Training Range Modernization: New Technology on Old Infrastructure

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ABSTRACT

This paper describes the challenges in modernizing existing training ranges in the Army. As existing live-fire training ranges age, they become more difficult to maintain as equipment breaks down and their foundational technologies become increasingly difficult to procure due to obsolescence. The prohibitively high cost of complete range replacement coupled with ever-tightening training budgets has driven efforts to find innovative ways to extend the lives of these ranges while providing a path for affordable modernization of the ranges to align with emerging range standards and specifications, while continuing to provide dynamic support to today's Warfighter.

The Army has developed and deployed a single common target control systems called TRACR (Targetry Range Automated Control and Recording) to support the command and control of the Future Army System of Integrated Targets (FASIT) devices. While TRACR is capable of controlling ERETS (Enhanced REmoted Target System) legacy targets via a hardware/firmware bridge to the legacy infrastructure, there is no means to deploy modern FASIT targets on these legacy ranges.

The use of Digital Subscriber Line (DSL) technology over existing range wiring (i.e., twisted pairs), allows incremental upgrades to modern FASIT devices and facilitates new technologies such as downrange cameras onto these existing ranges. This approach will modernize these legacy ranges without the need for expensive trenching and infrastructure upgrades.

ABOUT THE AUTHORS

Joe Smith is a Senior Software Engineer with Riptide Software. He has worked for the past three years as one of the primary developers of the TRACR control system, and has worked closely with PEO-STRI in the development of the FASIT standard. He has over seven years experience working on DoD training systems and 16 years of overall software development experience. He earned his B.S. and M.S. in Electrical Engineering from Florida Institute of Technology.

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INTRODUCTION

The U.S. Army has over the course of many years invested significant amounts of monies in the development, construction, equipping, operating, and maintaining various Live Fire Ranges in support of training soldiers and enhancing mission readiness and proficiencies. Many of these existing ranges are aging, and require increasing amounts of funds to maintain and operate. The current ranges support the operational needs of the ranges, but present challenges in obtaining spare/replacement parts, complying with Information Assurance requirements, and providing a growth path of the incorporation of new/emerging technologies.

The Army has made the determination and investment to establish a new common standard for all live-fire range targets and devices to be utilized throughout all of the various ranges. The Future Army System of Integrated Targets (FASIT) program establishes these common performance, communication, and protocol standards and specifications. The FASIT standards were built around the reliance of TCP/IP for all data communication. Establishing these standards will assist the Army in lowering the total ownership and operation costs of the Live Fire Ranges.

In conjunction with the FASIT standards, the Army has developed and deployed a single common target control systems called Targetry Range Automated Control and Recording (TRACR) to provide the command and control of these FASIT ranges. Additionally, via the TRACR efforts, the Army developed an interface adapter which allows the TRACR Control System to control a subset of the legacy targets known as Enhanced REmoted Target System (ERETS).

But these efforts only addressed the modernization of the control system on the ERETS ranges, and not the mechanism to upgrade the legacy ranges to the FASIT standards/targets. The difficult question was how to modernize an existing range to the FASIT standards while minimizing cost and range shut-down time. The straightforward means of infrastructure replacement would carry significant costs and require the individual range be shut-down for an extended period of time. Consideration of environmental impacts and the risk of unexploded ordnance only increased the potential cost and schedule impacts.

The answer to avoid the cost and schedule risks and burden, while maintaining performance and alignment to the current standards lies not with the replacement of the infrastructure, but in its utilization in a means that has been adapted by the commercial phone industry; overlaying a Digital Subscriber Line (DSL) onto the twisted pair wire infrastructure.

CURRENT RANGE INFRASTRUCTURE (ERETS)

The ERETS infrastructure is currently used on a large number of live-fire ranges. The ERETS system, an early 1980s design, began deployment in the mid to late 1980s and consists of two logical components: downrange target hardware and range control devices. In the range control tower, there is an RCS (Range Control Station) computer used to control the targetry on the range. These systems are DOS-based 286/386 systems equipped with a custom ERETS Range I/O card (ISA bus). The RCS is connected to an SDA (Signal Distribution Assembly) panel via a custom data cable. The SDA panel contains circuit boards that convert between internal TTL logic levels (0/5V) and the ±21.75V signal levels used for the downrange targetry. The system was designed to use up to 16 "wires", each of which consists of six twisted pairs. ERETS uses four of the pairs, leaving two as spares. Each wire is theoretically capable of supporting up to 45 targets, although in practice it is rare to encounter more than 32. ERETS uses a custom full-duplex serial protocol for communicating commands and targetry status.

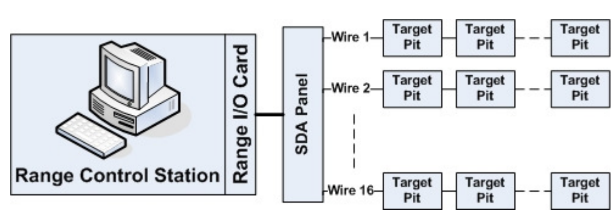

Figure 1 ERETS Infrastructure

The ERETS system is entirely Government owned, and was designed in a manner similar to a weapon system. This resulted in a highly robust system that is still in widespread use today. Despite the strength of the design, however, it was not immune to obsolescence. As time passed, critical system components could no longer be procured or repaired. In particular, a single point of failure in the system was the RCS. As personal computer technology progressed, the 286/386 computers gave way to Pentium® systems and more modern operating systems. The ISA slots that were once common were no longer available. The Range I/O card could no longer be procured, so as these cards failed over time, the stockpile of spares diminished until there were no more available. Fortunately, other electronic components of the ERETS system were more readily repairable by range maintenance personnel that had grown familiar with the components over the years. Even so, it became clear that in order to avoid a large number of costly range upgrades in the short term, it was necessary to develop a cost-effective solution to extend the life of existing ERETS ranges.

CURRENT CORPS OF ENGINEERING INFRASTRUCTURE STANDARDS

The Corps of Engineers (COE) construction and range standards are defined by CEHNC 1110-1-23, dated December 1994 and updated in March 2007, and were developed under the auspice of the Range and Training Land Program (RTLP) and Sustainable Range Program (SRP). The CEHNC standard defines many aspects of range planning, development, and operations, but clearly establishes the standards and requirements for communication infrastructure for new ranges.

The CEHNC standard indicates that "*... all targetry will be controlled over Ethernet based networks. These networks will be comprised of a combination of fiber optics and copper based systems maximizing the use of Commercial off the Shelf (COTS) electronic components and standards.*" This update resulted in the alignment of the CEHNC standards to the protocols and standards being defined by the FASIT program, i.e., TCP/IP based communications. In particular the CEHNC requires the use of multi-strand multi-mode fiber optic cable between the control tower and Master Target Data Panel (MTDP) and CAT5E or better between MTDPs and individual target positions.

Depending on the range layout and network design, multiple fiber optic cables are utilized within the infrastructure execution. The network design is based on the number of targets and the physical layout and placement of the range devices. The fiber optic infrastructure supports an unlimited number of targets on the infrastructure. This infrastructure approach ensures maximum growth and flexibility in moving training and control data over the range, to include training, audio, and video data.

TRACR/FASIT

Once the ERETS systems were fully fielded, a vacuum was left. New ranges were needed to meet the ever-growing needs of the training community, but there was no common, standards-based solution available to take the place of ERETS. Standardization efforts were underway, but progressing slowly. In the meanwhile, ranges were being deployed with vendor-specific proprietary solutions. As part of these solutions, vendors supplied their own range control software to control the targetry. As a result, range personnel were faced with the challenge of supporting hardware and software from multiple vendors. Some key problems associated with supporting these systems include:

- **Inconsistent interface**. The range control software offered by different vendors employs different user interfaces and operational workflow. This presents a training challenge for range personnel and soldiers as they often must become familiar with multiple systems.
- **Cross-vendor hardware compatibility**. Since each vendor's solution employed proprietary communication protocols, hardware could not be mixed between vendors. This presents an inventory management challenge to track and maintain downrange equipment as well as spares.
- **Version incompatibilities**. Occasionally different versions of the same vendor's solution were incompatible, effectively preventing hardware assets from being used on multiple ranges, increasing the logistics footprint of the systems, and presented an inventory management challenge.
- **Stovepipe solutions**. Since these proprietary range solutions were focused on targetry control, they typically did not provide interfaces for interfacing with external systems. This presents an operational challenge to effectively operate and coordinate multiple training systems and to aggregate the disparate results into meaningful after-action review materials.

In light of these issues, it became clear that a single, common targetry control system was needed to address the training needs of the Army.

PEO-STRI (Program Executive Office of Simulation, Training, and Instrumentation) recognized the need and launched an effort to develop such a solution. The project was dubbed TRACR, and was tasked with providing a single control system for non-instrumented U.S. Army ranges described in Army Training Circular TC 25-8. The system was mandated to, whenever possible, utilize and contribute common software components from/to the LT2 (Live Training Transformation) software product line. This component-based approach helped to expedite development by promoting and facilitating reuse. The solution was also required to support the control of existing ERETS ranges as well as support the emerging FASIT standards. The initial phase of the project was slated to support lane-based small arms ranges with later phases to incorporate the functionality necessary to control larger maneuver-based ranges. It was especially important at the time to quickly provide a simple, cost-effective solution for extending the life of existing ERETS ranges. To meet this need, a hardware adapter was designed and developed to convert the custom serial protocol utilized by ERETS into a simple TCP/IP based network protocol. The adapter allows the RCS and Range I/O card to be replaced with an inexpensive hardware device and a modern computer running the TRACR software. The approach proved to be a success, as has been deployed to 24 installations (80+ ERETS ranges) as of June 2009.

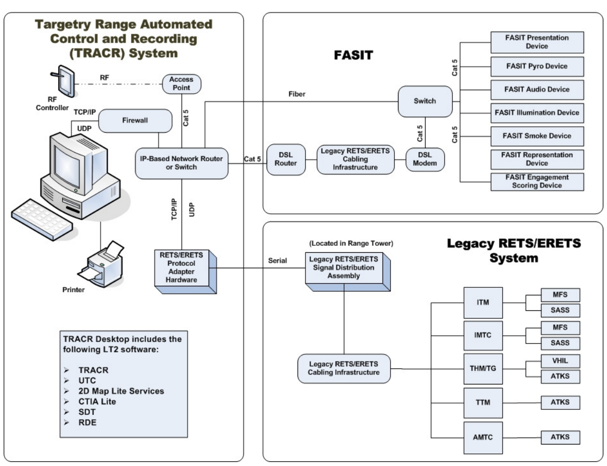

Figure 2 TRACR System Diagram

In order to promote the future growth of TRACR, support for the emerging FASIT targetry standard was designed and built in from the beginning.

The FASIT standard grew out of earlier attempts to develop targetry standards that had either taken too long to complete or had stalled entirely. FASIT built upon those early efforts and attempted to arrive at an achievable standard that was capable of evolving in a controlled fashion to address any minor deficiencies that might be present at the time of its initial release. Vendor input was solicited, both to receive guidance and to ensure industry support. The standard consists of a performance specification for supported targetry devices, and a set of ICDs (Interface Control Documents) that define power and communication connections and specify a set of network messaging interfaces for communicating with targetry devices.

The proliferation of vendor-specific proprietary solutions deployed after ERETS fueled the need to establish a common targetry standard. Having a standard in place allows the government to get the best value for their training dollar by putting vendors on a level playing field with respect to the targetry hardware being procured and deployed. Since the performance and interfaces are standardized, it doesn't matter who manufactures the equipment as long as it adheres to the standards.

Range Modernization Challenge

The challenge facing the range community and material developer is finding the mechanism/solution to migrate the legacy ERETS ranges and infrastructure to mirror the performance of the current Corps of Engineers standards, and support the FASIT specifications and protocols. The constraints facing this challenge are equally daunting; the solution must be inexpensive, not impact range training time, support flexibility and growth, and comply with Information Assurance requirements and frequency allocation restrictions.

There are multiple upgrade paths available, each with its own strengths and weakness against the criteria. While these solutions (range replacement, RS-485 and RF solutions) would yield viable solutions, the performance restrictions and increased costs just cannot be overcome. Until recently, the U.S. Army has only considered these alternatives. This has changed with the consideration of upgrading the ranges via DSL.

From the assessment of performance versus constraints, the best viable solution to employ is the DSL technology.

RANGE UPGRADE PATHS

Entire Range Replacement

Without modernization of aging training ranges, fulfilling the various training requirements down to the individual level for operations to support "go to war" capability within the Army cannot be done. The continued improvement of live-fire ranges and facilities is the key to the development of warfighting skills. As weapons systems become more lethal and the training scenarios change based on mission need or real-world situations, Army ranges must be capable of adapting to these changes.

When a range replacement requires acquiring new land, there are a number of considerations, including:

- Encroachment of commercial and private development
- Protection of threatened and endangered species
- Prevention of surface and ground water contamination
- Deterioration of air quality and sound pollution

These challenges are sufficiently difficult to overcome that sustaining current ranges is a critical task for the Army.

Entire Range Replacement includes a number of very costly endeavors in terms of funding and time. The removal of existing infrastructure seems to be the best fit for the problem at hand. However, the overall process defined by the Range and Training Land Program (RTLP) must be considered, a five to ten year process that includes all of the planning, programming (funding), design, and construction activities. Retrenching to upgrade power and data connections downrange to target emplacements in accordance with current COE standards entails considerable time and expense in the assessment of environmental impacts and possible clearing of unexploded ordnance (UXO). While the process of retrenching has a defined schedule, unknowns such as the discovery of UXO can introduce significant delays, making the range unavailable for training from four months to one year.

The costs associated with range replacement, depending on the type and size of the range in question, can often be prohibitively expensive for the Army. If the Entire Range Replacement alternative was used replace the aging ERETS Ranges, it would have cost the Army $40M to upgrade the infrastructure and replace approximately 10,000 targets on 90 ranges. (This estimate is based $3,289.00 per Stationary Infantry Target lifter, $6,775 for the range control station, and $100K for infrastructure upgrades.) For a typical Modified Record Fire (MRF) Range with 144 SITs, the range upgrade cost would be approximately $550K. In comparison, using TRACR and the ERETS protocol adapter hardware, the range upgrade cost would be approximately $7K. When performing a full range replacement, the range must also be taken out of service for the entire duration of the upgrade, making live-fire training unavailable to the soldiers stationed there. This type of costly range upgrade is precisely the situation the Army is trying to avoid.

Pros: FASIT compliant; promotes future growth.
Cons: Prohibitively expensive.

Upgrade Range to RS-485

Another upgrade path for the existing ranges to support newer technology is a commercial RS-485 network. Since RS-485 uses a differential balanced line over twisted pairs, it can be used over large distances, though the data throughput drops as distance increases. This approach would be viable for the live-fire ranges given the low data rates (for target control data only) and the extended range distances.

In general, RS-485 solutions require a minimum of wiring to achieve communications, however, in the target system ranges use case, all six twisted pairs of the ERETS infrastructure may be required to achieve the reliable bidirectional communication and network connections to each pit on the cable. This approach would not allow for any growth options within the RS-485 network. Likewise, the low data throughput at greater distances (100kb/s at 1200m) limits growth and ability to host audio or video data on the network. Maneuver range target distances can easily exceed 3000m.

RS-485 only defines the electrical characteristics of the driver and receiver, not the data protocol, so the target devices would not necessarily be compliant or compatible with the FASIT standards. Each target device vendor could define unique (and potentially proprietary) protocols, thereby further moving away from a common solution and lower costs.

Upgrading a range with a RS-485 network solution would require the emplacement of a RS-485 network box at each target position, replacing the current ERETS Target Interface Unit. This new box would have to supply power and communication connections to the target devices. The replacement cost, sans labor and new target, would be $1500 to $2000 per pit to upgrade, plus range tower communication bridges. Under the RS-485 path, the entire range would have to be upgraded at one time, making the range unavailable for an unacceptably long period.

Pros: Uses existing infrastructure, commercially available, reasonable cost
Cons: Limits range/data growth, non-FASIT compliant, requires range downtime

Upgrade to RF Solution

Another viable upgrade path for the existing ranges would be via an implementation of a Radio Frequency (RF) communication network. The RF implementation would allow multiple options in execution to support particular range needs. RF solutions could be TCP/IP compliant (e.g., IEEE 802.11g) or be based on vendor unique protocols. Data throughput, while a function of the bandwidth utilized, would be a constant, and would not degrade over distance. This approach would be viable for the Live Fire Training Ranges given the low data rates (for target control data only) and the extended range distances.

The amount of bandwidth required by an RF implementation would be a function of the number of targets utilized on the range, and data packet size and protocol used, and the frequency of transmissions between the control system and the targets. Carefully planning would be required to implement a viable RF solution. Additionally, frequency approval and clearances would be required on a per range basis; site to site variants would be likely. It is unlikely that a viable RF solution could be implemented that would support the real time transmission of audio and video data.

While it is possible to implement an RF solution that is compliant to the FASIT standards, generally speaking there is insufficient bandwidth on the 802.11x standards to support the number of targets and the frequency of messaging that would be seen during normal operations. As for RS-485, an RF implementation might not implement the FASIT standards , and thereby move further away from a common solution and lower costs.

As seen at the Fort Polk Battle Assault Course, each target position would require an antenna to communicate back to the control tower, and these antennas would be in the line of fire in live-fire events. Additionally, the antennas would cue the target location (i.e., provide an aim point prior to target exposure), resulting in negative training. Finally, a range tower antenna and downrange repeater antennas would be subject to being damaged by training rounds.

Upgrading a range with a RF network solution would require emplacement of a radio and antenna at each target position, replacing the current ERETS Target Interface Unit. This new box would have to supply power and communication connections to the target devices. The replacement cost, sans labor and new target, would be about $2000 per pit, plus the cost of the range tower communication bridges and antenna. The range could be upgraded incrementally, assuming the control system could support dual and divergent communication protocols.

Pros: Does not impact existing infrastructure, commercially available, reasonable cost
Cons: Limits data growth, non-FASIT compliant, requires frequency approval

Upgrade to Home Network Solution

ERETS uses a direct-burial cable containing six twisted wire pairs connecting the tower to downrange target pits. The cable is daisy-chained from pit to pit, forming a point to multipoint network. Since the ERETS system uses only four of the six available pairs, two twisted wire pairs are available for use, assuming that none of the pairs have been damaged (e.g. by lightning) after years of use.

One technology that was proposed for utilizing one of the extra wire pairs was HomePNA (Home Phoneline Network Alliance). The technology allows multiple computers to connect to a network utilizing the same phone line and communicate at broadband speeds. These attributes make this technology an attractive option for network enabling an ERETS range since its wiring topology is very similar to the environment this technology was intended to serve.

There are a few issues with the HomePNA technology that make it unsuitable for use in a range upgrade. First, the technology is somewhat immature. There are relatively few product offerings on the market in comparison to other more mature technologies such as DSL. The second issue is implied by the first part of its name, “Home”. The available equipment that implements this standard is designed for use in an indoor environment. Networking equipment being used on a range must be capable of operating in an outdoor environment in a wide range of temperatures. Third, there is a distance limitation of 600m. Larger maneuver-based ranges may span a few kilometers. Finally, the number of devices that can be connected to a wire pair is limited to 63. For these reasons, the HomePNA technology was ruled out as a viable option for range upgrades.

Pros: Utilizes existing infrastructure, supports FASIT communications
Cons: Immature standard, limited equipment availability, limited distance

Upgrade Range to DSL Network

DSL (Digital Subscriber Line) technology enables high speed network communications over standard phone lines. This makes the technology attractive for use in upgrading ERETS ranges. One limitation of the technology does introduce a challenge for use in the intended environment: DSL only allows a single client to use the wire pair at a time. After some research, we determined that commercially available DSL Ethernet Extender equipment could solve this problem. Ethernet Extender equipment is typically used as a cost-effective solution to provide high speed network connectivity to outlying buildings with existing phone cable, without having to install new fiber. Since the ERETS wires are daisy-chained from pit to pit, two DSL extenders could be placed at a target pit (one for incoming data, one for outgoing), providing a continuous path for network traffic. The equipment is available in "hardened" versions, making it suitable for use in an outdoor environment. The low latency and high bandwidth afforded by this solution allows an effectively unlimited number of connected targetry devices. It also enables more modern networked technologies such as IP video to be incorporated into existing ranges.

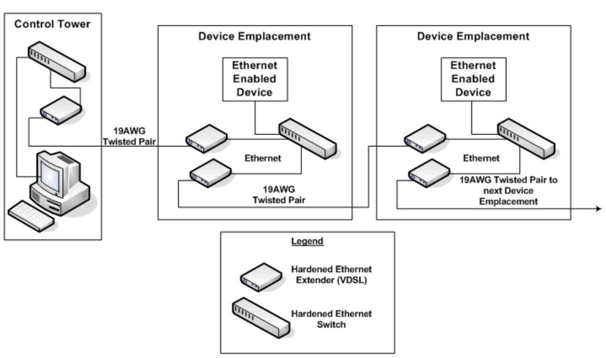

Figure 3 DSL over ERETS Wiring

The available twisted pairs in the existing ERETS data cable also provide flexibility. It allows for existing ERETS targetry to remain in operation on the wire, coexisting with modern FASIT targetry connected to one of the spare pairs via DSL (assuming at least one spare pair is viable). This allows upgrading the targetry pit-by-pit, spreading the cost of a range upgrade over time, and limiting range downtime while the upgrades are taking place. In the worst case, where there are no viable spare pairs, all target pits connected to the cable in question can be upgraded. Each target pit would be equipped with DSL equipment and FASIT targetry. While this type of upgrade is larger in scope than a single pit upgrade, it still provides significant savings in cost and downtime over a complete range upgrade. In addition, when an entire cable is being upgraded, flexibility is afforded in terms of network topology. Since each wire pair can serve as a separate network link, traffic can be segregated (e.g., video network separate from targetry). This also provides the potential to configure redundant network paths to mitigate single-point failures in the network chain.

Pros: Uses existing infrastructure, commercially available, reasonable cost, support growth, FASIT compliant, and no frequency approval required
Cons: Per-pit cost for DSL equipment as well as DSL and network equipment in control tower.

Conclusions

There are multiple solutions paths forward to migrate existing U.S. Army ranges from their current state to an improved state. However, only two paths provide solutions which result in FASIT compliance and support future data growth on the ranges. Of these two solutions, one will have a price tag in the millions of dollars to implement, while the other in the hundreds of thousands to implement (depending on the number of target positions on the range). Given the number of existing ranges in the Army, this cost avoidance and burden would be significant.

All of the paths defined within this paper will require communication bridges at the control tower, communication boxes in the target position, and new targets and devices. While individual costs will vary depending on the particular implementation, these costs become less significant in comparison to the total cost to implement. A primary fiscal decision is whether to incur the cost to completely reconstruct a range or to incur the life cycle costs associated with maintaining divergent/non-standard systems. Given all of these factors, the DSL solution represents the lowest total ownership costs.

Moreover, the FASIT standards and TRACR control system leverage the Live Training Transformation architecture and product line common components: Once the DSL networks are in place, the ranges will support the natural growth for extended range usage and interoperability with Live, Virtual, and Constructive simulations.

The DSL implementation solution represents a best path forward that will allow the U.S Army to modernize existing ranges at minimal costs, while supporting the same functionality as a new range. The DSL retrofit is analogous to replacing the worn shoes of a worthy horse.

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