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ABSTRACT

Since the beginning of 2000, the Joint European Torus (JET) has been used under the European Fusion Development Agreement (EFDA) as a user facility. In this framework, the UKAEA as 'Operator' maintains and operates the facility and installs enhancements on behalf of EFDA under contract to the European Commission. The experimental programme is proposed and implemented by the 'users', scientists and engineers on secondment form the European laboratories. These laboratories also supply equipment for enhancement of the facility. The overall programme is co-ordinated and managed by the EFDA JET Close Support Unit. There have since been five experimental campaigns. The historical rate of successful pulsing has been largely maintained. One major shutdown has been completed with substantial in-vessel and ex-vessel tasks, and various small enhancements have been installed. The first major enhancement is imminent. The UKAEA has an overriding responsibility for safety and for the environmental impact of the project, including management of waste. These responsibilities need to be reconciled with the Operation of the facility. This paper reviews the requirements and procedures for control of the interface between the Operator, the Close Support Unit and users, presents performance measures for key aspects, and summarises the experience of the UKAEA in the operation of JET.

1. INTRODUCTION

Since January 2000, the JET facility has been operated by the UKAEA under contract to the European Commission. This follows a period of 22 years of design, construction and operation as the JET Joint Undertaking, and coincided with an important loss of personnel and skill from the project. The management of JET Operations has had to evolve to accommodate the roles and responsibilities of the parties under this new organisation.

The EFDA JET Close Support Unit (CSU) is responsible for the management and co-ordination of the JET experimental programme, for analysis and dissemination of the results and for monitoring of the UKAEA implementation of the operating contract. The UKAEA are responsible for the management of the site and operation of the facility under the JET Operating Contract. The UKAEA has responsibilities under UK legislation for safety and for the control of discharges to the environment. In addition, the UKAEA is responsible for the de-commissioning of the JET facilities on completion of the project.

Enhancements are managed by the CSU. Each enhancement is led by a Project Leader from the Associations. Equipment is designed by Associations under contract to the Commission, and manufactured by industry also under contract to the Commission. The role of the Operator is to approve the designs, to ensure compatibility with the existing equipment, to ensure that the design and quality of manufacture are consistent with the safety case and environmental responsibilities, and to install and operate the equipment. In contrast, maintenance and refurbishments necessary to ensure reliable operation of the facility are the sole responsibility of the Operator and are implemented under UKAEA procedures.

A total of five campaigns, one major shutdown, and one modest shutdown have been completed.

The availability of the machine for operations has been high and the pulse rate has been similar to that achieved under the Joint Undertaking. The campaign C5 has been less satisfactory due to technical difficulties with the plant. The major shutdown was completed over the period April – November 2001. All of the planned activities were completed on time and within the agreed integrated dose to the workforce. The following restart was scheduled to last 14 weeks, but technical faults led to a two weeks delay in handover to the Task Forces.

2. MANAGEMENT SYSTEMS

2.1 JET OPERATIONS

The JET Operating Contract (JOC) is a contract between the European Commission and the UKAEA. The EFDA Associate Leader for JET is responsible for monitoring and control of the implementation of the contract by UKAEA. Responsibility within UKAEA lies with the Operations Director for Culham Division. Each party reports to supervisory committees. Within the project, there is a close working relationship at many levels, both formal and informal. A JOC Supervisory Board comprising the Directors and senior managers monitors performance, agrees draft high level work programmes, including dates for shutdowns and operating campaigns, and agrees the main activities during shutdowns. These are subsequently approved by various EFDA committees before being formally incorporated into the forward programme. This is a lengthy process but it does ensure consensus and understanding on key issues.

The physics programme is defined by a series of expert task forces in specific physics areas. An executive committee comprising senior managers from CSU and UKAEA, and the Task Force leaders agrees the detailed experimental programme prepared by CSU and the Task Forces, and the allocation of resources to the task forces, for example, neutron budgets or operation at TF fields above 3.4Tesla - such allocations are subsequently enforced by the Operator. The Operator is responsible for provision of Tokamak operational days necessary to implement the agreed programme, and for maintenance and refurbishment of the plant necessary to provide this operation. Detailed preparation and monitoring of operations are managed through weekly Co-ordination meetings including both Operator and CSU personnel.

The Operator in turn manages the implementation of the contract through a separate board and two further weekly co-ordination meetings, one to control commissioning, maintenance and repair activities to maximise the availability of the plant, and the second to control the design and integration of new facilities on the torus, including enhancements. With total of over 500 people, including industrials, working for the Operator, these coordination meetings play a central role in the implementation of the contact.

Operation of JET as a user facility exploited by visiting scientists requires long term planning and strict schedules of activities. Secondments of personnel to JET are planned many months in advance, and the overall experimental programme/shutdowns need to be planned typically 1-2 years in advance. Many of the Session Leaders are secondees who have been given extensive training by the Operator over many months; some eight experienced session leaders have trained a further 30 secondees to various levels of qualification since 2000. Session Leaders are licensed to operate within limits on plasma current and disruption forces depending on their level of training.

2.2 MANAGEMENT OF SAFETY

The UKAEA must ensure compliance with UK safety and environmental legislation. JET is a category 2 nuclear site (there being no foreseeable incident which would require off-site sheltering), which means that it is not a licensed site subject to Nuclear Installations Inspectorate procedures. JET operations are supported by written, peer-reviewed safety cases and carried out under the control of a nominated 'Authority to Operate' holder (ATOH). These officers are appointed by the Operations Director and carry personal responsibility for ensuring the safety of operations within their areas. Safety is monitored by a hierarchy of committees, the more senior including both outside experts and UKAEA regulators. A single safety case covers the JET torus and tritium plant ATO's; others include power supplies, diagnostics... Written procedures are implemented for definition and control of the boundary between ATO's. Each ATOH has procedures, local rules, risk assessments and appropriate incident response capability to cover work in their areas.

Safety management requires a clear division of responsibility between the UKAEA personnel operating the plant, and the EFDA personnel implementing the physics programme. The operation of the tokamak is the responsibility of the Engineer-in-charge (EIC) representing the torus ATOH. He has the responsibility for ensuring that all operations comply with UKAEA safety, environmental and machine integrity requirements. The Session Leader, who is appointed by the Task Forces to execute the experimental programme in the control room, defines the pulse requirements and produces the detailed pulse specification. However, the pulse is loaded by the EIC, confirmed by the EIC to be compatible with operating limits and safe to run, and executed by the EIC.

Whilst neutron production is a measure of success of the physics programme, it also activates the machine and leads to a radiation dose to workers. Dose limits to the workforce are defined by the Operator on ALARP grounds. The level of activation at the start of a shutdown is agreed by the Operator and the CSU. Limits on neutron production are managed using a model of activation of the machine by production of cobalt isotopes by 14MeV and by 3.4MeV neutrons. The CSU allocate neutrons to each session in a campaign consistent with the target activation limits, and these limits are enforced by the Engineerin-charge on behalf of the Operator.

2.3 CONTROL OF THE INTEGRITY OF THE MACHINE

The Operator is also subject to UK legislation on the environment and is responsible for the control of environmental discharges. Limits are defined in the site authorisation issued by the Environmental Agency. The Operator may insist on measures which ensure the control of discharges to the environment as well as for safety. Control of the tritium boundary in particular lies with the Operator on both safety and environmental issues. Responsibility for control of the integrity of the machine for issues not affecting safety and the environment, for example the coils or first wall tiles, is not clearly defined. Operating limits are defined in Attachments V of the JOC. The Operator has a further responsibility to impose tighter limits if required. The Operator must accept the design of new equipment as consistent with these limits, or agree more restrictive limits with CSU. In practice, the Operator has also defined detailed design requirements for certain equipment, notably invessel components, which have been accepted by CSU. These limits minimise the risk of in-vessel failures and thus reduce both down time and the dose to the Operator workforce. The analysis of coil limits carried out under the Joint Undertaking 4Tesla study is used by consensus to define coil operating limits.

In Tokamak operations, the Operator controls the machine integrity by a comprehensive set of Operation Instructions. These are widely used by the Task Forces to design pulse scenarios, but enforcement is ultimately the responsibility of the Engineer-in-charge representing the Operator. Session Leaders are accepted by the Operator to run only within a restricted range of plasma current and potential disruption forces, depending on their experience, as a further protection against damage to the plant.

3. PERFORMANCE MEASURES

3.1 OPERATIONS

The provision of performance measures allows review by the Operator and CSU on a factual basis, gives the Operator clear objectives, assists the Session Leaders in preparing their programmes, allows the Operator to identify critical maintenance, and helps maintain a good level of co-operation between Operator and experimental personnel.

Various statistics are routinely compiled, notably the number pulses per day, the number of successful pulses per day, the delivered heating power for each system and the lost time due to plant failures. Other performance measures are being introduced, in particular, an assessment of the physics output of a pulse by the session leader. From Fig 1 and Fig 2, the total number of pulses and the number of successful pulses per operating day over campaigns C1-C4 (2000/2001) are seen to be very similar to those obtained under the Joint Undertaking. The pulse rate is limited by hard limits, such as plant cooling time or data acquisition, by soft limits such as ‘thinking time’ by the session leader or the EIC, and by plant failures. All plant failures are recorded and lost time attributed to specific systems. Cumulative delays over C1-C5 are shown in Fig. 3 which clearly identifies the power supplies as critical plant.

In campaign C5, a series of technical problems led to important delays in the operation of the machine. These delays partly reflect the loss of commissioning time due to other technical faults during restart, and partly the loss of expertise. The critical change is the impact of such problems on the programme. It is very difficult to reschedule the programme at short notice, leading to loss of secondee time and much frustration. The Operator will in response seek more time for maintenance during operations, more contingency during shutdowns to ensure the reliability of the plant. The balance of spending between maintenance, refurbishment and operations is agreed by the Operator and CSU. Limited refurbishment of plant with potential for major delays in JET operations, including parts of the cryoplant, parts of the CODAS system and critical neutral beam line components is planned for the 2004 shutdown. Enhanced remote participation would allow increased flexibility in the programme.

3.2 ENHANCEMENTS

The Operator must also approve and accept the design of all new equipment as being compatible with safe operation of the facility, and thus must also define minimum quality standards during manufacture. CSU are responsibility for managing the design and procurement of enhancements by the Associations, including UKAEA, under orders raised by the Commission. Major procurements are carried out by the Commission under so-called Article 7 procedures working to specifications issued by the Associations and agreed by the Operator. The Operator is responsible for:

- Defining the design conditions and accepting the calculated loads and stresses.
- Assessing the compatibility of the design with existing equipment.
- Accepting the designs, in particular the provisions for quality assurance and safety.
- Accepting the equipment for installation on the machine.
- Installation of the equipment, including the design and provision of remote handling or other tooling.
- Commissioning and operation of the equipment.
- Disposal of loose waste arising.

This process clearly has many points of interface between the Operator, the CSU and the Associations. The Operator appoints liaison officers for each stage: the Contact Person manages the interface during the conceptual phase; the Operator Representative manages the interface during detailed design and procurement; the Installation and Commissioning Manager accepts the delivered equipment and installs/commissions the enhancement.

The key performance measure is the date of completion. Each partner is dependent on timely completion by the others, and the Operator is ultimately dependent on a timely supply of enhancements for installation on the machine. Experience shows that enhancements managed using S/T orders and notifications have progressed satisfactorily, and around 10 such enhancements have been completed or are imminent. For major enhancements, there is a lead time of typically 3 years between conception and completion. The first (the NB power supply upgrade) is now anticipated to be completed in early 2003. As JOC has an duration in the first instance of only three years, it has clearly been necessary to take into account requirements beyond the initial duration of the contract .

3.3 SHUTDOWNS

Shutdowns are planned 1-2 years ahead. Preparation of remote handling activities requires final design data at least 12 months in advance of the start of the shutdown. Final agreement on the scope of a shutdown is a key milestone only achieved a few months ahead in practice. Once agreed, the implementation is an Operator responsibility.

The critical performance measures for the Operator and CSU in shutdowns and interventions are listed in Table 1 along with the outcome for the shutdown which started on 1 April, 2001. Safety measures were all achieved in full; there were small overruns in cost and a two week delay in hand-over for operations after a 12 month outage. Severe restrictions were imposed on the size of the workforce as a cost control measure, but led to some inefficiencies and frustration. This, combined with additional work which arose during the shutdown, required these limits to be relaxed. The error field coils could not be completed due to theft of the cable.

CONCLUSIONS.

JET has been operated by UKAEA on behalf of EFDA as a user facility for visiting scientists since the start of 2000. In the period since, safe and effective operation of the facility has been achieved as a result of strong co-operation between the JET CSU, the Operator and the Task Forces. Management systems for agreement, implementation and control of the experimental programme and of enhancements to the facility, and procedures to ensure the safety of operations and control of the environment, have been put in place. The division of responsibility between the Operator and CSU has clarified with experience over this period, and performance measures are being put in place. Many smaller enhancements have been implemented and one major shutdown completed. Plasma operation under the new organisation has been very successful in delivering experimental time to the Task Forces.

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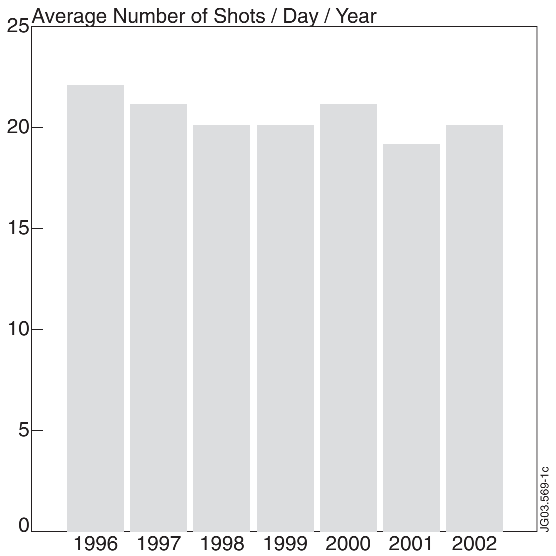

Figure 1: Pulses per day in the period 1996-2002.

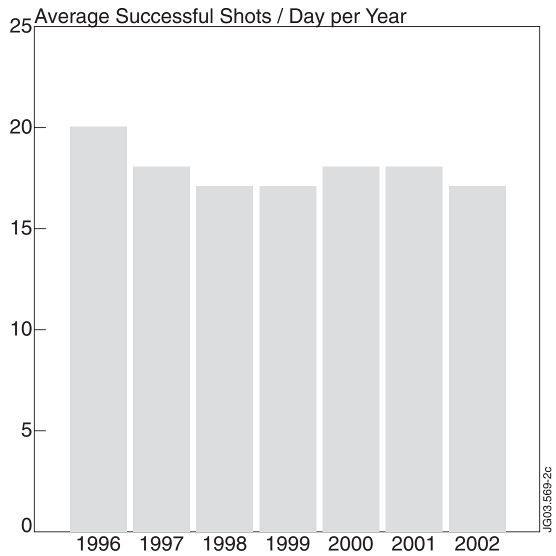

Figure 2: Fraction of successful pulses in the period 1996-2002.

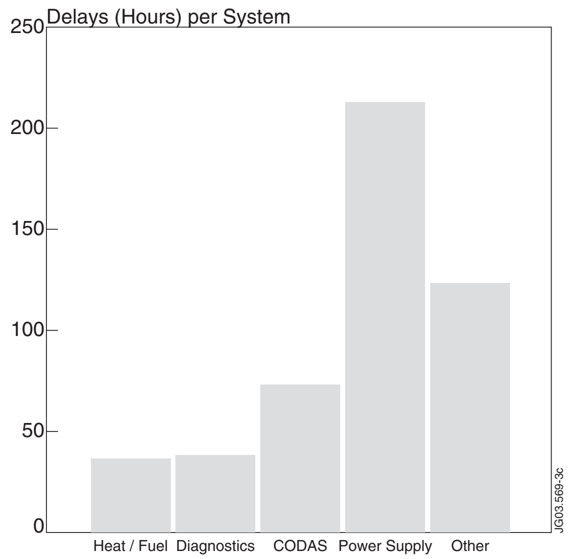

Figure 3: Delays attributed to specific plant in period 2000-2002.

Measure	Target	Outcome
Date of Completion: Shutdown (Torus Pumpdown) Restart	 26 November 4 March	 26 November 18 March
Scope of Work	Agreed Programme	All Except Two Error Field Coils
Cost of Workforce	£3.1 M	£3.4 M
Integrated Dose, In-vessel Work	22 Man.milliSieverts	21.2 Man.milliSieverts
Max. Individual Dose	3 MilliSieverts	2 MilliSieverts
Lost Time Accidents	<2	0

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Table 1: Performance measures for the 2001 shutdown.