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Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities

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Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities

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Agenda

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

Why a Single Stimulation Framework

- **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**

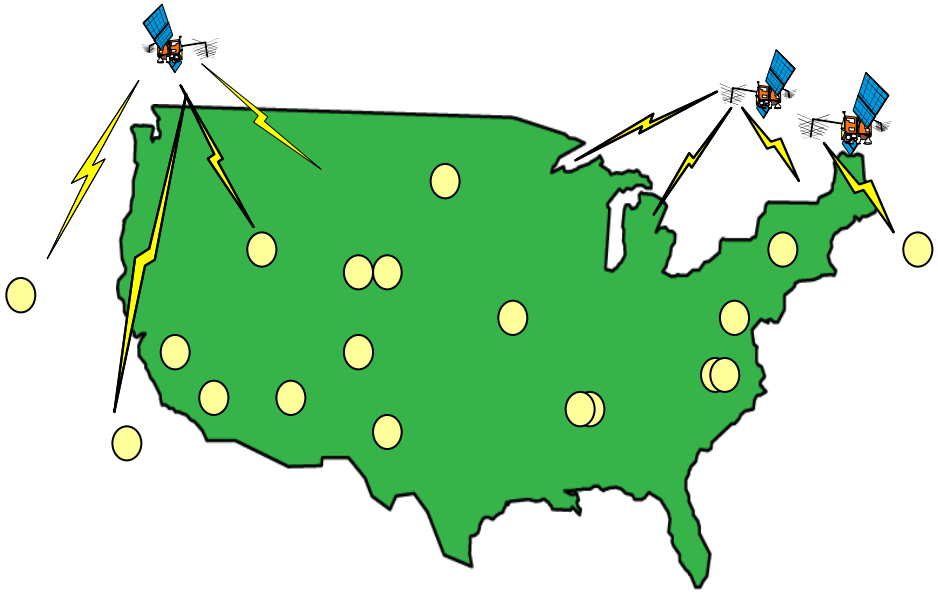
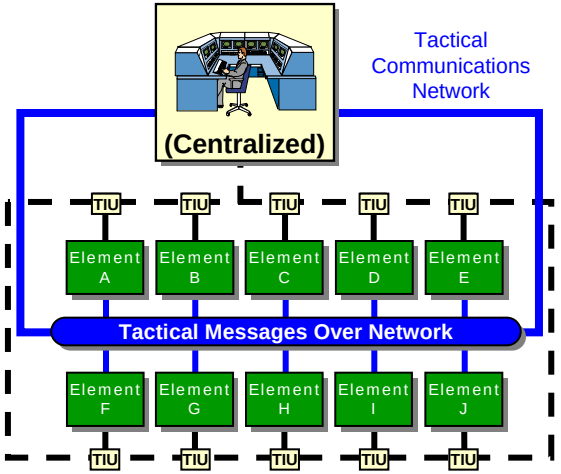
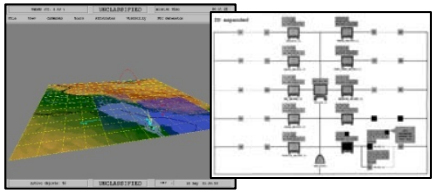


Figure: Example of Distributed Locations used in a Ground Test Architecture

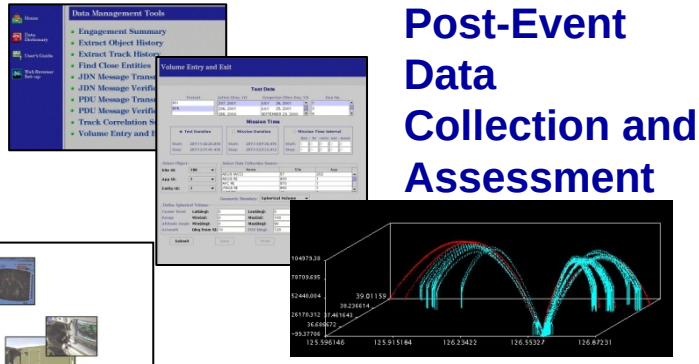


Distributed Single Stimulation Framework is...

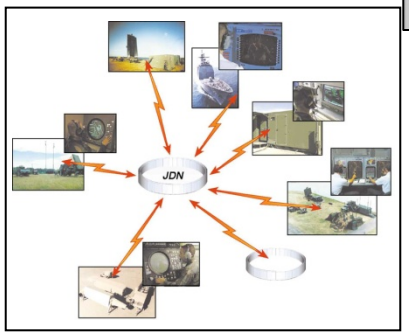
Coordinated Planning and Control



Monitor Event with Truth and Perceived Activity



Post-Event Data Collection and Assessment



Distributed Real-Time HWIL Connectivity

…Verified, Validated, and Accredited Hardware-in-the-Loop (HWIL) Stimulation Tool

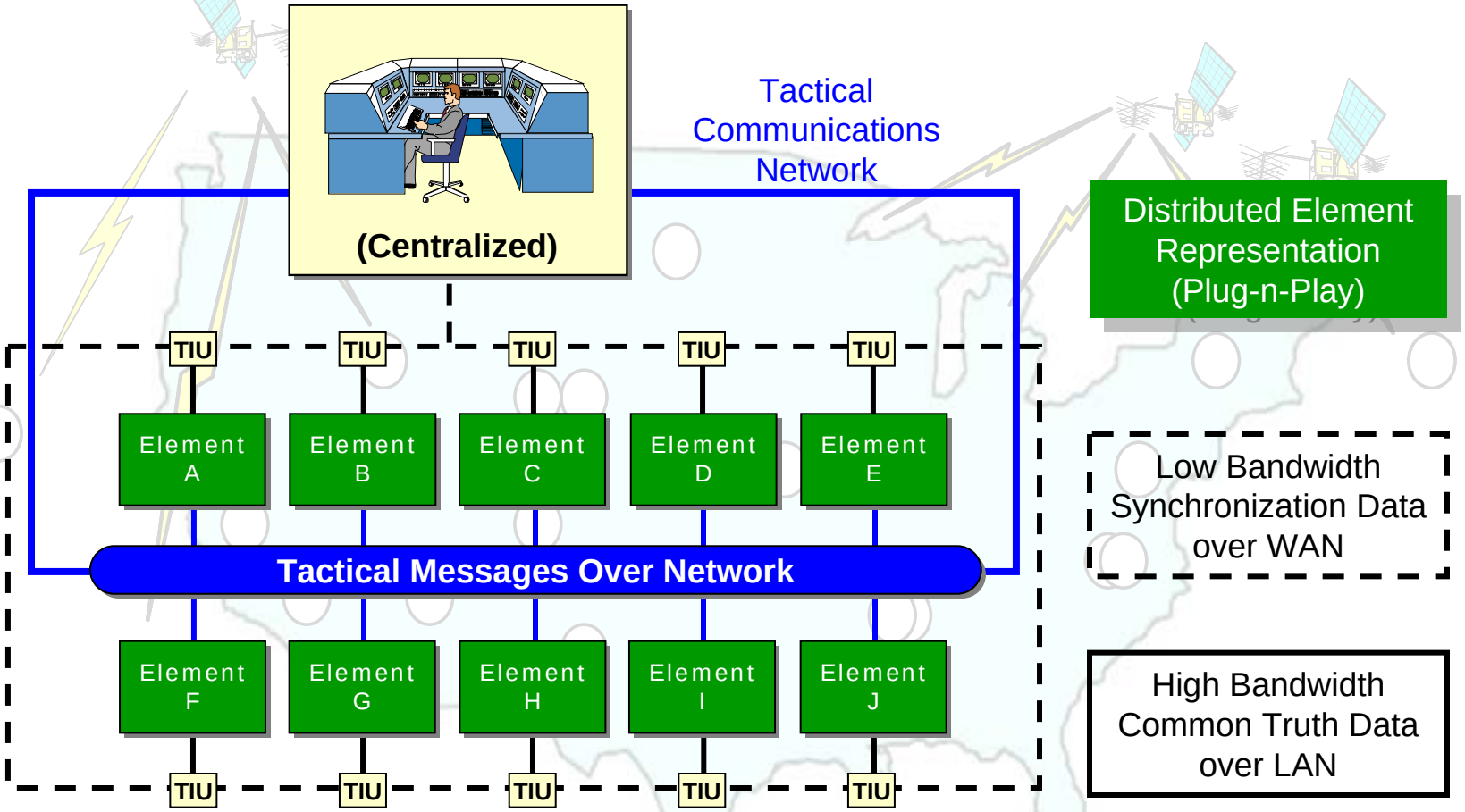
…Uses Approved Threats to Stimulate Tactical HW & SW Elements

…Link the Elements that Produce the Operational Messages

…Provide Characterization and Assessment of Units Under Test

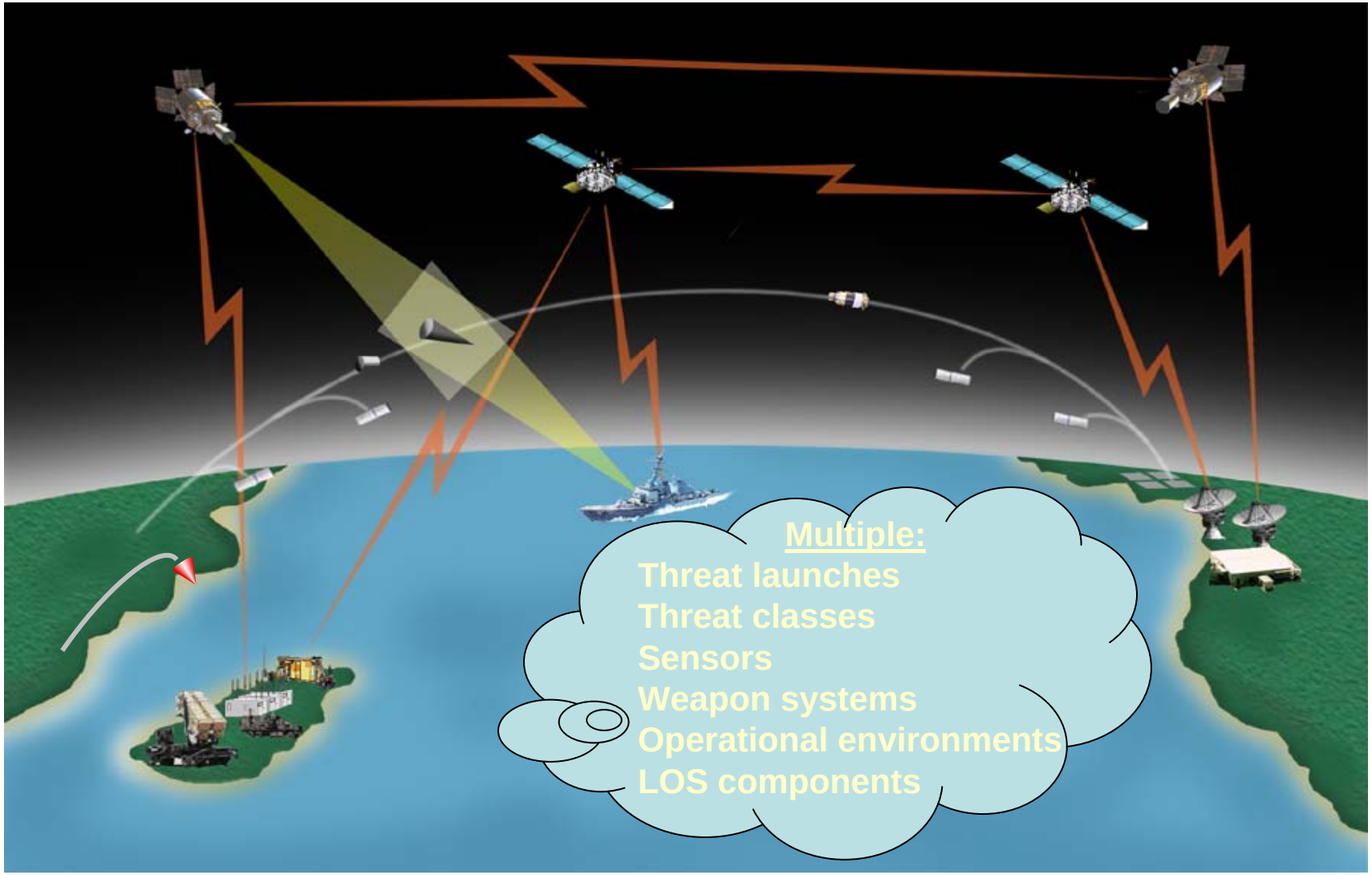
Real-Time, Dynamic, Interactive, Centrally Controlled, Geographically Distributed, GPS Synchronized System

Stimulation Framework Integrated Architecture Summary

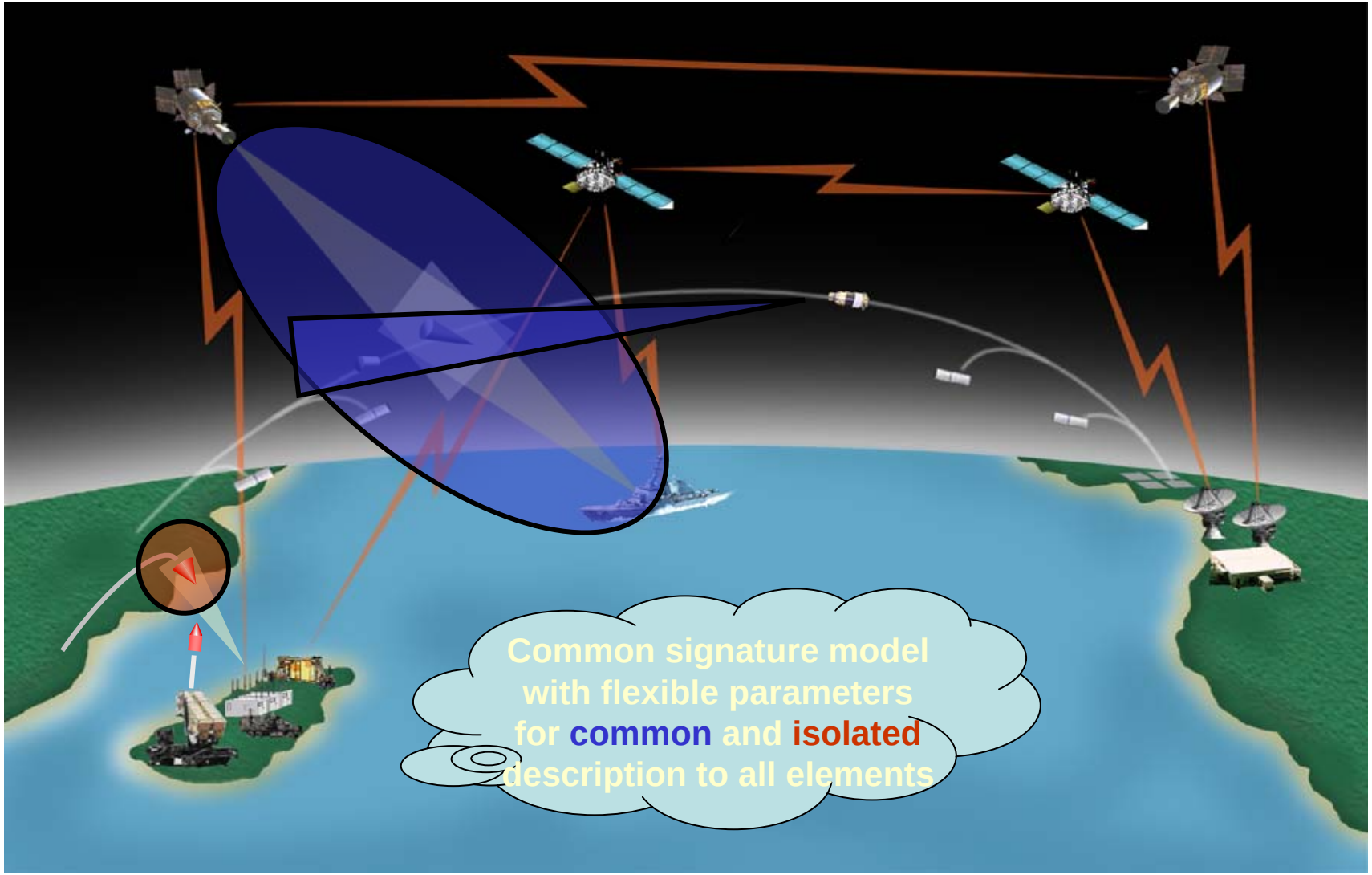


The Single Stimulation Framework Provides Centralized Control of Geographically Distributed System Components With Message Traffic Designed to Accommodate Network Capabilities and Allows for Easy System Reconfiguration to Test System Interoperability and Performance

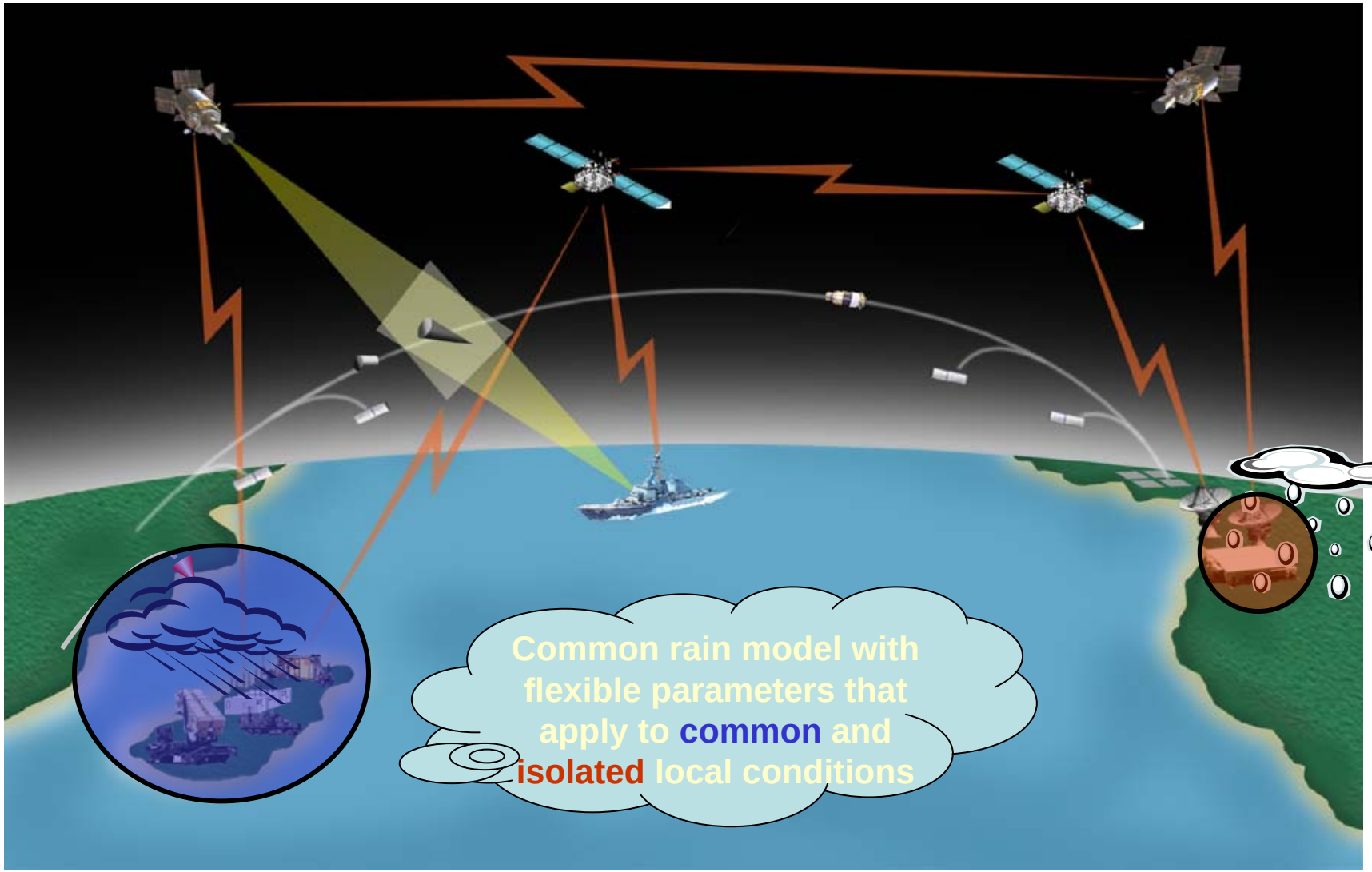
Notional Test Scenario



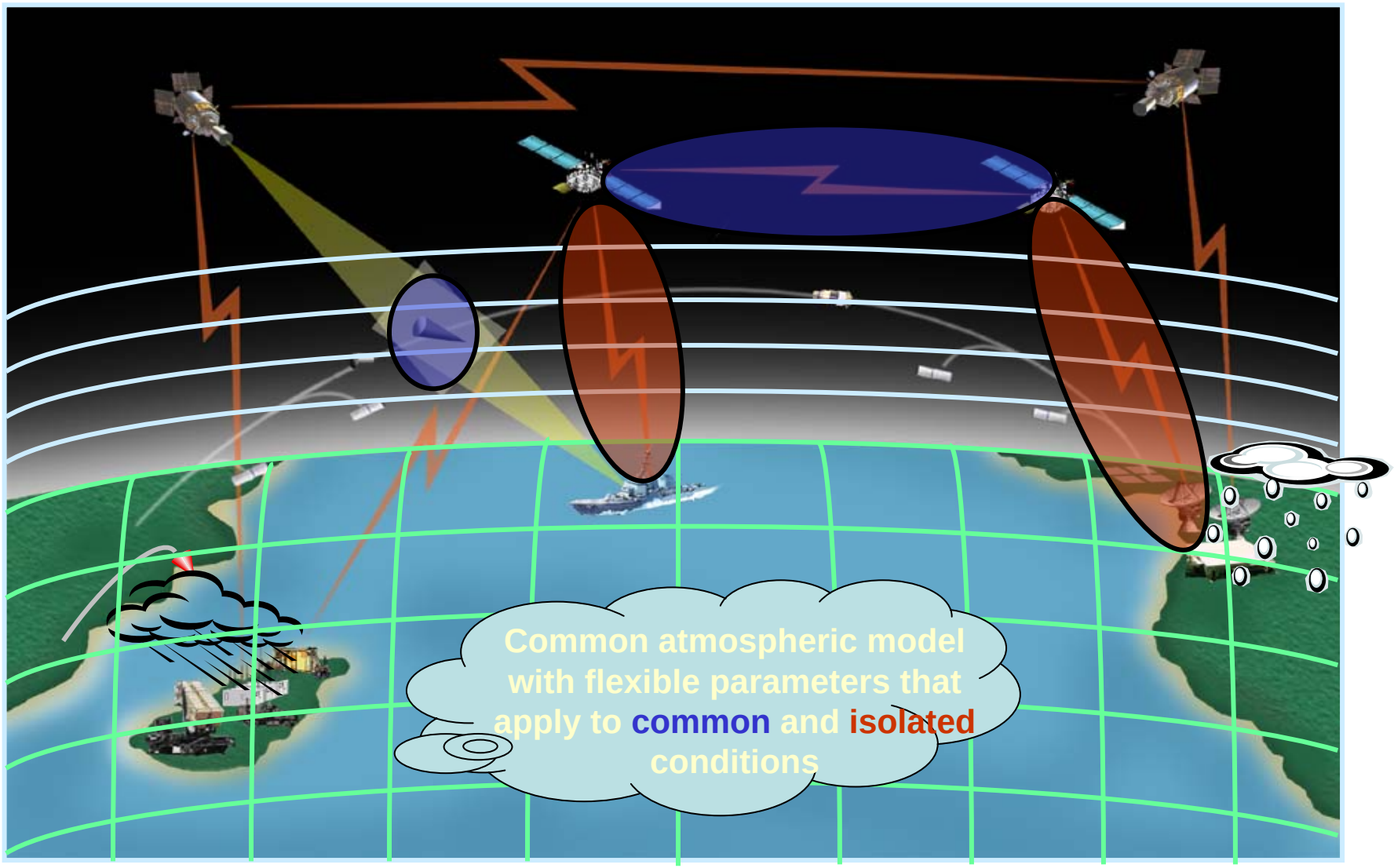
Signatures in HWIL



Environments in HWIL
-Rain-



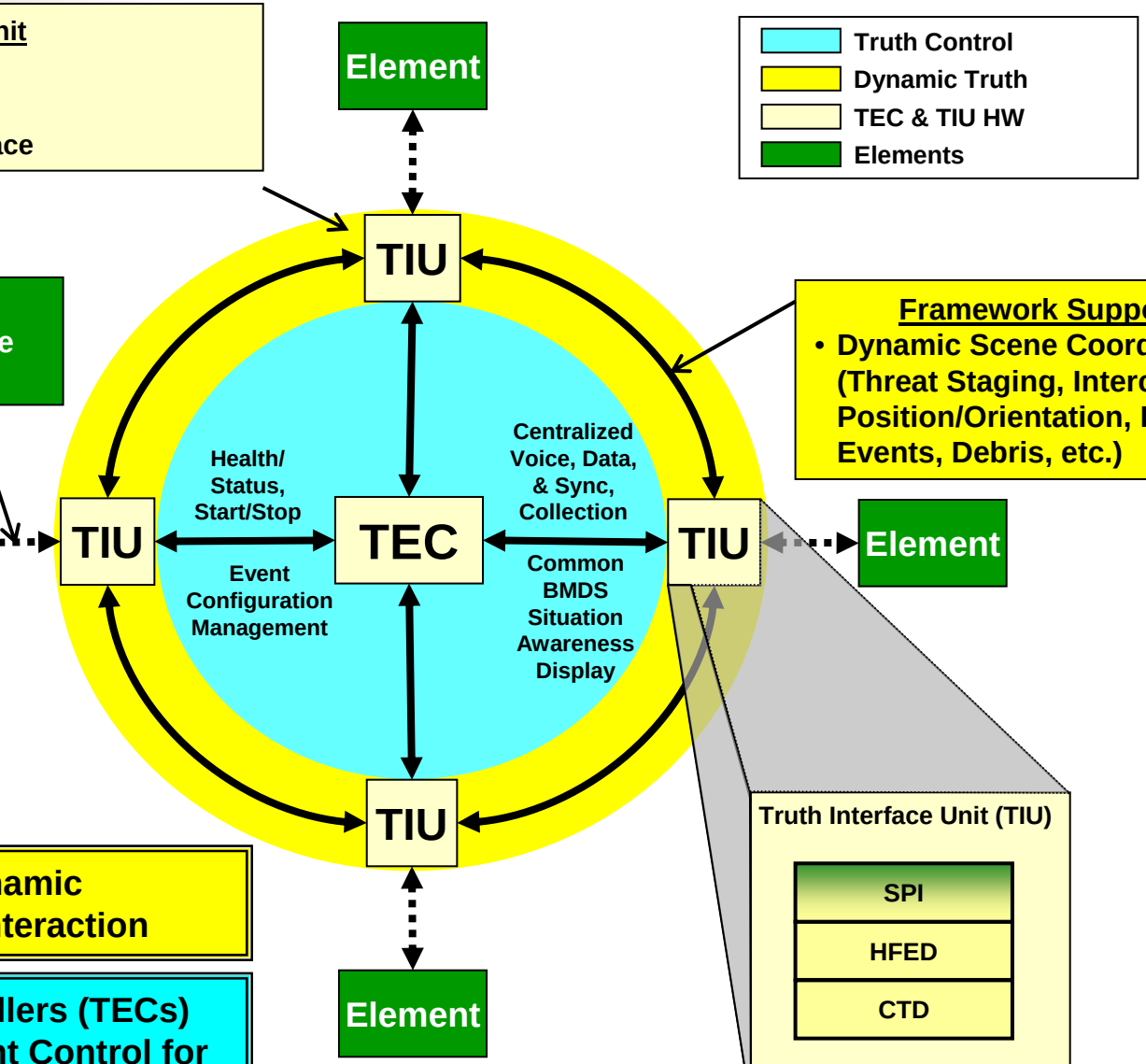
Environments in HWIL
-Atmospheric Model-



Multi-Element Stimulation Framework Design

Truth Interface Unit

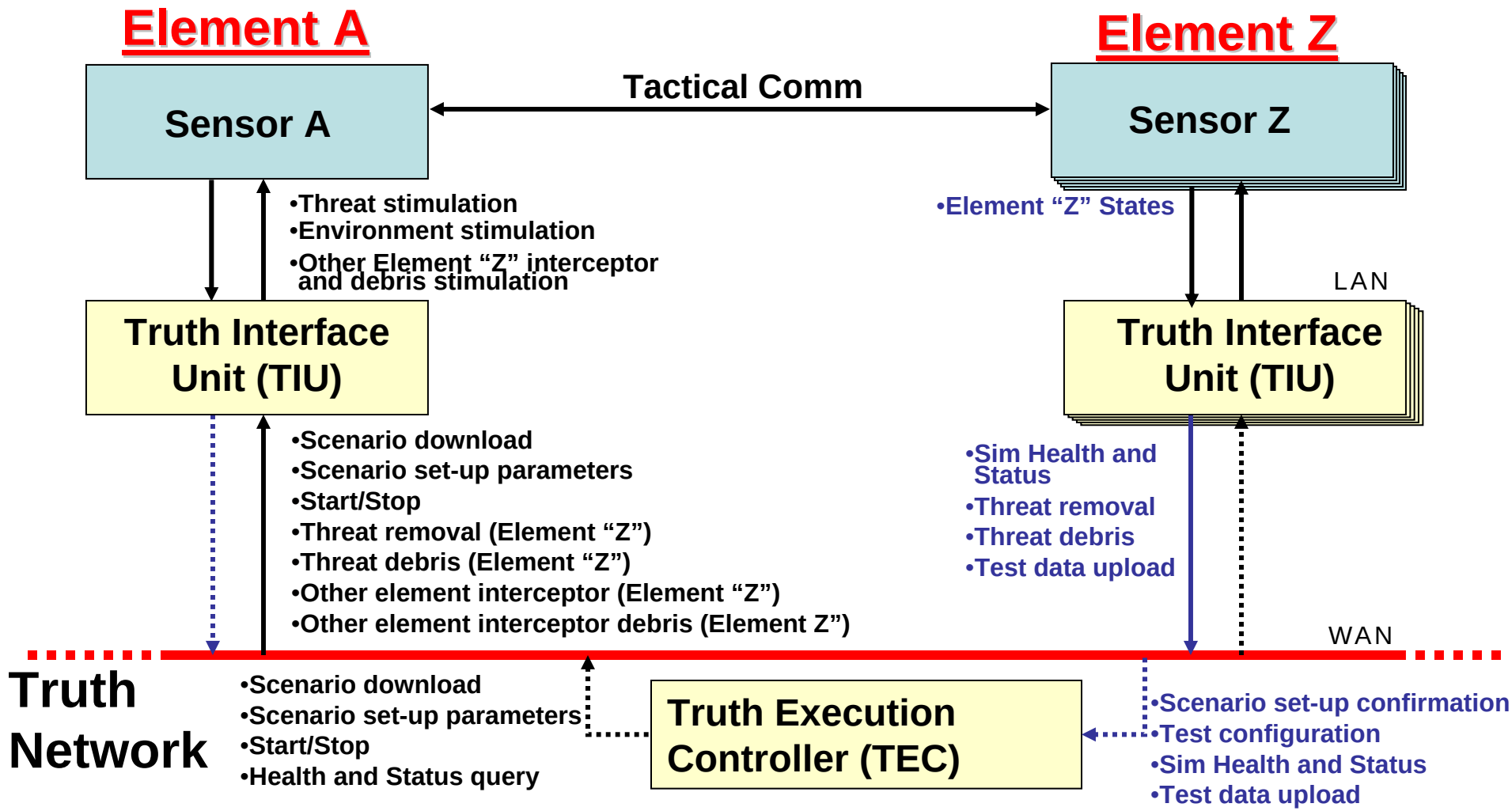
- CTD: Consistent Truth Drivers
- HFED: Hi-Fi Element Drivers
- SPI: Specific Personality Interface



TIUs Provide Dynamic Truth Injection and Interaction

Truth Execution Controllers (TECs) Provide Centralized Event Control for the Stimulation Framework

Truth Data Flow



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

Truth and Operational Data Flow

- 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*

DSSF Functional SW Overview

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

Notional Pre-Mission Functional SW Overview

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

Notional Mission Functional SW Overview

Test Case Injection

Mission (TEC) and Truth Interface Unit (TIU)

Threat presented to Element Driver (ED) via DIS PDU

DIS PDU provides: State Time; XYZ Position; XYZ Acceleration; XYZ Velocity; XYZ Orientation

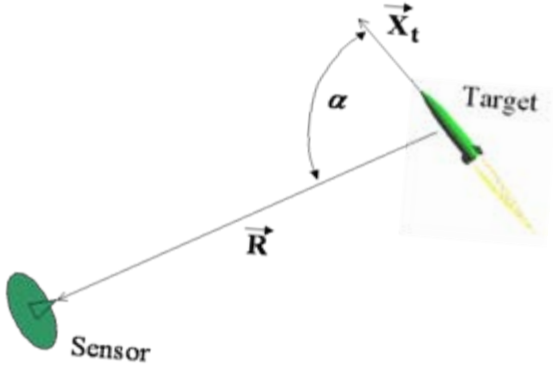
Test run PDUs presented are Recorded at each TIU

PDU Data Verification: State Count, maintain positional accuracies, thinning of some truth information due to Element bandwidth

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

PDU Data (truth) uploaded to Stimulation Database

Data available to Post-mission Tools



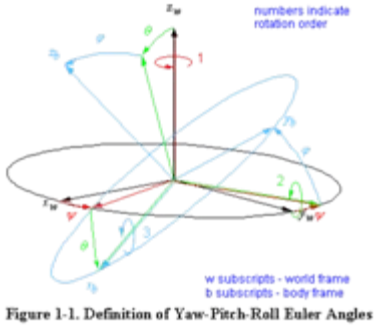


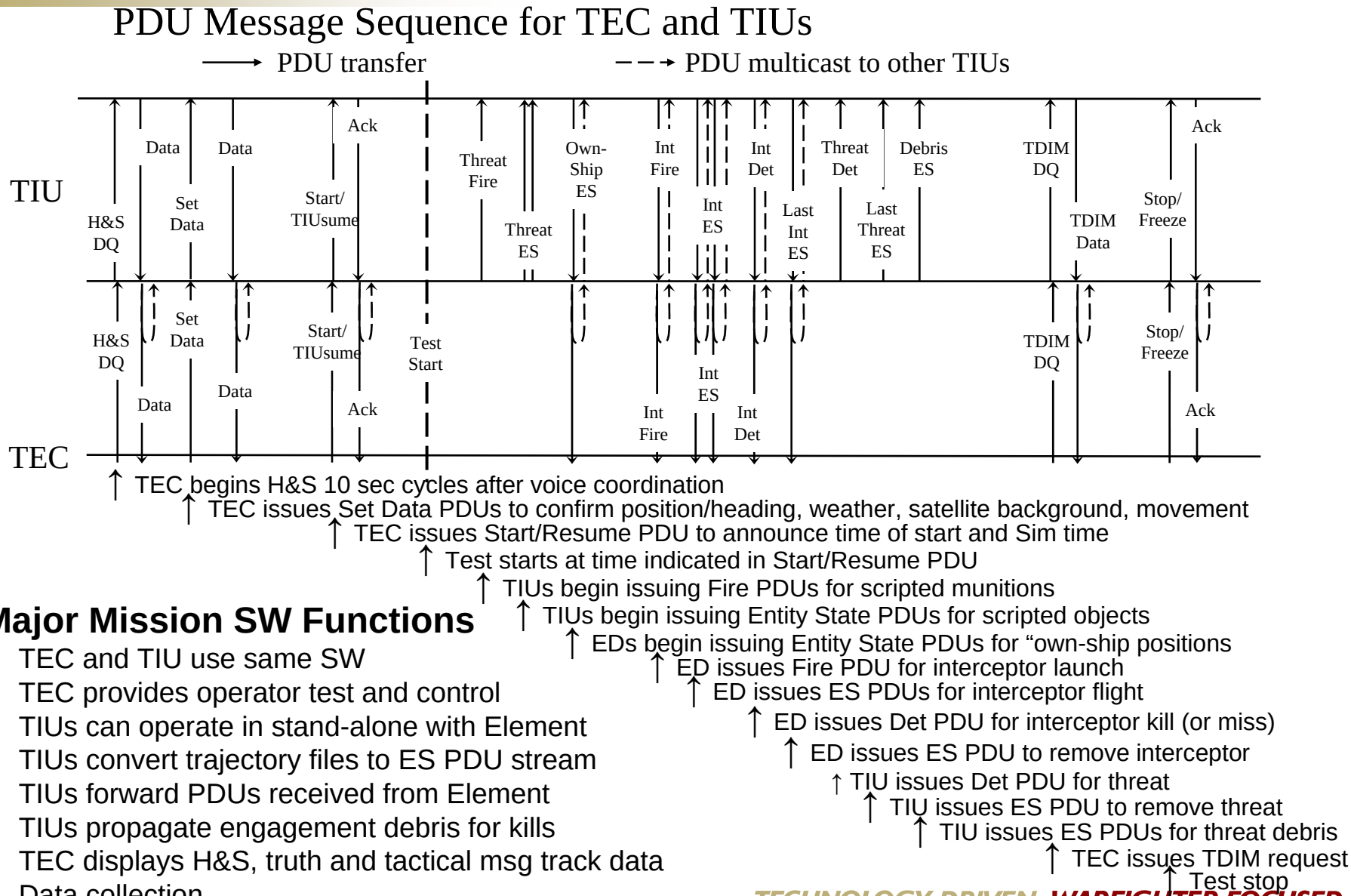
Figure 1-1. Definition of Yaw-Pitch-Roll Euler Angles

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

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

$\mathbf{p}$	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
Δt	time increment for the dead reckoning step
$[\mathbf{R}]_{w->b}$	entity's extrapolated world to body orientation matrix
$[\mathbf{DR}]$	dead reckoning matrix
$[\mathbf{R}_0]_{w->b}$	the entity's initial world to body orientation matrix

Notional Mission Functional Overview (Cont.)



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

Notional Post-Mission Functional Overview

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

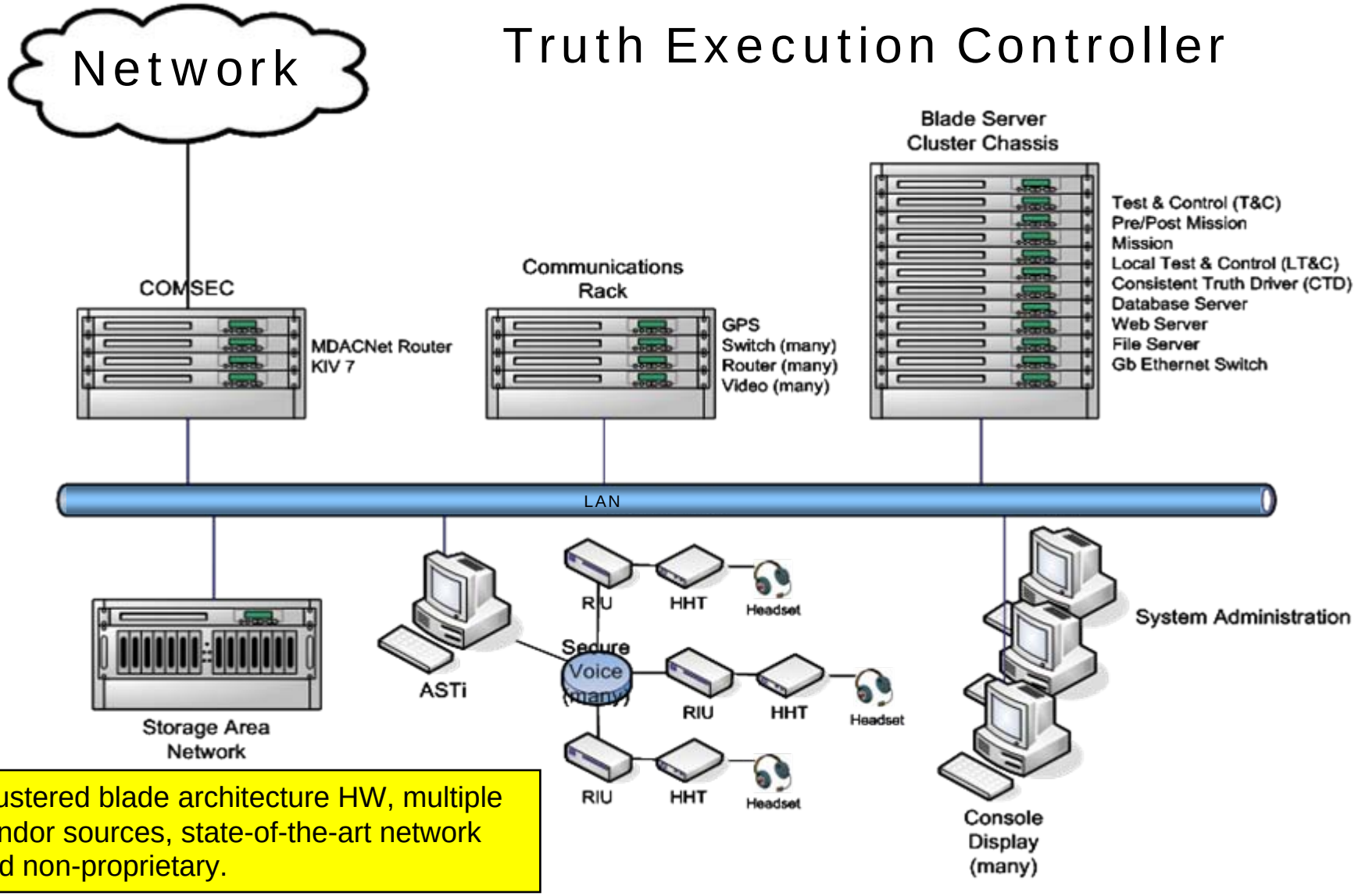
Analytical Tools
- Verify PDUs
- Verify Tactical Messages
- PDU Message Transmission Delay
- Tactical Message Transmission Delay
- Extract Object History
- Extract Track History
- Find Close Entities for Tactical Track Msgs
- Engagement Summary
- Track Correlation Summary
- Volume Entry and Exit

Access Control

Data File Status Report

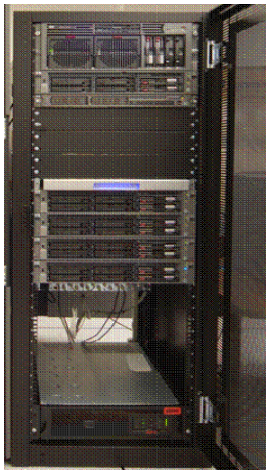
Quick Look Report

Stimulation Framework Hardware (TEC)



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

Stimulation Framework Hardware (TIU)

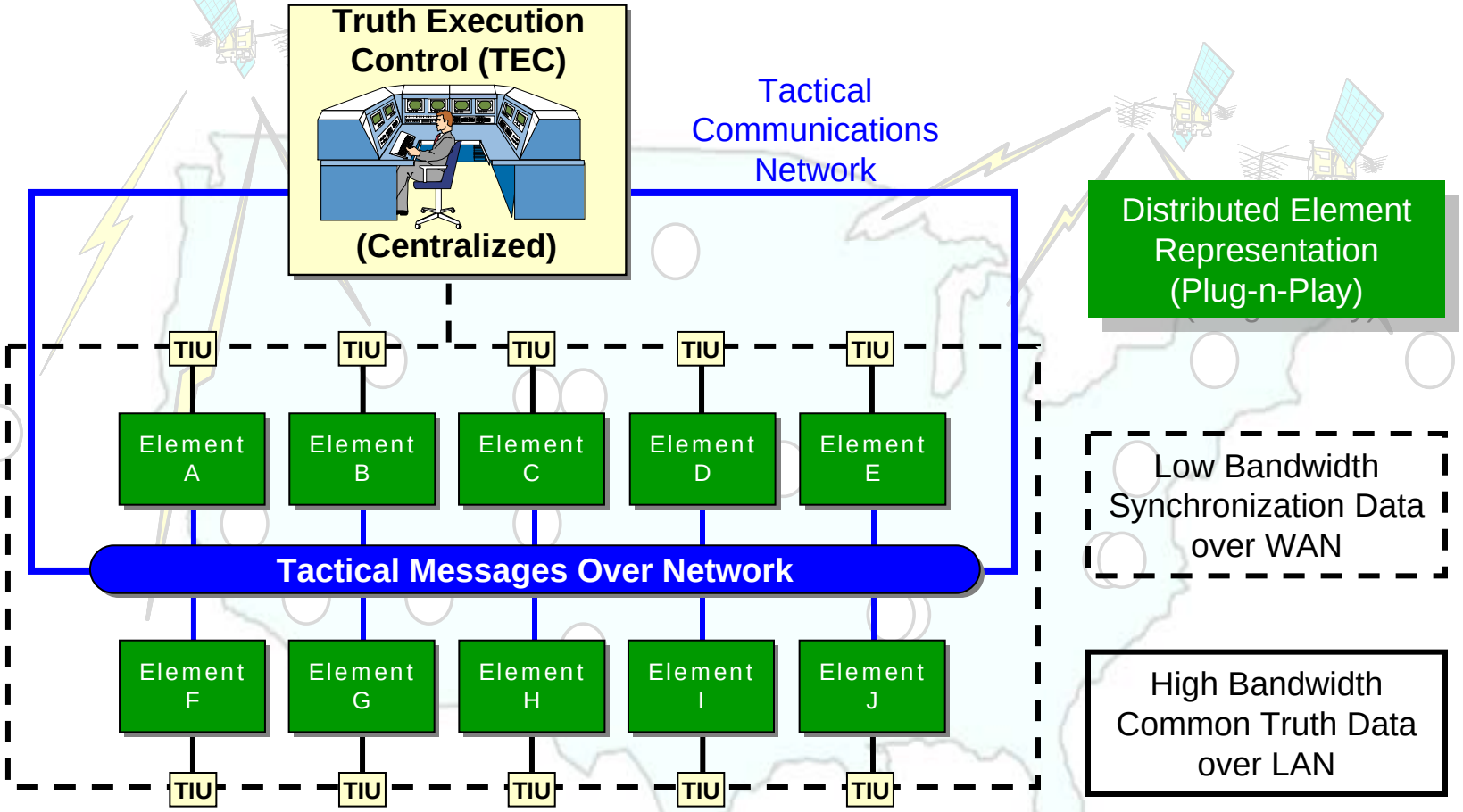


Truth Interface Unit – Rack (TIU-R)
- Highest Storage Capacity
- Processor Scalable
- Full Environment Stimulation capability
- TEC-Capable
- Transportable
- $$$

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
- $

Stimulation Framework Integrated Architecture Summary



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