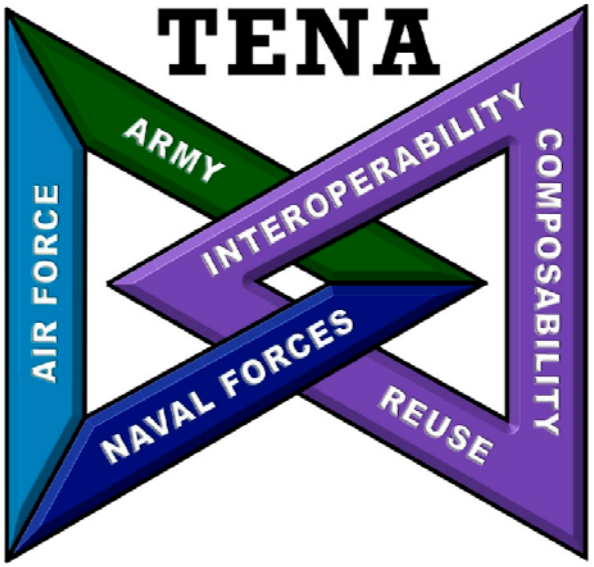


Joint Range Interoperability Achieved Through Implementation of Test and Training Enabling Architecture (TENA)

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**

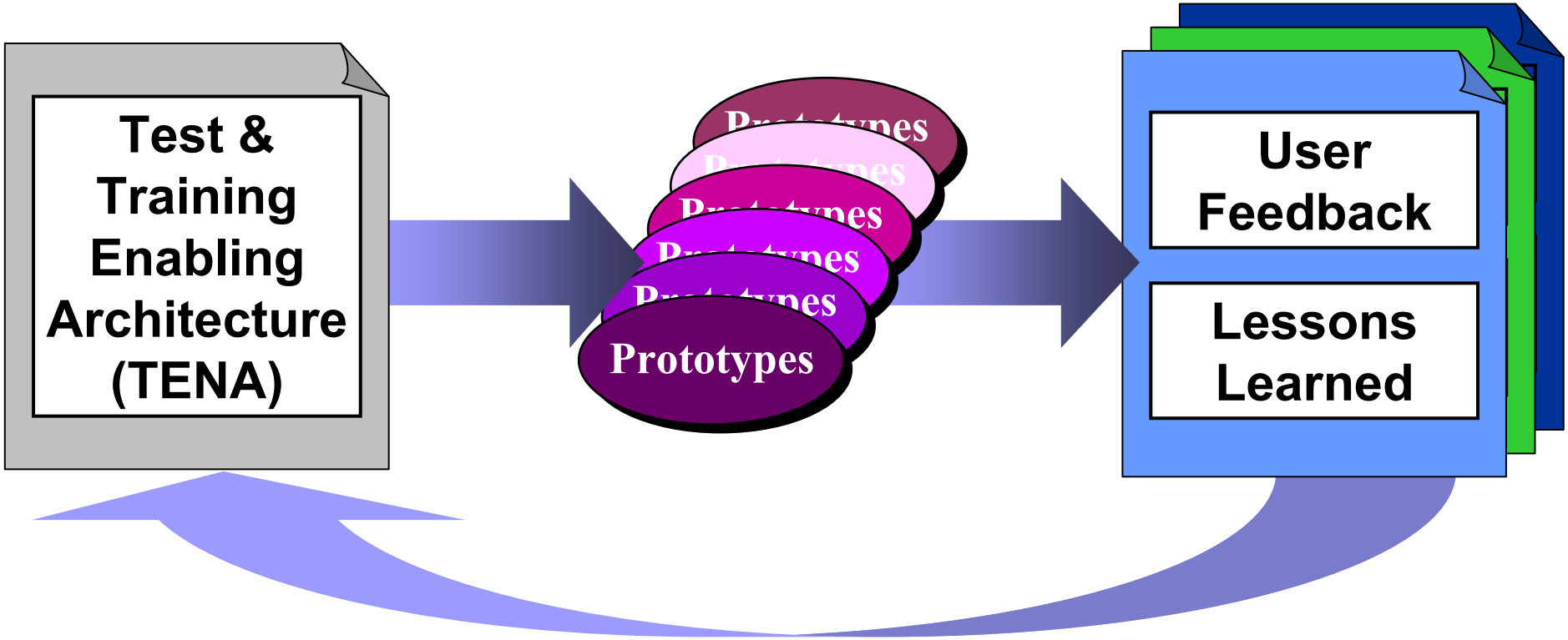
Architecture Management Team (TENA AMT)

- 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)
- 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

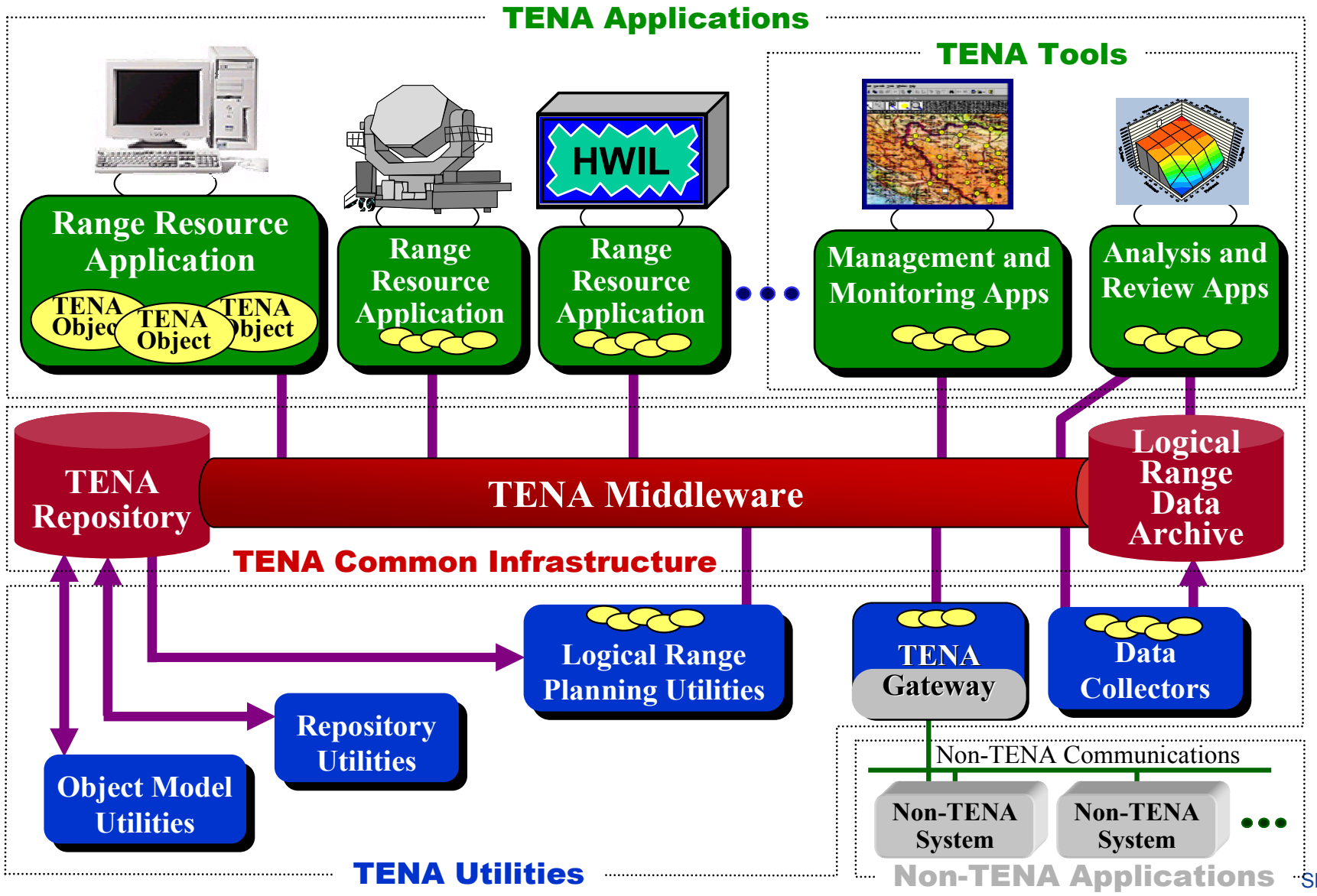
TENA Was Developed in Spirals with the Ranges Involved



- 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



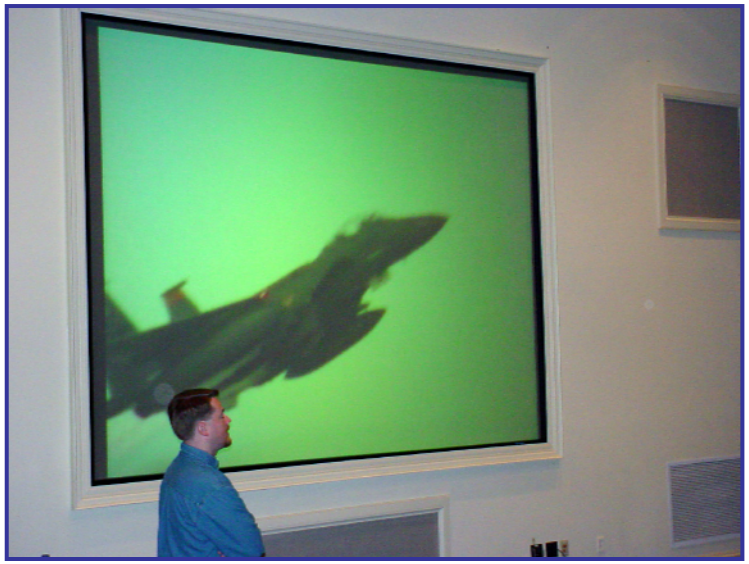
Ways TENA Middleware Can Exchange Data

- **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**

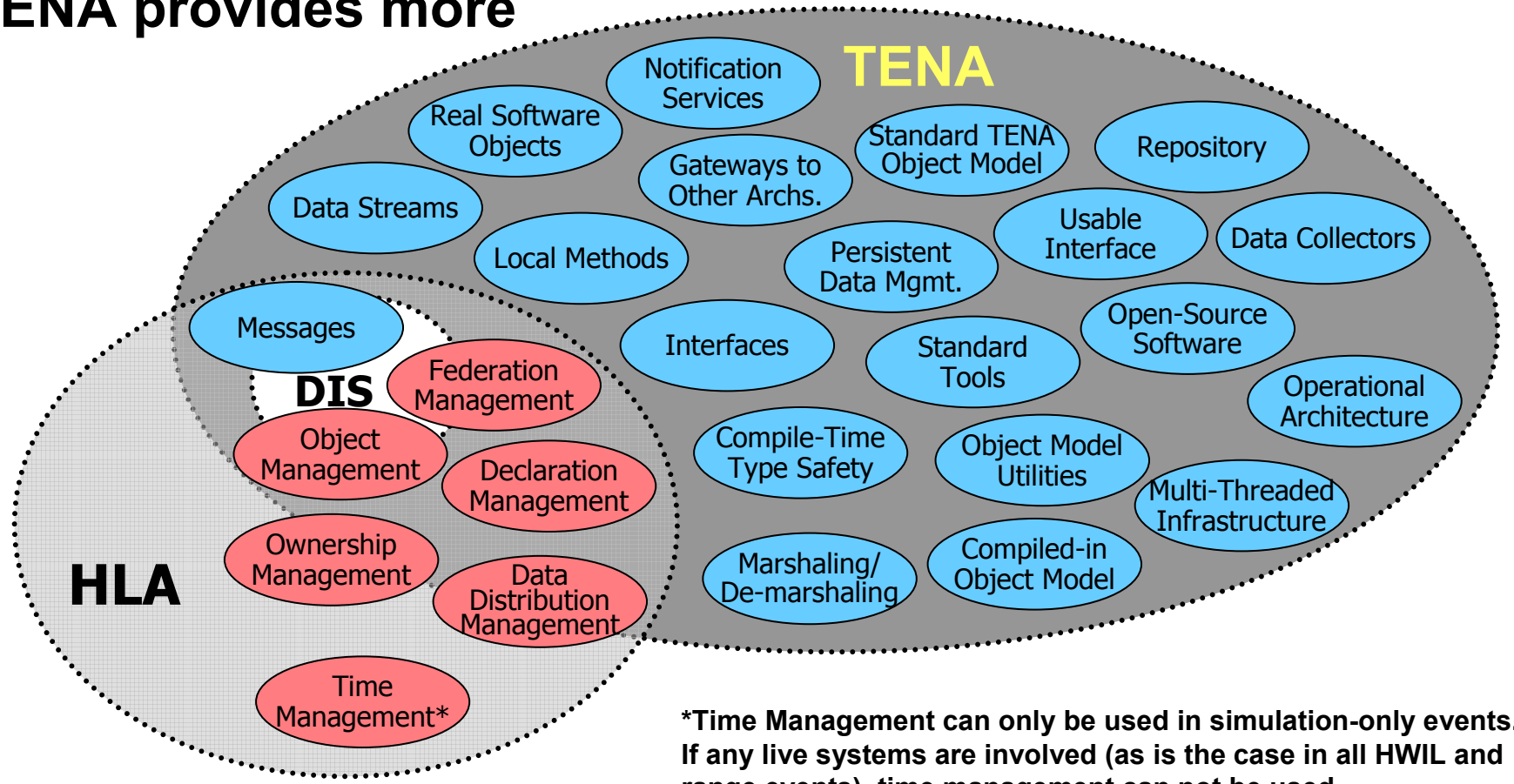
Live Video Stream Transmitted over Wireless Network



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)**

JNTC-Related Events

Event	Date	TENA Version	Object Model	Applications / reuse
MC-02	Jul 02	2.1	MC-02	2 apps, 2 new
RS-03	Jun 03			Cancelled due to Operation Iraq Freedom
JCIDEX 03	Aug 03	3.X	JCIDEX	6 apps, 1 reused, 5 new
HTE	Jan 04	3.X	JOM	9 apps, 6 reused, 3 new
CJTFEX	Jun 04	4.0.3	JOM	15 apps, 5 reused, 10 new
Cope Thunder	Aug 04	4.0.3	JOM	2 apps, 2 new
JRF-05	Mar 05	4.0.4	JOM	17 apps, 11 reused, 6 new

JNTC Range Integration Applications using TENA

Application	Events	Description
TIER	MC02, HTE, CJTFEX, JRF	NAWC-WD range systems interface application and display
Rangeview	MC02, JCIDEX, HTE, CJTFEX, JRF	Test range oriented display and analysis tool
ARDS	JCIDEX, HTE, CJTFEX, JRF	Test and training instrumentation system interface
PCDS	JCIDEX, HTE, CJTFEX	Air Guard training monitor, display and debriefing tool
Air Warrior (TIER)	MC02, HTE	AF training instrumentation systems interface
NTC-IS (TIER)	MC02, HTE,	Army, Natl Training Center instrumentation systems interface – DIS GW
IGRS	HTE	USMC instrumentation system interface
GOTH	HTE, CJTFEX, JRF	TENA to HLA Gateway, TENA OM and FOM specific
CDL	JCIDEX, HTE, CJTFEX, JRF	Engagement Adjudication workstation – "Common Data Link"
JTIDS IF (2 variants)	JCIDEX, CJTFEX, JRF	Tactical C2 messages systems interface – DIS Signal PDU or Socket J GW
TACO	HTE, CJTFEX	Analysis monitor and display tool, w/Patriot interface
WAM	CJTFEX, JRF	Analysis monitor and display tool
Static Tgt Gen	CJTFEX, JRF	Instrumentation simulator for non-moving, non-instrumented ground targets
CGS	CJTFEX, JRF	UAV /JSTARS Moving Tgt Indicator (MTI) / Fixed Tgt Indicator (FTI)
UAV	CJTFEX, JRF	Unmanned Aerial Vehicle (Predator) ground station TM and inst interface
ADOCS	CJTFEX	Army C2 messaging and database system
SureTrak	CJTFEX	Multi-source instrumentation interface and analysis – airspace monitor
TACTS GW	JCIDEX	Gulfport Air Natl Guard range ACMI instrumentation gateway
TENA-DIS	CJTFEX' JRF	TENA OM to DIS PDU translator for selected classes and PDUs

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

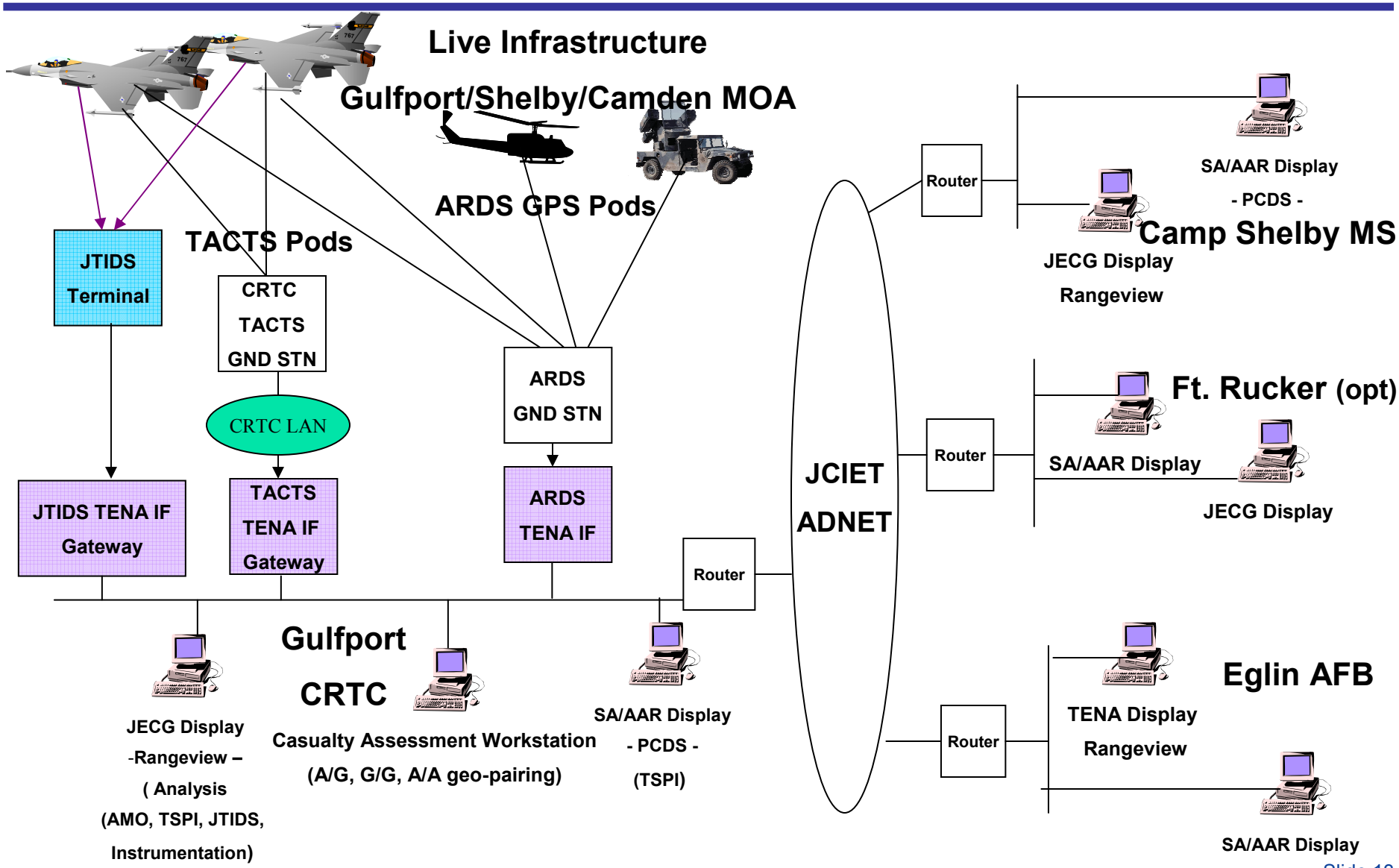
Integrating Software

Global Command & Control System

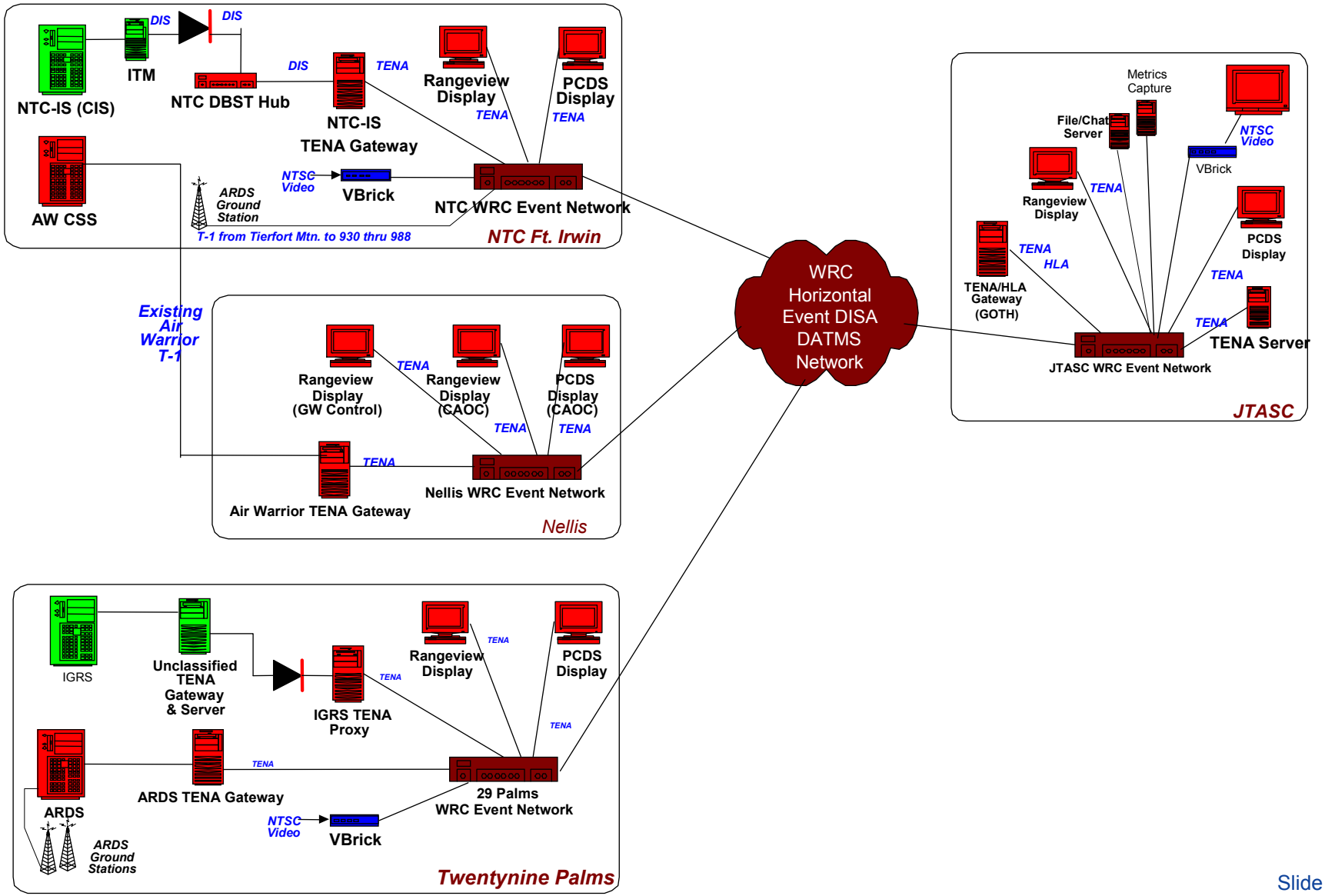
Model & Simulation Feed

Command, Control, Communications, Computers, Intelligence Feed

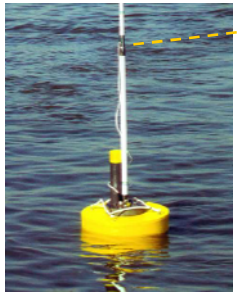
TENA Use in JCIDEX 03

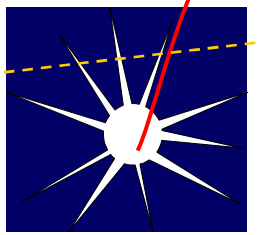


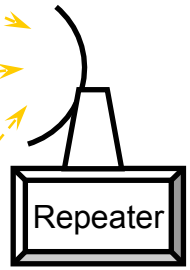
JNTC Horizontal Thrust Event Range Integration Solution

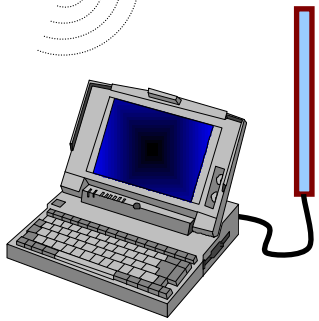


Gulf Range VAST / IMPASS

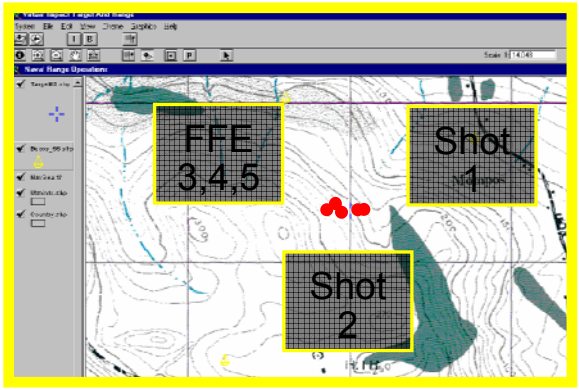








Shipboard Processing
Map Rendering
Virtual Target



Acoustic Processing
GPS
Communication Link

VAST / IMPASS Network Connectivity

Eglin Central Control Facility

TENA on NIPRNET

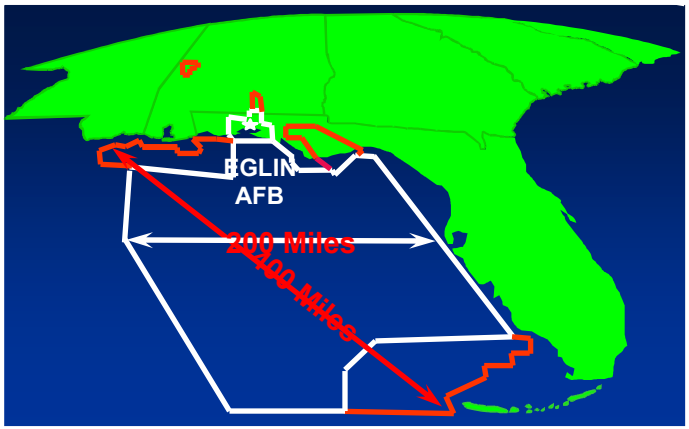
CDSA
Dam Neck, VA

TENA on Fiber

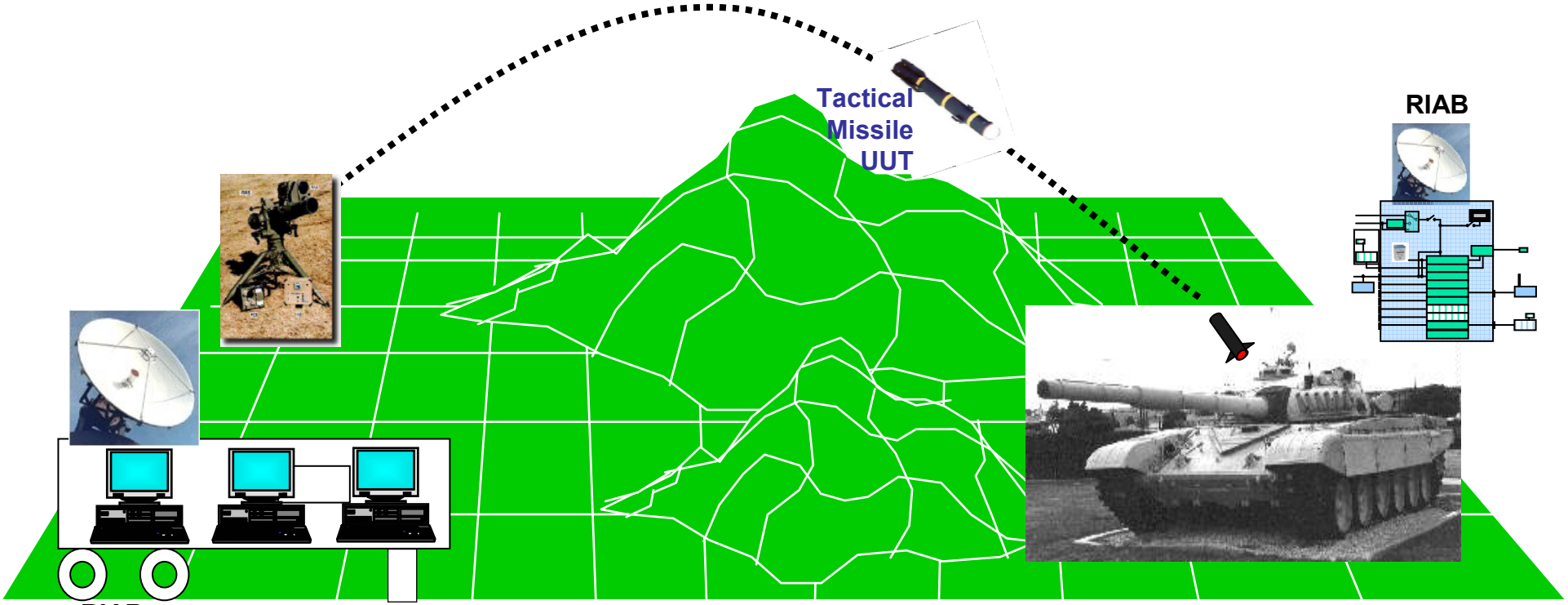
TENA on Microwave

Eglin Range Site A-15

CSS
Panama City, FL

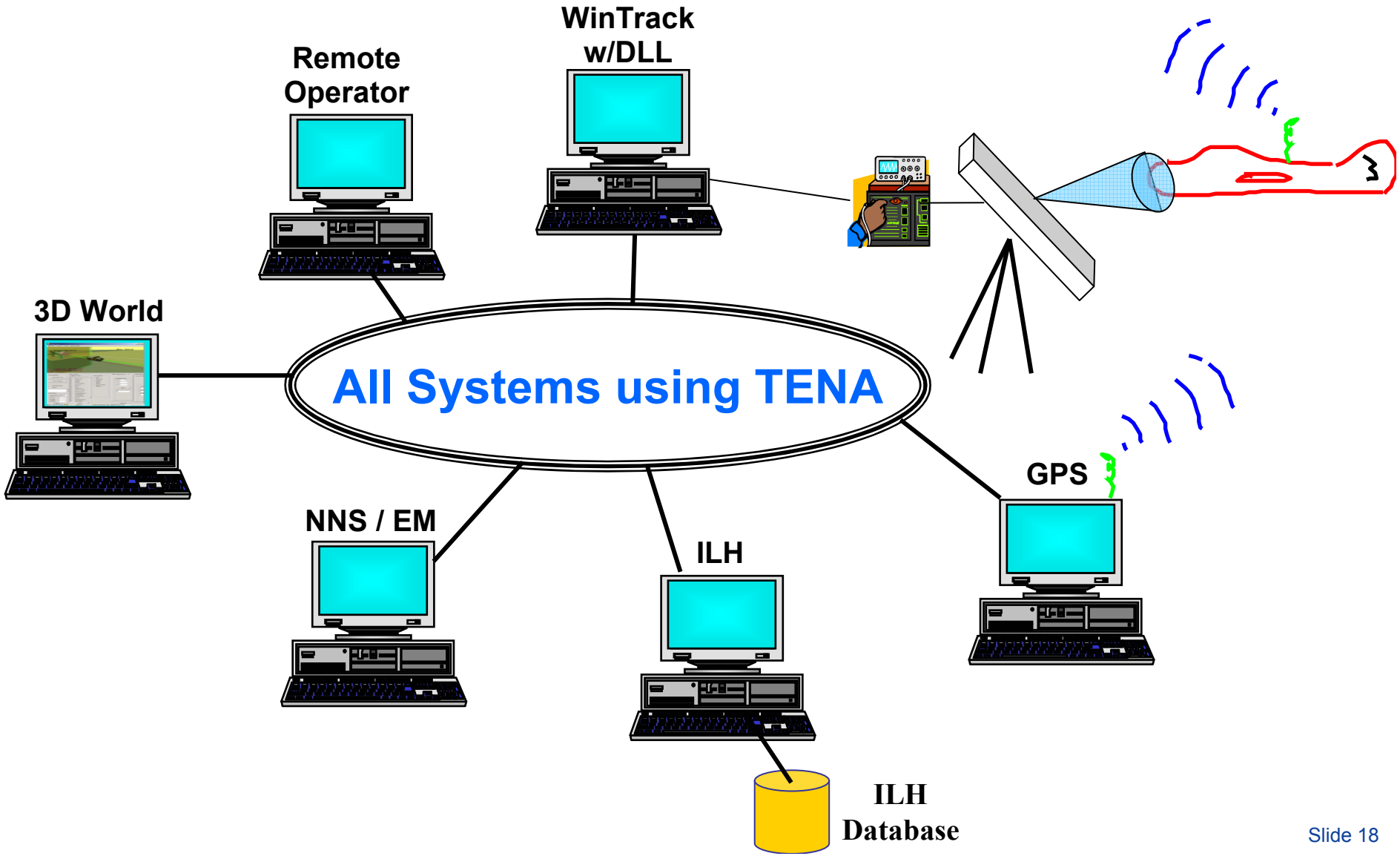


Redstone Technical Test Center Use of TENA



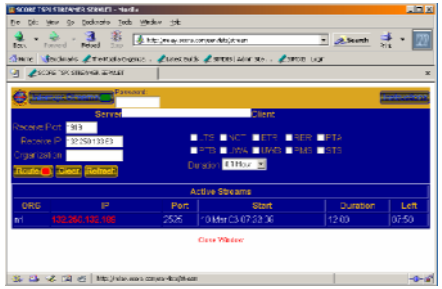
- MARDEC Support Active Protection System (APS)
  - FCS APS Candidate
- "Serial" Connection to RIAB
- TENA Control& Monitor
- Configuration Control in Range Software
- Data Logging via ILH Object

Weibel Radar Using TENA



SIMDIS Use of TENA

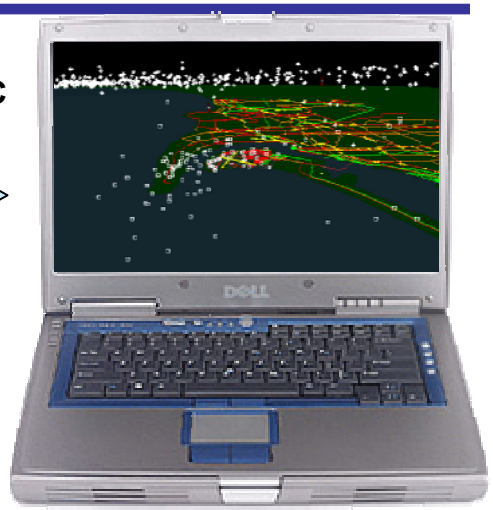
SCORE TSPI Feed



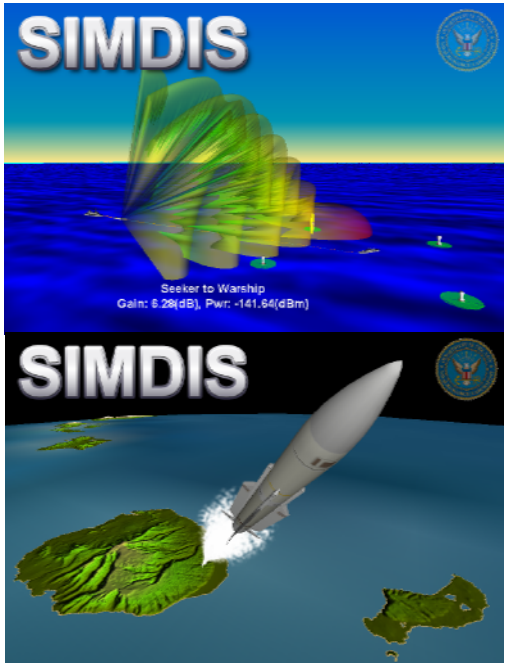
Southern California

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**

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)

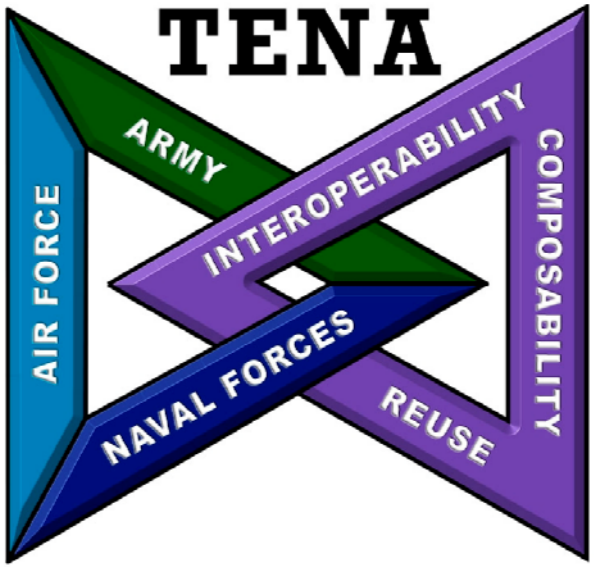
Summary

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
- **Get the TENA 2002 Document:**
  http://www.TENA-SDA.org/documents/tena2002.pdf
- **TENA SDA Project Topics:**
  TENA-SDA@tena-sda.org
- **Questions, comments, feedback about the TENA architecture or the TENA Middleware:**
  TENA-feedback@tena-sda.org
- **TENA user community:**
  TENA-users@tena-sda.org



Additional Slides Available But Not Planned to be Presented

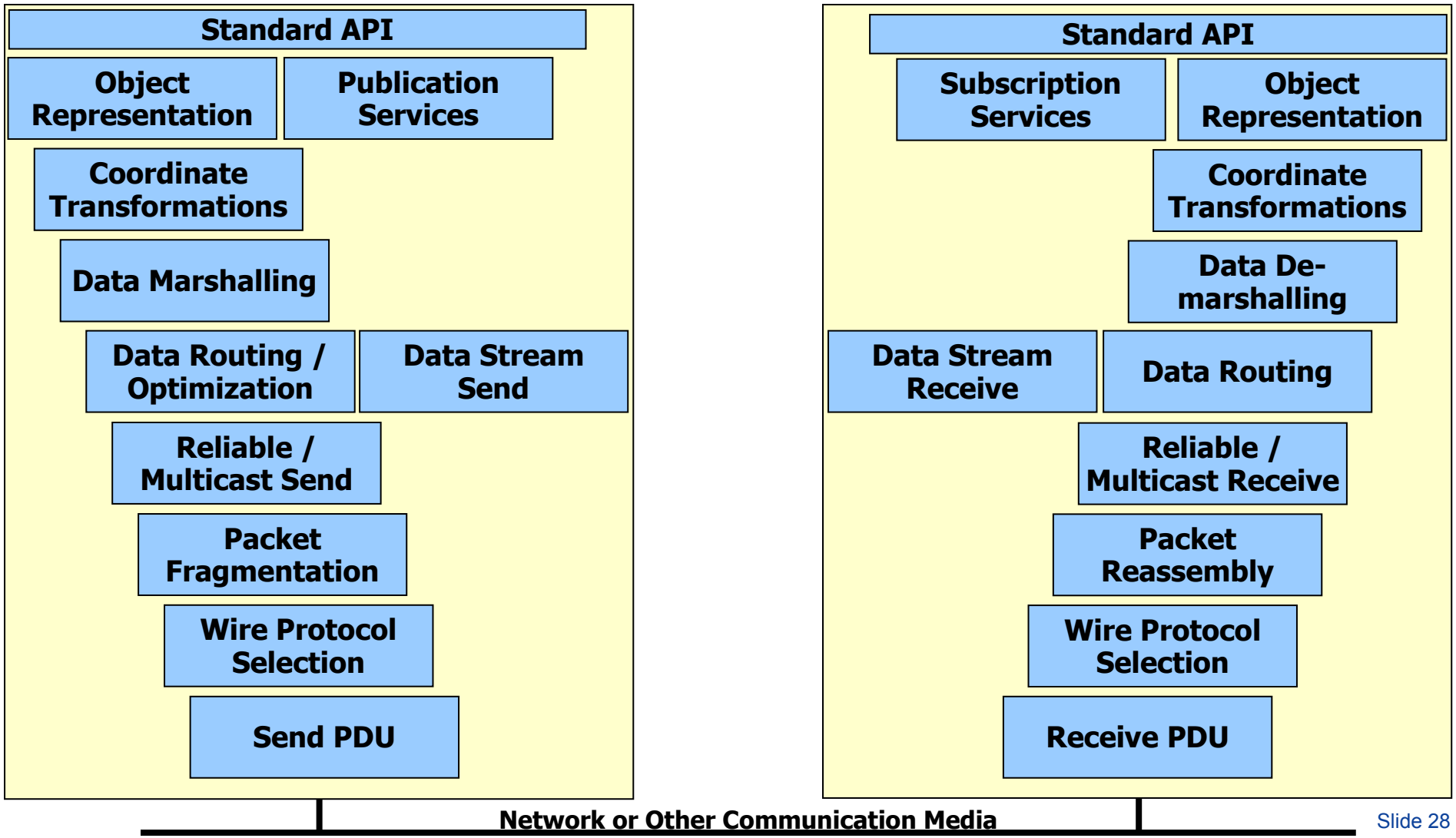
Some Limitations of Distributed Interactive Simulation (DIS)

- **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

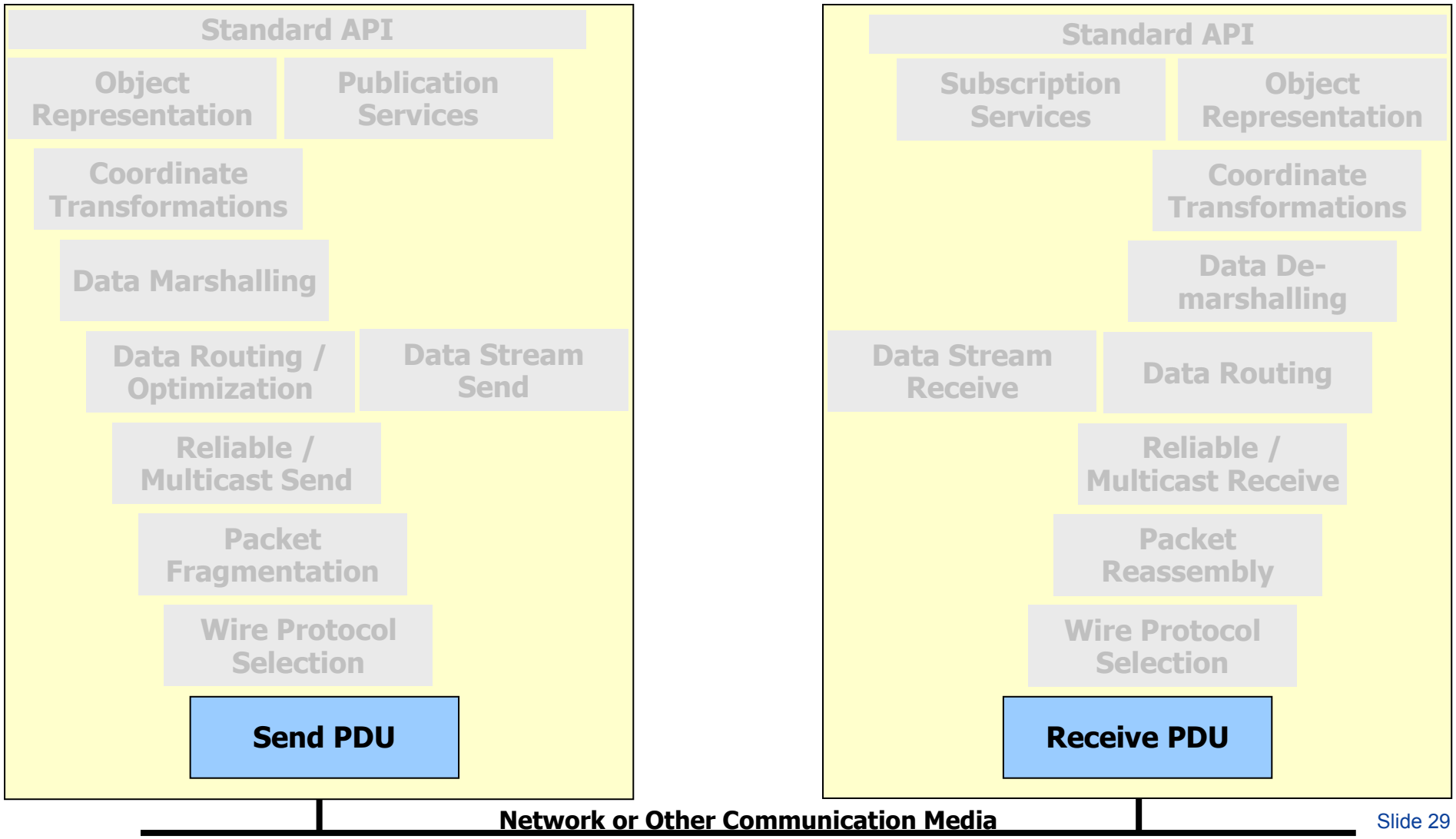
Some Limitations in High Level Architecture (HLA)

- **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

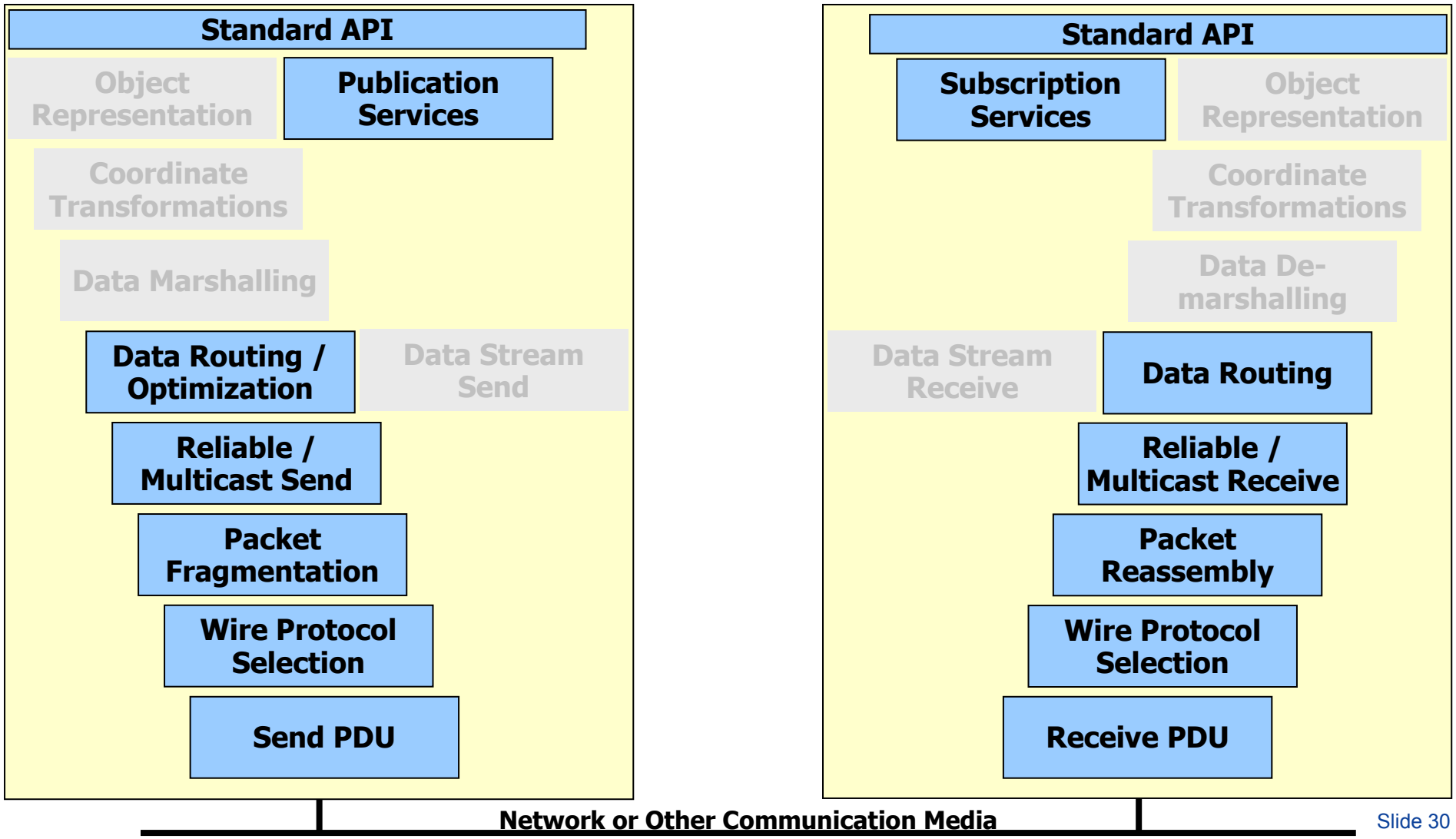
Functions to Send Data from One System to Another



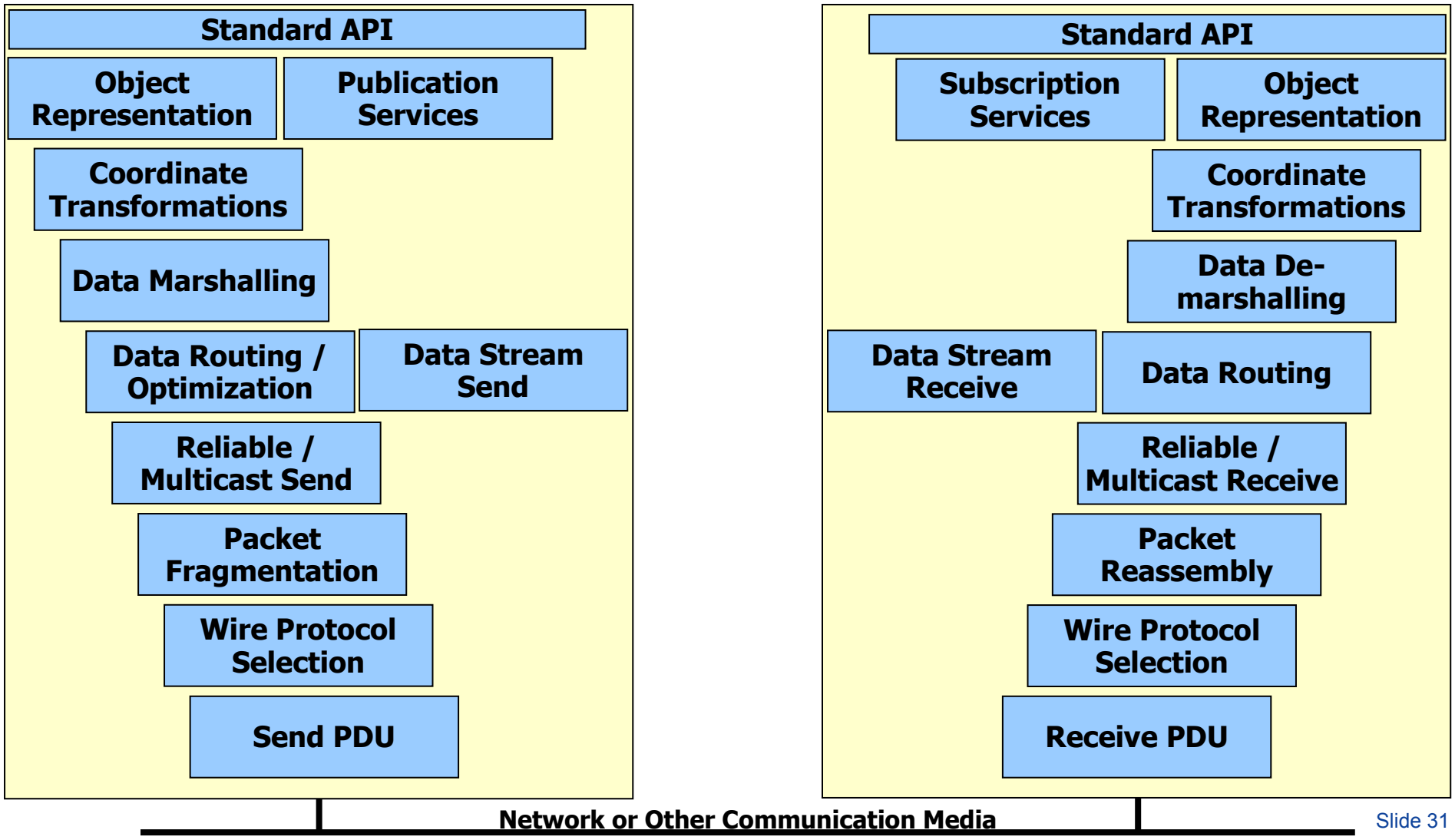
DIS Only Provides Specification for Network Data Packet



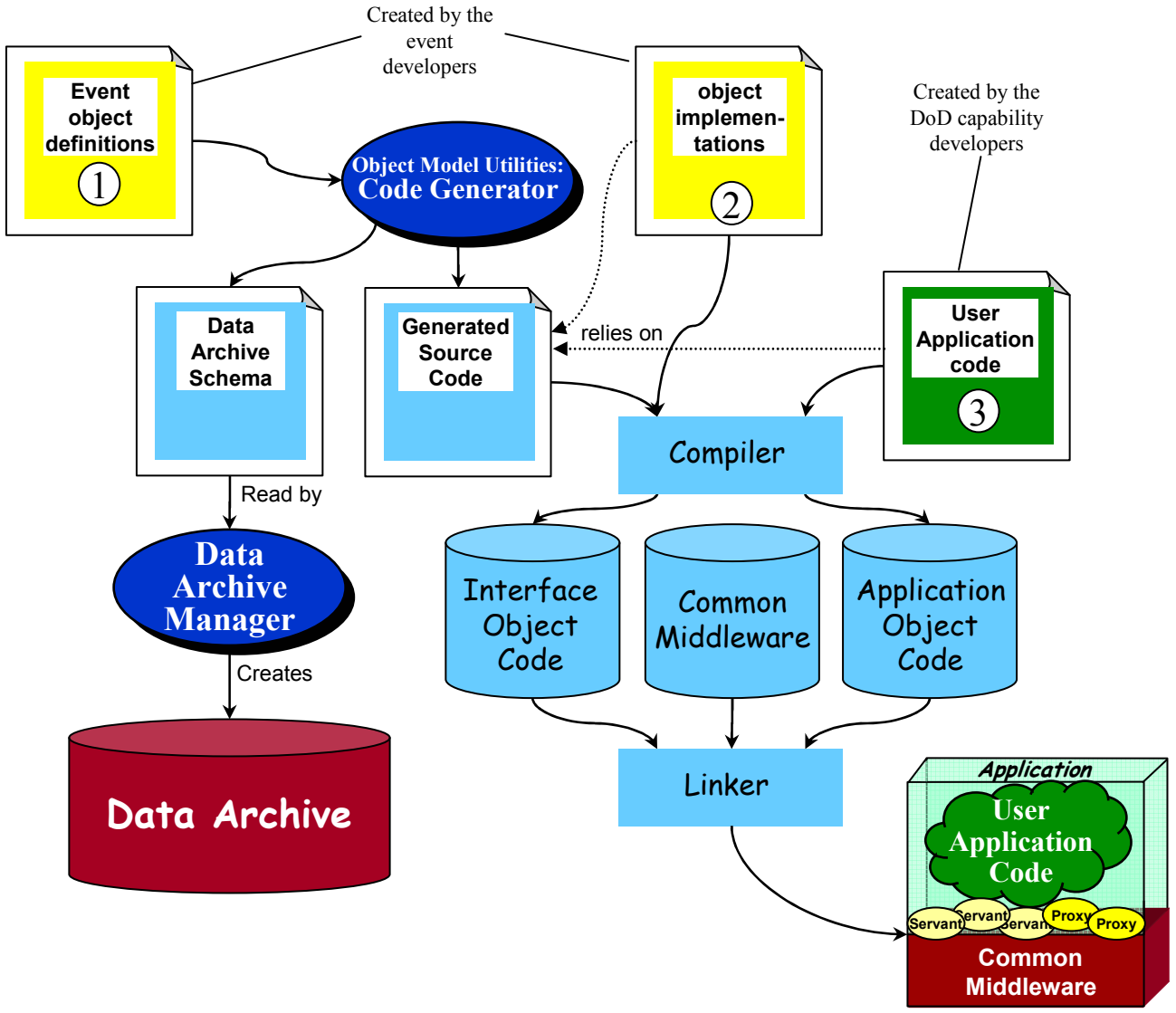
HLA Provides Some Publish and Subscribe Functionality



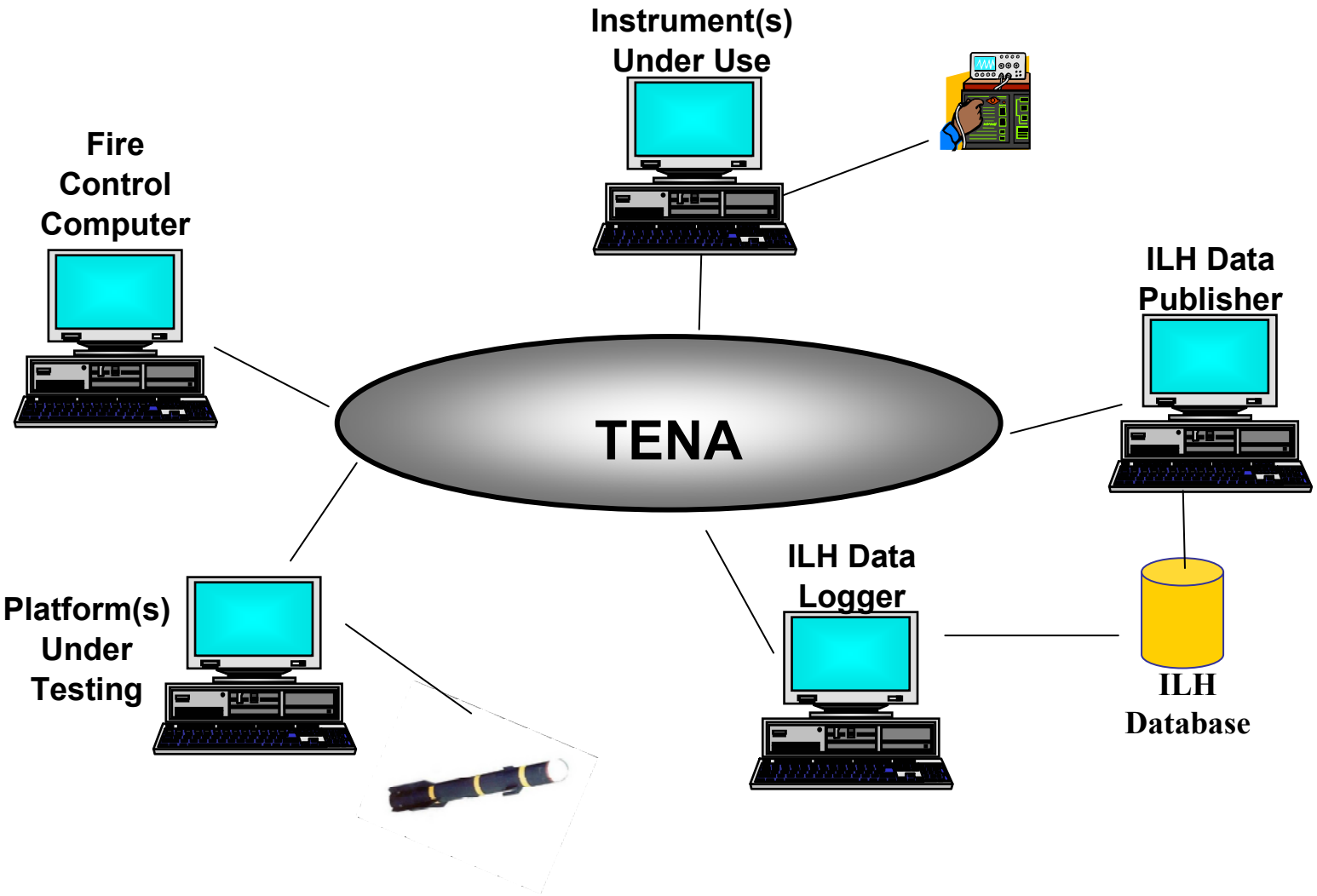
TENA Also Provides Data Translations & Marshalling



TENA Saves Time by Auto Code Generating Interfaces



Redstone Technical Test Center Use of 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*