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J. How, V. Schmidt,
and JET EFDA Contributors

The Technical Infrastructure for Remote Participation in the European Fusion Programme

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J. How[1], V. Schmidt[2],
and JET EFDA Contributors

EURATOM-UKAEA Fusion Association, Culham Science Centre, Abingdon, OX14 4XB, United Kingdom.
[1]Association EURATOM-CEA, DRFC, CEA/Cadarache,
F-13108 Saint Paul Lez Durance, France
[2]Consorzio RFX, Associazione EURATOM-ENEA, I-35127 Padova, Italy
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ABSTRACT

Remote Participation in European Fusion Research has now undergone a period of practical application with the C1-C4 Campaigns in the EFDA-JET Scientific programme in 2000 and 2001. We report on the Technical Infrastructure established at a European level in the JET framework for the support of this type of approach. We present the file technical poles of the RP project: Remote Data Access, Remote Computer Access, Network Connectivity, Telecommunications, and Support/ Documentation. Many of these subjects are covered in more depth in other papers at this conference. In each topic we describe the current state, but go on to address future progress, difficulties and open questions. We make recommendations for the future technical requirements, with a goal of a well established, closely bound "Virtual Fusion Association" for a combined European strategy, including the JET EP project, Inter-Association Collaborations, and the ITER project, in which physical location of scientific effort and support staff is expected to become less important than it is today.

1. INTRODUCTION

The European Union's current Fusion Programme has its origin under Article 4 of the Euratom Treaty of 1957 [1], in which the Commission is responsible for carrying out research in certain fields including the "study of fusion". The treaty was applied by forming a loose "Association" of Euratom laboratories", in some respects a forerunner for the presently proposed "European Research Area". Although mobility amongst European fusion physicists has always been high, "Remote Participation" was restricted both by technical limitations and by local work practices. The JET Joint Undertaking [2], set up in 1978 and staffed by long-term attachments from all the Associations, started to open up the European Fusion field, and substantial joint scientific work was undertaken.

However recent political and financial constraints have demanded more pooling of both human and material resources. This, coupled with recent advances in information technology, has driven a substantial revolution in working practices, making possible true work by "Remote Participation".

In 1999 the European fusion research programme was restructured around the European Fusion Development Agreement (EFDA) [3]. The JET Facility was handed over to the UKAEA [4] to operate the machine on behalf of the European Commission, and the Associations were mandated to provide the physics and development effort. The completely new legal and administrative structure of EFDA did not initially make provision for a "Remote Participation" Infrastructure. This is in contrast to the US Fusion Programme, which established and financed a central team with a direct mandate to improve the Remote Participation between US Fusion centres [5]. Hence, a "Remote Participation" project-like structure was formed by EFDA-JET in 2000 to support the work of the Science Task Forces [6]. The work reported in this paper was mainly organised around this project. This structured effort has been paralleled by more informal trends in many areas. Several Associations have started making use of modern communications methods to improve the collaboration possibilities both locally and internationally.

Also the many contracts and collaborations for the design of the ITER machine [7], and the JET "Enhanced Performance" (EP) upgrade [8] have started to look at such techniques. Hence the administrative infrastructure for RP is now being restructured under the Central Support Unit of EFDA at Garching with a view to widening it's scope to other major fusion experiments that and to engineering design activities for JET-EP and ITER.

2. THE EFDA-JET RP PROJECT

This project was lead by two Remote Participation Technical Co-ordinators in close collaboration with an RP Users Group and RP Technical Contact Persons from (nearly) all participating European Fusion Laboratories. The contract ended on 30 June 2001 but the Coordinators were also asked to prepare a framework for the continuation of the work under the auspices of the Garching EFDA-CSU.

As the subject of "Remote Participation" is very topical we had hoped to be able to benefit from experience in other scientific domains. However we were surprised to find that whilst partial solutions had been developed and were indeed available to us (example VRVS - see below), other laboratories did not have as much experience as we expected, and that no ready-to-use solutions to all requirements existed. The distinguishing aspects of Fusion have been *the very broad spectrum* of needs. Existing solutions excel in one or two aspects (a good example is the shared board-room business meeting, seldom used in Fusion), but few have the all-round applicability required by Fusion.

It has to be noted that the technical needs of Fusion are relatively modest. The ultimate aim is for Fusion staff to be able to work and collaborate irrespective of their physical location. We do not need the "terabytes" of daily data transfer seen in both astronomy and in high-energy physics, and we do not need the TV-quality teleconferencing facilities used for shared boardroom meeting. However we do require all these techniques and more, but at a relatively modest level.

Methods:

The needs of Fusion for RP within the JET programme were immediate, and indeed many initiatives were already underway. We benefited from a willingness and enthusiasm from the physics and technical staff Europe-wide to participate in the venture, and to share experience already gained. Our job as Co-ordinators was to put the effort on a solid basis, both for use and for future development. We hence divided the effort into five clear broad technical topics:

1. **Remote Data Access**
2. **Remote Computer Access**
3. **Telecommunications**
4. **Network Connectivity**
5. **Support and Documentation**

Work in these areas was instigated via four broad methods: Feasibility Studies, Specifications, Purchase/Commissioning, and Organisation of Support. A comprehensive data base was established containing all the requests from several sources including the Users Group Meetings, Management requests, JET Operations, and from the Association User Group representatives. Work was centred

on the direct needs of JET and hence the UKAEA-Operator provided the major part of the RP support and guidance under the terms of its Operating Contract for JET. Without this core of support and development the project could not have proceeded. The work in the Associations was organised around a set of "Notification" contracts plus informal collaborations, and participation in topical Study Groups.

The EFDA-JET contract for the RP Project has now come to an end. The work, for the most part, is well underway, and the needs are well identified. The EFDA Steering Committee has decided that this project should be formally continued, but transferred to the wider context of European fusion as a whole, and therefore administratively report to the EFDA CSU in Garching. The terms and mandate are presently being finalised. Nevertheless the RP work is continuing on all fronts. In this paper we describe the technical infrastructure that is in place whilst other contributions at this conference describe the technical details [xx1], [xx2], [xx3]. One contribution [xx4] describes the users view of the RP Infrastructure.

3. REMOTE PARTICIPATION TECHNICAL MEASURES

3.1. JET RDA (REMOTE DATA ACCESS) [9]

Remote Data Access provides transfer of data for analysis on local computers. A dedicated solution, known as JET RDA, provides read access to data held in the central JET data archive. Write access is also technically possible, subject to some controls and constraints, but to date has not been made available to the users. This is a JET development, based on a server-client architecture. The client software is portable and easily integrated with MATLAB, IDL, Fortran, and C/C++. It has so far been ported to Windows, several Unix flavours, and to Linux. Due to its architecture it has been decided that JET RDA only requires "weak" user authentication (by a combination of userID and password).

A number of issues are being addressed, or need to be addressed, particularly with the requirement to open up other European Fusion machines:

a) The upkeep of the JET RDA system is not insignificant at the Association Laboratories. It has been suggested that the MDSplus [10] interface system provides much simpler access. A pilot MDS server is being tried at JET.
b) In this context many physicists would like to see a common access method for data from all European Machines (and indeed US machines). It appears likely that an additional "layer" to access data from different experiments could be installed on top of the local experiment access methods at the laboratories to allow for a uniform access method while providing a security buffer between the user and the data server, and retaining the existing decentralised archives and the local access methods. A small working group is at present considering the various possibilities [xx1].
c) Some "Central Support" and "Central Licensing" is desirable if the standardisation is to succeed. This is an issue we would like to see addressed for the wholeof European Fusion.

3.2. JET RCA (REMOTE COMPUTER ACCESS)

JET RCA provides the same computer access as if the remote user were in an office on the JET site. Remote CITRIX ICA clients are used to connect to several Metaframe gateway servers at JET [11] that provide direct access to JET's office computing infrastructure and that are used as controlled "bridgeheads" inside the JET "fence" to log on to any of JET's other computer systems (Solaris and Linux), subject to the usual internal requirements of the site. Electronic authentication is provided by use of SecurID [12] token cards at the firewall. RCA is widely used from remote sites for several, distinct purposes:

- It provides full access to JET data and to all of JET's analysis and visualisation programs. This complements the RDA approach with which data are downloaded to remote computers and analysis is run on computers at the remote sites.
- It is used in experiment preparation as it provides access to the full range of dedicated session and experiment preparation tools not easily transportable to other platforms.
- It provides secure real-time read-only access to all plant status information by means of read-only access to all plant signals.
- It provides access to the internal JET web pages.

Remote Computer Access will continue to be required between laboratories, in addition to JET access; the JET RCA approach could be used as a blueprint for other Associations and, in particular, provide smaller laboratories with easy and fully supported access to the computing facilities at larger partner laboratories. Although this solution has proved very effective for the JET computer system, its use in other laboratories has raised a number of issues that still need to be addressed.

a) It has been questioned whether this level of security is necessary within the fusion community. A real community should have equal access to all computers and files in all centres and a security system structured on a European level. A study group will shortly be established, to make recommendations for a European Fusion strategy for the harmonisation of security measures.
b) Some machines do not have a local firewall around their control room computer system, and the operational computers are on the same network as the office computing. Hence remote access, whether via Citrix or not, represents a real security/safety risk. At the other extreme some machines have the safest option of *no* connection between their control room system and the laboratories computer infrastructure, so neither on-site nor off-site computer connections allow control room participation.
c) Over 250 active SecurID electronic token cards have been issued to JET users. A particularly attractive option would be the extension of the SecurID-based access authentication system to other laboratories using a single central fusion authentication server. In this way a single SecurID token card would enable access to several different protected sites. (see [13] Central Authentication Server).

3.3. TELECOMMUNICATIONS

Tele-collaboration Scenarios:

Tele-collaboration in various forms is increasingly used in the JET programme. A set of tools has been identified and is being installed at all sites to cover for a large range of tele-collaboration scenarios. These scenarios comprise a wide range of increasingly sophisticated arrangements.

- The simplest situation is the "desktop dialogue" between two scientists that want to discuss and, possibly, share interactively documents on their computers.
- In "Office-based Meetings" small groups communicate via audio and, possibly, live video, interactively sharing documents on their desktop computers.
- "Multi-centre Meetings" combine participants in one or more meeting rooms at different sites and some individual participants who all interactively participate in the meeting. This type of meeting (the typical examples are JET Task Force meetings) is based on formal presentations and requires the presence of a Meeting Chairperson and the help of Meeting Assistant.
- Some formal meetings may only need broadcasting ("streaming") without the interaction facility being made available remotely. A typical case is a Science Seminar.
- For scientists who are closely involved in experiment execution, a "Remote Control Room Extension" gives the possibility to interact with the JET control room in real time during experiment operation. This scenario is a combination of teleconferencing, broadcasting, and remote computer access.

In order to simplify the infrastructure and support requirements, and to provide smooth integration between the audio/video streams and computer applications it has been decided to only employ Internet-based tele-collaboration tools. This includes in particular teleconferencing. Telephone is reserved solely as backup in case of network failure.

Audio & Video:

Many different and mutually incompatible tools exist. Most of them use telephone line communications rather than the Internet. Only recently has a standard for Internet-based teleconferencing been defined: H323 [14]. No solution is truly platform independent. VRVS [15] ("Virtual Room Videoconferencing System") appears to be the best available solution for the fusion community's teleconferencing (audio and video) requirements. It is a freeware-based Caltech development for the CERN LHC computing community and now widely used in High Energy Physics. It is based on the concept of Virtual Meeting Rooms. VRVS has an active support and development team that is very effectively interacting with the users. It is available for Windows, most Unix versions, and Linux, but only has a non-interactive version for MacOS. Whilst VRVS was originally based exclusively on the RAT and VIC MBone tools [16], [17], its latest version is interoperable with H323 compliant videoconferencing systems (Microsoft "NetMeeting", Intel "Internet Video Phone"). The latest version is also bundled together with VNC (see next section) although full integration of the two products (VRVS and VNC via common fast shared "reflector" routes) has not yet been attempted.

Interactive Shared Desktop Tool:

Any remote collaboration scenario requires the possibility to remotely share a computer-based document. An elegant solution to this is the freeware "Virtual Network Computing" VNC [18]. It is, in essence, a remote display system that allows you to view a computing 'desktop' environment not only on the machine where it is running, but also from anywhere on the Internet and from a wide variety of machine architectures and platforms. The viewing software is very small and can be run from a web browser without any installation work.

Real-time Dialogue ("Chat") Tools:

Apart from being a useful tool in its own right (as a self-documenting halfway between telephone and e-mail exchange) a chat tool is an essential addition to any teleconference during set-up and for non-intrusive communication during the conference. There are now over 40 freeware chat utilities publicly available. Of these, two are now in regular use in the fusion community. The public-server Yahoo Messenger [19] is used for daily dialogue, replacing many telephone calls, and a JET-based private server runs Spaniel Chat [20] for the more secure control room communication.

Web "screen streaming":

Web streaming is a suitable way to provide remote users with a pre-selected set of data "channels". This can be live computer screens or video images. Several solutions have been investigated using either commercial tools like RealPlayer [21] (Example: DIII-D TV [22]) or VNC. The prototype "JET television system" (JTV) [23] is based on VNC. It allows JET users remote web access to 11 channels of live control room data and one channel on which slides of teleconferenced meetings are broadcast. The control room channels include the post pulse summary, the countdown mimic, and the real-time plasma current display, a slow webcam view of the Session Leader in the control room, and the Sessions Leader's workstation screen. Each channel uses two separate VNC servers: local applications run on one server, while JTV viewers connect to the other, carrying a "read-only" copy of the image. A utility script gives local staff control over the various JTV processes and the displayed applications. A version is now also installed at Tore-Supra in Cadarache to cater for future needs.

Web "Seminar Streaming":

The JTV screen streaming does not have audio channels, and cannot be used to broadcast complete seminars. So far audio communications have only been done with VRVS, Yahoo Messenger or Telephone. These are all interactive. We have recently started to look for simpler methods of "non-interactive" broadcast streaming, both in real time and on-demand (e.g. pressing a web button to see a replay of a seminar). The Camtasia utility [24] looks very promising for this purpose – allowing a desktop screen image plus sound to be broadcast and recorded (standard AVI format) during a VRVS/VNC-based teleconference.

Teleconferencing Hardware:

The hardware requirements for teleconferencing range from a cheap USB camera and headset to the special audio equipment for large conference room. A useful hardware recommendation list is given on the VRVS web pages [15]. In cases where there are several participants in a room a computer-connected conference phone with echo suppression is desirable (e.g. Polyspan Soundstation [25]). Unless all documents for a meeting are available in electronic form a scanner or document camera is required to get paper-based documents on the computer. A detailed technical note on teleconferencing equipment and software requirements for the fusion community has been issued [26].

Teleconferencing Backup:

It must be underlined that "low-technology" backup is always needed that is commensurate with the importance of the meeting. The Internet is not, nor never will be, 100% reliable in real time, especially when coupled to local equipment at each connection node. The minimum backup requirement, for a seminar for example, is to pre-transmit the documents and have a telephone hooked into the audio system. For three or more participants JET has subscribed to a telephone-based teleconferencing service [27]. We also advise fast access to a fax facility for discussion type meetings.

Current Issues and Problems in Tele-collaboration:

- Tele-collaboration is in a relatively solid position in our RP Infrastructure. More people and centres are realising daily that basic tele-collaboration is substantially easier than they anticipated, and relatively reliable. The combination of teleconferencing (VRVS) with shared desktop tool (VNC) has demonstrated to be very powerful. We need however to get into routine use, and away from the present ad-hoc rigs. This means that sites must make permanent installations. The investment costs are small compared with the potential mission cost savings, and the returns are high.
- A Remote extension of the JET Control Room has been installed at CEA-DRFC and is being used both for the participation in JET experiments and for small numbers of local staff to follow presentations given at JET and elsewhere.
- *Remote Engineering Tool*s: For JET EP and ITER Home Team engineering activities, remote access to CATIA [28] drawings is required. It appears that a commercial product, Enovia Portal [29] provides the required functionality for remote "viewing" of CATIA-based designs, whilst VNC seems to be the solution to provide remote access to a CATIA station for design purposes.

3.4. NETWORK CONNECTIVITY

As all tools are Internet-based, sufficient network connectivity in terms of throughput, response time, and reliability, is required between all participating sites. All European fusion laboratories are connected through the Pan-European TEN-155 research network [30]; local connections vary in speed and throughput with some of them presently insufficient.

Network Monitoring

A small study group has assessed appropriate monitoring tools, and deployment has started. The following products are being deployed:

- *PingPlotter[31]:* This is a (shareware, Windows-only) repetitive trace-routing tool with a well designed, intuitive graphical user interface and the possibility to store, accumulate and replot data. It includes auto-saving the raw and graphics data, and alarm signalling.
- Several network statistics sites have been implemented. JET provides (on its users web pages) response time and lost-packet graphics for all its partner labs.
- *Big-Brother:* The RFX laboratory in Padova, Italy [32] runs a Big-Brother based site [33] that includes continuous FTP transfer test against the JET site to produce as realistic access-time plots as possible.
- *Qcheck [34]:* This is a utility for testing network performance, it runs at the user's desktop to quickly identify network performance problems (response time, throughput, availability, and lost packets) and run traceroute between any two computers on the Internet, regardless of their locations (subject to the installation of Qcheck "endpoint" software on these computers).

Future Network Issues

- ***Network Security:*** levels and approaches vary greatly and can have a major impact when installing Remote Participation tools and opening up networks to remote users. A lot of expertise exists already so we encourage dialogue and an effort to share and normalize resources and techniques (see RCA security issues above*).*
- ***Internet Traffic:*** Priorities will have to be addressed by a combination of local measures and of the application of evolving Internet-wide tools. An example of a local measure is JET's two Internet connections: a slower one is used for general-purpose traffic, and a faster on is reserved for Fusion-only traffic. The Fusion community is keeping a watchful eye on emerging "guaranteed-bandwidth" or "Differentiated Services" standards and approaches (e.g. RFC 2475 of The Internet Society [35]).
- ***Network Capacity:*** between the laboratories will have to be continuously adjusted to reflect the expected increase in traffic. Even if the requirements of the Fusion community are not expected to come anywhere near the level required by the High-Energy Physics community [36], substantial increases will be required for most sites and tools for assigning traffic priorities will be required.
- ***Virtual Private Network (VPN):*** At present electronic communication in the Fusion community uses mainly standard Internet tools (e-mail in particular) and no particular confidentiality-protection measures (e.g. encryption) are applied generally. It seems advisable to introduce a scheme of compatible methods covering the entire Fusion community, possibly in the form of a European fusion-wide Virtual Private Network (VPN).

3.5. SUPPORT AND DOCUMENTATION

Considerable effort has been allocated by the JET Operator (UKAEA Fusion) to RP Support and Documentation, centred around the needs of the JET Scientific Programme. The channels for help are for the most part well established, and expertise in RP techniques is growing daily. The Users-Web pages at JET provide a central repository for documentation and procedures. In most Associations there are now technically competent teams or individuals who give help and advice on RP techniques. Whilst this is a considerable cost factor it requires only minor technical developments. The major laboratories have good computing infrastructure teams and have provided support as part of their infrastructure. There are a number of issues that are in progress, or will need to be addressed in the near future.

- ***Training:*** Following a request from the Technical Co-ordinators, the JET site will host a training period for European technical staff on RP techniques.
- ***Central Support:*** The excellent support, web and documentation site established for the JET Facility needs to be generalised to support the whole European Fusion effort. In fact we would like to see such a central organisation take a major role in development, standardisation, central data and software repository, user-support and licensing issues.
- ***European Fusion Intranet:*** Whilst most Fusion labs keep their internal information accessible via the web, many do not allow external access. Hence the information bases at the different labs are mutually inaccessible. A central fusion web site will shortly be created, but this could be harmonised with the Associations sites such that a distributed "European Fusion Intranet" is formed, with dedicated search tools, cross-linked data and address base, and central email gateway. The problem is only partially being addressed by the creation of "intermediate" restricted-access web-based information services and by gradually moving information from the internal webs to these shared webs. But each laboratory so far is creating its own intermediate web. This is one of the major items to be tackled in the future.

4. CONCLUSION

The Technical Infrastructure to Remote Participation in the European Fusion Programme, created for the JET Scientific Programme, is now well founded and developing rapidly. We have presented here the five poles of RP; Remote Data Access, Remote Computer Access, Telecommunications, Network Connectivity, Support/Documentation; and described the present technical status as well as future requirements. The JET facility has operated for two years successfully under the new EFDA based shared-exploitation scheme, and has been the catalyst for this RP effort. The JET Task Forces have expressed satisfaction at the progress in RP for Fusion. One of the more satisfying elements is that we have seen a major increase in the inter-association dialogue at all levels, both scientific and personal, and we note a boundless enthusiasm for such contacts.

The Infrastructure is currently being extended to:

- JET EP (Extended Performance) Activities
- ITER Home Team engineering activities and Site study

- Experiment-based or scientific collaborations between other fusion research sites in Europe
- Involvement of universities and other research organisations

The challenge is now to extend the RP infrastructure to create a single European Fusion Community, where physical location is a minor constraint for working methods, and where a common research strategy is possible.

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