The National Fusion Collaboration
A MICS/SciDAC National Collaboration Pilot Project

Presented by
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at
The SciDAC PI Meeting
March 22-24, 2004
Charleston, SC
PRESENTATION’S KEY POINTS

- SciDAC has changed the culture of collaborative FES research
  - FusionGrid services being used to benefit daily FES research

- The collaborative 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 (ITER)
  - Computation: Moving toward integrated simulation (FSP)
THE NFC IS HELPING TO ACHIEVE SCIDAC GOALS

- Create a collaboratory software environment to enable geographically distributed scientists to work effectively together as a TEAM and to facilitate remote access, through appropriate hardware and middleware infrastructure, to both facilities and data.

Lead with the science:
Ultimate goal of advancing research in science central to the DOE mission.
THE GOAL OF THE NFC IS TO ADVANCE SCIENTIFIC UNDERSTANDING & INNOVATION IN FUSION RESEARCH

More efficient use of experimental facilities
Integrate theory & experiment
Create standard tool set
Facilitate multi-institution collaboration
THE NFC IS BEING SUCCESSFUL FOR FUSION SCIENCE

- Success is not defined by demos or papers published
  — Although these are important aspects of the project

- Success is defined by positive impact on the science
  — True metric is the actions of the fusion scientists

- A main fusion code is *only* available via NFC Grid computing

- The fusion program is spending its *own* money to purchase equipment and to support the usage of new NFC functionality

- A fusion scientist decided to *remain in San Diego* and use NFC technology to lead the fusion experiment in England

There is no going back:
SciDAC has changed FES collaborative culture
THE NFC PROJECT BENEFITS FROM A DIVERSE TEAM

Synergistic benefits derived from interdisciplinary interactions

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Feedback

- ANL: Distributed Systems Lab
- ANL: Futures Lab
- General Atomics: DIII-D Fusion Lab
- LBNL: Distributed Systems
- MIT: C-Mod Fusion Lab
- Princeton Computer Science
- PPPL: NSTX Fusion Lab
- Utah: Scientific Computing & Imaging
NFC’S RELATION TO SCIDAC AND OTHER DOE PROJECTS

- DOE/OFES base program for FES research
  - Skilled computer scientists and computational resources
- Fusion science based SciDAC Programs
  - MHD, Microroturbulence, and rf heating
- Plasma Science Advanced Computing Institute (PSACI)
  - Strong endorsement of NFC plans & accomplishments by PSACI PAC
- Data Grid Toolkit; Security & Policy for Group Collaboration; Distributed Security Architecture
  - Secure access, authentication, authorization, Globus GSI/Akenti
- Particle Physics Data Grid; DOE Science Grid
  - Site security, Firewalls, and Grid security; 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
- Global Grid Forum and Common Component Architecture Forum
  - Community wide standards
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
EXPERIMENTAL 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 “real-time” analysis of many measurements
- More informed decisions result in better experiments
  - The collaborative control room
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
WORK TOWARDS THE COLLABORATIVE CONTROL ROOM

- Secure Data via MDSplus
- Prototype Computational Service
- Authorization & Enforcement
- Monitoring

- Production Computational Service
- Between Pulse Analysis
- Prototype Computational Reservation

- SCIRun Enhancements + Refinements
- Prototype Large Simulation Data Storage
- Simulation Data Server at NERSC

- Control Room Access to Large Simulation Datasets
- Usage and Evaluation During Tokamak Experiments

- Fusion AG Venue with Shared Applications
- AG on Tiled Walls

- Prototype Desktop AG
- Wall to Wall Sharing

- Prototype Tile Walls at D3D/NSTX

- Full Wall Install at D3D/NSTX
- Fully Utilized Tiled Displays in Control Room
- X-Windows Sharing Software

Collaborative Control Room

FusionGRID
www.fusiongrid.org
FUSIONGRID: SECURE ACCESS TO FUSION DATA

- MDSplus: remote access based on client-server model
  - In use for over 10 years (robust)

- MDSplus experimental data repositories on FusionGrid via Globus GSI
  - X.509 certificates

- Worldwide access for FusionGrid members
  - Non-U.S. MDSplus repositories can be made available as required
“This is a success”
- 4 times faster per run
- Up to 20 times faster per case
- Better support

The U.S. TRANSP Service
- 1,500 cases, 10,000 CPU hrs
- 9 fusion experimental machines
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
ADVANCED RESERVATION COMPUTATION FOR DATA ANALYSIS TO SUPPORT EXPERIMENTAL SCIENCE

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

- End-to-end agreement being prototyped in the NFC project
  - CPU reservation
  - Network transfer agreements based on simple prediction

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

FusionGRID
www.fusiongrid.org
TILED DISPLAYS TESTED IN FUSION CONTROL ROOMS

- 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
ACCESS GRID: REAL TIME COMPLEX COMMUNICATION

- Tested with off-site scientist to control room
  - Includes application sharing
  - Detailed data analysis discussion

- Feedback indicated the need for a greater control room presence for the off-site scientist

Personal Interface to the Grid (PIG) motivated by Fusion research
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
COLLABORATIVE CONTROL ROOM: A SENSE OF PRESENCE

- Shared Application
- Video & Audio
- Real Time Data Display
- Between Pulse Data
- Shot Cycle Status

SuperComputing 2003, Phoenix AZ
REMOTE LEADERSHIP OF THE JET TOKAMAK IN ENGLAND FROM SAN DIEGO USING FUSIONGRID SERVICES

January 2004, San Diego

- First attempt for real science and it was successful
- Similar collaboration planned: Japan - US and US-Germany

Working with JET and the UK e-Science Programme
ITER:
NFC TECHNOLOGIES SCALE TO THE NEXT DEVICE

- ~$5B class device, over 20 countries
  - Number 1 DOE/SC Facility Priority
  - International collaboration

- Pulsed experiment with simulations
  - ~TBs of data in 30 minutes

- Successful operation requires
  - Large simulations, shared vis, decisions back to the control room
  - Remote Collaboration via FusionGrid

- NFC technology being considered as the model for ITER
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
SAME TEAM HAS SUBMITTED A PROJECT RENEWAL

- Fusion community has responded positively to the work of the NFC
  - Encouragement has come from many groups/people

- Ease-of-use is a key area of focus
  - Certificate management, documentation, education, support
  - Ease of creating and adding a new FusionGrid service
  - Robust deployment of SCIRun for daily usage
  - Efficient data management of large simulation datasets

- FusionGrid computational services
  - The SciDAC funded codes GYRO and TORIC will be added
  - Production deployment of Akenti

- Collaborative tokamak control room
  - Enhanced AG along with control room presence
  - Co-located and remote X sharing to tiled displays
  - Advanced computational reservation on FusionGrid
SCIDAC IS HAVING AN IMPACT BEYOND DOE/SC

Predator & Lynx-SAR 30Mpixel Imagery

Command & Control: Tiled Displays being explored for Defense and Homeland Security

Ultra-high resolution optical imagery
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
  - 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 (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.