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Center for Innovation, Technology and Policy Research

Centro de Estudos em Inovação, Tecnologia e Políticas de Desenvolvimento

Annual Report 2002

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Instituto Superior Técnico, Lisboa
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IN+ **Center for Innovation, Technology and Policy Research**

Centro de Estudos em Inovação, Tecnologia e Políticas de Desenvolvimento

Annual Report: 2002

Contents

I. Research Team

II. Mission and Results

1. Mission and Organization
2. Research Team Experience
3. Research Topics and Results: Knowledge creation
   3.1 Laboratory of Thermofluids, Combustion and Energy Systems
   3.2 Laboratory of Environmental Systems
   3.3 Laboratory of Technology Policy and Management of Technology
4. Beyond Research: Knowledge Transfer and Diffusion
   4.1 Advanced Training – Main Post-Graduation Education Programmes
   4.2 Advanced Training – Workshops
   4.3 Main R&D Projects
   4.4 C&T commercialisation activities
   4.5 C&T culture and dissemination projects
   4.6 International Conference Series
   4.7 International networks
   4.8 Main Editorial Activities

Annexes:

A1: Indicators

A2: List of publications

A3: Individual CV's of doctorate researchers

I. RESEARCH TEAM (as by December, 2002)

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Nome completo	Grau académico	Categoria profissional	% tempo	Fracção elegível
Manuel Frederico Tojal Valsassina Heitor	AGREGAÇÃO	PROFESSOR CATEDRÁTICO	75%	1
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Edgar Caetano Fernandes	DOUTORAMENTO	PROFESSOR AUXILIAR	70%	1
Gabriel Paulo Alcantara Pita	DOUTORAMENTO	PROFESSOR AUXILIAR	40%	1
João Miguel Pires Ventura	DOUTORAMENTO	PROFESSOR AUXILIAR	40%	1
José Miguel Mendes Lopes	DOUTORAMENTO	PROFESSOR AUXILIAR	40%	1
Mario Nery Rodrigues Nina	DOUTORAMENTO	PROFESSOR ASSOCIADO	30%	1
Paulo Manuel Cadete Ferrão	DOUTORAMENTO	PROFESSOR ASSOCIADO	70%	1
Pedro Filipe Teixeira Conceição	DOUTORAMENTO	PROFESSOR AUXILIAR	25%	1
Rui Baptista	DOUTORAMENTO	PROFESSOR ASSOCIADO	60%	1

Bolseiros doutorados

Nome completo	Grau académico	Categoria profissional	% tempo	Fracção elegível
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Elsa Beatriz Padilla	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	100%	1
Nuno Arantes-Oliveira	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	60%	1
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II. Mission and Results

1. Mission

The activities of the Centre are multidisciplinary, linking basic and applied research to technology development, and focused on the issues of sustainability, namely in terms of the needs to secure the quality of the environment, together with the management of energy resources and the economic development. To achieve these objectives, the activities of the Centre are directed towards leading-edge developments and to promote the learning ability of graduate engineering students with the following specific goals:

- To improve knowledge in advanced fields of strategic technologies with emphasis on turbulent mixing and combustion processes, which have the potential to optimise the environment and the rational use of energy in industry;
- To develop and use advanced techniques for the analysis, monitoring and control of processes at laboratory and industrial scale, the later including technology and risk assessment.
- To promote the exchange of knowledge in advanced technologies for the optimisation of industrial processes, including the management of technology and innovation, as a way to promote competitive advantages at the corporate level;
- To derive science and technology policies and innovation strategies, namely in terms of environmental protection, rational use of energy and economic growth.

In this context, besides the development of basic research in energy and environmental-related processes, the Centre thus undertakes interdisciplinary research involving technology and policy, promoting ways in which industrial development can proceed in a sustainable and socially responsible manner.

In order to achieve these objectives, the Centre is organized in three main laboratories, aimed as follows:

- **LABORATORY OF THERMOFLUIDS, COMBUSTION AND ENERGY SYSTEMS**
  - To improve knowledge in advanced fields of strategic technologies with emphasis on turbulent mixing and combustion processes, which have the potential to optimise the environment and the rational use of energy in industry;
  - To develop and use advanced techniques for the analysis, monitoring and control of processes at laboratory and real scales.
  - To promote the exchange of knowledge in advanced technologies for the optimisation of industrial processes and energy systems

- **LABORATORY OF ENVIRONMENTAL SYSTEMS**
  - To develop and use advanced research methodologies for the analysis of environmental systems.

- To promote the exchange of knowledge in advanced technologies for the optimisation of industrial processes and environmental systems

- **LABORATORY OF TECHNOLOGY POLICY AND MANAGEMENT OF TECHNOLOGY**
  - To develop and use advanced research methodologies for the analysis of techno-economic systems.
  - To promote the exchange of knowledge in advanced technologies and the management of technology and innovation for the optimisation of industrial processes, as a way to promote competitive advantages at the corporate level;
  - To derive science and technology policies and innovation strategies, namely in terms of socio-economic development.

2. Research Team Experience

The R&D activities included in the present research programme, which have been particularly developed since 1998, have derived from those developed within the scope of the Combustion Laboratory of the Mechanical Engineering Department of I.S.T. for a number of years, which have been extended with the aim to integrate competencies at the level of technology policy and advanced socio-economic research methods. This is because the successful development and subsequent exploitation of energy and environment technologies requires, apart from improved knowledge of basic thermo-fluid mechanics, the understanding of policy issues and innovation strategies, in a context which promotes the sustainable development. The ultimate goal is to improve the process of industrial assimilation of knowledge, through a stepwise and interactive approach considering the overall values chain associated with industrial and corporate processes.

In addition, the activities developed in the last years have been planned on the basis that the most important challenges in maximising the impact of Science and Technology, S&T, on the well-being of nations, is to understand and maximising the complex processes that underlie world-class S&T research, commercialisation and management, including the protection of intellectual property and the integration of knowledge in a context of enhanced economic wealth and shared prosperity.

The concepts presented above are the result of a strong involvement of a number of resercahers in a considerably large number of international R&D projects since 1986. These projects have been developed in the scope of national projects and the BRITE/EURAM, Science, STEP, Environment, Joule and Esprit Programmes of the European Commission, as well as an increasing involvement with Portuguese and European industry. Apart from the national sectors of glass and crystal, R&D links have been established for a number of years with major European aeronautical companies (Rolls Royce, SNECMA, TURBOMECA, MTU, Rolls-Royce- BMW) and process industries (Saint Gobain). Briefly, the work evolved from basic research on turbulent fluid mechanics and combustion, namely through several master and doctorates programmes. Moreover, the research work has gained considerably from the successive organisation of the Intl. Symposia on Applications of Laser Techniques to Fluid Mechanics, which have been held in Lisbon since 1982. The symposia have contributed significantly to promote a series of international contacts and research activities in international cooperation.

More recently, the development of competencies in the area of science, technology and innovation policy has been successfully achieved following three main lines of development, namely: i) advanced training of young researchers in leading American universities, through PhD. Programmes in leading and emergent topics; ii) launching in IST of the Master programme on “Engineering Policy and Management of Technology”

in 1998, which has allowed to train young people in new areas of education at IST and promote new links with Portuguese companies; and iii) the organization of the Intl. Conferences on Technology Policy and Innovation, which were launched in July 1997 and carried out in close collaboration with a number of leading research groups worldwide.

3. Research Topics and Results: Knowledge creation

3.1 Laboratory of Thermofluids, Combustion and Energy Systems

The Laboratory is organised on the basis of *Research Areas*, which include a range of projects. These projects provide the necessary external funding, namely from national and international funding agencies and/or private companies. The following is a list of the main Research Areas, under which the most important activities under development are presented.

- **Turbulent mixing and combustion**
  - Improved understanding towards Lean Combustion
  - Shear-layer control and vortex-flame interaction
  - Non-premixed flame propagation in single and interacting combustion systems
  - Industrial burning equipment and energy systems
- **Thermo-Fluid-Dynamics of multiphase flows**
  - Liquid disintegration and spray formation
  - Turbulent Dispersion in multiphase flows
  - Dynamics of Spray-wall impingement
  - Heat transfer of impacting volatile poly-dispersions
- **Fire propagation and Risk Assessment**
  - Physical modelling of forest fire behaviour
  - Continuing training on technology-based hazards; support of specific studies and emergency plans; consulting on technology-based hazards.

Most of the research results achieved in these various areas may be summarized as follows.

a) Turbulent mixing and combustion

Shear-layer acoustic excitation: This work reports the experimental study conducted on a curved oscillatory boundary layer excited by a single frequency artificial signals. Physical analysis of turbulent shear layer morphology was based on instantaneous sequences of shadowgraph images and turbulent velocity characteristics by Laser Doppler Velocimetry measurements. The data was interpreted on a phase locked base to allow the characterization of the unsteady inner and outer shear layers that features to strong temporal and spatial deformations imposed by external induced oscillations. The analysis of vortex pairing dynamics allowed concluding that the pairing process in this flow corresponds to the jet column mode, as suggested for circular jet flow. The consequences of this flow behaviour into the combustion efficiency and pollutant reduction are being evaluated.

Publications:

- "Laser-Doppler Analysis of Oscillating Reacting Shear Layers", C. E. C. Cala, E. C. Fernandes and M. V. Heitor, paper presented at the 11th Conference on Applications of Laser Techniques to Fluid Mechanics, Lisbon, 2002.

Oscillating swirling flows and the onset of PVC - experiments without chemical reaction- isothermal flow: The swirling flow in a combustor model was examined for the conditions characterized by the presence of a breakdown zone and precessing vortex core (PVC). As defined by acoustic measurements the flow in the primary zone of the

combustor goes through certain development stages as the flow swirl intensity increases; a region of abnormal decreasing precession frequency was discovered. Direct LDA measurements revealed that these typical regimes are connected with the appearance and radial expansion of a central recirculating flow followed by PVC axial extension. A simple approximation for tangential velocity was used for reconstructing the PVC parameters from the averaged flow characteristics. Finally, a cross-spectral analysis of two-point acoustic signals provided information on the mode structure of the pressure fluctuations imposed by the precessing core. These data include results on the spatial configuration of the PVC axis represented by circumferential and axial wavenumbers. The latter was used to decompose the measured precession frequency through parts related to the pure vortex core rotation and its translational motion. The significant effect distinguishing the present work consists in the fact that the greatest contribution to the flow pulsation frequency is due to the axial translation of the spiral vortex.

In addition, the variation of axial wavelength vs. swirl number showed jumplike changing that could be interpreted as a transition between the two breakdown modes referred to in the literature as "bubble" and "spiral" types. In our case the bubble breakdown mode corresponds to flow regime with the abnormal frequency dependency on swirling intensity.

Publications:

- Anacleto P.M., Fernandes E.C., Heitor M.V., Shtork S.I. (2002) Unsteady vortex flow with breakdown and vortex core precession in dump region of a model combustor (*). In preparation for submission to "Experiments in Fluids".
- Comas O., Heitor M.V. and Shtork S.I. Experimental study of swirl flow structure in a model gas turbine combustor. Proc. 26th Siberian Thermophysical Seminar, June 17-19, 2002, Novosibirsk, Russia.

Experiments with chemical reaction: The swirling flow in a lean premixed prevaporised combustor model (LPP chamber) is studied, making use of high-speed photography, LDV, sound-probes, fine-wire thermocouples and suction probes for chemical gas analysis. The experimental study, which involved parametric changes of Re, S and □extends from the combustor primary zone to the premixing chamber, and was conducted with and without reaction, burning either gaseous propane or liquid fuel assisted with preheated air at 300ºC. Measurements show that the swirling flow mixture that enters the primary zone of the combustor chamber shows evidence of a PVC structure, for S>0.5, that embraces the central recirculation zone (CRZ). Further, reaction test results show that increasing the swirl number decreases CO and NOx concentrations at the combustor exit and reduces flame stability limits to levels close to the lean limit because of flashback. In addition, a detailed study of the reacting condition (S=1.05, □□0.5) was performed; the results indicate that the PVC is still present, embracing the base of the CRZ and staying in the inner shear layer where the flame should also be stabilized, contributing particularly to an abnormal radial distribution of Wrms. Large gradients of mean temperature and UHC concentration were found to be limited to the base of the CRZ.

Publications:

- P.M. Anacleto, E.C. Fernandes, M.V. Heitor and S.I. Shtork, (2002), "Swirl flow structure and flame characteristics in a model lean premixed combustor", Accepted for publication in Comb. Sci. and Technology
- Anacleto P.M., Fernandes E.C., Heitor M.V. and Shtork S.I. Characterization of strong swirling flows with precessing vortex core based on measurements of velocity and local pressure fluctuations. Proc. 11th Int. Symposium on Applications of Laser Techniques to Fluid Mechanics, Lisbon, July 8-11, 2002.

Other related academic publications:

- Sérgio Almeida (2002), Estudo de um fogão industrial, Graduation Project, IST-DEM-SS
- Vanda Geraldes (2002), O efeito de introdução de oslicações na linha de combustível no desempenho energético de um fogão doméstico, Graduation Project, IST-DEM-SS
- Luis Miguel Pina (2002) "Controlo Activo de Instabilidades", Graduation Project, IST-DEM-SS
- Gustavo Carneiro Brito, (2002), "Estratégia Predictiva para o Controlo Acústico de uma Câmara de Combustão", Graduation Project, IST-DEM-SS

b) Thermo-Fluid-Dynamics of multiphase flows

Unstable liquid films: An experimental study is made on thin flowing horizontal flows to analyse their natural instabilities. Parameters such as flow rate and initial thickness at the injector outlet were adjusted to span a wide range of conditions. Four different regimes were identified, as a result of the presence of a quasi-planar hydraulic jump for moderate flow rates. Film thickness was measured using a point contact method. Other measurements were performed: wavelength of the stationary waves found in the supercritical region, wave frequency and wave slope of the waves formed by the jump oscillations and which propagate through the sub critical region. Several phenomena such as hydraulic jump formation, momentum lost and wave properties clearly depend on the Weber number, as a result of the thinness of the film.

Publications:

- E. C. Fernandes, F. Maçarico, D. J. Santos, "An experimental study of a thin film flow with a planar hydraulic jump", Submitted to Exp. In Fluids, Dec-2002

Acoustic excitation of liquid-sheet disintegration process: The effect of acoustic excitation on the disintegration characteristics of air-assisted liquid sheets, which utilize water at ambient temperature, and for velocities up to 1.8 m/s, is investigated. The study using high-speed imaging techniques revealed that optimum frequency modulation of the perturbation generator has a pronounced influence on the associated surface waves and the subsequent breakup of the liquid sheet. The analysis includes characterization of critical wave amplitude, breakup length and breakup frequency, for Weber numbers in the range $0.30 < We_{abs.} < 0.44$, which are compared with flow features in the absence of acoustic excitation. The results show that acoustic perturbation can effectively suppress the dominance of gravitational and surface tension effects. As a consequence, for low Weber number flows, the interfacial waves exhibit regularity, and thus a better control of primary breakup processes of liquid sheet may be accomplished.

Publications:

- V. Sivadas*, E.C. Fernandes and M.V. Heitor (2002), "Acoustically excited air-assisted liquid sheets", accepted for publication in Exp. in Fluids

Dynamics of two - phase flows: The research work performed in this field addresses the physical processes involved in the impingement of liquid sprays against solid surfaces, with emphasis on the effects of cross flow conditions and vaporization. The work plan includes experiments in simple flow configurations with well-controlled boundary conditions and the development of appropriate sub-models for impingement and evaporation. The experiments were built based on similarity analysis in order for the study to be relevant for practical applications. Here, the concern was the development of new concepts of mixture preparation in internal combustion engines.

A more efficient control of the fuel supplied to the cylinder requires a fundamental knowledge of the fuel spray behavior at the impact with the surface; drag, dispersion and vaporization by the cross flow; gaseous mixture formation and combustion. An experimental installation has been built, which considers a PFI injector spraying gasoline onto a flat surface at ambient temperature. Experiments are now being conducted considering time and frequency of injections, which approach cold start conditions in real engines. The measurements include time-resolved PDA measurements of droplet size, velocity and volume flux in the vicinity of the target surface. The analysis of the results highlights the main parameters describing spray-wall interactions, which are relevant to physical modelling.

Another experiment has been built aimed at to account for the complexity introduced by the influence of non-scaled parameters on the description of droplet impact. Measurements have considered the deformation and splash of droplets impinging onto dry flat surfaces of different materials and with different surface profiles. The results showed that the nature of the target surface significantly alters the onset of splashing and the dimensionless roughness Ra/Ro alone does not describe completely the nature of the surface. Other characteristics describing the surface profile may also be considered, but more systematic measurements are still necessary in order to develop appropriate correlations. Also, the experiments will be used to develop appropriate physical models to describe the energy dissipated at the wall during droplet deformation.

Publications:

Paper waiting for publication:

- "Experimental characterization of spray-wall interaction in intermittent gasoline sprays under cross flow conditions", M. R. Panão and A. L. N. Moreira. Paper submitted to the Journal *Atomizatiom and Sprays*.

International Conferences

- "The dynamic behaviour of single droplets impacting onto flat surfaces" (2002), A. S. H. Moita and A. L. N. Moreira, *Proc. of the 18th Annual Conference on Liq. Atom. and Spray Systems, pp. 157 – 164.*
- "Spray impingement on a flat plate under cross flow conditions" (2002), M. R. Panão and A. L. N. Moreira, Proc. of the 18th Annual Conference on Liq. Atom. and Spray Systems, pp. 151 – 156.
- "Visualization and analysis of spray impingement under cross flow conditions" (2002), M. R. Panão and A. L. N. Moreira, SAE Technical Paper 2002 – 01 – 2664.
- "The Deformation of Single Droplets Impacting Onto a Flat Surface" (2002), A. S. H. Moita and A. L. N. Moreira, SAE Technical Paper 2002-01-2749.
- "Influence of Surface Properties on the Dynamic Behaviour of Impacting Droplets", 2003, A. S. H. Moita and A. L. N. Moreira, 9th International Conference on Liquid Atomization and Spray Systems
- "Experimental characterization of spray-wall interaction under cross-flow conditions", 2003, M. R. O. Panão and A. L. N. Moreira, 9th International Conference on Liquid Atomization and Spray Systems

National Meetings

- Moita, A. S. H. e Moreira, A. L. N. , "Motores de Injecção Directa: Comportamento Dinâmico das Gotas de Combustivel ao Incidirem nas Superficies do Cilindro", *2ºs Jornadas Politécnicas de Engenharia*, 13 – 14 November 2002.
- Panão, M. R. e Moreira, A. L. N., "Estudo Experimental do Spray de Combustivel em Motores de Combustão Interna", *2ºs Jornadas Politécnicas de Engenharia*, Escola Superior de Tecnologia de Setúbal, 13 – 14 Novembro 2002.

c) Fire propagation and Risk Assessment

Physical modelling of forest fire behaviour

The physical modeling of forest fire behaviour has been carried out based on two-dimensional models of fire spread across a bed including wind combined with slope conditions. In addition, the characterization of forest fire propagation in a pine needles fuel bed was also performed in the context of a Master's degree dissertation.

The forest fuel bed is a typical porous medium whose characteristics (shape and size of the particles, bulk density, packing ratio) modify the gas flow behind and ahead of the flame. In this context, current work coordinated by Joào Ventura and José Miguel Mendes Lopes includes the study of the following parameters: i) the variation of pressure drop with the main properties of the medium (fuel type, bulk density, packing ratio), and ii) heat transfer within the fuel bed, leading to the determination of the convection coefficient and its dependence on the main properties of the medium.

A computer code to simulate surface forest fire behaviour in heterogeneous terrain is being developed and optimised to run in a simple PC platform, but in a way which is compatible with GIS (ARCVIEW). It computes the burned area shape and evolution, as well as local results on rate of spread, flame length, fire line intensity, reaction intensity, and local times of beginning and end of propagation. It is based on FIRE1 from BEHAVE, and uses cellular automata to extend the use of FIRE1 to heterogeneous terrain and heterogeneous meteorological conditions.

Technological Risk Analysis and Support to the National Service of Civil Protection

Geographical Information Systems have been adapted and used to characterize natural risks in Portugal, with particular reference to the south and the zone of Alentejo. A plan of work in close collaboration with the National Service of Civil Protection is being coordinated by João Ventura in the following areas:

- Continuing training of the staff of the National Service of Civil Protection on technology-based hazards;
- To support specific studies and emergency plans;
- Consulting on specific aspects related with technology-based azards.

In addition, risk assessment of "Transportation of Dangerous Substances in Portugal" has been initiated aimed to characterize the flow of dangerous substances in the Portuguese territory and to gather information to assist emergency management of accidents, which may occur in this kind of transportation.

3.2 **Laboratory of Environmental Systems**

The research work under this theme has been aimed to develop and use advanced research methodologies for the analysis of complex systems and to promote the exchange of knowledge in advanced technologies for the optimisation of environmental systems. It involves the following main topics:

- Industrial Ecology Toolbox
  - Design for Environment – DFE
  - Hybrid Economic Input-Output Life Cycle Assessment – H-EIO-LCA
- Environmental Policy and Industrial Ecology Systems
  - The environment and the automobile
  - Ecological economics
  - Energy and environment
- Environmental physics

a) Industrial Ecology Toolbox

The research work developed is aimed at demonstrating the need to prepare the evolution to a new "Industrial Ecology stage". The requirements to step up to this new stage are classified at three levels, the need for an appropriate "environmental analysis methodologies toolbox", the establishment of a structured set of indicators to support sustainable policies and priority setting at a regional level, and finally, the development of a new organization of infra-structures, technologies, sectors and firms to promote co-operation between the various actors involved within an Industrial Ecology framework
The following papers were developed in this context:

- J. Ehrenfeld, P. Ferrão and I. Reis (2002) "Tools to support innovation of sustainable product systems", in: Knowledge for the Inclusive Development, pp. 417-433. Eds. P. Conceição, D. Gibson, M. Heitor and F. Veloso, Quorum Books.

Life Cycle Assessment – LCA:

- Ferrão, P., Ribeiro, P. and Silva, P. (2002). Avaliação de Ciclo de Vida de Embalagens de Bebidas e Bens Alimentares em Portugal Continental. Jornadas SPV, Lisboa, Sociedade Ponto Verde, 23 de Abril de 2002. [In Portuguese]

Design for Environment – DFE:

- S. Thore and P. Ferrão (2002) "The environmental impact of new products.", in: Technology Commercialisation: DEA and related analytical methods for evaluating the use and implementation of technical innovation, pp 277-290. Edited by S. Thore, Kluwer Academic Publishers .
- Ferrão, P., J. Amaral and P. Silva. 2003. Laying the foundations for a DfR tool for auto components. 14TH International Conference on Engineering Design ICED 03 Stockholm.

Hybrid Economic Input-Output Life Cycle Assessment – H-EIO-LCA:

- Ferrão, P. (2002). The use of EIO-LCA in assessing National Environmental Polices under the Kyoto Protocol: the Portuguese Economy. 6th International Conference on Technology Policy and Innovation, Kansai, Japan, 12-15 August 2002.

Material Flow Analysis – MFA:

- Canas, A., Análise da Intensidade de Utilização de Materiais na Economia, Dissertação para obtenção do Grau de Mestre em Engenharia e Gestão de Tecnologia, Departamento de Engenharia Mecânica, Instituto Superior Técnico, 2001.

System Dynamics – SD:

- Amaral, J., P. Ferrão and C. Rosas. 2002. Is recycling technology innovation a major driver for technology shift in the automobile industry under a EU context?. In Proceedings of the 6th International Conference on Technology, Policy and Innovation - Integrating Regional and Global Initiatives In the Learning Society. Kansai. August 2002.

b) Environmental Policy and Industrial Ecology Systems

The physical nature of the economy is emerging as a new paradigm, based on increasing public recognition of environment-economy interconnections. In this context, modern economies can be seen as ingesting raw materials, which are metabolised into products and services and also waste, in the form of materials/products without use and pollution. Environment-economy interconnections are dependent on economic activity fields or sectors, on the existing local infrastructures and future technological options, i.e. on the time and length scales imposed by the local-regional interactions at different levels (economic, regulatory, technological). The research developed concludes that innovation in environmental technologies may shift the spirit of product-oriented regulations and give rise to more efficient approaches if a transversal, Industrial Ecology perspective, integrating different products life cycles is adopted.

The following papers were developed in this context:

Automotive

- Ferrão, P., Amaral, J. and Reis, I. (2002). "The Industrial Ecology of the Automobile: a Portuguese Perspective." International Journal of Ecology and Environmental Sciences(28): 27-34 pp

Economy metabolism

- Ferrão, P. (2002). Economy's metabolism: Indicators, scales, and technology. 6th International Conference on Technology Policy and Innovation, Kansai, Japan, 12-15 August 2002.
- Canas, A., Ferrão, P. and Conceição, P. (2002) "A new environmental kuznets curve? Relationship between direct material input and income per capita: evidence from industrialized countries". Paper accepted for publication in the journal: Ecological Economics.

Electric and electronic equipments

- Giacommucci, M. Graziolo, P. Ferrão and A. Caldeira Pires (2002) "Environmental assessment in the electromechanical industry", in: Knowledge for the Inclusive Development, pp. 465-476. Eds. P. Conceição, D. Gibson, M. Heitor and F. Veloso, Quorum Books.

Packaging

- Ribeiro, P. (2002). Embalagens de Bens Alimentares: contributos para a definição de politicas eco-eficientes em Portugal. Dissertação para a obtenção do Grau de Mestre em Engenharia e Gestão de Tecnologia, Departamento de Engenharia Mecânica, Instituto Superior Técnico. [In Portuguese]
- Silva, P. (2002). Inovação ambiental na gestão de embalagens de bebidas em Portugal, Dissertação para a obtenção do Grau de Mestre em Engenharia e Gestão de Tecnologia, Departamento de Engenharia Mecânica, Instituto Superior Técnico. [In Portuguese]

c) Environmental Physics

The scientific activity in environmental physics has been developed within the framework of the project SAPIENS: POCTI/1999/CTA/35626 - Carbon Balance of Eucalypt Plantations in Portugal- the Kyoto Forest Problem. In the context of the Kyoto protocol, the activity developed is aimed at evaluating the magnitude, seasonality and repartition of the carbon fluxes and stocks in a Eucalyptus forest. Ultimately, the aim is to evaluate the potential of the eucalyptus forest to act as a carbon sink.
The research performed is mainly experimental and, as a consequence, a significant effort has been dedicated to set up an experimental rig at the Herdade da Espirra, Pegões, and now, a set of data taken from different sensors, during 2002, is available.

The following papers were developed in this context:

- Fluxos de momento, massa e energia na camada limite atmosférica em montado de sobro. Mestre Abel Rodrigues, Ph.D. in Environmental Engineering, IST, Junho de 2002.
- Filling the gaps in time series from a farm meteorological station , Palma, J., Domingos,J., Pita, G., Sousa, T. , VII congress of the European society for agronomy, Cordoba, Spain 15-18, July 2002.
- Full carbon balance in an eucalypt plantation in Portugal. [P7.23] The Carbon Balance of Forest Biomes, University of Southampton during the annual meeting of the SEB from the 1st to 4th of April 2003. J.S. Pereira (Instituto Superior de Agronomia, Lisbon); G. Pita, J. Silva (Instituto Superior de Técnico, Lisbon); A. Fabião, M. Carneiro, C. Nogueira (Instituto Superior de Agronomia; A. Rodrigues (Instituto Nacional de Investigação Agrária) & E. Ribeiro (Instituto Superior de Agronomia, Lisbon).

3.3 **Laboratory of Technology Policy and Management of Technology**

The work has drawn on recent conceptual approaches to economic growth, in which the accumulation of knowledge is the fundamental driving force behind growth. This fact is reflected in the trend in developed economies towards an increasing investment in advanced technology, research and development, education, and culture. Concepts such as learning ability, creativity and sustained flexibility gain greater importance as guiding principles for the conduct of individuals, institutions, nations and regions. It is thus legitimate to question the traditional way of viewing the role that contemporary institutions play in the process of economic development and to argue for the need to promote *systems of innovation and competence building* based on learning and knowledge networks. Under the broad designation of "learning and knowledge networks", the research results discuss the necessary balance between the creation and diffusion of knowledge and contribute to improve our understanding of the dynamics of the process of knowledge accumulation, which drives a learning society.

- Systems and Policies for Knowledge Creation, Diffusion and Usage
    - Higher Education Policy and Management
    - S&T and Innovation
- Learning Economy
    - Towards a "Learning Society"
    - Technology and Economic Inequality
- Management of Technology and Policy Implications

    - Globalization, diversification and technology capacity in the auto parts sector
    - Mobilizing information and communication technologies: implications for regional development
    - New energy systems: photovoltaic
- Strategy, Entrepreneurship and Technical change
    - Collaborative Learning and Virtual Teaming
    - Fostering entrepreneurship at the University

Main publications:

Books:

- P. Conceição, D. Gibson, M. V. Heitor, G. Sirilli, F. Veloso (eds.), (2002), *Knowledge for Inclusive Development*. Westport and London: Quorum Books.
- J.M.B. Brito, M. Heitor, M.F. Rollo (eds), (2002), "*Engenho e obra: uma abordagem á história da engenharia em Portugal no seculo XX*", Lisboa: Dom Quixote

Papers in Books and refereed journals:

- P. Conceição, M. V. Heitor (2002), "Knowledge Interaction Towards Inclusive Learning - Promoting Systems of Innovation and Competence Building", *Technological Forecasting and Social Change*, 69(7), pp.641-651.
- P. Conceição, D. Hammil, P. Pinheiro (2002), "Innovative Science and Technology Commercialization Strategies at 3M: A Case Study," *Journal of Engineering and Technology Management*, 19(1): 25-38.
- P. Conceição, M. V. Heitor (2002), "Knowledge Interaction Towards Inclusive Learning - Promoting Systems of Innovation and Competence Building", *Technological Forecasting and Social Change*, 69(7):641-651.
- Carneiro, R. and Conceição, P. (2002), "Beyond Formal Education: Learning-by-Doing, ICT Adoption and the Competitiveness of a Traditional Portuguese Sector," *European Journal of Education*, 37(3), pp.263-280.
- R Baptista (2002), "Productivity and the Density of Local Clusters", in "*Innovation Clusters and Inter-regional Competition*", Johannes Bröker, Dirk Dohse and Rüdiger Soltwedel (ed.s), The Series in Advances in Spatial Economics, Springer Verläg Publishers.
- P. Conceição, James K. Galbraith (2002), "Technological Intensity and Inter-sectoral Dynamics of Inequality: Evidence from the OECD, 1970-1990," *International Journal of Technology, Policy and Management*, 2(3), pp315-337.
- P. Conceição, and M. V. Heitor (2002), "University-based entrepreneurship and economic development: A learning-centred model", *International Journal of Technology, Policy and Management*, 2(3), pp220-239.

4. Beyond Research: Knowledge Transfer and Diffusion

The activities performed beyond the research work, but closely linked to the various R&D activities reported before, are described under the following themes:

- Advanced Training – Main Post-Graduation Education Programmes
- Advanced Training – Workshops
- Main R&D Projects
- C&T commercialisation activities
- C&T culture and dissemination projects
- International Conference Series
- Main Editorial Activities
- Awards

4.1 Advanced Training – Main Post-Graduation Education Programmes

The R&D activities performed at IN+ have been planned in close collaboration with various post-graduation programmes at IST, under which new young researchers are formed. One main programme is directly coordinated by members of IN+, and this programme have been particularly developed making use of IN+ resources:

- Master in "Engineering and Management of Technology", http://in3.dem.ist.utl.pt/master/

Thesis concluded:

Master:

- A. Galvão, 2002: Contribution to the Development of Performance Indicators of Wastewater Systems. (IST; supervision: J. Saldanha Matos)
- A. Canas, 2002: Análise da Intensidade de Utilização de Materiais na Economia. (IST; supervision: P Ferrão, P Conceição)
- D. Rubini, 2002: "A Critical Analysis of Science and Technology Parks: Learning from the Italian Experience". (IST; supervision: M. Heitor; P Conceição)
- P. Silva, 2002: Inovação ambiental na gestão de embalagens de bebidas em Portugal. (IST; supervision: Paulo Ferrão)
- P. Ribeiro, 2002. "Embalagens de bens alimentares: contributos para a definição de políticas eco-eficientes em Portugal". (IST; supervision: Prof. Paulo Ferrão).
- P. Faria, 2002. "A Case Study on Environmental Policy and Innovation – The Olive Oil Sector" (IST; supervision: P Ferrão, P Conceição)

4.2 Advanced Training – Workshops

The advanced Workshop series on "Science, Technology and Society", http://in3.dem.ist.utl.pt/adv/workshops/, developed through IN+ act as a forum to exchange ideas and an opportunity of scientifically discussing the global changes on the development and use of science and technology and related social and ecological consequences.

Analysis has shown that continuous technical change in business firms in modern societies require the close development of publicly funded research and associated training, so that the development of a country's science base is socially shaped (e.g. Pavitt, 1998; Research Policy). In this context, technology is not simply a tool or applied science, nor is science simply the result of knowledge accumulation. Rather,

science and technology are characterized by their entrenchment in society, thus requiring both interdisciplinary reflection and development of real-world strategies for action.

Based on this background, innovation has been increasingly considered as a key factor in corporate and socio-economic performance and analysis has shown the importance of decentralized industrial policy in support of wealth creation and the well-being of future generations. The workshops has taken place during one or two consecutive days, including only plenary sessions. Emphasis were given to structural aspects, namely through lectures delivered by national and international experts with the purpose of introducing fundamental concepts associated with the development of Science and Technology Policies. Technical sessions included expert topics which have raised world-wide attention, with emphasis on challenges and opportunities faced by enginners and researchers and technology managers in the context of the current European innovation policy.

The main workshops realized during 2002 were as follows:

- Workshop Oct.02 III: New Product Development in the Car Industry - October 21, 2002
- Workshop Oct.02 II: Product development and the culture of innovation in industry - October 7, 2002
- Workshop Oct.02: Engenharia de Produto de Bens de Equipamento no Norte de Portugal - 2 de Outubro, 2002
- Workshop Jun.02 III: Innovation for Portugal - 26 Junho 2002
- Workshop Jun.02 II: Collaborative design for new product development: Methods, tools and case studies - 24 Junho 2002
- Workshop Jun.02: Salão Internacional do Automóvel: Odisseia Automóvel 2002 - 6 Junho
- Workshop May.02 III: Desenvolvimento de produtos para a indústria automóvel - 28 de Maio de 2002 (Universidade do Minho)
- Workshop May.02 II: A ENGENHARIA E DESENVOLVIMENTO DO PRODUTO: O CONCEITO DOS DESIGN STUDIOS - PIEP, 21 de Maio de 2002
- Workshop May.02: Techgnology, Policy and Management: Learning by comparing transdisciplinary education and research programmes in Engineering Schools - May 20
- Workshop Apr.02: Engineering Design for Innovation: Lessons learned and perspectives for Portugal - April 30
- Workshop Mar.02 III: Engineering Design for Sustainable Mobility / IST, Centro de Congressos - 27 de Março
- Workshop Mar.02 II: Gestão e Política de Energia: REGULAÇÃO E REDES DE ENERGIA / IST, Centro de Congressos - 22 de Março
- Workshop Mar.02 I: Uma Agenda Nacional de Ensino e Investigação em Engenharia de Design: promover a inovação e a competitividade empresarial - 2ª feira, 11 de Março, 2002

4.3 Main R&D Projects

The following are the main R&D projects developed during 2002 by researchers at IN+:

- Direct Injection Spray Engine Processes - Mechanisms to Improve performance, Project DIME – ENK6-2000-00101
  Project Coordinator: Prof. Manuel Heitor
- "Dymanics and Control of Flame Stabilization and Propagation for Advanced Energy Systems".
  FCT-PCTI/1999/EME/34768, 1999-2003
  Project Coordinator: Prof. Edgar Fernandes
- TRESHIP- Technologies for Reduced Environmental Impact from Ships
  Instituto Superior Técnico, 1999-2003.
  Brite-Euram tematic network: BRRT-CT98-509.
  Project Coordinator: Prof. Paulo Ferrão
- "Inauto Autointeriores – Caracterização das Estratégias de Criação de Oportunidades e Promoção de Inovação ao Nível dos Materiais para o Interior de Veículos"
  Instituto Superior Técnico, 2001-2003.
  (Projecto financiado pelo Centro para a Excelência e Inovação na Indústria Automóvel, através do Programa Operacional da Economia)
  Project Coordinator: Prof. Paulo Ferrão
- "Ecotech – Apoio ao Desenvolvimento Eco-eficiente de Componentes Automóvel"
  Instituto Superior Técnico, 2001-2003.
  (Projecto financiado pelo Centro para. a Excelência e Inovação na Indústria Automóvel, através do Programa Operacional da Economia)
  Project Coordinator: Prof. Paulo Ferrão
- "A interacção entre partículas e estruturas turbulentas numa camada limite: Aplicação de diagnósticos laser para o estudo de transporte de sedimentos"
  Instituto Superior Técnico, 2000-2004.
  Projecto POCTI/EME/34183/2000.
  Project Coordinator: Prof. Paulo Ferrão
- "INAUTO – Design studios e gestão da tecnologia na industria automóvel"
  Instituto Superior Técnico, 2002-03.
  Projecto financiado pelo POE
  Project Coordinator: Prof. Manuel Heitor
- "Estudo de instabilidades precessionais do tipo vórtice helicoidal em câmaras de combustão de turbinas a gás com vista a obter baixos níveis de emissão dos poluentes CO e Nox".
  Instituto Superior Técnico.
  Projecto: FCT/SAPIENS99/PCTI/1999/EME/34768
  Project Coordinator: Prof. Edgar Fernandes
- Controlo das instabilidades associadas à injecção de combustível em câmaras de combustão.
  Instituto Superior Técnico, 2002-03.
  Projecto: FCT/SAPIENS99/PCTI/1999/EME/34586
  Project Coordinator: Prof. Manuel Heitor
- "MinKnock - Improving Engine Performance and Efficiency by Minimisation of Knock Probability".
  Instituto Superior Técnico, 2002-04.

Projecto financiado pelo programa Europeu Energie4-G2,Key Action 6, Contracto No. ENK6-CT2002-00643.
Project Coordinator: Prof. Edgar Fernandes

- "Flow and heat transfer characteristics of evaporating impinging sprays"
  Projecto POCTI/1999/EME/32960.
  Instituto Superior Técnico, 2001-2004.
  Project Coordinator: Prof. António Luis Moreira
- "Fluid-Particle correlations in Non-homogeneous Turbulent Two-Phase Flows"
  Projecto POCTI/2001/EME/38082.
  Instituto Superior Técnico, 2002-2005.
  Project Coordinator: Prof. António Luis Moreira
- "FATEC – Fábrica de Alta Tecnologia para a Fileira do Calçado".
  Projecto financiado pelo Programa Operacional da Economia, Contracto No. 03/183
  Instituto Superior Técnico, 2002-2005.
  Project Coordinator: Prof. Manuel Heitor
- "Beyond Engineering Education – How far Technical Universities have influenced Portuguese Society and Promoted Technical Change".
  Projecto POCTI/HCT/41796/2001.
  Instituto Superior Técnico, 2002-2004.
  Project Coordinator: Prof. Manuel Heitor
- "Desigualdade e Difusão da Tecnologia – Um Elo Negligenciado".
  Projecto POCTI/ECO/39755/2001.
  Instituto Superior Técnico, 2002-2004.
  Project Coordinator: Prof. Pedro Conceição
- "Glogablização, Diversificação e Captação Tecnológica : Estratégias e Efeitos Geográficos na Indústria de Componentes Automóvel".
  Projecto POCTI/42087/GES/2001.
  Instituto Superior Técnico, 2002-2005.
  Project Coordinator: Prof. Manuel Heitor
- "Carbon Balance of Eucalypt Plantations in Portugal- the Kyoto Forest Problem"
  Projecto POCTI/1999/CTA/35626
  Instituto Superior Técnico, 2002-2005.
  Project Coordinator: Prof. Gabriel Pita
- OCT / CIS III – "Proposta para a Execução do CIS III e de Obtenção de Informação sobre Inovação em Portugal Complementar à do CIS II"
  Instituto Superior Técnico, 2001-03.
  Projecto financiado pelo OCT/MCT
  Project Coordinator: Prof. Pedro Conceição

- OCT INOVAÇÃO – "Elementos para a Compreensão da Inovação em Portugal"
  Instituto Superior Técnico, 2001-03.
  Projecto financiado pelo OCT/MCT
  Project Coordinator: Prof. Manuel Heitor

4.4 C&T commercialisation activities

The Center has been involved in fostering C&T commercialization activities in a way to promote the creation and diffusion of knowledge beyond academia, by establishing conditions that will:

- Stimulate university entrepreneurship, through student and staff involvement in technology commercialisation projects;
- Foster advanced training and qualifications in technological platforms, by combining technical skills with a broader vision of the relationship between new technologies with economy and society;
- Promote entrepreneurial projects and the diffusion of applications/contents for new technologies.

The main project developed during 2002 was as follows:

- "Green.Wheel "
  http://www.green-wheel.net/
  (Financiamento público : POE)
  Coordinator: Prof. Manuel Heitor

  The **Green-Wheel Programme** is aimed at promoting technology-based entrepreneurship according to concepts that will foster sustainable human and entrepreneurial development, including the necessary development of new applications/contents associated with information and communication technologies, as well as a vast range of environment technologies, production processes, biotechnology and industrial processes that may directly contribute to sustainable development.

4.5 C&T culture and dissemination projects

The Center has been involved in fostering C&T culture through a series of major initiatives for children, youngsters and the population at large. During 2002, a major national exhibition was planned together with a competition for basic and secondary education, as described in the following paragraphs.

- "Engenho e Obra: Engenharia em Portugal no sec XX"
  http://www.engenharia.com.pt/
  Planning: January 2002 – December 2002
  Exhibition: 9 January – 2 March, 2003
  Coordinator: Prof. Manuel Heitor

  "Engenho e Obra" resulted from a wide-scope work programme, which was developed with the purpose of allowing the identification and analysis of the most important aspects of engineering in Portugal in the 20th century. Based on a multi-disciplinary research project involving a large group of engineers, historians, economists and technologists, the exhibit was designed with the goal of disseminating knowledge but, above all, of fostering a scientific-based technological culture, of spreading a historical message which allows citizens in general – and particularly younger generations – to learn and appreciate the facts and works, the strategies and conceptions, the failures and successes of 100 years of engineering knowledge, thought and achievement in Portugal. The exhibit reflected the "art of the engineer" as a creator, entrepreneur and innovator in the context of the historical development of engineering in Portugal, in order to better understand the

"moments of technological innovation" which occurred during the last one hundred years of the country's history.

The continuing challenges faced by Portuguese society, regarding the application of science and technology, are presented in the context of a growing centrality of the issues involving scientific activity. This analysis confirms the need to promote the pleasure of discovering, and a culture of innovation, while it requires the broadening of the base for learning and the promotion of the scientific foundations on which development must be sustained, in order to face the times of rapid technological change in which we live.

This exhibit was based on a historical matrix, containing 21 thematic zones and 6 contextual zones. The former correspond to the areas in which engineering took on greater importance and played a more innovative role in Portugal and, therefore, the 21 units are sorted in chronological order according to the main "technological innovation moments". The latter show the development of the historical framework in which engineering occurs and evolves during the 20th century in Portugal. They comprise the chronological treatment of the political setting, economic policy, the economic and social context, and the teaching of engineering and research.

- "PENSAR e FAZER engenharia com os mais novos"
  http://green-wheel.innovagency.com/site/gwb_competicao_01.asp?idioma=0&competicaoid=6
  National competition for basic and secondary education, 2002/03.
  Coordinator: Prof. Manuel Heitor

4.6 International Conference Series

The Center promotes the transfer and diffusion of knowledge through the organization of major international Conferences, which have considerably contributed to diffuse knowledge worldwide, and promote the internationalization of the Portuguese S&T system. Emphasis has been given, since 1982, to the application of laser techniques for fluid flow research, and this has contributed for the organization of a world leading conference in Lisbon every two years. Current activities include also the analysis of socio-economic research topics, namely looking at the role of knowledge for development. This has resulted in the organization of an international series of annual Conferences around the world.

The following are the most significant events planned and realized during 2002:

- **International Symposia on Applications of Laser Techniques to Fluid Mechanics**

The Symposia have contributed since 1982 for the presentation of new research on advanced techniques for flow measurement and results of significance to fluid mechanics. It has emphasized the application of laser, and other advanced techniques, to scientific and engineering investigations of fluid flow. Contributions to the theory and practice of measurement methods have been accepted where they facilitate new improved fluid mechanical investigations, and have included laser-

Doppler velocimetry, LDV, phase-Doppler velocimetry, particle image velocimetry, PIV, and laser induced fluorescence and other scalar diagnostics. Non-optical techniques that provide new and reliable information on fluid flows, heat and mass transfer and complement that obtained with laser diagnostics have also been considered for the various International Symposia.

The 11th Symposium was organized during 2002 and involved 39 formal sessions, involving about 180 technical papers in the following areas: LDV Signal and Data Processing;Two-phase flows instrumentation; Multi-Point Methods; Holographic PIVM; PIV Signal and Data Processing; Scalar diagnostics; Aerodynamic Flows; Biological and Complex Flows; Free Flows and Flames; Free Surface Flows; Wall Flows; Mixers; Separated Flows; Combustion and advanced combustor concepts; Engines;Sprays for Engines; Turbomachinery; Two-Phase Flows.

These Conferences have been launched in July 1982, in Lisbon, through a close partnership involving Professors Jim Whitelaw, Imperial College, Franz Durst, University of Erlagen, Ron Adrian, University of Illinois, and Diamantino Durão, IST. Since then, the Conferences have been organized in Lisbon, every two years, based on a close collaboration between the Center for Innovation, Technology and Policy Research, IN+, of the Instituto Superior Tecnico in Portugal, and the researchers mentioned before.

- **International Conferences on Technology Policy and Innovation**

The main objective of this series of international conferences on Technology Policy and Innovation is to bring together leading representatives of academic, business, and government sectors worldwide to present and discuss current and future issues of critical importance for using science and technology to foster regional economic development and shared prosperity at home and abroad . Multidisciplinary perspectives are encouraged to provide state-of-the-art and useful knowledge to decision makers in both the private and public sectors – including informed and effective education, business, and government policies and strategies for the global, knowledge economy.

The 1st International Conference on Technology Policy and Innovation was held in Macau, off the coast of China, July 2-4, 1997, with the theme “21st Century Opportunities and Challenges for Science, Technology and Innovation Policy”. The 2nd conference was held in Lisbon, Portugal, August 3-5, 1998, with the theme “Knowledge for Inclusive Development”. The 3rd Conference was held in Austin, Texas, August 30-September 2, 2000, with the theme “Global Knowledge Partnerships: Creating Value for the 21st Century”. The 4th Conference was held in Curitiba, Brazil, in August 2000, focusing on "Learning and knowledge networks for development". In 2001, the 5th Conference was held in Delft, the Netherlands, focusing on "Critical Infrastructures". The **6th Conference** was held in Kansai, Japan, in the summer 2002 emphasizing “Integrating Regional and Global Initiatives in the Learning Society”.

PUBLICATIONS: Selected and extended papers presented during the various Conferences has been published as follows:

- A series of special issues have been published in the international journal "Technological Forecasting and Social Change", http://in3.dem.ist.utl.pt/TFSC.
- A second series of special issues have been published in the Intl. Journal of Technology, Policy and Management, http://in3.dem.ist.utl.pt/s_issue/.
- Outstanding material presented during the Conferences has been published in a book series, as in http://in3.dem.ist.utl.pt/istpi/, through Greenwood Publishing Group Inc., and more recently from Purdue University Press.

These Conferences have been organized based on a close partnership between the IC2 Institute of The University of Texas at Austin, USA, and the Center for Innovation, Technology and Policy Research, IN+, of the Instituto Superior Tecnico in Portugal, but involving other major partners, as the Institute for International Studies of the Stanford University, USA, the Science and Technology Policy Research Unit of the University of Sussex, SPRU, UK, the Institute of Studies on Scientific Research of the italian National Research Council and the Delft University of Technology.

4.7 International networks

The following is a list of major international networks actively participated and/or coordinated by members of IN+ during 2002:

- **Graduate Consortium in "Technology, Management and Policy"**

Aim: To foster the academic analysis of Technology, Policy and Management in a way to bring together graduate students and researchers in Systems Engineering, Policy Analysis and Management and major faculties on Technology, Policy and Management.
Main partners:

- Faculty of Technology, Policy and Management – Delft Univ.Tech., NL
- Engineering and Public Policy – CMU, USA
- Engineering Systems Division – MIT, USA
- School of Public Policy – George Mason University, USA
- IST and the Centre for Technology, Policy and Innovation - UTL, PT

- **Cluster Entrepreneuship Task Force:**

Aim: to foster entrepreneurial education across Europe
Main partners: University of Technology Eindhoven; University of Technology Eindhoven; Universität Karlsruhe; Queen's University Belfast; University of Ulster; Imperial College, London; London Business School; Politecnico di Milano; London Business School; Politecnico di Milano; Ecole Centrale, Nantes; Ecole des Mines de Nantes

4.8 Main Editorial Activities

The following is a list of major editorial activities by members of IN+ during 2002:

- Technological Forecasting & Social Change - Special Issues
  Special Issues on "Science, Technology and Innovation Policies", as in http://in3.dem.ist.utl.pt/tfsc/

- Intl J. Technology, Policy and Management - Special Issues
  Special Issues on "Technology, Policy and Management", as in http://in3.dem.ist.utl.pt/s_issue/

- International Book Series on "Technology Policy and Innovation"
  The main objectives of this series, http://in3.dem.ist.utl.pt/istpi/ , are:
  - to publish leading scholarly work representing academic, business, and government sectors worldwide on technology policy and innovation; and
  - to present current and future issues of critical importance for using science and technology to foster regional economic development and shared prosperity.

  General Editors:
  - Manuel V. Heitor, Center for Innovation, Technology and Policy Research, Instituto Superior Técnico, Lisbon, Portugal
  - David V. Gibson, IC2 Institute, The University of Texas at Austin, Texas
  - Pedro Conceição, Center for Innovation, Technology and Policy Research, Instituto Superior Técnico, Lisbon, Portugal and

  Book edited in 2002:
  - P. Conceição, D. Gibson, M. V. Heitor, G. Sirilli, F. Veloso (eds.), (2002), *Knowledge for Inclusive Development*. Westport and London: Quorum Books.

- Our Books on History of Technology, through Dom Quixote
  - J.M.B. Brito, M. Heitor, M.F. Rollo (eds), (2002), "*Engenho e obra: uma abordagem á história da engenharia em Portugal no seculo XX*", Lisboa: Dom Quixote

Annex 1: Indicators (as required by Portuguese Science and Technology Foundation, FCT)

	Previsto	Realizado
Livros	2	2
Artigos em Revistas Internacionais	15	15
Artigos em Revistas Nacionais		
Comunicações em Encontros Científicos Internacionais	14	12
Comunicações em Encontros Científicos Nacionais	-	2
Relatórios	-	-
Organização de Seminários e Conferências	14	14
Teses de Doutoramento	1	-
Teses de Mestrado	4	4
Outras		
Modelos		
Aplicações Computacionais		
Instalações Piloto		
Protótipos Laboratoriais		
Patentes		
Outros		

Annex 2. List of Main Publications in 2002

Books

- P. Conceição, D. Gibson, M. V. Heitor, G. Sirilli, F. Veloso (eds.), (2002), *Knowledge for Inclusive Development.* Westport and London: Quorum Books.
- J.M.B. Brito, M. Heitor, M.F. Rollo (eds), (2002), "*Engenho e obra: uma abordagem á história da engenharia em Portugal no seculo XX*", Lisboa: Dom Quixote

Technical papers in International Journals and books

Laboratory of Thermofluids, Combustion and Energy Systems

- M. R. Panão and A. L. N. Moreira (2002): Visualization and analysis of spray impingement under cross flow conditions", in: *Gasoline Direct Injection Engines* 2002, SAE Publication SP-1719, pp.135 – 146.
- A. S. H. Moita and A. L. N. Moreira (2002): The deformation of single droplets impacting onto a flat surface, SAE 2002 Transactions, Journal of Fuels and Lubricants, pp. 1477 – 1489

Laboratory of Environmental Systems

- J. Ehrenfeld, P. Ferrão and I. Reis (2002) "Tools to support innovation of sustainable product systems", in: Knowledge for the Inclusive Development, pp. 417-433. Eds. P. Conceição, D. Gibson, M. Heitor and F. Veloso, Quorum Books.
- S. Thore and P. Ferrão (2002) "The environmental impact of new products.", in: Technology Commercialisation: DEA and related analytical methods for evaluating the use and implementation of technical innovation, pp 277-290. Edited by S. Thore, Kluwer Academic Publishers .
- Ferrão, P., Amaral, J. and Reis, I. (2002). "The Industrial Ecology of the Automobile: a Portuguese Perspective." International Journal of Ecology and Environmental Sciences(28): 27-34 pp
- Giacommucci, M. Graziolo, P. Ferrão and A. Caldeira Pires (2002) "Environmental assessment in the electromechanical industry", in: Knowledge for the Inclusive Development, pp. 465-476. Eds. P. Conceição, D. Gibson, M. Heitor and F. Veloso, Quorum Books.
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Laboratory of Technology Policy and Management of Technology

- P. Conceição, M. V. Heitor (2002), "Knowledge Interaction Towards Inclusive Learning - Promoting Systems of Innovation and Competence Building", *Technological Forecasting and Social Change*, 69(7), pp.641-651.
- P. Conceição, D. Hammil, P. Pinheiro (2002), "Innovative Science and Technology Commercialization Strategies at 3M: A Case Study," *Journal of Engineering and Technology Management*, 19(1): 25-38.
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