End-to-End System Test Architecture

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Net-Centric Mission Operations Features

Fully Synchronized Interoperable, Network of Networked Systems and Mission Capabilities

- Networked Battle Command To The Warfighter
- Networked Multi-Spectral Air, Ground, Space Sensors & Shooters
- Rapidly Reconfigurable Networked Real Time C4ISR Capabilities
- Adaptable Information Formats for Command/Mission
  - Simultaneous Real-time, Near-real Time, Non-real Time, Applications
  - Network-Centric Collaborative SOA / Infrastructure
  - Seamless Information Sharing Across Forces, Multinational and Interagency Partners
- Built-in Redundancy with Operations Continuity

Network of Networked C4ISR Capabilities

Net-Enabled Capabilities

- ***Shortens Chain of Attack***
- ***Provides***
  - ***Decision Superiority***
  - ***Greater Speed***
  - ***Greater Precision***
- ***Capabilities Supported***
  - ***Global Network Connectivity***
  - ***Network Enabled Platforms/Weapons***
  - ***Fused Intelligence***
  - ***Real Time Command / Control & Situational Awareness***

<u>Key:</u> Net-Centric Operations
IP-based Routing, Shared Data, Assured Service

Air Force Vision - One Network

- **Space Layer**
  - Transformational Communications – Satellite Constellations, Operations & Management Systems
- **Near Earth Orbit & Airborne Layer**
  - JTRS, Laser Optics, BMC2, NATO AGS, E-2C Hawkeye, J-UCAS, UAVs
- **Maneuver Layer (upper echelon)**
  - Future Combat Systems, Blue Force Tracking
- **Maneuver Layer (lower echelon)**
  - Sensors, Weapon Systems, Munitions Data link
- **Terrestrial Layer**
  - GIG-BE, Teleport, CAOC
- **Characteristics**
  - Robust Self-Forming, Self-Healing Network of Mobile War Fighters
  - IP Routing Platform For Information Flow Between Ground, Air and Space Networks

Merged Defense and Space Infrastructure

TEST & INTEGRATION CHALLENGES

- Netcentric Scope Encompasses Integration of Diverse Systems, Technologies, Applications, and Protocols Across Forces, Multinational and Interagency Partners. This Requires
  - Understanding, Test, and Verification of Transparent Interoperability of Protocols and Systems Across Network of Diverse Networks
  - Simulating Communications Systems, Sensors, Weapons, and War Fighters in an End-to-End Test Environment
  - Data Consistency End-to-End
  - Multi-step Processing End-to-End
  - Assured Service Interoperability End-to-End

Seamless Integration of Net-Centric Capabilities Requires Robust Test & Verification Environments

TECHNOLOGY & PROTOCOL ISSUES

- Technology and Protocol Standards Are Not Perfect
  - Diverse Systems Implementing the Same Standards May Support Different Requirements – Protocol Interoperability
  - Testing and Verifying Interoperability Across Network of Networks - Challenging
- OSI Protocol Layers Can Span Across a Single or Many Interfaces Across Network of Networks
  - Non-transparency of Protocol Layers - Costly Mission Failure
  - Isolating and Mitigating Issues with E2E Protocol Layers - Difficult, Time Consuming and Costly
  - Simulating, Testing, and Verifying Real-time, Near-real Time and Non-real Time Protocols E2E in Multi-vendor Environment – Complex and Time Consuming

Test & Verifications of Network of Networked Systems Logistically Complex

E2E TEST CONSIDERATIONS

- Any Net-centric Mission Systems Must Be
  - Tested in True Battlefield Network Conditions Prior to Deployment
    - End to End Protocol Interoperability Fundamental To Success of Netcentric Mission Operations
    - Network of Networked Systems Use Multi-layered Protocol Architecture to Communicate Transparently Across Networked Systems
  - Tested in a Distributed E2E Test Architecture Emulating Real-time, Near-real Time, and Non-real Time Protocols, Interfaces, and Technologies across Networked Systems
    - Designed with Hierarchical Protocol Architecture in Mind
    - Emulated All Segments
    - Supporting Virtual Test Systems For Multiple Test Scenarios

Net-Centric, Distributed, E2E System Test Architecture

Test Architecture Considerations

- Mesh vs Hub/Spoke Architecture
  - Cost, Schedule, & Protocol Considerations
  - Management, Control and Data Planes
  - Distributed vs Centralized Control
  - Overlay Protocol Architectures
  - Security Architecture, Protocols & Boundaries
    - Security at Physical and Higher Protocol Layers
  - Hardware, Software, Simulators, & Emulators Integration
  - Complex Protocol Interactions
- Architectural Requirements
  - Adaptability to Changes
  - Reconfigurable
  - Remote Configurability
  - Multi- Protocol Support
  - Protocol Fidelity

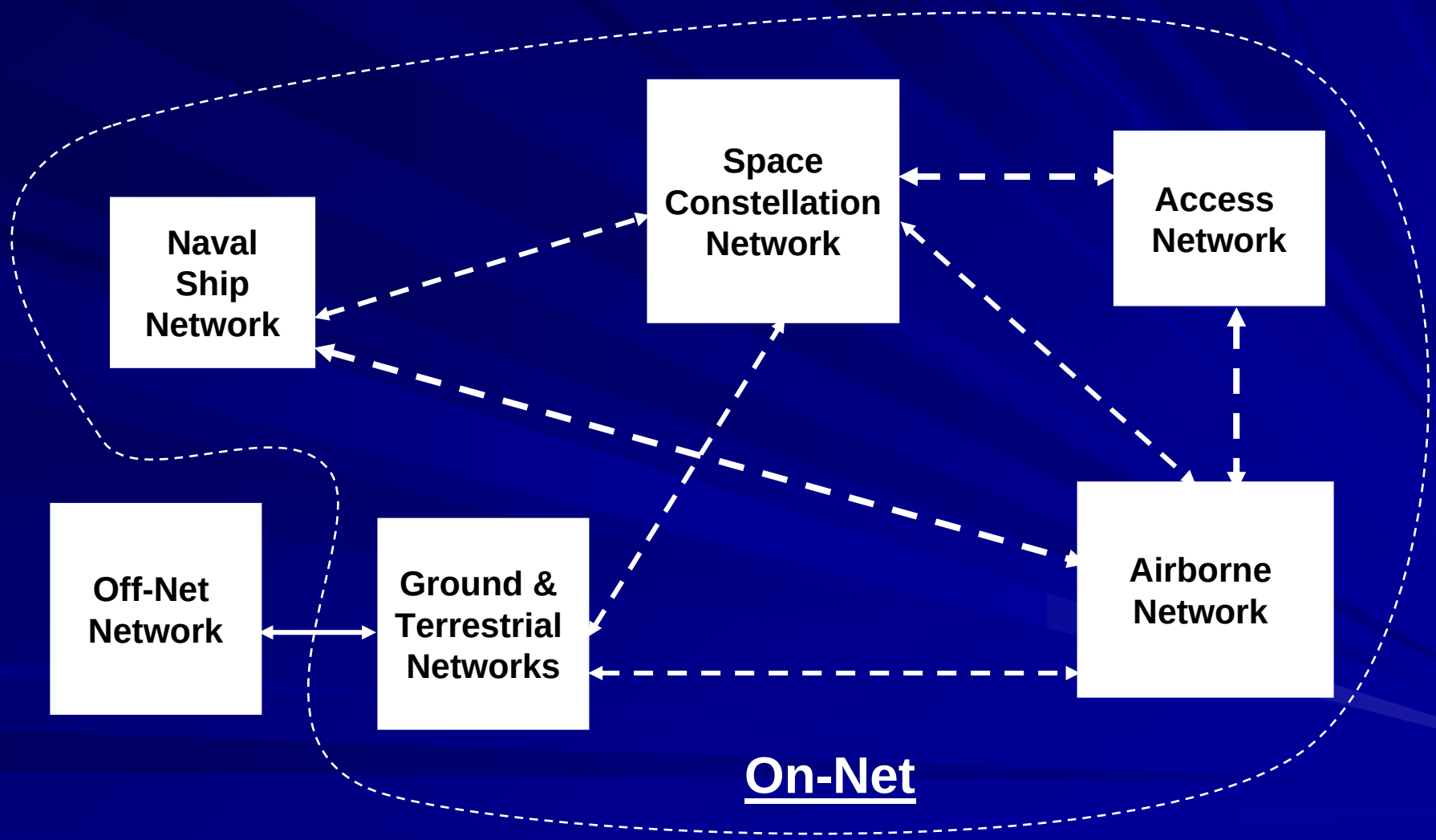
Adaptable & Reconfigurable Secured System Test Architecture

Distributed System Test Architecture Issues

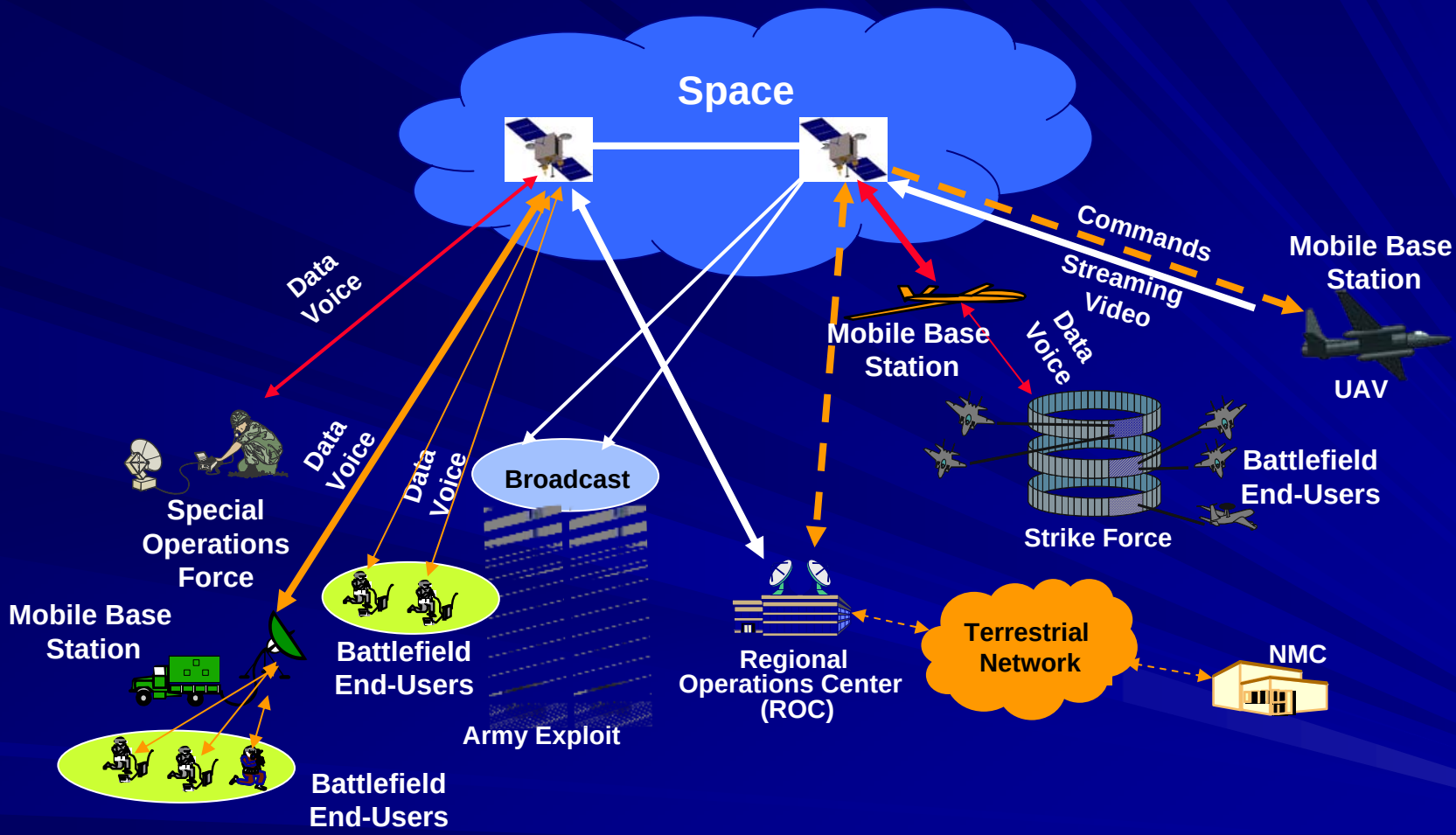
- Latency
- Security
- Timing
- Data Integrity
- Service Availability
- Race Conditions
- Priorities

Early Planning and Detail Requirements Specifications Essential

Network of Networks - A Simplified Example



Networked Satcom Service Example



On-net P2MP Streaming Video

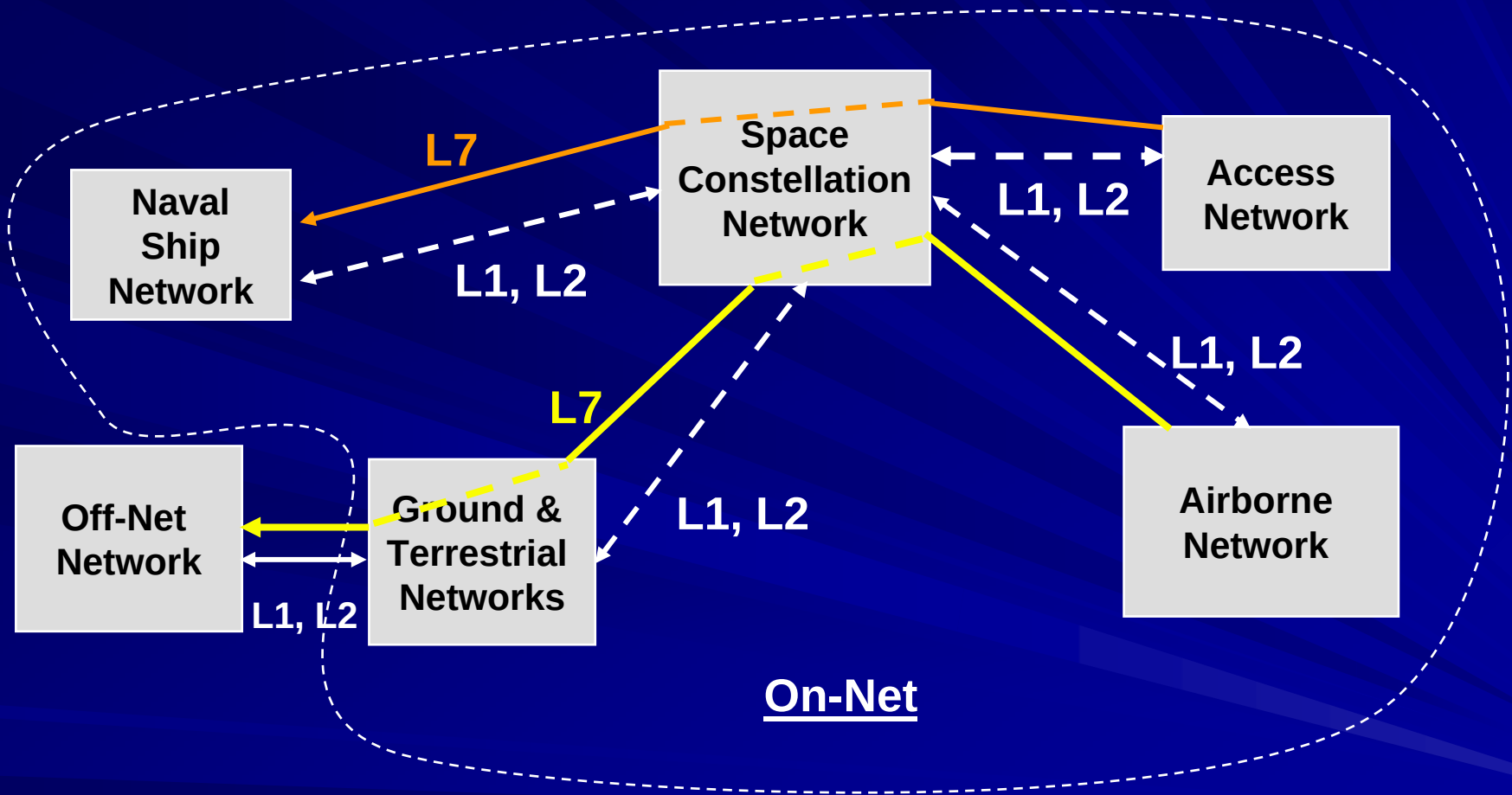
On-net P2P Data/Voice

On-net P2MP Data/Voice

Command

Thick Lines –Trunk Links

Networked Protocol Layers (L1, L2, L7) - Example



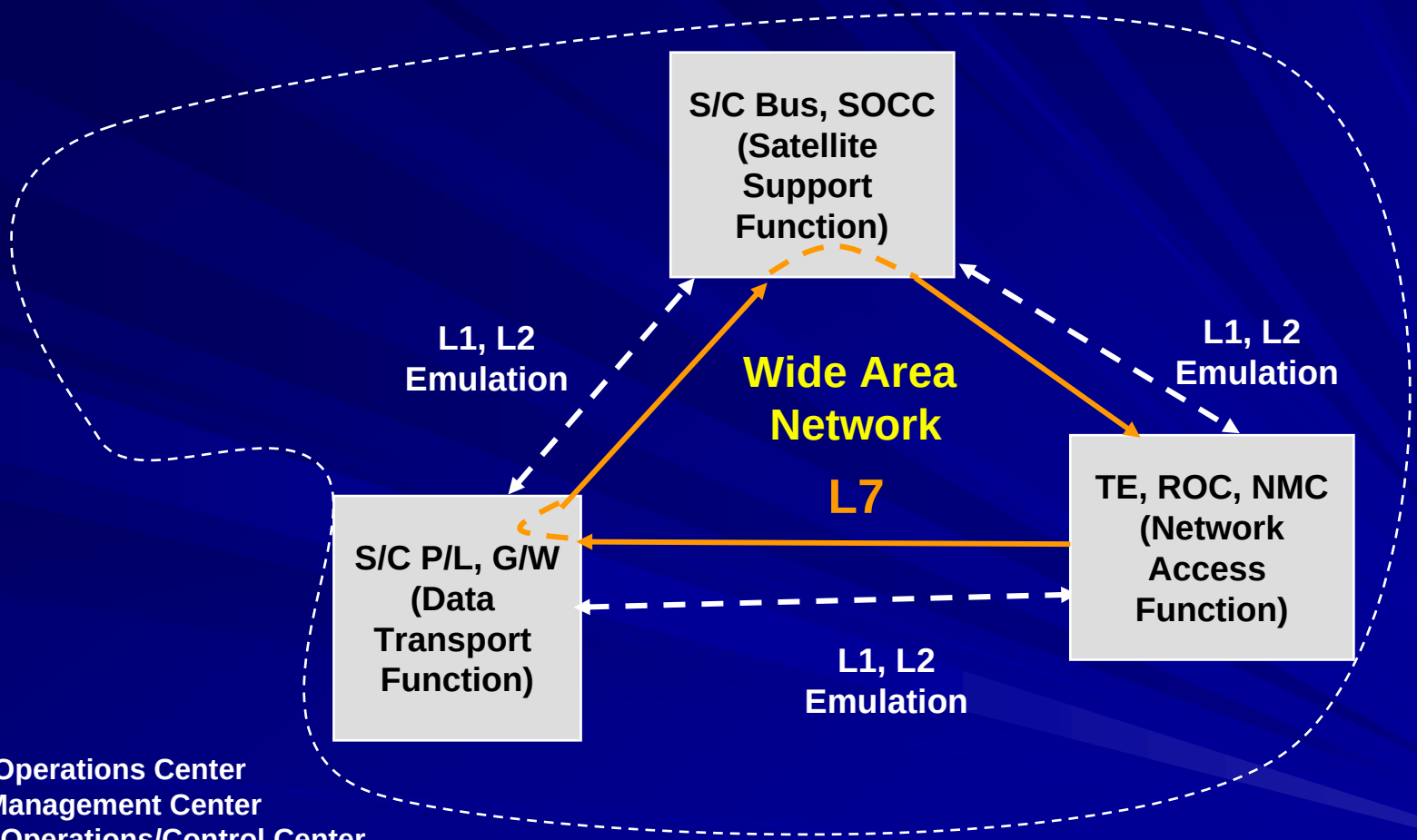
Testing L7 Performance Over Diverse L1 / L2 – Complex & Challenging

Protocol Performance

- **Physical and Data Link Layers (L1, L2)**
  - Terminate Between Adjacent Systems In The Same or Adjacent Networks
  - Data Link Layer Performance Depends on Physical Layer Performance
  - Application Layer Transparent to Physical and Data Link Layers
  - Example: Physical Layer - RF, SONET; Data Link Layer – Link 16, Ethernet MAC
- **Application Layer (L7)**
  - Traverses Multiple Networks & Terminates End to End
  - Rides On Diverse & Multiple Physical & Data Link Layers (L1, L2)
  - Uses Services of Lower Protocol Layers
  - L7 Performance and Data Integrity Depend on Lower Protocol Layer Performance (e.g. Timing)
  - Example: Email, Streaming Video, Audio, File Transfer, Web Browsing

L7 Performance Depends on L1 / L2 Performance

Distributed System Test Architecture - Example



S/C: Spacecraft
P/L: Payload
G/W: Gateway
ROC: Regional Operations Center
NOC: Network Management Center
SOCC: Satellite Operations/Control Center
TE: Terminal

Supports Virtual Test Systems for Multiple Test Scenarios

Distributed System Test Architecture Features

- Emulates Multi-Segments – Space, Air, Terrestrial Systems, Elements, Interfaces, & Protocols
- Consists of Geographically Distributed, Multiple
  - System Integration Labs (SILs)
  - Test Beds
  - Simulators
  - Emulators
  - Control Centers

  Interconnected by Wide Area Networks (WAN)
- Supports
  - Multi-Element and Flight Element Integration, Test and Verification
  - Multiple Software and Database Integration and Integrated SW Load Testing
  - Prototyping Hierarchical Protocol Layers and Interfaces
    - Simultaneous Test and Verification of Command / Control, Application, Network, and Lower Protocol Layers and Interfaces
      - Functions
      - Performance
      - Load
    - Prove Out C4ISR Interoperability End to End

Supports Simultaneous Test and Verification

Summary

- **Distributed Networked E2E System Test Architecture is Essential**
  - **To Ensure Interoperability of Networked C4ISR Capabilities Across Network of Diverse Networks Before Deployment**
    - **Test and Verify Transparency of All Networked Protocol Layers**
    - **Emulate and Test True Battlefield Conditions by Simulating Networked Elements, Protocols, Interfaces, and Systems**
    - **Support Test-Like-You-Operate**
    - **Facilitate Early Risk Reduction**

Verify Power of Networked War Fighting Before Deployment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