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Modeling and Simulation in Support of Network Centric Warfare Analysis

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Navy Modeling and Simulation Management Office (NAVMSMO)
OPNAV N61F21
Washington, D.C. 20350-2000
Jim Weatherly

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Outline

- Introduction
- Navy Network Warfare Simulation (NETWARS)
- Link-16 Modeling and Simulation (M&S) Efforts
- Efforts in Support of Knowledge Superiority and Assurance (KSA) Future Naval Capacity (FNC)
  - Toward a Unified Naval Network
  - Simulation-Assisted Protocol Design
- Related Efforts
  - Non-Intrusive Knowledge Suite (NIKS)
  - Lab and Field Experimentation
- Conclusion

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Background

Who We Are

- SSC-SD 2822 (Network Centric Warfare Analysis Branch)
- Represent Navy Modeling and Simulation Management Office (NAVMSMO), OPNAV N61-M, and N61F, for Joint C4ISR Communication M&S assessment domain
- Supporting Communication M&S for 10 years
- Lead Navy NETWARS developers

What We Do

- Perform C4ISR communication system performance analyses
  - Modeling and Simulation (M&S) is our most commonly used assessment method

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Communications System M&S Applications

Capacity Planning/Scalability

- Where are my network bottlenecks?
- How will my network support future growth?

Technology Impact

- How will my new application impact existing systems?
- Impact of NBC attacks on network performance?

Acquisition

- Why is this new router better for my network?

Prototype development and assessment

- Before it is deployed, what are the deficiencies in my new TDMA protocol?

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Communications System M&S Applications (continued)

Operational Decision Aids/Doctrine Development

- JTF OPTASK COMMS development guidance.

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SSC-SD M&S Capabilities and Resources

Simulation Tools

- Naval Simulation System (NSS)
- NETWARS/OPNET
- QualNet

Existing Communications Model Library

- COTS and GOTS protocols, devices, and systems
- OPNAV N61M C4ISR standard models

Scenario and Traffic Data models

- Navy Defense Reference Model (DRM)
  - Operational scenarios validated by Office of Naval Intelligence
- Probe and Information Exchange Requirement (IER) data
  - Import real probe traffic data into modeled networks

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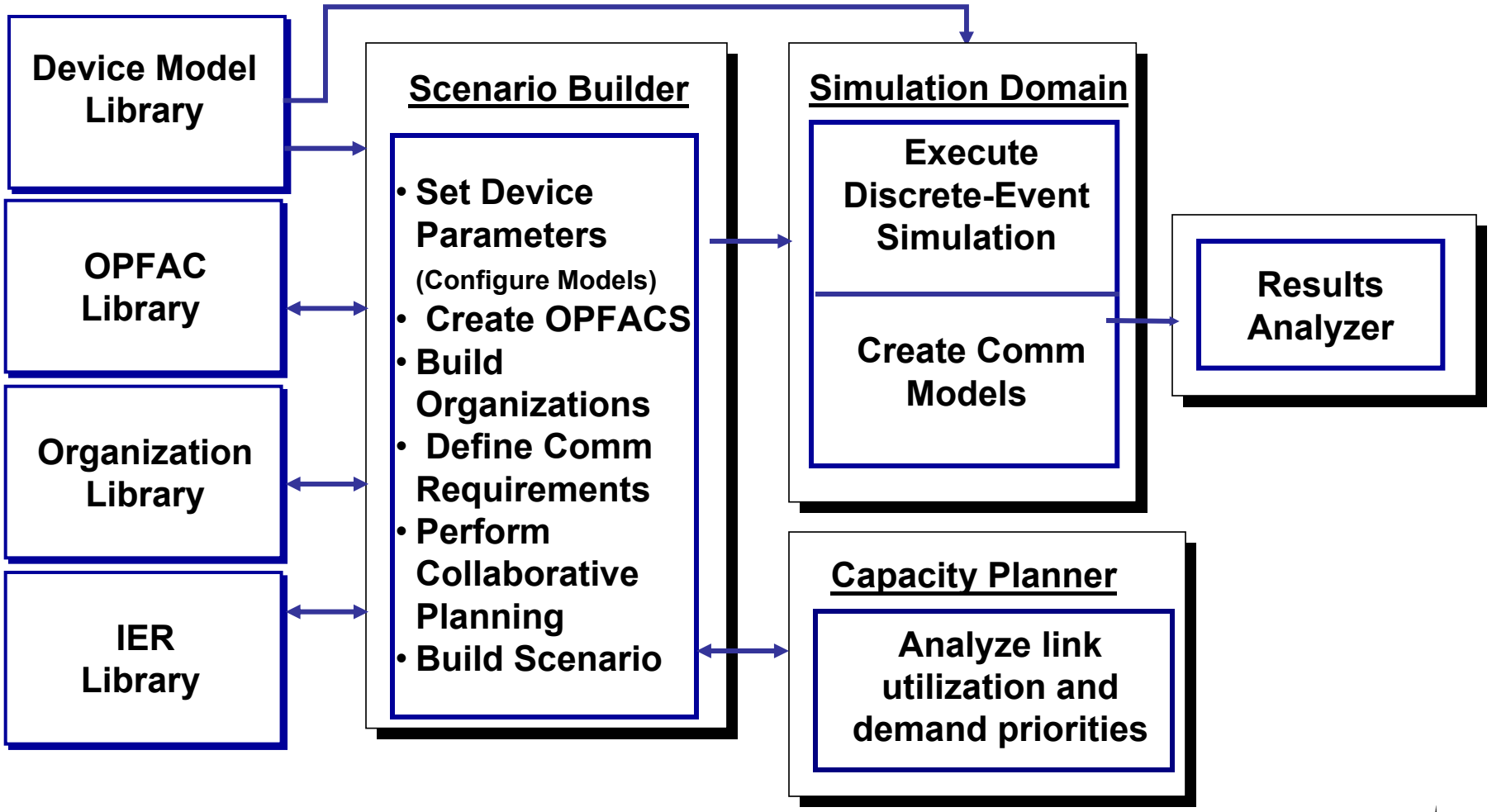
NETWARS Architecture



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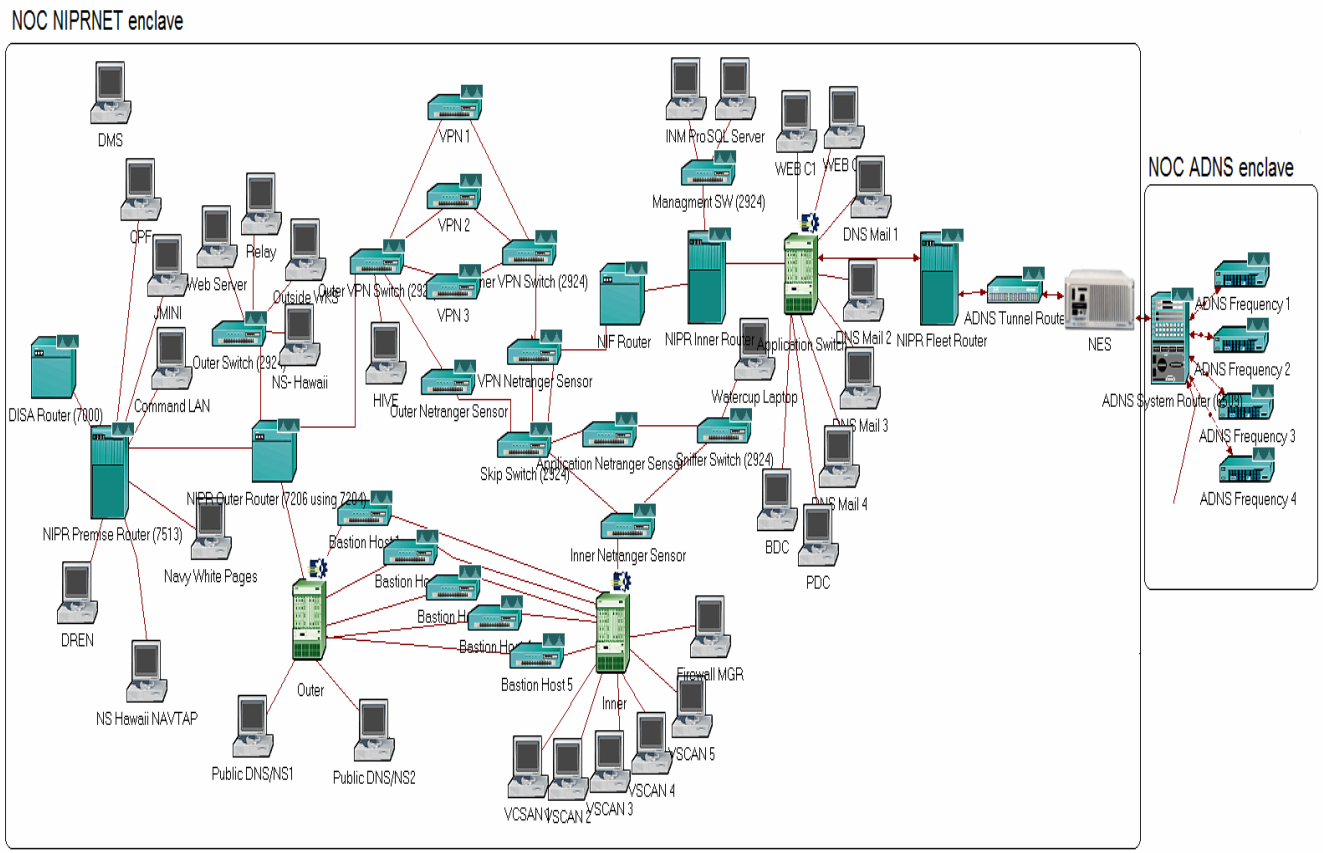
OPFACs of NIPRNET and ADNS Organizations



- 4 Network Operations Centers worldwide
- Templates: PRNOC SIPRNET & NIPRNET
- Template modification for UARNOC, IORNOC, ECRNOC

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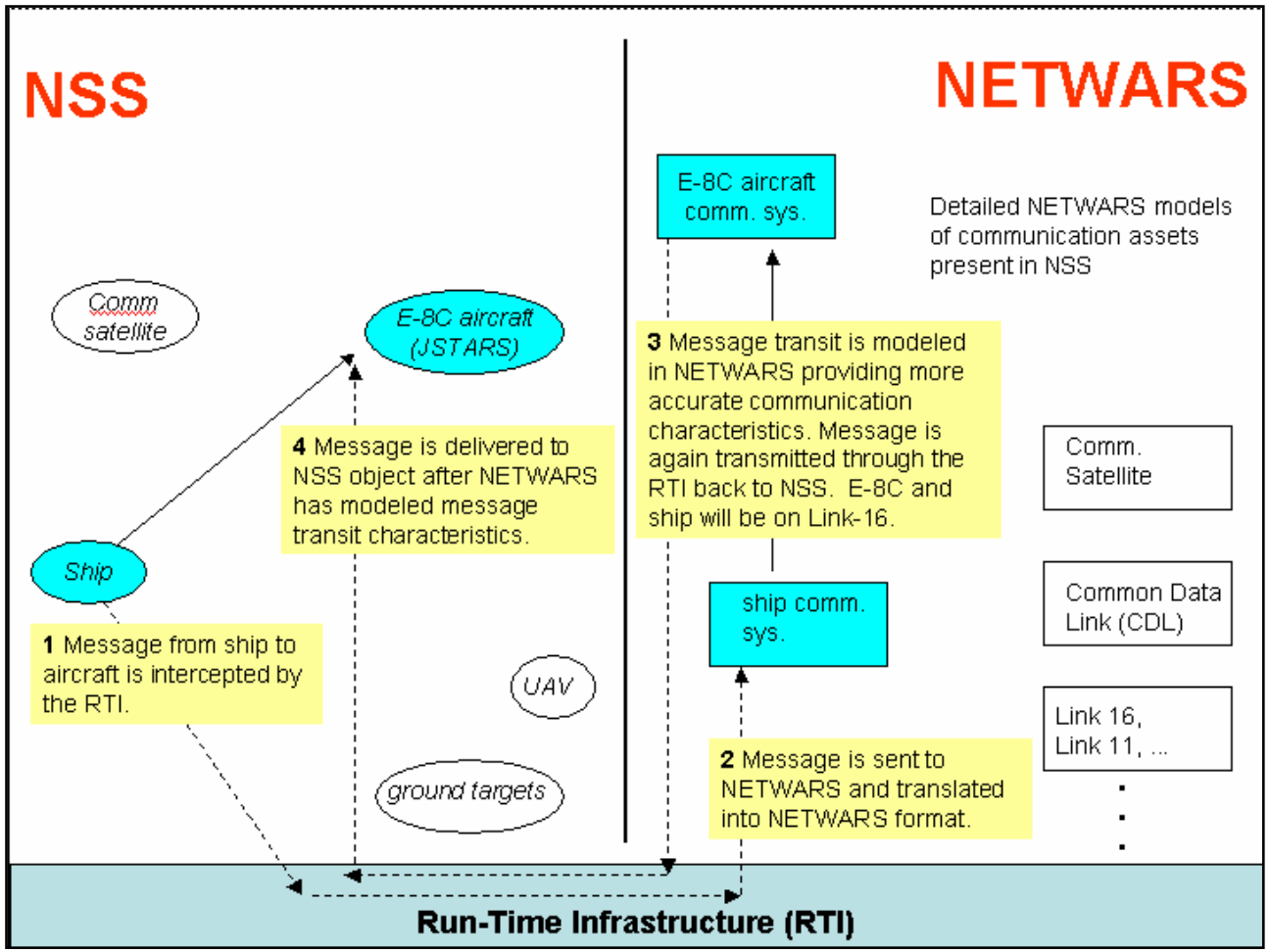
NSS-NETWARS Integration Overview



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Overall Functionality

Two main features

- **Extension of the Pegasus Federation Object Model (FOM)**
  - *Combat_Transmission_Request* to notify NETWARS when to send a message
  - *Combat_transmission_Receipt* to return to NSS the status of the transmission, and delay if the transmission is successful
- **DRTI NETWARS Plug-in to enable NETWARS to interact with NSS. Three components**
  - DRTI Process Model and Model Modifications
  - DRTI NETWARS ESA Support Module
  - DRTI Management Module

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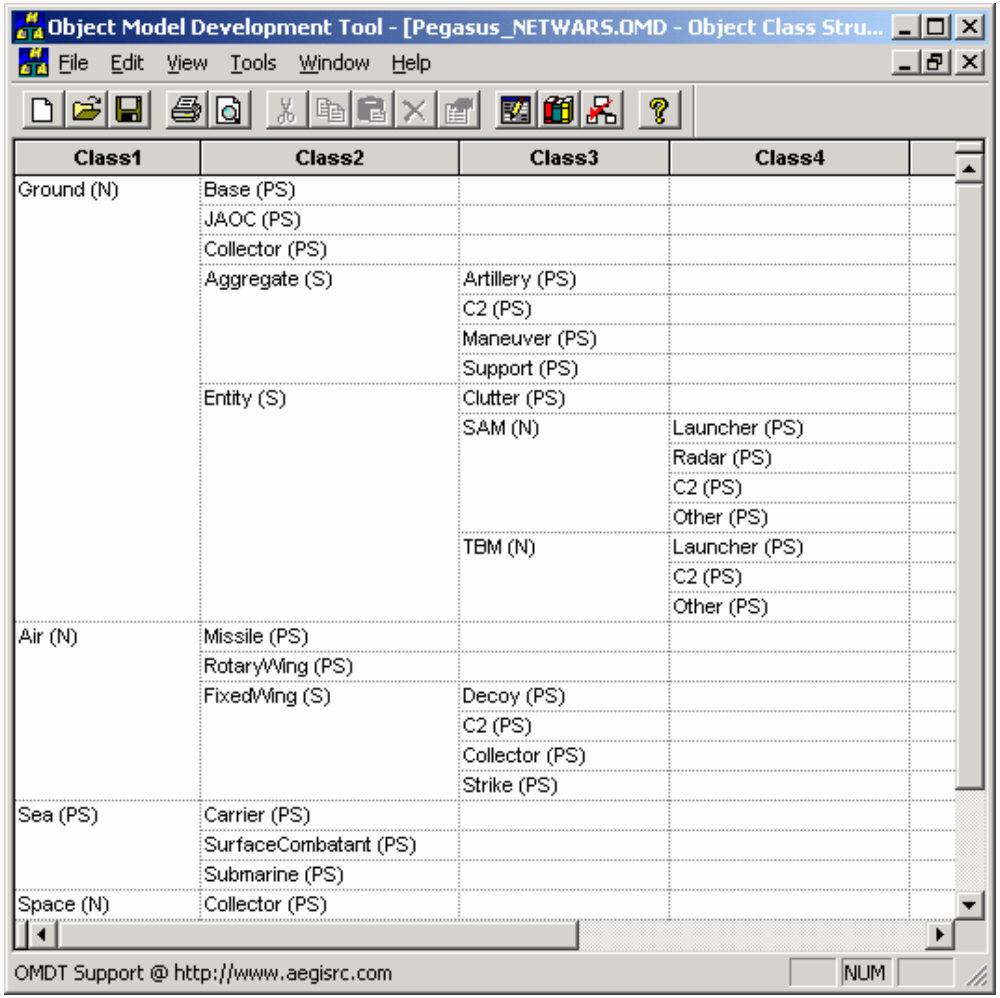
Federation Object Model Object Class Structure



Class1	Class2	Class3	Class4
Ground (N)	Base (PS)		
	JAOC (PS)		
	Collector (PS)		
	Aggregate (S)	Artillery (PS)	
		C2 (PS)	
		Maneuver (PS)	
		Support (PS)	
	Entity (S)	Clutter (PS)	
		SAM (N)	Launcher (PS)
			Radar (PS)
			C2 (PS)
			Other (PS)
		TBM (N)	Launcher (PS)
			C2 (PS)
			Other (PS)
Air (N)	Missile (PS)		
	RotaryWing (PS)		
	FixedWing (S)	Decoy (PS)	
		C2 (PS)	
		Collector (PS)	
		Strike (PS)	
Sea (PS)	Carrier (PS)		
	SurfaceCombatant (PS)		
	Submarine (PS)		
Space (N)	Collector (PS)		

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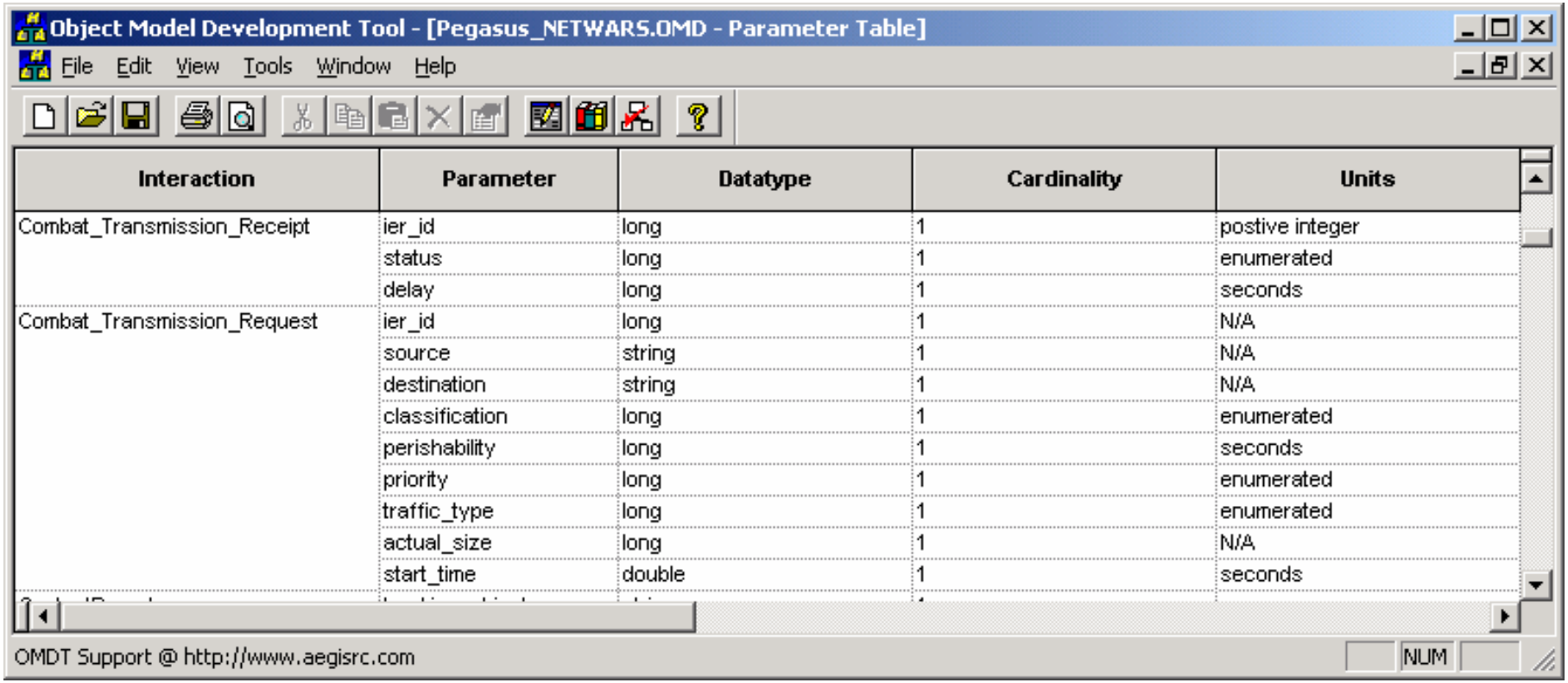
Federation Object Model Communications Interactions



Interaction	Parameter	Datatype	Cardinality	Units
Combat_Transmission_Receipt	ier_id	long	1	postive integer
	status	long	1	enumerated
	delay	long	1	seconds
Combat_Transmission_Request	ier_id	long	1	N/A
	source	string	1	N/A
	destination	string	1	N/A
	classification	long	1	enumerated
	perishability	long	1	seconds
	priority	long	1	enumerated
	traffic_type	long	1	enumerated
	actual_size	long	1	N/A
	start_time	double	1	seconds

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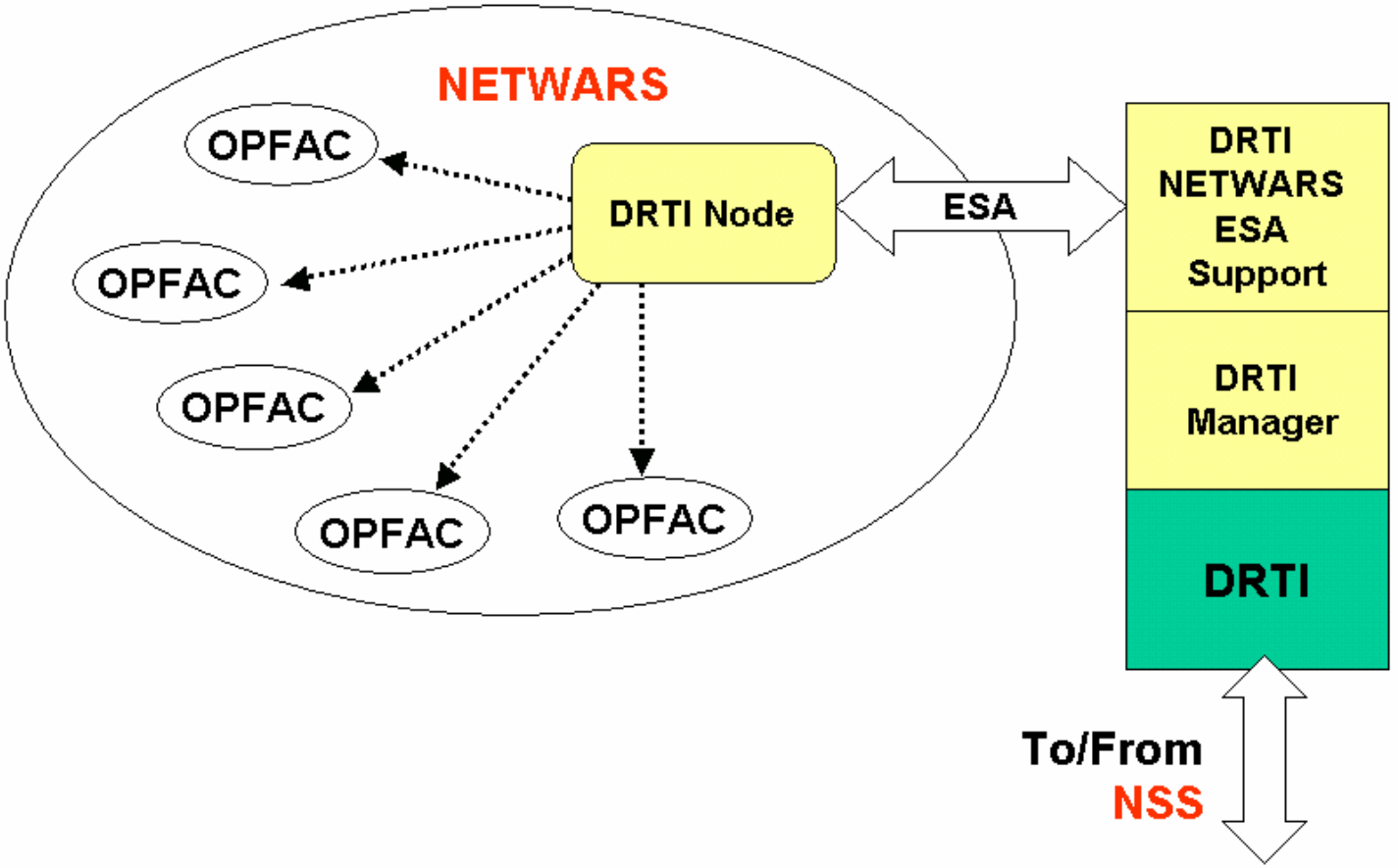
NSS-NETWARS Integration Architecture



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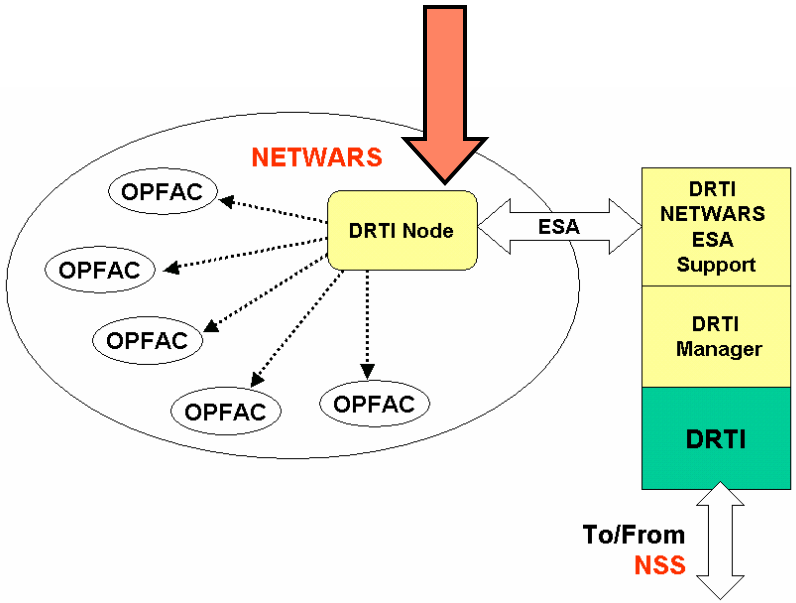
DRTI Process Model and Model Modifications



DRTI Process Model (of the DRTI Node Model) has two main tasks

- **Provide mechanism to apply position updates of entities in NSS to OPFACs in NETWARS**
- **Provide mechanism to initiate IERs and to return transmission status and delay back to NSS**

NETWARS process models *oe_iers* and *oe_status* are modified for sending a message from info provided by NSS, and to support capturing the delivery status of the message

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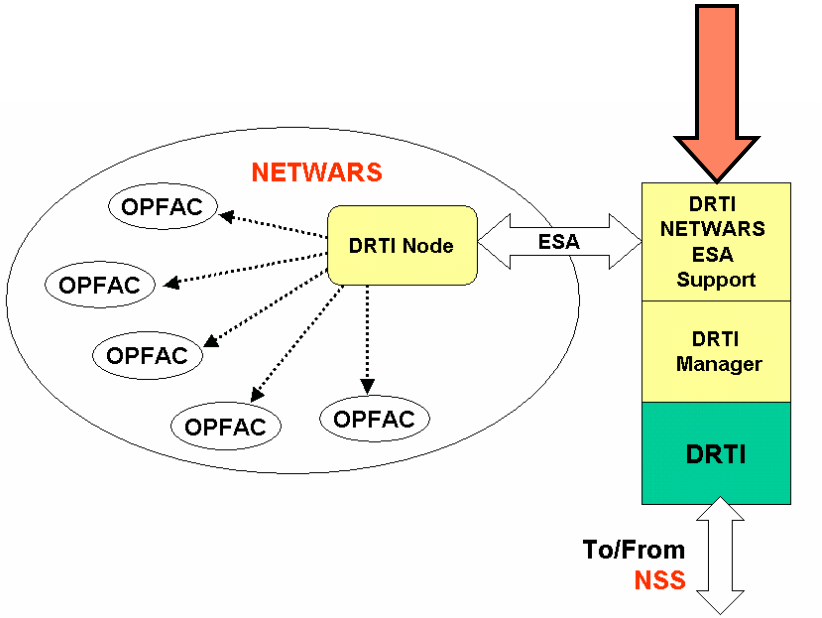
DRTI NETWARS ESA Support Module



DRTI NETWARS ESA Module uses the OPNET's External Simulation Access (ESA) package to provide communication between NETWARS entities and DRTI.

- **ESA provides an interface to pass information into and out of the NETWARS domain for scheduling mobility events and sending messages.**
- **ESA provides services to control the execution of events in NETWARS/OPNET.**

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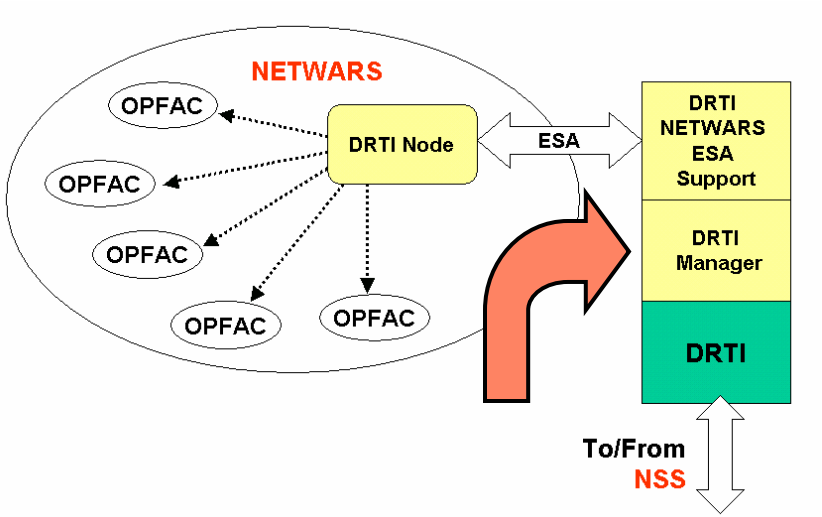
DRTI Management Module



DRTI Management Module performs the following tasks

- Initialize DRTI.
- Subscribe all relevant objects published by NSS.
- Subscribe to the Combat_Transmission_Request interaction and publish the Combat_Transmission_Receipt.
- Provide services to DRTI NETWARS ESA Support Module to advance RTI time and deliver all messages held by DRTI.

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Link-16 Modeling and Simulation Efforts

- Link-16 model was originally developed using OPNET in September 2001 to support a Time Critical Strike (TCS) study sponsored by the Assistant Secretary of Navy for Research, Development, and Acquisition Chief Engineer (ASN RDA CHENG)
- Subsequently, the Link-16 model was reused in several simulation-based efforts at SSC San Diego. Throughout these studies, the model was enhanced to meet additional requirements and evolved into a fairly high-fidelity, general purpose Link-16 communications model
- In 2003, the Link-16 Program Management Office (via ONR) began to use the model for prototyping potential Link-16 system enhancements
- In February 2004, the NETWARS PMO decided to adopt the Navy Link-16 model as the standard for Link-16 modeling for all the Joint Services. SSC San Diego is currently supporting this NETWARS standardization effort, including user interface enhancements and additional Joint Range Extension (JRE) support

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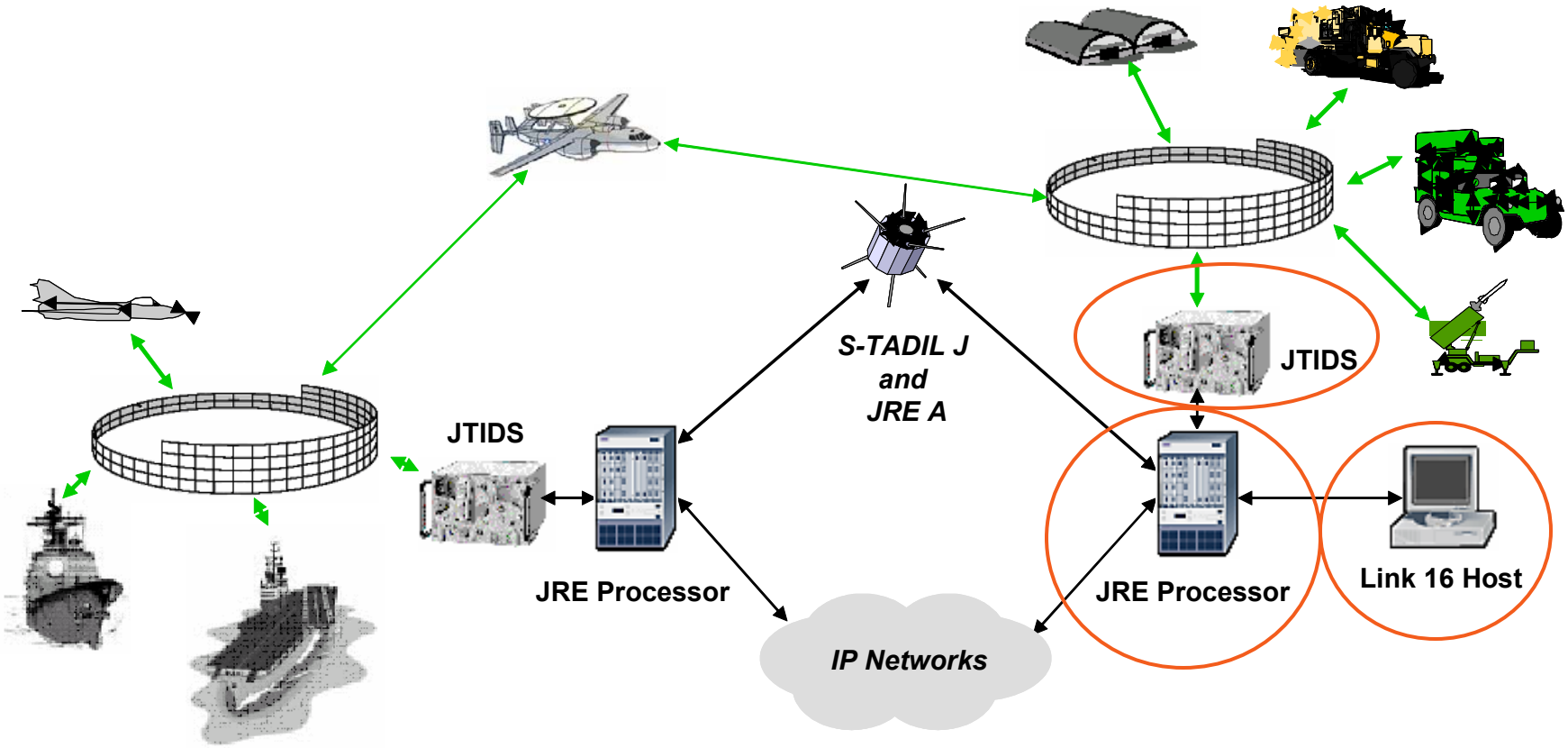
Link-16 Model Suite Devices



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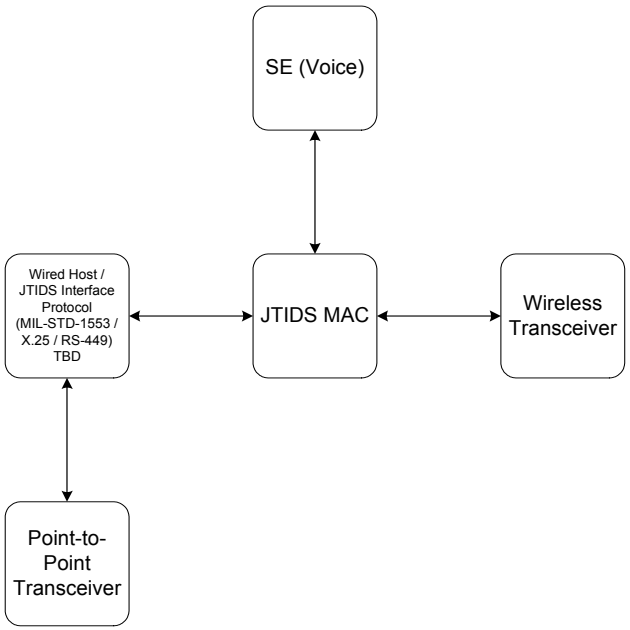
JTIDS Device Model



- **Three processors**
  - SE module for modeling voice IER generation and reception. (J-series messages are generated by tactical host and JRE Processor)
  - JTIDS MAC simulates the functionality of JTIDS terminal model
  - Wired Host/JTIDS Interface Protocol
- **Two interfaces**
  - Point-to-point wired transceiver
  - Wireless transceiver to communicate with other JTIDS device models

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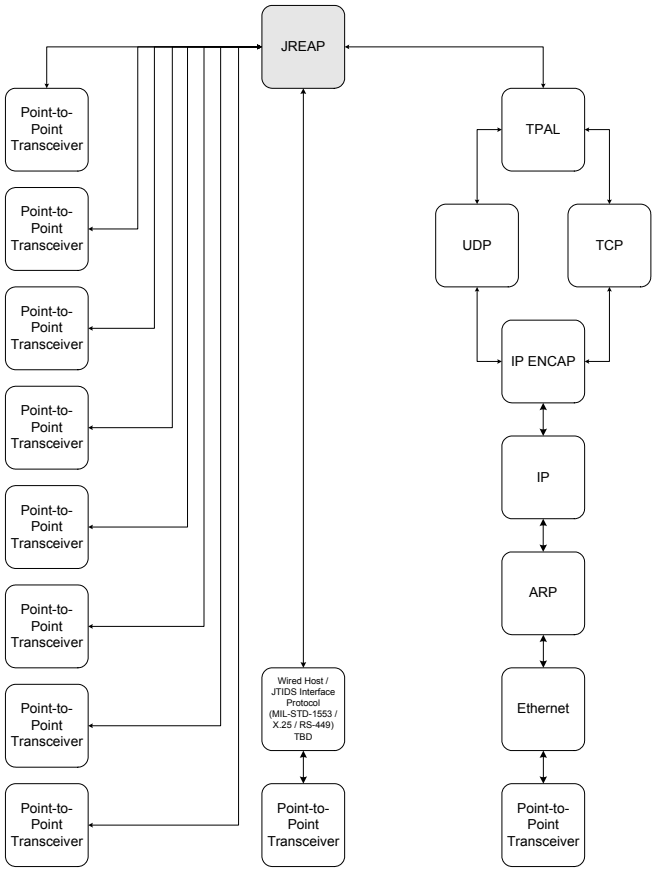
JRE Processor Device Model



- **JREAP, based on MIL-STD-3011, defines the protocols for transmission of Link-16 data over different type of long-haul media**
  - **JREAP-A: over broadcast SATCOM networks (e.g., MilStar and UHF DAMA)**
  - **JREAP-B: over point-to-point JRE media such as voice circuits – not supported by the JRE Processor Model**
  - **JREAP-C: over IP-based networks**
- **Ten interfaces**
  - **Four RS-232 ports**
  - **Four RS-422 ports**
  - **One 10/100BaseT ethernet port (JREAP-C)**
  - **One MIL-STD-1553B/X.25/RS-449 interface**

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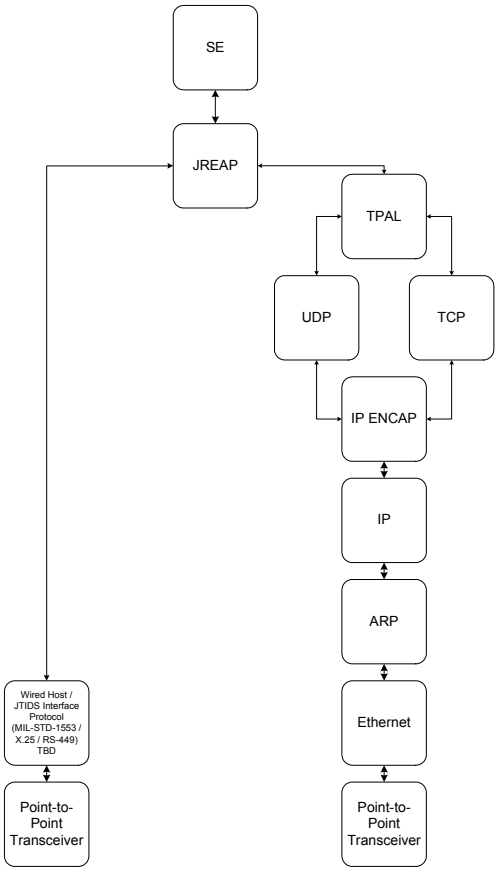
Link-16 Host Processor Device Model



- SE process model generates and receives J-series message traffic
- JREAP process model is an instance of the JREAP process model of the JRE Processor Device Model with modifications to support the local SE for generating and receiving J-series traffic
- Two interfaces
  - JREAP-C interface (10/100BaseT)
  - MIL-STD-1553B/X.25/RS-449 interface

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KSA FNC:
Toward a Unified Naval Network

- A Unified Naval Network will reduce network maintenance efforts and network outages between ships and shore sites
- Two routing architectures considered
  - The current Open Shortest Path First (OSPF) Design extended to a single worldwide routing domain
  - Proposed Traffic Flow Engineering (TFE) architecture using the Enhanced Interior Gateway Routing Protocol (EIGRP)
- A comparative study was conducted using the M&S tool QualNet

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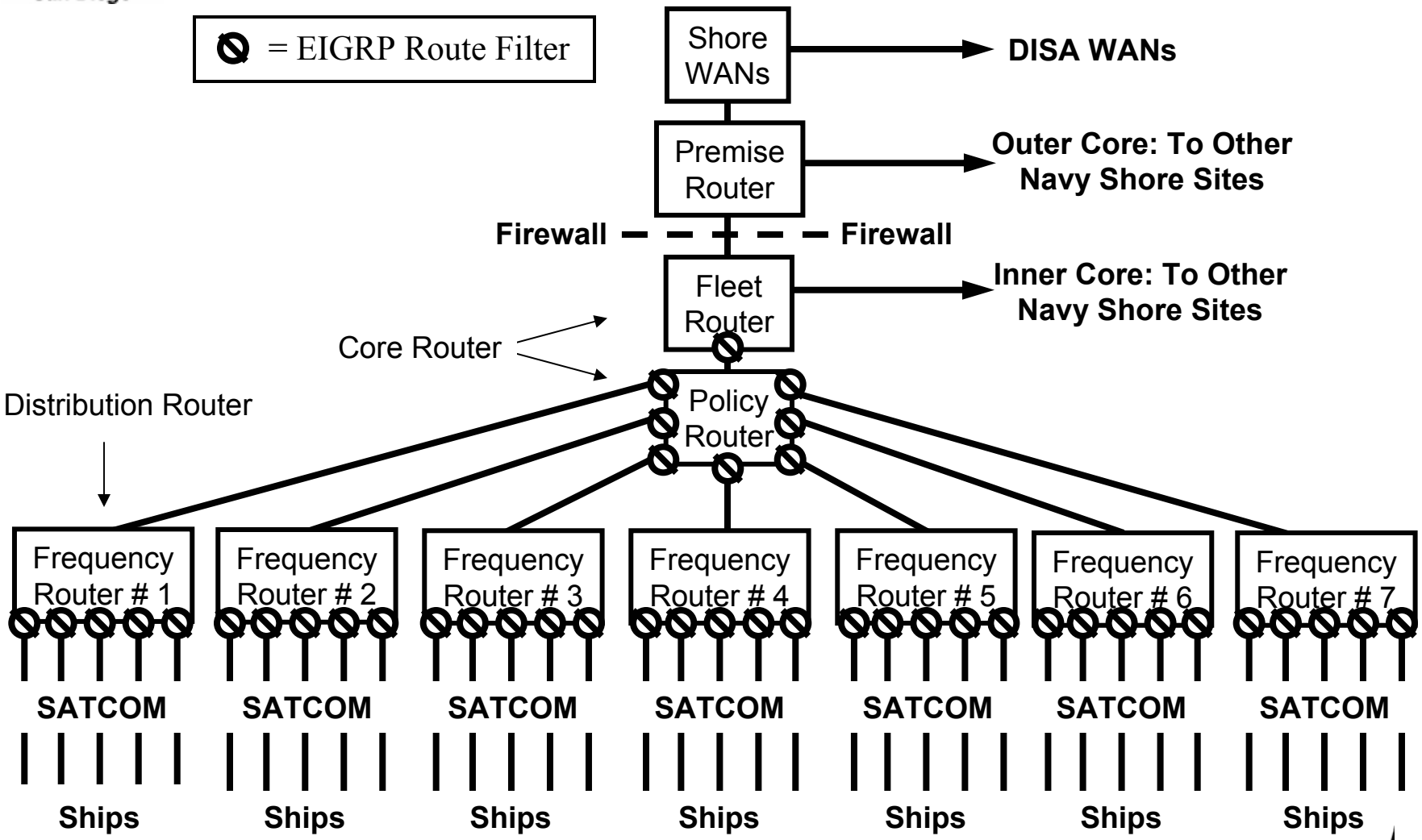
Route Filters within Navy Shore Site



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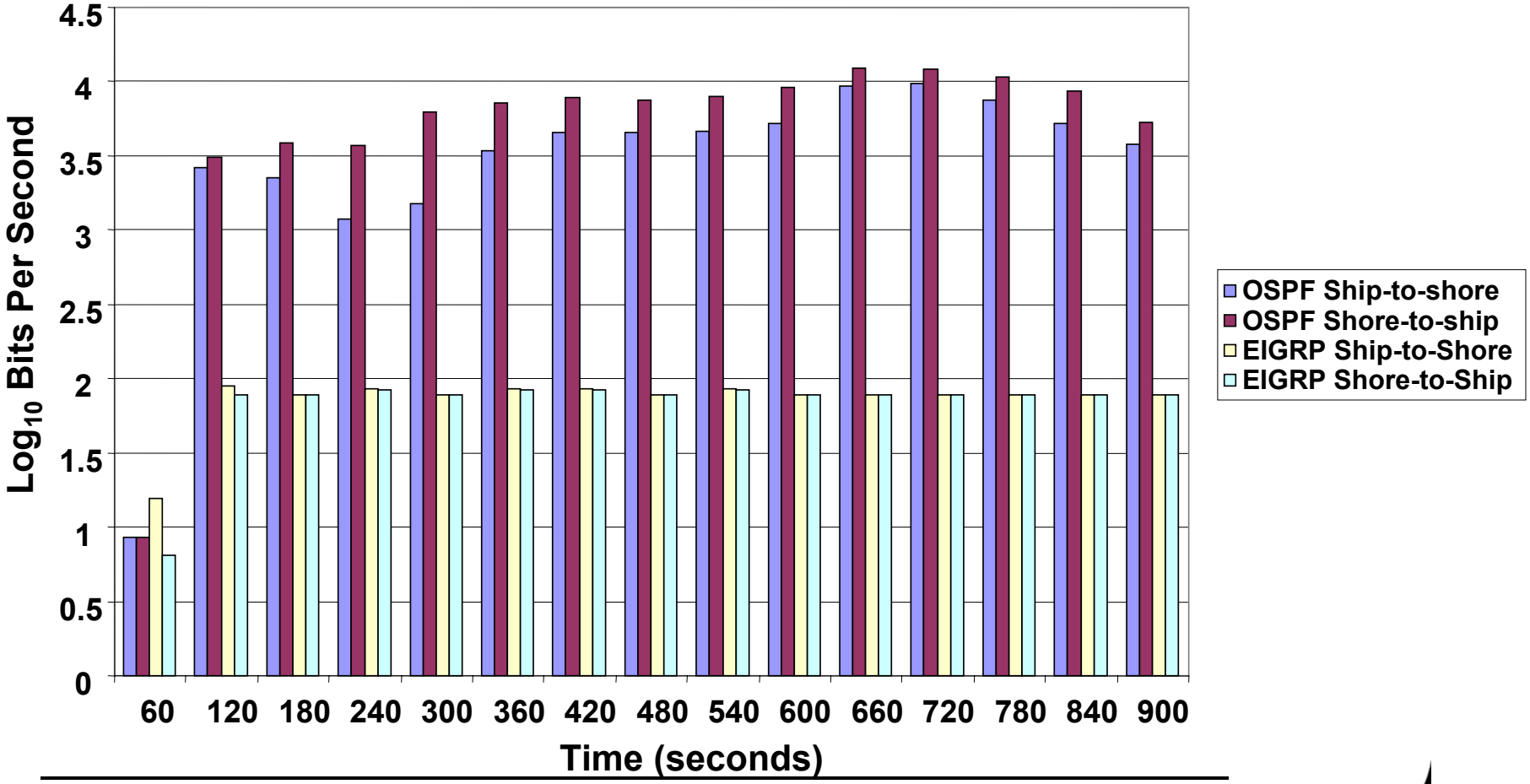
OSPF vs EIGRP Bandwith Consumption on a SATCOM Link



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KSA FNC:
Simulation-Assisted Routing Protocol Design

- The Goals of the Intra Battle Group Wireless Networking (IBGWN) project of the ONR Naval Battle Force Network (part of KSA FNC) include better adaptive, mobile, wireless networks connecting multiple Naval platforms within a battle group as well as joint battle fields
- A Simulation-Assisted Routing Design Analysis, based on link-layer (Layer 2) routing, was conducted using the M&S tool QualNet.

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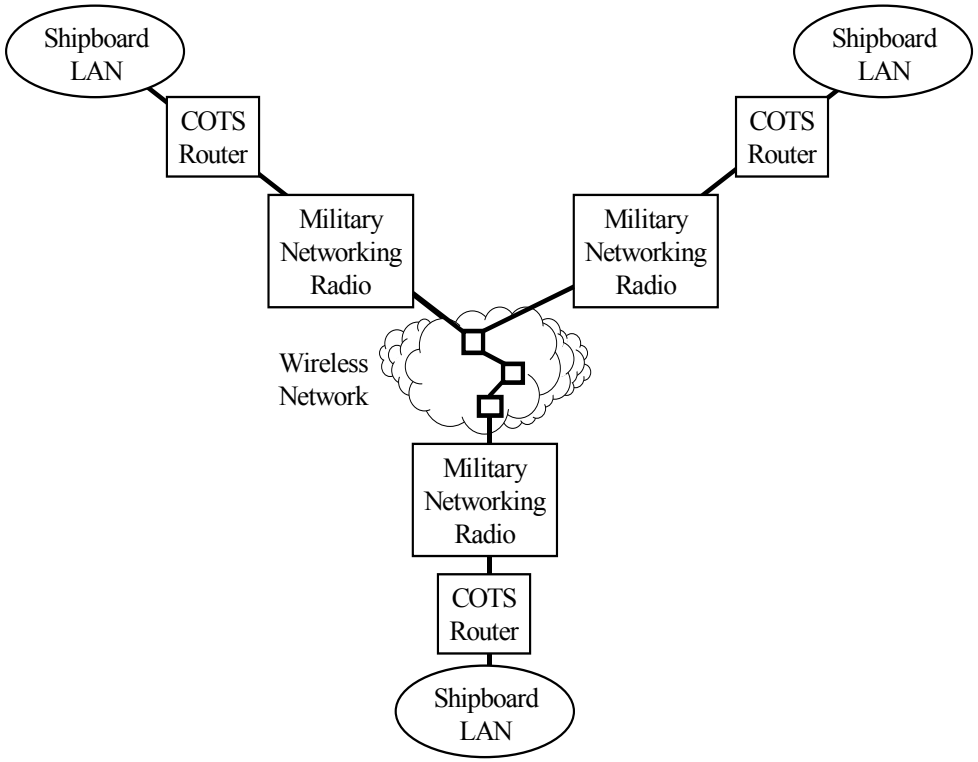
Routers and Networking Radios



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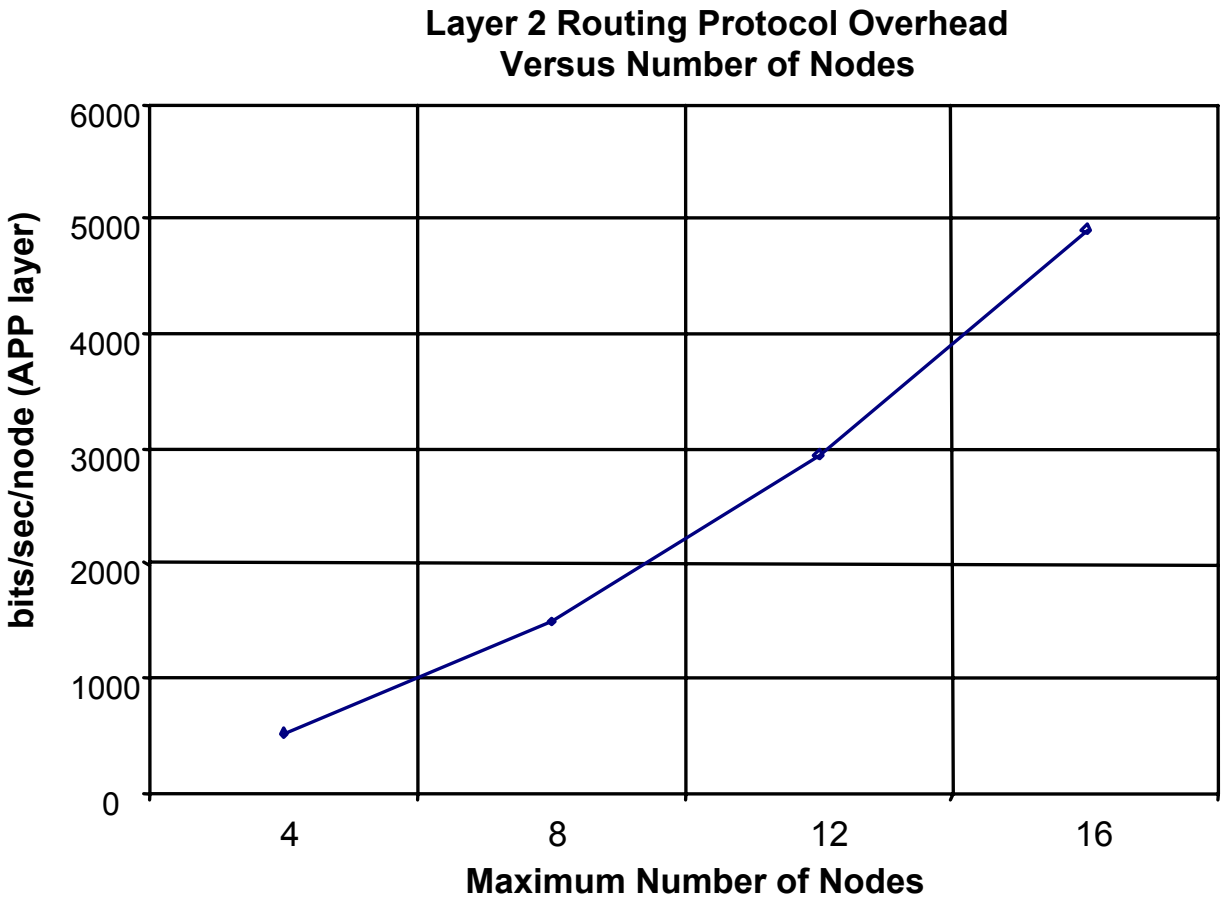
Routing Protocol Overhead vs. Number of Nodes



The connectivity matrix accounted for most of the bandwidth consumption

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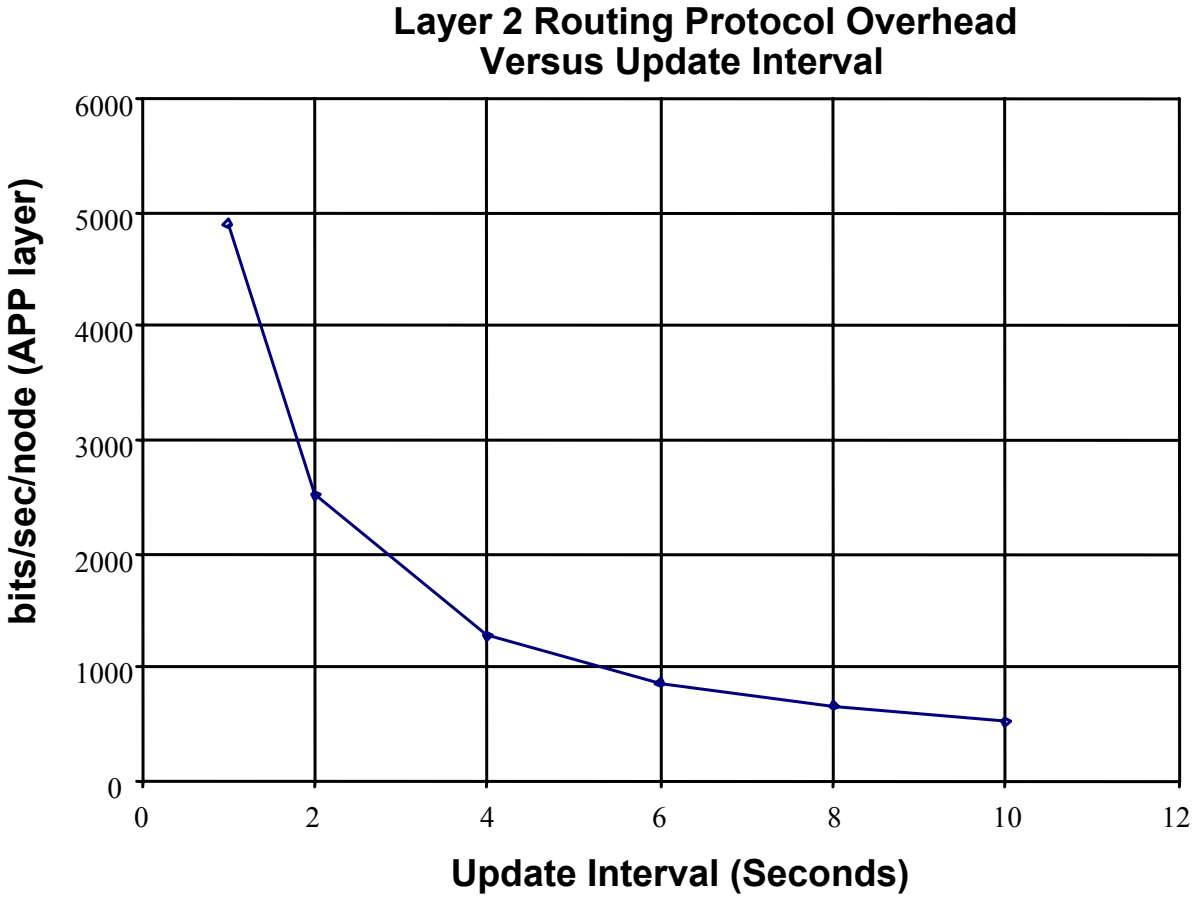
Routing Protocol Overhead vs. Update Interval



The increase in overhead is linear with the inverse of update interval

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Non-Intrusive Knowledge Suite (NIKS)

- Developed by the Cooperative Association for Internet Data Analysis (CAIDA, www.caida.org) under the direction of our Branch that served as the government Technical Agent for DARPA Network Modeling and Simulation (NMS) program
- Provide accurate and standardized datasets of network performance needed
  - to perform VV&A of M&S programs, and
  - to diagnose operational networks and systems
- Have applied for US Patent for NIKS.

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Non-Intrusive Knowledge Suite (NIKS)

- NIKS operates on *tcpdump* (www.tcpdump.org) and CAIDA's *CoralReef* software.
- The main module of NIKS is *crl_delay* that records all relevant info (such as source and destination IP addresses and ports, sequence numbers, packet lengths) and derived statistics of latencies for each TCP connection
  - TCP Round Trip Times for all TCP packets at any ethernet port
  - One-way latency between two ethernet ports when both ports see the same packet
- Similar info for other observed protocols (such as UDP or ICMP) is also recorded.

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Lab and Field Experimentation

- Our lab and field experimentation efforts are associated with
  - FORCEnet (Navy's initiative)
  - Joint Rapid Architecture Experimentation (JRAE) (Joint Service initiative)
- These experimentation efforts complement our M&S activities, providing for VV&A and enabling studies with greater focus on operational environment factors and Human Systems Integration (HIS)

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Lab and Field Experimentation: Process

- **Metrics**
  - Clear experimentation objectives facilitate the formation of analysis questions
- **Replication of Network and Applications**
  - Experimentation objectives determine required and acceptable fidelity levels
- **Data Collection**
  - Metrics derived from objectives dictate what data collection is required
- **Experiment Execution**
  - Monitoring collection devices (for data quality) and administering questionnaires/interviews with system operators (for HIS Metrics)
- **Analysis**
  - Quick-Look Report and Final Report

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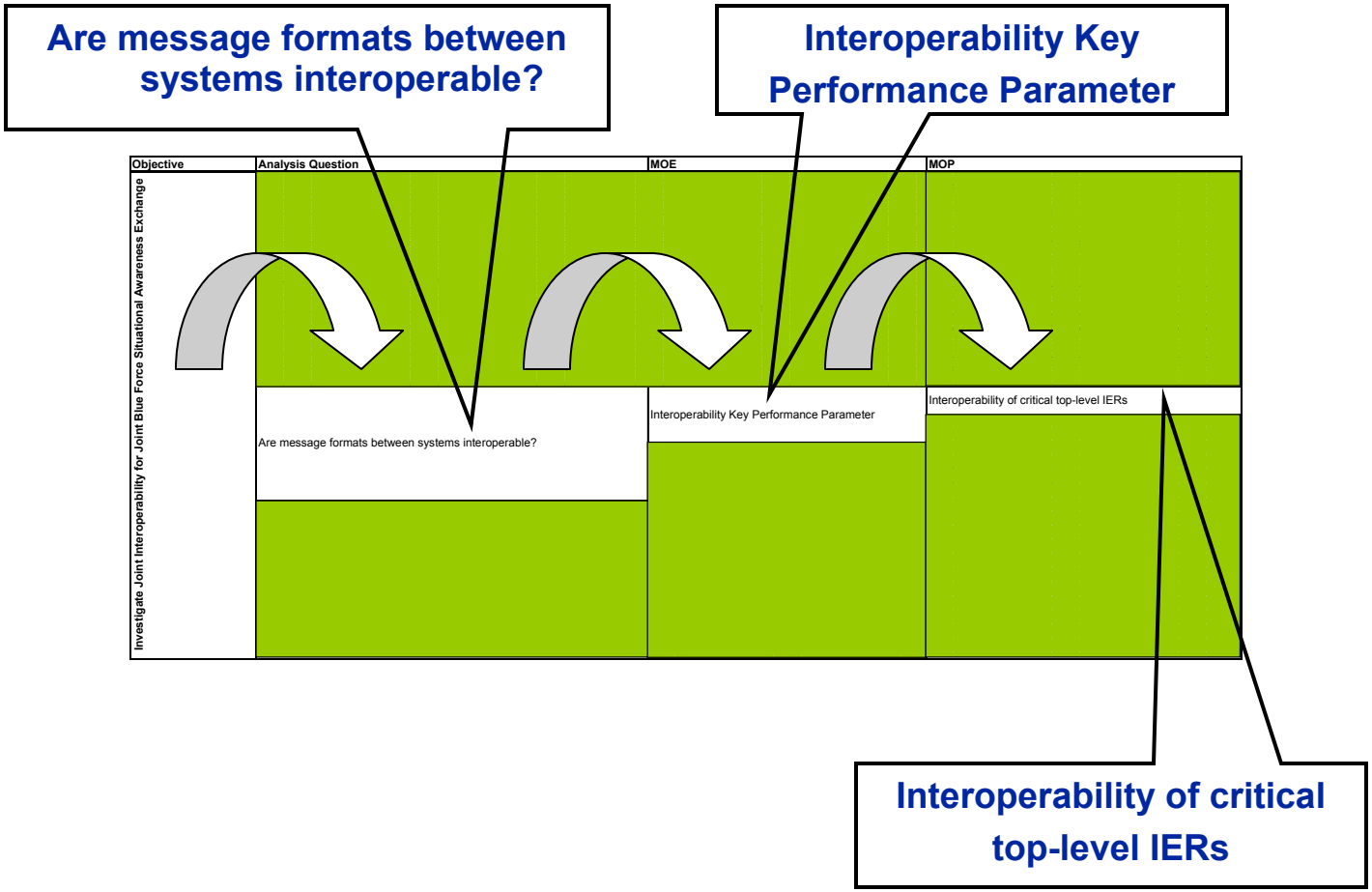
Data Collection Taxonomy of Objectives, Analysis Questions, MOEs, and MOPs



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Conclusion

Making Use of the Full Spectrum of Modeling and Simulation (M&S) environments is the key focus of our activities in Support of Network Warfare Analysis

- Develop standard, reusable, interoperable models to reduce cost and enhance model assessment time
- Work with all facets of the M&S community, which includes Joint Services, government agencies, deployed operational commands, academia and industry, to support the warfighter with the best possible analytical capability
- Continue to enhance our capability by working with
  - DoD High Performance Computing Modernization Office (HPCMO) to improve simulation runtime performance,
  - DARPA Network Modeling and Simulation (NMS) program office to leverage new technologies in M&S,
  - DMSO and NAVMSMO to support policy, standards and guidance.

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Q&A