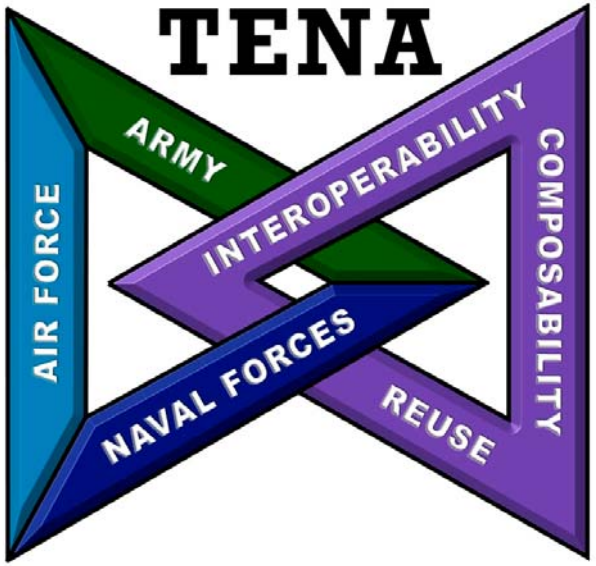


Test and Training Enabling Architecture (TENA) Offers Range Interoperability and Resource Reuse Solutions for Test and Training Ranges

Gene Hudgins

TENA User Support Lead

NDIA Test & Evaluation Conference, Jacksonville, FL

TENA Mission

Currently, range systems tend to be non-interoperable, "stove-pipe" systems

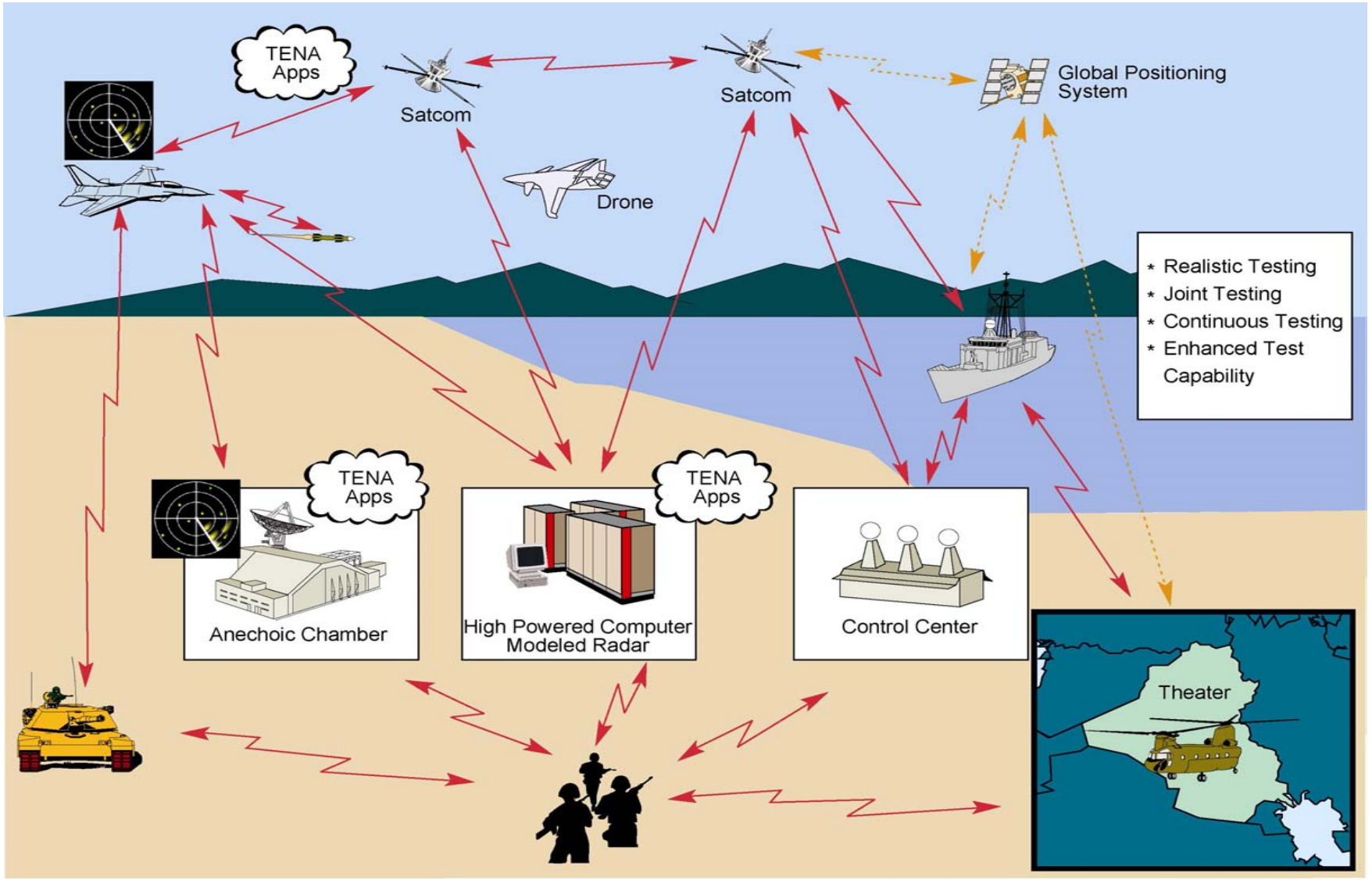
The purpose of TENA is to provide the architecture and the software implementation necessary to

- **Enable Interoperability among Range systems, Facilities, Simulations, C4ISR systems in a quick, cost-efficient manner, and**
- **Foster Reuse for Range asset utilization and for future developments**

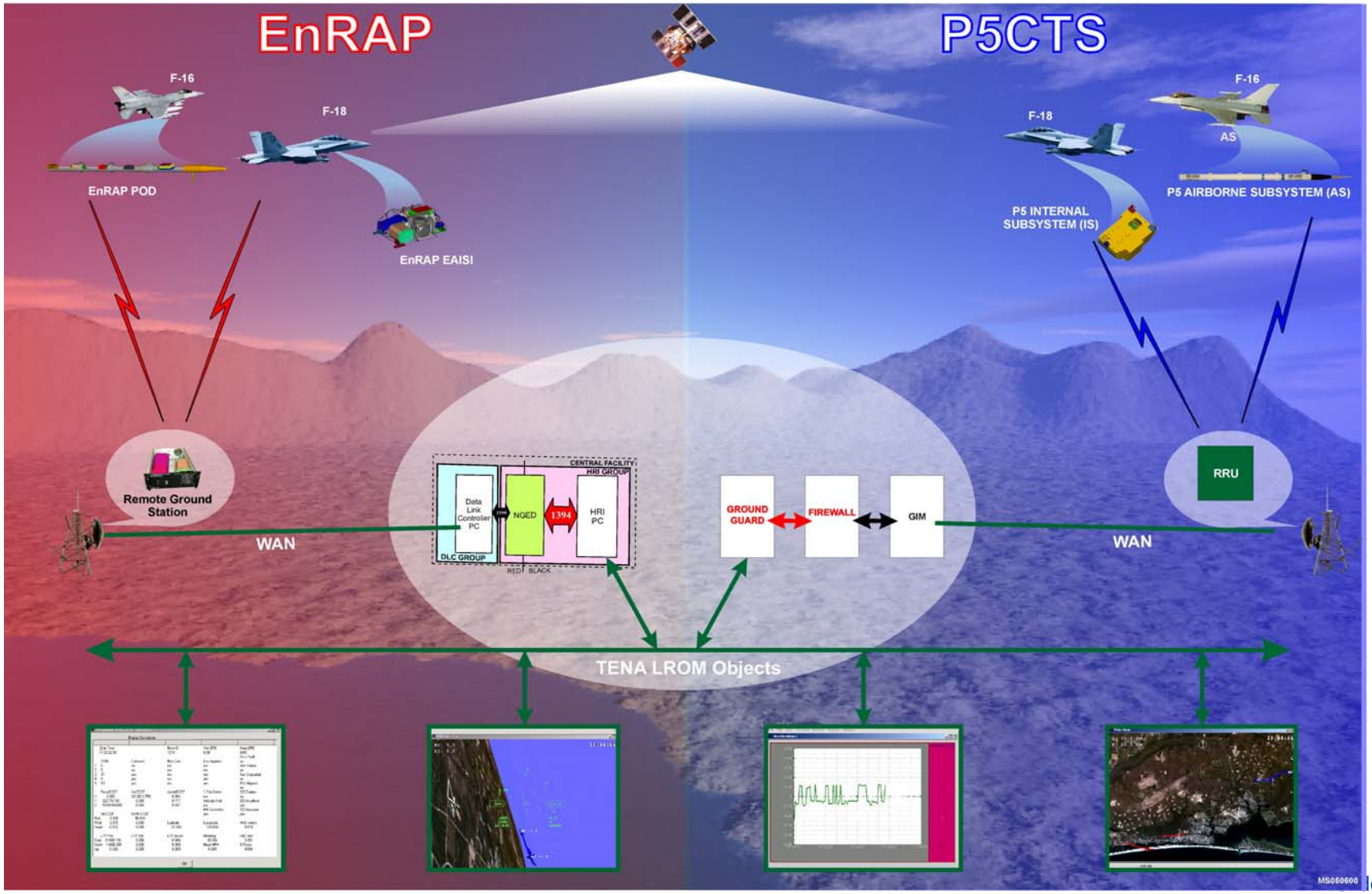
- **Support the Warfighter (Joint Vision 2010/2020)**
- **Enable Simulation-Based Acquisition**
- **Foster Test and Training Integration**
- **In the long term: SAVE MONEY!**

Lay the Foundation for Future Test and Training Range Instrumentation

CTEIP Integrated Architecture Global Command and Control Network



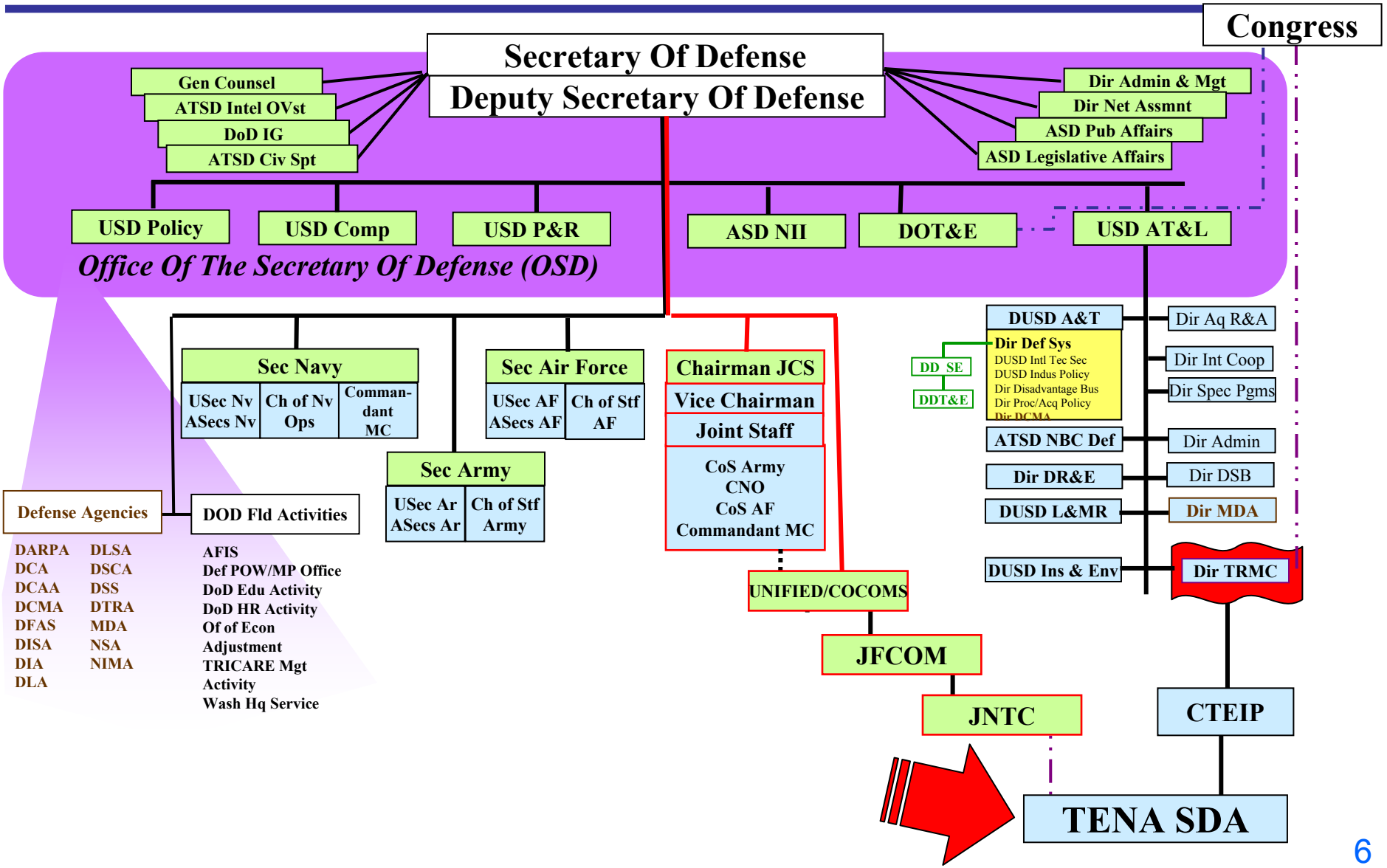
TENA is a Test and Training Interoperability Enabling Technology



TENA Software Development Activity (TENA SDA)

- **TENA Software Development Activity (TENA SDA) will assume sustainment and future development responsibilities for TENA for both the test and training communities**
- **Reports to CTEIP and the JNTC Joint Management Office (JNTC JMO) on all TENA-related activities, including but not limited to:**
  - Sustainment of TENA Middleware
  - Ports to different operating systems
  - Upgrades to the TENA Middleware
  - Upgrades to TENA-related tools and utilities (such as the auto-code generator)
  - Distribution of TENA Middleware
  - Distribution of source code generated from object models
  - Correction of software defects
  - Technical support to TENA users, including on-line help desk and TENA Training
- **Upgrades to TENA capabilities will stem from:**
  - Inputs from the Services (including from the annual reports the Services provide on their implementation of TENA on their systems)
  - Inputs from the T&E Executive Agent Needs and Solutions process
  - Joint training requirements through the JNTC JMO
  - Common requirements identified by members of the TENA AMT
  - Feedback provided by TENA users
  - Results/observations from test and training events
- **Other responsibilities include chairing the TENA AMT**

Where TENA SDA Fits in DoD



TENA Software Development Activity (SDA) Objectives

- **Refine and sustain the common Architecture for the test/training range community – "TENA" (Test & Training Enabling Architecture)**
  - Define a common **Object Model** to be used across the ranges
  - Continue development of a common Software **Middleware** that:
    - Uses the object model
    - Enhances interoperability and reuse among the ranges
- **Refine common understanding of range processes – the Logical Range Concept of Operations**
- **Define and prototype common Tools to configure and conduct multi-range, synthetic test events or training exercises**
  - Create distributed, synthetic battlespaces with real weapon systems
  - Link multiple ranges together to form a larger, cohesive range
  - Enable testing, assessment, experimentation, and training of weapon system interoperability, C4ISR, and system-of-systems

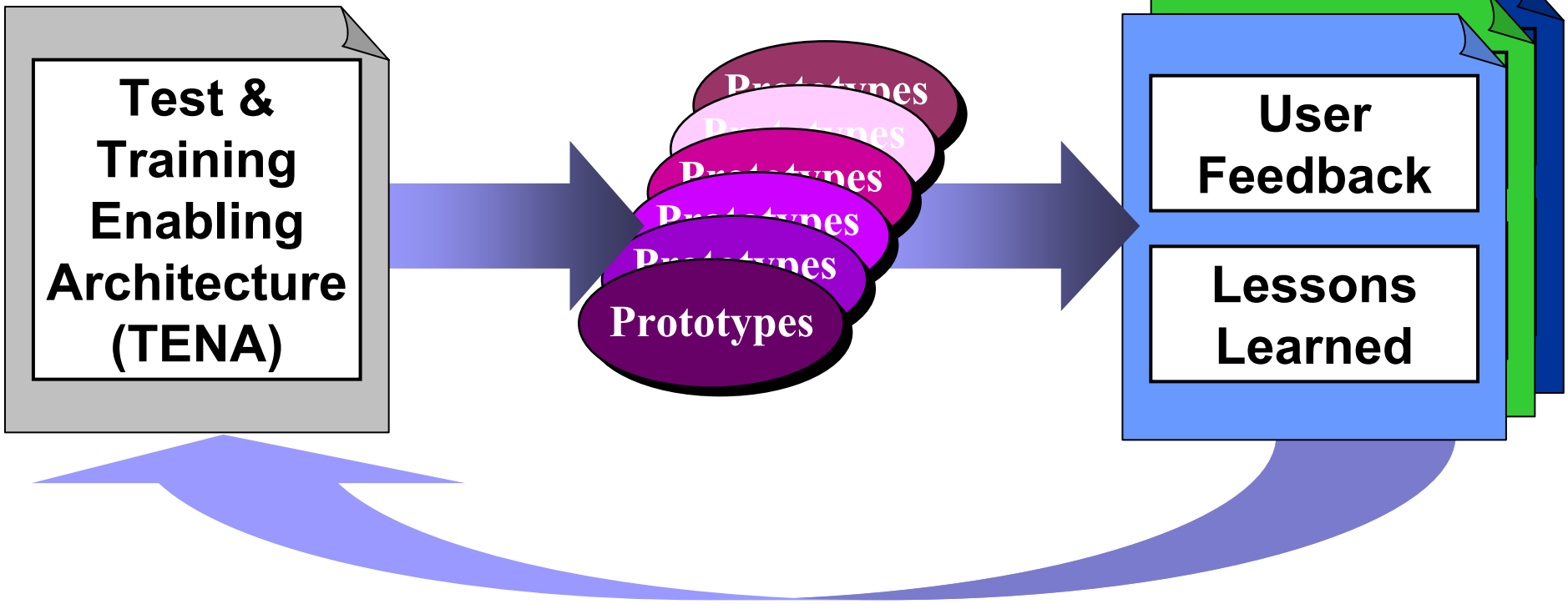
Architecture Management Team (TENA AMT)

- System Engineers & Technical Leads for the current major stakeholders of TENA
  - AAC, Eglin AFB FL
  - NUWC, Newport RI
  - RTTC, Huntsville AL
  - PMRF Synthetic Range
  - EPG, Fort Huachuca AZ
  - WSMR, White Sands NM
  - NAWC-AD, Pax River MD
  - P5 Combat Training System
  - Virtual Proving Ground (VPG)
  - Joint National Training Capability (JNTC)
  - NAWC-WD, China Lake & Point Mugu CA
  - Next Generation Range Instrumentation (NexRI)
  - New Generation Targetry System (NGATS)
  - Enhanced Range Application Program (EnRAP)
  - NAVSEA Warfare Center – Keyport, Keyport, WA
  - Common Training Instrumentation Architecture (CTIA)
  - Army Operational Test Command (OTC), Fort Hood, TX
  - NAVAIR Tactical Training Ranges Program Office (PMA-205)
- Design Decisions / Trade-offs / Status
- TENA Use Cases / Prototype Test Strategies
- Technical Exchanges of Lessons Learned
- Issues & Concerns Identification, Investigation, & Resolution

Meetings every 6-8 weeks

Raytheon, Boeing, SAIC, APL, MIT LL, JITC, DMSO, NRL, VMASC & ATC also attend & participate

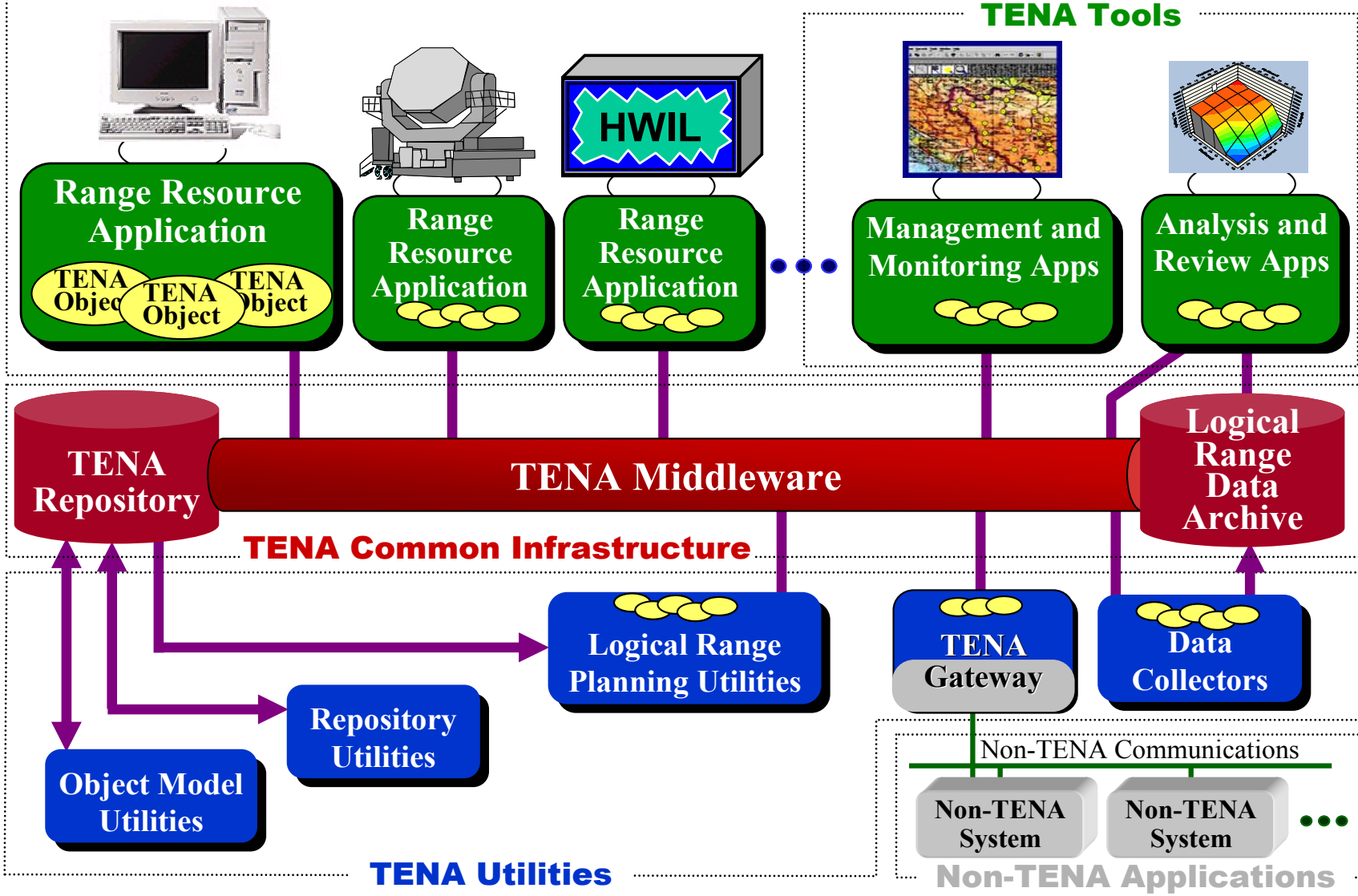
TENA Was Developed in Spirals with the Ranges Involved



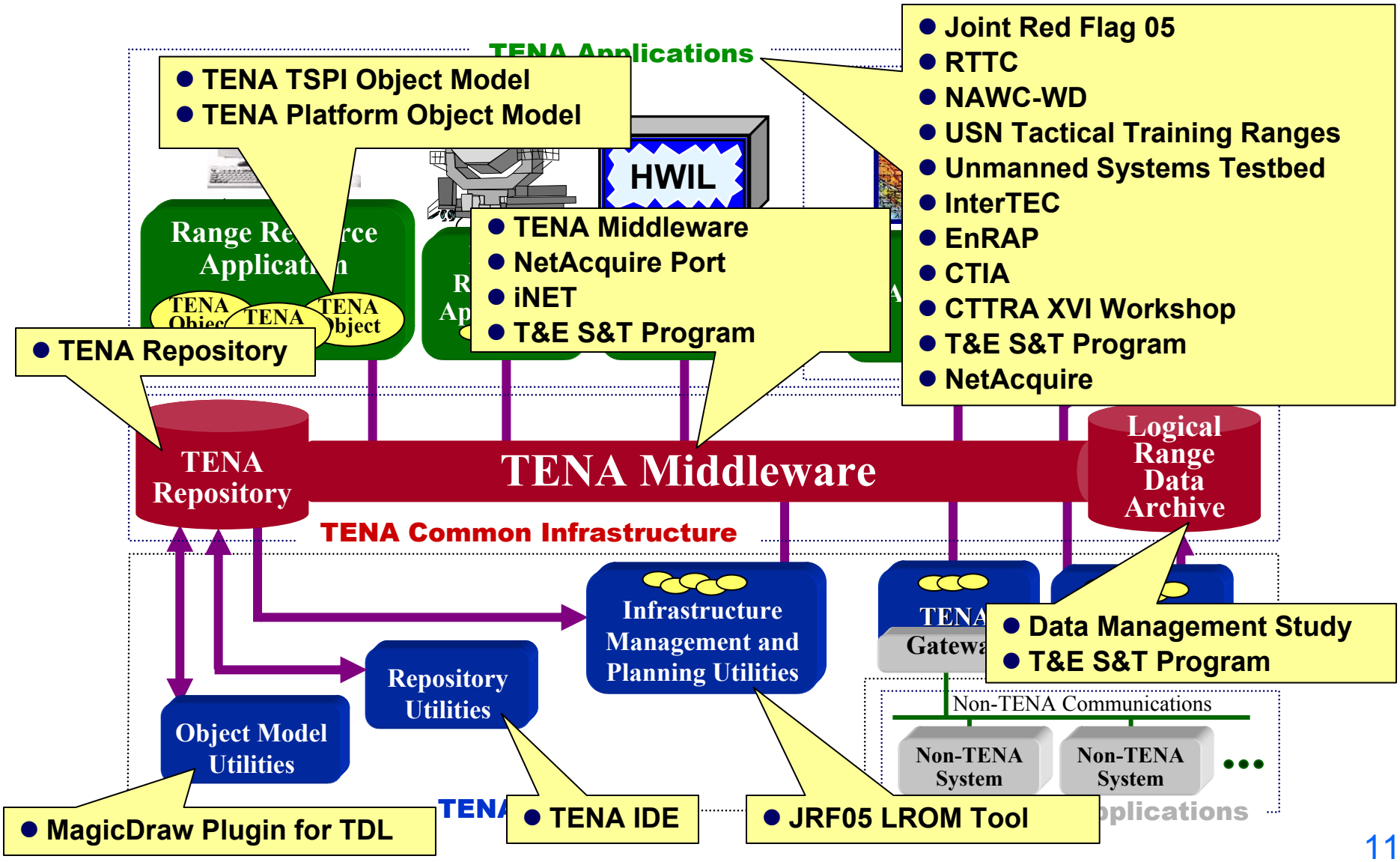
- TENA was revised based on user feedback and lessons learned from working software prototypes
- TENA will continue to evolve based upon emerging requirements
- TENA users (via AMT) determine what functionality is added to TENA

TENA is based on real-world tests at real ranges

TENA Architecture Overview



TENA Architecture Overview with Current Efforts Highlighted



Ways TENA Middleware Can Exchange Data

- **TENA presents to the range user a unification of several powerful inter-application communication paradigms**
  - **Publish/Subscribe**
    - Similar in effect to HLA, DIS, or other PDU-based communication systems
    - Each application publishes certain types of information (the publication state) which can be subscribed to by any other application
  - **Remote Method Invocation**
    - Similar to CORBA or Java RMI
    - Each object that is published may have methods that can be remotely invoked by other applications
  - **Messages**
    - Individual messages that can be sent from one application to one or more other applications
  - **Data Streams**
    - Native support for audio, video, telemetry, and tactical data links

Data Streams Demonstrated at Recent AMT Meeting

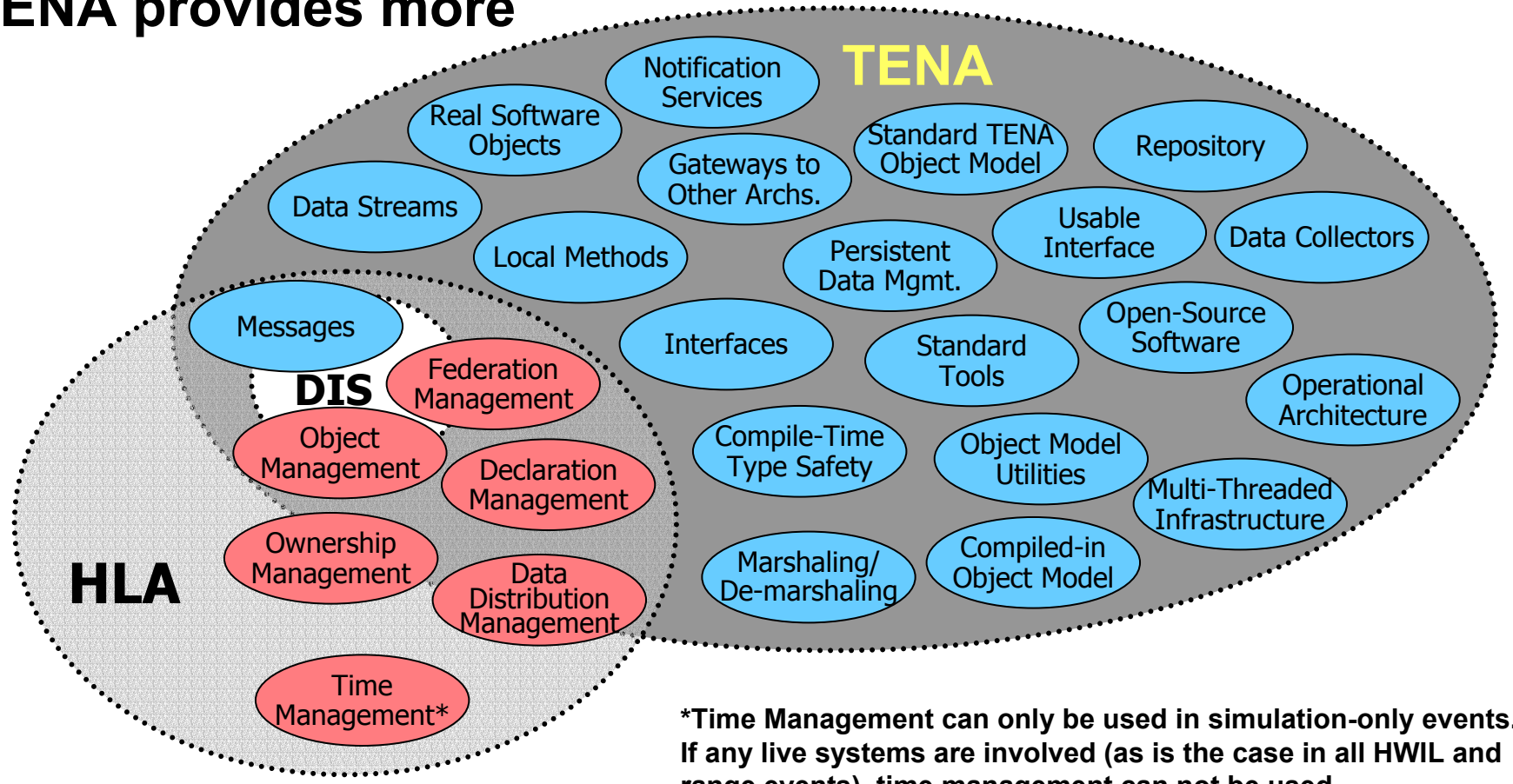
- **TENA provides remote control of data streams**
  - **Allows COTS/GOTS (such as, third-party vendor) streaming solutions and technologies to be used**
  - **TENA approach promotes interoperability and reuse by standardizing software interfaces and supporting the packaging of server/client stream components**

Live Video Stream Transmitted over Wireless Network

Video Stream File Played Back over Wireless Network

Capabilities of DIS, HLA, and TENA

- DIS only provides network, "on-the-wire" standard
- HLA provides some services and capabilities
- TENA provides more



*Time Management can only be used in simulation-only events. If any live systems are involved (as is the case in all HWIL and range events), time management can not be used

Joint Forces Command (JFCOM) Use of TENA

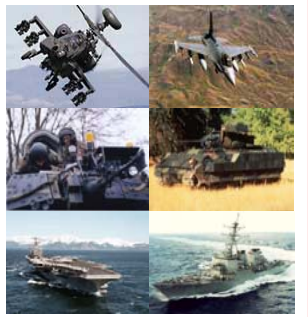
- **Live Data Instrumentation Infrastructure**
  - **TENA serves at JNTC integration architecture for range interoperability and bridge to simulation network**
- **Progressive support to JFCOM/JNTC Events:**
  - **Millennium Challenge 2002 (MC-02)**
    - **TENA provides common data model via gateways to integrate Range Instrumentation into JTASC GCCS**
  - **JCIDEX-03**
    - **Enhanced data model and native TENA interfaces for Range Instrumentation and Analysis Systems for JCID and RTCA assessment**
  - **WRC Horizontal Thrust Event (HTE)**
    - **TENA Application Management Object implemented to control Range Instrumentation data feeds and integrate for JCAS assessment**
  - **CJTFEX-04**
    - **Reuse of data model and native TENA interfaces for Range Instrumentation and Analysis Systems for JCID and JT&E**
  - **Joint Red Flag 2005 (JRF-05)**
    - **Combines: Red Flag 05, Virtual Flag, Roving Sands 05, Battle Group Inport Exercise (BGIE), Joint Systems Training Exercise (JSTE)**

Range Integration in Millennium Challenge 2002 (MC02)

Blue Forces

- Ships
- Ground forces
- Aircraft

Opposing Forces



- Aircraft & air targets
- Ships
- Ground forces

Nellis AFB
TENA Gateway

Land Range/China Lake
TENA Gateway

National Training Center/Ft. Irwin
TENA Gateway

Electronic Combat Range/China Lake
TENA Gateway

Sea Range/Point Mugu
TENA Gateway

US Marines/So. California Logistics Airfield

Joint Network

Joint Training, Analysis, and Simulation Center

TENA Gateway

Integrating Software

Global Command & Control System

Model & Simulation Feed

Command, Control, Communications, Computers, Intelligence Feed

TENA Use in JCIDEX 03

Live Infrastructure

Gulfport/Shelby/Camden MOA

ARDS GPS Pods

TACTS Pods

JTIDS Terminal

CRTC TACTS GND STN

CRTC LAN

ARDS GND STN

JTIDS TENA IF Gateway

TACTS TENA IF Gateway

ARDS TENA IF

Router

JCIET ADNET

Router

Router

Router

SA/AAR Display - PCDS -

Camp Shelby MS

JECG Display Rangeview

Ft. Rucker (opt)

SA/AAR Display

JECG Display

Eglin AFB

TENA Display Rangeview

SA/AAR Display

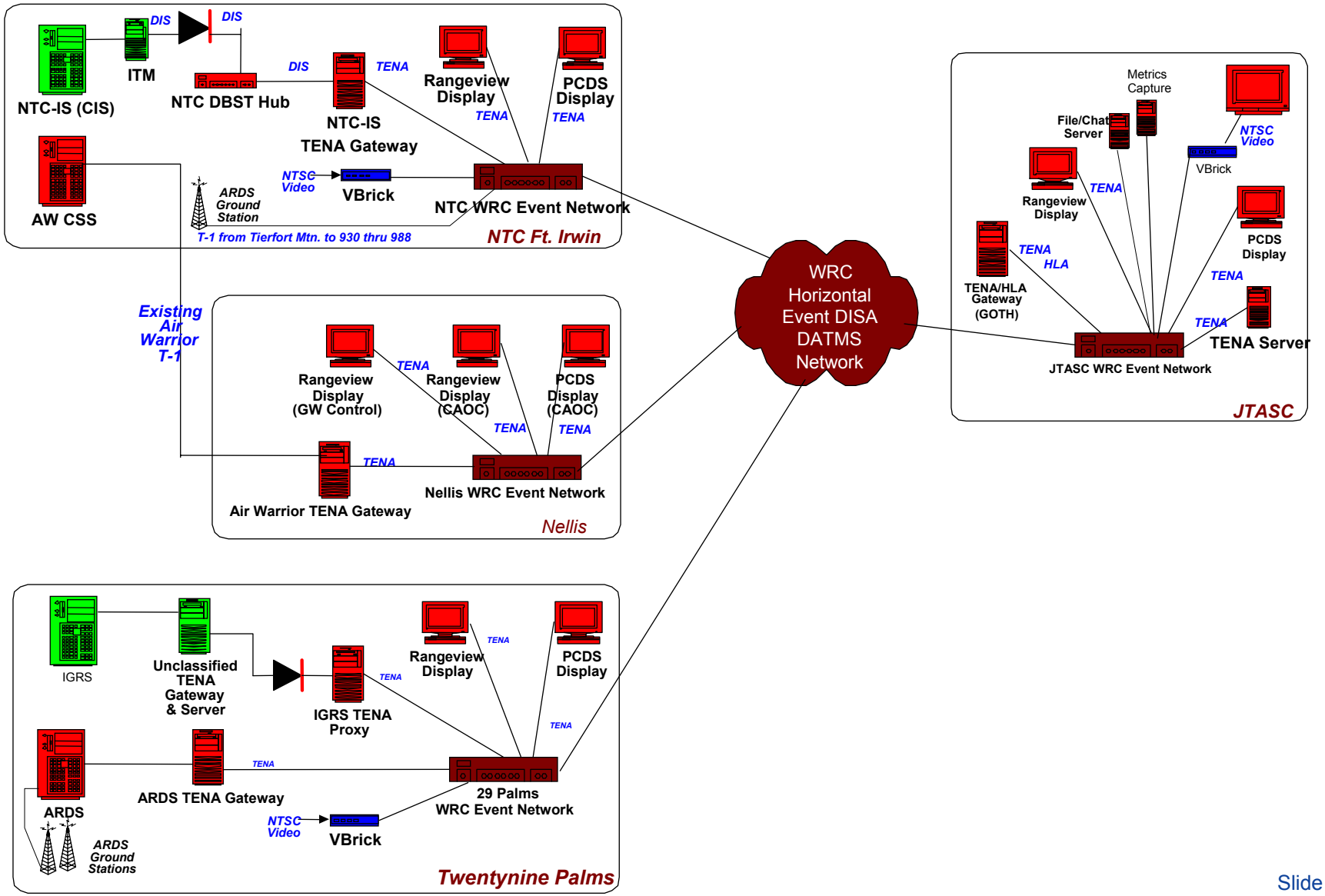
Gulfport CRTC

Casualty Assessment Workstation (A/G, G/G, A/A geo-pairing)

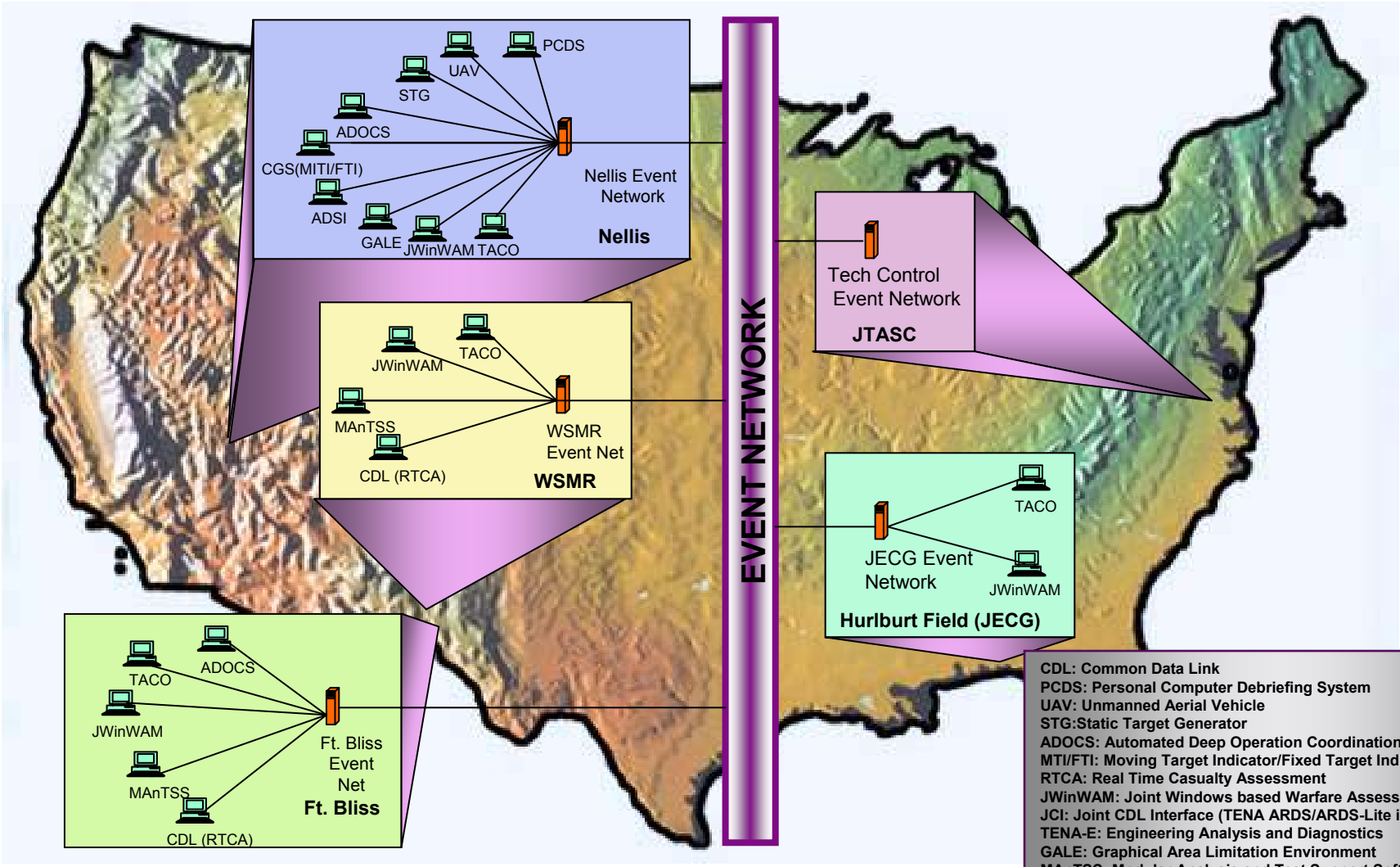
SA/AAR Display - PCDS - (TSPI)

JECG Display -Rangeview – (Analysis (AMO, TSPI, JTIDS, Instrumentation)

JNTC Horizontal Thrust Event Range Integration Solution



Joint Red Flag 2005



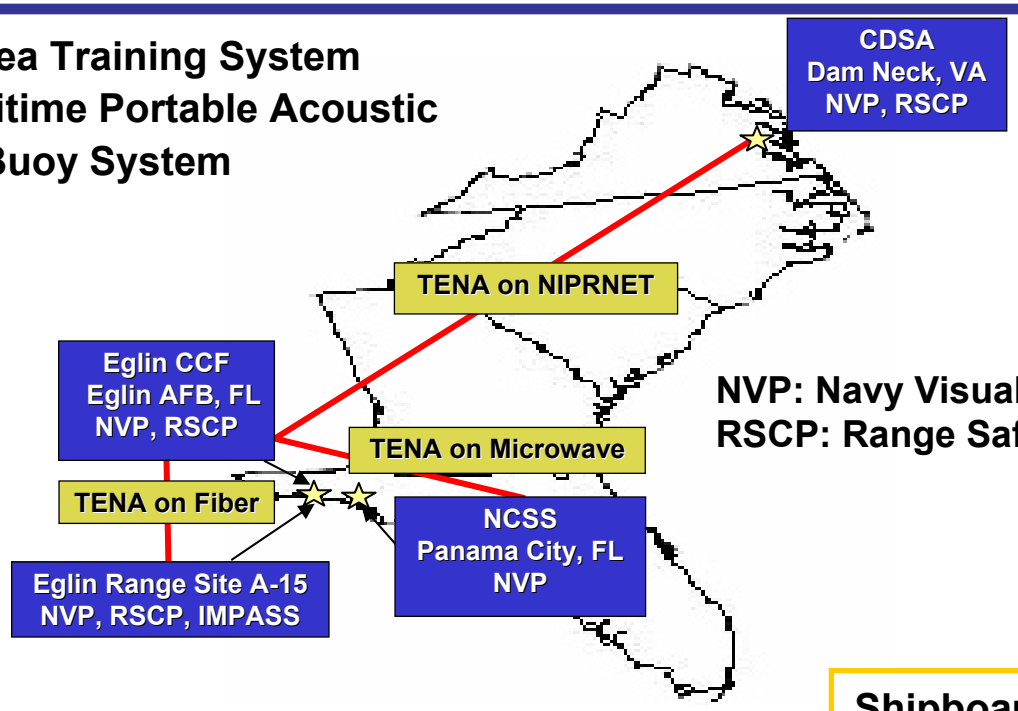
CDL: Common Data Link
PCDS: Personal Computer Debriefing System
UAV: Unmanned Aerial Vehicle
STG:Static Target Generator
ADOCS: Automated Deep Operation Coordination System
MTI/FTI: Moving Target Indicator/Fixed Target Indicator
RTCA: Real Time Casualty Assessment
JWinWAM: Joint Windows based Warfare Assessment Model.
JCI: Joint CDL Interface (TENA ARDS/ARDS-Lite interface)
TENA-E: Engineering Analysis and Diagnostics
GALE: Graphical Area Limitation Environment
MAnTSS: Modular Analysis and Test Support Software (White Cell)
TACO: TACtical Office
CGS: Common Ground Station
ADSI: Air Defense Systems Integrator

Systems Using TENA in JNTC Exercises

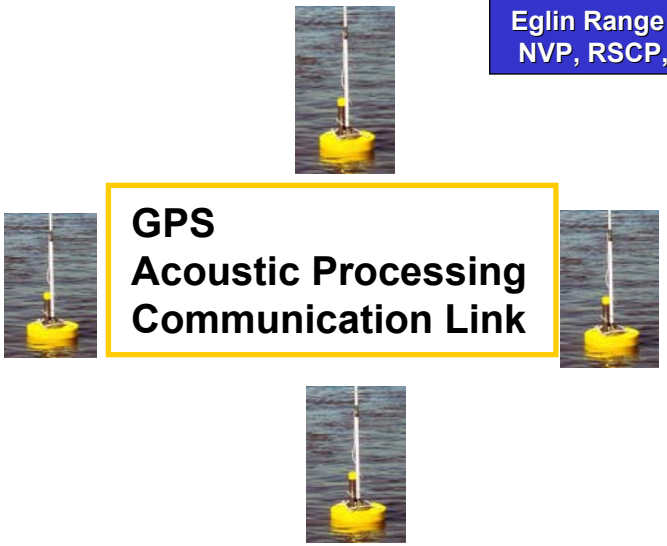
- Advanced Range Data System (ARDS and ARDS-Lite) instrumentation interface
- Air Force Air Warrior instrumentation interface
- Army National Training Center Instrumentation System (NTC-IS) instrumentation interface
- Army Test and Evaluation Command engagement adjudication workstation (named the Common Data Link – CDL)
- Automated Deep Operation Coordination System (ADOCS)
- GALAXY A LATR-type system used by the United Kingdom
- JNTC Live-to-Simulation gateway TENA to High Level Architecture application (named GOTH)
- Joint Close Air Support Joint Test & Evaluation COMBAT analysis system and display
- Joint Tactical Information Distribution System (named RAT TRAP)
- Large Area Tracking Range (LATR) system
- Marine Corps Integrated Global Positioning System Radio System (IGRS) instrumentation interface
- NAVAIR After Action Review AAR/Monitor Display (Personal Computer Debriefing System - PCDS)
- Navy Naval Air Systems Command (NAVAIR) RangeView analysis system and display
- Patriot Program Office, Tactical Office (TACO) analysis and display system
- Static Target Generator (STG)
- SureTrak Airspace radar monitoring system
- TENA to Distributed Interactive Simulation (DIS) analysis system (named TOSTADA)
- Time, Space, Position Information (TSPI) Internal Entity Re-formatter (TIER)
- Warfare Assessment Model (WAM) system

VAST / IMPASS Over-the-Water Scoring

VAST: Navy Virtual At Sea Training System
IMPASS: Integrated Maritime Portable Acoustic Scoring and Simulator Buoy System

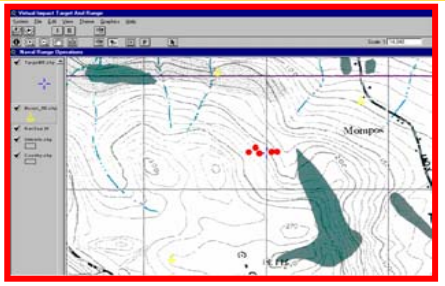


NVP: Navy Visualization Program
RSCP: Range Safety Control Program

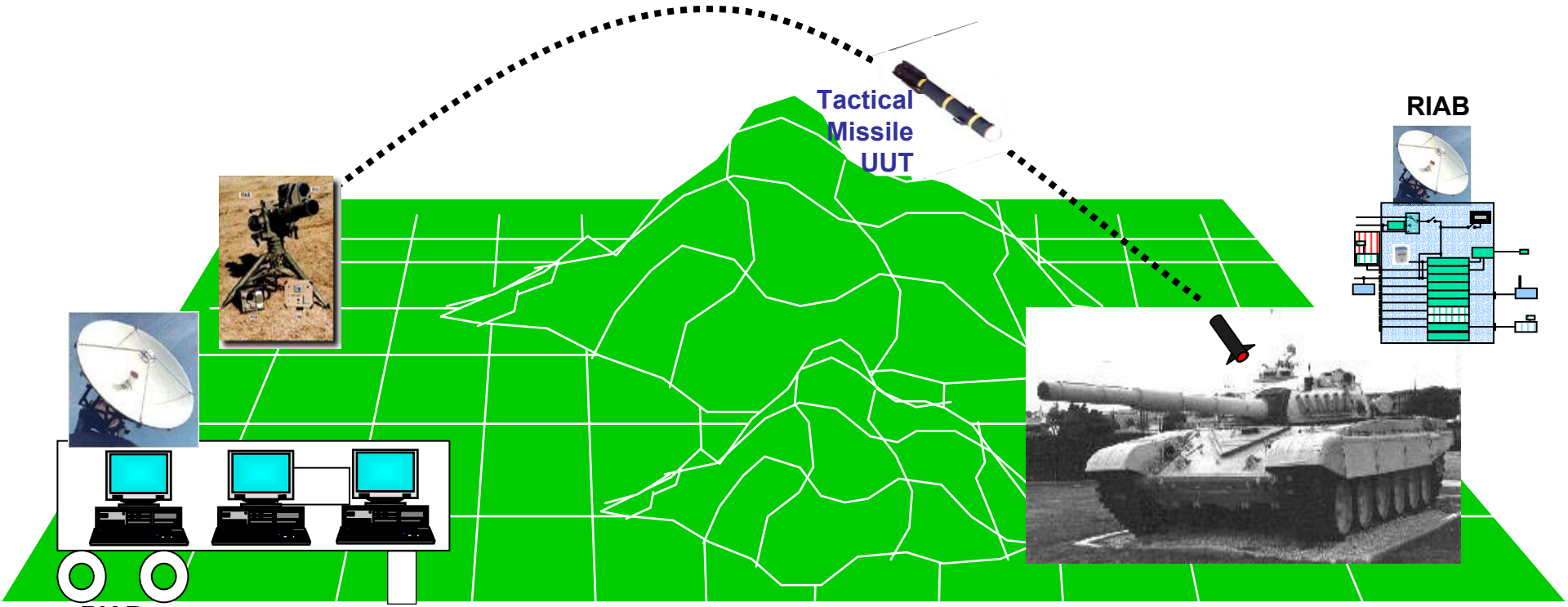


GPS
Acoustic Processing
Communication Link

Shipboard Processing
Map Rendering
Virtual Target



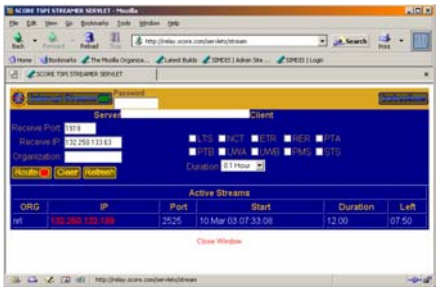
Redstone Technical Test Center Use of TENA



- MARDEC Support Active Protection System (APS)
  - FCS APS Candidate
- "Serial" Connection to RIAB
- TENA Control& Monitor
- Configuration Control in Range Software
- Data Logging via ILH Object

SIMDIS Use of TENA

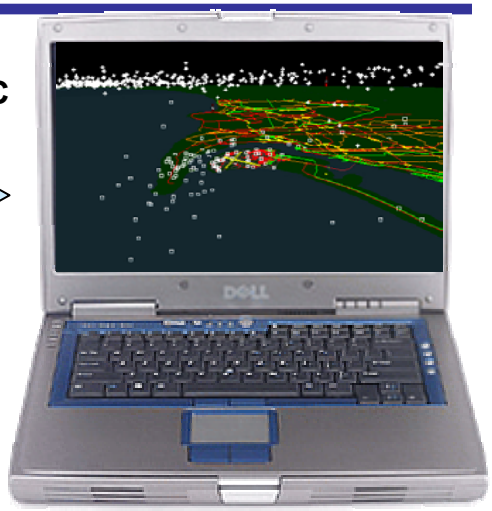
SCORE TSPI Feed



Southern California

TENA

NRL Washington, DC



- Duration testing using SCORE TSPI data feed
  - Four consecutive days
    - Win XP, Red Hat 9, Solaris 5.8
    - Processed 180,000+ entities
  - Two consecutive days
    - Win XP, Red Hat 9
    - Processed 53,000+ entities
- Results and observations
  - No issues with discovery latency
  - No issues with update latency
  - No issues with CPU usage
  - No issues with memory usage

Threat Systems Test of TENA

- Testing and analysis by Scientific Research Corporation (SRC)
- Results and observations:
  - TENA middleware appears stable and predictable
  - TENA object model format is sufficient for representation of threat systems
  - TENA provides satisfactory functionality and performance to be utilized within a threat simulation scenario and for fielding threat simulations

NetAcquire Using TENA
Real Time Embedded Instrumentation

- **Direct hardware interfaces not standard on COTS desktops**
  - Aerospace serial I/O formats (synchronous, telemetry, special protocols, etc.)
  - GPS (time and position)
  - Analog input / output
  - Digital and pulse input / output
  - IRIG timing
  - Avionics buses (1553, ARINC, 1394)
  - GPIB (IEEE-488) instrumentation
  - Inexpensive, ruggedized, mobile form-factor

- **Accomplishments:**
  - **Took NetAcquire only 11 days to port TENA into their products**
  - Direct synchronous serial hardware interface to FPS-16 radar system
  - Little or no programming required to support other radar data formats
- **NetAcquire runs a true real-time operating system, device drivers, and application software**
  - Provides TENA with deterministic and bounded response times

The Way Ahead for TENA

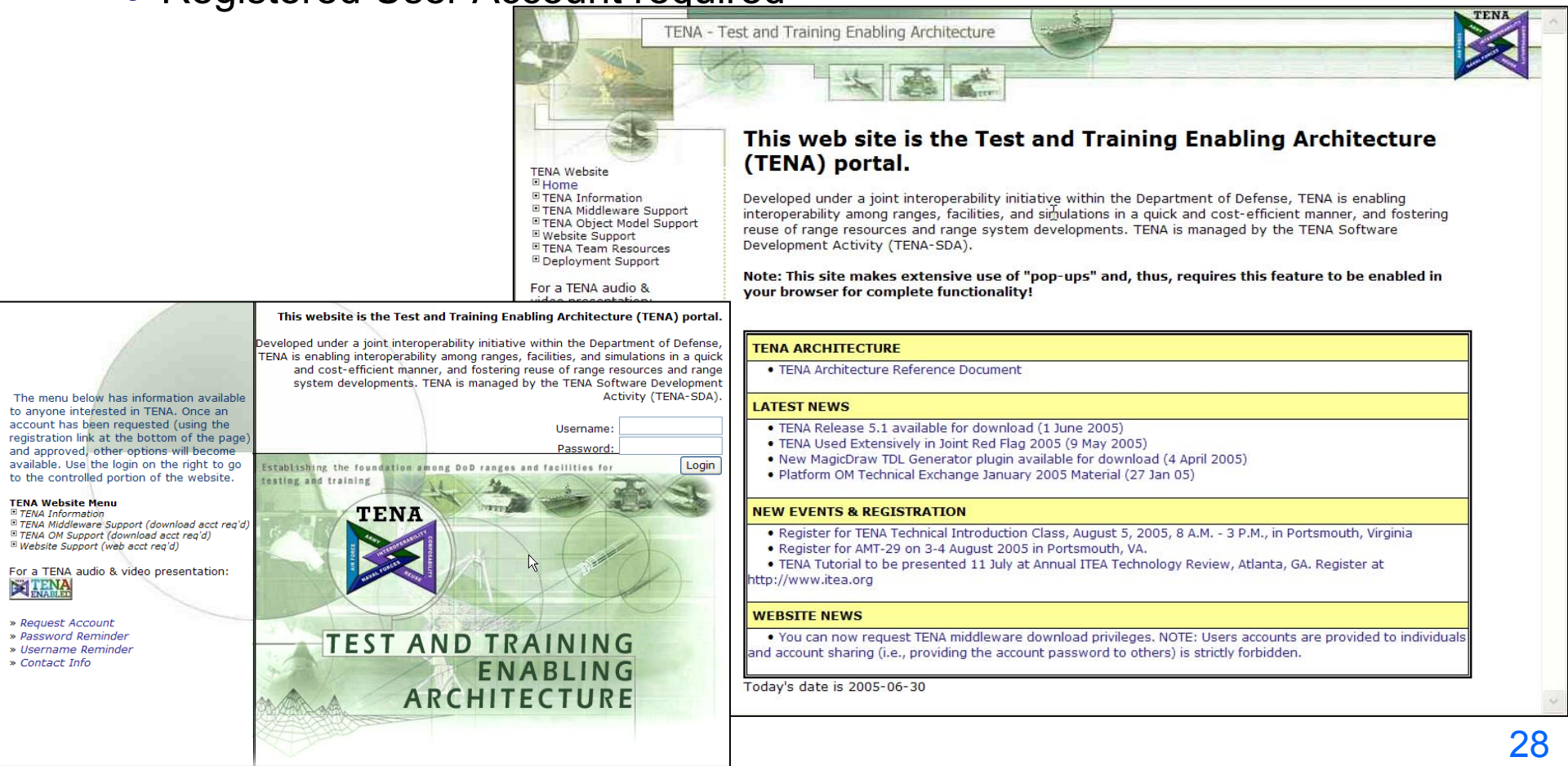
- **Continue partnership Joint National Training Capability (JNTC)**
  - Use the JNTC and JNTC-like events to reduce risk and refine application of TENA
    - Weapons Tactics & Instruction (WTI 06-2)
    - Terminal Fury
    - Talisman Saber
- **Joint Mission Environment Test Capability (JMETC)**
    - Army Cross Command Collaboration (3CE)
    - InterTEC
    - IO Range
    - Cope Thunder
- **Technically support and partner with PMs in their assessment and implementation of TENA for Test and Training applications**
- **Use the current TENA Requirements-Driven and Stakeholder-Prioritized process to spiral develop and prototype further TENA capabilities**

TENA Training Available

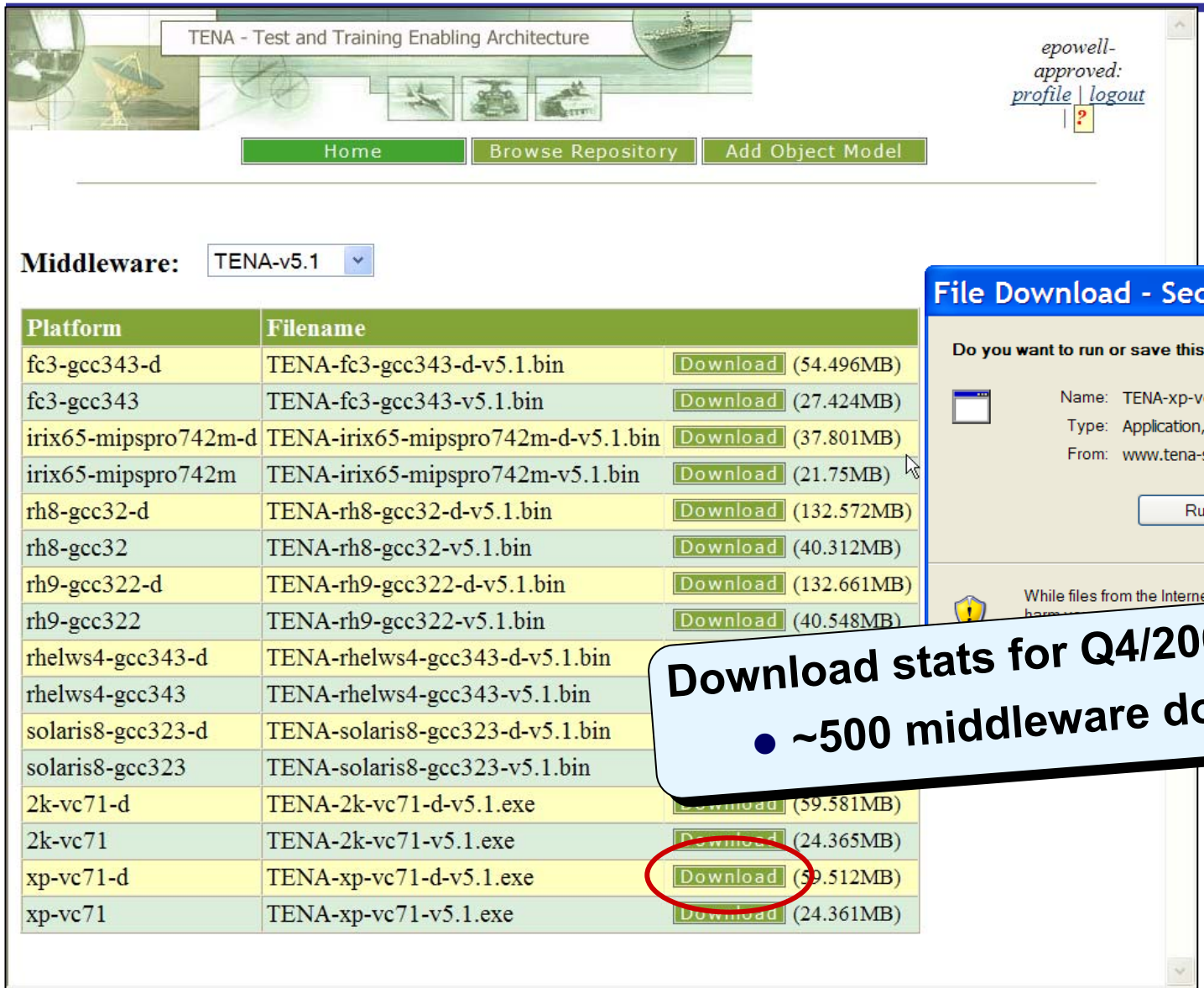
- **TENA Technical Overview Course (TOC)**
  - Designed for the non-programmer
  - Provides basic familiarization on TENA and Logical Ranges
  - Lecture format (full day, half day, and two-hour versions available)
- **TENA Technical Introduction Course (TIC)**
  - One day, lecture class for software programmers
  - Introduces design concepts to build TENA-compliant applications
  - 14 classes held to date
    - More than 350 software programmers trained to date
    - Classes held at White Sands, Point Mugu, RTTC, Eglin, Orlando, Alexandria, and London
- **TENA Middleware Hands-on Training (HOT)**
  - Four-day, computer class for software programmers
  - Provides several examples & exercises to learn the TENA Middleware API
  - 12 classes held to date
    - More than 250 software programmers trained to date
    - Classes held at White Sands, Point Mugu, RTTC, Eglin, Alexandria, China Lake, and Dugway (Salt Lake City)

Obtaining & Installing the TENA Middleware and Object Models

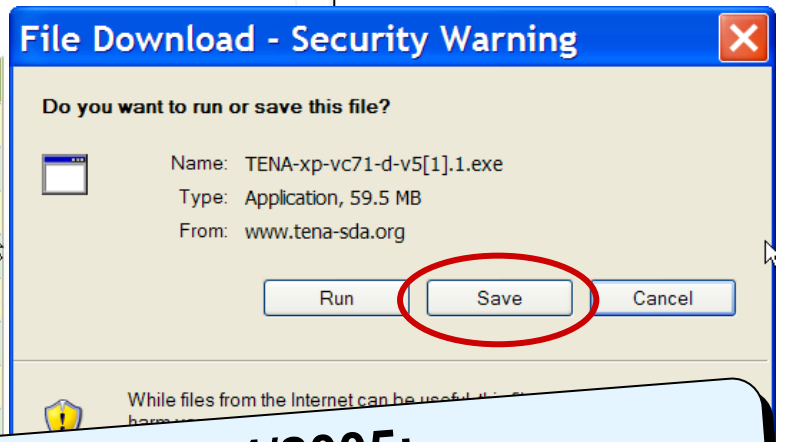
- **Get Middleware from the website**
  - http://www.tena-sda.org, log in, go to TENA Middleware Support
  - Registered User Account required



Downloading the TENA Middleware



Platform	Filename	
fc3-gcc343-d	TENA-fc3-gcc343-d-v5.1.bin	Download (54.496MB)
fc3-gcc343	TENA-fc3-gcc343-v5.1.bin	Download (27.424MB)
irix65-mipspro742m-d	TENA-irix65-mipspro742m-d-v5.1.bin	Download (37.801MB)
irix65-mipspro742m	TENA-irix65-mipspro742m-v5.1.bin	Download (21.75MB)
rh8-gcc32-d	TENA-rh8-gcc32-d-v5.1.bin	Download (132.572MB)
rh8-gcc32	TENA-rh8-gcc32-v5.1.bin	Download (40.312MB)
rh9-gcc322-d	TENA-rh9-gcc322-d-v5.1.bin	Download (132.661MB)
rh9-gcc322	TENA-rh9-gcc322-v5.1.bin	Download (40.548MB)
rhelws4-gcc343-d	TENA-rhelws4-gcc343-d-v5.1.bin	
rhelws4-gcc343	TENA-rhelws4-gcc343-v5.1.bin	
solaris8-gcc323-d	TENA-solaris8-gcc323-d-v5.1.bin	
solaris8-gcc323	TENA-solaris8-gcc323-v5.1.bin	
2k-vc71-d	TENA-2k-vc71-d-v5.1.exe	(59.581MB)
2k-vc71	TENA-2k-vc71-v5.1.exe	(24.365MB)
xp-vc71-d	TENA-xp-vc71-d-v5.1.exe	Download (59.512MB)
xp-vc71	TENA-xp-vc71-v5.1.exe	(24.361MB)



Download stats for Q4/2005:

- **~500 middleware downloads**

TENA Supported Platforms

Operating System	Compiler Type	Status
Embedded Planet (Linux Real-Time OS)	GCC 3.2.2	Supported **(5.1.1 release)**
Linux - Fedora Core 3	GCC 3.4.3	Supported
Linux - Fedora Core 4	GCC 4.0.1	Supported **(5.1.1 release)**
Linux - Red Hat 8.0	GCC 3.2	Supported
Linux - Red Hat 9.0	GCC 3.2.2	Supported
Linux - Red Hat Enterprise WS 4	GCC 3.4.3	Supported
Phar Lap ETS - NetAcquire (HW integrated Windows Real-Time OS)	MS Visual C++ 7.1	Supported (through CRADA with NetAcquire)
SGI IRIX 6.5.22m	GCC 3.3	Supported
Solaris 8	GCC 3.2.3	Supported
Solaris 10	Sun SPRO 5.8 (w/wo 64 bit mode)	Supported **(5.1.1 release)**
Windows 2000	MS Visual C++ 7.1	Supported
Windows XP	MS Visual C++ 7.1	Supported
MAC OS 10.4.2	GCC 3.3	Unable to support with 5.1.1 release due to TAO 1.3 incompatibility, will add when TAO is upgraded
VxWorks 6.1	GCC 3.3.2	Port in progress

Installing the Release

The TENA Middleware Release Notes
Release 5.1

Prepared for:

Central Test and Evaluation Investment Program (CTEIP)

The TENA Middleware was developed under contract 1435-04-01-CT-31085
in which the regulations from DFARS 252.227-7013 and 252.227-7014 are enforced.

Science Applications International Corporation
Kingstowne, VA

The TENA Middleware Installation Guide
Release 5.1

Prepared for:

Central Test and Evaluation Investment Program (CTEIP)

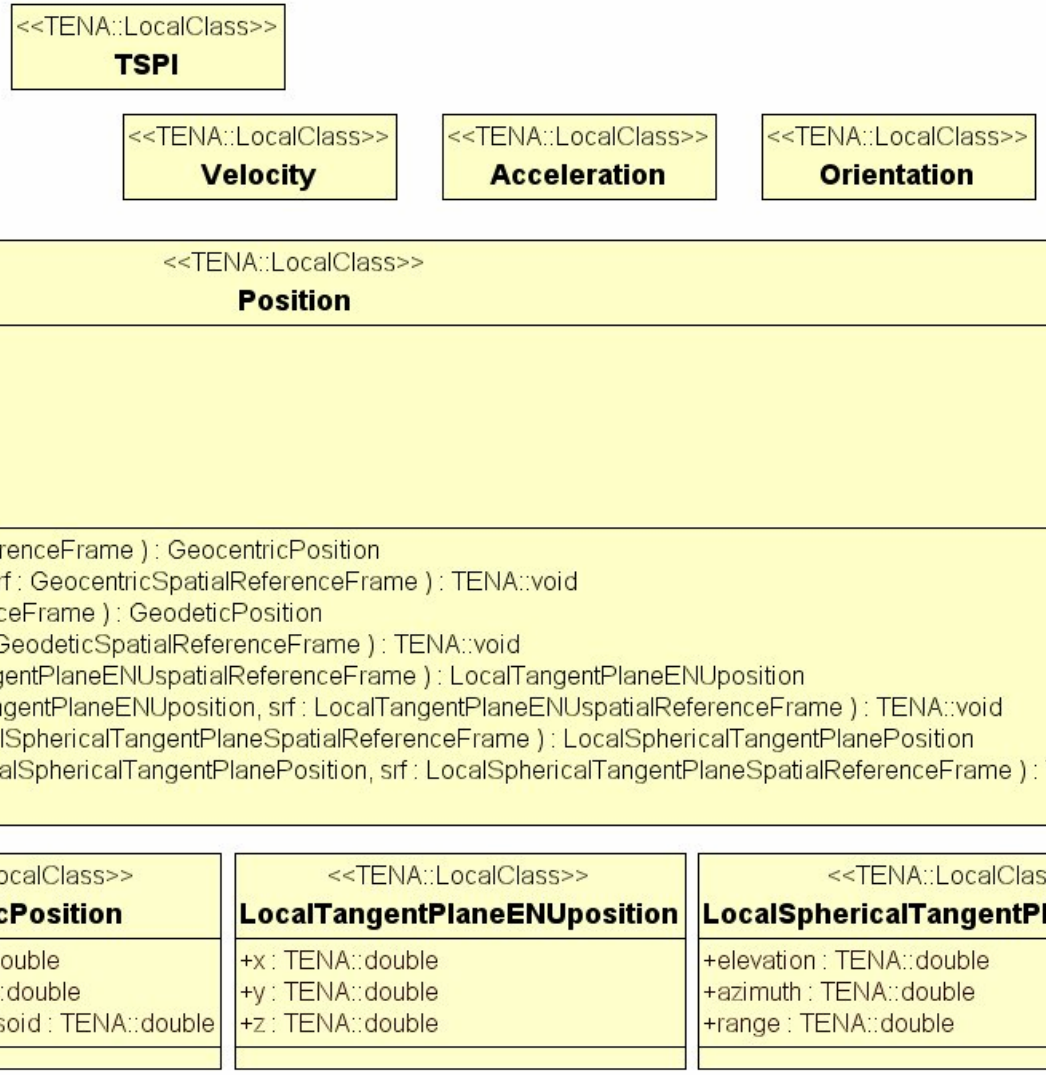
The TENA Middleware was developed under contract 1435-04-01-CT-31085
in which the regulations from DFARS 252.227-7013 and 252.227-7014 are enforced.

Science Applications International Corporation
Kingstowne, VA

TENA Standard Object Models

- **TENA-Platform:**
  - TENA-Platform-v3.1
  - TENA-PlatformDetails-v3
  - TENA-Affiliation-v1
  - TENA-UniqueID-v2
  - TENA-PlatformType-v1
  - DIS-EntityType-v1
  - TENA-Munition-v2.1
  - TENA-Engagement-v3.1
  - TENA-Organization-v1
  - TENA-EmbeddedSystem-v2
  - TENA-EmbeddedSensor-v2
  - TENA-EmbeddedWeapon-v2
- **TENA-AMO:**
  - TENA-AMO-v1
- **TENA-TSPI:**
  - TENA-TSPI-v4
  - TENA-Time-v1.1
  - TENA-Position-v1
  - TENA-Velocity-v1
  - TENA-Acceleration-v1
  - TENA-Orientation-v1
  - TENA-AngularVelocity-v1
  - TENA-AngularAcceleration-v1
  - TENA-ORM-v1
  - TENA-SRF-v1
  - TENA-SRFserver-v1

TENA-TSPI-v4
(TENA SDA Supported)



TENA Solutions to Interoperability Challenges

- On-the-Wire Specification vs. API Standard
  API Standard allows future technological advances for data transmission to be much more cost-effectively incorporated
- Single Reference Frame vs. Multiple Reference Frames
  Multiple Reference Frames allow different range systems to operate in the coordinate system most optimum for their range
- Single Level vs. Multiple Levels of Compliancy
  Multiple Levels of Compliancy allow a more meaningful definition of compliancy to be used among Range engineers & investment managers
- Run-Time Interpreter vs. Compile-Time Integration
  Compile-Time Integration allows for inconsistencies to be discovered when the software is being upgraded vice during the event
- Hand-Coded vs. Auto-Code-Generated Interfaces
  Auto-Code-Generated Interfaces can be produced more reliably and tremendously faster than traditional hand-coded interfaces

Summary

TENA is an Architecture for Ranges, Facilities, and Simulations to Interoperate, to be Reused, to be Composed into greater capabilities

- TENA can be downloaded from the Web (for free)
  - TENA Middleware currently works on Windows, Linux, and Sun
- Users are involved in the process to develop and expand the architecture
  - CTTRA Workshops, AMT Meetings, and RCC Coordination
- TENA is the JNTC architecture for Live integration
- TENA is being used in a number of applications including vendor instrumentation systems

Important Contact Information

- **Project Website: http://www.tena-sda.org**
  - Download TENA Middleware
  - Submit Helpdesk Case (http://support.fi2010.org)

- **TENA Architecture Reference Document**
  - http://www.tena-sda.org/documents/tena2002.pdf

- **TENA Feedback: feedback@tena-sda.org**
  - Provide technical feedback on TENA Architecture or Middleware
  - Ask technical questions regarding TENA
  - Provide responses to AMT action items
  - Request TENA training