1. INTRODUCTION

1.1. FOREWORD

This document describes the main activities carried out in 2003 in the frame of the Contract of Association between the European Atomic Energy Community (EURATOM) and "Instituto Superior Técnico" (IST) and presents a summary of the main scientific and technical results.

The Contract of Association EURATOM/IST frames the Portuguese participation in the EURATOM Specific Research and Training Programme in the Field of Nuclear Fusion Energy, hereinafter referred as Community Fusion Programme. This Programme has as its long-term objective the development of a prototype commercial fusion power plant. It is presently implemented through several Agreements, in particular: (i) Contracts of Association signed between EURATOM and Institutions of the Member States of the European Union and Switzerland (Associates); (ii) The European Fusion Development Agreement (EFDA); and (iii) the Mobility Agreement, both signed by EURATOM and the Associates.

The workprogramme of the Association EURATOM/IST includes activities carried out in Portugal (mainly related with the tokamak ISTTOK) and abroad related with the operation and scientific exploitation of large and medium-sized tokamaks and stellarator (JET, ASDEX-Upgrade, TCV, MAST and TJ-II) and the design of the next generation fusion devices (ITER and W7-X). Particularly important in 2003 was the Portuguese participation in the JET experimental campaigns (Figure 1.1).

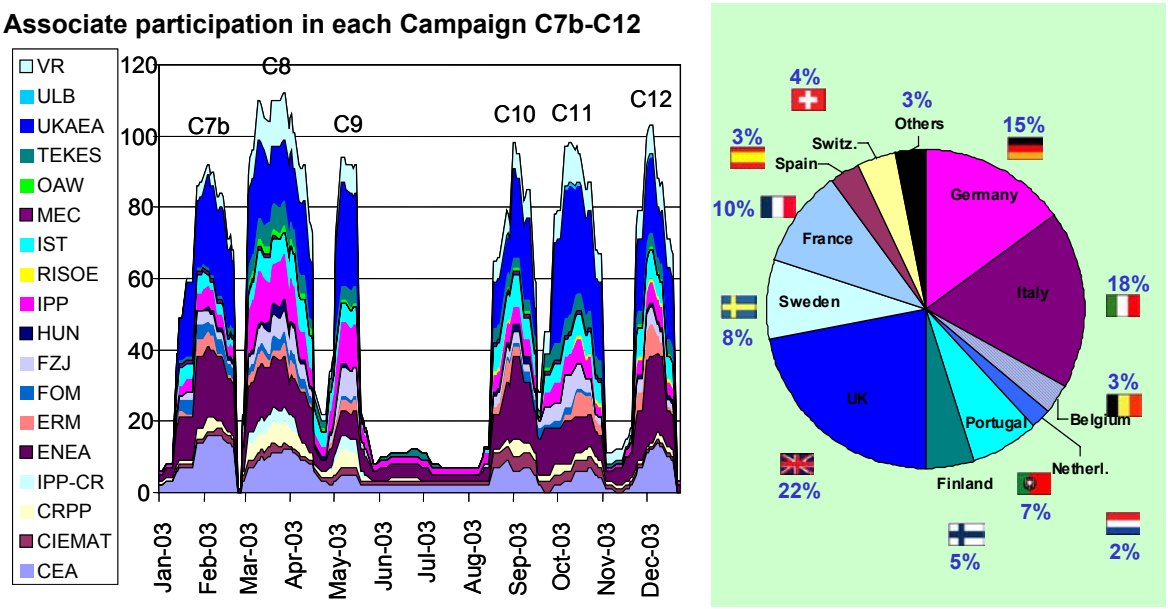

Figure 1.1 – Participation of the Associates in the 2003 JET experimental campaigns

1.2. MAIN PROJECTS OF THE ASSOCIATION EURATOM/IST IN 2003

The Association EURATOM/IST had in 2003 the following main Projects:

- Tokamak ISTTOK;
- Participation in the collective use of the JET facilities by the EFDA Associates;
- Participation in the ASDEX-UPGRADE Programme;
- Participation in the TJ-II Programme;
- Participation in the MAST Programme;
- Participation in the TCV Programme;
- Participation in the ITER Project;
- Other activities on theory and modeling;
- Other activities on control, data acquisition and signal processing;
- Activities in the Fusion Technology Programme;
- Keep-in-touch activities on inertial fusion energy.

The research and development activities carried out in the frame of these projects are summarized in section 1.3 and described in detail in chapters 2 to 12, which also present the main scientific and technical results. Chapter 13 describes other fusion related activities and chapter 14 contains the list of publications.

Table 1.1 presents information about the responsible person(s) and the Institutions involved in each Project.

1.3. SUMMARY OF THE ACTIVITIES

1.3.1. Tokamak ISTTOK

This Project had this year four main research lines: tokamak operation, testing of the liquid metal limiter concept, diagnostic developments and plasma physics studies.

- *Tokamak operation*

ISTTOK was in operation in 2003 during 33 weeks. The remaining time was used for the maintenance of the discharge systems, the implementation of some diagnostic improvements and for the annual holidays.

- *Testing of the liquid metal limiter concept*

IST/CFN has proceeded with the collaboration with the Association EURATOM/University of Latvia on the testing of the liquid metal limiter concept. The design of the liquid metal system (LMS) and the definition of the technical characteristics of the LMS components have been finalized. A digital system to control the LMS operation has been developed. An experimental stand to test the influence of a pulsed magnetic field on the behavior of the liquid metal jet has been designed and commissioned. The electrical circuit required to generate a 0.15 T B-field during 100 ms has been implemented and tested. IST/CFN staff has participated in Riga in two experimental campaigns concerning the testing of the MHD stability of the liquid gallium jet as well as the optimization of the injector. IST/CFN organized in 2003 an international workshop on the use of liquid metals in fusion research.

Project	Responsible Person(s)	Collaborating Institutions	
		Portuguese	Other
Tokamak ISTTOK	José Cabral Carlos Varandas	CFN[1], UBI[2], GEI[3], CFA[4]	CIEMAT[5], IPP-Kharkov[6], UI[7], IFUR[8], IFUSP[9]
Participation in the collective use of the JET Facilities by the EFDA Associates	Fernando Serra	CFN, GEI, UBI	EFDA[10] CSU[11] Culham UKAEA[12]
Participation in the ASDEX Upgrade programme	Maria Emília Manso Fernando Serra	CFN	IPP-Garching[13]
Participation in the TJ-II programme	Carlos Varandas Maria Emília Manso	CFN, GEI	CIEMAT
Participation in the MAST programme	Carlos Varandas Maria Emília Manso	CFN	UKAEA
Participation in the TCV programme	Carlos Varandas	CFN	CRPP[14]
Collaboration with the ITER Project	Carlos Varandas Maria Emília Manso	CFN	EFDA CSU Garching
Other studies on theory and modelling	Fernando Serra J. Pedro Bizarro	CFN	IFP[15], PT[16], DFRC[17]
Other activities on control and data acquisition	Carlos Varandas	CFN, GEI	IFUSP
Keep-in-touch activities on inertial fusion energy	J.T. Mendonça	CFP[18]	
Activities in the Fusion Technology Programme	E. Alves	ITN[19]	ENEA[20]

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

- *Diagnostic developments*

The development of a new spectrometer devoted to the analysis of Gallium spectral lines[21] has proceeded. A new arrangement of three emissive probes and one cold probe has been implemented for the study of Reynolds stress and the radial fluctuation-induced flux in the ISTTOK edge region[22]. Improvements have been made on the operation software of the diagnostic real-time for plasma control and on the numerical codes for the analysis of the plasma equilibrium. A new time-of-flight energy analyzer (TOFEA) prototype with cylindrical

[1] CFN means "Centro de Fusão Nuclear"
[2] UBI means "Universidade da Beira Interior"
[3] GEI means "Grupo 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] IFUR means "Institute of Physics of the University of Riga"
[9] IFUSP means "Instituto de Física da Universidade de São Paulo"
[10] EFDA means "European Fusion Development Agreement"
[11] CSU means "Close Support Unit"
[12] UKAEA means "United Kingdon Atomic Energy Authority"
[13] IPP-Garching means "Max-Planck-Institut für PlasmaPhysik"
[14] CRPP means "Centre de Recherches en Physique des Plasmas de École Polytechnique Fédérale de Lausanne"
[15] IFP means "Istituto di Física del Plasma"
[16] PT means "Politécnico di Turino"
[17] DFRC means "Department de Recherches sur la Fusion Controlée".
[18] CFP means "Centro de Física dos Plasmas"
[19] ITN means "Instituto Tecnológico e Nuclear"
[20] ENEA means " Ente per le Nuove Tecnologie, l'Energie e l'Ambiente"
[21] Work in collaboration with the Association EURATOM/ University of Latvia.
[22] Work in collaboration with the University of Innsbruck of the Association EURATOM/OAW.

electrostatic plates, together with switched power supplies for driving the TOFEA electrostatic plates, has been developed, tested and implemented. Plasma signals have been obtained on the "start" and "stop" detectors in modulation mode of HIBD operation with frequencies up to 100 kHz. A new diagnostic for the monitoring of the C^{III} spectral line has been brought to operation. Concerning the Thomson scattering diagnostic, the laser has been repaired, a new cooling system has been designed, a new beam delivery system has been designed taking into account the new constrains imposed by the implementation on ISTTOK of the liquid metal limiter system and new hardware as well as software have been developed for the link of the dedicated data acquisition system of this diagnostic to the central ISTTOK system. The conceptual design of a multi-fiber Thomson scattering diagnostic has started[23]. A Gunderstrup probe provided by IPP-Prague and an emissive electrode for biasing experiments have been implemented on ISTTOK.

- *Plasma physics studies*

Studies on the investigation of the plasma column macroscopic oscillations, analysis of emissive electrode and limiter biasing experiments[24] as well as measurements of fluctuation and Reynolds stress with emissive probes[22] were carried out in 2003.

1.3.2. Participation in the collective use of the JET facilities by the EFDA Associates

IST/CFN has proceeded with its participation in the collective use of the JET Facilities by the EFDA[25] Associates, with activities in the areas of operation, scientific exploitation, enhanced performance project and management.

- *Operation*

Three members of the IST/CFN staff have been involved in the JET operation: Dr. Sebastien Hacquin has participated in the JET Operation Team, through a Secondment Agreement with the Association EURATOM/UKAEA, working in the Reflectometry and LIDAR Diagnostics Group; Mr. Luis Meneses and Mr. Nuno Cruz have provided technical support to the operation and maintenance of the KG8 correlation reflectometer.

- *Scientific exploitation*

The participation in the JET 2003 Work Programme had contributions from fifteen scientists to the experimental campaigns C8-C12 at the JET site. The work was focused on code developments, leading to the following plasma physics studies related mainly with Task Forces M, D and E: (i) use of ICRH in JET discharges for the prevention of core impurity accumulation; (ii) sawtooth experiments with counter NBI; (iii) statistical study of neo-classical tearing modes onset; (iv) impurity penetration through the edge transport barrier; (v) sawtooth stabilization by ICRH driven fast ions as function of global parameters; (vi) sawtooth stabilization during ICRH at low plasma densities in JET; (vii) confinement effects of large islands; (viii) effect on the fast particle population of externally induced error fields; (ix) studies on density limit disruptions; (x) investigation of the

[23] Work in collaboration with the "Laboratório Associado de Plasmas do Instituto Nacional de Pesquisas Espaciais ", of S. José dos Campos, Brasil.
[24] Work in collaboration with the "Laboratório de Plasmas, do Instituto de Física, da Universidade de S. Paulo", Brasil.
[25] EFDA means "European Fusion Development Agreement"

runaway electrons at disruptions in JET; (xi) investigation of slowly rotating islands in JET discharges; (xii) application of the Choi-Williams distribution to the time–frequency analysis of phenomena in fusion plasmas: precursors of edge localized modes and washboard modes; (xiii) combined mass-energy analyzer for the investigations of SOL plasmas; (xiv) probability density function of the radial structure of turbulence in fusion plasmas; (xv) determination of the particle and energy fluxes in the far SOL during ELMs using the reciprocating probe diagnostic; (xvi) effect of toroidal field reversal on the SOL properties; (xvii) ELMs studies with microwave reflectometry; (xviii) plasma physics studies from MSE measurements.

- *Enhanced Performance Project*

IST/CFN was in 2003 responsible for six tasks of the JET Enhanced Performance Project: Mw Access-Project Management and Implementation, Real-Time Diagnostic, FDA Project Design and Procurement Activities, MPR-Project Design and Procurement Activities[26], TOF-Project Design and Procurement Activities[26] and RTP-Development Real-time Test Facility.

The task *Mw Access – Project Management and Implementation* had in 2003 the participation of CFN-IST, IPP, FOM, CNR and CIEMAT. Dr. Luis Cupido has been the Project Leader. The design of all parts of the system has been completed and the specifications and contracts for manufacturing have been elaborated.

The task *Real-Time Diagnostic* aims at making the motional Stark effect diagnostic (KS9RT) fully automatic in its operation. The time evolution of the front-end frequency response on data acquisition has been checked. The Faraday correction on the calculated light polarization angle has been improved by reading the toroidal magnetic field in real-time on the ATM real time measurement and control network. The comparison of results provided by the real-time and off-line MSE systems has been performed for various pulses.

Concerning the *FDA-Project Design and Procurement Activities,* the final testing of the operation in the JET CODAS of the fast ADC upgrade system for the heterodyne radiometer (kk3) diagnostic was carried out in 2003. A remote boot system has been implemented and tested. The software to support the insertion of a seventh transient recorder module has been developed and configured.

Regarding the *RTP -Development Real-time Test Facility*, the conceptual design of the system has been made. A proposal regarding the use of this system on the JET Real-time upgrade Phase 2 has been elaborated and discussed with the EFDA Culham Close Support Unit. The development of the PCI DAC modules has begun.

Concerning the *MPR-Project Design and Procurement Activities* and the *TOF-Project Design and Procurement Activities*, IST/CFN staff discussed in 2003 new data acquisition requirements of the diagnostic with the Project Leader. The schematic, printed circuit board, programmable logic and control DSP firmware of both the PCI time digitizer and the PCI transient recorder modules have been designed. A prototype of each module have been assembled and tested.

- *Management*

The Association EURATOM/IST has collaborated on the management of the use of the JET facilities by the EFDA Associates in the following manner: (i) Dr. Bruno Gonçalves as a member of the staff of the Close

[26] Work in collaboration with the Association EURATOM/SKN.

Support Unit to the EFDA Associate Leader for JET; (ii) Dr. Duarte Borba as deputy Task Force Leader for TFM; (iii) Prof. Horácio Fernandes and Dr. Paulo Varela as members of the Remote Participation Users Group.

1.3.3. Participation in the ASDEX-UPGRADE Programme

The Portuguese participation in the ASDEX-Upgrade[27] (AUG) Programme has been mainly focussed on the areas of microwave reflectometry (microwave systems and electronics, control and data acquisition, data processing, modeling and plasma physics studies), MHD and turbulence studies and management.

- *Microwave reflectometry*

Concerning the *microwave systems and electronics*, the heterodyne Q-band fixed frequency channel using synthesizer sources has been implemented and tested. A new routing of the in-vessel waveguides has been developed to avoid future PSL induced damage to the waveguides. The in-vessel access of W band oversized waveguides as well as new routing of the oversized W band waveguides outside the vessel have been changed to accommodate the shift to the C port access, imposed by the installation of the new ECRH antennas. Some parts of transmission line that have been damaged in the last AUG campaign, namely the high-field side Ka band (waveguide and directional coupler) and Q band for X mode operation (waveguides) have been repaired/replaced.

Regarding *control and data acquisition,* the control clients have been adapted to allow secure remote operation. Due to security/management restrictions, the implementation of a SSL/TLS secure encrypted communication layer on the client and daemon server has been replaced by a different approach. A simple socket tunneling procedure using SSH has been implemented, which provides secure access to in-site workstations, allowing remote use of the operation/monitoring clients. The daemon to control the Fluctuation Monitor System and the respective C/X windows client has been implemented. The control software of the Fluctuation Monitor System uses a client/server approach, like in the broadband system. This software has been completed and is expected to be in advanced test/debug phase in the beginning of 2004 experimental campaign. A Java version dedicated to the Broadband System client has been implemented and tested. Another Java version dedicated to the Fluctuation Monitor System client has been developed.

Concerning *data processing*, the following main activities were carried out in 2003 aiming to improve the accuracy of automatic density profiles, in particular in the presence of high plasma turbulence as well as transient phenomena, such as ELMs: automation of the O-mode density profiles initialization using X-mode data; automatic removal of ELM effects from burst-mode (level-2) profiles; preliminary work concerning the automatic selection of the optimized window length for the spectrogram analysis of reflectometry data.

In the area of *diagnostic developments*, a software tool to simulate O/X mode reflectometry experiments has been developed aiming to improve the accuracy of profile initialization from O mode and to investigate the possibility of measuring $B_t(r)$ with combined O and X mode probing. The reliability and accuracy of plasma position measurements from reflectometry in typical plasma scenarios using a specially developed workbench of numerical tools has been assessed.

Regarding *modeling*, the signature that q=2 type islands produce on the reflectometry signals has been studied aiming at investigating the possibility of localizing rational surfaces as a contribution of reflectometry to

[27] ASDEX-Upgrade is a tokamak of the Association EURATOM/IPP, in operation in Garching.

the estimation of the q-profile. The burst-mode analysis used for density profile evaluation with a 2D FDTD full-wave code has been validated.

Finally, the study of the impact of type I and type III ELMs on the plasma edge density profiles as well as MHD and turbulence studies were performed in 2003.

- *MHD and turbulence*

Turbulence in the scrape-off layer (SOL) region of a tokamak plasma using fluxtube codes, such as DALF or GEM has been computed. Alfvén instabilities have been studied aiming to contribute to the optimisation of the design and future operation of a fusion tokamak reactor.

- *Management*

Two members of the IST/CFN staff have participated in the management of the AUG project: Prof. Maria Emilia Manso is a member of the AUG Programme Committee and Dr. Duarte Borba is the Task Force Leader for TF V (MHD).

1.3.4. Participation in the TJ-II Programme

The CFN participation in the TJ-II[28] Programme has been mainly focussed on the areas of microwave reflectometry, heavy ion beam diagnostic and edge plasma physics.

- *Microwave reflectometry*

The microwave reflectometry activities were focused in 2003 on the development of an advanced reflectometer for plasma fluctuation studies with increasing measuring capability, utilizing only one single frequency that can be hopped during the discharge. The development and testing of the system at CFN have been finalized. This reflectometer has been implemented and tested on the TJ-II stellarator.

- *Heavy ion beam diagnostic*

This diagnostic has been designed to operate with two detectors for the secondary ions: (i) a 30^{o} Proca-Green electrostatic energy analyzer; and (ii) a multiple cell array detector (MCAD). The tests of the MCAD implemented in 2002, based on deep Faraday cup type cells, have been completed. The operation of the multiple cell array detector was performed during the TJ-II experimental campaigns. Several improvements on the signal conditioning and data acquisition system have been implemented.

- *Edge plasma physics studies*

Turbulent transport studies concerning the dynamic coupling between transport and parallel velocity as well as the analysis of the effect of the shear layer on the radial correlation of transport have proceeded in 2003. IST/CFN has constructed a graphite electrode or edge biasing experiments on TJ-II to be performed in 2004.

1.3.5. Participation in the MAST Programme

This Project aims at the development and scientific exploitation of a microwave reflectometer for MAST[29]. During 2003 the hardware was inspected and the testing of the system was performed. The transmission line has

[28] TJ-II is a stellarator of the Association EURATOM/CIEMAT, in operation in Madrid.

been improved as well as the procedure to implement the system in the machine. The data of the 2003 experimental campaign has been assessed.

1.3.6. Participation in the TCV Programme

The main objectives of this Project are the development and scientific exploitation of three X-ray diagnostics (a horizontal Pulse Height Amplitude (PHA) spectrometer, a vertical PHA spectrometer and a rotating crystal spectrometer) and the development of an advanced plasma control system for TCV[30].

- *Horizontal PHA diagnostic*

The horizontal PHA diagnostic was in operation during the 2003 TCV experimental campaigns, allowing the measurement of the electron temperature and analysis of the line radiation in the soft X-ray range from 1 to 10 keV. The Raymond-Smith code has been adapted to the TCV conditions. The results obtained with this code, which simulates the SXR emissions for certain plasma parameters and impurity content, have been compared with those obtained with the improved Maxwellian mathematical model. The Matlab programs used for data analysis have been refurbished. The old data has been studied using the refurbished Matlab programs, the algorithm developed for the VME module and the Raymond-Smith code. Two new mathematical models (an improved Maxwellian and a Neoclassical model that accounts for diffusion phenomena inside the plasma bulk) have been developed and tested aiming at finding the factors which induced the abnormal SXR distribution and account for the irregular behaviour of the bremsstrahlung tail, many times observed, both in old and more recent spectra.

- *Vertical PHA diagnostic*

This project has been put forward to meet the need for high throughput, fast data acquisition and real-time data analysis capabilities. The original classic spectrometer is being transformed in a real-time diagnostic by using a commercial CAMAC unit and a multi-DSP-based VME (RTPROV) system, specially developed by CFN for data acquisition, real-time parallel processing and feedback control. IST/CFN staff has supervised the project to make sure that all requirements were met. The diagnostic has been provisionally assembled on TCV in order to allow the tests of two dedicated acquisition system, based on a commercial CAMAC unit and on the RTPROV board. The RTPROV hardware and software have been adapted to the requirements of the PHA diagnostics. The software at the VME host and DSP levels for the VPHAD, including the algorithm for the calculation of the electron temperature, has been developed and tested. The software to integrate the PHAD data acquisition system into the TCV control and data acquisition system has been also developed.

- Rotating crystal X-ray diagnostic

This diagnostic, based on a twenty-years old apparatus loaned by the Plasma Physics Princeton Laboratory, has been envisaged to record the soft-X-ray line radiation from highly charged ions of low to medium Z elements from the hot core of the TCV plasma, along a horizontal line of observation. It would provide information on the central ion temperature, electron temperature and ion-charge state distribution from which the ionization

[29] MAST is a Mega Ampere Spherical Tokamak of the Association EURATOM/UKAEA, in operation in Culham.
[30] TCV is a "Tokamak de Configuration Variable" of the Association EURATOM/Confederation Suisse, in operation in Lausanne.

equilibrium and ion transport might be deduced. In 2003 IST/CFN staff has performed the testing of the multi-channel plates (MCP) and vacuum conditions of the diagnostic. Intensive procurement of firms that could provide new crystals and MCPs with the required specifications at a reasonable price has been made. CFN and CRPP have performed a joint assessment of the best way to conduct the process of refurbishment of the rotating crystal spectrometer. A report has been submitted in December 2003 to the CFN and CRPP management.

- *Advanced plasma control system*

The research line on *advanced plasma control system* aims the development of a new real-time plasma control system, based on the CFN real-time parallel processing multi-DSP-based VME (RTPROV) board. The conceptual design of the real-time plasma control system, performed in collaboration with the TCV Control Group, has been finalized. Some improvements of the RTPROV board have been made to meet the TCV requirements. The commissioning and testing of fourteen RTPROV boards has started. The DSP operative system has been updated. The development and testing of the DSP application software for the TCV plasma control has started. Linux drivers have been developed to access the board by the VME master. Two new boards were developed in 2003: (i) a digital input/output board (XIO) that brings digital inputs and outputs from the P2 connector of each RTPROV v1.1 to the front panel; and (ii) a bus board (DMBUS to be inserted behind the VME bus in the P2 connectors, enabling the broadcast data transfer from one board to all other boards in the VME bus that are configured to use the DMBUS protocol. The development of the software interface for MDSPLUS graphics user interface as well as of the software needed to integrate this system in the main TCV control system has been initiated.

1.3.7. Participation in the ITER Project

The Portuguese participation in the ITER Project included in 2003 activities related with diagnostics design and integration, microwave reflectometry and ITER Negotiations.

- D*iagnostics design and integration*

Prof. Artur Malaquias belonged during 2003 to the ITER International Team, working at Garching. He has been involved in diagnostic systems design and co-ordination of design effort, in the integration and distribution of diagnostic systems and in the co-organization of scientific meetings. Prof. Malaquias participated in 2003 in: (i) the relocation of some systems to more suitable ports; (ii) upgrade of the microwave diagnostics implemented in eport#11 to include the Doppler reflectometry system and the integration of individual motion decoupling devices for the wave-guides; (iii) elimination of the graphite reflectors X-ray array and its replacement by a new system at eport#9; (iv) redesign in eport#9 of the X-ray survey and the VUV survey in respect to their function covering now the spectral range by means of 6 sub-bands and to their vacuum chambers plus refurbishment procedures; (v) development of a new arrangement for the port plug shielding blocks and inter-space shielding; (vi) replacement of the previous X-ray system by a completely new design based on imaging crystals and relocated to eport#9; (vii) definition of a new positioning of the ECE system in order to optimise the plasma coverage; (viii) integration at the upper port level of two newly designed diagnostics: the VUV-imaging and the upper imaging X-ray; and (viii) design of the optical periscopes for the CXRS and MSE diagnostics.

- *Microwave reflectometry*

IST/CFN proceeded in 2003 with studies for plasma position/shape measurements as required for ITER. The microwave and millimeter wave technologies that, besides reflectometry, will also be used by ECE and ECA diagnostics on ITER, have been assessed. The conceptual design of an advanced FM-CW reflectometer (beyond the state of art) capable of performing profile measurements at very high densities/long distances has been finalized. The selection of microwave components for a prototype system has been initiated. The FM-CW reflectometers developed by CFN for the ASDEX Upgrade tokamak have explored the control of plasma position and shape from reflectometry, as required for ITER long pulse operation.

- *ITER Negotiations*

Prof. Carlos Varandas has attended two meetings in 2003 of the ITER negotiations, as member of the delegation of the European Union

1.3.8. Other activities on theory and modeling

Besides the work on theory and modelling previously presented, this section reports on three topics: (i) role of magnetic reconnection (ideal and resistive) processes in the dynamics and confinement of thermonuclear plasmas; (ii) non-inductive current drive; and (iii) reconstruction of tokamak MHD equilibrium.

- R*ole of magnetic reconnection (ideal and resistive) processes in the dynamics and confinement of thermonuclear plasmas*[31]

Studies of the destabilization of metastable modes by resonant magnetic fields and of the effects of the poloidal $\vec{E} \times \vec{B}$ velocity (V_θ^{ExB}) proceeded in 2003.

- *Non-inductive current drive*

The wave field across a caustic, in the framework of geometrical optics, has been computed. The spectral-gap problem for Lower Hybrid (LH) current drive has been studied. IST/CFN staff has participated in the design of the ITER-like lower hybrid launcher[32].

- *Reconstruction of tokamak MHD equilibrium*

A new perturbative method to avoid the drawbacks of iterative approaches has been developed. This method has been illustrated with ASDEX-Upgrade data.

1.3.9. Other activities on control, data acquisition and signal processing

This Project aims the development of: (i) a galvanic isolated PCI transient recorder module; (ii) an event-driven reconfigurable real-time processing system for the next generation fusion experiments; (iii) a low-cost, fully integrated, event-driven real-time control and data acquisition system for fusion experiments; and (iv) a water-cooled, high compaction ratio Linux cluster.

[31] Work carried out in collaboration of CNR-Milano, of the Association EURATOM/ENEA.
[32] Work performed in collaboration with the Association EURATOM/CEA.

- *Galvanic isolated PCI transient recorder module*

The module architecture has been defined accordingly to the JET requirements. The schematic, printed circuit board, programmable logic and control DSP firmware of the module have been designed. A prototype has been assembled and tested. The operation of this module was successfully demonstrated at JET in August.

- *Event-driven reconfigurable real-time processing system for the next generation fusion experiments*

Adequate software and hardware platforms have been identified. A preliminary multiple FPGA/DSP based hardware design was developed. The software design workflow was performed.

- *Low-cost, fully integrated, event-driven real-time control and data acquisition system for fusion experiments*

A System-On-Chip architecture suitable for the development of low-cost, modular, long operation period and network interconnected data acquisition and control instruments has been identified. The preliminary design of data acquisition and control module with a high number of channels was performed. An initial cost and performance estimation was made, which indicates that this module can be produced at very low cost per channel and can speed the data acquisition subsystem commissioning task.

- *Water cooled linux cluster*

This project aims the development of a Pentium 4 linux based cluster intended for heavy numerical calculus. The conceptual design, commissioning and testing of the system were made in 2003. The operation software has been developed. The present version of this cluster is characterized by 24 Gflop per 8 CPU with a high volume compaction ratio and a low cost design. This is done by water cooling the 2.4 GHz CPUs so that 8 boards/1 GRam can be housed in a regular 21", 6U rack system. The cluster has a 1Gbit ethernet dedicated switch.

1.4. HUMAN AND FINANCIAL RESOURCES

Table 1.2 and 1.3 contain information about the human and financial resources of the Association EURATOM/IST.

Area		**Type of Activity**	**Professionals**			**Non Professionals**	**Total**
			Ph.D	**Master**	**Graduation**		
Physics	Magnetic Confinement	Research	22.45	15.0	15.40	0	52.85
		Administration	0	0	1.00	1.0	2.00
		Technicians	0	0	0	3.0	3.00
		Secretariat	0	0	0	4.0	4.00
	Inertial Confinement	Research	7.00	0	5.0	0	12.00
		Secretariat	0	0	0	0.3	0.30
Technology		Research	0.79	0	0.85	0	1.64
Total			30.24	15.0	22.25	8.3	75.79

Table 1.2 – Personnel of the Association EURATOM/IST in person year

Category	Expenditure in €
General Support	
Physics	
Magnetic Confinement	3,617,887
Inertial Fusion Energy	750,000
Underlying Technology	32,113
European Fusion Development Agreement	
Technology Tasks	100,000
Article 5 Contracts	223,184
Article 6 Contracts	344,504
Article 9 secondments	58,743
Mobility	338,805
Total	5,465,236

Table 1.3 – Expenditure (in Euros) in 2003 of the Association EURATOM/IST