident with the LVC Ground Stations and connected to the LVC network. It would contain all the necessary subsystem simulations to replicate a live E-2. Through TADIL-J and the simulation networks, the E-2 would pass tasking information to the strike aircraft.

POTENTIAL NAVY IMPLEMENTATION

Readiness Generation & Applicable Mission Areas

Training in an I-LVC environment can generate significant readiness in various warfare areas. For example, we have demonstrated the execution of: Live Air vs. Constructive Air with constructive weapons; Live Air vs. Constructive Surface with constructive weapons; Real-Time Kill Removal; use of constructive weapons such as AMRAAM, JDAM, AA-10C, SA2, and SA6. The capability exists today to support generating readiness in mission areas such as Anti-Air-Warfare; Strike Warfare; and Electronic Warfare areas with tactically relevant and credible I-LVC technology. More specifically, mission tasks such as target acquisition & target attack, Offensive Counter Air (OCA), Defensive Counter Air (DCA), Time Sensitive Targeting; Close Air Support; and Suppression of Enemy Air Defense (SEAD) can be completed with an I-LVC training capability. Not only can readiness be generated, but the training can be significantly enhanced by increasing the overall threat intensity with the use of constructive air and ground based assets.

Benefits & Cost Savings

The benefits of training with an I-LVC capability are numerous and include:

- Reduction in the number of live adversary aircraft required for training conducted in a "Beyond Visual Range (BVR)" environment which helps mitigate the on-going reductions to the Flight Hour Program
- Increasing the threat capability and density with improved adversary presentations
- Reductions in the fatigue life on operational jets used as adversary A/C.
- Live training against sophisticated EW threats potentially mitigating the need to purchase expensive / difficult to acquire EW assets
- Mitigation of certain range encroachment issues which support the DoD's Sustainable range Initiative.

Although the true cost savings have not been calculated, there are two telling examples related to Navy F/A-18's and Air Force F-15E's. From the Navy perspective, it is estimated the F/A-18 aircraft have an approximate annual Flight Hour Budget of $1200M. Roughly, 25 percent or more of the budget is allocated to F/A-18 sorties providing adversary air support. With the use of constructive air threats, this number could be significantly reduced. An internal analysis showed that for an Air Force F-15E squadron, specific Air Intercept, Surface Attack, and Surface Attack Tactics training supported by I-LVC can save one squadron over $25M per year. Analysis shows that an I-LVC capability provides a positive net present value within two to three years of the initial procurement outlay.

Implementation

The OFP changes completed for the F/A-18E/F Super Hornet can potentially serve as the launch point for LVC integration on Navy tactical aircraft, provide a proof of concept demonstration, and overall reduce risk for Navy implementation. The follow-on fielding of a Navy unit level I-LVC program would be designed around assisting in the development of a Navy LVC Concept of Operations (CONOPS), refining Navy LVC Architecture, and gaining a better understanding of the actual readiness that can be generated in terms of the Training & Readiness manual.

After fielding of an initial unit level capability, the next step would be expanding the capability to Naval Air Station Fallon where the entire carrier air wing could conduct comprehensive training supported by I-LVC while integrating every element of the air wing into realistic scenarios. This effort would feature growing the LVC platform capability along with connectivity to ground based virtual simulations such as F/A-18 Tactical Operational Flight Trainers and E-2 simulators.

Finally, enlarging the 'Kill Chain' with an LVC capability for Aegis and Littoral Combat Ship class platforms would add tremendous value to the distributed training events for Strike Groups conducted throughout the Fleet Readiness Training Plan (FRTP).

The ultimate objective is to field an I-LVC capability that can support integrated joint forces, geographically separated, in a realistic, tactically and operationally challenging training environment.

CONCLUSION

As highlighted in this paper, significant writings and directives existing to state that there is an LVC requirement for the DoD.

To date, an experimental I-LVC capability has been developed for the F/A-18 Super Hornet. It has been demonstrated to work with existing training and simulations systems and can potentially generate training readiness for the US Navy while creating cost efficiencies for training.

I-LVC software has been demonstrated on-board the platform avionics. A LVC Processor capability has been developed to reduce the reliance upon the Operational Flight Program and operationally demonstrated in conjunction with the P5 CTS/TCTS training system.

With the inclusion of available encryption devices in the TCTS, this capability could move forward as a near term training capability for the US Navy. Increases in high bandwidth data rates provided by future data link developments will provide the capacity necessary to utilize the full capabilities with an embedded LVC processor to meet large scale exercise training requirements.

While a virtual battle management command and control element is near term and readily available, research is still needed to understand the means to connect and inject the E-2 Hawkeye into the I-LVC environment.

REFERENCES

[1] Department of Defense (DoD) Directive 1322.18, dated 13 January, 2009.

[2] Office of the Under Secretary of Defense for Personnel and Readiness; Director, Readiness and Training Policy and Programs, Strategic Plan for Transforming DoD Training, dated 8 May 2006.

[3] "Advancements of Integrated LVC Applied to Tactical Aviation Aircraft Training", Interservice/Industry Training, Simulation, and Education Conference Proceedings, 2010, Paper 10152.

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[5] E-2C Hawkeye Brochure. http://www.as.northropgrumman.com/products/e2chawkeye/index.html