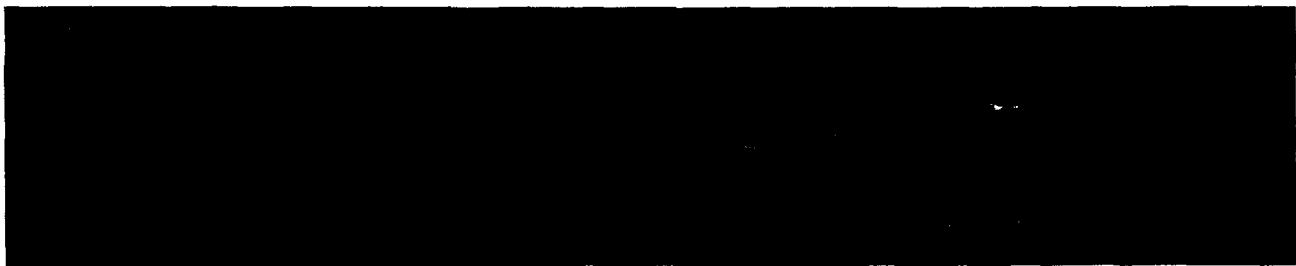


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INSTITUTE FOR SIMULATION AND TRAINING



Contract Number N61339-89-C-0043
PM TRADE
DARPA

August 7-8, 1990

Summary Report

The Third Workshop on Standards
for the Interoperability of
Defense Simulations

Volume II: *View-Graphs from Plenary
Sessions*



IST

91-11422



Institute for Simulation and Training
12424 Research Parkway, Suite 300
Orlando, FL 32826

University of Central Florida
Division of Sponsored Research

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This report presents a summary of the activities of The Third Workshop on Standards for the Interoperability of Defense Simulations sponsored by DARPA and PM TRADE, and hosted by IST/UCF on August 7-8, 1990.					
The primary goal of this workshop was to recommend revisions to the proposed <u>Draft Standard for Protocol Data Units in Distributed Interactive Simulation (DIS)</u> published in June 1990 by IST.					
This volume contains the view-graphs from the Plenary sessions.					
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Contract Number N61339-89-C-0043
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August 7-8, 1990

Summary Report

The Third Workshop on Standards
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Volume II: *View-Graphs from Plenary
Sessions*

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12424 Research Parkway, Suite 300
Orlando, FL 32826

University of Central Florida
Division of Sponsored Research

IST-CR 90-13

PREFACE

Purpose

The purpose of this report is to present the minutes from the Third Workshop on Standards for the Interoperability of Defense Simulations. This workshop took place in Orlando, Florida on August 7-8, 1990 and was hosted by the Institute for Simulation and Training (IST), a part of the Division of Sponsored Research for the University of Central Florida (UCF).

This continuing work on standards is sponsored by the Defense Advanced Research Projects Agency (DARPA) and is administered by the Army Project Manager for Training Devices (PM TRADE).

Background

This is the third workshop concerning the development of technical standards for networking defense simulations. These standards are intended to meet the needs of large scale simulated engagement systems which are being used increasingly to support system acquisition, test and evaluation, tactical warfare simulation and training in DoD. The primary goal of this workshop was to recommend revisions to the proposed Draft Standard for Protocol Data Units in Distributed Interactive Simulation (DIS) published in June 1990 by IST. Another goal of the workshop was to continue work towards developing standards in other areas of Distributed Simulation.

Workshop Summary

The two day workshop focused on three major topic areas. These are: Communication Protocols, Terrain Databases, and a new area called Performance Measures.

Discussions in the Communication Protocols Working Group were led by Joe Brann, IBM and Mike McGaugh, McDonnell Douglas. This group concerned itself with resolving issues related to the Draft Standard. Recommendations were made for incorporation in the revised draft standard which will be published in January 1991. One subgroup, the Communications Architecture Subgroup, met separately. This group focused on issues related to communications architecture. In particular, this group sought to more clearly define the services that a DIS requires from the communication architecture supporting the DIS application. This group was led by Steve Blumenthal, BBN and Al Kerecman, USACECOM.

Discussion in the Terrain Database Working Group was led by Mr. Dexter Fletcher, IDA. This group continued its work with representation and interpretation of terrain data.

A new working group, the Performance Measures Working Group, met to discuss human and equipment performance measures. This working group was led by Dr. Bruce McDonald, IST. This group focused on operator and equipment performance measures as well as required level of fidelity.

This report has been issued in three volumes. Volume I contains the minutes for the plenary session and a list of attendees. Volume II contains the view-graphs from the plenary sessions. Volume III contains the view-graphs used in presentations made in the individual working groups.

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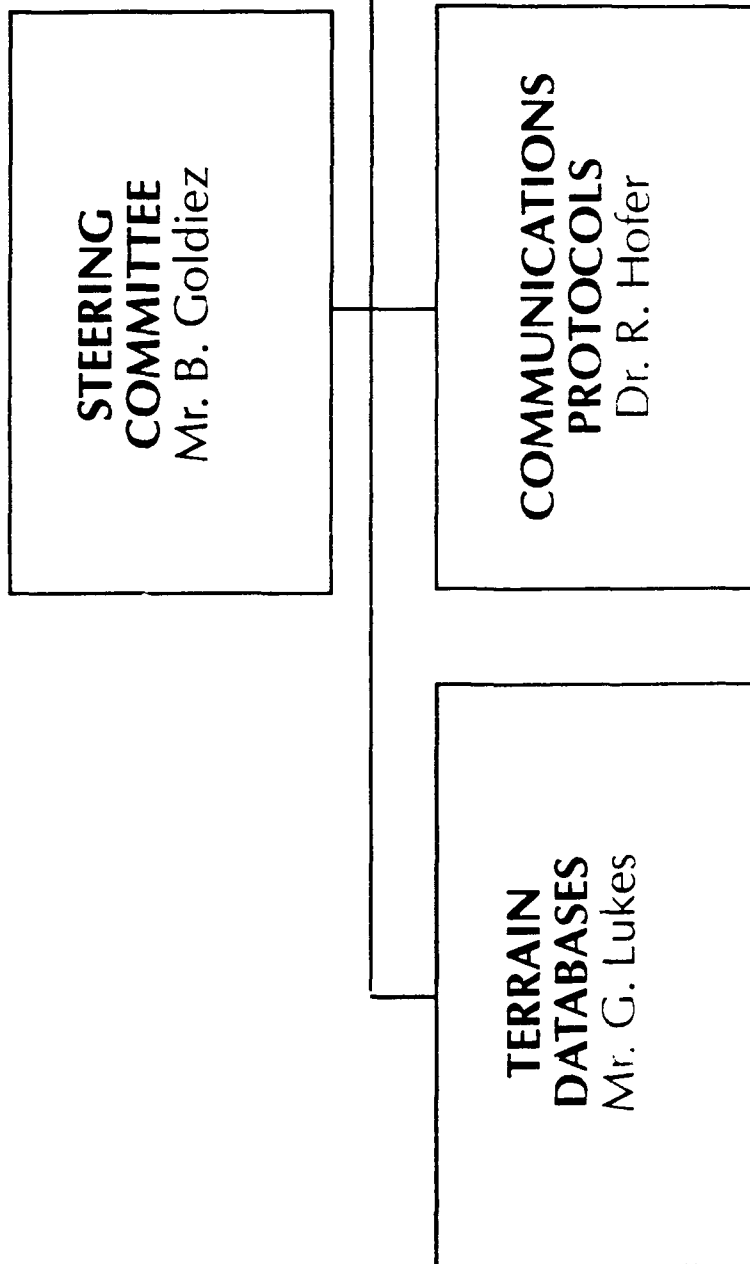
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WELCOME ANNOUNCEMENTS AND REVIEW OF AGENDA

**Mr. Brian Goldiez
Chairman of the Steering Committee
Institute for Simulation and Training**



STEERING COMMITTEE MEMBERS

Brian Goldiez	IST
Dr. Bruce McDonald	IST
Dr. Ron Hofer	PM TRADE
Gene Wiehagen	PM TRADE
LTC (P) Jim Shiflett	DARPA
Maj. Jim Wargo	DARPA
LCDR Dennis McBride	DARPA
George Lukes	USA-ETL
LTC Steve Sarner	USAF-SIMSPO
Bill Harris	NTSC
Neale Cosby	IDA
Dr. Dexter Fletcher	IDA
Dr. Joe Brann	IBM
Sam Knight	CAE-Link
Dr. Duncan Miller	BBN
Richard Moon	Evans and Sutherland
Tom Nelson	McDonnell Douglas
Mike McGaugh	McDonnell Douglas

PROGRAM

Tuesday, 7 August 1990 - Amelia / Sanibel

- 0730 **Registration**
- 0830 **Welcome, Announcements and Review of Agenda**
Mr. Brian Goldiez
Chairman of the Steering Committee
Institute for Simulation and Training
University of Central Florida
- 0900 **Keynote Address**
The Honorable Christopher Jehn
Assistant Secretary of Defense for
Force Management and Personnel
- 0930 **Standards Progress**
Dr. Bruce McDonald
Program Manager
Institute for Simulation and Training
University of Central Florida
- 1000 **Break**
- 1030 **Overview of Standard**
Christina L. Pinon
Project Engineer
Institute for Simulation and Training
University of Central Florida
- 1100 **Question and Answer Period**
Panel: Dr. Bruce McDonald
Christina L. Pinon
Karen Danicas
Robert Glasgow
- 1130 **Lunch (not provided)**

PROGRAM Con't

Tuesday, 7 August 1990 - Amelia / Sanibel

- 1300 - 1330 **"Distributed Warfighting Simulation,"**
Maj. James Wargo, DARPA
- 1330 - 1350 **"Technology Push - Requirements Pull:
A Navy Position, "**
T. Tiernan, K. Boner, NOSC
- 1350 - 1410 **"Top Level Standard Implementation,"**
T. Hoog, ASD/ENET
- 1410 - 1430 **"The Advantage of Using Quaternions
Instead of Euler Angles for Representing
Orientation, "**
Dr. J. Burchfiel, BBN
- 1430 - 1450 **"Bit Encoded Attributes in Distributed
Interactive Simulation: Why They are a
Bad Approach and How to Fix Them,"**
M. Robkin & R. Saunders, Hughes Sim.
Systems
- 1450 - 1510 **"The ACME Radar PDU -- An Alternative
Approach to Emissions, "**
A. Catman, BBN
- 1510 - 1540 **Break**
- 1540 - 1600 **"Seven Critical Technical Issues in the
Draft Military Standard for Distributed
Interactive Simulation,"**
R. Schaffer, BBN
- 1600 - 1620 **"Floating Point is Faster and More Flexible
Than Fixed Point,"**
J. Smith, BBN
- 1620 - 1640 **"Query Protocol for Distributed Interactive
Simulation,"**
M. Robbins & R. Saunders,
- 1640 - 1700 **"The Importance of Experimental Evaluation
in Protocol Design,"**
R. Rabines and A. Pope, BBN

PROGRAM

Wednesday, 8 August 1990

0730 **Registration**

0830 **Working Sessions**

Terrain Databases - Amelia

Panel: Mr. George Lukes, ETL

Sub-group: Correlation

Sub-group: Dynamic Terrain

Sub-group: Unmanned Forces

Sub-group: Interim Terrain Database

Communications Protocols - Sanibel

Panel: Dr. Ron Hofer, AMC PM TRADE

Sub-group: Interface

Sub-group: Time/Mission Critical

Sub-group: Security

Sub-group: Communication Architecture

Performance Measures - Marco A

Panel: Dr. Bruce McDonald, IST/UCF

Sub-group: Operator Performance Measures

Sub-group: Equipment Performance Measures

Sub-group: Fidelity Measures

1130 **Lunch (not provided)**

1300 **Working Sessions Continue**

1330 **Government - Only Session** (concurrent with
subgroup discussions)

1500 **Break**

1530 **Subgroup Recommendations to Conference - Amelia / Sanibel**

1630 **Concluding Remarks/Announcements**
Mr. Brian Goldiez

PROGRESS ON STANDARD FOR THE INTEROPERABILITY OF DEFENSE SIMULATIONS

**Dr. Bruce McDonald
Program Manager
Institute for Simulation and Training**

FUNDING

Funded by DARPA

Administered by PMTRADE

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WHAT IS DISTRIBUTED INTERACTIVE SIMULATION (DIS)?

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**DIS IS INTENDED FOR
COMBINED ARMS EXERCISES
WHERE EMPHASIS IS ON TEAM
INTERACTION**

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**DIS IS NOT INTENDED
FOR INITIAL OPERATOR
SKILLS TRAINING**

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DIS WILL BE USED TO

- Train teams
- To function smoothly with other teams
- Evaluate the ability of equipment to function smoothly with other equipment and personnel

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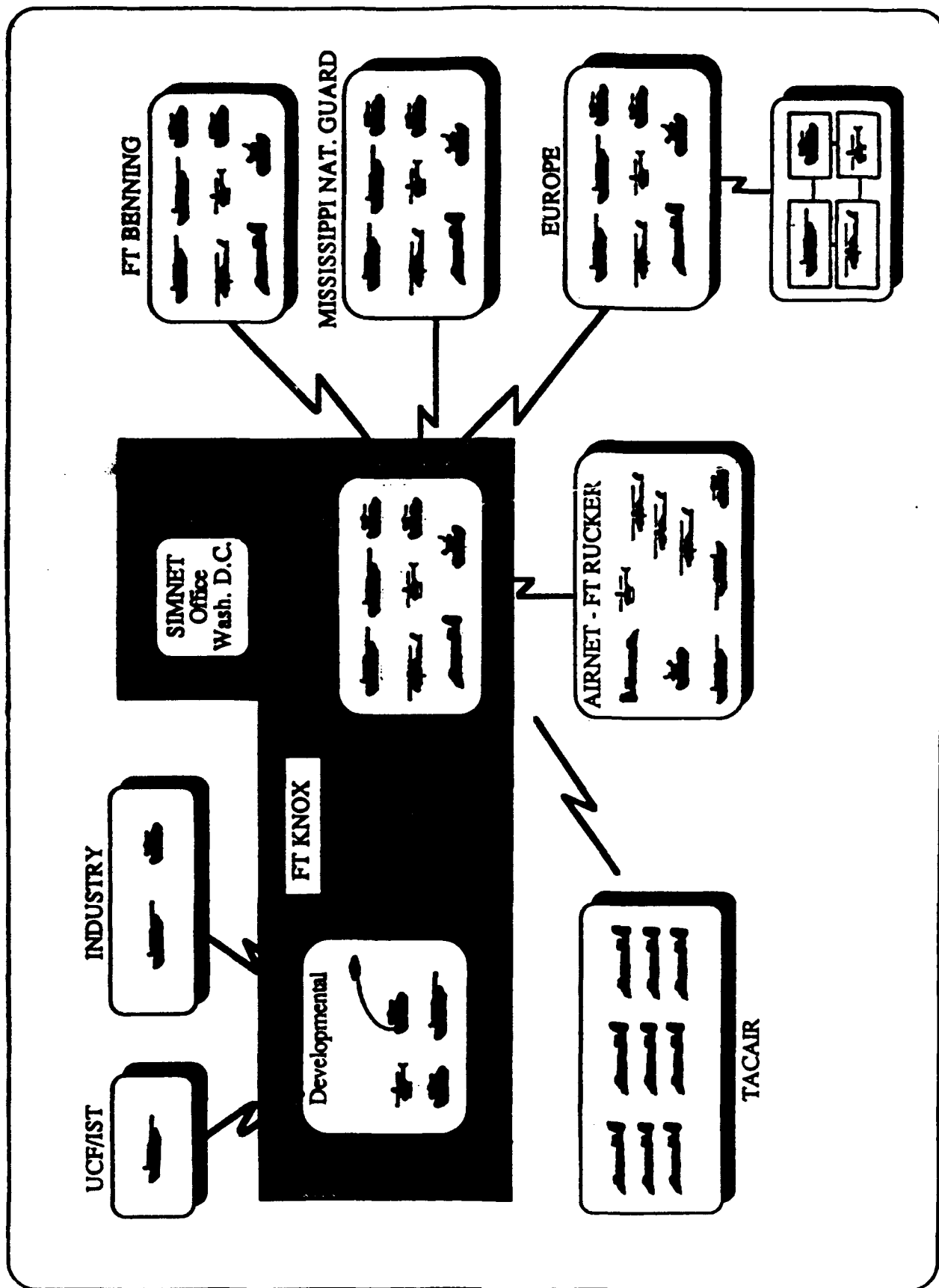
APPLICABILITY OF STANDARD

- Communications
- Between dissimilar simulations
- Over long haul network
- Between simulation and actual equipment

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SIMNET as a Combined Arms Joint Military Technology

HISTORY

FIRST WORKSHOP	AUGUST 1989
SECOND WORKSHOP	JANUARY 1990
SUBGROUP MEETINGS	MARCH 1990
INITIAL DRAFT STD	JUNE 1990

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SCOPE OF STANDARD

Standardize distributed interactive simulation
at the protocol data unit level

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PURPOSE

- Standard
 - Standardize protocol data units
- Rationale Document
 - Explain why
 - Document other decisions

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APPROACH

- Aggressively propose workable solutions
 - Don't wait for perfect solution
 - Avoid "needs further study"
- Allow for expansion and modification

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OPEN SYSTEMS INTERCONNECT (OSI) COMMUNICATIONS PROTOCOL

- NIST issued FIPS two years ago
- Communications systems must include government OSI protocol (GOSIP)
 - All new systems
 - All major upgrades
- Effective 15 August 1990
- DIS Standard assumes OSI protocol

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IST STARTING STUDY OF OSI PROTOCOL PERFORMANCE

- Measure performance of current TCP/IP Protocol
- Create OSI stacks and measure performance
 - ISO Development Environment (ISODE) and Light Weight Presentation Protocol (LWPP)
 - TCP/IP, XTP, Etc.
 - Ethernet, Token Ring, FDDI
- Make use of SPAWAR Light Weight Protocol

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HOW YOU IMPACT THE STANDARD

- Contribute to subcommittee recommendations
- Submit position papers

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WHERE DO WE GO FROM HERE?

- Finalize current set of PDU's
- Recommend other PDU's
 - Simulation Management
 - Performance Measures
 - Data Collection
- Develop overall application/system description

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WHERE DO WE GO FROM HERE?

(Cont)

- Develop or select standards
 - Terrain Database
 - Emitter Database
- Develop Recommendations
 - Level of Fidelity
 - Security
 - Unmanned Forces

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AFTER THE WORKSHOP

- Position paper deadline 1 November
- Complete draft standard early January
- Obtain copies from UCF
- Next workshop in March

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STANDARDS APPROVAL PROCESS

- PMTRADE Executive Agent
- Project number from Battle Creek, Michigan
- Approval by PMTRADE, NTSC, USAF SIMSPO
- Coordination with industry and DOD
- Resolve comments by DOD
- Approve documents
- PMTRADE maintain documents



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STANDARDS APPROVAL PROCESS

(Cont)

- Copies to Philadelphia
- PMTRADE/ANSI convert to ISO standard
- PMTRADE/ANSI work with ISO
- Approval as ISO standard
- Cancel MIL-STD
- PMTRADE maintain currency

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ACCURACY OF REPRESENTATION

In specifying accuracy requirements remember to differentiate between

- Internal model of own platform - High accuracy
- Representation of other platforms - Less accuracy

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FIDELITY TRADEOFFS

DIS requires many simulators

- Requires low cost simulators
- Requires tradeoffs in fidelity

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GOALS OF WORKSHOP

- Complete draft standard for PDU's
- Address other issues

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SUMMARY OF DRAFT STANDARD AND RECOMMENDATIONS SINCE 15 JUNE 1990

**Christina Pinon
Project Engineer
Institute for Simulation and Training**

SUMMARY OF THE DRAFT STANDARD

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DRAFT STANDARD DOCUMENTS

- RATIONALE DOCUMENT
 - Working group recommendations
 - Position papers
 - Subsequent subgroup meetings
 - IST Analysis
- STANDARD DOCUMENT
 - Requirements for messages concerning the interaction of entities in a DIS exercise

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DISTRIBUTED INTERACTIVE SIMULATION

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DISTRIBUTED INTERACTIVE SIMULATION DEFINITION

An exercise in which simulated entities, generated by a number of interconnected simulation devices, are able to interact within a computer generated environment.

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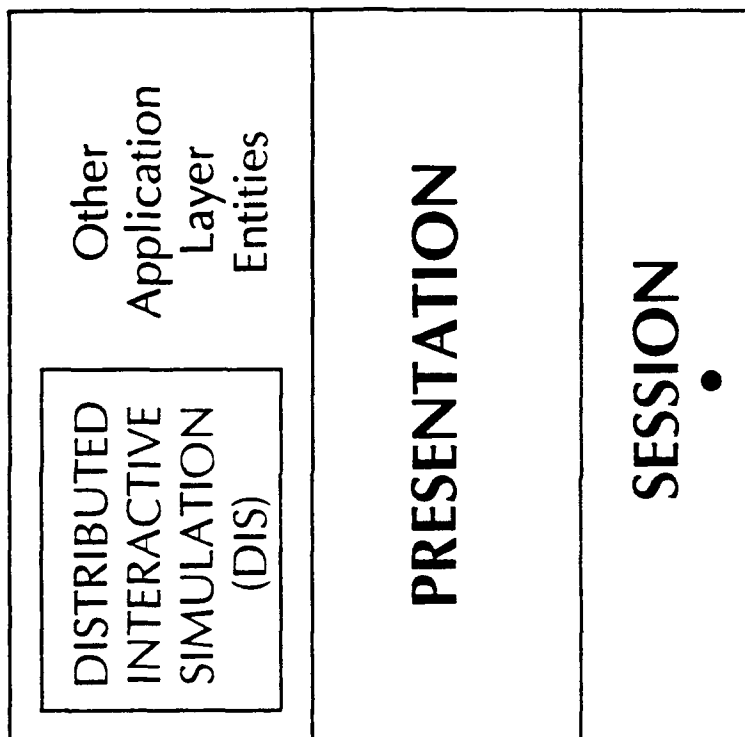
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OSI REFERENCE MODEL

LAYER

APPLICATION

7



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DIS COMPONENTS

Entity
Information

Entity
Interaction

Environment
Information

DIS
Management

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ENTITY INFORMATION

- Entity Type
- Location and Orientation
- Appearance
 - Visual
 - Electronic Sensors

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ENTITY INTERACTION

- Weapons Fire
- Update Rate Control
- Logistics Support
- Collisions
- Electronic Interactions

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ENVIRONMENT INFORMATION

- Terrain
- Weather Conditions
- Degrees of Daylight/Darkness
- Other Environment Effects

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DIS MANAGEMENT

- Network Management
- Simulation Management
- Performance Measures

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DIS DRAFT STANDARD

Entity
Information

Entity
Interaction

Environment
Information

DIS
Management

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Protocol Data Units for DISTRIBUTED INTERACTIVE SIMULATION

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PDU HEADER

FIELD SIZE (bits)	PROTOCOL DATA UNIT HEADER FIELDS	
8	EXERCISE IDENTIFIER	8 bits uns int
8	PROTOCOL DATA UNIT KIND	8 bit enum
16	PADDING	16 bits unused

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ENTITY INFORMATION

- Entity Appearance

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ENTITY APPEARANCE PDU

FIELD SIZE (bits)	ENTITY APPEARANCE PDU FIELDS	
48	ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
16	PADDING	16 bits unused
32	ENTITY TYPE	32 bits uns int
96	ENTITY MARKING	Entity Marking - 12 element character string
32	ENTITY CAPABILITIES	ENTITY CAPABILITIES - 32 bits, boolean characters
32	TIME OF ISSUE	TIME STAMP - 32 bit uns int
32	ENTITY APPEARANCE	APPEARANCE - 32 bit uns int
96	ENTITY LOCATION	X COORDINATE - 32 bit signed integer
		Y COORDINATE - 32 bit signed integer
		Z COORDINATE - 32 bit signed integer
96	ENTITY VELOCITY	X COMPONENT - 32 bit signed integer
		Y COMPONENT - 32 bit signed integer
		Z COMPONENT - 32 bit signed integer

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ENTITY APPEARANCE PDU

96	ENTITY ACCELERATION	X COMPONENT-32 bit signed integer
		Y COMPONENT-32 bit signed integer
		Z COMPONENT-32 bit signed integer
96	ENTITY ORIENTATION	YAW ANGLE - 32 bit BAM
		PITCH ANGLE - 32 bit BAM
		ROLL ANGLE - 32 bit BAM
96	ENTITY ANGULAR VELOCITY	YAW RATE - 32 bit signed integer
		PITCH RATE - 32 bit signed integer
		ROLL RATE - 32 bit signed integer
16+(N)(16) (N = Number of Articulated Parts)	ARTICULATED PARTS	#articulated parts*-16 bits uns int
		Part 1 AZIMUTH - 8 bit BAM
		Part 1 ELEVATION - 8 bit BAM
		Part 2 AZIMUTH - 8 bit BAM
		Part 2 ELEVATION - 8 bit BAM
		.
		.
		.
		Part N AZIMUTH - 8 bit BAM
		Part N ELEVATION - 8 bit BAM

*** NOTE:**

For even numbers of articulated parts, a 16 bit padding shall be added to maintain 32 bit boundaries.

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FIGURE 4-16. Entity Appearance PDU (cont.)

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ENTITY INTERACTION

- Fire
- Detonation
- Update Request
- Update Response
- Service Request
- Service Cancel
- Service Complete
- Resupply Offer
- Repair Offer
- Collision

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FIRE PDU

FIELD SIZE (bits)	FIRE PDU FIELDS	
16	EVENT ID	16 bit uns int
48	FIRING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
48	TARGET ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
48	MUNITION ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
96	BURST DESCRIPTOR	MUNITION - 32 bit uns int
		DETONATOR - 32 bit uns int
		QUANTITY - 16 bit uns int
		RATE - 16 bit uns int
96	LOCATION	X COORDINATE - 32 bit signed integer
		Y COORDINATE - 32 bit signed integer
		Z COORDINATE - 32 bit signed integer
96	VELOCITY VECTOR	X COORDINATE - 32 bit signed integer
		Y COORDINATE - 32 bit signed integer
		Z COORDINATE - 32 bit signed integer
32	RANGE	32 bit uns int

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DETONATION PDU

FIELD SIZE (bits)	DETONATION PDU FIELDS	
16	EVENT ID	16 bit uns int
48	FIRING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
32	TIME OF DETONATION	32 bit uns int
96	BURST DESCRIPTOR	MUNITION - 32 bit uns int
		DETONATOR - 32 bit uns int
		QUANTITY - 16 bit uns int
		RATE - 16 bit uns int
48	MUNITION ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
16	PADDING	16 bits unused
96	VELOCITY VECTOR	X COORDINATE - 32 bit signed integer
		Y COORDINATE - 32 bit signed integer
		Z COORDINATE - 32 bit signed integer
96	LOCATION	X COORDINATE - 32 bit signed integer
		Y COORDINATE - 32 bit signed integer
		Z COORDINATE - 32 bit signed integer

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UPDATE REQUEST PDU

FIELD SIZE (bits)	UPDATE REQUEST PDU FIELDS	
48	ISSUING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
48	CHANGING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
8	PDU Kind	8 bit enum
24	Padding	24 bits unused
192	LINEAR THRESHOLD	X THRESHOLD - 32 bit uns int
		Y THRESHOLD - 32 bit uns int
		Z THRESHOLD - 32 bit uns int
	ROTATIONAL THRESHOLD	YAW ANGLE - 32 bit BAM
		PITCH ANGLE - 32 bit BAM
		ROLL ANGLE - 32 bit BAM
32	DURATION OF CHANGE	32 bit uns int

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SERVICE REQUEST PDU

FIELD SIZE (bits)	SERVICE REQUEST PDU FIELDS	
48	REQUESTING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
48	SUPPLYING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
8	SERVICE TYPE	8 bit uns int
24	PADDING	24

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COLLISION PDU

FIELD SIZE (bits)	COLLISION PDU FIELDS	
48	ISSUING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int
48	COLLIDING ENTITY ID	SITE ID - 16 bit uns int
		HOST - 16 bit uns int
		ENTITY - 16 bit uns int

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OTHER DETAILS RELATED TO THE PDU'S

- Header
 - Indicates type of PDU to follow
- Padding - 32 bit boundary
 - Efficient processing for 16 & 32 bit machines
- Information that would help in filtering out PDU's near beginning

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PROGRESS SINCE JUNE 15

- Thirteen Position Papers
- Informal Comments
- Subgroup Meeting - July 17 & 18

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POSITION PAPER ISSUES

- Use of Euler Angles
- Dead Reckoning
- Articulated Parts
- Data Representation
- Update Rate Control
- Weapons Fire & Combat Damage
- Electronic Emissions

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POSITION PAPER ISSUES

(Cont)

- Experimental Evaluation
- Validation
- Use of Fixed Point
- Bit-encoded Attributes
- Air Force Requirements
- Navy Requirements

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POSITION PAPER RECOMMENDATIONS

- Use Quaternions instead of Euler Angles for orientation representation
- Allow for specification of a variety of dead reckoning algorithms
- Dead reckon articulated parts
- Perform experimental evaluation and validation on recommended protocol

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POSITION PAPER RECOMMENDATIONS (Cont)

- Allow floating point representation where appropriate
- Replace bit-encoded attributes with a hierarchically defined keyword string
- Add six new PDUs to allow entities the ability to query each other for information

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INTERFACE & TIME/MISSION CRITICAL

Subgroup Meeting July 17 & 18

- **TIMESTAMPS**
 - Absolute and Relative (LSB)
 - Time at which data is valid
 - Simulators using absolute timestamp should support the use of relative
- **BAMs**
 - Should be represented by UNSIGNED integers
- **NEGATIVE NUMBERS**
 - Represented as TWO'S COMPLIMENT

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SUBGROUP RECOMMENDATIONS (Cont)

- Use diagrams to help clarify certain requirements
- All instances of UNSIGNED INTEGERS used for calculations should be specified as SIGNED
- Need representation for:
 - Tracers
 - Amphibious Vehicles

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SUBGROUP RECOMMENDATIONS

(Cont)

- Interim RADAR PDU recommended for Electronic emissions until database developed for EMITTER PDU
- Include function of GUISES

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ISSUES FOR FURTHER STUDY

- Articulated parts
- Electronic emissions
- Use of Quaternions in place of Euler angles
- Production of a Handbook to accompany Standard

iST

Institute for Simulation & Training



DISTRIBUTED WARFIGHTING SIMULATION

**LTC Mark Pullen
LCDR Dennis McBride
MAJ James Wargo
DARPA/TTO**

DWS

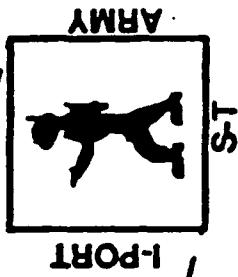
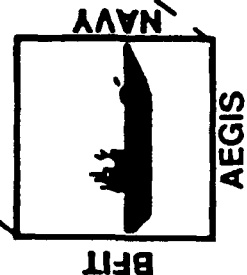
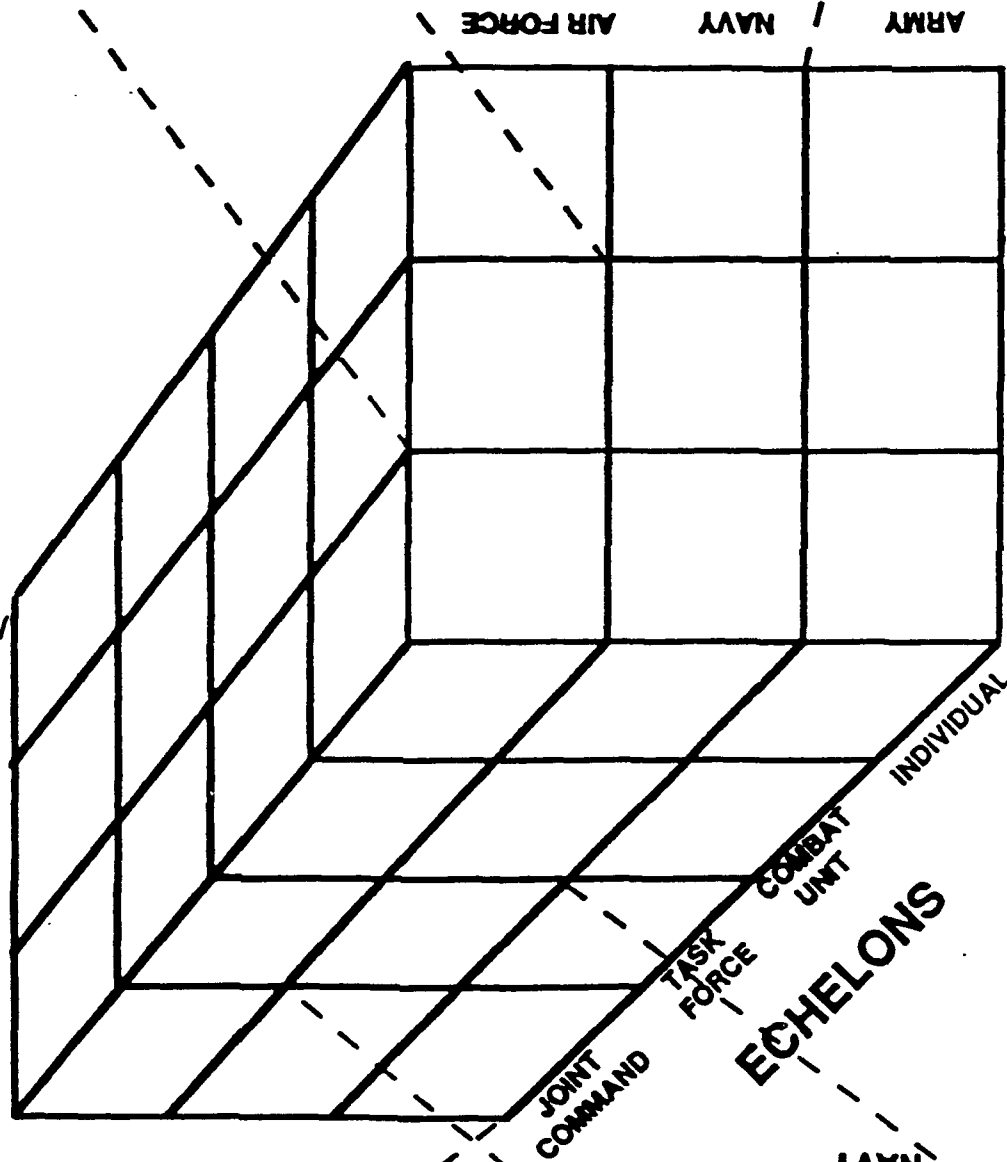
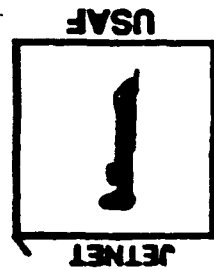
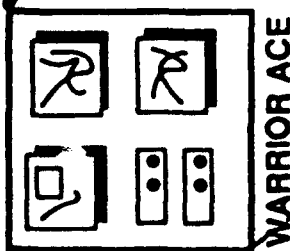
23 July 90

- 1 -

SEAMLESS SIMULATION: The need for standards for integrated warfighting

Common Architecture of Heterogeneous Simulations with Network Standards

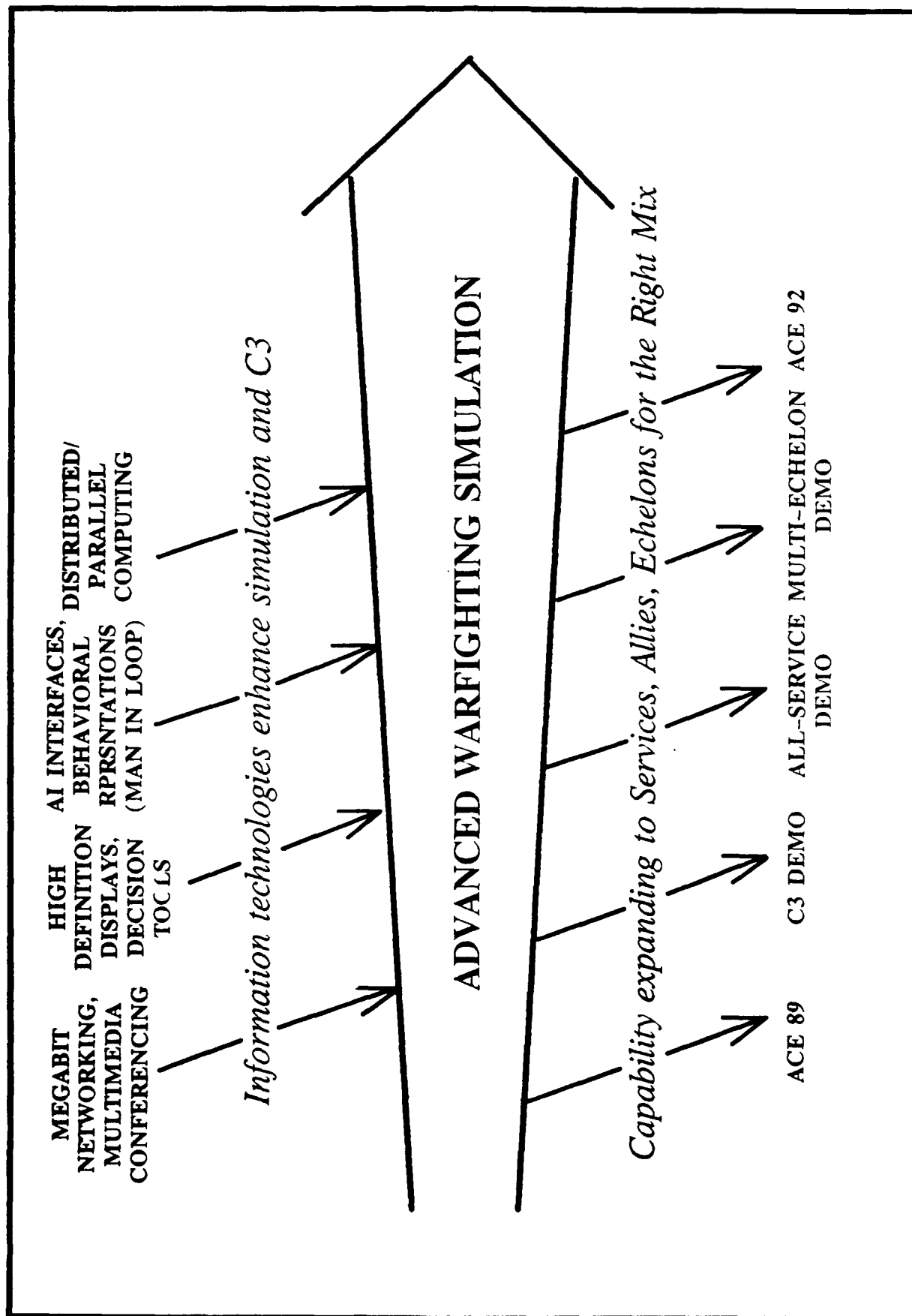
Across all Services at all Echelons

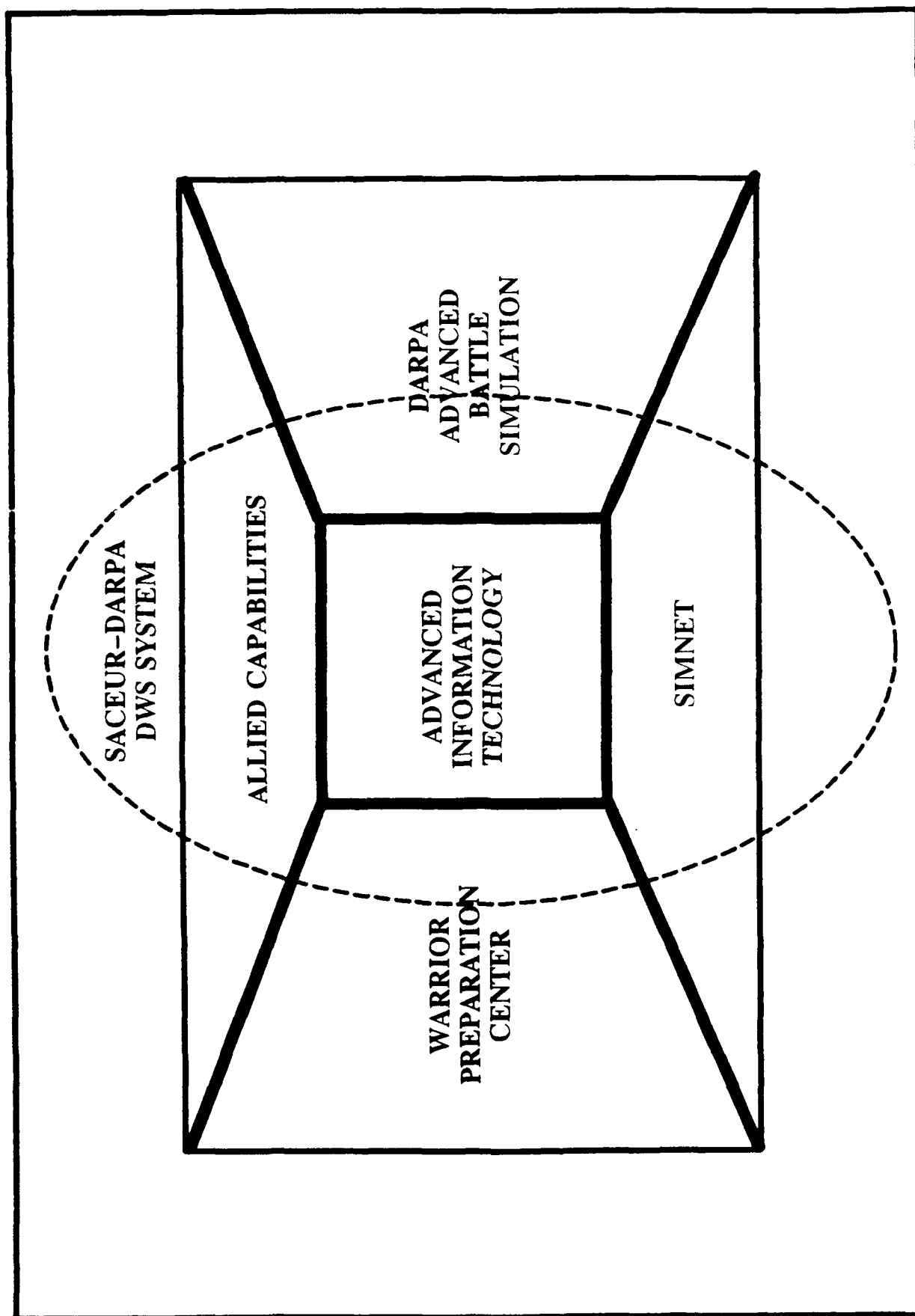


PROPOSED SACEUR-DARPA DISTRIBUTED WARFIGHTING SIMULATION SYSTEM

PURPOSES:

- Technology for interoperation of NATO wargaming simulation: multiple sources, multiple levels
- Testbed to evolve simulation and C3 technologies for DWS application
- Supports SACEUR wargaming ACE-92 and beyond
- Convergence of exercise and real-world C3





23 July 90

DWS

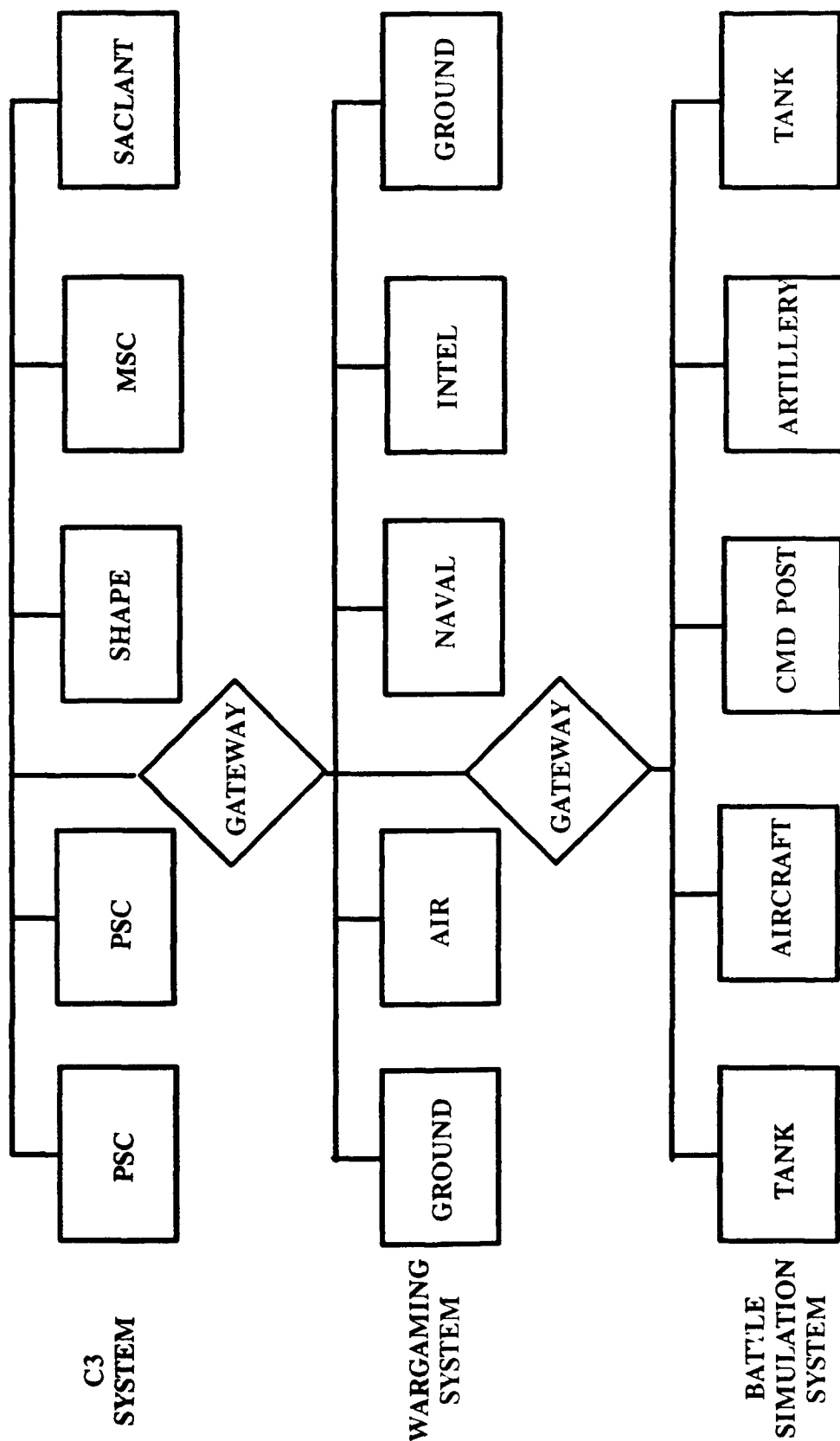
- 4 -

PROTOCOL-BASED INTEROPERABILITY

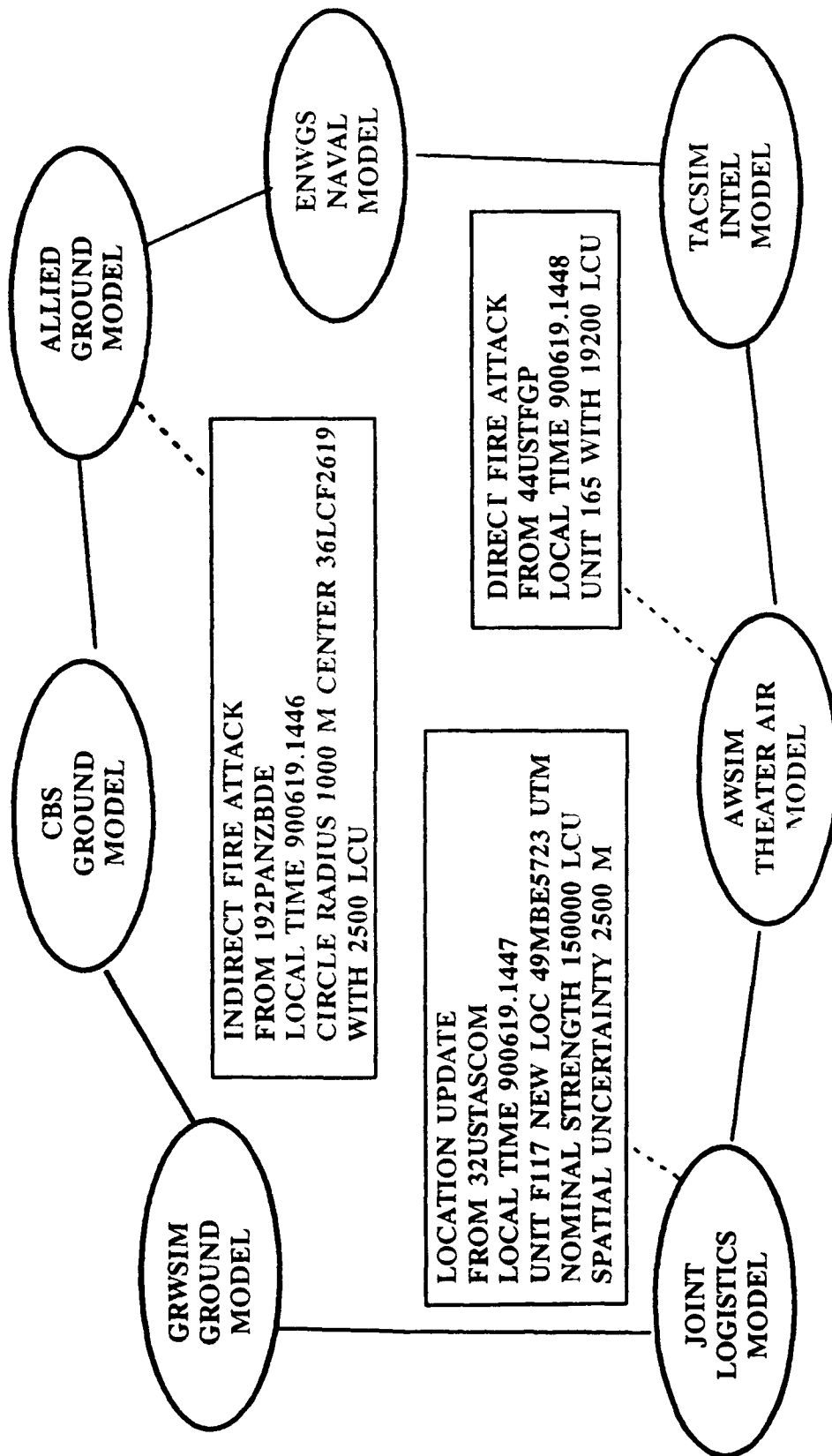
ADVANTAGES

- **players and processing can be partitioned**
(allows physical separation using network)
- **facilitates joining various Service models**
(land, air, sea, intelligence, logistics, ...)
- **allows models to be tailored to forces**
(particularly valuable for NATO)
- **adding/replacing models becomes easier**

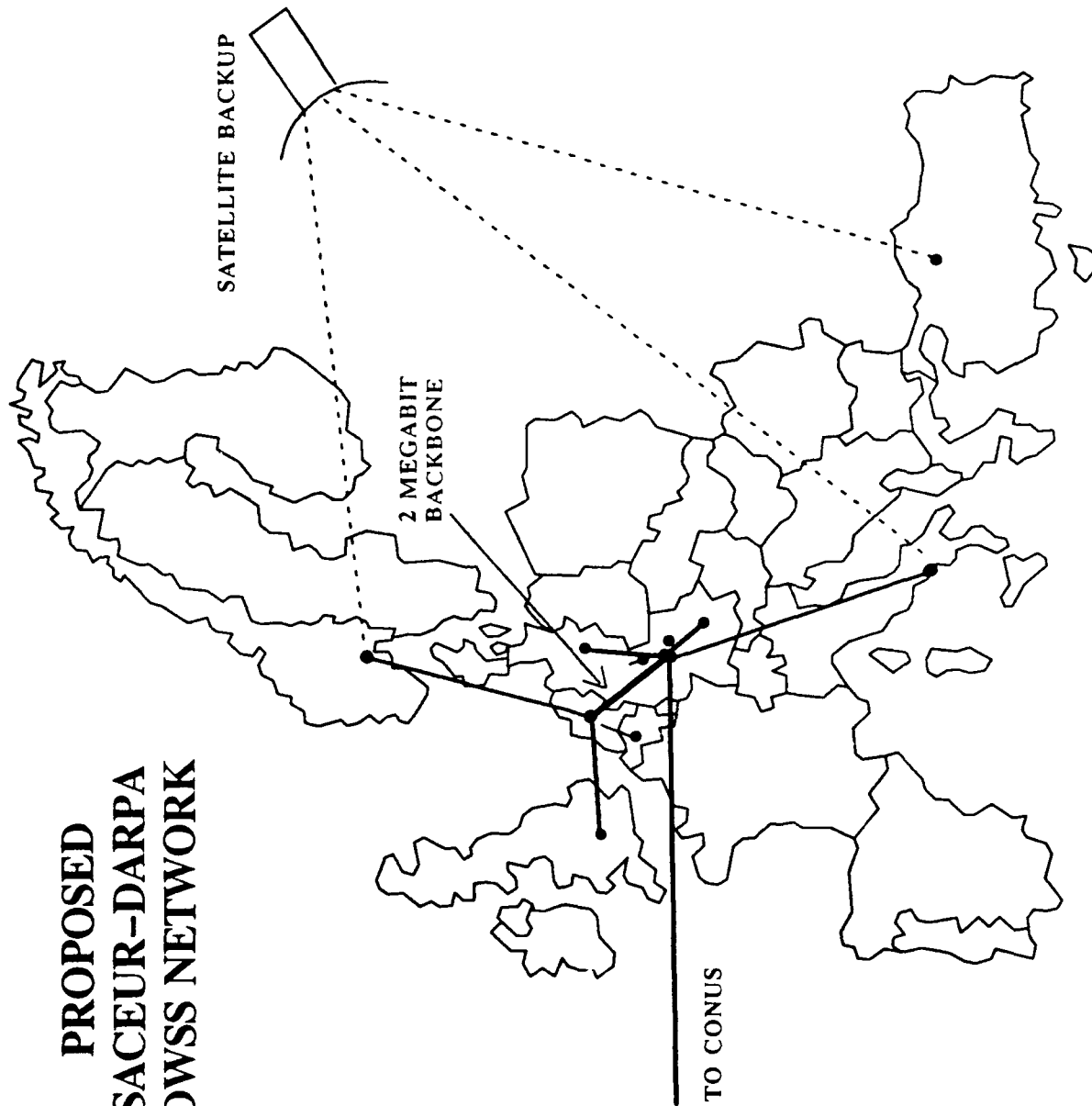
MULTIECHELON INTEROPERABILITY



PROTOCOL APPLICATION EXAMPLES



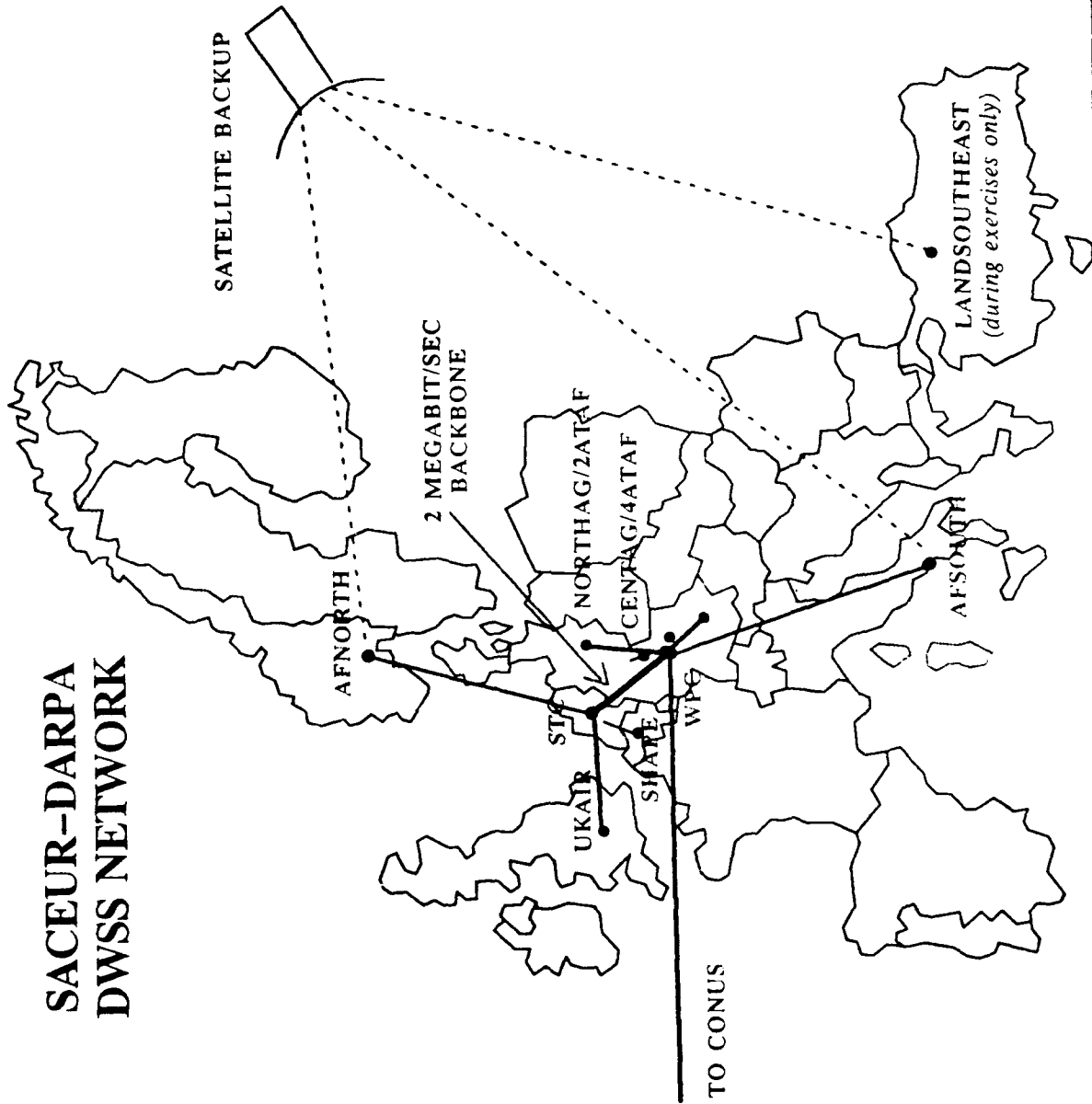
**PROPOSED
SACEUR-DARPA
DWSS NETWORK**



23 July 90

DWS

SACEUR-DARPA DWSS NETWORK



FOR OFFICIAL USE ONLY

24 July 90

SACEUR-DARPA DWSS

DRAFT

PROPOSED SACEUR-DARPA DISTRIBUTED WARFIGHTING SIMULATION NETWORK

(DWSNet)

- Video/multimedia conferencing, voice, and fax via ST real-time packet protocol
- Initially connects SHAPE, MSC and PSC headquarters, STC, WPC
- Expandable to Corps-level players for major exercises using WPC shelters
- Integrated shared-transponder satellite using NATO satellite provides redundancy and remote site connections
- SACEUR will encourage national connections

SACEUR-DARPA DWSS BENEFITS

SACEUR

- NATO-wide exercises with reduced travel & damage
- Prototype for quantum leap in NATO C3
- "Right mix" of training at all levels, enhanced via computing and networking
- Multi-way technology transfer among Allies

DARPA

- Major new capability for US Defense
- Showcase for advanced information technologies
- Testbed for advanced distributed simulation technology
- Technology transfer mechanism

DARPA TERRESTRIAL WIDEBANDNET

(TWBNet)

- Most robust of the T1 networks in Defense Research Internet
- Connects most major C3/wargaming sites, others to be added
- Will be tied to DWSNet by 1/2 megabit/second fiber link
- Supports TCP/IP protocols and ST (stream) virtual circuits
- Will support OSI protocols mid-1991
- Supports packet multimedia conferencing: video, voice, text, graphics, data
- Internettted East and West Coast with NSF, DOE and NASA T1 nets, MILNET

DWS

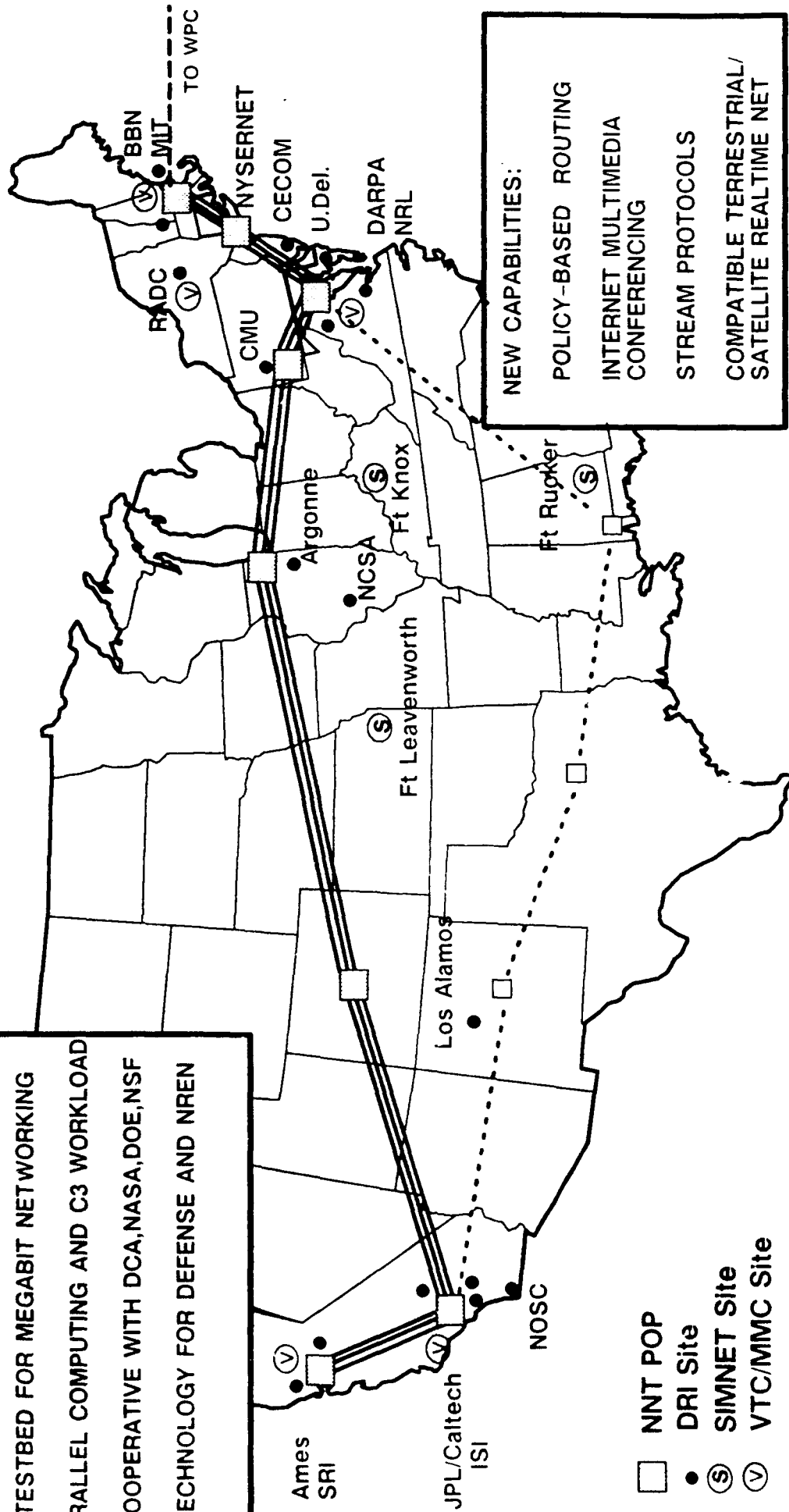
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- 11 -



Defense Research Internet (5/90)

TESTBED FOR MEGABIT NETWORKING
PARALLEL COMPUTING AND C3 WORKLOAD
COOPERATIVE WITH DCA,NASA,DOE,NSF
TECHNOLOGY FOR DEFENSE AND NREN



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DC 11/5/91

PAGE 82

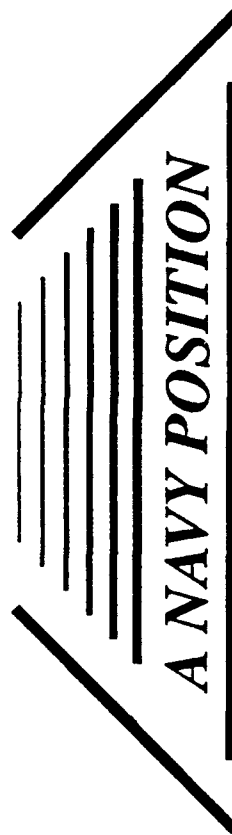
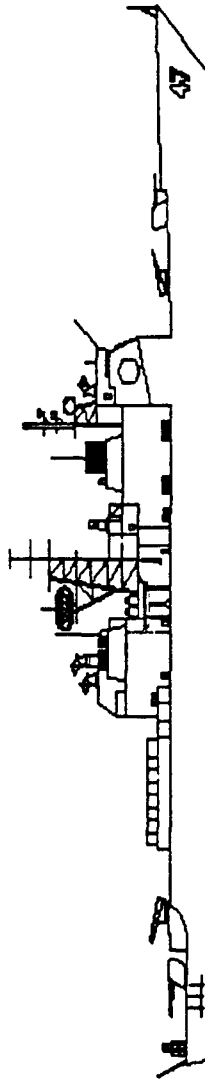
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Naval Ocean Systems Center
San Diego, CA 92152-5000

TECHNOLOGY PUSH



REQUIREMENTS PULL



Thomas R. Tiernan
Kevin E. Boner
(619) 553-3562/3558

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San Diego, CA 92152-5000

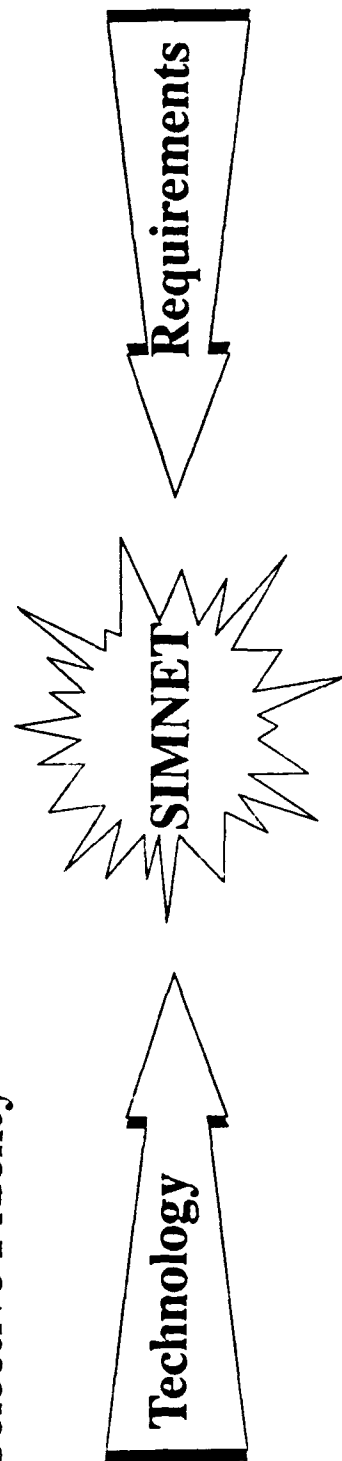
TECHNOLOGY PUSH

DARPA

- ☐ Local Area Networking
- ☐ Long Haul Networking
- ☐ Computer Image Generation
- ☐ Mass Produced High Tech Simulators
- ☐ Special Effects
- ☐ Selective Fidelity

ARMY

- ☐ Combined Arms Warfighting



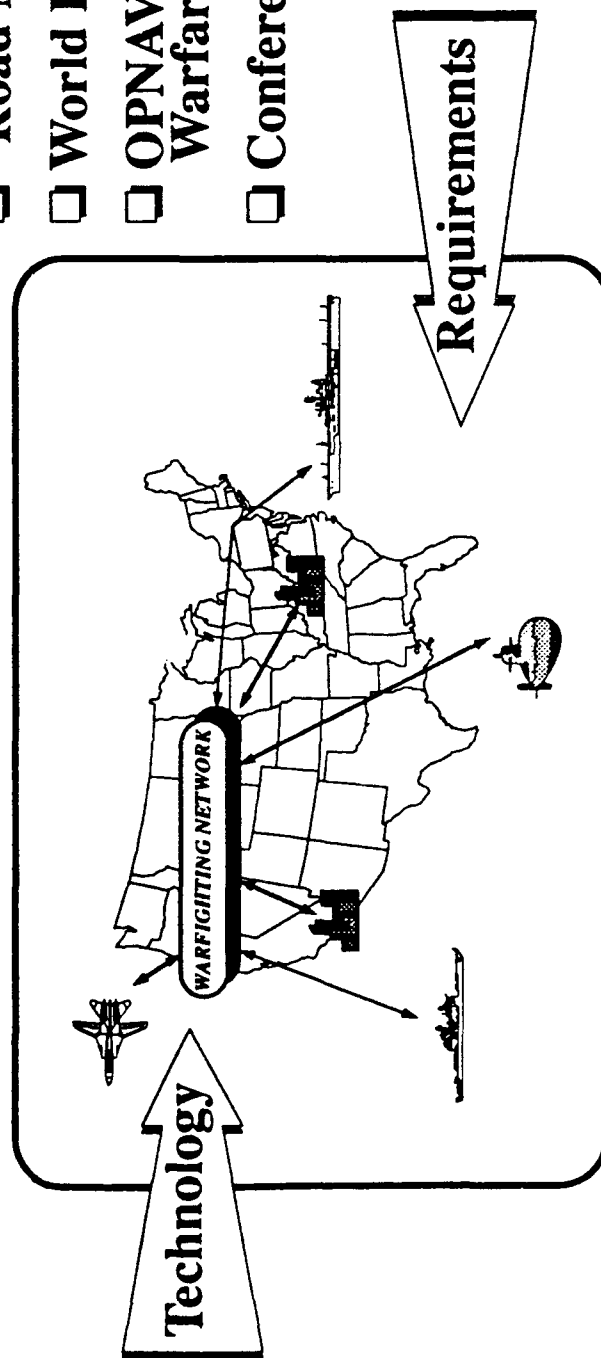
REQUIREMENTS PULL

UCF

- ☐ Standards for the Interoperability of Defense Simulators

NAVY

- ☐ BFIT O.R.
- ☐ BFIT Battle Exercises
- ☐ "Road Map Analysis"
- ☐ World Range Concepts
- ☐ OPNAVINST Surface Warfare Strategy
- ☐ Conference Papers

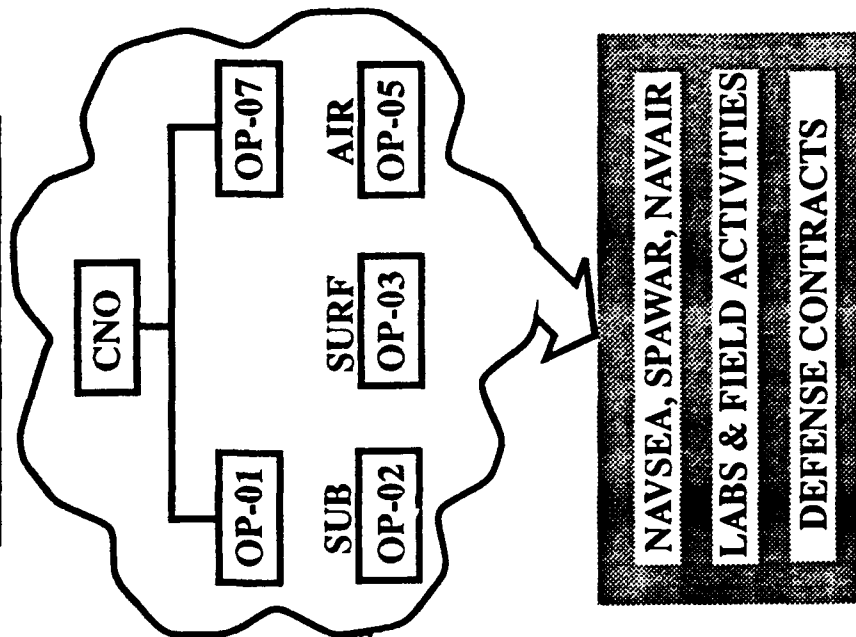


A NAVY POSITION

Standards Approval Process

- ☐ PMTrade Executive Agent
- ☐ Approved by PMTrade, NTSC, SIMSPO
- ☐ Coord. Industry & DOD
- ☒ Resolve Comments by DOD
- ☐ Approve Documents
- ☐ Convert to ISO Standard
- ☐ Approve ISO Standard
- ☐ Cancel MIL-STD

Navy Organization



Naval Ocean Systems Center
San Diego, CA 92152-5000

NAVY TECHNICAL INTERCHANGE MEETING

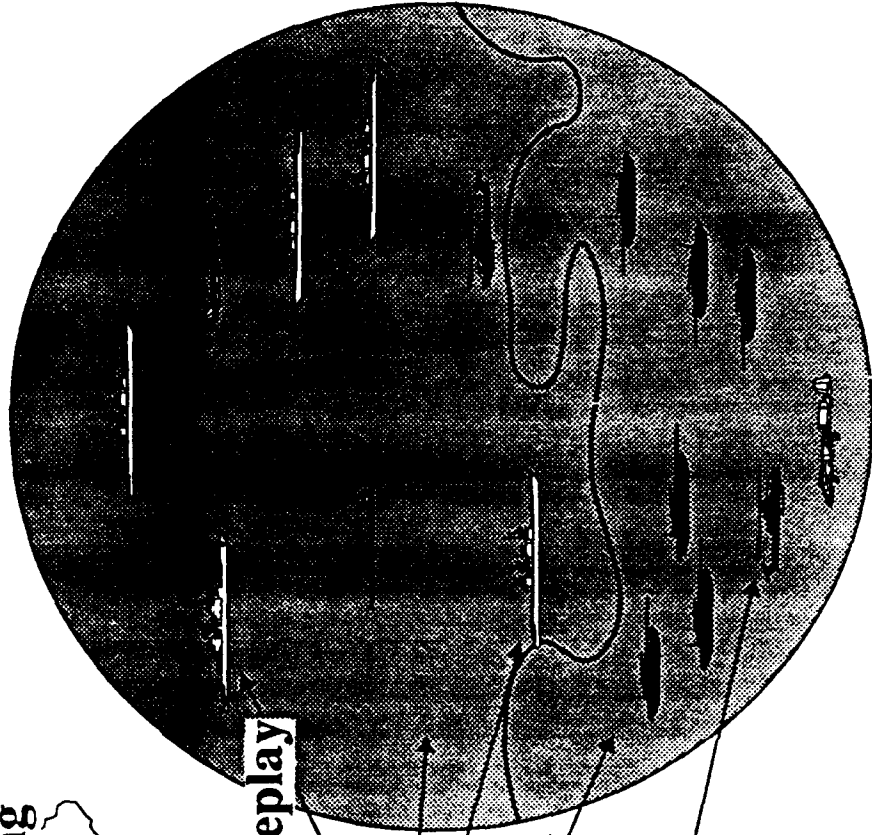
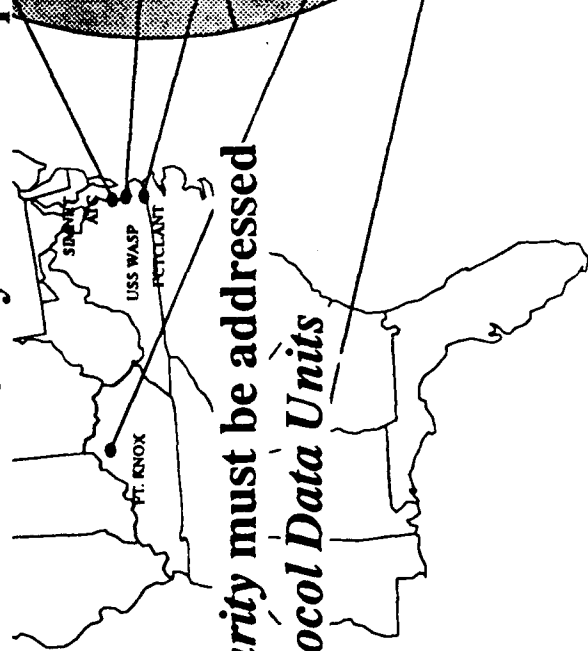
Topic: Standards for Interoperability of Defense Simulators

Attendees: OP-732
OP-39
SPAWAR
NAVSEA
NAVAIR
NOARL
NUSC
NOSC
NCTC

Consensus: * Requirements Pull exists but ad hoc & informal
* Process for achieving "A Navy Position"

BFIT / SIMNET PROOF of PRINCIPLE

- ☐ Validated Distributed Processing
- ☐ Demonstrated Networking
 - ✓ Existing Trainers
 - ✓ Operational Equipments
 - ✓ New Simulation Systems
- ☐ Verified Power of Dynamic Freeplay



PHYSICAL WORLD

SCENARIO WORLD

- Security must be addressed
- Protocol Data Units

ENTITY PDU

*** ENTITY TYPE DEFINITION IS BY SHIP CLASS**

- PROVIDE BY SHIP TYPE AS EACH SHIP IN A PARTICULAR CLASS MAY HAVE DIFFERENT CAPABILITIES

*** ARTICULATED PARTS STRUCTURE DOES NOT HANDLE MULTIPLE MOVING PARTS**

- ALLOW FOR AN ARTICULATED PART TO HAVE SUB-ARTICULATED PARTS

*** ENTITY'S APPEARANCE ATTRIBUTE THAT DESCRIBES THE SURFACE DOMAIN FOR A SURFACE PLATFORM**

- ALLOW FOR LOCATION OF FLAME

- ALLOW FOR MULTIPLE LIGHTING SYSTEMS

- ELIMINATE MUZZLE FLASH BITS SINCE THEY ARE GENERATED BY FIRE PDUs

EMITTER PDU

*** NO DIRECTION SPECIFICATION FOR EMITTER**

- ALLOW FOR DIRECTION FOR EMITTERS

*** WITH THREE VARIABLES TO POINT INTO THE "DATABASE TABLE" THE NUMBER OF ENTRIES REQUIRED IN THE DATABASE MAY BE TO LARGE**

- ALLOW FOR POSSIBLE COMBINATION OF PARAMETER VALUES FOR
SEPARATE ENTRIES IN THE DATABASE TABLE

*** DATABASES**

- STANDARDIZATION

- CORRELATION

RESUPPLY PDU

*** CANNOT SPECIFY TYPE AND AMOUNT OF FUEL AND AMMUNITION**

- ALLOW FOR SPECIFYING THE TYPE AND AMOUNT OF FUEL DESIRED AND AMMUNITION

*** IF RESUPPLY CANCELLED, NOTHING TRANSFERRED**

- ALLOW FOR PARTIAL RESUPPLY

OTHER CONCERNS

- * OCEAN CHARACTERISTICS**
- * ENVIRONMENTAL AREA (TYPE OF WEATHER,
SEA STATE, WATER TEMPERATURE, ETC.)**
- * SECURITY**
- * LARGE SCALE EXERCISES (AGGREGATE PDU)**

SUMMARY

Information:

- ☐ *Technology Push*
- ☐ *Requirements Pull*
- ☐ *Navy Position: Process*

Concerns:

- ☐ *Entity PDU*
- ☐ *Emitter PDU*
- ☐ *Resupply PDU*

TOP LEVEL IMPLEMENTATION

**Thomas Hoog
ASD/ENET**

CURRENT STATE

- **DRAFT STANDARD PUBLISHED FOR REVIEW**
- **PROPOSED NETWORK STANDARD DESCRIBED**
- **SOME ISSUES IDENTIFIED AND CLOSED**
- **SOME ISSUES IDENTIFIED AND REMAIN OPEN**

CONCERN

SOMETHING IS MISSING

SOLUTION PROPOSED FOR AN UNDEFINED PROBLEM

SOME QUESTIONS

- **WHAT ARE THE TRAINING REQUIREMENTS ?**
- **WHAT ARE THE PERFORMANCE REQUIREMENTS ?**
- **WILL THERE BE A SINGLE OR MULTIPLE STANDARDS ?**
- **WHEN WILL IDENTIFIED OPEN ISSUES BE RESOLVED ?**
- **HOW WILL NEW ISSUES BE RESOLVED ?**
- **WHAT IS THE PLAN FOR IMPLEMENTING THE STANDARD ?**
- **HOW WILL THE STANDARD BE MATURED ?**

RECOMMENDATIONS

- **APPLY THE SYSTEMS ENGINEERING PROCESS**
 - IDENTIFY SPECIFIC TRAINING REQUIREMENTS
 - DERIVE TOP LEVEL PERFORMANCE REQMTS
 - DEVELOP DETAILED IMPLEMENTATION REQMTS
 - DEVELOP VALIDATION REQUIREMENTS
- **DOCUMENT THE PLAN FOR DEVELOPMENT AND IMPLEMENTATION OF STANDARD**
- **PLAN FOR MATURATION OF THE STANDARD**

ACTIONS NEEDED

- **A ROADMAP IS NEEDED SO ALL PARTICIPANTS CAN ADEQUATLY PLAN TO SUPPORT THE DEVELOPMENT AND USE OF THE STANDARD**
- **ESTABLISH A GROUP TO DEVELOP THE ROADMAP, MONITOR PROGRESS AND RESOLVE INTEGRATION AND IMPLEMENTATION ISSUES.**

The Advantages of Using Quaternions Instead of Euler Angles for Representing Orientation

Dr. Jerry Burchfiel

BBN Systems and Technologies

August 7, 1990

Benefits of Quaternions over Euler Angles

- **No numerical integration, no attendant errors.**
- **No singularities in frame update equations**
- **About a third the computational effort**

Recommendation:

- **The DIS Standard should use quaternions, not Euler angles, to represent orientation.**

Dead Reckoning or Remote Vehicle Approximation

Idea - Receiver extrapolates appearance of remote vehicle between appearance updates

Benefit - Network traffic and packet processing load on receiving simulator are greatly reduced

Current State - Simnet extrapolation is forward extrapolation of last position using constant velocity (dead reckoning). Orientation is constant.

Opportunity - Use a higher order model for aircraft. Maneuvers can be closely modelled by constant turning rate ω about axis n , with constant velocity in platform coordinates. (Smooth turn, no angular acceleration).

What Are Euler Angles?

- **Defined as a specification of orientation, Leonhard Euler, 1752.**
- **Three angles. In British Aerospace Tradition, (Tait - Bryan angles) Yaw ψ ; Pitch θ ; Roll ϕ**

Recommended in July Draft of DIS Standard

Problem: Coordinate system is singular at $\theta = \pm \pi / 2$. Roll and Yaw are indistinguishable there. Result in a gyroscope is called "gimbal lock".

As a result, NASA doesn't use Euler angles in spacecraft. (Shuttle uses quaternions.)

Problem: Simple integration of Euler angle rates doesn't result in constant rate turn. (see video demo by Tod Shannon)

Correct Integration of Euler Angle Rates

Calculation of ω from Angle Rates

$$\begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} = \begin{bmatrix} \cos \theta \cos \psi & -\sin \psi & 0 \\ \cos \theta \sin \psi & \cos \psi & 0 \\ -\sin \theta & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{d\phi}{dt} \\ \frac{d\theta}{dt} \\ \frac{d\psi}{dt} \end{bmatrix} \quad (6-1)$$

Rotational Extrapolation Algorithms Using Euler Angles

$$\begin{bmatrix} \frac{d\phi}{dt} \\ \frac{d\theta}{dt} \\ \frac{d\psi}{dt} \end{bmatrix} = \begin{bmatrix} \cos \psi \sec \theta & \sin \psi \sec \theta & 0 \\ -\sin \psi & \cos \psi & 0 \\ \cos \psi \tan \theta & \sin \psi \tan \theta & 1 \end{bmatrix} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} \quad (6-2)$$

Conversion to Rotation Matrix:

$$R = \begin{bmatrix} \cos \theta \cos \psi & \cos \theta \sin \psi & -\sin \theta \\ \sin \phi \sin \theta \cos \psi - \cos \phi \sin \psi & \sin \phi \sin \theta \sin \psi + \cos \phi \cos \psi & \cos \theta \sin \phi \\ \cos \phi \sin \theta \cos \psi + \sin \phi \sin \psi & \cos \phi \sin \theta \sin \psi - \sin \phi \cos \psi & \cos \theta \cos \phi \end{bmatrix} \quad (6-4)$$

What are Quaternions?

- **4 - number representation for orientation. (also called Euler parameters).**
- **Discovered by Sir William Hamilton, 1843.
(Brougham Bridge, Royal Canal, Dublin)**

Update Formulas Using Quaternions

Quaternion for finite rotation:

$$\Delta Q(\theta, \mathbf{n}) = \cos(\theta/2), \mathbf{n} \sin(\theta/2). \quad (8-1)$$

Frame Update:

$$Q(n+1) = Q(n) \Delta Q. \quad (8-2)$$

Multiplication of two quaternions :

$$Q \cdot V = (q_0, \mathbf{q}) (v_0, \mathbf{v}) = q_0 v_0 - \mathbf{q} \cdot \mathbf{v}, \\ q_0 \mathbf{v} + v_0 \mathbf{q} + \mathbf{q} \times \mathbf{v} \quad (8-3)$$

Matrix Equivalent:

$$\mathbf{R} = (2 q_0^2 - 1) \mathbf{I} + 2 q_0 [-\mathbf{q} \times] + 2 [\mathbf{q} \mathbf{q}^t] \quad (8-5)$$

Where:

$$[-\mathbf{q} \times] = \begin{bmatrix} 0 & q_3 & -q_2 \\ -q_3 & 0 & q_1 \\ q_2 & -q_1 & 0 \end{bmatrix} \quad (8-6)$$

Benefits of Quaternions over Euler Angles

- **No numerical integration, no attendant errors.**
- **No singularities in frame update equations**
- **About a third the computational effort**

Recommendation:

- **The DIS Standard should use quaternions, not Euler angles, to represent orientation.**

Alternate Position

Randy Saunders

ALTERNATE POSITION QUATERNIONS vs EULER ANGLES

Assumptions

- Image generators use Euler angle input.
- Low fidelity simulators will not dead-reckon orientation.
- High fidelity simulators can best afford additional operations.
- Expressing angular velocity with respect to OS center supplants ω need?

ALTERNATE POSITION QUATERNIONS vs EULER ANGLES

Alternatives

	HIGH FIDELITY	LOW FIDELITY
TRANSMIT EULER ANGLES	1) Convert E → Q 2) Q Dead-Reckon 3) Convert Q → E Each Cycle Cost 1 = 65ms (int) = 179ms (float) Cost 2+3 = 170ms (float)	1) Use E as is 2) Don't Dead-Reckon)* Cost = 0
TRANSMIT QUATERNIONS	1) Use Q as is 2)+3) as above)* Cost1 = 0 Cost 2+3 = 170 ms (float) $\Delta \text{Cost} \approx \frac{1}{(\# \text{ TT/Sec} * \text{ DR SEC})}$	1) Convert Q → E 2) Don't Dead-Reckon)* Cost 1 = 110ms (float) Cost 2+3 = 0 $\Delta \text{Cost} = \infty\% = 110 \frac{\text{ms}}{\text{DR. SEC}}$

Bit Encoding Alternatives

**Mike Robkin, Randy Saunders
Hughes Simulation Systems**

August 7, 1990

HUGHES

Bit Encoding Attributes is a Bad Approach

- The Problems
- Possible Solutions

- Bit encoding is not appropriate for static or complex information.
 - Reduces data size at the expense of flexibility.
 - Static information should be sent infrequently, so there is no need to reduce its bandwidth.
 - Requires defining the size, form, and content of the data.
 - Defining a data size limits the maximum amount of information.
 - Difficult to define current information requirements.
 - Impossible to predict future requirements.
 - Changing a bit encoded standards will make forward and backward compatibility between simulators unlikely.
- Bit encoding has not adequately defined articulated parts.
- Bit encoding is only appropriate for easily defined, high frequency information.

BIT Encoding Bad Examples

HUGHES

- Only 32 possible countries. The draft standard left out major armed forces and potential adversaries and allies such as:
 - Israel
 - Vietnam
 - North Korea
 - South Korea
 - India
 - Pakistan
 - All of SEATO (Australia, New Zealand, Phillipines...)
 - PLO and most of the Middle East
- All possible Weapons, Sensors, Platforms, Vehicles, Munitions, and Configurations have to be predefined.
 - Jane's lists 18 variants of the Mig-21
 - 5 variants of the F-15

Proposed Solution

HUGHES

- Break up information into three PDUs
 - Definition PDU
 - Static information
 - Articulated Parts Definition PDU
 - Defines simulated articulated parts
 - Appearance PDU
 - Entity position, attitude, acceleration
 - Articulated parts position record
- } keyword text string
- } encoded

- Contains mostly static information
 - Defines the entity, its capabilities, armament, and markings.
 - Transmitted every 3-5 min or after Query.
 - "Change Flag" marks changed or new data.
- Consists of Hierarchical Text Strings
 - Keywords can be parsed out to desired level (tanks can ignore subs).
 - New technology can be incorporated by just adding vocabulary.
 - Entirely new fields can be added without modifying old simulators.
 - Old simulators can ignore or redefine unknown keywords with no loss of fidelity.
 - Station / pylon / launcher / weapon combinations can be defined.
 - Applicable to high and low fidelity simulators.
 - Distinguished network entities (application gateways) can provide additional data to support low fidelity simulators in a high fidelity environment.

Definition PDU Syntax

HUGHES

- String composed of keywords
 - Words separated by a delimiter "."
 - Words describing entire capabilities enclosed by "()"
- Hierarchy:
 - 1 Change flag
 - 2 Current domain
 - 3 Basic entity type
 - 4 Country of design
 - 5 Country of deployment
 - 6 Armed Forces branch
 - 7 Model
 - 8 Version
 - 9 Capabilities
 - 10 External Attachments
 - 11 Markings

Definition PDU Examples

HUGHES

0.LAND.TANK.USA.USA.M1.A1....PLANTOON
LEADER.SINGGARS.(MARKING.123-45)

0.AIR.FIGHTER.USA.USA.USAF.F16.A.(RADAR.APG-66).(IFF.AN/APX-101..
.(TARGETING.LANTIRN).(ECM.AN/ALQ-131)..
.(STATION 1.AIM9-L)..
.(STATION 4.MAU.TER.MK82B.EMPTY.MK82B)..
.(STATION 5.MAU.AN/ALQ-131)..
.(STATION 6.MAU.LAU.EMPTY)..
.(STATION 9.AIM9-F).(MARKING.84-734)

1.SEA.SHIP.USA.USA.USN.CG.AEGIS54.
.(SONAR.SQS-53B.TACTAS).(RADAR.SPY1A.SPS49.SPQ9).
.(MARKING.ANTIETAM)

0.LAND.LIFEFORM.USA.USA.USN.SEAL.(WEAPON.LAW.STINGER.M-60). 7

- Dynamic content of draft standard Appearance PDU
 - Time of issue
 - Location
 - Velocity
 - Acceleration
 - Orientation
 - Angular Velocity
 - Other bit encoded appearance information
 - Articulated parts record — New format needed

Articulated Parts Appearance Problems

HUGHES

- High-Tech articulated parts:
 - B-2 split spoilers
 - B-2 engine inlets doors
 - V-22 rotating nacelles
 - LHX notar louvers
- Currently undefined articulated parts:
 - weapon bay doors (ATF, bombers)
 - canards
 - rear cargo doors
 - Oblique wing position
 - engine inlet cover doors (Mig-25)
 - moveable jet nacelles (SR-71)
 - exhaust gas ports (various stealth)
 - rotating wings (F-14)
 - forward swept wing control surface (X-29)
 - vehicle hatches
 - vehicle gun ports

• Difficult to define current requirements, impossible to predict future ones.

Articulated Parts Implementation

HUGHES

- **Static Data**
 - Sent infrequently or for Query.
 - Vocabulary and order defined by standard.
 - Text strings define location of information
 - "number of fields" "first field" "second field"..
example: 10.left flap.right flap.rudder.landing gear.tail hook...
- **Dynamic Data**
 - Sent frequently, compact data to reduce bandwidth.
 - 16 bit integer values for articulated part position. Units predefined by the standard and vocabulary.
example: (10,1234,5454,7812,...)
- **Receiving Entities** can identify from the static string which dynamic fields they need.
- New fields can be added without upgrading existing simulators.

Conclusion

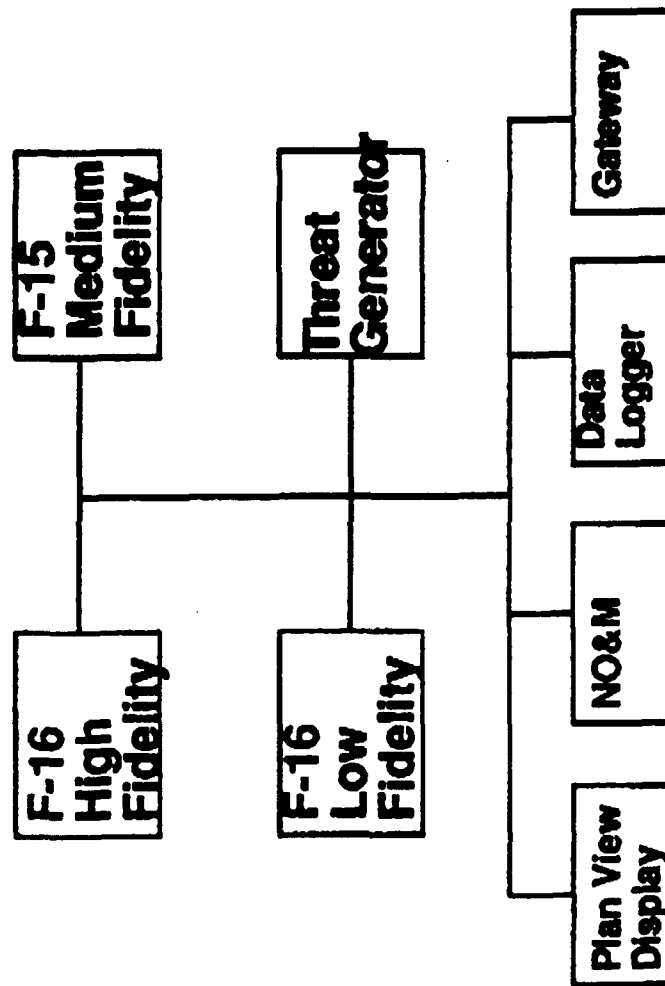
HUGHES

- Use three PDUs to define entity appearance.
 - Entity Definition PDU
 - Articulated Parts Definition PDU
 - Appearance PDU
- Flexible where appropriate.
- Compact to minimize the bandwidth of rapidly changing data.

The ACME Radar PDU

Alan Oatman - BBN

Aircrew Combat Mission Enhancement (ACME aka SIMNET-AF)



NOM = Network Operations and Maintenance

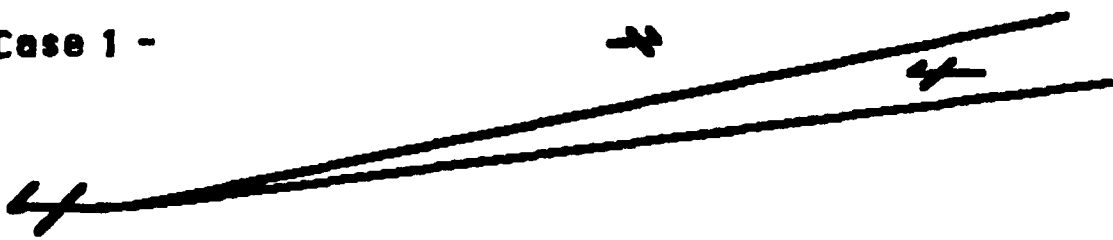
BEN ASD

Position :

**Advocating adoption of
the ACME Radar PDU in the
DIS Draft Standard**

BEN ASD

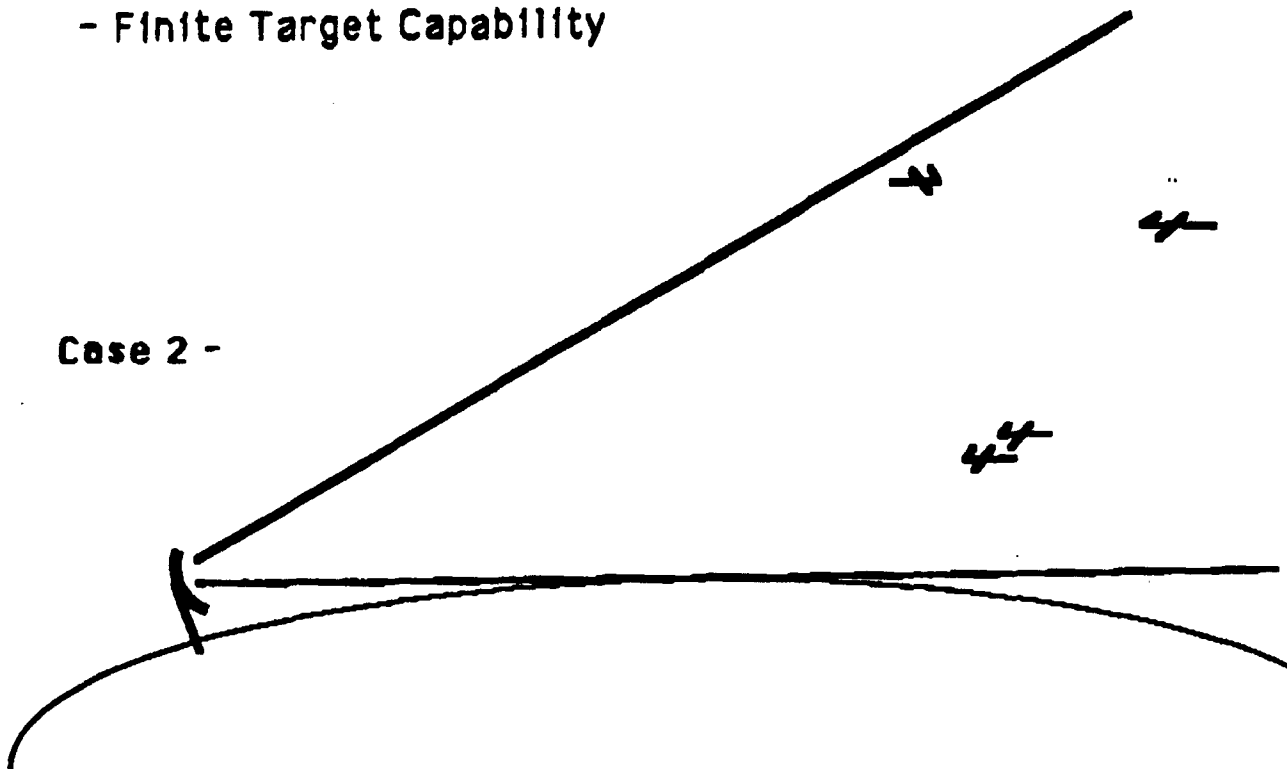
Case 1 -



Fire Control Radar

- Shorter Range
- Multi-mode
- Direct link to Weapon System
- Finite Target Capability

Case 2 -



Long Range Search

- Long Range
- Single Mode (some cases)
- Not directly linked to Weapon System
- Nearly Infinite Target Capability

DIS Emitter PDU Proposal

**Emitting Entity Identifier
Emitting Entity Type
Time of Emission
Emitter Location
Number of Emitters
Database Number
Database Access Information**

BEN ASD

ACME Radar PDU

Vehicle Identifier
Emitter Location
Time of Emission *
Number of Emitters
Radar System Identifier
Radar Mode
Specific Data (growth)
Azimuth Center
Azimuth Width
Elevation Center
Elevation Width
Power
Number Illuminated
array of Vehicle Identifiers
array of Radar Data applicable

* = added since position paper submitted

BBN ASD

Remaining Concerns

- * Radar Jamming
 - Deception
 - Noise
- * IFF Interrogation
- * Bi-static Radar
- * Security
- * Cooperation with
Weapon Handover
- * JTIDS
- * Occulting

BBN ASD

Conclusions

Proposed DIS Emitter PDU in current form is not adequate

Proposed Radar PDU will resolve many immediate requirements and should be included in DIS Standard

Much more research is required in the area

BBN ASD

Seven Critical Technical Issues in the Draft Military Standard for Distributed Interactive Simulation

**Richard Schaffer
Alan Dickens
Brian Vaughan
Arthur Pope**

INTRODUCTION

- Defining application layer DIS protocol is a complex, challenging task.

Goal: Support the full complexity of the modern battlefield.

- Seven Major Issues
 - For line by line comments, see *Questions and Comments on the Draft Military Standard for Distributed Interactive Simulation*.
- Receiving the issues by December.

ISSUES

- Scope and communications requirements
- Dead reckoning
- Articulated parts
- Restrictive data representations
- Dynamic thresholds
- Weapons fire and combat damages
- Ada Representation

SCOPE AND COMMUNICATIONS REQUIREMENTS OF DIS PROTOCOL

- Implicit design considerations need to be made explicit.
- Functions to be performed by the DIS system, and the goals and constraints guiding the design.
- Architectural model of the DIS system, defining the components of the system and identifying the interfaces between those components.
- Communications services upon which the DIS protocol is based.

DEAD RECKONING

What is Dead Reckoning?

The procedure by which a simulator calculates the state of remote vehicles in the intervals between receipt of Entity Appearance PDUs.

What does the draft standard propose?

- Position dead reckoned based on velocity in world coordinates and acceleration in world coordinates.
- Orientation dead reckoned based on Euler angle rates.
- Articulated parts are not dead reckoned.

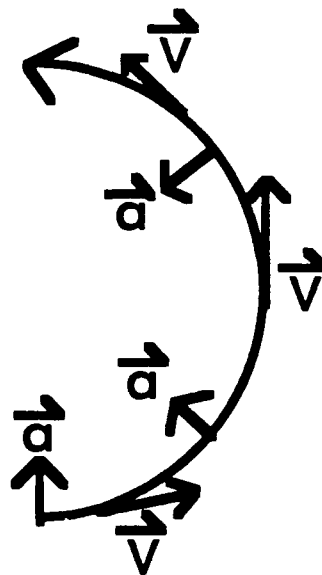
ISSUES IN HIGHER ORDER DEAD RECKONING

- Coordinate system for velocity and acceleration.

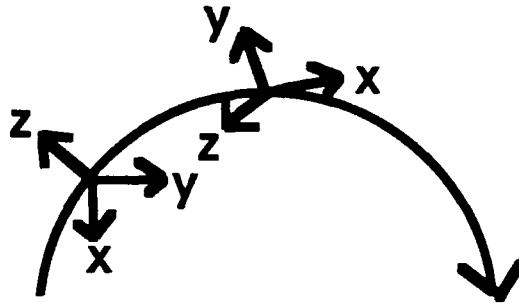
It doesn't matter much. But the technique for dead reckoning is critical and must be specified.

Implicit: vectors stay constant in world coordinates.

Better: vectors stay constant in platform coordinates.



- Limited flexibility of dead reckoning policy.

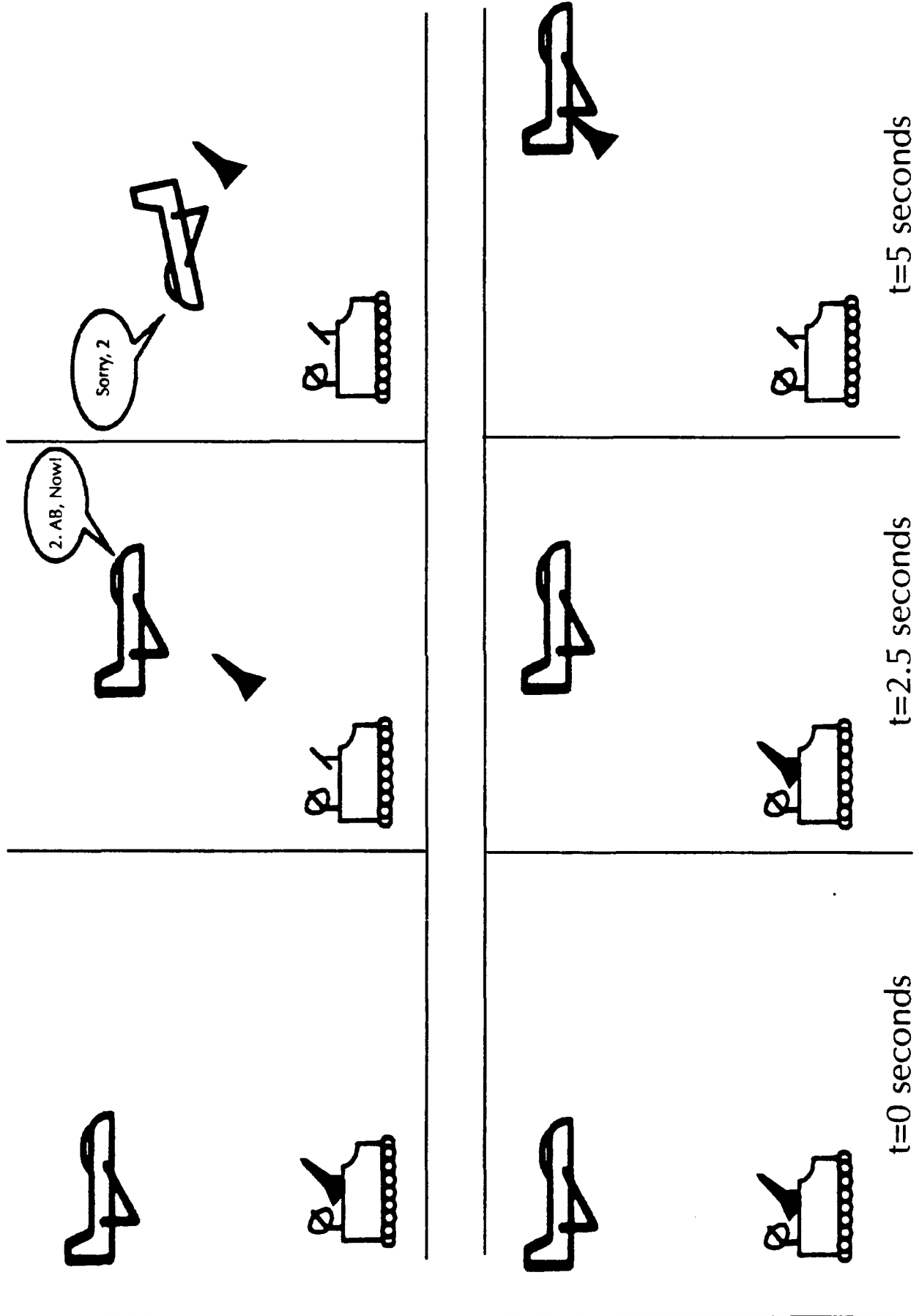


Example: Tumbling Ballistic object

- Dead reckoning of articulated parts.
- Euler rates not suitable for simple extrapolation.
- Higher order extrapolation, if part of the standard, is NOT optional for receivers.

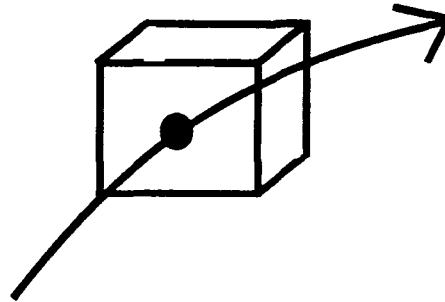
"This rate will provide additional information for simulators which may be using higher order dead reckoning algorithms." (Rationale 7.1.6)

Aircraft Using Higher Order Extrapolation



Notice:

- 1) The sender's internal state is the same in each case.
- 2) Dead reckoning is based on a contract issued by the sender.



- 3) The receiver ignores this contract at its peril.
- 4) The receiver can try to do better within the constraints of the contract.
- 5) The sender is free to use a lower order policy, setting higher order rates to zero.

ARTICULATED PARTS

- Motion of an arbitrary part cannot be represented by an azimuth and an elevation.

Linear motion:

submarine masts
recoiling guns
extendible antennas

General motion:

refueling drogues

- A reference direction for azimuth and elevation must be defined.
- Motion of parts must be a reason for sending an Entity Appearance PDU.
- Thresholds must be specified.
- A mechanism for Dead Reckoning articulated parts is desirable.

RESTRICTIVE DATA REPRESENTATION

- Maximum rotation rate of 1/2 revolution per second.
- World coordinates
Resolution: 1 centimeter.
Maximum value: 21,475 kilometers
- Orientation of articulated parts
Resolution: 1/2 revolution (1.4 degrees or 25 mile)
- Platform type codes

Shallow hierarchy: domain and country only

DYNAMIC THRESHOLDS

- Response to multiple, conflicting requests. Choose tightest? loosest? most recent?
- Network oscillations if conflicting requests permitted.
- Articulated parts may need separate thresholds.
- Needs further specification.

WEAPONS FIRE AND COMBAT DAMAGES

- Draft requires considerably more computation and is less flexible than SIMNET implementation.
- Draft:
 - Detonation PDU
- SIMNET
 - Indirect Fire PDU
 - Impact PDU
 - Identify of victim
 - Impact parameters in platform coordinates.
 - Parametric information about munition and impact.

Ada REPRESENTATION

- Ada is suitable to define the protocol.
- However, if definition is not to be just pseudo-code, must receive:
 - unsigned integers
 - representation clauses

```

subtype Integer_32 is Integer;
Integer_32_Length : constant := 4;  -- 4 bytes for this example.
                                     -- assuming this is running.
                                     -- on a 32 bit machine.
-- subtype bam is unsigned_32;
--      This subtype is a nonsequitur in Ada
--      The following is the closest that one can get and check for
--      the sign in software.

subtype Unsigned_32 is Integer_32;
Unsigned_32_Length : constant := 4;
type Angular_Velocity_Vector is
    record
        Roll_Rate   : Integer_32;
        Pitch_Rate  : Integer_32;
        Yaw_Rate    : Integer_32;
    and record;

Angular_Velocity_Vector_Roll_Rate_Offset : constant := 0;
Angular_Velocity_Vector_Pitch_Rate_Offset :
    constant := Angular_Velocity_Vector_Roll_Rate_Offset +
        Integer_32_Length;
Angular_Velocity_Vector_Yaw_Rate_Offset :
    constant := Angular_Velocity_Vector_Pitch_Rate_Offset +
        Integer_32_Length;
Angular_Velocity_Vector_Length :
    constant := Angular_Velocity_Vector_Yaw_Rate_Offset +
        Integer_32_Length;

Angular_Velocity_Vector_Roll_Rate_Size : constant := Integer_32 size;
Angular_Velocity_Vector_Pitch_Rate_Size : constant := Integer_32 size;
Angular_Velocity_Vector_Yaw_Rate_Size : constant := Integer_32 size;

for Angular_Velocity_Vector use
    record
        Roll_Rate at Angular_Velocity_Vector_Roll_Rate_Offset
            range 0 .. Angular_Velocity_Vector_Roll_Rate_Size - 1;
        Pitch_Rate at Angular_Velocity_Vector_Pitch_Rate_Offset
            range 0 .. Angular_Velocity_Vector_Pitch_Rate_Size - 1;
        Yaw_Rate at Angular_Velocity_Vector_Yaw_Rate_Offset
            range 0 .. Angular_Velocity_Vector_Yaw_Rate_Size - 1;
    and record;

```

HOW DO WE RESOLVE THESE ISSUES BY DECEMBER?

1. Form technical working groups
 - Dead reckoning.
 - Articulated parts.
 - Ada representation issues.
 - Dynamic thresholds.
 - Flexible data representation.
2. Release a new draft standard for review before December (October?).
 - Substantial number of inputs from July working group meetings
 - More inputs from this conference.
3. Limit scope of December draft
 - Identify mechanisms for expansion.
 - Pursue issues sufficiently to assure any necessary "hooks" are included.
 - Recommend an interim solution where an issue can't be completely resolved.

Floating Point Is Faster And More Flexible Than Fixed Point

Joshua E. Smith

PROPOSED:

**That the Standard Protocol for
Distributed Interactive Simulation
use IEEE Standard 754-1985 for
Binary Floating Point representation
wherever natural.**

- **Extensibility**
- **Floating Point is Faster**
- **IEEE is Faster**
- **Recommendations**

32-bit Fixed Point

Largest Value: $\frac{\pm 2^{31}}{\text{DENOMINATOR}}$ (21,474,836.48 Meters)

Smallest Value: $\frac{1}{\text{DENOMINATOR}}$ (0.01 Meters)

Significant Digits₁₀ : 9

32-bit Floating Point

Largest Value: $\pm 2^{127}$ (1.7×10^{38} Meters)

Smallest Value: $\frac{1}{2^{126}}$ (1.18×10^{-38} Meters)

Significant Digits₁₀ : 7

[Sign: 1] [Exponent: 8] [Mantissa: 23]
 31 30 23 22 0

64-bit Floating Point

Largest Value: 2^{1023}

Smallest Value: $\frac{1}{2^{1022}}$

Significant Digits₁₀ : 15

[Sign: 1] [Exponent: 11] [Mantissa: 52]
 63 62 52 51 0

BBN

Architecture: 68030/68882 @ 25Mhz: Current 6600

	<i>Trial 1</i>	<i>Trial 2</i>
int addition:	84 ns	84 ns
double addition:	1084 ns	1084 ns
int subtraction:	66 ns	83 ns
double subtraction:	1083 ns	1066 ns
int multiplication:	766 ns	1783 ns
double multiplication:	1883 ns	1900 ns
int division:	3633 ns	3633 ns
double division:	3117 ns	3117 ns

Architecture: 68020/68881 @ 20Mhz: Sun 3/60

	<i>Trial 1</i>	<i>Trial 2</i>
int addition:	100 ns	100 ns
double addition:	1440 ns	1440 ns
int subtraction:	100 ns	100 ns
double subtraction:	1440 ns	1440 ns
int multiplication:	2260 ns	2240 ns
double multiplication:	2800 ns	2480 ns
int division:	4460 ns	4720 ns
double division:	4460 ns	4060 ns

Table 1: Motorola Time Results

Architecture: Sparc @ 20Mhz (50 ns/cycle): Sun Sparcstation 1

	<i>Trial 1</i>	<i>Trial 2</i>
int addition:	50.4 ns	50.3 ns
double addition:	101.1 ns	101.4 ns
int subtraction:	68.7 ns	43.9 ns
double subtraction:	112.7 ns	98.1 ns
int multiplication:	6679.1 ns	6692.9 ns
double multiplication:	103.6 ns	107 ns
int division:	5648.2 ns	5655.7 ns
double division:	2869.3 ns	2878.4 ns

Table 2: Sparc Time Results

Architecture: MIPS R3000 @ 25Mhz (40 ns/cycle): Mips M/2000

	<i>Trial 1</i>	<i>Trial 2</i>
int addition:	38 ns	38.6 ns
double addition:	37.7 ns	38.7 ns
int subtraction:	40.6 ns	40.5 ns
double subtraction:	40.2 ns	40.4 ns
int multiplication:	406.3 ns	407.4 ns
double multiplication:	40.5 ns	40 ns
int division:	1343 ns	1343.1 ns
double division:	569.9 ns	574.4 ns

Table 3: Mips Time Results

	<i>Trial 1</i>	<i>Trial 2</i>
Fixed point to IEEE 32 bit float:	446.8 ns	447.3 ns
IEEE to worst case format:	406.2 ns	406.3 ns

Table 4: Conversion Time Results (Mips)

RECOMMENDATION

The DIS protocol standard should use IEEE floating point for the following fields:

4.1.1/4.2.1	Angles	(radians)
4.2.2	Angular Velocity	(radians/second)
4.2.3	Articulated Parts	(radians, meters)
4.2.6	EM Characteristics	
4.2.11	Vehicle Rotation	(radians, dimensionless)
4.2.14	Linear Acceleration	(meters/second/second)
4.2.15	Linear Velocity	(meters/second)
4.2.19.2	Supply Quantity	
4.2.22	World Coordinates*	(meters)

* Double Precision

Advantages of Query PDUs

Randy Saunders, Mike Robbin

Hughes Simulation Systems

August 7, 1990

HUGHES

OUTLINE

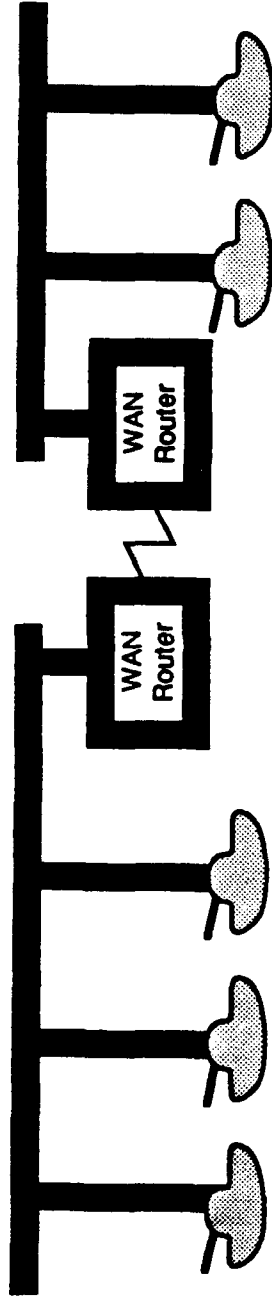
HUGHES

- Draft Standard Topology Assumptions
- Possible Alternative Topologies
- Query Alternatives
- Traffic Analysis
- Recommendations

Topology Assumptions

HUGHES

- Simulator Interface is ISO Layer-7 (Application)
- Network is a Continuous Multi-cast Medium



Pro

- SIMNET Uses this Structure
- Ethernet Implementation is Multi-cast

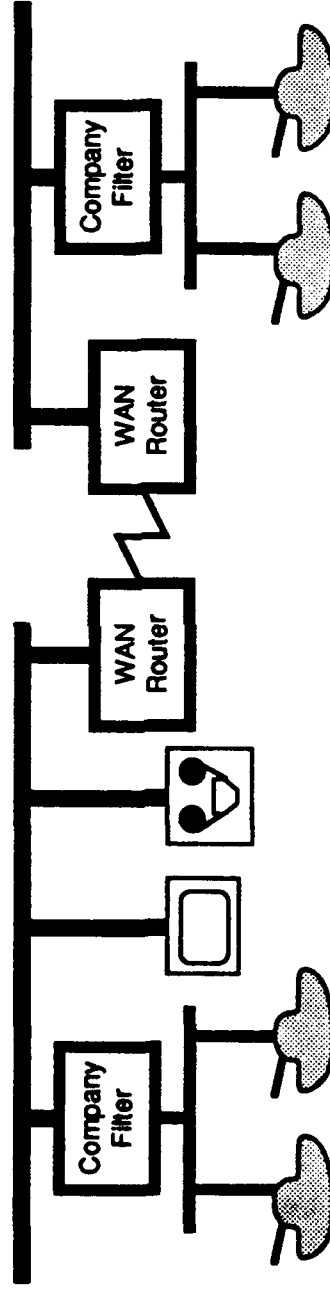
Con

- No Known Military Organization Uses this Structure
- Each Simulator Must Process Each Packet (at least trivially)
- Medium Bandwidth Requirements Unbounded

Alternative Topologies

HUGHES

- Hierarchical Structuring of Network
- Intelligent Consolidation of Traffic
- Distinguished Entities with Special Jobs



Pro

- Follows Military Organization
- Filters (Application Gateways) Contain Bandwidth

Con

- More Nodes in Network

Draft Standard Assumes that Periodic Transmission of Redundant Data Provides All Necessary Updates

Pro

- **SIMNET Works this Way**
- **Passive Listening for 5 Seconds Details Entire Simulated World**

Con

- **Redundant Data Wastes Bandwidth**
- **Alternate Topology Benefits are Wasted**

We Propose Query PDUs be Added and Redundant Transmissions Eliminated

Pro

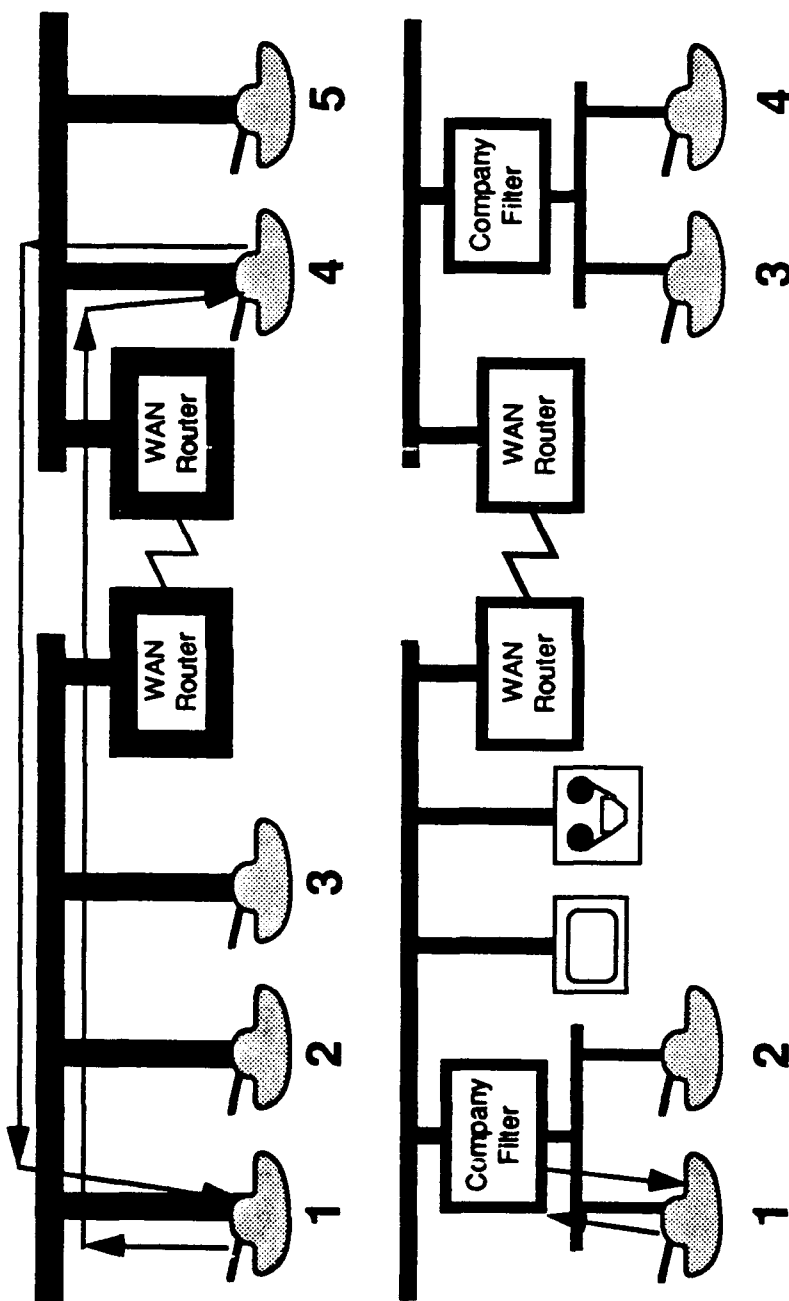
- **Minimize Data Bandwidth**
- **Topology Can Improve Performance**

Con

- **Active Listening Required to Understand Simulated World**

- **Queries Can be Specific or General**
 - Receiver must evaluate if query applies to it unless connection based mediums are provided.
 - Queries could depend on other factors, location for instance, to better support initialization or memory management.
- **Queries Can Request Appearance Data**
 - Provides one-shot update outside dead reckoning.
- **Queries Can Request Definition/Characteristic Data**
 - Provides means to inquire about specific data needs.
 - Provides a way for a distinguished entity to provide data which is not supported by the simulator itself.
- **Queries Can Request General Data About Exercise**
 - Weather and dynamic terrain information could be supported using this mechanism.

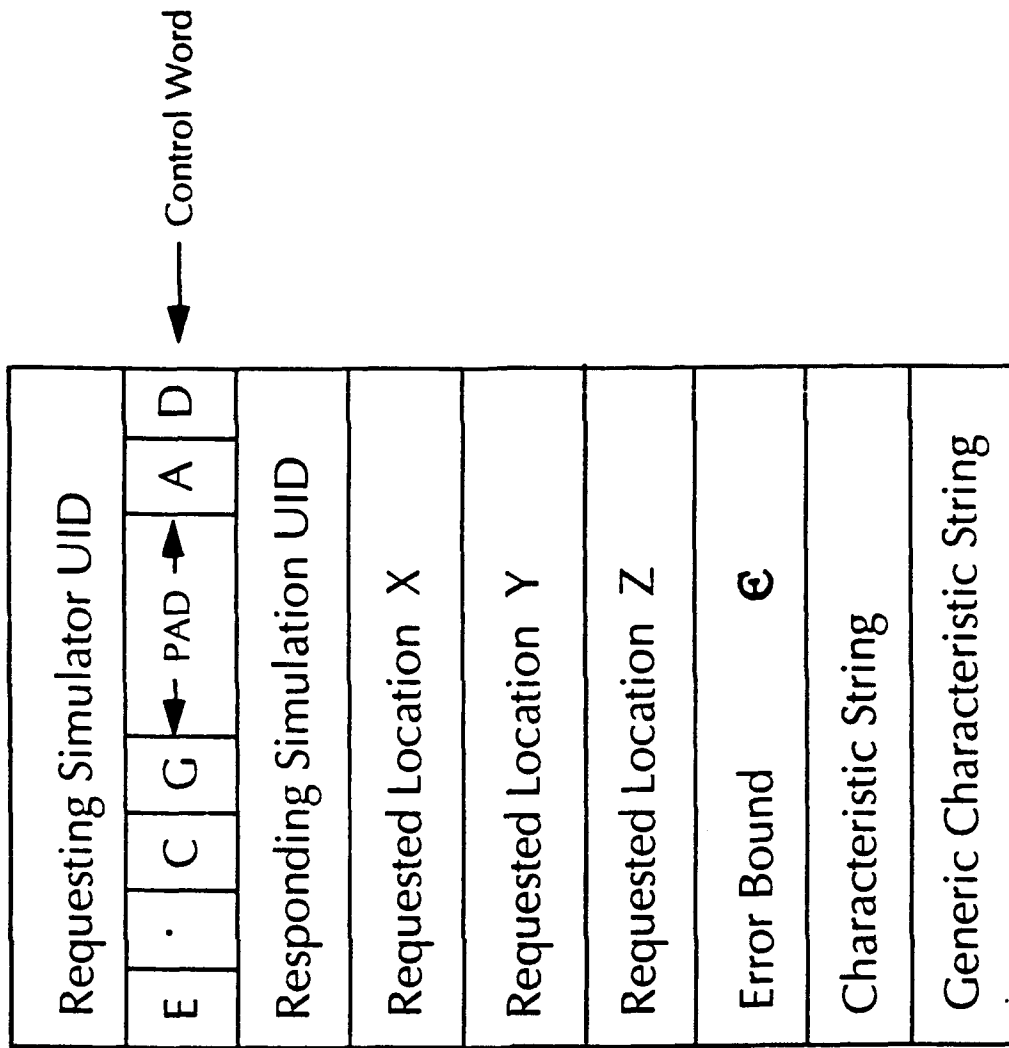
• Tank 1 Query of Tank 4



- Rough Analysis Supports Keeping Options Open
- Real Measurements Required for Reasonable Implementation Risk
- One Size Does NOT Fit All

- **Add 6 Query PDUs (or 1 PDU with more structured contents)**
 - Provides means to get data transmitted only when necessary.
 - Makes intellegent networks and distinguished entities much more effective means to improving system performance.
- **Change Thinking on Idle Retransmission Time to 5 Minutes**
 - Eliminate useless traffic from stopped vehicles.
- **Determine Effectiveness of Query as an Initialization Mechanism**
 - Allows easy entry into running scenarios.
 - Other decision factors may be needed (within 5km of location X).

POSSIBLE! QUERY PDU



THE IMPORTANCE OF EXPERIMENTAL EVALUATION IN PROTOCOL DESIGN

ROLANDO RABINES

**ADVANCED SIMULATION,
BBN SYSTEMS AND TECHNOLOGIES**

OVERVIEW

The Problem

- **Potential for standardizing a set of protocols that may be ineffective in supporting the intended applications.**

The Cause

- **Certain protocol design elements embody complex engineering trade-offs that cannot be adequately understood solely on the basis of theoretical analysis.**

A Solution

- **Incorporate experimental evaluation into the standards development process.**
- **Testbed evaluation before standardization.**

THE VALUE OF PROTOTYPING

- **Early implementation of key portions of complex engineering systems helps define requirements and manage development risks.**
- **Multiple organizations should begin to rapidly prototype the new standards as they are drafted.**
- **Multiple implementations would help to clarify various aspects of the standard.**

THE VALUE OF AN APPLICATION TESTBED

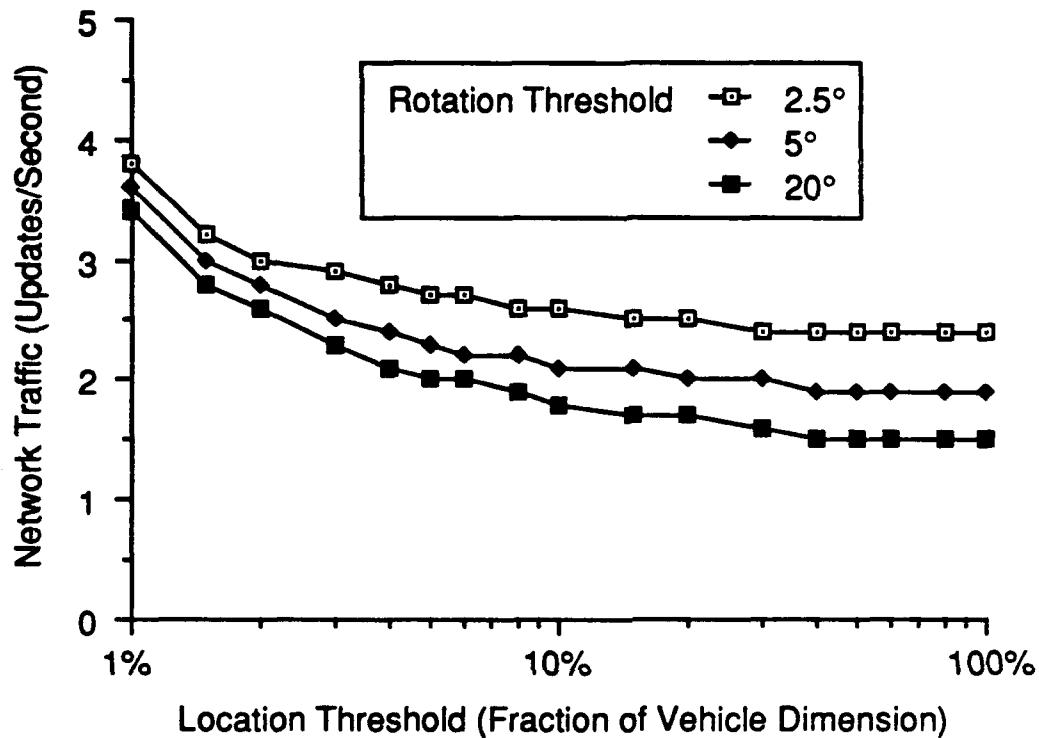
- **Testbed characterizes the environments in which distributed interactive simulations are expected to operate.**
- **Help designers identify areas of concern related to the utility of a product.**
- **Evaluate consequences of various protocol design alternatives.**

AN APPROACH TO EXPERIMENTAL EVALUATION IN PROTOCOL DESIGN

- **A new protocol feature is first evaluated by performing paper and pencil analyses.**
- **Develop rapid prototype implementation and evaluate using a laboratory testbed.**
- **Perform design and evaluation steps in a rapid prototyping loop.**
- **Testbed includes actual simulation exercises previously recorded.**
- **Minimize risk of spending resources developing a solution that could be unworkable in a real application.**

CHOOSING DEAD RECKONING ALGORITHMS

- **Experimental Evaluation is particularly important (if not required) for choosing dead reckoning algorithms.**
- **Dead reckoning achieves a trade-off among three factors: network traffic, computation performed by each simulator device, and precision.**
- **Choice of dead reckoning algorithm depends on the type of vehicle simulated.**
- **In the case of a tank, network traffic is not substantially reduced when dead reckoning is allowed to take into account higher-order derivatives of vehicle motion.**



- This graph shows the effect that various rotation and location thresholds have on the frequency of updates from an M1 simulators employing velocity-based dead reckoning.

RECOMMENDATION

- **Evaluate complex, new protocol features by developing prototype implementations.**
- **Gauge the consequences of various protocol design alternatives using an application testbed.**

Subgroup Recommendations

Terrain Databases Working Group

Dexter Fletcher

CORRELATION AND INTEROPERABILITY

(With a visual system bias)



Correlation

Statistical Measures

- Easy to compute
- Meaning re: Interoperability?

Intervisibility

- Straightforward but intensive
- Predict some aspects of visual system interoperability

Scripted Automated Task Comparisons

- Human defines script to meet requirements of an exercise

Scripted Human Task Comparisons

- Human defines script and carries out tasks

Unscripted Exercise Rehearsals

- Subjective but most direct method to obtain useful info



Interoperability

Communications Protocols Working Group

RECOMMENDATIONS INTERFACE AND T/M CRITICAL

- 1 - Orientation shall be represented using Euler angles.
- 2 - Angles shall be represented in BAMs:
 - + 32 bit integers $360^\circ = 2^{32}(\text{Orientation})$
 - + 16 bit integers $360^\circ = 2^{16}(\text{Articulated Parts})$
- 3 - A field shall be added to the Appearance PDU to indicate the dead reckoning algorithm to be used for this entity type. (More subgroup discussion to follow to determine algorithm.)
- 4 - The Simulation Management function should:
 - a. Establish default update thresholds
 - b. Establish minimum default update rate

RECOMMENDATIONS INTERFACE AND T/M CRITICAL Cont'd

- 5 - Floating point numbers (IEEE format) shall be used to represent position, real numbers. (Counters-integer, angles - integers)
- 6 - Articulated Parts issue to be handled by a newly formed subgroup.
- 7 - DETONATION PDU shall contain:
 - 1- Entity coordinates of target entity
 - 2- World coordinates of Detonation location
 - 3- Energy and directionality
 - 4- Fire result
 - 5- Range in meters
- 8 - DoD definition to be used for DIRECT/INDIRECT FIRE

RECOMMENDATIONS INTERFACE AND T/M CRITICAL Cont'd

- 9 - Query PDU's to be examined further.
- 10- TIMESTAMPS
 - 32 bit unsigned integers
 - LSB timestamp RELATIVE + ABSOLUTE
- 11 - Emitter information shall be represented by ACME PDU as interim solution. Subgroup to examine issue further.
- 12 - Bit ordering shall be specified using diagram.
- 13 - Muzzle flashes shall be represented using information in the FIRE PDU (bits in Appearance field taken out)
- 14 - Rotation rates shall be represented by 32 bit signed integer representing BAMs/M.S.

RECOMMENDATIONS INTERFACE AND T/M CRITICAL Cont'd

15 - World coordinates

- 3 elements each 64 bit floating pt (Double precision)

Entity coordinates

- 2 elements each 32 bit floating pt

REQUIRED NETWORK SERVICES FOR INCORPORATION INTO DIS

- * Multicast/Broadcast for normal PDU traffic
- * Real-time Delivery
 - < 500ms buffer-to-buffer
- * Packet Delivery in Sequence, as required
- * Minimal Delay Dispersion
- * Minimal Loss Rate (quality of service)
- * Single LAN to Global Networking of LANs
- * Classified & Unclassified Services
 - use appropriate guidelines (NSA, DoD, ...)
 - security can be derived from the scenario being run. Let the scenario determine the level and type (physical, communication, or computer) of security needed.
 - point-to-point for authentication
 - controlled access
 - partitionable/comparmentalized communities of interest (CUIs)
- * Use ISO/CCITT Guidance for Site Addressing
 - site administrators assign specific intra-site addresses
 - exercise/test coordinator assigns addresses for members participating in exercise
 - set up schema to identify a specific multicast group
 - a. setup multicast group
 - dynamic (area for research)
 - static (presently in SIMNET)
 - b. how does simulator join exercise (and get address)
 - off-line (human sets up/configures)
 - on-line (performed by computer)
- * Need a Transaction Protocol to Support Simulation Management
 - look at SIMNET association service (3 primitives: multicast, sending PDUs, transaction)

Note: 1) Performance characteristics are due to the type of application running - can't really standardize in this area; can only try to optimize.

2) Use ISO 7498 addendum to reference writing service primitives.

Performance Measures Working Group

Bruce McDonald

I.R. Appearance

Transmit Temp.

Skin

Engine Compartment

Exhaust

IST

Institute for Simulation & Training

Articulated Parts

Visual of Radar Antenna Rotate-Not Reg.

Emitter PDU's Need North Time Hack

Every 5 Secs.

Visual of 5" Gun Mount Positions-Not Reg.

Ailerons & Rudder Position-Not Reg.

Speed Brakes-Required

iST

Institute for Simulation & Training

Articulated Parts

Submarine

Up and Down

Periscope

Snorkel

Smoke

No Smoke

Radar

Missile Launcher

ESM Loop

iST

Institute for Simulation & Training

Generic Perf. Meas. PDU

Header
Time Stamp
Meas.
Meas. #
Meas. Variable
Meas.#
Meas. Variable



Institute for Simulation & Training

Query PDU

Header
Entity Addresses
Meas.
Meas. #

ist

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Observed Event PDU

Header

Time Stamp

Meas. #

iST

Institute for Simulation & Training

Perf. Meas. Req.

Table #
Phase #
Header ST
Entity Addresses
Meas.
Meas. #
Rate
Meas. #
Rate

ist

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Table

#1 Def.

#2 Def.

#3 Def.

#4 Def.

ist

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Recommendations

Need Heirarchical Entity ID's

Define Atmosphere In Terms of Parameters

Humidity

Temp

Etc.

ist

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