Joint Range Interoperability Achieved Through Implementation of Test and Training Enabling Architecture (TENA)

Gene Hudgins
TENA Event Support Lead

21st National Test & Evaluation Forum, Charlotte, NC
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
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)

- Meetings every 6-8 weeks
- Raytheon, Boeing, SAIC, APL, MIT LL, JITC, DMSO, NRL, VMA & ATC also attend & participate

- Design Decisions / Trade-offs / Status
- TENA Use Cases / Prototype Test Strategies
- Technical Exchanges of Lessons Learned
- Issues & Concerns Identification, Investigation, & Resolution
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 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)
# JNTC-Related Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>TENA Version</th>
<th>Object Model</th>
<th>Applications / reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC-02</td>
<td>Jul 02</td>
<td>2.1</td>
<td>MC-02</td>
<td>2 apps, 2 new</td>
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<tr>
<td>RS-03</td>
<td>Jun 03</td>
<td></td>
<td></td>
<td>Cancelled due to Operation Iraq Freedom</td>
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<tr>
<td>JCIDEX 03</td>
<td>Aug 03</td>
<td>3.X</td>
<td>JCIDEX</td>
<td>6 apps, 1 reused, 5 new</td>
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<tr>
<td>HTE</td>
<td>Jan 04</td>
<td>3.X</td>
<td>JOM</td>
<td>9 apps, 6 reused, 3 new</td>
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<tr>
<td>CJTFEX</td>
<td>Jun 04</td>
<td>4.0.3</td>
<td>JOM</td>
<td>15 apps, 5 reused, 10 new</td>
</tr>
<tr>
<td>Cope Thunder</td>
<td>Aug 04</td>
<td>4.0.3</td>
<td>JOM</td>
<td>2 apps, 2 new</td>
</tr>
<tr>
<td>JRF-05</td>
<td>Mar 05</td>
<td>4.0.4</td>
<td>JOM</td>
<td>17 apps, 11 reused, 6 new</td>
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<tr>
<td>Application</td>
<td>Events</td>
<td>Description</td>
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<tr>
<td>TIER</td>
<td>MC02, HTE, CJTFEX, JRF</td>
<td>NAWC-WD range systems interface application and display</td>
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<tr>
<td>Rangeview</td>
<td>MC02, JCIDEX, HTE, CJTFEX, JRF</td>
<td>Test range oriented display and analysis tool</td>
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<tr>
<td>ARDS</td>
<td>JCIDEX, HTE, CJTFEX, JRF</td>
<td>Test and training instrumentation system interface</td>
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<tr>
<td>PCDS</td>
<td>JCIDEX, HTE, CJTFEX</td>
<td>Air Guard training monitor, display and debriefing tool</td>
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<tr>
<td>Air Warrior (TIER)</td>
<td>MC02, HTE</td>
<td>AF training instrumentation systems interface</td>
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<tr>
<td>NTC-IS (TIER)</td>
<td>MC02, HTE</td>
<td>Army, Natl Training Center instrumentation systems interface – DIS GW</td>
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<tr>
<td>IGRS</td>
<td>HTE</td>
<td>USMC instrumentation system interface</td>
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<td>GOTH</td>
<td>HTE, CJTFEX, JRF</td>
<td>TENA to HLA Gateway, TENA OM and FOM specific</td>
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<tr>
<td>CDL</td>
<td>JCIDEX, HTE, CJTFEX, JRF</td>
<td>Engagement Adjudication workstation – “Common Data Link”</td>
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<tr>
<td>JTIDS IF (2 variants)</td>
<td>JCIDEX, CJTFEX, JRF</td>
<td>Tactical C2 messages systems interface – DIS Signal PDU or Socket J GW</td>
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<tr>
<td>TACO</td>
<td>HTE, CJTFEX</td>
<td>Analysis monitor and display tool, w/Patriot interface</td>
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<tr>
<td>WAM</td>
<td>CJTFEX, JRF</td>
<td>Analysis monitor and display tool</td>
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<tr>
<td>Static Tgt Gen</td>
<td>CJTFEX, JRF</td>
<td>Instrumentation simulator for non-moving, non-instrumented ground targets</td>
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<tr>
<td>CGS</td>
<td>CJTFEX, JRF</td>
<td>UAV/JSTARS Moving Tgt Indicator (MTI) / Fixed Tgt Indicator (FTI)</td>
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<tr>
<td>UAV</td>
<td>CJTFEX, JRF</td>
<td>Unmanned Aerial Vehicle (Predator) ground station TM and inst interface</td>
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<tr>
<td>ADOCS</td>
<td>CJTFEX</td>
<td>Army C2 messaging and database system</td>
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<tr>
<td>SureTrak</td>
<td>CJTFEX</td>
<td>Multi-source instrumentation interface and analysis – airspace monitor</td>
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<tr>
<td>TACTS GW</td>
<td>JCIDEX</td>
<td>Gulfport Air Natl Guard range ACMI instrumentation gateway</td>
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<tr>
<td>TENA-DIS</td>
<td>CJTFEX, JRF</td>
<td>TENA OM to DIS PDU translator for selected classes and PDUs</td>
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</tbody>
</table>
Range Integration in Millennium Challenge 2002 (MC02)

Blue Forces
- Ships
- Ground forces
- Aircraft

Opposing Forces
- Aircraft & air targets
- Ships
- Ground forces

Joint Training, Analysis, and Simulation Center

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

Model & Simulation Feed

Command, Control, Communications, Computers, Intelligence Feed

Global Command & Control System

Integrating Software

TENA Gateway
TENA Use in JCIDEK 03

Live Infrastructure

Gulfport/Shelby/Camden MOA

ARDS GPS Pods

JTIDS Terminal

JTIDS TENA IF Gateway

CRTC TACTS GND STN

CRTC LAN

ARDS TACTS TENA IF Gateway

ARDS GND STN

ARDEs TACTS TENA IF

JCIET ADNET

Camp Shelby MS

Ft. Rucker (opt)

Gulfport CRTC

ARDS CRTC

Casualty Assessment Workstation

(A/G, G/G, A/A geo-pairing)

JECG Display

- Rangeview -

(Analysis

(AMO, TSPI, JTIDS,

Instrumentation)

JECG Display

- Rangeview

- PCDS -

(AMO, TSPI, JTIDS,

Instrumentation)

JTIDS TENA IF Gateway

SA/AAR Display

JECG Display

Camp Shelby MS

Ft. Rucker (opt)

Eglin AFB

SA/AAR Display

Rangeview

SA/AAR Display

Rangeview

SA/AAR Display

Slide 13
JNTC Horizontal Thrust Event Range Integration Solution
VAST / IMPASS
Network Connectivity

Eglin Central Control Facility

TENA on NIPRNET

CDSA
Dam Neck, VA

TENA on Fiber

Eglin Range Site A-15

TENA on Microwave

CSS
Panama City, FL
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
Weibel Radar Using TENA

All Systems using TENA

- Remote Operator
- WinTrack w/DLL
- 3D World
- NNS / EM
- ILH
- GPS
- ILH Database

CTEIP
IMPROVING I&E CAPABILITIES
**SIMDIS Use of TENA**

- **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
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
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
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)
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

- FI 2010 Project Website, links to Middleware, help desk: [http://www.TENA-SDA.org](http://www.TENA-SDA.org)


- TENA SDA Project Topics: [TENA-SDA@tena-sda.org](mailto:TENA-SDA@tena-sda.org)

- Questions, comments, feedback about the TENA architecture or the TENA Middleware: [TENA-feedback@tena-sda.org](mailto:TENA-feedback@tena-sda.org)

- TENA user community: [TENA-users@tena-sda.org](mailto:TENA-users@tena-sda.org)
Additional Slides Available But Not Planned to be Presented
Some Limitations of Distributed Interactive Simulation (DIS)

- Network protocol standard only (no other services)
- Fixed protocol data units (no flexibility)
  - Data PDUs serve as workarounds but are not standardized
  - All data must fit within Ethernet frame size (~1500 bytes)
- Unreliable delivery only (no reliable delivery of data)
- Data broadcasted to all nodes (drives bandwidth up at all sites)
  - Requires every system to process every message (regardless of need)
  - No optimized delivery schemes / No multicast
- Many workarounds has resulted in many variants of DIS
- Only one coordinate system available
  - Everything must be defined in geocentric terms
  - Coordinate conversions take time and can add unnecessary uncertainty
Some Limitations in High Level Architecture (HLA)

- **No composability of objects**
  - Prevents incorporation of small, reusable “building blocks” (like TSPI)

- **Not Object-Oriented**
  - No remote method invocations (needed to easily remote control devices)
  - No local classes (needed to embed standard translation algorithms)

- **No Control of Data Streams**
  - Needed for video, audio, telemetry, tactical data links, etc.

- **No Object Pointers (for better data associations)**

- **No Marshalling / Demarshalling**
  - Makes users worry about big endian / little endian issues

- **No compile-time error checking (impacts reliability)**
  - Data discrepancies discovered during event

- **Multiple, Non-interoperable RTIs**
  - RTI now must be purchased (even though the American taxpayer has already paid for one, it is no longer distributed)
  - Makes some users buy multiple RTIs to support different exercises
Functions to Send Data from One System to Another

**Sender**
- **Standard API**
  - **Object Representation**
  - **Publication Services**
  - **Coordinate Transformations**
  - **Data Marshalling**
  - **Data Routing / Optimization**
  - **Reliable / Multicast Send**
  - **Packet Fragmentation**
  - **Wire Protocol Selection**
  - **Send PDU**

**Receiver**
- **Standard API**
  - **Subscription Services**
  - **Object Representation**
  - **Coordinate Transformations**
  - **Data Demarshalling**
  - **Data Stream Receive**
  - **Data Routing**
  - **Reliable / Multicast Receive**
  - **Packet Reassembly**
  - **Wire Protocol Selection**
  - **Receive PDU**
DIS Only Provides Specification for Network Data Packet

**Sender**
- Standard API
- Object Representation
- Publication Services
- Coordinate Transformations
- Data Marshalling
- Data Routing / Optimization
- Reliable / Multicast Send
- Packet Fragmentation
- Wire Protocol Selection
- Send PDU

**Receiver**
- Standard API
- Subscription Services
- Object Representation
- Coordinate Transformations
- Data De-marshalling
- Data Stream Receive
- Data Routing
- Reliable / Multicast Receive
- Packet Reassembly
- Wire Protocol Selection
- Receive PDU

Network or Other Communication Media
HLA Provides Some Publish and Subscribe Functionality

**Sender**

- **Standard API**
  - Object Representation
  - Publication Services
  - Data Marshalling
  - Data Routing / Optimization
  - Reliable / Multicast Send
  - Packet Fragmentation
  - Wire Protocol Selection
  - Send PDU

**Receiver**

- **Standard API**
  - Object Representation
  - Subscription Services
  - Data De-marshal/ing
  - Data Routing
  - Reliable / Multicast Receive
  - Packet Reassembly
  - Wire Protocol Selection
  - Receive PDU

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Network or Other Communication Media

Slide 30
TENA Also Provides Data Translations & Marshalling

Sender
- Standard API
  - Object Representation
  - Publication Services
  - Coordinate Transformations
  - Data Marshalling
  - Data Routing / Optimization
  - Reliable / Multicast Send
  - Packet Fragmentation
  - Wire Protocol Selection
  - Send PDU

Receiver
- Standard API
  - Subscription Services
  - Object Representation
  - Coordinate Transformations
  - Data Demarshalling
  - Data Stream Receive
  - Data Routing
  - Reliable / Multicast Receive
  - Packet Reassembly
  - Wire Protocol Selection
  - Receive PDU
TENA Saves Time by Auto Code Generating Interfaces

Created by the event developers

Created by the DoD capability developers

Event object definitions

Object Model Utilities: Code Generator

Object implementations

Generated Source Code

Compiler

User Application Code

Application Object Code

Data Archive Schema

Data Archive Manager

Creates

Read by

Interface Object Code

Common Middleware

Application Object Code

Data Archive

Linker

Created by the event developers

relies on

1

2

3

Object Model Utilities: Code Generator

Compiler

User Application code

Application Object Code

Common Middleware

User Application Code

Servant

Proxy

Proxy

Servant

Common Middleware
Redstone Technical Test Center
Use of TENA

Instrument(s) Under Use

Fire Control Computer
Platform(s) Under Testing

ILH Data Publisher
ILH Data Logger
ILH Database

TENA
TENA Middleware
Platform / Language Support

- **Release 4.0 Platform Support**
  - Windows 2000 (sp4) with MSVC++ 7.0
  - Windows 2000 (sp4) with MSVC++ 7.1
  - Windows XP (sp1) with MSVC++ 7.0
  - Windows XP (sp1) with MSVC++ 7.1
  - Linux Red Hat 8.0 (2.4.18 kernel) with gcc 3.2
  - Linux Red Hat 9.0 (2.4.20 kernel) with gcc 3.2.2
  - Sun Solaris 8 (SPARC) with gcc 3.2.3
  - SGI IRIX 6.5 (22m) with gcc 3.3

- **Release 4.0 Language Support**
  - C++ support provided with current release
  - OCX (COM) wrapper developed by TENA User (RTTC)
  - Java wrapper methodology provided by TENA User (Eglin)

- **Next Release**
  - Support for VxWorks
## Summary of Key TENA Functionality Beyond HLA

### Standard Object Model
TENA provides for the managed evolution of a standardized Object Model (interfaces, data formats, data definitions, control commands, etc.)

*Significance:* Range-community-wide agreed upon data formats, definitions, etc. promotes interoperability to a greater degree than the HLA specification

### High Performance and Reliability
TENA Objects are “compiled-in” when the application is made TENA-compliant

*Significance:* Higher performance, plus higher reliability since any errors in data formats will be discovered during software compiling (pre-mission) rather than during the test mission (at run-time)

### Manages Persistent Data
TENA provides for the management and standardization of database information throughout the range event lifecycle, including scenario information and data collected during an exercise

*Significance:* Interoperability is achieved before, during, and after a range event, leading to easier setup, initialization, and analysis, saving both time and money

### Support for Data Streams
TENA supports real-time delivery and storage of data stream information (audio, video, and telemetry)

*Significance:* A substantial amount of test information is streaming data. Fully integrating data streams into TENA provides high-performance management of this type of information in a standard, reusable, interoperable fashion

### Support for More Complex, Meaningful, User-Defined Object Models
TENA allows for objects to be composed of other objects (objects can contain other objects)

*Significance:* Small “building block” objects (Time, Position, Orientation, etc.) can be standardized and reused to efficiently define other more complex objects, yielding more interoperability quickly at less cost than with the HLA

TENA Middleware marshals/demarshals data, rather than relying on individual applications to do so

*Significance:* Middleware marshaling makes it easier to integrate different computer platforms (Windows, Linux, Sun, etc.) in a distributed test event and avoid integration errors due to inconsistent user-written software

TENA supports remotely invoking “methods” (control commands, operations, processes) of another application

*Significance:* Software interfaces can be designed more naturally and effectively for distributed test events