1. INTRODUCTION

1.1. PREFACE

Portugal participates in the Fusion Programme of the European Atomic Energy Community (EURATOM) through:

- The Contract of Association signed on January 1st 1990 between EURATOM and "Instituto Superior Técnico" (IST).
- The European Fusion Development Agreement, signed by EURATOM and the Associates.
- The Agreement on the Promotion of Staff Mobility in the field of Controlled Thermonuclear Fusion, also signed by EURATOM and the Associates.

The Portuguese participation in this research and development (R&D) programme has the following main objectives:

- Operation of a fusion plasma device at IST, for the development of a scientific programme on tokamak physics, testing of new diagnostic, control and data acquisition techniques and education and training of engineers and physicists on plasma physics and engineering.
- Participation in the R&D programmes of other fusion experiments.
- Participation in the Fusion Technology Programme
- Keep-in-touch activity of the R&D on inertial fusion energy
- Increasing of the public understanding of nuclear fusion

To fulfil these objectives the Association EURATOM/IST has carried out in 2000 activities in the frame of the following projects:

- Tokamak ISTTOK
- Participation in the use of the JET Facilities by the EFDA Associates
- Reflectometry Diagnostics for Fusion Plasmas
- Engineering Systems and Tools for Fusion Devices
- Studies on Non-Inductive Current Drive
- Studies on Transport and MHD
- Keep-in-touch Activities on Inertial Fusion Energy
- Participation in the Technology Fusion Programme

which are briefly summarized in the next section of this chapter and described in detail in chapters 2 to 9 of this document, where some technical notes concerning the main results obtained in these projects are also presented. Chapter 10 reports other fusion related activities and Chapter 11 contains information about the scientific publications of the Association.

Table 1.1 presents information about the responsible person(s) for each project as well as the collaborating Institutions.

Project	***Responsible Person(s)***	***Collaborating Institutions***	
		Portuguese	***Other***
Tokamak ISTTOK	Carlos Varandas José Cabral	CFN[1], UBI[2], CEI[3], CFA[4]	CIEMAT[5], IPP-Kharkov[6], UI[7]
Participation in the use of the JET Facilities by the EFDA Associates	Fernando Serra	CFN, UBI	EFDA[8] CSU[9] Culham UKAEA[10]
Reflectometry diagnostics for fusion plasmas	Maria Emília Manso Fernando Serra	CFN, CEI	IPP-Garching[11], UKAEA, CIEMAT, DFRC[12]
Engineering systems and tools for fusion devices	Carlos Varandas	CFN, CEI CFA	CRPP[13], CIEMAT, UKAEA
Studies on non-inductive current drive	J. Pedro Bizarro	CFN	DFRC
Studies on transport and MHD	Fernando Serra	CFN	IFP[14]
Keep-in-touch activities on inertial fusion energy	J.T. Mendonça	CFP[15]	
Participation in the Technology Fusion Programme	Carlos Varandas J.C. Soares	ITN[16], CFN, CEI	ENEA[17]

Table 1.1 – Responsible person(s) and Institutions involved in each project

[1] CFN means "Centro de Fusão Nuclear"
[2] UBI means "Universidade da Beira Interior"
[3] CEI means "Centro de Electrónica e Instrumentação da Faculdade de Ciências e Tecnologia da Universidade de Coimbra"
[4] CFA means "Centro de Física Atómica da Universidade de Lisboa"
[5] CIEMAT means "Centro de Investigaciones Energeticas Medioambientales y Tecnologicas"
[6] IPP- Kharkov means "Institute of Plasma Physics of the National Science Center" "Kharkov Institute of Physics & Technology".
[7] UI means University of Innsbruck.
[8] EFDA means "European Fusion Development Agreement"
[9] CSU means "Close Support Unit"
[10] UKAEA means "United Kingdon Atomic Energy Authority"
[11] IPP-Garching means "Max-Planck-Institut für PlasmaPhysik"
[12] DFRC means "Department de Recherches sur la Fusion Controlée"
[13] CRPP means "Centre de Recherches en Physique des Plasmas de École Polytechnique Federal de Lausanne"
[14] IFP means " Istituto di Física del Plasma"
[15] CFP means "Centro de Física dos Plasmas"
[16] ITN means "Instituto Tecnológico e Nuclear"
[17] ENEA means " Ente per le Nuove Tecnologie, l'Energie e l'Ambiente"

1.2. SUMMARY OF THE ACTIVITIES

The *tokamak ISTTOK* was in operation during about 20 weeks in 2000 due to several problems on the vacuum and slow control systems. Activities in the areas of discharge production systems, diagnostics and tokamak physics have been carried out. Concerning the discharge production systems some repairs on the vacuum systems have been performed and the development of a new slow control system has been initiated. Regarding diagnostics, a new set of three emissive Langmuir probes, a movable electrode and a second optical fiber on the Thomson scattering diagnostic have been installed. Improvements of the ion gun of the heavy ion beam diagnostic have begun. Studies of the runaway generation and of the disruptive instability, analysis of the plasma stability modifications produced by an external helical current established between two localised limiters, studies of the influence on the plasma confinement and stability from a limiter biasing process with an alternating voltage, determination of the edge plasma potential profile with emissive Langmuir probes and measurements of the plasma potential by the HIBD with a time-of-flight method have been made.

The Association EURATOM/IST participated in 2000 in *the use of the JET Facilities by the Associates*, in the frame of the "European Fusion Development Agreement" through the "JET Operation Contract" and the "JET Implementing Agreement". Activities in the areas of operation, scientific exploitation and management have been carried out. Two engineers were seconded to the JET Operating Team, working on the Motional Stark Effect and reflectometry diagnostics. Concerning the scientific exploitation, nine Portuguese physicists have participated in the JET campaigns as well as on the evaluation of the experimental data. The main areas of work have been transport, MHD activity and Diagnostics. Regarding the management activities, IST/CFN staff has participated in meetings of the EFDA JET Sub-Committee and of Ad-Hoc Groups for the evaluation of the JET Enhancement Performance Project, diagnostics and remote participation. One physicist was a member of the EFDA Culham Close Support Unit.

The project *"Reflectometry Diagnostics for Fusion Plasmas"* aims at the design, construction, testing, implementation, operation and maintenance of reflectometry systems on ASDEX Upgrade, JET, TJ-II, MAST and ITER, as well as the development of data analysis methods and plasma physics studies based on data provided by these diagnostics. On *ASDEX-Upgrade* activities on microwave circuits and electronics, control and data acquisition, data processing and evaluation, plasma physics studies and ITER relevant studies have been performed. Concerning the microwave circuits and electronics the following tasks have been made: installation of one channel in the V-band to monitor continuously the level of fluctuations at selected plasma layers, development of in-phase and quadrature heterodyne detection for the previously mentioned channel, development of a new system for remote control of the fluctuations monitor, design and construction of a new antenna with a hog horn configuration for the V-band channel, inspection during the August shutdown of the in-vessel waveguides circuits and antennas, implementation of modifications in the antenna protections and assessment of the problems of the signal-to-noise ratio of the V and W-band channels. Regarding control and

data acquisition, a multiple serial port SBUS card was installed on the control workstation and the control software was integrated in the main configuration and software running in the workstation. Concerning data processing and evaluation IST/CFN has developed software tools to enable the routine evaluation of density profiles and their availability to the users 10–15 minutes after each discharge and to extract automatically the temporal evolution of the radial position and density gradient at selected density layers, under the presence of plasma turbulence. Plasma Physics studies on the sustainement times during inboard pellet launch experiments and turbulence during improved confinement scenarios and ECRH modulation experiments have been carried out. The ITER relevant activities have included experimental and simulation studies to interpret the signatures of the MHD modes on the broadband reflectometry signals, measurements on edge plasma position aiming at demonstrating that reflectometry signals can be used in feedback loops for machine protection and plasma control and the study of a method based on a neural network approach to reduce the computation time needed for evaluation of edge plasma position to times compatible with the control requirements. On *TJ-II* the following activities have been performed: analysis of the frequency results showing the effect of heating on the plasma turbulence, assessment of the problems detected in broadband operation, study of a new installation of the system in the stellarator hall to minimize the effect of ground loops, and development of a sweep signal switcher to enable sequential sweeping of different frequency bands without dead time between band segments. On *MAST* IST/CFN has constructed microwave antennas, the drivers and the power supplies for the microwave generators and the detections amplifiers, assessed the conditions required to integrate the data analysis tool in the MAST data acquisition environment and selected and ordered the HTO oscillators. Concerning *ITER* the following tasks were carried out: participation in the EU-ITER Progress Meeting on Diagnostics, acceptance of major responsibility in a Design Task to re-evaluate the conceptual design of reflectometry for ITER presented in the Final Design Report and elaboration of the content of a R&D Task entitled “Construction and Test of a Typical Microwave Run”. Finally this project included the development of a Finite Difference Time Domain two dimensional code suited for broadband O-mode reflectometry, the application of this code to the study of typical features encountered on the ASDEX Upgrade discharges and the beginning of a collaboration between IST and two French research organisms: CEA and CNRS.

The project **“***Plasma Engineering Systems and Tools for Fusion Devices”* aims at developing of plasma engineering systems, data analysis methods and plasma physics studies based on the experimental results obtained with the developed diagnostics. The project included in 2000 the following research lines: X-ray diagnostics for TCV, distributed system for fast timing and event management on MAST, heavy ion beam diagnostic for the TJ-II stellarator, laser induced fluorescence diagnostic for TJ-II, digital instrumentation for control and data acquisition and Wigner distributions for time-frequency analysis of fusion plasma signals. Concerning the *X-ray diagnostics for TCV*, the following activities have been carried out: operation of the equatorial Pulse Height Analysis (PHA) spectrometer, development of software for the routine analysis of the

diagnostic data, modifications on the PHA diagnostic to extend the detected energy range from soft to hard X-ray region, installation of lead shielding of the detector, installation of a new collimator with variable aperture aiming at to control the incoming X-ray flux, design and construction of a new mechanical support structure of the detector assembly, development of MATLAB routines to extract the Thomson scattering data and to compare the electron temperatures obtained with both diagnostics, evaluation in Lisbon of a rotating crystal spectrometer lent by the Princeton Plasma Physics Laboratory, repair of the protection components of the detectors and testing of the vacuum chamber and definition of the characteristics of a step-by-step motor and a high voltage power supply for this new diagnostic. Regarding the *distributed system for fast timing and event management on MAST* the following tasks have been performed: laboratory tests of eleven VME modules, software for testing and operation, implementation, testing and operation of the VME system on the MAST tokamak, re-programming of the Field Programmable Gate Array (FPGA) of the timing unit aiming at the utilization of the VME system in discharges lasting up to 100 seconds, end of the design of the circuit of the CAMAC version of the Event and Pulse Node (EPN) module, commissioning of the CAMAC version of the EPN module and development of software for the CAMAC version. Concerning the *TJ-II heavy ion beam diagnostic* the following tasks have been made: improvement of the dedicated control and data acquisition system, collaboration on the implementation and beginning of operation of the ion injector and electrostatic energy analyser, design of a new version of the transimpedance amplifier, implementation of a first multiple cell array detector (MCAD), preliminary studies of filters for the MCAD, study of a modified biased split detector for the electrostatic energy analyser. Regarding the *TJ-II laser induced fluorescence system* the IST/CFN staff has carried out the following tasks: maintenance of the laser, final setting of the new cooling system, improvements on the hardware of the diagnostic, design of the dedicated control system for this diagnostic, implementation and testing of the diagnostic on the TJ-II device. In the research line of *development of digital instrumentation for control and data acquisition* the following main activities have been performed: implementation of 3 MWords memories in the 4 channels 250 MSPS VME transient recorder modules, development of a 8 independent channels 12 bits 3 MSPS maximum sampling rate 512 kWords per channel VME transient recorder module, development of a 4 channels 12 bits 65 MSPS maximum sampling rate 1 Mword per channel VME transient recorder module, end of the development of the PC version of a multiple Digital Signal Processor (DSP) system for real-time parallel processing and feedback control. and testing of the multiple DSP system in Garching.

The activities of the project *"Studies on Non-Inductive-Current Drive"* have been focused in two research lines: studies on lower-hybrid (LH) current drive (CD) and development of kinetic codes to solve the Fokker-Planck (FP) equation. A fully 3-D (toroidicity plus ripple) tokamak ray-tracing code for LH wave propagation is being developed and the diffraction effects on LH wave propagation have been studied. Kinetic codes for RF heating and current drive (H&CD), using both finite differences and transition probabilities, have been perfected.

The activities of the project *"Studies on Transport and MHD Activity"* have been focused in the fine research lines: influence of mode coupling on the nonlinear evolution of rotating magnetic islands, MHD activity and loss of confinement in JET radiative mantle experiments, influence of sawtooth pre-cursors at the onset of neo-classical tearing modes, effect of plasma rotation on sawtooth stabilization by neutral beam injection and internal kink stability analysis of JET impurity seeded discharges.

The project *"Keep-in-Touch Activities on Inertial Fusion Energy"* included the following activities: implementation of a triple beam scheme, an all-optical-fibre based triggering system and a new control system for the L2I laboratory, design of the next laser system up-grade, development of a compact single-shot auto-correlator for high power pulse width control, modelling of a frequency-resolved optical gating (FROG) pulse diagnostic, development of a plasma density diagnostic, installation of an electron spectrometer, implementation in the vacuum chamber of three-dimensional triple beam focusing geometry and development of fast electronic of the target area data acquisition and control system.

The project *"Portuguese Participation in the Fusion Technology Programme"* included in 2000 activities carried out in the frame of Underlying Technology, on fusion material characterization and surface ion beam modifications, and of four Technology Tasks, on Beryllium pebble bed electrical resistivity in the presence of ionising radiation, SiC/SiC ceramic composites, qualification of high performance steels and monitoring system for a laser-in-vessel viewing system.