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Center for Innovation, Technology and Policy Research
Centro de Estudos em Inovação, Tecnologia e Políticas de Desenvolvimento

Annual Report 2003

Available at <http://in3.dem.ist.utl.pt>

Instituto Superior Técnico, Lisboa
March 2004



Annual Report: 2003

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I. RESEARCH TEAM (as by December, 2003)

Investigadores doutorados Integrados



Nome completo	Grau académico	Categoria profissional	% tempo elegível	Fracção
Manuel Frederico Tojal Valsassina Heitor	AGREGAÇÃO	PROFESSOR CATEDRÁTICO	75%	1
Antonio Luis Nobre Moreira	DOUTORAMENTO	PROFESSOR AUXILIAR	50%	1
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 [58]

Nome completo	Grau académico	Categoria profissional	% tempo elegível	Fracção
Burkhard N. Schrage	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	100%	1
Elsa Beatriz Padilla	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	100%	1
Nuno Arantes-Oliveira	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	60%	1
Serguei Ivanovich Chtork	DOUTORAMENTO	INVESTIGADOR PRINCIPAL	100%	1
Ángela Pereira De Matos Canas	MESTRADO	OUTRA	100%	
Carla Maria do Rosário Costa	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Casimiro Eduardo Da Conceição Cala	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Hugo Duarte Alves Horta	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Jorge Olivio Penicela Nhambiu	MESTRADO	INVESTIGADOR AUXILIAR	100%	
José Manuel Pinto Amaral	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Maria João dos Santos Rodrigues Pinto	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Miguel Martinho Lopes Praca	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Paulo Gil Dos Santos Silva	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Paulo Jorge Santos Monteiro Anacleto	MESTRADO	INVESTIGADOR AUXILIAR	30%	
Paulo Jorge Trigo Ribeiro	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Pedro Ferreira	MESTRADO	INVESTIGADOR AUXILIAR	30%	
Pedro Manuel Sousa Mendes Oliveira	MESTRADO	OUTRA	30%	
Richard Joseph Nunes	MESTRADO	INVESTIGADOR AUXILIAR	100%	
Alexandre José Pessanha de Oliveira Caimoto Duarte	LICENCIATURA	INVESTIGADOR AUXILIAR	100%	
Ana Luísa Marceneiro de Paiva	LICENCIATURA	INVESTIGADOR AUXILIAR	100%	
Ana Moita	LICENCIATURA	INVESTIGADOR AUXILIAR	100%	
Ana Paula Pires	LICENCIATURA	INVESTIGADOR	50%	

Ana Sofia Rodrigues Mascarenhas	LICENCIATURA	AUXILIAR INVESTIGADOR AUXILIAR	100%
Anabela de Jesus Adriano Piedade	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
António Miguel Areias Dias Amaral	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
David Filipe de Jesus dos Santos	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Eugénia Maria Bengalinha Ramiro	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Inês dos Santos Costa	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Joana Serra da Luz Mendonça	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
João Veríssimo Meyer	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Joaquim Miguel Serra Cardeira	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
José Carlos Bento de Carvalho	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Jose Luiz de Araujo Moutinho Neto	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Leonardo Springer Marques Moreira	LICENCIATURA	INVESTIGADOR AUXILIAR	75%
Manuel João de Albuquerque Rocha Pereira	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Maria José das Dores Francisco	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Miguel Rosa Panão	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Miguel Simões Torres Preto	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Nuno José Pereira Ávila Martins	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Nuno Manuel Rolo Creado	LICENCIATURA	INVESTIGADOR AUXILIAR	30%
Patrícia Isabel Alves Gomes Lages	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Paula Meireles	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Pedro Morais Martins de Faria	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Pedro Queiroga Ramos Nazareth	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Predrag Starcevic	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Robert Edward Leandro	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Vitor Manuel Guerreiro Lopes	LICENCIATURA	INVESTIGADOR AUXILIAR	100%
Carlos Eduardo Leite da Silva Correia	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
David Miguel Ribeiro Dias Lopes	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Humberto de Moura Loureiro	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Jordi Pirk	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Marcos Tiago Simões Calção	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Marta Isabel Pimenta Verdete da Silva Carvalho	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Miguel Ângelo Nunes Gaião	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Nuno Miguel Faria Cegonho	BACHARELATO	INVESTIGADOR AUXILIAR	100%
Paulo Alexandre de Maria Veríssimo	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%
Pedro Rama	BACHARELATO	NÃO APLICÁVEL (bolseiro)	50%
Rui Bruno Junqueira Mendonca Albuquerque Mendes	BACHARELATO	NÃO APLICÁVEL (bolseiro)	100%

Colaboradores [2]

	Nome completo	Grau académico	Categoria profissional	% tempo elegível	Fracção
	Aldina Maria Pedro Soares	MESTRADO	INVESTIGADOR AUXILIAR	50%	n.a.
	Filipe Manuel Simões Santos	MESTRADO	ASSISTENTE	30%	n.a.

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.

In addition to these three laboratories, the Center as developed the **IST Design Studio**, which aims at renewing and strengthening research and education in engineering design in a way to improve manufacturing competitiveness and innovation. The studio is centred on activities developed through the IST's M.Sc. on "Engineering Design", <http://in3.dem.ist.utl.pt/mscdesign/>, in close collaboration with industry, bringing together staff, researchers and students from the IST's Department of Mechanical Engineering, as well as from the Department of Engineering and Management Science, the Department of Civil Engineering and Architecture and the Department of Informatics. Its ultimate goal is to help extending the enterprise value chain in emerging and traditional sectors by incorporating the necessary design skills for new product development practices. To achieve this goal, our strategy is to introduce and promote product development strategies in Portugal by establishing a sustainable research and education programme to develop and transfer knowledge of engineering design, which will enable companies to continually:

- integrate design competencies
- improving product quality, and
- significantly reduce leadtime in product development, while
- increasing performance/cost ratio.

Our vision for the coming decade is the establishment of routine procedures of collaborative product development in Portuguese manufacturing, allowing the incorporation of design competencies in industry in a way to increase product value and reduce product development lead times, while simultaneously reducing life-cycle costs, improving quality and satisfying the general design requirements of minimum energy consumption, recycling capability and environmental friendliness.

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 researchers 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 and of the Master programme on “Engineering Design” in 2002, 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.
- **Advancements towards the development of ultra-clean vehicles**
 - Fundamental processes in IC engines: transient fuel injection; cold-start mixture formation process
 - Optimization of hybrid power propulsion systems for sustainable and flexible mobility

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

a) Turbulent mixing and combustion

Current understanding of turbulent combustion identifies turbulence / chemistry interactions and the role of different turbulent scales on the flame surface as crucial for the future development of combustion technologies and play a major role in the definition of turbulent combustion regimes. In addition, these interactions influence the scalar dissipation and, for example, turbulent heat fluxes, as counter-gradient diffusion occurs when the flow field near the flame is dominated by thermal dilatation due to chemical reaction.

Experimental work in progress at IN+ emphasises the use of sophisticated laser diagnostics with high spatial and temporal resolution, which can provide innovative results on the characterisation of scalar dissipation, turbulent heat fluxes and vorticity near the flame front. This includes the quantification of scalar-dissipation based on the combination of a Laser Doppler Anemometer with a LRS (Laser Rayleigh Scattering); the characterisation of eddy length scales and of vorticity distribution with a Particle

Image Velocimetry; or the characterization of the acoustic field induced by combustion based on purposed built optical and sound probes.

Sample publications in 2003 include:

- Anacleto, P. M., Fernandes, E. C., Heitor M. V. and Shtork, I, (2003). "Swirl flow structure and flame characteristics in a model lean premixed combustor", Combust. Sci. and Tech., 175, pp.1369 - 1388.
- Cala C.E., Fernandes E.C., Heitor M.V., Shtork S.I. (2003) Characterization of unsteady swirling flow based on phase averaging of pressure and LDA probe signals. 5th Euromech Fluid Mechanics Conference, EFMC-2003, August 24-28, 2003, Toulouse, France.
- V. Sivadas, E.C. Fernandes and M.V. Heitor (2003) Acoustically excited air-assisted liquid sheets. Exp. In Fluids, 34, pp.736-743.

b) Thermo-Fluid-Dynamics of multiphase flows

Liquid disintegration and spray formation

The impact of droplets onto solid surfaces occurs in a variety of technological and environmental processes. Improved understanding requires a better knowledge of the thermo-fluid-dynamic mechanisms of interaction between the impacting droplet and the surface.

Studies have considered the dynamic behaviour of droplets of different liquids impacting on flat, horizontal and dry commercial surfaces. The studies are being developed on a fundamental basis and are aimed at analyze the various outcomes of droplet impact and establish the influencing parameters. In this context, since the nature of the target surface plays a vital role, special attention has been given to its characterization. The nature of the surface is characterized by the wettability, as defined by the equilibrium contact angle and by its topography (surface roughness). The topography is characterized by roughness amplitude (quantified with the mean roughness, Ra and the mean peak-to-valley roughness, Rz) and its fundamental wavelength.

Sample publications in 2003 include:

- "Experiments on impinging intermittent sprays: dynamic behaviour of impact", A. L. N. Moreira, A. S. H. Moita and M. R. Panão, III Congresso Luso – Moçambicano de Engenharia, Maputo, Moçambique, 19 – 21 Agosto, 2003.
- "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

Fluid – dynamics of spray-wall impingement

When a spray impacts on a solid surface, different phenomena may occur depending on the kinetic energy and angle of impact of individual droplets, liquid properties and nature of the surface: droplets may adhere to the target surface, the resulting liquid film deform periodically up to all the energy at impact is dissipated, eventually causing radial instabilities which may grow and disrupt to give rise to secondary smaller droplets, which detach from the surface; re-atomization may also occur due to other mechanisms such as rebound or film stripping.

A basic picture of the impingement process is usually constructed based on single

droplet impingement, either on dry or wetted surfaces. However, in a poly-disperse spray, different phenomena occur simultaneously due to impact of multiple droplet sizes, which interact in a complex manner and the spray cannot be described as a summation over the entire droplet size range. In addition, when the spray is intermittent and the interposed surface is cold, the dynamic behaviour of the re-atomized droplets also depend on the transient formation of a liquid film; local temporal variations of its height and velocity associated with multiple drop impact; interaction between crowns of splashing drops and tiny bubble formation; secondary airflows induced by momentum transfer between the spray front and the surrounding air.

Those are the important phenomena determining features such as mixing and combustion in reciprocating and gas turbine engines, heat transfer rates in spray cooling systems, or the quality of the surface in surface treatment applications. A better knowledge of those mechanisms is therefore needed to improve the performance of practical devices, but still depends on the availability of detailed experiments in laboratory configurations.

Sample publications in 2003 include:

- M. R. O. Panão and A. L. N. Moreira (2003), “Experimental characterization of spray-wall interaction under cross-flow conditions”, 9th International Conference on Liquid Atomization and Spray Systems

Heat transfer characteristics of impinging volatile sprays

During recent years there has been an increasing demand for new techniques capable of removing high heat fluxes and it is expected that this demand will continue to increase in the future. Spray cooling is one of the most promising techniques being considered for the removal of high heat fluxes. Current and potential applications of spray cooling can be encountered either in large scale applications (e. g., in the metallurgical industry to achieve fast and controlled cooling, the nuclear industry to cool fission and fusion components) as in small scale applications such as in the medical industry to cool ion beam targets or the cooling of high temperature superconductors and electronics components.

However, lack of fundamental research is limiting the potential of spray cooling applications. Determination of heat transfer coefficients involves near simultaneous effects of multiple droplet impact upon a two-phase boiling film; droplet-film splashing, vapour bubble formation, evaporative mass loss, film thickness development, heat transfer to a hot wall emanating a heat flux, surface wave propagation, surface temperature effects, vapour partial pressure effects, and turbulence effects all influence the transient heat transfer coefficient. Additional key parameters determining heat transfer rate are related to spray mass flow rate, droplet size, spray and plate material thermo-physical properties, plate surface roughness, plate orientation to the spray direction, and area coverage of the spray onto the plate. A research program is being conducted, which includes experimental and analytical studies to fully characterize the thermal behaviour of spray cooling under steady state and transient conditions.

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 João 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.

Main publications in 2003 include:

- Mendes-Lopes J M C, Ventura J M P, and Amaral J M P: "Flame characteristics, temperature-time curves, and rate of spread in fires propagating in a bed of Pinus pinaster needles", Int. J. Wildland Fire, Vol. 12, N. 1, pp. 67-84, 2003

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 hazards.

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.

d) Clean vehicles for sustainable mobility

Recent technologic developments toward increasing the efficiency of car engines consider the use of hybrid power trains, which combine an electrical power system with an Internal Combustion Engine. However, restart of the IC engine poses particular problems, associated with the demands for a smooth and fast restart, as well as with the fact that 60% to 80% of emissions comes from "cold start" emissions, that is, pollutants that are emitted before the catalytic converter is hot enough to begin catalysing

combustion products. As a result control methods have to be devised to optimise fuel injection at restart.

However, regardless the fuel-air mixing strategy used (either Spark-Ignition Direct-Injection, Compression Ignition Direct Injection or Port-Fuel Injected), mixture preparation and flame propagation depend on spray/flame impingement onto interposed surfaces: there, unvaporised/unburned droplets will stick, rebound, spread or splash, depending on the relative magnitude between the several forces exerted upon each droplet, with eventual secondary re-atomisation of larger droplets; or a flame may locally quench due heat transfer with the surface thus causing knock. In addition, at cold start, an unburned fuel film would prevail longer at the impact surfaces, thus making it necessary to supply amounts of fuel exceeding those required for the ideal mixture ratio. As a result, the engine experiences an unstable burn with an associated significant increase in the emissions of unburned hydrocarbons. A better understanding of those interaction mechanisms is required to devise methods to control fuel injection, which may improve engine performance. This is one of the objectives of our research.

In addition, when a hybrid power system is considered, a series configuration is preferred because it allows keeping the IC engine working steadily at its maximum efficiency to deliver power to a battery and, then, the electrical engine provides the transient power. However, the power required by the engine depends on the car use (door-to-door or road drive), which makes it impossible to have the IC engine working at its maximum efficiency for all driving conditions. Improvements could be achieved if the injection mode can be controlled to achieve optimum operation. In this context, the behaviour of drivers is also accounted, not only in the typology of the power system, but also for the estimation of energy and resource consumption.

The ultimate goal towards the design and promoting the use of eco-combustion systems is to burn under lean condition, regarding the pollutant emission regulation while maximizing the global system efficiency. This concept is valid for a complete range of burning systems going from the domestic appliances to gas turbine combustors. However, under lean operating conditions there are self-sustained flame instabilities limiting the range of operations, induced either by the weakness of the lean flame stabilization process or shear layer instabilities, which are the main limitation for practical implementation of the concept. On the other hand, the burning system can benefit from those instabilities if they are controlled, because extended stability limits can be achieved, through hysteresis effects, as well as turbulent mixture can be enhanced, through large vortex motion.

The work developed in this topic then focus on unsteady flows and active control schemes studies, with the following main publications:

- "Injecção em motores de combustão interna" - In: AUTO-PROFISSIONAL, Produtos & Serviços, Maio 2004
- Experimental research for optimising internal combustion engines in: CORDIS, Portugal R&D Information Service
- "Flow characteristics of spray impingement in PFI injection systems", by M. R. O. Panão and A. L. N. Moreira

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:

Design for Environment – DFE:

- 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, Sweden, Stockholm.

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

- Ferrão, P., Nhambiu, J, and Suh, S. (2003) “Industrial Ecology of Portuguese Glass Products based on Hybrid Input-Output Analysis”. International Society or Industrial Ecology - Conference 2003: Industrial Ecology for a Sustainable Future. Ann Arbor, USA, June, 29th- July,2nd, 2003.

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:

The environment and the automobile:

- Ferrão, P. (2003) “O ambiente e o sector automóvel”. Ambiente 21, rubrica de inovação científica. Nº 8, ano II, pp. 52-53.

Ecological economics:

- Canas, A., Ferrão, P. and Conceição, P. (2003) “A new environmental kuznets curve? Relationship between direct material input and income per capita: evidence from industrialized countries”. Journal: Ecological Economics. Volume 46, Issue 2, September 2003 , Pages 217-229.

Energy and environment:

- P. Ferrão e M. Águas (2003) “Energia e Ambiente”, in: Engenho e Obra: Uma Abordagem à História da Engenharia em Portugal no Século XX., pp. 304-313. Dom Quixote.
- Ferrão, P., Jordão, M.F., Mendes, A.S. (2003). “ Uma bolsa de resíduos para Portugal”. Congresso sobre tecnologias de valorização de resíduos, organizado pela APEMETA com a colaboração do Instituto dos Resíduos. ExpoAmbiente 2003, FIL, Lisboa, 6 e 7 de Novembro de 2003.

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:

- 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).
- Fluxos de Massa e Energia na Camada Limite Atmosférica em Montado de Sobro, Abel Martins Rodrigues, Gabriel P.A. Pita, Silva Lusitana 11(1) 31-60, 2003
- Caracterização do Escoamento e Fluxo Atmosférico de Calor Latente em Montado de Sobro, Abel Martins Rodrigues, Gabriel P.A. Pita, Silva Lusitana 11(2) 165-184, 2003

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 (edited):

- D. Gibson, C. Stolp, P. Conceição, and M. V. Heitor (eds.), (2003), *Systems and Policies for the Global Learning Economy*. Westport and London: Praeger.
- M. Heitor, J.M.B. Brito, M.F. Rollo, H. Cayatte, J. Pessoa, R. Trindade (eds), (2003), “*Engenho e obra: memória de uma exposição*”, Lisboa: Dom Quixote
- P. Conceição, M. V. Heitor, B.-A. Lundvall (eds.), (2003), *Innovation, Competence Building, and Social Cohesion in Europe- Towards a Learning Society*, London: Edward Elgar.

Books in preparation:

- P. Conceição, M. V. Heitor (forthcoming), *Innovation for All? Learning from the Portuguese path to technical change and the dynamics of innovation*. Westport and London: Praeger.
- M. Heitor, J.M.B. Brito e M.F. Rollo (eds), (forthcoming), “*Momentos de Inovação e Engenharia em Portugal no século XX*”, Lisboa: Dom Quixote

Technical papers in journals and books (international referee):

- P. Conceição, M. V. Heitor, G. Sirilli and R. Wilson (2003), “The Swing of the Pendulum from Public to Market Support for Science and Technology: Is the US Leading the Way?”, *Technological Forecasting and Social Change*, 71(5).

- C. Costa, M. Fontes and M. Heitor (2003), “A Methodological Approach to the Marketing Process in the Biotechnology-based Companies”. *Industrial Marketing Management Journal*
- M. Heitor and J. Moutinho (2003) “Digital Cities and the opportunities for mobilizing the information society: case studies from Portugal”, in M. Tanabe, P. van den Besselaar and T. Ishida, Eds., *Digital Cities III – Computational and sociological approaches*. Springer Verlag.
- P. Conceição, M. V. Heitor, F. Veloso (2003), “Infrastructures, Incentives and Institutions: fostering distributed knowledge bases for the Learning Society”, *Technological Forecasting and Social Change*, 70, pp.583-617.
- P. Conceição, and M. V. Heitor (2003), “Technological Innovation and Productivity Growth: A Perspective after the IT Bubble’s burst”, *International Journal of Technology, Policy and Management*, 3(2), pp. 113-126.
- Conceição, P. and Heitor, M. (2003). “Systems of innovation and competence building across diversity: Learning from the Portuguese path in the European context” in Larisa V. Shavinina (Ed.). In “*International Handbook on Innovation*”, Elsevier, pp.945-975.
- Conceição, P. and Heitor, M. (2003). “Techno-economic Paradigms and Latecomer Industrialization” in *UNESCO Encyclopedia of Life Support Systems (EOLSS)*, Eolss Publishers, Oxford, UK
- F. Santos and M. Heitor (2003). “The cognocratic organization: toward a knowledge theory of the firm”, in D. Gibson, C. Stolp. P. Conceição, and M. V. Heitor (eds.), *Systems and Policies for the Global Learning Economy*. Westport and London: Praeger, pp. 465-481.
- P. Conceição, D Gibson, M Heitor and C. Stolp (2003). “Knowledge and Innovation for the Global learning Economy: building capacity for development”, in D. Gibson, C. Stolp. P. Conceição, and M. V. Heitor (eds.), *Systems and Policies for the Global Learning Economy*. Westport and London: Praeger, pp. 11-43.

3.4 IST Design Studio

The importance of designing discovery approaches that go beyond scientific method has been widely discussed, and the strategy of the IST Design Studio is focused on stimulating a creative attitude towards innovation. In general, the analysis shows that in the emerging learning economies, the secret of success is a combination of expertise in a productive manner. This breaks with existing concepts of time, space, mass and behaviour. In fact, current technological systems are complex, and carry many levels of cultural meaning, which per se brings new challenges and opportunities for innovative product development.

The building-up of design capabilities involves multiple learning routes, including formal and informal processes, where the roles of design development and production experience are simultaneously important. In this context, the IST Design Studio agenda was launched in 2003 based on a matrix of strategic scientific areas and integrating projects. While the scientific areas represent disciplinary-based knowledge in the way traditionally developed in engineering schools, the integrating projects are the actual cross-functional tools to achieve the required practical relevance of the research agenda. These projects will appear in clusters and should allow the clear implementation of industry-science relationships.

The research agenda in engineering design has been implemented by integrating expertise in eight different groups of scientific areas, including:

- Materials and Manufacturing Technologies
- Mechanics
- Electronics and Microsystems
- Sustainability
- Simulation and virtual prototyping
- Systems & design methods
- Management of technology and business innovation
- Design

The projects considered of strategic value for Portugal by the time of the definition of the IST Design Studio are grouped in the following topics:

- Autoparts for the future
- Train applications
- Sustainable mobility
- Design for citizenship
- Collaborative design

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. Two main programmes are directly coordinated by members of IN+, and these programmes have been particularly developed making use of IN+ resources:

- Master in “Engineering and Management of Technology”, <http://in3.dem.ist.utl.pt/master/>
- Master in “Engineering Design”, <http://in3.dem.ist.utl.pt/mscdesign/>

Thesis concluded:

Master:

- A.L. Alves, 2003: Alternative transport solutions: on the use of high-speed boats. (IST; supervision: M. Heitor)
- N. Ávila, 2003: Industry-Science Relationships: evidence from Portugal. (IST; supervision: M. Heitor, P Conceição)
- M. Leocádio, 2003: “RAMS” – Reliability, Availability, Maintainability, Safety: Application to Railway Vehicles. (IST; supervision: M. Heitor)
- Pedro Faria, 2003: A Case Study on Environmental Policy and Innovation - The Portuguese Olive Oil Sector in the 1990’s. (IST; supervision: Paulo Ferrão)
- Letras, J. (2003) “Critical aspects in the design for plastics packaging: a design for environment and design for recycling perspective”. Dissertação de mestrado em Engenharia e Gestão de Tecnologia”. (IST; supervision: Prof. Paulo Ferrão).

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 engineers and researchers and technology managers in the context of the current European innovation policy.

The main workshops realized during 2003 were as follows:

- *History of Engineering in Portugal, three series of Seminars, Lisbon, 9 January- 2 March, 2003*
- *Telecomunicações: Desafios e Oportunidades para Novos Negócios, Março - 8, 14 e 28, 2003*
- *University Technology Transfer: Research Methods and Policy Analysis Issues, May 2003*
- *Innovation and competence building for Europe: Towards a learning society a seminar on socio-economic research and innovation policy, October 2, 2003.*
- *Innovation across borders - October 27, 2003.*
- *Diffusion of Photovoltaic Solar Energy into Urban Areas - November 22, 2003*
- *Security of Supply in Competitive European Electricity Markets - October 25, 2003.*

4.3 Main R&D Projects

The following are the main R&D projects developed during 2003 by researchers at IN+:

- TRESHIP- Technologies for Reduced Environmental Impact from Ships
Instituto Superior Técnico, 1999-2003.
Brite-Euram thematic 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

- “Estudo para a Implementação de uma Unidade de Resíduos de Fragmentação”
Instituto Superior Técnico, 2003.
Projecto financiado pela Ecometais – Sociedade de Tratamento e Reciclagem, SA.
Project Coordinator: Prof. Paulo Ferrão
- “A interação 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
- “Desenvolvimento de um Sistema Integrado de Gestão de Resíduos”
Instituto Superior Técnico, 2003/2004.
Projecto financiado pelo INR-Instituto de Resíduos.
Project Coordinator: Prof. Paulo Ferrão
- “DEUSA - Desenvolvimento Empresarial Urbano Sustentável em Aveiro”
Instituto Superior Técnico, 2003/2005.
Projecto nº 04/00180, no âmbito das Parcerias Empresariais do Programa PRIME.
Project Coordinator: Prof. Paulo Ferrão
- “INAUTO – Design studios e gestão da tecnologia na industria automóvel”
Instituto Superior Técnico, 2003.
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 injeção de combustível em câmaras de combustão.
Instituto Superior Técnico, 2003.
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, 2003.
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
- “Desenvolvimento de um Módulo Assentos para uma Viatura Automóvel”.
Instituto Superior Técnico, 2003-2004.
Projecto financiado pela ACECIA, Componentes Integrados para a Indústria Automóvel, ACE
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

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 activities and projects developed during 2003 are 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.

- “VECTORe”
<http://www.green-wheel.net/>
(Financiamento público: POE)
Coordinator: Prof. Manuel Heitor

The main objective of this program was to provide engineering students and researchers with entrepreneurial skills complementary to their technological and scientific education. The program guided participants through a range of issues that cover the entrepreneurship process from idea to business, including strategic planning, potential and competitive market analysis, product and process management, gathering resources and financing, and internationalization. More than just simple pursue the objective of creating a start-up, this program was about thinking and acting like an entrepreneur– focused on recognizing and evaluating opportunities, locally and globally, permanently challenging the vision and improving the strategy, investing in team talent and motivation and generally promoting the creation of a culture of innovation.

The primary focus of the program was to accompany those students and participants who have either a concrete entrepreneurial idea or a strong entrepreneurial ambition. The program was structured in such a way that it provides some theory around the recurring and typical challenges encountered in the entrepreneurial process.

Primarily designed for junior and senior students in engineering sciences, the admission to VECTOR^e was selective and required candidates to have a technologically- or

innovation-based idea or project, to either develop a business plan or to write a case study on a company during the program.

Students were asked to prepare thoroughly for and actively participate in the class discussions. Three hours preparing the class and another three hours working on the business plan elaboration was the approximate time a week of the program. In order to get a passing grade, students were asked to develop and submit either a business plan or a written case study, during the program.

General Class structure:

- Tuesday, 18:00 to 21:00h, IST: “theory of entrepreneurship” and the essential tools, frameworks and models; class or case discussion; special knowledge and professional expertise;
 - Wednesday, 18:00 to 20:00h, in a selected Company: company presentation and guided visit, class discussion and final conclusions.
 - VECTOR^e Competition, December 14 , 2003: Business Plan presentations and evaluation.
- “Solvay Ideas Challenge ”
<http://www.green-wheel.net/>
Coordinator: Prof. Manuel Heitor

Conscious of an undisputed link between research and innovation, IN+ and *Solvay Portugal* tested an innovative approach to link academic R&D teams to main market issues through a “business plan competition” followed by a tour to several research centers in Portugal. The main goal of the Challenge Tour was to take a personal contact and to go inside of the best chemical research teams, visit their labs, know their knowledge fields, know them personally and make ourselves known among them. In seven months, the Challenge Tour visited Portugal from South to North and shared innovation spirit and openness. More than one hundred researchers assisted to specific presentations and encouraging news have arrived by e-mail and from newspapers feedback. As a result, fourteen projects have been presented to the competition, and a winner selected by a jury composed by all presidents of Portuguese chemical engineering departments.

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 2003, a major national exhibition was organized 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/>
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.

Main figures:

Area: 3000 m²

Visit duration: 2-4 hs.

Photographs: 120

Equipment and models: 312

Projection points: 82

Films: 21

Slides and image projection: 12

Interactive multimedia applications: 17

- The film: “Engenho e Obra – Engineering in Portugal in the 20th Century”

Produced by Fado Films and Gonçalo Galvão Teles, written by Diana Andringa and directed by Teresa Olga, the documentary entitled “Engenho e Obra: Engineering in Portugal in the 20th Century”, which accompanies the exhibition, aims at showing not only what direction engineering took, but also its teaching and the engineering profession itself, over the last century.

Following a chronological sequence, sometimes tortuous due to the internal chronology of each of the sub-areas (corresponding to the different modules of the exhibition), the documentary joins the images of the different periods with the

opinions of several engineers who talk about their work, and also of sociologists, historians, and professionals in the areas working in close contact with engineering, be it civil, mining or, most recently, bio-engineering.

With the cooperation of the archive of RTP (Portuguese state television) and ANIM (National Archive of Moving Images) – to whose professionals we are grateful for their contribution to this project - and of companies, laboratories and institutes that, going against the traditional Portuguese tendency for collective amnesia, preserved their film heritage, the authors of the project, in this documentary, present images that have not been shown in Portugal for a long time, from institutional films, cinematographic news and even advertisements that made history.

It will thus be possible to remember the commotion caused by the first trams in Oporto and Lisbon, the work in the mines of S. Pedro da Cova in the early days of last century, the works of the Junta Autónoma das Estradas, the pioneering work of the National Civil Engineering Laboratory (LNEC), the publicity around the launching of the torpedo-boat destroyers, the CP railroads, the construction of carriages by Sorefame, and the inauguration of the Lisbon underground, and the publicity of the company Oliva. Some engineers who stood out from the usual anonymous condition of their profession, such as Alfredo Bensaúde, Duarte Pacheco, Manuel Rocha, and Edgar Cardoso, will also be remembered. Furthermore, the current trends of engineering will be shown and some who are currently in the frontline of research in Portugal, particularly in telecommunications, robotics and bio-engineering, will be heard.

- “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, 2003.
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 2003:

- **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 planning of the 12th Symposium was organized during 2003 in order to involve approximately forty 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 Erlangen, 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" and the **7th Conference** was held during the period June 10-13, 2003 in Monterey, México, under the theme "Connecting People, Ideas, and Resources across Communities".

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 2003:

○ **Globelics, www.globelics.org :**

Aim: to improve understanding of the role of innovation and competence building systems for economic development. The aim is to establish a worldwide network connected through regular meetings (annual conferences and Ph.D. courses) and through an ICT-infrastructure (website, electronic publishing and ICT based discussion fora on specific topics). It may take the form of a dense European network with central European institutions, linked to regional nodes in respectively Latin America (Rio), Asia (Beijing), Africa (Johannesburg) and Eastern Europe (Moscow). Gradually the network may bring in other institutions around the world that pursue high quality research and research training in the area.

Globelics will be involved in the organisation of two annual conferences - one for senior scholars and one for Ph.D.-students. A programme for researcher training will be established. Globelics will also constitute a framework within which specific projects involving international collaboration around comparative research may first initiated and later their results discussed and disseminated.

Main partners: The members of the scientific committee of GLOBELICS are the following:

- Bengt Åke Lundvall, Prof., Department of Business Studies, Aalborg University, Denmark;
- Luc Soete, Prof., Faculty of Economics and Business Administration, Maastricht University, the Netherlands;
- Frieder Meyer-Krahmer, Prof., Fraunhofer-Institut für Systemtechnik und Innovationsforschung (ISI), Germany;
- Jose Eduardo Cassiolato, Prof., Instituto de Economia da Universidade Federal do Rio de Janeiro, Brazil;
- Richard Nelson, Prof., Columbia Graduate School of Business, Columbia's School of International and Public Affairs, and Columbia Law School, U.S.;
- Christopher Freeman, Emeritus Professor, Science and Technology Policy Research, University of Sussex, U.K.;
- João Caraça, Prof., Calouste Gulbenkian foundation, PT;
- Jorge Niosi, Dr., University of Québec, Canada;
- David Kaplan, Prof., Science and Technology Policy Research Centre, University of Cape Town, South Africa;
- Manuel Heitor, Prof., Center for Innovation, Technology, and Policy Research, Portugal;
- Shulin Gu, Dr., School of Economics and Management, Tsing Hua University, China.

○ **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 Entrepreneurship 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 2003:

- 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
- Our books through Edward Elgar
INNOVATION, COMPETENCE BUILDING, AND SOCIAL COHESION IN EUROPE: Towards a Learning Society
Editors: Pedro Conceição, Manuel V. Heitor and Bengt-Åke Lundvall
Publication date: October 2003
<http://in3.dem.ist.utl.pt/edwardelgar/>
- Our Books on History of Technology, through Dom Quixote
M. Heitor, J.M.B. Brito, M.F. Rollo, H. Cayatte, J. Pessoa, R. Trindade (eds), (2003), "Engenho e obra: memória de uma exposição", Lisboa: Dom Quixote
http://www.engenharia.com.pt/esxx_publicacao_00.asp

4.9 Main publications (opinion articles) in Newspapers

The following is a list of sample opinion articles published by members of IN+ in major Portuguese newspapers during 2003:

- PÚBLICO, Dec 29th, 2003
"Por Que Falha a Energia Solar em Portugal?"
Maria João Rodrigues
- PÚBLICO, Dec 15th, 2003
"A Infância Prolongada da Biotecnologia em Portugal"
Nuno Arantes e Oliveira
- PÚBLICO, Dec 8th, 2003
"Que Tipo de Educação Deve Ser Apoiada pelo Estado?"

- Pedro Conceição
- PÚBLICO, Dec 1st, 2003
"Será necessário estimular a evolução do ensino superior em Portugal?"
Manuel Heitor
 - PÚBLICO, Nov 17th, 2003
"Aumento da I&D em Portugal: que Papel para o Financiamento Público?"
Pedro Conceição e Manuel Heitor
 - PÚBLICO, Nov 10th, 2003
"Será que precisamos de cientistas?...e do Estado?"
Manuel Heitor
 - PÚBLICO, Jul 27th, 2003
"Será que a Inovação pode ser questionada?"
Manuel Heitor
 - PÚBLICO, Feb 3rd, 2003
"Portugal não Inovador? Sim, mas..."
Pedro Conceição e Manuel Heitor

4.10 Awards

The following is a list of major awards received by members of IN+ during 2003:

- "Solvay Innovation Trophy 2003" for "Management Improvement", através do projecto "Solvay Ideas Challenge", <http://www.green-wheel.net/>
Main members at IN+: Manuel Heitor and Maria Jose Francisco, with Paulo Conde from Solvay Portugal.
- Dibner Award 2003 – Society for the History of Technology, SHOT, Best Exhibition, através do projecto "Engenho e Obra"
Main members at IN+: Manuel Heitor, with Organizing Committee of the exhibition "Engenho e Obra".
- Prémio TELEciência 2003 (4º lugar) - V Festival Internacional do Filme de Divulgação Científica, através do filme "ENGENHO E OBRA: engenharia em Portugal no seculo XX"
Main members at IN+: Manuel Heitor, with Organizing Committee of the exhibition "Engenho e Obra".

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

	Previsto	Realizado
Livros	4	3
Artigos em Revistas Internacionais	16	14
Artigos em Revistas Nacionais	8	6
Comunicações em Encontros Científicos Internacionais	19	18
Comunicações em Encontros Científicos Nacionais	-	2
Relatórios	-	-
Organização de Seminários e Conferências	10	10
Teses de Doutoramento	1	-
Teses de Mestrado	5	5
Outras		
Modelos		
Aplicações Computacionais		
Instalações Piloto		
Protótipos Laboratoriais		
Patentes		
Outros		

Annex 2. List of Main Publications in 2003

Books

- D. Gibson, C. Stolp, P. Conceição, and M. V. Heitor (eds.), (2003), *Systems and Policies for the Global Learning Economy*. Westport and London: Praeger.
- M. Heitor, J.M.B. Brito, M.F. Rollo, H. Cayatte, J. Pessoa, R. Trindade (eds), (2003), “*Engenho e obra: memória de uma exposição*”, Lisboa: Dom Quixote
- P. Conceição, M. V. Heitor, B.-A. Lundvall (eds.), (2003), *Innovation, Competence Building, and Social Cohesion in Europe- Towards a Learning Society*, London: Edward Elgar.

Technical papers in International Journals and books

Laboratory of Thermofluids, Combustion and Energy Systems

- Anacleto, P. M., Fernandes, E. C., Heitor M. V. and Shtork, I, (2003). "Swirl flow structure and flame characteristics in a model lean premixed combustor", *Combust. Sci. and Tech.*, 175, pp.1369 - 1388.
- V. Sivadas, E.C. Fernandes and M.V. Heitor (2003) Acoustically excited air-assisted liquid sheets. *Exp. In Fluids*, 34, pp.736-743.
- Mendes-Lopes J M C, Ventura J M P, and Amaral J M P: "Flame characteristics, temperature-time curves, and rate of spread in fires propagating in a bed of Pinus pinaster needles", *Int. J. Wildland Fire*, Vol. 12, N. 1, pp. 67-84, 2003

Laboratory of Environmental Systems

- Canas, A., Ferrão, P. and Conceição, P. (2003) “A new environmental kuznets curve? Relationship between direct material input and income per capita: evidence from industrialized countries”. *Journal: Ecological Economics*. Volume 46, Issue 2, September 2003 , Pages 217-229.

Laboratory of Technology Policy and Management of Technology

- P. Conceição, M. V. Heitor, G. Sirilli and R. Wilson (2003), “The Swing of the Pendulum from Public to Market Support for Science and Technology: Is the US Leading the Way?”, *Technological Forecasting and Social Change*, 71(5).
- C. Costa, M. Fontes and M. Heitor (2003), “A Methodological Approach to the Marketing Process in the Biotechnology-based Companies”. *Industrial Marketing Management Journal*
- M. Heitor and J. Moutinho (2003) “Digital Cities and the opportunities for mobilizing the information society: case studies from Portugal”, in M. Tanabe, P. van den Besselaar and T. Ishida, Eds., *Digital Cities III – Computational and sociological approaches*. Springer Verlag.
- P. Conceição, M. V. Heitor, F. Veloso (2003), “Infrastructures, Incentives and Institutions: fostering distributed knowledge bases for the Learning Society”, *Technological Forecasting and Social Change*, 70, pp.583-617.
- P. Conceição, and M. V. Heitor (2003), “Technological Innovation and Productivity Growth: A Perspective after the IT Bubble’s burst”, *International Journal of Technology, Policy and Management*, 3(2), pp. 113-126.
- Conceição, P. and Heitor, M. (2003). “Systems of innovation and competence building across diversity: Learning from the Portuguese path in the European context” in Larisa V. Shavinina (Ed.). In “*International Handbook on Innovation*”, Elsevier, pp.945-975.
- Conceição, P. and Heitor, M. (2003). “Techno-economic Paradigms and Latecomer Industrialization” in *UNESCO Encyclopedia of Life Support Systems (EOLSS)*, Eolss Publishers, Oxford, UK

- F. Santos and M. Heitor (2003). "The cognocratic organization: toward a knowledge theory of the firm", in D. Gibson, C. Stolp. P. Conceição, and M. V. Heitor (eds.), Systems and Policies for the Global Learning Economy. Westport and London: Praeger, pp. 465-481.
- P. Conceição, D Gibson, M Heitor and C. Stolp (2003). "Knowledge and Innovation for the Global learning Economy: building capacity for development", in D. Gibson, C. Stolp. P. Conceição, and M. V. Heitor (eds.), Systems and Policies for the Global Learning Economy. Westport and London: Praeger, pp. 11-43.
- Nuno Arantes-Oliveira, Jennifer Berman and Cynthia Kenyon (2003). "Modulation of the Insulin Pathway by the Gonad in C. Elegans: Animals that Live Six Times as Long as Normal". Science 302: 611.

Technical papers in National Journals and books

Laboratory of Environmental Systems

- Ferrão, P. (2003) "O ambiente e o sector automóvel". Ambiente 21, rubrica de inovação científica. Nº 8, ano II, pp. 52-53.
- P. Ferrão e M. Águas (2003) "Energia e Ambiente", in: Engenho e Obra: Uma Abordagem à História da Engenharia em Portugal no Século XX., pp. 304-313. Dom Quixote.
- Fluxos de Massa e Energia na Camada Limite Atmosférica em Montado de Sobro, Abel Martins Rodrigues, Gabriel P.A. Pita, Silva Lusitana 11(1) 31-60, 2003
- Caracterização do Escoamento e Fluxo Atmosférico de Calor Latente em Montado de Sobro, Abel Martins Rodrigues, Gabriel P.A. Pita, Silva Lusitana 11(2) 165-184, 2003

Laboratory of Technology Policy and Management of Technology

- P. Conceição, M. Heitor e H. Horta (2003). "Reflexões sobre o ensino superior em Portugal: perspectivas para o desenvolvimento institucional", em A. Amaral (ed.), "Avaliação, revisão e consolidação da legislação do ensino superior", CIPES, Fundação da Universidades Portuguesas, pp. 175-195.
- M. Heitor (2003). "Bases de conhecimento e parcerias para a inovação", em M.J. Rodrigues, A. Neves e M.M. Godinho (eds), "Para uma Política de Inovação em Portugal", Lisboa: Dom Quixote, pp.183-210.

Technical papers and communications in International Conferences

Laboratory of Thermofluids, Combustion and Energy Systems

- Cala C.E., Fernandes E.C., Heitor M.V., Shtork S.I. (2003) Characterization of unsteady swirling flow based on phase averaging of pressure and LDA probe signals. 5th Euromech Fluid Mechanics Conference, EFMC-2003, August 24-28, 2003, Toulouse, France.
- "Experiments on impinging intermittent sprays: dynamic behaviour of impact", A. L. N. Moreira, A. S. H. Moita and M. R. Panão, III Congresso Luso – Moçambicano de Engenharia, Maputo, Moçambique, 19 – 21 Agosto, 2003.
- "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
- M. R. O. Panão and A. L. N. Moreira (2003), "Experimental characterization of spray-wall interaction under cross-flow conditions", 9th International Conference on Liquid Atomization and Spray Systems

- M. N. Nina and O. S. Ferreira (2003), “Flame Stability and Dynamic Effects in Lean-Burn Well Stirred Reactor”, Published in the Book of Extended Abstracts available at the International Colloquium on Combustion and Noise Control, Cranfield University, UK, 11 – 14 August 2003
- M. Nina and O. Ferreira (2003), Modelling Pollutant Emission in a well-Stirred Reactor”, Clean Air 2003 – Seventh International Conference on Energy for Clean Environment, Lisbon, 7-10 July 2003.
- Silva C, Farias T, and Mendes-Lopes J: “Calculation of Tailpipe Emissions in Ecogest”, accepted for oral presentation at 7th International Conf. on Energy for a Clean Environment, Lisbon, July 2003
- Silva C, Farias T, and Mendes-Lopes J: “Calculation of Fuel Consumption and Engine-out Emissions in Ecogest”, accepted for oral presentation at 7th International Conf. on Energy for a Clean Environment, Lisbon, July 2003

Laboratory of Environmental Systems

- Ferrão, P. C., Ribeiro, P. T. & Silva, P., 2003. Life Cycle Assessment of Food and Beverage packaging as a Tool for Policy Definition: the Portuguese Case Study, Presented at the Second ISIE conference, Industrial Ecology for a Sustainable Future, Ann Arbor, Michigan, USA, 29 June - 2 July 2003.
- 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, Sweden, Stockholm.
- Ferrão, P., Nhambiu, J, and Suh, S. (2003) “Industrial Ecology of Portuguese Glass Products based on Hybrid Input-Output Analysis”. International Society or Industrial Ecology - Conference 2003: Industrial Ecology for a Sustainable Future. Ann Arbor, USA, June, 29th- July, 2nd, 2003.
- J.S. Pereira, G. Pita, J. Silva, A. Fabião, M. Carneiro, C. Nogueira, A. Rodrigues , E. Ribeiro (2003) 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.

Laboratory of Technology Policy and Management of Technology

- Pedro Conceição, Beatriz Padilla, Pedro Faria, Miguel T. Preto and Pedro Ferreira (2003). Does Inequality Hinder the Diffusion of Technology? Preliminary Explorations, Presented at 7th International Conference on Technology Policy and Innovations, Monterrey, México, June 2003.
- Pedro Conceição, Pedro Faria (2003), Technology Diffusion of Modeling ICTs: Brief Overviews and Gaps. Presented at the “Clean Technologies Diffusion Workshop” IPTS, Seville, Spain November 2003.
- Pedro Conceição, and Manuel Heitor (2003). “The swing of the pendulum: from market to public funding of S&T?”, Presented at 7th International Conference on Technology Policy and Innovations, Monterrey, México, June 2003.
- M. Heitor, R. Nunes and P. Conceição (2003). “Technological Change and the challenges for Regional Development: Building ‘social capital’ in Less Favored Regions”, Presented in the Intl. Conference on “Social capital, innovation and regional development”, European Commission.
- P. Conceição, M. Heitor and F. Veloso (2003). “Innovative shocks and productivity”, Presented at the Conference “What do We Know About Innovation? A Conference in Honour of Keith Pavitt”, The Freeman Centre, University of Sussex, Brighton, U.K., 13th-15th November 2003.

Technical papers and communications in National Conferences

- Ferrão, P., Jordão, M.F., Mendes, A.S. (2003). “ Uma bolsa de resíduos para Portugal”. Congresso sobre tecnologias de valorização de resíduos, organizado pela APEMETA com a colaboração do Instituto dos Resíduos. ExpoAmbiente 2003, FIL, Lisboa, 6 e 7 de Novembro de 2003.
- Ferrão, P., Ribeiro, P. T. & Silva, P., 2003. Análise de Ciclo de Vida de Embalagens Domésticas, Apresentado nas Jornadas Técnicas Internacionais de Resíduos, Leiria, 22-24 de Outubro de 2003.

Master thesis

- A.L. Alves, 2003: Alternative transport solutions: on the use of high-speed boats. (IST; supervision: M. Heitor)
- N. Ávila, 2003: Industry-Science Relationships: evidence from Portugal. (IST; supervision: M. Heitor, P Conceição)
- M. Leocádio, 2003: “RAMS” – Reliability, Availability, Maintainability, Safety: Application to Railway Vehicles. (IST; supervision: M. Heitor)
- Pedro Faria, 2003: A Case Study on Environmental Policy and Innovation - The Portuguese Olive Oil Sector in the 1990's. (IST; supervision: Paulo Ferrão)
- Letras, J. (2003) “Critical aspects in the design for plastics packaging: a design for environment and design for recycling perspective”. Dissertação de mestrado em Engenharia e Gestão de Tecnologia”. (IST; supervision: Prof. Paulo Ferrão).
- Oscar D.C. Silva Ferreira “ Combustão de Pré-Misturas Pobres em Reactor de Mistura Perfeita”, DEM-IST, Março de 2003, (IST; supervision: Prof. Mário Nina).