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NCW END-TO-END (NETE) MODEL FOR FUTURE C2 ARCHITECTURE ASSESSMENTS

Topic: Assessment, Tools, and Metrics

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NCW END-TO-END (NETE) MODEL FOR FUTURE C2 ARCHITECTURE ASSESSMENTS

Abstract

In this paper, we discuss NETE -- a Net-Centric Warfare (NCW) End-to-End model. NETE is a medium fidelity constructive simulation of the Global Information Grid (GIG) infrastructure, Service networks, and their integrated operations in support of definable mission areas. For example, NETE represents netted fires and other mission threads, and the enabling C2 as supported by the 'network of networks'. NETE includes representation of Internet Protocol (IP) based GIG infrastructure and interoperability with current tactical networks, like Link-16. The NETE model provides a means to assess the ability of a defined network to support a concept of operations with resource management to allow the assessment of latencies under varying loads. System loading is accomplished by a generation of background traffic or through sensitivity analyses where the threat level is adjusted. NETE also calculates the impact of network 'jitter' on mission timelines. The fidelity and specific nature of the model is extensible by the operator. To date, we have modeled Transformational Communications supporting missile search operations, missile defense engagement operations, architectures for Responsive Space Operations and Homeland Security. NETE provides a new tool to assess future C2 concepts and architectures as supported by emerging GIG infrastructure and Service NCW networking capabilities.

1.0 Introduction

The emerging Global Information Grid (GIG) and related core enterprise services promise transformational capabilities to future commanders and war fighters. The vision of Net-Centric Operations (NCO) is where war fighters execute synchronized, parallel operations enabled by shared situational awareness and supporting collaboration services. Additionally, each Service is enhancing their 'component' networking capabilities. For example, the Army is developing the Future Combat System (FCS)[1] that will use both GIG infrastructure and other network elements, such as WIN-T (Wireless Internet-Tactical) and JTRS (Joint Tactical Radio System), with software programmable radios. These networks will be supported by, and interoperate with, the

[1] Future Combat Systems (FCS); www.army.mil/fcs/

GIG Enterprise Services to comprise a flexible network of networks. Figure 1 depicts the NETE model top-level view showing Service nets (e.g., Navy's FORCEnet) interoperating with GIG infrastructure. Future C2 CONOPS developers and system acquisition system engineers need tools to assess the ability of emerging capabilities to support innovative operational concepts and to perform trades in an NCW end-to-end context. The NETE environment is well suited for network algorithm development for functions such as network Quality of Service (QoS) or Policy-Based Network Management and Information Assurance (IA).

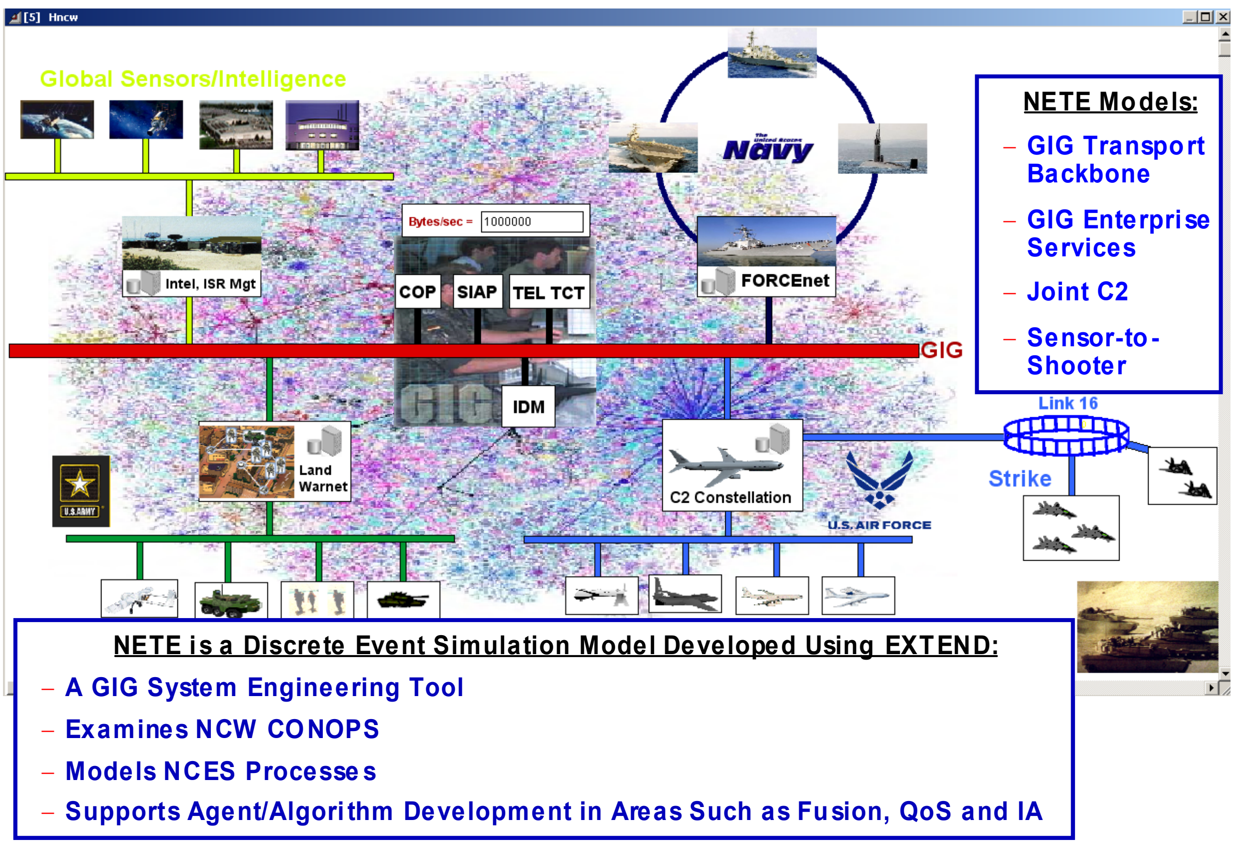

Figure 1: NCW End-To-End (NETE) Model

Tools, such as NETE, are needed to estimate end-to-end mission performance as supported by new networking capabilities. Figure 1 illustrates the scope of the NETE tool, encompassing GIG and service NCW network emerging capabilities. Metrics that NETE can produce include not only network latency and 'jitter', but also the implication of latencies on mission performance and the capability of the total system under 'load'. NETE helps address key issues for emerging NCW concepts such as: can the emerging capability support the new CONOPS and C2

Architectures, under realistic, high-demand conditions? The following paragraphs describe NETE capabilities in more detail.

2.0 Example Applications of NETE

The GIG transport layer including Internet Protocols (i.e., IPV4/6) are represented in NETE. One application we developed examines the following issue: how would the high bandwidth Transformational Communications Satellite (TSAT) [2] capability support future missions where, for example, the CONOPS is simultaneous distribution of streaming video to multiple nodes (C2, processing, operations)? This example, shown in Figure 2, is a 'post before process' concept and can greatly improve overall system reaction time through synchronized processes (vs. sequential process).

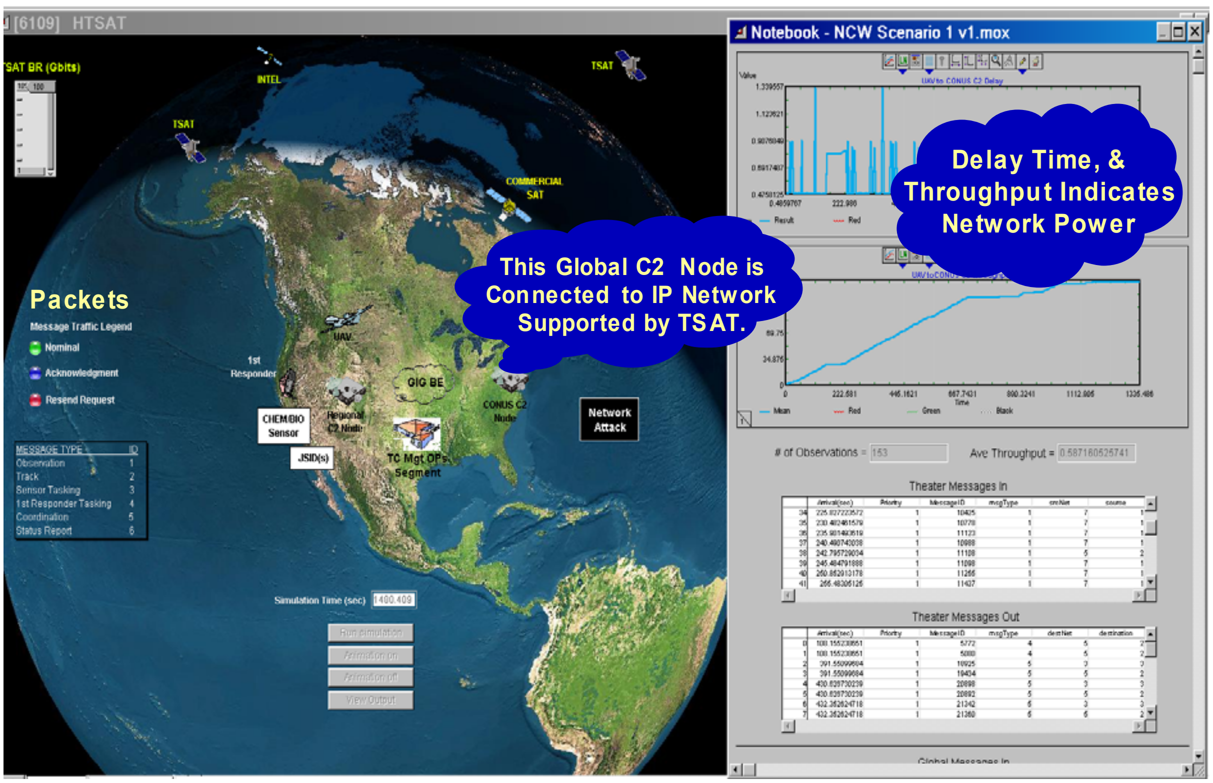

Figure 2: TSAT Supporting Homeland Security 'Post Before Process' Operation

[2] Transformational Satellite Communications (TSAT); www.af.mil/mediacenter/pressrelease.asp?prID=123006700

Figure 2 is a screen capture of a Homeland Security scenario in the NETE application. In this application, NETE measures the network power in terms of responsiveness and throughput. The scenario begins with an alert generated by a local Chemical-Biological Sensor. This event triggers a C2 action to deploy an Unmanned Aerial Vehicle (UAV) to the area of the crisis. The model also allows examination of simultaneous information warfare (net attack). For this case, the information warfare (IW) attack is a 'worm' intended to disrupt emergency reaction times by saturating the C2 network.

In the next example, NETE models TSAT providing Regional Missile Defense connectivity, as illustrated in Figure 3.

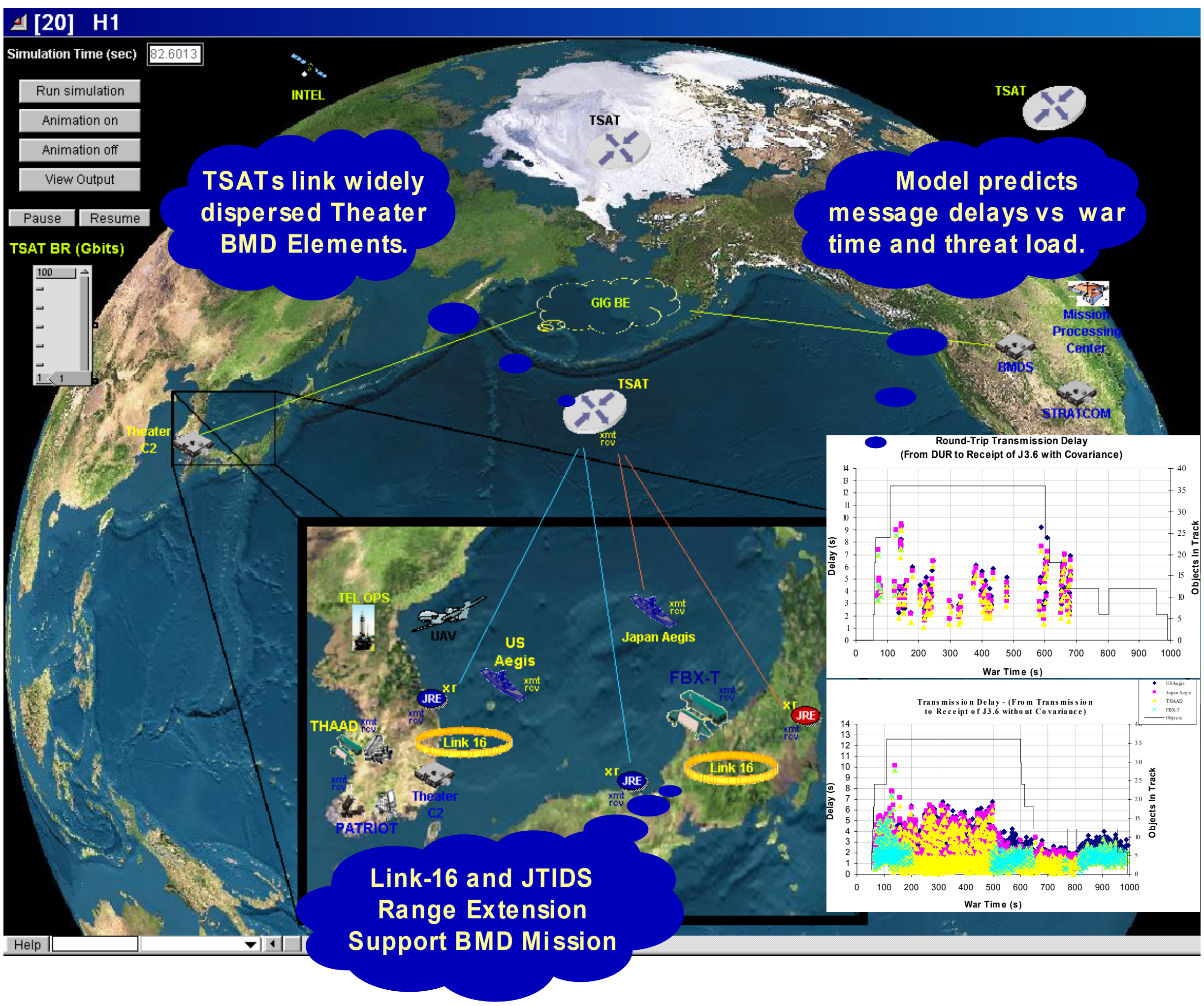

Figure 3: NETE Models Regional Missile Defense Connectivity Using TSAT for JTIDS Range Extension

Here, NETE models a network-of-networks design consisting of the TSAT high bandwidth IP routing and the Link-16 tactical data net for air and missile defense. The metric in this application is complex-- we measured a trace of communication from an initial Link-16 track to request amplifying information to respond to the request. The messages traverse Link-16, and the Joint Tactical Information distribution System (JTIDS) Range Extension provided by Ultra-High Frequency (UHF) Demand Assigned Multiple Access (DAMA) satellites and the TSAT constellation. The model represents the network and the missile defense C2 and engagement operations supported by the network. This allows network metrics such as jitter to be directly related to mission metrics like impact of delays on available missile defense battle space. NETE is currently being used to model the Army FCS architecture employing the JTRS software Programmable radios and a network also underdevelopment- WIN-T. WIN-T will include satellite communications and other elements to link Army Unit of Action (UA) at the brigade level with Joint and higher echelon Army units.

3.0 The NETE Role Within a Modeling and Simulation Tool Set

NETE fits within an overall M&S toolset as shown in Figure 4. Models at the base of the M&S 'pyramid' are physics based tools. The Operations Network (OPNET)[3] model is an example of tools at this level. These tools are used to examine systems or subsystem designs and their performance within their physical environment. OPNET, for example can investigate radio frequency propagation in various environmental conditions. Higher up the pyramid are models that investigate system and system of system operations within realistic resource constraints.

We have developed and used NETE to investigate network ability to support mission operations, including emerging NCW CONOPS. Thus, NETE looks at C2 and decision-making timelines within the context of a realistic network model that represents network resource limitations (bandwidth) and for the protocol as it designed to operate. Results from NETE can be used to represent communications delays in higher-level 'campaign' models like SPARTA's System Effectiveness Analysis Simulation (SEAS). SEAS is a model in the Air Force toolset and is

[3] OPNET Technologies; www.opnet.com

widely used for space mission utility studies. SEAS calculates measures of effectiveness (MOEs), whereas NETE generally calculates measures of performance (MOPs), such as mission response time or network 'jitter'. One way to use these tools together is to use MOPs from NETE to represent network delay times in the SEAS model where the overall campaign is simulated.

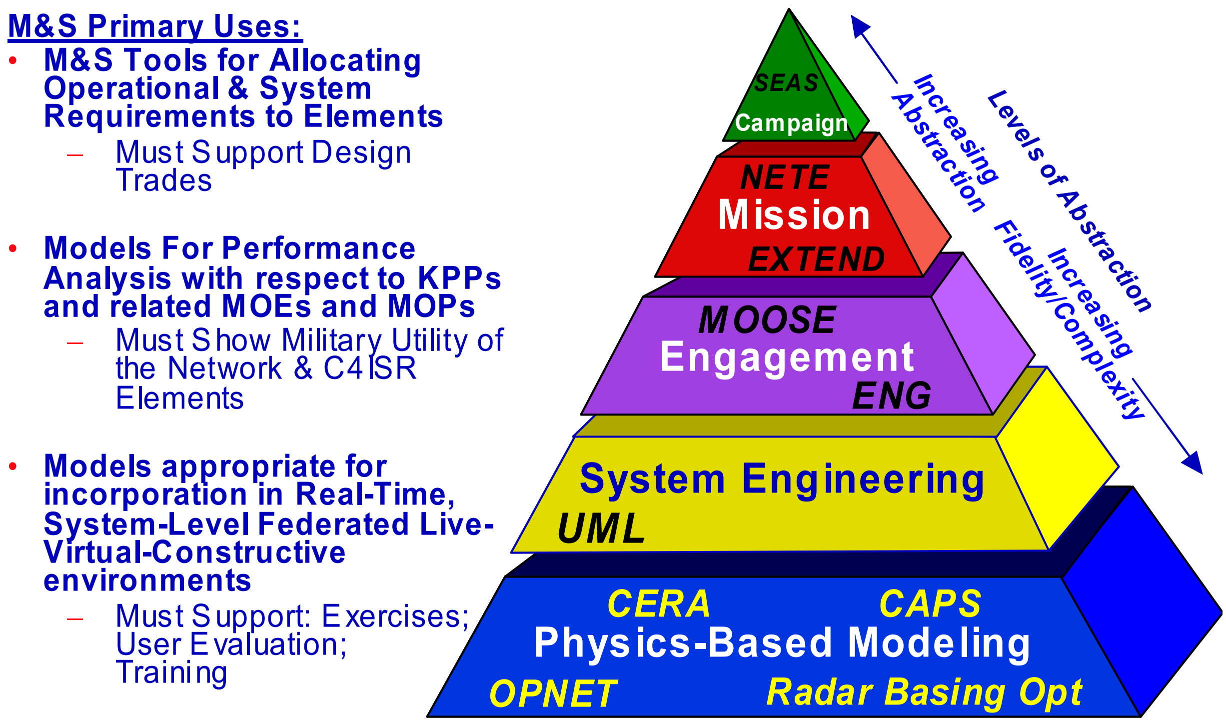

Figure 4: The Role of NETE Within the Overall Modeling Toolset

4.0 NETE Use With OPNET

OPNET and NETE (within the toolset) can be used together to effectively assess GIG and related issues. We describe two circumstances where the models are used together to address complex network issues. The first case is illustrated in Figure 5. In this application, NETE models the end-to-end mission performance on the system elements (sensor, C2, etc.) and the supporting network. The network is modeled at medium fidelity within NETE. OPNET is used to verify the network models and results from NETE. This combination is an *effective and efficient* approach to understanding complex end-to-end NCW related System-of-System issues.

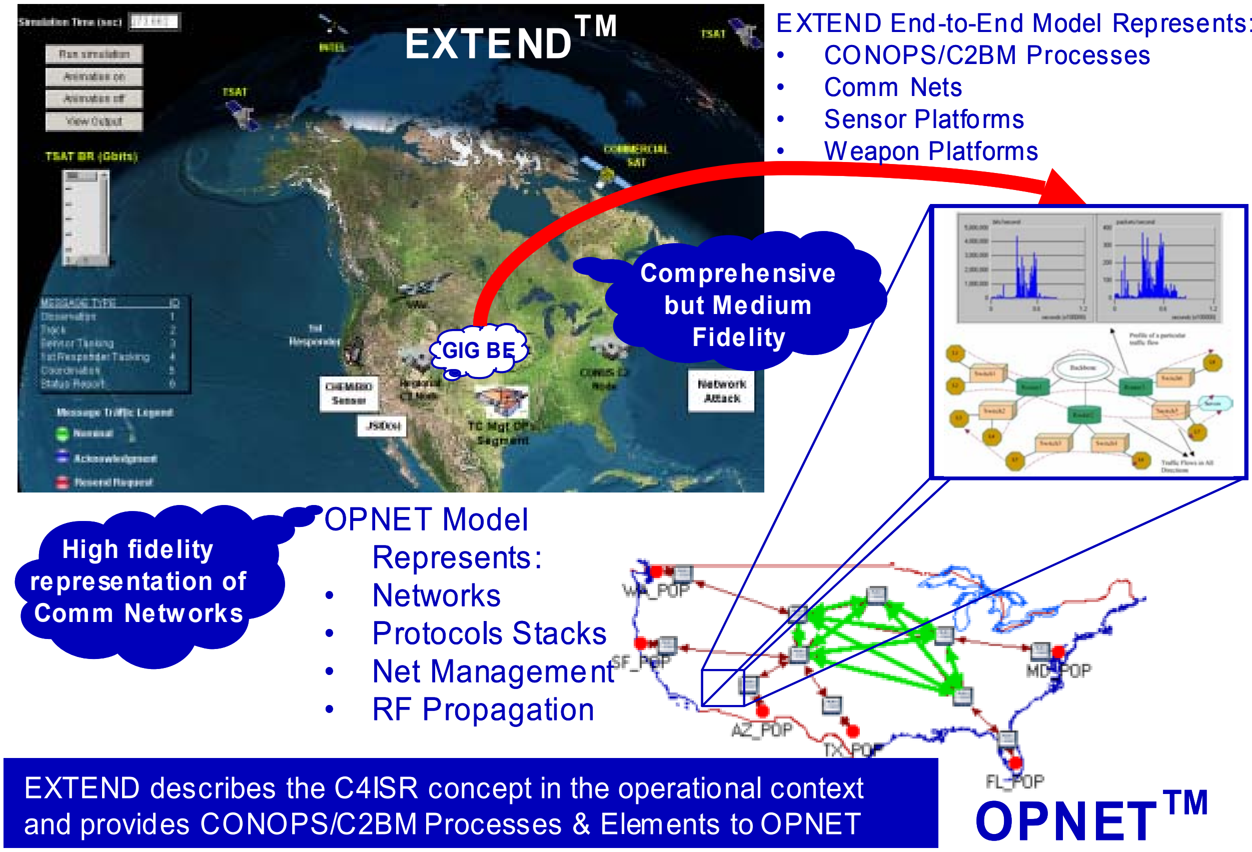

Figure 5: OPNET is Used to Cross-Check/Verify NETE Network Representation

The second use of the two models as a set is illustrated in Figure 6. In this case, OPNET is used to analyze isolated physics-based aspects of network performance. For example, OPNET could be used to estimate performance of a new waveform in complex terrain. This estimate is then used to represent the phenomenon in NETE, as a probability of propagation at varying range, for example. This allows efficient end-to-end examination of complex network mission performance issues with realistic representation of key functions. The alternative is to forgo high-fidelity characterization of key areas or high-fidelity (long run time) representation within a single model. Neither of these alternatives is as attractive as the model tool set approach- in this case the best use of OPNET and NETE as a combined and effective set.

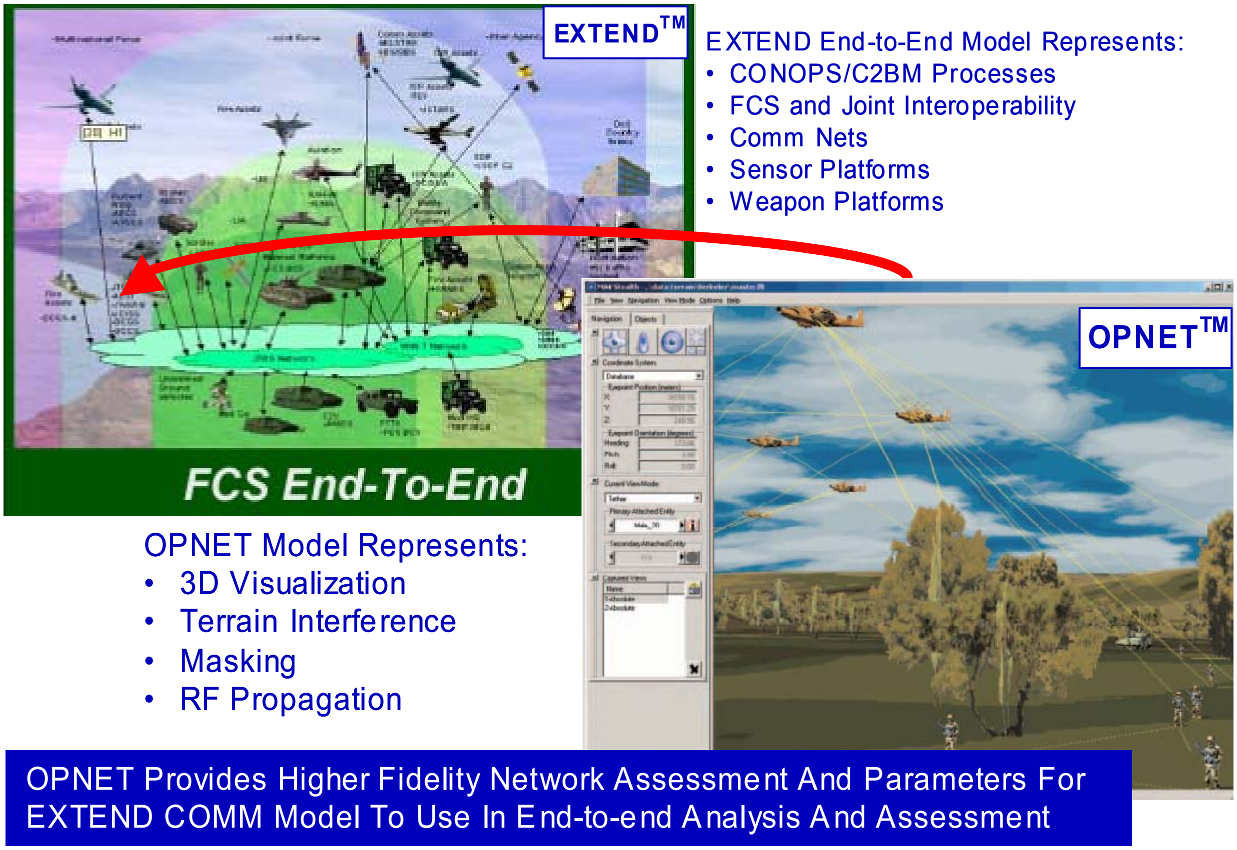

Figure 6: OPNET is Used to Provide Parameters Used to Represent Network Performance

5.0 NETE Architecture

NETE is developed in an open, Commercial-off-the-Shelf (COTS) environment in a model development tool- EXTEND™[4]. EXTEND™ models are developed using 'blocks', as shown in Figure 7. Blocks represent high order modeling constructs such as queues and service delays. EXTEND™ models represent a system as 'entities' flowing through a process.

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[4] Imagine That Inc. EXTEND™ Developers; www.imaginethatinc.com

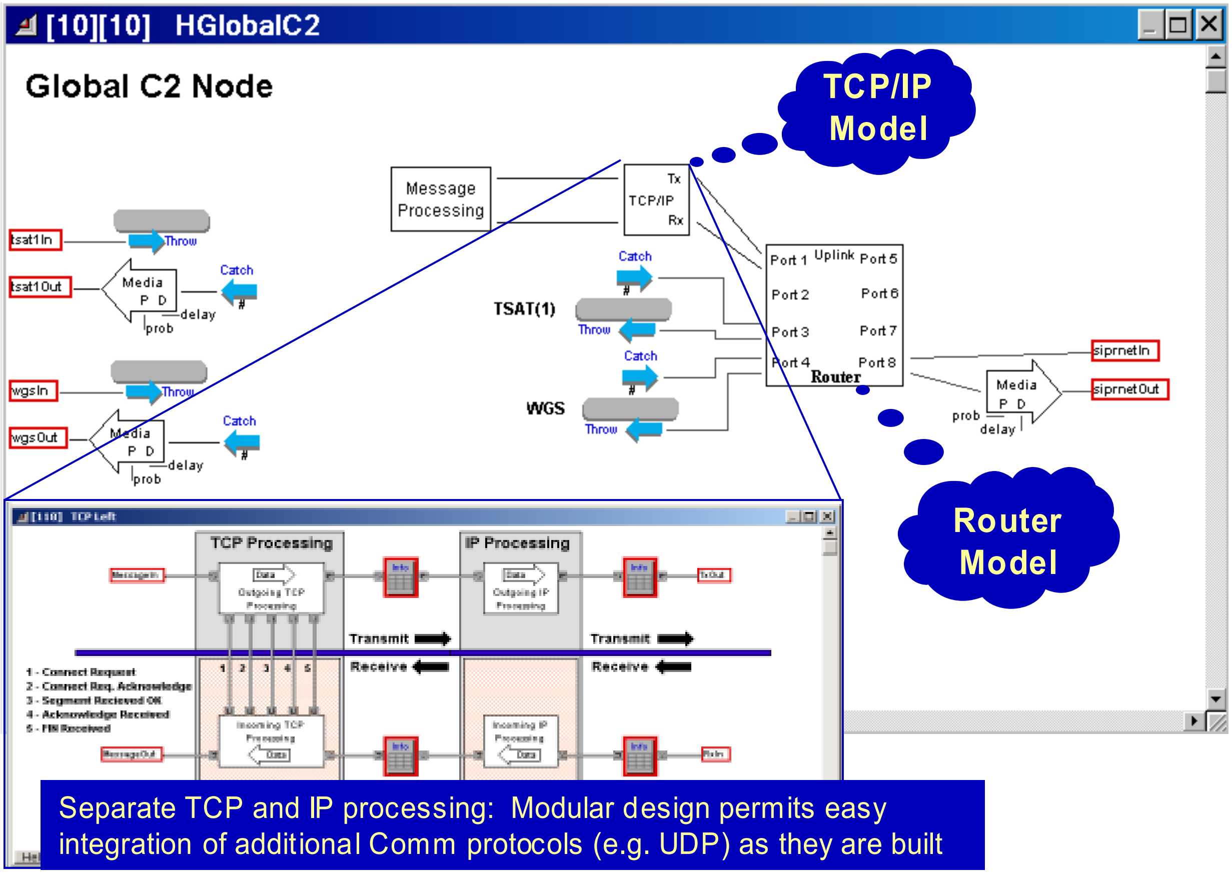


Figure 7: NETE Model of a C2 Node is developed from Lower Level Models

In the NETE application the entities are elements such as 'packets' flowing through a routed network. NETE also represents sensor, shooter and C2 processes using 'hierarchy' blocks. Hierarchy blocks are higher order processes made up of lower level constructs. Figure 8 is a model of a router in EXTEND^{TM}. C2 processes are generated in a variety of means including 'scripted ' responses to integration of decision models such as Bayesian belief nets to represent dynamic C2 fusion and decision processes. The end-to-end system is built using a set of blocks that represent modeling elements such as radios, routers, sensor platforms and C2 nodes. Postulated alternative C2 networks are represented by reconfiguring/reusing the blocks. Many representations in NETE are parameter driven so that, for example, alternative routers can be represented by applying the proper parameter for features such as buffer space.

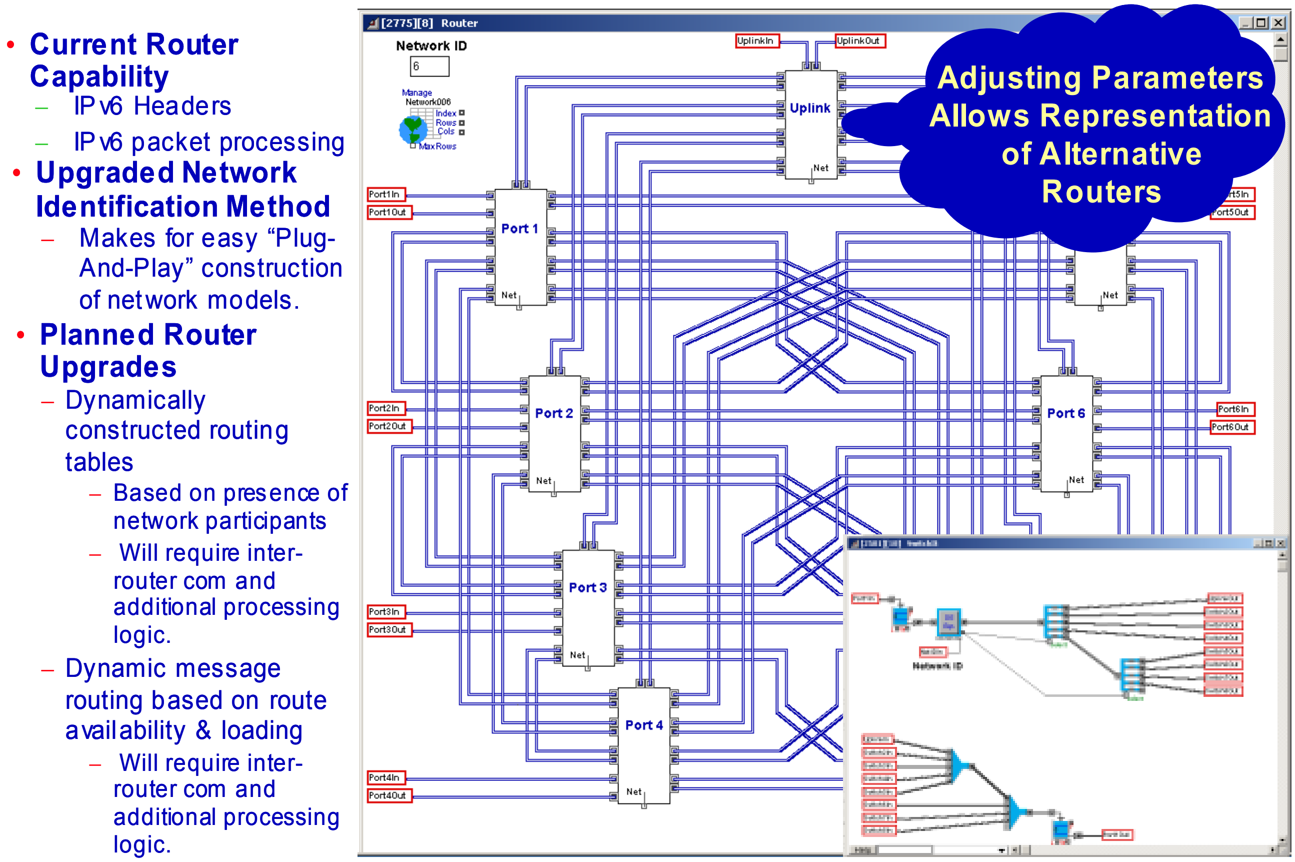


Figure 8: NETE Router Model Built From Lower Level Blocks

Threat processes are represented in a like manner (using blocks to represent threat elements). Where more detailed physics-based models are needed, NETE interfaces with these models in several possible ways: run time calls from NETE to compiled code; models that have been inserted into NETE blocks; and run time access to a model exposed as a service.

NETE represents some network elements such as hand shaking protocols/logic at high fidelity. This allows realistic representation of network resource/capacity issues at high fidelity within an overall medium fidelity, fast execution end-to-end model. Figure 9 is a NETE model of a hand - shake procedure within the TCP/IP protocol.

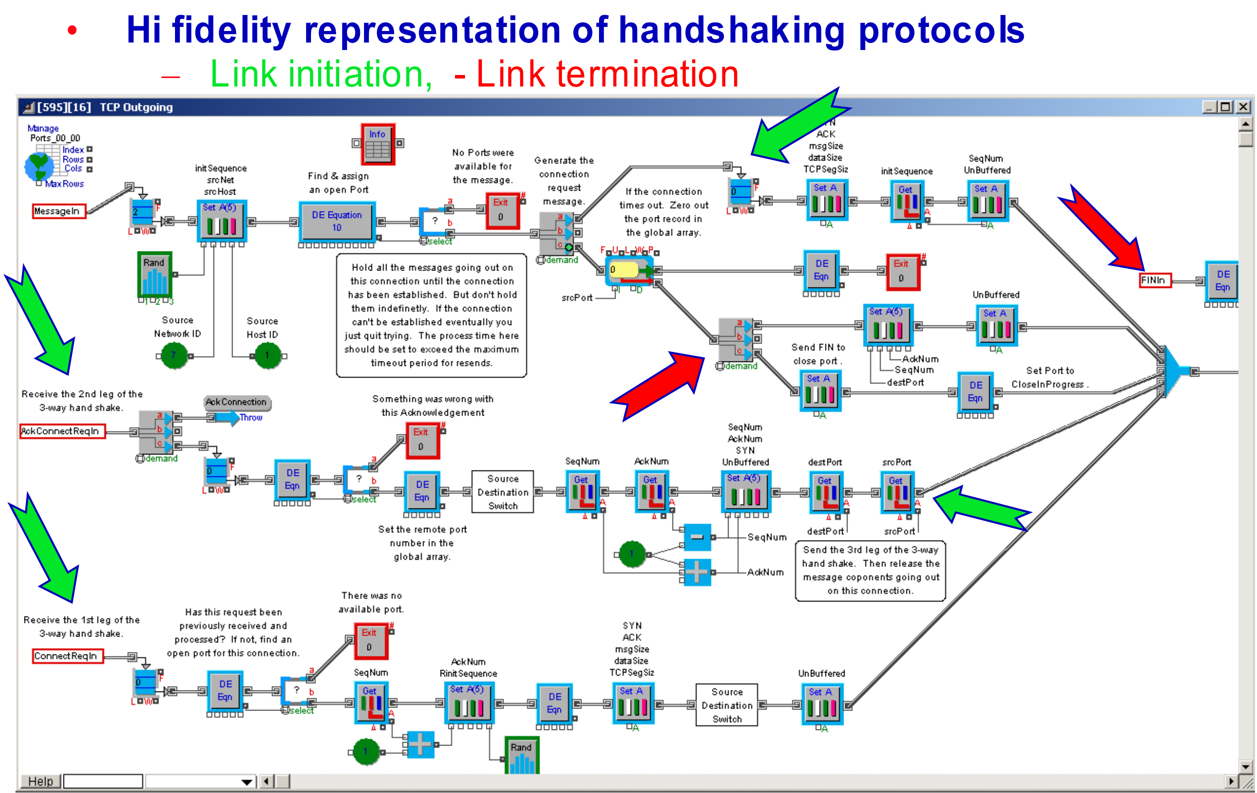


Figure 9: NETE High Fidelity Procedure Model

6.0 NETE Upgrade Plans

We continue to upgrade NETE models to meet the needs of new model uses. Figure 10 summarizes current upgrade plans.

7.0 NETE Model Library

The NETE block structure, such as the Router Block shown above, provides an excellent means to reuse models in new projects. The models can be maintained in libraries and shared within a project and with new efforts. Models can be maintained at several levels. Entire models can become an element in a new model; libraries of low-level reusable blocks can be organized and shared; and finally user defined blocks can be reused. Figure 11 shows SPARTA's collection of reusable NETE models.

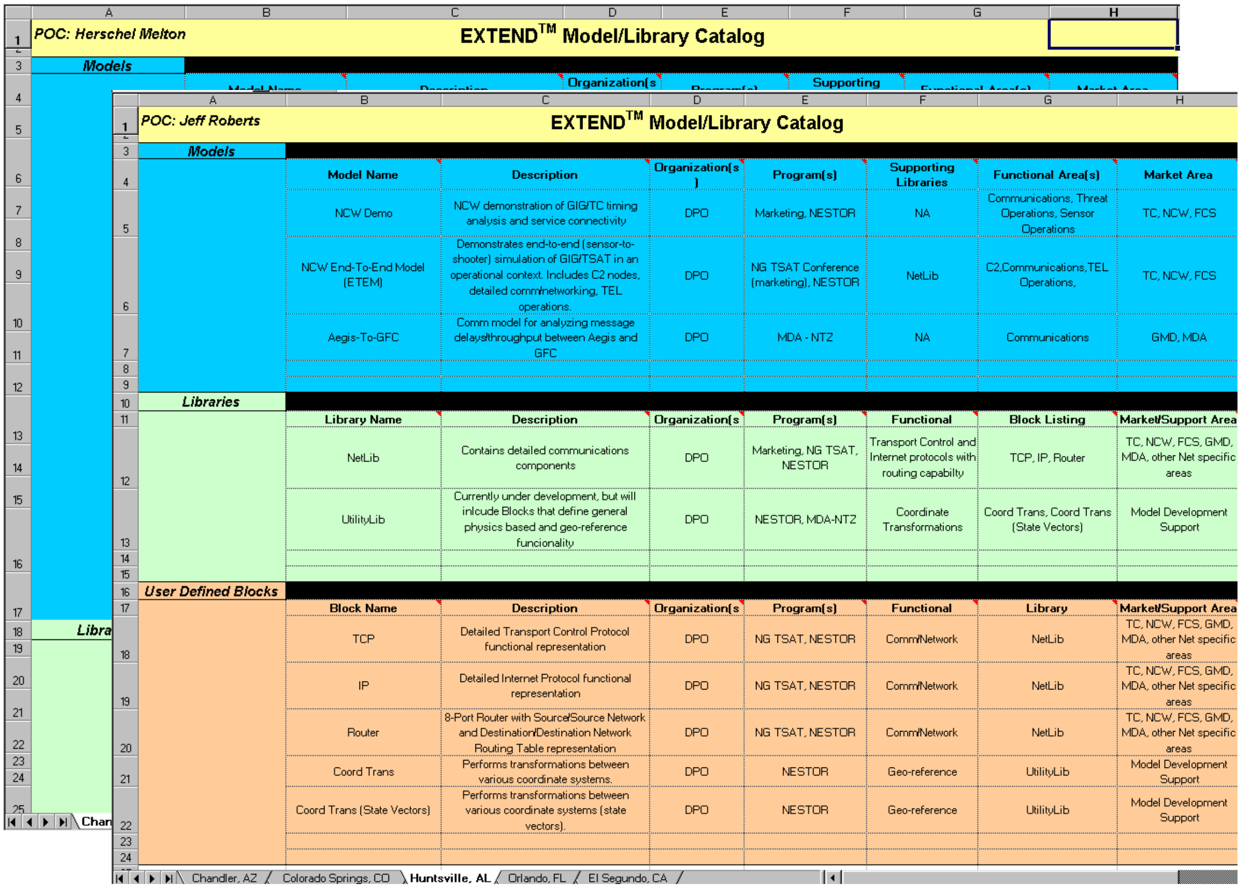
Enterprise Services

Function	Current Capability	Future Capability
Information Distribution	Scripted Publish- Subscribe; Developed Off-line CID VOI Model	Incorporate VOI as 'Smart Pull' Mechanism
Information Assurance (IA)	Scripted Net Attack	Incorporate GSAKMP for Group Security Key Management
Quality of Service (QoS)	Trades to Understand Quality of Service Capability/Issues	QoS Monitoring/Algorithms

C2BM

Function	Current Capability	Future Capability
Sensor Management	Scripted 'Trigger Events' Cause Sensor Tasking; Integrated BBN for VOI Based Tasking	Decision Architecture Approach-Sensor Policy Generation
Weapon Management	Engagement Events (Available Battle Space) Internally Derived	Ditto for Weapon Policy Generation
Fusion	CID Fusion Model (Integrated NETE with BBN Modeling Environment-NETICA)	Decision Architecture Performs Levels 1-4 Fusion (Focus on 1 and 4); Includes CID Fusion

Figure 10: NETE Upgrade Plans for Enterprise Services and C2BM



POC: Herschel Melton

EXTEND™ Model/Library Catalog

POC: Jeff Roberts

EXTEND™ Model/Library Catalog

Models

Model Name	Description	Organization(s)	Program(s)	Supporting Libraries	Functional Area(s)	Market Area
NCW Demo	NCW demonstration of GIG/TC timing analysis and service connectivity	DPO	Marketing, NESTOR	NA	Communications, Threat Operations, Sensor Operations	TC, NCW, FCS
NCW End-To-End Model (ETEM)	Demonstrates end-to-end (sensor-to-shooter) simulation of GIG/TSAT in an operational context. Includes C2 nodes, detailed comm/networking, TEL operations.	DPO	NG TSAT Conference (marketing), NESTOR	NetLib	C2,Communications,TEL Operations,	TC, NCW, FCS
Aegis-To-GFC	Comm model for analyzing message delays/throughput between Aegis and GFC	DPO	MDA - NTZ	NA	Communications	GMD, MDA

Libraries

Library Name	Description	Organization(s)	Program(s)	Functional	Block Listing	Market/Support Area
NetLib	Contains detailed communications components	DPO	Marketing, NG TSAT, NESTOR	Transport Control and Internet protocols with routing capabilty	TCP, IP, Router	TC, NCW, FCS, GMD, MDA, other Net specific areas
UtilityLib	Currently under development, but will inlcude Blocks that define general physics based and geo-reference funcionality	DPO	NESTOR, MDA-NTZ	Coordinate Transformations	Coord Trans, Coord Trans (State Vectors)	Model Development Support

User Defined Blocks

Block Name	Description	Organization(s)	Program(s)	Functional	Library	Market/Support Area
TCP	Detailed Transport Control Protocol functional representation	DPO	NG TSAT, NESTOR	Comm/Network	NetLib	TC, NCW, FCS, GMD, MDA, other Net specific areas
IP	Detailed Internet Protocol functional representation	DPO	NG TSAT, NESTOR	Comm/Network	NetLib	TC, NCW, FCS, GMD, MDA, other Net specific areas
Router	8-Port Router with Source/Source Network and Destination/Destination Network Routing Table representation	DPO	NG TSAT, NESTOR	Comm/Network	NetLib	TC, NCW, FCS, GMD, MDA, other Net specific areas
Coord Trans	Performs transformations between various coordinate systems.	DPO	NESTOR	Geo-reference	UtilityLib	Model Development Support
Coord Trans (State Vectors)	Performs transformations between various coordinate systems (state vectors).	DPO	NESTOR	Geo-reference	UtilityLib	Model Development Support

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Figure 11: NETE Model Library Supports Reuse and Rapid Prototyping of New Models

8.0 Summary

NETE is a medium fidelity, end-to-end model used to analyze GIG and NCW related CONOPS and design concepts. It is based on COTS model development environment- EXTEND™. NETE is readily extensible and has good reuse and sharing characteristics. NETE is being used in a growing set of studies. For example, NETE is currently the basis for a new effort that will model FCS concepts and network designs. The tool will support requirements definition and trade studies for the Army FCS Lead System Integrator. NETE variants are also being used to study Responsive Space Operations architectures. In this application, the emphasis is on end-to-end architecture responsiveness (timeliness). As the GIG is defined and components are acquired, it is critical that complete end-to-end analysis be performed to analyze capability and CONOPS before deployment. NETE is one end-to-end model that can be used in the community to understand net-ready concepts.