Networking and Information Technology Research and Development: Scientific and Technical Aspects

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Director

National Coordination Office for

Information Technology Research and Development

Federal Networking & IT Research Opportunities FY 2004

October 2, 2003

The Federal government plays a critical role in supporting fundamental research in networking and IT

- Federally-sponsored research builds the technology base on which the information technology industry has grown
- Federal government funds basic research not funded by industry
  - High risk, innovative ideas whose practical benefits may take years to demonstrate
- Networking and Information Technology R&D (NITRD) Program helps focus interagency IT R&D:
  - Identify common research needs
  - Plan inter-agency research programs
  - Coordinate and collaborate on research announcements and funding
  - Review research results and adjust accordingly
- NITRD evolved from the Federal High Performance Computing and Communications (HPCC) Initiative, Computing Information and Communications (CIC) Program, and Next Generation Internet (NGI) Program
- NITRD is assessed by the President's Information Technology Advisory Committee

Participating Agencies and Departments

- Department of Defense
  - Defense Advanced Research Projects Agency (DARPA)
  - Defense Information Systems Agency (DISA)
  - National Security Agency (NSA)
  - Office of the Director of Defense Research and Engineering (ODDR&E)
- Department of Energy
  - Office of Science (DOE/SC)
  - National Nuclear Security Administration (DOE/NNSA)
- Department of Health and Human Services
  - National Institutes of Health (NIH)
  - Agency for Health Research and Quality (AHRQ)
- Department of Commerce
  - National Institute of Standards and Technology (NIST)
  - National Oceanic and Atmospheric Administration (NOAA)
- National Science Foundation (NSF)
- National Aeronautics and Space Administration (NASA)
- Environmental Protection Agency (EPA)
- Observer: Federal Aviation Administration (FAA)

Agency NITRD Budgets by Program Component Area

Budget slide to be included when budget is officially released.

National Coordination Office (NCO) for Information Technology Research and Development (IT R&D)

Mission: *To formulate and promote Federal information technology research and development to meet national goals*

- NCO Director reports to the Director of the White House Office of Science Technology Policy (OSTP) and co-chairs the Interagency Working Group for IT R&D
- Coordinates planning, budget, and assessment activities for the Federal multi-agency NITRD Program
- Supports the six technical Coordinating Groups (CGs) that report to the Interagency Working Group
  - Research planning workshops, conferences, and meetings
  - Presentations, white papers, and reports
- Supports the President's Information Technology Advisory Committee

NITRD Program Coordination

WHITE HOUSE

Executive Office of the President
Office of Science and Technology Policy

National Science and Technology Council

President's Information Technology Advisory Committee (PITAC)

U.S. Congress

NITRD Authorization and Appropriations Legislation

National Coordination Office (NCO) for Information Technology Research and Development

Interagency Working Group (IWG) on Information Technology R&D

Participating Agencies: AHRQ, DARPA, DOE/NNSA, DOE/SC, EPA, NASA, NIH, NIST, NOAA, NSA, NSF, ODDR&E

- **High End Computing Coordinating Group (HEC CG)**
- **Large Scale Networking Coordinating Group (LSN CG)**
- **High Confidence Software and Systems Coordinating Group (HCSS CG)**
- **Human Computer Interaction & Information Management Coordinating Group (HCI & IM CG)**
- **Software Design and Productivity Coordinating Group (SDP CG)**
- **Social, Economic and Workforce Implications of IT and IT Workforce Development Coordinating Group (SEW CG)**

Publications

- Annual publication of the Supplement to the President's Budget also known as the "BLUE BOOK," describes the NITRD Program**:**

  http://www.itrd.gov/pubs/blue03/

- President's Information Technology Advisory Committee (PITAC) Reports:

Transforming Access to Government Through Information Technology
http://www.itrd.gov/pubs/pitac/pres-transgov-11sep00.pdf

Developing Open Source Software to Advance High End Computing
http://www.itrd.gov/pubs/pitac/pres-oss-11sep00.pdf

Digital Libraries: Universal Access to Human Knowledge
http://www.itrd.gov/pubs/pitac/pitac-dl-9feb01.pdf

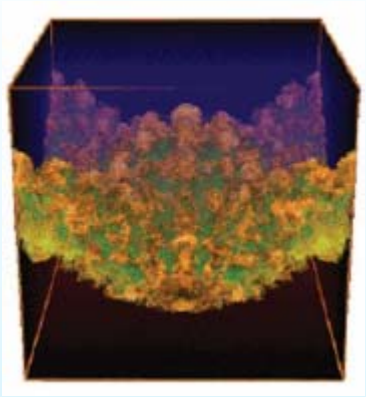
Transforming Health Care Through Information Technology
http://www.itrd.gov/pubs/pitac/pitac-hc-9feb01.pdf

Using Information Technology To Transform the Way We Learn
http://www.itrd.gov/pubs/pitac/pitac-tl-9feb01.pdf

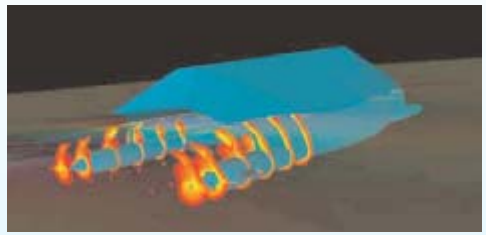
High-End Computing (HEC)

- **High-End Computing: Leading edge of high performance computing**
- **FY 2003 Focus: New plan for high-end computing research, resources, and acquisition (High-End Computing Revitalization Task Force)**
- **Workshop on the Roadmap for the Revitalization of HEC organized by Computing Research Association: http://www.cra.org/Activities/workshops/nitrd/**

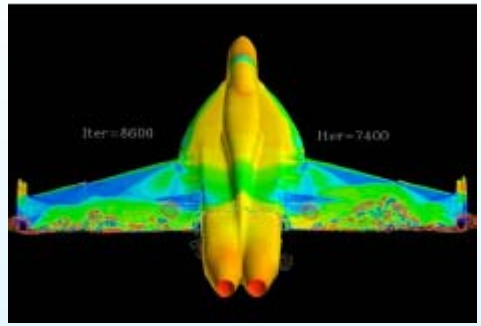
Applications of High-End Computing:
Big Problems with Big Impacts



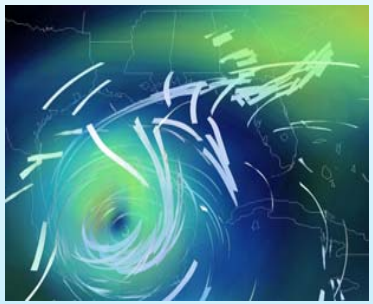
Nuclear Stockpile Stewardship



Ship Design

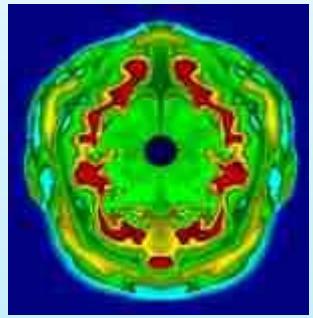


Aeronautics

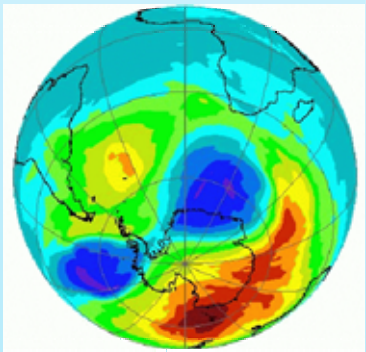


Weather Prediction

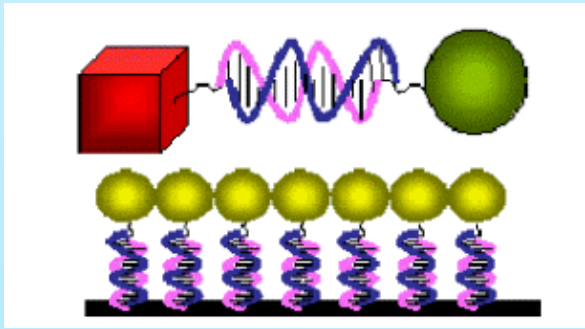
Cryptography



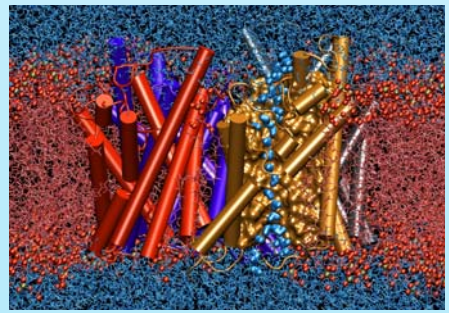
Astrophysical Simulation



Climate Modeling



Nano-Science



Biology

Examples of HEC Application Areas with Federal Interest

- Nuclear stockpile stewardship (multi-discipline physics models)
- Global and regional climate modeling
- Weather and ocean forecasting
- Geophysics (earthquakes, volcanoes, landslides, plate tectonics, magneto-dynamics)
- Astrophysics (star and galaxy dynamics)
- Aeronautics and aerospace design (air-frames, re-entry vehicles)
- Engineering design of ships, land vehicles, buildings
- Weapon designs and weapon effects
- Armor design
- Survivability/stealthiness design
- Signal and image processing
- Signals intelligence (e.g., cryptanalysis)
- Electromagnetics
- Molecular modeling for chemical risk assessment
- Biophysics (e.g., protein folding)
- Pharmacology
- Quantum chemistry
- Materials modeling and design (e.g., concrete)
- Quantum chromodynamics

Opportunities for using HEC to Advance Science Will Continue in Existing and New Areas (1)

Application	Science Accomplishment	Required Capability Multiple	Benefit to Nation
Signals Intelligence	Model, simulate, and exploit foreign codes, ciphers and complex communications systems.	**1000**	Supports U.S. policy makers, military commands and combat forces with information critical to national security, force protection and combat operations.
Directed Energy	To advance the directed energy systems design process out of the scientific research realm into the engineering design realm	**1000**	Ability to efficiently design next generation directed energy offensive and defensive weapon systems. Change the design process from years to days.
Signals Image Processing & Automatic Target Recognition	To replace electromagnetic scattering field tests of actual targets with numerical simulations of virtual targets	**1000**	Creates the ability to design more stealthy aircraft, ships, and ground systems and creates the ability to rapidly model new targets enabling more rapid adaptation of fielded weapon systems' ability to target new enemy weapon systems.
Integrate Modeling and Test of Weapon Systems	To model complex system interaction in real time with precision	**1000**	Creates the ability to replace many expensive, dangerous and time consuming ground tests with virtual tests resulting in lower test costs and more rapid development of weapon systems.
Climate Science	Resolve additional physical processes such as ocean eddies, land use patterns, and clouds in climate and weather prediction models.	**1000**	Provide U.S. policymakers with leading-edge scientific data to support policy decisions. Improve climate and weather prediction skill at timescales from minutes to decades.
Weather and Short-term Climate Prediction	Enable dynamical prediction of frequency and intensity of occurrence of hurricanes/typhoons and severe winter storms 90 days in advance.	**1000**	Provides critical support to deployed naval, air and land forces in local, regional and global combat environments. Lives saved and economic losses avoided due to better severe weather prediction.
Solid Earth Science	Dynamic earthquake forecasting with 5 year lead time.	**100**	Provide prioritized retrofit strategies. Reduced loss of life and property. Damage mitigation.
Space Science	Realistically simulate explosive events on the sun, the propagation of the energy and particles released in the event through the interplanetary medium, and their coupling to Earth's magnetosphere, ionosphere, and thermosphere.	**1000**	Provide decision makers (both civilian and military) with status and accurate predictions of space weather events on time scales of hours to days.
Subsurface Contamination Science	Simulate the fate and transport of radionuclides and organic contaminants in the subsurface.	**1000**	Predict contaminant movement in soils and ground water and provide a basis for developing innovative technologies to remediate contaminated soils and ground water.

National Security

Environment

Opportunities for using HEC to Advance Science Will Continue in Existing and New Areas (2)

Application	Science Accomplishment	Required Capability Multiple	Benefit to Nation
Magnetic Fusion Energy	Optimize balance between self-heating of plasma and heat leakage caused by electromagnetic turbulence.	**100**	Underpins U.S. decisions about future international fusion collaborations. Integrated simulations of burning plasma crucial for quantifying prospects for commercial fusion.
Combustion Science	Understand interactions between combustion and turbulent fluctuations in burning fluid.	**100**	Understand detonation dynamics (for example, engine knock) in combustion systems. Solve the "soot" problem in diesel engines.
Astrophysics	Realistically simulate the explosion of a supernova for the first time.	**1000**	Measure size and age of Universe and rate of expansion of Universe. Gain insight into inertial fusion processes.
Structural and Systems Biology	Simulations of enzyme catalysis, protein folding, and transport of ions through cell membranes.	**1000**	Ability to discover, design, and test pharmaceuticals for specific targets and to design and produce hydrogen and other energy feedstocks more efficiently.
Catalyst Science/ Nanoscale Science and Technology	Calculations of homogeneous and heterogeneous catalyst models in solution.	**1000**	Substantial reductions in energy costs and emissions associated with chemicals manufacturing and processing. Meeting federally mandated NOx levels in automotive emissions.
Nanoscale Science and Technology	Simulate the operation of nanoscale electronic devices of modest complexity.	**1000**	Takes miniaturization of electronic devices to a qualitatively new level enabling faster computers, drug delivery systems, and consumer and military electronics.
Nanoscale Science and Technology	Simulate and predict mechanical and magnetic properties of simple nanostructured materials.	**1000**	Enables the discovery and design of new advanced materials for a wide variety of applications potentially impacting a wide range of industries, including the high-tech industry that generated more than $900 billion in sales and accounted for 4 million jobs in 1999 and the $34 billion disk drive industry.

Energy and Physics

Biology and Nanoscience

User and Agency Views on High-End Computing

- **HEC solves problems with major impact on society and Government that cannot otherwise be solved**
  - HEC R&D and HEC computing must be driven by application needs
- **Current systems**
  - Hard to use
  - Enable us to do “old science” well, but not the new science we need
- **Mission requirements and scientific leadership require radical improvements in *time-to-solution***
- **Inadequate resources – both capacity and capability**

Goals of High-End Computing Revitalization Task Force

- **Revitalize U.S. leadership in high-end computing as a key tool for science and technology**
  - Make high-end computing easier and more productive to use
  - Make high-end computing readily available to Federally funded missions that need it
  - Sustain the development of new generations of high-end computing systems
  - Effectively manage and coordinate Federal high-end computing

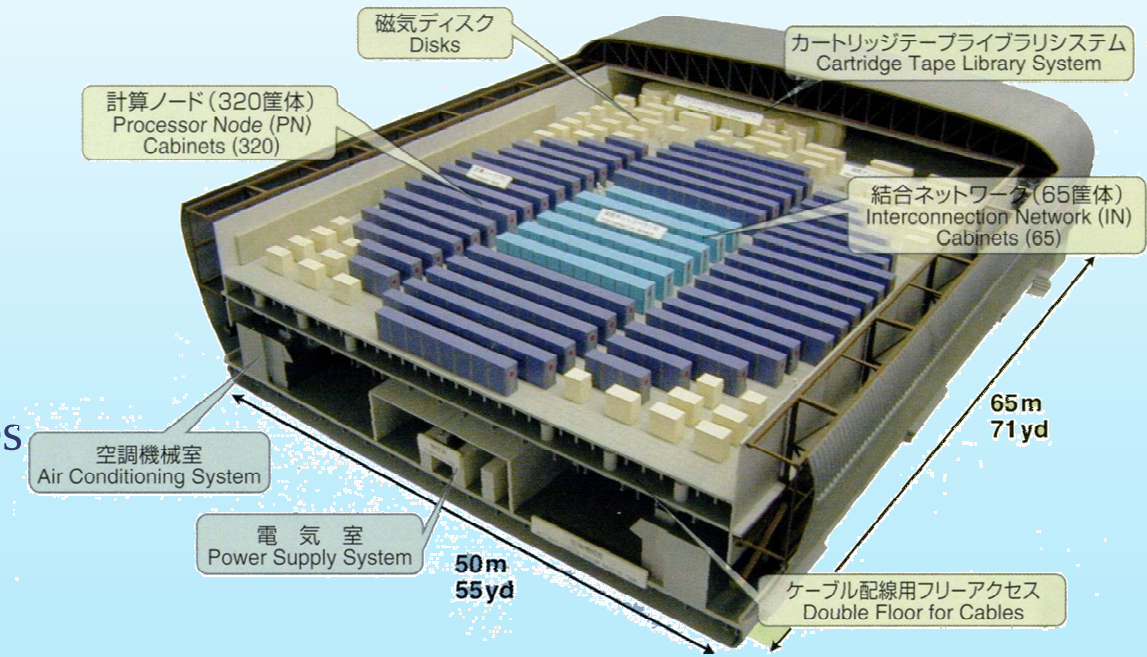
Japanese Earth Simulator

- **Entered service March 2002**
  - Took the #1 spot on the TOP500 Supercomputer list
  - Helped inspire a new look at U.S. high-end computing
- **What it was:**
  - A multi-agency cooperative research project
  - A well-designed, well-engineered, and very expensive computer based on proven technology
  - An attention-getting event that elevated the prominence of what was already considered to be an important issue
  - A challenge that provided added incentive for action
  - A reminder that U.S. high-end computing planning was not as well coordinated as it should have been
- **What it wasn't:**
  - A technology surprise or revelation
  - Demonstration that the U.S. has lost scientific leadership

Earth Simulator Has Inspired a New Look at U.S. High End Computing

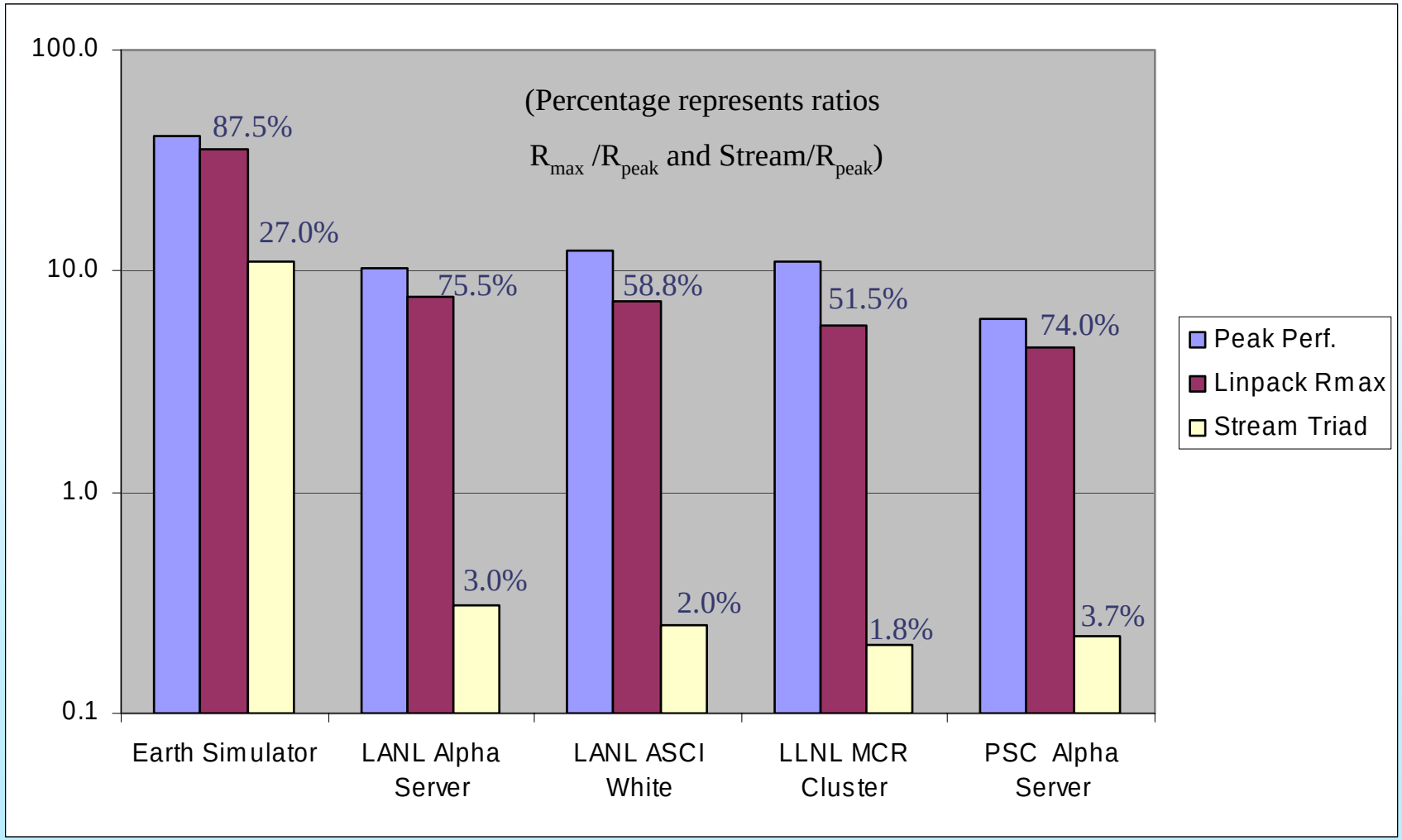
- Based on the NEC SX architecture - 640 nodes, each node with 8 vector processors (8 GFlops peak per processor), 2 ns cycle time, 16GB shared memory
  - Total of 5120 total processors, 40 TFlops peak, and 10.24 TB memory
- Interconnect via single stage crossbar switch (1800 miles of cable), 83,000 copper cables, 16GB/s cross section bandwidth
- 700 TB disk space
- 1.6 PB mass store
- Area of computer =

  4 tennis courts, 3 floors
- Highly efficient for climate and weather codes



Source: http://www.es.jamstec.go.jp/esc/eng/outline/outline02.html

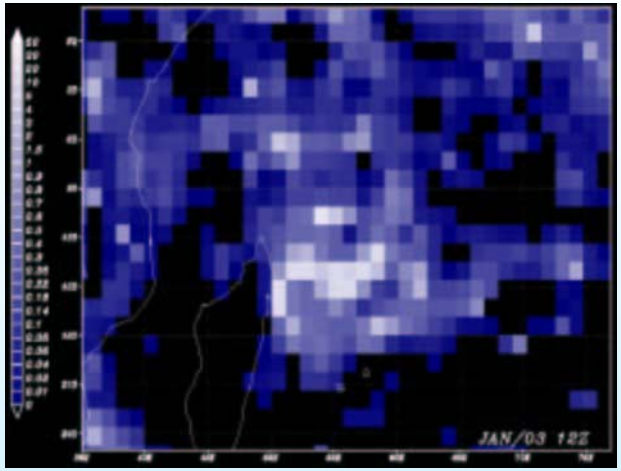
Performance Measures of Selected Top Computers



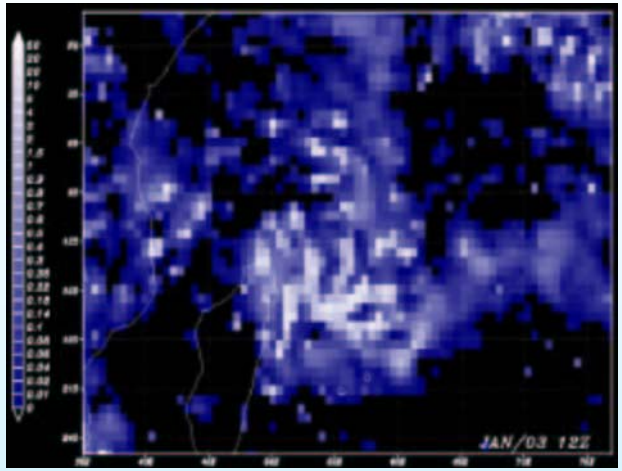
Note Logarithmic Y axis

Computational Power of Japanese Earth Simulator Allows Better Resolution of Local Features

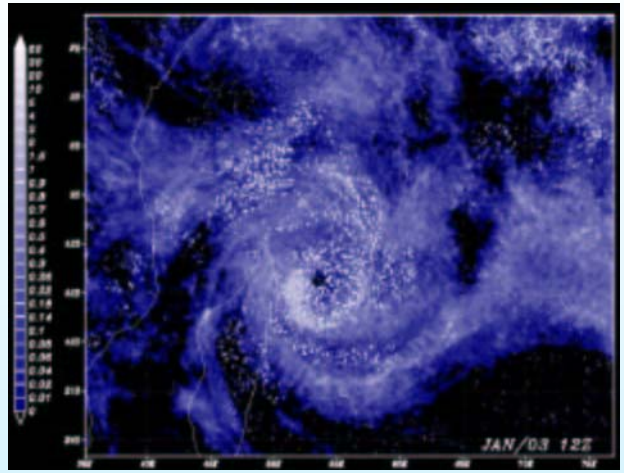
Simulation of Tropical Cyclone Near Madagascar



125.1 km grid



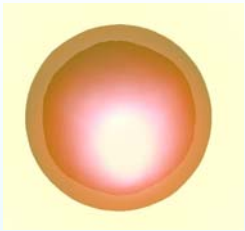
62.5 km grid



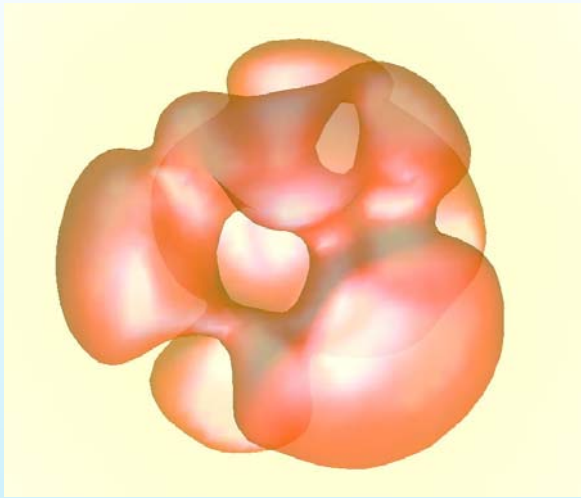
10.4 km grid

Examples of High-End Computing Applications

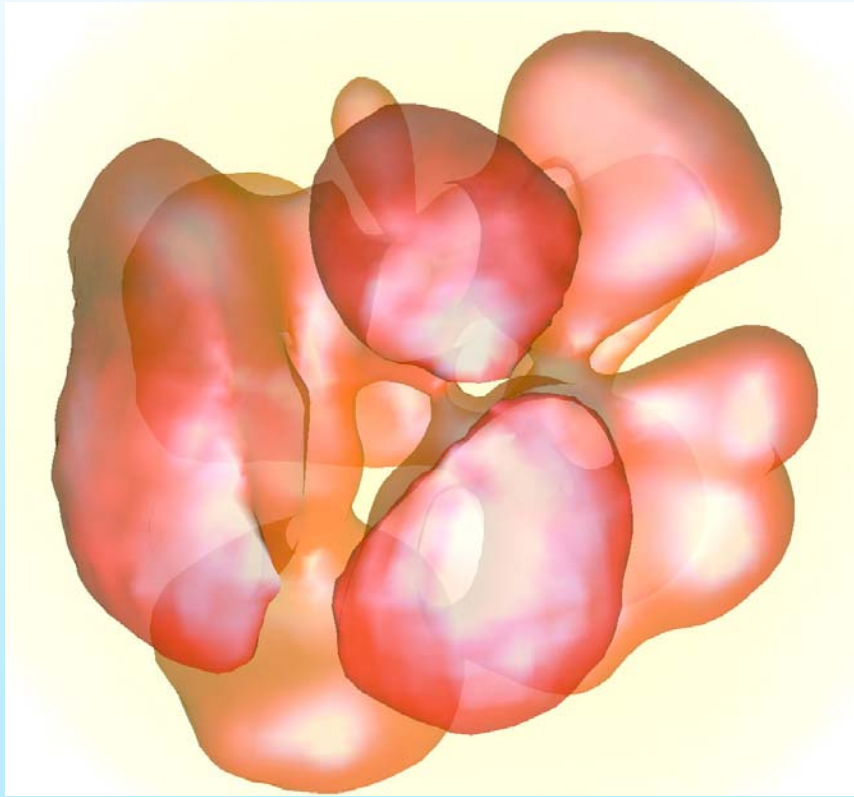
Explosion of a Super-Nova (not to scale) (DOE/SC)



Start



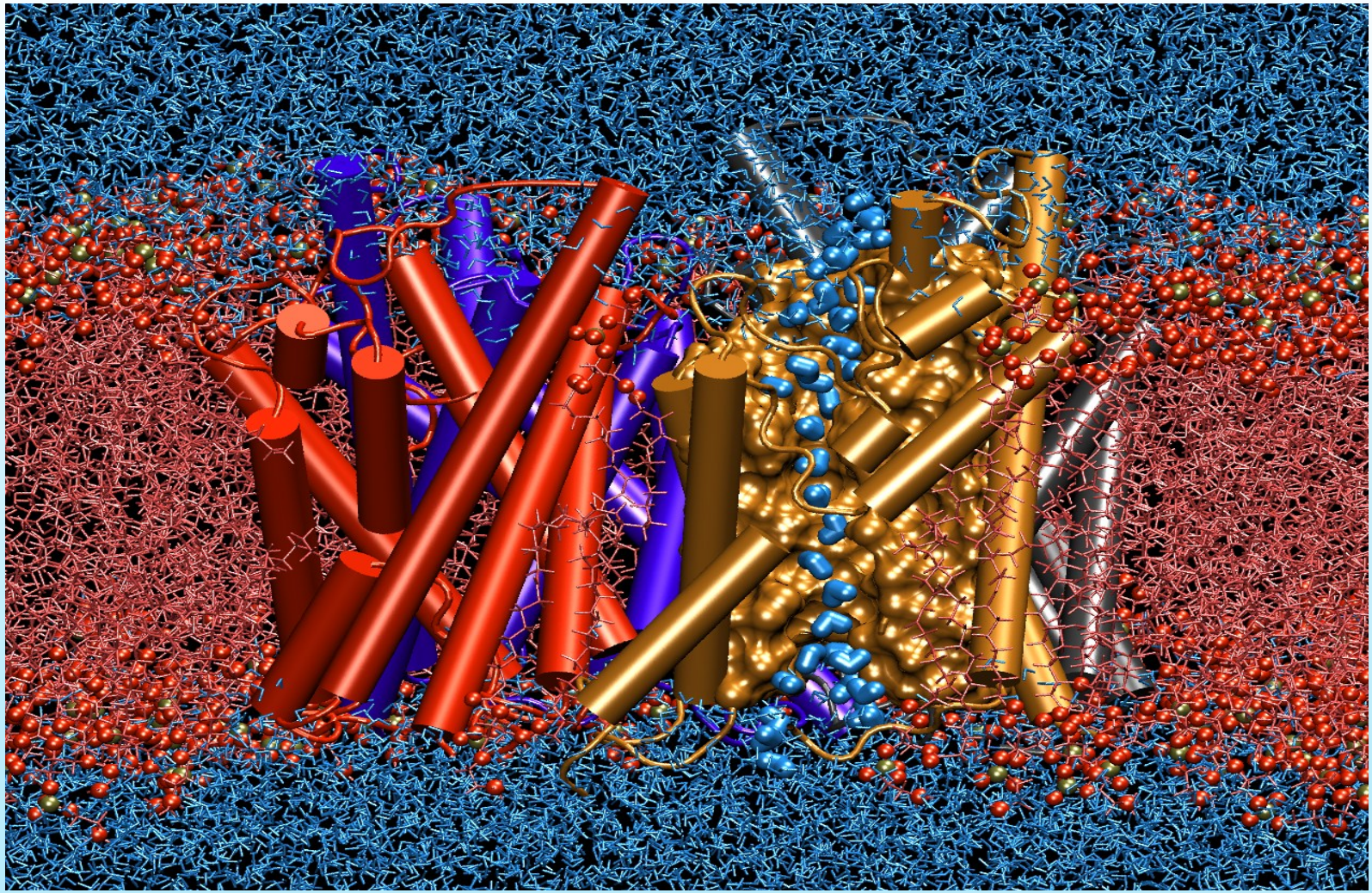
Middle



End

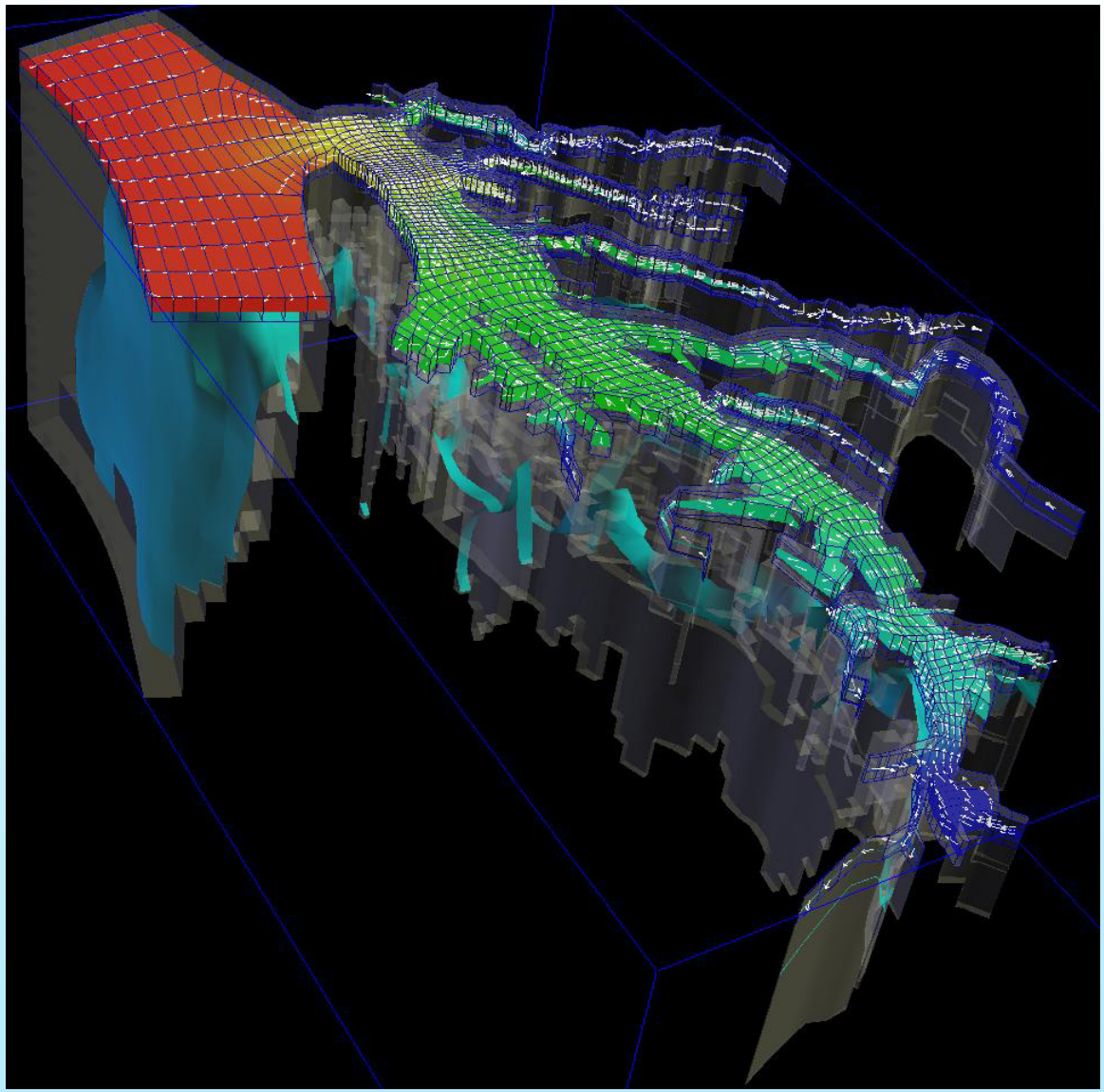
Simulation of Aquaporin Protein Inside a Cell (NSF & NIH)

Visualization shows transport of water molecules into cell.



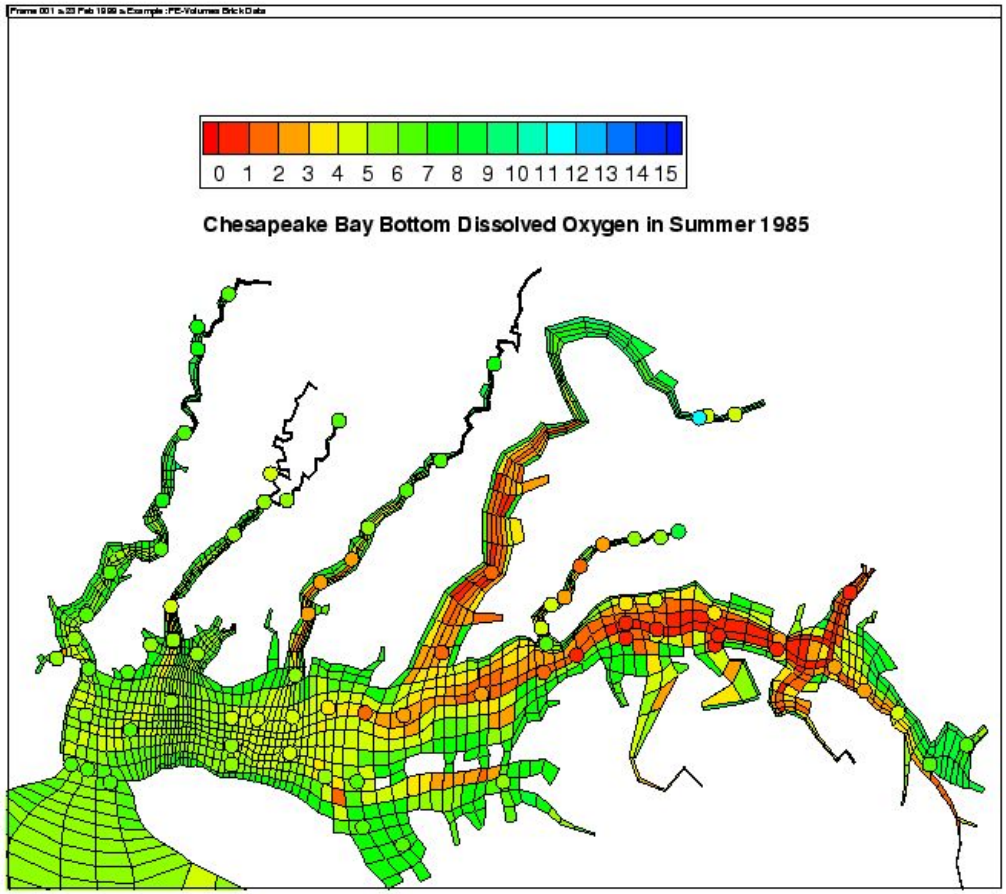
Environmental Modeling of the Chesapeake Bay (NOAA, EPA, DoD)

- Image shows visualization of computed salinity in the Bay (red is high salinity).
- South is up.
- Visualization is an important part of the model, because users may not be skilled computational scientists.



Environmental Modeling of the Chesapeake Bay (NOAA, EPA, DoD)

- Model is checked against measured data.
- Model has shown that approximately 1/4 of the nitrogen added to the Bay starts as air pollution, some from sources hundreds of miles from the Bay's watershed.



LSN and its Teams

- **Large Scale Networking (LSN) Coordination Group**
  - Coordinates high performance research network policy, interagency collaboration, and resource cooperation
  - Agency participants: NIH, NSF, DARPA, DOE(SC), DOE(NNSA), ODDR&E, NIST, NASA, AHRQ, NOAA, NSA
- **Joint Engineering Team (JET)**
  - Provides engineering coordination among high performance research networks for transparency, interoperability, and sharing of resources
- **Network Research Team (NRT)**
  - Provides coordination among high performance networking research programs to leverage resources and promote collaboration and exchange of information
- **Middleware and Grid Infrastructure Coordination (MAGIC)**
  - Promotes high performance research network middleware tools development, interoperability, research coordination, and infrastructure persistence

LSN Collaboration Research Areas

- Networking research into basic technologies, optical networking, services, and application
- Security
- Networking infrastructure for production, experimental, and research networks
- Network middleware and Grid
- Collaboration technologies
- Network monitoring and measurement
- Wireless, ad hoc, and sensornet capabilities
- Automated resource management
- Standards and specifications
- Crisis response and critical infrastructure protection
- Education and training

Large Scale Networking Workshops

- **Workshop on the Blueprint for Future Science Middleware and Grid Research and Infrastructure**
  - August 26-28, 2002
- **New Directions in Scalable Cyber-Security in Large Scale Networks: Deployment Obstacles**
  - March 2003
- **NSF Workshop on Security at Line Speed**
  - August 11-13, 2003
- **Inaugural Cyber Trust Principal Investigators Meeting and Research Directions Workshop**
  - August 13-15, 2003

Examples of Agency LSN Programs (1)

- **NSF**
  - Grid Physics Network (GriPhyN)
  - Gemini: Connect 8.1 meter telescopes in Hawaii and Chile
  - AmericasPathway (AmPath)*
  - STARLight
  - High Performance Wireless Research and Education Network (HPWREN)*
- **DOE/SC**
  - Particle Physics Data Grid (PPDG)*
  - National Fusion Collaboratory (NFC)*
  - Earth System Grid (ESG)
  - DOE Science Grid
  - Collaboratory for Multiscale Chemical Sciences (CMCS)
- **NASA**
  - Ground-Truthing Experiment*
  - NASA Information Power Grid

* ***Described in this talk***

Examples of Agency LSN Programs (2)

- **NIST**
  - Agile networking infrastructures
  - Interoperability testbed, software
- **ODDR&E**
  - Adaptive protocols for mobile wireless networks
  - Scalable optical networking for multilayer battlespace control
  - Mobil wireless scalable peer-to-peer networking
- **NIH**
  - Telemammography for the Next Generation Internet: National Digital Mammography Archive
  - Radiation oncology treatment planning/care delivery
  - Remote, real-time simulation for teaching human anatomy and surgery
  - Mobile telemedicine*

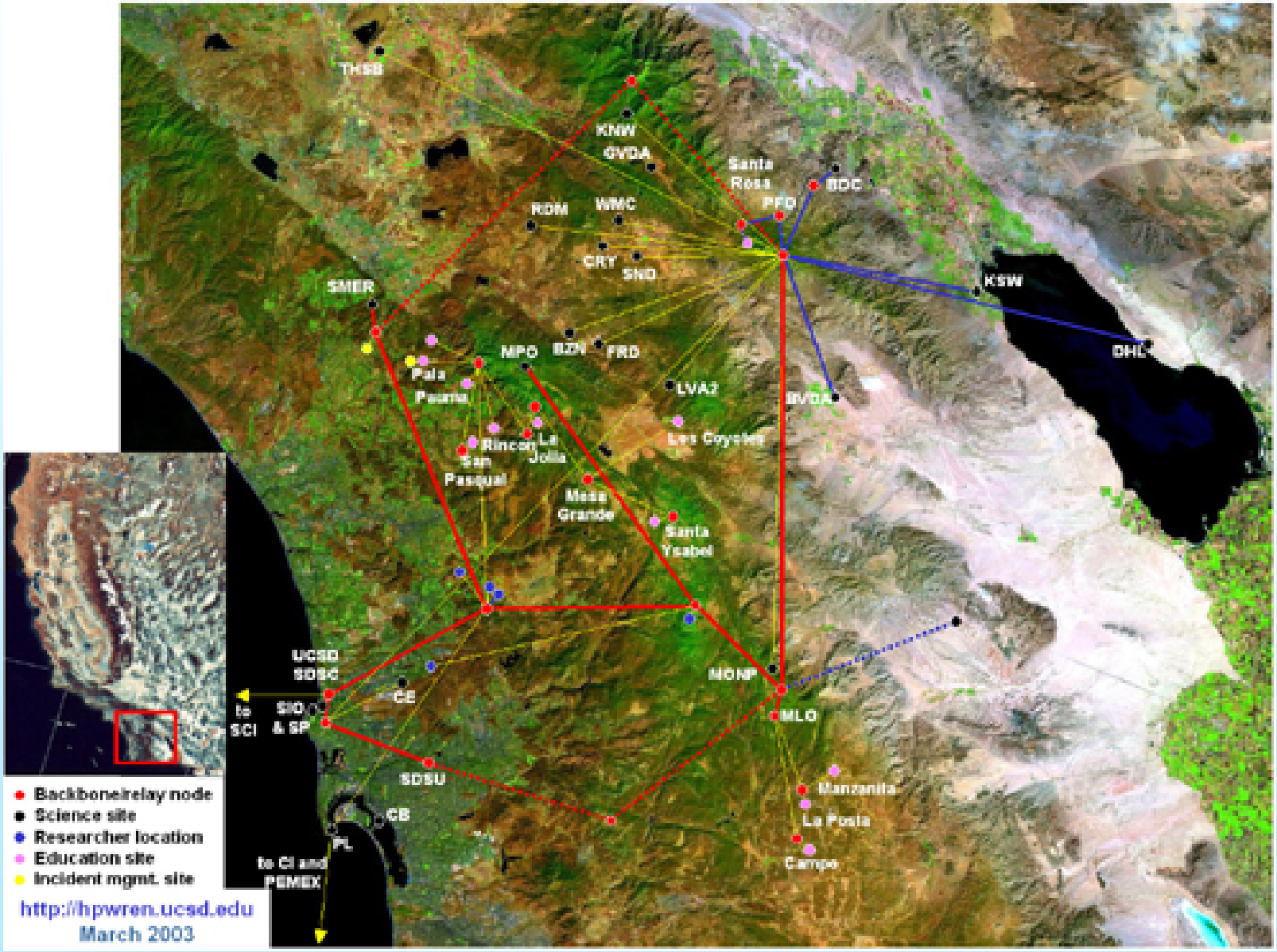
* ***Described in this talk***

Examples of Agency LSN Programs (3)

- **NSA**
  - Ultra high-speed firewalls
  - Nonlinearity and transients in optical networks
  - Optical burst switch protocols
- **NOAA**
  - Near-real-time Doppler radar data support to weather modeling
  - Crisis response weather data support

AmericasPath (AmPath) Service Area

High Performance Wireless Research and Education Network (HPWREN)



Particle Physics Data Grid (PPDG) Communities & Applications: High Energy Physics Problem Scale

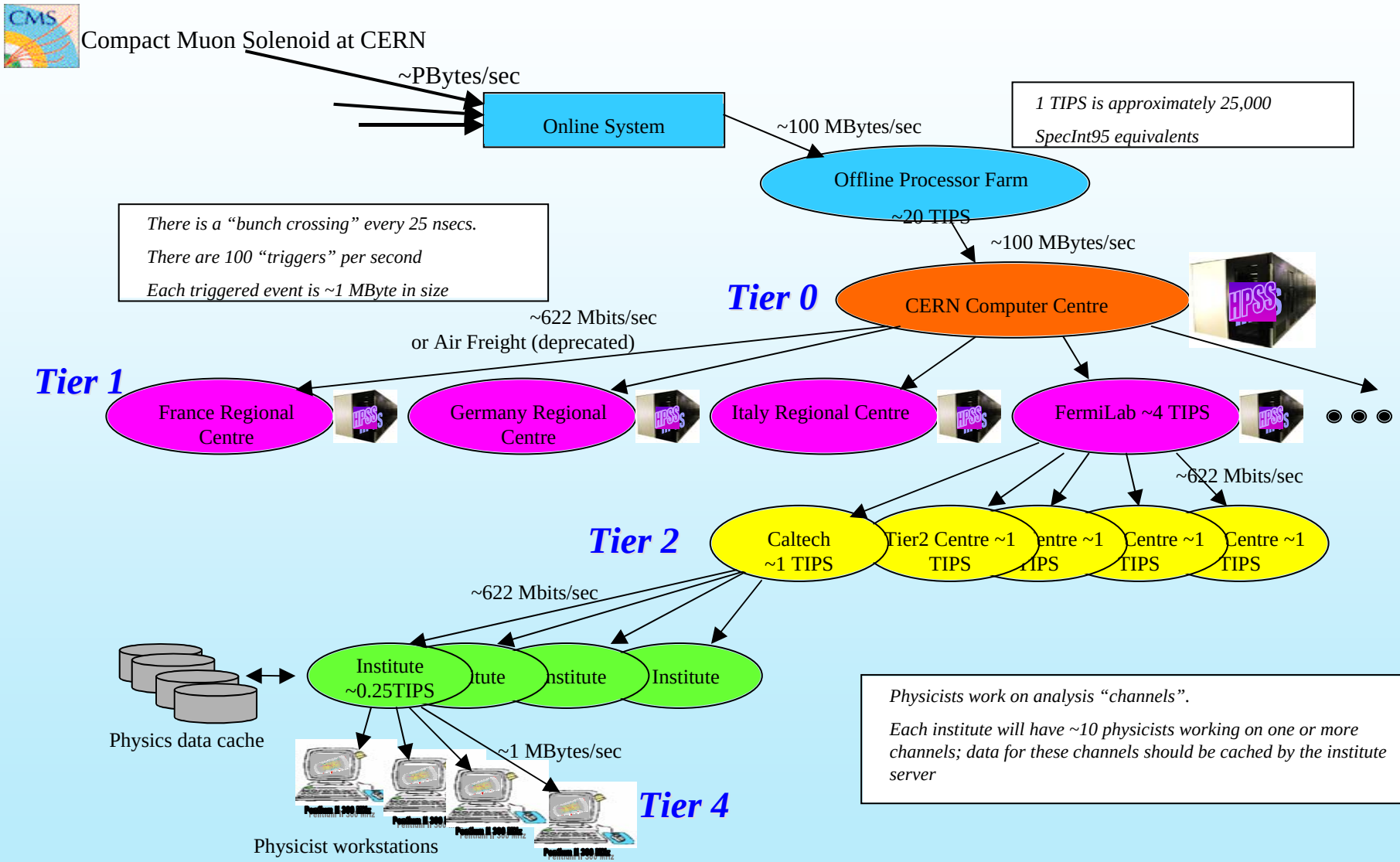
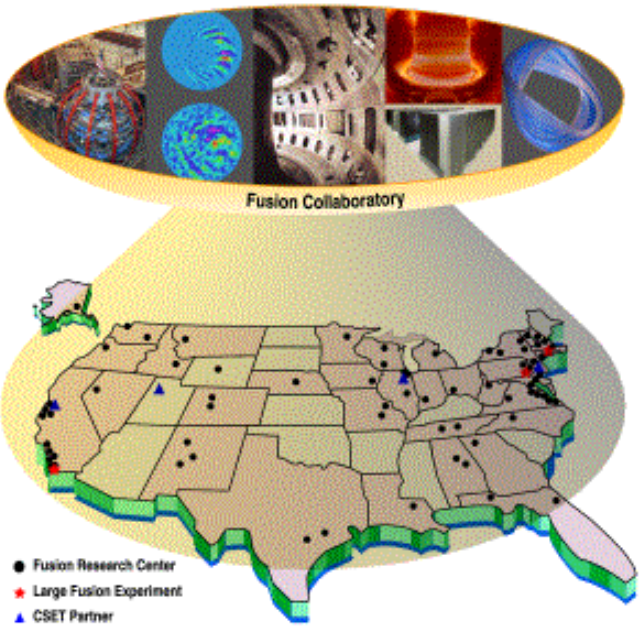


Image courtesy Harvey Newman, Caltech

National Fusion Collaboratory

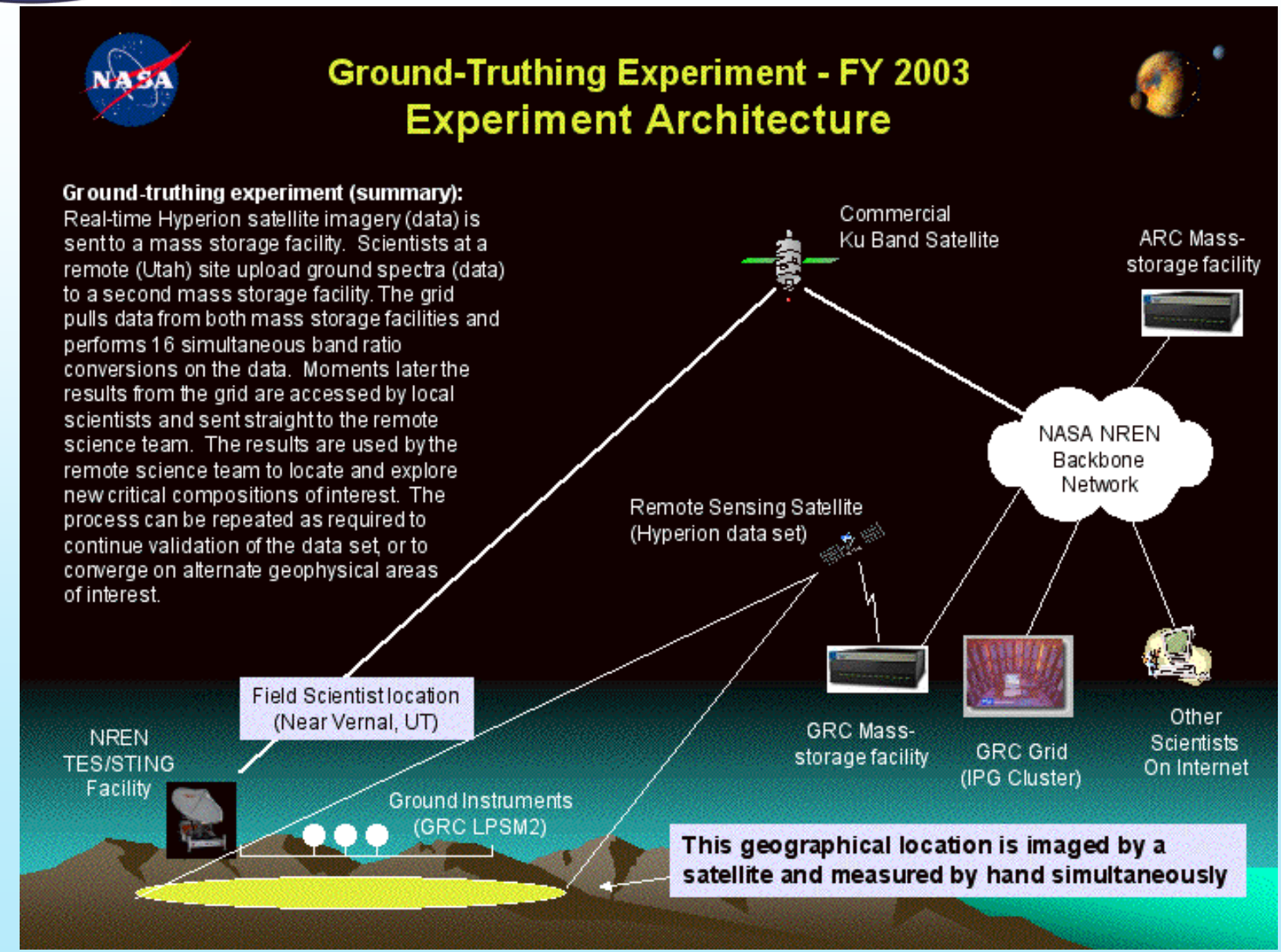
THE GOAL OF THE NFC IS TO ADVANCE SCIENTIFIC UNDERSTANDING & INNOVATION IN FUSION RESEARCH

Collaboratory is required to advance fusion science: geographically diverse community (37 states, 3 large experiments), leading to 1 worldwide experiment



- Diverse team
  - ANL: DSL & FL
  - GA: DIII–D Fusion Lab
  - LBNL: Distributed Systems
  - MIT: C–Mod Fusion Lab
  - Princeton Computer Science
  - PPPL: NSTX Fusion Lab
  - U. of Utah: Scientific Comp. & Imaging
- Objective is to advance fusion science
  - Experimental facilities
  - Integrate experiment, theory, modeling
  - Create a common toolkit for services

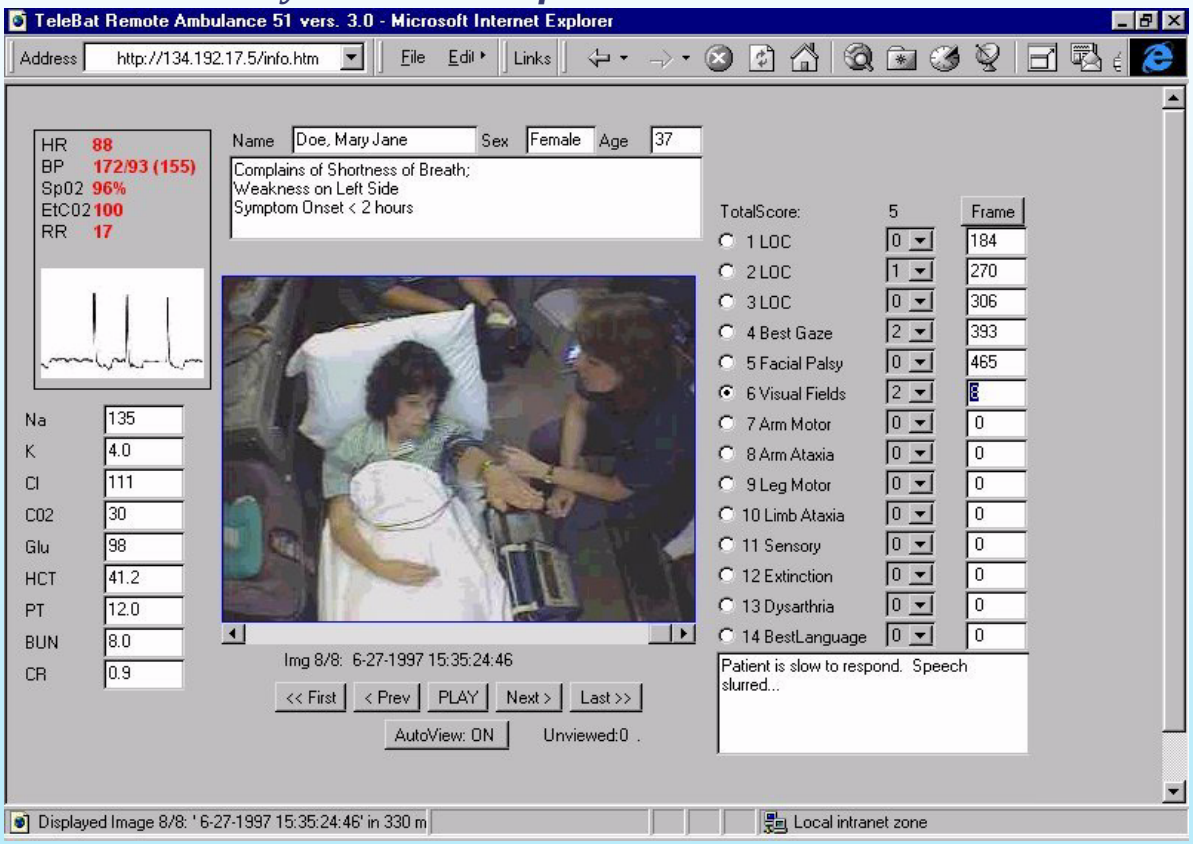
NASA Ground-Truthing Experiment



NIH Mobile Telemedicine

- Optimizes treatment options in the "Golden Hour"
- Initiates the patient record in the ambulance
- Enhances the efficiency of the ER
- Improves patient outcomes

Intuitive Physician's Interface



- Adjustable image compression quality (medium JPEG compression here)
- Adjustable image size (320x240 24-bit images here)
- About 5 Kbps per phone line (4 phone lines)
- Resulting in diagnostic quality slowscan video images at about 2.5 seconds per image

Northrop Grumman, Fairfax, VA
University of Maryland in Baltimore, Baltimore, MD

High Confidence Software and Systems

- **Research and technology development to achieve security, survivability, availability, reliability, and safety of systems that rely on information technology**
- **Assurance of information-centric systems through:**
  - Research in theoretical foundations
  - Development of tools and techniques (with linkages to domain-specific languages)
  - Engineering and experimentation
  - Demonstrations and pilots
- **Examples of applications:**
  - Certification of software for infusion pumps used in hospitals to deliver IV medications
  - Certification of FAA flight control systems before use
  - Certification of security of software in Common Criteria Program
- **High Confidence Software and Systems Research Needs:**
  - http://www.itrd.gov/pubs/hcss-research.pdf

Software Design and Productivity

- **Develop methods and tools for software requirements, specification, design, and implementation that will produce software that is simultaneously:**
  - On time
  - Within cost
  - Meets functional requirements
- **Recent problems with control software for military F/A-22 aircraft highlight importance of software design and productivity**
- **Workshop on New Visions for Software Design and Productivity: Research and Applications, published January, 2003**
  - http://www.itrd.gov/pubs/sdp_wrkshp_final.pdf

Human-Computer Interaction and Information Management

- **Research and technology development in:**
  - Human sensory-motor and cognitive systems to improve the interaction of people and machines
  - Management and exploitation of data and information
  - Multilingual document translation and understanding
  - Collaboratories
- **HCI and IM are on a continuum**
- **Report of Workshop on HCI&IM Research Needs to be published shortly:**
  - Information Creation, Organization, Access, and Use
  - Managing Information as an Asset
  - Human-Computer Interaction and Interaction Devices
  - Evaluation Methods and Metrics

For Further Information

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