EUROPEAN FUSION DEVELOPMENT AGREEMENT

JET

EFDA–JET–CP(06)03-07

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A Unified Approach to Equilibrium Reconstruction

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** See annex of J. Pamela et al, "Overview of JET Results ",*
(Proc. 20th IAEA Fusion Energy Conference, Vilamoura, Portugal (2004).

Preprint of Paper to be submitted for publication in Proceedings of the
33rd EPS Conference,
(Rome, Italy 19-23 June 2006)

1. INTRODUCTION

Equilibrium reconstruction forms the core of most tokamak modelling activities. Until now the general practice has been for various tokamaks experiments to have their own unique equilibrium reconstruction codes, such as particular versions of EFIT [1, 2, 3, 4] or the CLISTE [5] code. This paper describes **EFIT-f95** and **EFIT2006**, two new machine-independent versions of the EFIT code.

2. EFIT-F95

The EFIT-f95 code is the first **Fortran 95** machine independent version of EFIT, based on the EFIT source code originally developed for MAST. It is better structured than the existing JET EFIT code so was chosen as the basis for integration between JET and MAST. The internal data organisation uses the ITM-defined hierarchical data structure [6]. The structure is populated using generic interfaces to databases via IDAM [7] and MDS+[8] and by the contents of local namelist files. The current JET iron model is included in the code. Idiosyncrasies between the MAST and JET versions of EFIT have been resolved with code control switches. The code was tested with 2 different Fortran 95 compilers (Portland and Intel). The same executable file can now be used to reconstruct both MAST and JET equilibria.

3. EFIT2006

EFIT2006 is a new machine-independent version of the EFIT code. The implementation adopts a data structure design based on the ITM6 project and utilises modern computing practices (for example object-oriented design and XML). Compared to EFIT-f95, EFIT2006 offers a greatly improved user-interface and an underlying architecture that is well suited for integrated tokamak modelling.

4. ISSUES WITH PRESENT-DAY EQUILIBRIUM RECONSTRUCTION FACILITIES

At present users requiring an equilibrium reconstruction of a tokamak plasma must deal with the following issues:

1. There is no standard equilibrium reconstruction code.
2. Equilibrium codes generally have built-in machine-specific features.
3. The ability to handle time-variation of “non-standard” constraints may be limited.
4. There is no consensus on methods for:
    - i) accessing experimental databases.
    - ii) inputting data from users.
    - iii) creating and using a complete input data set for “standalone” operation.
    - iv) passing equilibrium data to other codes.
5. There is no standard definition of units.
6. Documentation may be inadequate.

5. DESIGN OF EFIT2006

Many of the above issues are concerned with the interface of the equilibrium code to the outside world. Significantly these issues are generally relevant to all tokamak analysis codes. Conceptually, we divide the development of EFIT2006 into two parts: an EFIT engine and a driver. The engine contains the reconstruction algorithm for a single time-slice, while the driver handles all the data flow. The standard practice of computing tabulated response functions between the computational grid, the poloidal field coils, and the magnetic diagnostics is implemented via a second engine and driver. Qualitatively the situation is illustrated in figure 1. The figure shows the basic structure of an object-oriented model. Such a model consists of a set of objects, each one of which may contain both data and functions operating on the data. In figure 1 each functional unit is denoted as a series of three concentric rings. The engines, in this case EFUND (computes tabulated response functions) and EFIT (computes equilibrium reconstruction for a single time-slice), are situated within the inner ring. The outer ring contains two sets of data objects describing (a) the tokamak parameters and (b) the code-specific parameters. Data in these objects are obtained from an experimental data base using IDAM or MDS+, or alternatively from a local file using Extensible Markup Language [9] (XML). An additional facility has been provided to translate FORTRAN-style namelists to XML, enabling a fourth possible means of data entry. The use of XML enables the user to enter structured information in a very flexible manner with low coding overheads. Since the data is represented in a text format it is not suitable for large data sets and for this purpose facilities to read and write binary files are provided.

The middle ring contains structures that are either required as input by the engine, or are populated by the engine upon completion of its task. Two tasks may need to be undertaken. These are marshalling tasks i.e. remapping data between structures; and data selection tasks which for time-dependent data may involve data interpolation or the use of some other criterion to populate data structures required by the engine. The area beyond the outer ring denotes the outside world. The flow of data is indicated by arrows. An important principal illustrated by the figure is that all input and output is handled by the objects in the outer ring; whereas the data objects in the middle ring do not interact directly with the outside world. Also, data selection and marshalling is not always necessary, for example a “limiter” object describing the limiter position can be used directly by the EFIT engine. In general, the data input into the engine consists of a set of one or more objects, and on completion of its task the engine places its output into a single object.

The close association of member data and member functions is a natural feature of the object-oriented approach. The resulting code is more easily maintained than equivalent code written, for example, in Fortran 95. The advantages of an object-oriented approach are particularly significant for the ITM project where the underlying data description is strongly hierarchical.

The implementation of the driver has been carried out using C++. This has the added advantage of a freely available document generator DOXYGEN [10] that facilitates the generation of high-quality documentation maintained in-line with any code developments. Currently, the engine modules EFIT and EFUND are implemented in Fortran 95. These modules contain no default settings and all free parameters must be provided by the driver. The physics units follow ITM guidelines. The code has been run successfully on MAST, JET and ITER, in the latter case using data simulated by the DINA-CH code, accessing data via MDS+, IDAM and XML. Figure 2 shows a reconstruction of a 15MA ITER plasma.

SUMMARY

In summary, a new unified equilibrium reconstruction code called EFIT2006 has been developed with a C++ driver. Its design overcomes major shortcomings of present equilibrium reconstruction codes and its use has already been demonstrated on three tokamaks. In the future, the code will be applied to more tokamaks and the underlying architecture of the code will enable the code to be extended to carry out integrated tokamak simulations.

ACKNOWLEDGEMENTS

This work was partly funded by the United Kingdom Engineering and Physical Sciences Research Council and by the European Communities under the contract of Association between EURATOM and UKAEA, and between EURATOM and CIEMAT.

REFERENCES

[1]. L.L. Lao et al Nuc Fusion Vol **22** (1985) 1611.
[2]. L.L. L ao et al Fusion Science and technology, **48**, 968(2005).
[3]. D.P. O'Brien et al Nuc Fusion vol.**32** (1992) 1351.
[4]. W. Zwingmann Nuc Fusion Vol.**43**,(2003) 842.
[5]. P.J. McCarthy Physics of Plasmas Vol. 6 (1999) 3554.
[6]. G.T.A. Huysmans et al “Integrated Tokamak Modelling TaskForce: The integrated Modelling Project on Equilibrium and Linear MHD Stability”, At this conference.
[7]. D.G. Muir et al 16th Annual Conference on High-Temperature Plasma Diagnostics, 7 to 11 May 2006, Williamsburg, Virginia, USA, paper THP26, (to be publ in Revof Scientific Instruments). [8]. JA Stillerman et al Rev of Scientific Instruments vol.68 (1997).939.
[9]. http://www.w3.org/XML/.
[10]. http://www.stack.nl/~dimitri/doxygen/

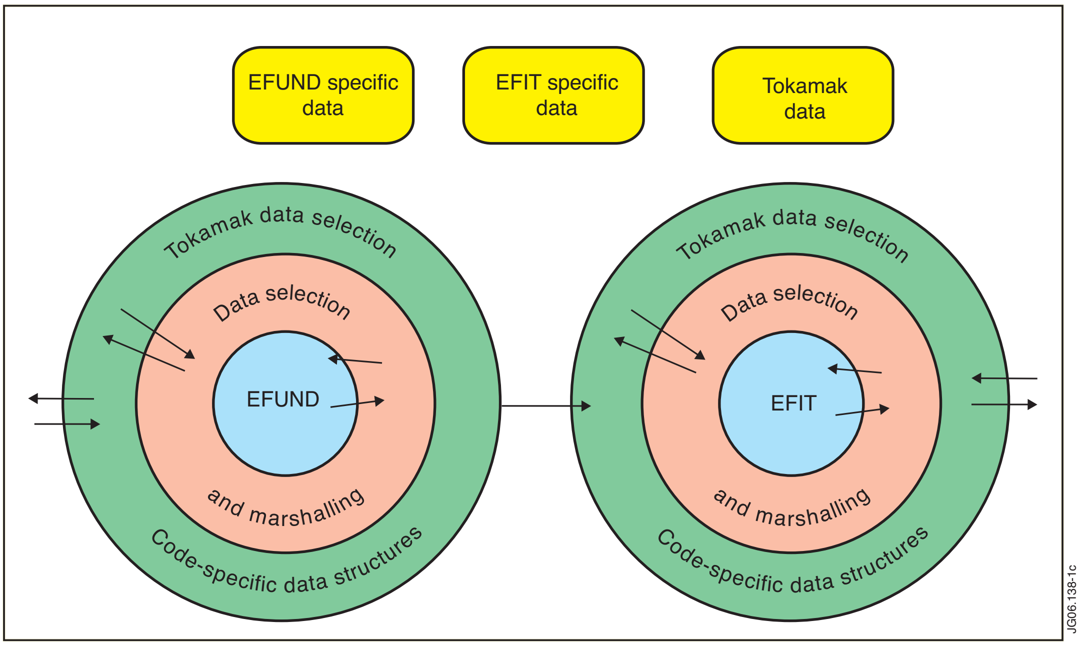

Figure 1: Data flow diagram.

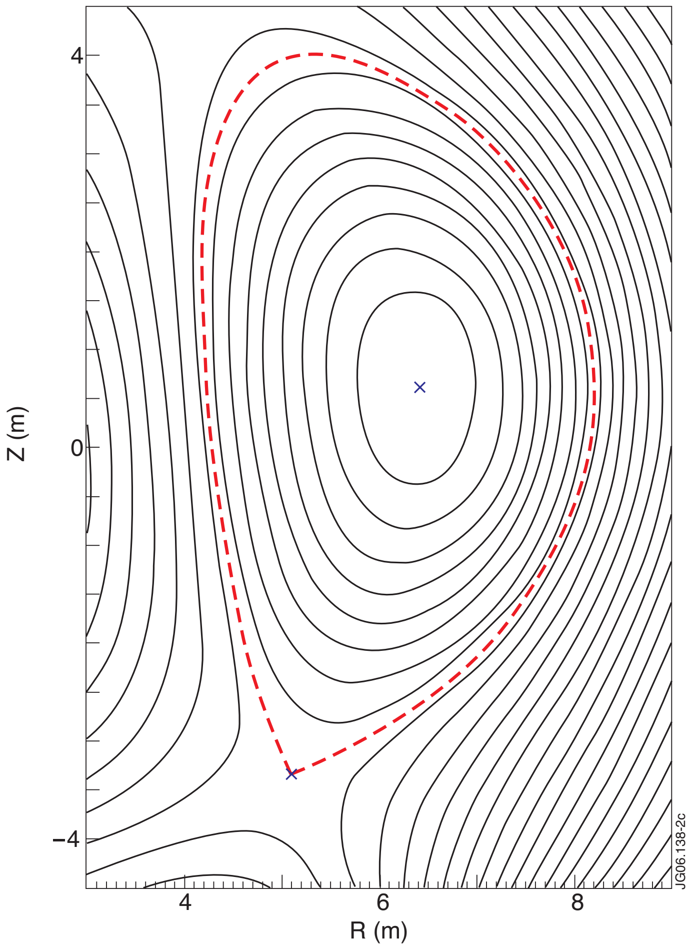

Figure 2: Reconstruction of ITER simulated data using EFIT2006