Information Technology for the Twenty-First Century (IT^2)

Briefing to House of Representatives

February 16, 1999

Ruzena Bajcsy

Chair, IT^2 Interagency Working Group

Assistant Director of the National Science Foundation for Computer and Information Science and Engineering

Agenda

- Overview
  - Ruzena Bajcsy
- Agency Roles
  - DOD: Col. Swinson
  - DOE: Mike Knotek
  - NASA: Lee Holcomb
  - NIH: Don Preuss
  - NOAA: Tom Pyke
  - NSF: George Strawn

Information Technology for the Twenty-First Century (IT^2) - An Investment in America's Future

- President Clinton and Vice President Gore propose a $366M increase in the Government's investment in IT R&D for the fiscal year 2000 budget
- IT^2 builds on the Government's previous accomplishments and current investments

The Federal Government Plays a Critical Role in Supporting Fundamental IT R&D

- Federally-sponsored research has helped build the technology base on which the computing industry has grown
- Fundamental research is key to stimulating innovation, and innovation is key to continued U.S. leadership in IT
- Federal research funding complements, rather than preempts private research investments:
  - The benefits of fundamental research are generally too distant and too uncertain to receive significant industry support

Federal Funding for Research Helps Create the Human Resources That Drive the IT Revolution

- Federal funding for research plays a critical role in educating students in the computing field
- Approximately 60 per cent of IT^2 funding will be spent at universities
- IT^2 funding will train students and help create exciting research environments to attract and retain faculty

Compelling Reasons to Increase IT R&D (1)

- IT is a growing component of the U.S. economy, currently accounting for more than $750 billion in annual revenue
- IT leadership will be critical in the 21st century
- Past Government-funded IT R&D has yielded huge economic return on investment, and continues its pivotal role in promoting innovation
- IT is beneficial to a wide range of important national goals, including a world-class education system, a strong defense, access to affordable high-quality health care, and improved quality of life for Americans

Compelling Reasons to Increase IT R&D (2)

- As our economy and society increasingly depend on IT, we must be able to design information systems that are more reliable and more secure
- IT will revolutionize our national science and engineering R&D strategy - high-performance computing and simulation technology will allow researchers to develop life-saving drugs more rapidly, better understand the functions of our genes once they've been sequenced, more accurately predict tornadoes, and design engines that are cleaner and more fuel-efficient
- Funding research will help the intellectual base grow, thereby ensuring continued innovation

IT's Potential Benefits are Enormous:

- Improved quality and delivery of health care
- Stronger national security
- Safer and cheaper transportation by air, land, and sea
- More efficient and responsive government
- Better quality and delivery of education and training to all Americans
- Increased productivity of research in all disciplines
- A safer and improved environment through efficient design and operation of buildings, vehicles, and equipment
- Better warnings of dangerous weather
- Improved climate models to support more informed decisions
- Faster response to hazardous materials releases
- Decreased reliance on untested and insecure information systems

IT^2: Built on a Firm Foundation

- IT^2:
  - Builds on previous and current programs, including the Federal High Performance Computing and Communications (HPCC) Program, the Federal Next Generation Internet (NGI), and the Department of Energy's Accelerated Strategic Computing Initiative (ASCI)
  - Responds to recommendations from the President's Information Technology Advisory Committee (PITAC)
  - Reflects output from numerous workshops held by research communities

Major IT^2 Investments

- IT^2 will increase Federal investments in:
  - Fundamental IT research
  - Advanced computing for science, engineering, and the Nation
  - Research in the ethical, social, and economic implications of the Information Revolution, and support for the education and training of America's IT workforce

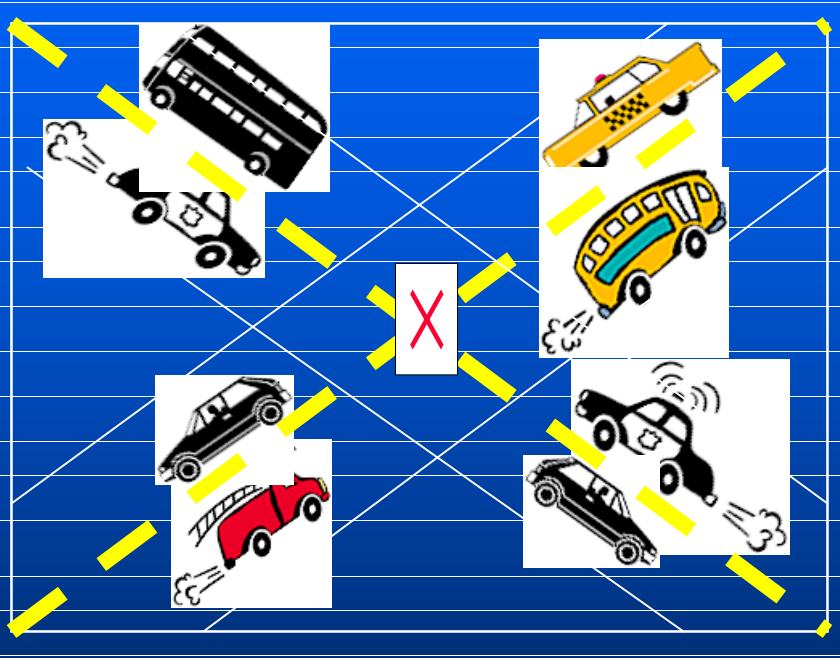
Fundamental IT Research

- Long-term high-risk investigations of key issues in computer science and engineering
- Research focal points:
  - Software
  - Human computer interfaces and information management
  - Scalable information infrastructure
  - High-end computing

Fundamental IT Research: Software

- Highest IT R&D priority according to PITAC
  - The demand for software exceeds our ability to produce it
  - Today's software is fragile, unreliable, and difficult to design, test, maintain, and upgrade
- Proposed research areas:
  - Software engineering
  - End-user programming
  - Component-based software development
  - Active software/Adaptive software
  - Autonomous software/Embedded Computing
  - High-assurance software

No Surprise Software

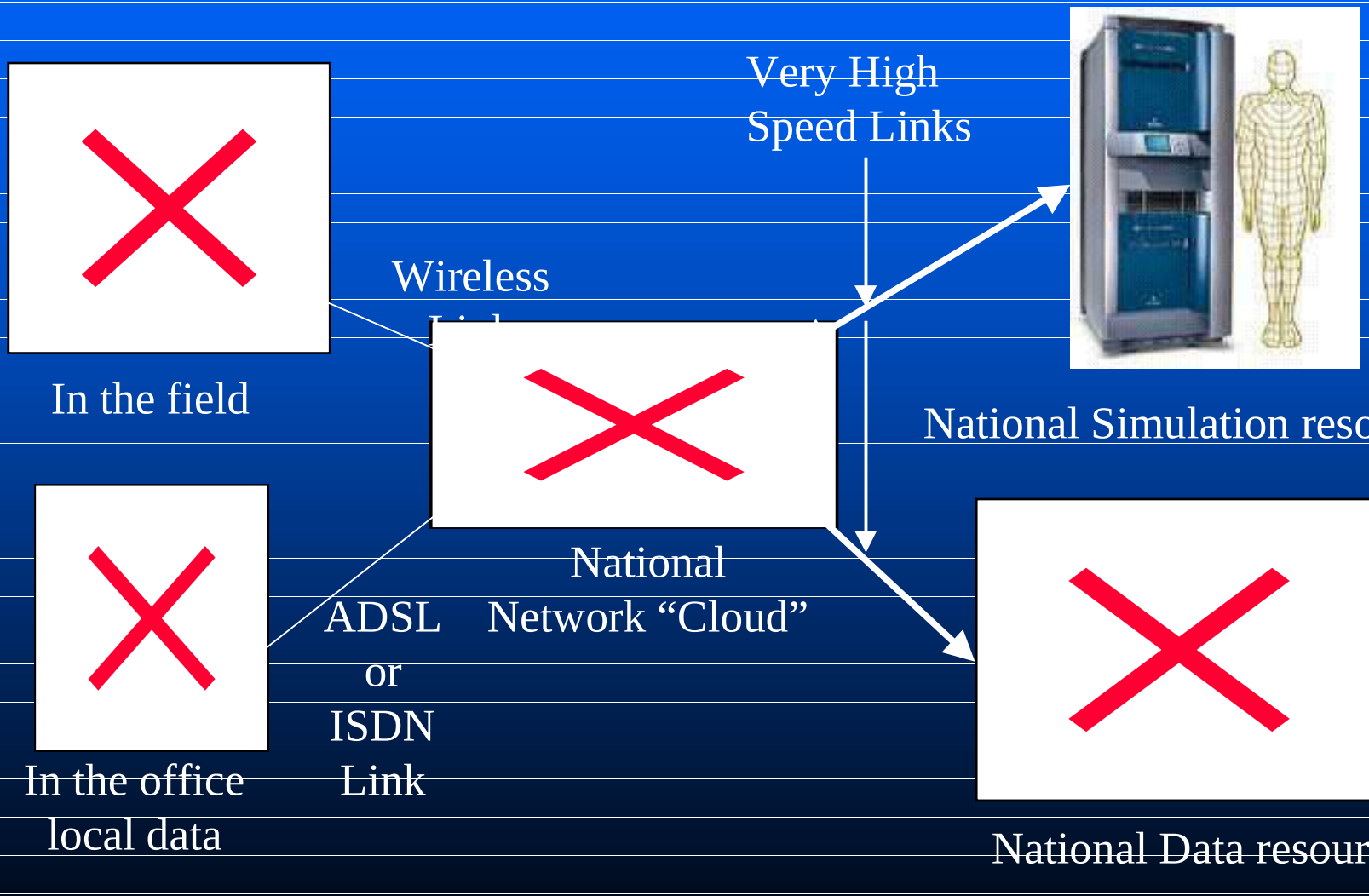


No Roads, no rules
Chaos and Surprise

Science and order
No surprises

Scalability and Ubiquitous access

Information, simulation and access from a single user to a variety of resources, distributed and of vastly different scales



Fundamental IT Research: Human Computer Interaction and Information Management

- Research to improve the ways we interact with computers
  - Computers are still too hard to use; surveys show that computer users waste over 12 percent of their time because they can't understand what their computers are doing
  - Improved accessibility for people without a keyboard (for example, mobile professionals and doctors) and persons with disabilities and the elderly
  - Better techniques for locating data and extracting "knowledge" from data
- Proposed research areas (examples):
  - Computers that speak, listen, and understand human language
  - Information visualization

Fundamental IT Research: Scalable Information Infrastructure

- Research to support the phenomenal growth of the Internet
  - In 1985 the Internet connected 2,000 computers
  - Today it connects over 37 million computers
  - Future networks will connect at least a billion users and will be more complex - they will connect sensors, wireless modems, and embedded devices
- Proposed research areas:
  - Deeply networked systems (scalability)
  - Anytime, anywhere connectivity (wired and wireless)
  - Network modeling and simulation

Fundamental IT Research: High-End Computing

- Leading-edge research for future generations of computing to:
  - Improve computational speed on applications
  - Increase the efficiency of massively parallel systems, with a focus on systems software
  - Develop technologies to enable future systems capable of a thousand trillion (10^{15}) calculations per second
- Proposed research areas:
  - Improved supercomputer performance and efficiency
  - Creation of a computational grid
  - Revolutionary computing

Advanced Computing for Science, Engineering, and the Nation (1)

- IT^2 will obtain computers that are 100 to 1,000 times more powerful than those now available to the civilian research community, and make them available on a competitive basis
  - These systems will have several thousand processors, high speed shared and distributed memory, and state of the art switching technology
  - Install and develop systems capable of 5 trillion (a thousand billion) computations per second by the end of fiscal year 2000, and 40 trillion by the year 2003

Advanced Computing for Science, Engineering, and the Nation (2)

- Develop scientific and engineering simulation software and tools to make these computing systems useful research tools:
  - Advanced technologies in computational algorithms and methods and in software libraries
  - Problem solving and code development environments and tools
  - Distributed computing and collaborative environments
  - Visualization and data management systems

Advanced Computing for Science, Engineering, and the Nation (3)

- Establish and fund multidisciplinary teams working on our most challenging problems, including:
  - Predicting climate change
  - Predicting severe weather
  - Understanding genetic function
  - Computational seismology
  - Simulating combustion
  - Simulating materials
  - Modeling the evolution of the universe
  - Simulating complex vehicles and missions

Economic and Social Implications of IT and IT Workforce

- Increased research in economic and social impacts will:
  - Help in the design of information systems
  - Identify barriers to adopting IT and its applications
  - Provide more empirical data to policymakers
  - Encourage the solution of problems caused by IT
- Proposed efforts in training IT workers at U.S. universities:
  - Faculty access to modern curricula and instructional material
  - Graduate and post-graduate traineeships
  - University research grants through other components of this initiative will help support graduate students

IT^2 Management

- Senior management team reporting to the President's Advisor for Science and Technology will:
  - Help establish and monitor goals
  - Allocate research tasks
  - Ensure tight Federal coordination
  - Ensure open competitive allocation of funds
- Working group reporting to the senior management team:
  - Chaired by NSF Assistant Director for Computer and Information Science and Engineering
  - Members appointed by principal agencies
  - Oversee research in all major IT^2 areas
  - Develop and operate advanced infrastructure made available under IT^2 funding
  - Ensure competitive purchase, siting, and availability of new computers
  - Ensure availability of systems to appropriate research teams

Proposed FY2000 Budget

Agency	Fundamental Information Technology Research	Advanced Computing for Science, Engineering, and the Nation	Ethical, Legal, and Social Implications and Workforce Programs	Total
DOD	$100M	---	---	$100M
DOE	$ 6M	$ 62M	$ 2M	$ 70M
NASA	$ 18M	$ 19M	$ 1M	$ 38M
NIH	$ 2M	$ 2M	$ 2M	$ 6M
NOAA	$ 2M	$ 4M	---	$ 6M
NSF	$100M	$ 36M	$ 10M	$146M
Total	$228M	$123M	$ 15M	$366M

Next Steps

- Refine management structure
- Continue to refocus and strengthen related ongoing programs
- Continue to seek external advice from industry and academia
- Develop detailed technology and programmatic roadmaps

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DOD Participation

Briefing to House of Representatives

February 16, 1999

Col. Mark Swinson

Information Technology Office

DARPA

DOD SOFTWARE FOR AUTONOMOUS AND EMBEDDED SYSTEMS

*Develop the **missing software** to enable pervasive employment of autonomous systems – both robots and knowbots*

Program Goal

Autonomous:
Several robots/person
"unit commander"

Proposed Research

State-of-the-Art

Telesupervised:
One robot/person
"tank commander"

State-of-the-Practice

Teleoperation:
Several people/robot
"tank driver"

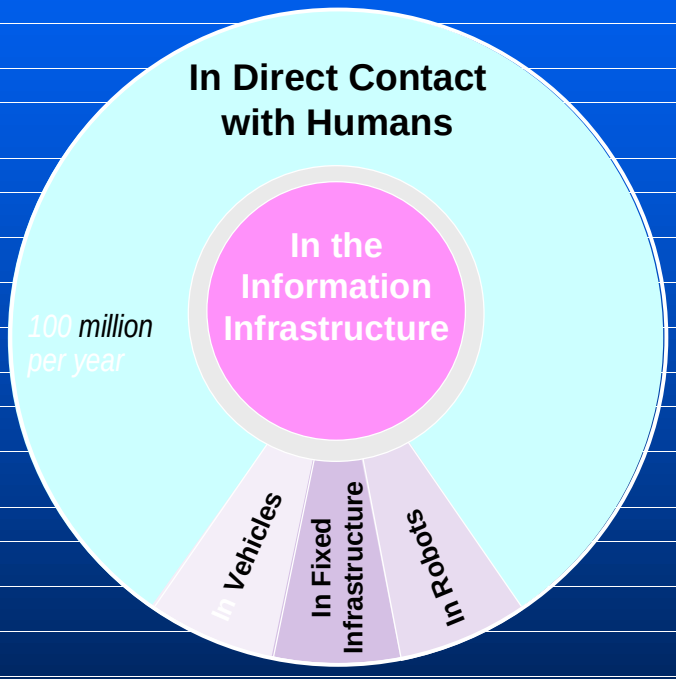
Sample Applications

Countermine, Urban Operations, Search & Rescue, Firefighting, Force Protection

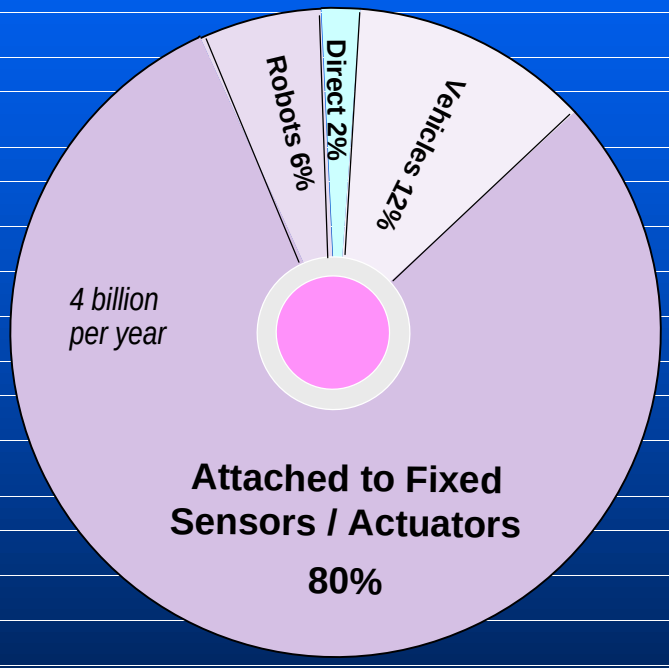
Leverage the Phenomenal Progress Made in Mechatronics

DOD
DEEPLY NETWORKED SYSTEMS

Where Has DARPA Focused?



Where Will The Processors Be?



- Current Internet technology targets only 2% of all computers
- The remaining 98% are embedded within devices
- This project will extend the "depth" of the network to reach these stranded computational resources

Information Technology for the Twenty-First Century (IT^2)

DOE Participation

Briefing to House of Representatives

February 16, 1999

Mike Knotek

Program Advisor for Science and Technology

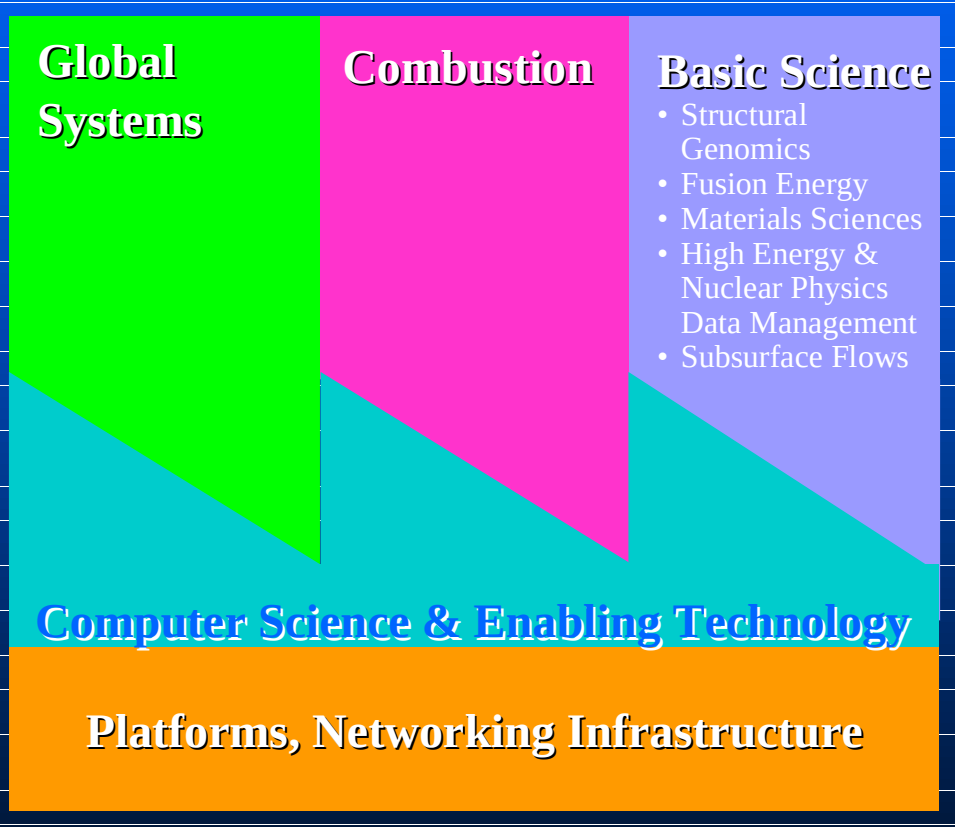
Office of Secretary of Energy

DOE

DOE
Scientific Simulation Initiative

Principal Objectives

- Revolutionize scientific research by the application of teraflop computational resources
- Understand, model and predict the effects on the Earth's global environment of atmospheric greenhouse gas emission, with an emphasis on carbon dioxide
- Understand, model and predict the behavior and properties of combustion processes and devices
- Discover, develop, and deploy crosscutting computer science and applied mathematics



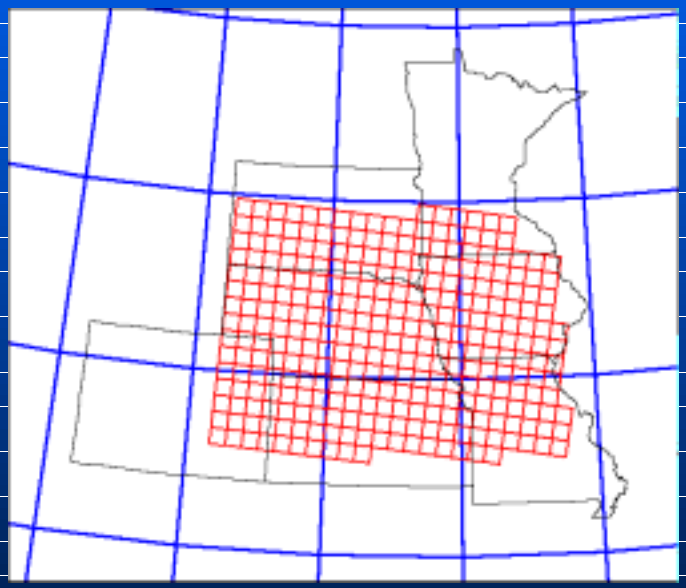
Establish a national terascale (Capable of doing 1 trillion operations per second) distributed scientific simulation infrastructure

DOE
Scientific Simulation
Global Systems

Demands on Climate Models

- 1990-1992: Bounding Global Climate Change -- is there a problem? *Required a few, coarse resolution equilibrium model runs*
- 1993-1998: Estimating Future Climate Change -- How big is the problem? *Required a few (~10), medium resolution, time-dependent runs*
- 1999-2000: Predicting the Details of Greenhouse Gas Scenarios -- What are regional impacts? *Requires many (~1000), high resolution, time-dependent runs for more effective forecasts affecting agriculture, local economies, natural resources, and energy consumption.*

Current & Future Climate Modeling Grids



Increased spatial resolution is essential to simulate regional climate change, affecting weather and resource management

DOE
Scientific Simulation Initiative *(SSI)*

- The complexity of challenges requires extensive partnering between agencies and across scientific and technology disciplines
- Teams will be chosen through open, competitive processes.
- Crosscutting technical problems must be solved in both the ASCI and SSI programs within DOE, and in the programs of NSF, NOAA, NIH, and NASA.
- All aspects of the SSI will be managed under a project format to assure the achievement of the high level of functionality required.

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NASA Participation

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Lee Holcomb

Chief Information Officer

National Aeronautics and Space Administration

Benefits of NASA Participation

- Enable autonomous spacecraft and rovers
- Allow science data understanding from large and distributed streams of data
- Enable new concepts in aviation operations that will allow aircraft to safely and effectively negotiate clearances and routings
- Revolutionize the nation's science and engineering infrastructure enabling an intelligent synthesis environment
  - Reduce design and development time to 12 to 18 months
  - Reduce testing requirements 75%
  - Predict life-cycle cost to within 10%

NASA
Fundamental IT Research - Intelligent Systems

~~Automated Reasoning~~

- Model-Based Reasoning
- Case-Based Reasoning
- High Assurance Software
- Biologically-Motivated (Biomimetic) Adaptive System
- Planning & Scheduling

~~Human-Centered Computing~~

- Knowledge Management and Institutional Knowledge Capture
- Optimized Displays
- Immersive / Haptic Environments
- Internet-Based Knowledge Representation
- Cognitive Architectures

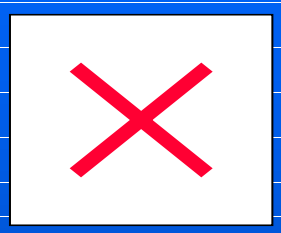
~~Intelligent Systems for Data Understanding~~

- Geographically Distributed Computing
- Reconfigurable Computer Architectures
- Biologically-Motivated (Biomimetic) Computer/Component Architectures and SW
- Knowledge Discovery and Data Mining

~~Revolutionary Computing~~

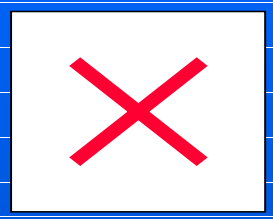
- Quantum Computing
- Chemical/Biochemical Systems
- Optical & Optoelectronic Systems
- High Fault Tolerance and Scalability

NASA: Intelligent Synthesis Environment (ISE) Program Elements



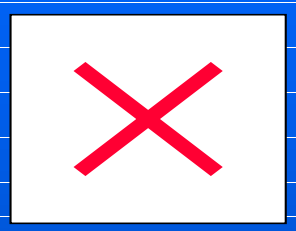
Rapid Synthesis and Simulation Tools

Intelligence-based tools for analysis and design of complex systems from concept through disposal



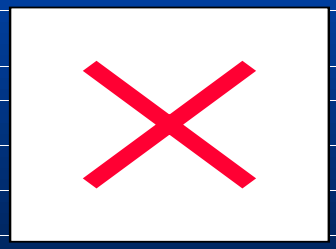
Cost and Risk Management Technology

Advanced cost analysis and risk tools for fully integrated life cycle simulations.



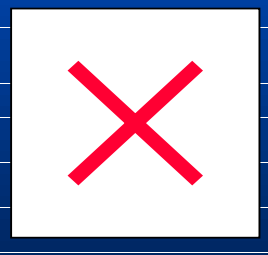
Life-Cycle Integration and Validation

Integration methods, smart interfaces and frameworks to achieve seamless "plug and play" integrated design and analysis.



Collaborative Engineering Environment

Inserting the state of the art collaborative infrastructure and methods into enterprise use through application testbeds.



Revolutionize Cultural Change, Training and Education

Changing the engineering education and culture to take full advantage of ISE and information technology .

Information Technology for the Twenty-First Century (IT^2)

NIH Participation

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Don Preuss

CTO, Center for Information Technology

National Institutes of Health

NIH's support of IT^2 through:

- Basic Research
  - Develop software programs and algorithms designed to meet the needs of biomedical researchers
  - Develop simulation methods for implementing models of molecular, cellular, organ and epidemiological systems on parallel architectures
  - Continue work on the BMAP--Brain Molecular Anatomy Project

NIH's support of IT^2 through:

- High End Computing:
  - Imaging - Image Archiving and Reconstruction
  - Human Genome Project -- BioInformatics
  - Develop the technology and algorithms to allow labs to build their own low-cost, high-throughput supercomputers from off-the-shelf computers
- IT Workforce:
  - Stimulate integration of physicists, engineers, mathematicians, and computer scientists into the biological and imaging sciences
  - Focus in BioInformatics with a concentration on use of the technology and tools development

Information Technology for the Twenty-First Century (IT^2)

NOAA Participation

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Tom Pyke

Director , Office of HPCC

NOAA

NOAA

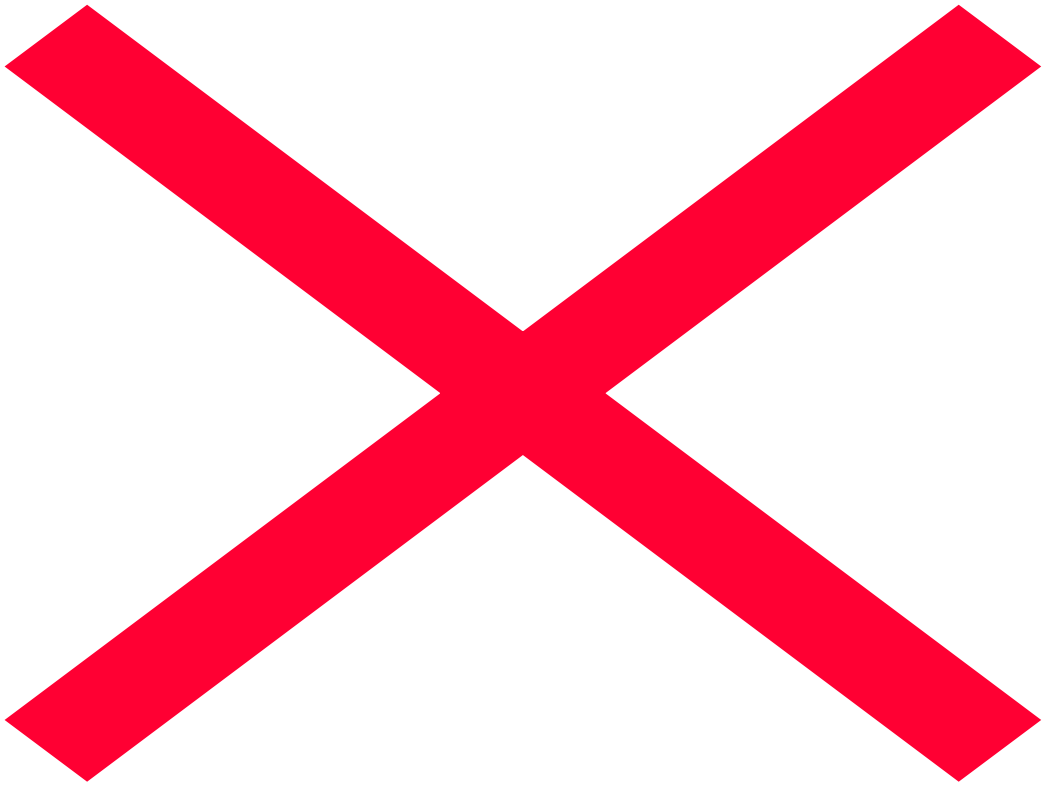
- HURRICANES
  - NOAA expects to be able to reduce 72 hour forecasts of hurricane track error by 20% from 220 to 175 nautical miles
  - Improve forecasts of hurricane intensity by 20-30% over current forecasts through use of higher resolution models and more sophisticated physics made possible by advanced computing and atmospheric science.
  - Recognize hurricane forecast situations that have inherently low predictability through the use of compute-intensive ensemble techniques
- TORNADOES
  - NOAA forecasters expect to be able to forecast tornadoes as much as 2 hours in advance (the current standard is 15 minutes) through the use of ultra-high resolution, limited-area models made possible by advanced IT as well as advanced atmospheric understanding

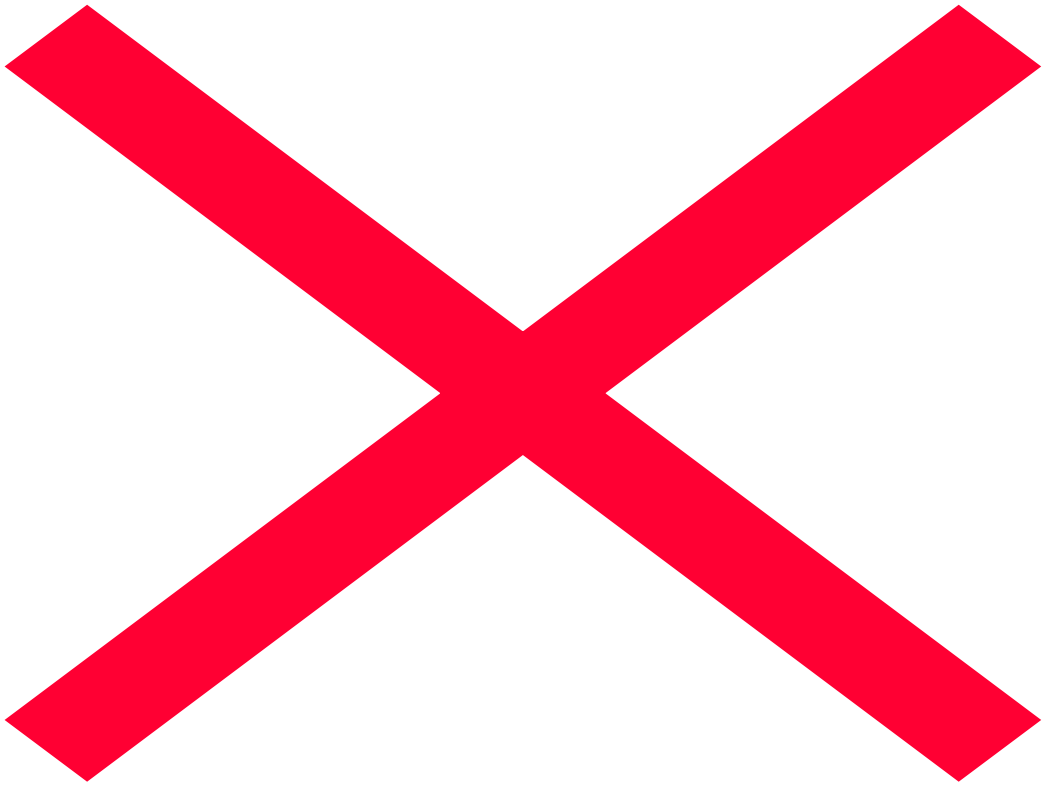
NOAA

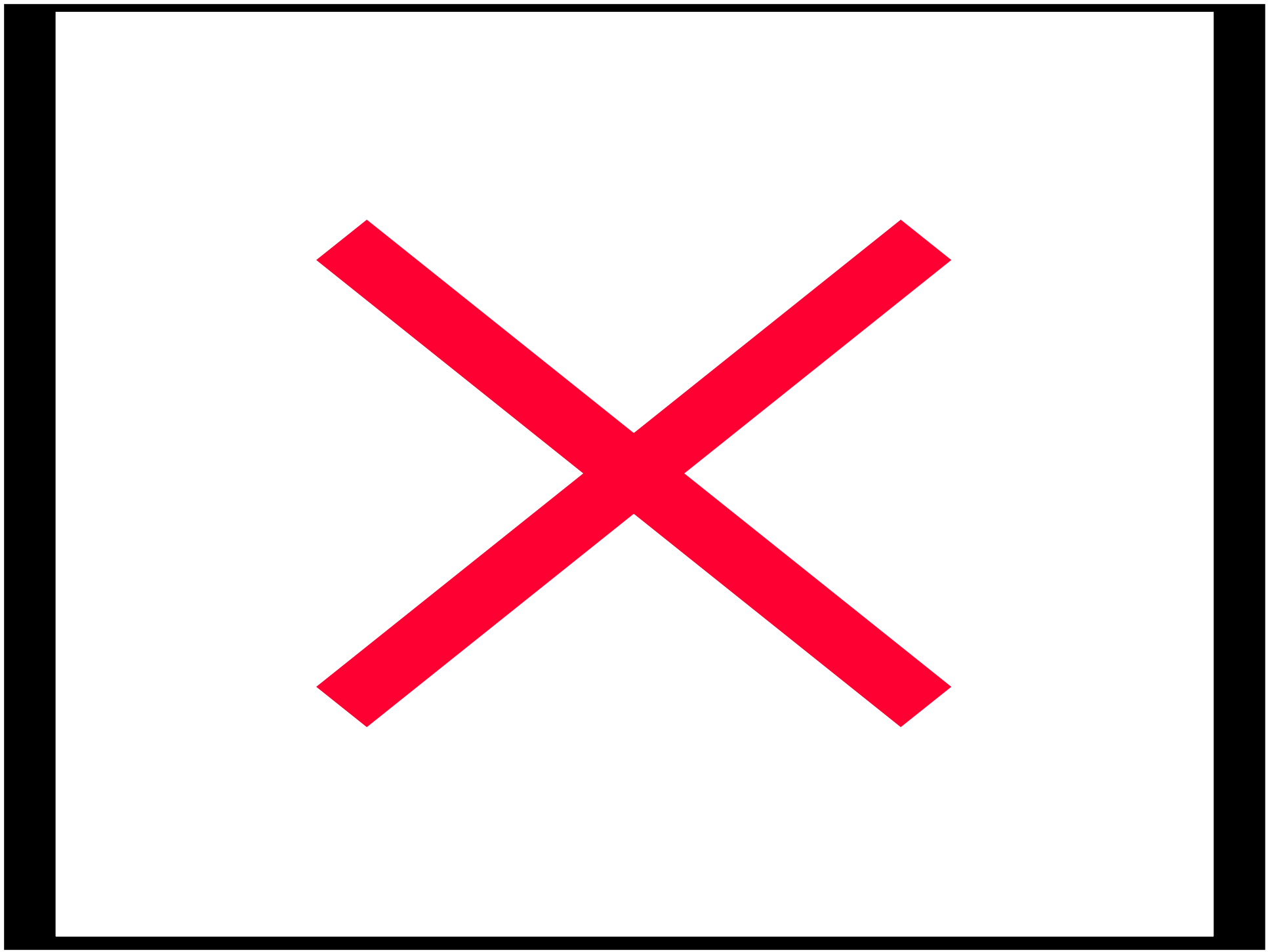
- SEASONAL TO INTERANNUAL CLIMATE
  - NOAA will improve forecasts of seasonal to interannual climate by including the full global air-sea interaction and hydrology, and enhanced probabilistic guidance using ensembles.
- ROUTINE FORECASTS
  - NOAA will provide 5-day forecasts with the accuracy of current 4-day forecasts, a 20% improvement.
- LONG-TERM CLIMATE
  - There will be a 50% reduction in climate modeling uncertainty through more complete treatment of clouds. These science-based improvements will produce a more fact-centered basis for optimal policy decisions in the future.

NOAA
IT Contributions

- Software
  - Component-based software development
- Improving the efficiency of High-End Computing
  - Creating new algorithms
  - Developing programs that can be easily moved from one high-end computer to another
- Applications
  - Provide a high-end development platform for GFDL to develop advanced climate and weather models
  - Largest production runs will be on the largest DoE/NSF machines







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NSF Participation

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George Strawn

Deputy Director Computer and Information Science and Engineering

NSF

NSF
IT^2 Budget

$100M	Fundamental IT Research (single investigator, project, and center research modes)
36M	Terascale Computing Infrastructure
10M	Social and Workforce Issues
$146M	Total

NSF
Fundamental IT Research (1)

- No-surprise Software
  - Performance engineered
  - Hardware/software co-design
  - High confidence systems
- Human-Computer Interaction and Information Management
  - Multiplying individuals' capabilities
  - Meeting and working in Cyberspace
  - Ubiquitous content infrastructure

NSF
Fundamental IT Research (2)

- Scalable Information Infrastructure
  - Broadband tetherless communications
  - Understanding large networks
  - Integrating end-to-end performance
- High-end Computing
  - Algorithms for complex computation
  - Terascale computer science
  - Empowering computational discovery

NSF
Advanced Computing and Social and Workforce Issues

- Advanced computing infrastructure
  - open competitive access to terascale computing
  - broadband network partnership building on NGI
- Issues for society
  - understanding the social, ethical, economic, political, and legal ramifications of IT
  - developing a more skilled workforce