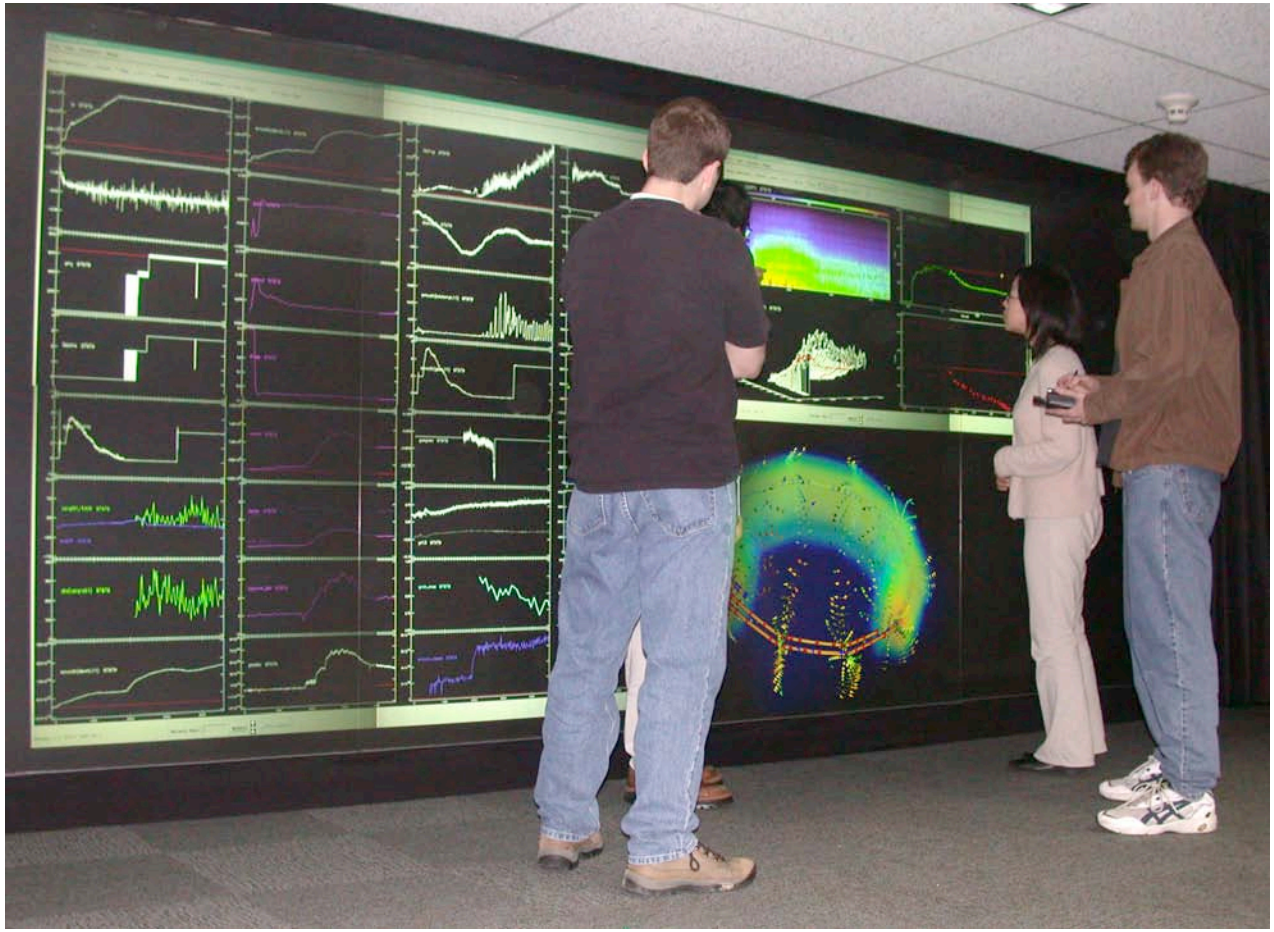
Grids for Experimental Science:

The Virtual Control Room



Presented by
David P. Schissel
Lead–PI

at
CLADE 2004
June 7, 2004
Honolulu, HI

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PRESENTATION'S KEY POINTS

- The National Fusion Collaboratory (NFC) is enabling fusion scientists to explore Grid capabilities in support of experimental sciences
  - MICS/SciDAC Pilot Collaboratory Project
- The collaborative or virtual control room is being realized
  - Secure computational resources scheduled as required
  - Rapidly compare experimental data to simulation results
  - Share individual results with the group via shared displays
  - Fully engaged remote scientists with audio, video, shared displays
- Collaborative technology critical to the success of the FES program
  - Experimental: Fewer, larger machines in future (KSTAR, ITER)
  - Computation: Moving toward integrated simulation (FSP)

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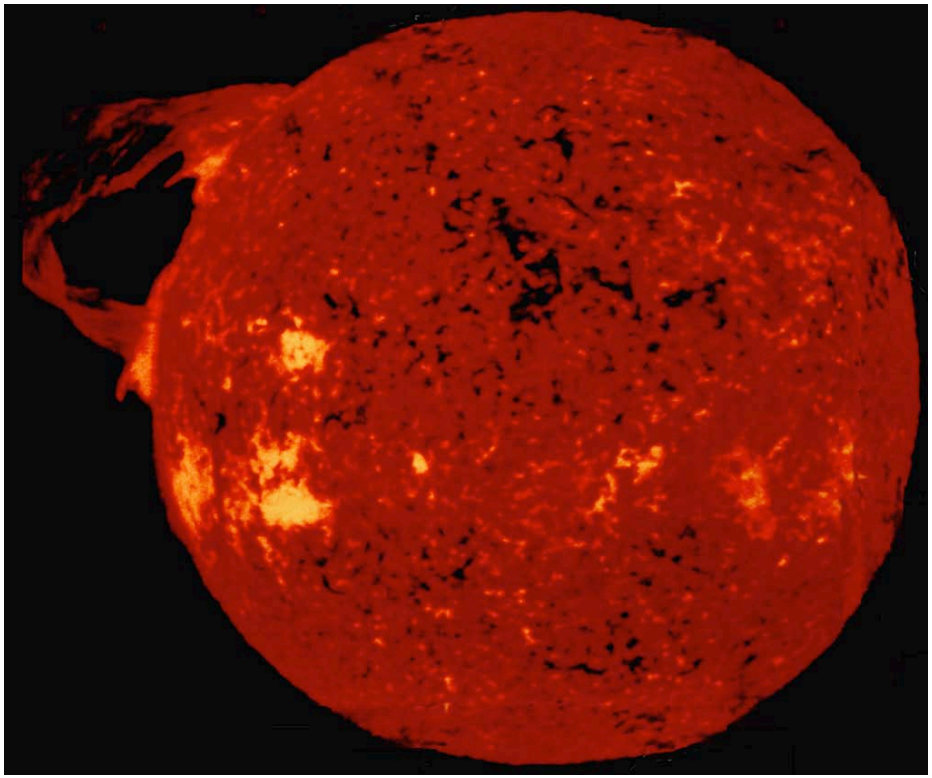
FUSION: A NEARLY INEXHAUSTIBLE ENERGY SOURCE

- Joining two light nuclei ($E=mc^2$)
  - Pickup truck fusion fuel = 21,000 railcars of coal



- Like charges repel
  - High velocity (temperature)
- High temp removes electrons
  - Plasma
- Long term goal – develop reliable energy system that is environmentally and economically sustainable
  - One international machine ITER is next step

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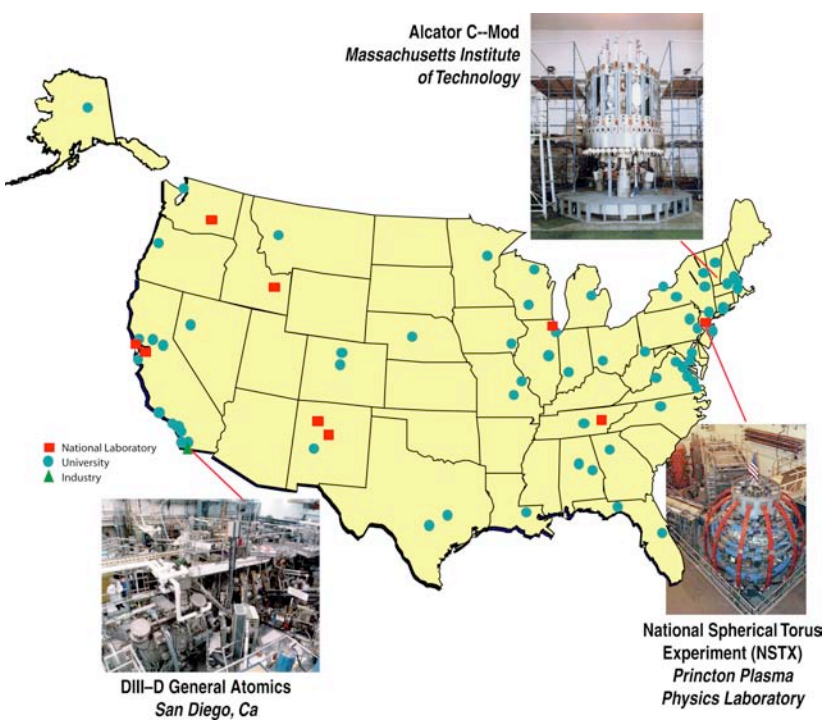
THREE LARGE U.S. EXPERIMENTAL FACILITIES AND A VIBRANT THEORETICAL COMMUNITY

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



- 3 Large Experimental Facilities
  - ~$1B replacement cost
- 40 U.S. fusion research sites
  - Over 1500 scientists
- Efficient collaboration is required!
  - Integrate geographically diverse teams
- One future worldwide machine
  - Not based in US
  - US needs collaboration tools to benefit

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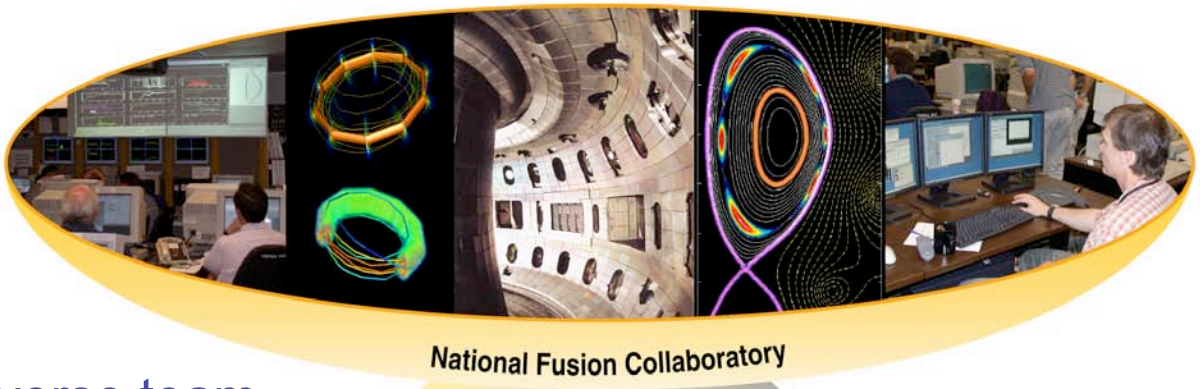
THE NATIONAL FUSION COLLABORATORY PROJECT: A MICS/SciDAC NATIONAL COLLABORATORY PILOT

Advancing the science of fusion energy: experiment & theory
http://www.fusiongrid.org/



- Benefit from a diverse team
  - Legacy of SciDAC

THE VISION FOR THE FUSION COLLABORATORY

- Data, Codes, Analysis Routines, Visualization Tools should be thought of as network accessible services
  - Ease of use with access stressed rather than portability
- Shared security infrastructure with distributed authorization and resource management
  - X.509 along with resource owner & VO authorization
- Collaborative nature of research requires shared visualization applications and widely deployed collaboration technologies
  - Flexible collaborative environment to integrate separated groups
- Not focused on CPU cycle scavenging or “distributed” supercomputing

Optimize the most expensive resource - people’s time

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PLACING DISTRIBUTED APPLICATIONS OUT ON THE WAN PRESENTS SIGNIFICANT CHALLENGES

- Crosses administrative boundaries
- Increased concerns and complexity for security including authentication and authorization
- Resources not owned by a single project or program
- Distributed control of resources by owners is essential
- Needs for end-to-end application performance & problem resolution
  - Resource monitoring, management & troubleshooting not straightforward
  - Higher latency challenges network throughput & interactivity
- Real-time computations to support experimental operations
- People are not in one place for easy communication

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EXPERIMENTAL SCIENCES PLACES A LARGE PREMIUM ON RAPID DATA ANALYSIS IN NEAR-REAL-TIME

DIII-D Control Room

- Pulsed experiments
  - 10s duration plasma every 20 minutes
- 20-40 people in control room
  - More from remote locations
- 10,000 separate measurements/plasma
  - kHz to MHZ sample rates
  - Between pulse analysis

- Not batch analysis and not a needle in a haystack problem
  - Rapid “real-time” analysis of many measurements
- More informed decisions result in better experiments
  - The collaborative or virtual control room

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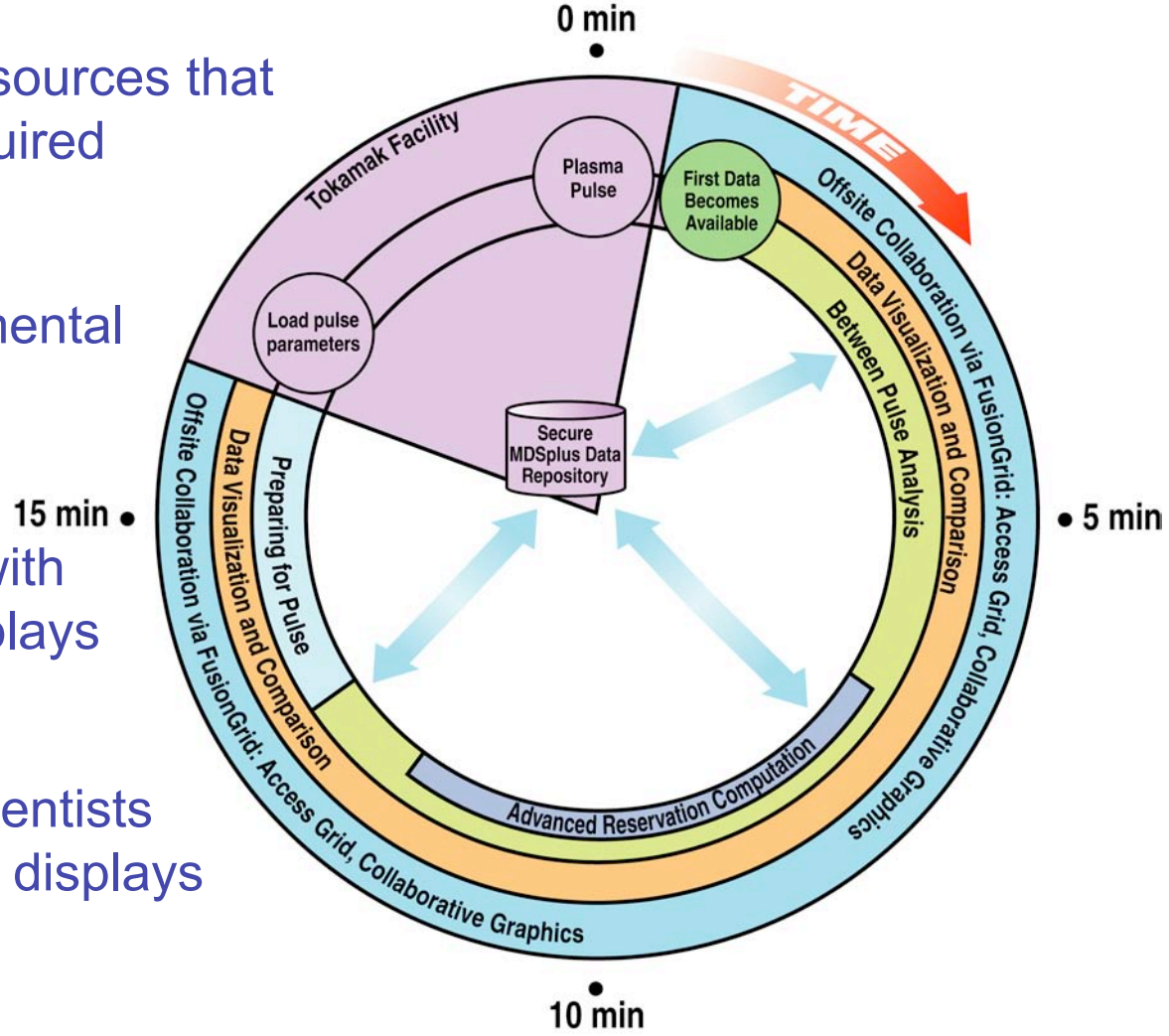
THE COLLABORATIVE CONTROL ROOM IS FUNDAMENTAL TO ADVANCING FUSION SCIENCE

- Secure computational resources that can be scheduled as required
- Rapidly compare experimental data to simulation results
- Share individual results with the group via shared displays
- Fully engaged remote scientists with audio, video, shared displays



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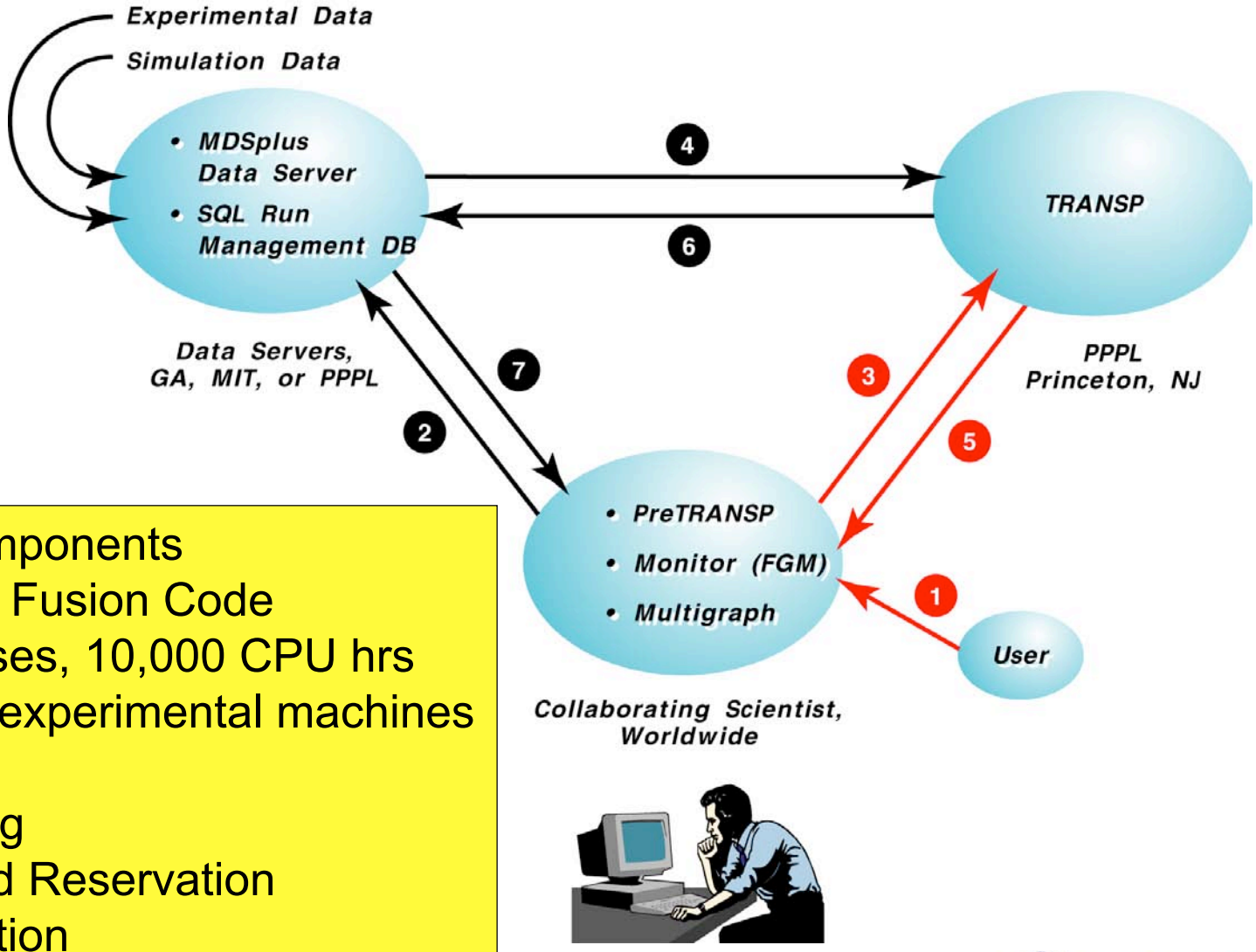
TRANSP WAS FIRST GRID SERVICE DEPLOYED: ANY CODE CAN BE A GRID SERVICE



Required Components

- TRANSP Fusion Code
  1,800 cases, 10,000 CPU hrs
  9 fusion experimental machines
- MDSplus
- Monitoring
- Advanced Reservation
- Visualization

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SECURE ACCESS TO FUSION DATA VIA MDSplus

- MDSplus: remote access based on client-server model
  - Used at more than 30 sites (robust)
- Service rather than file oriented
- Hierarchical, self descriptive, extensible, scalable, simple but powerful API
- MDSplus secured on FusionGrid via Globus GSI
  - Underlying technologies are X.509 certificates and OpenSSL
- Parallel network transfer via XIO - useful for high latency networks

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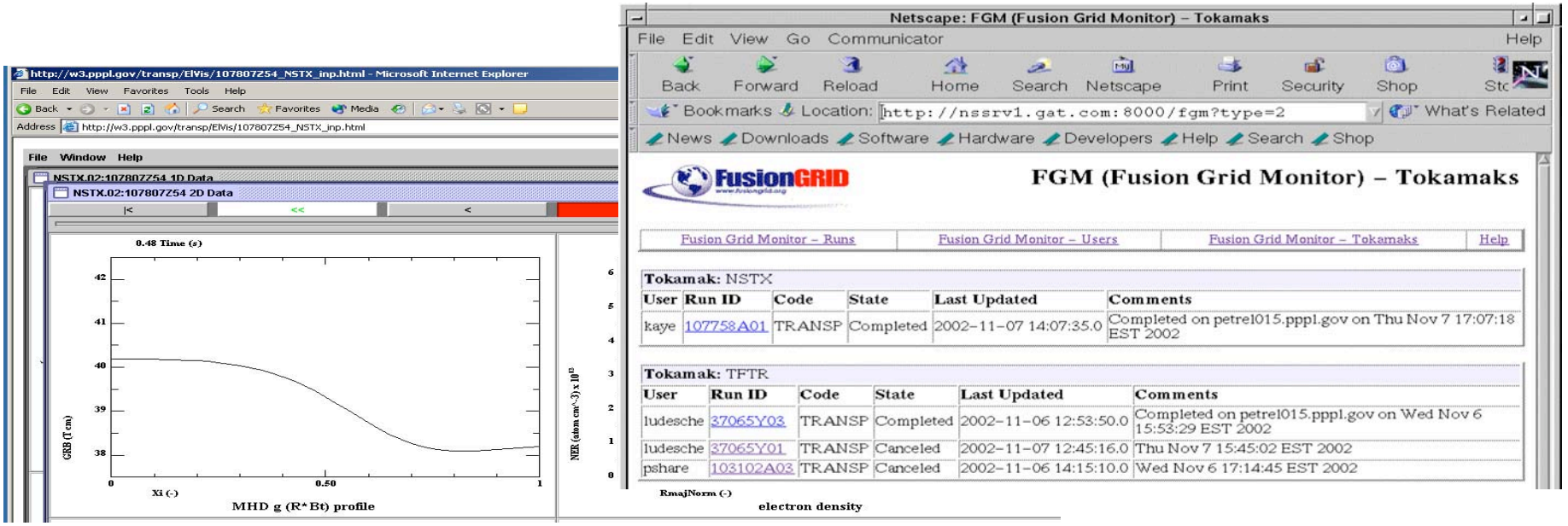
FUSION GRID MONITOR: AN EFFICIENT APPLICATION MONITORING SYSTEM FOR THE GRID ENVIRONMENT



- Users track and monitor the state of applications on FusionGrid
  - Output dynamically via HTML, Built as Java Servlet (JDK2.1)
- Code maintenance notification
  - Users notified, queuing turned off, code rebuilt, queue restarted
- Results of simulation visualized during run
  - Both input and output quantities

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ADVANCED RESERVATION COMPUTATION FOR DATA ANALYSIS TO SUPPORT EXPERIMENTAL SCIENCE

- Long-term vision: Fusion code on supercomputer between pulses
  - Data management
  - Network QoS
  - Visualization
  - CPU scheduling
  - Faster CPUs and algorithms

- Prototype (GT3) agreement based system enabling scientists to create agreement for the delivery of QoS on application executions run between experimental cycles
  - Advanced reservation of CPUs enforced through pre-emption
  - Allows requestor to obtain information and negotiate an agreement
  - Prediction and rate limiting of network traffic
  - Contributing to the WS-Agreement standard at GGF

- FusionGrid service TRANSP will be tested between pulses
  - First such capability for FES research

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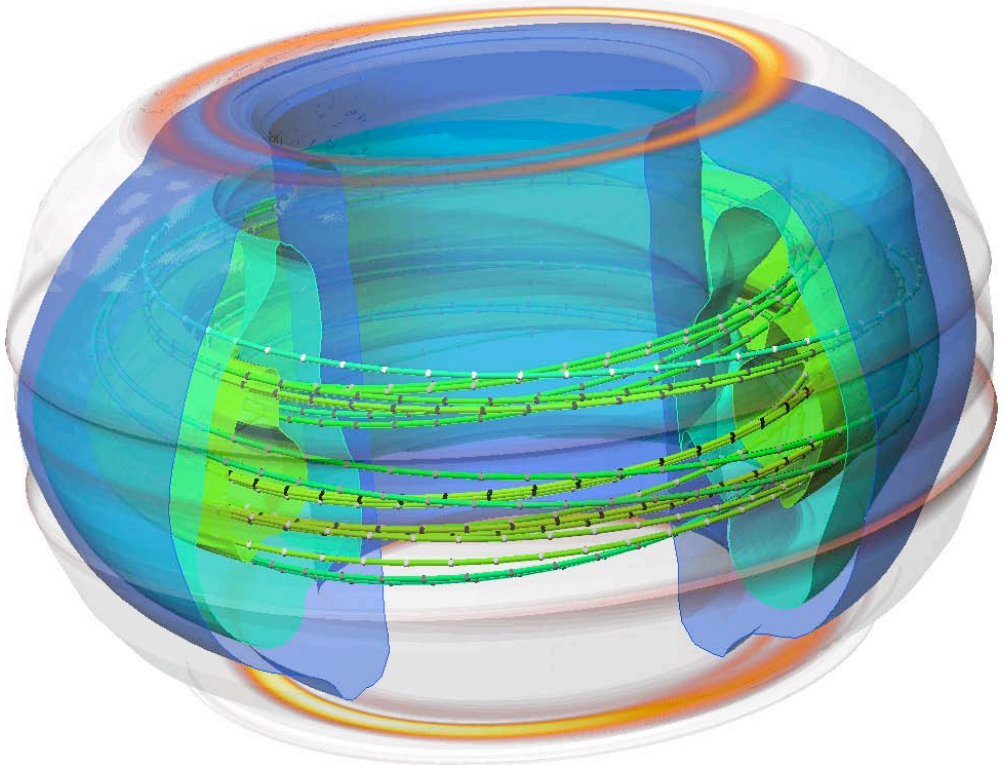
SCIRUN TO VISUALIZE COMPLEX SIMULATIONS FOR BETTER UNDERSTANDING

- Open source, multi-platform capable for a wide user base
- To facilitate quantitative comparison of simulations & experimental results



SciDAC CEMM NIMROD Simulation of a DIII-D Plasma

Raising the challenge of very large datasets
- MDSplus
- Storage method
- Data location
- Parallel I/O

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TILED DISPLAYS INSTALLED IN FUSION CONTROL ROOMS

DIII-D Tokamak Control Room

NSTX Tokamak Control Room

- Enhanced collaboration within the control room
  - Software for application sharing to tiled walls
- Very well received by fusion scientists
  - Fusion research funds used to purchase tiled walls for control rooms

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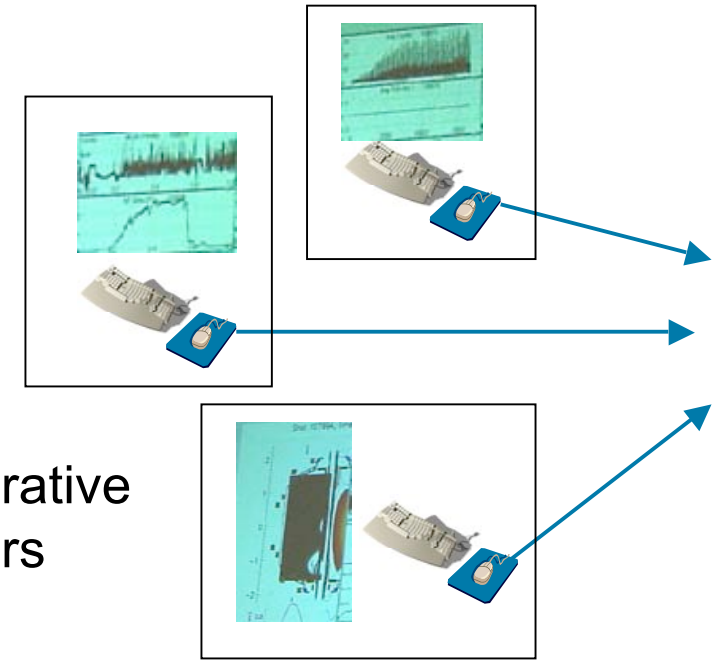
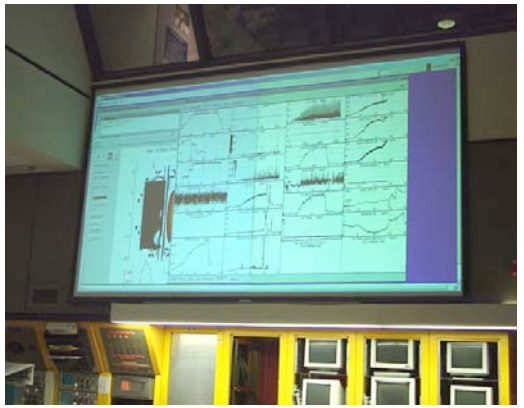
APPLICATION SHARING WITHIN FUSION CONTROL ROOM

- Display information sharing
  - Scientists can move computational results from their PCs to the shared display
  - Visualizations from all scientists can be compared side-by-side
- Concurrent Control
  - Scientists can simultaneously edit and interact with applications
  - Researchers can annotate visualizations simultaneously
  - Access and edit control are policy driven and configurable



Collaborative Users



Shared Display

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ACCESS GRID: REAL TIME COMPLEX COMMUNICATION

AG in DIII-D Tokamak Control Room - July 2003

- Multi-site participants
  - Rich collaborative environment
  - Includes application & data sharing
- Modest cost of entry
  - Open source software
  - Commodity hardware

- Being used for seminars, working meetings, tokamak operations

Personal Interface to the Grid (PIG) motivated by Fusion research

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SC03 DEMO: COLLABORATIVE CONTROL ROOM

- Fully interactive discussions utilizing AG
  - Includes shared applications
- Presence beyond AG communication
  - What one “sees and hears” in the control room
- Enhanced collaboration within the control room
  - Tiled displays and a shared X environment
- Advance reservation computation
  - Between pulse data analysis

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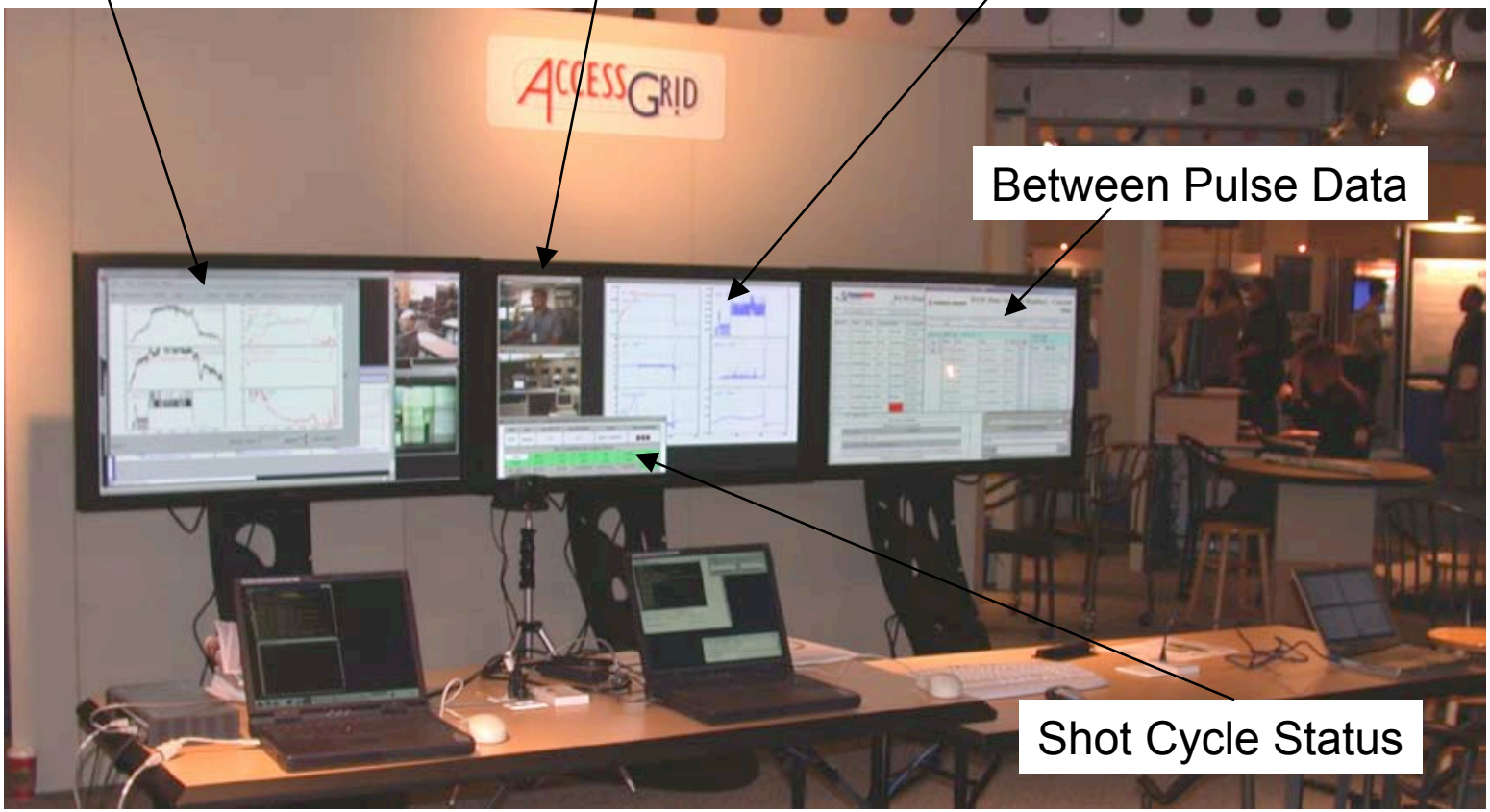
COLLABORATIVE CONTROL ROOM: A SENSE OF PRESENCE



SuperComputing 2003, Phoenix AZ

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REMOTE LEADERSHIP OF THE JET TOKAMAK IN ENGLAND FROM SAN DIEGO USING FUSIONGRID SERVICES

January 2004, San Diego

Working with JET and the UK e-Science Programme

- First attempt for real science and it was successful
- Successful & subsequently done: Japan - US & US-Germany

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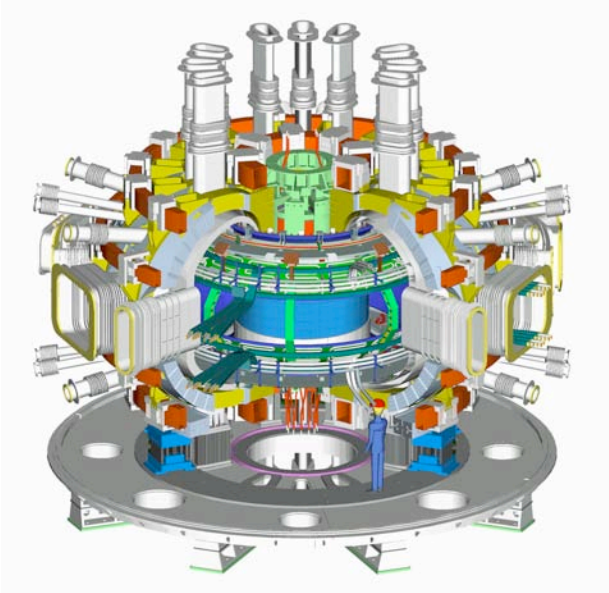
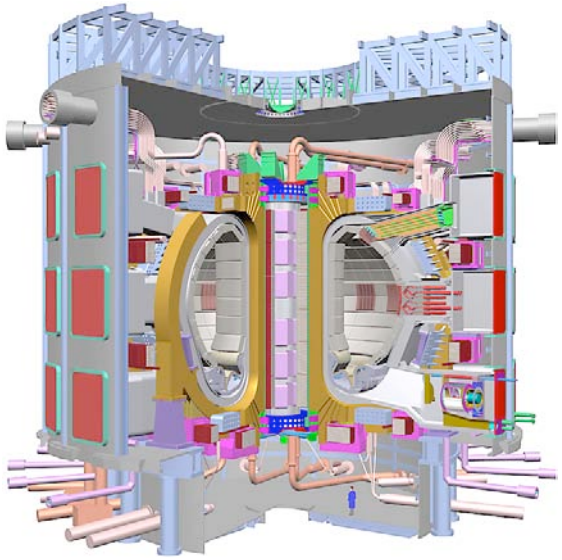
NFC TECHNOLOGIES SCALE TO THE NEXT DEVICE





- Pulsed experiment with simulations
  - ~TBs of data in 30 minutes
- Non-U.S. located devices
  - Collaboration for max U.S. benefit
- Successful operation requires
  - Large simulations, shared vis, decisions back to the control room
  - Remote Collaboration via FusionGrid
- Virtual control room concept being discussed as model for these devices
  - ITER: France or Japan
  - KSTAR: Korea

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LESSONS LEARNED AND OUTSTANDING ISSUES

- Certificate management for users and developers too difficult
  - This is their first experience with FusionGrid: needs to be positive
- Software infrastructure required for a new service is too complex
  - Simple for the non-specialist (Professor & grad student)
- Difficulties combining Grid-security and Site-security (firewalls)
  - Greatly limiting the potential expansion of the FusionGrid userbase
- Manipulating large multi-dimensional datasets is still a challenge
  - Need to test new approaches
- Control room presence is more than audio/video & shared apps
  - Include things one sees & hears when physically in control room
- Users like frequent and rapid prototyping tests
  - They feel involved and it is educational to both sides

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CONCLUDING COMMENTS

- The National Fusion Collaboratory Project is implementing and testing new collaborative technologies for fusion research
  - FusionGrid services being used to benefit daily FES research
- Clear vision forward to the collaborative control room
  - Real-time support for experiments is critical
  - Concept encompasses most if not all collaborative FES needs
- Collaborative technology critical to the success of the FES program
  - Experimental: Fewer, larger machines in future (KSTAR, ITER)
  - Computation: Moving toward integrated simulation (FSP)

> *First on our list is fusion. The prospect of limitless source of clean energy for the world leads with our commitment to join the international fusion energy experiment known as ITER.*
> – Secretary of Energy Spencer Abraham, November 10, 2003
> Introducing the Department's 20-year plan for building the scientific facilities of the future.

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