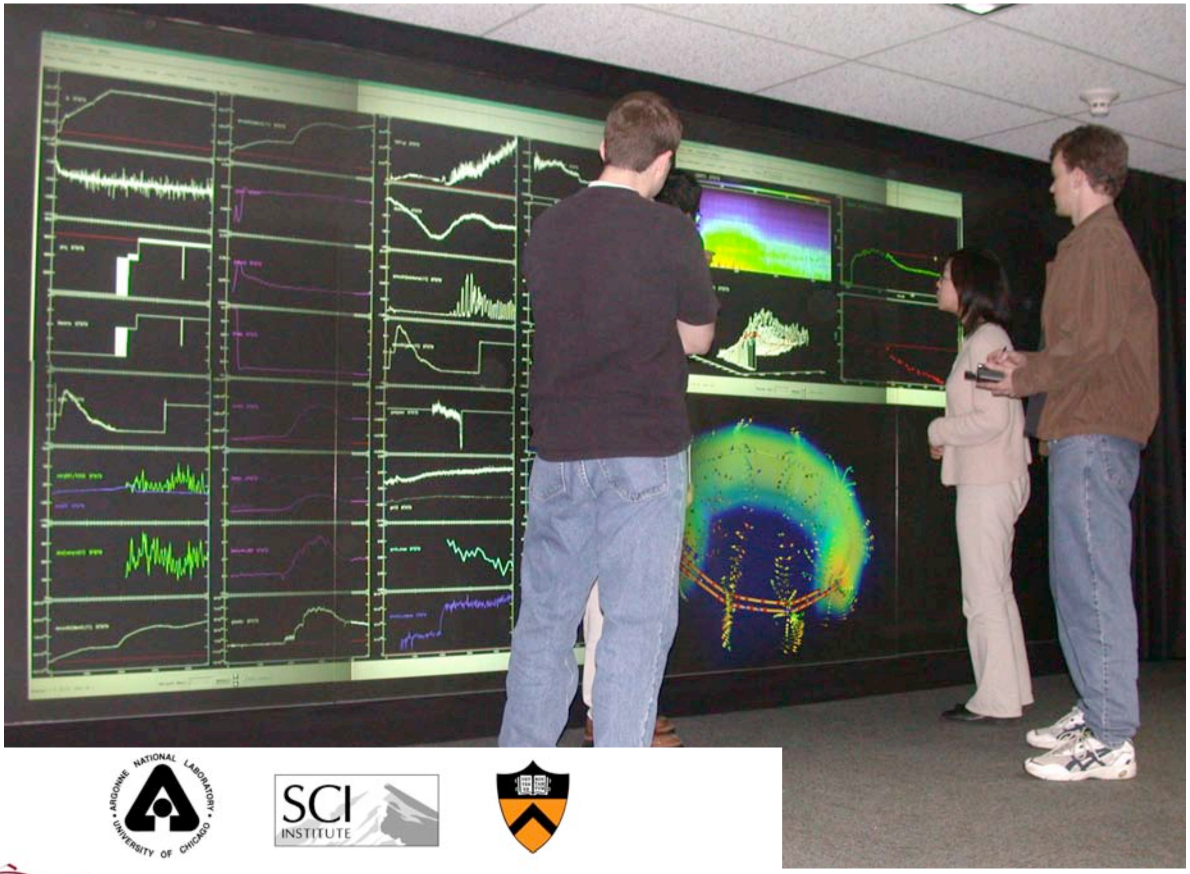
Collaboration For Fusion Science



by
David P. Schissel

Presented at
PSACI PAC Meeting
Princeton, NJ

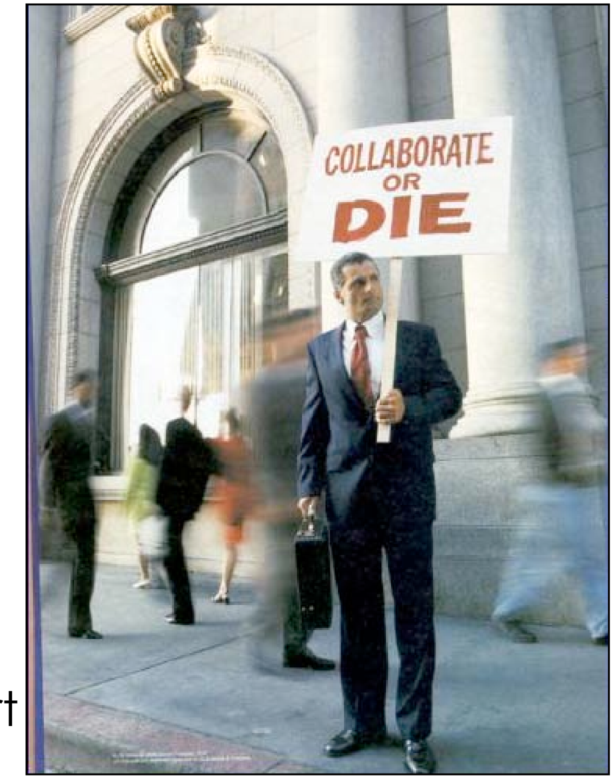
June 2–3, 2005

Acknowledgment

- **The National Fusion Collaboratory Project Team Members**
  - ANL, GA, LBL, MIT, PPPL, PCS, Utah
- **The Staff of the DIII-D National Fusion Facility**
- **Our European Colleagues**
  - Farthing (JET), Schmidt (RFX), How (ITER-EU)
- **Work is supported by the USDOE Department of Energy**
  - SciDAC: Office of Advanced Scientific Computing Research
  - Significant leveraging: Office of Fusion Energy Sciences

Presentation's Key Points

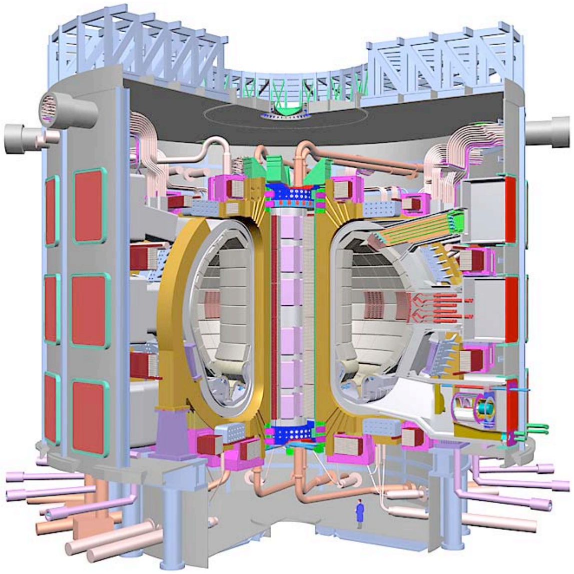
- **Collaborative technology critical to FES**
  - Fewer larger machines (ITER)
  - A full integrated simulation (FSP)
- **FES scientists are using NFC Project tools**
  - Lead with the science
  - Modifying/creating new software
- **Collaborative technology critical to fully exploit present and future facilities**
  - ITER will not be in the U.S.
  - Supercomputer: real-time experimental support



- **Extend our existing collaborative tools to meet future needs**
  - Both functionality and to the broader international FES community
  - Assist in creating collaborations in other scientific disciplines

Presentation's Outline

- **Motivation for fusion's present and future collaborative needs**
  - Only three large U.S. experimental facilities
  - ITER outside the U.S.; one U.S. integrated simulation code
- **Progress of the National Fusion Collaboratory Project**
  - FusionGrid created for data, computation, human collaboration
  - Some international usage
- **Future needs motivated by lessons learned**
  - Integrated easy to use framework
  - Robust and reliable
- **Expand our usage**
  - South Korea, China, EU, Japan
  - Supercomputer



Fusion Science Today is very much a Team Sport

Active Collaborations 2004

- 90 institutions participate
- 425 active users
- 317 scientific authors
- Students and faculty from
  - 65 universities
  - 28 states

US Labs

ANL (Argonne, IL)
LANL (Los Alamos, NM)
LBNL (Berkeley, CA)
LLNL (Livermore, CA)
ORNL (Oak Ridge, TN)
PPPL (Princeton, NJ)
SNL (Sandia, NM)

Industries

Calabasas Creek (CA)
CompX (Del Mar, CA)
CPI (Palo Alto, CA)
Digital Finetec (Ventura, CA)
DRS (Dallas, TX)
DTI (Bedford, MA)
FAR Tech (San Diego, CA)
IOS (Torrance, CA)
Lodestar (Boulder, CO)
SAIC (La Jolla, CA)
Spinner (Germany)
Tech-X (Boulder, CO)
Thermacore (Lancaster, PA)
Tomlab (Willow Creek, CA)
TSI Research (Solana Beach, CA)

US Universities

Auburn (Auburn, Alabama)
Colorado School of Mines (Golden, CO)
Columbia (New York, NY)
Georgia Tech (Atlanta, GA)
Hampton (Hampton, VA)
Lehigh (Bethlehem, PA)
Maryland (College Park, MD)
Mesa College (San Diego, CA)
MIT (Boston, MA)
Palomar (San Marcos, CA)
New York U. (New York, NY)
SDSU (San Diego, CA)
Texas (Austin, TX)
UCB (Berkeley, CA)
UCI (Irvine, CA)
UCLA (Los Angeles, CA)
UCSD (San Diego, CA)
U. New Mexico (Albuquerque, NM)
U. Rochester (NY)
U. Utah (Salt Lake City, UT)
Washington (Seattle, WA)
Wisconsin (Madison, WI)

Russia

Ioffe (St. Petersburg)
Keldysh (Udmurtia, Moscow)
Kurchatov (Moscow)
Moscow State (Moscow)
St. Petersburg State Poly (St. Petersburg)
Triniti (Troitsk)
Inst. of Applied Physics (Nizhny Novgorod)

European Community

Cadarache (St. Paul-lez, Durance, France)
Chalmers U. (Goteberg, Sweden)
CFN-IST (Lisbon, Portugal)
CIEMAT (Madrid, Spain)
Consorzia RFX (Padua, Italy)
Culham (Culham, Oxfordshire, England)
EFDA-NET (Garching, Germany)
Frascati (Frascati, Lazio, Italy)
FOM (Utrecht, The Netherlands)
Helsinki U. (Helsinki, Finland)
IFP-CNdR (Italy)
IPP (Garching, Greifswald, Germany)
ITER (Garching, Germany)
JET-EFDA (Oxfordshire, England)
KFA (Julich, Germany)
Kharkov IPT, (Ukraine)
Lausanne (Lausanne, Switzerland)
IPP (Greifswald, Germany)
RFX (Padova, Italy)
U. Dusseldorf (Germany)
U. Naples (Italy)
U. Padova (Italy)
U. Strathclyde (Glasgow, Scotland)

Japan

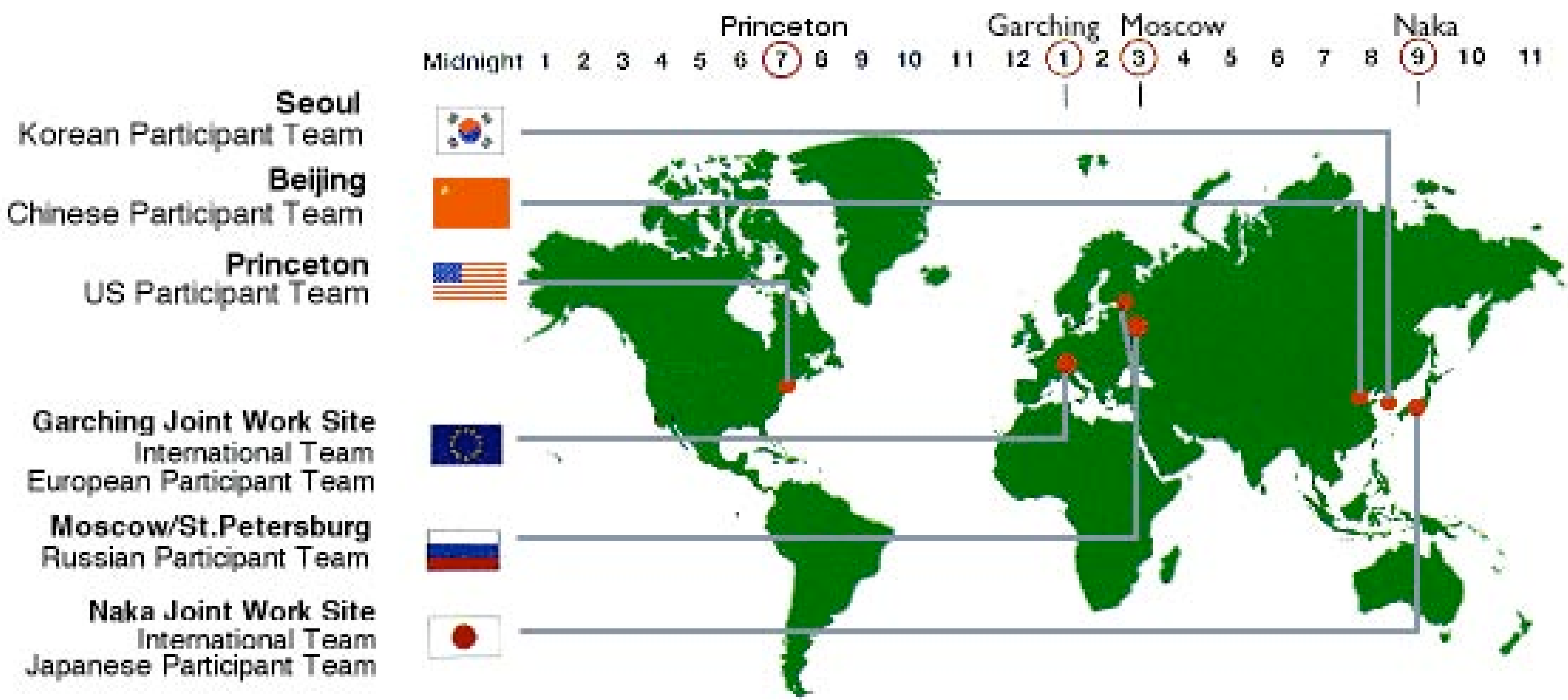
JAERI (Naka, Ibaraki-ken, Japan)
JT-60U
JFT-2M
Tsukuba University (Tsukuba, Japan)
NIFS (Toki, Gifu-ken, Japan)
LHD

Other International

Australia National U. (Canberra, AU)
ASIPP (Hefei, China)
Dong Hau U. (Taiwan)
KBSI (Daegon, S. Korea)
KAERI (Daegon, S. Korea)
Nat. Nucl. Ctr. (Kurchatov City, Kazakhstan)
Pohang U. (S. Korea)
Seoul Nat. U. (S. Korea)
SWIP (Chengdu, China)
U. Alberta (Alberta, Canada)
U. of Kiel (Kiel, Germany)
U. Toronto (Toronto, Canada)

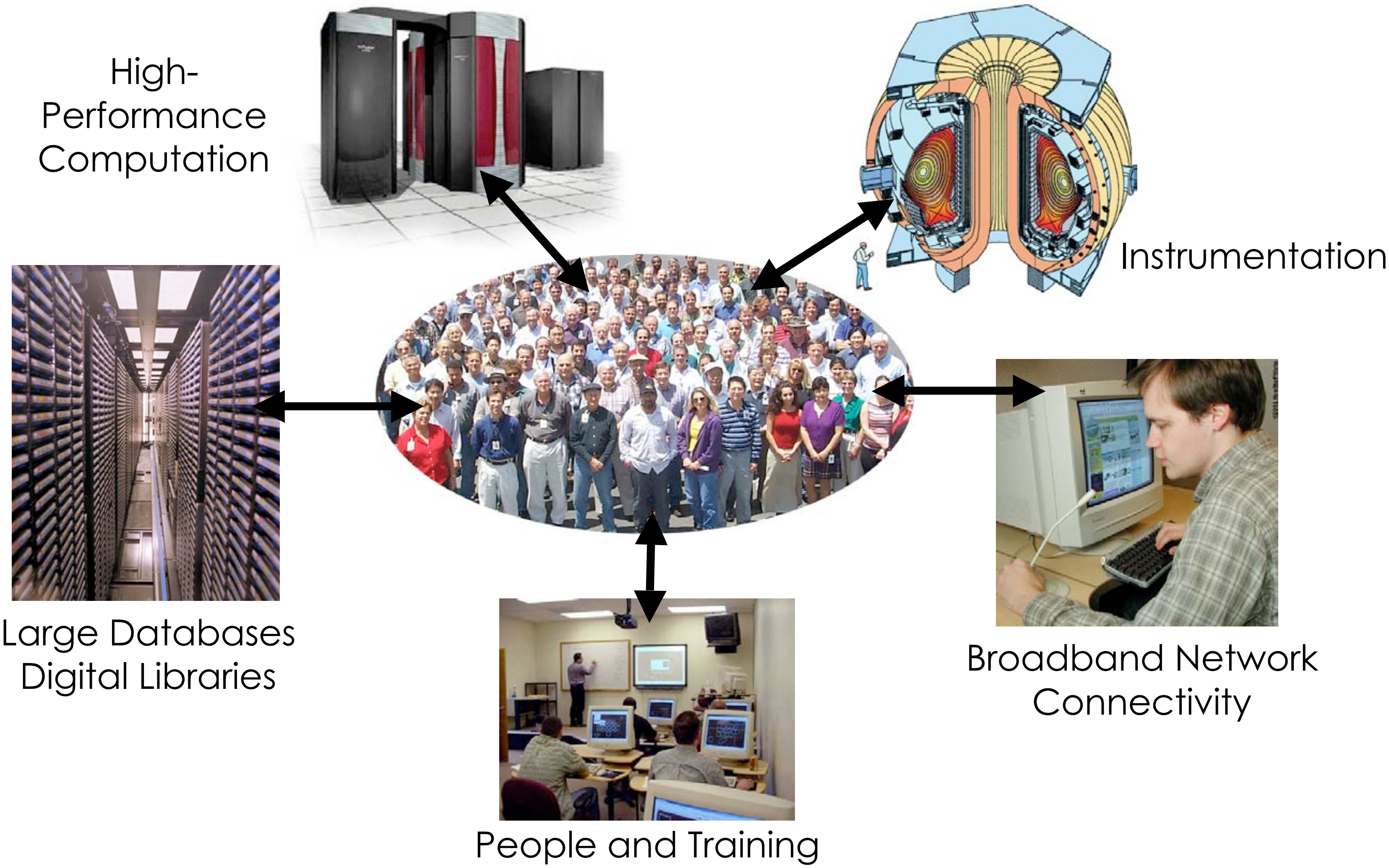
An Example From The DIII-D National Fusion Facility

Fusion Science will continue to be a Team Sport

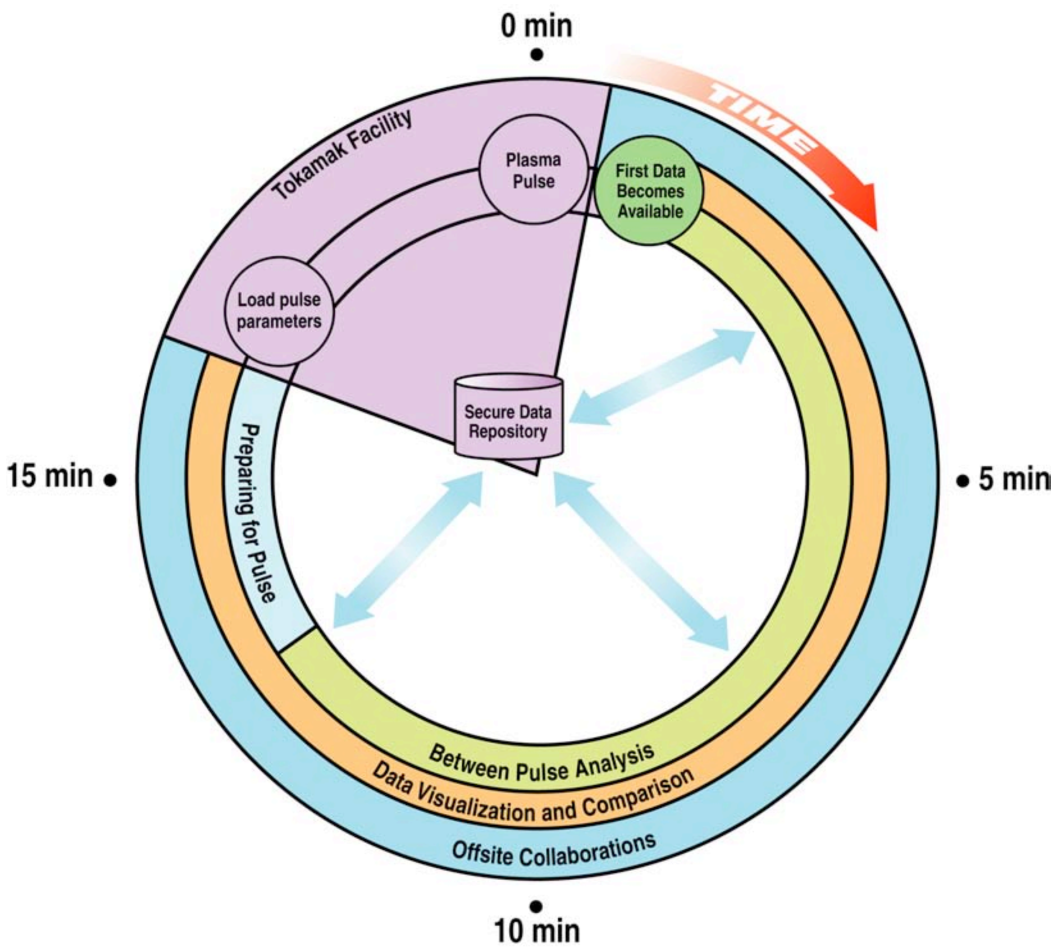


The Six ITER Partners

Assemble Required Expertise & Resources as needed



Experimental Fusion Science is and will continue to be a Very Demanding Real-Time Activity



Office of Science
U.S. DEPARTMENT OF ENERGY

FusionGRID
www.fusiongrid.org

Placing Distributed Computing Applications on the Wide Area Network Presents Significant Challenges

- **Crosses administrative boundaries**
- **Increased security complexity including authentication & 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 simple
  - Higher latency challenges network throughput & interactivity
- **People are not in one place for easy communication**

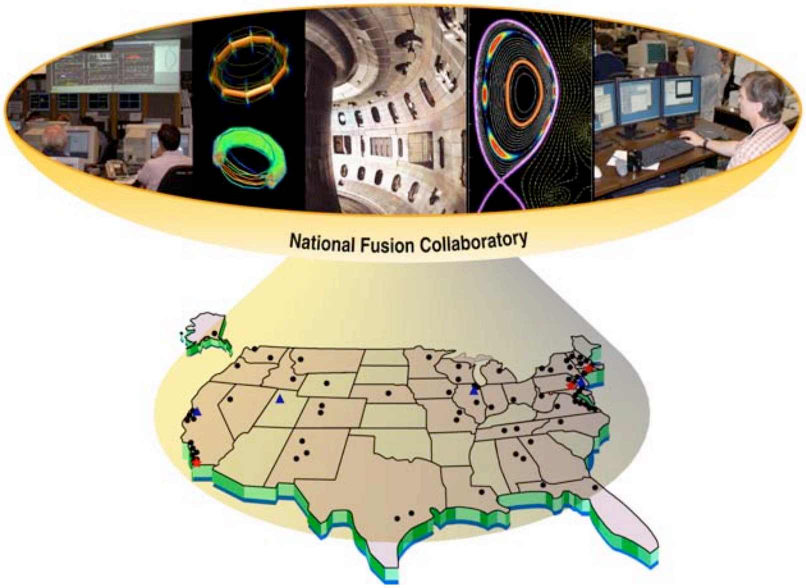
The National Fusion Collaboratory Project

- **Funded by the DOE Office of Advanced Scientific Computing Research**
  - A SciDAC Pilot Collaboratory Project - through FY06

- **Unify distributed MFE research into a U.S. Virtual Organization**

GOALS

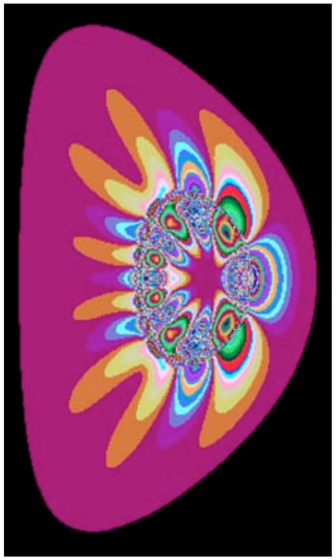
- More efficient use of experimental facilities
- Integrate theory & experiment
- Facilitate multi-institution collaboration
- Create standard tool set



ASCR   SciDAC Scientific Discovery through Advanced Computing   FusionGRID www.fusiongrid.org

The Vision for the NFC's Technologies: Optimize the Most Expensive Resource – People's Time

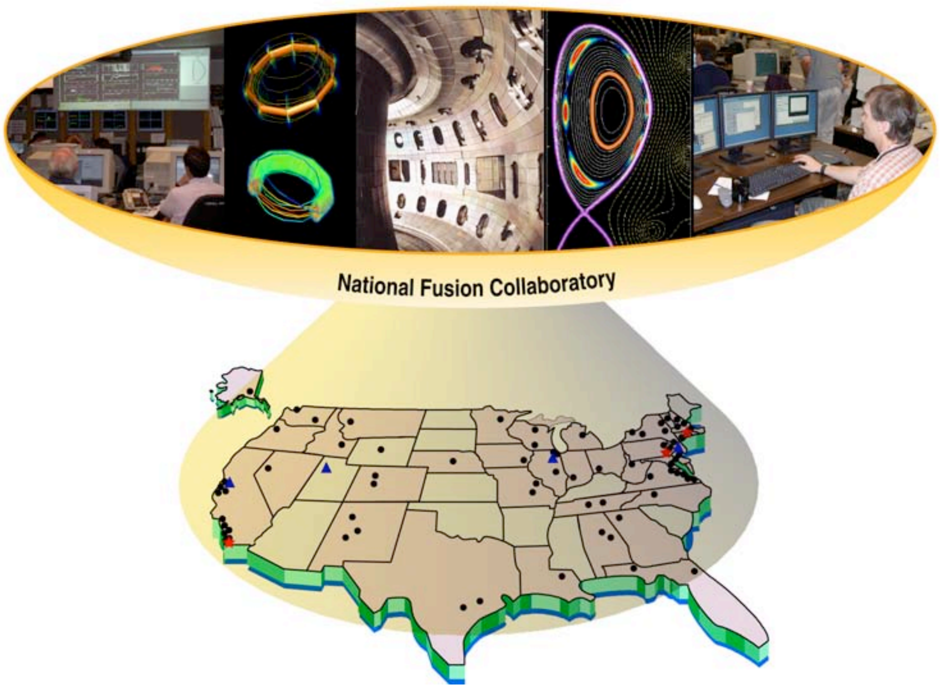
- **Data, Codes, Analysis Routines, Visualization Tools should all be thought of as network accessible services**
  - Access is stressed rather than portability
  - Transparency and ease of use are crucial elements
  - Not CPU cycle scavenging or "distributed" supercomputing



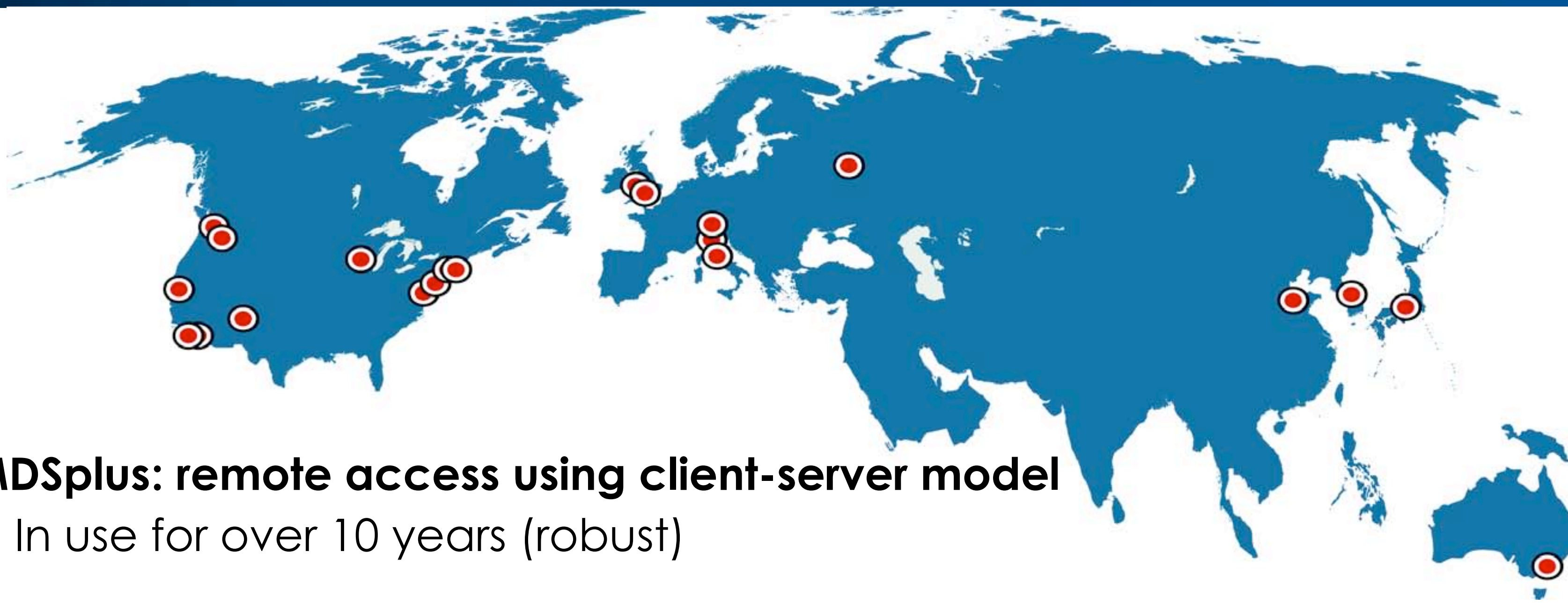
- **Shared security infrastructure with distributed authorization and resource management**
  - Ease of use: "security with transparency"
  - X.509 certificates from a trusted Certificate Authority
  - Distributed authorization (ROAM) for stakeholder resource control
- **Collaborative nature of research requires shared visualization applications and widely deployed collaboration technologies**
  - Ease of use: "security with transparency"
  - Integrate geographically diverse groups

FusionGrid: Secure Access to Resources

- **Authentication: PKI via X.509 certificates**
  - FusionGrid CA
  - FusionGrid RAs (Humans)
- **Centralized certificate management**
  - MyProxy server
  - More secure & easier to use
- **Onetime FusionGrid login**
  - Globus toolkit (GSI & GRAM)
- **Authorization: Customized (ROAM)**
  - All resources call central Policy Decision Point
  - Policy for all resources in a relational database



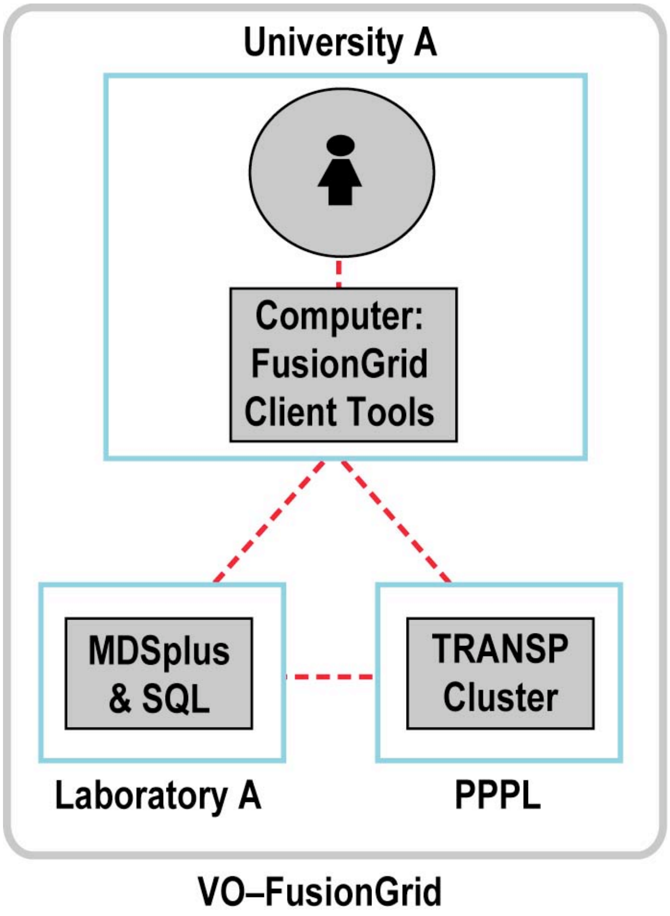
FusionGrid: Secure Access to Fusion Data



- **MDSplus: remote access using client-server model**
  - In use for over 10 years (robust)
- **Wide adoption worldwide**
  - Unified data interface (e.g. Visualization)
- **MDSplus data access now can be secure**
  - FusionGrid authentication (Globus GSI with certs)
  - FusionGrid authorization with ROAM

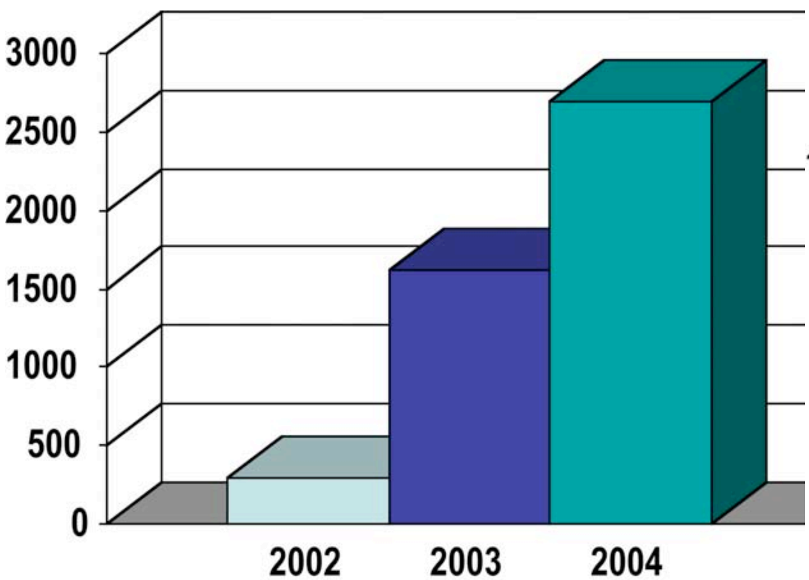
TRANSP: Successful Grid Computing for Fusion Science

- **The U.S. TRANSP Service**
  - 5,800 cases, 35,000 CPU hours
  - 10 fusion experimental machines
- **Centralized expertise for better support**
  - Debugging, maintenance, monitoring
- **Reduced administration work at other labs**
  - Smaller sites to use bigger codes
- **Between shot analysis demonstrated**
- **Model for other codes**
  - GATO released rapidly
  - Algorithm collaboration with Keyes

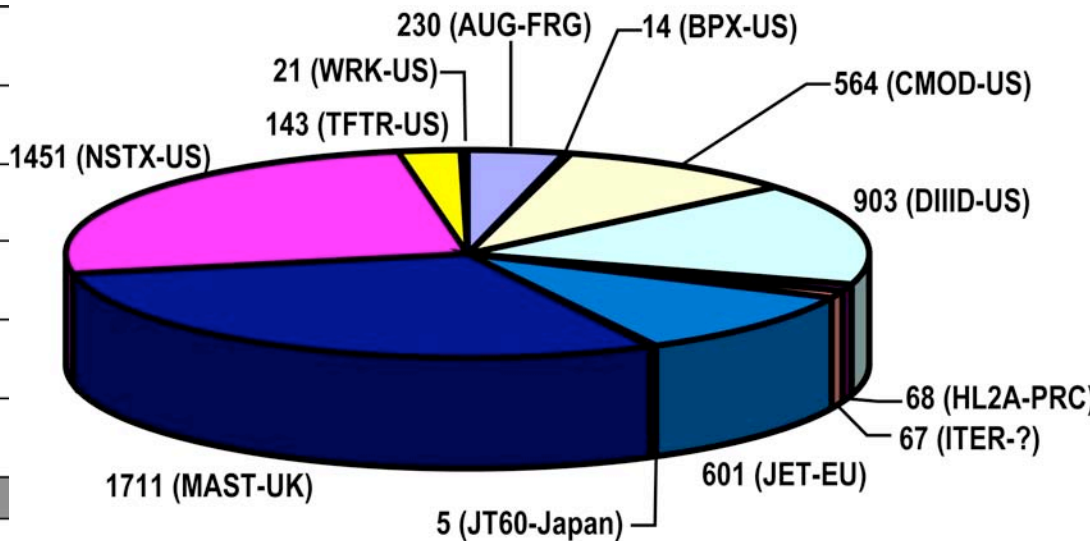


FusionGrid's Usage Continues to Grow

Total TRANSP Runs Per Year



TRANSP Runs In FY 2004



Shared Displays Installed in Fusion Control Rooms

NSTX

DIII-D

C-Mod

Access Grid: Real Time Complex Communication

Scientific Leadership of JET in UK from US

January 2004, San Diego

Remote Participation from JET to DIII–D

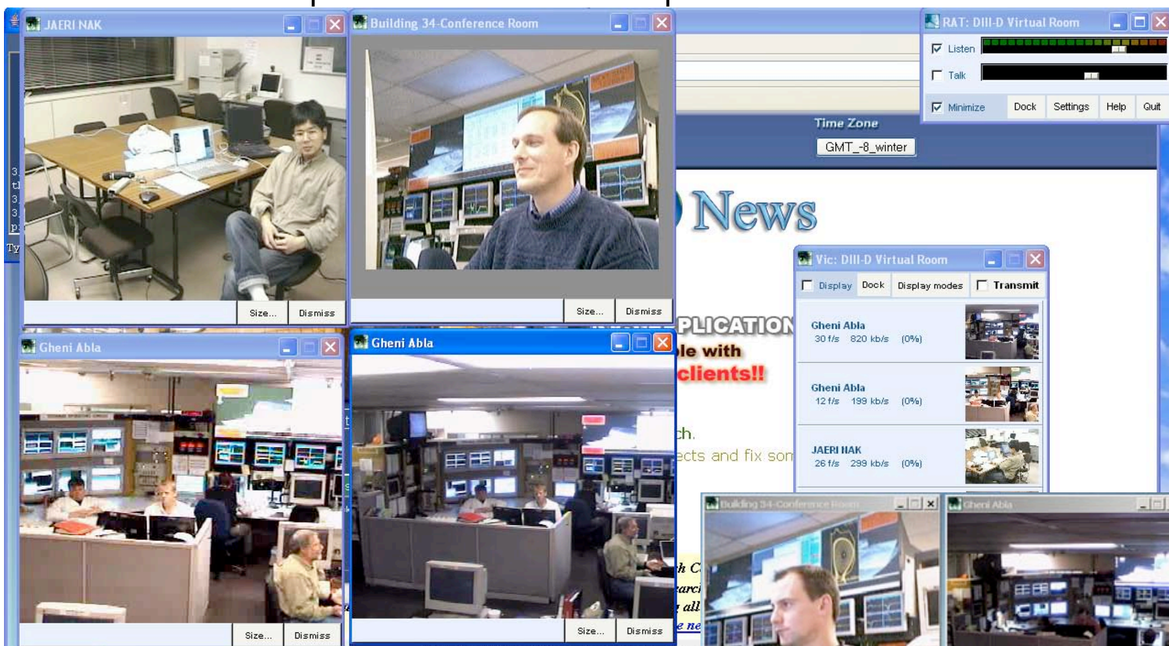
May 2004, DIII–D Tokamak Control Room

- **Being used for seminars, working meetings, tokamak operations**
  - Linux, Windows, and Macintosh OS X; small to large immersive nodes

- **For tokamak operations, the collaborative control room**
  - Software framework: sharing humans data, applications, info

VRVS Being Used For Its Web Based Client

JAERI Participation in DIII-D Experiment March 2005

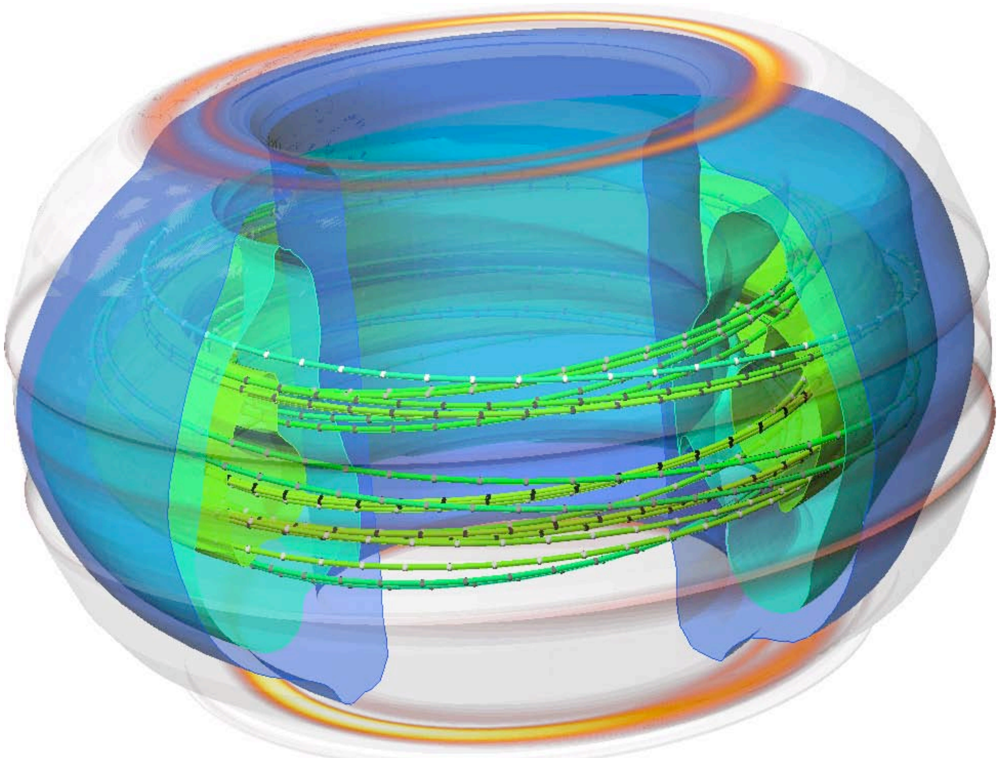


- **Closed source model limits customized expansion**
- **Web client is easy for scientists to get started**
  - Since March 9, 2004:
    341 unique Users
    539 unique computers
    3480 total hits

JET Participation in DIII-D Experiment January 2005

SCIRun To Visualize Complex Simulations

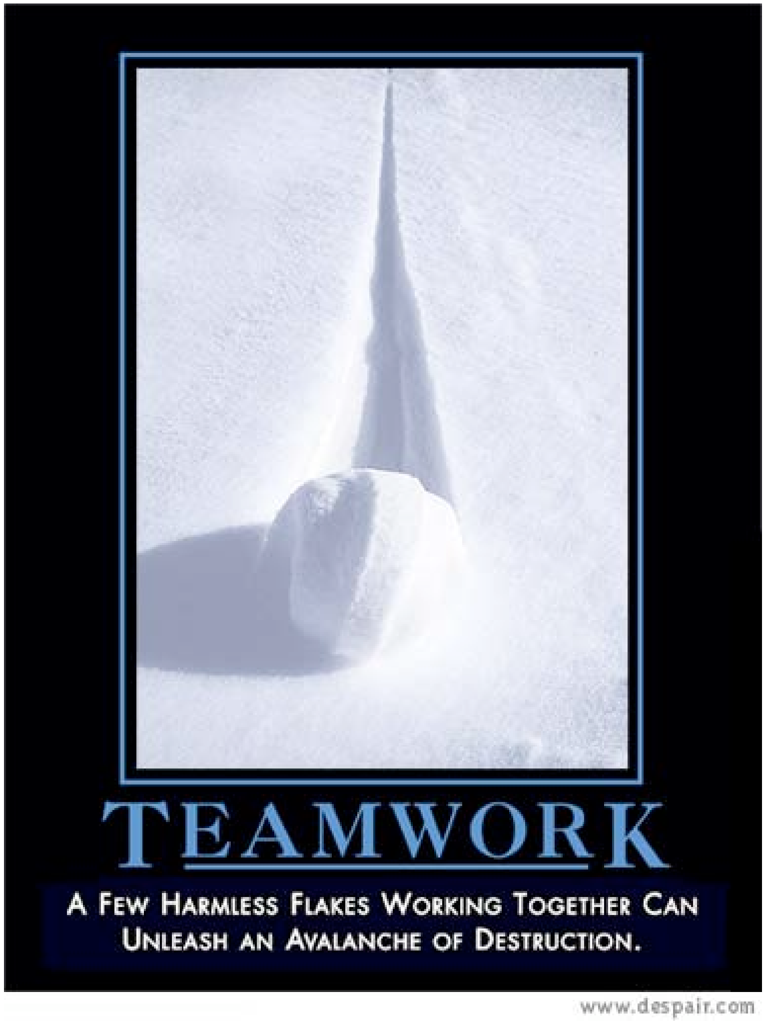
- Open source, multi-platform capable for a wide user base
- Facilitate quantitative comparison of simulations & experimental results



SciDAC CEMM NIMROD Simulation of a DIII–D Plasma

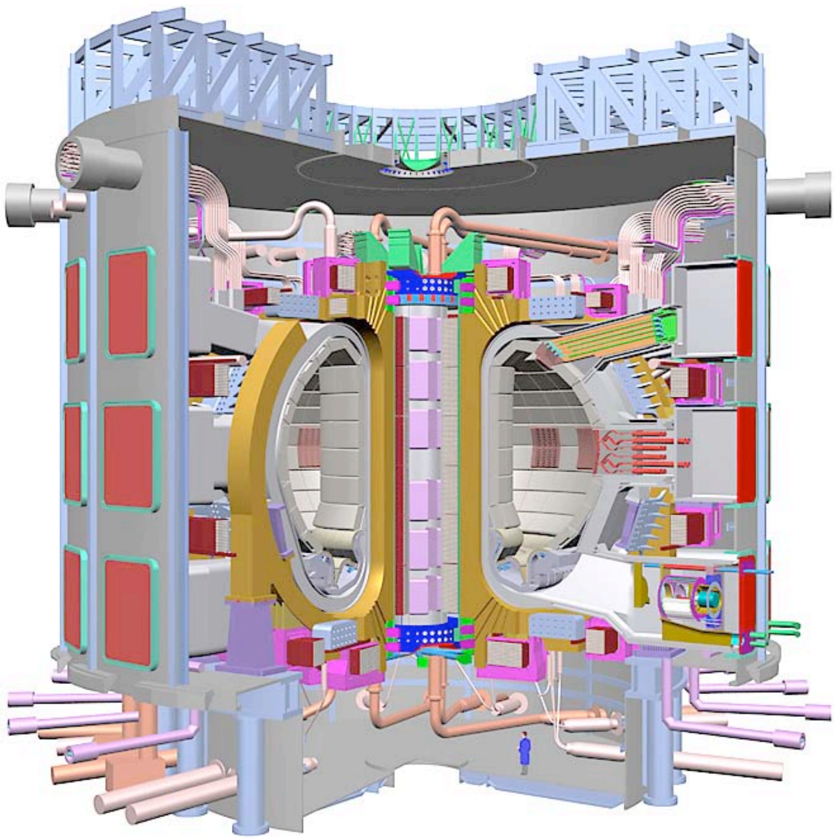
Challenge of large datasets
- MDSplus
- Storage method
- Data location
- Parallel I/O

NFC Project Goal's for the Next Year Will Result in a Solidification and Enhancement of FusionGrid Services



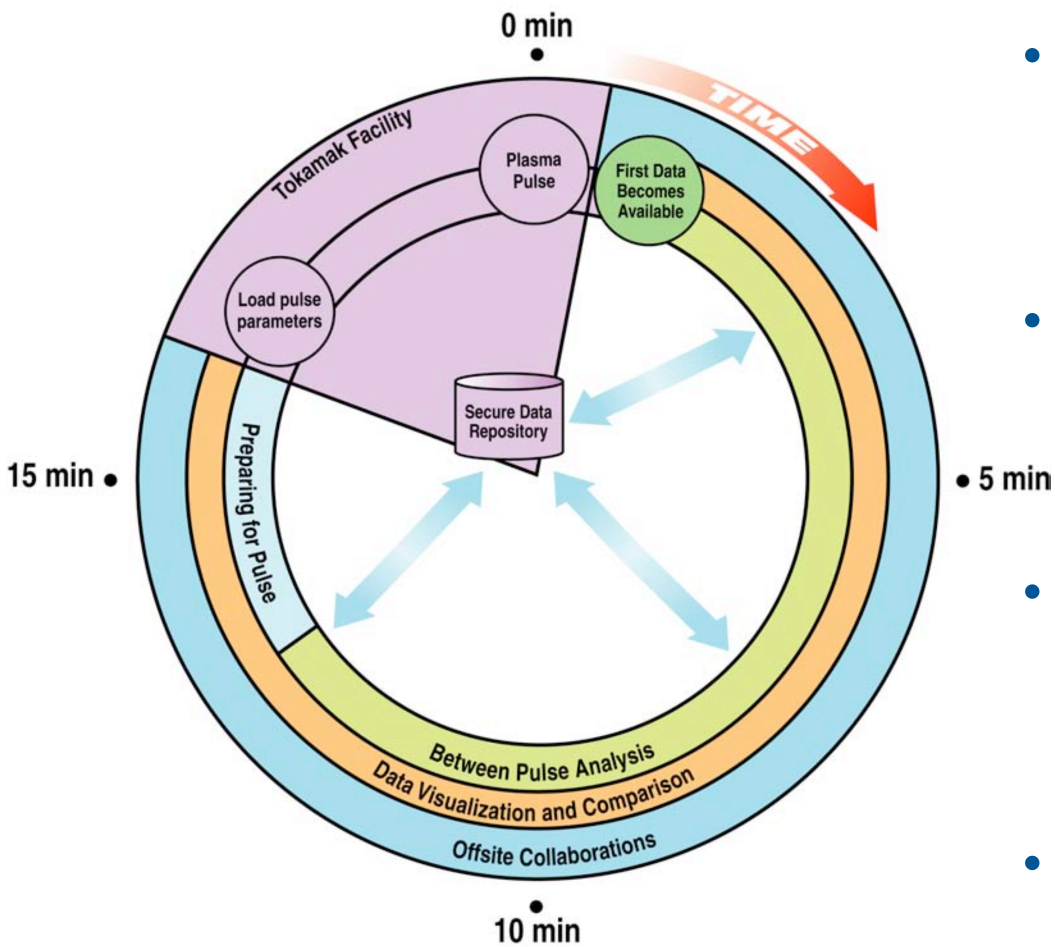
- **Security**
  - All platforms, MDSplus packaged
- **Computational Services**
  - Onetwo, GYRO, GS2, TORIC released
  - Between shot TRANSP routine
  - Parallel MDSplus I/O with XIO
- **Human Remote Collaboration**
  - AG Web client, recording, unicast
  - AG: NSTX, ASDEX, JET for experiments
- **Shared Displays**
  - Heterogeneous robust sharing software
- **Visualization**
  - Unified SCIRun released

ITER'S Success Both to the U.S. and the World Requires Robust Remote Collaboration Capability



- **One physical location not in the U.S.**
  - International collaboration
- **Pulsed experiments with simulations**
  - ~TBs of data in 30 minutes
- **Successful operation requires**
  - Large simulations, shared vis, decisions back to control room
- **Grid and ACE technologies critical**
  - Design, engineering, construction, & operations

These Needs Define the Collaborative Control Room

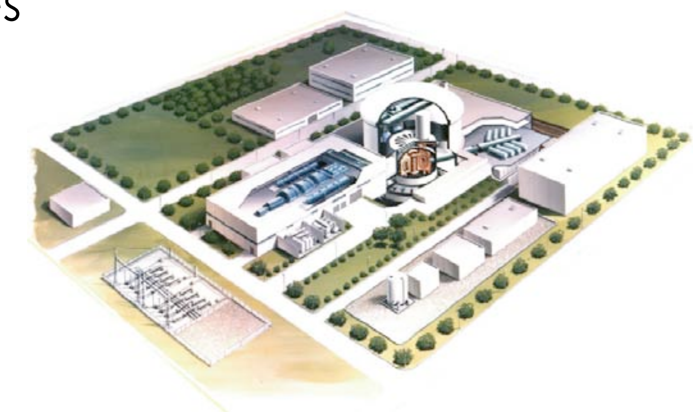


- **Secure computational resources scheduled as required**
- **Rapidly compare experimental data to simulation results**
- **Share individual results with the group via shared large displays**
- **Fully engaged remote scientists with audio, video, shared displays**

Substantial Work Required to Make the Collaborative Control Room Ready and Robust

Secure computational resources scheduled as required

- **Security: the interplay between Grid-Security and Site-Security**
  - This involves firewalls and X.509 certificates
  - Physical token like SecureID
  - NAT & IPV6



- **Limiting the user base expansion**
  - Every new user can not be an exception

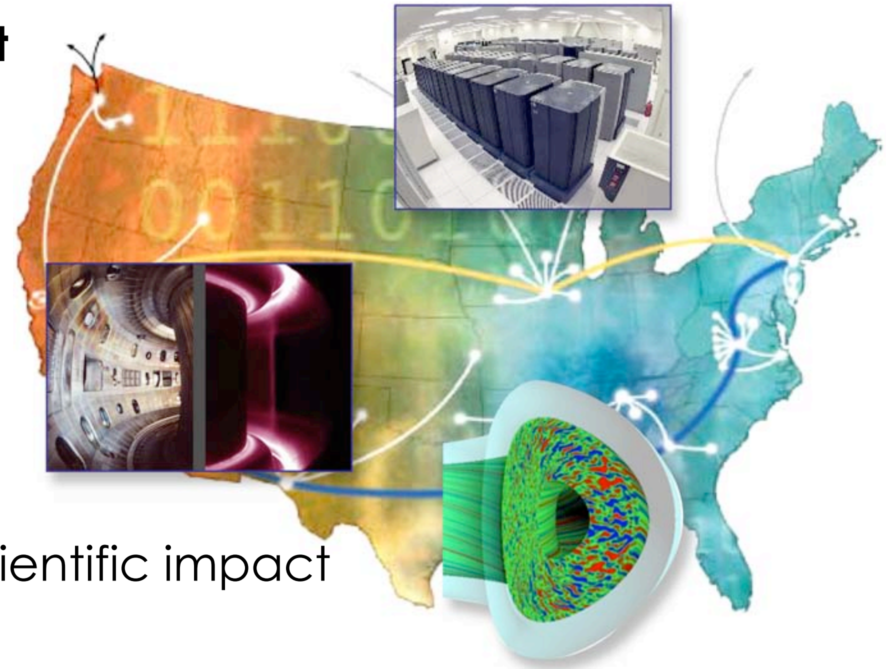
- **Simplified software infrastructure for the non-specialists**
  - To support a growing user base

- **Even more challenging crossing international borders**

Substantial Work Required to Make the Collaborative Control Room Ready and Robust (2)

Secure <u>computational resources scheduled as required</u>

- **Deploying a supercomputer to support pseudo real-time analysis**
  - Network QoS
  - CPU scheduling
  - Faster CPUs and algorithms
  - Data management

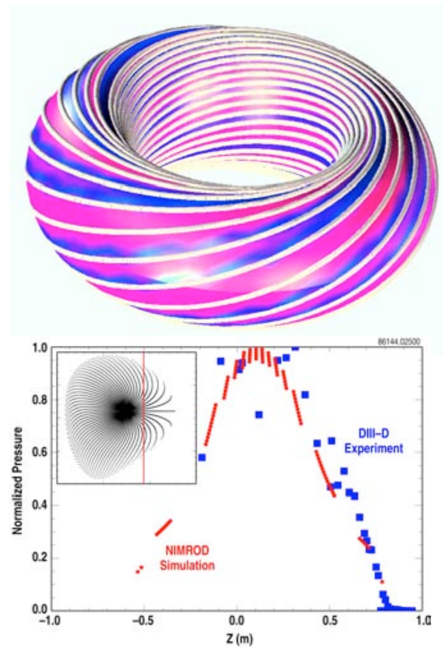


- **Substantially enhanced data analysis**
  - Historically this had made a huge scientific impact
- **Can have a safety impact for future devices**
  - e.g. ITER: <10% of high power discharges can disrupt

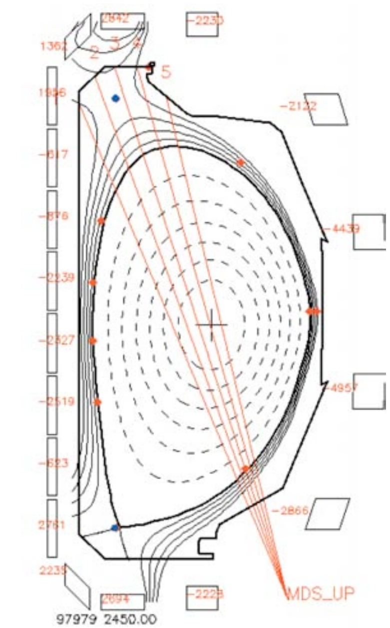
Substantial Work Required to Make the Collaborative Control Room Ready and Robust (3)

Rapidly compare experimental data to simulation results

- **Data Management**
  - Useable to both experimental and simulation scientists
  - Intelligent caching, parallel I/O
- **Visualization**
  - Facilitate understanding
  - Quantitative
  - Decision making



3D Plasma Simulation

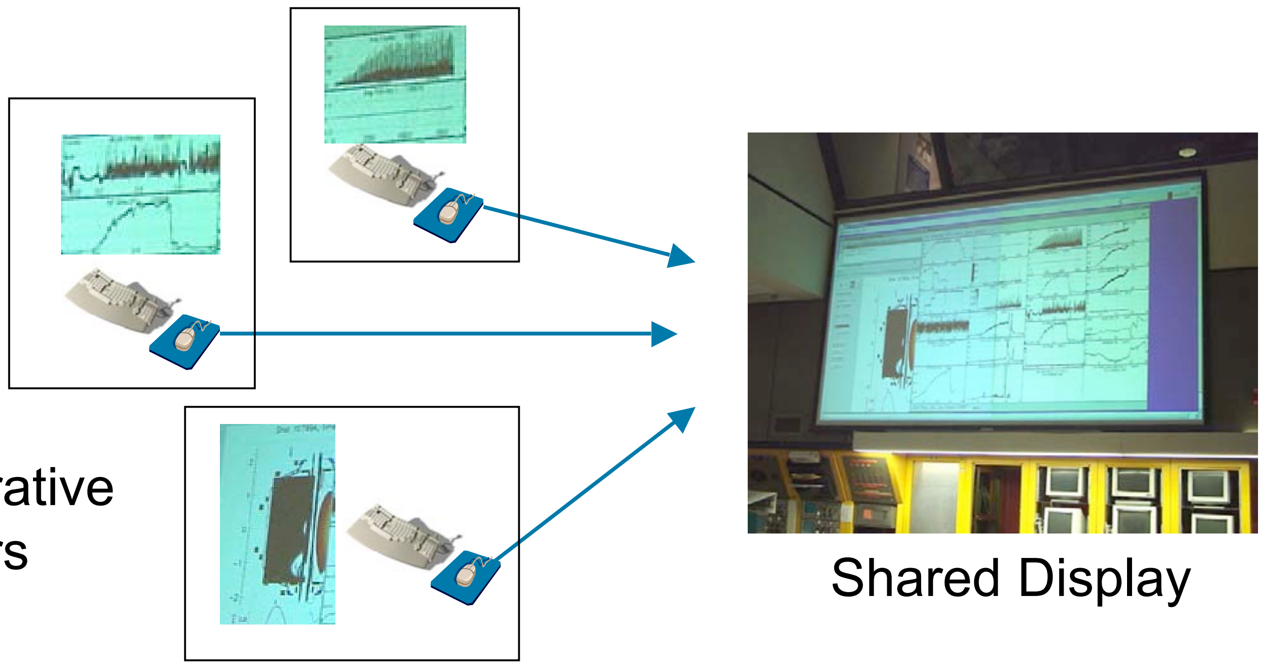


Experimental Reconstruction

Substantial Work Required to Make the Collaborative Control Room Ready and Robust (4)

Share individual results with the group via shared large displays

- **Display information sharing**
  - Move computational results from scientist's desktop to shared display
- **Concurrent control**
  - scientists can simultaneously edit, interact, annotate visualizations



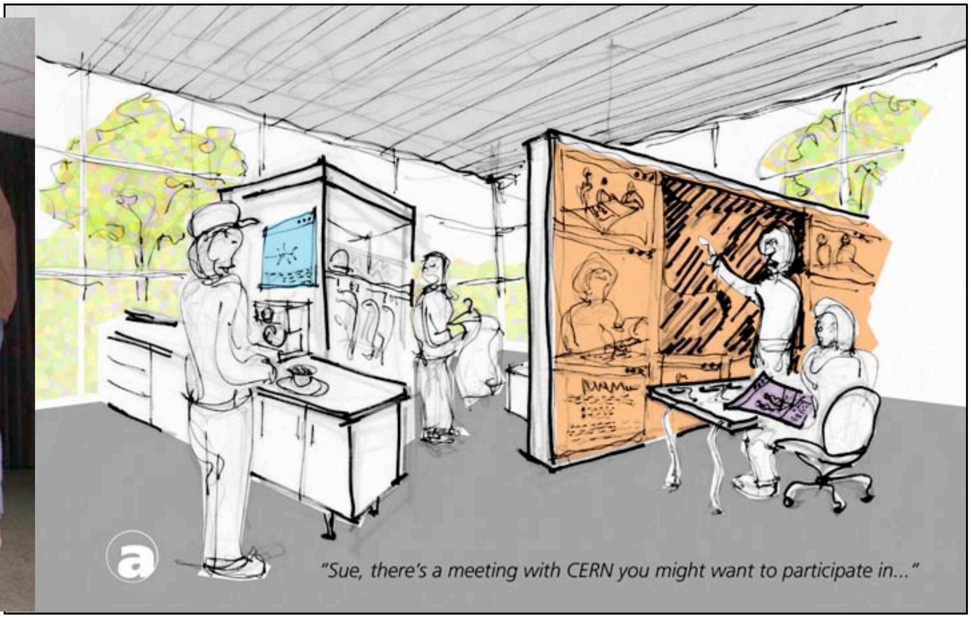
Collaborative Users

Shared Display

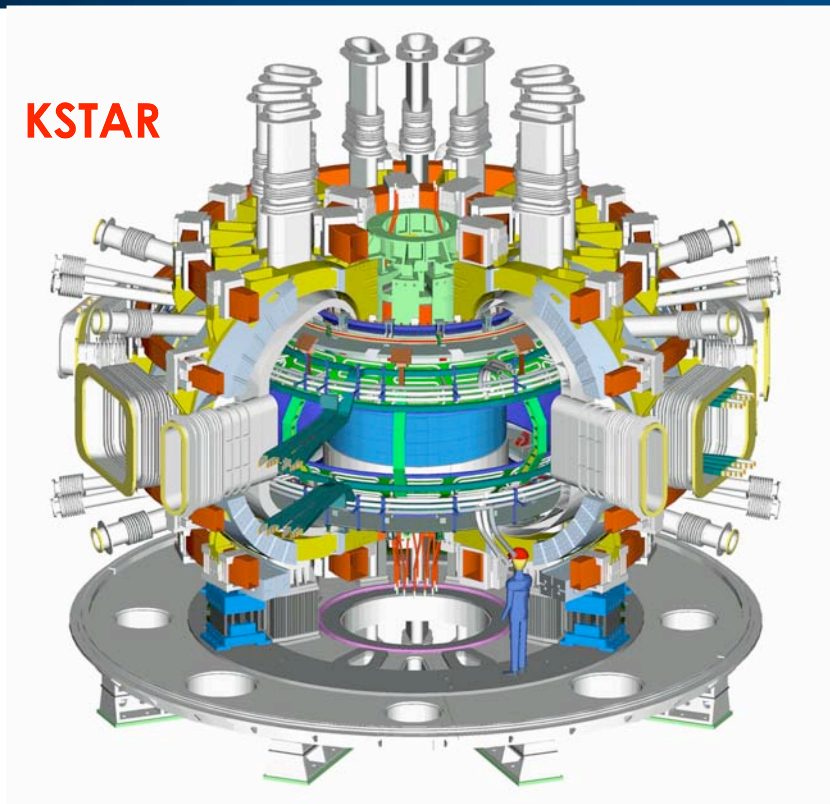
Substantial Work Required to Make the Collaborative Control Room Ready and Robust (5)

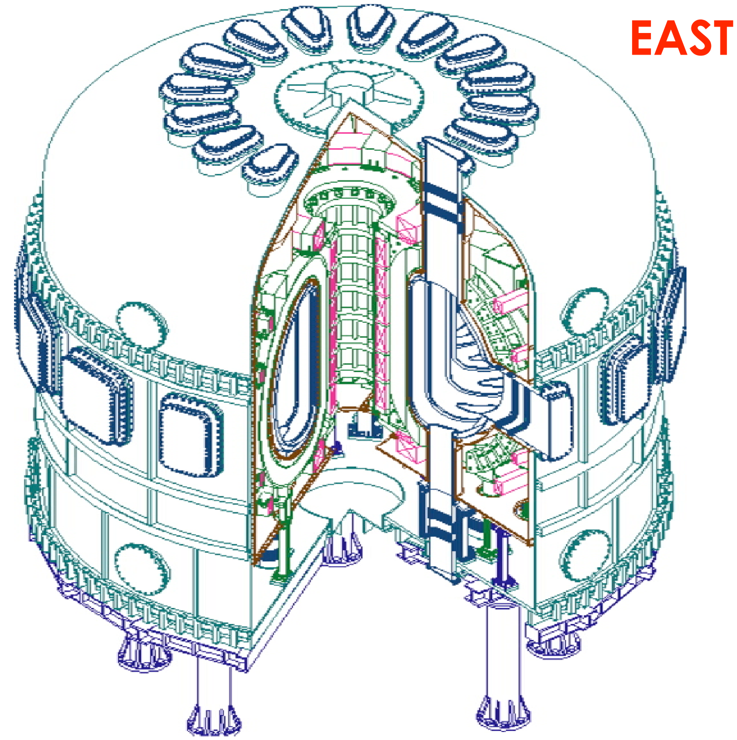
Fully engaged remote scientists with audio, video, shared displays

- **Unified & Robust Collaborative Environment**
  - Working in synergy, not scattered pieces (AG, VNC, Jabber, MDSplus…)
  - People (large & small groups), Data, Visualizations, Chat, Info
  - An eye towards new standards & the commercial world (e.g. SIP/VOIP)
  - Tolerance for failure is very small (~$1M/plasma in ITER)



As we Focus on ITER do not Lose Sight of the Near Term

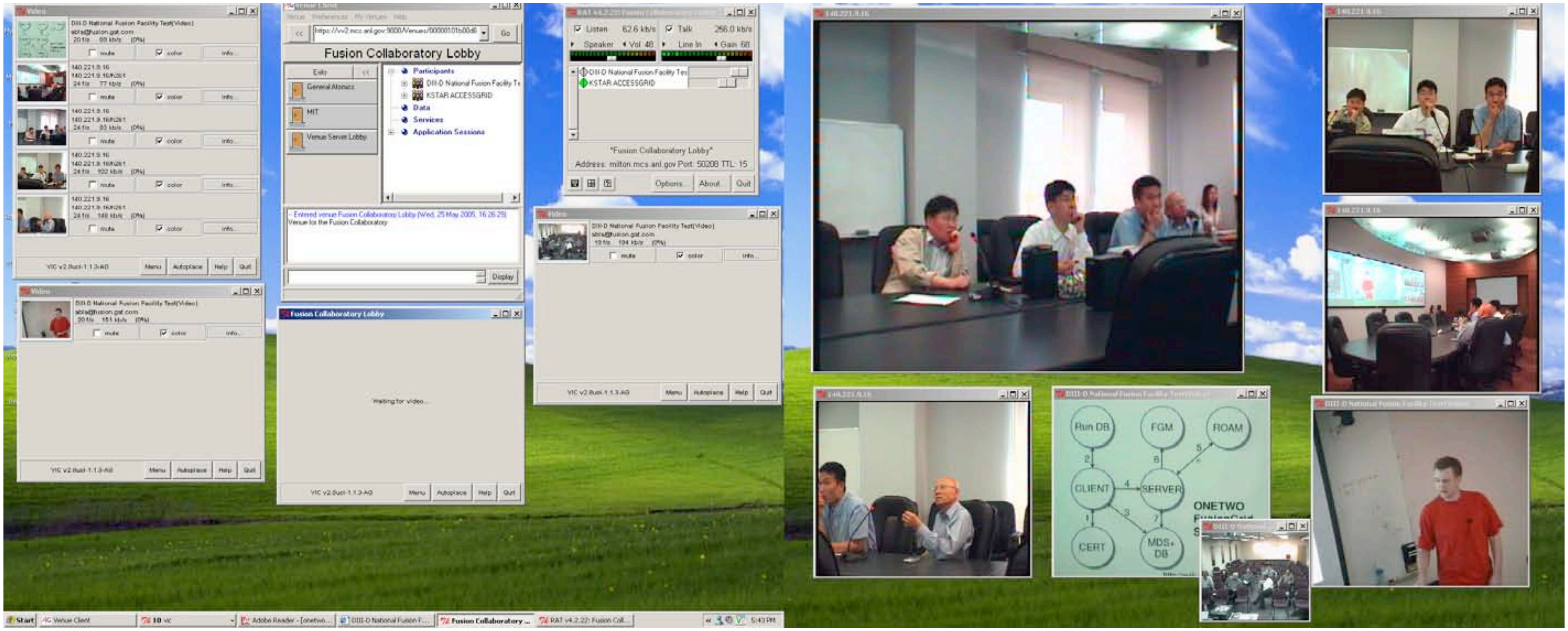




- KSTAR in South Korea and EAST in China will be excellent proving grounds for remote collaboration technology
- Technology will be used during experiments while ITER is being built

Work with KSTAR has been Initiated

First Joint Working Meeting via Access Grid May 2005



KSTAR Work Includes Computational Grid and ACE

- **FusionGrid for KSTAR**
- **MDSplus for data**
- **Onetwo as new service**
- **AG meetings routine**

- **Technology will be used to complete numerous physics tasks**
  - Improve FusionGrid's Transport and Stability codes
  - KSTAR Transport/Stability Modeling & Scenario Development

White Paper Written Proposing EAST Collaboration

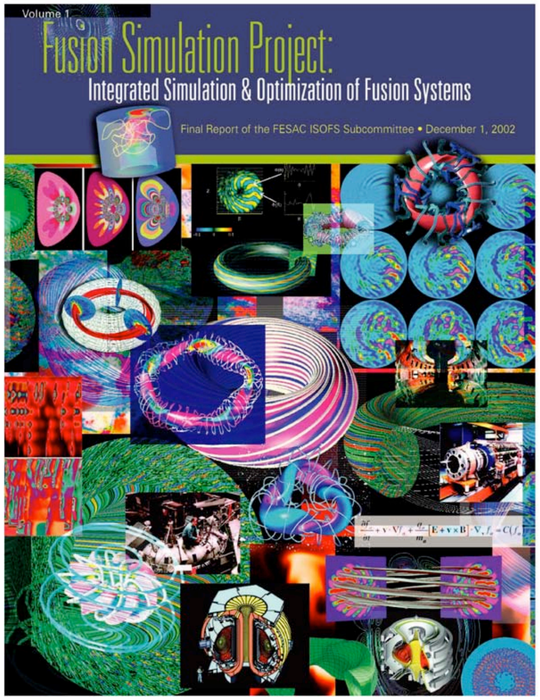
- **Goal is to enhance joint fusion research between U.S. and China**
  - Through the deployment of Grid and ACE infrastructure

- **Accomplished by deployment of existing FusionGrid**
  - Conduct interactive working meetings
  - Internet based access to modeling and analysis tools
  - Remote experimental participation on DIII-D and EAST

- **Three phase approach**
  - Beta project involving GA/DIII-D and Hefei China
  - Linkage of multiple fusion institutions in the U.S. and China via FusionGrid
  - Expanding the linkage to other collaborations between the two countries which are supported by the USDOE Office of Science and the Chinese Academy of Sciences

FSP Success Requires Collaborative Technology

- **Simulation data validation via comparison to experimental data**
  - Implies a complete data management system for FSP
- **Visualization tools**
  - Numerous tools but common data API
- **FSP as resource over WAN**
  - FusionGrid service
- **FSP used during experiments**
  - More intelligent decisions
- **FSP is a collaborative project**
  - Working meetings, shared code debugging, etc.



Response to PAC's General Charge

- **Challenge to effectively utilize terascale computing to produce significantly new scientific insights/breakthroughs**
  - Pseudo real-time FusionGrid computing during tokamak operations
  - Path to utilize terascale computing to support experimental operations
- **Clearly demonstrate partnerships with OASCR to deliver new capabilities**
  - Strong OASCR/OFES-funded working relationship established
  - Middleware, Network QoS, Algorithms, Visualization, Remote sharing
- **How it can enable the U.S. a meaningful scientific leadership role and cost effective participation on expensive non-U.S. facilities**
  - Experimental: Be effective in day-to-day remote machine operation
  - Computation: Offer U.S. codes/resources as services

Concluding Comments

- **The NFC Project is implementing & testing new collaborative technology**
  - Accomplishing SciDAC's goal: Lead with the science
  - FusionGrid services being used to benefit daily FES research
  - Good leveraging of resources between OASCR and OFES
- **Clear vision & work scope forward to the Collaborative Control Room**
  - Real-time support for experiments is critical
  - Concept encompasses most if not all FES collaborative needs
  - Clear software enhancements required for success
- **Collaborative technology critical to the success of the FES Program**
  - Experimental: Fewer, larger future machines (EAST, ITER, KSTAR)
  - Computation: Moving towards integrated simulation (FSP)
- **Such technology can be potentially applied to new sciences leading to new collaborations, particularly with China and South Korea**