A SUCCESSFUL MODEL OF COOPERATION BETWEEN A PUBLIC UNIVERSITY AND INDUSTRIAL COMPANIES THROUGH A HYBRID PUBLIC/PRIVATE R&D INSTITUTE

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ABSTRACT

The pattern of Portuguese Industry is typically composed by small and medium sized enterprises. In many cases, the dimension of these companies unable a general innovation culture for their products, with their own human resources. In these cases, innovation can successfully be achieved through suitable cooperation models and technological transfer between Universities and/or its Research and Development (R&D) Interface Organizations.

This paper describes a successful model of cooperation between a hybrid private/public Institute, INEGI, with more than 60 Industrial Associates and National and International Industrial Companies. It is also shown the advantage of having industrial R&D Projects running inside the Faculty and the benefits obtained with the involvement of students in these projects. Examples are presented with paradigmatic projects, with high industrial impact, leading to effective competitive growth, both on Portuguese and International companies. The intervention areas of these projects cover a large variety of multidisciplinary topics, from renewable energies, processes and mechanical systems development, composite structures, rapid prototyping and advanced technologies, industrial management, to the creation of technological spin-offs.

INTRODUCTION

The challenges and the broad objectives faced by the European Union countries, where Portugal is integrated, can only be ensured by the significant increase in productivity and competitiveness of its business at a global scale. Far away are the days when it was possible to think of production vectors as the principal means of business competitiveness. The opening of the European Union (EU) to a number of countries from the old "Eastern bloc", the recent development of the Asian economy, globalization and the imperatives of sustainable development, demands that Intelligence and Knowledge will be the main factor of progress through Research, Development and Innovation (R&D+i).

To achieve these objectives, it is fundamental to establish an efficient relationship among the Universities, Technology Centers, R&D+i Centers and the Industrial Sector. Only with this strategy it will be possible to achieve a real convergence between Portugal and the rest of the EU countries.

The activity of INEGI - Institute of Mechanical Engineering and Industrial Management, is part of this strategy, by developing, in collaboration with companies and other entities of the National and International science and technology system, projects of R&D that cover broad areas of Mechanical Engineering, Production Engineering and Industrial Management. The industrial sectors in which the Institute develops its activity are the Automotive, Aeronautics and Aerospace, Construction, Transportation, Cork and Wood, Energy, Environment and Defense. The main task is to assure that the knowledge produced in the University is transferred to Industrial companies.

The economic value of knowledge should be a priority for the nation and represents a factor of development, capable of generating competitive advantages.

Technology transfer between Universities and Industry has been a widely discussed issue in Portugal, and it is recognized that there is still a long way to go. Technology Centers and
R&D Centers have been playing a key role in establishing this bridge of knowledge.

The University of Porto (UP), in which INEGI is integrated, is the largest Portuguese University, with more than 24.000 students, 2.200 teachers, 1.300 technicians and 14 Faculties, covering almost all areas of knowledge. Its connection to the business world is, in most cases, assured through autonomous institutions, of public, private or hybrid nature, with the mission of transfer the knowledge of new strategies, methodologies, products, processes and systems. These institutions have the task of achieving successful technology transfer and transform knowledge in practical applications useful to business and industry.

DESCRIPTION OF INEGI

INEGI (figure 1) was born in 1986 to establish a strong connection between the Department of Mechanical Engineering (DEMec) of the Faculty of Engineering of University of Porto (FEUP) and the economic tissue of Northern Portugal.

Figure 1 - INEGI facilities on the campus of FEUP.

In this context, the Institute appears with the Mission to contribute towards the increase of competitiveness of Portuguese industry through research and development, demonstration, transfer of technology and training in the areas of engineering design, materials, production, energy, maintenance, management and environment. Today, this goal is achieved with the permanent INEGI’s staff, students and professors from DEMec and other Engineering Departments of FEUP and other organizations. Since its creation, the Institute developed over 1200 projects for public and private organizations, where the students, from DEMec and other departments and institutions, have the opportunity to see and participate in innovative industrial projects, anticipating their contact with industrial problems and enabling their introduction to the industrial world.

The management executive board of INEGI is composed by five elements, two of them representing the public interests of the University, and the other three representing the private interests of the companies. The Shareholders of the Institute are the University of Porto, with 40% of the capital, while the other 60% are detained by more than 60 private companies and 3 associations representing industrial sectors.

Over its 24 years of existence, INEGI developed and consolidated a position of industrial partner for R&D projects, and presently more than 60% of its total turnover comes from industrial projects with companies. Is a “Non-Profit Private Association” with a status of "Public Utility", and achieves its mission through the implementation of collaborative R&D+i in five main fields of intervention, namely:

- Knowledge creation and technological development before industrial application: typically funded by programs to support research in science and technology as the ones promoted by FCT – Portuguese Foundation for Science and Technology;
- R&D+i with companies, through co-funded programs to support the development of industry: a very significant part of the activity is the achievement of collaborative R&D+i in partnership with companies, using the existing incentives within the National and EU Framework programs;
- Scientific and technological consultancy: business support in the scientific and technological aspects in the field of activity; engineering and product development, technological processes, energy, environment and industrial management;
- Specialized training: highly specific with the best players, tailored to the specific needs of companies.

In addition to the more scientific and technological activity, also supported the creation of spin-offs for exploitation and commercial development of technologies developed or under development at the Institute.

The headcount currently consists of 215 persons, 67 are university professors, cooperating under protocols established with the University of Porto, and 61 are masters and PhD students with scholarships. This framework, with 87 full-time employees ensures a dynamic response to company needs.

INEGI also integrates final year senior students to do their master's thesis, through integration in ongoing R&D projects or laboratory activities. The Institute also serves as a launching pad for highly specialized engineers that start their career at the Institute, before being hired by industrial companies; many of them project partners of the Institute.

In 2009, the turnover was over 5 million Euros and over 300 papers were published in journals and national and international conferences. More than 50 master's and PhD thesis were accomplished, not only within the scope of Mechanical Engineering, but also on Industrial Design, Environmental Engineering, Biomedical Engineering, Maintenance, and others.

AREAS OF COMPETENCE

The ability to develop industrial solutions is supported on a wide range of skills related to the field of Mechanical
When necessary, external expertise is incorporated through the participation of staff from other departments or other research and higher education institutions.

The Institute encourages multi-disciplinary partnerships due to the increasing technological complexity of the current challenges that require the integration of several scientific and technological fields, leading, in many cases, to innovative solutions. In its relationship with companies, project teams are created with the participation of senior members of the companies to maximize knowledge sharing.

The generation of knowledge and development of new technologies are supported by the activity of several scientific and technological units, covering almost all specialties of Mechanical Engineering and Industrial Management.

**DESCRIPTION OF ACTIVITY**

Considering the number and diversity of projects in which INEGI is involved, this paper only presents a sample of the more relevant projects recently developed with a significant industrial impact [1-2]. The selected projects are included in the following fields:

- Energy and Sustainable Development
- Product Development
- Aeronautics and Aerospace
- Composite Materials Technology
- New Technologies and Rapid Prototyping
- Tribology, Vibrations and Industrial Maintenance
- Optics and Experimental Mechanics

**Energy and Sustainable Development**

This is an area with significant activity, with cooperation in the following fields:

- Characterization of industrial effluents and environmental consultancy;
- Noise measurement;
- Evaluation of environmental conditions in working places;
- Energy and Environment;
- Renewable energy and fuel cells.

INEGI has a certified national laboratory (IPAC - Portuguese Institute for Accreditation, according to NP EN ISO/IEC 17025), performing tests to determine noise emissions and gaseous effluents.

In partnership with SRE - Soluções Racionais de Energia, SA, a National company, developed power sources based on fuel cells and solutions for storing and distributing of hydrogen. In 2005, the first fuel cell power system for portable and mobile systems was developed (up to 500W). After three years of research a power supply of 100W, designated HW 125, was launched in the global market by SRE (figure 2).

![Figure 2 - HW125 Hydrogen Fuel Cell power supply.](image)

The contribution in the area of Wind Energy is broad and widely recognized, with an important role in achieving the target of 1000MW installed in Portugal in 2005 (3800MW will be available in 2010).

A fruitful relationship was developed with a wide range of customers operating in the wind energy market and whose results have allowed an interesting contribution for the development of wind power in Portugal. The involvement has different shapes and helped to develop the majority of projects implemented in Portugal until December 2008. Referring the installed capacity, about 80% of the connected power has been developed with INEGI’s assistance.

From the nearly 2800MW of installed power by the end of 2008, the Institute was involved in 80%. The assistance consisted in 47% of wind resource studies and 44% in measuring campaigns; supporting manufacturers in calls as warranty verification, covered 30% of that power, and 28% in the form of due-diligences (figure 3).

![Figure 3 - Activity in the area of Wind Energy.](image)
The intervention regarding consultancy in wind energy is growing in other countries such as Spain, Italy, France, Poland, Romania, Hungary, Albany, Angola and Brazil (figure 3).

A total of more than 580 stations of wind measurement stations were installed and 210 are currently in operation.

The Institute collaborated actively in the preparatory work of a German group for the installation in Portugal of several factories to build wind turbines components and a research center.

The experience of more than 15 years in the assessment of wind energy potential created internal advanced competences that are now starting to be used for offshore studies in the Atlantic Portuguese coast (figure 4).

Figure 4 - Statement of INEGI in the area of Wind Energy.

The exploitation of wave and tidal energy is also a priority due to the potential they represent.

With the MARTIFER ENERGY Company, began a collaborative project to develop a new innovative system for wave energy generation (figure 5). The system will be installed near Peniche, in the Pilot Wave and Wind Energy Farm created by the Portuguese Government for prototype testing and development.

Figure 5 - Wave energy prototype (Martifer Energia).

Product Development

INEGI has a wide experience in cooperative projects with companies and R&D+i institutions in the area of product and processes development. Specific skills for this activity are considered essential to increase the competitiveness of the national industry. In recent years, a consistent grow of this area and of engineering disciplines related to management and product development has been very useful for the implementation of innovative practices in our partners as well as strategic planning, structured methodologies, project management and coordination of activities with other functional areas.

Another very important aspect is the use, training and dissemination of support tools for product development, such as modeling tools, CAD "Computer Aided Design," structural design tools, CAE "Computer Aided Engineering" and numerical simulation tools for production processes, FEM "Finite Element Modeling".

Other relevant instruments to reduce development times and enhance cooperation between companies are the tools supporting product development in a distributed and collaborative simultaneous engineering, product information management and virtual prototyping. Capabilities in the field of engineering and product development, coupled with skills in the field of rapid prototyping, process simulation and prototype manufacturing in different materials, lead to unmatched capabilities in this field and a unique national institution with this profile. The area of product development is recognized by its excellence both at national and international markets. Several products are today on the global market, some of them with international excellence awards.

In 2004 the PET Project that consists on the development of mammography equipment (Figure 6), was launched using PET technology - "Positron Emission Tomography." This is an initiative of a consortium involving, in addition to INEGI, other universities, national laboratories and hospitals, and also counts with the collaboration of CERN - European Center for Nuclear Research, in the area of photons detection technology. This Project developed new medical equipment that significantly improves the ability to detect, in an earlier stage of development, the breast cancer in comparison with existing techniques. The Institute is responsible for the design and assembly of the robotic system, the mechanical components of the PET detectors, the control temperature system, and the integration of the equipment components developed by the partners.

Figure 6 - PET Equipment for mammography.
Since 2009, an upgraded version of this equipment is installed at the IPO - Portuguese Institute of Oncology, for validation and clinic tests, with very promising results.

Another project that contributed to preserve the tradition of Porto city, with its historical centre classified by UNESCO as world heritage, was the development and implementation of an innovative brake emergency system for electrical Historic Trams (Brill 21E, better known as Brill Drive) that improved the braking efficiency and security in steep slopes, allowing the preservation and use of this non-pollutant traditional transportation vehicles built in the 20’s and 30’s decades (figure 7).

The innovation consisted in applying a braking system based on the use of electromagnetic skates that directly rub on the rails. Each skate has an electrical coil that generates a magnetic flux in its core and polar bodies, creating an attraction force between the skate and the rail, thus generating a braking force.

Figure 7 - New braking system of Porto Historic Trams.

Another partnership with a multinational company and other institutions led to an industrial product of great notoriety and success in national and international market. This project consisted in the development of a new domestic gas container for the largest Portuguese oil and Gas Company and was internationally awarded in 2005 with the "Spirit of Conquest" of the "JEC Composite Innovations Awards Program" (figure 8).

The challenge was to significantly reduce this product weight, making transportation more comfortable, and respecting European directives concerning health weight limits for human use. The INEGI’s participation covered the development of a new hybrid structure composed by a thinner steel core reinforced with a filament winding composite process, testing the behavior of the reservoir and pressure testing of vaporization.

This product has been constantly redesigned (figure 9) to obey specific standards from different countries and other type of applications (domestic, camping and industrial), and largely exceeded the initial commercial expectations, continuously receiving international awards.

Figure 8 - Bottle Gas "Pluma" and manufacturing process.

Figure 9 - Gas containers for different applications.

INEGI has a recognized research team in the field of heat transfer, combustion and energy. The constitution of a partnership with one of the world leader manufacturer of water heaters, "BOSCH" group, led to several innovations in these equipments (figure 10).

Figure 10 – "Bosch" water heater for domestic application.
This collaboration involves multidisciplinary expertise, particularly in the areas of combustion, mechanical design, automation, instrumentation and control work, sheet metal, mechanical vibrations and experimental analysis, using computerized tools to support engineering and cooperative project management. It also involves the ability to build and test prototypes of parts, tools and products for experimental trials in the field. These new products are the result of long term cooperation, having great success in international markets due to its high power/volume ratio, price and unparallel environmental characteristics concerning pollutant emissions.

In 2006 the unit of composite materials was challenged to develop and deliver, in collaboration with CIMAR (Centre for Marine Research of UP), new equipments for ocean research.

A new hyperbaric chamber was designed to allow labatorial simulation of underwater conditions existent at 2000 meters depths (figure 11). Based on the production technology developed for gas containers, a new filament winding composite chamber, extremely light (about one quarter of the weight of conventional metal solutions), was designed to withstand extreme pressures and with high durability in saline environment.

![Figure 11](image11.png)

**Figure 11** – Hyperbaric chamber for marine biology research.

Ocean technology is a strategic area with several projects underway. The Institute participates actively in the management board of IDCEM (Institute for the Development of Knowledge and Science of the Sea) and of Oceano XXI, the Portuguese National Ocean Cluster, identifying research equipment needs for oceanographic research (figure 12).

![Figure 12](image12.png)

**Figure 12** – Ocean buoys for oceanographic monitoring.

A research project with several partners from Portugal and North of Spain is developing innovative ocean buoys for oceanographic monitoring (mechanical, biological and environmental data).

As an affiliate of the Laboratory for Underwater Systems and Technologies (LSTS) FEUP, INEGI participates in the design, development, testing and delivery of three new platforms for AUV’s, Autonomous Underwater Vehicles (figure 13), for inspection of ocean submerged structures. This project is co-financed by the National Innovation Agency. The institute is responsible for structural composite materials expertise and rapid prototyping.

![Figure 13](image13.png)

**Figure 13** – Underwater vehicles for ocean inspections.

Offshore platforms located in ocean regions with high depths demand special requirements regarding anchorage and associated cables. In partnership with a National company, a new drive system and cable reel was developed. The nylon cables reached a tensile resistance of 20,000 kN, value that was never achieved before in the world. The innovation was the strength and stiffness of the nylon material cables, needed in the oil industry, for oil exploitation in deep ocean waters, as in the Gulf of Mexico.

INEGI developed a equipment that includes a hydraulic tension system for the cable production unit and a winding reel with 5 meters diameter, 8 meters wide and a total weight of 60 tons (figure 14).

![Figure 14](image14.png)

**Figure 14** – Winding reel system with the nylon cable.
**Aeronautics and Aerospace**

This is an active and growing field of INEGI’s activity, with international recognized expertise in the area of structural integrity, development of design methodologies and design of structures in composite materials.

Partnerships in several projects with the European Space Agency (ESA), NASA and the Aeronautical Sector (Boeing, Airbus, Embraer, Lockheed-Martin, MT-Aerospace, EADS-CASA Espacio, etc.) and several European Universities are the recognition of the Institute’s competences.

The European project PIBRAC aims to develop a new generation of brake system for commercial aircrafts. This system (Figure 15), which is a disruptive technology with the conventional systems for aircraft brakes, uses piezoelectric crystal plates that when submitted to an electric current, generate a braking force. INEGI is responsible for modeling and simulation of the piezoelectric actuator and for the design of the complete brake system.

![Figure 15 - Development of a new brake system generation for the Airbus plane.](image)

Considering the current world concerns about aircraft security, the French company SAGEM, leads a project that aims to develop a security system for civilian aircraft against portable missile attacks (figure 16). INEGI is enrolled in the development of the mechanical parts and optical and laser technology of the system that, located on the bottom part of the airplane fuselage, deviate the missile trajectory.

![Figure 16 – Mechanical component for the CASAM missile system.](image)

In the area of aerospace (figure 17), as “Prime” contractor, developed for ESA the following research activities:

- Methodologies to predict the yield strength and load capacity of mechanical couplings in advanced composite materials;
- Definition of load capacity of mechanical joints in composites;
- Analysis of the influence of extreme temperatures in the rigidity and behavior of mechanical joints.

This project involved the following activities:

- Mechanical tests on composite materials using advanced techniques of data acquisition, acoustic emission and imaging;
- Development of analytical and numerical tools for the prediction of damage and rupture of joints;
- Development of a "standard" procedure for the design and dimensioning of mechanical joints.

Another aspect of this project was the manufacture of "breadboard joint structures" to demonstrate the joints resistance based on innovative concepts.

![Figure 17 - Development of innovative connections in composite materials for aerospace.](image)

Cooperation with NASA in the development of computer models to simulate the mechanical behavior of advanced composite materials, which were implemented in the finite element code ABAQUS (used by AIRBUS, BOEING and LOCKHEED MARTIN). The criteria developed were implemented in the HYPERSIZER rupture code (figure 18).

![Figure 18 - Finite Element Analysis of structural links in composite materials.](image)
Composite Materials Technology

Composite materials and structures are essential for the development of applications where light weight and resistance are key factors for the success of these solutions. The Composite Materials and Structures group has shown great dynamism, as evidenced by the number of successful projects developed involving conception of new products, innovative solutions and new structural advanced manufacturing technologies (figure 19). The following projects are examples of this dynamic:

- Development of different type of components and structures for aerospace and aeronautic;
- FEUP students enrolment in the "Air Cargo Challenge" through the construction of structural parts for experimental aircraft;
- Partnership with the Office of the Naval Architect Tony Castro from United Kingdom. INEGI participated in the preparatory work leading to the project of a FEUP Competition Sailing Boat;
- Cooperation with the company ALTO (INEGI’s spinoff), for the development and manufacture of pultruded bars and partnership with CLEVER Reinforcements Ltd, for the development and production of pultruded carbon-vinilester components for the international construction market, aiming the reinforcement of bridges, buildings, etc.;
- Innovative applications of composite materials in optical systems for cameras, scopes and telescopes, musical instruments, etc.;
- Components for racing cars and continuous development and improvement of vehicles for participation in the Shell Eco-Marathon, a vehicle with current consumption of 1173Km/liter and an "Urban Concept Car" – Eco-INEGI (1st place in 2007 to 2009 for fuel vehicles).

New Technologies and Rapid Prototyping

The German company ZOLLERN & Comandita challenged INEGI to develop, in partnership, a manufacturing process to produce aluminum impellers for car turbochargers (figure 20). The success of this research led to the establishment in 2008, in Porto region, of a manufacturing plant to produce 1,000,000 aluminum impellers per year. The project included the development and implementation of a casting process against gravity, under vacuum, using the foundry technology in plaster molding with silicone moulds. The Institute was also engaged in the definition of the new industrial unit, involving the project, equipments manufacturing, layout studies and installation of the industrial machines.

Considering the success of this partnership, and the specific technological knowledge gained with this project, the company decided to pursue with an even higher challenge; develop the ceramic shell manufacturing technology for casting titanium and other reactive alloys. This technology is extremely complex due to the need of vacuum or controlled atmosphere for melting and casting. A special furnace and ceramics, accessories and casting conditions were developed to fulfill these manufacturing requirements (figure 21). INEGI is now using all the experimental knowledge obtained with this project to produce titanium parts for the medical (implants and prostheses) and aeronautical sectors.

Figure 20 - Aluminum impellers for turbochargers.

Figure 21 - Production of ceramic shells to cast titanium impellers.
The skills developed in the CAD/CAM area, rapid prototyping, rapid tooling and conversion technologies, have been useful for industrial sectors such as architecture, design, jewelry, hardware, furniture and artistic cast, medical devices, etc. (figure 22) [3].

Figure 22 – Prototypes obtained for numerous applications and sectors by Rapid Prototyping and conversion technologies.

**Tribology, Vibrations and Industrial Maintenance**

This group has a range of services in the field of lubricants, vibrations and industrial maintenance.

The project EREBIO "Emission Reduction from Engines and Transmissions Substituting Harmful Additives in Biolubricants by Triboreactive Materials", developed solutions for the application of biodegradable lubricants. The replacement of traditional oils, involves a material adaptation to the new conditions. The ultimate goal involves the application of biodegradable and non-toxic oils, accompanied by an improved performance in terms of dissipated power, better gear performance, lower operating temperature and higher longevity of the component and the lubricant. The results of this project have four distinctive applications: car engines, heavy-duty diesel engines (marine and stationary), gearboxes and industrial gears (INEGI's work is focused on these last two applications).

The SIMCABLE project (figure 23) had the goal of developing, in partnership with FICOSA International, a simulation model of the mechanical behavior of cables used to in the automotive industry for activation of different devices. This simulation model will be used as a tool to support the development and design of the driving systems. A software application has been developed that determines the mechanical loads involved and the performance in cable transmissions with manual or mechanical drive. The main advantages of using a computer model that simulates the mechanical behavior of the cables is the rapid design of specific solutions to ensure smooth run, immediate response in the design of the application, fast budgeting and significant reduction of experimental validation.

Figure 23 - Cables drive system for the Automotive Industry.

**Optics and Experimental Mechanics**

The laboratory of Experimental Mechanics does the following work:

- Determination of the stress state of structural components;
- Construction and analysis of experimental models;
- Diagnosis of failures due to overload or other causes;
- Experimental tests of resistance in structures and equipments;
- Development of specific equipments for non-destructive tests to different types of materials, including composites;
- Design and construction of special testing equipments.

The laboratory can perform both static and dynamic tests, incorporating computer data storage and telemetry systems. Several systems for displacements and deformations measurements, based on modern techniques of holographic interferometry, are used. These systems may use continuous emission lasers for quasi-static applications and pulsed lasers to measure dynamic phenomena. Several devices also allow the use of Moiré techniques and photoelastic analysis (figure 24).

Figure 24 - Laser system for measurements on different type of materials and components.
The group also develops processing and image analysis systems (figure 25) that are available to support the measurements performed by interferometry or techniques based on structured light.

Another development of this group is related with a special sensor to avoid plantar lesions in diabetes patients. According to specialists, one in ten people with diabetes tends to suffer from this problem. The new device sensor can be a great ally in the early diagnosis, allowing, in time, repair of damage and preventing irreparable lesions. The process of data acquisition is carried out in dynamic regime able to store the equivalent of one day of data generation. With a small size, allowing the incorporation into a shoe sole, the sensor monitors all the forces exerted during real patient movements. With the information obtained and adequately treated, doctors can deliver the most appropriate treatment and prevent eventual injuries. In a wider perspective, the information generated by this system will bring benefits in the design of orthoses, small "prostheses", to be applied in the shoe to correct posture and foot placement.

CONCLUSIONS
This paper gives an overview of INEGI’s recent multidisciplinary activity. The wide range of projects and the partnership with companies and research centers, both national and international, was only possible due to the participation of university staff with recognized international expertise and the highly specialized staff of the Institute. The enrollment of all these companies and R&D+i Institutions in our projects, demonstrate the relevance of INEGI’s activity and the strong contribution it currently gives to the Portuguese industrial sector, as an engine of Innovation and Competitiveness.

The current challenges of INEGI are to achieve a larger entrepreneurship culture and internationalization, and to be recognized as a Center of Excellence in the areas of Mechanical Engineer focused in this paper. We are strongly committed to this process and rely on state agencies and incentive programs for the industrial sector competitiveness encouragement to support us in our mission.

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The authors, executive members of INEGI’s Board, feel great respect and pride in the work presented in this document. We would like to express our gratitude to all the participants in these projects, for their effort, competence and dedication. INEGI is an Institution of the Portuguese Scientific and Technological System, with 24 years of history, and is now internationally recognized as an important agent of Innovation, and an essential partner for company’s competitiveness on the global market. We are convinced that INEGI has a solid expertise and a multidisciplinary nature that gives it a high scientific and technological potential that must be preserved and encouraged.

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