

The Inaugural W2COG Working Symposium
24-26 May 2005

Link-16 Network Management System (NMS)

John H. Fikus, Ph.D.

Prediction Systems, Inc. (PSI)





Topics

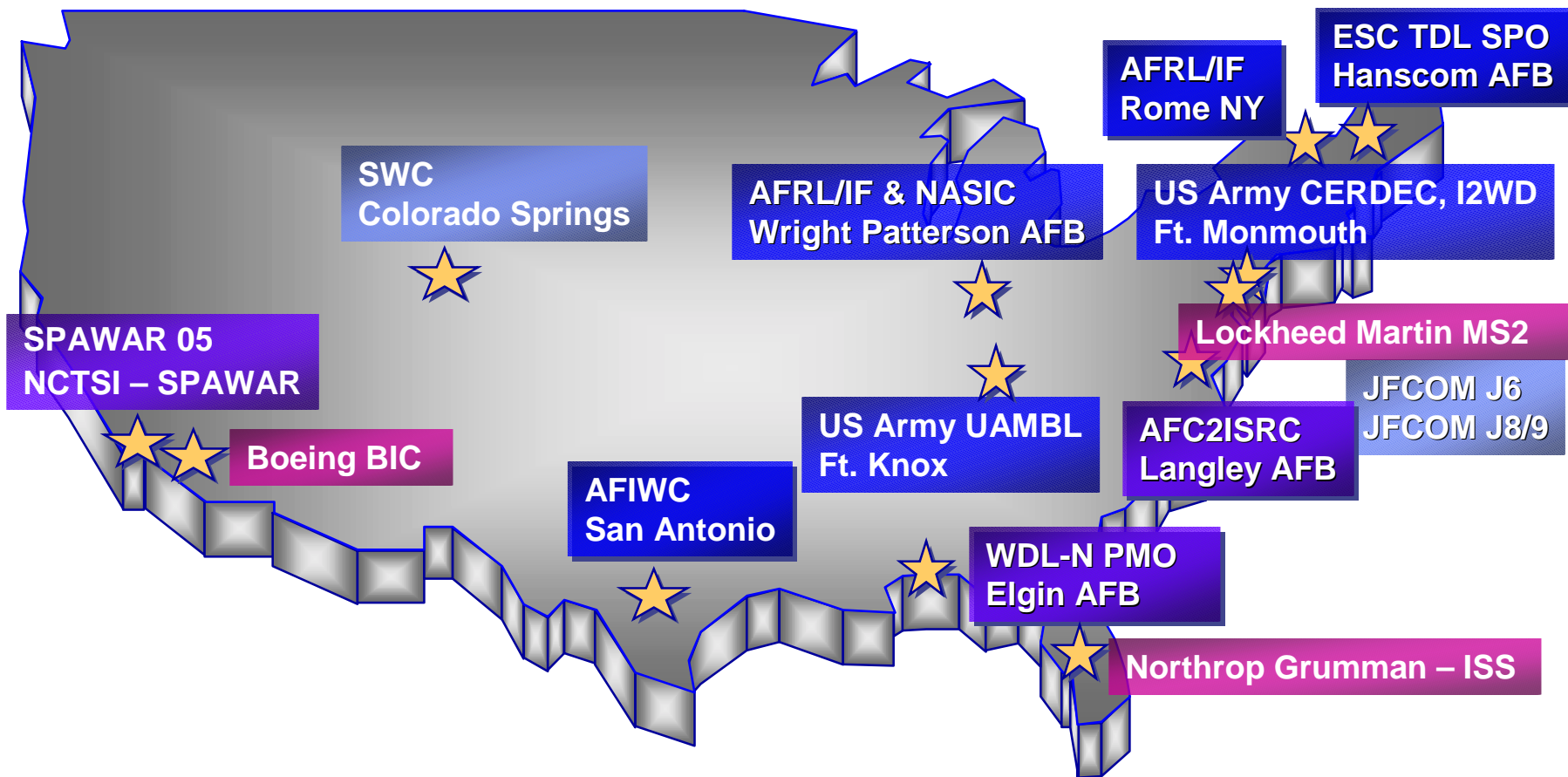
- ◆ Overview of PSI.
- ◆ What is Link-16?
- ◆ How does Link-16 relate to NCO/NCW?
- ◆ Link-16 NMS:
 - Description, Benefits, Capabilities, Applications.
- ◆ Impacts and challenges to adoption.
- ◆ Future direction and teaming relationships.



Who is PSI? Corporate Overview

- **Privately Held Corporation Founded in 1974**
- **Offices in Spring Lake & Wall, New Jersey**
- **Principal Business:**
 - **Modeling & Simulation (M&S)**
 - **Building Planning Tools**
- **Technology Focus:**
 - **Communications Systems**
 - **Real-Time Control Systems**
 - **Net Centric Warfare**
 - **Architecture Assessment**
- **Business Focus - Realization of Customer Solutions for:**
 - **Planning, Analysis and Management of Complex Systems**
 - **Development, Test, Optimization and Training**
- **30 Years of Experience with DoD Systems/Projects**

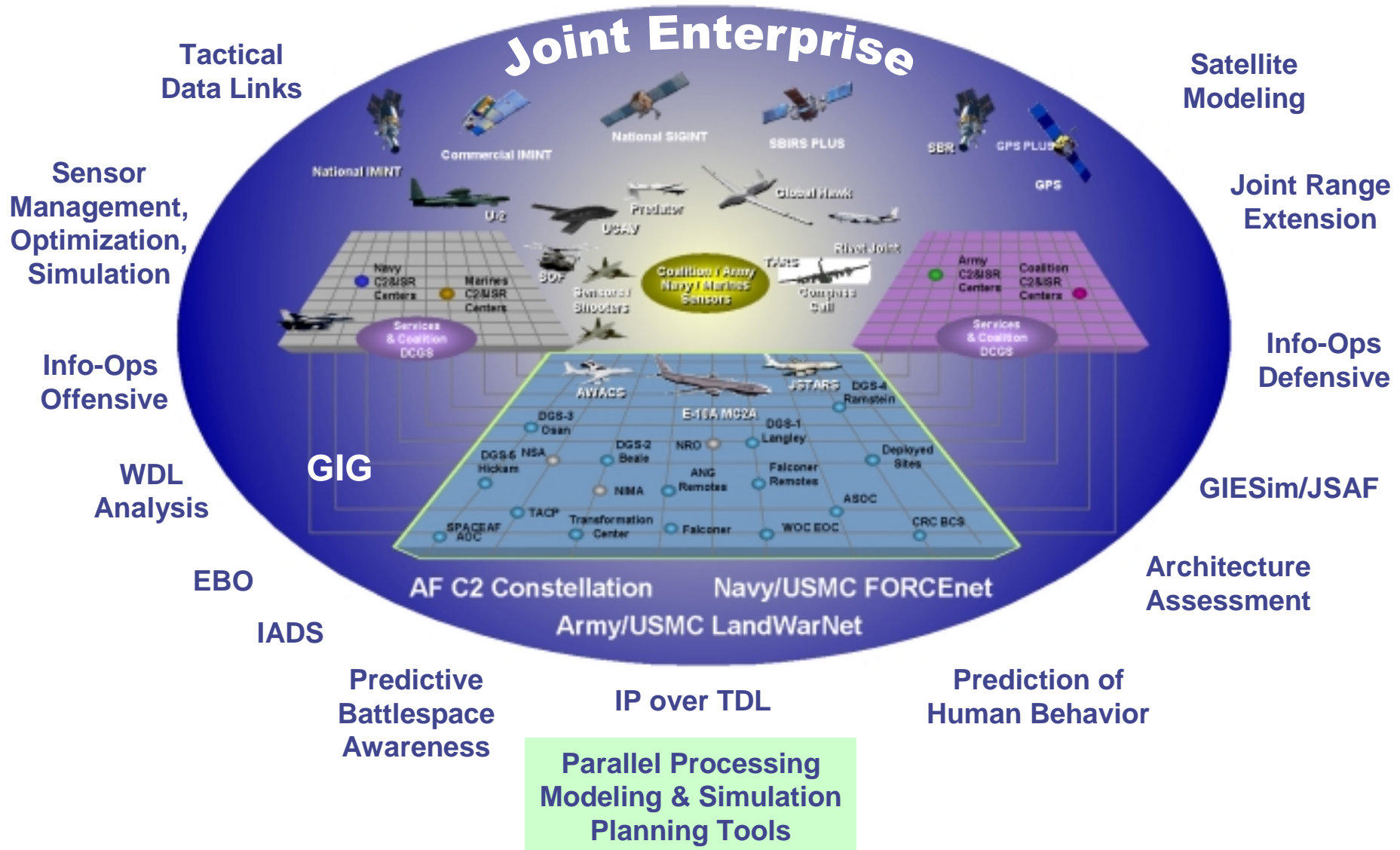
DoD Customers & Industry Partners



M&S / Planning Tool Solutions



Projects in Network Centric Warfare





PSI Leading-Edge Technology

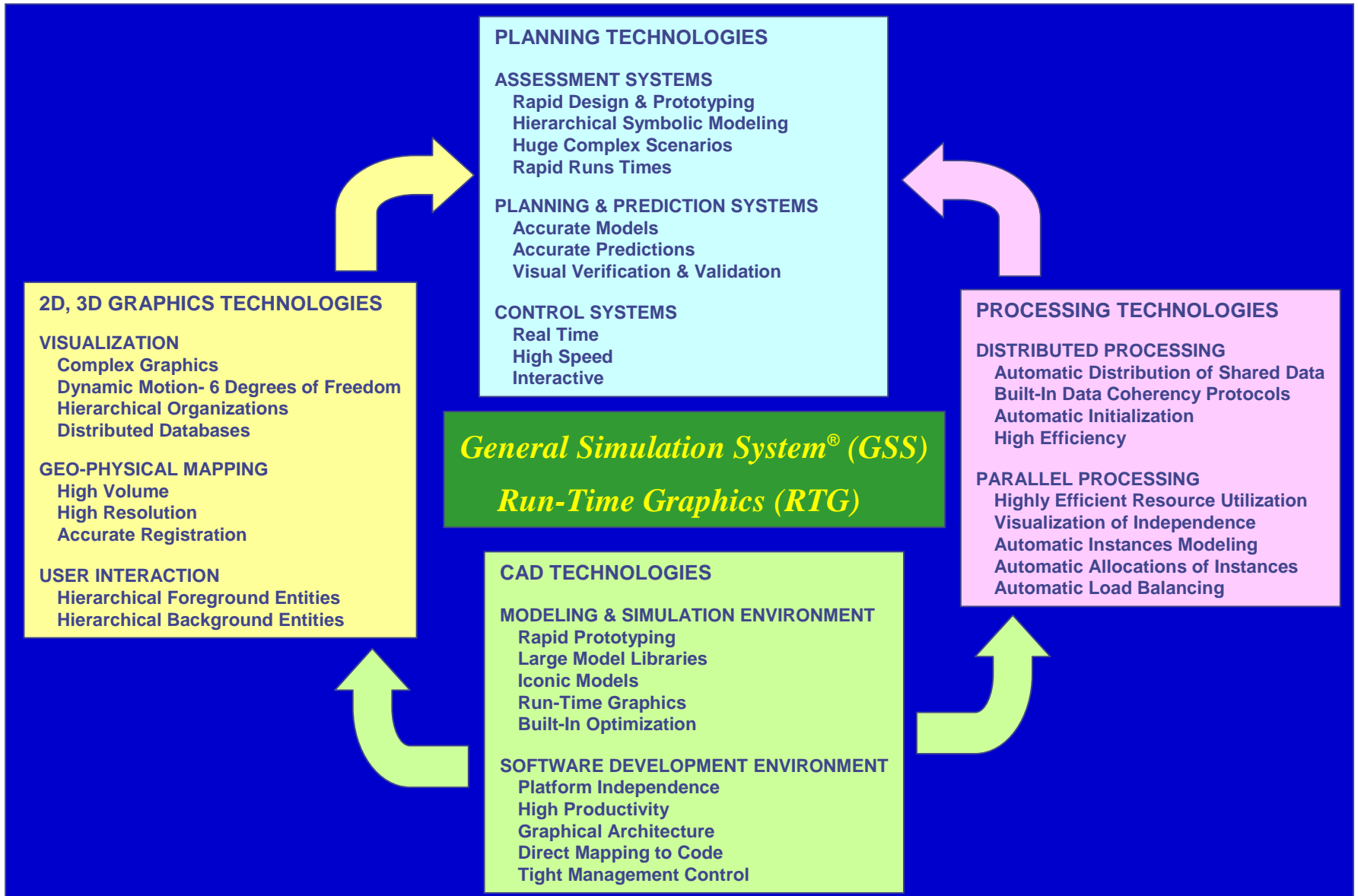


PSI's Core, Leading-Edge Technology

General Simulation System™ (GSS) & Run-Time Graphics™ (RTG)

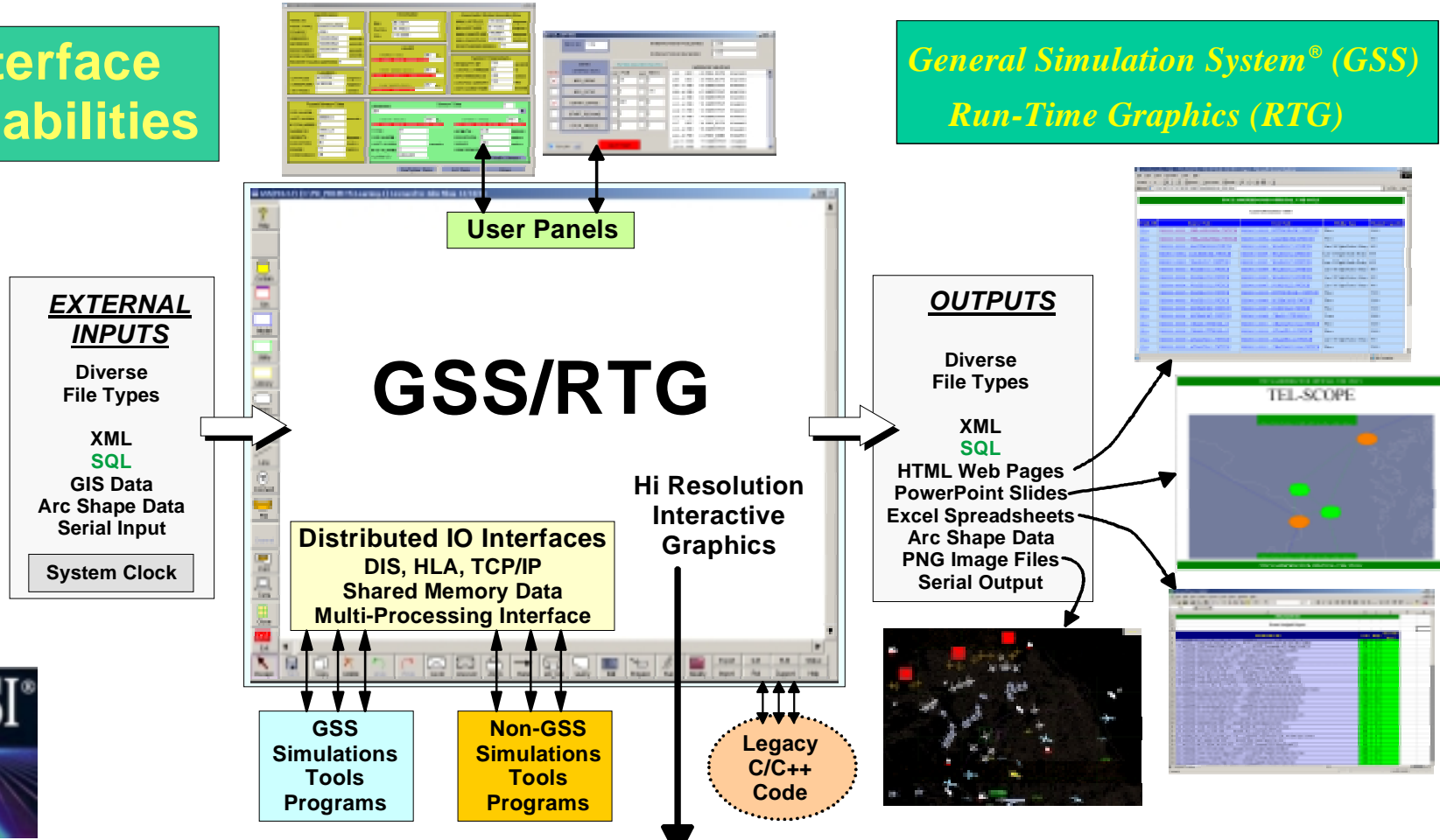
- **High Productivity CAD Software Development Environment and Fast Run-Time Execution**
 - **Supports Rapid Development of:**
 - High Fidelity, Easy to Understand Models
 - Simulations and Planning Tools
 - **Powerful Run-Time Execution:**
 - High Performance Execution
 - High Resolution Graphics
 - Supports Dynamic Interactive Modifications
 - Built-in Optimization
 - Flexible System Interfaces
- **Large and Growing Base of Models**

PSI Core Technology Edge – GSS/RTG



Interface Capabilities

General Simulation System® (GSS) Run-Time Graphics (RTG)



Hi Resolution/Performance Graphics





Minimizing Development & Sustainment Risk

Moving Towards A Defacto Standard

- ◆ GSS applications DODIIS certified:
 - GSS-based TEL-SCOPE certified in record time.
- ◆ Broad DoD customer base of GSS applications.
- ◆ GSS supports many open interfaces.
- ◆ GSS is a high productivity M&S development environment.
- ◆ GSS supported by full set of User Manuals & Training courses.
- ◆ W2COG:
 - Working to simplify current complex acquisition language (250+ Pages)
 - ◆ Current approach can rule out needed innovations, e.g., GSS-based applications.
 - ◆ OSD/NII simplifying rules.
 - Working with PSI on GSS.
 - PSI is a charter member.



Link-16



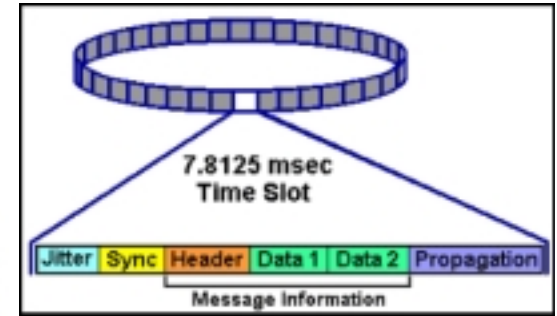
What is Link-16?

- ◆ Link-16 is a complex, predefined messaging standard (MIL-STD 6016C) that is used in JTIDS, MIDS and future JTRS radios.
- ◆ The terms Link-16, JTIDS and MIDS are often used interchangeably.
- ◆ JTIDS stands for Joint Tactical Information Distribution System.
- ◆ JTIDS and the newer Multi-Function Information Distribution System (MIDS) are the most sophisticated wireless tactical data systems currently in use by the joint services and coalition platforms.
- ◆ JTIDS is used for computer-to-computer communications, and supports a wide range of capabilities including: position and navigation, situation awareness, surveillance, weapons coordination and management, mission control, threat warning, platform status, etc.
- ◆ Link-16 also supports Voice, Free Text and Variable Format Messages



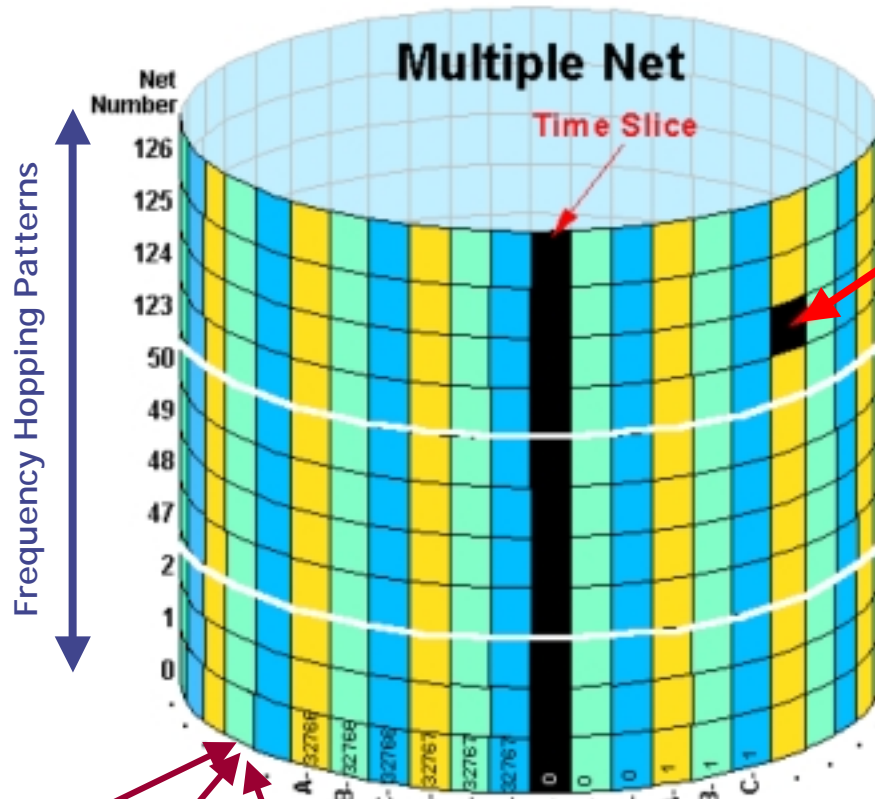
JTIDS/MIDS Comm Architecture

(TDMA, FDMA and CDMA)



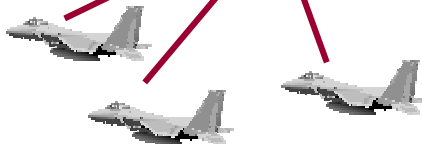
Time Slot

Time Division Multiple Access (TDMA)



Frequency Division Multiple Access (FDMA)

Code Division Multiple Access (CDMA)



Encryption Security
-Transmission (TSEC)
-Message (MSEC)

**UHF Lx Band frequency spectrum
Between 960 MHz and 1215 MHz.**



Link-16 Uses TDL-J (J-Series) Messages

- ◆ TDL-J Words are:
 - 70 bits long, fixed format words.
 - Fields are bit-oriented for minimal overhead.
- ◆ Each Message consists of 1-10 J-Words
- ◆ Each Message has a specified set of transmit and receive rules, which can specify:
 - Response times
 - Repetition rates
 - Receipt Compliance
 - Predefined values for different fields



TDL-J (J-Series) Messages

Message Category	Message Sets
Network Management	J0.x, J1.x
Precise Participant Location & Identification	J2.x
Surveillance	J3.x
Antisubmarine Warfare (ASW)	J5.4
Intelligence	J6.0
Information Management	J7.x, J8.x
Weapons Coordination & Management	J9.x, J10.x
Control	J12.x, J14.x, J17.x, J16.x (reserved)
Platform & System Status	J13.x
Threat Warning	J15.0
Text Messaging	J28.2(0)
National Use	J28.x, J29.x, J30.x
Miscellaneous	J31.x
Round Trip Time (RTT)	RTT-A, RTT-B, RTT-REP



TDL-J Message Addressing

	L/S	0	1	2	3	4	5	6	7
Network Mgt	J0	J0.0	J0.1	J0.2	J0.3	J0.4	J0.5	J0.6	J0.7
Network Mgt	J1	J1.0	J1.1	J1.2	J1.3	J1.4	J1.5	J1.6	
PPLI	J2	J2.0		J2.2	J2.3	J2.4	J2.5	J2.6	
Surveillance	J3	J3.0	J3.1	J3.2	J3.3	J3.4	J3.5	J3.6	J3.7
ASW	J5					J5.4			
Intel	J6	J6.0							
Information Mgt	J7	J7.0	J7.1	J7.2	J7.3	J7.4	J7.5	J7.6	J7.7
Information Mgt	J8	J8.0	J8.1						
Weapons Coord & Mgt	J9	J9.0	J9.1	J9.2					
Weapons Coord & Mgt	J10			J10.2	J10.3		J10.5	J10.6	
Control	J12	J12.0	J12.1	J12.2	J12.3	J12.4	J12.5	J12.6	J12.7
Platform & System Status	J13	J13.0		J13.2	J13.3	J13.4	J13.5		
Control	J14	J14.0		J14.2					
Threat Warning	J15	J15.0							
Control (USN Reserved)	J16	J16.0	J16.1	J16.2	J16.3	J16.4	J16.5	J16.6	J16.7
Control (Weather OT)	J17	J17.0							
National Use	J28	J28.0	J28.1	J28.2	J28.3	J28.4	J28.5	J28.6	J28.7
National Use	J29	J29.0	J29.1						
National Use	J30	J30.0	J30.1	J30.2	J30.3	J30.4	J30.5	J30.6	J30.7
Misce	J31	J31.0	J31.1						J31.7
Round Trip Timing	RTT	RTT-A	RTT-B	RTT-REP					

J28.2(0)

Addressability Designation Colors	1	1 or B
	1-N	1-N or B
	non-C2 Grp	
	Connectivity Q	
	2-7 Spec (relay)	
	Ack (g-g cmplx)	
Spec Brdcast		
Spec Resp		

46% of TDL-J Messages Support some form of addressing

J3.2 Air Track Message Example

◆ J3.2 – Air Track Message consists of 3-6 TDL-J Words.

- J3.2I: Initial Word
- J3.2E0: Extension Word
- J3.2C1: Continuation Words
- J3.2C2-3: Continuation Words (optional)
- J3.2C4: Continuation Words

J3.2I

J3.2E0

J3.2C1

J3.2C4



J3.2I – Air Track Message Word*

```

-----
24 23 22 21 20 19: 18: 17: 16: 15: 14: 13: 12 11 10: 09 08 07: 06 05 04 03 02: 01 00:
-----
<---      :SIM:      :EMG:FT :PP :EX : MESSAGE : SUBLABEL, : WORD :
          :IND:SPI:IND:IND:T/I:IND: LENGTH : J-SERIES : LABEL, J-SERIES :FORMAT :
          : : : : : : : INDICATOR : : : : :
-----
          : 1 : 1 : 1 : 1 : 1 : 1 : 3 : 3 : 5 : 2 :
-----

49 48 47 46 45 44: 43 42: 41 40 39 38: 37 36 35 34 33 32 31 30 29 28 27 26 25
-----
<---      : : : : :
          :ALT SRC: STRENGTH : TRACK NUMBER, REFERENCE
          : : : :
-----
          : 2 : 4 : 19
-----

: 69: 68 67 66: 65 64 63 62: 61 60 59 58: 57: 56 55 54 53 52 51 50
-----
: : IDENTITY : IDENTITY : TRACK QUALITY :ID : ALTITUDE, 25 FT
:SI :-----: IDENTITY : TRACK QUALITY :ID : ALTITUDE, 25 FT
:IND: ID AMP : CONFIDENCE : :DIF:
: : DESCR : : : :
-----
: 1 : 3 : 4 : 4 : 1 : 13
-----

```

*From MIL-STD-6016C



J3.2I – Air Track Message Fields*

REFERENCE	DATA FIELD DESCRIPTOR	BIT POSITION	# BITS	RESOLUTION, CODING, ETC
1550 001	WORD FORMAT	0-	1 2	00
270 004	LABEL, J-SERIES	2-	6 5	00011
271 005	SUBLABEL, J-SERIES	7-	9 3	010
800 001	MESSAGE LENGTH INDICATOR	10-	12 3	0 NO ADDITIONAL WORDS. 1-7 NUMBER OF ADDITIONAL WORDS.
385 003	EXERCISE INDICATOR (EX IND)	13	1	
839 001	PPLI TRACK NUMBER AND IDENTITY INDICATOR (PP T/I)	14	1	
354 002	FORCE TELL INDICATOR (FT IND)	15	1	
355 002	EMERGENCY INDICATOR (EMG IND)	16	1	
292 002	SPECIAL PROCESSING INDICATOR (SPI)	17	1	
1604 001	SIMULATION INDICATOR (SIM IND)	18	1	
769 002	TRACK NUMBER, REFERENCE	19-	37 19	
386 013	STRENGTH	38-	41 4	
364 001	ALTITUDE SOURCE (ALT SRC)	42-	43 2	SET TO ZERO WHEN ALTITUDE, 25 FT IS UNKNOWN.
365 033	ALTITUDE, 25 FT	44-	56 13	
1860 001	IDENTITY DIFFERENCE INDICATOR (ID DIF)	57	1	
280 001	TRACK QUALITY	58-	61 4	
1663 001	IDENTITY CONFIDENCE (ID CON)	62-	65 4	
376 007	IDENTITY	66-	68 3	
376 001	IDENTITY AMPLIFYING DESCRIPTOR (ID AMP DESCR)	66-	68 3	
1861 001	SPECIAL INTEREST INDICATOR (SI IND)	69	1	

*From MIL-STD-6016C



J3.2C1 Air Track Amplification

Continuation Word Air Platform Field*

J3.2I

J3.2E

J3.2C1

6 bits



NO STATEMENT	0
FIGHTER	1
FIGHTER BOMBER	2
ATTACK	3
BOMBER	4
RECONNAISSANCE	5
TANKER	6
TANKER (BOOM ONLY)	7
TANKER (DROGUE ONLY)	8
INTERCEPTOR	9
TRANSPORT	10
AIRBORNE COMMAND POST (ACP)	11
MISSILE CARRIER	12
MISSILE	13
ELECTRONIC WARFARE (EW)	14
ANTISUBMARINE WARFARE (ASW)	15

AIRBORNE EARLY WARNING AND CONTROL (AEW)	16
MARITIME PATROL AIRCRAFT (MPA)	17
SEARCH AND RESCUE (SAR)	18
DRONE	19
REMOTELY PILOTED VEHICLE (RPV)	20
FIXED WING GUNSHIP	21
CIVIL, AIRLINER	22
CIVIL, GENERAL	23
LIGHTER THAN AIR (LTA)	24
GLIDER	25
DECOY	26
HELICOPTER (HELO)	27
ATTACK HELICOPTER	28
HELICOPTER GUNSHIP	29
ANTISUBMARINE WARFARE HELICOPTER (ASW HELO)	30

MINE WARFARE HELICOPTER	31
TRANSPORT HELICOPTER	32
TACTICAL SUPPORT PATROL	33
MISCELLANEOUS FIXED WING	34
MISSILE CONTROL UNIT	35
SURFACE-TO-AIR MISSILE (SAM)	36
AIR-TO-SURFACE MISSILE (ASM)	37
SURFACE-TO-SURFACE MISSILE (SSM)	38
LOGISTIC	39
AIR-TO-AIR MISSILE (AAM)	40
SUBSURFACE-TO-SURFACE MISSILE	41
SURFACE-TO-SUBSURFACE MISSILE	42
CRUISE MISSILE	43
BALLISTIC MISSILE	44
AIRBORNE LAND SURVEILLANCE	45
AIRBORNE LASER	46
UNDEFINED	48 THROUGH 62
RESET TO NO STATEMENT	63

*From MIL-STD-6016C



Why is Link-16 Important?

- ◆ Link-16 is the pre-eminent Tactical Data Link (TDL) in use today.
- ◆ Highest Bandwidth TDL. *Though not a LAN in the Sky.*
- ◆ Link-16 has low susceptibility to Jamming.
- ◆ Link-16 is over 20 years old, and use today is *accelerating* due to experience in ODS & OIF.
- ◆ Link-16 Supports:
 - Situational Awareness (PPLIs)
 - Tracks, Targets, Weapons Coordination



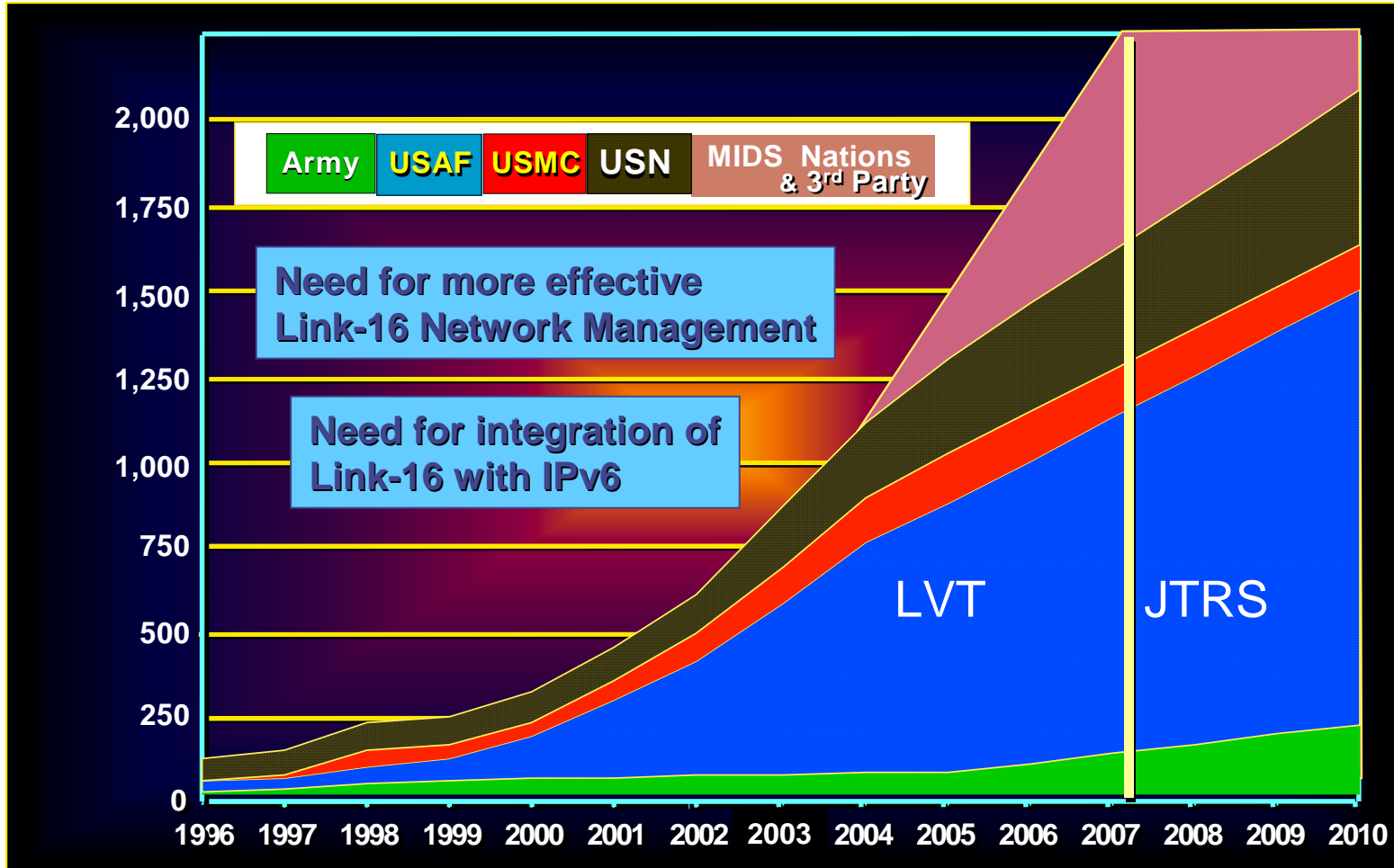
Link-16 and NCO



Why is Link-16 Important to NCO/NCW?

- ◆ Link-16 is *the* tactical RF communications heart of NCO/NCW.
- ◆ Link-16 is the “last digital mile” to the war fighter.
- ◆ Link-16 utilization is expected to increase over the next 5+ years.
- ◆ Link-16 platforms will be around for 10-20 more years. There is a HUGE investment in equipment, testing, deployments, etc.

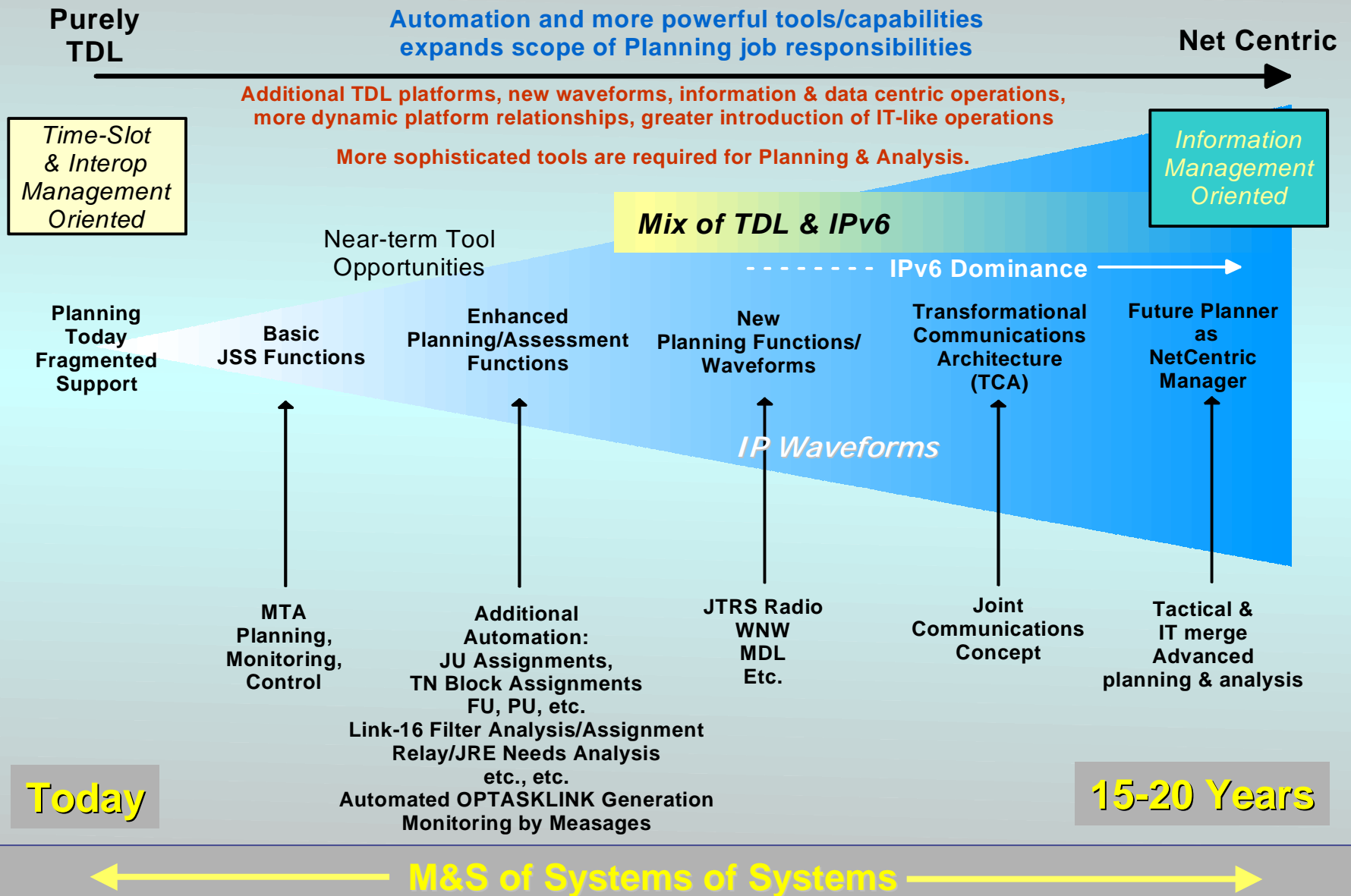
Exponential Growth in Link-16 Platforms



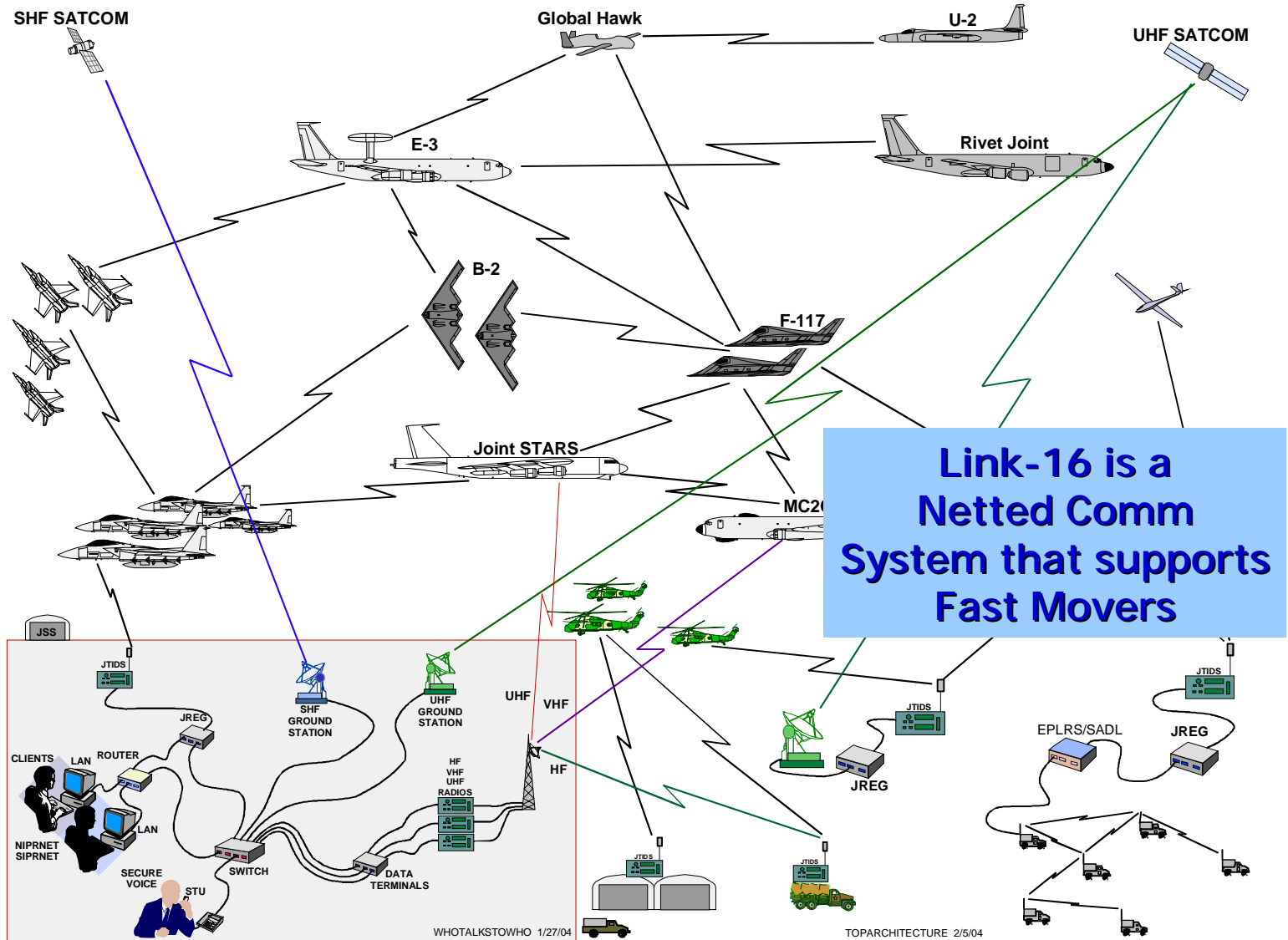
From: 102_USN_Tactical_Links_Overview,
 Capt S. Des Jardins, USN,
 March 2005 Multi Link
 Users Conf Presentation Material

MIDS Third Party Potential: 7625

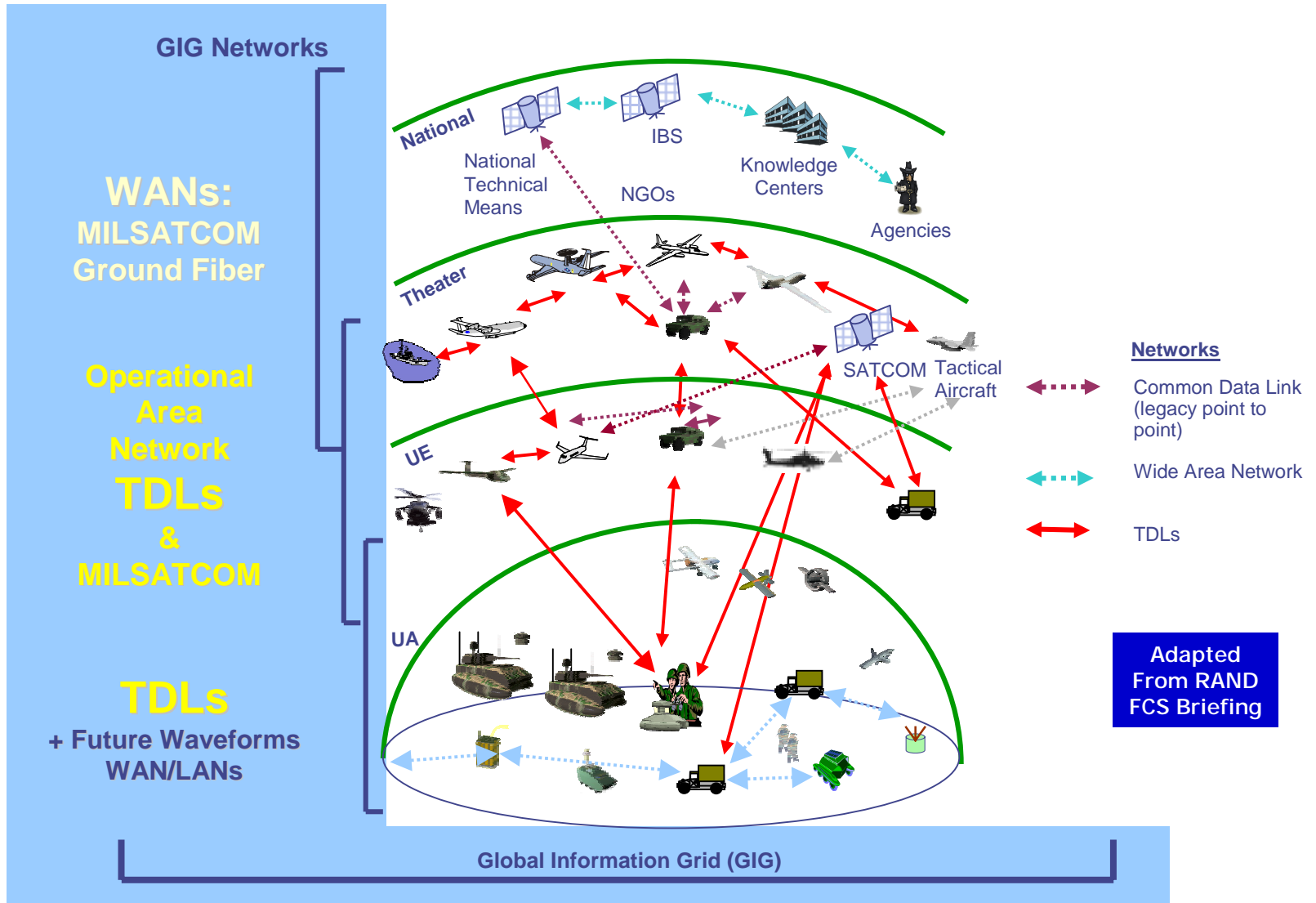
Evolution of "MTA" Planning Functions and Scope



Networks Required to Support Tactical Environments & Missions Today



TDLs in Relation to the GIG





Challenges in Network Centric Transformation

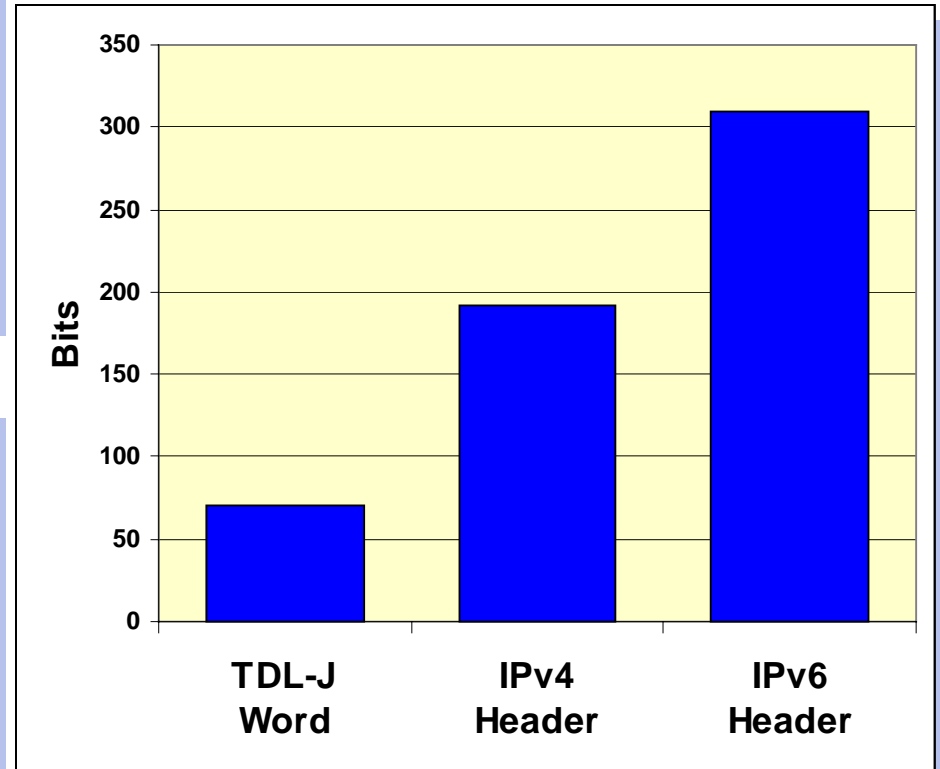
- ◆ Exponential Growth & Utilization of Link-16.
- ◆ Maximizing use of Link-16
 - Leveraging and extending Link-16 *"legacy"* terminals
 - WDL-A, JTRS Link-16, etc.
- ◆ Link-16 relationship to IPv6 & IP Waveforms
 - Integration of TDLs into IP environment.
- ◆ IPv6 Performance:
 - Tactical Message Latency
 - Waveform Susceptibility
- ◆ Integration of stove-piped systems:
 - AOC
 - ◆ DLARS, TBMCS (T-Bone), GCCS (JC2), etc.
- ◆ Large investments - limited answers (or analyses) to date.

IPv4 & IPv6 Headers vs. TDL-J

IPv4 Header: 192 bits

0 bits	4	8	16	24	31
Version	IHL	Service Type	Total Length		
Identifier		Flags	Fragment Offset		
Time to Live	Protocol	Header Checksum			
Source Address (32bit)					
Destination Address (32bit)					
Options and Padding					

TDL-J Word: 70 Bits



IPv6 Header: 310 bits

0	4	12	16	24	31
Version	Class	Flow Label			
Payload Length		Next Header	Hop Limit		
Source Address (128bit)					
Destination Address (128bit)					

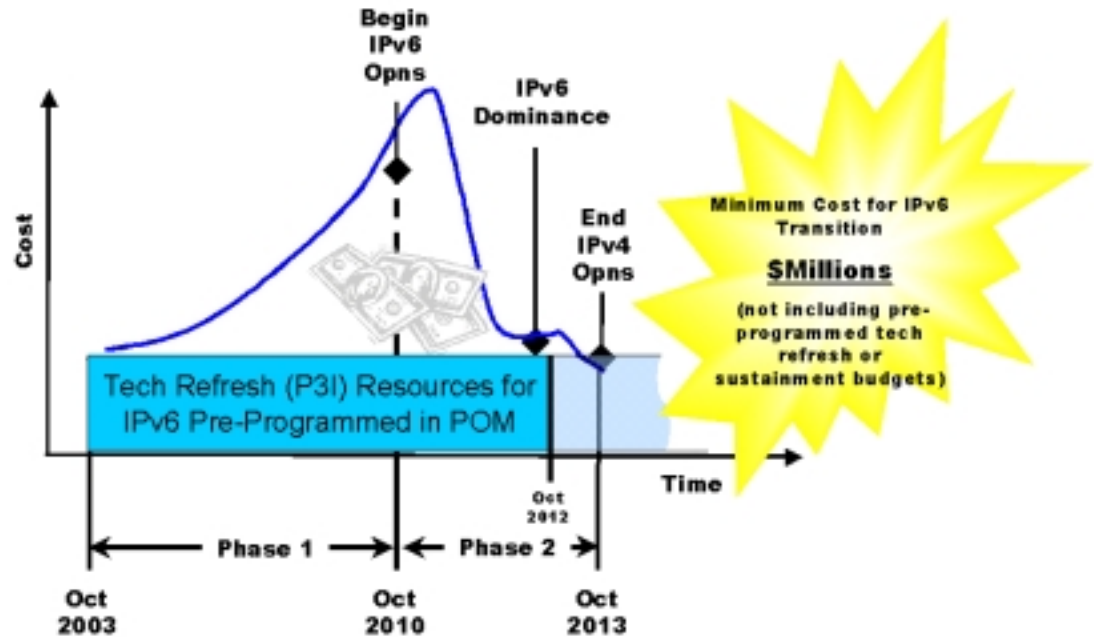
Army Perspectives on IPv6 Migration*

Acquisition Challenges

- 2008 Native IPv6 mandate changed to goal due to cost.
- Technical Challenges:
 - Transition:
 - Standards still Drafts
 - Security
 - Tactical Wireless:
 - Routing
 - Header compression
 - Mobile IPv6:
 - Security
 - New Service
 - Dual Stack Routing
 - Application Migration

Cost Graph

Procurement, Development, Testing, Experimentation, Transition Mechanisms



- **IPv6 Viewed as Critical Force Multiplier**
- **Lagging areas may delay “Native IPv6”**
 - Transition Mechanisms, QOS,
 - Security, IPv6 over Wireless

* Based on IPv6 Briefing to Dr. Frankel, May 2004,
www.opengroup.org/gesforum/uploads/40/5542/Army_Open_Group.ppt



Perceptions on Link-16

- ◆ Link-16 is inflexible.
- ◆ Link-16 is “full” or “saturated”.

Reality:

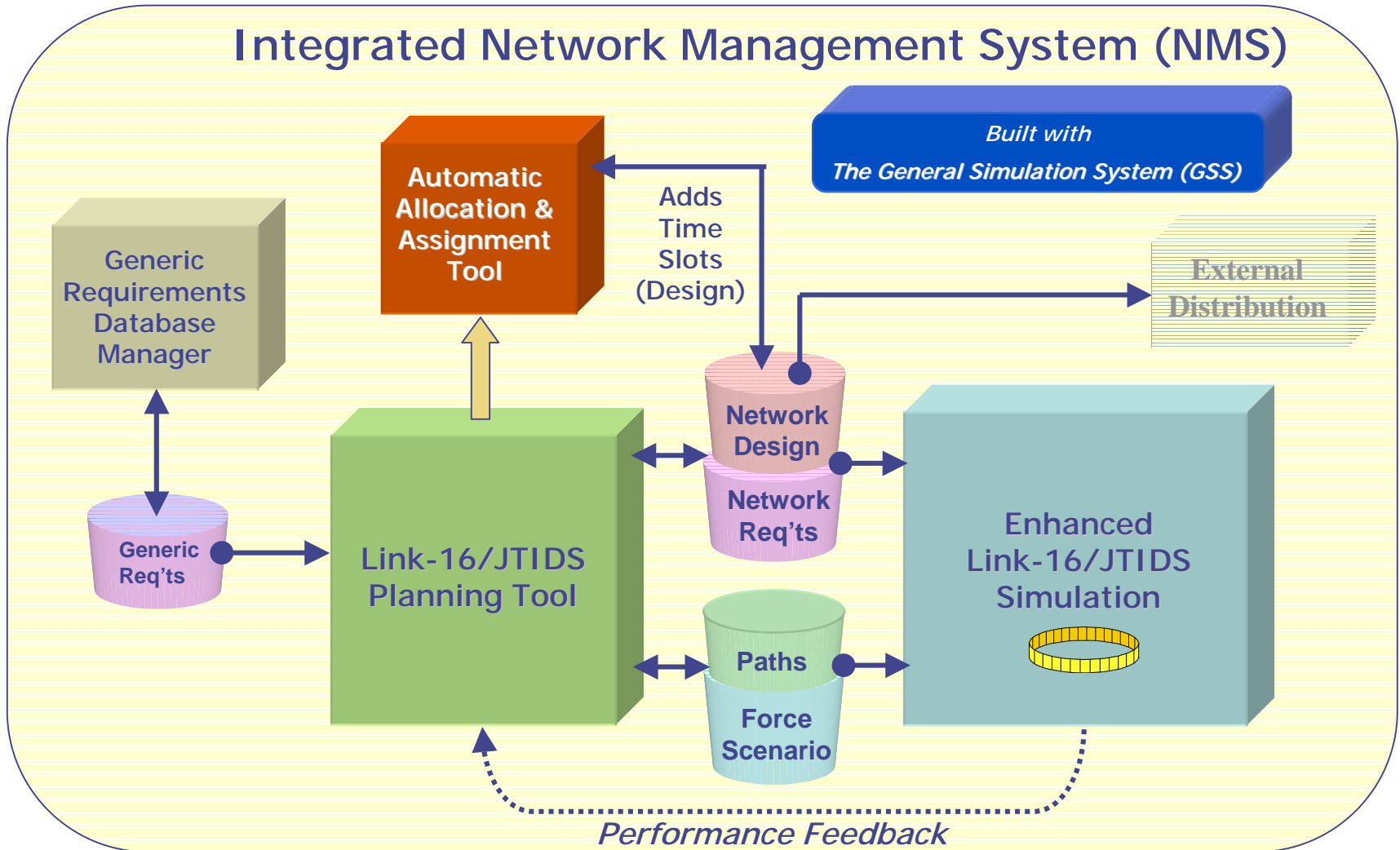
- ◆ Link-16 network management approach is over 20 years old, and hasn't changed much.
- ◆ Only a fraction of the JTIDS/MIDS capabilities are actually used.

Solution:

The PSI Link-16 Network Management System (NMS).

Link-16 Network Management System

Scenario & Network Design, Simulation



Link-16 NMS Capabilities

- ◆ **Accurate & Fast Radio Propagation:**
 - Effects of 3D Terrain
 - Effects of Transmitter Power Levels & Antennas
 - Dynamic Calculation of Mutual Interference & Noise
- ◆ **Visualization:**
 - 2D Terrain & Contours, Political Areas
 - Platform Icons (Air, Sea, Ground)
 - RF Link Connectivity
 - ◆ In tabular form
 - ◆ Dynamically between platforms over the terrain
 - Dynamic Position Updates
- ◆ **Automatic Allocation of Time Slots**
- ◆ **Dynamically Assess Network Performance**





Link-16 NMS Components & Benefits

Generic Requirements Database Manager

Manage Communications Requirement Generically

Plan

Link-16/JTIDS Planning Tool

Link-16 Operational Network Planning Tool

- Provides facilities for adding, changing and deleting flight paths
- Flight paths can be created and modified graphically
- Provides facilities to create and view operational nets & links graphically
- Interactive creation, store and recall of operational scenarios

Solves Link-16 Saturation "Problem"

- Maximal Use of Existing Link-16 Capabilities, Full Use of Space, Time & Traffic Requirements
- New Terminal Algorithms to Maximize Capacity, Increased Terminal Assignments

Design

Automatic Allocation & Assignment Tool

Link-16 Automated Time Slot Allocation & Assignment

Builds Network in Minutes

- Provides Manual Time Slot Overrides

Test

Enhanced Link-16/JTIDS Simulation

High Fidelity Link 16 Simulation

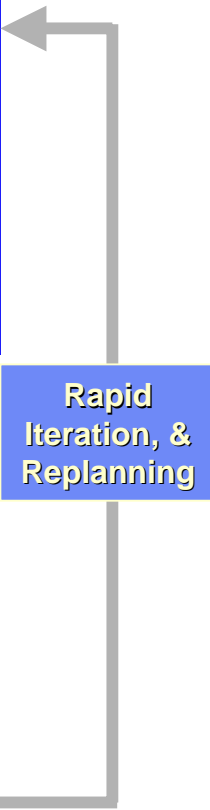
- Validate Network Designs Quickly
- Test Different Operational Scenarios
- Generate Network Traffic
- Produce Metrics

Low Risk, Low Cost Validation

High Speed Models

Dynamic Scenarios & Traffic

Automatically Collects: MOPs & MOEs





Overall Benefits

- ◆ Network Performance:
 - 5-10 time more network capacity anticipated.
 - ◆ Leverage full capabilities of the terminal
 - ◆ Expand terminal capabilities:
 - More assignments
 - New algorithms
- ◆ Huge reduction in Network design and build times.
- ◆ Rapid, low-cost and low-risk validation of network designs by high-fidelity simulation.

Realize the flexibility and capacity to meet the Increasing operational demands of Link-16 for NCOs.

Impacts and Challenges

◆ The “Usual suspects”:

- Inertia
- Doctrine, Policy, Organization, Socialization
- Acquisition cycles

◆ Link-16 is a *“legacy”* radio system

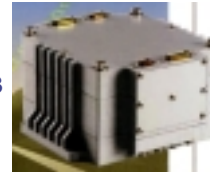
◆ Link-16 NMS Tool Set:

- Disruptive technology.
- Needs hardening and “productization”.
 - ◆ Initial testing in actual terminals
 - ◆ Preliminary operational use to gather feedback
 - ◆ Integration into AOC...

Future Direction of Tool Set

- ◆ Tasked to put our network design into new and existing terminals for testing.

New WDL-A 50 in³



MIDS-LVT



- ◆ Documenting algorithms and enhancements for sizing by terminal builders.
- ◆ Applications:
 - On-Going analysis of Link-16 as a Weapons Data link (WDL) for Small Bombs.
 - Link-16 Simulation interface to JSAF to support C³ in war gaming.
- ◆ Basis for PSI Architectural Assessment work.

JSAF-JTIDS Test Scenario



AFRL GIESim

UAV

SOF

No Direct Comm to F-15 in valley

F-15

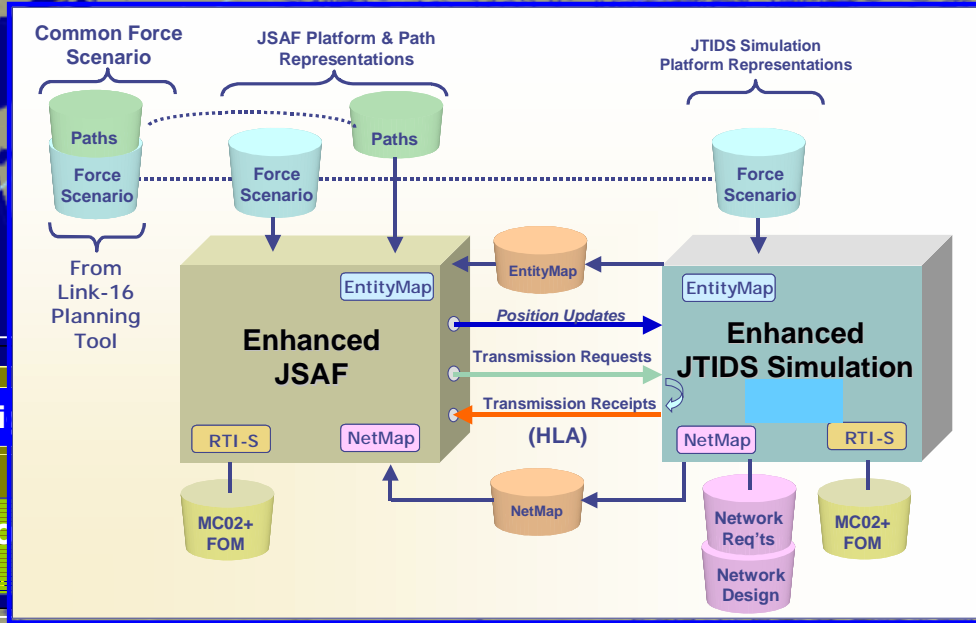
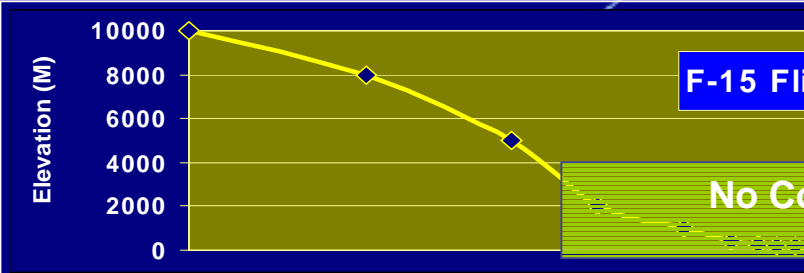
LEGEND

Communications

- Direct OK
- Direct NG
- Relay OK

- Target
- Pop-up Threat

F15 Flight Path





Partnering and Teaming Link-16 NMS and GSS

- ◆ Open to ideas.
- ◆ Briefing widely across services.
- ◆ Exploring a number of relationships.



Link-16 NMS Demo and Q&A