LVC Interoperability 101

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Analyze. Integrate. Innovate.

Unclassified

Agenda

1. Learning Objectives
2. LVC Interoperability Overview
3. Interoperability Through Standards
4. Interoperability Using Gateways and Cross Domain Solutions
5. LVC Interoperability Use Case
6. Summary

1. Learning Objectives

- The tutorial is intended for decision makers who need a top-level understanding of Live, Virtual and Constructive (LVC) interoperability and the supporting standards, technology and processes.
- The tutorial will provide:
  - An overview of recommended concepts, processes and tools needed to achieve interoperability
  - Use Case that demonstrates interoperability solutions meeting a military training need
  - Summary with recommendations
- The objective of this tutorial is to provide managers and those new to LVC technology the high-level insight needed to support intelligent decision making when encountering a need for interoperability

2. LVC Interoperability Overview

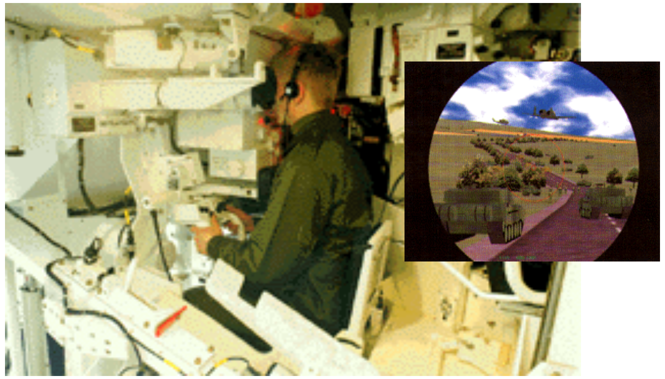
- Simulation Definitions
- LVC Interoperability Definitions
- Distributed Environment Overview

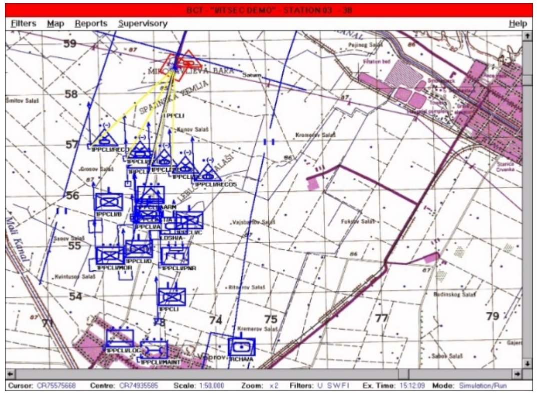
LVC Interoperability Overview

- Simulation
  - A software model that runs over time
  - All but war is simulation
- Simulation Interoperability
  - The ability of connected systems to communicate and function together

Interoperable components can be combined to create an application… applications can be composed to create a system, and systems can be combined to create a System of Systems (SoS)

Live Virtual Constructive (LVC) Definition





Live Simulation
"Real people operating real systems"

- Real environment
- Real systems
- Real people
- Real-time

Virtual Simulation
"Real people operating simulated systems"

- Various kinds of platform simulators
- Virtual Environment
- Real-time

Constructive Simulation
"Simulated People operating simulated systems"

- Computer Generated Forces (CGF)
- Virtual Environment
- Faster/slower than real-time

Distributed Simulation

- A distributed simulation is a system that:
  - Involves several independent processes executing on one or more computational nodes
  - Interoperates using a common services and/or protocol over a network
- Simulations can be distributed over a number of different components, ideally loosely coupled or "federated"
  - Allows growth over time
  - Allows components to be replaced or upgraded easily
  - Add additional computational power if needed

- Distributed Simulation can be used to support
  - Warfighter Training, Command Post Exercises, Enhanced Modeling and Simulation Objectives, Research, Development Test and Evaluation (RDT&E), etc

Distributed LVC Event

- Distributed LVC Event
  - An activity to integrate and execute LVC simulations in a virtual environment so that “real-world” processes and “things” can be exercised to investigate and solve complex issues
    - Real-time for live systems, Can be faster than real-time for virtual and constructive systems
  - Technique used to enhance weapons system development, test and training
  - Can be an effective tool to enhance effectiveness, reduce risk, reduce cost
  - Examples include
    - Stimulating a ”real” fire control radar with simulated targets to conduct common operator training exercises at multiple training locations

Connected LVC systems

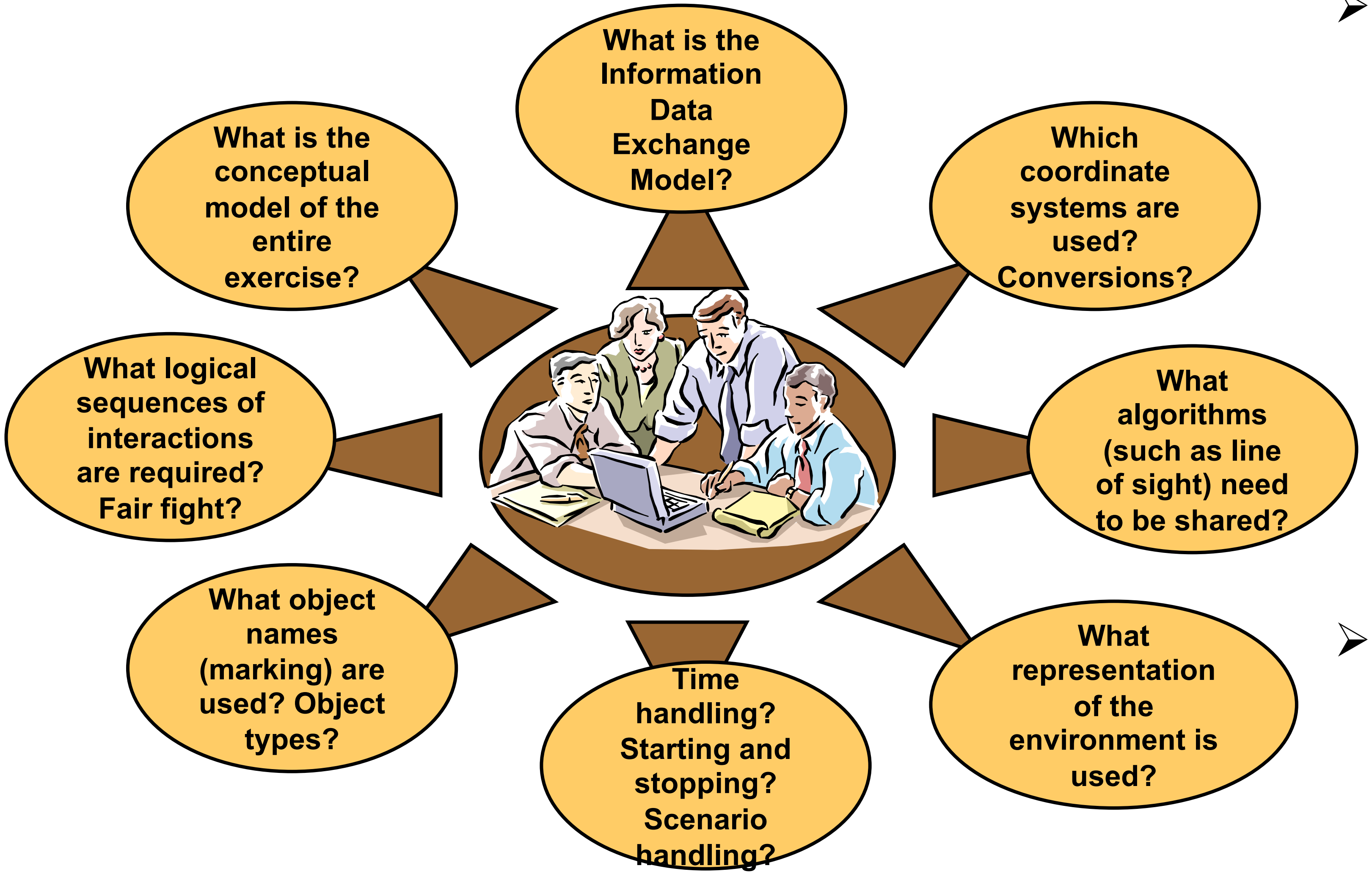
Virtual and/or Real Environment

LVC Event

Interoperability Requirements

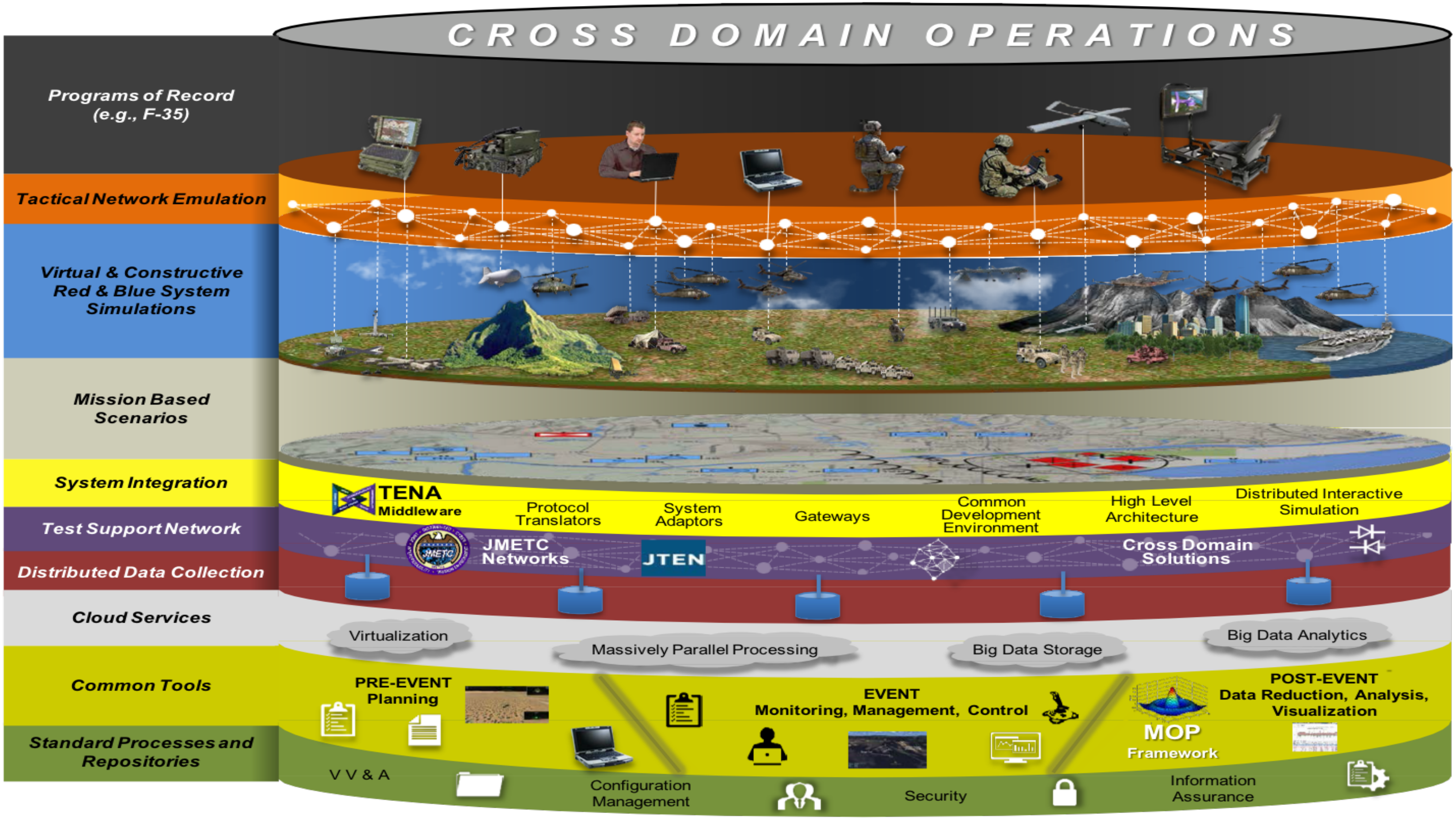
- Interoperability Requires
  - An ability to meaningfully communicate
    - A common “language” to describe the LVC systems
    - A data distribution mechanism with well-defined rules and/or services
    - A reliable network
  - A common context
    - A common understanding of the environment and time
    - A common technical process
- Efficient software reuse and composability is enabled by
  - Well-defined software interfaces and access to reusable components
  - *The ability to replace models at the component level, without interrupting the larger system or requiring software changes or recompilation to other system components*

Typical Interoperability Discussions



- It's a unique language and skill set that takes time to understand and adopt
  - Involvement with the interoperability community optimizes this process
- Applying **standard** architectures, processes, technologies and lexicon is a key to success

LVC Distributed Event Environment

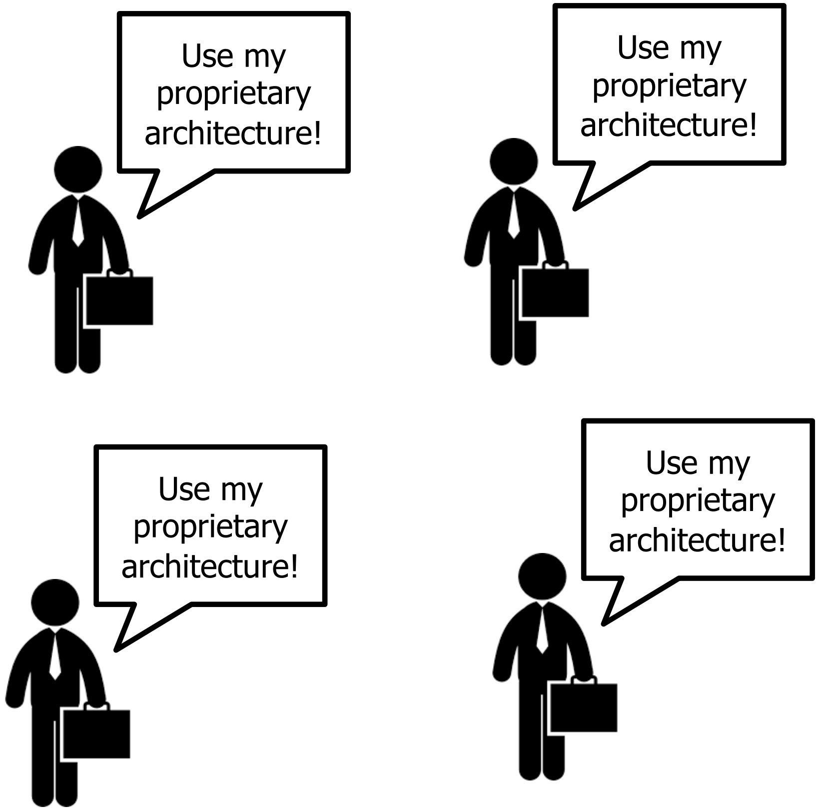


Joint Mission Environment Test Capability (JMETC) vision of Standards-based LVC Event Environment

3. Interoperability through Standards

- The Value of Standards
- Past and Current Interoperability Standards
  - DIS, HLA and TENA
- Recommended LVC Integration Approach

The Value of Interoperability Standards



Open Standard Solutions

- Data Model
- Application Programmers Interface (API)
- Integration Processes

Good for **me** right now

Remove Stovepipes

Good for **all**
now and in the future

Goals of Interoperability Standards

Technical Aspects

- Enable efficient distributed simulation
  - Throughput, latency, scalability etc.
- Support simulation specific requirements
  - Not limited to data distribution
  - Provide common services (Remote Methods, Time Management, Ownership (control over data elements), etc.)
- Isolate simulator from physical transport method (i.e. network)
  - Avoid technology lock-in

Business Aspects

- Promote interoperability and reuse
  - Leverage exiting solutions for other needs
  - Increased customer support
- Vendor independent
  - Vendors and organizations equally comfortable with the standard
  - Open standard for contributions and influence
  - Easily replace interoperability implementation
- Domain neutral
  - Support the simulation market as a whole, multi-purpose
  - Possibility to attract a large number of vendors and users

Interoperability Approaches of the Past

- Standardize on a vendor solution
  - Optimized for a specific need
  - Creates a vendor-lock situation for computers and/or software
- Standardize on programming language
  - Optimized for a specific need
  - Problems may occur when maintaining code developed using older programming languages and compilers…the remember ADA mandate?
- Incorporation of new software technologies becomes very difficult (Service Oriented Architectures (SOA), cloud based solutions, scripting languages, etc.)

This approach was adopted when reuse, composability and interoperability were not high priorities

Modern Interoperability Approaches

- Standardize on the **Data Model**
  - Data Model is the defined network protocol or message format
  - This defines the data needed to interoperate
- Standardize on a software **Application Programmers Interface (API)**
  - Provides software interface to interoperability services and solutions for distributed simulations
- Standardize on **Processes**

These Modular Open Systems Architecture (MOSA) concepts enable success and solution flexibility … now and in the future

Interoperability Standard: Data Models

- Enable semantic interoperability among simulation applications
- Provide the “common language” that all simulation applications use to communicate
- Data Models = Object Model(OM) = Data Exchange Agreement (DEM)

Conceptual Level
(common understanding of information)

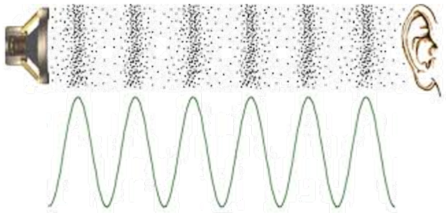
Pragmatic/Dynamic Level
(common use of information)

Semantic Level
(information exchange)

Syntactic Level
(data exchange)

Technical Level
(networking)

Levels of Interoperability (Tolk)



Object Model

A document describing the data that will be exchanged

Airplane!

Interoperability Standard: API

- Application Programmers Interface (API) is a software interface to software services that enable interoperability
  - Time Management
    - Manage and synchronize time between participating applications
  - Quality of Service (in simulation)
    - Services for managing how data is distributed on the network
  - Ownership Management
    - Transfer of modelling responsibility from one participating application to another
  - Data Distribution Management, DDM
    - Data filtering based on regions or any other attribute to reduce data load
  - Remote Method Invocation, RMI
    - Participating applications can have methods that can be remotely invoked by other applications

These services have made significant enhancements to LVC interoperability. Understanding these capabilities and implementing them using common practices improves performance and reduces risk

Interoperability Standards: Integration Process

- A well-defined Integration Process is critical to success
  - First step in planning for an LVC Environment is identification and adoption of a proven process to support the design, integration and execution of the environment
  - To ensure the environment is designed and configured to meet the event requirements, a structured process is necessary to properly identify needs, deigns and solutions.
    - Several standard, and proven, processes exist.
    - Do not add risk to your program by “winging it” through a very complex endeavor

Open Standards

- According to the Software Engineering Institute a system is open if:
  - It is fully defined
  - Available to the public
  - Maintained according to group consensus
- Support Organizations for Interoperability Standards include:
  - Institute of Electrical and Electronics Engineers (IEEE) https://www.ieee.org/standards/index.html
  - Simulation Interoperability Standards Organization(SISO) https://www.sisostds.org/
  - TENA Architecture Management Team https://www.tena-sda.org

The "Big 3" LVC Interoperability Architecture Standards

- Distributed Interactive Simulation (DIS) - IEEE 1278
  - **Protocol standard**
  - Covers several levels of interoperability
  - Broadcast/Multicast UDP (Best effort)

Interoperability Standard:
Data Model

- High Level Architecture (HLA) – IEEE 1516-2010 and NATO STANAG 4603
  - **API standard**
  - Separate semantic model expressed in a (Federation) **Object Model**
  - Services standard – A rich set of interoperability services

Interoperability Standard:
Data Model, API & Process

- Test and Training Enabling Architecture (TENA)
  - **API standard** –auto-generated user software for quality and usability
  - Semantic model expressed in a **Standard Object Model**
  - Includes standard object model, extensive middleware services and a set of interoperability & event support tools

Interoperability Standard:
Data Model, API & Process

Interoperability vs Interconnectivity

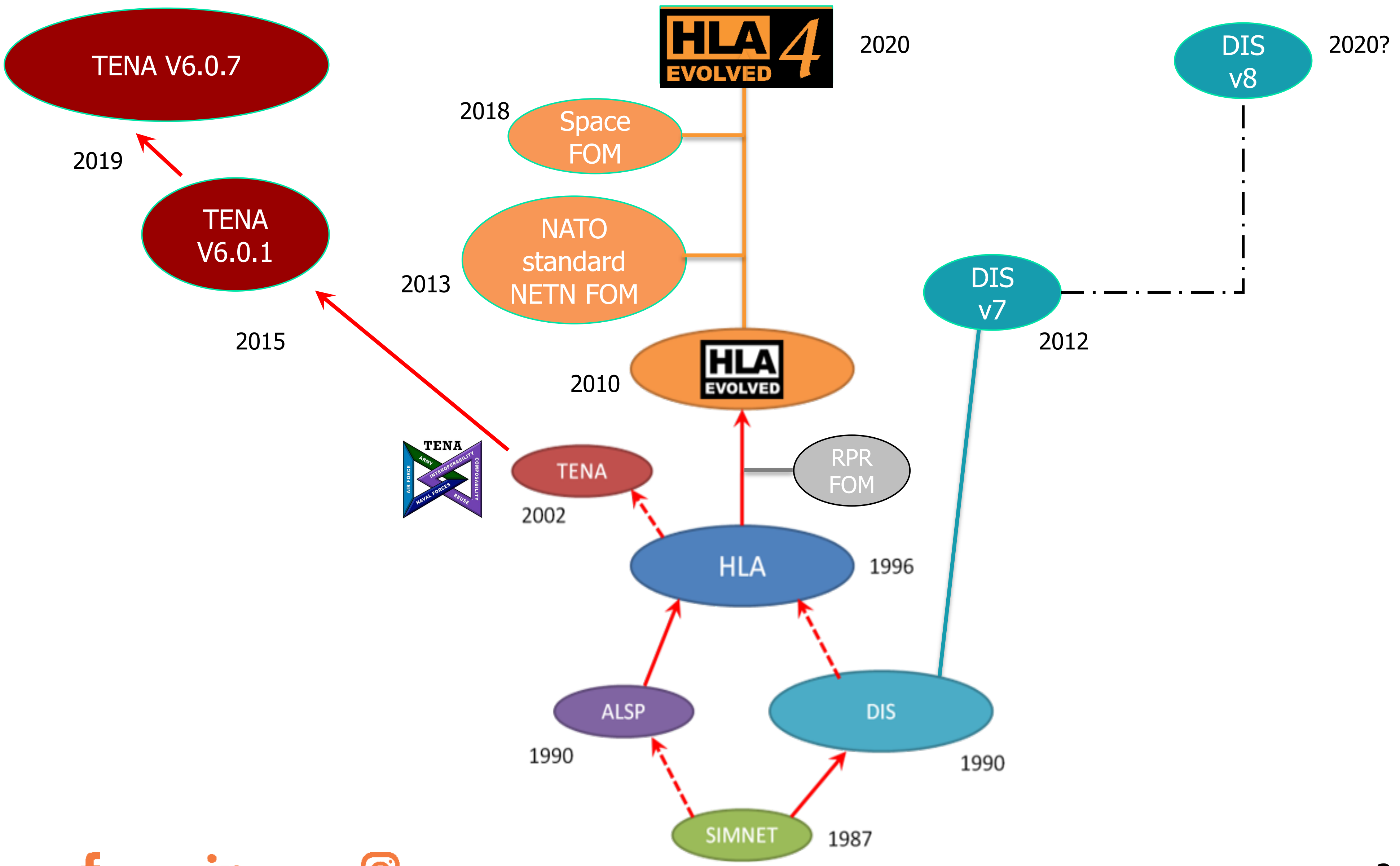
- LVC "Interoperability" requires data exchange with other systems without requiring modification to already connected systems, thus **permitting flexible connections**.
- "Interconnectivity" involving some data exchange protocols requires system-wide changes, recompilations of source code, re-linking to new software libraries, etc, thus **implementing specific connections**.
- Many (an infinite number?) of data messaging methods exist. Examples are:

Name	Primary Application	Simulation Services	Interoperability	Interconnectivity
Google ProtoBufs	General purpose			✓
CAN bus	Automotive			✓
Link-16 J messages	Air-to-Air, Air-to-Ground			✓
DIS	Simulation		✓	(Ctrl)
HLA	Simulation	✓	✓	
TENA	Simulation especially for Equipment/System testing	✓	✓	
DDS	Internet of Things			✓

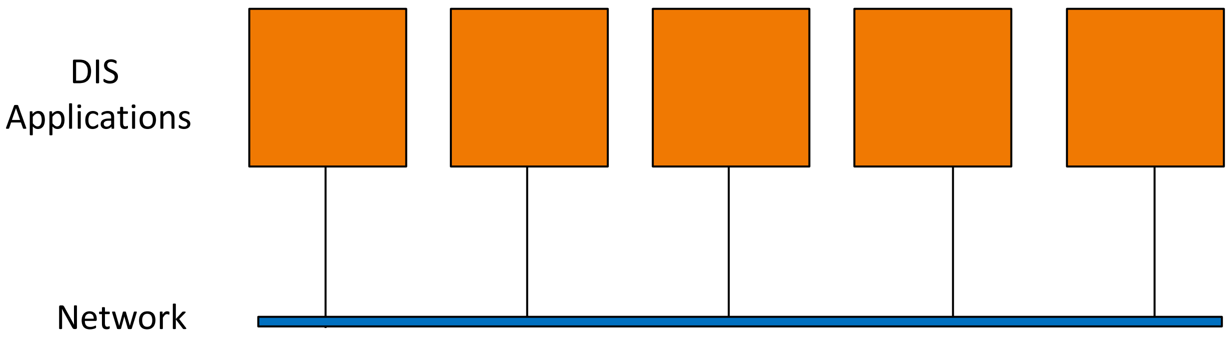
Interoperability vs Interconnectivity

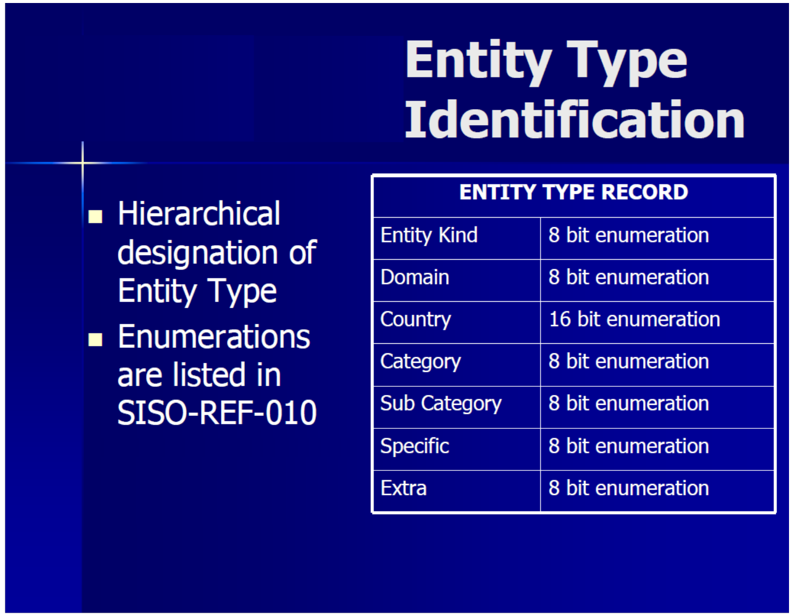
- Data Distribution Service (DDS)
  - **<u>API standard</u>**
    - Available through the Object Management Group (OMG) … www.omg.org
    - For real-time interconnectivity of systems exchanging data via DDS
    - Common application is for "Internet of Things" (IoT), to enable interconnected systems to exchange data over a network
  - DDS uses some similar concepts as TENA and High Level Architecture (HLA)
    - Publish-Subscribe architecture
    - Data model … HLA has a *"Federation Object Model"* … DDS has a *"Data Space"*
  - Targeted use = interconnectivity, e.g. Internet of Things (IoT) applications
  - Does not provide runtime interoperability services (e.g. time management) like HLA
  - Cannot be used in place of HLA but could be used in conjunction with HLA
  - Often confused item:
    - HLA has a "Run Time Infrastructure" (**RTI**) … DDS has no equivalent
    - The best known company providing DDS software is "Real-Time Innovations" (**RTI**)

Timeline Of Interoperability Standards



Distributed Interactive Simulation (DIS) Overview

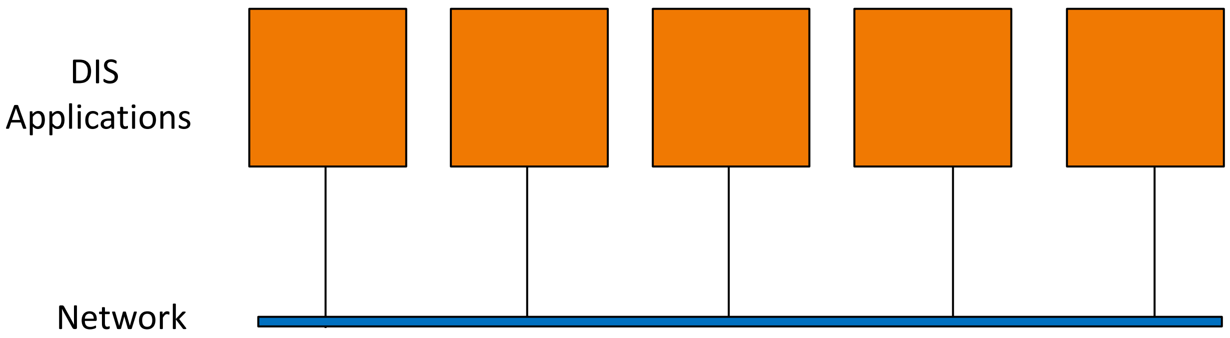


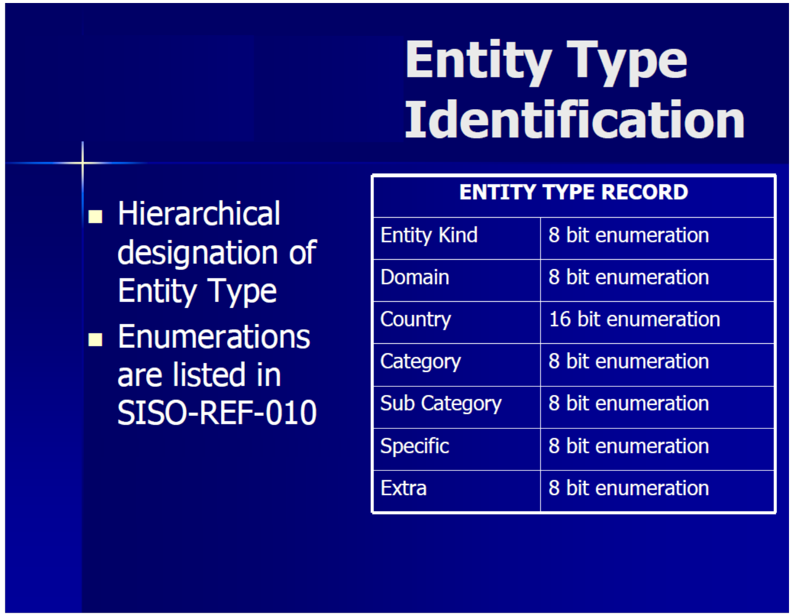


ENTITY TYPE RECORD	
Entity Kind	8 bit enumeration
Domain	8 bit enumeration
Country	16 bit enumeration
Category	8 bit enumeration
Sub Category	8 bit enumeration
Specific	8 bit enumeration
Extra	8 bit enumeration

- DIS IEEE 1278 is an "Over the Wire" specification
  - Defines the structure of data sent over the network using a Protocol Data Unit (PDU)
  - Is a binary protocol where individual bits are defined and bit order and byte order is mandated
  - Defines behavior of message handling. Receiving participants must review each packet for applicability
  - Does not include an "API" or implementation details or solutions
  - Follows the COTS and Open Source business models
  - Primarily focuses on military systems/requirements
- DIS participants must Broadcast or Multicast data on a local network using UDP network transfer protocol

Distributed Interactive Simulation (DIS) Example PDU





Entity Type Identification

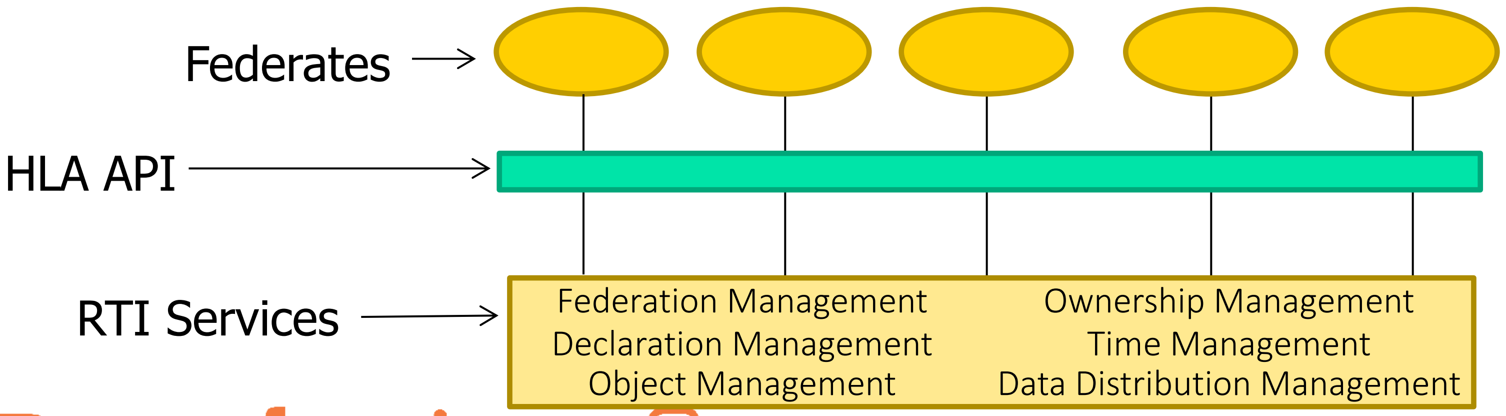
- Hierarchical designation of Entity Type
- Enumerations are listed in SISO-REF-010

ENTITY TYPE RECORD	
Entity Kind	8 bit enumeration
Domain	8 bit enumeration
Country	16 bit enumeration
Category	8 bit enumeration
Sub Category	8 bit enumeration
Specific	8 bit enumeration
Extra	8 bit enumeration

- Examples: DIS “Entity Type” PDU
  - USAF F-16C Falcon
    - Entity Kind = 1
    - Domain = 2
    - Country = 225
    - Category = 1
    - **Sub Category = 3**
    - **Specific = 3**
    - Extra = 0
  - USAF F-22B Raptor
    - Entity Kind = 1
    - Domain = 2
    - Country = 225
    - Category = 1
    - **Sub Category = 6**
    - **Specific = 2**
    - Extra = 0

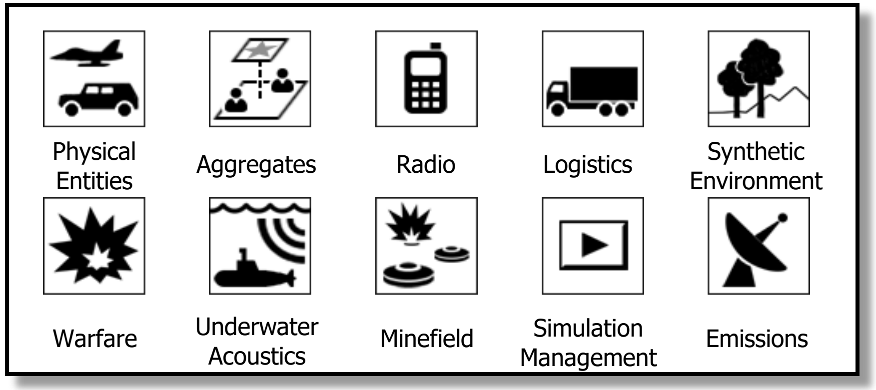
High Level Architecture (HLA) Overview

- Defines services for simulation data exchange and coordination provided by a Run-Time Infrastructure (RTI)
- Services are accessed through a standardized interface.
- A data model (Federation Object Model FOM) expressed in a standardized text file, using the xml standard, defines how objects interact with each other
- Information exchange governed by Federation Agreements and supporting federation Information Data Exchange Models (IDEM)
  - e.g. when, where and how to utilize the service to distribute data in order to exchange information
- Uses COTS and Open Source business models

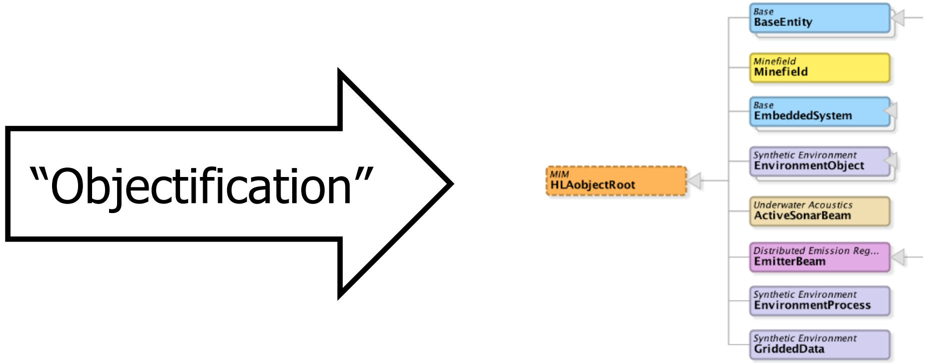


Federation Object Model
<FOM>
<Shared object classes>
<Shared interaction classes>
<More>
</FOM>

DIS and HLA Data Model & Standardization

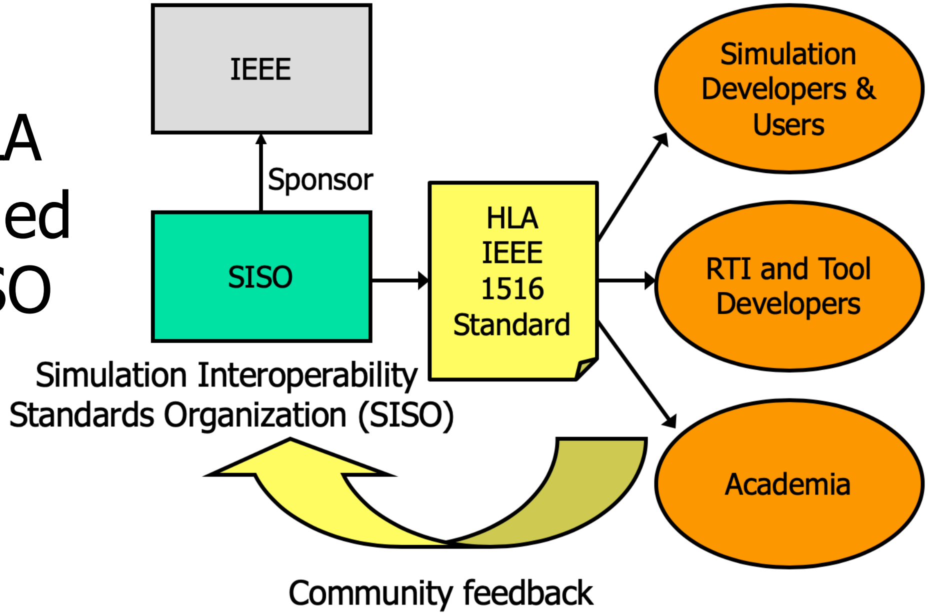


DIS IEEE 1278 Data Model



HLA Real-time Platform Reference FOM (RPR-FOM) SISO-STD-001

DIS and HLA are maintained through SISO



- Government
- Industry
- Academia
- Etc

- COTS, GOTS
- In-house
- Open source
- Other

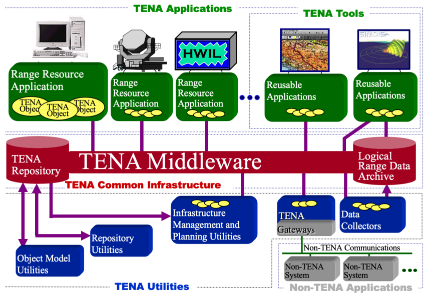
- Research
- Student projects
- Courses

IEEE is the external standards body for SISO

TENA Overview

TENA is the DoD GOTS live range integration architecture

- What does TENA enable?
  - Interoperability between inter- and intra-range assets
  - Elimination of proprietary interfaces to range instrumentation
  - Efficient incremental upgrades to test and training capabilities
  - Integration of Live, Virtual, and Constructive assets (locally or distributed)
  - Sharing and reuse of common capabilities across existing and new investments



- What is included in the TENA architecture?
  - Customizable "data contracts" that standardize repeatable information exchange
  - Interoperability-enabling, auto-code generated software libraries
  - A core set of tools that address common test and training requirements
  - Collaboration mechanisms that facilitate sharing and reuse

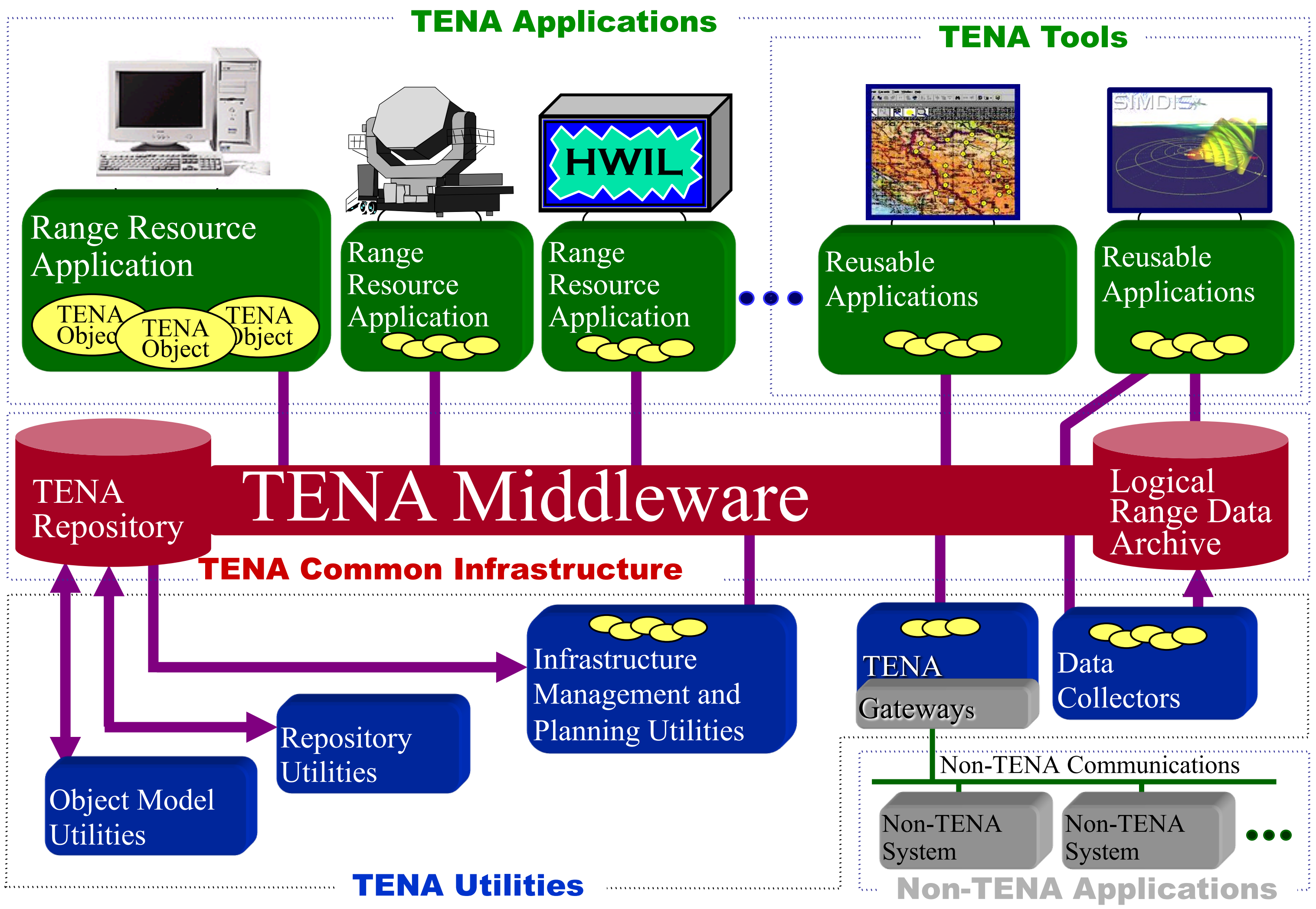
TENA ENABLED
Test and Training Enabling Architecture

- TENA is continuing to be evolved and has institutional funding

TENA-Enabled Interoperability

• Common specifications for test and training data • Data Dissemination across variable applications, platforms, programming languages, networks, and classification levels • Data Collection and Playback	Data Management
• Local and Remote Command and Control • Health & Status Monitoring	Event Management
• Real-Time simulations • Stimulation of live sensors and instrumentation • Connecting non-interoperable inter- and intra-range systems	LVC Integration
• Eliminating proprietary interfaces to range instrumentation • Sharing and reuse of common range tools and capabilities • Online Collaboration and File Sharing	Sharing & Reuse

Test and Training Enabling Architecture (TENA) Overview

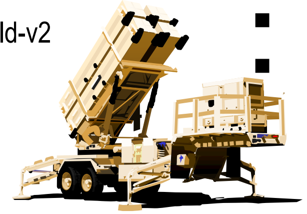


- 100% Government off the Shelf (GOTS)
  - Initially developed to support the demands of live system testing
  - Provides tools for common Event Planning, Execution, and Analysis functions
  - Provides Subject Matter Experts to support distributed exercise and system integration
  - Community-managed Open Architecture and Standards
  - Constantly improved to meet new user requirements
  - Download TENA Middleware and tool set
    - http://www.tena-sda.org

TENA Data Model & Standardization

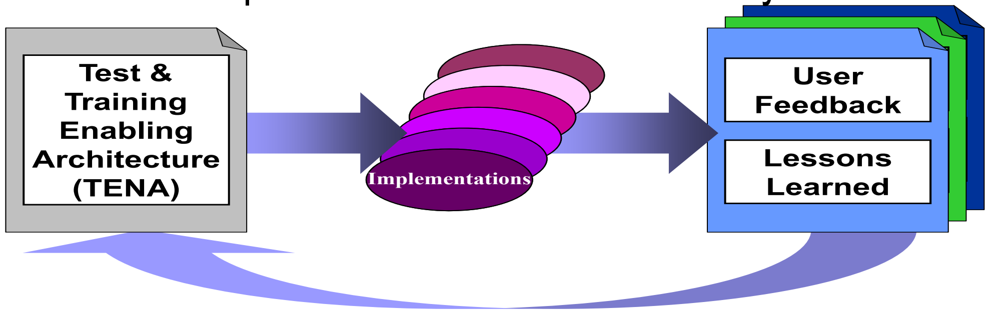
- The DoD maintains the extensive and extendable TENA Standard Object Model
- Object Models were initially based on Live Test and Training Range requirements
- Virtual and constructive simulation requirements are now included

- Platform Related
  - TENA-Platform-v4
  - TENA-PlatformDetails-v4
  - TENA-PlatformType-v2
  - TENA-Embedded-v3
  - TENA-Munition-v3
  - TENA-SyncController-v1
  - TENA-UniqueID-v3
- JNTC OMs (for Training)
  - JNTC-AirRange-v2
  - JNTC-CounterMeasure-v2
  - JNTC-IndirectFire-v2
  - JNTC-Instrumentation-v2
  - JNTC-NBC-v2
  - JNTC-ObstacleMinefield-v2
  - JNTC-Threat-v2



- Time-Space Position Information (TSPI) Related
  - TENA-TSPI-v5
  - TENA-Time-v2
  - TENA-SRFserver-v2
- Other examples
  - TENA-AMO-v2
  - TENA-Engagement-v4
  - TENA-Exercise-v1
  - TENA-GPS-v3
  - TENA-Radar-v3.1
  - TENA OM for RPR FOM
  - TENA OM for HLA
  - TENA om for DIS
  - Etc, etc., etc.

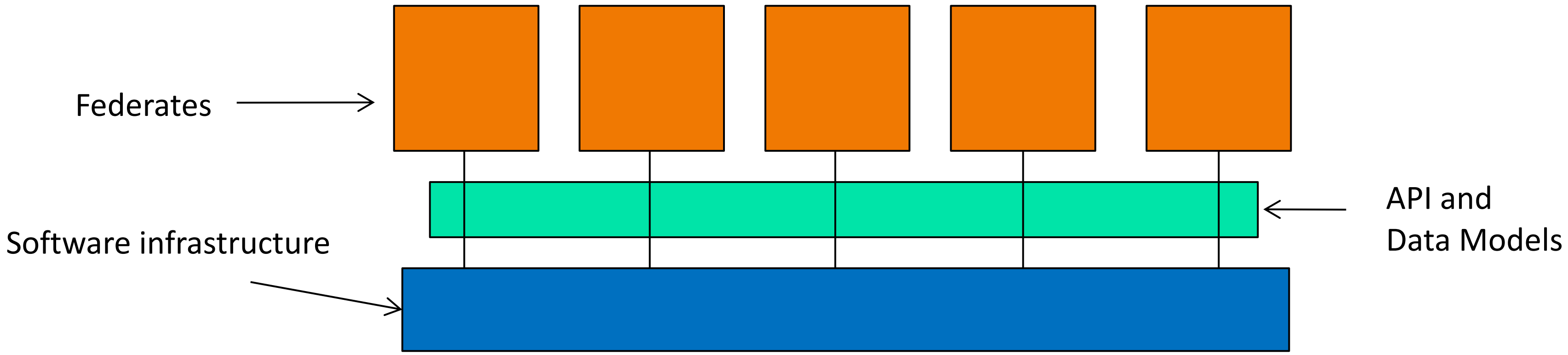
- TENA is funded, maintained, enhanced and provided via US Department of Defense (DoD) Test Resources Management Center (TRMC)
  - Also sponsors JMETC for DoD-wide persistent network connectivity



TRMC's TENA Architecture Management Team (AMT) comprised of Govt, industry and academia

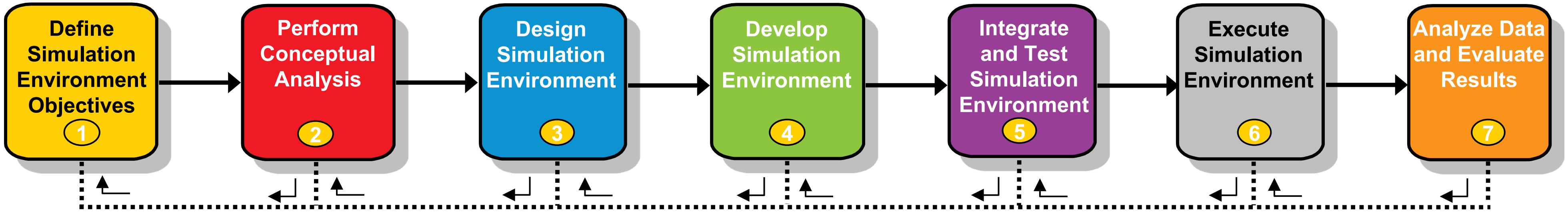
Recommended Integration Approach

- Identify a Common Architecture
  - Utilize horizontal Integration using Enterprise Service Bus (ESB) concept (HLA, TENA, etc.) when possible
- ESB Provides Ability to Meaningfully Communicate for Reuse and Composability
  - Standard Data Model to describe the data communicated
  - Standard Services Interfaces (API)
    - Software provides the Standard Services using Standard APIs
      - e.g. Services to distribute the data model
- Subsystems are called ***Federates***. The Integrated System is called a ***Federation***.



Identify Integration Process

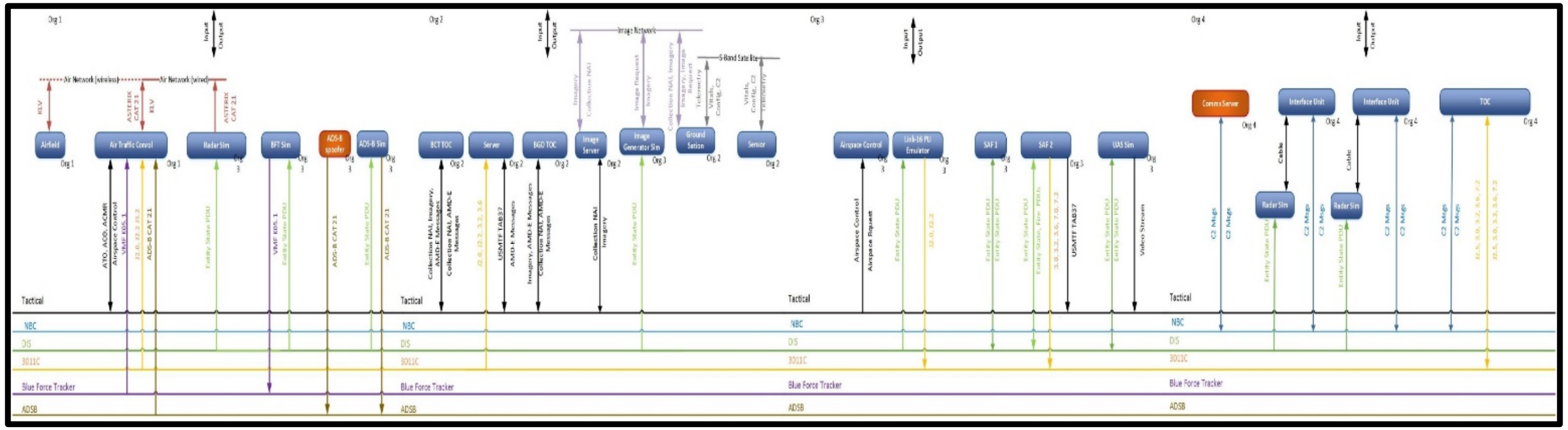
- Suggested standards and guidelines include
  - IEEE Std 1730-2010 - IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)
  - IEEE Std 1730.1-2013 - IEEE Recommended Practice for Distributed Simulation Engineering and Execution Process Multi-Architecture Overlay (DMAO)
  - TENA Concepts of Operations (CONOPS)
- HLA Distributed Simulation Engineering and Execution Process (DSEEP) Overview
  - IEEE 1730-2010 was developed based on authoritative systems engineering processes that were adopted and extended to address distributed simulation requirements
  - Identifies and describes the sequence of activities necessary to construct and run distributed simulations
  - A high-level process that is relevant to and can facilitate the development of solutions
  - Is independent of interoperability architectures

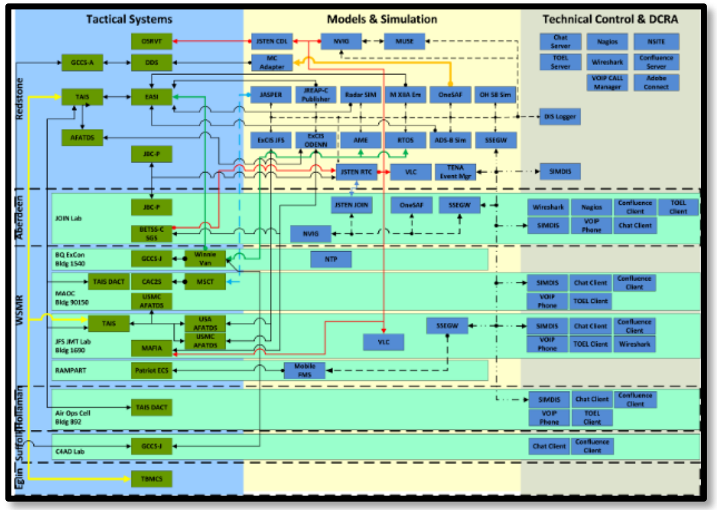


Focus on Communication

- Tools like Interface Matrices and Connectivity Diagrams are effective at communicating event design across the team
  - These diagrams ensure clear communication and that implementation mirrors design
  - Key data includes: Location, IP, Port, Protocol, messages, and system names

Source System	Source Instance	Target	Target Instance	Logged By	Protocol	Message	Transport	Address	Address Type	Port	Description	Event Purpose	Update Condition	Tested
UAS Sim	Org 4	EADSIM	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.72	Multicast	3000	Ground Truth Entity state	Position of UAS	DIS Dead Reckoning	
OneSAF	Org 4	EADSIM	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.72	Multicast	3000	Ground Truth Entity state	Position of ground entities and RWA	DIS Dead Reckoning	
OneSAF	Org 4	Radar Sim	Org 2	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.72	Multicast	3000	Ground Truth Entity state	Position of RWAs	DIS Dead Reckoning	
EADSIM	Org 4	OneSAF	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.72	Multicast	3000	Ground Truth Entity state	Position of FWA, TELs, and TBMs	DIS Dead Reckoning	
EADSIM	Org 4	Radar Sim	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.72	Multicast	3000	Ground Truth Entity state	Position of FWA, TELs, and TBMs	DIS Dead Reckoning	
EADSIM	Org 4	Link-16 PLI Emulator	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.73	Multicast	3000	Ground Truth Entity state	Position of Blue FWA	DIS Dead Reckoning	
EADSIM	Org 4	UAS Sim	Org 4	MAK DIS Logger	DIS	Entity State PDU	UDP Multicast	225.10.27.73	Multicast	3000	Ground Truth Entity state	Position TELs	DIS Dead Reckoning	
EADSIM	Org 4	Sat Sim	Org 4	MAK DIS Logger	DIS	Fire PDU	UDP Multicast	225.10.27.74	Multicast	3000	Weapon fire	Represent TBM fire	Launch	
EADSIM	Org 4	EOC Lite	Org 2	NSITE	30111-C	J 3.0	UDP Multicast	225.10.2.2	Multicast	3100	Surveillance - Referance Point	TBM Laucnh point	N/A	
EADSIM	Org 4	ATC	Org 5	NSITE	30111-C	J 3.2	UDP Multicast	225.10.2.2	Multicast	3100	Surveillance - Air Track	Air track from radar	N/A	
Link-16 PLI Emulator	Org 4	ATC	Org 5	NSITE	3011-C	J 2.0	UDP Multicast	225.10.2.2	Multicast	3100	PPLI - Indirect Interface Unit	Forwarded postion message from FWA		
ADS-B Sim	Org 4	ATC	Org 5	Wireshark	ASTERIX	CAT 21	UDP Multicast	225.10.2.3	Multicast	TBD	Aircraft Position	Position of FWA		
ADS-B Spoofer	Org 4	ATC	Org 5	Wireshark	ASTERIX	CAT 21	UDP Multicast	225.10.2.3	Multicast	TBD	Aircraft Position	Fake postions fo FWA		
JSTEN	Org 4	ATC	Org 5	NSITE	VMF	K05.1	UDP Multicast	TBD	Multicast	TBD	Entity Position	Emulation of Blue Force Tracker	BFT publishing rules	



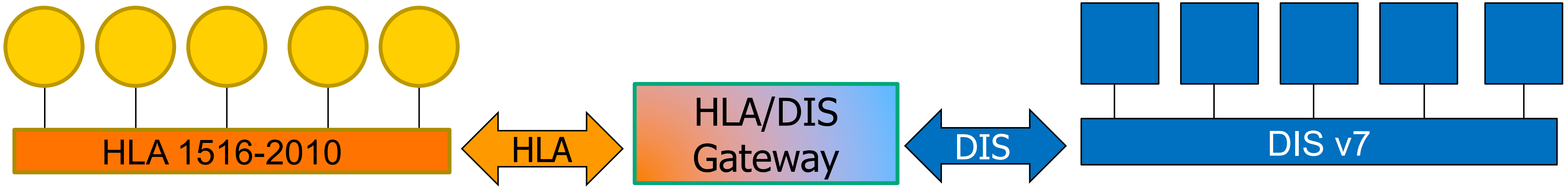


See vI/ITSEC 2020 Tutorial 20017 : by Mr. Michael O'Connor, Trideum Corporation for more details

4. Interoperability Using Gateways

- Complex LVC environments may require interoperability between simulation federations using different architectures
- Gateways are bridges between different simulation architectures
  - Examples:
    - TENA used at a test range interoperating with other facilities using DIS, HLA, or both
    - Legacy DIS-based system interoperating with newer HLA-based system

Example gateway



Interoperability Using Gateways

- Gateways
  - Translate data and services between different middleware, object models, and services
  - Can filter data, transferring some data while blocking other data
  - Can provide logging, monitoring, and detection and notification of errors or issues
- Caution: Placing a gateway may create a single point of failure for the system. Careful system design can minimize this potential problem.
- A top level "system design" trade-off analysis that considers schedules, costs, technical factors, etc., should determine the best of two implementation methods
  1. Selecting a common architecture for the entire LVC environment, or
  2. Implementing, integrating, testing, operating and maintaining gateways.

Interoperability Using Gateways

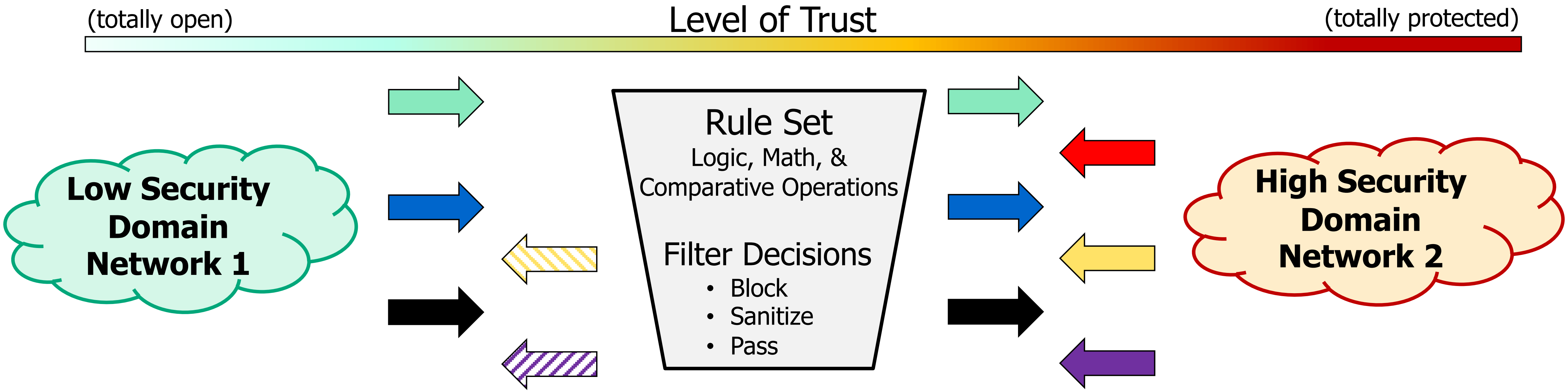
- Commonly used gateways are available as Commercial Off-The-Shelf (COTS) products from numerous vendors.
  - Check carefully the product's list of translated data types, models, and services!!
- TENA-related gateways can be downloaded from the TENA website.

- Sometimes unique modifications are needed, especially when a gateway is interfaced to a "stove-piped" (non-standards-based) system.

Multiple Levels of Security

- Definitions:
  - **Security Domain**
    - System or group of systems operating under a common security policy
  - **Cross Domain Solution** (CDS) … aka Multi Domain Operations (MDO)
    - An information assurance solution that provides the ability to access or transfer information between two or more security domains
    - Enables data transfers between Unclassified, Secret, Top Secret, Top Secret/SCI
- When establishing a complex distributed environment, information transfer between two or more security domains may be needed
  - Most organizations do not have any effective means to address this issue
    - As a result, too often the "solution" is a brute-force denial of access to information, thus severely limiting system effectiveness

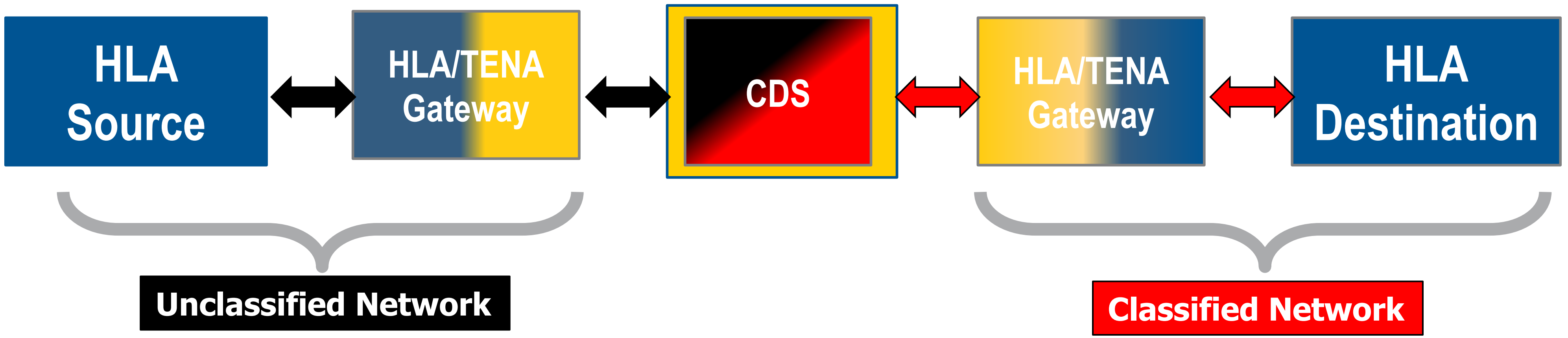
Purpose of Cross Domain Solutions



- Enforces Relevant Security Classification Guidance
  - The CDS default state is to block all traffic.
  - Data owner guidance is implemented through user-definable, event-specific, Rule Sets.
  - Rule Sets define if and how designated traffic can pass through.
    - Rules must support event objectives and classification guidance.
      - **Logical operations** (e.g. AND, OR, NOT)
      - **Mathematical operations** involving object attributes (e.g. addition, subtraction, multiplication, division, exponents, logs, trig)
      - **Comparative operations** (<, ≤, >, ≥, =): how object attributes relate to fixed values

CDS: Multiple Protocol Example

- Gateways enable broader use of existing CDSs



- There are two federations running *in different Security domains*, each using HLA to interoperate
- The example CDS meets requirements yet has a native TENA interface
- Gateways are used to translate between HLA-based simulations and TENA
- Approach enables HLA-based environments to use existing TENA-based CDS

5. LVC Interoperability Use Case

- **The Task**: A ground-based Command and Control (C2) system is being enhanced and must be tested.
  - The present test method stimulates the C2 system under test with real data sent from a live aircraft via a Tactical Data Link (radio).
  - This is a ***very*** expensive way to test a ground-based C2 system.
  - Great savings would be achieved if the tests used a flight simulator instead of a real aircraft.

C2 system under test

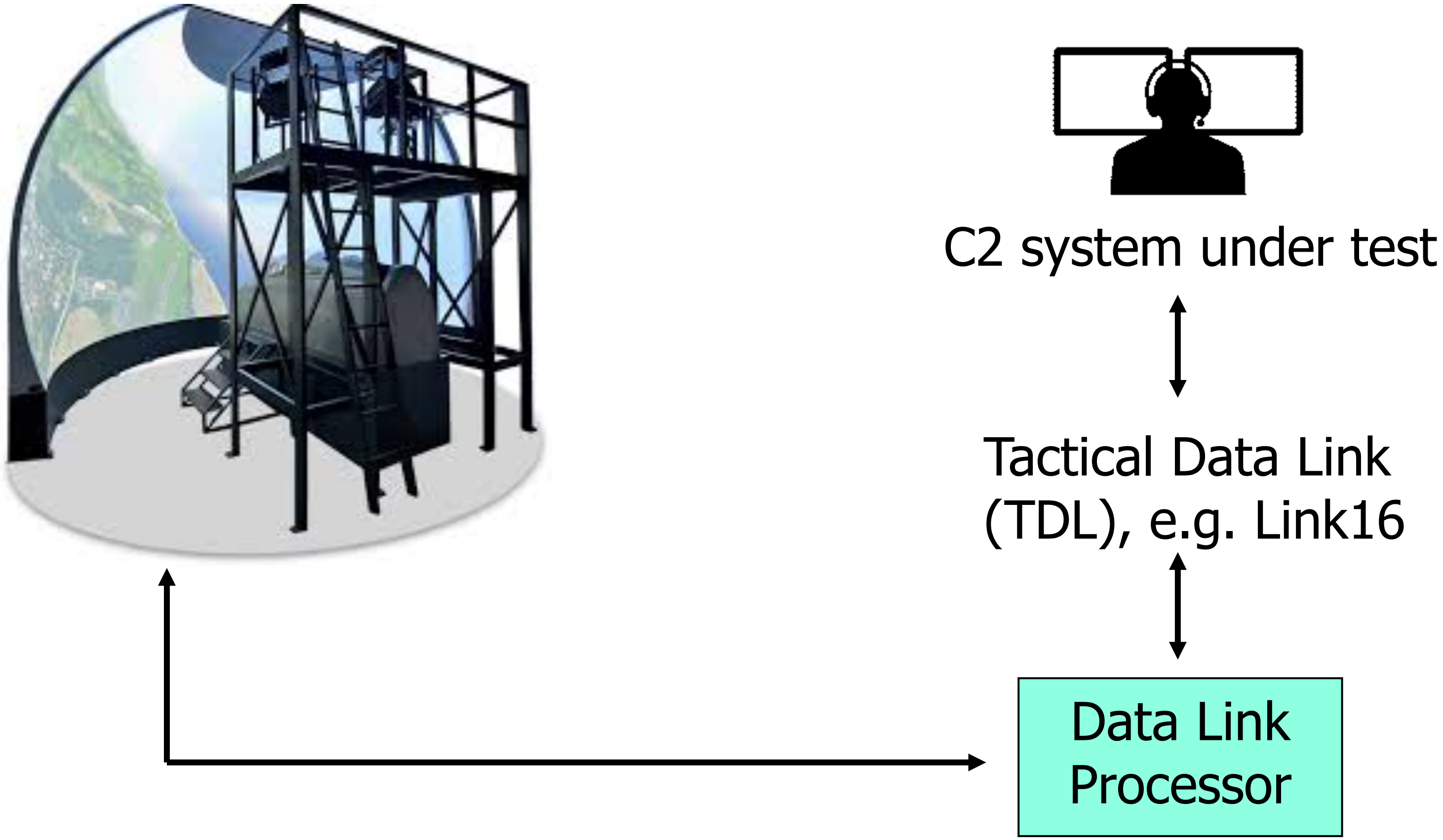
↕

Tactical Data Link (TDL), e.g. Link16

↕

LVC Interoperability Use Case

- An available flight simulator has a Link 16 “Data Link Processor” (interface), so the flight simulator can be used to stimulate the C2 system under test.



Everything’s good … right?

LVC Interoperability Use Case

- Analysis of the “real world” reveals:
  - The flight simulator has an older HLA 1.3 interface … and uses a vendor-modified version of the RPR-FOM *(“Didn’t anyone tell them to avoid building stove-pipes?!!”)*
  - A scenario generator, with DIS & SIMPLE interfaces, is available to insert simulated tracks of other aircraft into the Link 16 network.
  - The data link processor has a SIMPLE interface.
  - Link 16 is represented in two ways, standards-based and non-standards-based.

HLA 1.3 with proprietary additions to FOM

C2 system under test

Tactical Data Link (TDL), e.g. Link16

Data Link Processor

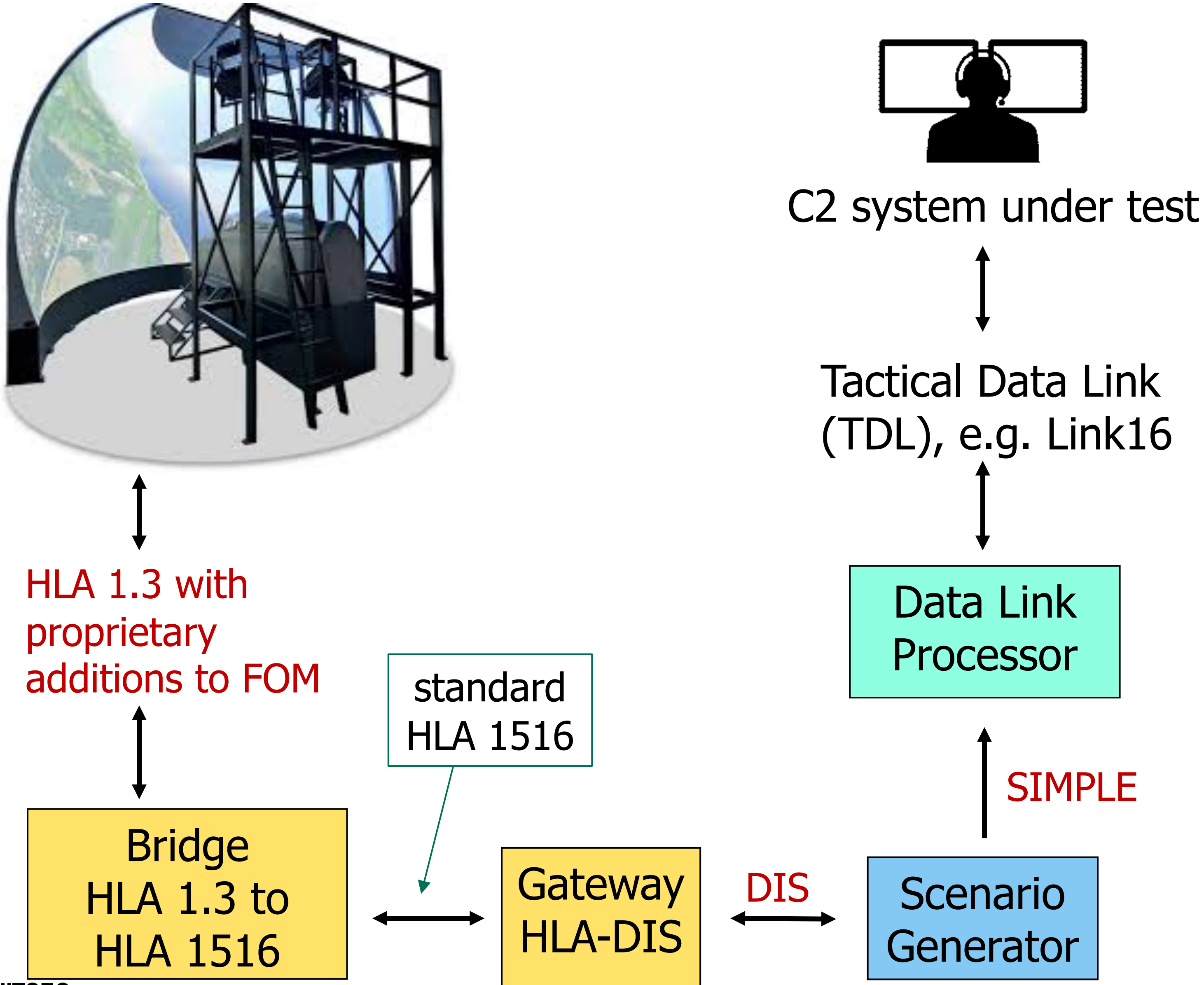
SIMPLE

DIS

Scenario Generator

LVC Interoperability Use Case

- DSEEP-driven feasibility study suggested:
  - Use HLA as the common interoperability solution
  - Insert an HLA to HLA bridge to filter/modify vendor-specific (non-standard) RPR-FOM extensions
  - Use a gateway from HLA/RPR-FOM to DIS, to connect with the Scenario Generator
- Some Limitations Accepted:
  - Simulator data is accepted as the “ground truth”
  - “J messages” from flight simulator are not bridged
  - No voice communications



LVC Interoperability Use Case

- Integration spiral demonstrated:
  - Selecting HLA as a standard was appropriate due to HLA technology and performance plus existing HLA-based solutions and experience
  - RPR-FOM extensions, HLA to DIS gateway, and HLA to HLA bridge concepts were acceptable
  - The DIS network did not work due to computer clocks not being in sync (or set correctly)
  - The scenario generator's DIS interface only worked in one direction
  - Security aspects needed further analysis
- <u>Success</u>! Initial tests produced good results with previously known limitations
- Additional actions required:
  - Updating the Scenario Generator's DIS interface
  - Getting approval from responsible authorities to synchronize the computer clocks
  - Getting approval to run tests with a dedicated Link16 network and the participating real aircraft on the ground (when the flight simulator was not being used as a substitute for the real aircraft, and to validate data)

6. Summary: Standards

- There are several standards available for Live-Virtual-Constructive interoperability
  - Some are especially made to support simulation
  - Some are focused on use with live systems
- Standards needs to be maintained and updated
  - New requirements emerge over time
- Standards need to be balanced between stability and flexibility
  - **Stable** enough to allow systems to be developed that support the same version of the standard
  - **Flexible** enough to be useful and support current requirements plus new and evolving requirements

Summary: Standards (2)

- Standards should not be selected only on technical merits
  - A “Community of Users” helps tremendously
    - Ensures long-term use of a standard … avoids obsolescence
    - Promotes evolution of a standard
    - Communication forum about common LVC applications, problems, and solutions
  - Industry Support (the marketplace) is very important
    - Government and Commercial Off-The-Shelf (GOTS/COTS) products, generally costing less than custom-developed solutions
    - On-demand training courses
    - On-demand technical assistance
    - Promotes adoption and evolution of standards (e.g. trade show demos)
- Organizations should try to use a limited number of interoperability LVC standards
  - Deviations must be expected to fit unusual situations
  - Develops “in-house” skills and experience that will be needed on future programs
  - Adopt Gateways as initial approach to integrate disparate architectures

Summary: Standards (3)

- Integrating LVC-based systems via distributed simulation is a powerful capability
  - LVC interoperability across domains, e.g. involving multiple military groups, creates operationally realistic environments
    - Supplementing a single system with other LVC systems greatly enhances realism of training
      - The whole is greater than the sum of its parts
    - Integrating C2 systems with LVC systems builds environments that are operationally realistic
      - ***"Train As We Fight"***
  - Standards enhance integration and reuse of other LVC assets, tools and technologies
  - Standards eliminate or greatly reduce time, cost, and performance risks of developing specialized systems (remember: ***"Avoid stove-pipes."***)
  - Standards-based instrumentation and management functions within an environment provide coordination of planning and execution, data collection and analysis, and repeatability
  - Leveraging existing standards and existing networks let program managers "do more with less"

Summary: Standards (4)

- Distributed simulation has advanced greatly since first attempts in the 1980's. Simulation developers today can establish LVC environments to solve very complex problems, at the System of Systems level, relatively easily and quickly.
  - Selection of the appropriate interoperability architecture … DIS, HLA, or TENA … is sometimes at the user's discretion, but other factors may favor one architecture over the others, such as technical features, the need to connect with systems already in place, or organizational policies.
  - Be sure to choose between DIS, HLA, or TENA, based on current information!
    - We're in the year 2020 now, not 1986, 2000, or even 2010
-]Best advice…Get involved!!!

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