MIT Portugal

Highlighting Collaborative Research

September 2010

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Massachusetts Institute of Technology

Our Growing Impact

We have built a research platform for cutting-edge concepts in emerging areas of science and technology. Our emphasis is on novel biomedical therapies and devices, sustainable energy and transportation systems, and new engineered products. With fully integrated test beds and with Portugal as a scalable living laboratory, we design, test, and implement these new products and systems for markets worldwide, as well as train future leaders in the relevant disciplines.

Today, these efforts are embodied in an open, broad, and deep collaboration that takes the form of a multi-level partnership between Portuguese research institutions, universities, and companies and the Massachusetts Institute of Technology (MIT). This partnership makes use of Portugal's unique positioning and its vibrant research community. It is creating a new generation of leaders with unique abilities and a global perspective, ready to carry new products and services forward into international markets.

With joint research teams working on both sides of the Atlantic, the MIT Portugal Program brings faculty and students from Europe to America, and vice versa, to study and conduct research in Portugal together with companies. The program has strengthened partnerships between Portuguese university groups and industry in our target application areas: **Stem Cell Engineering for Regenerative Medicine, Sustainable Energy and Transportation Systems, and Materials and Design-Inspired Products**.

Projects on **Stem Cell Engineering for Regenerative Medicine** involve faculty, students, and collaborators in developing novel therapies and their clinical implementation. Research in this area has focused on the treatment of cancer, hematological and genetic disorders, and autoimmune diseases, and addresses both development and implementation. As neurobiologist and MIT President Susan Hockfield has said, efforts such as these involve "the great convergence of the life sciences with engineering and the physical sciences."

By working to develop **Sustainable Energy and Transportation Systems**, researchers aim to enhance the sustainability of economic activities in harmony with the natural and built environments. Through this targeted application area, research centers and companies in Portugal work with the MIT Energy Initiative and bring together city officials and urban experts from around the world to benchmark sustainability and help design, test, and implement new policies for greener cities. We explore new concepts and solutions for urban mobility and leverages the emerging field of urban metabolism. The aim is to make Portugal a center for new research and advanced training, bringing together industry and academia to address markets worldwide. This effort builds on test beds developed recently in Portugal to demonstrate various forms of electric mobility integrated in smart energy grids that may increase the use of renewable sources of energy generation, and integrates research developed by more than 80 doctoral researchers at Portuguese universities.

Research on **Materials and Design-Inspired Products** integrates science and technology to create competitive solutions for targeted markets in the mobility industries and the health sector, where our pioneering work on medical devices designed to improve daily life complements our focus on regenerative medicine. The MIT Portugal joint venture in this area is aimed at contributing towards a new paradigm for engineering research and education in Europe. It is based on an application-driven approach and promotes knowledge-based manufacturing and competitive product development.

To these three application areas we add basic research on the **Fundamentals of Engineering Systems**. This roots the MIT-Portugal collaboration firmly in this emerging field that integrates engineering, management, and social sciences to achieve the best possible understanding, design, and implementation of highly complex, technology-based systems. Holistic thinking about complex systems is at the core of the entire program.

To solidify our research advances, three strategic research and training networks have been established in the last year with industry, academia, and government entities. These networks will link key MIT and Portuguese efforts already underway with ongoing initiatives in Portugal – and thus help advance new knowledge and the application of that knowledge in these areas of focus.

- The **e2 Research Network** focuses on emerging energy systems that integrate forms of electric mobility, including new hardware and software developments, as well as smart energy grids and renewable sources of energy generation to develop new sustainability solutions.

- **StemCell Network** is an international, multi-institutional effort to foster novel medical breakthroughs that are expected to create new business opportunities to promote well-being.

- The **Sustainable Cities Research Network and Forum**, launched together with the MIT Energy Initiative, brings together city officials and experts from around the world to develop and discuss emerging concepts in urban metabolism studies and related knowledge and make use of urban mobility solutions to promote smart cities.

Beginning in 2008, all new funding for research through this collaborative venture has been awarded through an open process of Calls for Proposals, providing a high level of competitiveness and encouraging a wide expansion of MIT-Portugal collaborative research into sectors of industry that had not yet been reached. Thus far, there have been two rounds of Calls for Proposals, and they have proven to be a powerful mechanism through which we attract industry and other non-academic participation to the MIT Portugal Program. One of the unique aspects of this approach is that every research grant we make requires industry participation. In this way, we are creating and reinforcing real practical working connections with the companies already involved with the MIT Portugal Program and ensuring that we continue to attract new companies.

Our commitment to innovation and entrepreneurship includes an annual *Venture Competition*, part of the **Innovation and Entrepreneurship Initiative** — a collaboration between MIT and ISCTE-IUL, a business school in Lisbon. With €1 million award funding in 2010 and more than 100 emerging technology ventures submitted, the competition aims to stimulate economic activity and to move technologies into the global marketplace.

The MIT Portugal Program's industry affiliates — today more than 50 companies — engage our students, faculty, and researchers with a broad array of stakeholders, from hospitals to public transport agencies to Portuguese and multinational companies. Industry partnerships spur technology-venturing education and help reinforce the competitive advantage of modern companies to penetrate in emerging markets worldwide.

Paulo Ferrão, National Director
Dan Roos, Director at MIT

Milestones

October 2006
- MIT-Portugal Program launched in address by Portuguese Prime Minister

November 2006
- MIT faculty make first of 15 visits to Portuguese high schools

May 2007
- Institutional member of MIT's Industrial Liaison Program

Summer 2007
- Development of smart classrooms and other collaborative infrastructure at Portuguese universities

October 2007
- 1st anniversary as first group of graduate students matriculates at six Portuguese universities

November 2007
- Luso-American Foundation (FLAD) establishes MIT-Portugal Enhanced Fund at MIT

February 2008
- Deans of Portuguese engineering schools gather with faculty leaders in their first-ever joint working session

March 2008
- More than 200 attend the MIT Europe Conference held in Lisbon

July 2008
- Portugal first sustaining public member of the MIT Energy Initiative
- BioTeam wins the first BioCant Ventures Prize

September 2008
- Rolls Royce becomes first international industrial affiliate and opens valuable internship opportunities for PhD students

November 2008
- First JobShop held with Leaders for Technical Industries students to select industry-sponsored thesis topics

January 2009

- FCT awards collaborative research grants to 14 outstanding projects from consortia of Portuguese research institutions and industry partners

March 2009

- Three-day gathering of MIT and Portuguese entrepreneurship experts to discuss academia-industry partnerships

April 2009

- Portuguese renewable energy company SGC signs a five-year, €1 million affiliation agreement
- Agreement with the regional government of the Azores, University of Azores to develop advanced studies program and for R&D and demonstration projects in Sustainable Energy Systems, including the Green Islands project
- MIT and the Portuguese Ministry of Science, Technology and Higher Education announce revisted strategy, focusing on sustainable energy and transportation systems; stem-cell research for regenerative medicine; and materials and design-inspired products

June 2009

- Second International Engineering Systems Sympoisum held at MIT

July 2009

- Several hundred leaders of the scientific community and industry and research executives gather in Portugal for 1st Annual Conference, "Engineering for Better Jobs"
- Agreement signed in Lisbon to form an Engineering Systems Consortium of 27 educational and research institutions

September 2009

- UTEN Internships at MIT for senior technology transfer and innovations officers from Portuguese universities

November 2009

- First ever national certificates of graduation granted to Master and Advanced Studies students
- Research Networks launched
- MIT President Susan Hockfield visits Portugal

December 2009

- ISCTE launch International Entrepreneurship Initiative and Technology Ventures Competition

March 2010

- Record number of PhD candidacies, including graduates of many of the world's top universities

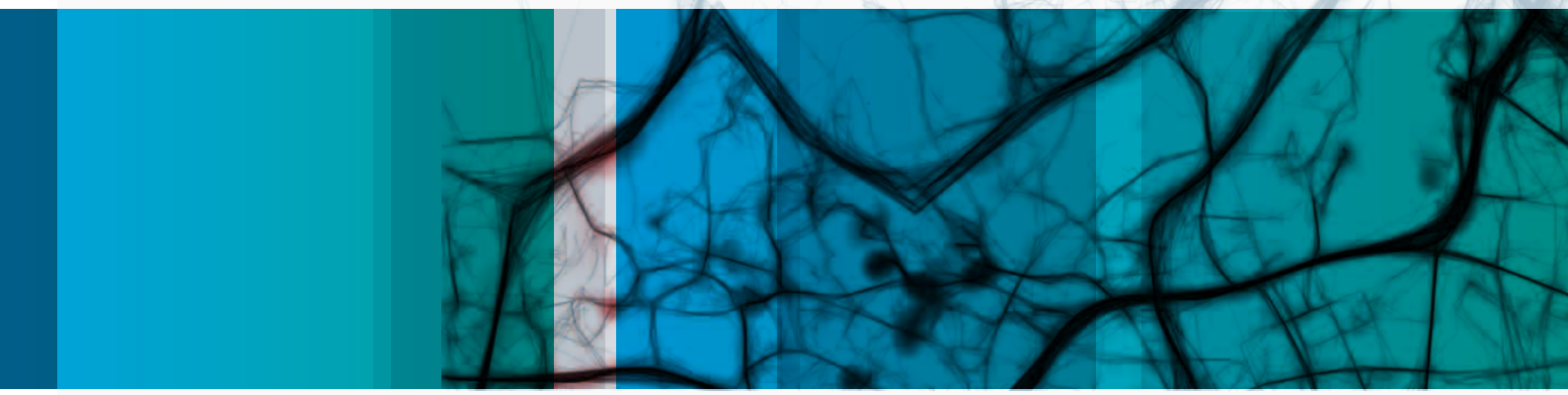
May 2010

- First Education Innovation Awards given to outstanding faculty in Portugal

July 2010

- Continental Group signs research partnership agreement

Research



Visualization of Lisbon traffic created by University of Coimbra researchers based on a month of taxi fleet data

Stem Cell Engineering for Regenerative Medicine

Through the StemCell Network, conducting joint research in the life sciences, engineering, and the physical sciences to enable the development of novel therapies and their clinical implementation to treat severe and often life-threatening illnesses

Our researchers are working at the cutting-edge of medical advances in Regenerative Medicine, which aims to improve the length and quality of patients' lives by restoring, maintaining, or enhancing tissue and organ function. Projects address stem cell-based therapies and tissue engineering for treatment of hemato-oncologic diseases, cardiovascular diseases (the major cause of deaths in Portugal), neurodegenerative diseases (with cases estimated to double in Portugal over the next decade), bone, skin and cartilage disorders, and urinary tract repair. This field represents a major opportunity for Portuguese research groups, hospitals, and industry.

The robust, cross-cutting research portfolio has four primary objectives: improve the basic understanding of the fundamental processes that control stem cell activity and their differentiation; enhance the technologies for isolating stem cells from adult tissues and expanding those cells in vitro, and the protocols for differentiation and transplantation; develop novel biomaterials and surfaces that can elicit specific reactions to cells, supporting cell growth and differentiation and organizing cells into tissues; and design specific motifs at different length scales to improve functionality of tissue-engineered constructs.

Ultimately, this research aims to advance novel bioprocesses for maintenance and expansion of human stem cells, as well as their differentiated progeny, as well as micro/nanofabrication technologies to produce tissues-like substitutes. The research has the potential to provide a competitive advantage in other areas, too: development of products such as innovative scaffold biocompatible materials for 3-D cultivation of stem/progenitor cell, functional human tissue-like substitutes and controlled-release particles to program the differentiation of stem cells. In addition, the development of in vitro tests for cytotoxicity, cell differentiation, genomic stability of expanded cells, and biocompatibility can profit from these scientific results, reducing the need for animal tests.

Scientific Coordinators: Joaquim Sampaio Cabral (IST) and Dava Newman (MIT)

Extending life through faster stem-cell development

This project focuses on expedited isolation and *ex vivo* expansion of mesenchymal stem cells (MSCs). Work began in 2007 and focuses on how MSCs are used in the treatment of graft-versus-host disease (GVHD). A common complication of bone marrow transplantation, GVHD is a severe and fatal disease: the functional immune cells in the transplanted marrow recognize the recipient as "foreign" and attack immunologically. In addition, the MSCs have been used to facilitate allogeneic hematopoietic stem cell engraftment and decrease regimen-related toxicity.

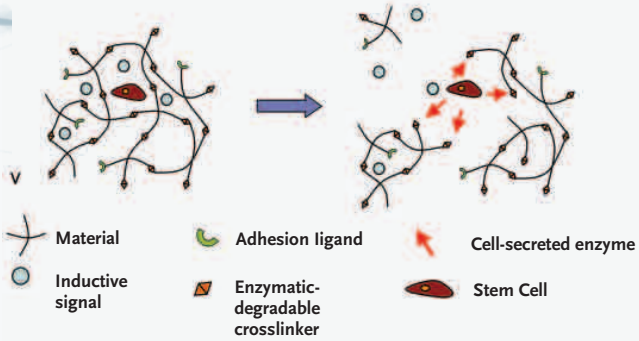
Eight patients have already benefited from this pioneer work: three with acute GVHD, one with extensive chronic GVHD, two with familial HLH, and one each with Hurler's syndrome and aplastic anemia. As our research helps accelerate treatment production, more patients will be able to have a measurable improvement in their lifespan.

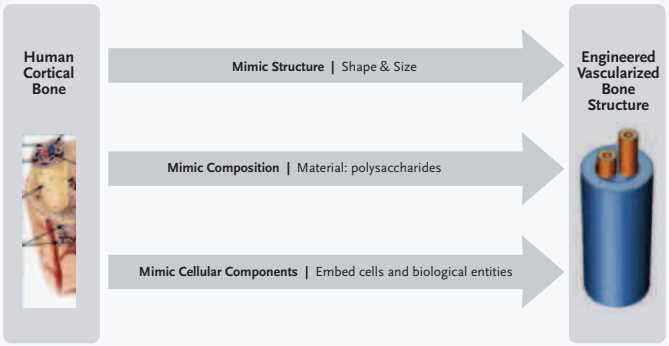
Principal Investigators: Joaquim Sampaio Cabral, Cláudia Lobato da Silva (Instituto Superior Técnico); Sangeeta Bhatia (MIT)

Main Institutions: Institute for Biotechnology and Bioengineering at Instituto Superior Técnico; MIT; Instituto Português de Oncologia Francisco Gentil de Lisboa; Centro de Histocompatibilidade do SulEuropean Group for Blood and Marrow Transplantation; Associação Portuguesa Contra a Leucemia; Grupo Mello Saúde; Harvard-MIT Division of Health Sciences and Technology

A multidisciplinary team has developed a tissue engineering platform that enhances stem cell viability and differentiation towards vascular lineage. When the resulting tissue constructs are transplanted they have been shown to accelerate healing in diabetic wounds.

Microengineered hydrogels developed at the 3B's Research Group (UMinho) aim at mimicking natural vascularized bone tissue to aid regeneration





Regenerating ischemic tissues through transplantation

This interdisciplinary project — which combines the expertise of research groups in bioengineering, stem cell biology, biomaterials, imagine, nanomedicine, and drug delivery — has major implications for public health.

Cardiovascular disease is the leading cause of death in the Western world. Among patients who survive a myocardial infarction, many develop a chronic form of heart disease that involves progressive deterioration of the heart muscle and restriction in blood supply known as ischemia. Clinical data indicate that cardiac function may improve by applying stem cells and biomaterials.

Researchers are developing therapies and testing multiple strategies for the regeneration of cardiac muscle after infarction. The first involves transplanting progenitor cells isolated from human cord blood or human embryonic stem cells in three-dimensional scaffolds. Preliminary results from animal testing show that these can preserve heart contractile performance for six weeks after myocardial infraction and decrease infarct size as compared to control animals. Another strategy involves using cardiac patches to deliver biomolecules. In some cases, stem cell grafting is being monitored using nanotechnologies and Magnetic Resonance Imaging, providing new insights into the regenerative mechanism induced by transplanted cells and allowing manipulation of cells in situ.

Taking the project further, researchers are exploring the use of stem cells and biomaterials for the regeneration of chronic wounds in diabetic patients. Many such wounds heal under appropriate care, but the process is retarded or nonexistent in some cases. When we transplanted into diabetic wounds the tissue constructs we developed, which enhance stem cell viability and differentiation towards vascular lineage, we succeeded in accelerating the healing as compared to controls.

Principal Investigators: Lino Ferreira; Eugénia Carvalho (Associated Laboratory Centro de Neurociências e Biologia Celular); Lino Gonçalves (Unidade de Cardiologia dos Hospitais da Universidade de Coimbra); Robert Langer (MIT); John Martin (University College London)

Main Institutions: Associated Laboratory Centro de Neurociências e Biologia Celular; Unidade de Cardiologia dos Hospitais da Universidade de Coimbra; Crioestaminal; MIT; University College London; Fundação para a Ciência e Tecnologia; Biocant; Harvard-MIT Division of Health Sciences and Technology

Regenerating bone tissue

When human tissue — cartilage and bone — is injured or becomes dysfunctional through illness or trauma, could it be replaced with hybrid materials? Researchers are exploring how to manipulate both stem cells from various sources and selected biomaterials to regenerate human tissue.

The focus is on innovative scaffold biocompatible materials that can act simultaneously as delivery systems and as part of a regenerative medicine approach, complemented by the use of autologous stem/progenitor cells. Researchers are developing microengineered hydrogels (with controlled microstructures) that have defined shapes and can mimic natural vascularized bone tissue as much as possible, both in shape and size. It is highly technical and scientific work requiring the use of micro- and nanotechnologies to fabricate biomaterials with effective microsized structures that can mimic the micro- and nano-bioenvironments, generating scaffolds which in turn will act as active agents in the process of tissue regeneration.

The selection of biomaterial is of the utmost importance. Researchers have studied several natural biodegradable polymers extensively to find ones with great potential for tissue engineering applications. Modifications enable their use in micromolding and photolithography, two nano- and microtechniques key to the work.

As the work proceeds, researchers anticipate the micro/nano design features of these materials to provide cues for developing adult stem cells into osteoblasts and endothelial cells, producing a highly functional, vascularized bone substitute. Already, cooperation with several Braga and Oporto hospitals has provided the team with adipose tissue samples (resulting from reconstruction surgeries and liposuction procedures) for use in autologous therapies. Moreover, strategies for incorporating biological agents (using both nanoparticles and non-viral gene delivery systems) into the developed hydrogels will enhance stem cells differentiation into the target phenotypes.

Principal Investigators: Rui Reis (University of Minho); Robert Langer (MIT); Ali Khademhosseini (Harvard-MIT Division of Health Sciences and Technology)

Main Institutions: 3Bs Research Group — Biomaterials, Biodegradables and Biomimetics, University of Minho Department of Polymer Engineering; MIT; Harvard-MIT Division of Health Sciences and Technology; European Institute of Excellence on Tissue Engineering and Regenerative Medicine, Guimarães, Portugal

Otto Bock researchers and Portuguese Paralympic athletes join a team led at IST in developing the DACHOR hybrid active orthoses project

Materials and Design-Inspired Products

Integrating science and technology to create competitive engineered products and solutions for targeted markets in the mobility industries and the health sector

Research projects within the Materials and Design-Inspired Products target application area concentrate on topics related to design and advanced manufacturing in the automotive, aeronautical, and medical device sectors; many also include novel research on the product development process. Gaining greater proficiency in product development is an important component in moving modern economies forward and securing the economic future.

Research in this area is contributing to the **e2 Research Net** to facilitate new designs of integrated forms of electric mobility, with emphasis on building prototypes and specialized parts for electric vehicles. The work includes control systems for electric motors and power supplies, smart vehicle-grid connection, and motor-in-wheel concepts.

Scientific Coordinators: Olga Carneiro (UMinho) and Chris Magee (MIT)

Enhancing mobility with hybrid orthoses

Thanks to an innovative powered ankle-foot orthosis being developed by Portuguese and MIT researchers, individuals with reduced mobility and neuromuscular disabilities of the locomotion apparatus may experience improved locomotion and muscular rehabilitation and increased autonomy — all leading to a better quality of life.

The research is part of our Hybrid-Human research efforts. The enhanced orthotics will provide support for general gait disabilities and for rehabilitation of the musculoskeletal apparatus. The hybrid nature of this powered orthosis is due to an external mechanical actuation complemented by functional electrical stimulation. It also improves on other devices with the reduced power, size, and weight of the external actuators.

The research efforts implement multibody dynamics methodologies to model and optimize altered human gait and implement adaptive control architectures to distribute the control forces between actuators. The research team has successfully developed new computational modeling tools and control methods as well as new mechanical designs. Novel hybrid adaptive biorobotic technology that is in a first stage, implemented computationally using advanced 3D multibody integrated models, will be materialized in a later-stage physical prototype.

In addition to the improved quality of life for patients that will come as a result of this novel locomotion-enhancing device, there is a new tool available to physiatrists to devise new and more efficient treatment plans that can lead to faster patient recovery and rehabilitation with improved results.

Advanced wearable medical devices with onboard sensing and actuation are envisioned for the future, and opportunities to spin off products from the research will lead to commercialization and startup businesses.

Principal Investigators: Miguel Tavares da Silva (Instituto Superior Técnico); Jorge Martins (Instituto Superior Técnico); Paulo Flores, Luís Ferreira da Silva (University of Minho); Dava Newman, Hugh Herr (MIT)

Main Institutions: Biomechanics Research Group/IDMEC; Instituto Superior Técnico; DEC/CT2M; University of Minho; Man-Vehicle Lab, MIT; Media Lab Biomechatronics Lab, MIT; PLUX-Wireless Biosignals; Otto Bock Portugal; Centro Hospitalar Lisboa Central

Saving lives with stent grafts

As endovascular aneurysm repair (EVAR) becomes more commonplace, a new generation of implantable stent grafts is required. Most of the stent grafts in use today today still present some post-surgery complications, but MIT and Portuguese researchers are piloting technologies to enable "smart" stent grafts that will save lives in the treatment of aneurysms. Working in collaboration with the Vascular Surgery Division of Hospital S. João, in Porto, researchers have defined specifications for these stent grafts: they must be thin, flexible, possess enhanced medical performance, and must be embedded with the capability to diagnose bad placement and detect leaks.

Research teams are now developing a new technology based on nano-engineered materials to fabricate flexible pressure sensors that will be embedded in the stent grafts to detect endoleaks. Results from assessments using compute fluidic dynamic models show the feasibility of these sensors to minor endoleaks. Tests also show that the stent grafts have structural integrity.

The research results will provide the medical community with a better understanding of how an aneurysm evolves following EVAR, especially as the new technology enables placement of a cluster of sensors. In addition, by using novel biocompatible materials and employing telemetric circuit design, this research is showing that the infrastructure and know-how needed to integrate sensors in stent grafts at minimal costs is available in Portugal — which has direct implications for maintaining a vibrant and sustainable medical device industry in the country.

Principal Investigators: Luís Rocha (University of Minho); Brian Wardle (MIT)

Main Institutions: University of Minho; MIT; Faculty of Engineering-University of Porto; Hospital São João; Instituto Superior Técnico

Developing integrated systems for smart vehicle interiors

Many factors will determine what the vehicles of the future will look like. One is the degree to which they can incorporate new high-performance mechanical systems that make the vehicle safer, smarter, and more cost-effective.

Researchers in Portugal and at MIT are developing novel integrated systems for the automotive industry to turn conventional interiors into "smart" interiors. This next generation of interiors will use smart sensor and actuator devices that employ information processing technologies for diagnosis and control of select vehicle functions, increase the aesthetic quality of vehicles, and greater safety, comfort, and performance.

As part of this work, researchers are developing and assessing the performance of optimized interfaces between humans and both electronic and mechanical devices. New integrated actuation methods that receive information directly from sensors are also under development. The team will create functional prototypes with integrated optical fiber sensors in polymeric foils, using standard industrial fabrication processes, and are preparing cost-modeling of the integration process with full cost break-down and sensitivity analysis. In addition, researchers are investigating reliable, low-cost manufacturing solutions that meet automotive industry requirements.

Experience thus far suggests a strong interest from the automotive industry to use such integrated systems in their vehicles to reduce weight, increase the functional span of the vehicle, and reduce both component and assembly costs.

Principal Investigators: Francisco Pires (Faculty of Engineering-University of Porto)

Main Institutions: Faculty of Engineering-University of Porto; Instituto Superior Técnico; MIT; University of Minho; FiberSensing; IBER-OLLEF; Sunviauto; TMG Automotive

Sustainable Energy and Transportation Systems

Addressing the global challenge of meeting critical mobility and energy needs under significant resource constraints

Managing mobility, energy, and material resources and designing appropriate infrastructures offer clear paths toward a sustainable future. The "smart" aspect has our researchers collaborating to develop tools to transform regional and local infrastructures so they work in concert with the environment. Portuguese and MIT researchers are also exploring how to achieve such a transformation robustly and cost-effectively — the "smart" aspect. Planning requires smart design of efficient houses, buildings, and neighborhoods; understanding the metabolism of urban and regional areas; clean, safe, and convenient transportation systems; integrated local energy supplies and energy networks; and new businesses to develop and deploy them based on understanding the technological opportunities and the "market," including consumer preferences and behavior.

Researchers are expanding the tools and models typically used in these areas. For instance, existing energy models have proven inadequate at incorporating large-scale penetration of renewable energy supplies, structural shifts in energy demand, and changes in vehicles and fuels (such as biofuels and electric transportation) — three major areas of energy supply and demand. Including these factors in current generation models is a major shift in energy systems modeling and design approaches. Technology choice and technology utilization are now separate analytic and design components. This shift is also designed to provide prescriptive results to local and regional actors, not only generic insights to national policymakers.

Developing new methodological frameworks, a key component of our work in this application area, cannot be done in the abstract. Their robust and timely development requires rich case studies — like our Green Islands Project (described below) from regions with binding constraints, conducted collaboratively with government and industry stakeholders willing to assume leadership roles.

Scientific Coordinators: Paulo Ferrão (IST), José Viegas (IST), John Fernandez (MIT), Chris Zegras (MIT)

Green Islands Project: Demonstrating sustainability to the world

Sometimes, a relatively small laboratory can produce ideas that demonstrate to a much larger world the potential for meaningful change. In the Azores archipelago, researchers from Portuguese institutions and MIT are working with the regional government, industry, and academia to design and demonstrate major components of an efficient and renewable energy future. The Green Islands Project is a lead cross-cutting effort, and represents a partnership with the Government of the Azores, its people, and interested businesses.

For the Azores, energy self-sufficiency is a critical issue — and so the islands provide an outstanding test-bed for what is called the Green Islands Project. The aim of the projects under this broad umbrella is to reduce the Azores' use of fossil fuels to a significant degree and introduce new ways of dealing with the energy and transportation challenges of the 21st century. The operational constraints are much more immediate than on the Portuguese mainland, providing an immediacy to some of the efforts that greatly enhances the results. Researchers are collecting and integrating information characterizing the nine islands that comprise the archipelago, from energy and transportation demand data to information about their renewable resources, including geothermal, wind, biomass, and so on.

The Green Islands Project is far more than just another case study. Students and faculty from MIT and Portugal are working with the Azores regional government, energy companies, and the Universidade dos Açores on an integrated research portfolio to develop both a strategic energy vision for the islands as well as targeted demonstration projects in high-penetration renewable electric generation, smart grids and smart buildings, the deployment of electric vehicle technologies, and biofuels from agriculture and wastes.

Developing new methods to identify sustainable energy pathways, whether for a town, island, or an entire country must be done in a concrete context, with research leading to real, on-the-ground demonstrations that involve communities, companies, and the public sector. Anything less falls short of meeting society's real economic and environmental challenges.

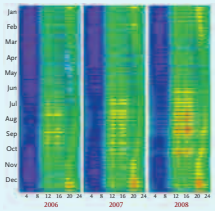
Principal Investigators: Paulo Ferrão (Instituto Superior Técnico), Steve Connors (MIT); Cabral Vieira (Regional Government of Azores)

Main Institutions: EDA; EDP; GALP; EFACEC; MARTIFER; SGC Energia

"The Green Islands initiative is a unique opportunity for Portugal's main energy companies. We are developing and deploying innovative solutions in areas such as energy systems integration, smart grids, and electric vehicles. Working with MIT-Portugal has put us in the forefront of a new paradigm – decentralized, intelligent energy systems – that we will make a reality within the next decade."

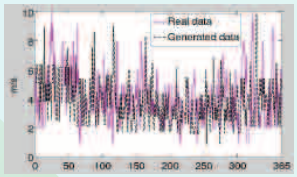
– António Vidigal
CEO, EDP-inovação

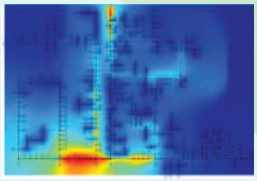
Understanding the systems



Electricity demand dynamics
Edward Spang

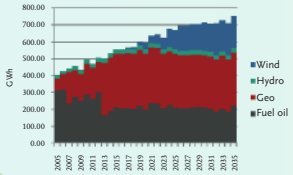
Renewable resource dynamics
Kiti Suomalainen



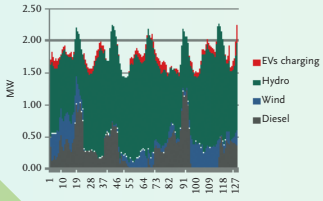


Grid congestion studies
Pedro Almeida and Filipe Joel Soares

Multi-scale modeling



Analysis of yearly and hourly electricity production
André Pina



Energy meters get tweeting

Fleet evolution analysis model
Patrícia Baptista

Implementing

Designing Sustainable Energy Systems

Sustainable Energy and Transportation Systems

Negawatts — changing the paradigm of family electricity consumption

Smart grids and smart metering may offer opportunities to manage electricity consumption at the family household level — a necessary paradigm shift in designing the most sustainable energy systems. To capture the opportunity requires building families' awareness of their electricity consumption habits and how their home appliances and devices consume energy.

The Negawatts Project is the first in a series of experiments to build that awareness. Researchers installed smart meters in more than a dozen homes in Oeiras, near Lisbon. Host families also have the ability to track their consumption through Google Power Meter in real time and observe the effect of turning a particular appliance, television, or other device on or off.

In this research, Joana Abreu, a PhD researcher, has also developed different algorithms to analyze family consumption patterns so that we may provide adequate feedback that will facilitate family changes in energy use. Families that optimize consumption can see the benefit directly on their electricity bills.

The research also studies the average yearly electricity of the typical Portuguese household, from an econometric perspective, to create a reference point for electricity consumption benchmarking. Using multivariate regression models, the team assessed the importance of characteristics of the family dwelling as well as socioeconomic factors in determining electricity consumption patterns. The insights from econometric models have complemented insights from researchers' detailed measurements of electricity consumption in Portuguese households, and the combination of this knowledge is enabling the design of new business models and effective energy-efficiency policies.

Principal Investigators: Carlos Silva, Joana Abreu, Jorge Vasconcelos, Paulo Ferrão (Instituto Superior Técnico), Câmara Municipal de Oeiras

Main Institutions: Instituto Superior Técnico; Office of Municipal Development of the City of Oeiras; Yello Strom

Assessing high speed rail for Portugal

Portugal has made a commitment to develop high-speed rail in the country, and researchers from Portuguese institutions and MIT are involved in two interrelated projects that focus on elements critical to successful implementation and operation.

Research teams are defining the performance requirements to achieve a solid system. This involves developing new lifecycle costing models to support efficient design and maintenance strategies. It also involves creating the tools to evaluate different investment scenarios through different stages of the project with different objectives (construction, maintenance, operation goals) and that make it possible to incorporate every potential stakeholder need.

Another project involves developing a generalized global risk assessment for the high-speed rail network, so that technical and natural hazards (floods, landslides and earthquakes) can be considered more effectively in project assessment, management, and construction. For this, tools have been created so that robust designs can be implemented that optimize the allocation of available resources and minimize the consequences of critical adverse events. The tool allows designers to deal with uncertainty, based on the definition of potential adverse future scenarios.

This research has already paid off in the form of a decision-aid tool for tunneling that is being employed in a segment of the high-speed RAVE network and that is being expanded in scope to assist in other situations.

Principal Investigators: Raimundo Delgado (Faculty of Engineering-University of Porto); João Lima (Faculty of Sciences and Technology-University of Coimbra)

Main Institutions: Faculty of Sciences and Technology-University of Coimbra; MIT; Instituto Superior Técnico; RAVE

AirNets — improving airport networks to reduce congestion

How do delays spread through the airport system? How does airline competition affect airport congestion, and how do efforts to mitigate congestion at airports affect airline scheduling and profits? What can be done to design airline networks to reduce airport congestion? These are the questions at the heart of the AirNets project underway by a team of MIT and Portuguese researchers.

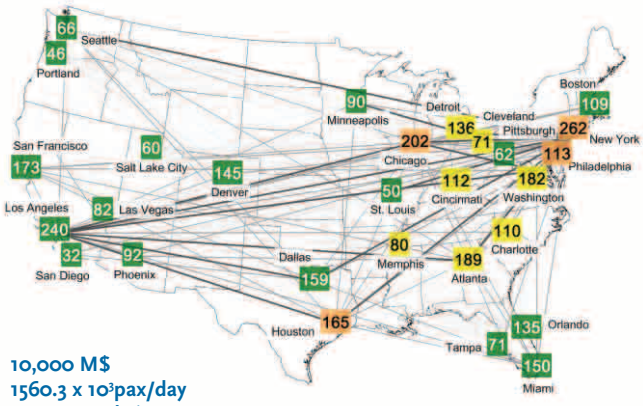
The research seeks to understand the role that infrastructure-related costs, constraints, and policies play in causing delays at local airports and system wide, how airline scheduling and network configurations are affected, and whether airport and airline networks can be evolved to solve some of the systemic problems that air travelers face every day. To answer those questions, the project team is developing models of air transportation networks that are sensitive to infrastructure congestion, development costs, and demand management policies, and using these models to explore the impacts of alternative policies and strategies that airlines and government regulators might adopt.

Already, collaboration with several key aviation entities has begun or is under discussion, including the U.S. Federal Aviation Administration (FAA) and National Aeronautics and Space Administration (NASA), the German Aerospace Center (DLR), EUROCONTROL — The European Organisation for the Safety of Air Navigation, the European Center for Aviation Development (ECAD), and Portuguese airlines TAP and SATA. In Germany, researchers are applying the team's work to study national airport expansion priorities.

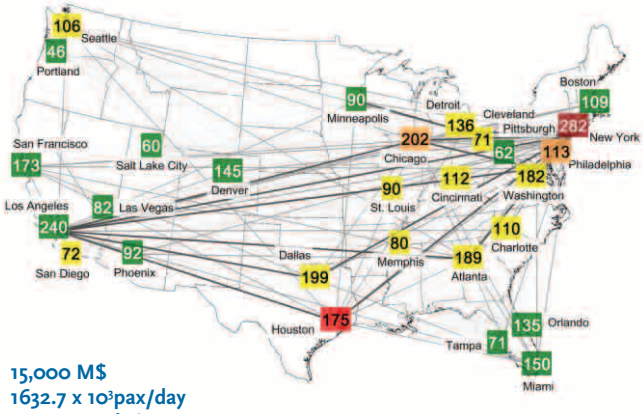
Principal Investigators: António Antunes (Faculty of Sciences and Technology-University of Coimbra); Amedeo Odoni (MIT)

Main Institutions: Faculty of Sciences and Technology-University of Coimbra; MIT; Faculty of Engineering-University of Porto; Instituto Superior Técnico

AirNets researchers have developed an analytical model for airport and air network expansion to address congestion. This figure shows optimum evolution of the United States main airport network where capacity expansion is a function of investment budget.



10,000 M$
1560.3 x 10³pax/day
6 congested airports



15,000 M$
1632.7 x 10³pax/day
0 congested airports

Urban concept prototype from the MOBI-MPP electric vehicle project

The *e2 Research net:* energy systems and electric mobility

The Sustainable **E**nergy Systems & **E**lectric Mobility Research Platform & Network (**e2 net**) integrates research teams across the entire MIT-Portugal joint venture and aims to make Portugal a center for new research and advanced training in systems of electric mobility and renewable sources of energy generation. Bringing together industry, academia, and governmental agencies, **e2 net** builds on recent initiatives in Portugal to implement various forms of electric mobility, and integrates research developed by various groups of senior researchers at Portuguese universities and companies. The ultimate goal is to provide new solutions and systems for markets worldwide, making use of emerging competencies and new understanding from test-beds in Portugal.

MOBI-MPP — promoting new paradigms of mobility with sustainable electric vehicles

Researchers know that only through an integrated Engineering Systems approach will it be possible to develop the sustainable vehicles of tomorrow that will truly accomplish the new paradigms of mobility being discussed today. Under the aegis of MOBI-MPP, researchers are developing fully operational prototype systems that can be incorporated into electric vehicles, and include control systems for the powertrain (electric motor and power supplies), a smart vehicle-grid connection that includes two-way operation and sinusoidal energy consumption, an efficient range-extender unit, a motor-in-wheel concept, and even some full vehicle prototypes. The project team is also developing tools for evaluating the impact of various electric mobility solutions, and extending its expertise to include how to incorporate natural fibres into automotive components.

Already, there are some significant accomplishments. Researchers have designed, simulated, and constructed a system for intelligent charging and discharging (vehicle-to-grid) of batteries. Protocols have been created with one Portuguese municipality and three Portuguese industrial partners regarding electric vehicles (beyond automotive alone), and these protocols are being used today. A unique database of electric/hybrid vehicles and systems with more than 600 entries, created by the team, is helping inform the direction of research, and researchers have published several studies on electric vehicle road simulation and flexible design concepts and sustainability assessment, including an eco-score system that could find widespread use in the automotive industry.

These projects, which involves specific partnerships between industrial companies and university research/technological centers, are helping place Portugal at the forefront of electric vehicle research and development in Europe, boosting Portuguese economic competitiveness in the global market with the promise of spurring creation of business opportunities both with industrial partners both present and future, as well as for technology-based startups.

Principal Investigators: Jorge Martins (University of Minho)

Main Institutions: University of Minho; Faculty of Engineering-University of Porto; Instituto Superior Técnico; MIT; EFACEC; CEIIA; SIMOLDES; INTELI

Connecting electric vehicles to the grid

Under the Green Islands-related initiatives, MIT and Portuguese researchers are designing ways to deploy electric vehicles and help the Azores power grid operate more reliably and cost effectively at the same time. It is a significant challenge because of the Azores grid's small size compared to the mainland, where electric vehicle connectivity is a low-risk proposition. The researchers must also address the isolated nature of the grid, its large geothermal generation, and the fact that the grid is on remote islands with a large penetration of wind generation that provokes considerable variability in electricity generation. These are major planning and operational issues.

A key aspect of the research involves electric vehicles, a new family of grid "players" that can behave as flexible loads or mobile storage devices. If properly interfaced with the grid, electric vehicles can be used to help manage the integration of geothermal generation by consuming electricity during valley hours. They can also help manage the integration of wind generation by adapting the rate of charge of their batteries according to the wind power variability, reflected in the system frequency, thus participating in primary frequency control. This requires installing a communication and management infrastructure with aggregators that serve as interface between local system operators and the electric vehicles.

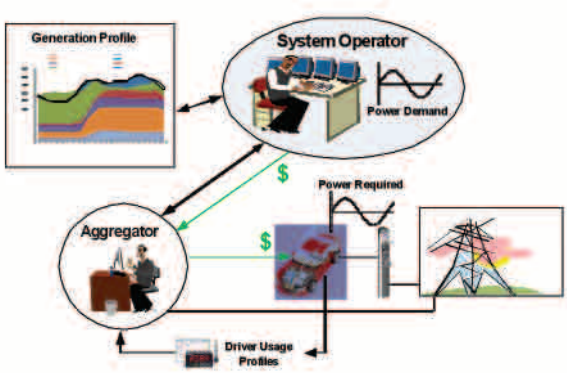
Project researchers are studying the simulation of the operating conditions, developing a system architecture, and identifying the specific management and control solutions that need to be adopted.

The lessons of this "smart grids" research in the Azores have direct application to other end uses and for households and businesses that may need to shift or adapt actively their consumption patterns to incorporate smart devices – from appliances to production machinery — of the future.

Principal Investigators: João Peças Lopes (Faculty of Engineering-University of Porto); Steve Connors (MIT)

Main Institutions: Faculty of Engineering-University of Porto; MIT; ARENA; Electricidade dos Açores; INESC-Porto; Instituto Superior Técnico; NOVABASE; Regional Government of the Azores; University of the Azores

Schematic of electric vehicle-to-grid system

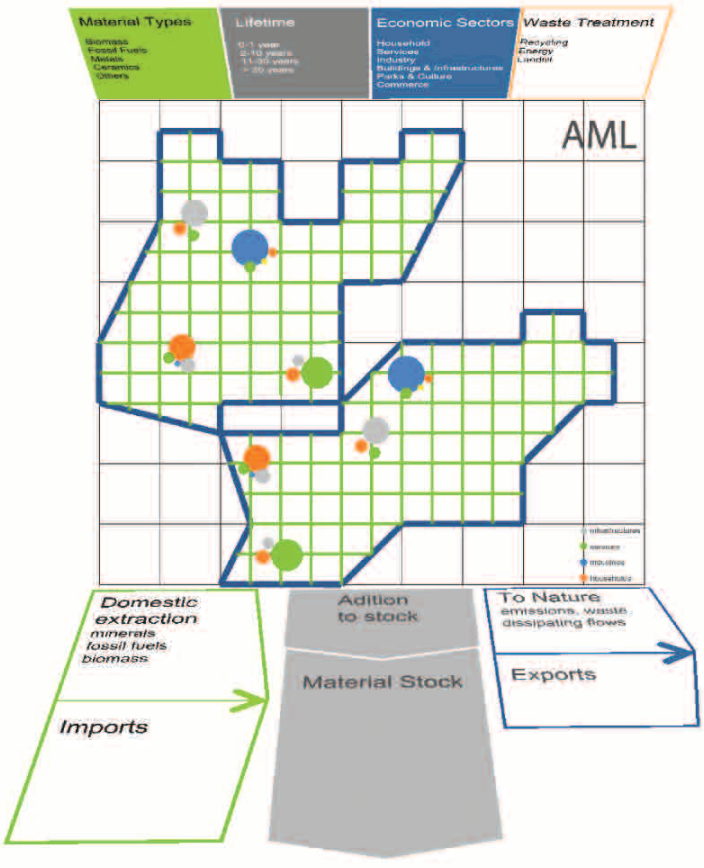


Sustainable Cities Research Net and Forum

The Sustainable Cities Research Network and Forum

The Sustainable Cities Research Network and Forum brings together the MIT Energy Initiative with researchers in Portugal, as well as city officials and urban experts from around the world, to benchmark sustainability and help design, test, and implement new policies for greener cities. It leverages the emerging field of urban metabolism, aiming to advance global efforts toward a humane and sustainable urban future, and makes use of real-world experiments in Portuguese cities and regions.

Material Flow Analysis for Lisbon metropolitan area considers imports, exports, stocks of materials, product lifetime, and economic activity distribution



"Urban Metabolism": assessing the resilience of cities

In the globalized economy, cities depend for their sustainability on resources and ecological services from distant ecosystems and on the logistics of the supply chain. These are regulated by complex systems that themselves comprise interrelated subsystems with links to the world. Hence, cities are particularly vulnerable to diverse challenges that may affect their supply chain of goods, water, or energy, causing disruptive and potentially catastrophic results. Changes in one subsystem ripple through the entire structure, and put the well-being of residents at risk.

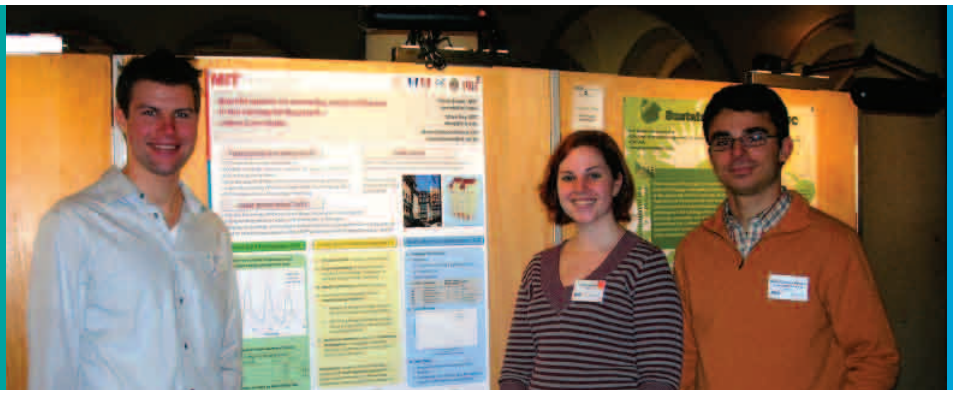
The resilience of urban systems is the ability of a city to overcome sudden failures of supply without significant reorganization and unanticipated investment in the infrastructure and other critical systems of the urban economy. Researchers are at the leading edge of developing and employing state-of-the-art methods to track urban resource flows and related sustainability indicators, and design infrastructures and services. It is part of a new field, "Urban Metabolism," aimed at contributing to greater urban resilience.

Material Flow Analysis (MFA) has been used throughout the research conducted to consider imports, exports, and stocks of materials, materials composition of products, lifetime of products, and economic activity distribution. The analysis quantifies the flow of products and their material composition, and has been used to characterize the Lisbon City flows for different types of materials. It is also being used to characterize the resource intensity of different economic activities. The project team is also creating an "urban planner toolset" that will inform new options to develop more sustainable and resilient urban areas.

Principal Investigators: Paulo Ferrão (Instituto Superior Técnico), John Fernández (MIT), António Vidigal (EDP Inovação), João Nuno Mendes (GALP).

Main Institutions: Instituto Superior Técnico; MIT; EDP Inovação; GALP; Lisbon City Council

MIT students Stephen Ray and Carrie Brown and Sustainable Energy Systems/IST student Nuno Clímaco Pereira with their award-winning poster on efficiency in buildings



Integrating transportation innovations with urban revitalization

There are many ideas that have been suggested for transportation innovations in urban settings. With all of them, a key challenge is how define solutions that leverage these innovations to promote desirable urban development patterns and outcomes, and vice versa, so the ultimate result is urban revitalization.

Researchers are doing just that, working to define strategic options for integrating transportation innovations and urban revitalization. This includes identifying solutions with the potential to attract private investment in cities and that contribute to sustainable development of urban areas.

So far, there have been some significant impacts from this work. Researchers have developed and articulated a set of integrated land use and transport models to assess revitalization strategies, and have also created a scenario planning approach to test these strategies and gauge their performance. Through a participatory approach that is still rather atypical in Portugal, the team has engaged stakeholders from the three main Portuguese cities — Lisbon, Oporto, and Coimbra — in three workshops to develop scenarios for urban revitalization. In taking this approach, the researchers have demonstrated to stakeholders the role of innovation in the process of developing public policy.

Principal Investigators: José Viegas, Rosário Macário (Instituto Superior Técnico); Joseph Ferreira, Chris Zegras (MIT)

Main Institutions: Faculty of Sciences and Technology-University of Coimbra; Instituto Superior Técnico; MIT; Carris; Institute for Mobility and Land Transport; Public Development Company of Lisbon

Making city transportation more efficient while enhancing the travel experience

With real-time access to integrated information about the state of all components (infrastructure and vehicles) of urban transport systems, planning and managing those systems takes on a whole new dimension of efficiency.

Researchers are developing innovative models and applications on several fronts to make this a reality. In cooperation with Brisa, Portugal's major motorway operator, one application allows for short-term prediction (from 5 to 30 minutes into the future) of traffic situations on a very busy motorway in the Lisbon area operated by Brisa, the nation's major motorway operator. This is part of a much greater effort that involves exploring what can be done to make urban mobility more pleasant and efficient. Researchers have developed operational and business models for shared taxis and express mini-buses, leading to configurations that can provide much higher efficiency in how road space and travel time are used, and approximate what might be attained using a private car. These configurations are expected to be deployed soon, and sophisticated software for the shared taxi business is under development.

In parallel, researchers have made considerable progress in fusing data on urban mobility from multiple sources that will allow a much richer real-time representation of what is happening in the field. This will be the basis for an application that takes private cars, buses, the metro, single or shared taxis, and under current and predicted short-term configurations and suggests the most efficient modes and paths along various dimensions, including quickest, least expensive, lowest number of transfers, and so on. Researchers expect this application to lead to a fundamental change in the perception of the service offered by public transport, especially as it reduces the uncertainty of wait times, which is the major component of its perceived cost.

This research promises to have tremendous impact that will be felt, and will increase, over several decades as new insights are successively explored, experimented with, and used to make further improvements to the system.

Principal Investigators: Carlos Bento (Faculty of Sciences and Technology-University of Coimbra); José Viegas (Instituto Superior Técnico); Moshe Ben-Akiva, Assaf Biderman (MIT)

Main Institutions: Faculty of Sciences and Technology-University of Coimbra; MIT; BRISA; Faculty of Engineering-University of Porto; Instituto Superior Técnico

Fundamentals of Engineering Systems

Advanced data analysis of intensive care units at Beth Israel Hospital in Boston by MIT and Portuguese researchers aims at improving patient survival rates.

Fundamentals of Engineering Systems

The intellectual foundations of our research is found in holistic thinking about complex systems and the emerging field of Engineering Systems, which integrates engineering, management, and the social sciences to achieve the best possible understanding, design, and implementation of the highly complex, technology-based systems on which society is increasingly dependent. This approach accounts for multiple stakeholder perspectives and for flexibility, robustness, scalability, safety, security, durability, sustainability, reliability, quality, recyclability, and maintainability — the "ilities" often left out of traditional analysis, but critical to developing lasting solutions.

Four methodological clusters comprise research in this area. *Design and Implementation* research spans engineering, logistics, economics and finance, marketing, and human resources to enhance the ways in which ideas can be materialized as competitive new products or large, efficient, multifunctional services and systems. This research accounts explicitly for functional needs and the need to plan for future uncertainties.

To ensure system flexibility and thus make it possible to address rapid shifts in societal requirements, technical options, and markets, we also focus on advanced methods and models related to *Uncertainty and Dynamics*. Our research identifies key sources of uncertainty in each particular context; models and quantifies uncertainties for system design, implementation, and management; uses robust and flexible strategies to design systems both to mitigate downside risks and take advantage of upside opportunities; and builds in robustness and flexibility to tackles how safety and resilience change over time.

Research into *Networks and Flows* helps create the big-picture view needed to create sustainable solutions to modern challenges. We explore complex technical, social, and management systems, applying modern graph and network theory, but in a way that allows a representation of the dynamics and uncertainties most relevant to Engineering Systems.

Finally, researchers explore the *Interface of Humans and Technology*, examining how human attitudes and behaviors affect the successful use of technologies, as well as designing methodologies that account explicitly for the human interface.

Scientific Coordinators: João Sousa (IST) and Dan Roos (MIT)

Improving the survival of critically ill hospital patients

A team of MIT and Portuguese researchers are using Engineering Systems approaches to address a life-or-death issue: improved survival rates for critically ill hospital patients. The project is a response to growing interest among healthcare decision-makers in systems solutions to the key challenge of how to improve quality while reducing costs. Recent research points to "systems problems" behind the high number of preventable deaths in hospitals from medical errors, spurring further interest in systems solutions.

Two major medical centers — one in Lisbon and another in Boston — collaborate in our research. These settings provide outstanding opportunities to address the clinical process design using the fundamentals of Engineering Systems. Each hospital's unique approaches in state-of-the-art intensive care units (ICU) allows researchers to capture highly detailed data on patients' illness characteristics and clinical care.

An ICU is a particularly good place to examine the benefits from implementing Engineering Systems approaches. ICU patients are among a hospital's sickest, providers continually make life-and-death decisions, and the high-acuity, complex environment offers many opportunities to test systems-related improvements to quality, safety, or clinical effectiveness.

Researchers are developing Engineering Systems models to predict, within suitable confidence limits, which patients will experience key adverse outcomes in the context of current system design and conventional care processes. Those analyses, combined with more detailed analysis of large volumes of physiological, demographic, and clinical process data, allow researchers to explore how to optimize the scheduling and use of patient-care resources.

The goal is to improve survival rates in ICUs with advanced quantitative analysis techniques that identify aspects of the hospital system that may be linked to worsened health outcomes. Early results demonstrate the promise of research in this area to create solutions for society within extremely complex, technology-based systems.

Principal Investigators: João Sousa (Instituto Superior Técnico); Stan Finkelstein (MIT)

Main Institutions: IST; MIT; Beth Israel-Deaconess Medical Center; Hospital da Luz

Integrating technology, management, and policy towards risk governance: application to forest fires

Forestry is a major industry in Portugal, and losses from forest fires are a major drag on productivity. The fires are also a substantial social challenge as they threaten communities throughout the country. Hence, forest fires are a matter of significant national importance.

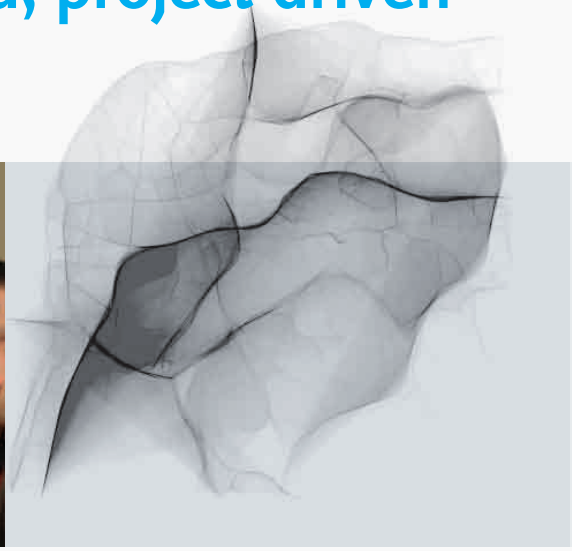
To help minimize the losses, researchers are advancing the understanding of how to implement best practice in Uncertainty and Dynamics, one of the fundamentals of Engineering Systems. Where and when forest fires will start are highly uncertain, and they are subject to the dynamics of weather and the occurrence of hot and dry regimes, as well as the dynamics of forest growth and the accumulation of fuels that favor their propagation.

The approach taken integrates technology, management, and policy, and is a prototype for many of the challenges that the Engineering Systems field addresses. Researchers will gain a greater understanding of the mechanisms that favor and retard the spread of fires and of how fire-fighting resources should best be managed — in particular, where they should be placed strategically and how they should be redeployed as fires occur. Working with Portugal's most significant forest resources company, MIT and Portuguese researchers have taken the first steps to creating an integrated approach to identify improvements to the policies and operational practices that guide industry and government authorities.

Principal Investigators: João Claro (Faculty of Engineering-University of Porto), Richard de Neufville (MIT)' Tiago Oliveira (PORTUCEL)

Main Institutions: Faculty of Engineering-University of Porto; MIT; PORTUCEL

Education:
research-based, project-driven



Advanced training of scientists and engineers through the MIT-Portugal joint venture provides a broad world view that goes well beyond any specific natural science or engineering domain. Young researchers and students are engaged at a systems level to explore and understand the social and technical issues that cannot be divorced from the work they will be undertaking as they enter industry, or that will be part and parcel of their research and education if they remain in academia.

Seven new graduate degrees in Portuguese universities with MIT

Research-based, project-driven advanced training in cutting-edge areas of science and technology has been introduced and is being experienced through four Doctoral courses and three Executive Master's courses launched in Portugal through the MIT-Portugal collaboration. These are national courses in which three or more Portuguese universities cooperate with MIT: some eight Portuguese universities and twenty Portuguese research centers and national laboratories are now linked to twenty-six MIT departments and all five Schools within MIT. The areas of study include:

Doctoral Programs (PhD):

Bioengineering
Transportation Systems
Sustainable Energy Systems
Leaders for Technical Industries

Executive Master's Programs:

Complex Transport Infrastructure Systems (M.Sc.)
Sustainable Energy Systems
Technology Management Enterprise

Each of MIT-Portugal's education programs has established strong ties with industry and continues to do so as we build a research and knowledge network to solidify the transformation of training: entering Doctoral and Master's students for the past two years have been 45 percent international.

Direct interaction with MIT students and faculty is at the core of the MIT-Portugal collaboration. Students also become affiliate members of the MIT Alumni Association to help foster lifelong connections to the program. MIT faculty spend time in Portugal on a regular basis, teaching and advising students, meeting with industry, and engaging in joint research. This holistic engagement is key to delivering a unique educational experience that is well grounded in research.

In November 2009, in a ceremony that included MIT President Susan Hockfield and several deans of Portuguese institutions, fifty-nine graduates of the Executive Master's courses were recognized with national certificates of graduation at a ceremony in Lisbon. These certificates recognize the completion of courses offered in association with the consortium of Portuguese universities supported by MIT through the MIT Portugal Program. It was the first such ceremony in Portugal, and marked the induction of these graduates as Affiliate Members of the MIT Alumni Association.

Sustainable Energy Executive Master students on a company site visit during their intensive one-week trip to Cambridge

Experiencing doctoral education with students from around the world

Students come from more than thirty countries. At present, 14 percent of doctoral program applicants are graduates of schools listed among the "Top 200 World Universities" by Times Higher Education, including Imperial College London, ETH Zurich, KTH Royal Institute of Technology in Sweden), the University of Michigan, and MIT. Some 40 percent of admitted candidates for the 2009 and 2010 academic years are international students. Applications to our doctoral programs from students outside Portugal rose by 50 percent for the 2009-10 academic year, with applications from 56 countries.

In addition, dozens of MIT graduate students are dedicating their thesis research to Portuguese topics. In several cases, these students have spent extensive time in Portugal to meet with stakeholders. For example, PhD graduate Travis Dunn wrote a thesis that focused on improving understanding of the relationship between institutional structures and infrastructure investment patterns, and relied on a range of both quantitative and qualitative data from multiple Portuguese sources. Master's graduate Lisa Rayle researched inter-agency collaboration in metropolitan planning, and conducted in-person interviews with policymakers and others in the Portuguese urban planning community. Angelo Guevara's doctoral research was mainly concerned with the implementation of a residential location choice model for the city of Lisbon.

Enhancing the research and knowledge network through on-site work at MIT

The MIT Portugal collaborative venture provides unique opportunities for students and scholars in Portugal to visit MIT for extended periods of learning, research, and interaction on campus. Some sixty-two doctoral students and twenty-four visiting scholars have already spent a month or more at MIT during the last two academic years, and forty-three Executive Master's students have enjoyed intensive one-week visits to MIT.

David Malta's experience is representative of how important these visits are to the success of the program and the role they can play in helping achieve the goals. David was a member of the Bioengineering team that in 2008 won the Biocant Ventures Prize, established to speed commercial development of promising technologies. Since the fall of that year, David has been a visiting student in Sangeeta Bhatia's laboratory at MIT, engaged in research on microscale technologies for tissue repair and regeneration. He will return in September 2010 to the Stem Cell Bioengineering Lab at IST in Portugal, where some of the same projects are underway, and will continue to serve as a liaison between the two labs. This type of collaboration strengthens both laboratories and figures strongly in the goal of building a strong research and knowledge network.

Modernizing engineering curricula

The strong links between the program in Portugal and MIT faculty continue to pay tremendous dividends for the education component of the MIT-Portugal collaborative venture. Nearly three dozen MIT professors and lecturers have been involved with colleagues at Portuguese universities in teaching and curriculum development. Already, twenty-seven new modules have been developed for teaching in Portugal, many of which introduce curricular elements that are novel both to MIT and to Portuguese engineering education, including:

- **Engineering Systems Research Methods**, designed to lay a foundation for empirical research in the social sciences and engineering systems.
- **Innovation Management**, which offers an introduction to technology commercialization, with an emphasis on technology-based entrepreneurship
- **Bioengineering Innovation Teams**, through which Bioengineering Systems students participate on BioTeams that prepare them for the real-world challenges of commercializing technologies in the marketplace.

Students in Portugal have also enjoyed unprecedented classroom interaction with some of MIT's most distinguished faculty. For example, Professors Danny Wang and Robert Langer – two of MIT's fourteen Institute Professors – lecture in Bioprocess Engineering and Cell and Tissue Engineering for Bioengineering PhD students, alongside Portuguese faculty colleagues. With this combination of teaching in person and via videoconference, MIT makes sustainable contribution to educational delivery in Portugal.

Education

MIT President Susan Hockfield presents a certificate during the first national ceremony honoring 59 Executive Master graduates

Exposing students to industry beyond the classroom

Exposure to industry has become a real highlight for students. Specific examples include the exposure of Bioengineering and Sustainable Energy Systems students and faculty to SGC Energia's bio-diesel production facility to address chemical processes for converting vegetable oils and biomass wasted into liquid fuel.

Over the past two years, students in the Master's course in Complex Transportation Infrastructure Systems have visited many different agencies and cutting-edge projects throughout Europe. These technical tours have taken students to the Barcelona Port and Logistics Platform; Antwerp's port and railway station; French railways and Paris buses and bike-sharing programs; Stuttgart's railway station; and the Frankfurt Airport. The technical tours give students a first-hand look at the types of projects and opportunities available for graduates of the program, and familiarize students with some of the some basic technologies and concepts in real-world settings.

Leaders for Technical Industries students engaged industrial affiliates in a "Job Shop" that introduced the students to a host of potential industry-designed PhD research projects.

When Rolls Royce became the first international industrial affiliate to join the MIT Portugal Program, focusing on research in Engineering Design and Advanced Manufacturing, it opened up valuable internship opportunities for PhD students. Carla Pepe, a doctoral student in the Leaders for Technical Industries program, spent six months at a Rolls Royce research laboratory in England before returning to Portugal for further training and to complete her thesis investigating the use of standard activities to improve product development and the implications for the innovative environment of the design team. Her research team included her Rolls Royce supervisor. She has since been invited to return to Rolls Royce as an employee at the conclusion of her studies.

Student research targeting key societal challenges

Students take on key societal challenges as part of their research through their involvement in projects such as Green Islands, CityMotion, and stem cells. The visualization of taxi fleet movements in Lisbon is leading to better decision-making tools for traffic planners and travelers, with global implications. The development of smart energy meters for Portuguese homes is tapping into the power of Google's Power Meter technology. Stem cell therapies are helping extend the lives of Portuguese cancer patients, but the knowledge being developed will eventually help patients everywhere.

Fellowships for students

The Portuguese Science and Technology Foundation provides a limited number of PhD fellowships, which are selected through annual competitions. In addition, corporate fellowships are available through many programs.

By the Numbers

People

303 PhD students

62% Percentage of Portuguese students entering in 2010/2011

165 PhD scholarships granted

120 Student visitors at MIT to date

214 Portuguese faculty participants

159 Executive Master's students and graduates

38% Percentage of international students entering in 2010/2011

147 MIT students supported

23 Job contracts for new faculty and researcher hires

8 Post-doctoral research contracts

28 Visiting faculty and scholars with appointment at MIT to date

62 MIT faculty participants

44 Students' countries of origin

1200+ Applicants to education programs

Partners

28 Portuguese higher education institutions and research laboratories involved in R&D activities

8 Portuguese academic institutions offering PhD degrees in association

54 Education Consortium members (Schools of Engineering, Science and Technology; other associated schools; Portuguese laboratories and national laboratories; and MIT schools, departments and initiatives)

59 Program Affiliates (companies, institutions, associations)

Resources

10.4 M Euros Funds allocated in Portugal through August 2009

345 K Euros Contributions by CTIS corporate Education Affiliates to support scholarships

4 M Euros Funds allocated for new projects awarded through open calls (2009-10)

27.2 $M Funds allocated at MIT through July 2010

Experiencing Technology Commercialization

Presentation at the Innovation and Entrepreneurship Initiative Venture Competition

To create the science- and technology-based entrepreneurial ecosystem of a modern economy requires establishing the programs, policies, and social networks that foster successful relationships between researchers, companies and society at large. It means learning how best to license technologies and then seeing that process through. It means nurturing an understanding of what entrepreneurship means among faculty and students, and rewarding innovation with research funds and awards. And it means building direct relationships between academia and industry partners to enhance the connection of academic research to the social and economic needs it must serve.

Contributing to UTEN, The *University Enterprise Technology Network*

UTEN's mission is to build a professional, globally competitive, and sustainable technology transfer and commercialization network in Portugal by leveraging international partnerships. The MIT-Portugal venture and collaborative research is supporting this long-term goal through a series of workshops and on-the-job training for technology transfer and commercialization officers. Specialized **workshops to foster the exchange of experiences** and training weeks emphasize cross-border and international technology transfer aimed at long-term commercialization and industrial liaison relationships. **On-the-job- training of Technology Transfer officers** is also strengthening these efforts. For instance, over a two-week period in late 2009, Maria Oliveira, director of the Innovation Office at the University of Porto, and Ana Teresa Pinto, director of the University of Aveiro's Technology Transfer Office, were hosted by the MIT Technology Licensing Office and spent considerable time with leaders of the MIT Industrial Liaison Program. They also met with other key MIT entrepreneurial staff from the Venture Mentoring Services, iTeams, and the Leadership for Global Organizations program. Their time at MIT helped them establish a network in Boston.

Exposing students to entrepreneurship

Bioengineering students are immersed in innovation education, which includes special training followed by the Spring term "BioTeams" project. Students are given real technologies developed at laboratories in Portugal and, after a two-week immersion in classes on innovation, work in teams over the course of the subsequent seven months to evaluate their technologies, validate assumptions, and gauge their market potential. They learn about the realities of the business world and build strong connections as they network with Portuguese companies and stakeholders throughout the world. The BioTeams concept in Portugal leverages best practices in collaborative entrepreneurial education at MIT's Sloan School of Management and the MIT School of Engineering. Past teams have competed for corporate-sponsored awards given to the BioTeam with the most outstanding go-to-market plan for that semester.

Innovation and Entrepreneurship Initiative

An annual Venture Competition was created in close collaboration with ISCTE-IUL, a Lisbon business school, to promote new business ventures from emerging technologies. The competition is part of the Innovation and Entrepreneurship Initiative (IEI), a collaboration with several partners from a broad array of MIT entities, including the Deshpande Center for Technological Innovation, the Entrepreneurship Center, and the School of Engineering. Caixa Capital, the risk investment arm of Caixa Geral de Depositos, is the IEI's Founding Patron and funds the Venture Competition awards.

The inaugural competition joined nearly 100 teams, grouped into four tracks: Sustainable Energy and Transportation, Life Sciences (including Medical Devices), Information Technology & the Web, and Products and Services. Twenty semifinalists were announced on July 8, 2010, chosen for the strength of their teams and their innovations, having a clear path to revenue, their international scope, and the market opportunity of their project. Submissions included: new biotech approaches to fighting breast cancer, aiding organ transplantation, and personalize maxilla-facial regenerative medicine; new methods of harnessing clean renewable energy from such diverse sources as ocean waves and engineered floor tiles; artificial intelligence-based credit screening services and cloud-based call center services for small- and medium enterprises; consumer music distribution; self-regenerating biocidal material designed to lower hospital infection rates; and life-monitoring comfortable fashion for the physically impaired.

Outreach:
fostering science and technology education and culture

MIT Professor Larry Young presents to over 500 students and faculty at the Escola Superior Camões in Lisbon

Inspiring Portuguese secondary school students

When a 16-year-old student told a radio program in January 2010 that he was going to be the first Portuguese astronaut to go to Mars, it wasn't simply the imagination of a young man running away. He had been motivated by a talk at the Camões Secondary School in Lisbon by MIT Prof. Laurence R. Young, who was describing a future Mars mission. It was organized as part of the "MIT Professors Visit Schools" series in collaboration with Ciência Viva, an organization that promotes science and technology in Portugal. Young is the Apollo Program Professor of Astronautics and Professor of Health Sciences and Technology at MIT, founding director of the National Space Biomedical Research Institute in Houston, Texas, and a former NASA Payload Specialist Astronaut. Already, through 14 visits by MIT faculty from all of our disciplinary areas to schools in Portugal, the series has reached more than 2,500 students.

> *"As I have seen over and over again, you are creating an extraordinary culture of scientific creativity and innovation in Portugal."*
>
> *– MIT President Susan Hockfield*

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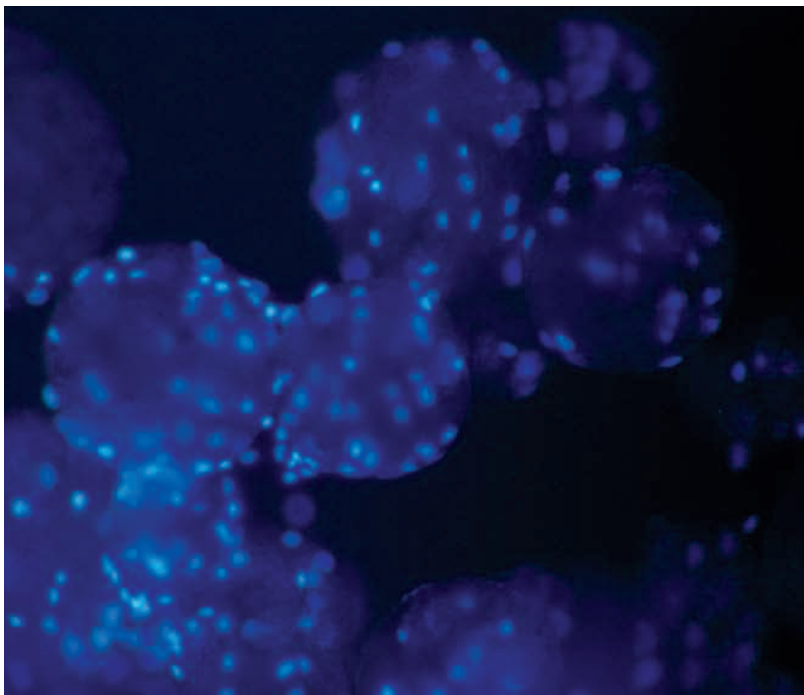

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