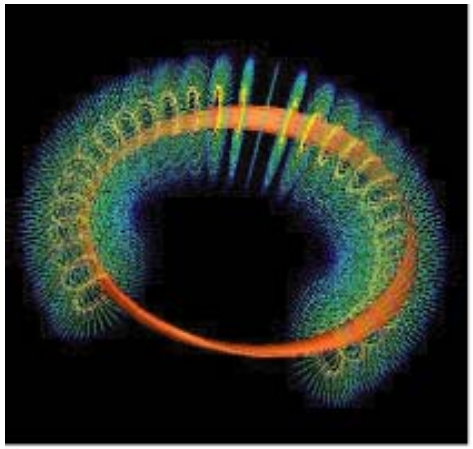

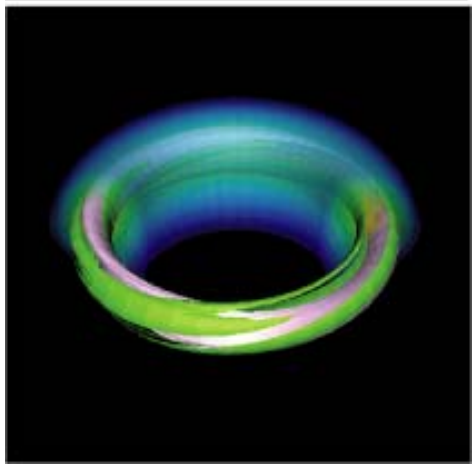

THE NATIONAL FUSION COLLABORATORY

Presented by

Martin Greenwald

ESSC – March 19, 2003

http://www.fusiongrid.org

Nature of Fusion Research Drives Requirements for Computing and Networking

- Experiments
  - Characterized by near real-time interactions of large, extended teams
  - Faster between-pulse analysis translates directly to productivity
  - Barriers to use of powerful analysis tools can be significant
- Theory and Computation
  - Simulations producing very large data sets (GB $\Rightarrow$ TB $\Rightarrow$ PB)
  - Interactive visualization and analysis present a severe challenge for computing and networking
  - Increased code sharing and collaborative development

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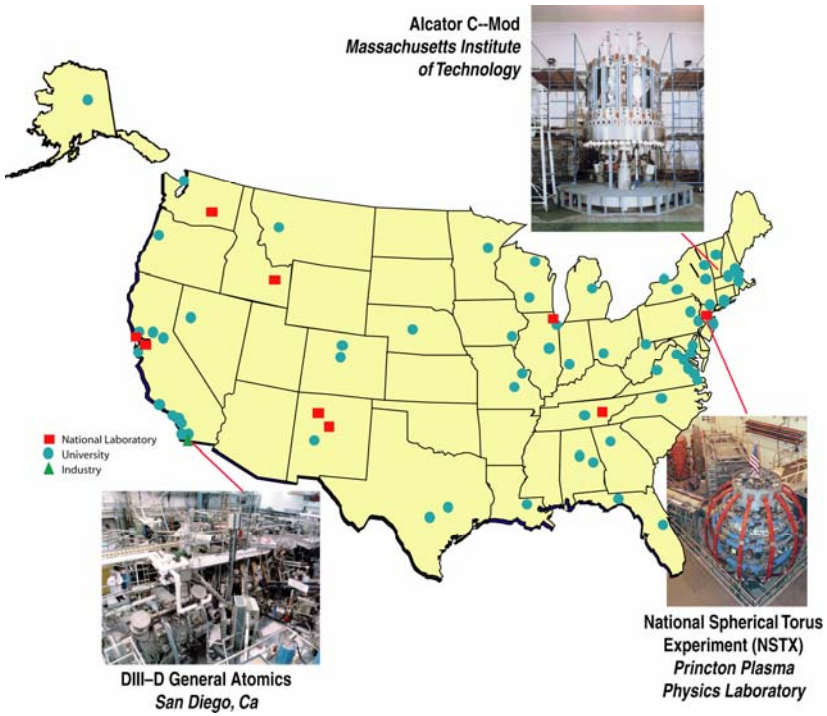
Collaborations in the Fusion Program

Collaboratory is required to advance fusion science: geographically diverse community



- 3 Large experimental facilities (4th under construction)
- > 40 U.S. fusion research sites in 37 states - Over 1500 scientists
- Significant International collaborations

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Collaboratory's Goal is to Advance Scientific Understanding & Innovation in Fusion Research

- Enable more efficient use of experimental facilities through more powerful between pulse data analysis
- Allowing transparent access to analysis and simulation codes, data, and visualization tools, resulting in more researchers having having access to more resources
- Enable more effective integration of experiment, theory, & modeling
- Facilitate multi–institution collaborations
- Create a standard tool set for data access, security, and vis allowing researchers to build these into their own applications

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Vision for the Fusion Collaboratory

- Data, Codes, Analysis Routines, Visualization Tools should be thought of as network accessible services.
- Shared security infrastructure.
- Collaborative nature of research requires shared visualization applications and widely deployed A/V technologies

- We are not focused on CPU cycle scavenging or “distributed” supercomputing (typical GRID justifications)
  - **Optimize the most expensive resource - people’s time**

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Vision – Resources as Services

- Access is stressed rather than portability
- Users are shielded from implementation details.
- Transparency and ease-of-use are crucial elements
- Shared toolset enables collaboration between sites and across sub-disciplines.
- Knowledge of relevant physics is still required of course.

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Vision – Security Infrastructure

- Strong authentication identifies users (currently based on x.509 certificates from DOE Science Grid).

- Distributed authorization allows stakeholders to control their own resources.
  - Facility owners can protect computers, data and experiments
  - Code developers can control intellectual property
  - Fair use of shared resources can be demonstrated and controlled.

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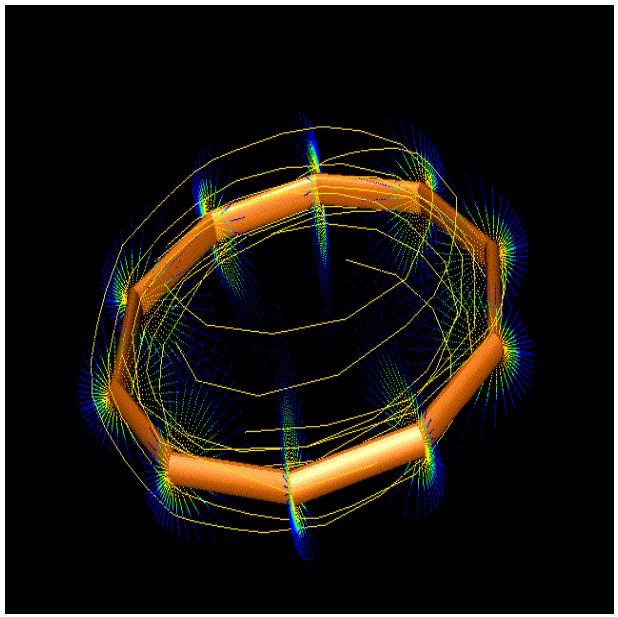
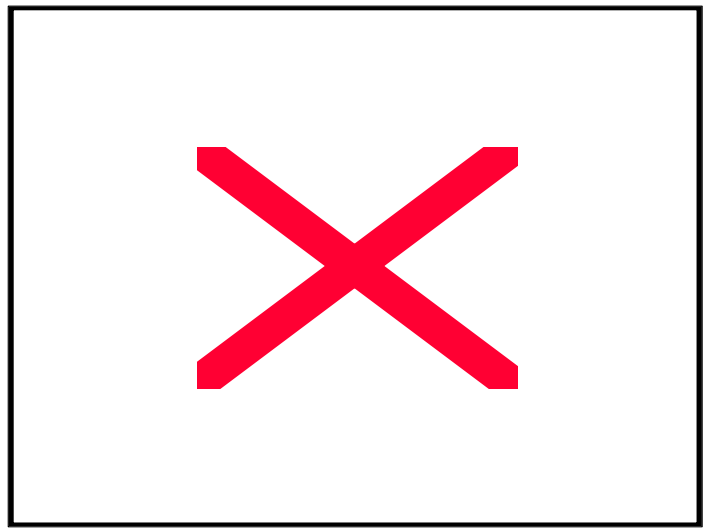
Vision – Visualization and A/V Tools

- Maximum interactivity for visualization of very large data sets





- Use of extended tool sets for remote participation
  - Flexible audio and video links
  - Shared applications

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Who is Working on the Collaboratory?

- **Fusion Labs**
  - General Atomics
  - MIT – Plasma Science & Fusion Center
  - Princeton Plasma Physics Laboratory

- **Computer Science Labs**
  - Argonne National Laboratory
  - Lawrence Berkeley National Laboratory
  - Princeton University
  - University of Utah

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Input from Fusion Science Programs is Actively Sought

- Presence at scientific meetings in Apr. 02 and APS-DPP in Nov. 03
  - Both the experimental and theoretical user community
  - First of their kind demonstrations at these meetings
- Demonstrations to the large experimental teams
  - Shared visualization ANL to San Diego and PCS to PPPL
- Comments and discussions with Oversight Committee
  - Represents broad cross–section of fusion community

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NFC Tools and Technologies

- Secure MDSplus using Globus GSI available
  - Authentication and Authorization using DOE CA/ AKENTI
- TRANSP code - worldwide production usage on FusionGrid
  - GRAM, Beowulf cluster, client applications, complete job monitoring
- Personal Access Grid (PIG) software and specifications available - Installed at MIT and GA; PPPL has large AG node
- SCIRun for 3D visualization including MDSplus stored data
- Toolkits for sharing visualization wall to wall and on AG
  - Tiled walls at GA and PPPL

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MDSplus – Data Standard for the Fusion Grid

- MDSplus is a set of software tools for data acquisition and storage and a methodology for management of complex scientific data. http://www.mdsplus.org
- Developed by MIT, LANL, IGI (Padua)
- **"Service"** rather than file oriented
- Hierarchical, self-descriptive, extensible, scalable, simple but powerful API
- Remote access based on client-server model - MDSIP (RPC)
- Servers at about 30 fusion sites – mostly experiments

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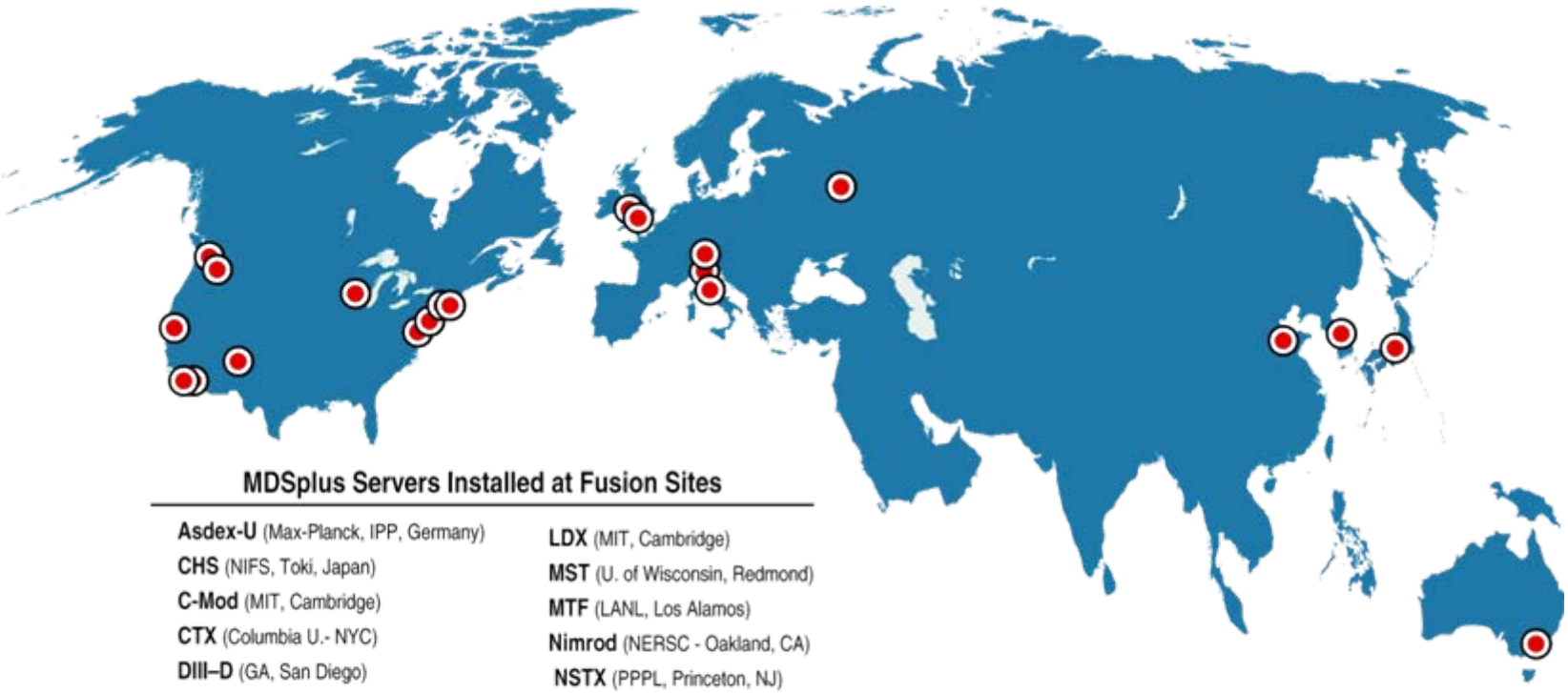
MDSplus is Widely used in the Fusion Community



MDSplus Servers Installed at Fusion Sites

Asdex-U (Max-Planck, IPP, Germany)
CHS (NIFS, Toki, Japan)
C-Mod (MIT, Cambridge)
CTX (Columbia U.- NYC)
DIII–D (GA, San Diego)
FRX-L (LANL, Los Alamos)
FTU (Frascati, Italy)
gs2 (U. Md. - College Park, Md)
H1 (ANU, Canberra, Australia)
HANBIT (Taejon, Korea)
HBT-EP (Columbia U.- NYC)
HIT (U. of Washington, Seattle)
ITPA Database Group
JET (Culham, UK - EFDA)
LDX (MIT, Cambridge)
MST (U. of Wisconsin, Redmond)
MTF (LANL, Los Alamos)
Nimrod (NERSC - Oakland, CA)
NSTX (PPPL, Princeton, NJ)
PISCES (UCSD, San Diego)
RFX (IGI, Padua, Italy)
T-10 (Kurchatov, Moscow, Russia)
TCS (U. of Washington, Seattle)
TCV (EPFL, Lausanne, Switzerland)
TH-7U (Tianjin U., China)
TIP (U. of Washington, Seattle)
ZAP (U. of Washington, Seattle)

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MDSplus Enhancements for Collaboratory

- MDSplus data system secured with Globus GSI
  - Underlying technologies are X.509 certificates/SSL
- Will use MDSplus layer to secure PC based relational database (SQL Server)
- Parallel MDSplus I/O - gridpst (grid parallel socket tunnel) ⇒ **cross country data transfer at wire speeds**
- Important shared fusion codes modified to use MDSplus for I/O (EFIT, TRANSP, gs2, NIMROD)
- Looking at remote job submission through MDSIP

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TRANSP – A Set of Tools for Time Dependent Analysis and Simulation of Tokamak Plasmas

- Over 20 years of development by PPPL (+ others)
  - >1,000,000 lines of Fortran, C, C++
  - >3,000 program modules
  - 10,000s lines of supporting script code: perl, python, shell-script
  - Used internationally for most tokamak experiments
  - Local maintenance has been **very** manpower intensive

- Now fully integrated with MDSplus data system
  - Standard data “trees” developed for MIT, GA, PPPL, JET
  - Standard toolset for run preparation, visualization

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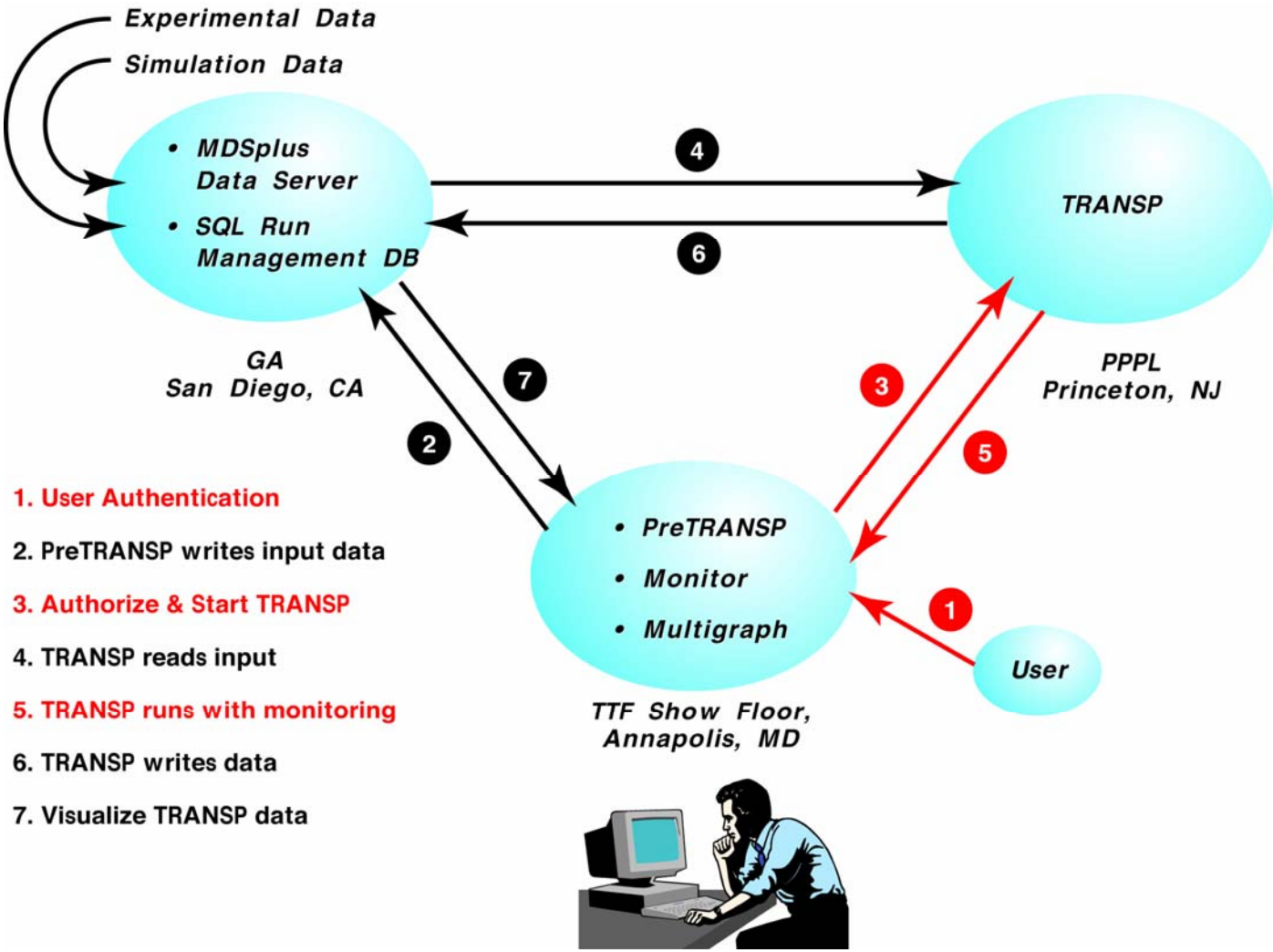
TRANSP Implemented as FusionGrid Service



1. User Authentication
2. PreTRANSP writes input data
3. Authorize & Start TRANSP
4. TRANSP reads input
5. TRANSP runs with monitoring
6. TRANSP writes data
7. Visualize TRANSP data

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TRANSP Service

- Advantages of grid implementation
  - Remote sites avoid costly installation and code maintenance
  - PPPL maintains and supports a **single** production version of code on well characterized platform

- Production system
  - 16 processor linux cluster
  - Dedicated PBS queue
  - Tools for job submission, cancellation, monitoring

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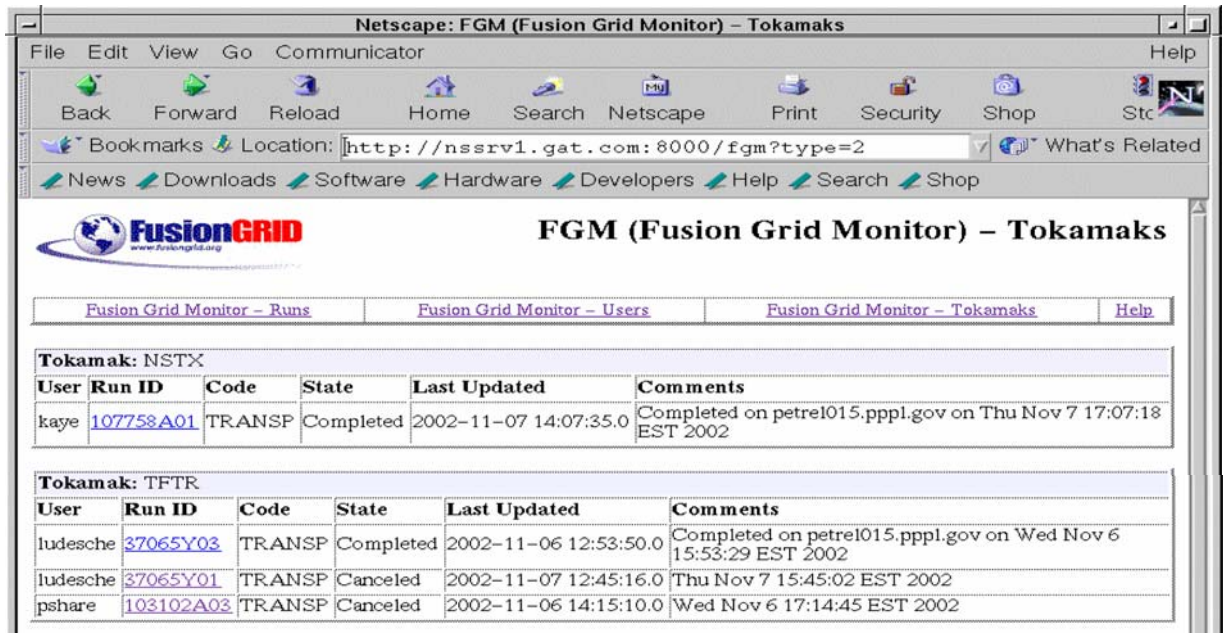
TRANSP Jobs Tracked by Fusion Grid Monitor



Tokamak: NSTX

User	Run ID	Code	State	Last Updated	Comments
kaye	107758A01	TRANSP	Completed	2002-11-07 14:07:35.0	Completed on petrel015.pppl.gov on Thu Nov 7 17:07:18 EST 2002

Tokamak: TFTR

User	Run ID	Code	State	Last Updated	Comments
ludesche	37065Y03	TRANSP	Completed	2002-11-06 12:53:50.0	Completed on petrel015.pppl.gov on Wed Nov 6 15:53:29 EST 2002
ludesche	37065Y01	TRANSP	Canceled	2002-11-07 12:45:16.0	Thu Nov 7 15:45:02 EST 2002
pshare	103102A03	TRANSP	Canceled	2002-11-06 14:15:10.0	Wed Nov 6 17:14:45 EST 2002

- Java Servlet derived from GA Data Analysis Monitor
- User presented with dynamical web display
- Sits on top of relational database – can feed accounting database
- Provides information on state of jobs, servers, logs, etc.

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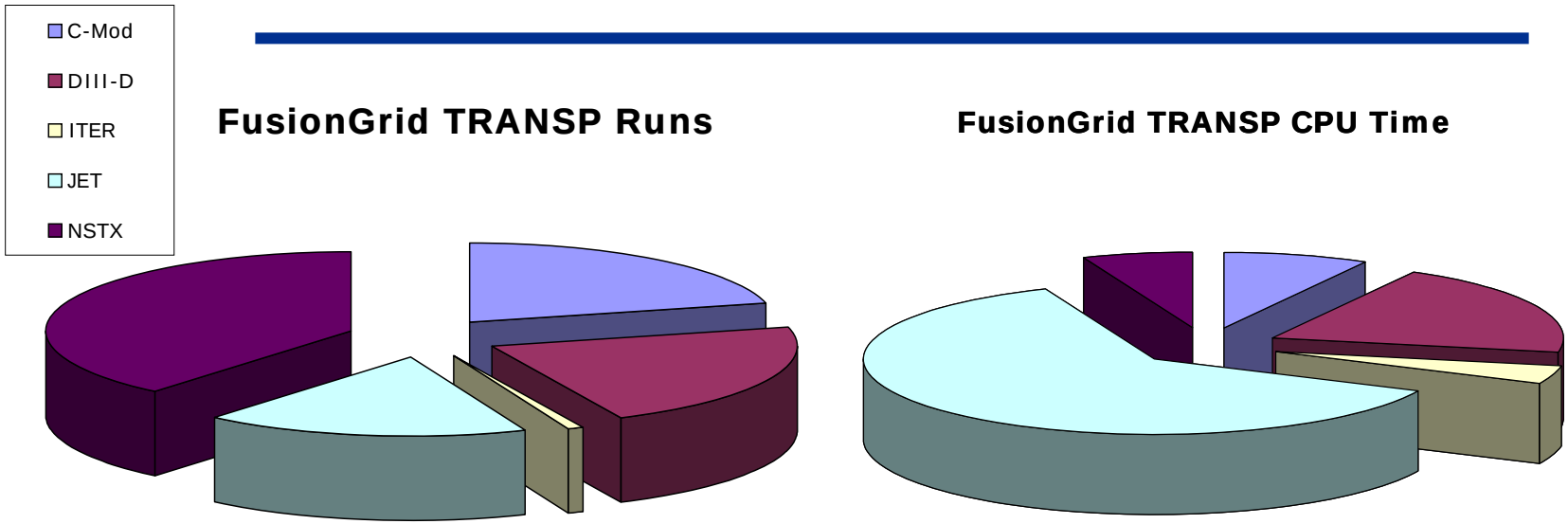
TRANSP Code - Accounting



- Statistics for October, the first full month of operation
- Note US scientists supporting JET (UK based) and ITER
- Raises interesting authorization policy issues
  - One scientist may work on several projects with different authorization

Advanced Visualization in Collaborative Environment

- Strive to dramatically reduce the hurdles that presently exist for collaborative scientific visualization
- Leverage existing technology where possible
  - SCIRun for advanced scientific visualization
  - Integrate AG collaborative tools with tiled display walls
- Collaborative Control Room
  - Large on–site group interactively work with small to large off–site group
- New visualization software
  - Simultaneous sharing of complex visualization
  - Error representation in complex experimental & simulation data

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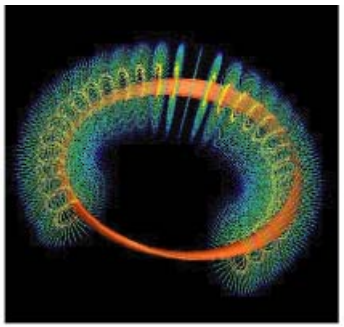
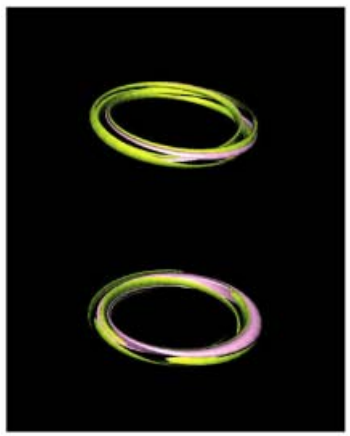
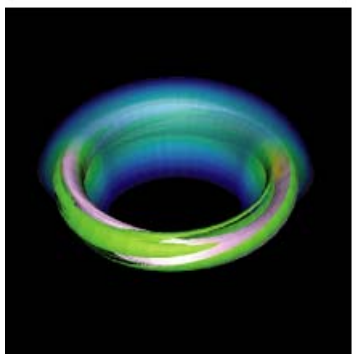
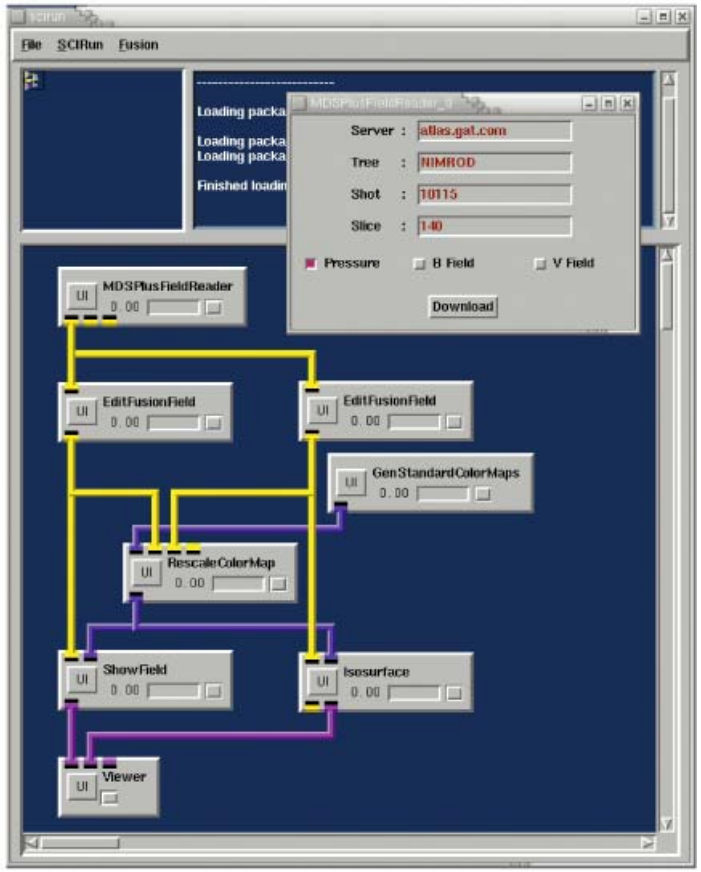
Visualization Using SCIRun









- SCIRun adapted for Fusion Simulations
  - From UII
  - Open source
  - Runs on low-cost platforms
- NIMROD data from MDSplus
- Raises challenge of very large data sets

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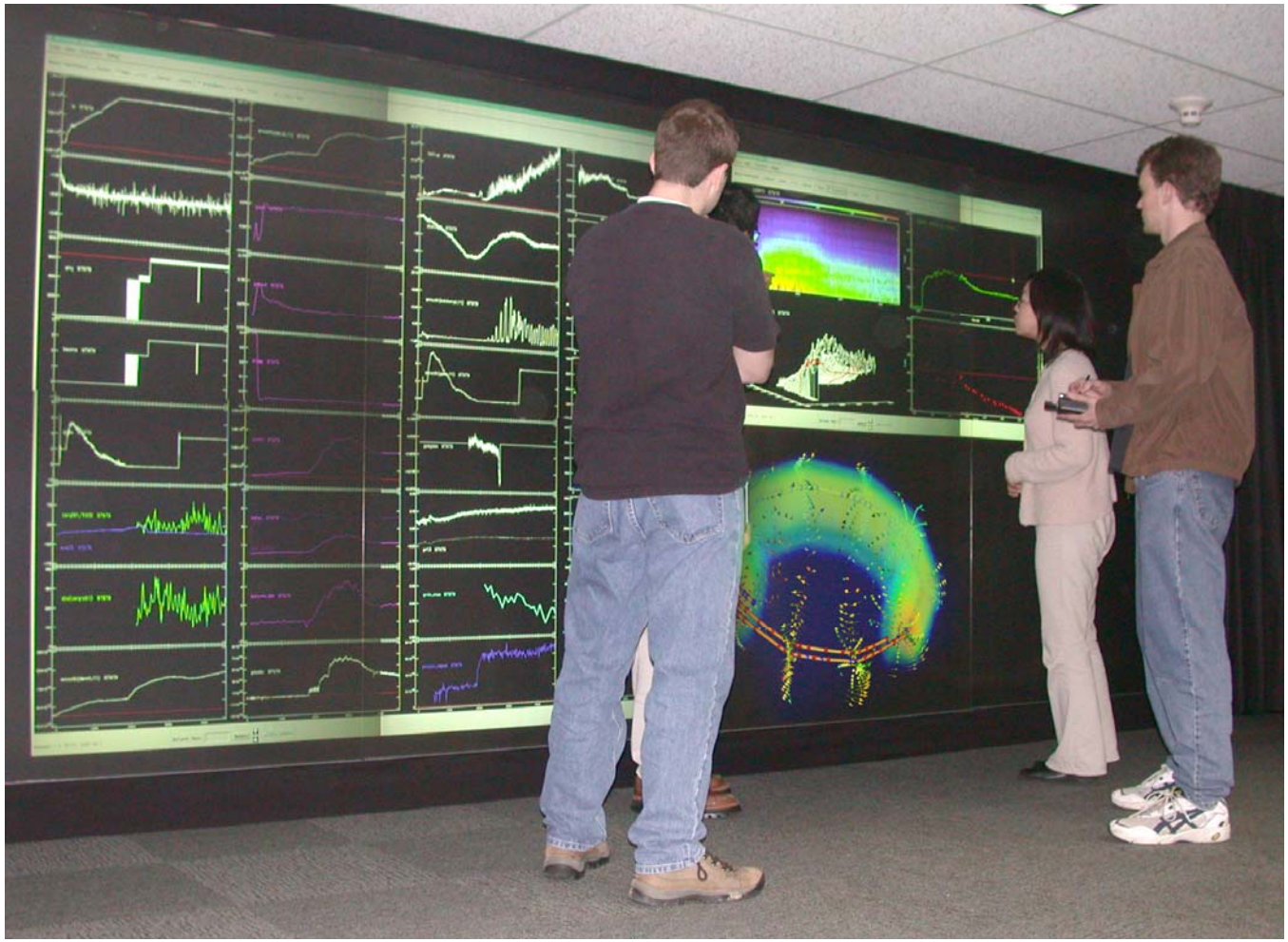
Tiled Walls Allow a Large Group to Explore Information in Collaboration More Effectively



General Atomics Advanced Imagery Laboratory

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Remote Communication with Personal AG Node

- Targeted for the small research center
  - For one to one and one to many interactions
- Usage example: communication to a tokamak control room
  - Includes sharing of complex visualization

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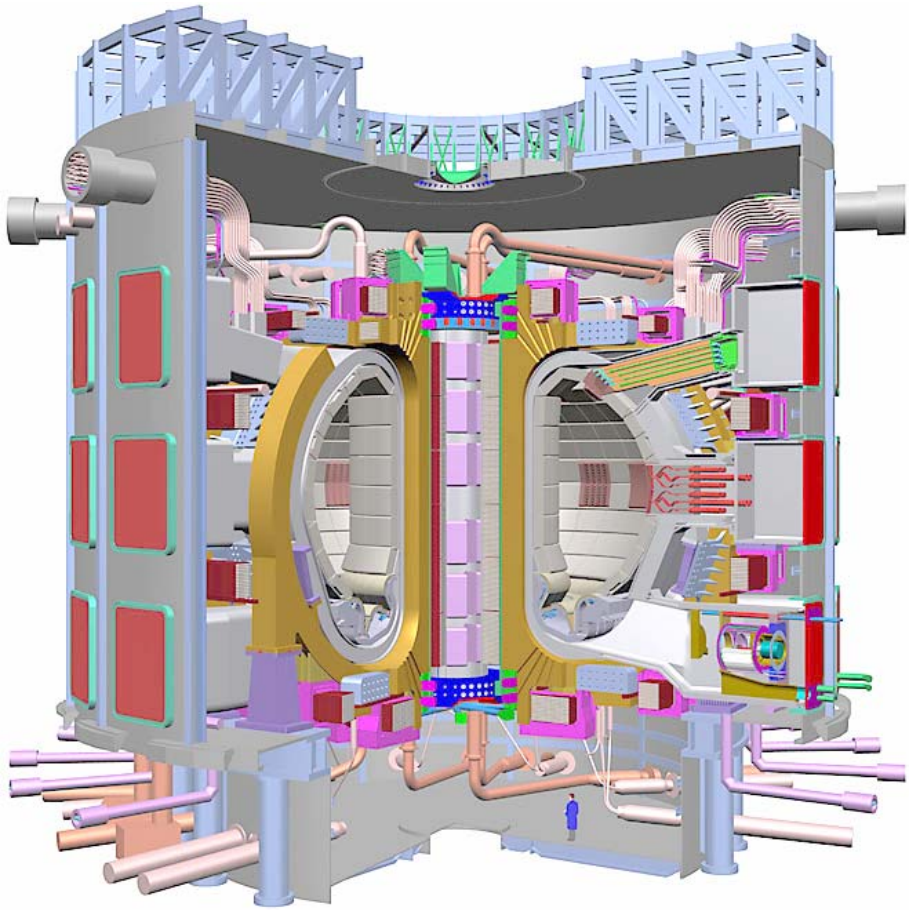
ITER – It's Back and It's Baad

- US rejoining negotiations
- $5B class experiment, over 20 countries, thousands of scientists
- Planning for data systems just beginning
- Will produce very large data sets
- Remote participation is assumed



Relation to Other SciDAC Projects

- SciDAC Center for Extended Magnetohydrodynamic Modeling
  - NIMROD data in MDSplus visualized by SCIRun presented at APS/DPP
- SciDAC Plasma Microturbulence Project
  - GS2 code being tested on FusionGrid for broader & easier usage
- Data Grid Toolkit; Security & Policy for Group Collaboration: Distributed Security Architecture
  - Secure access, authentication, authorization, Globus GSI/Akenti
- Particle Physics Data Grid;
  - Site security, Firewalls, and Grid security;
- DOE Science Grid
  - CA for FusionGrid
- Middleware to Support Group to Group Collaboration
  - AG development: user education & testing & feedback
- eServices Infrastructure for Collab Science; Portal Web Services
  - NFC & Fusion science as customer

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First Year Accomplishments (1)

- FusionGrid created: MDSplus data access secured with GSI
- First service in production mode: TRANSP code, authorization via GRAM
- Demonstrations to user community at large science meetings
- Prototyped: between pulse pre-emptive scheduling, parallel MDSplus I/O
- GS2 (3D, non-linear, gyro-kinetic simulation) in pre-production mode
  - Considerably less time to grid-enable the second code

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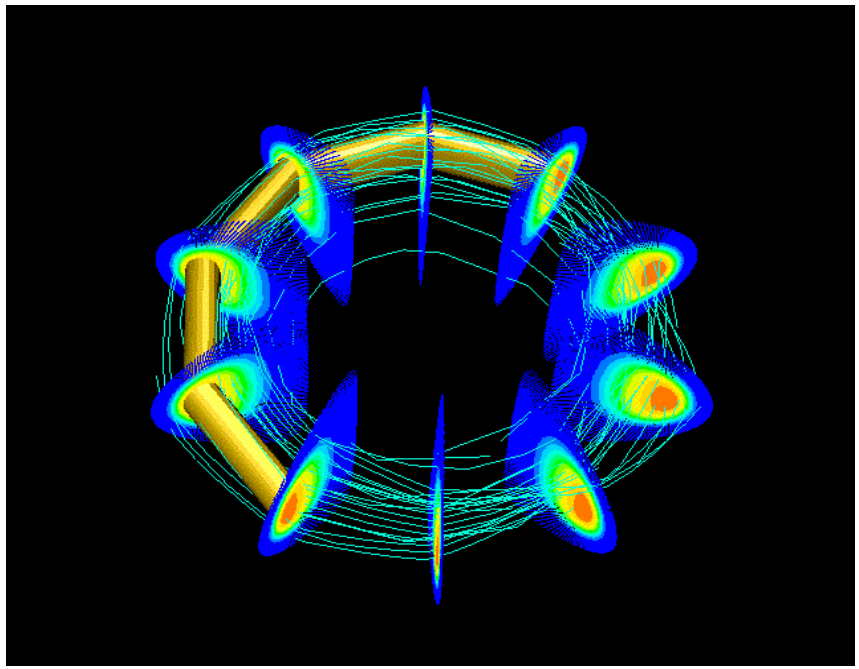
First Year Accomplishments (2)

- SCIRun visualization of NIMROD fusion data via MDSplus
  - New capability for 3D visualization & animation
  - Used for real research
- Access grid functional on tiled wall: Personal Access Grid (PIG) developed
- Collaborative visualization and shared applications tested



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Issues for Future Work

- Ease-of-use and Ease-of-installation still need a lot of work
  - Especially on security/certificate side
- Still have conflict on site security vs application security paradigm (firewalls, NAT, SecureID…)
- Globus undergoing major transformation
- Can “lighter weight”, small footprint software provide some of the needed capabilities?
- Toolset “hardening” required
- Manipulating very large multi-dimensional data sets is still a challenge
  - Need to test new approaches

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Concluding Comments

- The National Fusion Collaboratory Project is implementing and testing new collaborative technologies for fusion research
  - Grid computing
  - Shared visualization and communication
- Collaborative technology critical to the success of FE program
  - Experiments: Fewer, larger machines in future (ITER, CTF…)
  - Computation: Moving toward integrated simulation
- High-performance network is essential for all applications

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