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TRMC Support for the TM Community

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Abstract:

The nature of telemetry often requires operators to be on location with receive system(s) or remote consoles, resulting in costly TDY and possibly a shortage of operators to support all scheduled events. To mitigate these issues, the Test Resource Management Center (TRMC) has developed a remote-control capability (along with centralized data collection) to eliminate existing personnel requirements at both locations, **greatly reducing operational costs** and providing **real-time insight** to system status. The TRMC's Joint Mission Environment Test Capability (JMETC) is a distributed LVC capability using a hybrid network solution for all classifications and cyber, and the Test and Training Enabling Architecture (TENA) is the middleware selected for use in JMETC Secret Network (JSN) events. TENA provides for real-time system interoperability, as well as interfacing existing range assets, C4ISR systems, and simulations - fostering reuse of range assets and future software systems. These capabilities allow the most efficient use of current and future TM range resources via range resource integration, critical to validate system performance in a highly cost-effective manner. This presentation will inform the audience as to the current impact of TRMC capabilities on the T&E community; as well as their expected future benefits to the range community and warfighters.

Key words: TENA, JMETC, BDA, multi-site, multi-domain

TRMC Solutions for the Telemetry Community

As in the past, present telemetry (TM) support requires operators to be on location with the TM receive system or at a remote TM console (with a remote TM antenna control unit). This often results in temporary duty (TDY) for operators and potentially an insufficient number of operators to support all scheduled operations. The capability to remotely operate the telemetry system (i.e., perform status monitoring, data distribution, and/or command and control from a centrally-located, manned site) greatly reduces operational costs of TDY to remote TM sites. A remote-control capability could altogether eliminate the existing requirement for personnel at both the local TM system antenna site as well as the TM control facility, alleviating previous manpower issues (Figure 1).

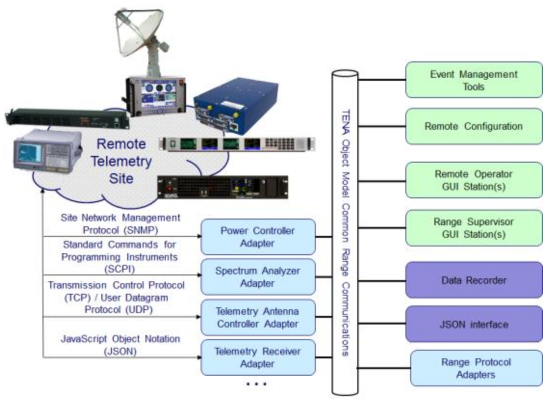

Fig. 1. Architecture to a Remote TM Site.

The original design of the DoD test and training range infrastructure was not intended to be interoperable, and rapidly became inadequate in this new era of warfare. The cost-effective integration of range data and telemetry resources is critical to ensuring the war-worthiness of today's advanced weapon systems and platforms which populate the air, land, sea, and cyber areas of operations. To ensure the advantages of range interoperability are available across the DoD, the OSD Test Resource Management Center (TRMC) Central Test and Evaluation Program (CTEIP) developed and is constantly refining the Test and Training Enabling Architecture (TENA).

TENA is a common architecture providing real-time software system interoperability and the capability to interface existing range assets, systems, and simulations at distributed facilities. Government-owned and free for anyone to use, TENA allows the most efficient use of current and future range resources via range resource integration. This integration invariably fosters interoperability and reuse within the test and training communities – critical in validating system performance in a highly cost-effective manner.

TENA provides a middleware software component and can be used on any internet protocol (IP)-based range or distributed network, such as the Joint Mission Environment Test Capability (JMETC) networks and the Joint Staff (JS) J7 Deputy Director Joint Training (DDJT) Joint Training Enterprise Network (JTEN).

Upgrading an existing range system to TENA can be achieved in a drastically shorter time frame than traditional software integration efforts. Additional benefits include the cost-effective replacement of unique range protocols, enhanced exchange of mission data, and organic TENA-compliant capabilities at sites which can be leveraged for future events, enhancing both reuse and interoperability.

The JMETC Secret Network (JSN), which leverages the Secret Defense Research and Engineering Network (SDREN) for connectivity, is the test and evaluation (T&E) enterprise network solution for secret testing. SDREN is a network established to support research, development, testing and evaluation, and science and technology activities in the DoD. The persistent JSN infrastructure includes sites at Defense industrial facilities and peering with sites on other DoD networks at like classification such as the Secret Internet Protocol Router Network (SIPRNet).

JMETC also offers a network capability to its customers with a requirement for higher-than-secret classifications of distributed testing, cyber testing, or unique requirements that don't fit the JMETC JSN model. The JMETC Multiple Independent Levels of Security (MILS) Network (JMN) is the enterprise network solution for higher test event classifications, as well as those which are cyber-specific.

The primary product of T&E is the data and knowledge gained through the collection of information about a system or item under test. The amount of information needed to acquire this knowledge is growing exponentially due to more complex systems needing to operate in System of Systems (SoS), Family of Systems (FoS), Joint, and Coalition environments. With many DoD tools and methods remaining largely the same for decades, the T&E infrastructure necessary to collect and analyze this information has not evolved alongside this increased complexity, becoming increasingly deficient and ineffective. By contrast, corporations have dramatically changed their methodologies – modernizing their analytics capabilities to keep up with the massive influx of data.

To properly test and evaluate today's advanced military systems, the T&E community must leverage new algorithms using the equivalent processing power of many computers in parallel to effectively analyze large amounts of data. This process is called "big data analytics (BDA)" and the Test Resource Management Center is taking the initiative to develop better tools and techniques to empower DoD analysts to make better and faster decisions using more of the collected data than was previously usable.

Current Telemetry Applications

OmegaNExT TENA Adapter (X-5000 Decommutator TENA Adapter): The TENA OmegaNExT Adapter (Figure 2) is a TENA-enabled application that receives telemetry data from an OmegaNExT X-5000 decommutator and converts that data into TENA State3D Data and TENA DataTable Data. Once the OmegaNExT data is converted into TENA Data, the State3D Object and the DataTable object can interact with other TENA-enabled applications within the same Execution.

The TENA Adapter is able to receive live or recorded data from a running OmegaNExT Client.

Text boxes within the adapter Graphical User Interface (GUI) enable the user to enter the names of parameters within the OmegaNExT Stream. The user can find the parameters in the OmegaNExT Client that correspond to a specific measurement (example: finding the parameters that respond to ECEF-X, ECEF-Y, and ECEF-Z or parameters that respond to latitude, longitude, and height above the ellipsoid). Settings involving the type of Position (Geocentric or Geodetic), Angle Unit (Radians or Degrees), or Orientation Types (Euler or Yaw/Pitch/Roll) can also be selected depending on the stream.

Custom parameters that may not fit in the State3D Parameter categories can be added to a data table at the bottom of the GUI. The parameter type (int, float, etc.) and the parameter unit (meters, radians, degrees, pressure) can be selected as well.

The update frequency can be set to whenever a certain parameter updates or when any parameter updates.

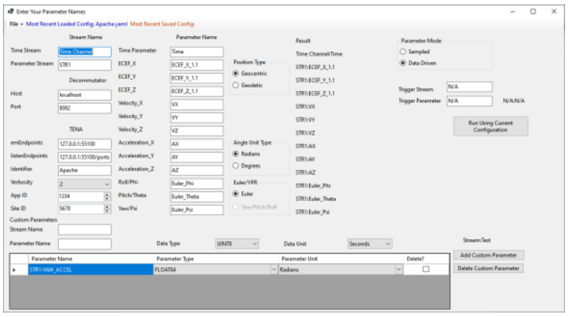

Fig 2. OmegaNExT Adapter GUI Display.

Automatic Dependent Surveillance-Broadcast (ADS-B) Adapter: Starting January 1, 2020, aircraft must be equipped with an air traffic control "Automatic Dependent Surveillance-Broadcast (ADS-B) Out" to fly in most controlled airspace. ADS-B is a surveillance technology in which an aircraft determines its position via satellite navigation, and periodically broadcasts position (and other information), enabling it to be tracked. The TRMC is creating a library of software products called Range System Adapters which present a common distributed communication mechanism for the remote configuration, monitoring, and control of range systems. As such, the TENA Software Development Activity (SDA) has developed an ADS-B Adapter – a software application designed to expose a common communication interface to an existing range system by wrapping the system's custom external interface.

The ADS-B Adapter is a computer process separate from the software running an existing system. By "wrapping" the existing ADS-B system, there is no modification of the existing system, allowing use on legacy systems that cannot be updated or have limited communication capabilities. The ADS-B Adapter translates identification and position information sent by aircraft and interfaces an application called a dump1090 server (Transmission Control Protocol (TCP)/IP connection), which translates signals received by the Software Defined Radio (SDR) to a data stream that makes it available via a TCP service.

The TRMC-developed ADS-B Adapter provides a low-cost solution to acquire live/local aircraft information: an SDR radio and antenna costs >$100 and the dump1090 server software is freely available, open-source software and works with a variety of SDRs and antennas. The ADS-B Adapter is free, government-off-the-shelf (GOTS) software and when used in conjunction with the TENA Data Collection System (TDCS), captures/replays repeatable and realistic local air traffic scenarios in simulated environments (Figure 3).

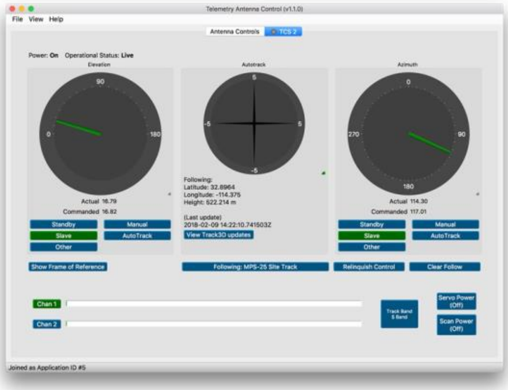

Fig 3. TENA ADS-B Adapter Telemetry Antenna Control Display.

TENA Plugin for SIMDIS: SIMDIS is a Naval Research Laboratory (NRL) set of software tools that provide two and three-dimensional interactive graphical and video display of live and post-processed simulation, test, and operational data. SIMDIS has evolved from an NRL display tool for the output of missile models, to a premier GOTS product for advanced situational awareness and visual analysis (Figure 4). The TENA plugin for SIMDIS allows a set of TENA Stateful Distributed Objects (SDOs) and messages to be used in SIMDIS (e.g. SIMDIS can be used in conjunction with the TENA ADS-B Adapter to provide a display of local aircraft identification and position).

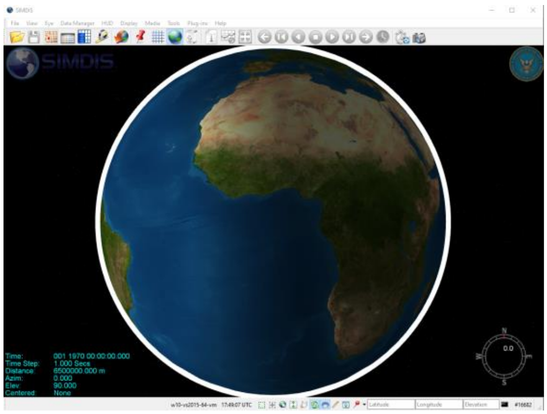

Fig 4. SIMDIS GUI Display.

TENA Interface for Yuma Proving Ground (YPG) TCS Antenna: YPG, located in Yuma, Arizona has chosen to add a TENA interface to their TCS Antenna Control Unit (ACU) model M1 used on their TM pedestals. The Antenna Control System SDOs created by the ACU adapters are visible on SIMDIS and the Instrument System Assignment Tool (ISAT),

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where SIMDIS shows the system with a beam indicating where it is pointed and ISAT allows users to select a Track SDO to send cueing data to the ACU. The operator then uses the data to point the system. Operational testing is currently underway on the remote monitoring and control capabilities of the telemetry antenna system using TENA.

Cloud Hybrid Edge-to-Enterprise Evaluation & Test Analysis Suite (CHEETAS) Tool: The TRMC has developed and successfully demonstrated a rapid Knowledge Management/Big Data Analysis capability to support hypersonic flight test. During a recent high-priority hypersonic test mission at Edwards Air Force Base, CA, post-test data processing (download, conversion, and validation – all necessary steps that must occur prior to data analysis) took approximately ten hours using existing capabilities. Working with the 419th Flight Test Squadron the following week, the TRMC team processed the same raw mission data with the CHEETAS tool in less than 15 minutes. Using CHEETAS cut the time required to get the test data into the hands of analysts by over 95%.

The CHEETAS framework provides a common tool suite for building evaluation infrastructure for disparate acquisition portfolios. Developed and supported by TRMC, CHEETAS is provided to the test community for free and is currently in use at multiple locations throughout the test community. CHEETAS is vendor- and hardware-agnostic, and can run on anything from a laptop to a full GPU-enabled, hyper-converged cluster, to a commercial cloud environment. CHEETAS is providing game-changing knowledge management and big data analysis capability both pre-flight and post-mission to support the testing of hypersonic boost-glideweapons and other systems requiring large-scale test data collection.

Data Processing Timeline: Traditional Software vs. CHEETAS

Description	Traditional Software *(what was used for ARRW mission)*	TRMC CHEETAS GOTS Software *(evaluated week after ARRW mission)*
Data Size	57 GB DTD X 3 DTDs	*57 GB DTD X 3 DTDs*
Dataset Used	BIMDAS Data Collection Memory Modules	BIMDAS Data Collection Memory Modules
Ingestion Equipment Capacity	Single RMM Reader *(serial process)*	8 RMM Read Simultaneously *(parallel process utilizing multi-cartridge reader)*
Data Ingestion Time 1 Module	55 minutes	3 minutes 7 seconds
Data Conversion Time 1 Module	9 hours 39 seconds	11 minutes 4 seconds *(included data validation)*
Data Available for Analyst Use	Approx. 10+ hours post-test	Approx. 15 minutes post-test
Computer System	Data Ingestion Workstation	Spare 4-year-old High Performance Desktop

CHEETAS Enables Timely Delivery of Validated Data to Analysts for Future Tests

Fig 5. CHEETAS Data Processing Time.

Past TM Uses of TENA

Eglin Gulf Test Range (EGTR) Gulf Range Enhancement (GRE) Program: As in the past, present telemetry Theater Missile Defense (TMD) missile systems are designated to provide regional defenses against present and future conventional, chemical, biological, or nuclear ballistic, cruise, or air-to-surface guided missiles that can endanger deployed U.S. forces as well as U.S. friends and allies throughout the world. Eglin Air Force Base (AFB) in Florida is enhancing the capability of the EGTR to conduct TMD programs via the GRE program. This development includes the selection and construction of land-launch facilities; the modification of land, sea, and air safety zones; and the subsequent conduct of TMD missile system test and training flights within the enhanced EGTR. When complete, this expansion will allow launched target missiles to be halted by interceptor missiles with the intercepts occurring in the airspace over the Gulf of Mexico.

The EGTR expansion will provide greater flexibility in test scenarios than is possible using other ranges, and permits more realistic testing of TMD interceptor systems. This next-generation architecture is expected to be completely remote controlled when classification allows.

To make this happen, GRE engineers met with representatives of the TENA Software Development Activity (SDA) concerning the many TENA capabilities which would benefit this new architecture. TENA, chosen for the command and control (C2) portion of the GRE plan, will support remote operations of numerous Joint Gulf Range Complex test assets. TM equipment currently identified to be accessed via TENA adapters and controlled by TENA interfaces include the following: ACUs, digital switches, Time to Live (TTL) splitters, data link test set / Bit Error Rate Test (BERT), monitoring systems, spectrum analyzers, Global Positioning System (GPS) receivers, oscilloscopes, TM receivers, telemetry recorders, power strips, dehydrators, IP cameras, and uninterruptible power supplies (UPS). The long-term plan is for all GRE devices to be retrofitted with TENA adapters and interfaces.

Naval Air Station (NAS) Patuxent River, MD (Pax River) Atlantic Test Range (ATR): The Pax River ATR is another excellent example of how beneficial TENA can be for TM control. Before work began to develop and field an enterprise approach to remotely monitor and operate all components of remote ATR ground telemetry systems, Pax River was faced with four major, and incredibly common, TM range issues: operator proximity, lights-out operations, a generalized interface, and Information Assurance (IA) requirements.

The existing approach at Pax required TM operators to be on location with the TM ACU during missions. Any near-term remote operations concepts required a one-to-one correlation between the remote ACU and remote TM Antenna, and no sub systems were supported. They also had no ability to fully power-on, configure, operate, or obtain the status of their remote Auto-Tracking Telemetry System (ATAS) and Mobile Telemetry Acquisition System (MTAS) systems, therefore requiring personnel on-site to perform power-on and to configure all systems with no distributed status available from TM system components.

Vendor-specific interfaces and data models were used, which meant operators had to gain proficiency on each system component. This generalized interface prohibited uniform operator consoles, and limited the ability to easily access and share relevant metrics and engineering data. Furthering the problem was that Pax River had a limited ability to meet evolving IA requirements and Security Technical Implementation Guides (STIG) on system components.

Working alongside members of the TENA SDA, NAS Pax River developed an enterprise approach to remotely manage and operate all components of remote ground telemetry systems. This method provides a common architecture (TENA) which interfaces system components, regardless of system manufacturer. Upon completion, this effort now provides for single operator control of several remote TM systems, therefore reducing travel and manning requirements at remote sites. It also allows TM status information, setup, and control to be distributed to appropriate destinations for system verification and operations.

Additional Applications: Other TM applications of TENA are ongoing at White Sands Missile Range (WSMR) in New Mexico and Vandenberg AFB in California. WSMR reached out to the TENA SDA seeking a TENA-capable range interface unit (RIU) for existing radars; a TENA-capable Telemetry Tracker pointing data interface (as a modification to the existing RIU); and a persistent, distributed TENA capability through WSMR's Inter Range Control Center (IRCC). TENA is currently being used to connect FPS-16 radars, telemetry systems, and optics systems. Future plans at WSMR include the use of TENA for Real-Time Data Processing (RTDPS). Redstone Test Center also used TENA to pull real-time Time, Space, Position Information (TSPI) data via a "Data Adapter Tool" which fused other real-time TSPI sources. The Data Adapter Tool allows operators at RTC to now transport data via TENA using the Standard platform object model.

Understanding TENA

Understanding composability is the ability to rapidly assemble, initialize, test, and execute a system from members of a pool of reusable, interoperable elements, the TENA architecture is a technical blueprint for achieving an interoperable, composable set of geographically distributed range resources (both live and simulated) that can be rapidly combined to meet new testing and training missions in a realistic manner. TENA is made up of several components, including a domain-specific object model that supports information transfer throughout the event lifecycle, common real-time and non-real-time software infrastructures for manipulating objects, as well as standards, protocols, rules, supporting software, and other key components.

The TENA Middleware (currently at Release 6.1.0beta2 and available for free download at the TRMC web site: https://www.trmc.osd.mil) combines distributed anonymous publish-subscribe and model-driven, distributed, and object-oriented programming paradigms into a single distributed middleware system. This unique combination of high-level programming abstractions yields a powerful middleware system that enables TENA middleware users to rapidly develop complex yet reliable distributed applications.

The TENA object model consists of those object/data definitions derived from range instrumentation or other sources, which are used in a given execution to meet the immediate needs and requirements of a specific user for a specific range event. The object model is shared by all TENA resource applications in an execution. It may contain elements of the standard TENA object model although it is not required to do so. Each execution is semantically bound together by its object model.

Therefore, defining an object model for a particular execution is the most important task to be performed to integrate the separate range resource applications into a single event. In order to support the formal definition of TENA object models, a standard metamodel has been developed to specify the modeling constructs that are supported by TENA. This model is formally specified by the Extensible Markup Language (XML) Metadata Interchange standard and can be represented by Universal Markup Language (UML). Standards for representing metamodels are being developed under the Object Management Group Model Driven Architecture activities. The TENA Object Model Compiler is based on the formal representation of this metamodel, and TENA user-submitted object models are verified against the metamodel. However, it is important to recognize the difference between the TENA metamodel and a particular TENA object model. The object captures the formal definition of the particular object / data elements that are shared between TENA applications participating in a particular execution, while the object model is constrained by the features supported by the metamodel.

Another significant benefit for TENA users is auto-code generation. The TENA Middleware is designed to enable the rapid development of distributed applications which exchange data using the publish-subscribe paradigm. While many publish-subscribe systems exist, few possess the high-level programming abstractions presented by the TENA Middleware. The TENA Middleware provides these high-level abstractions by using auto-code generation to create complex applications, and these higher-level programming abstractions (combined with a framework designed to reduce programming errors) enable users to quickly and correctly express the concepts of their applications. Re-usable standardized object interfaces and implementations further simplify the application development process.

Through the use of auto code generation, other utilities, and a growing number of common tools, TENA provides an enhanced capability to accomplish the routine tasks performed on the test and training ranges in support of exercises. The steps in many of the tasks are automated, and thanks to the enhanced software interoperability provided by TENA, the information flow is streamlined between tools and the common infrastructure components.

TENA utilities facilitate the creation of TENA-compliant software and the installing, integrating, and testing of the software at each designated range. This complex task falls to the Range Developer who, in this phase, performs the detailed activities described in the requirement definitions and event planning, as well as the event construction, setup, and rehearsal activities of the range's Concept of Operations. While some manual exercise and event setup is required at ranges, TENA tools, as they are developed and become accepted across the range community, make exercise pre-event management easier.

Support for TENA Users

The TENA SDA has developed a website that provides a wide range of support for the TENA user, including an easy process to download the Middleware, free of charge. The website also offers a helpdesk and user forums that will address any problems with the Middleware download and implementation. The TENA SDA is very aware of the need to inform range managers and train TENA users, and the TENA SDA presents regular training classes that are designed to meet attendees' needs; from an overview or technical introduction of TENA, all the way to a hands-on, computer lab class on the TENA Middleware.

TENA's continuing evolution in its support of the test and training range community is managed by an organization of users and developers. TENA is maintained according to a consensus of its users, which assemble as the JMETC Configuration Review Board (JCRB). These meetings are generally held at technical exchanges JMETC holds each year called the JMETC Technical Exchange (JTEX). At these meetings, users are updated on TENA usage, problems, and advancements. Although the agenda involves briefings, it is open to wide-ranging discussions. This ensures the users' concerns and inputs are understood, recorded, and action items are made if necessary. Of equal importance, TENA developers and management have had a long and mutually beneficial relationship with the Range Commanders Council.

Conclusion

Although it was a technological and software evolution that was the impetus for TENA's growth in its enabling of range interoperability and resource reuse, the Middleware found its needed validation on DoD test and training ranges. On these ranges, the U.S. Military evaluates the warfighting equipment, personnel, and concepts that are deployed in support of ongoing missions around the globe. Unfortunately, test and training events only provide the opportunity for evaluation. It is the data collection and analysis that determines the war-worthiness of the equipment or concept; this data can quickly and definitively illuminate any necessary improvements needed to ensure effective and safe weapon system operation and training. TRMC TENA, JMETC, and Big

Data Knowledge Management are time-tested, proven, integral parts of that equation.

JMETC reduces the time and cost to plan and prepare for distributed events by providing a persistent, readily-available network, and the TENA common integration software is easily-integrated into telemetry environments and applications. Even the remote-control capability alone alleviates previous manpower issues and greatly reduces operating costs for the telemetry community.

The TRMC is constantly building on a DoD T&E data management and analysis capability that leverages commercial big data analytic and cloud computing technologies to improve evaluation quality, reduce decision-making time, and reduce T&E cost. This vision encompasses a big data architecture framework – its supporting resources, methodologies, and guidance – to properly address the current and future data needs of weapon systems testing.

Transforming the current T&E data infrastructure to one employing a Big Data approach will support both current warfighter T&E needs and the developmental and operational testing of future weapon platforms. The T&E community will be able to realize improvements in cost avoidance and cost reductions, in faster and more accurate T&E responses, and in overall T&E capabilities. Using TENA, JMETC, and BDA, Test Directors can put their focus back where it needs to be – on the warfighter and the task at hand.

For more information, contact Ryan Norman, Chief Data Officer and Lead, Joint Mission Environments, E-mail: jmetc-feedback@trmc.osd.mil or tena-feedback@trmc.osd.mil. For the Unclassified, Controlled Unclassified Information (CUI), U.S. Government / Contractor website, go to https://www.trmc.osd.mil; for Distribution A, non-U.S. Government / Contractors, please visit https://www.tena-sda.org.

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Glossary

ACU: Antenna Control Unit
ADS-B: Automatic Dependent Surveillance – Broadcast
AFB: Air Force Base
ATAS: Auto-tracking Telemetry System
ATR: Atlantic Test Range
BDA: Big Data Analytics
BERT: Bit Error Rate Test
C2: Command and Control
CHEETAS: Cloud Hybrid Edge-to-Enterprise Evaluation and Test Analysis Suite
CTEIP: Central Test and Evaluation Investment Program
CUI: Controlled Unclassified Information
DDJT: Deputy Director Joint Environment
EGTR: Eglin Gulf Test Range
FoS: Family of Systems
GOTS: Government Off-the-Shelf
GPS: Global Positioning System
GRE: Gulf Range Extension
GUI: Graphical User Interface
IP: Internet Protocol
IRCC: Inter Range Control Center
ISAT: Instrument System Assignment Tool
JCRB: JMETC Control Review Board
JMETC: Joint Mission Environment Test Capability
JMN: JMETC MILS Network
JS: Joint Staff
JSN: JMETC Secret Network
JTEN: Joint Training Enterprise Network
JTEX: JMETC Technical Exchange
MILS: Multiple Independent Levels of Security
MTAS: Mobile Telemetry Acquisition System
NAS: Naval Air Station
NRL: Naval Research Laboratory
RIU: Range Interface Unit
SDA: Software Development Activity
SDO: Stateful Distributed Objects
SDR: Software Defined Radio
SDREN: Secret Defense Research and Engineering Network
SIPRNet: Secret IP Router Network
SoS: System of Systems
STIG: Security Technical Implementation Guide
TCP: Transmission Control Protocol
TDCS: TENA Data Control System
TDY: Temporary Duty
T&E: Test and Evaluation
TENA: Test and Training Enabling Architecture
TM: Telemetry
TMD: Theater Missile Defense

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TRMC: Test Resource Management Center
TTL: Time to Live
UML: Universal Markup Language
UPS: Uninterruptible Power Supply
WSMR: White Sands Missile Range
XML: Extensible Markup Language
YPG: Yuma Proving Ground