

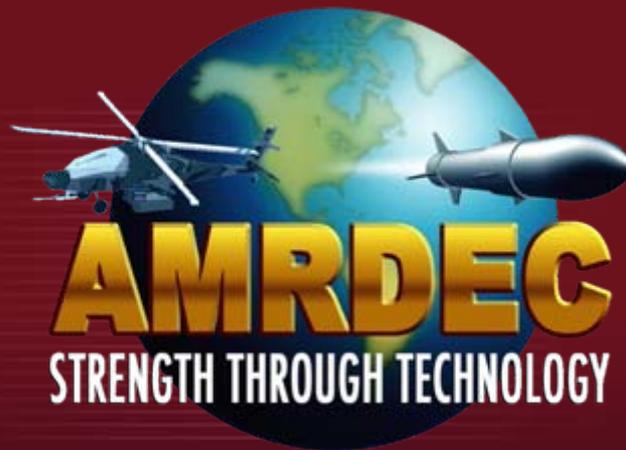


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**Presented to:**

AIAA Missile Science Conference

# Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

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20 November 2008

## Report Documentation Page

*Form Approved  
OMB No. 0704-0188*

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1. REPORT DATE <b>01 NOV 2008</b>	2. REPORT TYPE <b>N/A</b>	3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities</b>		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>U.S. Army Aviation and Missile Research, Development and Engineering Center, Redstone Arsenal, Alabama, 35898</b>		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>			
13. SUPPLEMENTARY NOTES <b>See also ADM202644. AIAA Missile Sciences Conference Held in Monterey, California on November 18-20, 2008, The original document contains color images.</b>			
14. ABSTRACT			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>	<b>UU</b>
			18. NUMBER OF PAGES <b>21</b>
			19a. NAME OF RESPONSIBLE PERSON

# Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities

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- **Distributed Single Stimulation Framework (DSSF) Objectives**
- **Notional Scenarios to be represented**
- **DSSF Design and Truth Data Flow**
- **Software Architecture**
- **Hardware Architecture**
- **Summary**

- The goal of a Geographically Distributed HWIL event is usually system-level interoperability and performance evaluation
- System-level evaluation requires centralized control and commonality of inputs to ensure all participating elements are acting upon the same information
- Inconsistent representation of physics can inject test-induced errors into the performance of the system
- If Element “A” processes threat system “X” one way, and Element “B” processes it another and both send data to Element “C”, artificial errors may be injected into the test that lead to false performance results

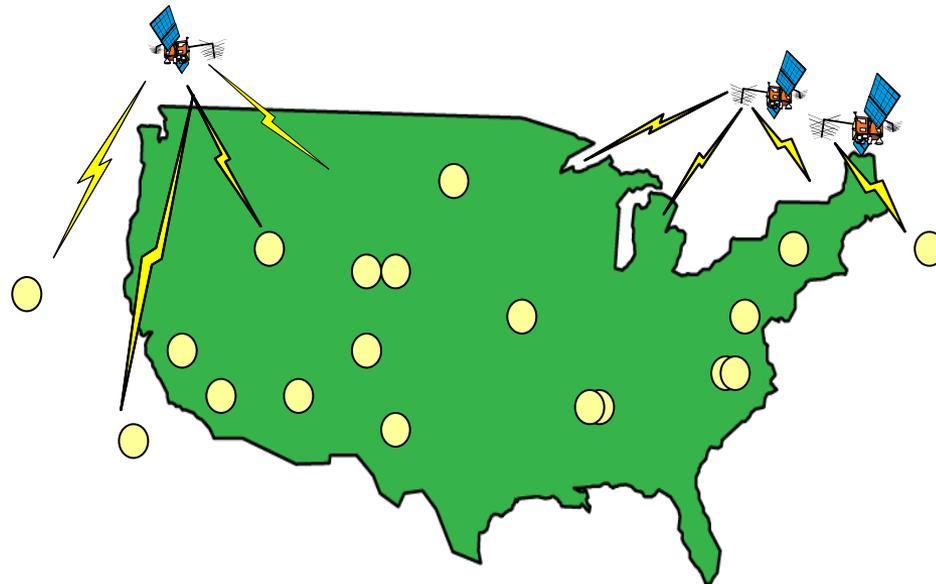
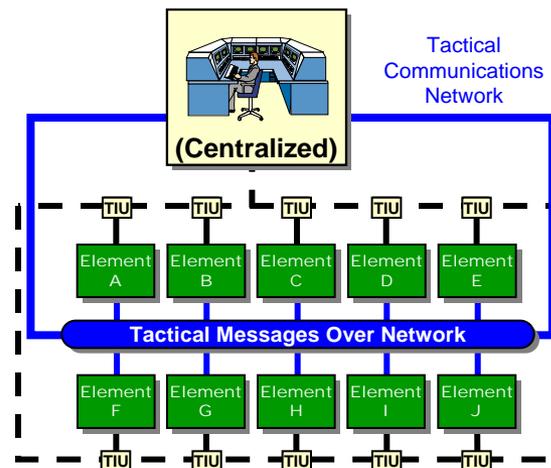
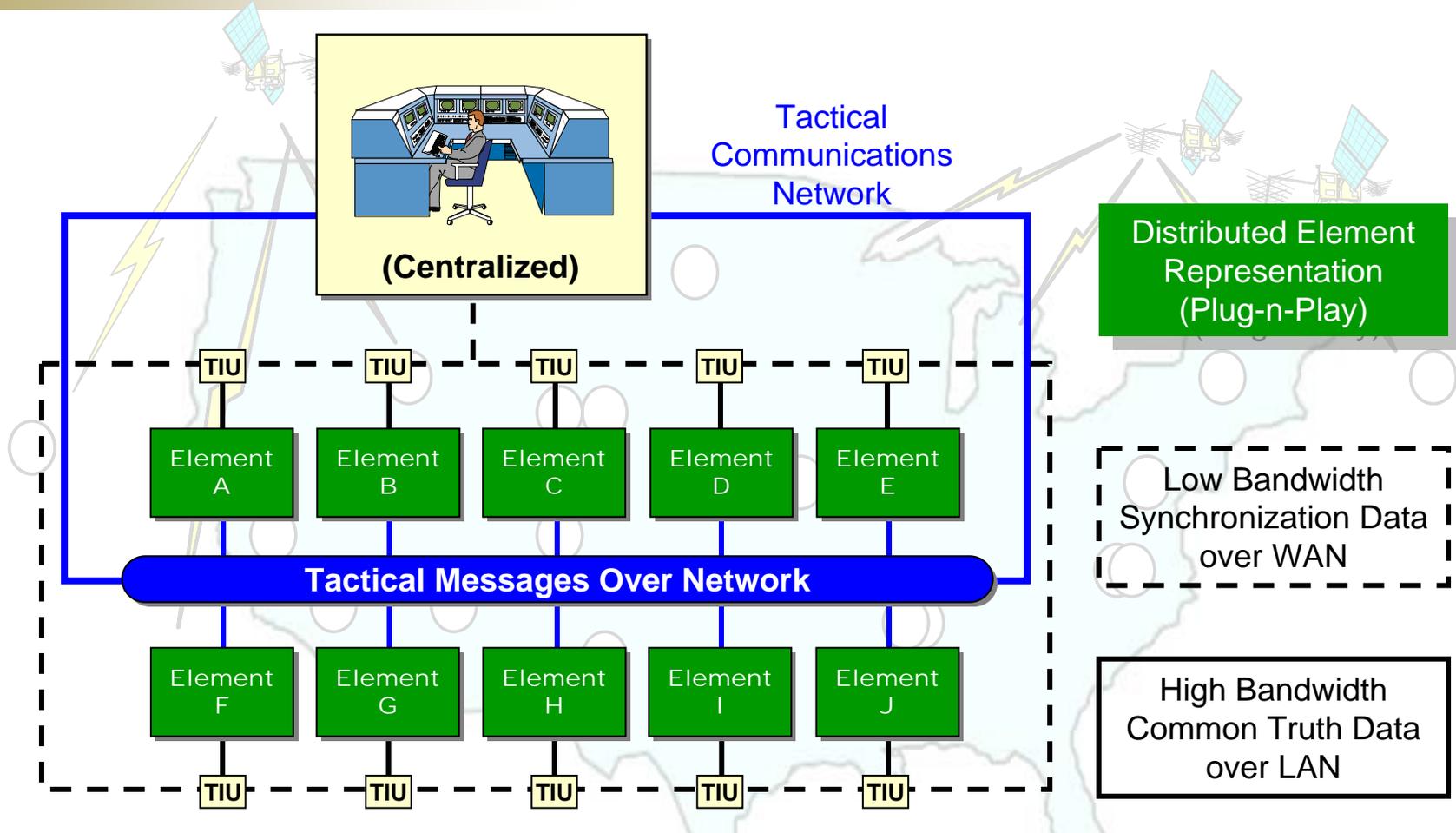


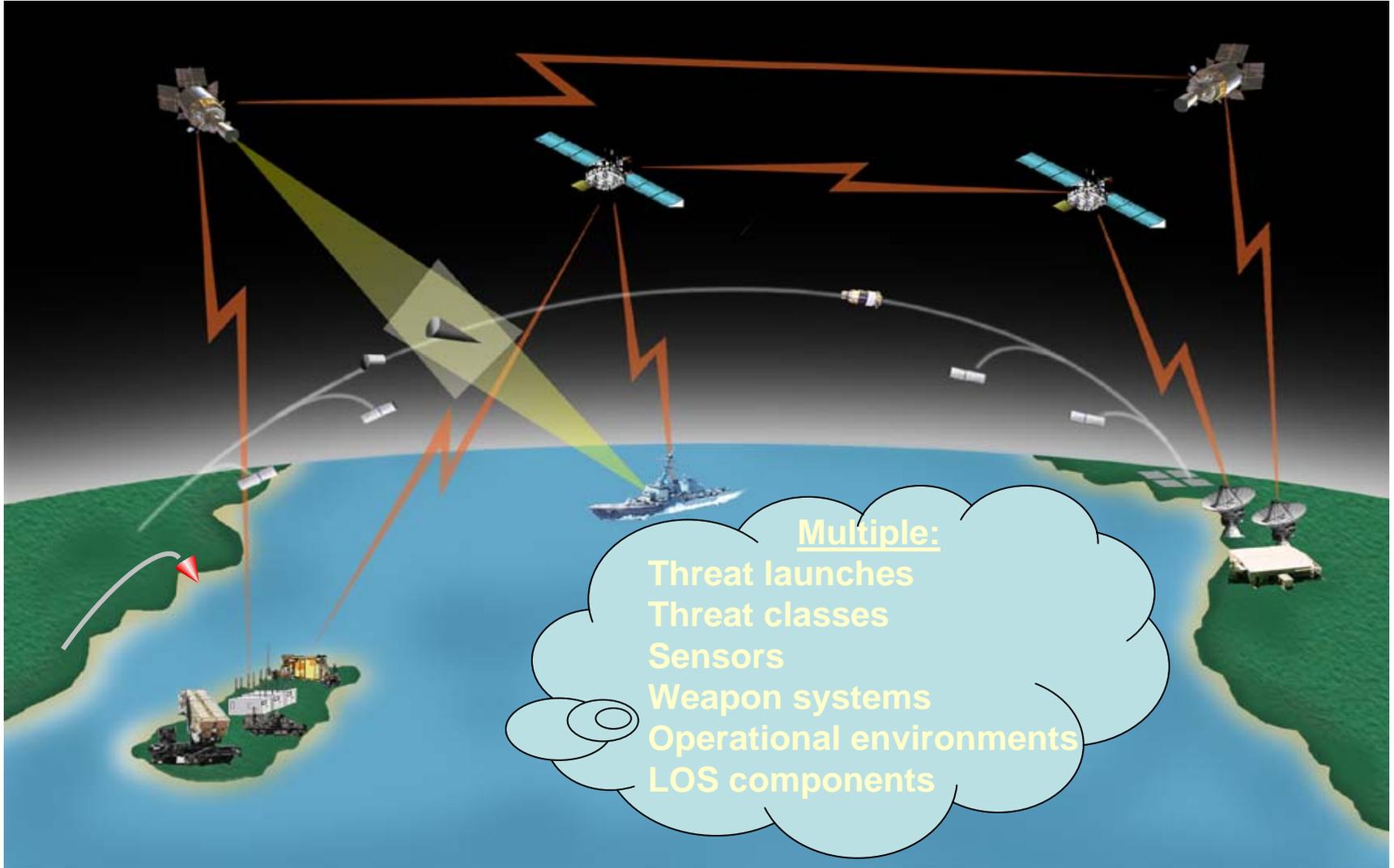
Figure: Example of Distributed Locations used in a Ground Test Architecture

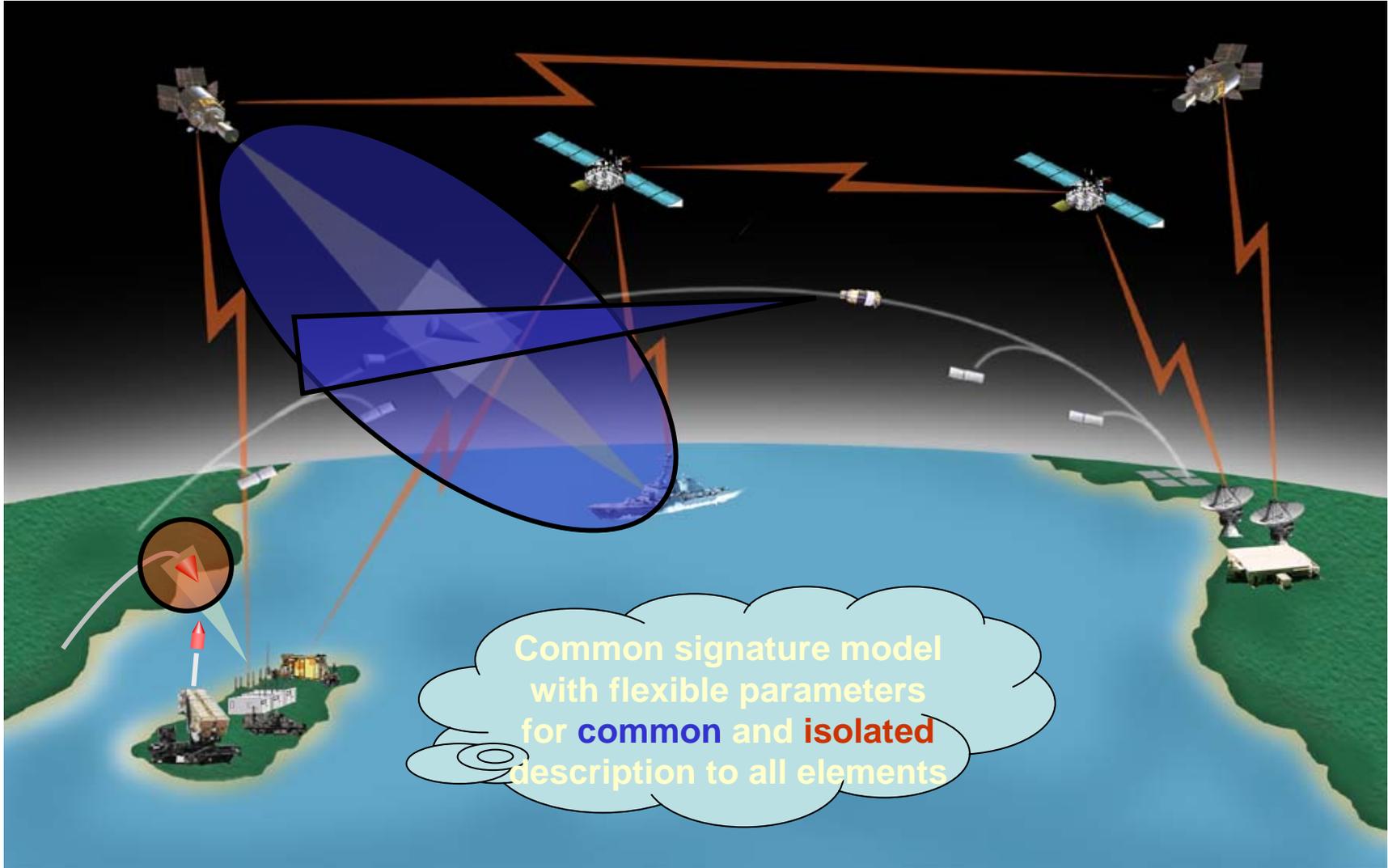


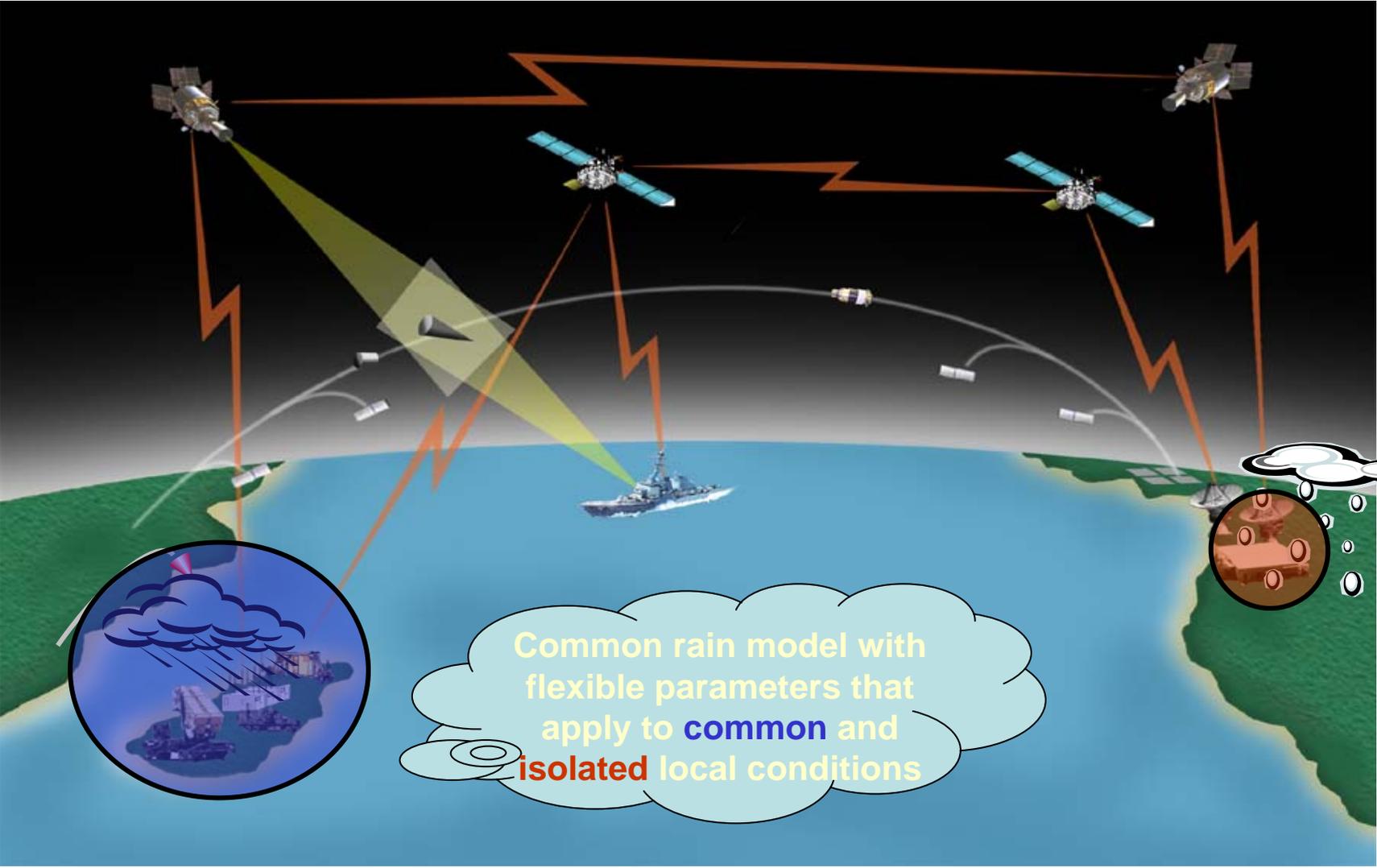




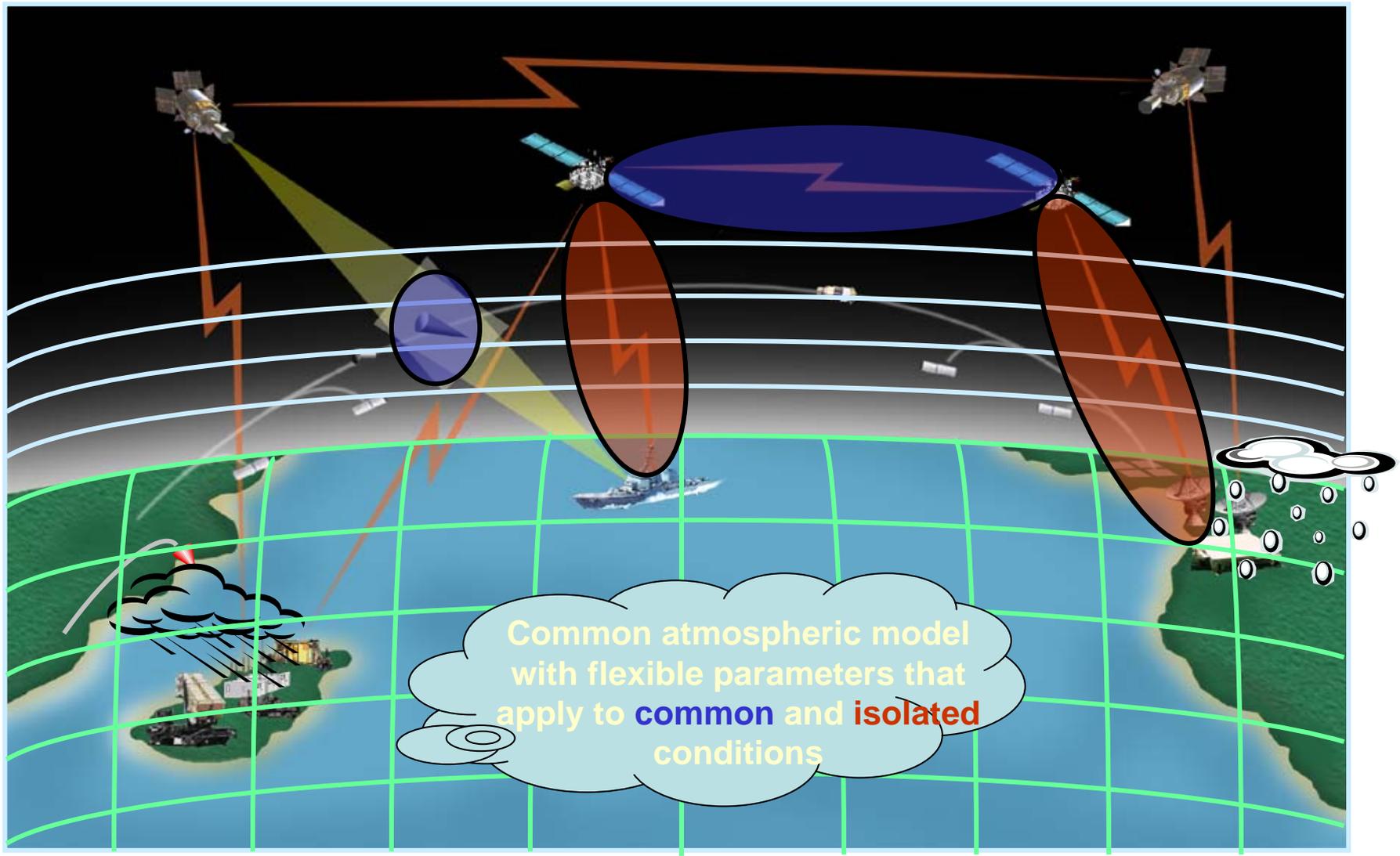
The Single Stimulation Framework Provides Centralized Control of Geographically Distributed System Components With Message Traffic Designed to Accommodate Network Capabilities and Allows for Easy System Reconfiguration to Test System Interoperability and Performance

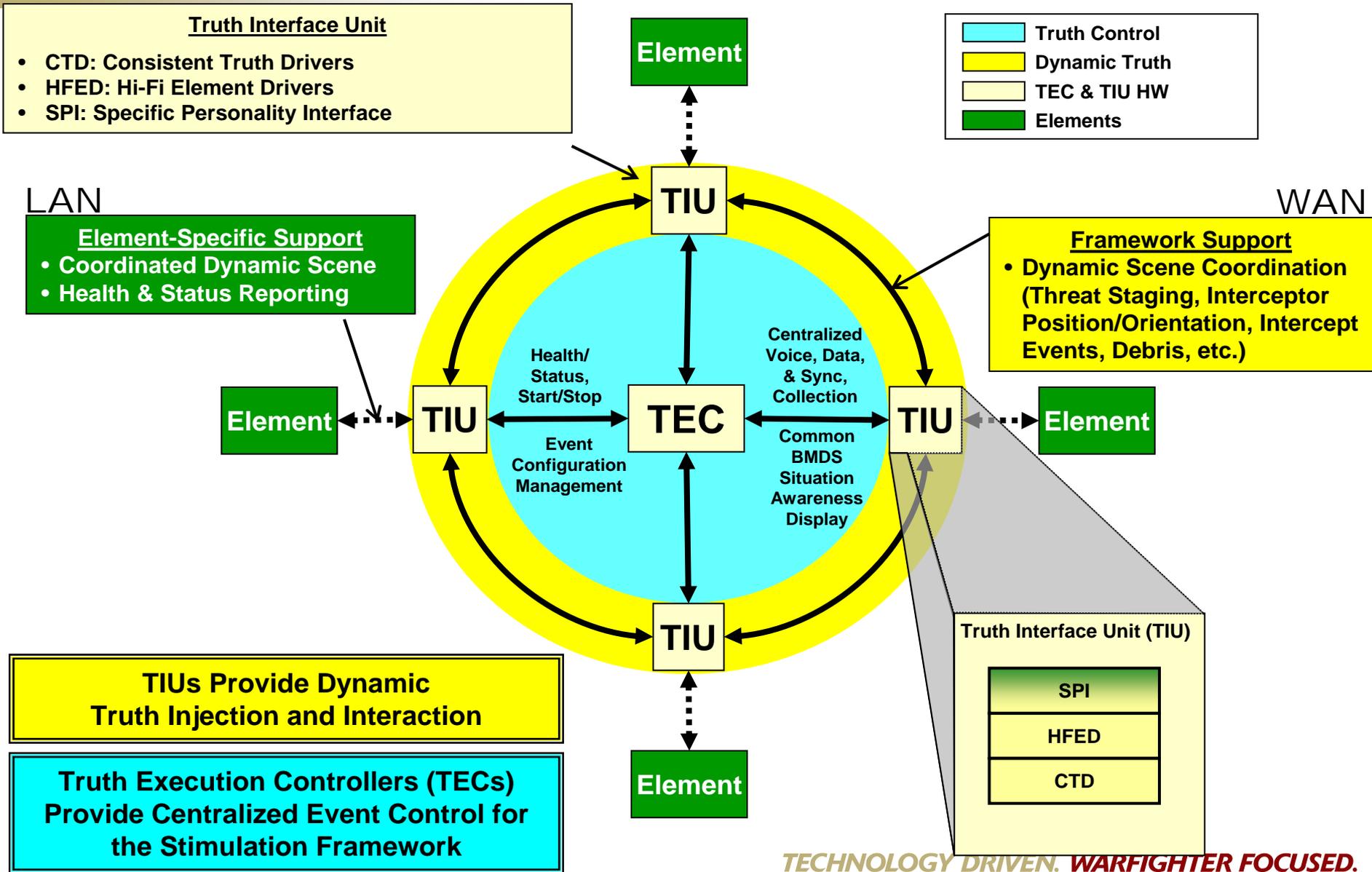


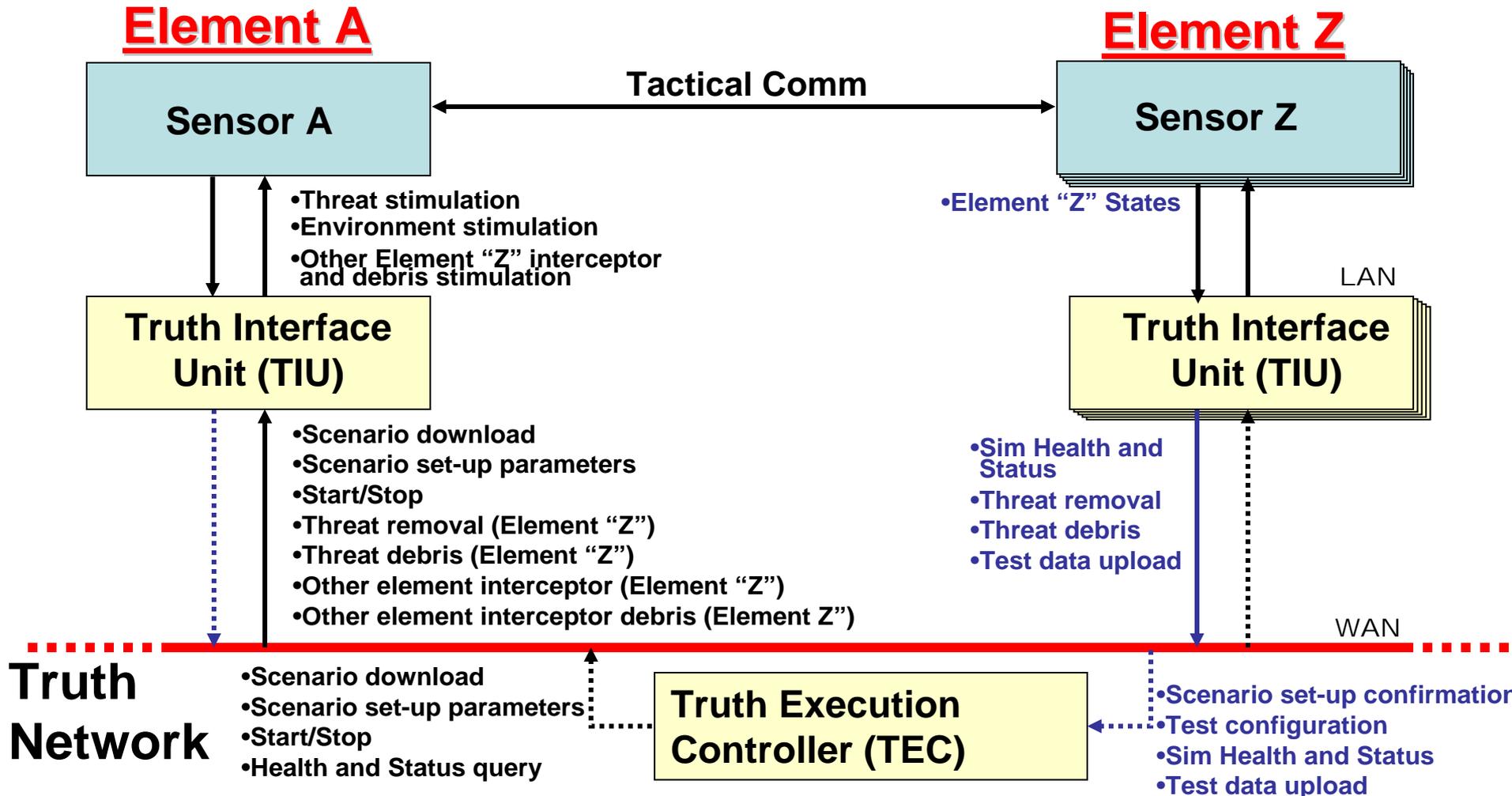




# Environments in HWIL -Atmospheric Model-





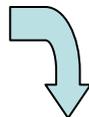


**All truth data exchanges are defined in the Interface Control Document (ICD)**

- Truth Network Data
  - Scenario download from TEC to TIU
  - Event Test Start/Stop
  - Event Test Health and Status
  - Interceptor position, velocity, and acceleration truth data from Element A to TEC and Elements Z
  - Interceptor debris truth data from Element A to TEC and Elements Z
  - Threat detonation/removal from Element A to TEC and Elements Z
  - Threat debris truth data from Element A to TEC and Elements Z
  - *No tactical communication messages/data from Element sensor or Element Battle Managers*
- Operational Network Data
  - Sensor track data from Element A to Elements Z
  - Battle Manager control and response messages
  - Tactical action reporting
  - Operational Health and Status
  - *No truth stimulation or event control data*

## Pre-Mission

- Define Test Cases for event
- Parse trajectories
- Blue force laydown
- Radar Cross Section and Electro Optical data
- Other Test Configuration parameters
- Test Case download to TIUs



## Mission

- Establish test control voice
- TEC starts Health & Status reporting cycles
- TEC exchanges initiation parameters with elements
- TEC issues Start
- Event Test start
- TIUs begin threat state injection to elements
- TIUs distribute “own-ship” state vectors from elements
- TIUs distribute interceptor state vectors
- TIUs propagate engagement debris for kills
- TEC displays H&S, truth and tactical msg track data
- TEC requests test integrity metrics
- TEC issues Stop



## Post-Mission

- Data file upload from all elements
- Parse data into Oracle database
- Data file status report
- Quick-Look report
- Database queries, plots
- Analytical tools
- Data file download

**Software is government-owned,  
developed, and non-proprietary**

## Input

### Trajectory Data

- Time zero based trajectories, flight paths
- Multiple Threat formats and Update rates
- Earth Centered Inertial (ECI) or Earth Centered Rotating (ECR)
- Gravity terms up to 18x18 per request
- 3 DOF and 6 DOF capable

### Scatter Point RCS Data

### Test Case Description Document

- Launch Times
- Blue Force lay down

### ICD Parameters

- Entity Type enumerations
- Element identifiers
- IP addresses, port numbers

## Processes

### Pre-Mission Data Parsers

- Convert ECI to ECR, Euler angles to Quaternions
- Insert state vectors into threat library database
- Dead Reckoning flags state vectors required to maintain one meter position accuracy
- Install RCS/EO data in database

### Test Case Builder

- Assemble trajectories from threat library and offset to prescribed launch times
- Blue force laydown
- Connectivity parameters
- Environmental parameters
- IFF scripts
- Pk=0/1 scripts

### Test Case Download

- Creates Test Configuration "flat files"
- Creates threat scenario preview report
- Creates 17 column format

### Install Test Configuration Data on TIUs

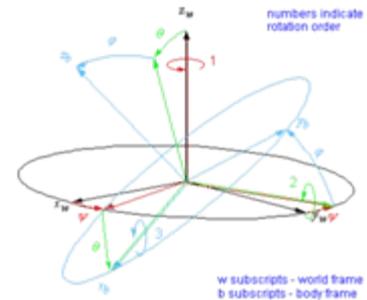
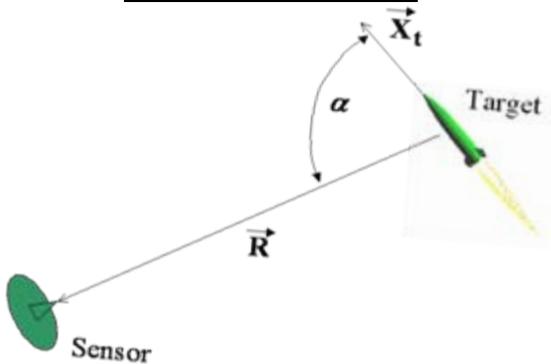
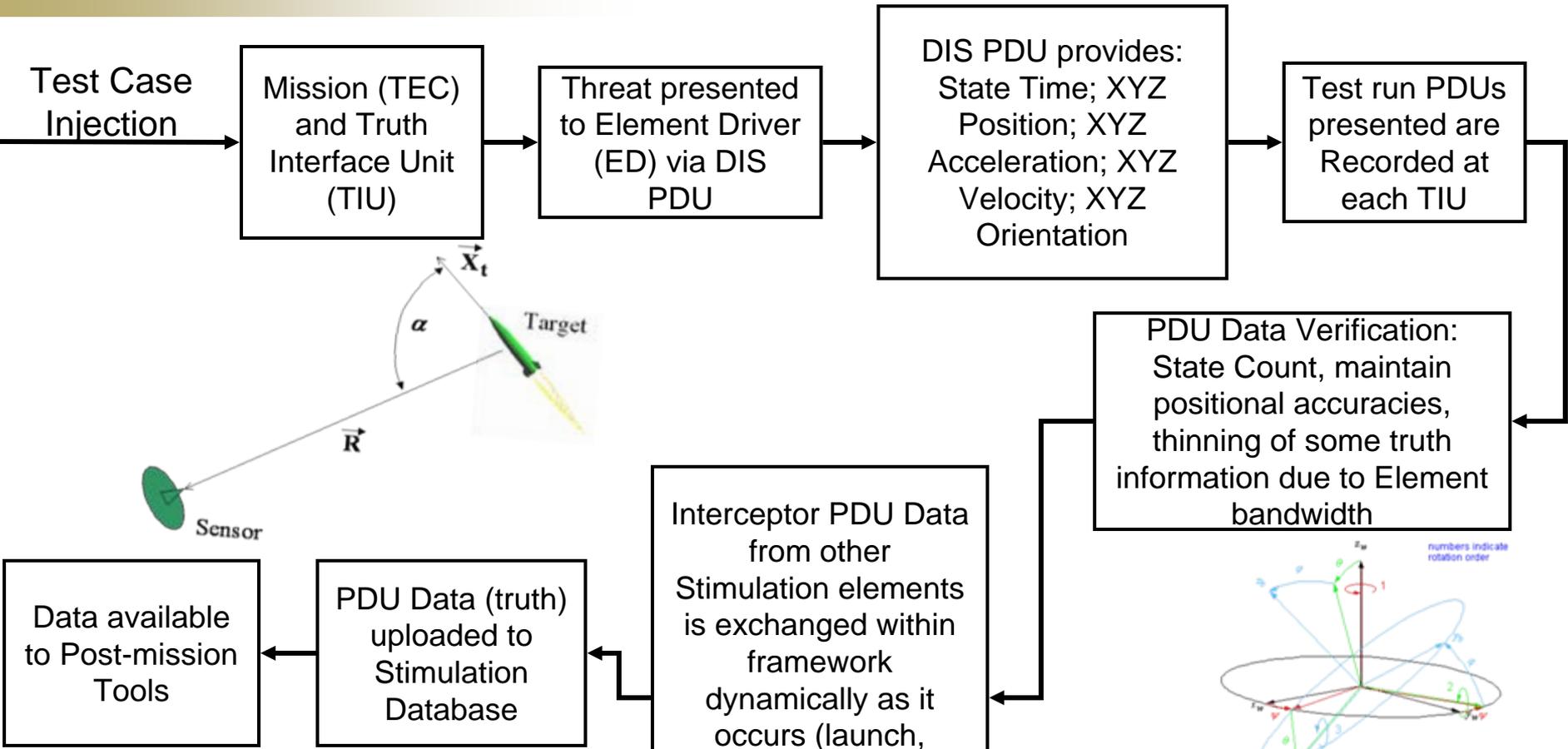


Figure 1-1. Definition of Yaw-Pitch-Roll Euler Angles

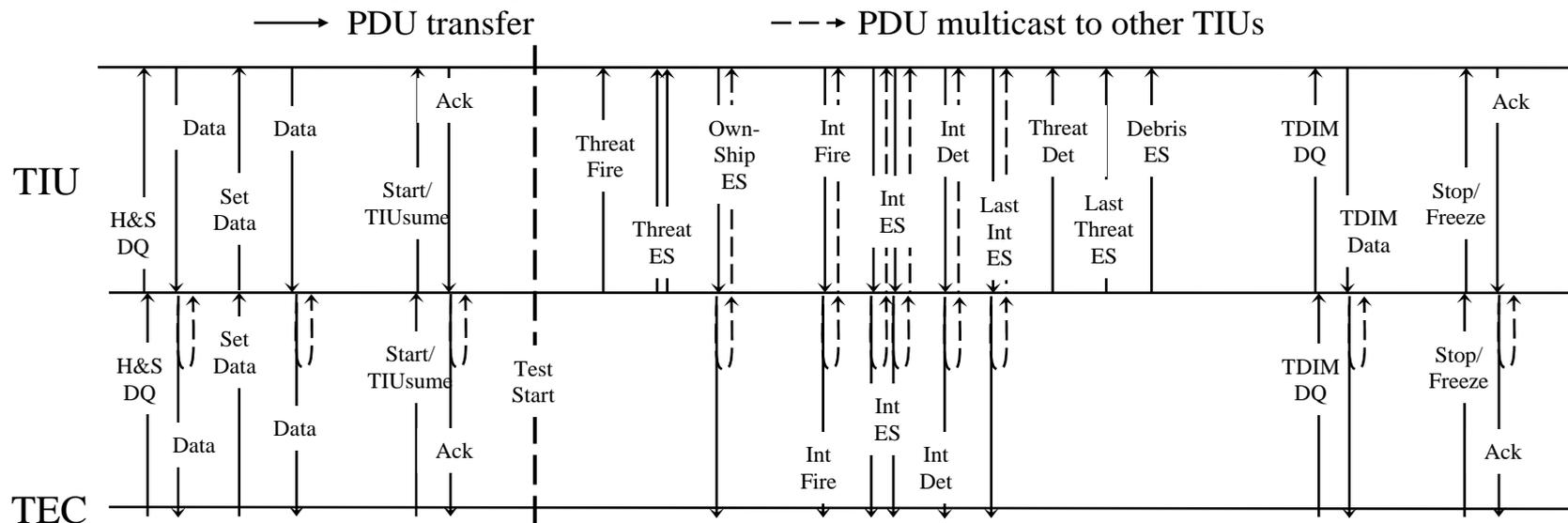
- $\mathbf{p}$  extrapolated position vector in world coordinates
- $\mathbf{p}_0$  position vector in world coordinates at the initial time
- $\mathbf{v}_0$  velocity vector in world coordinates at the initial time
- $\mathbf{a}$  acceleration vector
- $\Delta t$  time increment for the dead reckoning step
- $[\mathbf{R}]_{w \rightarrow b}$  entity's extrapolated world to body orientation matrix
- $[\mathbf{DR}]$  dead reckoning matrix
- $[\mathbf{R}_0]_{w \rightarrow b}$  the entity's initial world to body orientation matrix

Interceptor PDU Data from other Stimulation elements is exchanged within framework dynamically as it occurs (launch, position, kill, detonation, altitude, weather, merge blue force)

$$\mathbf{p} = \mathbf{p}_0 + \mathbf{v}_0 \Delta t + \frac{1}{2} \mathbf{a} \Delta t^2$$

$$[\mathbf{R}]_{w \rightarrow b} = [\mathbf{DR}] [\mathbf{R}_0]_{w \rightarrow b}$$

## PDU Message Sequence for TEC and TIUs



↑ TEC begins H&S 10 sec cycles after voice coordination  
 ↑ TEC issues Set Data PDUs to confirm position/heading, weather, satellite background, movement  
 ↑ TEC issues Start/Resume PDU to announce time of start and Sim time  
 ↑ Test starts at time indicated in Start/Resume PDU

### Major Mission SW Functions

- TEC and TIU use same SW
- TEC provides operator test and control
- TIUs can operate in stand-alone with Element
- TIUs convert trajectory files to ES PDU stream
- TIUs forward PDUs received from Element
- TIUs propagate engagement debris for kills
- TEC displays H&S, truth and tactical msg track data
- Data collection

- ↑ TIUs begin issuing Fire PDUs for scripted munitions
- ↑ TIUs begin issuing Entity State PDUs for scripted objects
- ↑ EDs begin issuing Entity State PDUs for "own-ship positions"
- ↑ ED issues Fire PDU for interceptor launch
- ↑ ED issues ES PDUs for interceptor flight
- ↑ ED issues Det PDU for interceptor kill (or miss)
- ↑ ED issues ES PDU to remove interceptor
- ↑ TIU issues Det PDU for threat
- ↑ TIU issues ES PDU to remove threat
- ↑ TIU issues ES PDUs for threat debris
- ↑ TEC issues TDIM request
- ↑ Test stop

## Data Flow

### Test Conductor

- Creates Test Run in Oracle database



### Test Participants

- Log-in to database at appropriate TEC
- Submit Test Assessment Form (if required)
- Upload data files



### Data Parsers

- Attach raw data files to test run
- Parse multiple message types and Correlation data into database tables
- Create Quick-Look Report



### Data Users on Truth Network

- Log-in to database at appropriate TEC
- Select Test Run of interest
- Can download any raw data file
- Can query and plot data from any database table
- Can use analytical tools
- Can export query, tool output tables

## Post-Mission Features

### Playback

- User at TEC can playback recorded truth and tactical events on display
- User at TEC can playback voice recordings

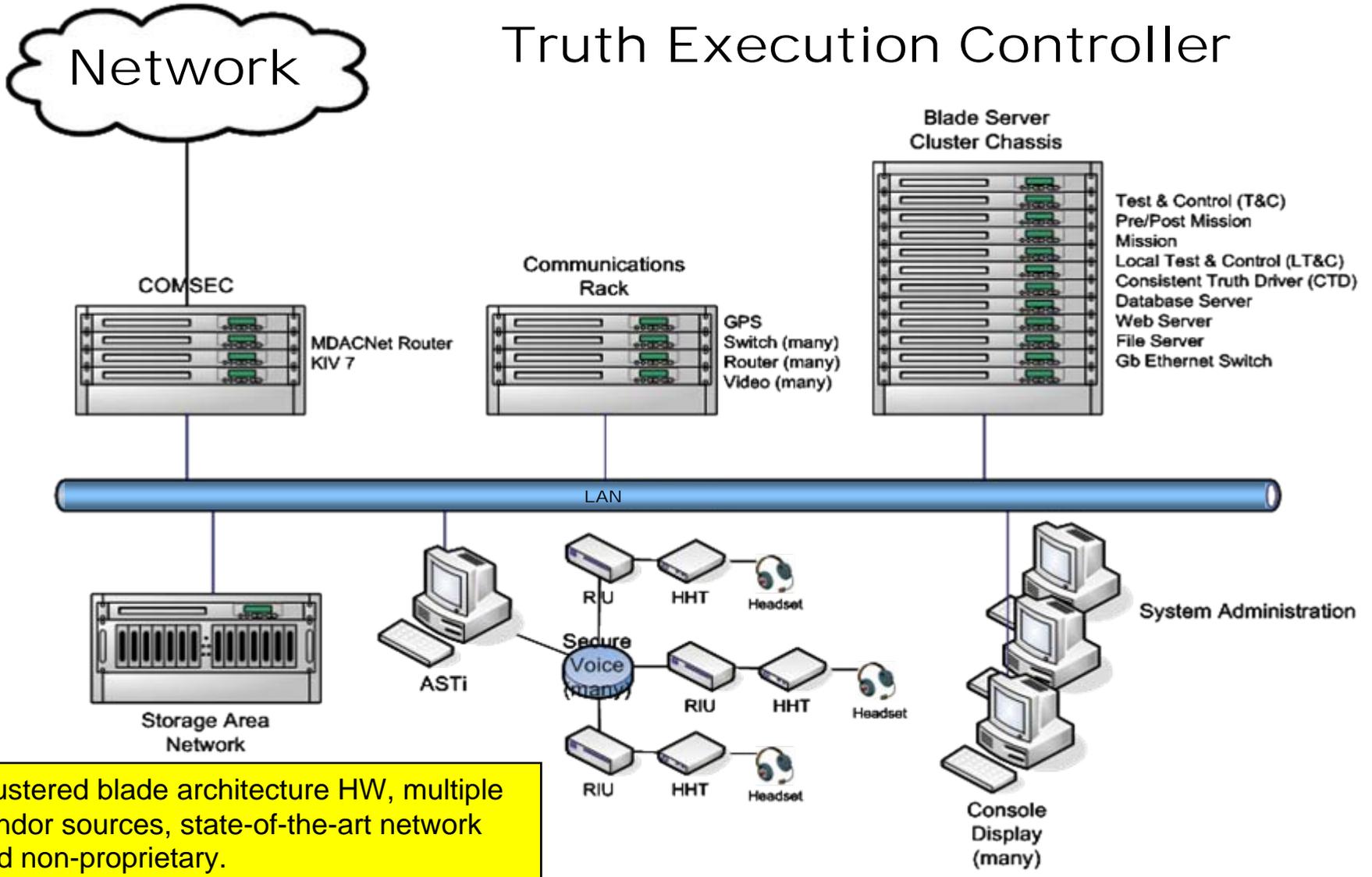
### Analytical Tools

- Verify PDUs
- Verify Tactical Messages
- PDU Message Transmission Delay
- Tactical Message Transmission Delay
- Extract Object History
- Extract Track History
- Find Close Entities for Tactical Track Msgs
- Engagement Summary
- Track Correlation Summary
- Volume Entry and Exit

### Access Control

### Data File Status Report

### Quick Look Report



Clustered blade architecture HW, multiple vendor sources, state-of-the-art network and non-proprietary.



## Truth Interface Unit – Rack (TIU-R)

- Highest Storage Capacity
- Processor Scalable
- Full Environment Stimulation capability
- TEC-Capable
- Transportable
- \$\$\$



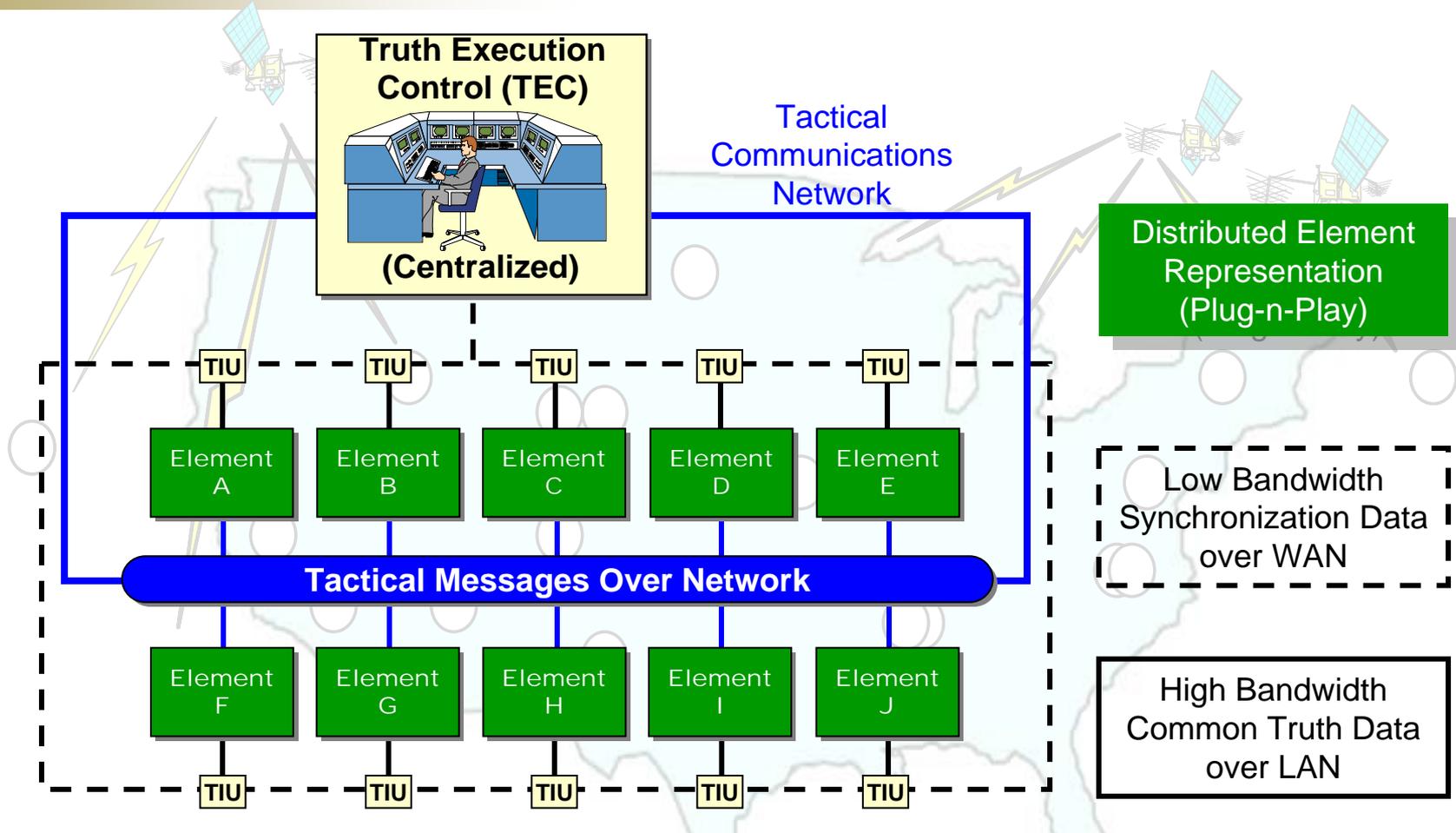
## Truth Interface Unit – Portable (TIU-P)

- Smaller Storage Capacity than TIU-R
- Dual or Quad-Core Processors capable
- Limited Environment Stimulation capability
- TEC-Capable
- Ruggedized/Reinforced, Mobile
- \$\$



## Truth Interface Unit – Laptop (TIU-L)

- Smaller Storage Capacity than TIU-R
- Dual or Quad-Core Processors capable
- Limited Environment Stimulation capability
- TEC-Capable
- Commercial Laptop, Mobile
- \$



The Single Stimulation Framework Provides Centralized Control of Geographically Distributed System Components With Message Traffic Designed to Accommodate Network Capabilities and Allows for Easy System Reconfiguration to Test System Interoperability and Performance