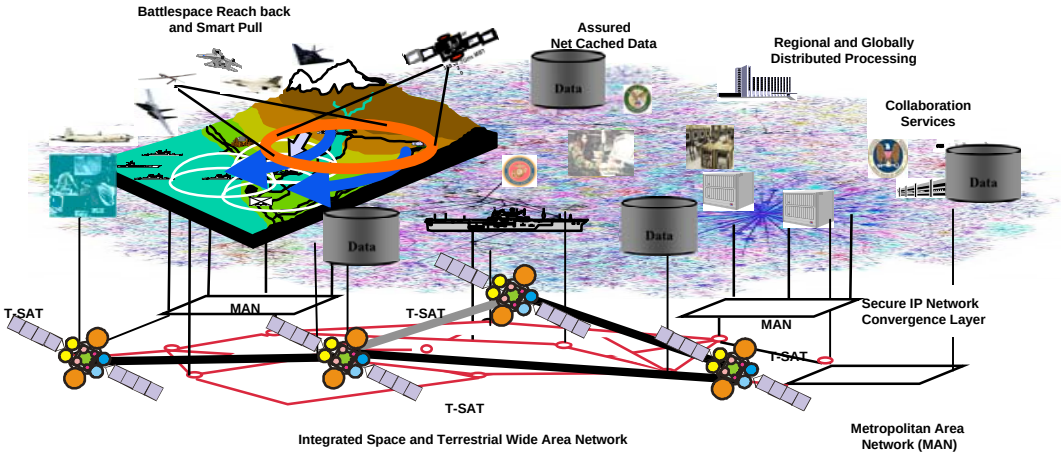
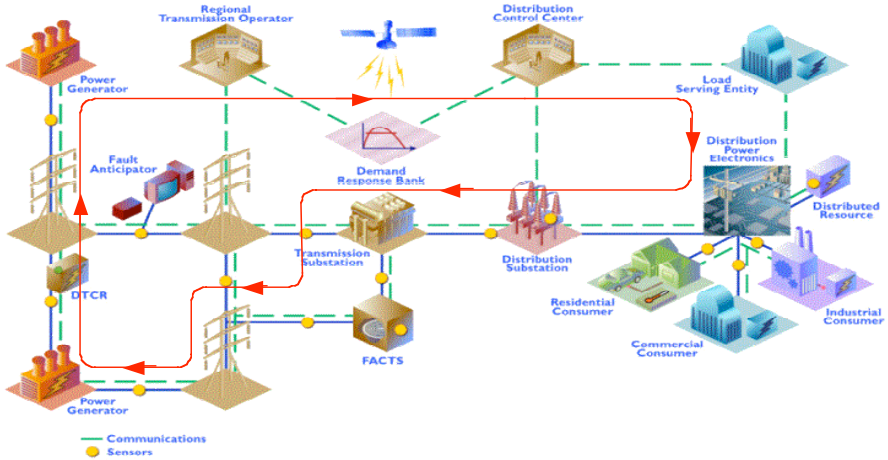
Communication Networks – Modeling, Simulation & Emulation

Jim Nutaro
Computational Sciences and Engineering Division

Goal - Modeling of Large Scale, Complex System of Systems that are Dependent on Information Flow

- Future Combat System
  - ORNL part of FIST team.
- Real-time Cyber Security Situational Awareness
  - Joint USSTRATCOM-DISA Effort for DOD.
  - ORNL lead player for USSTRATCOM.
- Critical Infrastructure Network
  - Example: The Electric Power Grid
  - ORNL DHS National Lab in charge of TVTA for cyber.
- Sensor Networks
- Information Operations

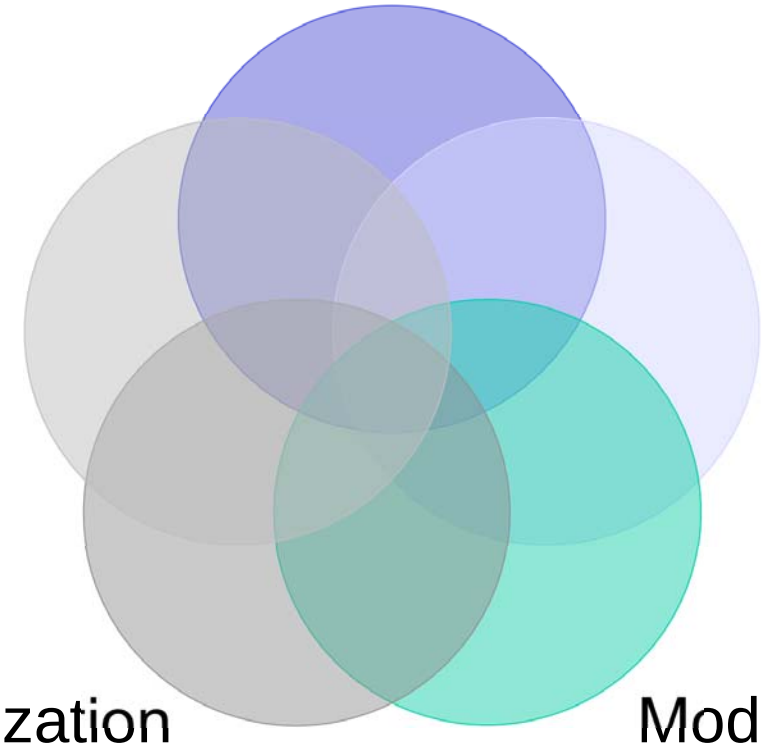




Communications M&S – Overview

Interoperability
- Wired, wireless, hybrid simulators
- Simulator-independent models

Scalability
- Size and speed
- Supercomputing

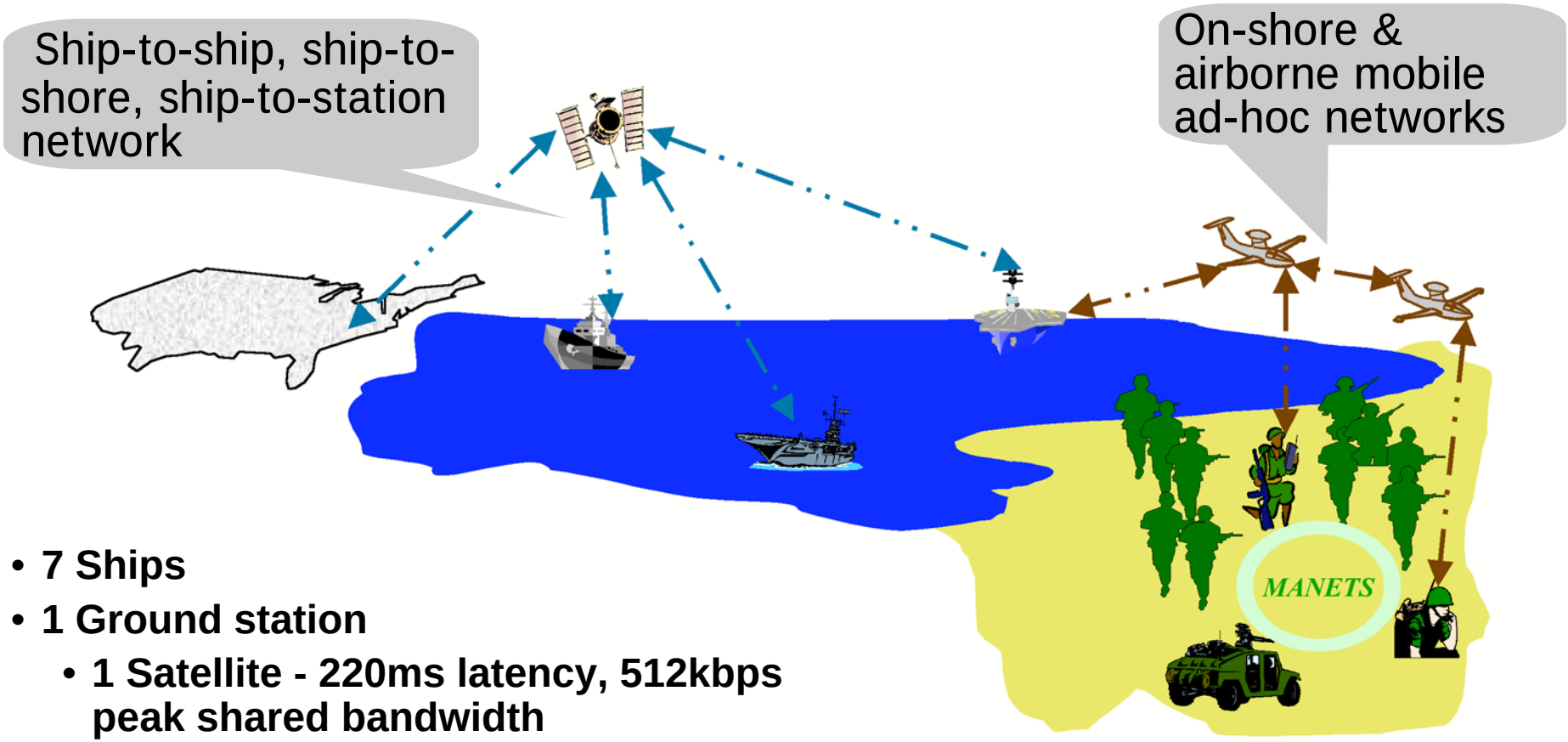


Applications
- Network security
- Testing and analysis

Visualization
- 10^4-10^6 nodes, links
- Animation & Sonification

Modeling
- Wireless for MOUT
- Modeling frameworks

Interoperable Tools – Example Scenario



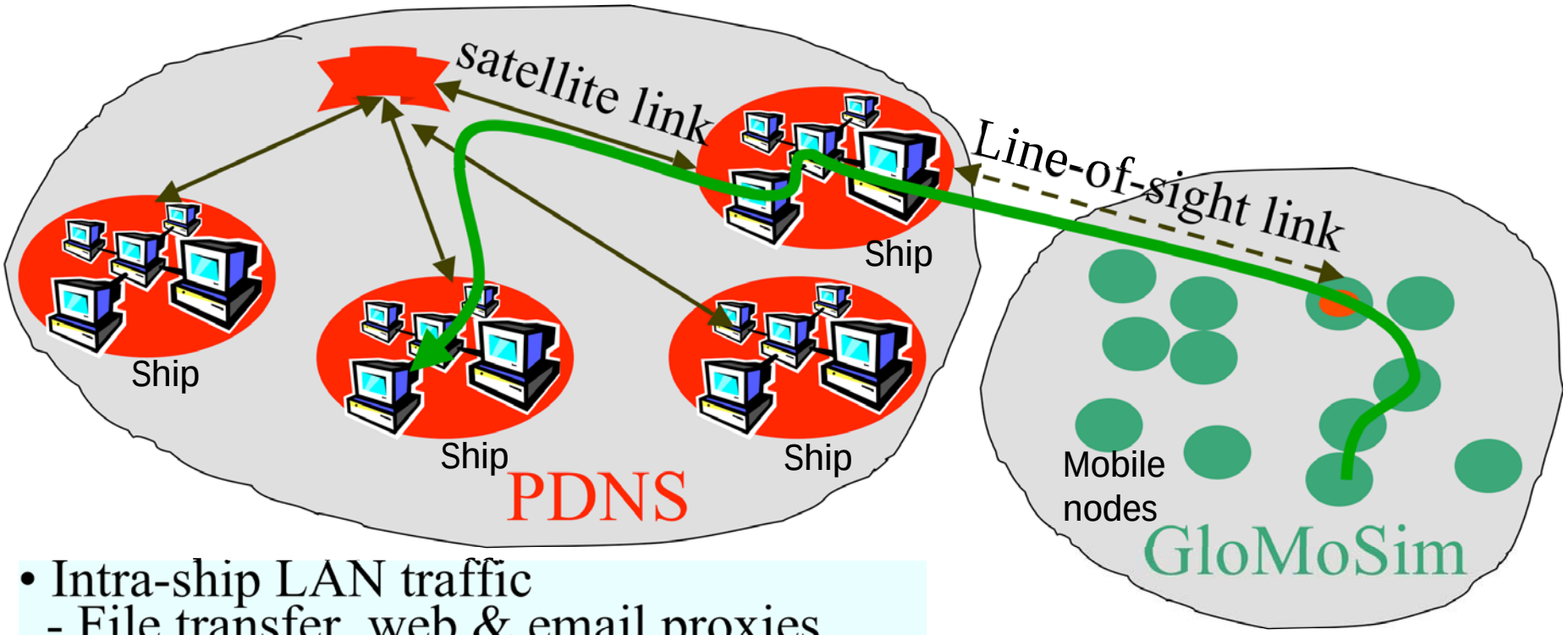
- **7 Ships**
- **1 Ground station**
  - **1 Satellite - 220ms latency, 512kbps peak shared bandwidth**
- ***Packeteer* traffic shaper on each ship**
- **Ethernet LAN on each ship**
- **COTS hardware/software on each ship**
  - **Running Windows NT, Solaris**
  - **Lotus Domino, Internet Explorer, …**

Given:

- Afloat Naval Exercise Data (JWID00) at Reconfigurable Land-based Test Site (RLBTS) modeled in ns-2

- Ship-to-shore & Shore-to-Objective Maneuver (STOM) data modeled in GloMoSim

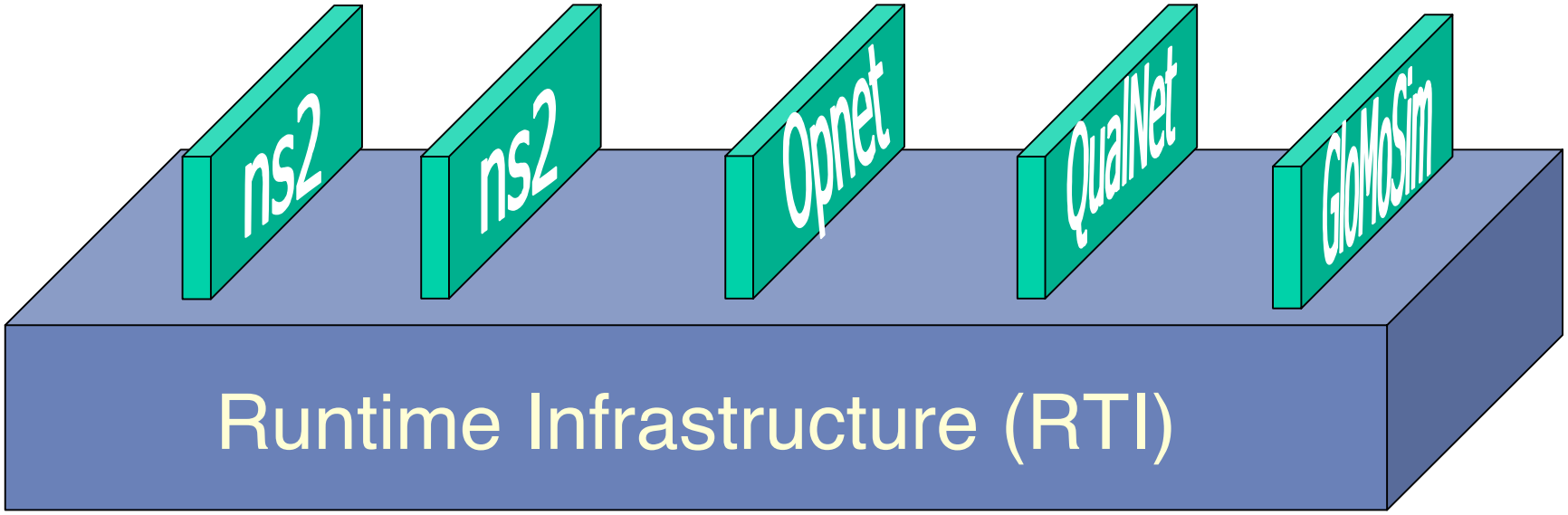
Integrated Tool Configuration



- Intra-ship LAN traffic
  - File transfer, web & email proxies, …
- Inter-ship WAN traffic
  - Position updates, calls for fire, …
  - Web, email, chat, …

- Cluster traffic
  - Images, orders, updates, …
- Remote traffic, …
  - Orders, video streams, …

Integration Methodology & Framework



Integration Services

- Semantic Integration
  - Protocol and item registration
  - Consensus computation
  - Message Export / Import services
- Parallel Execution
  - Multicast-based Event distribution
  - Synchronization (Time Management)

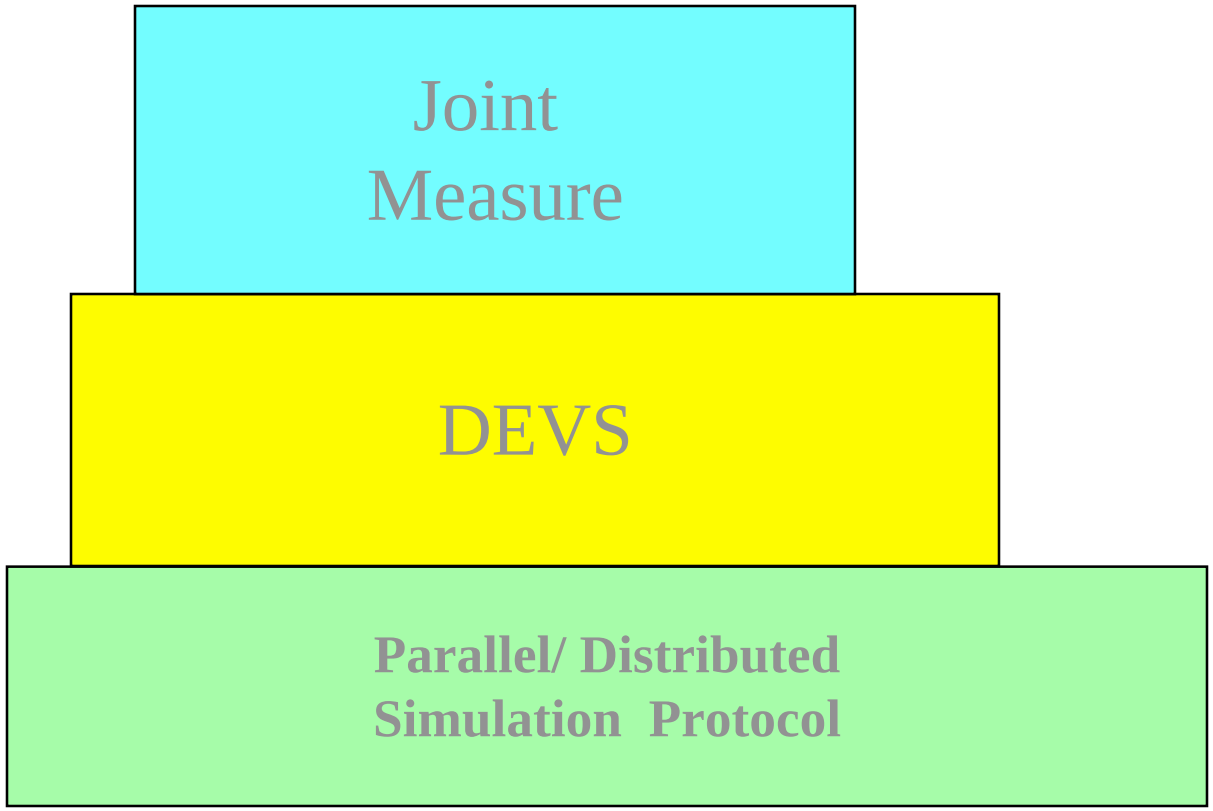
Example – DEVS & Support of Joint Measure

A platform effectiveness modeling tool Created at Lockheed Martin.

Models are specified using the DEVS formalism.

DEVS is implemented as an object oriented simulation toolkit.

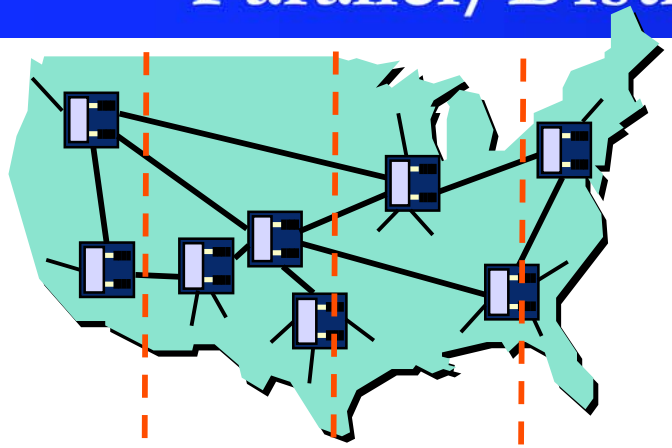
Joint MEASURE was implemented with DEVS-C++ from the University of Arizona.



Component Model (Actual Reuse) Matrix

Project / Model	Critical Mobile Target	Global Positioning System III	Arsenal Ship	Coast Guard Deep Water	Space Operations Vehicle	Common Aero Vehicle	Joint Composite Tracking Network	Integrated System Center	Space Based Laser	Space Based Discrimination	Missile Defense (Theater / National)
Radar Model	X		X	X	X	X	X				X
IR Sensor Model	X				X		X	X	X	X	X
Missile Model			X				X	X	X		X
Laser Model								X	X	X	X
Comm. Model	X			X		X	X	X			X
Command Control Model	X		X								X
Earth & Terrain Model	X	X	X		X						X
Weather Model	X										X
Waypoint & Heading Nav Model	X	X	X	X	X		X				X
Orbital Propagate Model	X	X			X			X	X	X	X
Ballistic Trajectory Model			X		X	X				X	X

Parallel/Distributed Network Simulation



Network Models

Popular sequential models (ns-2) parallelized by integrating multiple instances of itself.

ns-2 Sequential Simulator

ns-2 Sequential Simulator

ns-2 Sequential Simulator

ns-2 Sequential Simulator

Runtime Infrastructure

Supercomputer

Application (GTNetS, ns-2, …)

Runtime Interface

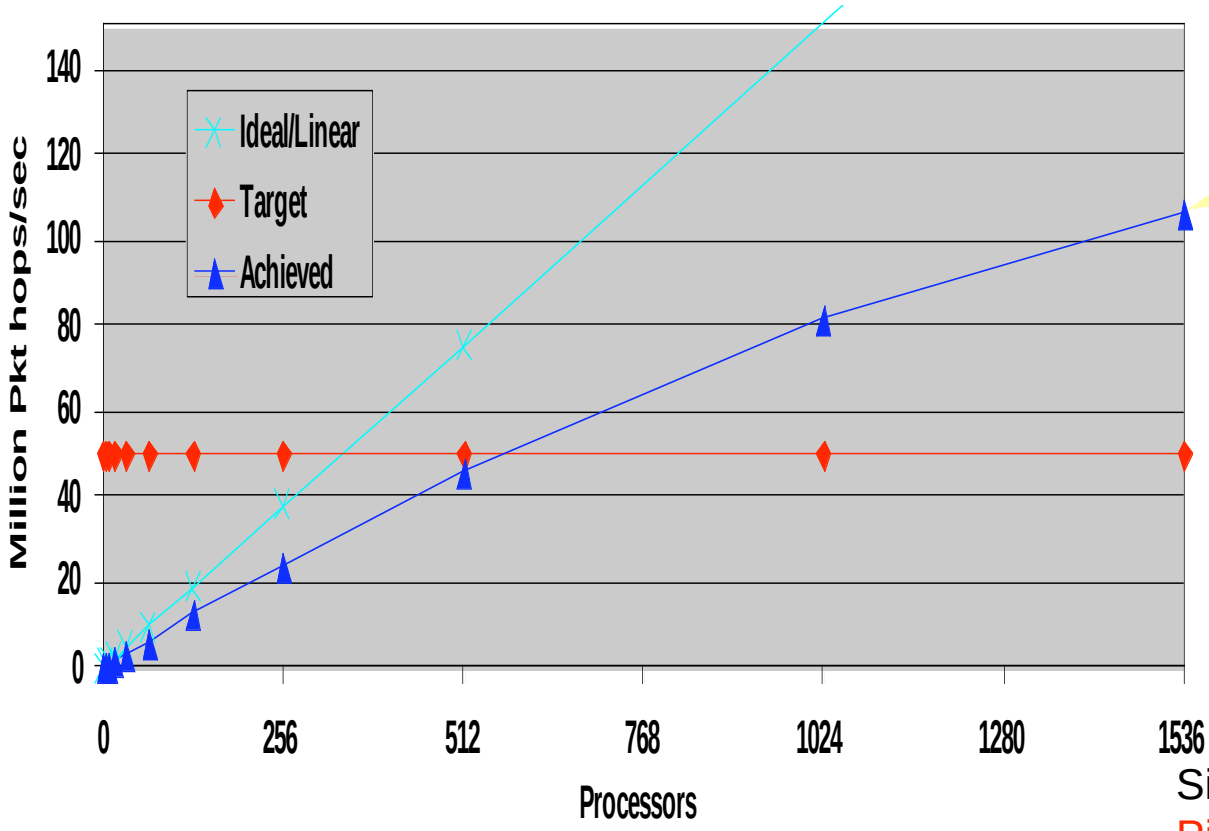
Other Services

Virtual Time Synchronization

Asynchronous Distributed Reductions

Heterogeneous Network Communication

Large-scale Packet-level Simulation



Reported in MASCOTS'03

106 million pkt hops/sec, 4 million simulated nodes

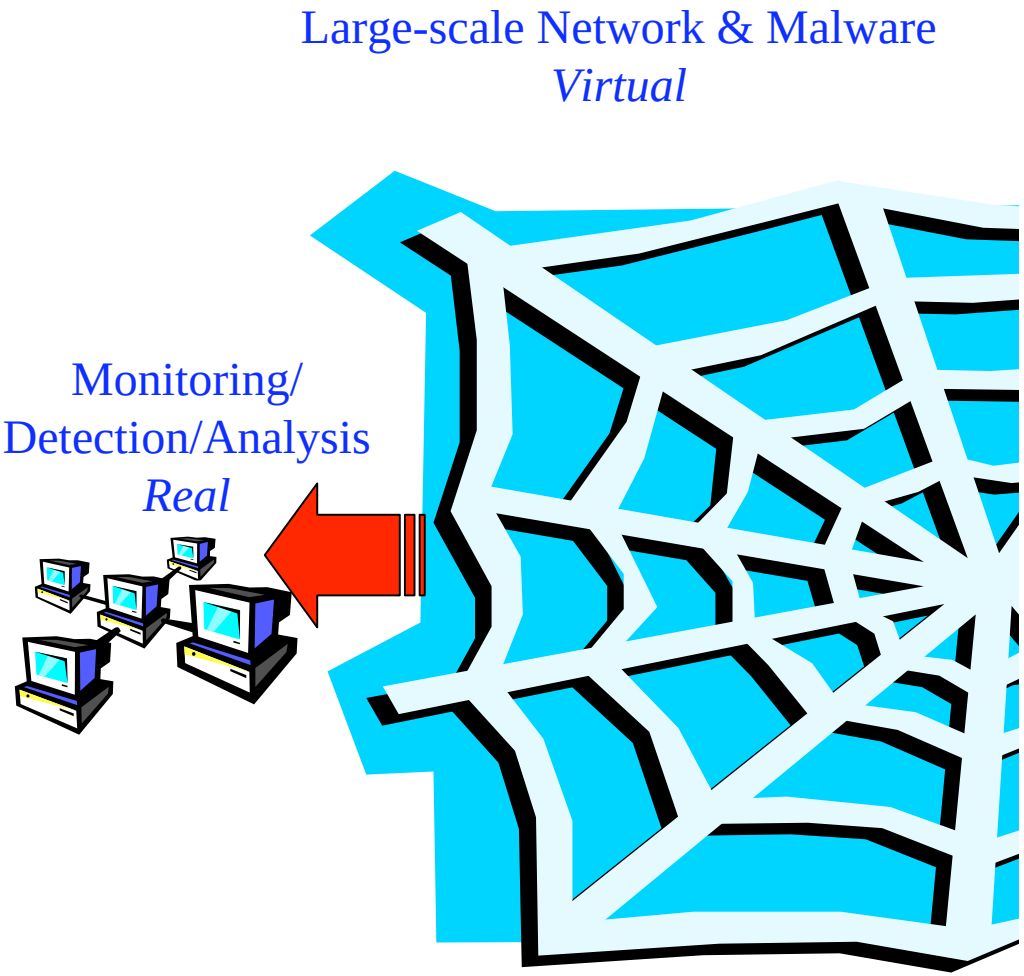
Simulation Platform: Lemieux
Pittsburgh Supercomputing Center
www.psc.edu/machines/tcs/lemieux.html

Some of our recent milestones in parallel/distributed network simulations:

- **Record: Among the largest & fastest packet-level network simulations to date**
- Shown: No. of packet transmissions simulated per second with *pdns* on *Lemieux*
- Benchmark: A "standard" benchmark (*Campus network*) scenario

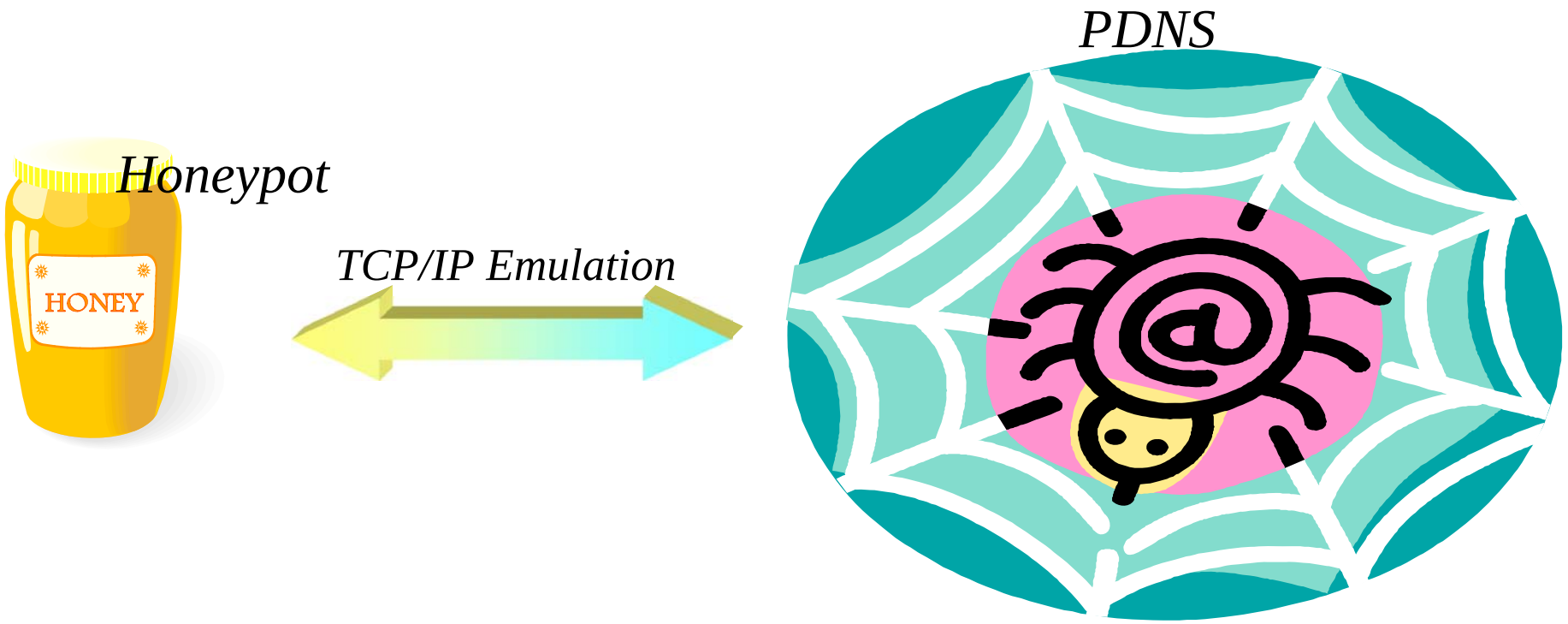
Testing Network Defenses

- Interface actual security applications with virtual networks
  - Transparent, plug-n-play into large virtual “network battlefield”
  - Test against large-scale virtual attack scenarios
  - Requires TCP/IP emulation...

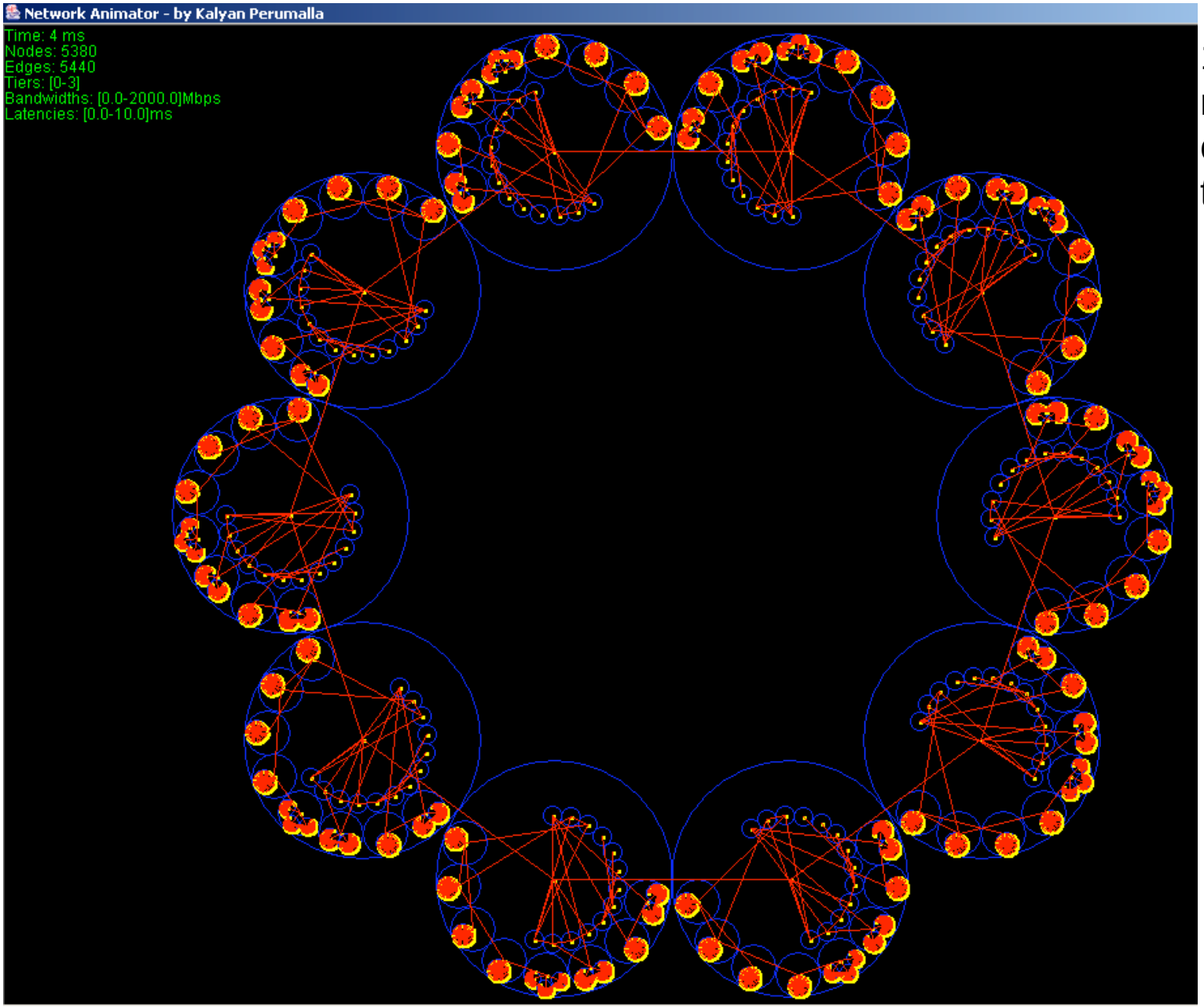


Example - Honeypot Emulation

- Attack *actual* honeypot with *simulated* worms
- Test honeypot operation and effectiveness



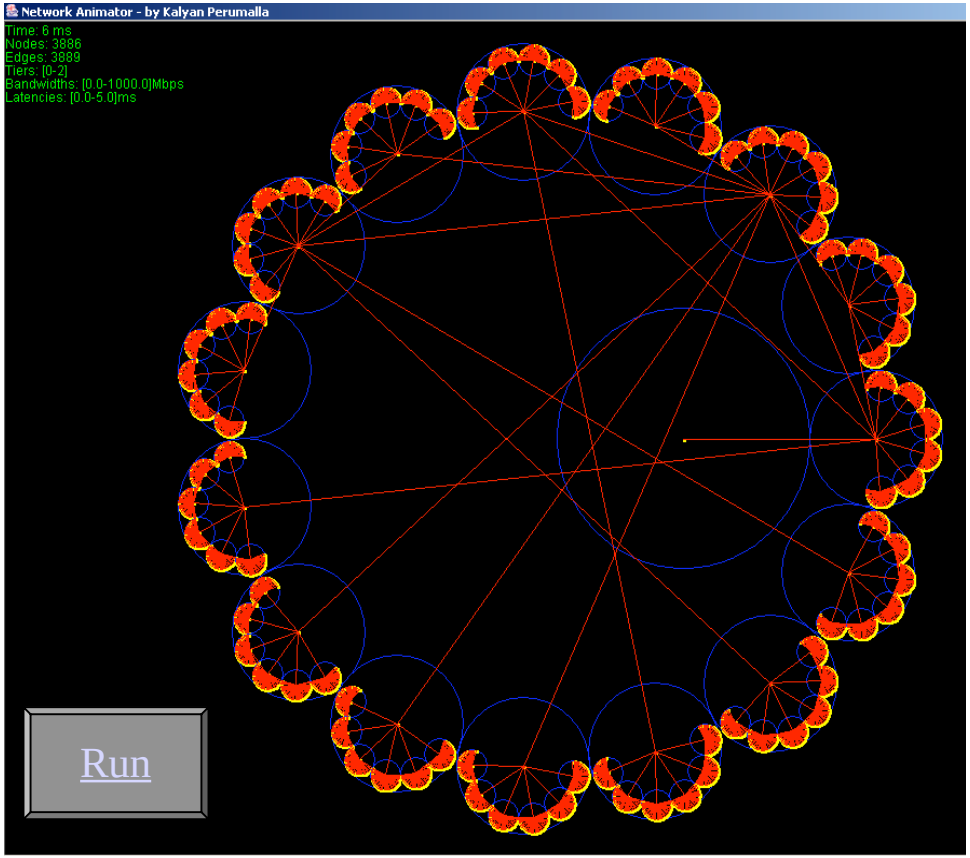
Visualization of Multiple Campus Networks



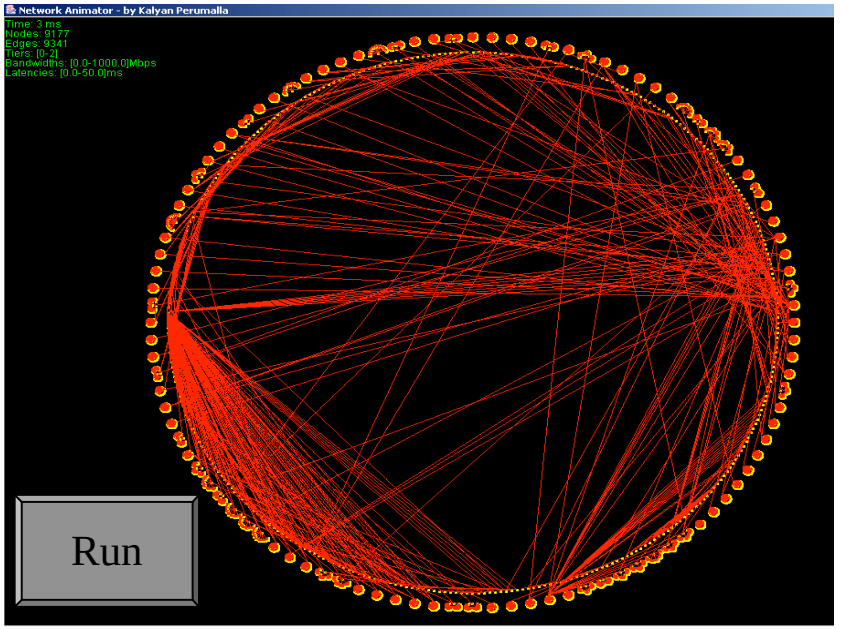
10 campus networks connected together

Portions of "Military Enterprise" Networks

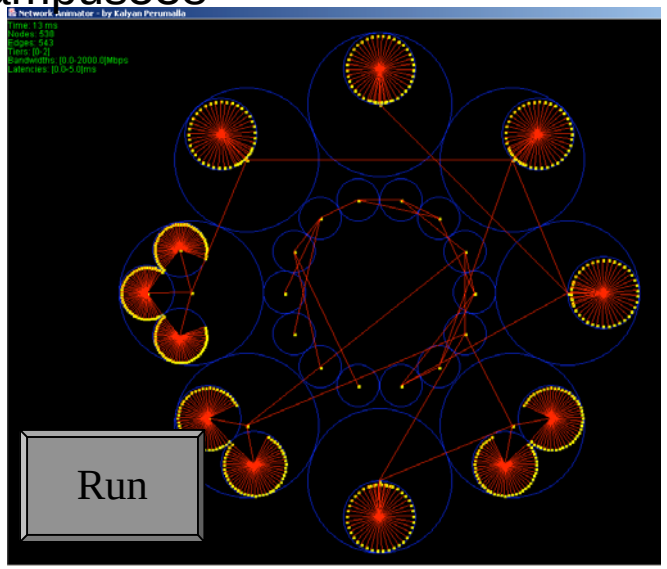
dartmouth3886



ornl9177

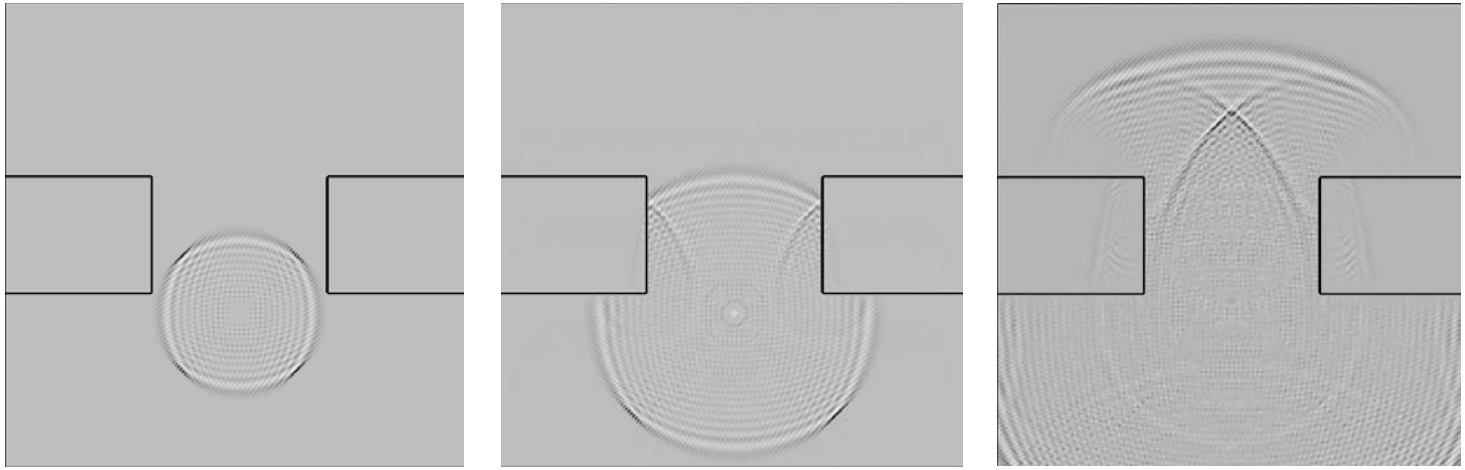


campus538



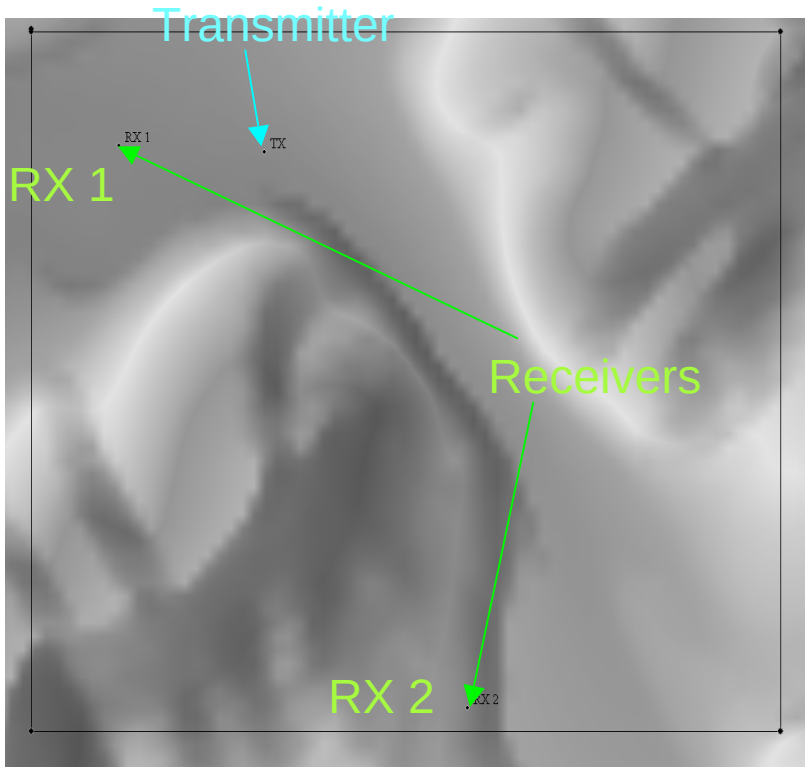
*Network snapshots from *netanim* visualizer

Fast radio channel simulation

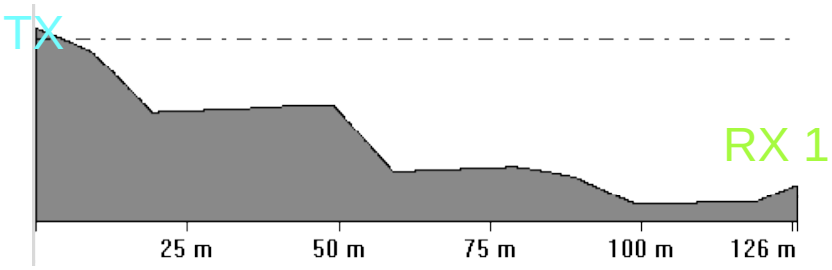


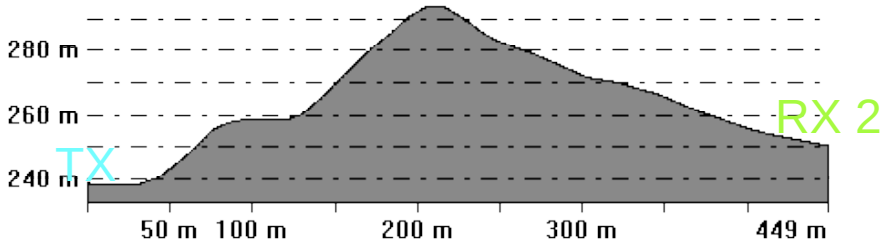
Radio wave propagation through a gap in a concrete wall.

A comparison of empirical and wave propagation models



Model	RX 1 path loss	RX 2 path loss
Wave equation	58.3	78.3
Free space path loss	48.7	59.7
Free space path loss with knife edge diffraction	48.7	112.49
Log-distance path loss, n = 4	70.7	92.7
Log-distance path loss, n = 3	59.7	76.2





In Conclusion

- ORNL has a substantial research program in large scale system modeling, with an emphasis on communications dependent systems
- Simulation integration
  - Component based simulation
  - DoD High Level Architecture
- High performance computing for large scale systems
  - Parallel discrete event simulation
  - High performance simulation with component based frameworks
- Communication Network Applications
  - M&S for network security
  - Network emulation
  - Wireless channel modeling
  - Visualization and Sonification
- Modeling frameworks for complex systems