The Breakout Year for Capitalizing on Live-Virtual-Constructive (LVC) Training

With the Advanced Training Environment – It's the Safe Bet

1 CUBIC'S ADVANCED TRAINING ENVIRONMENT

Since inventing Air Combat Maneuvering Instrumentation (ACMI) in the early 1970s, Cubic Global Defense (Cubic) continues to innovate the training environment for combat forces around the globe. The principle goal of a training environment is to allow warfighters to train as they fight using their warfighting systems, resulting in the most effective training. Any modifications to tactics or procedures to accommodate the training environment create bad habits—also known as "negative training." The secondary goal of a training environment is efficiency where the generation of realistic, cost-effective threats and tailored training objectives is based on an individual's proficiency gap. Cubic, along with partners and customers, has achieved both goals and created an advanced training environment so realistic that warfighters are demanding it be installed now.

There are a few technological prerequisites for an advanced training environment. The two most notable are moving data and protecting data. Moving large volumes of data to accommodate Large Force Exercises (LFEs) or small unit training requires a scalable, ad hoc network. The data that enables realistic interaction among participants must be sharable at appropriate classification levels. This requires robust encryption (National Security Agency [NSA] Type 1) and Multiple Independent Levels of Security (MILS). Cubic has addressed both with low latency and high data integrity.

Training with cross-domain kill webs adds additional complexity over traditional air combat training. Kill web tactics demand higher training data throughput, encryption, greater engagement distances and advanced sensors.

Figure 1.1-1. Cubic's Advanced Training Environment. Cubic's *advanced training environment is based on a family of systems approach and supports competency development, proficiency, and mission readiness.*

Cubic has always considered training holistically; as a family of systems that replicates real-world attributes enabling the development of Tactics, Techniques, and Procedures (TTPs). An advanced training environment minimizes training artificialities and supports the operators with a Simplified Plan, Execution, Analysis, and Reconstruction (SPEAR) cycle across the spectrum of individual to the Large Force Exercise scenarios. Such an advanced training environment supports competency development, proficiency, and mission readiness (Figure 1.1-1.)

2 LVC IS CRITICAL FOR ADVANCED TRAINING

2.1 CHANGES IN THE ENVIRONMENT

Fourth and Fifth generation platforms, sensors, and weapons provide a far greater performance envelope than in prior decades. These performance advantages were developed to counter emerging threat capabilities that seek to limit or overwhelm friendly forces (Figure 2.1-1). Most of the last 15 years of conflict focused on counterinsurgency operations. During that time, near-peer adversaries have fielded threat capabilities that preclude a "business as usual" approach to employment of traditional TTPs requiring a pivot to advanced kill web TTPs designed to counter these more capable threats.

Traditional range infrastructure and training environments do not provide adequate space, multi-domain asset participation, capable threats, and threat density to challenge our systems and operators to the levels needed in a near-peer conflict. The ability to train to kill webs across warfare domains is critically important. This requires linking joint kinetic and non-kinetic effects, 4th and 5th generation platforms and their sensors into a coherent outcome that overwhelms adversary systems in capability, range, and duration.

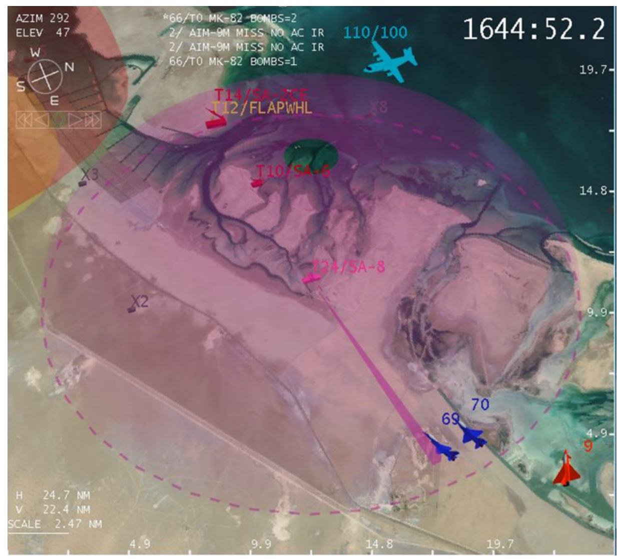

Figure 2.1-1. Complex Threat Environments and Advanced Capabilities Are Stretching Current Training Capabilities. *LVC training systems enable our combat forces to execute the advanced kill web tactics needed to win the next fight.*

The Joint Force has struggled to integrate this dynamic set of capabilities because they have not been able to effectively train to kill web employment. Our simulator and constructive threat generation systems have taken large strides in replicating potential threat scenarios; however, a significant gap remains in training and operator proficiency when the live training component of our training continuum is exercised. To offset this proficiency gap and to fully realize the potential of the integrated Joint Force, we need an advanced training environment where high-fidelity LVC training can be leveraged.

2.2 LVC THRESHOLD REQUIREMENTS

Cubic worked closely with the Air Force Research Laboratory (AFRL) and Naval Air Systems Command (NAVAIR) as the industry Systems Integrator (SI) in the development and demonstration of the Secure Live, Virtual, and Constructive Advanced Training Environment–Advanced Technology Demonstration (SLATE-ATD) to validate the end-to-end capabilities required to meet high-fidelity LVC training requirements. AFRL had the bold initiative to develop leap-ahead technology and demonstrate a realistic, 18-plane LFE with some free-play, where it would have been much less risky to demonstrate a tightly controlled 4-ship event. NAVAIR brought testing rigor to the project, ensuring we gathered data that would verify the ATD's objectives. In completing the ATD, Government and industry consortium was able to effectively document the minimum (threshold) system specifications to provide a robust LVC training environment scalable for individual, unit and collective (LFE) scenarios in both tethered (integrated with ground station) and untethered (rangeless) modes beyond the limits of the Nellis Test and Training Range (NTTR). To achieve this LVC advanced training environment, the requirements shown in Table 2.2-1 must be present:

Table 2.2-1. System of Systems Capabilities Requirements*

Requirement	Description
Joint Interoperability and Integration	Advanced tactics require the collaboration and performance of integrated tactics across Department of Defense (DoD) service lines. The technical requirements to facilitate joint operations must be accurately represented and able to be assessed.
4th to 5th Gen Fighter Aircraft Integration	Within the same service, varying levels of technically advanced fighter aircraft are required to communicate and operate together.
Fighter- Command and Control, Intelligence, Surveillance, and Reconnaissance (C2ISR) Integration	Advanced tactics, including integrated fire control, require accurate data and information flows between fighter aircraft and Command and Control (C2) platforms. This integration is fundamental to advanced tactics and presents discreet technical requirements that must be addressed by design in future LVC solutions.
Continuum of Training across Optimized Fleet Response Plan (OFRP)	The OFRP is the United States (U.S.) Navy's overarching operational framework. In support of the OFRP, the Fleet Training Continuum (FTC) presents guidance for training in increasingly difficult scenarios and environments. LVC solutions must be able to support the full spectrum of scenarios and environments accurately.
Deployable/Internal Mount Solution	Previous analysis shows that internal mount solutions will ultimately provide the most realization of future LVC capabilities as well as allow aircraft to be externally configured as they would for actual operations. Accurate external configuration is fundamental to realistic training.
Tethered and Untethered Operations	LVC solutions must incorporate the technology that facilitates worldwide, realistic training.
Single-Ship to Large Force Scalability	From the most basic single-ship operations to comprehensive real-world scenarios, simultaneous operations across all event and package sizes must be accomplished. The spectrum of difficulty needed to meet all training requirements requires varying numbers of entities that represent blue forces, red forces, and the operational training environment.
Persistent/On-Demand Capability	Training in LVC environments must be provided by solutions that facilitate ease of setup and operation from single ship to LFEs.
Augment Red-Air Capacity	Red capabilities must be represented accurately, and force capacity must be augmented through LVC integration to provide realistic training opportunities. This includes representation of capability that is currently available in current live red-air capabilities.
Full Mission Systems: Kinetic and Non-Kinetic	Real-world mission objectives require both kinetic and non-kinetic effects to be accomplished. These effects in an LVC context must be accurately modeled and trained to, and they present unique technical considerations.
Cohabitability/Optimal Frequency Bands	The bandwidth data transport characteristics, via the waveform, must support bidirectional LVC systems while cohabitating in the Continental United States (CONUS) 1780-1850 MHz band or potentially Outside the Continental United States (OCONUS) S or C bands with existing and new DoD users due to the Advanced Wireless Service (AWS)-3 auction, and commercial users in adjacent Long-Term Evolution (LTE) bands.

Requirement	Description
Signal Agility/Dynamic Cohabitability	The network waveform must provide signal agility to enable dynamic cohabitability that is adaptable with other DoD and commercial users in band.
Secure Waveform	The network must be protected by an NSA-certified Tier I device that supports Operational Security (OPSEC) even under the most complex operational scenarios.
Low Latency and Aircrew Proficiency	The network latency combined with the Operational Flight Program (OFP) aircraft software integration should allow for real-time aircrew performance evaluation required to analyze aircrew proficiency and warfighting metrics to support high-fidelity debriefs and follow-on training events.

*Achieving Air and Surface Dominance through a Joint Secure Interoperable LVC Solution, I/ITSEC 2018 Whitepaper, CDR T. Weaver, R. Brisbon

The above requirements are logically grouped into five enabling pillars of LVC training systems (Figure 2.2-1). The cumulative effect of all five pillars together allow the warfighter to blend synthetic (constructive and virtual) data seamlessly into their platform mission systems, and to fully exploit live capabilities in a secure threat representative training environment.

- **Pillar 1**: Consists of Common Protocols for LVC Data and Communications – essential for live platforms, simulators, and constructive threat generators to exchange and interact with the training environment and one another.
- **Pillar 2**: High Fidelity Accredited Models that faithfully replicate platform, sensor, weapon, and other effect (EW, kinetic and non-kinetic) attributes that are projected into live platform mission system displays enable advanced “guising” of threats and enable the platform’s mission systems to interact with the modeled blue and red entities as if they were real.
- **Pillar 3**: Core enabling technologies include Encryption, Multiple Intependent Levels of Security (MILS), Cross Domain Solution (CDS) Guard, dedicated LVC Processor, and a dedicated radio/datalink.
- **Pillar 4**: An LVC waveform with sufficient bandwidth, low-flat latency, spectrally efficient (cohabitating in signal and space with operational waveforms), and capable of adapting to compressed frequency bands available for training.
- **Pillar 5**: Operational Flight Program (OFP) hooks that enable the platform to interact with entities and their effects through the LVC Processor as if they were real-world participants in the training exercise.

Any proposed solution must show the five pillars of high-fidelity LVC across multiple platform types, otherwise it will not close the training gaps noted in the DoD’s Capability-Based Assessment for LVC.

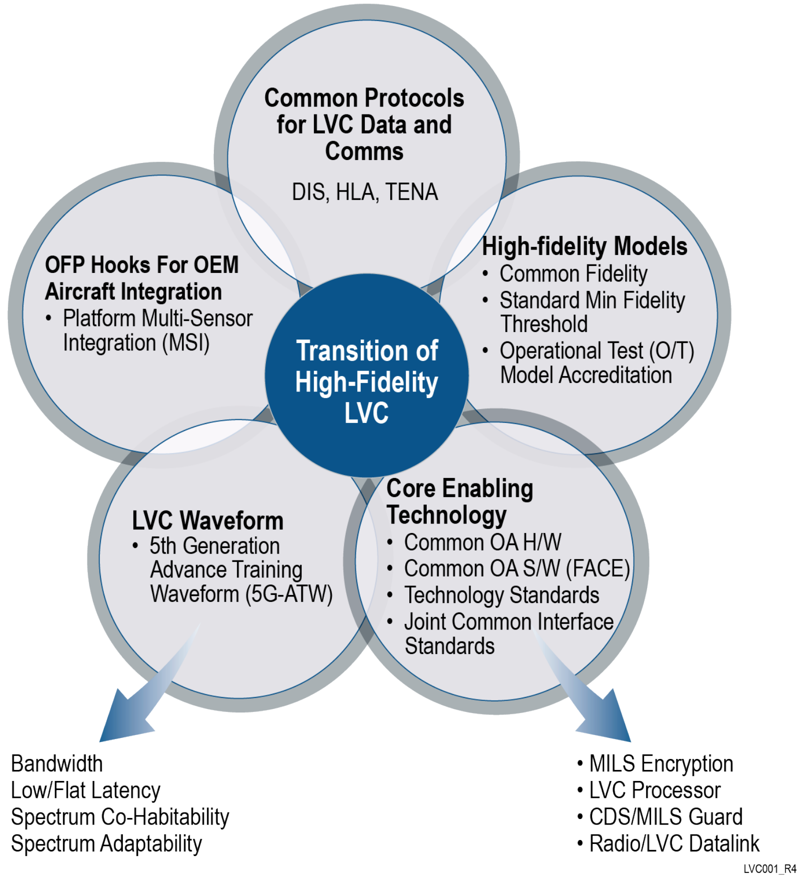

Figure 2.2-1. Five Pillars of High-Fidelity LVC. *All 5 pillars are needed to conduct High Fidelity LVC training.*

KEY POINTS FOR CUSTOMERS

2.3 BEWARE OF PROMISES FROM THE LVC BANDWAGON

There are many vendors that will claim they “do” LVC when in reality they are only able to provide a subset of the overall requirement to support high-fidelity LVC. As an example, linking simulators and a constructive threat generation system (Virtual-Constructive [VC]) provides some training value to operators seeking to build familiarity and switchology (muscle memory) via “reps and sets.” This does not fully close the training gap because physiological and psychological effects experienced using live platforms with real-world physics and affected system performance are not addressed. Whether training in a single domain counter air mission or integrating fires across multiple domains, warfighter performance is not as capable without live training.

Figure 2.3-1. LVC training standards are essential to integrate Joint Fires and Effects. *JTAC using Virtual UAS to conduct training will require common interoperable standards.*

Similarly, embedded training solutions (Live-Constructive) are typically based on simplified threat look-up tables/canned reactions, which are best reserved for initial system familiarization training and not for advanced tactics development and proficiency. Other short-sighted solutions overlay data on displays that is not generated by the platform's computing power, giving a false sense of weapon and sensor performance. The use of "flying simulators" falls into this category. Other "gotchas" relate to Joint, Interoperable standards. Providing a proprietary platform-specific solution that is not using common protocols, data links, and interface standards is counter to the open architecture and interoperability required to train the Joint Force against near-peer threats. (Figure 2.3-1)


Figure 2.3-2.LVC Training in Action. *A USAF F-15E launching with a SLATE pod for an LVC LFE event at Nellis AFB.*

In stark contrast, live aircraft flying with SLATE pods participated in High Fidelity LVC training during the SLATE-ATD LFE events at Nellis AFB throughout the second half of 2018. Feedback from fleet aircrew flying in these LFE events validated the enhanced training value delivered by the SLATE LVC system using the five pillars of LVC (Figure 2.3-2).

2.4 HOW EFFICIENT IS YOUR POTENTIAL VENDOR WITH YOUR MONEY?

Cubic Global Defense is a training company that does not sell operational systems because it focuses on unique training needs. This is important because Cubic understands the cost of training is typically deferred behind operational priorities, and thus they design solutions to meet low cost budgets. Training customers are always looking for ways to stretch their funds to address shortfalls. Cubic is mindful of these fiscal realities and includes upgrade paths into a family of systems that preserve customer prior investments. A case in point is encryption. Cubic got into the encryption business because no defense contractor offered an affordable encryptor at training system prices. Now there is an affordable encryption solution designed specifically for training CONOPS and training budgets that was proven during the SLATE-ATD.

2.4.1 Reuse of Prior Investments in Range Infrastructure

Cubic's LVC solutions reuse proven P5 Combat Training System (P5CTS) infrastructure and add additional interfaces, leveraging a multi-level security architecture to provide all exercise participants with real-time, secure Time Space Position Information (TSPI) and system data to execute desired complex training objectives. During the SLATE-ATD, Cubic's reuse and adaptation of current P5CTS components provided a significant cost and time savings to the Government at roughly 30% of the cost other vendors proposed.

2.4.2 Proprietary Systems Versus Open Architectures

Cubic worked with Government laboratories to finish the development, design, and deployment of the U.S. Government-owned 5G-ATW waveform into our Software-Defined Radio (SDR) for SLATE-ATD. This Government-owned waveform and training architecture means customers can avoid vendor lock and preserve longer-term compatibility with the U.S. Government's LVC architecture.

2.4.3 Multiple Independent Levels of Security - Speed to Certification

Based on decades of experience in fielding customer training solutions, Cubic designed an LVC system from the start to consider MILS. An Interim ATO was granted in record time, and an expansion of the certification to accommodate export approval will be similarly achieved. Other vendors struggle to adopt their legacy approaches to training systems requiring global deployment with coalition partners and fail to achieve certification after multiple attempts at stretching their limited scope initial certifications.

2.5 EXPERIENCE COUNTS

Cubic experience includes the following:

- Brings 45 years of delivering and supporting ACMI systems
- U.S. DoD Program of Record (POR) has over 1,600 pods and 16 active CONUS Air Combat Maneuvering (ACM) ranges flying on over 20 3rd-, 4th-, and 5th-Generation platform types.
- Offers the only U.S. Government-approved F-35 (5th Gen) Internal P5 CTS solution.
- Seventeen Coalition Partners and 30 ACMI ranges worldwide use Cubic's ACMI systems.
- This is not just a pod and ground station, but a family of systems approach.
- SPEAR™ is Cubic's next-generation live-monitor and debrief system for multi-domain training.
- Encryption/MILS – Provides an NSA Type 1-channel MILS solution.
- Platform interface – Accommodates power-only to full 1553/1760 MIL standard interfaces between platform bus and pod or internal mount subsystem to capture platform data in real time needed for effective range monitoring and debrief.
- Air, Surface Ship, Vehicle, Personnel subsystems – From individual soldier to the latest 5th-Generation aircraft, surface ship combatants to ground vehicles, Cubic designs compatible systems to enable customer participation in advanced training environments.
- Advanced data analytics (Figure 2.5-1) – Applying data science to captured training data, Cubic can assist instructors and commands with rapid analysis of trends and opportunities to improve training syllabi and performance.

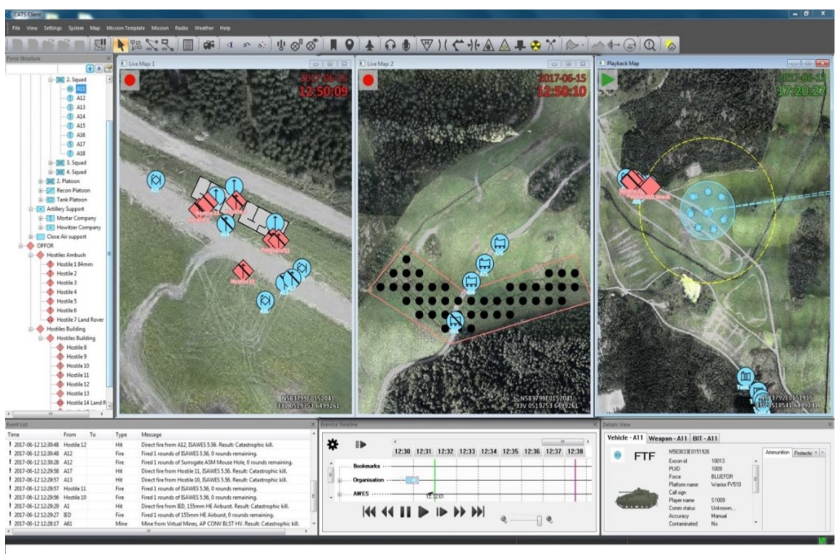

Figure 2.5-1. Advanced Data Analytics. *Instrumentation of the environment and the participants allows more data to be captured during training events. Applying machine learning and advanced analytics to the data yields insights and opportunities to improve the training evolutions, resulting in capable forces the Senior Commander requires to win the fight.*

2.6 PERFORMANCE COUNTS

2.6.1 Availability/ Reliability

When training sortie completion matters and Cubic's systems deliver. Cubic's current ACMI systems (P5 CTS and Tactical Combat Training System [TCTS] 1) enjoy a 96%+ worldwide availability rate for fielded systems. During the SLATE-ATD Capstone event, all the available 16 aircraft launched with full mission-capable SLATE pods and functioning ground station infrastructure throughout multiple weeks of live flying in 110 ^{0}F ambient day temperatures. Unlike previous generation ACMI pods, the SLATE system displays detailed BIT status on each internal component to the Live Monitor computer, as well as status/statistics for message traffic between components. The SLATE system incorporates a level of diagnostics and intuitive graphical user interface never seen before in an Air Combat Training System. Additional results from the ATD are described in the following sections.

2.6.2 SLATE-ATD Results

Figure 2.6.2-1 shows USAF F-15E and F-16s during SLATE-ATD at Nellis AFB. Table 2.6.2-1 lists key capabilities that were validated at SLATE Capstone.

Figure 2.6.2-1. On the Flight Line. *The SLATE pods flew on fleet F-15E, F-16, and F/A-18 E/F/G aircraft during the SLATE-ATD against representative advanced threat scenarios.*

Table 2.6.2-1. Key Capabilities.

Key Capabilities Validated at SLATE CAPSTONE	Comment
Interoperability between Live Aircraft of Multiple Types	F-18 linked via 5G-ATW with F-15 and F-16 in red and blue roles.
5G-ATW data link capacity, throughput, quality of service, and performance in stressing scenario	Maximum Message Count achieved, minimal dropped packets and dropouts, low-latency, maximum range (tethered and untethered).
Injection of Synthetic Entities (VC) into Live Cockpit (L) (“Synthetic-Inject-To-Live” [SITL])	Real-time execution of scenario model; no perceived difference between L, V, or C.
Multiple Independent Levels of Security (MILS) encryption technology and rule sets (NSA Type 1 Encryptor)	Four Levels demonstrated with an NSA Type 1 Encryption.
Live aircraft interchangeable as blue and red air	F/A-18E/Fs, EA-18Gs, and F-15Es performed in both blue and red air role.
Effective Threat Guising by Live Aircraft	F-16s/F-15Es Guised as representative red threat.
Aircraft OFP changes able to process 5G-ATW and provide constructive and virtual injects to the cockpit	Aircraft processed 5G-ATW signals from pod; correctly displayed L, V, and C entities in cockpit.
Red and blue constructive weapon launches and flyouts	Weapons launches and flyouts for Live vs. Live, Live vs. Constructive, and Virtual vs. Constructive for both air-to-air and air-to-ground.
Red and blue constructive weapon kills, misses, and detonations	Kills demonstrated for Live, Virtual, and Constructive entities.

Key Capabilities Validated at SLATE CAPSTONE	Comment
F-16 and F-18 simulators connected to ground station and Distributed Mission Operations Network (DMON) and displaying L, C's and V's	F-16 and F-18 interconnected with Ground Station and fully functional within LVC architecture.
Realistic and effective training	Aircrew interviews and surveys indicated that no differences perceived between L, V or C threats.
LVC performance of SLATE system, interfaces, and data standards in Government-owned, non-proprietary architecture and waveform	Compressed DIS and DIS data standards, MILS, and cross-domain solutions validated; 5G-ATW data link validated under stressing scenario.

2.6.3 Modern Production Facilities for Upgrading and New Product Orders with Secure Supply Chain and Reliable Partner Ecosystem

Cubic continues to invest in modern International Organization for Standardization (ISO) standards-based facilities and secure supply chains for parts provided by our team of partner companies. We recently modernized our San Diego, California, manufacturing facility to support our Cubic LVC production orders, in addition to expanding our other manufacturing facilities.

Are you ready to take your training to the next level? Cubic is designing and developing the future of LVC systems. Today.

ACRONYMS

Acronym	Definition
5G-ATW	5th Generation Advanced Training Waveform
ACM	Air Combat Maneuvering
ACMI	Air Combat Maneuvering Instrumentation
AFRL	Air Force Research Laboratory
ATD	Advanced Technology Demonstration
AWS	Advanced Wireless Service
C2	Command and Control
C2ISR	Command and Control, Intelligence, Surveillance, and Reconnaissance
CDS	Cross-Domain Solutions
CONUS	Continental United States
DIS	Distributed Interactive Simulation
DMON	Distributed Mission Operations Network
DoD	Department of Defense
FACO	Final Assembly and Check-Out
FTC	Fleet Training Continuum
HLA	High-Level Architecture
H/W	Hardware
ISO	International Organization for Standardization
LFE	Large Force Exercise
LTE	Long-Term Evolution
LVC	Live, Virtual, and Constructive
MILS	Multiple Independent Levels of Security
MSI	Multi-Sensor Integration
NAVAIR	Naval Air Systems Command
NSA	National Security Agency
NTTR	Nellis Test and Training Range
OCONUS	Outside the Continental United States
OEM	Original Equipment Manufacturer
OFP	Operational Flight Program
OFRP	Optimized Fleet Response Plan
OPSEC	Operations Security
O/T	Operational Test
P5 CTS	P5 Combat Training System
POR	Program of Record
QA	Quality Assurance
SDR	Software-Defined Radio
SI	System Integrator

Acronym	Definition
SITL	Synthetic-Inject-To-Live
SLATE-ATD	Secure Live, Virtual, and Constructive Advanced Training Environment–Advanced Technology Demonstration
SPEAR™	Simplified, Planning, Execution, Analysis, and Reconstruction
S/W	Software
TCTS	Tactical Combat Training System
TENA	Test and Training Enabling Architecture
TSPI	Time Space Position Information
TTP	Tactics, Techniques, and Procedures
U.S.	United States
VC	Virtual Constructive