Proceedings of the 2020 Winter Simulation Conference
K.-H. Bae, B. Feng, S. Kim, S. Lazarova-Molnar, Z. Zheng, T. Roeder, and R. Thiesing, eds.

LOW ALTITUDE AIR DEFENSE TRAINING SYSTEM

John R. Surdu
Dirk Harrington
Jason Black
Tony Lynch
Wyatt Schmitz
Jordan Bracken

Cole Engineering Services, Inc.
12253 Challenger Parkway
Orlando, FL. 32825, USA

ABSTRACT

The Army has a significant training gap for Stinger gunners and teams. In particular, there is no solution that enables Stinger teams to get credit for successful engagements in large force-on-force exercises if the aircraft are not equipped with MILES detectors, which is apparently usually the case. This paper describes the development of a surrogate Stinger missile that facilitates both home station and deployed force-on-force training. The effort described in this paper resulted in a single device that addresses the training previously addressed by the three other devices, all of which are aging and often irreplaceable. This paper describes the design of the Low Altitude Air Defense Training System (LAADTS), the implementation of the prototype and results, and the future work.

1 INTRODUCTION

Placing a Stinger into operation and engaging targets is a complicated process, involving many steps that must be accomplished in the correct sequence (Gung Ho Vids 2015). Training of Stinger gunners is one of the top training priorities for the US Army; however, there are few training devices to train Stinger teams, whether in Air Defense units or non-dedicated teams in infantry units. For home station training, units may have access to the Field Handling Trainer (FHT) and the Tracking Head Trainer (THT). The FHT is described by Air Defense soldiers as a lead-filled pipe with no functionality. The THT enables soldiers to train to put the Stinger into operation and to track targets, but most of these are vintage (from the 1980s) and are not replaced when they break. A battalion might have one or two THTs. The Improved Moving Target Simulation (IMTS) enables gunners to track 1980s vintage drones. These devices are not suitable for force-on-force training at a training center.

There are approximately 75 laser-based (i.e., Multiple Integrated Laser Engagement System [MILES]) Stinger simulators, 65 of which are at the National Training Center (NTC). The challenge is that in most cases, the Army and Air Force aircraft participating in exercises at the NTC rarely have MILES receivers. As one Air Defense general officer recently described, real time assessment of successful air defense engagements does not occur. He related an anecdote that occurred at the NTC in which they had photographic evidence that a Stinger team successfully engaged a low-flying jet. Because they could not get credit for real-time casualty assessment, the jet went on to bomb a brigade command post and received credit for doing so. The brigade headquarters was erroneously assessed as casualties and taken out of the exercise for two hours until the air defenders could get credit for the kill.

US Army PM TRADE (Training Devices) contracted us to demonstrate whether current location and orientation sensor accuracy were sufficient to create a force-on-force Stinger training capability. The effort described in this paper resulted in a single device that addresses the training previously addressed by the FHT, THT, and Improved Moving Target Simulator (IMTS). This paper describes the design of the Low Altitude Air Defense Training System (LAADTS), the implementation of the prototype and results, and the future work.

2 THE PURPOSE

Army Stinger training has historically been part of a specific Military Occupational Specialty (MOS) where soldiers with MOS 14P were the dedicated MANPADS (Man Portable Air Defense System) team members. With long term deployments in the current theater of operations, Stingers became much less relevant because of complete air superiority. This impacted the overall strategic view of low level air defense coverage to the combined arms forces and resulted in the removal of MANPADS teams from maneuver units. Since that occurred, the Army has moved towards the Avenger system as the low level air defense system and relegated Stingers to use by maneuver units as requested for soldiers to receive an Additional Skill Identifier (ASI). The first maneuver soldiers went through a five week condensed version of Air Defense Artillery (ADA) training in May of 2017 (Department of the Army 2018). These soldiers represented the Infantry, Armor, and Logistics. This is a paradigm shift from the Army's historical perspective on close in ADA where maneuver units had dedicated MANPADS (CALL 2018).

The challenge facing the Army is how to sustain the 14P soldiers in their ability to engage aircraft with Stingers, and also the large task of sustaining and training the maneuver force (CALL 2018). Historically the ADA community used a number of training tools to maintain proficiency. This included everything from an installation based M134 IMTS operating from a single fixed location on an installation, which provides a large dome with projected images on it down to the much older and no longer supported M60 FHT (which last received any maintenance manual updates in October of 2003), or the even older M134 and M160 THT whose last manual update was March of 1992. All of the individual training systems had additional appended equipment to collect or provide inputs to the training, or as in the case of the MILES Stingers to engage aircraft equipped with instrumentation. Figure 1 shows both the M134/160, which uses an appended "Performance Indicator Assembly" to capture the firing steps of individual soldiers, and a nonstandard BCU (Battery Coolant Unit), which is larger and weighs more than the actual BCU on a Stinger. Unlike the LAADTS, this system does not capture any metrics on training over time that the LAADTS has incorporated into its Instructor Operator System (IOS).

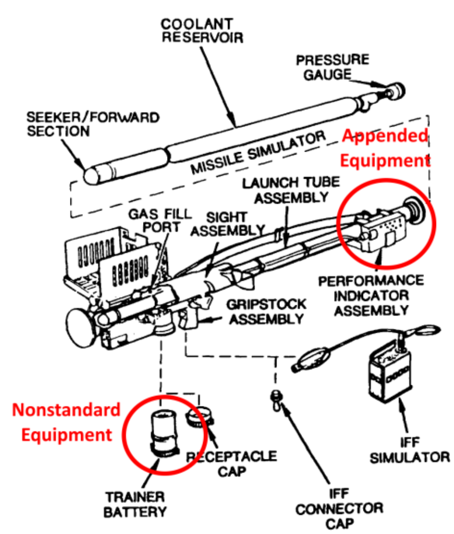

Figure 1: M134/M160 Tracking Head Trainer additional equipment provides negative training (Department of the Army 1984)

When the Army moved to compress the ADA community removing MANPADS teams, they also consolidated the old Army Field Manuals FM 44-18 and FM 44-18-1 into the single Army Techniques Publication 3-01.18 (Department of the Army 2018). Both FM 44-18 and FM 44-18-1 discussed the use of the different training tools for Stinger training, ATP 3-01.18 no longer provides any insight into the use of those training tools. An assumption for this lack of inclusion could be that none of the older training tools, the FHT (Department of the Army 1984) or the THT (Department of the Army 1984), are supported because the lack of any logistical sustainment trail. During discussions with an ADA Master Gunner, he made the comment that when they turned in a THT to be repaired, the depot level maintenance stated the trainer had to be disposed of because it was no longer supported.

Currently the IMTS (Thales 2018) is used to fill the training gaps created by aging and scarce THTs. The IMTS (Thales 2018) must be scheduled well ahead through the installation Digital Training Management System (DTMS), a centralized scheduling system where units will compete for training time. This leaves individual soldiers and teams without a robust ability to train and be prepared for the Stinger Gunnery Tables outlined in the Maneuver Leader's Guide to Stinger (CALL 2018).

While the LAADTS training for all ten levels of the Gunnery Tables for Stinger (Department of the Army 2018) at the point of need, where soldiers spend the majority of their time at Home Stations preparing for their Gunnery Tables in support of their Maneuver elements its primary use case is live, collective, force-on-force training. Current training tools provide no integrated training capability at Home Stations or the Army's premier training locations as described section 1 above. The CTCs (Combat Training Centers) are completely lacking in any ability the individual Stinger gunners to defend the maneuver units effectively. LAADTS supports Home Station using the Home Station Instrumentation Suite (HITS) and also at the CTCs using CTC-IS. The LAADTS can directly engage live moving aircraft within the battlespace and provide real time adjudication of engagements closely replicating the firing of a live Stinger.

The LAADTS provides immediate feedback on proper Tactics Techniques and Procedures (TTPs) using modern relevant technology with no appended equipment on either the target or the Stinger. Importantly, air defenders will be able to "get credit" for hits during collective training, impacting the flow of the exercise.

The LAADTS system consists of three main components: a custom-built FIM-92 replica with proprietary hardware and software, an Instructor Operator System (IOS) that allows trainers to grade gunners, and a set of microservices that provide high-fidelity terrain correlation, wound adjudication, and interoperability with existing training services. The LAADTS system marks an evolutionary turn in MANPADS training by providing a robust solution to one of highest training gaps (Milly and Esper 2018).

LAADTS' primary component is the custom built FIM-92 training devices. This Stinger surrogate has all the functioning components of an operational Stinger, including the uncage, tracking, safety, and firing switches. The Identification Friend or Foe (IFF) antenna does not operate as an antenna, but the operator must properly deploy it, screw in the Battery Coolant Unit (BCU), and press the various switches in the correct sequence.

The second major component of LAADTS is the IOS, which is implemented on a ruggedized Android tablet computer. The IOS runs a custom app that allows trainers to score gunners through the approved Go/No-Go firing procedures. LAADTS connects to the IOS via Bluetooth and communicates shot records in real time. LAADTS utilizes Google Protobuf (Google Developers 2020) for efficient message passing between components. Based on messages received from the Stinger surrogate and human observation, the IOS grades and records results of the operator putting the weapon into operation and engaging targets. As each procedure is executed, the appropriate tone is played to ensure gunners are receiving the audible feedback they expect from the real Stinger. The Stinger also grades the gunner on proper leading by analyzing the sight picture relative to the range ring. Image processing resulting from machine learning scores the gunner by overlaying a virtual super-elevation and lead reticle into the sight picture. The IOS allows trainers to create custom procedures and criteria to facility unique or evolving doctrine. A single IOS tablet can service up to seven gunners simultaneously.

The functions described to this point enable the LAADTS to replace the FHT and THT. They support individual training at home station, such as in a motor pool. Where low-flying aircrafts are not present, the unit can hang a something hot from a flag pole or mast to act as a target. Where low-flying aircrafts are present, LAADTS enables operators to track and engage aircraft and get credit for having executed their procedures properly.

The third major component of LAADTS is the LAADTS Interface Services (LIS). LAADTS uses these interface services to connect to instrumentation systems, such as Combat Training Center Instrumentation System (CTC-IS) and Home Station Instrumentation and Training System (HITS). When LAADTS is connected to LIS, LAADTS subscribes to the position and location information (PLI) of the aircraft in a training event. When a gunner engages targets with LAADTS, the weapon monitor uses its own position and orientation information to determine which possible aircraft the gunner is engaging. Then the appropriate tone is played when the gunner interrogates the target for IFF. When the gunner fires the missile, hit or miss information is sent through LIS to the site's instrumentation (e.g., CTC-IS or HITS) where the target can be notified of its status. This allows Stinger gunners, trainers, and helicopter pilots to all receive immersive training through their respective systems. At the end of the exercise trainers are able to generate a take-home package for each of the gunners in PDF form.

3 SYSTEM DESIGN

As discussed in the previous section, LAADTS is composed of three major components. The surrogate Stinger launch tube contains a thermal sensor and the first major component, the Weapon Monitor (WM). The WM is a small computing device with built-in Bluetooth radio and LTE radio. The Weapon Monitor also includes an orientation sensor. The WM exchanges information with the second major component, the IOS, via Bluetooth. As the soldier executes each step of putting the weapon into operation and engaging targets information is sent as JSON (JSON 2020) packets from the WM to the IOS.

The Weapon Monitor also collects images from the thermal sensor and uses image processing to assess whether the soldier properly tracked and super-elevated the launch tube before firing. The assessment is performed on the Weapon Monitor but forwarded to the IOS for display, reporting, and after-action review.

The LAADTS patented Stinger training technology uses computer vision (Figure 2) to identify targets using a custom-built board providing the following: CPU, LTE, Bluetooth radio, Wi-Fi radio, inertial measurement unit (IMU), general purpose input and output (GPIO), and USB-C. LAADTS is able to read the camera's feed live and run algorithms over the images to facilitate the scoring of the gunner. The IFF switch, uncage button, and trigger are wired via GPIO that the weapon monitor listens to and responds with the appropriate audible tones. For grading purposes messages are passed between the Stinger and IOS over Bluetooth. Using Google Protobuf (Google Developers 2018), the same messages are able to be passed to LAADTS Services for distribution to additional systems over LTE. The thermal camera is an industrial-quality camera with a range that extends beyond the operational capability of the Stinger missile.

Figure 2. Thermal image of a commercial aircraft captured with the LAADTS thermal sensor.

The IOS utilizes the latest Android technology to provide a robust scoring and evaluation capability for gunner trainers. The IOS can connect to multiple stingers simultaneously allowing a single trainer to provide instruction to up to seven gunners. The IOS is an optional component and LAADTS can provide gunner training independent of a trainer if desired. When connected to LAADTS Services over LTE (Figure 3), the gunner can engage and stimulate CTIA-enabled systems, such as helicopters. When the gunner properly engages the target and a hit is recorded the helicopter's devices will be stimulated. Again, Google Protobuf (Google Developers 2020) is used providing a strongly-type network-efficient messaging protocol. By utilizing Protobufs, LAADTS also enables other systems to interface in the system by sharing the Protobuf file.

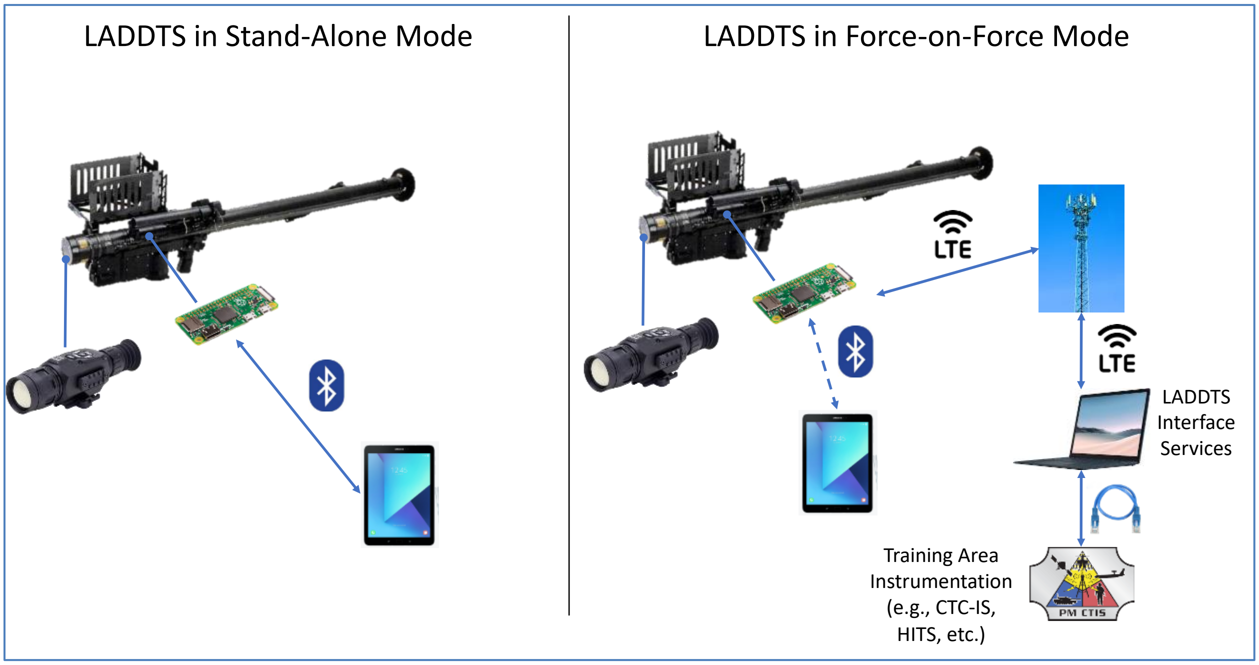

Figure 3. System view of LAADTS.

When the soldier is participating in a force-on-force exercise engaging aircraft, the Weapon Monitor is connected via LTE radio to the LIS on a remote computer. LIS communicates with the appropriate instrumentation system at the training location. LIS subscribes to the PLI of all aircraft in the exercise. When the soldier presses the IFF interrogation button, the Weapon Monitor reports its location and orientation to the OBSAT Interface Services, which uses that information and the PLI of aircraft to determine which aircraft the soldier is engaging. The LIS informs the Weapon Monitor whether the target is friendly or hostile, so that the appropriate IFF tone is presented to the soldier. When the soldier fires the LAADTS, the Weapon Monitor determines if the soldier properly performed all steps in the engagement process, tracked the target, and super-elevated the launch tube. This information is sent to LIS, where the real-time adjudication of hit or miss is conducted. LIS performs this hit or miss determination on the remote computer because, in the future, the computation should inform the target that it has been interrogated and engaged so that it can perform countermeasures, and those countermeasures should impact the probability of a hit.

Note that whether operating in stand-alone or force-on-force modes, the functions of the Weapon Monitor are identical with the exception that the Weapon Monitor reports soldier performance to both the OBSAT interface Services and the IOS. In force-on-force mode, the IOS is optional, but in stand-alone mode the IOS is mandatory.

4 IMPLEMENTATION AND RESULTS

One of the key features of the LAADTS solution is the trivial amount of work it takes to use the system and the quality of the result (Figure 4). CESI (Cole Engineering Services, Inc) created a very user friendly experience for the Instructor and Gunner. The production quality, fieldable LAADTS is IP67 compliant to protect the internal electronics and made of a material to withstand shock from drops or falls and water submersion up to three feet. The unique design of the hardened solution eliminates negative training, as the LAADTS has the same attaching mechanism from the gripstock to the launch tube. With the current design of the LAADTS, the absence of appended or protruding electronics retains the look and feel of the real FIM-92 Weapon System. The LAADTS has the same weight and center of gravity as the real FIM-92. All components of LAADTS closely resemble the real FIM-92 to mitigate or eliminate negative training while using the LAADTS.

Figure 4. Training exercise using the LAADTS overseen with the Instructor Operating Station

The first main component of the LAADTS is the launch tube, where the Weapon Monitor resides. The launch tube and all electronics inside are IP67 rated. From the bottom front of the launch tube is an IP67 rated connector pad to connect to the gripstock and an IP67 rated on/off switch. Once powered on and booted, the Weapon Monitor will begin wireless transmission of its status to the IOS tablet. The electronics inside the launch tube capture six degree of freedom (6-DOF) orientation data and video images from the thermal sensor. The Weapon Monitor uses machine learning to identify target and assess target tracking and launch tube super-elevation based on gunner actions. The gunner must super-elevate the launch tube before pulling the trigger. The Weapon Monitor uses this information to calculate hit probability and transmit data to the IOS in real-time. The Weapon Monitor exchanges information with the gripstock and additional actuators on the launch tube. The gripstock includes the same buttons and switches of the real

Stinger to enable the trainee to operate LAADTS in a realistic manner. The additional electronics on the exterior of the launch tube include a cheek vibration actuator and a speaker to present the correct tones and sensation of the real FIM-92 during the sequence of steps in engaging a target.

The thermal sensor in the launch tube records a frame from its own video stream and relays to the Weapon Monitor using a direct cable link. The white-hot formatted image is passed through to the recognition models, which is a trained Model Net V3/Caffe model, in order to locate aircrafts with the frame captured. The models are implemented using the OpenCV library. The output of the model calculations is a single processed image marked with labels and bounding geometry to identify targets. In stand-alone mode (see Figure 3), the Weapon Monitor determines if the gunner successfully engaged the target and produces a "go/no-go" result and forwards appropriate information, via Bluetooth radio, to the IOS. In force-on-force mode, the Weapon Monitor passes this information via an LTE radio to the LAADTS Interface Services where a hit/miss calculation is made against aircraft in the training event.

The LAADTS gripstock attaches and detaches from the launch tube as it does with the real FIM-92. Each of the buttons and switches are wired to a special connector that communicates ate to the Weapon Monitor using the contact pad on the bottom of the launch tube. The knobs and switches are also IP67 rated. Each of the buttons and safe/arm lever of the gripstock are active and wired to the specialized connector. The Battery Coolant Unit (BCU) requires a quarter turn insert method to attach to the gripstock, just like the actual FIM-92. The Weapon Monitor recognizes when the BCU is inserted and the Safe/Arm lever is engaged. As a gunner proceeds through the firing procedures, LAADTS plays appropriate tones through the speaker. These tones serve as audible queues to inform the user of the progress throughout the procedures. For example, different tones play whenever a charged BCU is inserted and the Stinger is switched to "armed," while a target is being tracked, and when the triggered is pulled.

The second major main component of the LAADTS is the Instructor's IOS, which is mandatory in stand-alone mode but optional in force-on-force mode. This ruggedized Android tablet allows an instructor to interact with up to seven Weapon Monitors simultaneously to facilitate individual and group training. The tablet connects to each of the LAADTS launchers automatically. The instructor can monitor connection status, status of the Weapon Monitors, and engagement results for each gunner. After each Weapon Monitor connects to the IOS, the Instructor can add additional information for the gunner trainees, exercise-specific training procedures, and precise sighting calibrations for the LAADTS devices if desired. Paired devices have this information loaded automatically from past training exercises to reduce startup time for conducting new training exercises.

The IOS tablets are pre-loaded with the most current setup and engagement procedures; however, instructors can add additional steps to create custom procedures to meet unit-specific SOP and training needs. Events such as IFF interrogation, weapon uncaging, correct super-elevation, and target lead are automatically recorded in the IOS. Some steps require human observation and recording by the instructor, such as whether the trainee held his or her breath before firing the weapon. The IOS shows the "go/no-go" results of each step in the firing procedure. This feature enables a single instructor to oversee proper firing procedures across multiple LAADTS Stingers. After each event, the instructor can export a "Take Home Package" PDF to an inserted SD card, which details the performance of each of the trainees that participated in the exercise. This facilitates recording trainee performance on the various firing tables for the Stinger.

After each exercise, the instructor can export a "Take Home Package" PDF to an inserted SD card, which details the performance of each of the gunner trainees that participated in the exercise. The file will confer information on the performance of the participants of the training exercise with images for weapon accuracy and grading based on correct adherence to the exercise specific training procedures.

Home station sustainment training: The trainer has the ability to conduct training in three different ways. In stand-alone mode, the trainer can setup individual gunner training or a group gunner training using an elevated stationary object that conducts heat to track and follow the procedures to fire the LAADTS. This is ideal for home-station sustainment training. Also in stand-alone mode, gunner may engage moving targets, such as real aircraft or drones. Instructors can take their units to areas where drones or other flying vehicles are present. The Weapon Monitor and the trainer assess "go/no-go" for each step in the firing procedure.

Real time casualty assessment under field conditions: In stand-alone mode, the results of the engagement are forwarded to the IOS for inspection and recording by the trainer. The instructor can use the IOS to conduct an after action review with the gunners. In force-on-force mode, the LAADTS is used to assess hits and misses against actual aircraft participating in a training event and enables air defenders to practices tables eight through ten under field conditions. Unlike laser engagement systems, such as MILES, the aircraft participating in the event need not be equipped with special laser sensors, but they are required to broadcast their PLI to the instrumentation system of the training area. The LIS communicates with the instrumentation system and subscribe to information about aircraft in the training area. LIS uses the reported gunner location and weapon orientation to determine which aircraft the gunner is tracking and sends the aircraft ID and relationship (is it friendly, "blue," enemy, "red," or unknown). This information enables the LAADTS to play the correct IFF tone to the gunner. When the gunner fires the missile, LAADTS provides the "go/no-go" information along with one or more low-resolution images (to conserve training area bandwidth) to prove a successful or unsuccessful engagement to LIS. The LIS uses this information to compute a probability of hit and then generates a random number to determine if the aircraft was hit. The LIS can use additional information from the instrumentation system, such as whether the aircraft was employing appropriate countermeasures, to modify the probability of hit. If the aircraft is hit, the instrumentation system is informed. It is then up to the exercise director to decide whether to remove the aircraft from the event.

5 FUTURE WORK

During force-on-force mode, CESI is currently working on the LAADTS to have an on-power requirement for four days. Before starting the actual training, the gunner or logistics personnel will turn on the launch tube and connect the gripstock. The LAADTS will resemble a FIM-92 case. As future work, we need to acquire an actual Stinger transport case so that we can fabricate replicas.

The LIS has implemented a single interface microservice: CTIA-4. Moving forward, additional microservices are needed for different instances of CTIA and CTC-IS, HITS, and perhaps FlexTrain. In this way, the instrumentation infrastructure will be transparent to users during force-on-force events.

The patented OBSAT technology used in the Stinger can be applied to additional weapon systems. We have already begun developing a mortar trainer and a simulator for the MAAWS rocket launcher. Adapting the technology to other weapon systems has proven to be a straight-forward task, but that work needs to be resourced.

6 SUMMARY

Air defense training is a critical training gap for the US Army. This effort eliminated the use of lasers and leveraged modern image processing technologies to create a capable and expeditionary (i.e., portable) training system. LAADTS supports all Stinger gunnery training tables from 1 to 12. The low-cost device supports home-station sustainment as well as real-time casualty assessment during force-on-force training. The solution has no appended equipment in stand-alone mode and reduces or eliminates negative training by emulating the form, fit, and function of all components of the Stinger.

REFERENCES

Center for Army Lessons Learned (CALL). 2018. Maneuver Leader's Guide to Stinger: Lessons and Best Practices.

Department of the Army. 2018. Army Techniques Publication (ATP) 3-01.18, *Stinger Team Techniques.*

Department of the Army. 2003. Operator's and Organizational Maintenance Manual for Stinger Guided Missile System. TM 9-1425-429-24P.

Department of the Army. 1984. *Stinger Team Operations FM 44-18-1.*

Google Developers. 2020. Protocol Buffers. https://developers.google.com/protocol-buffers, accessed 1st April.

Grinston, M., McConville, J., McCarthy, R. 2019. *The Army Modernization Strategy*.
Gung Ho Vids. 2015. How to Fire a Stinger. https://www.youtube.com/watch?v=q0nuhI05QyA, accessed 1st April.
JSON. n.d. Introducing JSON. https://www.json.org/json-en.html, accessed 1st April.
Milly, M., Esper, M. T. 2018. *The Army Strategy*.
Thales. 2018. Improved Moving Target Simulator (IMTS): Stinger Missile Trainer (Stinger Missile Trainer). https://www.intersense.com/?nproject=leading-water-manufacturer, accessed 1st April.

AUTHOR BIOGRAPHIES

JOHN R. SURDU is a senior scientist and project manager at Cole Engineering Services, Inc. He earned his Ph.D. in computer science from Texas A&M University. He has served in a variety of leadership positions within the US Army, including the PM for the One Semi-Automated Forces (OneSAF) program. He served as an assistant professor at the United State Military Academy, West Point. He is a former DARPA PM. He is the primary inventor on two patents related to live training. His email address is buck.surdu@cesicorp.com.

DIRK HARRINGTON is a project manager at Cole Engineering Services, Inc. He earned a BS in Computer Science from Florida Southern College. He has completed his course work for an MS in Computer Science from Florida Institute of Technology. He was the architect and original implementor of the *User Data Gateway* for the constructive simulation OneSAF. His e-mail address is dirk.harrington@cesicorp.com.

JASON BLACK is Senior Systems Engineering Lead at Cole Engineering Services, Inc. He has a B.S. in Electrical Engineering from Florida Atlantic University. He has worked in the defense training simulation industry for more than 10 years. He had also maintained a leadership role in different areas of business for more than 20 years. He is currently the primary and secondary inventor on 4 patents in the realm of head wearable technologies. His email address is Jason.Black@CESICorp.com

WYATT SCHMITZ is a junior developer at Cole Engineering Services, Inc. He earned his computer engineering undergraduate degree from the University of Central Florida. He has supported software development for several responsive webpages. He has acted as the team lead for mobile applications for real-time, geolocation based on-demand services. He is the lead mobile developer for the live training team. His email address is wyatt.schmitz@cesicorp.com

JORDAN BRACKEN is a software developer at Cole Engineering Services, Inc. He earned his undergraduate degree in Game Development at Full Sail University. He has been developing at Cole Engineering Services, with efforts focused on supporting the implementation of code, maintaining project standards, and stabilizing software features. His email is Jordan.Bracken@cesicorp.com.