



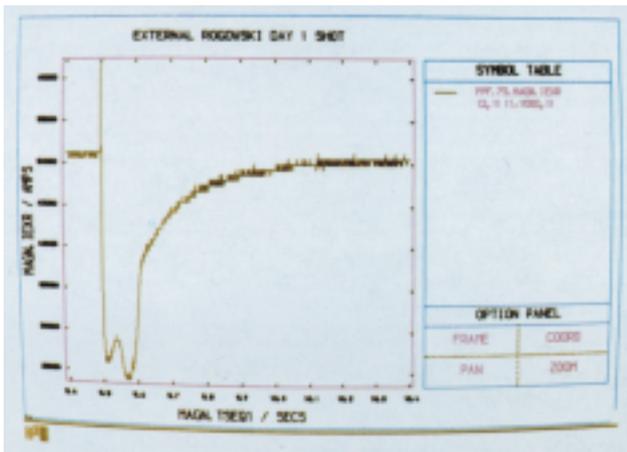
# EFDA-JET Bulletin

## 25 June 2003

# 20 years from the first plasma at JET

July 2003

JET came to life with the first plasma on June 25th 1983 after five years of frantic construction. It was a great day even if a plasma of only a few kA was achieved. At this time all the elements of the machine were not yet tested including the plasma positioning which was not active; nevertheless JET was in operation.



The first plasma was 19kA, 100ms

A few months later we achieved a one MA plasma for more than 2 seconds and won our bet with TFTR. Later on, in 1984, the solemn JET inauguration by the Queen and the President F. Mitterand had taken place.

This first plasma opened the way to a long story of successes and performances. I would like only to mention here the first experiment with tritium where 2 MW of fusion power were produced to be increased later on to 16 MW. I still think that JET could double its fusion power but this is the responsibility of the present team.

JET is the physics model for ITER and, without the results achieved, ITER would not have been possible. I want to praise the European team who constructed the project, a team who was so dedicated and who felt so strongly that this project belonged to them. This team was composed of physicists and personnel coming mainly from the European fusion laboratories.



An ammeter was the only instantaneous diagnostics



The author (left) with Hans-Otto Wüster, the first JET director, on Day one

All of us owe a great thanks to those who fought and allowed JET construction to be decided in 1978. I would like also to remember Hans-Otto Wüster, the first JET Director.

The decision was only possible thanks to the confidence and the will of Donato Palumbo, the fusion Director at the European commission who supported the Joint European Torus.

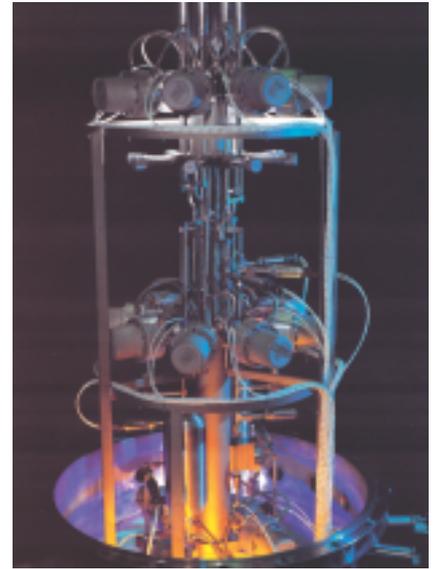
**Paul-Henri Rebut**

# JET returns to operation with Tritium

The JET Campaign C11, which begins on 29 September 2003, marks a return to operation which will capitalise on two unique facilities of the JET device – the capability to run plasmas using tritium fuel, and the use of tritium Neutral Beams.

JET has not run with mixed deuterium-tritium (D-T) plasmas since the ground-breaking DTE1 campaign in late 1997. During that campaign D-T plasmas were obtained with D:T ratios all the way from 99:1 to 10:90. The DTE1 experimental campaign broke world records for fusion power from a plasma with 16 MW in 'Hot-Ion' Edge Localised Mode (ELM) free plasmas. The campaign established that the performance obtained in D-T plasmas in the ITER standard scenario, the ELMy H-mode, could be scaled successfully from JET-sized plasmas to predict the fusion yield in ITER. The DTE1 experiments also made use of the 'correct' fusion fuel mix to shed light on the mechanisms for many tokamak phenomena, from the threshold power needed to attain the H-mode to the physics of applying Ion Cyclotron Radio Frequency (ICRF) heating to D-T fusion plasmas.

This new campaign, the first use of tritium under the EFDA banner, will focus on plasmas where the tritium is introduced into the plasma in 'trace'



*The Deuterium-Tritium gas introduction system for neutral beam*

## Trace Tritium Experiment campaign

- Five weeks of operation until 31 October
- 20 experiments scheduled
- coordinated by Task force DT
- six other Task forces involved: S1, S2, H, M, D, E

quantities (at the level of a few percent concentration in the deuterium background). When used in this manner, tritium offers the unique advantage that its presence, which is signalled by the detection of 14 MeV neutrons from the interaction with the background deuterium plasma, can be accurately monitored thus providing important information on thermal particle and fast particle transport (the latter case coming when the tritium is injected via tritium Neutral Beams). The measurement of transport of tritium, being that of a fuel ion, gives important information on neoclassical and anomalous particle transport in tokamaks. To mark the use of tritium in trace quantities, Campaign C11 at JET goes under the name of the '*Trace Tritium Experiment (TTE)*' campaign.

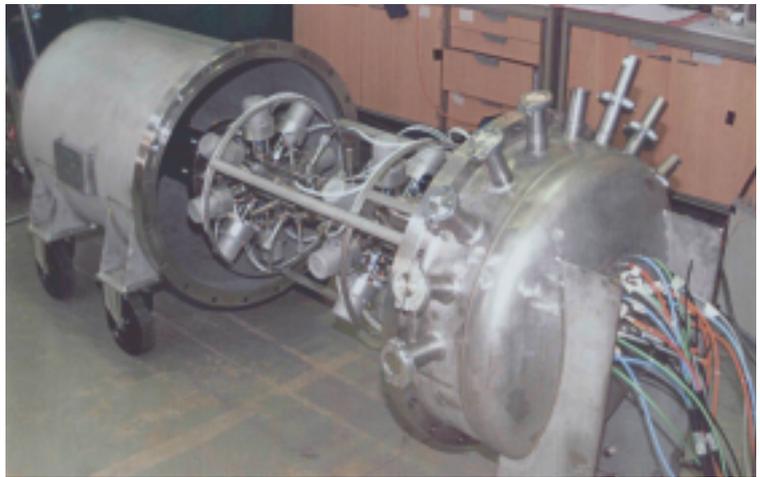
Although JET has not introduced tritium since 1997, there remains the legacy of the DTE1 campaign in the form of more than a gram of tritium residing in the in-vessel surfaces, mainly on the inboard side of the divertor structure. This residual tritium presence has dictated that the JET Operators, the JET Joint Undertaking to the end of 1999 and subsequently UKAEA Culham Division, have always had to follow strict procedures of operation and maintenance of the machine and work to an approved 'Safety Case'.

This Safety Case has had to be assessed for the new experiments however, which has entailed a significant amount of work for the Operator Team. Although the plasma will only see quantities of tritium of order tens of milligrams, this requires several grams of tritium to be supplied to introduction systems, notably the JET Neutral Beam (NBI) system. Thus the Safety Case burden on the Operator is very nearly that involved in a full '50:50' D-T experiment. In this sense a 'Trace' Tritium Experiment is an investment in the re-establishment of full D-T capability which would be required if JET were to return to full D-T operation.

## Main topics of the campaign

- fuel-ion particle transport
- fast-ion particle transport
- fuel and helium transport - comparative studies
- fuelling of Internal Transport Barriers
- ICRF heating of tritium minority ions
- Fast particle physics

The Operator team have now revised the JET Safety Case to allow tritium *introduction and experiments* up to modern UK practice, which has moved on since the original DTE1 in 1997. The machine safety systems have therefore been rigorously analysed and approved in 'fitness for purpose' studies, and systems such as the tritium Torus and NBI gas introduction systems have been revamped and brought into operation with deuterium. A significant program of operations staff training for D-T operation has been undertaken. During the recent machine intervention period at JET (19 May-26 June), the machine and personnel safety systems were extensively and successfully tested prior to their use in the TTE campaign.



The JET neutral beam Deuterium-Tritium Gas Introduction System during assembly. The secondary containment vessel is open in the photograph and the internal process pipework, valves and instrumentation are visible.

The stage is therefore set for the first introduction of tritium, during NBI and plasma commissioning, on 22 September. We look forward to the TTE campaign living up to the promise, and re-establishing, in an active way, JET's tritium credentials.

## JET Experiments

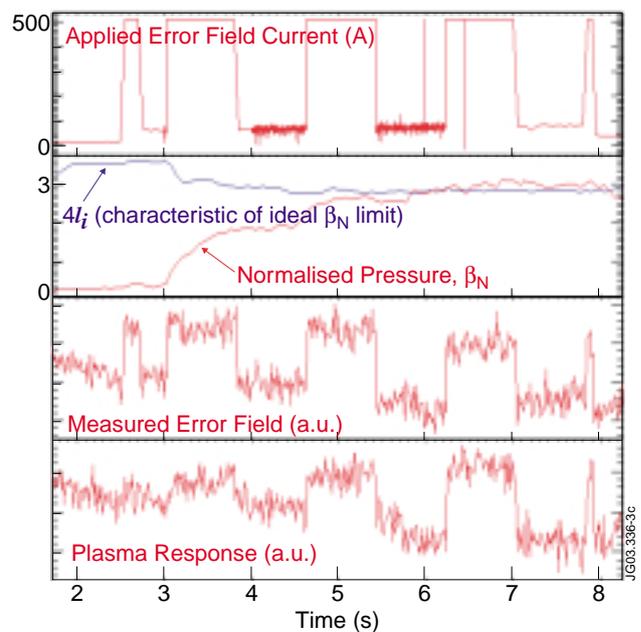
# New light on role of the error field correction

The stability Task Force (M) on JET have commenced the first experimental studies in the European Union in the field of Resistive Wall Mode physics. The experiments address the issue of Error Field Amplification (EFA) effects at high plasma pressures (near the "no wall ideal limit"). These effects can lead to a slowing of plasma rotation, allowing the growth of wall modes and termination of the plasma.

DIII-D showed that by minimising the error fields, the plasma rotation could be maintained, allowing access to much higher normalised plasma pressures. A new example from JET is shown in the figure, where we see that the magnetic detector orthogonal to the applied error field, starts to see a response from the plasma as it approaches the ideal limit.

The JET results are the first confirmation of EFA outside DIII-D, and provide a basis to extrapolate with device size. This is important because ITER will need to run its advanced scenarios above the no wall limit, in order to obtain sufficient pressure driven currents to be self-sustaining.

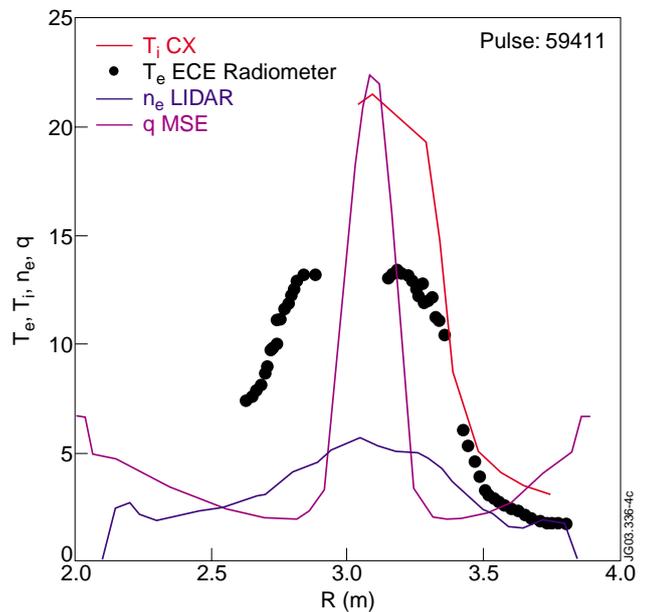
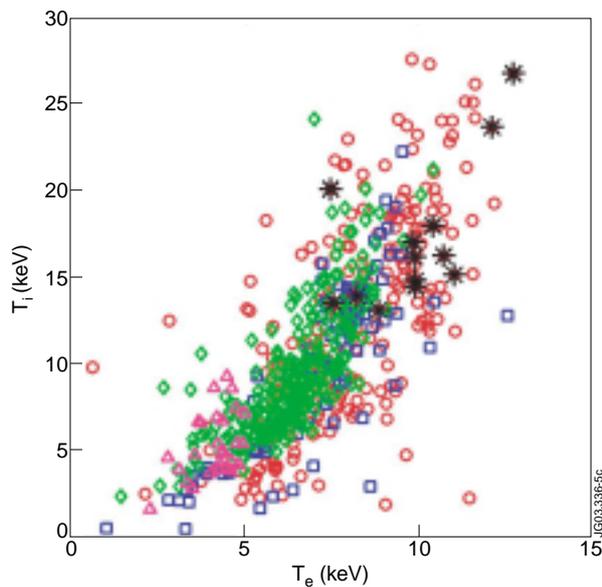
The key question is will ITER need active wall mode feedback, or could good error field correction with some momentum injection achieve the same result? With the new JET data and detailed modelling, now underway, we can start to address this question.



The magnetic detector orthogonal to the applied error field, starts to see a response from the plasma as it approaches the ideal limit.

# Stronger barriers with mode conversion

Ion cyclotron resonance heating power with high  $^3\text{He}$  concentrations ( $\sim 11\%$ ) in Deuterium plasma has been applied to Internal Transport Barrier (ITB) scenarios ( $B_T=3.6\text{T}$ ,  $I_p=2.8\text{MA}$ ). Radio-frequency heating results partly in ion heating through  $^3\text{He}$  minority and partly in electron heating through mode conversion, electron Landau damping and transit time magnetic pumping. In both ion and electron components the power deposition is more localized than in standard hydrogen minority heating. This is likely the reason why high performance ITBs were achieved at moderate additional power levels (13MW neutral beam heating + 3MW ion cyclotron heating).



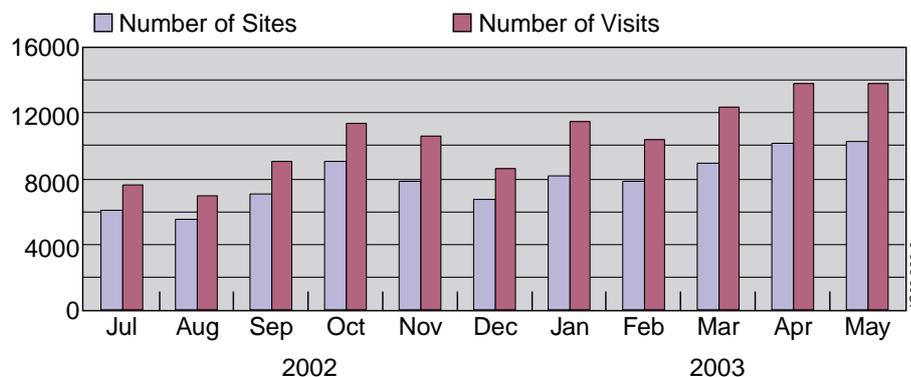
Profiles of ion and electron temperature ( $T_i$ ,  $T_e$ ), electron density ( $n_e$ ) and safety factor ( $q$ ) in Pulse No: 59411

The ITBs are characterized by simultaneously high ion and electron temperatures (see figure above) at peak density values  $\sim 5 \cdot 10^{19} \text{ m}^{-3}$ . The figure on the left shows how these experiments compare with the JET internal transport barrier database.

Central ion temperatures and electron temperatures for representative pulses in the JET Internal Transport Barrier database, showing the shots with  $^3\text{He}$  radio-frequency heating in black.

## JET Web site

In this age of the Internet, it is not a surprise that the JET web site is an efficient way to promote our research. The log file of our public site <http://www.jet.efda.org/> gives specific feedback of its success in this respect. In May 2003, more than ten thousand sites (unique IP addresses/hostnames) visited the JET public website, paying a total of 13823 visits (a visit groups a number of consecutive requests from a single site).

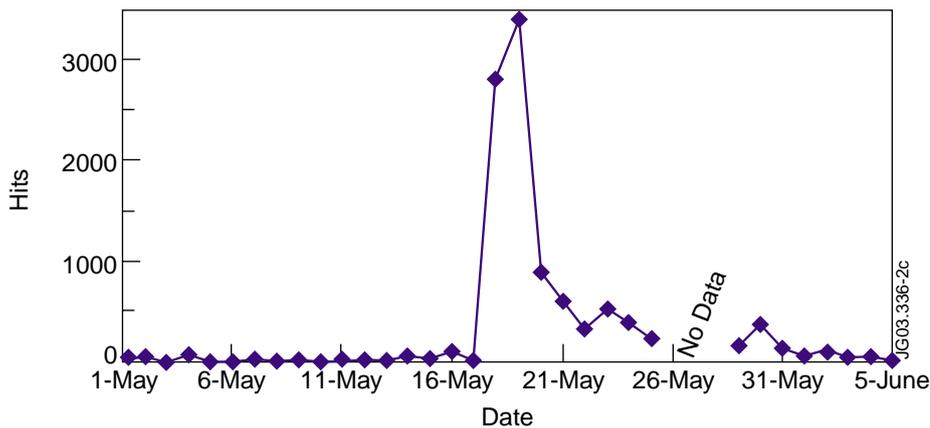


Statistics on JET public website

A conservative estimate indicates that more than ten thousand people access the JET website every month. It is also worth noting that the number of visits has almost doubled in the last year (see figure).

The interest in JET appears to be correlated with publicity of fusion as the peak in access from New Zealand in May demonstrates (see figure below). The event behind this peak was a feature on fusion research at JET, broadcast on prime-time TV in New Zealand on Monday morning 19<sup>th</sup> May (see *EFDA-JET press release from May, 21*).

What better way to show the importance and synergy of mass media and web presentation in providing information? Based on these statistics we intend to invest more effort in our public webpages: a new look is being developed that will feature "Focus On" articles, a series of items about different aspects of JET life. In addition, the news column will be updated more frequently, the navigation improved and the search facility simplified.



*Hits on our public website coming from .nz domain. The sharp increase appears overnight from 18<sup>th</sup> to 19<sup>th</sup> May GMT (add 11 hours to get New Zealand local time). Minor peaks correspond to early weekends.*

Different considerations apply to the JET Users web pages. Around seven thousand visits from one thousand sites are received each month at <http://users.jet.efda.org/>. That is, when compared to public pages, the user pages have fewer visitors but they read in more detail. The user pages, which are password protected outside JET, are popular with people involved in the JET programme. In fact, as a part of collective use of JET, any fusion expert of any EFDA Association or collaborating institutions worldwide can obtain access upon request. These web pages feature, amongst other things, a Pinboard widely used as a forum to discuss draft JET publications, a Message Board with private adverts, informative pages about the web (including statistics), and, most importantly, self-maintained pages of JET groups and Task Forces. We have asked Dr Richard Pitts from CRPP, Task Force E Deputy Leader, who has recently improved Task Force E web pages, for his views on this matter:



*Dr R. Pitts*

“Who would deny in today’s information age that the web is not a tremendous resource? Its power is used to good advantage by the JET Users website. Without it the large collaborative, European-wide effort that JET now represents would be considerably more arduous and, arguably, untenable. Much the same applies to individual Task Forces which represent the core of the JET scientific programme. A well structured and navigationally easy website can be built with only basic knowledge of HTML programming and yet can offer enormous benefit to the Task Force. Whilst more interactive complexity is clearly possible, Task Force pages are more often than not maintained by those who know the Task Force best - the TF leadership team. The structure must therefore remain modular and easy to extend without recourse to expert knowledge. Centralisation of good shot lists, experimental session planning documents,

Task Force publications, meeting presentations, experimental logbooks and many other useful documents requires nothing more than sensible organisation of simple pages and, once the hard work of defining the structure is done, a little effort in maintenance and updating as the scientific output proceeds. This small investment can be of great benefit to the efficiency and output of any Task Force, large or small.”

# EFDA-JET chairs EIROforum Assembly

On July 1<sup>st</sup>, the EFDA Associate Leader for JET Dr Jérôme Paméla started to assume a one year chairmanship of the EIROforum, a co-operation between European Intergovernmental Research Organisations. According to its charter (see <http://www.eiroforum.org/>) the primary goal of EIROforum is to play an active and constructive role in promoting the quality and impact of European Research. EIROforum has all the necessary assets for success. All seven member organisations are among world leaders in their respective fields of science and have significant experience in integrating national and international activities. One of the most active EIROforum Thematic Working Groups, the Outreach and Education Group, organises the popular Physics on Stage festival for science teachers from all over Europe. Details of the next Physics on Stage, which is organised as a part of the European Science and Technology Week in November 8-15 in the Netherlands, can be found on <http://www.physicsonstage.net/>.

EFDA is represented at the EIROforum Assembly by its Associate Leader for JET, Jérôme Paméla, and is assisted by the EIROforum Coordination Group Members, Michael Watkins and Michael Pick. Jérôme Paméla had the honour to give the first "EIROforum Briefing in the status of European science" talk to Members of European Parliament on June 17 in Brussels, entitled "ITER: Europe's role in developing fusion power".

"The ground-breaking work on JET and other devices forms the basis on which ITER has been designed. This gives us great confidence that ITER will be successful," said Jérôme Paméla. "JET and ITER are like stepping stones on the path to achieving fusion."

## Members of EIROforum:

European Organisation for Nuclear Research, **CERN**  
European Fusion Development Agreement, **EFDA**  
European Molecular Biology Laboratory, **EMBL**  
European Space Agency, **ESA**  
European Southern Observatory, **ESO**  
European Synchrotron Radiation Facility, **ESRF**  
Institut Laue-Langevin, **ILL**



Gérard Coudron MEP (right) with Dr. Jérôme Paméla in Brussels

Chaired by Gerard Caudron MEP, the event attracted sixteen MEPs as well as a number of MEP Assistants and key members from the Permanent Representations from Belgium, France, Germany, Spain and UK, to the EU commission.

Other notable guests included Francois deDonnea, Belgian Minister for Science and Yvan Capouet, Head of the Cabinet of Philippe Busquin, European Commissioner for Research. They and the other guests took the opportunity to meet some of the younger scientists working in the European Fusion Programme: Yasmin Andrew (UKAEA), Marc Beurskens (FOM), Mathias Brix (FZJ), Pascale Monier-Garbet (CEA) and David Ward (UKAEA).

## Close Support Unit in Culham

The turnover of the CSU staff continues according to the spirit of EFDA mobility. Fusion Technology has got two new responsible officers: **Gino Piazza**, arrived in March from FZK, and **Sandrine Rosanvallon**, arrived in June from CEA. **Sergio Ciattaglia** from ENEA has moved from CSU Culham to CSU Garching. **Jan Mlynar** from Institute of Plasma Physics, Prague, started in March and he is the first member of the CSU coming from one of the ten countries that enlarge the European Union next year. His duties are in the field of Public Relations, with special accent on the JET website.

# EFDA-JET leads cooperation among the Large Tokamak Facilities

The 18th Executive Committee Meeting for the IEA Implementing Agreement on Cooperation among the Large Tokamak Facilities was held at Culham 4-5 June 2003 under European Chairmanship, with representatives from EFDA-JET, JT-60U, DIII-D, C-Mod and ASDEX Upgrade.

The meeting reiterated the importance of co-ordinated experiments amongst several tokamaks. The International Tokamak Physics Activity (ITPA) has set priorities for such experiments in areas such as internal transport barriers, pedestal and edge physics, advanced scenarios, divertor and Scrape-Off Layer physics, disruptions and confinement scaling. From these priority areas a list of experiments has been drawn up and scheduled in the experimental programmes of participating machines for the current year. JET has already completed about half of its share of these experiments.



*Participants to the meeting, from the left to the right:  
Y Kawano (Japan), R Stambaugh (USA), N Sauthoff (USA), E Oktay (USA), O Gruber (Germany), M Kikuchi (Japan),  
M Watkins (EFDA), J Paméla (EFDA), M Cox (UKAEA), S Clement-Lorenzo (EU)*

The EU, US and Japanese representatives gave also an account of their respective fusion programmes.

In Japan ITER will be the focus and, independent of ITER decisions, four centralised programmes have been promoted by a Special Working Group for fusion research. In particular, high priority has been placed on the National Centralised Tokamak Device Programme which will overlap with ITER operation. It comprises the operation of JT-60U to be followed by the construction of its superconductive upgrade JT-60SC. The other three programmes are the Laser Fast Ignition Programme, the Large Helical Device Programme and international collaboration in reactor engineering using the future International Fusion Materials Irradiation Facility (IFMIF).

In the US the fusion budget for 2004 has been approved at a similar level to that in 2003. It is anticipated that the base US programme will not be curtailed with US participation in ITER. As a result DIII-D, C-Mod and NSTX have developed 5-year plans, with emphasis on increased exploitation.

In the EU the collective use of JET under EFDA is continuing as the key EU facility with significant enhancement planned for 2004. The extension of EFDA beyond the end of 2004 is under consideration. Vigorous participation in EFDA-JET by EU laboratories has continued in 2003 at a level of about 300 scientists. Several laboratories from the future EU countries, such as the Czech Republic, Hungary and Romania have begun participation in EFDA-JET after signing the EURATOM treaty and EFDA. Discussions are currently underway for participation by Latvia. In addition a bilateral agreement with the Russian Federation has been signed and Russian participation in EFDA-JET is likely to start this summer. This would augment the large collaborations which already exist with the US and Japan.

# Project Management Training Course

During March-April 2003 a Project Management Training Course was held at a venue in the New Forest near Southampton (UK). This 3-day course was run three times, attended by a total of more than 40 people from the Associations (mostly Project Leaders), the JET Operator and EFDA CSU, all involved in the JET Enhancement Programme linked to the 2004 shutdown. The course was preceded by an introductory day held at Harwell in November 2002 where all the attendees worked together on how to run enhancement projects within the complex EFDA organisation.

The course was tailored in collaboration with a training company, Hemsley Fraser, to make it very interactive, with group exercises and presentations on pre-selected topics being prepared beforehand.

## The main topics of the course:

- General organisational constraints
- Project lifecycle
- Planning
- Communication
- Management of suppliers
- Risk Management
- Organisation of the 2004 Shutdown
- Quality Assurance

The overall objectives were to improve project management techniques and reinforce the team spirit of all those involved in the JET Enhancement Programme, particularly important when they come from all over Europe, with even some from the United States.

The course was very successful, with active and lively participation from all attendees – and strong "fusion-style" discussions as well! Improved communications have already resulted, as seen in the very successful JET Enhancement General Progress Meeting held at Culham on 12-13 June 2003.

The main content of the course is available on the EFDA-JET Users' Website on the Enhancement page. Many thanks to all those who took part so enthusiastically!

## JET Events

January 13	Delegation of French Ministry of Finance and French Ministry of Industry	June 4-8	JET participates at Cheltenham Science Festival
January 16	James Owendoff - US DOE	June 5	IEA Large Tokamak Executive Committee (see article)
February 20	London Diplomatic Science Club	June 17	EFDA-JET EIROforum Briefing talk to MEPs in Brussels (see article)
February 21	ITER Japan Delegation led by Vice minister K. Namiya	June 24	EFDA Steering Committee
March 19-21	IEA workshop on In-vessel tritium inventory	June 25	Derek Robinson Memorial Seminar (see EFDA Newsletter)
March 25-26	IEA workshop on Management of wastes from fusion facilities	June 25	JET celebrates 20 years from the first plasma (see article)
April 28-30	18th CCLH Meeting		
May 19	Reporting Meeting for Campaigns C5 - C7b		

## Culham Families and Friends Day

EFDA supports UKAEA Culham Division in the final preparations for the Families and Friends Day scheduled for Saturday 6<sup>th</sup> September. It is planned that – amongst others - the JET Torus Hall, JET Remote Handling, MAST and START areas will all be open. The interactive Fusion Roadshow originating from FOM will be shown in the JET main seminar room, live music from a jazz band will be provided, display stands will illustrate activities of Culham social clubs and a number of attractions will be organised for children. The event is open to any relations or friends of staff members - subject to pre-registration.