Crisis, Innovation, Opportunity: Where Does HPCC Go From Here?

Supercomputing '96
Pittsburgh, PA
November 20, 1996

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Director
National Coordination Office for
Computing, Information, and Communications

Version 2.5

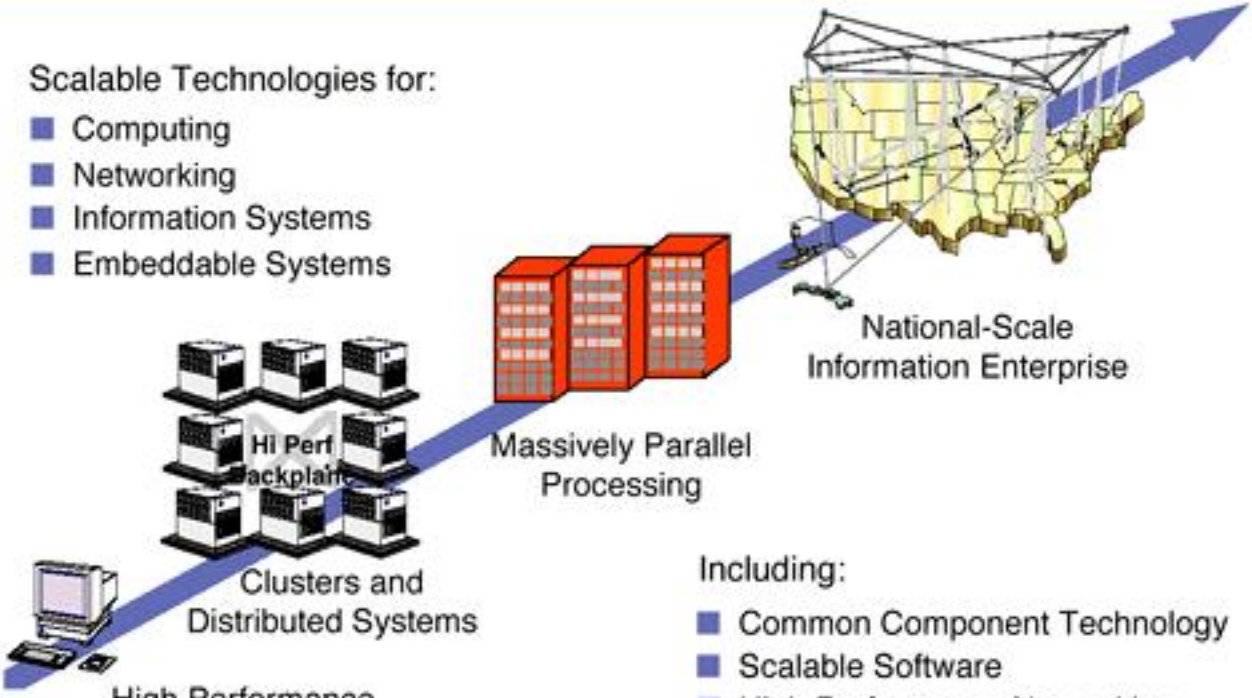
"Crises" and Opportunities

- Downsizing, Funding Environments
- Vector Processing
- Parallel Processing
- Scalable Technology
  - Trickle down?
  - Trickle up?
  - Commodity Components
- Markets have seen:
  - Monopolistic Periods
  - Competitive, Startup Periods
  - Shakeouts
- International Competition & Trade

A Recurring Vision (1993-1994)

Scalable Technologies for:

- Computing
- Networking
- Information Systems
- Embeddable Systems



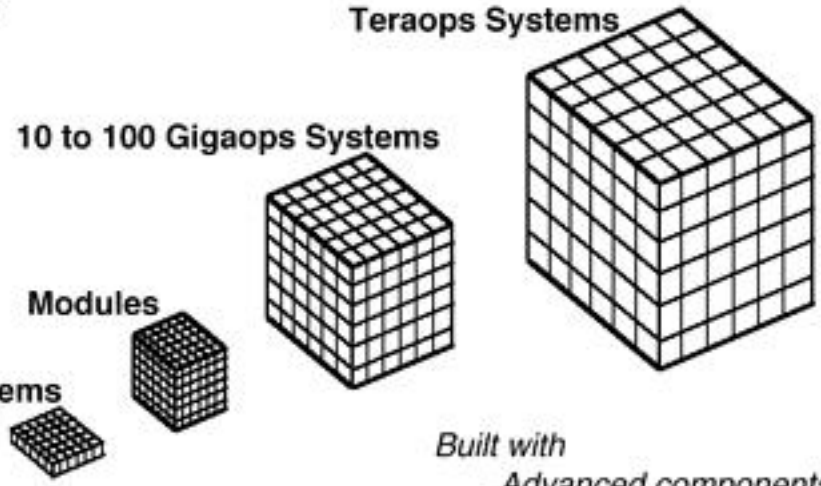
Including:

- Common Component Technology
- Scalable Software
- High Performance Networking
- Information Infrastructure

Version 1

Scalable Parallel Computing Technology Base mid-1990s

Computing Systems Scalable over a Wide Performance Range



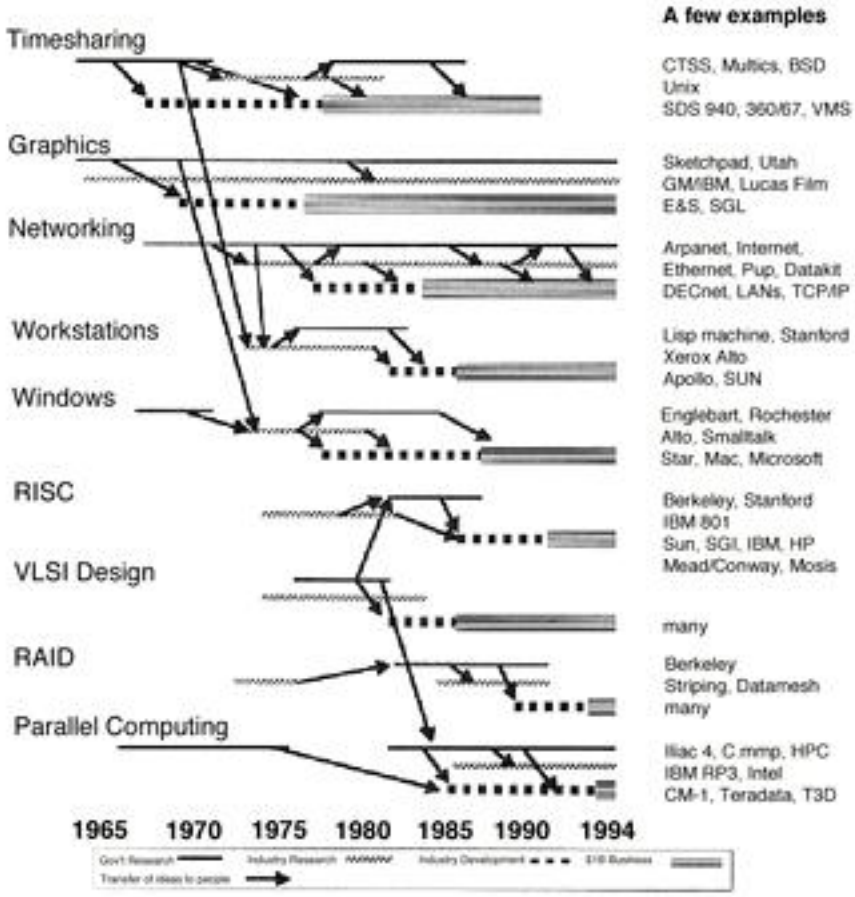
Components

- Microprocessors
- Scalable Coupling
- Memory
- Packaging
- Interconnect

Built with Advanced components in Advanced Designs for Units of Replication

HPC Food Chain

- Basic materials, physics, math, etc.
- Microelectronics
- Component computing technologies (hardware, software)
- Computing system technologies
  - Systems
  - Compilers, debuggers, performance evaluation tools, etc.
- Integrated experimental systems
- A rich world of applications!



from

1995, Fig. 1.2

Strategic Advantage

- Computing, Information, and Communications is the key to the future
- Where will strategic advantage emerge for:
  - National Security
  - Aircraft Design
  - Health Care
  - Biomedicine
  - Climate, weather, environment modeling
  - Business models
  - Academic Research
  - Many, many others

“Foundation for America’s Information Future”

Video

Federal HPCC Program "Blue Books"

HPCC "Blue Books"

"Blue Books" are annual reports presenting HPCC Program Plans and accomplishments

FY 1997

FY 1996

FY 1995

FY 1994

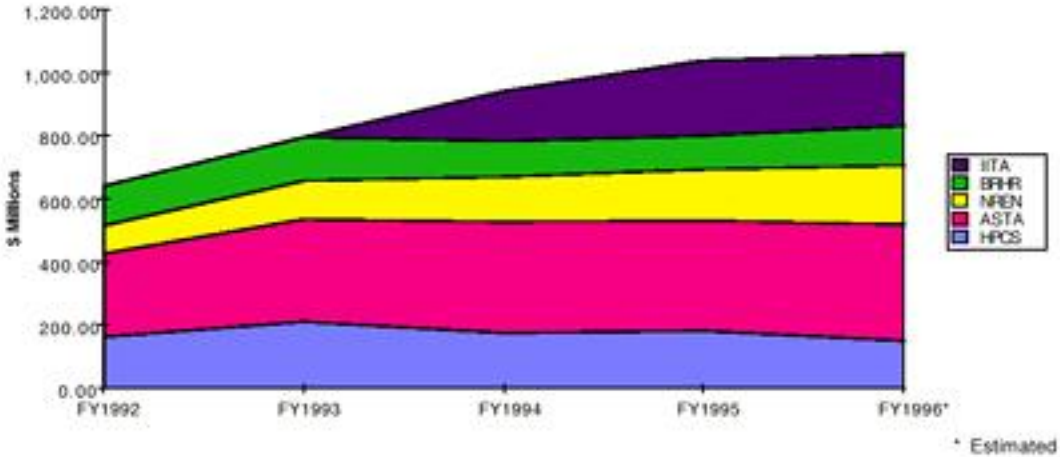
History of the Federal HPCC Program

- The Federal HPCC Program:
  - Chartered by Congress FY 1992 through FY 1996 with the High Performance Computing Act of 1991
  - Focused on:
    - High Performance Computing Systems
    - Advanced Software Technology and Algorithms
    - National Research and Educational Network
    - Information Infrastructure Technology and Applications
    - Basic Research and Human Resources
  - Was coordinated through the High Performance Computing, Communications, and Information Technology (HPCCIT) Subcommittee and NCO

Participating Agencies

- Defense Advanced Research Projects Agency (DARPA)
- National Science Foundation (NSF)
- Department of Energy (DOE)
- National Aeronautics and Space Administration (NASA)
- National Institutes of Health (NIH)
- National Security Agency (NSA)
- National Institute of Standards and Technology (NIST)
- Department of Education (ED)
- Department of Veterans Affairs (VA)
- National Oceanic and Atmospheric Administration (NOAA)
- Environmental Protection Agency (EPA)
- Agency for Health Care Policy and Research (AHCPR)

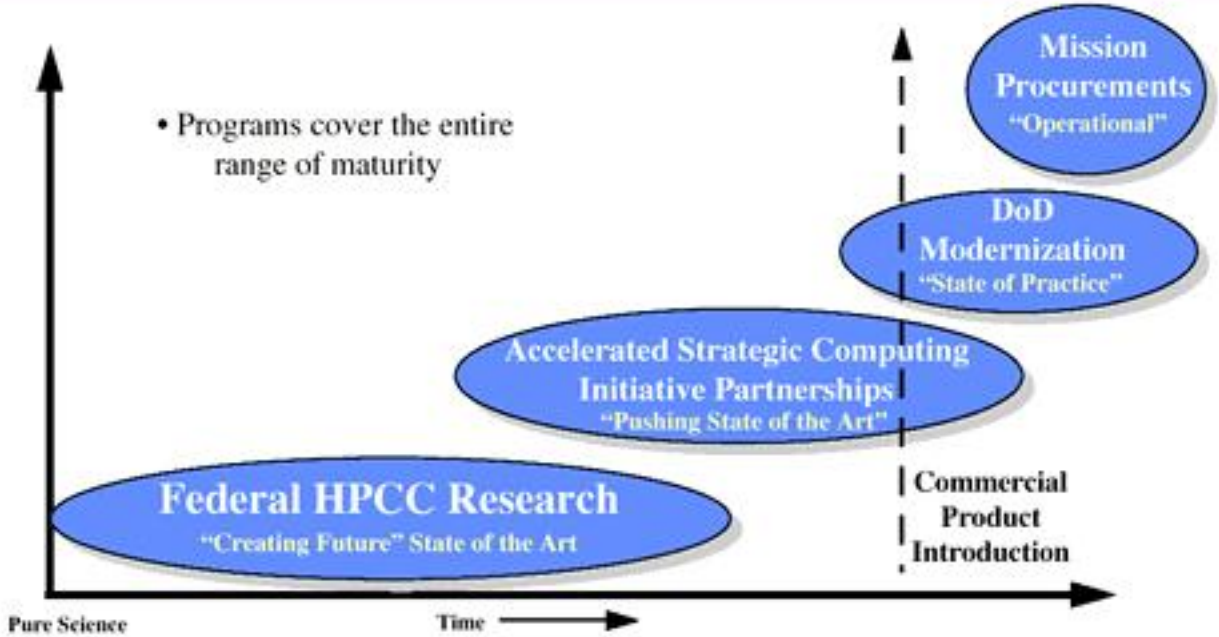
Estimated Federal HPCC Program "Actual" Dollars by Components



NCO for CIC Resources

- FY 1997 Blue Book: Advancing the Frontiers of Information Technology
- FY 1996 Blue Book: Foundation for America's Information Age
- FY 1996 Implementation Plan
- The Federal High Performance Computing and Communications Brochure
- America in the Age of Information: A Forum, 1995
- Available on WWW server
  - http://www.hpcc.gov

Federal Programs Support and Need Commercial Products



Characterization of Maturity

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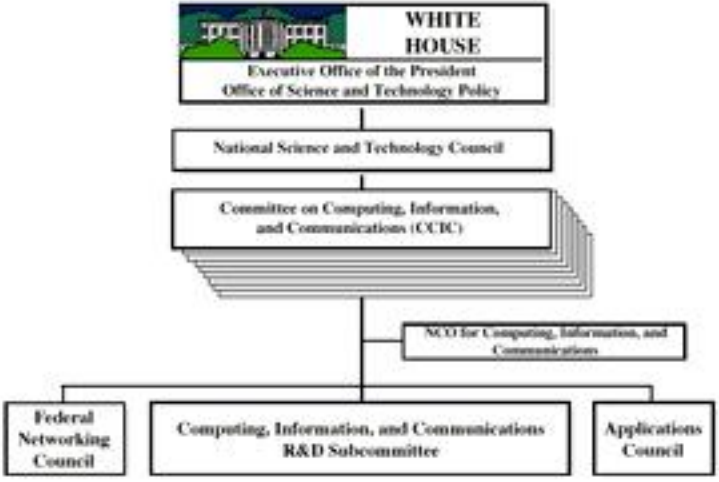
CCIC Organizational Structure



CCIC Strategic Planning - Phase II

(November 1996)

Discussions/Feedback:

- CISE Advisory Group
- AEA
- HPCC Consortium
- CASC
- IEEE
- PCAST
- Computer Science Tech Board
- Electronic Subcommittee
- Pasadena II Workshop
- CSPP
- XIWT
- RCI
- ACM
- CRA
- SURA

Sept 94 — CIC Strategy Group Established

Feb 95 — CIC Plan Published

May 95 — FY 1996 Federal HPCC Program Documents

July 95 — CIC Workshop - 6-7 July

Aug 95 — CIC Forum Report for Review

Mar 96 — FY 1997 President's Budget

May 96 — CCIC Decisions

Sept 96 — CIC R&D Review
Budgets Submitted

Feb 97 — FY '98 Pres Budget

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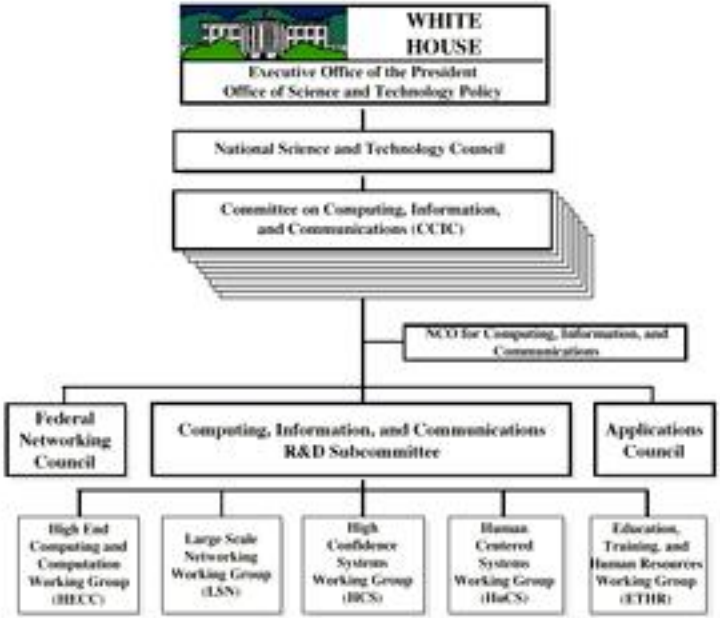
New CCIC R&D Structure

- Broader collaborative R&D investments
- Five Program Component Areas (PCA)
  - High End Computing and Computation
  - Large Scale Networking
  - High Confidence Systems
  - Human Centered Systems
  - Education, Training, and Human Resources
- Each PCA will:
  - Span areas in which multiple agencies have interests/programs
  - Include hardware, software, algorithms, and applications
  - Focus on specific research goals, ensure adequate investments, and maintain necessary budget visibility
- Technology R&D may span multiple PCAs

Organizational Structure



FY 1997 HPCC Crosscut Budget Request
(Dollars in Millions)

Agency	HECC	LSN	HCS	HuCS	ETHR	TOTAL
DARPA	75.05	115.93	10.00	117.03	7.51	325.52
NSF	129.17	72.26	1.21	57.76	19.11	279.51*
DOE	93.29	14.79		12.98	3.50	124.56
NASA	70.70	20.20	1.00	6.40	10.70	109.00
NIH	23.40	22.90	4.94	29.59	5.38	86.21
NSA	25.93	3.50	7.30			36.73
NIST	5.79	2.96	4.40	10.36		23.51
ED				11.40	6.61	18.01
VA	1.00	9.45	2.30	1.80		14.55
NOAA	6.30	2.70		0.50		9.50
EPA	6.58			0.60		7.18
AHCPR				4.20		4.20
TOTAL	437.21	264.69	31.15	252.62	52.81	1,038.48**

* Following the National Research Council and NSF Advisory Committee recommendations, the NSF FY 1997 allocation for HPCC excludes $29.60 million for applications in cutting edge discipline-oriented computations, as well as for basic research in theoretical computer science that were previously allocated to HPCC. Other NSF activities in HPCC are increasing in FY 1997, resulting in a slight net reduction in the total.

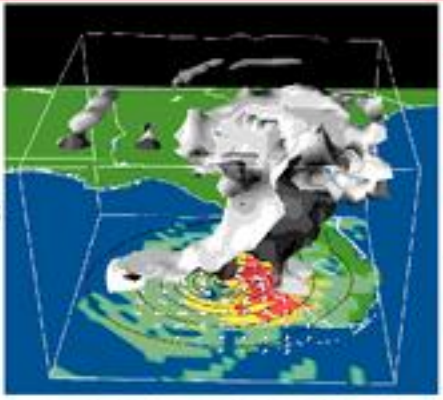
** These totals vary slightly from the President's HPCC Budget. For example, funding for the Department of Transportation, a candidate HPCC agency, is not included.

Example Research Agenda for:

High End Computing and Computation

- High performance computing technologies, architectures, and experimental systems
- System software technologies and tools for high-end systems
- Program development environments for high-end computation
- Fast, efficient algorithms for simulation, modeling, and visualization
- New and very advanced concepts including quantum, biological, and optical computing
- Storage, interconnection, and data technologies for high-end computing systems
- New devices, components, and experiments in critical technologies
- Advanced simulation of physical phenomena and Grand Challenge-class applications

Examples of High End Computing and Computation Projects



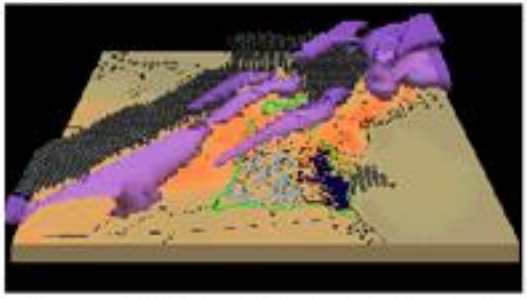
Tropical Storm Gordon, just before becoming a hurricane

GFDL/NOAA Hurricane Model

- Hurricane Prediction System
- 1993 - Run in semi-operational test mode
- 1994 - Part of National Centers for Environmental Prediction operational hurricane forecast suite
- 1995 -Model became fully operational
- 1996 - High resolution models run on highly parallel systems for the Centennial Olympics
- Run for tropical systems at all development stages
- Found to be in top performance group for forecasts out to 36 hours and superior to all other forecast models at 48 and 72 hours

Environmental Modeling

- Parallel logarithms used to model movement of groundwater contaminants
- Numerical simulations to estimate impact of decades of toxic pollution
- Research on nonlinear optimization and control techniques used to minimize groundwater cleanup costs
- Regional Particulate Model (RPM) developed to monitor air quality by region
- Parallel computing used to quantify potential effects of earthquakes on new construction and to assist in creating new safety codes



Simulation of nitrogen deposition to the Chesapeake Bay and surrounding areas during a rainstorm.

Biomedical Imaging, Biomedicine, Biomechanics, and Molecular Biology

HPCC Grand Challenge applications impacts all phases of biomedicine

- Simulates human motion on earth and in space
- Combines computer modeling with x-ray scattering
- Algorithm development to model and simulate DNA
- Searches and analyzes protein sequence data
- Determines energy profiles of important biological molecules

Prototype Workstation Interface

23-Degrees-of Freedom Model for Simulating Human Motion

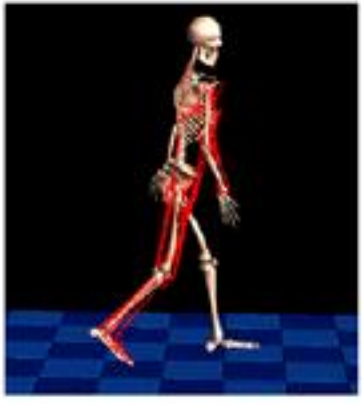


Image acquisition and storage technology

- Integrates medical images from diverse sources
- Securely stores and displays digital data and delivers information to physicians remotely
- Enables teleconsultation with top specialists even in remote or rural areas
- Supported by HPCC R&D investments

Example Research Agenda for:

Large Scale Networking

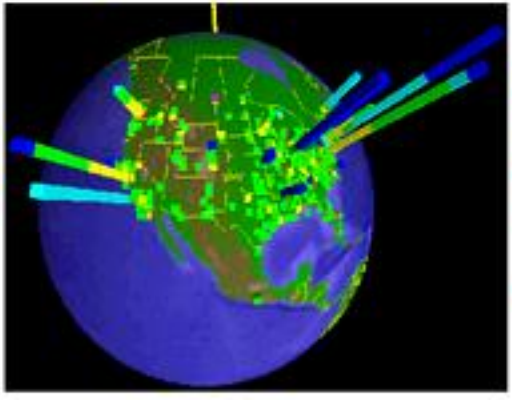
- Fast, efficient routing and enhanced network service
- High performance networking research infrastructure
- Design and scalability issues of large multi-node networks
- Very high performance network components and testbeds
- Network-centric computing including system software and program development environments for scalable distributed systems
- National Challenge-class application drivers such as:
  - Distributed information acquisition tools
  - Digital library technologies
  - Computer-based patient records
  - Electronic commerce

Next Generation Internet Initiative

Initiative Goals	Metrics
1. Connect universities and national laboratories with high-speed networks that are 100-1000 times faster than today's Internet	End-to-end performance; Number of institutions connected
2. Promote experimentation with the next generation of networking technologies	Quality of service; Adoption of technologies by commercial Internet
3. Demonstrate new applications that meet important national goals and missions	100+ high importance applications; Value of applications in testing network technologies

Examples of Large Scale Networking Projects

- I-Way was an extensive networking project introduced at Supercomputing '95
- Experimental, high performance network
- Linked over a dozen high performance computers and advanced visualization machines
- Used as testbed to prototype:
  - Teraflop-class wide area computing
  - An advanced application development resource



- Begun with development of ARPANET in late 1960s
- Network infrastructure created with NSFNET in 1985
- Development of Mosaic browser in early 1990s
- Community level service turned over to private sector Internet service providers in April 1995
- Unprecedented Internet growth stimulated by HPCC R&D and from public and private investment

Example Research Agenda for:

High Confidence Systems

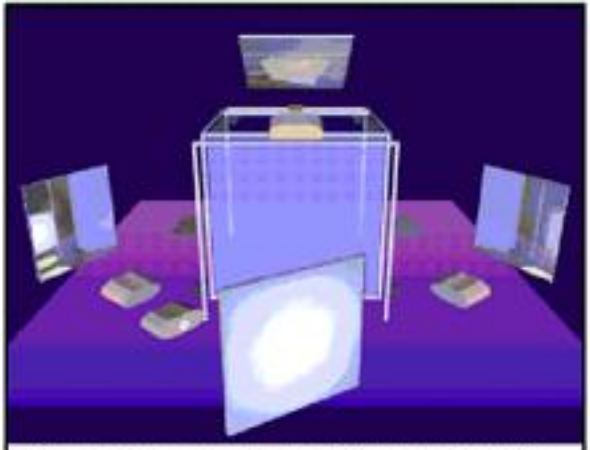
- High Confidence Computing
  - Fault tolerant, secure hardware, and operating systems
  - Secure, trusted agents
- High Confidence Networking
  - Dynamically secure enclaves
  - Robust firewalls
  - Management of massive networks under load, failure, and intrusion
- Encryption, Assurance, and Integration
  - Formal system specifications and verification
  - Advanced algorithms
  - Tools for designing, integrating, and evaluating systems
- Large Scale Systems
  - Analysis and simulation
  - Testing, evaluation, and standards development

Example Research Agenda for:

Human Centered Systems

- Collaboration technologies and applications, including collaboratories, distributed multi-media, middleware, and control of remote instruments
- Multi-modal human-system interactions
- Document understanding and multilingual language technology
- Information agents and environments
- Virtual reality environments and applications
- Knowledge repositories for information access, management, and applications
- Interdisciplinary research in human cognition applied to tools for content recognition and human-system interaction

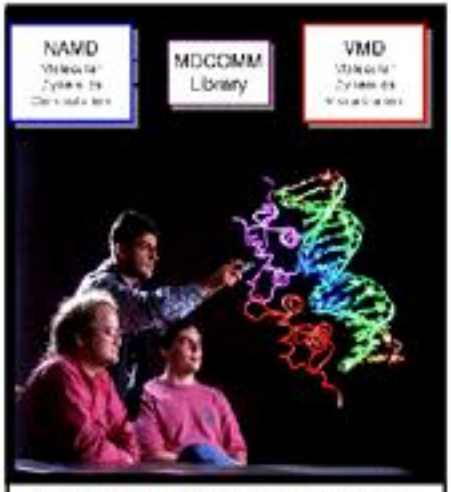
Examples of Human Centered Systems Projects



Surround-screen, surround-sound, projection based virtual reality systems (CAVE)

- Visualization, virtual reality, and human-machine interfaces
- Ability to generate, collect, and manipulate vast amounts of data
- Development of a prototype "omnifocus" electronic camera

- Health care and biomedical imaging
- Enhance patient care, improved drug design, and broaden access to medical information



Prototype visual medical chart integrating multi-disciplinary medical images

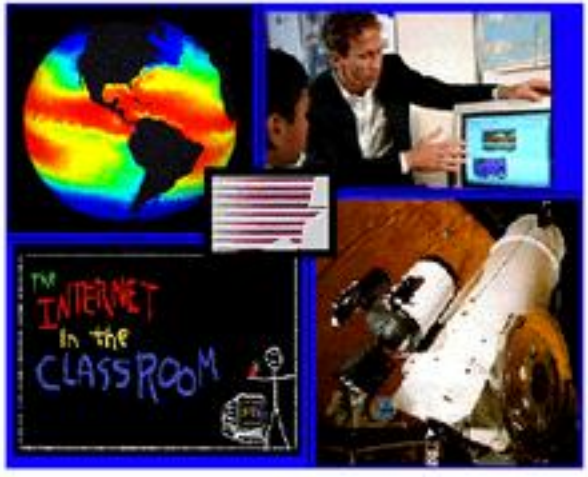
Example Research Agenda for:

Education, Training, & Human Resources

- Lifelong learning technologies
- Curricula, fellowships, and scholarships for computational, computer, and information sciences and engineering
- Demonstration and development of innovative information infrastructure and technologies for education
- Research supporting distance learning for remote sites

Examples of Education, Training, and Human Resources Projects

- Math and Science Gateway and Gateway for Educators provide web site with access to science and math resources for students and teachers
- Enable design and deployment of multimedia modules used in interactive tutorials
- HorizonNet demonstrates low cost Internet access for a school consortium
- Develop interactive and visualization tools for special educational projects



Users of High Performance Computing Technologies

The First 10

- Tolerate anything to find a solution

Users of High Performance Computing Technologies

The First 10

- Tolerate anything to find a solution

The Next 100

- Presume stability, but with driving needs tolerate some pain

Users of High Performance Computing Technologies

The First 10

- Tolerate anything to find a solution

The Next 100

- Presume stability, but have driving needs and tolerate some pain

The Next 1,000

- Want stability, might test the water,but only in their own discipline

Users of High Performance Computing Technologies

The First 10

- Tolerate anything to find a solution

The Next 100

- Presume stability, but with driving needs tolerate some pain

The Next 1,000

- Want stability, test the water, in their own discipline

The Next 10,000,000

- Want everything...and for free

What's Important?

- Sustained investments for the long term
  - Commitment to Science and Engineering
- Innovative Technology Transition
- A new generation of partnerships between
  - Government
  - Industry
  - Academia
- People
  - Users
  - Managers
  - Scientists and Researchers