TOOLS FOR REMOTE COLLABORATION ON THE DIII–D NATIONAL FUSION FACILITY

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DISCLAIMER

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ABSTRACT

The DIII–D National Fusion Facility, a tokamak experiment funded by the U.S. Department of Energy and operated by General Atomics (GA), is an international resource for plasma physics and fusion energy science research. This facility has a long history of collaborations with scientists from a wide variety of laboratories and universities from around the world. That collaboration has mostly been conducted by travel to and participation at the DIII–D site. Many new developments in the computing and technology fields are now facilitating collaboration from remote sites, thus reducing some of the needs to travel to the experiment. Some of these developments include higher speed wide area networks, powerful workstations connected within a distributed computing environment, network based audio/video capabilities, and the use of the World Wide Web. As the number of collaborators increases, the need for remote tools become important options to efficiently utilize the DIII–D facility. In the last two years a joint study by GA, Princeton Plasma Physics Laboratory (PPPL), Lawrence Livermore National Laboratory (LLNL), and Oak Ridge National Laboratory (ORNL) has introduced remote collaboration tools into the DIII–D environment and studied their effectiveness. These tools have included the use of audio/video for communication from the DIII–D control room, the broadcast of meetings, use of inter-process communication software to post events to the network during a tokamak shot, the creation of a DCE (Distributed Computing Environment) cell for creating a common collaboratory environment, distributed use of computer cycles, remote data access, and remote display of results. This study also included sociological studies of how scientists in this environment work together as well as apart. As a result of these studies, there is now in place an automated distributed processing environment connected to the real-time experimental operations which can be joined by users at remote locations. This environment will allow further exploration of the technology and sociology of remote participation in the DIII–D program. Having the tools in

place has already permitted remote participation in DIII–D experiments that would not have occurred otherwise, and thus the introduction of these tools has shown the initial feasibility of increasing and improving remote collaboration.

I.   INTRODUCTION

Collaboration has historically been an important part of the fusion energy research program, and this collaboration has occurred not only on national but international levels as well. In particular, collaboration is becoming even more important as research experiments have become concentrated into fewer, larger, and more expensive facilities. The proposed next generation experiment is an international effort and will be operated with worldwide involvement. Future facilities are expected to support continuous operation, for which real-time experimentation becomes an important issue. As fusion research experiments have become larger and more expensive it has become necessary for personnel from other labs to travel to the facility in order to conduct experiments. However recent technological advancements can alleviate some of these travel needs and enable researchers to participate in the experiment almost as if they were on site. In order to minimize travel by scientists to experimental facilities, and to sustain continued interactive involvement from home institutions, studies have been underway of how to establish geographically distant centers for interactive participation in experiments.

The DIII–D National Fusion Facility is a tokamak experiment funded by the U.S. Department of Energy (DOE) and operated by General Atomics (GA), and is an international resource for plasma physics and fusion energy science research. A Remote Experimental Environment (REE) project, part of the Distributed Collaborative Experimental Environments initiative (DCEE) [1], has taken place in the past two years that has created capabilities for the facility that did not exist before and which permit remote interaction in various ways. Remote participation has become practical only recently due to technological advances including high performance wide area networks of powerful workstations connected within a distributed computing environment. In particular, inter-process communication over high speed wide area networks provides real-time synchronization and exchange of data among multiple computer net-

works. Also audio and video tools can now provide enough information for a remote presence to the DIII–D control room by presenting critical operations information to the off-site collaborators and a feeling of presence at the site. These concepts now formally embrace what is often referred to as a "Collaboratory" [2].

On June 11, 1997, the DIII–D experiment for the day was conducted in part by personnel located at Lawrence Livermore National Laboratory. This included the session leader who directs the experiment, the physics operator who ran the plasma control system to set the plasma shape, and the neutral beam timing operator who ran the neutral beam timing system to set beam timing. Several lines of audio/video communication were used for communicating with personnel in the DIII–D control room. This demonstration represented the culmination of the REE project which has been studying ways to enable control of DIII–D from outside the facility.

In the remainder of this paper, the REE project will be discussed including its development and testing towards remote collaboration including sociological studies. The June 11 experimental day will be discussed, and finally the status of current capabilities will be summarized along with future plans.

II.   THE REE PROJECT

The REE project is a collaboration among GA, Lawrence Livermore National Laboratory (LLNL), Oak Ridge National Laboratory (ORNL), and Princeton Plasma Physics Laboratory (PPPL). The objective of the REE project is to provide a testbed for exploring the concept of a "Collaboratory" for national fusion research. The testbed relies on three major capabilities:

1.   Distributed utilization of resources and people

2.   Robust, interactive communications and information exchange

3.   Ability to control systems from remote locations.

The testbed utilized for this study is the DIII–D tokamak at General Atomics. This testbed serves as a testing environment for advanced computing and control and collaboration concepts applicable to future experiments while enhancing the ability to conduct research on the existing facility. Also, participants in this effort functioned as a distributed working group and utilized the collaborative tools during the development.

The various laboratories worked on different aspects of the project, but of course overlapped in their work as well. These areas included:

1.   Establish OSF/DCE infrastructure (LLNL)

2.   Demonstrate audio/video tools in a scientific collaboratory (PPPL)

3.   Demonstrate distributed tools and applications using DCE (LLNL)

4.   Evolve the DIII–D distributed data model (ORNL)

5.   Systems integration for the DCE demonstration facility (GA)

A central feature of the study was to use the Open Software Foundation (OSF) Distributed Computing Environment (DCE) to develop and test concepts in distributed analysis, visualiza-

tion, and control utilizing the DCE security and naming services with global distributed file access using the Distributed File Services (DFS). Interprocess communications software developed at LLNL was chosen to provide asynchronous communication among processes. PPPL contributed an event management service that was modified to utilize asynchronous messages in order to communicate over the wide area network and manage the information flow in a distributed task environment.

Another important part of this project was a sociological study of how scientists react to this collaborative environment. For example, the introduction of cameras into the control room has evoked attitudes from "neat technology" to be able to communicate with others off-site to "big brother" is watching so be careful what you do or say. These studies contribute to an understanding of how scientists work as well as influencing the technologies for doing remote collaboration.

III. REE DEVELOPMENT AND TESTING

Preliminary development focused on the introduction of elements into the DIII–D environment to facilitate remote collaboration. These included facilities for personal communication, software for process communication, software for improved data access, Web browser applications, and software for remote control.

Remote participation in an interactive experiment requires support for disseminating information and for personal communications between collaborating scientists. LLNL has collaborated with GA for many years and has long used Internet Relay Chat (IRC) as a highly reliable and interactive means of communicating between sites. Scientists have maintained essentially instantaneous communication with each other which often aids in diagnosing fault situations that arise during operations while also maintaining dialogue concerning the progression of the experiment.

IRC is however limited in the amount of information that can be conveyed, and it does not provide the feeling of "presence" at the experiment. A large part of the REE project has been the addition of audio/video tools to the DIII–D facility which has become possible due to recent technological advances. Over the past two years as audio/video communications have been setup and utilized, they have become an important element of use for those located remotely. Morning status meetings as well as the control room views are broadcast daily during tokamak operations over both MBONE (multicast backbone) [3] and CU-SeeMe [4]. These have been particularly important for LLNL personnel who have been collaborating for a long time, and they are becoming more important for PPPL personnel who are beginning to collaborate more as a result of the TFTR shutdown. These broadcasts of audio and video are provided using SGI Indy workstations using MBONE technology to provide IP based communication links among multiple facilities to off-site researchers. Also used has been CU-SeeMe on desktop computers which provides a

point to point link for audio/video broadcasts. By use of reflector software, CU-SeeMe can also provide the broadcast among multiple facilities. This communication has primarily been used for the one-way dissemination of information. Remote scientists can "attend" the morning status meetings before operations where the experimental plan for the day is presented. After the meeting, the camera view switches to the control room. There are several fixed cameras in the room along with one movable camera. It is possible via a Web browser interface application developed by PPPL to actually control which camera is broadcasting as well as to move the movable camera to a selected view. Figure 1 shows the Web browser interface screen. From the Web browser, clicking on a particular camera will display that view. Also clicking on a particular square of the control room grid will cause the movable camera to view that grid area.

Broadcasting control room audio has been a more difficult problem than the video mostly because more real information is expected. The control room is a very noisy environment both due to equipment that is present and due to the large number of people present, engaged in numerous conversations. Thus broadcast of the sound from the entire room itself is ineffective. What has been done is to mix the microphone audio from the tokamak operator (who makes announcements about the starting of a shot and the progress of the shot) and audio from the session leader (who makes announcements about the physics of the shot and results). Two way interactive communications, while available, have typically only selectively been used at the present time.

A DCE cell was installed with cell management services provided by the LLNL computing center. The fusion DCE cell forms a nationwide distributed computing "cluster" of workstations located at GA (southern California), LLNL (northern California), ORNL (Tennessee), and PPPL (New Jersey). A variety of UNIX workstations are part of this cell including HP, SGI, DEC, and SUN. Interprocess communications software (IPCS) developed at LLNL [5] currently provides asynchronous communication among processes distributed at all sites and forms the basis for wide area network synchronization to the experimental operations and coordination of tasks running both inside and outside of the DCE environment. An event management service (QCS)
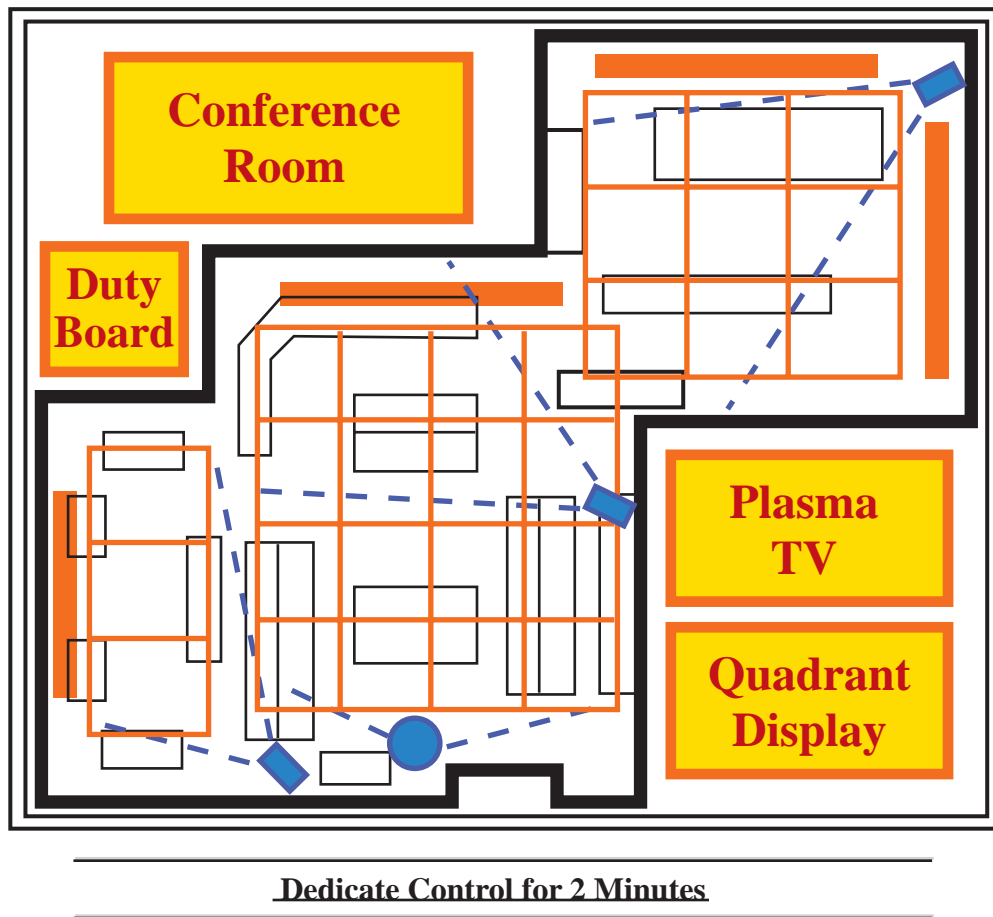
DIII–D Video Systems Control

Fig. 1. DIII–D Web browser camera control page.

developed at PPPL [6] was modified to utilize IPCS messages in order to communicate over the wide area network and manage the information from in a distributed task environment. The QCS management task runs on a node within the DCE cell that is at GA, although in principle it could run on any node in the DCE cell.

Using results of a GA and ORNL review of the data flow in the DIII–D experimental environment, GA has modified and distributed the experimental data file system to provide enhanced event identification required to synchronize and manage information flow and processing during the experiment. A variety of events are sent via IPCS to the QCS event manager which can then

in turn execute tasks anywhere on the network. Most of these events declare that data of a certain experiment has been acquired, magnetics for example. In addition, there are certain status events such as: start of the discharge and time zero of the shot.

With the addition of the event management services running over the wide area network and the event declarations for data availability produced by the data acquisition system, it is possible to automate and synchronize the distributed computations with the real-time experimental operations environment. This allows for a minimization of the latency time between the data availability and the processing results for displays required both by the operations group in the DIII–D control room and for those remotely participating researchers. Similarly, using the event server, it is possible to declare availability of the processed data and launch the necessary visualization applications to generate the desired display. These concepts are illustrated by Fig. 2.
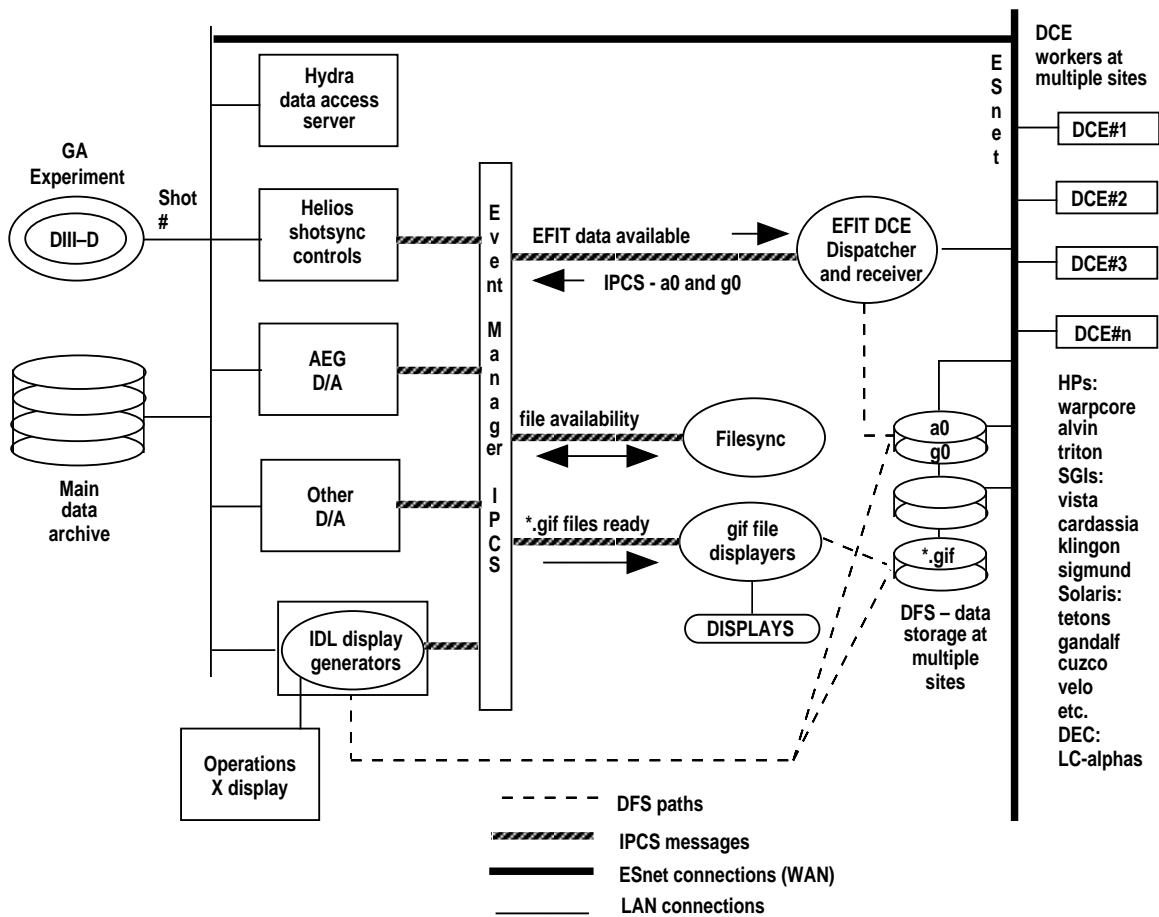

Fig. 2. Event and data flow within the DCE cell.

DIII–D is a cyclical experiment with discharges lasting about 5–10 seconds and occurring every 10–12 minutes. Local computers acquiring data are not part of the DCE cell, yet access to acquired data is desired as soon as possible after a tokamak discharge in order to determine what changes need to be made for the next discharge. GA provides a library of data calls [7] to provide remote access to data elements (pointnames). In effect any pointname once acquired can be accessed regardless of its location or the location of the user accessing it. This includes a user literally anywhere on the network. In order to improve the efficiency of this data access, work is in progress to migrate raw data into the DCE environment. Once there, data is accessible on DFS disks which provide a caching capability. This makes data access more efficient than accessing raw data directly over the network. With these enhancements in place a testbed is formed for evaluating the performance and suitability of OSF/DCE in the experimental operations environment. In the future, the database which includes calculational results will also be made part of this environment.

For demonstration, the fully distributed processing required to analyze the resulting physical equilibrium of the plasma produced in an experimental discharge was chosen. Reconstruction of magnetic equilibrium is done by the EFIT code. This code was modified to run in the DCE environment on multiple cpus with the intention of significantly increasing the number of equilibrium reconstructions available to researchers in the control room by running parallel processing within the workstation cluster. A preliminary estimate is that there is a threefold increase in the processing throughput with the number of workstations currently available.

To achieve an increased measure of heterogeneity in applications, certain applications were migrated to the Web browser environment. Shot synchronized Web browser displays are automatically updated via the message passing system to provide experimental status information, such as instrumentation on line, state of acquisition, time to the next discharge and which systems are busy (often called the shot clock display) as is illustrated in Fig. 3. Web access to the DCE environment is provided for scientists to launch the distributed equilibrium reconstruction analysis (EFIT) previously discussed as shown in Figs. 4 and 5 which show the interface that

DIII–D Status - Shot is 92875

Date	Time Started	Aproximate Secs to T0
7/11	12:41:39 PDT	

Last Shot State	Last Shot Event
resync_setup	null_event

DIII–D Subscribers

🟢	D3D_MASTERTIMER	ga_d3d	Ready	Diagnostic
🟢	CERDATA	d3dwsd	Ready	Diagnostic
🟢	BOLOMS	theodore	Ready	Diagnostic
🟢	RESBOLOMS	ga_d3d	Ready	Diagnostic
🟢	DAPS_SERVER	ga_d3d	Ready	Display
🟢	$$wma05562	alvin	Ready	Display
🟢	$$leonaa16873	hydra	Ready	Display

Fig. 3. Shot status display page.

provides users access to DCE compute cycles for interactive personalized analysis of experimental data. Results can be distributed to users on the network via Web browsers or X-windows displays which show EFIT results or waveform displays of discharge parameters, Fig. 6.

Much of the instrumentation control for diagnostics on the experiment has been implemented with X-windows based interfaces which make remote operation feasible. Some instruments have even been run from internet access. Remote control of magnetic shaping and heating and fueling systems have also been implemented with X-window interfaces, however this level of remote control of the experiment is limited due to the electrical nature of the experiment and personnel

DIII–D Efit Forms

There are now three EFIT forms to chose from.

⬤ DCE Client side - Selected UNIX Machines

This form is the preferred one. It is only available if you have run your browser (Netscape) on a machine with the EFIT helper application. If you've run it on HP or SGI at either LLNL or GA there's a good chance I've configured this for you. This version will be faster than any other. Results are written as completed. This version has load leveling and slices are given more than one attempt at running. Files show up on the same machine as the browser was run on. You will also own the files created.

⬤ DCE Server side - Mac, PC, and UNIX

This form is for users wanting to run the DCE version but are running the browser on a machine without the EFIT helper application. This includes all PC's and Mac's. The DCE efit is started on hydra.gat.com with an "rsh" command on the server machine. The server uses my own account (meyer) so make sure I have write access to the directory. All paths and directories on the form refer to hydra.gat.com paths and all results are copied there.

⬤ RSH Efit - Anywhere but please try the DCE versions first.

This form is the old one you may have been used to. Like the DCE server side it starts processes using "rsh" on the server under my account. Unlike the DCE version you will have to wait for all slices to be completed to see any results. Any slices not created due to EFIT error or convergence problems are not rerun. Again, all results are sent to hydra.gat.com.

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Fig. 4. Web page EFIT submission form options.

safety issues. Thus administrative policy limits the degree to which these systems may be remotely controlled. Nevertheless a high degree of "remote control" can be achieved as has been previously demonstrated in another collaboration between LLNL and the MIT Plasma Fusion Center on the C-MOD tokamak [8]. During this operation, an experimental research plan was directed from LLNL with plasma shape, 1.5 MW of RF heating power, density feedback, and a reciprocating probe all controlled from the LLNL site during the execution of a divertor physics experiment. Part of the REE study was to bring this level of remote control and more to the

DIII–D Efit Form

───────────────────────────────

(Submit Request)

Please enter the directory for results.

Please enter the shot number, start time, time inc, number of slices, and full path to snap file:

`shot`   ☐ Check here for next shot

`start` `inc` `num`

`/link/efit/efit_snap.dat`

What grid/prec should be used?

1. 33x33 ○ single ○ double
2. 33x65 ◉ single ○ double
3. 65x65 ○ single ○ double
4. 129x129 ○ single ○ double

Do you want verbose output from dispatcher?   ○ **yes** ◉ **no**

What data server should be used?   `hydra.gat.com`

How many times should a slice be rerun?   `1`

What computers should be used? Don't use the host you selected for the data service or the host you are running Netscape on.

1. ☐ Helios.gat.com
2. ☒ Uscwsd.gat.com
3. ☐ Hydra.gat.com
4. ☒ uscws5.gat.com
5. ☒ vista.llnl.gov
6. ☒ cardassia.llnl.gov
7. ☒ klingon.gat.com
8. sigmund.llnl.gov
9. ☒ warpcore.llnl.gov
10. ☐ alvin.llnl.gov
11. ☒ triton.gat.com

(Submit Request)

Fig. 5. Web page EFIT submission form parameters.

DIII–D tokamak. With the addition of enhanced security features associated with authentication and resource authorization, it may be possible in the future to run most systems.
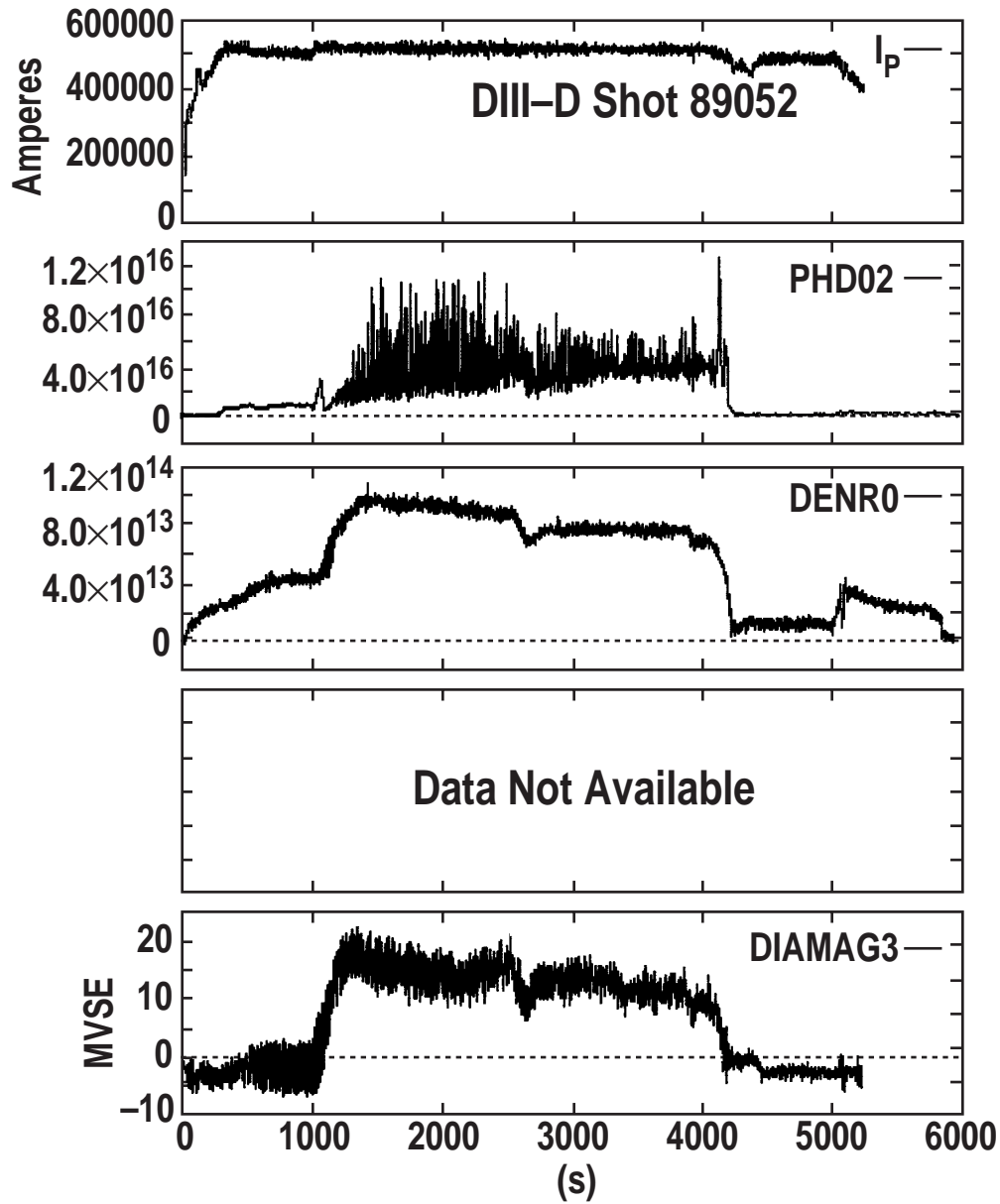
Fig. 6. Typical analysis and waveform displays from the Web browser.

In summary, the result of the REE development work is to have in place a fully automated distributed processing environment asynchronously slaved to the real-time experimental operations. Users both on and off site have access to the synchronization messages and event declaration. A secure distributed environment has been provided for high performance compute intensive applications such as the equilibrium reconstruction., x-ray and radiated power tomography

applications. Results are stored in the DFS global file system which is accessible from the visualization codes and can produce X windows displays needed for participation in the experimental operations. Since DFS is employed both for storing results and for graphics codes, analysis can be run at arbitrary sites and thus all collaborators have ready access to the data and codes.

IV.   REE SOCIOLOGICAL STUDIES

An integral part of the REE project was a sociological study [9]. This study actually covered four different areas of scientific research, one of which was the DIII–D tokamak experiment. On several occasions observations were made of personnel in the DIII–D control room on experiment run days. Also, numerous scientists, both GA employees and collaborators, were interviewed as part of the study. These studies provide a basis for understanding how distributed computing technologies can influence and support remote collaboration of scientific experiments. Understanding the work practice of experimental scientists provides input to the design of technologies for these collaboratories. The size and customization of equipment and the rapid iteration of experimental parameters challenge traditional groupware approaches. The introduction of collaboratory technologies will impact the work activity and the work activity will influence the design and use of the technologies in ways that are different from many groupware situations today. Understanding the work activity as well as the technology is critical to the long-term success of these projects. The first part of this study is to look at current scientific work activity. A later part will look at initial deployment of collaboratory technologies and their uses. The goals of the first part of this study are:

1.   Provide documentation on the current work activity of scientists that are the user community of collaboratories.

2.   Provide a means of validating with the users themselves the representation and summary of their work and concerns.

3.   Offer collaboratory designers and developers an external perspective on the way scientists talk about their work

Some of the characteristics that came out of this study include:

1. Expensive and hard-to-duplicate equipment (a tokamak)

2. Rapidly iterating and changing experimental parameters (changing parameters between tokamak discharges)

3. Multiple person, multiple specialties needed for carrying out experiments (physics, engineering, computer, technician personnel)

4. Collaborators who are already geographically distributed (physicists at different Fusion laboratories)

The most significant implication of the field study observations thus far is that the ways in which the collaboratory work differs from much of the work which collaboration technologies support today. Thus what seems like a good idea from a computing point of view may not be reasonable in the true scientific environment.

For collaborators that are already remote the desire for remote collaboration is high. For those scientists already on site at GA, the remote collaboration is often seen as an intrusion. Thus education of the local staff is important in gaining acceptance for remote collaboration. During the course of the REE project, there were MBONE video conferences several times a month. The office where these were held was next to the office of one of the GA physicists. Over the course of time the GA physicist kept overhearing the video conferences through the wall. This eventually led to a substantial interest in the idea of remote collaboration. The GA physicist was going to be the session leader for an upcoming run day and he was working together with a physicist at Garching on plasma physics issues. This was a great opportunity for trying interactive remote collaboration and communicating during the experiment run day. A MACintosh with CU-SeeMe was set up for the GA physicist in the DIII–D control room and the two of them were in fact able to communicate and discuss ideas throughout the run day. The Garching researcher also had logged into GA remotely and was able to run the data display

codes, REVIEW and 4D, to examine data coming from the experiment. They plan to do this again during a run day in September.

V.   THE JUNE 11 EXPERIMENTAL DAY

Having developed appropriate tools, what remained was actually running the experiment remotely. Some requirements for this demonstration had not been done previously including siting certain key people at a remote site, running the Plasma Control System (PCS) from the remote site, and setting the Neutral Beam timing from the remote site.

The purpose of the remote collaboration testing on June 11 was to demonstrate the significant level of participation in real-time operations currently possible from a remote location by conducting a physics experiment on DIII–D from the LLNL remote experimental site (RES). The experiment chosen was part of the Helium campaign under investigation by LLNL personnel. This involved investigating L-H transition physics, plasma detachment from the divertor, and comparisons with the UEDGE code predictions. The four main objectives for the demonstration were:

1.   Demonstrate the safe operation of the Plasma Control System (PCS) and the neutral beam waveform control from the LLNL RES (remote experiment site).

2.   Execute a physics run from the LLNL RES thus completing a sequence of experiments associated with an independently approved experiment.

3.   Provide data on the amount of information flow and communications needed to support joint local and remote operations.

4.   Provide information for development of remote operations techniques for ITER.

This experiment day was a next step in demonstrating the viability of using remotely located researchers for integrated operation of the DIII–D tokamak. It helps to substantiate the viability of distributed operations, indicate potential areas for further development, and expand the potential roles of collaborations in the DIII–D national program.

The operation of DIII–D requires communication between a number of people running the experiment. With some members of the experimental team at a remote site, four critical lines of communication were identified that needed to be specifically addressed. These are:

1. Between the Physics Operator at LLNL who determines plasma shapes and the Chief Operator at DIII–D who has overall responsibility for tokamak operations.

2. Between the Neural Beam physicist at LLNL who sets neutral beam timing and the Neutral Beam Operators at DIII–D who are responsible for the beam lines.

3. Between the Session Leader at LLNL who directs the experiment and the Local Session Leader at DIII–D who is doing overall coordination.

4. Between participants at LLNL, and those at DIII–D.

Note also that there is critical communication between the session leader and the physics operator, but these are both located at LLNL. Some diagnostic instrumentation and analysis were also controlled remotely.

Figure 7 illustrates these lines of communication. An SGI (cyclop) and SGI (cardassia) were used for communication between the Physics Operator and the tokamak Chief Operator using a private MBONE session. The camera view of the Chief Operator was of the RES at LLNL. The camera view of the Physics Operator was the tokamak control console. The normal MBONE broadcast of the DIII–D control room was from another SGI (klingon) which also provided audio communications between the Session Leader (using SGI vista) and the Local Session Leader. Again the Local Session Leader viewed the LLNL RES. The Session Leader viewed the usual DIII–D control room view. The Neutral Beam Physicist and the Neutral Beam Operators communicated using MACintosh computers running CU-SeeMe. The physicist's view was of the Neutral beam console area and the operators view was of the NB controller in the RES. For the purposes of this day, a MACintosh was set up in the conference room running CU-SeeMe audio in order for the Session Leader at LLNL to have two way communication with the conference room.
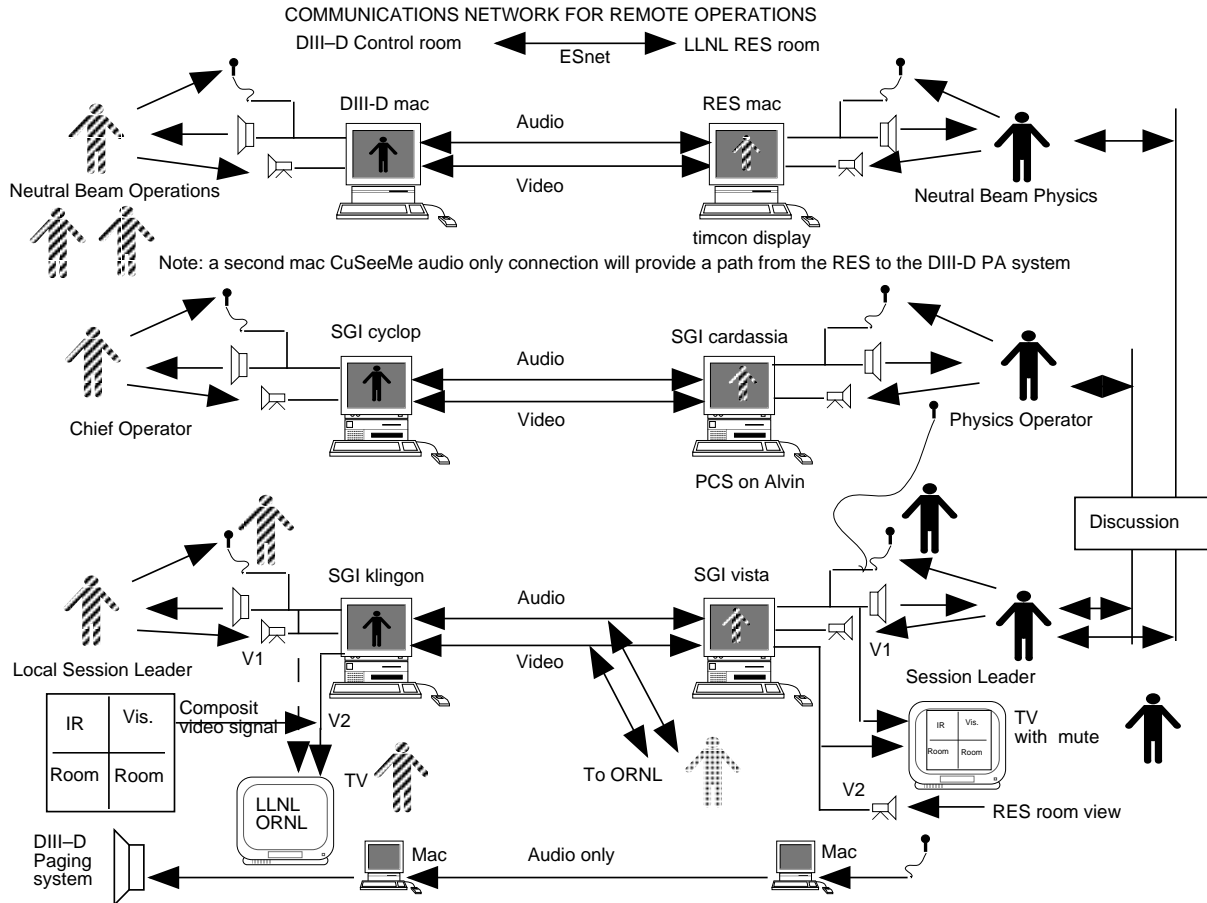
Fig. 7. A schematic representation of the lines of communication between LLNL and GA.

The camera views of the LLNL RES were not only available on the SGI screen but by means of video output were displayed on a large monitor. By this means personnel in the DIII–D control room could see the view of the LLNL control room. Having this display on a large monitor greatly increased the feeling of presence. It is a very different feeling than a voice on the other end of a telephone. It made the LLNL control room feel as part of the DIII–D control room.

In addition, a scientist from ORNL who spends most of his time at GA, instead stayed at ORNL for this day. He continued to examine data from his diagnostic and viewed activities that were occurring in the DIII–D control room. Personnel at PPPL also looked in for this operations day.

The experimental day was a success and produced good physics results. Many who had expressed pessimism or ambivalence towards the remote operations ended the day with considerable enthusiasm, for example the Physics Operator who was a GA employee but had traveled to LLNL for purposes of this demonstration. The experimental day was troubled by numerous technical problems in particular with power supplies, instrumentation, and computers. However, none of these was a result of or caused by the remote operations.

VI.   CURRENT STATUS AND FUTURE PLANS

In summary, the tools for remote collaboration that we now have include: broadcast of the morning status meeting, selectable control room views, Chief Operator comments, Session Leader comments, potential for two-way communication, DCE cell, event management, IPCS for asynchronous message communication, QCS capabilities for activating tasks anywhere in the network, wide area access to raw data, distributed processing, and Web browser capabilities for monitoring the shot. Having the tools in place has already permitted remote participation in DIII–D experiments that would not have occurred otherwise, and thus the introduction of these tools has shown the initial feasibility of increasing and improving remote collaboration.

The current testbed allows the opportunity to explore the technology and sociology of remotely participating in the operation of DIII-D. This is an evolutionary effort as researchers are just now learning many of the issues associated with research at a distance. Based on the experience obtained in the use of this environment and a sociological evaluation of the operation effort, the environment will be optimized and more distributed applications will be added. The addition of security enhancements currently being pursued by others will allow more flexibility in the control applications area.

At present, this collaboratory is gaining in the number of users as scientists at more remote sites are informed of its capabilities or are beginning collaboration on the DIII–D tokamak. In particular, with the shutdown of TFTR, there will be a substantial increase in collaboration from PPPL scientists. Already PPPL has setup a remote control room and is accessing and displaying data in real time as the experiment is in progress. We anticipate that other facilities in the U.S. magnetic fusion research program will extend the work done thus far to fit site specific needs.

There are many improvements that still need to be made and more studies to be done. The use of the DCE cell has been minimal and much more use of it could be very beneficial to the

fusion research environment. More use needs to be made of the ability for users to execute codes automatically during operations via IPCS/QCS. Many audio/video improvements need to be made, particularly with regard to the DIII–D conference room. This will be facilitated because that room is being completely reconstructed for other reasons, and this is an opportunity for audio/video capabilities to be built into it. The room will be enlarged by nearly 50% and better sound insulation will be utilized to insulate from various outside noises such as air-conditioning. Better methods for two way communication with researchers needs to be investigated.

Many improvements are currently planned for the audio and video broadcasts. Some anticipated improvements include adding a new video board to the SGI in the DIII–D control room. The board will allow multiple video inputs so that the viewer can simultaneously see the control room and personal views of collaborators by connecting to the same SDR session twice. The board also has a video output to drive displays in the room so that the local researchers can see researchers at a remote site. Also to be purchased is a large TV monitor for displaying the views of researchers at remote sites. For improved audio, a Coherent CallPort with extension microphone will be purchased. This has integrated microphones and speakers which provide hardware echo cancellation and background noise suppression. Similar items are planned for the conference room.

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