MIT Portugal

2009 FCT Competition for Funding in Context of the MIT-Portugal Program

Terms of Reference for the Call for Proposals

Contents

Introduction

This document provides information relevant to the Call for Proposals funded by FCT in the framework of MIT–Portugal Program, oriented to specific themes and included in the following application areas:

- **Sustainable Energy and Transportation Systems**
- **Stem Cell Engineering for Regenerative Medicine**
- **Materials and Design Inspired Products**
- **Fundamentals of Engineering Systems**

This call assumes a partnership of at least two different research centers in Portugal, with the participation of at least one company, governmental or other independent non-academic organization, and one research team at MIT.

This announcement is open to all MIT faculty, and MIT faculty and staff participation in projects will be supported by funds of the MIT-Portugal Program at MIT. This work will be conducted in accordance with the terms and conditions of the MIT-Portugal Program Agreement between FCT and MIT.

Further information regarding MIT funding or the call at MIT, can be requested from portugalcall09@mit.edu, and can also be found at www.mitportugal.org.

Further information regarding the call in Portugal can be requested from researchcall09@mitportugal.org, and can also be found at www.mitportugal.org.

Regulations governing access to FCT funding are available at:

http://alfa.fct.mctes.pt/apoios/projectos/regulamento

The announcement of the opening of the call is available at:

http://alfa.fct.mctes.pt/apoios/projectos/concursos/mit

1: Sustainable Energy and Transportation Systems Application Area

The development of sustainable energy and transportation systems addresses the global challenge of providing critical services to increasingly urban populations under significant resource constraints. The topics below are intended to provide solutions to this challenge by promoting cross-disciplinary research that supports the strategic direction of the MIT Portugal Program.

The Sustainable Energy and Transportation Systems Application Area intends to support a diverse range of research projects that address the many challenges of developing sustainable urban and regional futures. These may include focused research projects contributing to specific technologies and strategies (such as vehicle-to-grid) as well as large, integrated initiatives serving the needs of multiple stakeholders and complex governmental and business alliances (such as Green Islands).

Value in the results of this research includes both convergence toward the practical development of energy and resource efficient urban futures as well as integration of distinct technologies toward well defined research priorities. The portfolio of research supported within the Sustainable Energy and Transportation Systems Application Area is intended to lead toward implementable scenarios of urban and regional systems that support and enhance the various pathways toward a sustainable society.

Research within this area is grouped in three main research areas:

Sustainable Urban Systems

- *Urban Metabolism: analysis of material and energy resource flow, formulation of socioeconomic and biogeochemical interactions, development of practical urban sustainability indicators,*
- *Sustainable, Smart and Efficient Energy Systems: evaluation and design of long-term energy infrastructure alternatives using local energy resources and energy efficiency, including smart energy networks and transportation systems, and state-of-the-art informatics.*

Transportation and Mobility Systems

- *Intelligent Transport Systems: fully incorporating information and communication technology advances into the planning, design, implementation and operation of transportation systems, both passenger and freight and urban and inter-urban.*

- *High Speed Rail: formulation, evaluation and design of the main strategic options related to the planning, financing, and operations of the high speed rail (HSR) system.*

Bioenergy

- *Development and implementation of biofuels and bioenergy systems primarily for sustainable transportation applications, including economic and environmental assessment and technology development.*

Each research area addresses various aspects of technology development and implementation with an emphasis on the design, integration and implementation of new systems that meet long-term environmental, energy security, economic, and social criteria.

The design of future sustainable energy and transportation systems which are "*green,*" "*smart,*" and *"efficient"* requires an understanding of a region's current systems, including detailed characterizations of the attributes of its energy and transportation networks (supply) and demands, and of the main factors influencing the evolution of those supplies and demands, including renewable resource dynamics.

By integrating new and existing systems methodologies – aimed at not only the characteristics of new energy, transportation and information technologies – but how they interact with one another and the existing system, innovative new approaches to meeting our future energy and transportation service needs will be identified.

To effectively confront the challenges requires trans-disciplinary research, explicitly linking energy and transportation and application of new research fields, such as Engineering Systems.

Research priorities for work in the five research areas include but are not limited to:

Sustainable Urban Systems

Urban Metabolism:

- Approaches to assessing resource efficiency and resilience in urban building and transport systems, infrastructure, and land use patterns through the development of appropriate and practical sustainability indicators based on regional material and energy flows
- Assessment of the transport modal preferences associated with various settlement patterns, and of the costs associated with land use and transportation policies to improve energy and

ecological impacts; development of innovative transport services, for passengers and goods for low density applications such as small islands

- Characterization of building stock dynamics incorporating assessments of indoor and outdoor environmental conditions as related to urban land use policy for better green buildings

Sustainable, Smart and Efficient Energy Systems:

- Advanced techniques for energy and material demand characterization, including approaches to renewable resource assessment, which take into consideration daily, seasonal, inter-annual and climate related uncertainties across multiple renewable resources, and energy and material demands
- Development of new active power systems management and control solutions and tools which enable large-scale integration of distributed renewables, microgeneration and poly-generation, electricity storage and large electric vehicle-to-grid deployment, dealing with security of supply considerations in addition to total system energy and environmental performance and management
- Design and evaluation of technological portfolios at a building or neighborhood level, based on dynamic, renewable or microgeneration controllable energy supplies and demands, including active demand approaches, and models for coherent projections of socio-economic and behavioral drivers to local energy and materials demands
- Identification and evaluation of novel "Green Business" opportunities for economic development (data centers, green capital development, export potential, etc.) especially opportunities which help the network balance dynamic supplies and demands; decision support approaches for energy sustainability multicriteria evaluation

Transportation and Mobility Systems

Intelligent Transport Systems

- Development, evaluation, and/or pilot applications of sustainable urban and/or inter-urban mobility services (passenger and/or freight/logistics) that fully capitalize upon the value created by Information and Communication Technologies, including dimensions such as: innovative public-private institutional configurations and business models for service management, implementation, and regulation; integration with urban/regional development goals and objectives, including via improved tactical or operational planning support systems; new and/or enhanced travel modes, vehicle control systems, traffic management systems, and information services,

High Speed Rail (HSR):

- Development of approaches to assess long-term planning, finance, operations and maintenance strategies for HSR systems, including dimensions such as: life-cycle cost analysis or related techniques; uncertainties in demand, material life-spans, maintenance strategies and practices; HSR integration with urban and/or regional development goals and objectives; HSR integration with the networks and operations of other modes, including conventional railways (passenger and freight), and air, road, etc.; and relevant business and financial models.

Bioenergy

- Extended Life-Cycle Assessment of potential bioenergy products, including economic and environmental assessment of liquid biofuels for transportation
- Development of efficient technologies to be integrated into synthetic fuel plants: focus on feedstock gasification, syngas production and syngas quality improvements
- Development of process simulation systems for advanced thermo-chemical processes that enable the optimization of energy integration, yield improvement of different bioproducts, and economic optimization; development of bioproduct upgrading from synthetic crude; and also focus on upgrade and experimental end-use testing of upgraded bioproducts
- Evaluation of the multi-functionality of bioenergy systems towards the optimization of biofuel by- (and co-) product use, and residues valorization, including economic and environmental optimization of novel biodiesel production and distribution systems, exploring their compatibility with current fuel distribution systems
- Traditional and alternative methods of Biodiesel production including trans-esterification and processing of energy crop oils, valorization of biodiesel by-products, improvements to operating facilities, intensive low-energy production of microalgae, large-scale extraction of oils from microalgae, and valorization of microalgae solid wastes

2: Stem Cell Engineering for Regenerative Medicine

Regenerative Medicine aims at improving the length and quality of life by restoring, maintaining, or enhancing tissue and organ function, by merging of different fields including stem cell research, biomaterials development and tissue engineering. A variety of novel approaches are used to address tissue/organ insufficiency including: stem cell-based therapies for the regeneration of damaged tissues; tissue engineered implants and bio-hybrid organs to replace tissue function. Stem cells in particular have the ability to self-renew and to differentiate into cells that are found throughout the body. The possibility of using stem cells and their differentiated progenitors to treat numerous degenerative disorders has stimulated great interest in developing safe transplantable sources of stem cells able to repopulate damaged tissues.

The research in the cutting-edge area of Stem Cell Engineering for Regenerative Medicine within the MIT-Portugal Program addresses stem cell-based therapies and tissue engineering for treatment of hematological diseases, neurodegenerative diseases, bone, skin and cartilage disorders, vascularization of ischemic tissues and urinary tract repair. To build a robust research portfolio, a cross-cutting research project in Stem Cell Engineering for Regenerative Medicine is being developed and targeting to: i) improve the basic understanding on the fundamental processes which control stem cell activity and their differentiation; ii) enhance technologies involved in isolation of stem cells from adult tissues, expansion of those cells in vitro, differentiation and transplantation protocols; iii) develop novel biomaterials and surfaces able to elicit specific reactions to cells, supporting cell growth and differentiation and organizing cells into tissues; and iv) design specific motifs at different length scales to improve functionality of tissue engineered constructs.

Within this call for research projects, proposals supporting and enhancing the Stem Cell Engineering for Regenerative Medicine cross-cutting project will be accepted, using the following Human Stem Cell model systems: hematopoietic stem/progenitor, mesenchymal stem, embryonic stem, induced pluripotent stem and vascular progenitor cells.

Below are the specific areas of inquiry that could leverage the cross-cutting project in Stem Cell Engineering for Regenerative Medicine, which are eligible for research:

- New large-scale bioreactors and processes, including ex-vivo free-serum culture conditions, for the maintenance and expansion of long-term transplantable human stem cells, as well as their differentiated progeny to mass-produce human cells ensuring their availability for cell-based therapies;
- High-Throughput Screening platforms for stem cell research and drug screening;
- Engineered innovative scaffold biocompatible materials, including a new generation of biomimetic biomaterials and nanobiomaterials, for 3-D stem/progenitor cell and functional human tissue-like substitutes, using microfabrication and nanofabrication technologies ;
- Engineered and targeted controlled-release delivery systems for stem cells.

3: Materials and Design Inspired Products

Materials and Design Inspired Products is a research area of the MIT-Portugal Program targeting products and associated services resulting from the integration of science and technology (including advanced modeling tools) into competitive solutions and new developments for niche markets in the mobility industries (e.g., automotive and aeronautics) and health sector (medical devices), and for other opportunities that arise from the efforts of entrepreneurs and graduates involved in the Program.

Applied research in this area is expected to follow an Engineering Systems approach integrating different aspects of the product development chain with social science and management issues, as shown in the figure (further information at http://esd.mit.edu/HeadLine/ESD_StrategicPlan2008.pdf).

Relevant knowledge development in the framework of the product development chain requires different stages to be addressed, namely: concept/idea development, modeling, prototyping and evaluation, manufacturing, and supply chain management, using an engineering systems approach, i.e., considering the adequate management and social contexts. In fact, a major objective of this Call, is to foster integrated analysis and novel solutions for problems comprising more than one of those stages performed by multidisciplinary groups.

Areas for the Open Call

The Call will be open on two main areas, including the research topics listed below:

Research areas	Research topics
➢ Systems and components for electric vehicles (EV)	• In-vehicle power systems • Lightweight materials and structures • Manufacturing concepts • Sustainability issues
➢ Medical devices	• Micromanufacturing in medical devices • Smart medical devices • Operations management in medical device manufacturing • Hybrid Human-Machine Systems

Areas Description

➢ ***Systems and components for electric vehicles***

- *In-vehicle power systems*

When a vehicle is defined by its power system, as is the case for the EV, the developer is confronted with a host of challenges that are typically not central to automobile design. For most of its century of widespread use, the automobile has been marked by the mobility (and the concomitant experience) it supplies, rather than how that mobility is achieved. This new approach will require a host of technological innovations, tied closely to the management of the customer's demand and driving experience. In this regard, the vehicle's "electric-ness" affords an opportunity to reframe consumer expectations while creating the potential for a new conception of personal mobility, namely:

- To reshape the character of mobility through new methods for the delivery of motive power.
- To address the question of range and acceleration options will be shaped not only by innovative traction power systems, but also by the ways in which the energy employed by that traction system is stored and distributed to both the powertrain and the rest of the vehicle subsystems (controls, entertainment, navigation, etc.).
- Technical challenges centered on developing a consumer experience that is not merely comparable to that of conventional vehicle systems (e.g., safety, reliability), but also one that delivers the kind of special experience that will be required to build market demand beyond its "early adopter" core. These may include integration into a "smart grid," allowing the consumer not only to recharge the vehicle using off-peak power, but also to load-level household demand for power during peak electrical demand if the vehicle is available.

Examples of potential projects: powertrain and propulsion solutions; energy storage, conversion and management; and passenger safety from electrical risk.

- *Lightweight materials and structures*

An electric drivetrain and power system imposes constraints upon vehicle design that will lead designers toward aggressive mass reduction targets as a key requirement of any proposed design. This goal will require new ways of thinking about current materials systems, as well as developing new ones for vehicle applications. These systems will result from non-traditional materials for vehicle structures, but also from the application and/or development of new materials forming, joining and finishing technologies that are economically suited to the likely scale of production and flexible against changes in that scale. Moreover, these targets will have to be met within an existing set of performance criteria (safety, reliability, maintainability, serviceability, etc.) that are unlikely to be loosened.

Examples of potential projects: design concepts for EV bodies; composites and advanced alloys; and materials for improved safety.

- *Manufacturing concepts*

Realizing an affordable EV will depend not only on the development of innovative designs, but also of effective manufacturing processes. Traditionally, this industry has relied upon mass production to achieve reasonable costs. Unfortunately, current consumer pressures for product diversity, as well as the exploratory nature of introducing EV, a product with novel characteristics, preclude conventional strategies. As such, the automotive industry must develop technologies and operational strategies affording flexibility in production with limited economic compromise. In today's complex supply chains, this flexibility depends heavily on the ability to coordinate production across organizationally and geographically distributed suppliers. Given the scope and complexity of a modern vehicle, new methods are needed to design and evaluate the performance of such supply chains under real-world uncertain conditions. Such methods need to evolve to consider the implications of regional conditions and the ultimate impact on product quality and customer perception.

Examples of potential projects: flexible production technologies; multi-vehicle platforms; and supply chain challenges in EV manufacturing.

- *Sustainability issues*

Although there are no direct emissions from the motor of an operating EV, the production, powering, and disposal of these vehicles depends upon the operation of a much larger system that does generate very real emissions having very real consequences. Determining the life cycle impacts of EV, therefore, presents important challenges to analysts and policymakers who rely upon their findings. Several topics are of interest when it comes to evaluating the life cycle sustainability impacts of EV, namely:

- The sustainability of the materials, manufacturing operations, and product disposal as they apply to EV. Materials will undoubtedly be used in EV body structures, batteries, and motors that are not currently used at mass production levels within the automotive industry, and it will be important to explore the potential life cycle environmental impacts (including resource scarcity) of using such materials. Strategies to reduce environmental impacts will be an important contribution.
- The environmental impact of EV mass production and use. Research within this space should explore the environmental burdens of the systems required to produce (i.e., supply chains) and power electric vehicles and the strategies to reduce them. Temporal effects of transitioning from production and service systems used for fossil fuel powered cars to those for electric vehicles will be of particular interest.

Examples of potential projects: sustainability of materials, manufacturing and disposal; and environmental impact of electric vehicle mass production and use.

- ***Medical devices***

  - *Micromanufacturing in medical devices*

Recent advances in micromanufacturing techniques are opening new opportunities in the medical device industry. This sector is growing in growing in Europe for approximately 10% per year, consistent with the developments in health care and an aging population. There exists a real opportunity to combine Portugal's strong biological and health sciences industry and emerging bioengineering activities with manufacturing capabilities to achieve knowledge-based innovation in this field. The opportunities are both in the manufacturing infrastructure and in the development of microsystems with enhanced performance.

Microsystems in medical devices are important for sensing elements, actuators or both, contributing to a new generation of medical devices: smaller, more reliable and with better functionalities. Integration of such systems in the fabrication cycle brings additional challenges as it requires the combined use of different materials and processing technologies at a very small scale. Therefore, innovation in micromanufacturing and assembly technologies in controlled/clean environments has major importance to achieve a faster time to market and competitive processes. New design methodologies can also contribute to improve all phases of the development cycle in this area, which has unique challenges due to its specific regulatory framework.

Examples of potential projects: microfabrication and microassembly in controlled environments; and design of microsystems for medical devices

  - *Smart medical devices*

Advances in new materials, microsensors, and microactuators technologies are leading to a new class of promising products, normally referred to as smart devices, able to monitor their environment and perform accordingly.

Among other possibilities, such types of behavior can be obtained by the use of novel materials whose physical properties can change significantly with the surrounding environment or by active biological agents. Research at the interface between these two approaches that aims to develop hybrid solutions combining advanced materials, namely those with novel nanoarchitectures and/or biological functions, is expected to lead to enhanced competitive features and high added-value.

Functionalized medical devices with environmental dependent response including diagnostic and active drug delivery devices are well known examples of potential applications. In addition,

embedded sensing and/or actuation capacity (through the use of functional or nano-engineered materials) are alternative routes to assure higher efficiency and new functionalities in this sector.

Examples of potential projects: environmental dependent response / active drug delivery; and devices with embedded sensors and actuator capacity.

- *Operations management in medical device manufacturing*

The regulatory affairs associated with the medical device industry, in terms of operating environments, manufacturing practices, and quality assurance, present additional challenges to the management of complex production and assembly lines.

Furthermore, the management of supply chains that have to serve public and private institutions operating 24 hours a day and fit in new business models to supply the health sector is a field for research activity at the modeling or experimental level.

Examples of potential projects: management of production and assembly lines under good manufacturing practices (GMP); and supply chain management in medical device industry.

- *Hybrid Human-Machine Systems*

Health care applications of biotechnology are some of the most exciting areas of technical innovation. This topic addresses engineering to enhance performance at the organ, limb, and body-level interfaces. We envision a future where 'disabilities' are eliminated and human-machine devices and exoskeletons enhance performance and overcome debilitating musculo-skeletal pathologies. Research breakthroughs in human performance modeling, embedded biosensors, realizable exoskeletons and medical orthotics and prostheses are needed to assure the best healthcare assessments, enhance rehabilitation and performance, create markets and implement novel designs for better quality of life solutions.

Examples of potential projects: prostheses, orthoses, and exoskeleton design; and algorithms, control systems and embedded biosensors.

4: Fundamentals of Engineering Systems

Engineering systems is an emerging field that integrates engineering, management and social sciences to achieve the best possible understanding, design, and implementation of highly complex, technology-based systems. The present call seeks research proposals in the following interdisciplinary approaches and methodological areas:

- **Design and Implementation**: Research on this topic should seek to improve the various processes associated with design and implementation, including requirements development, product architecture and design, program and project management, and new reliability/robustness/testing methods. This call seeks proposals to create new methods and models that use holistic approaches to incorporate implementation and enterprise adoption challenges.
- **Uncertainty and Dynamics**: Research on this topic should address key sources of uncertainty in a given engineering systems context. Proposals are sought that will model and quantify these uncertainties so that they can be taken into account during system design, implementation, and management in order to create strategies for the robust and flexible design of systems.
- **Networks and Flows**: Research on this topic should apply modern graph and network theory to complex systems in a way that allows the representation of the dynamics and uncertainties that are most relevant to engineering systems. Research proposals are invited that seek to characterize technical, social, and/or managerial functions as modeled networks in order to illuminate issues in system design and implementation.
- **Interface of Humans and Technology**: This area focuses on illuminating the complex relationship between designers, users, and technology to facilitate design improvements and effective operation of complex systems. Proposals are sought that aim to develop methodologies and investigate key questions ranging from system design, to human-in-the-loop modeling, to process interventions, and to organizational structures.

The present research call is directed to research teams that want to contribute to this new field by simultaneously: 1) developing new engineering systems methodologies, which may evolve from an innovative combination of two or more methodologies; 2) tackling-issues pertaining to complex socio-technical systems in a specific domain/context; and 3) achieving a deeper understanding of fundamental engineering systems concepts.