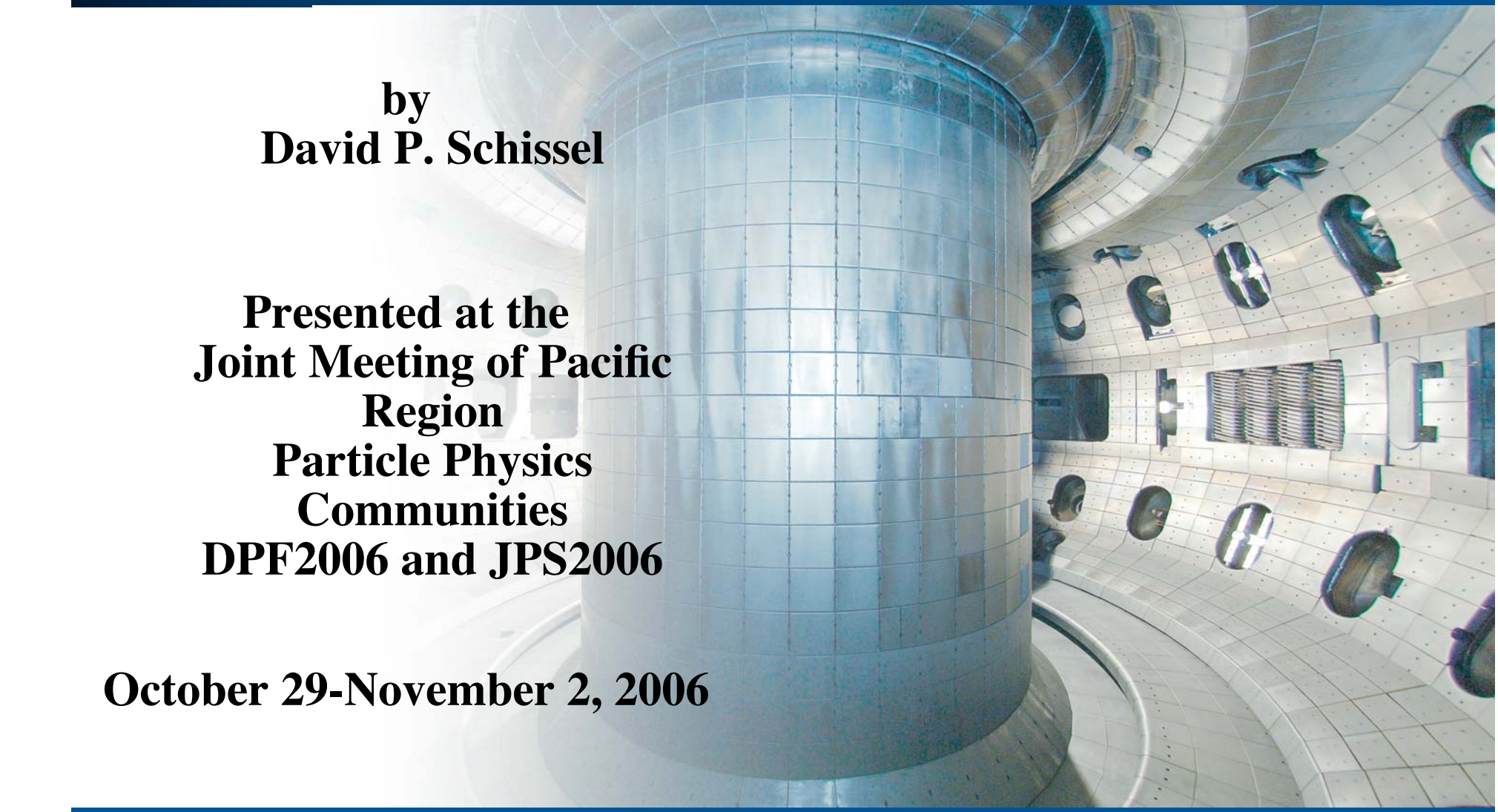
Collaborative Technologies for Distributed Science



by
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Presented at the
Joint Meeting of Pacific
Region
Particle Physics
Communities
DPF2006 and JPS2006

October 29-November 2, 2006

DIII-D NATIONAL FUSION FACILITY

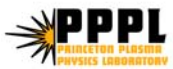
GENERAL ATOMICS

Acknowledgment

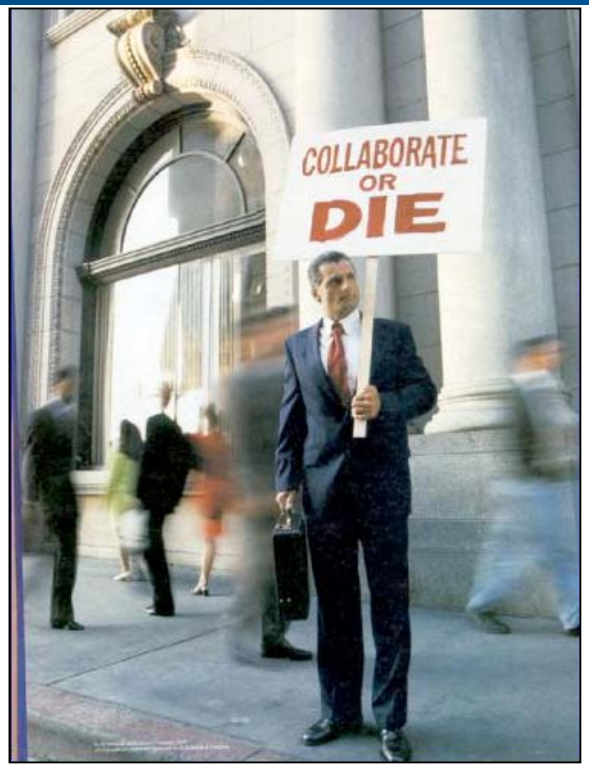
- **The National Fusion Collaboratory Project Team Members (Distributed)**
  - C-Mod (MIT), DIII-D (GA), NSTX (PPPL)
  - Argonne National Lab, Lawrence Berkley Lab, Princeton University, University of Utah

- **The Staff of the DIII-D National Fusion Facility**

- **Work is supported by the USDOE Department of Energy**
  - SciDAC: Office of Advanced Scientific Computing Research
  - Fusion Research: Office of Fusion Energy Sciences



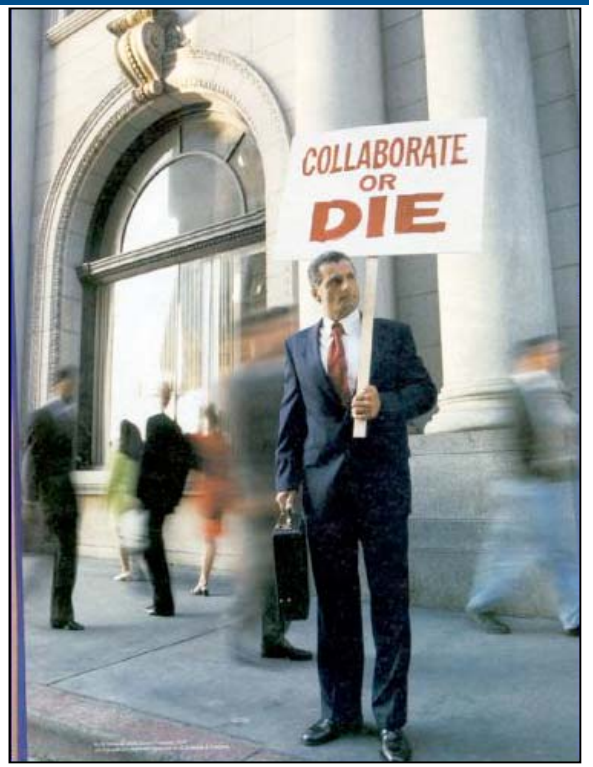
Presentation's Key Points: Fusion Energy Perspective



- **International collaboration is our future:**
  ITER will be the most important facility for 20-25 years
  - For the US to get the most from the project, we must be prepared to exploit the machine remotely
- **Remote collaborations on domestic facilities will continue to be important**
  - Preparation and support for ITER
- **National Fusion Collaboratory Project (FusionGrid)**
  - Scientists using NFC developed tools to enhance current collaborations
  - Remote collaboration: session leadership becomes routine
- **Extend our existing tools to meet future needs**
  - Functionality, international FES, other SC programs (e.g. HEP)
  - Prototype tools and methodology for ITER

Presentation's Key Points: In General

- **Collaboration needs of FES and HEP are similar**
  - ITER, LHC@FNAL, ILC
- **Collaborative Workspaces**
  - Ad-hoc and structured communication
  - Shared applications
- **Secure Computational Services**
  - Improved security
  - Continuous data sources: MDSplus
- **Requirements overlap justifies joint research**
  - Benefit DOE/SC: OFES, OHEP, and OASCR



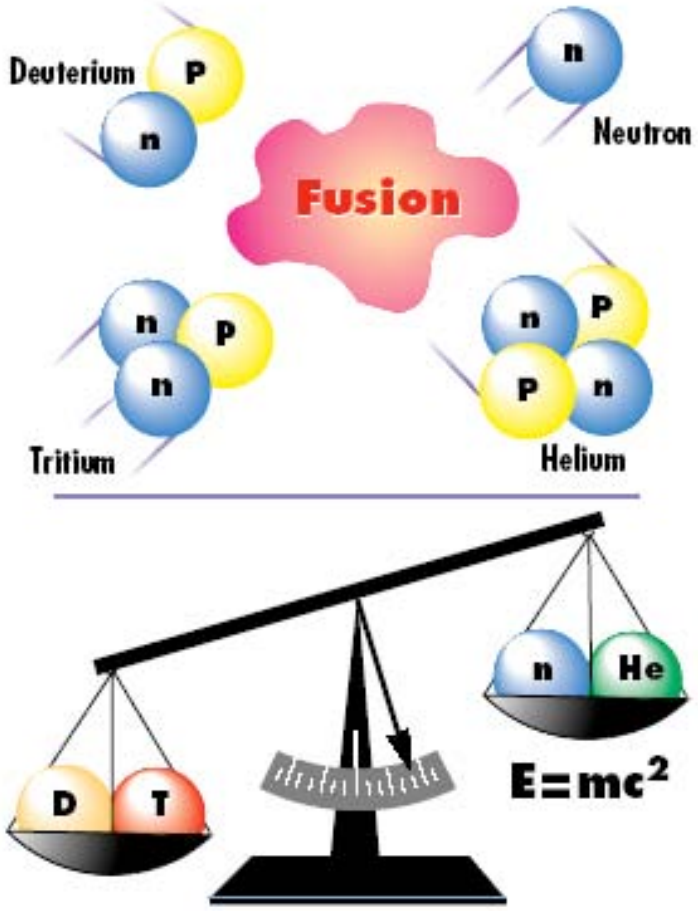
Outline of Talk

- **What is fusion?**
  - Power of the stars and with an aim to harnesses on earth
- **Where is fusion research performed?**
  - International and moving to ITER in France
- **What does fusion research involve?**
  - Demanding near-real-time experimental program
  - Theoretical program on massively parallel machines for simulations
- **What collaboration tools are assisting in the international research?**
  - SciDAC funded FusionGrid: Collaboration and Grid computing
- **How closely aligned are the needs of FES and HEP?**
  - For collaborative activities, they appear very closely aligned

1. What is Fusion?

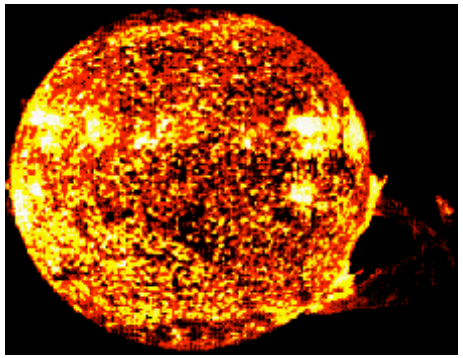
The nuclear reaction whereby the nuclei of light isotopes, like Hydrogen are joined (fused) to form heavier elements, releasing large amounts of energy.

The Fusion Reaction Powers the Stars and Produces the Elements of the Periodic Table



- For 50 years worldwide, teams have been trying to exploit the fusion reaction as a practical energy source

- The promise is for an environmentally friendly method for generating electricity with an inexhaustible fuel supply



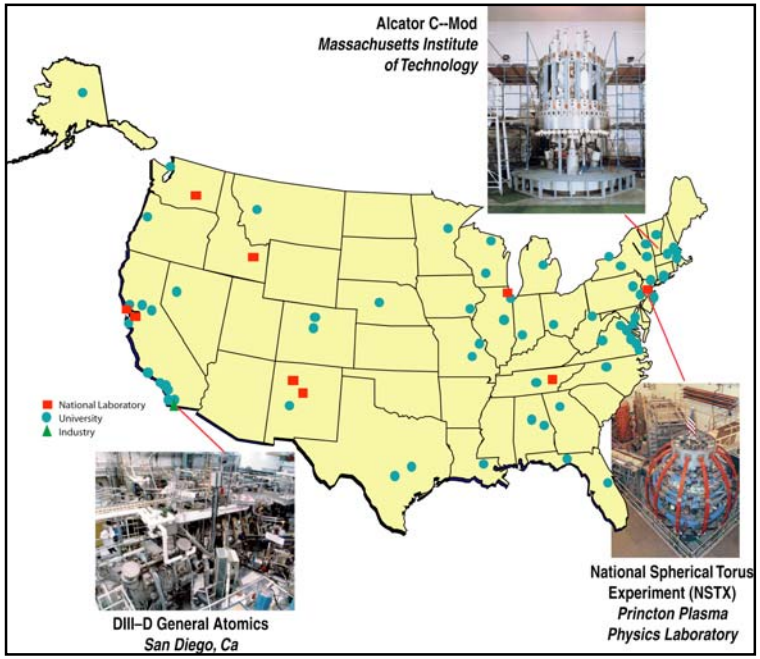
Fusion Research Presents Many Challenges

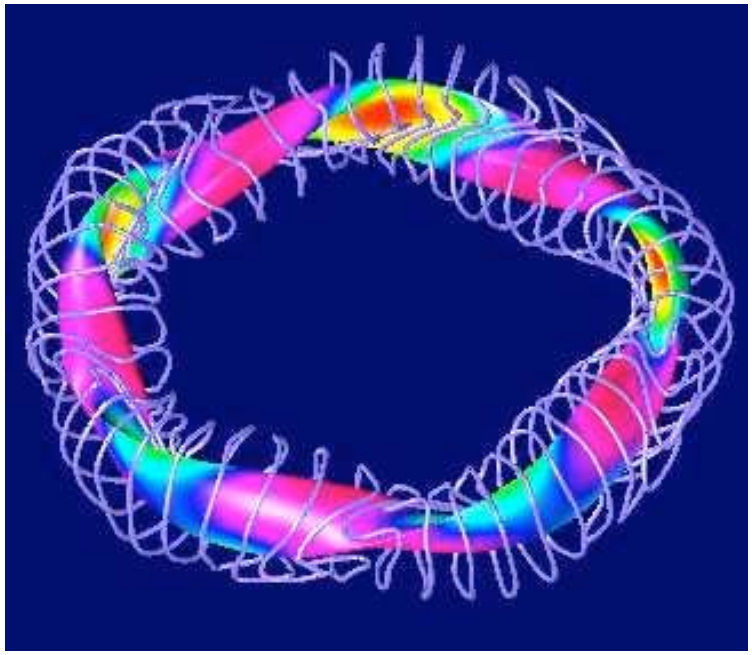
- **Development of physical models for plasma stability and transport**
  - Vast range in space and time which can span over 10 decades
  - 3D motion, extreme anisotropy, free energy driven turbulence
- **Design large experiments**
  - 3D coupling of electromagnetics, structures, heat transfer, neutronics
- **Development of complex diagnostics**
- **Development of plasma heating and fueling methods**
- **Acquisition, analysis, display and interpretation of large quantities of experimental data**
- **All of these are computationally intensive**

2. Where is Fusion Research Performed?

Truly a worldwide open scientific endeavor that is highly collaborative.

Three Large U.S. Experimental Facilities and a Vibrant Theoretical Community





- **3 Large Experimental Facilities**
  - ~$1B replacement cost
- **67 U.S. fusion research sites**
  - Over 1500 scientists
- **Numerous theoretical groups**
  - High-performance computing
- **Efficient collaboration is required**
  - Geographically diverse teams

Fusion Science Today is Worldwide Team Sport

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

Active Collaborations 2004

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

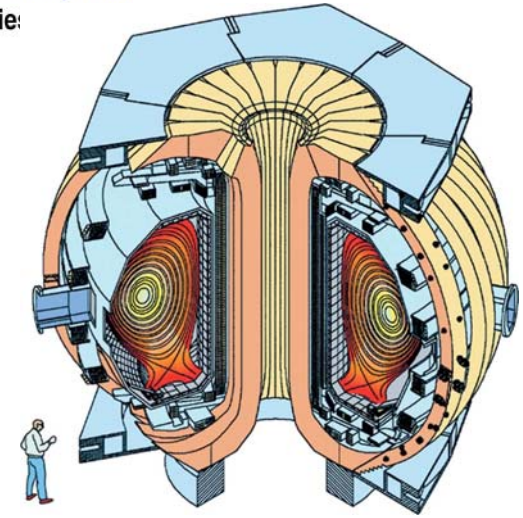
Cadarache (St. Paul-lez, Durance, France)
Chalmers U. (Goteberg, Sweden)
CFN-IST (Lisbon, Portugal)
CIEMAT (Madrid, Spain)
Consorzia RFX (Padua, Italy)
Culham (Culham, Oxfordshire, England)
EFDA-NET (Garching, Germany)
Frascati (Frascati, Lazio, Italy)
FOM (Utrecht, The Netherlands)
Helsinki U. (Helsinki, 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)



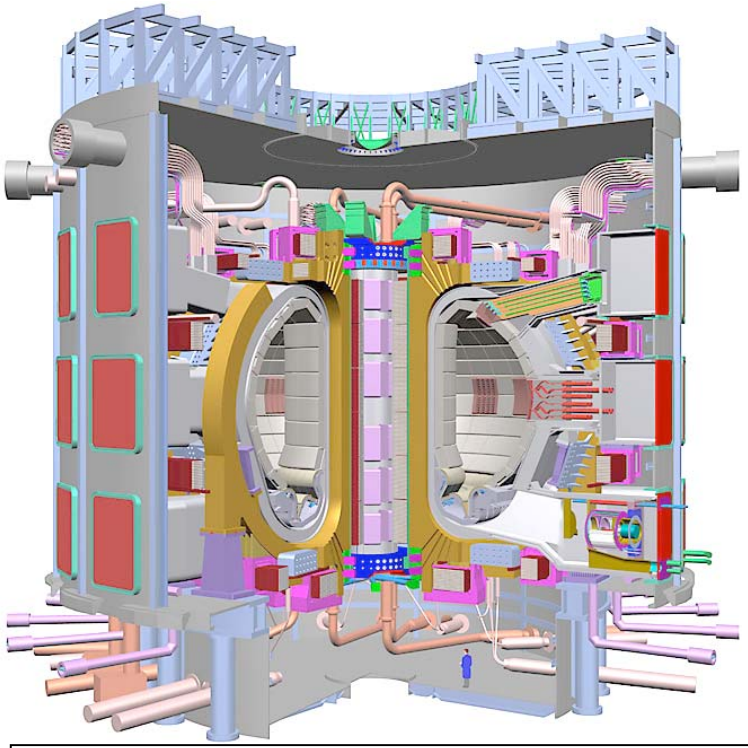
An Example From The DIII-D National Fusion Facility in San Diego

DIII-D NATIONAL FUSION FACILITY

GENERAL ATOMICS

Fusion Science Today is Worldwide Team Sport

Next Fusion Device is ITER to be Built in France



- **China, Europe, India, Japan, South Korea, Russia, United States**
- **~5B total construction cost**
  - First plasma ~10 years
- **Burning plasma experiment**
  - Demonstrate physics viability

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.

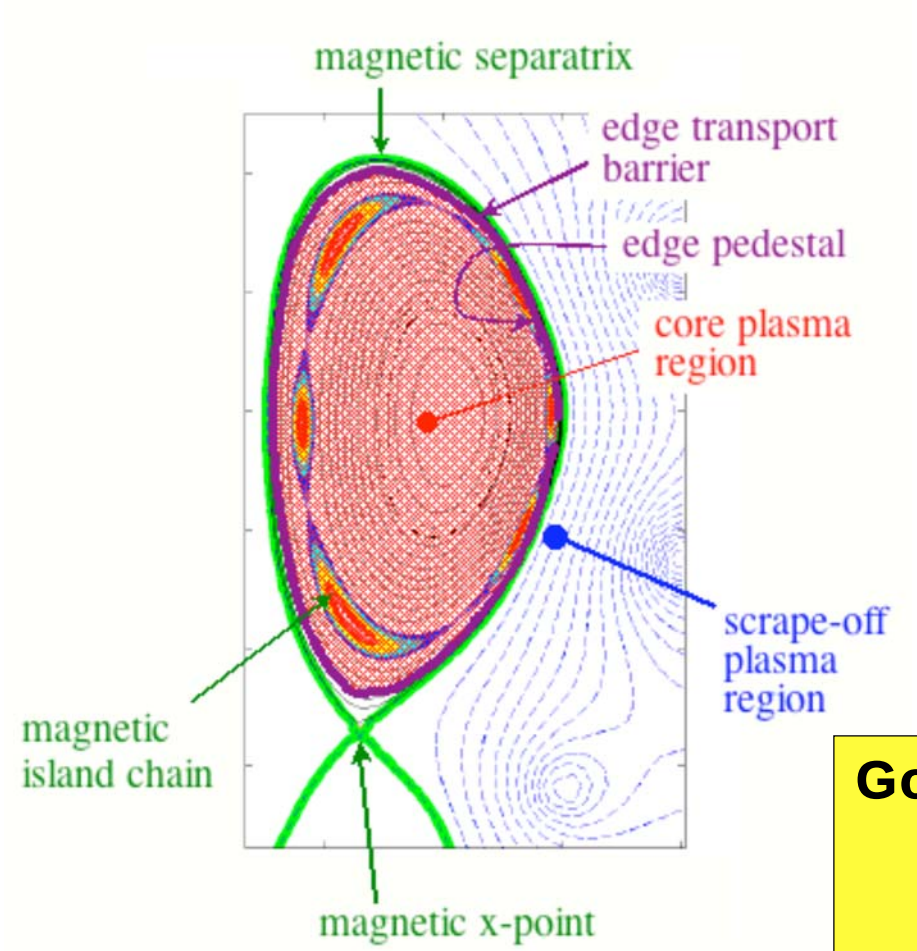
– Secretary of Energy Spencer Abraham, November 10, 2003

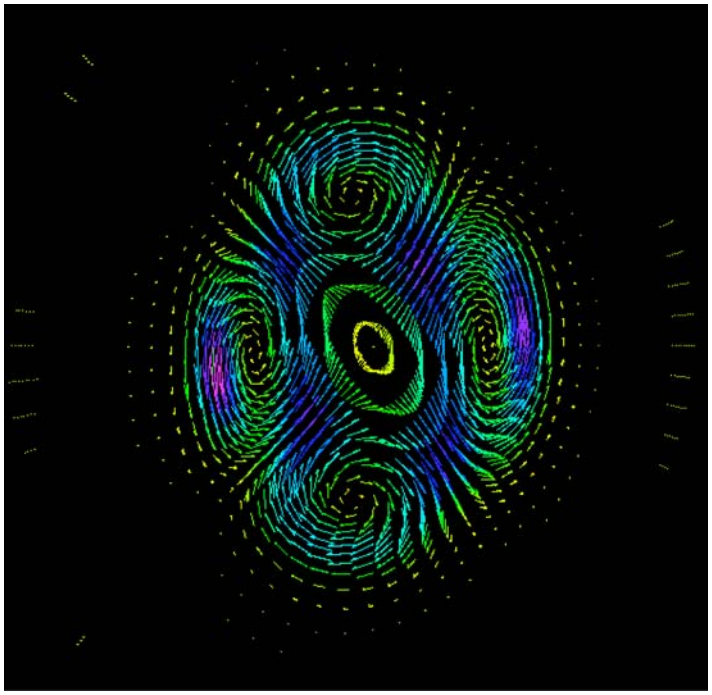
Introducing the Department's 20-year plan for building the scientific facilities of the future.

3. What does Fusion Research Involve?

The combination of complex simulation codes running on massively parallel computers and very large scale experimental facilities.

Fusion Simulation Project (FSP): Integrated Simulation and Optimization of Fusion Systems





Goals of joint OFES & OASCR Program:

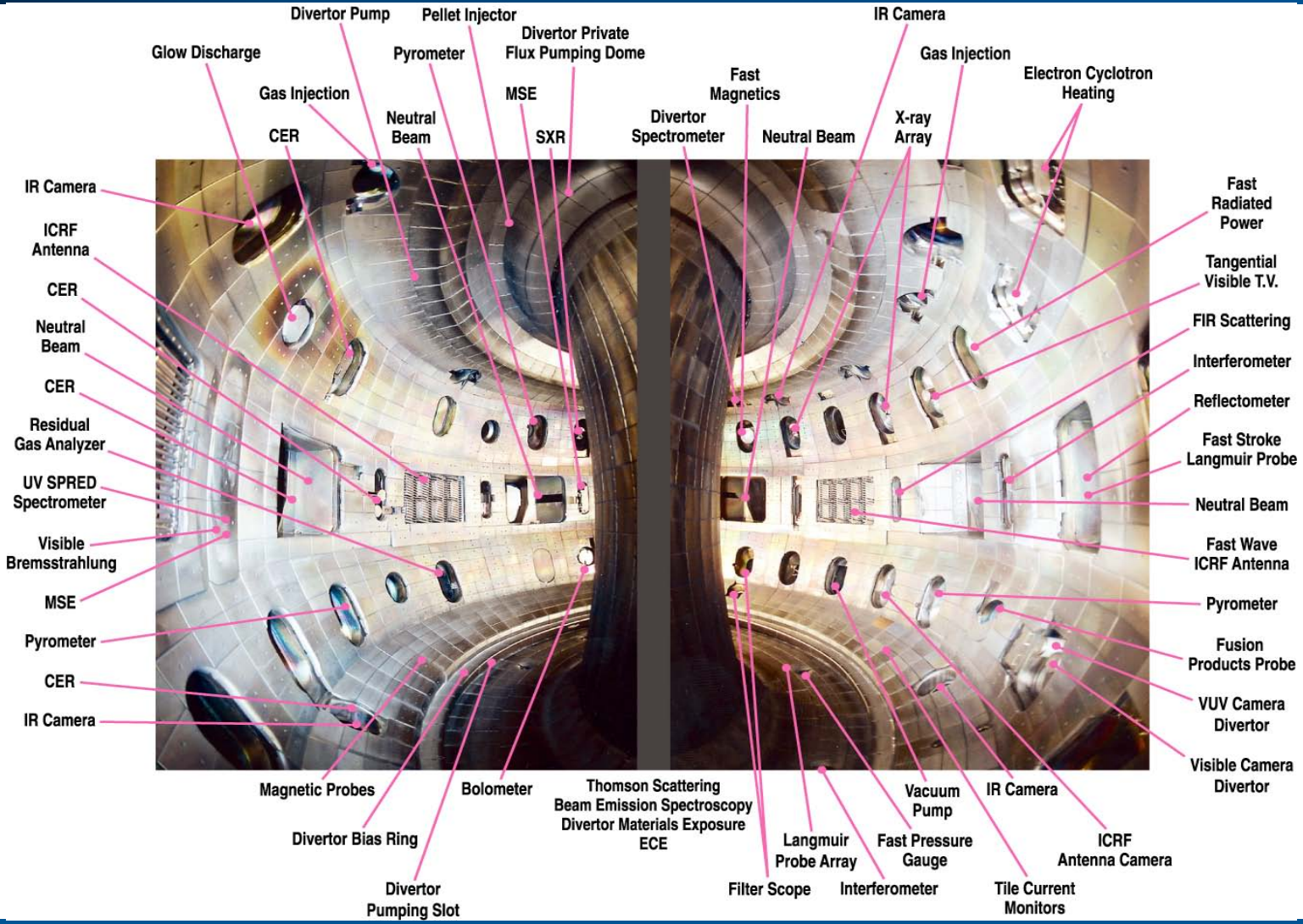
- Comprehensive models
- Architecture for integration
- Computational infrastructure

Experimental Fusion Sciences Places a Large Premium on Rapid Data Analysis in Near-Real-Time

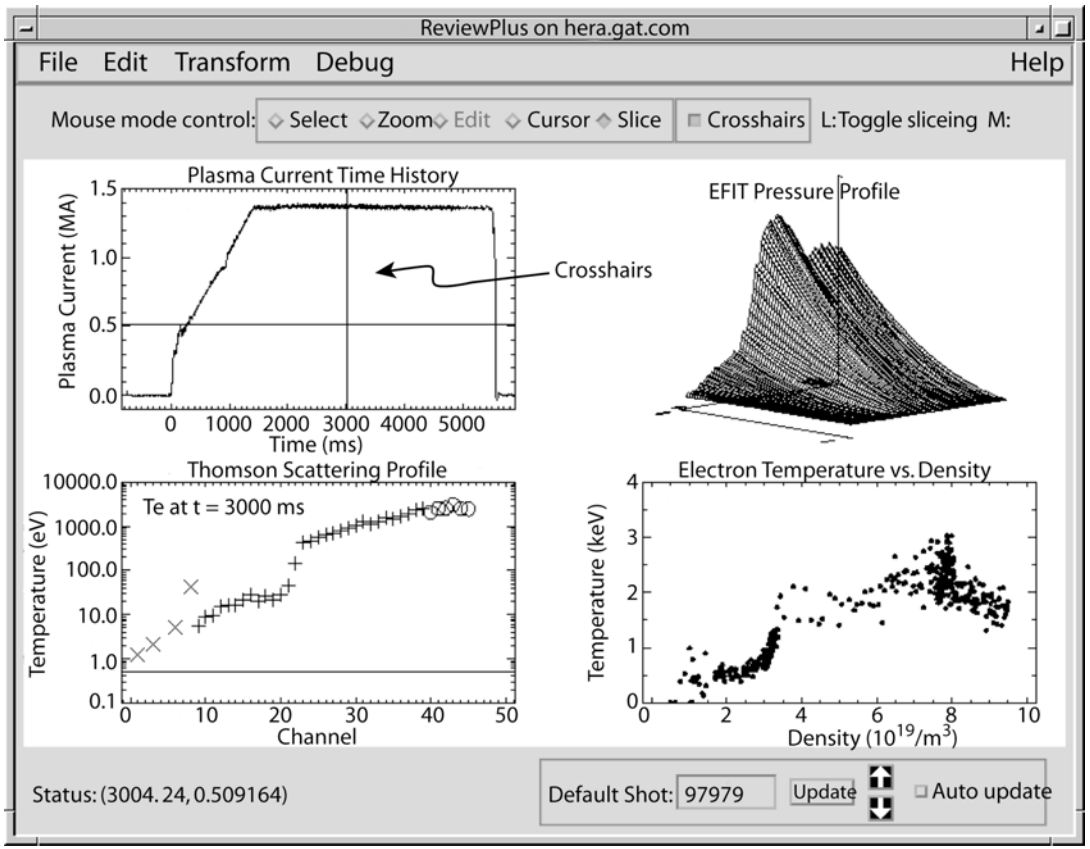
- **Pulsed Experiments**
  - 10s duration plasma every 20 minutes
- **20-40 people in control room**
  - More from remote locations
- **10,000 separate measurements/plasma**
  - kHz to MHz sample rates
  - Between pulse analysis

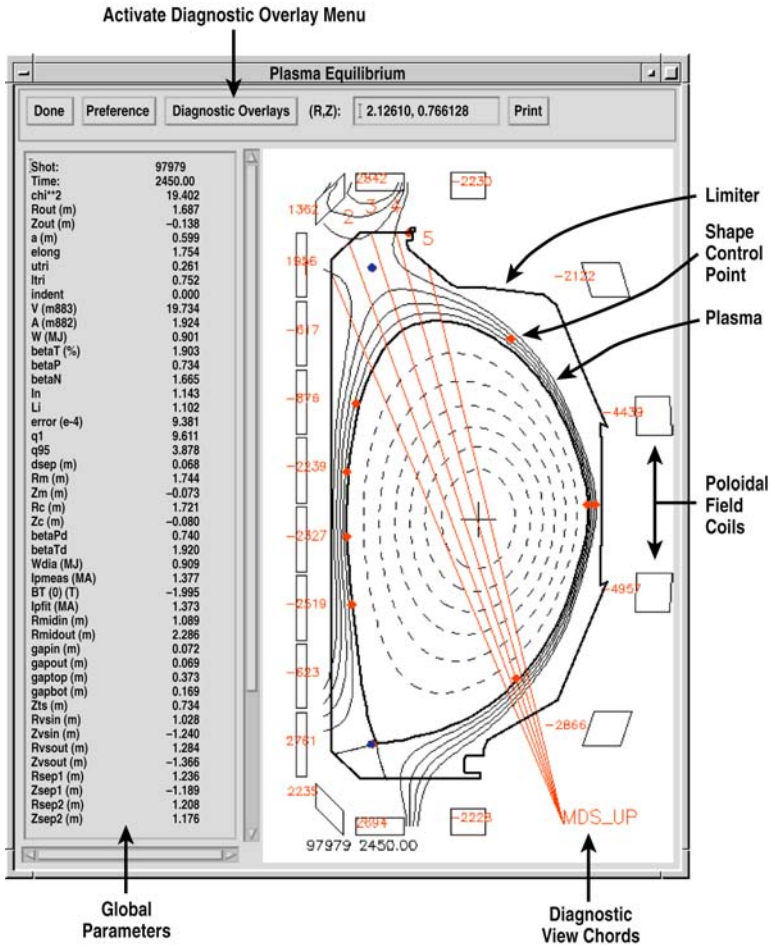
- **Not batch analysis and not a needle in a haystack problem**
  - Rapid near-real-time analysis of many measurments
- **More informed decisions result in better experiments**
  - The collaborative control room

Fusion Tokamaks have Extensive Diagnostics

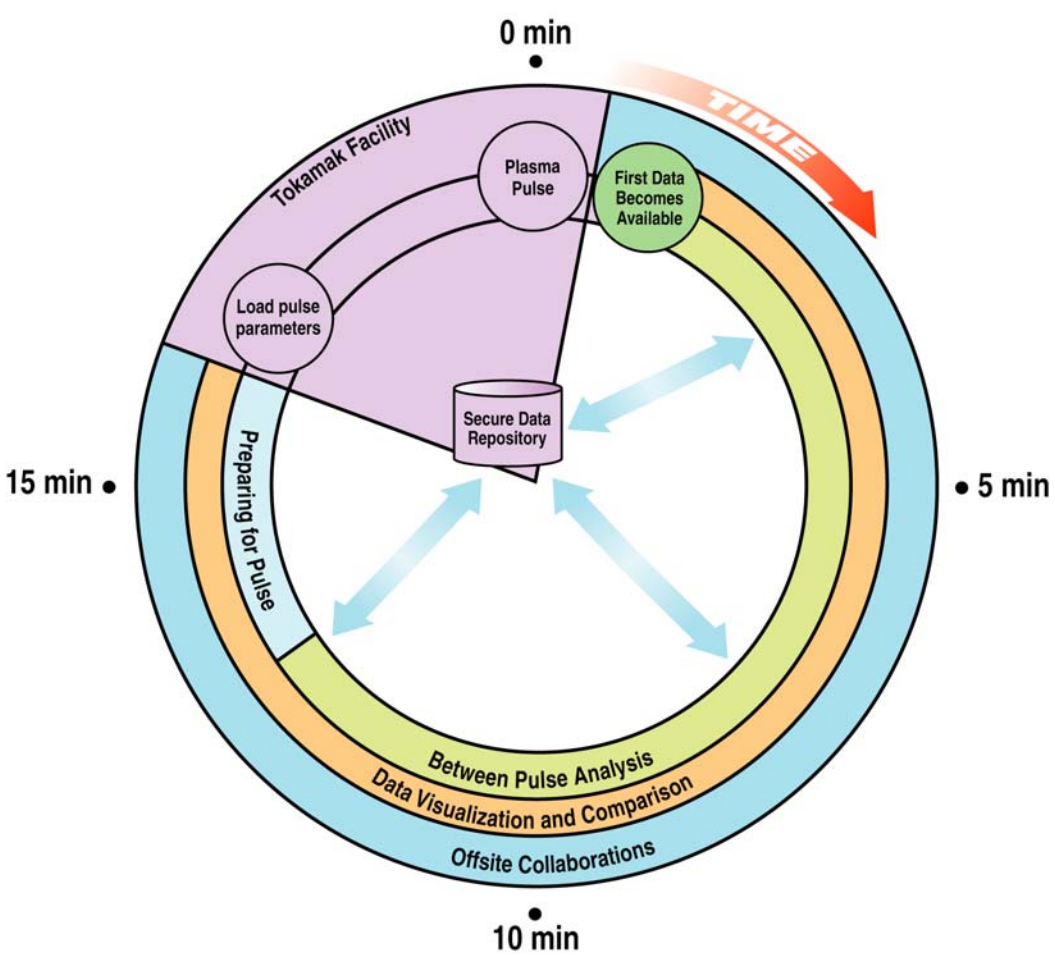


Custom Applications Allow Detailed Scientific Analysis Between Pulses





Experimental Fusion Science is an Endless Cycle of Analysis and Decision Making



4. What Tools are being Used to Assist the International Collaborative Nature of Fusion Research?

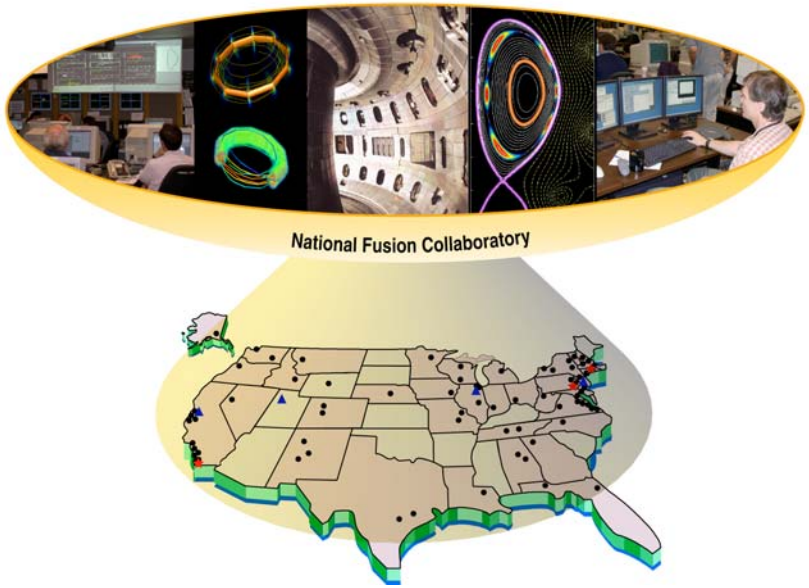
A wide variety of techniques are being investigated and used but in the United States the SciDAC Program funded FusionGrid: A collaboratory pilot program for fusion energy research.

The National Fusion Collaboratory Project (FusionGrid)

- **Funded by the US DOE under the SciDAC Program (2001-2006)**
  - A distributed team: C-Mod, DIII-D, NSTX; ANL, LBL, PCS, Utah
  - Started as a pilot project but has transitioned to production usage
- **Unify distributed MFE research into a U.S. Virtual Organization**

Vision: Optimize the People's Time

- Remote Experimental Operation
- Network Accessible Services (SOA):
  Data, Codes, & Visualization
  Not CPU cycle scavenging
- Shared Security Infrastructure:
  Security with Transparency
  Distributed Authorization



ASCR

SciDAC
Scientific Discovery through Advanced Computing

FusionGRID
www.fusiongrid.org

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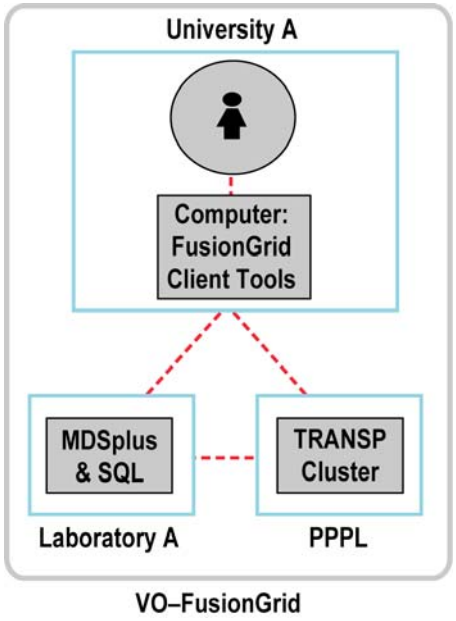
GENERAL ATOMICS

FusionGrid: Unified Security Model with Data Access And Successful Grid Computing for Fusion Science

- **Authentication: PKI via X.509 certificates**
  - FusionGrid CA & RAs
  - Centralized certificate management
  - Onetime login
- **Authorization: Centralized ROAM**
  - Controlled by resource providers
  - More secure & easier to use
- **Data: Secure via MDSplus**
  - Client-server model
  - Not file transfer
- **Computational Grid**
  - Better support
  - Reduced Admin load



MDSplus data system used worldwide

Access Grid and VRVS Being Used For Communication

Access Grid

- **Seminars, working meetings, operations**
  - Linux, Windows, & Macintosh OS X
- **Operations: collaborative control room**
  - Software framework:
    sharing humans, data, applications, info

May 2004, DIII–D Tokamak Control Room

January 2005, DIII–D Tokamak Control Room

VRVS

- **Web client**
  - Small footprint
- **Closed source**
  - Limits expansion

Shared Display Walls Installed in Fusion Control Rooms

- **Customized Apps**
  - Display Walls
- **Sharing to the group**
  - Collocated
- **Sharing from off-site**
  - "See my graph"

5. How Closely Aligned are the Needs of FES and HEP?

The requirements appear to be very similar to the needs of running ITER in France from the United States.

Challenges: International, Remote Participation

- **Scientists will want to participate in "live" experiments from their home institutions dispersed around the world**
  - View and analysis data
  - Manage ITER diagnostics
  - Lead experimental sessions (we are already breaking new ground here)

- **Requirements are full-time: before, after, and during an experiment**

- **Collaborations span many administrative domains**
  - Resource management - local control is essential
  - Trouble shooting/end-to-end problem resolution

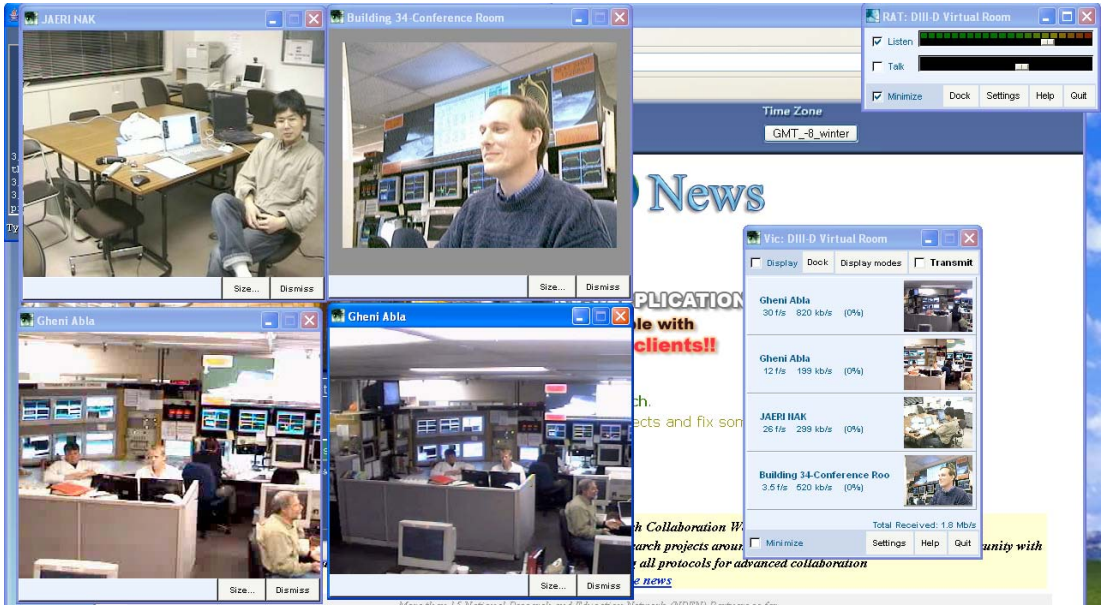
- **Cyber security must be maintained, plant security must be inviolable**

Both Remote and Distributed have Challenges

- Informal interactions in the control room are crucial part of the research
- We must extend this into remote and distributed operations - lower barriers and friction
- Fully engaging remote participants is challenging
- Working as distributed team beyond just the experimental day
- The NFC Project has given the U.S. fusion program a good start

Components for Successful Remote Participation

- **Transparent remote access to data**
  - Secure and timely
- **Real-time information**
  - Machine status
  - Shot cycle
  - Data acquisition and analysis monitoring
- **Shared applications**



- **Provision for robust ad hoc interpersonal communications**
  - e.g. Informal discussion, time-critical contact
- **Provisions for robust structured communications**
  - e.g. Planning and review

Concluding Comments

- **The NFC Project has implemented new collaborative technology**
  - Attacking problems defined by fusion scientists
  - FusionGrid services being used to benefit daily FES research
- **Service oriented computation on FusionGrid has proved successful**
  - Optimize the most expensive resource - people's time
- **Clear vision & work scope forward to the Collaborative Control Room**
  - Real-time support for experiments is critical
  - Clear software enhancements required for success
- **Helps to position US to exploit ITER**
- **Requirements of HEP appear similar and justify joint research**
- **Path to success that benefits FES and HEP and leverages OASCR work**