

## Evolution of Networked Virtual Environments

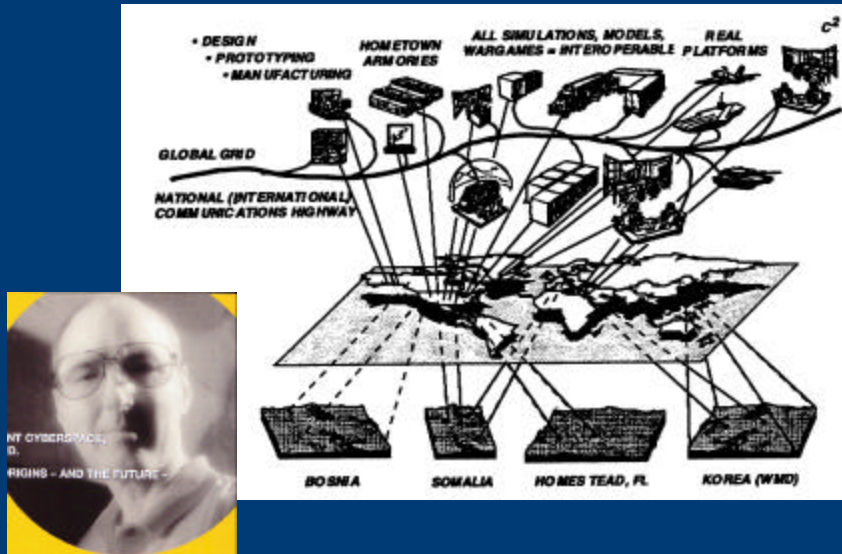
Class 8  
Dr. Roger Smith

<http://www.simulationfirst.com/ein5255/>

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## Jack Thorpe's Vision



## From Battlezone to SIMNET



Battlezone  
1980

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SIMNET  
1983-90



## SIMNET Design Principles

- Object/Event Architecture
  - Vehicles and Engagements
- Common Environment
  - Terrain and Culture
- Autonomous Simulation Nodes
  - Broadcast Events
- Transmission of Ground Truth
  - Local Perception and Effects
- Transmission of State Change
  - Not Static Data
- Dead Reckoning Algorithms
  - Extrapolate Last Reported State



## Object/Event Architecture

### Objects

People  
Monsters  
Vehicles  
Missiles



### Events

Explosions  
Destruction  
Orders

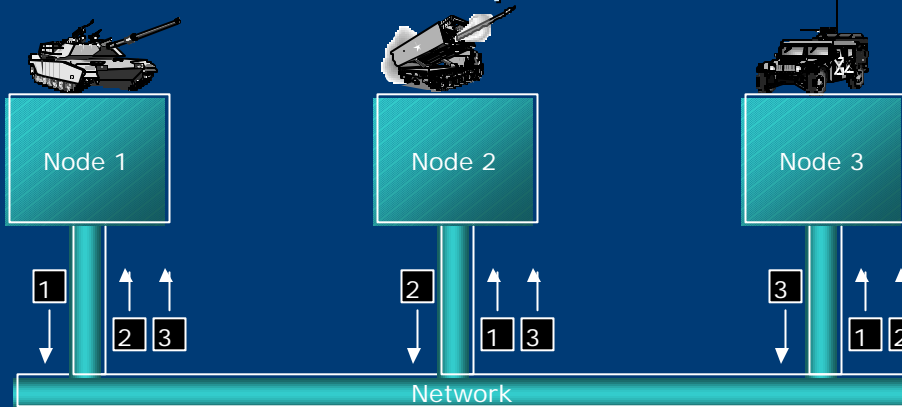


### Environment

Terrain      Roads  
Textures      Rivers  
Weather      Trees



## SIMNET/DIS Independent Nodes



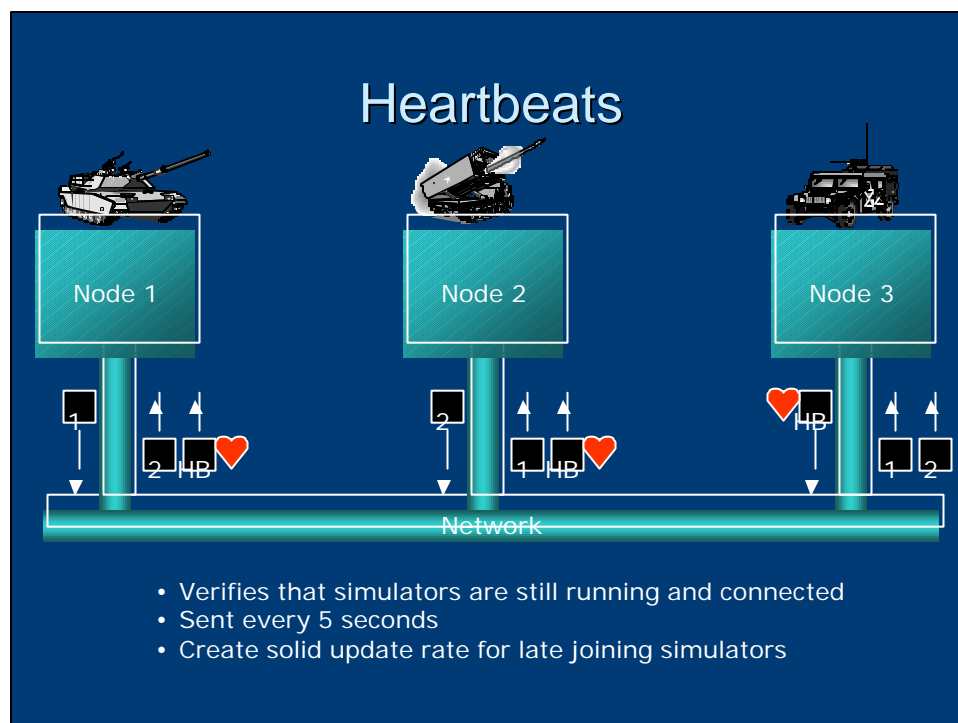
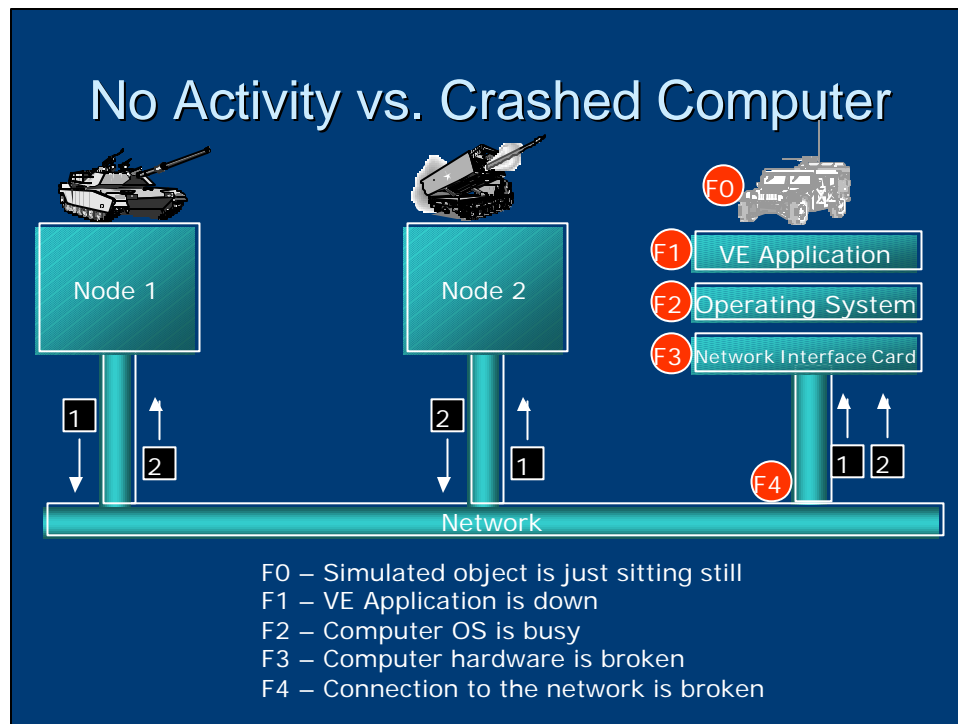
- Reduces System-wide Failure
- Enables Broadcasting to Reduce Message Duplication (255.255.255.255)
- Allows Late Joining or Early Departure
- Eliminates Need for a Simulation Server (Bottleneck)

## Update Message = Network Packet

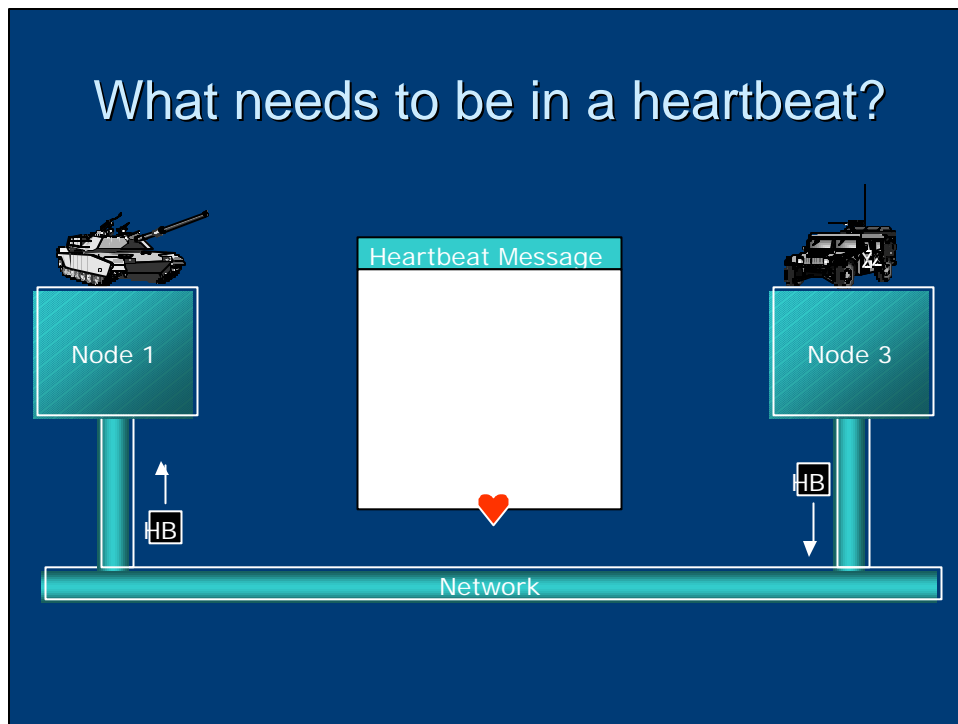
Field Name	Contents	Field Size (bytes)
Vehicle ID	Site	6
	Host	
	Vehicle	
Vehicle Class	Tank	1
	Simple	
	Static	
	Irrelevant	
Force ID		1
Guises	Distinguished	8
	Other	
World Coordinates	Location: X,Y,Z	24
Rotation Matrix		36
Appearance		4
Markings	Text Field	12
Timestamp		4
Capabilities		32
Engine Speed		2
Stationary bit and padding		2
Vehicle Appear Variant	Velocity Vector	24
	Turret Azimuth	
	Gun Elevation	

Total = 156 bytes



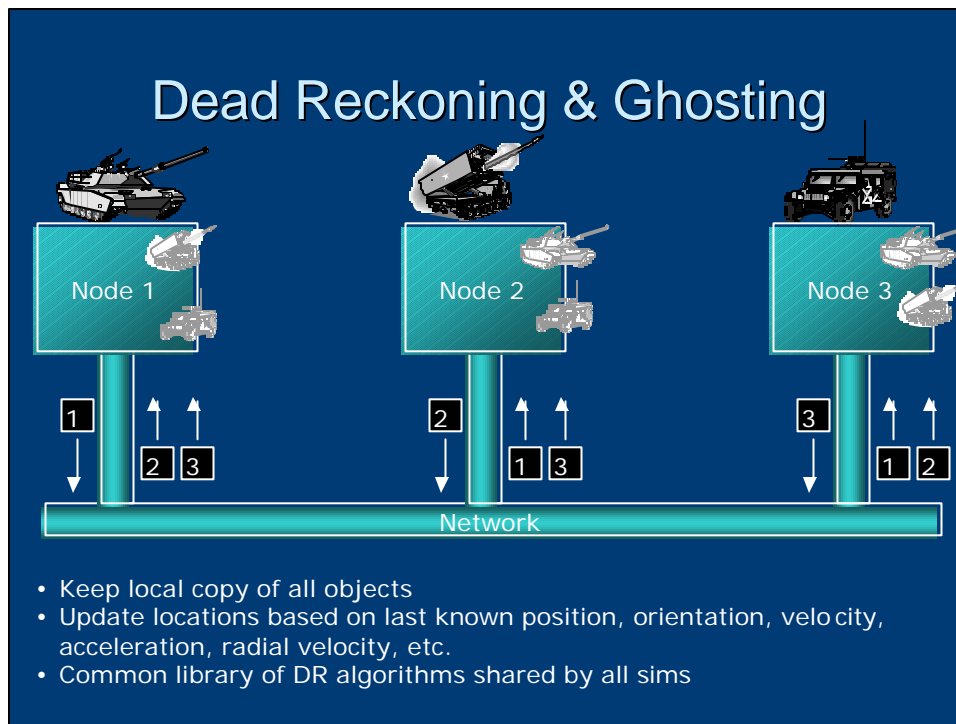


## What needs to be in a heartbeat?



## Update/Message Rate

- Frame Rate
  - Guarantees accurate representation
  - Strong impact on number of nodes on network
  - Difficult to connect different simulations
- Significant Events
  - Messages on changes
  - Heartbeats to keep alive
- Dead Reckoning
  - Greatly reduce network traffic
  - Increases max nodes on network
  - Brings together sims with different rates
  - Requires ghosting remote objects

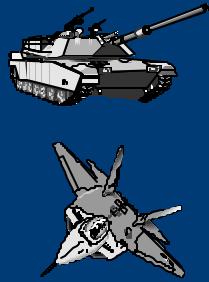


## Orders of Dead Reckoning

Zeroth-order DR	$DrLocation = LastKnownLocation$
First-order DR	$DrLocation = LastKnownLocation + LastKnownVelocity * TimeElapsed$
Second-order DR	$DrLocation = LastKnownLocation + LastKnownVelocity * TimeElapsed + (1/2) * LastKnownAcceleration * TimeElapsed^2$

"Skate to where the puck will be – not where it has been."  
 - Wayne Gretsky

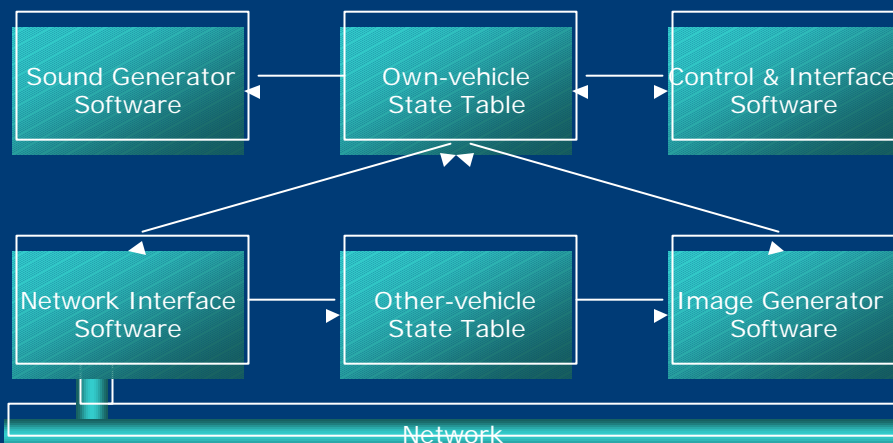
## DR Savings - Examples

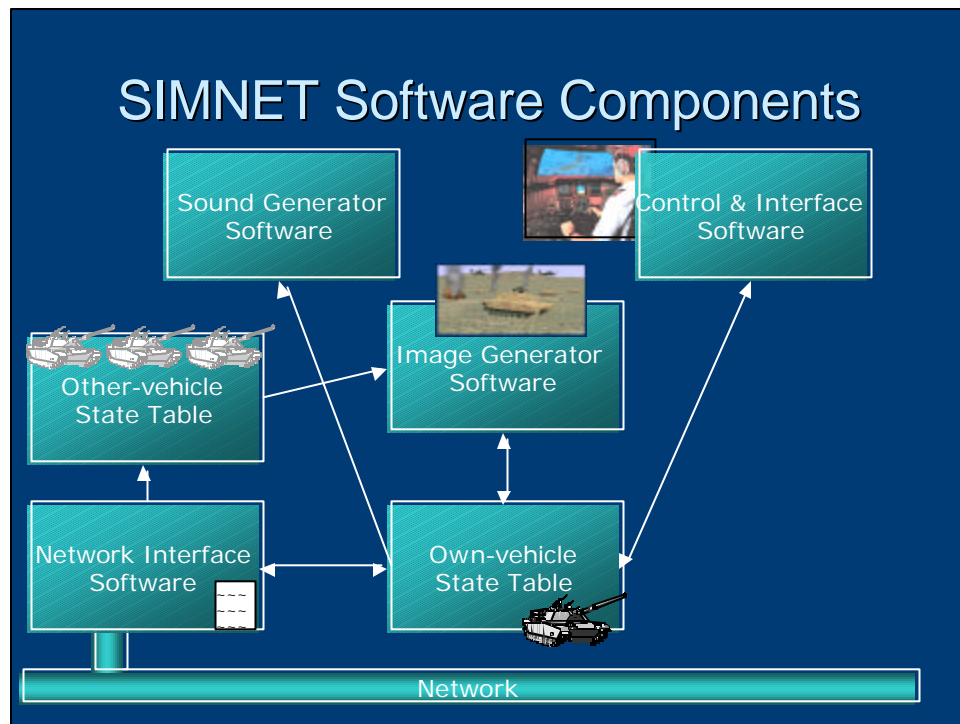


Without DR	With DR
10-15 updates/second	1 update/second
30-60 updates/second	3 updates/second

Allows at least 10X increase in number of objects in virtual world.

## SIMNET Software Components





## 1987 Canadian Armor Trophy

- US Armor Crews Prepare with SIMNET
- Simulation Allows Many More Practice Sessions
- US Team Wins Canadian Armor Trophy for first time in a Decade



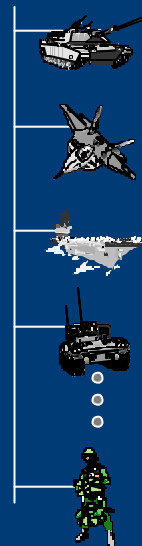
## Battle of 73 Easting



- Battle of 73 Easting, 26 February 1991
  - 2nd Armored Cavalry Regt destroyed dug-in Iraqi Armor Division
- Data collection to pinpoint vehicle locations, movements, and engagements
- Soldier review to refine events
- Replay of a real engagement in 3D environment
- Stimulus for huge visions of future simulations

## Distributed Interactive Simulation

- Object/Event Architecture
  - Vehicles and Engagements
- Common Environment
  - Terrain and Culture
- Autonomous Simulation Nodes
  - Broadcast Events
- Transmission of Ground Truth
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## Entity State PDU

Field Size (Bits)	Entity State PDU Fields	Field Description
96	PDU HEADER	Protocol Version - 8-bit enumeration Exercise ID - 8-bit unsigned integer PDU Type - 8-bit enumeration Protocol Family - 8-bit enumeration Time Stamp - 32-bit unsigned integer Length - 16-bit unsigned integer Padding - 16 bits unused
48	ENTITY ID	Site - 16-bit unsigned integer Application - 16-bit unsigned integer Entity - 16-bit unsigned integer
8	FORCE ID	8-bit enumeration
8	3 OF ARTICULATION PARAMETERS (n)	8-bit unsigned integer
64	ENTITY TYPE	Entity Kind - 8-bit enumeration Domain - 8-bit enumeration Country - 16-bit enumeration Category - 8-bit enumeration Subcategory - 8-bit enumeration Specific 8-bit enumeration Extra - 8-bit enumeration
64	ALTERNATIVE ENTITY TYPE	Entity Kind - 8-bit enumeration Domain - 8-bit enumeration Country - 16-bit enumeration Category - 8-bit enumeration Subcategory - 8-bit enumeration Specific 8-bit enumeration Extra - 8-bit enumeration

(continued on next slide)

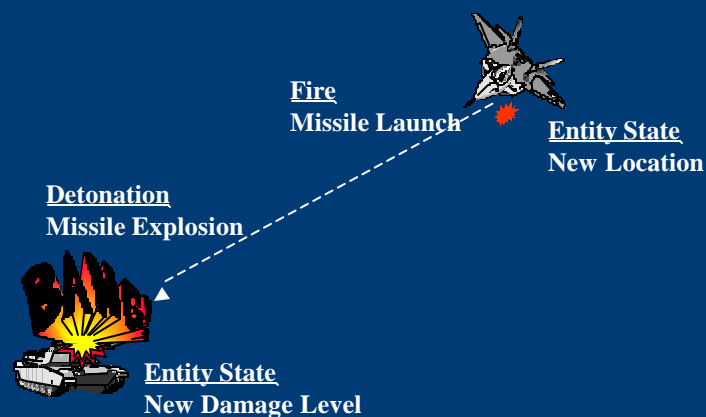
## Entity State PDU (cont)

96	ENTITY LINEAR VELOCITY	X Component - 32-bit floating point Y Component - 32-bit floating point Z Component - 32-bit floating point
192	ENTITY LOCATION	X Component - 64-bit floating point Y Component - 64-bit floating point Z Component - 64-bit floating point
96	ENTITY ORIENTATION	Psi - 32-bit floating point Theta - 32-bit floating point Phi - 32-bit floating point
32	ENTITY APPEARANCE	32-bit record of enumerations
320	DEAD RECKONING PARAMETERS	Algorithm - 8-bit enumeration Other Parameters - 120 bits unused Entity Linear Accel - 3X32-bit floating point Entity Angular Accel - 3X32-bit floating point
96	ENTITY	Character Set - 8-bit enumeration
32	MARKING CAPABILITIES	11 8-bit unsigned integers 32 Boolean fields
n X 128	ARTICULATION PARAMETERS	Parameter Type Designator - 8-bit enumeration Change - 8-bit unsigned integer ID - attached to - 16-bit unsigned integer Parameter Type - 32-bit parameter type record Parameter Value - 64-bit

## DIS PDUs

- Entity Information/Interaction
  - Entity State
  - Collision
- Warfare
  - Fire
  - Detonation
- Logistics
  - Service Request
  - Resupply Offer
  - Resupply Received
  - Resupply Cancel
  - Repair Complete
  - Repair Respond
- Distributed Emission Regeneration
  - Electromagnetic Emission
  - Designator
- Radio Communication
  - Transmitter
  - Signal
  - Receiver
- Simulation Management
  - Start/Resume
  - Stop/Freeze
  - Acknowledge
  - Action Request
  - Action Response
  - Data Query
  - Set Data
  - Data
  - Event Report
  - Message
  - Create Entity
  - Remove Entity

## DIS PDU Operations



## PDU Volumes

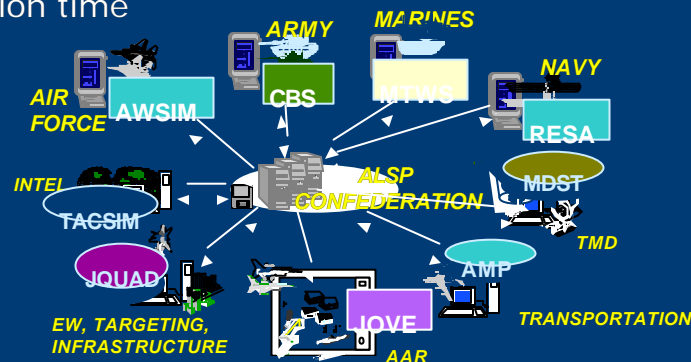
1993 I/ITSEC Demonstration with 79 Nodes

Entity State	96%
Other	4%
Fire	4%
Detonation	4%
Collision	1%
Logistics	0%
Sim Mgt	0%
Emission	38%
Transmitter	50%
Signal	0%
Acoustic	2%
Stealth	1%
Others	0%

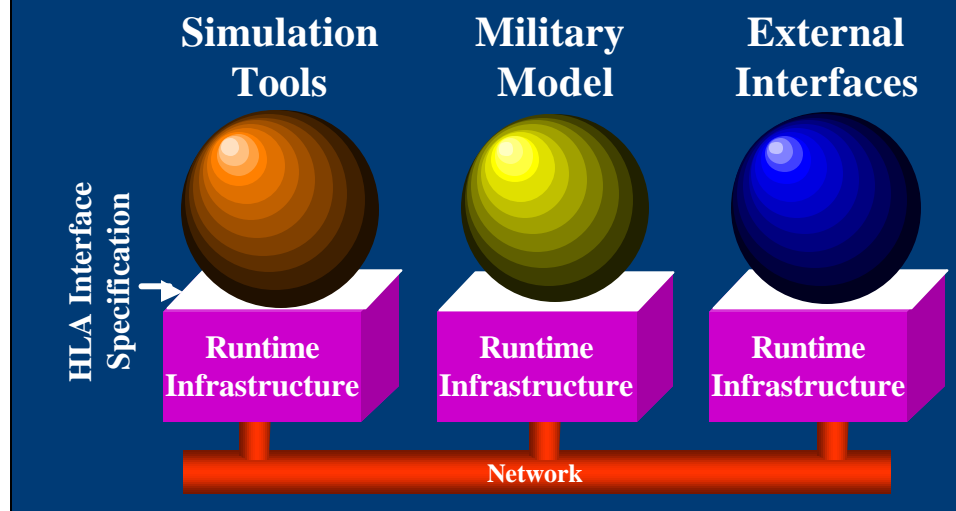


## Aggregate Level Simulation Protocol

- Application of SIMNET and DIS principles to constructive simulations
- Synchronized advance of simulation time
- Adherence to common object model
- Object ownership and control



## High Level Architecture and the Runtime Infrastructure



## Distributed Simulation Protocols

