ITC TENA-Enabled Range Roadmap Paper

Paul Schoberg
PMRF CIO
paul.schoberg@navy.mil

Harry Beatty, EE
PMRF Technical POC
harry.l.beatty@navy.mil

Robert A. McKinley
TRAX-International, Senior Systems Engineer
robert.a.mckinley.ctr@navy.mil

ABSTRACT

This paper discusses the Department of Defense (DoD) direction to provide an environment for realistic Test & Evaluation in a Joint operational context and enhance interoperability and reuse with other test ranges and facilities though the use of the Test and Training Enabling Architecture (TENA) and connectivity to the Joint Mission Environment Test Capability (JMETC) joint test infrastructure. The intent of the "TENA-Enabled Range Roadmap" is to describe how TENA would be incorporated into PMRF's range infrastructure through both near-term upgrades and long-term system replacement. While details of this implementation plan are specific to PMRF, this roadmap can serve as a blueprint for TENA implementation at other ranges throughout the DoD.

KEYWORDS

TENA, JMETC, Interoperability, Sensors, Source Integration Server, Message-centric, Object Model

INTRODUCTION

PMRF's Real-Time Computing Center (RTCC) is the range's data processing nerve center. RTCC computers receive data from sensors and provide track data to all mission participants. Software processes in the RTCC monitor sensor data, filter and process information, distribute data to real-time participants, and record information for later playback and analysis by program personnel.

The Range Operations and Control Center (ROCC) is PMRF's operations center. It consists of four separate rooms that can be configured to accommodate mission requirements. There is a single large room in the ROCC that can be partitioned as required to support multiple simultaneous missions or accommodate physical separation for "Need-to-Know". There are console positions for Operations Conductor (OC), Missile Flight Safety Officer (MFSO), Range Contractor Controller (RCC), PMRF Technicians, and Range Users (Customers).

The Data Analysis Center (DAC) provides a secure location for immediate post-event analysis. Workstations are equipped with commercial analysis package including MATLAB and LABVIEW. During a live event, data analysis algorithms in the DAC identify best sensor source. In the postoperation environment, DAC applications act as consumers of event data.

Data processing applications consist of both data producers and data consumers. Display software and message recorders typically function as final data consumers, while data producers begin with the range sensors and instrumentation. Intermediate software processes function as both data producers and consumers. While display software typically runs on PC-based computers (mostly Red Hat Linux with a few Windows machines), custom data processing software runs predominantly on Sun Blade 2500 Workstations. In order to maintain long term IA accreditation, the RTCC will need to transition to a Linux environment.

The transition to Linux presents its own set of challenges, which were the primary reason for installing updated Sun workstations rather than moving straight to PC-based architectures. Specifically, in-house data processing applications were written at a low level according to Sun-supported big-endian convention (Most significant byte first). Since PC architecture follows little-endian convention (least significant byte first), all software developed at PMRF will need to be rewritten. This externally-mandated conversion presents a target of opportunity to leverage TENA in the core data processing applications. Indeed, some of the problems presented by the byte-swapping necessity can be abstracted by TENA, allowing programmers to focus on higher-level logic.

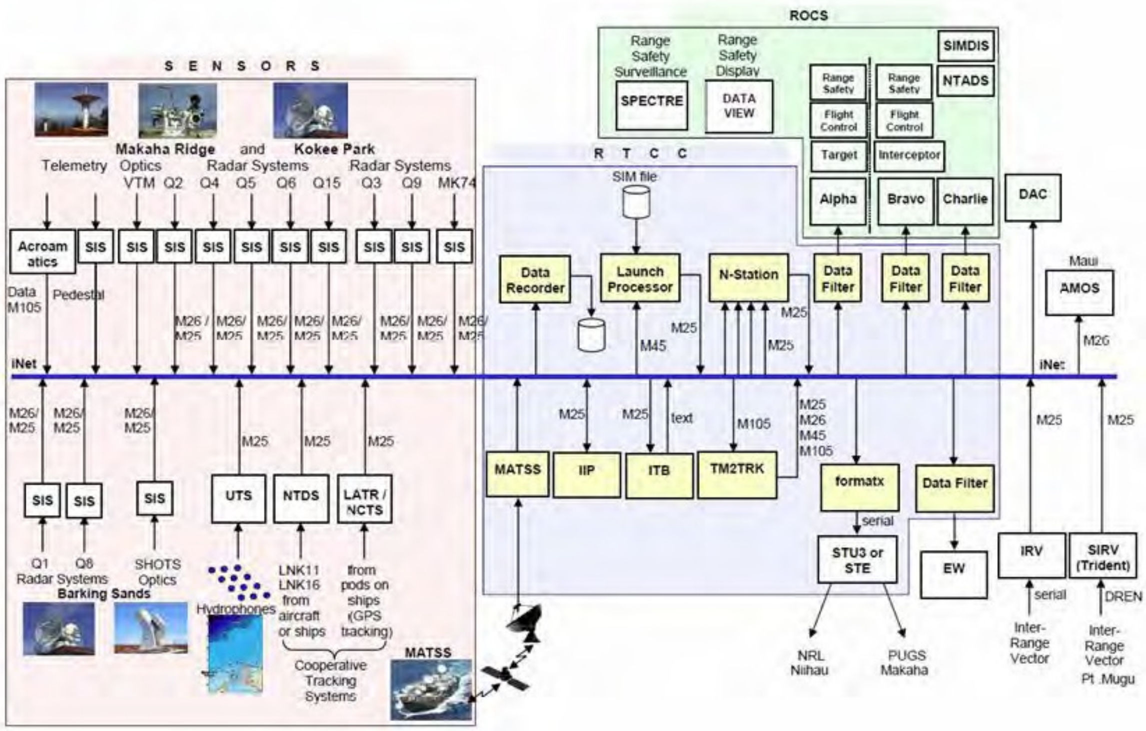
As outlined above, PMRF operates in a mixed Solaris/Linux/Windows environment. There is little in the way of large monolithic computers, and the client/server model does not readily apply. Instead, each workstation is free to act as an independent agent. Data processing is organized in a data-centric, message-based fashion. Application software may be broadly classified as data producers, data consumers, or some combination of the two.

PMRF operates and maintains a myriad collection of sensors including radars (both surveillance and tracking), telemetry, optics, electronic warfare, underwater, and space-borne sensors. Integrating data from so many disparate sources is accomplished via a uniform sensor interface known as the Source Integration Server (SIS). The SIS software was developed for PMRF by Raytheon Solipsys in the mid-1990s. It provides a unified interface between the native sensor and PMRF data formats. Data processing applications receive information from a SIS rather than directly from a sensor. While the downstream SIS output is uniform from the range's perspective, the complexity and variation between sensors necessitates a custom SIS application for each individual sensor.

PMRF's classified Instrumentation Network (iNet) provides the data backbone for mission support. While the term "iNet" is technically defined to mean the network and associated infrastructure, it is used informally at PMRF to mean one or more of the following (Depending upon context):

- iNet – Instrumentation Network
- iNet Protocol/iNet Spec – Formal specification for iNet data.
- iNet Messages/iNet Traffic – Data packets that conform to the iNet Protocol.
- iNet Applications – Data processing applications that produce, route, and interpret iNet message traffic. During a mission, iNet applications can run on any computer connected to the iNet.

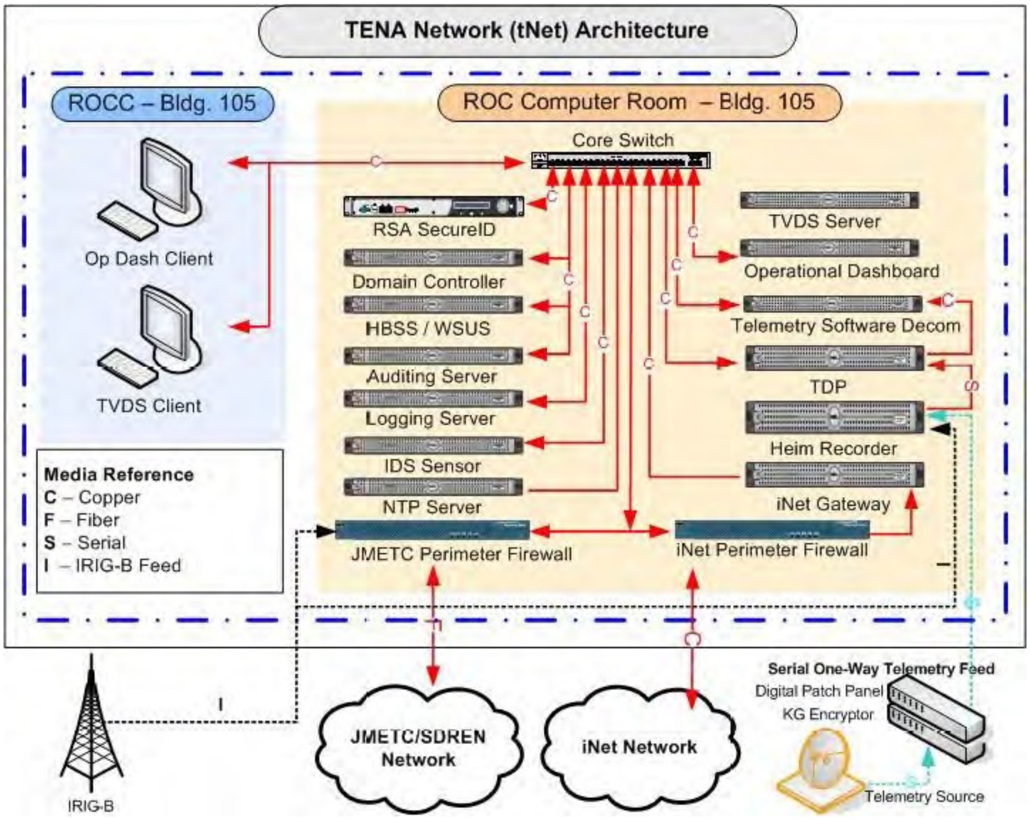
Figure 1 presents a conceptual overview of the iNet design.



(Figure 1. iNet OV-1)

iNet data processing follows a message-centric approach. Messages are encapsulated as User Datagram Protocol UDP packets and routed to mission displays, data recorders, and range safety applications. The iNet Specification includes 43 message types. Common iNet messages are: MSG25-Track Data (Static), MSG 26-Track Data (Variable), MSG 37-Radar, MSG 45-Event, MSG 55-Vehicle Identification Table (VIT), MSG 66-Sensor Identification Table (SIT), MSG 105-Telemetry, and MSG 135-Text Message. From the perspective of a live event (for example, missile intercept), track messages (iNet MSG 25/26) are arguably the most important message types in use. Track messages contain Time-Space-Position-Information (TSPI) data and are identified by Vehicle ID (VID) and Sensor ID (SID). The VID/SID pair is defined before each mission and organized in the Instrumentation Plan (IP). Each mission's IP exists as an Excel spreadsheet that is parsed to create text inputs for mission-specific software setup scripts.

The iNet is accredited as a stand-alone network ONLY. Although this limitation was identified as a capability gap at PMRF, the security risk associated with connecting the network to remote installations was considered too high. To achieve the somewhat conflicting dual goals of both connecting to remote range facilities and research labs while maintaining the appropriate security posture for the iNet, PMRF stood up a test bed which connects to the iNet across a dual-firewalled demarcation zone (DMZ) on one side and the Joint Mission Environment Test Capability (JMETC) Virtual Private Network (VPN) residing on the SECRET Defense Research and Engineering Network (SDREN) on the other. The test bed thus provides the interface to remote locations. PMRF is able to communicate with any sites that have SDREN nodes while still providing appropriate insulation against intrusion to the iNet.



(Figure 2. Test Bed Architecture)

The test bed will be used for application development, modification and testing. Modified software can then be ported to the iNet for certification. Figure 2 shows the test bed architecture.

Given that the test bed and the iNet have separate accreditation packages; both will need to exist as separate entities for IA purposes. However, this distinction merely highlights the DMZ capacity the test bed provides and should not be sufficient reason to perpetuate the myth of duplicated functionality.

TENA

In contrast to the iNet's message-based approach, TENA enables software abstractions of assets. For example, consider a tracking radar. As implemented at PMRF, the radar interfaces through a dedicated SIS to produce track messages which are then placed onto the iNet. The SIS receives iNet track messages as input, performs data fusion functions, and tells the radar to adjust azimuth and elevation accordingly. Each SIS is customized to the particular radar at PMRF. TENA provides a mechanism to abstract the radar as a standard object that has both attributes (for example, azimuth/elevation) and functions (for example, pointRadar (), trackMissile (), etc.). These standard radar objects can exist as software that can be implemented at multiple ranges, not just PMRF.

In addition, TENA provides a publish/subscribe mechanism that can allow mission participants to communicate with one another only when necessary. For illustration purposes, consider an intercept mission awareness display that needs to update to reflect mission status: prelaunch, first stage, booster, separation, burnout, warhead separation, and intercept. As currently implemented, this theoretical display must receive iNet message at a 10-20 Hz rate, the vast majority of which will be of no use. Under TENA, the application registers its wish to be notified only when each event occurs.

The examples above are given merely to illustrate the gulf between a message-based approach and the potential capabilities of a fully mature object-based approach. The transition from one to the other will not be easy, and software will require the robust test bed which has been previously discussed.

The transition from the current data processing architecture to a TENA-enabled environment entails a fundamental shift away from a message-centric focus to an asset-centric focus that is a natural consequence of an object-oriented approach. This transition will follow a three-phased approach. The goal of Phase 1 is to implement TENA as the "on-the-wire" protocol at PMRF. In Phase 2 core data processing applications will become TENA-enabled, and in Phase 3, TENA will be implemented at PMRF sensors.

Phase 1 and 2 include components from iNet and a previously developed test bed network. When PMRF secures funding and implements this transition plan through Phase 2, this distinction will cease to be relevant. While it is convenient to think in terms of "iNet" and test bed for planning purposes, the goal is a single infrastructure capable of supporting real-time events coupled with reach-back capability to other ranges, producing a distributed Test and Training infrastructure. The networking infrastructure currently labeled "test bed" will exist as a DMZ between the networking infrastructure currently labeled "iNet" and remote locations accessible via SDREN and beyond.

In all cases, both networks are all-inclusive terms meant to incorporate both physical networking infrastructure (data transport) and real-time software applications (data processing).
The goal of phase 1 will be to implement TENA as the primary intra-range communication mechanism between data producers and data consumers at the range. Specifically, TENA will be the data distribution mechanism between the Real Time Computing Center (RTCC), which houses PMRF's core data processing applications, and the Range Operations Control Center (ROCC), which is responsible for range operations, including range safety, flight control, and data display. The primary benefit of this step is that TENA's publish-subscribe capabilities can enhance PMRF's data filtering and distribution capabilities by decreasing manual setup, increasing flexibility, and enabling a true separation of data consumers based on their "need-to-know" during a single event, or during concurrent events with different customers on the range.

Upon completion of phase 1, TENA will not be the only protocol on the wire on PMRF networks. However, TENA will be the primary protocol used to distribute data to end-users on the range. At this point in the migration, sensors will continue to publish data using the iNet protocol, and core data processing applications, many of which publish data for display and recording, will also use the iNet standard. Similarly, displays within the ROCC will have an iNet rather than TENA interfaces. Gateways will be used on both ends of the data distribution channel. Conceptually, this is analogous to distributed events executed over the JMETC Wide Area Network (WAN) in which TENA has been used as the over-the wire protocol, with sites continuing to use other protocols locally. In this phase, object models maybe non-standard in the instances in which such an approach speeds initial implementation. There is little downside to the use of non-standard OMs in this implementation, in which TENA is limited to data distribution over an internal network between gateways.

In Phase 1 the use of TENA will be internal to the range, and as a result will not enable interoperability with other ranges or DoD test assets. Nonetheless, this is a critical step that will enhance data distribution capabilities at PMRF, demonstrating the benefits of using the TENA Middleware as an intra-range protocol.

PMRF will leverage the current design of the test bed network that fosters development and testing of TENA-enabled applications. The iNet is accredited as a stand-alone network. As currently implemented and documented in the Authority To Operate (ATO), the test bed network is connected to the iNet across a dual-firewalled DMZ. The connection across a DMZ creates a connection between PMRF resources and other SDREN installations while still observing relevant IA restrictions that are required for the legacy iNet infrastructure to operate. iNet message traffic aggregates through a single point through a firewall and is picked up by a single location on the test bed. This allows system administrators greater flexibility and control over the types of iNet messages they wish to permit to cross the DMZ. While iNet messages can then be distributed onto the test bed as is, this single point of entry naturally lends itself to a TENA gateway. iNet messages can be encapsulated as TENA Message Object Models (OMs), the test-bed will be used for new TENA implementations without adding risk to existing operations.

The purpose of Phase 2 is to transition from TENA Gateway-enabled data distribution to a native TENA-enabled capability. PMRF's core applications, including displays, range safety applications, and data distribution applications will be modified to subscribe and publish directly to TENA objects. Gateways will still be used as the interface to sensors, and object model implementation will be a mix of standard and non-standard object models. This phase consists of three main efforts:

- Modify all core applications to both receive and output TENA Message OM.
- Push TENA-enabled data processing out from the core iNet applications in two directions:
  - Source Integration Server (SIS). This is an "upstream" push from data distribution to PMRF's integrated interface to physical sensors.
  - Display software. This is a "downstream" push from data distribution to final real-time Consumers of mission data.
- Implement dynamic configuration updates.

In Phase 1, the TENA gateways will sit between the core data processing and display software, allowing for TENA-based data distribution between data producers in the RTCC and data consumers in the ROCC. These gateways will allow PMRF to translate and route TENA Message OMs, but the TENA OMs will need to be translated back to the iNet protocol for display. In Phase 2, all data filtering applications within the RTCC will be modified to subscribe and publish TENA Message OMs, and as a result, they will be moved within the TENA execution. The Phase 1 gateway that was used to translate between the data filters will no longer be required, and a new gateway will be implemented "upstream" in front of the SIS. Of all PMRF data sources, only the sensors will remain outside the TENA execution. Sensors are, of course, the original producers of all relevant mission data, and are thus the most critical element. Any move to push TENA towards the sensors must be undertaken in a methodical, careful manner. TENA Gateways that translate SIS iNet message outputs to TENA OMs for iNet applications provide the first step along this path.

Modification of downstream applications, including displays, to accept TENA Message OM rather than iNet message traffic will allow PMRF to completely remove the gateways that were required in Phase 1 to translate from TENA objects back to the iNet protocol prior to display. The net effect is to move the TENA gateways from the communication link between core data processing and display software (i.e., towards the end of the data processing workflow) to the communication link between the SIS and iNet (i.e., early in the data processing workflow).

Finally, a dynamic configuration update capability will be implemented with TENA. This will allow for control of relevant data being sent to discrete locations which will result in both reduced bandwidth and greater capability for supporting joint missions at PMRF while demonstrating TENA's remote method capabilities. It will further highlight the point that rapid advancements can be made by taking advantage of the TENA middleware installed on RTCC computers in Phase 1.

While certainly not an insurmountable obstacle, the transition of all data processing applications presented here is a non-trivial effort. Most applications were written at a relatively low level and as a result incorporate networking code tied to the Solaris Big-Endian architecture. Red Hat 5.5 (the proposed replacement OS) runs on PC-based architectures and therefore adheres to the Little-Endian standard. All software will thus require byte-swapping logic in order to run properly. This issue is further complicated by PMRF's proposed transition from 32-bit to 64-bit architecture.

The goal of Phase 3 is to complete the push of TENA capabilities completely out from the iNet into SIS applications, removing gateways as the primary mechanism for interfacing to PMRF sensors. The SIS existing software will need to be modified to incorporate native TENA capability.
The flexibility and reuse promised by TENA can help PMRF provide better capabilities to its customers while simultaneously reducing risk and enabling cost-sharing of application and system development with other ranges. To fully realize this potential, the range must first revamp core data processing to both provide TENA-enabled capabilities to end users and interact with TENA-enabled native sensors.

In the near term, TENA will be implemented within each system SIS, but as major upgrades or replacements take place, the TENA Middleware can be implemented within the computers of the sensor itself. Currently, radar systems receive pointing data in the form of iNet messages and send out track data. This functionality could ultimately be implemented using the TENA publish/subscribe mechanism within the back-end radar processor. In addition, high level control of the radar could also be implemented using TENA control mechanism, including remote method invocation and application management objects.

Telemetry systems at PMRF support the real-time transfer of data from interceptors and targets down to the command and control systems on the ground. Telemetry information includes trajectory and status information. This data is used for range safety as well as to support T&E requirements. PMRF's telemetry facilities are located at Makaha Ridge and Kokee State Park (Pictures).

TENA can be incorporated into PMRF telemetry systems in a number of ways. These are described below:

Pointing data – Telemetry antennas receive pointing data, which could be derived locally at PMRF or from a distribute site. Currently, any pointing data is sent in the form of iNet messages, but in future upgrades. The telemetry systems could be upgraded to subscribe directly to TENA object models that contain track data.

Telemetry data processing – Telemetry data processors receive Range Commanders Council (RCC) IRIG 106 standard Phase Coded Modulation (PCM) data and perform the decommutation process. As data is demultiplexed from the PCM stream, it is written to iNet messages. Future implementations of telemetry data processors could use the TENA Middleware to publish data directly to TENA object models for distribution on the range. TheTENA community is currently developing a Measurand object model to publish telemetry data that cannot otherwise be incorporated into other standard TENA object models, including standard platform OM.

Recorders and displays – Currently PMRF strip chart recorders and display systems subscribe to iNet messages. Once telemetry data processing units publish TENA objects, recorders and display could subscribe directly to TENA.

Optical sensors at PMRF collect data in support of T&E missions. In the near-term, TENA will be implemented within each system SIS, but as major upgrades or replacements take place, the TENA Middleware can be implemented within the optics mount itself.

The optics mount could subscribe to TENA object models to receive track data, and beyond that, remote method invocation could be used to actively control pointing on the sensor itself. In terms of data publication, optical trackers could be advertised and distributed using the TENA Video Distribution System (TVDS), which was originally developed at other ranges. TVDS would add flexible distribution of video over IP networks at PMRF and also support recording and replay for analysis and pre-mission training.

TENA could be incorporated into the antenna control units (ACU) of the PMRF Flight Termination Systems (FTS) to provide three major benefits:

- A common ACU solution that works with FTS from multiple vendors
- FTS ACU could subscribe to TENA objects to receive pointing data
- TENA Remote method invocations could be used to implement remote control of ACU to minimize staffing requirements and for remote, off-axis systems. Moreover, TENA application management objects could be used to monitor health and status of all FTS systems and used to coordinate handoff of primary termination responsibility to different systems as a function of target and interceptor positions.

PMRF provides electronic warfare (EW) test and training capabilities for surface and air systems. TENA could be incorporated into these systems in a number of ways as system upgrades take place. Currently, PMRF's EW systems receive pointing data in the form of iNet track messages so that they know at what azimuth and elevation to emit energy. As TENA becomes the "over-the-wire" protocol at PMRF, the EW emitter platforms will need to subscribe directly to TENA object models rather than iNet messages.

TENA could also be used in the future to provide remote control of and distribution of data from applications at Pohakuloa Training Area (PTA) on the island of Hawaii.

Finally, TENA and the JMETC infrastructure could also be used to tie PMRF EW capabilities to other labs and facilities within the DoD, which would provide data and profiles to stimulate systems at PMRF. This reach-back to other labs and facilities would enhance the capabilities of PMRF EW systems.

The Mobile at Sea Sensor (MATSS) provides a large, stable, mobile, open ocean sensor platform that supports radar, optics, telemetry, flight termination system, and high rate over-the-horizon (OTH) SATCOM functions. Many of the sensors onboard MATSS relies on wireless communications to sore, specifically Ku and C band satellite communications. As a result, TENA implementations for low bandwidth data links, developed by the TRCE project, would be used onboard MATSS.

CONCLUSION

The new Next-Generation Range Control & Data Distribution (NGRC&DD) project at the Pacific Missile Range Facility is designed to move the range to a TENA-enabled environment. Implementation will occur in three phases. Phase 1 will implement TENA as a key data distribution mechanism between data producers and data consumers on the range. In Phase 2, core applications at PMRF will be TENA-enabled. These applications include display systems, range safety applications, and data distribution applications. In Phase 3, TENA will be introduced at the sensors themselves. Sensor gateways will be removed, and the TENA middleware will be implemented within the SIS, the interface between each individual sensor and the rest of the range's assets. PMRF will then be in a position to integrate native TENA sensors to the range as systems are upgraded and replaced. This will also allow the range to reuse TENA applications developed at other ranges.

As the project proceeds, existing TENA Object Models from the TENA-SDA repository will be utilized as a primary resource, supplemented by additional development of PMRF TENA Object Models as needed. Resultant new Object Models as well as Lessons Learned will become part of the TENA repository for reuse by the other ranges, allowing smoother transition to TENA throughout DoD. This will in turn provide seamless integration of the ranges as DoD moves further along with interconnection of test and training ranges to support both multi-range Geographical Testing and Distributed Testing of multiple systems.