

# MIT-PORTUGAL COLLABORATION

## *PROGRAM OVERVIEW*

OCTOBER 2006

1. The Portuguese Government, through the Ministry of Science, Technology and Higher Education, is entering into a long-term collaboration with the Massachusetts Institute of Technology (MIT) focusing on basic research and education. The objectives, framework and structure of the collaboration were developed during a five month assessment study conducted by MIT between February and July 2006, which concluded that the excellence of the research identified in Portuguese research centers throughout the assessment exercise recommends that MIT foster collaborations with Portuguese institutions. Also, the study acknowledges that the commitment of the Portuguese Government in strengthening science and technology and in promoting international collaborations in higher education and in science and technology is making Portugal an interesting place for doing research and a relevant partner for future collaborations in the emerging knowledge-based, globalized economy.
2. The Portuguese Government intends to strengthen the country's knowledge base at an international level through a strategic investment in people, knowledge and ideas and the MIT-Portugal Program has been designed together with other international partnerships with renowned research and education institutions worldwide to contribute adequate funding to support the development of basic research and education and to foster a set of new and **diversified institutional partnerships**. It should also be noted that the goals of the overall operation include launching and promoting new **research-based consortia** at a national level and the MIT-Portugal Program contributes for this effort by involving 10 schools of higher education and 7 different universities, together with a large number of research centres and Associated Laboratories, as well as State Laboratories.
3. The assessment involved extensive discussions and preliminary planning by faculty at MIT and in Portugal to determine the principle focus areas of investigation as well as key institutional, operational, financial and technical issues, and has resulted in **two main foci for collaborative agreements**. These are: i) a formal, ongoing cooperative arrangement in the area of management sciences which will be explored in a program design and planning process concerning a possible multi-year collaboration around **management education and technology-based entrepreneurship**; and ii) a five-year agreement for research and education with an **engineering systems** focus, responding to the increasing size, scope and complexity of systems in today's global competitive environment.
4. The cooperative arrangement in the area of **management sciences** will be conducted at MIT through the Sloan School of Management (MIT Sloan) to work with leading schools in Portugal, fostering new horizons for transatlantic collaboration in management science and technology-based entrepreneurship in a way oriented towards the goals of the revisited Lisbon strategy for competitiveness and employment in Europe. The specific objectives for the first year include: 1) jointly develop a global MBA program aimed at attracting students from Portugal and other nations, in a way to strengthen the international reputation and visibility of business education in Portugal; 2) jointly develop a "Sloan-Lisbon Seminar Series on Management Science" in order to strengthen PhD management education and help building national and international relationships and research consortia; and 3) jointly develop a mid-career program in technology-based entrepreneurship.
  - 4.1 The program will involve MIT Sloan and Portuguese faculty and visiting appointments at MIT will enrich the collaboration.
  - 4.2 Following the MIT's assessment report of July 2006, the design of the global MBA program will be led by the School of Economics and Business at the Portuguese Catholic University (FCEE/UCP) and the School of Economics at the Universidade Nova de Lisboa (FE/UNL) and will also involve faculty of ISCTE Business School (ISCTE) and of the School of Economics and Management at the Technical University of Lisbon (ISEG/UTL).
  - 4.3 Three seminars will be arranged for the academic year 2006/07 with active participation of MIT faculty. The four schools mentioned above will jointly arrange the Seminar Series in close collaboration with MIT Sloan.
  - 4.4 A mid-career program in technology-based entrepreneurship will be planned, following the MIT assessment study conducted during the period February-July 2006.
  - 4.5 The program governance structure includes a Program Governing Committee, responsible for policy oversight with respect to overall objectives of the relationship, and Operating Committees for the activities planned.
5. The collaboration focused on **engineering systems** gives emphasis to large-scale systems that not only have critical technological components, but also have significant enterprise and socio-technical level interactions that call for engineers in leadership positions to have training in engineering systems that goes beyond traditionally defined engineering disciplines. The program will be

coordinated at MIT by the Engineering Systems Division, and will include collaborations with various other departments, divisions, and schools at MIT. The following specific fields were identified as the initial focus areas for the MIT Portugal collaboration, on top of which an integrative anchor program (in engineering systems) will be developed:

- **Engineering Design and Advanced Manufacturing:** This focus area emphasizes the development of design as a key academic field. This is aimed at enabling the development of a cadre of innovative leaders who are educated not only in the fundamental elements of technology management and design, but also trained in the practical exploitation of those core skills in the formation and leadership of knowledge-based creative enterprises. There will be particular emphasis in the automotive and aeronautic sectors, as well as in medical devices.
  - **Transportation Systems:** The ultimate goal of this area is to promote the design and operation of integrated, technology-intensive, intermodal transportation systems, considering the integration of intelligent transportation systems (ITS), the high-speed rail system and airport infrastructures.
  - **Energy Systems:** Extending far beyond traditional energy research, this area will focus on the dynamics among energy services and supplies, including opportunities for developing combined heat and power and incorporating renewables in the distribution network.
  - **Bio-Engineering Systems:** Efforts in this focus area will build on the research capacity existing in Portugal and develop emerging aspects of bio-engineering, cell and tissue engineering, and bioprocess and computational biology.
- 5.1 Each of these focus areas is described in the Appendix. A number of joint research and educational projects will be undertaken in each focus area involving participants from both Portugal and MIT. Educational programs will vary for each focus area and will consist of a mix of doctoral programs, professionally-oriented master degrees, and short courses. Faculty will be encouraged to make new educational material publicly available, namely making use of Creative Commons licensing. At MIT, OpenCourseWare (<http://ocw.mit.edu>) will be used.
  - 5.2 An integrative anchor program will feature research and curriculum development led by the Engineering Systems Division. Research addressing fundamental issues in engineering systems such as complexity, uncertainty, large-scale system architecture, security, and sustainability will cut across the Focus Areas, providing coherence around emerging themes. Related curriculum development efforts on methodologies and fundamental system concepts will provide materials that could be used in education programs in different focus areas. A video-conference seminar series will help sustain a cross-Atlantic research community of interested scholars and educators.
  - 5.3 The program will involve MIT and Portuguese faculty, graduate students, post-doctoral associates and research staff. Visiting appointments of faculty at MIT and in Portuguese institutions will enrich the collaboration. Portuguese graduate students will spend time at MIT as visiting students and Portuguese students will be encouraged to apply to MIT for graduate degrees. The collaboration will involve opportunities for a significant number of professionals as shown in Attachment.
  - 5.4 To develop the program in Portuguese institutions it is expected, besides the involvement of their faculty, the establishment of new contracts with invited professors and postdoctoral researchers with recognized merit in international basis, in a way that reinforces their education and research capability, involving a total of around 14 new professorships and 18 post-docs annually in the program. The program will also involve around 35 new graduate students and 80 new professional master students annually in Portuguese institutions.
  - 5.5 The program envisages the collaboration of students, researchers and professors of Portuguese institutions with research teams at MIT, where the "Portugal Program at MIT" will be developed, involving around 38 professors, 15 post-docs and 46 graduate students at MIT annually. MIT will also be available to receive up to 33 graduate students and 15 researchers/professors from Portuguese institutions visiting MIT each year. All MIT professors, researchers and PhD students will have a co-affiliation with a Portuguese Institution.
  - 5.6 The anticipated total public budget for the first 5 years of the MIT-Portugal partnership in engineering systems amounts to around 65 Million Euros (82 Million USD), from which 33 Million Euros are to fund activities at MIT (41 M.USD) and 32 Million Euros are public funding to Portuguese institutions. In addition, private funding will be used to support activities in industrial affiliates and to support advanced professional education programs.
  - 5.7 The specific activities to be undertaken by MIT and the Portuguese consortia will be specified in Annual Plans. Since the projects involve both MIT and Portuguese institutions, the successful execution of joint activities will require each side to carry out their contractual responsibilities. The MIT Annual Plan will focus on those activities that MIT will undertake, while the Portuguese Annual Plan will focus on the activities by all the Portuguese institutions involved in each Focus Area. The Portuguese organizations involved in the MIT-Portugal Collaboration explicitly acknowledge their institutional commitment to the overall program and

- the specific activities in the Annual Plan by means of a written commitment, on which MIT may rely, to participate in the MIT-Portugal Collaboration through collaborations with MIT in the Focus Areas. These commitments specify how each institution will contribute to the overall program in general and specified projects in particular.
- 5.8 The program governance structure includes a Program Governing Committee responsible for policy oversight with respect to overall objectives of the relationship as well as approval of the annual plan and budget allocation for the proposed activities in the annual plan; a Program Operating Committee responsible for developing and initially approving annual plans in the focus areas; and an External Review Committee which will review and comment on the Annual Plan, and evaluate the Program based on the specified Program objectives. The Program Governing Committee and Program Operating Committee will, simultaneously with their respective review and approval of MIT's Annual Plan, apply the same review and approval process to the Annual Plan of the Portuguese institutions that are committing to collaborate with MIT on a project or program. The External Review Committee, which will meet at least twice each year, consists of distinguished external advisors with expertise in the Focus Areas and will have an important role in the development of the program. Their independent review will include recommendations about alterations in the Annual Plan and budget to support achievement of the overall objectives of the MIT-Portugal Collaboration.
- 5.9 Each of the thematic focus areas will involve a new companion effort, "MIT-Portugal Industrial affiliates" with the goal of fostering new research consortia in collaboration with MIT, leading to new frontiers of transatlantic collaboration in science and technology. EDAM will launch the first affiliates program with a set of leading companies in the automotive sector, including VW AutoEuropa, the largest car assembler in Portugal, and major auto-parts manufacturers, as listed in Annex.
- 5.10 The MIT Program Director is Daniel Roos, Professor and Founding Director of the Engineering Systems Division. The Portuguese Program Director is Paulo Ferrão, Professor at Instituto Superior Técnico, Technical University of Lisbon. Both will be assisted by a team of joint coordinators for each focus area, as follows:
- *Engineering Design and Advanced Manufacturing, EDAM:*
    - MIT Professor Joel Clark, Engineering Systems and Material Science and Engineering and MIT Professor Chris Magee, Engineering Systems Division and Mechanical Engineering
    - António Cunha, Professor, School of Engineering, University of Minho
  - *Energy Systems:*
    - MIT Professor David Marks, Engineering Systems Division and Civil and Environmental Engineering, and Steve Connors, MIT Laboratory for Energy And Environment
    - Paulo Ferrão, Professor, Instituto Superior Técnico, Technical University of Lisbon
  - *Transportation Systems:*
    - Joe Sussman, MIT Professor, Engineering Systems Division and Civil and Environmental Engineering
    - João Bento, Invited Professor, Instituto Superior Técnico, Technical University of Lisbon
  - *Bioengineering Systems:*
    - Dava Newman, MIT Professor, Engineering Systems Division and Aeronautics and Astronautics
    - Manuel Nunes da Ponte, Professor, School of Sciences and Technology, Universidade Nova de Lisboa

## Appendix A: List of University Research Groups and Industrial Affiliates in Portugal

In the scope of the **Engineering Systems** program, each one of the four thematic areas will integrate, from the Portuguese side, partnerships among several higher education and research institutions, as follows.

- **Engineering Design and Advanced Manufacturing, EDAM:**

- Escola de Engenharia, Universidade do Minho (UM)
  - Centro Algoritmi
  - IPC – Instituto de Polímeros e Compósitos
- Faculdade de Engenharia da Universidade do Porto (FEUP)
  - IDMEC: - Instituto de Engenharia Mecânica - Unidade de Concepção e Validação Experimental
  - INEGI: - Instituto de Engenharia Mecânica e Gestão Industrial
  - EXPMAT – Mecânica Experimental e Novos Materiais;
  - NOTEPAP – Novas Tecnologias e Processos Avançados de Produção
  - ISR Porto – Instituto de Sistemas e Robótica
  - LEPAE – Laboratório de Engenharia de Processos, Ambiente e Energia
- Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - ICEMS – Instituto de Ciência e Engenharia de Materiais e Superfícies
  - IDMEC – Instituto de Engenharia Mecânica
  - IN+ - Centro de Estudos em Inovação, Tecnologia e Políticas de Desenvolvimento

The partnership also includes the following Associate Laboratory:

- Instituto de Engenharia de Sistemas e Computadores do Porto, INESC-Porto

- **Transportation Systems:**

- Faculdade de Ciências e Tecnologia, Universidade de Coimbra (FCT/UC)
  - Centro de Investigação em Engenharia Civil da Faculdade de Ciências e Tecnologia da Universidade de Coimbra
- Faculdade de Engenharia da Universidade do Porto (FEUP)
  - CITTA - Centro de Investigação do Território, Transportes e Ambiente
- Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - CESUR, Centro de Sistemas Urbanos e Regionais
  - ICIST, Instituto de Engenharia de Estruturas, Território e Construção

The partnership also includes the following State Laboratory:

- Laboratório Nacional de Engenharia Civil (LNEC)
  - Departamento de Transportes

- **Energy Systems:**

- Faculdade de Ciências, Universidade de Lisboa (FCT/UL)
  - Centro de Física da Matéria Condensada da Universidade de Lisboa
- Faculdade de Engenharia da Universidade do Porto (FEUP)
  - IDMEC: - Instituto de Engenharia Mecânica - Unidade de estudos avançados de energia no ambiente construído
- Instituto Superior de Economia e Gestão, Universidade Técnica de Lisboa (ISEG)
- Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - ICIST, Instituto de Engenharia de Estruturas, Território e Construção
  - IDMEC – Instituto de engenharia mecânica
  - IN+, Centro de Estudos em Inovação, Tecnologia e Políticas de Desenvolvimento
  - MARTEC- Centro de ambiente e tecnologia marítimos

The partnership also includes the following Associate Laboratories:

- Instituto de Sistemas e Robótica, ISR
- Instituto de Engenharia de Sistemas e Computadores do Porto, INESC-Porto

It is also planned that under the scope of the current reform of State Laboratories, the future Laboratory of Energy and Geology (LNEG) also participates in this focus area.

- **Bio-Engineering Systems:**

- Escola de Engenharia, Universidade do Minho (UM)
- Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa (FCT/UNL)
- Faculdade de Engenharia da Universidade do Porto (FEUP)
- Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)

The partnership also includes the following Associate Laboratories:

- Centro de Neurociências e Biologia Celular (CNBC)
- Instituto de Biotecnologia e Bioengenharia (IBB)
- Instituto de Biologia Molecular e Celular (IBMC)
- Instituto de Tecnologia Química e Biológica (ITQB)
- Laboratório de Química Verde (Requimte)

It is also planned that under the scope of the current reform of State Laboratories, the future Instituto Nacional de Recursos Biológicos (I-RBN) also participates in this focus area, together with any other relevant Associated Laboratory

The Program will be developed in close collaboration with “**MIT-Portugal Industrial affiliates**” with the goal of fostering new research consortia in collaboration with MIT and Portuguese research groups. Specific groups may be developed for each of the thematic focus areas and EDAM is launching the first affiliates program with a set of leading companies in the automotive sector, including the following companies and institutions:

- VW Autoeuropa
- Amorim Industrial Solutions
- Celoplás
- Iber-Oleff
- Inapal Metal
- Inapal Plásticos
- Manuel da Conceição Graça
- Plasdan
- Simoldes Plásticos
- Sunviauto
- TMG Automotive
- CEIIA; Centro de Engenharia

This group of industrial affiliates will be extended to other areas in the coming months, based on specific assessments and the interest shown by other companies in Portugal and abroad.

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## Appendix B: Transportation Systems

### **Introduction**

An overarching focus of the MIT/Portugal Transportation Systems Program is the design of complex large-scale systems that have major societal impact and provide opportunities for sustainable economic development. The transportation system in Portugal is clearly one such system. There is substantial current interest in Portugal in modal components of the transportation system including a new airport in the Lisbon area, an intercity high-speed rail system connecting to a Europe-wide system, and the implementation of various Intelligent Transportation Systems (ITS) applications around the nation. In this focus area, we will consider all of the above, not as independent modally-oriented transport elements, but rather as an integrated whole. The vision for the transportation component of the MIT-Portugal Collaboration is the design of an **integrated, technology-intensive, intermodal transportation system**.

To work toward this vision, we will establish **an integrated program of educational and research activities**, dealing not only with the transportation system itself but also the interconnections between transportation and other major societal subsystems, including the economic development system, the environmental system and the land-use system.

In this program of education and research, MIT will work in close cooperation with universities, industrial companies and research laboratories in Portugal. The participation and performance of the Portuguese entities will be critical to MIT's ability to perform in this program. The centrality of transportation to social goals and industrial development makes it a vital area to pursue in the MIT-Portugal Collaboration.

### **Leadership**

A critical success factor in the transportation systems focus area will be effective and committed leadership for the program. It is anticipated that Prof. Joseph Sussman will continue to lead from the MIT side and Dr. Joao Bento will continue to lead from the Portugal side. In addition, we recommend that the lead institution for this focus area on the Portugal side should be the Instituto Superior Técnico (IST), with Professor José Manuel Viegas, the chair of their transportation group, playing the key role. It is important that IST acknowledge the central position they will have in this focus area and recognize the need to support this initiative.

### **Education and Research Elements**

The MIT-Portugal Collaboration is intended to be a coordinated and integrated set of education and research activities. The program is composed of *integrating* elements, and *domain-specific* elements in education and research, which are intended to operate in a coordinated manner.

### **Education**

The initial focus of the educational program is the development of curriculum materials for a new Master of Science (MSc) degree in Transportation, to be developed in a coordinated manner by MIT working with IST as the lead institution for the transportation systems focus area, and also including Porto and Coimbra. The curriculum materials will be made available to educational institutions in Portugal for non-commercial, educational purposes. The Portuguese institutions that participate in the development of materials will be responsible for implementing the program. The theme of this MSc Program in Transportation is *Complex Transportation Infrastructure Systems: Conceiving, Designing, Integrating and Operating the Transportation Enterprise*. This education element is itself viewed as an integrating mechanism for the overall program. Our goal is that this program will serve an international market,

attracting talented transportation students and professionals by creating a world-class transportation educational enterprise in Portugal.

In addition to the MSc degree program, MIT and the Portuguese institutions anticipate offering short courses and executive courses, typically of one week in duration, which we hope will attract an international audience and add to the visibility of the educational enterprise. Furthermore, it is envisaged that, upon confirmation of interest by Portuguese companies, longer-term training programs could also be part of the collaboration.

While the initial educational focus on the MIT-Portugal transportation program will be the MSc degree, the longer-term goal is to create an international PhD program housed in the Portuguese universities and supported by MIT faculty. The PhD program will be developed and implemented during this 5-year collaboration, with the intent of attracting the best of the MSc students to continue for the PhD.

## **Research**

### Coordinating Research

Paralleling the MSc program, we plan a *coordinating research activity* entitled “**Strategic Planning for the Regionally-Scaled Integrated Intermodal Transportation Enterprise: Toward Sustainable Development**”. This project will create a framework for the domain-oriented research projects to be described later and will directly relate to the theme of the MSc program introduced above. This research is intended to create a conceptual intermodal strategic plan for Portugal, and further, to develop general methods in support of the strategic planning process for the transportation enterprise.

In addition to the integrated strategic planning research activity, there will be three domain-oriented research programs, which will be coordinated by the integrating strategic planning research program. We will further integrate these research efforts by applying and further developing methods (real options analysis and design structure matrices) that can be used in several of the domain-oriented projects.

### Intelligent Transportation Systems (ITS)

ITS is an important new component in surface transportation as introduced over the last several decades. We will advance ITS in Portugal with research focused on several topics. These include:

- *ITS: Understanding the Benefits and Costs:*  
This project will study the many opportunities in ITS to improve congestion, safety and environmental impact in the transportation system.
- *New Methods Related to Understanding, Valuing and Deploying ITS:*  
We will consider ITS as a “real option” in providing flexibility to counter the uncertainties in surface transportation. Pioneered by faculty in the Engineering Systems Division at MIT, real options analysis is a methodology used in system design that draws on concepts used in financial planning under uncertainty, enabling the evaluation of flexibility in design choices.

Working on ITS regional architectures to understand new institutional relationships that can facilitate the effective deployment of ITS technologies is of ongoing interest to MIT researchers. The Design Structure Matrix (DSM) method of building regional architectures is a research area of great promise.

### Airports

- *Airports as Complex Systems: Dealing with Uncertainty*  
Studying the potential new Lisbon airport from a complex systems perspective is of tremendous practical value and can advance our intellectual agenda in this program as well. The idea of real

options analysis as a way of considering how one flexibly deals with uncertainties involved in such an enterprise is of great interest.

### High-Speed Rail

Another proposed major infrastructure development in Portugal is a high-speed rail system, currently contemplated to go north from Lisbon to Porto, and east from Lisbon to the Spanish frontier, connecting to the Spanish HSR system and to the HSR system interconnecting Europe. We plan several research projects in this area.

- *Modal, Intermodal Connectivity and Competitive Issues in HSR*  
Of interest here is explicitly considering the intermodal connection between the high-speed rail system and the air transportation system in Portugal and indeed in all of Europe. The integration of these modes as well as the competition between them is a critical area for research. Further, how Portugal will integrate with a European system of high-speed rail, both technologically and institutionally, is of considerable importance and will be considered in the research element as well.
  
- *Generalized Global Risk Assessment of the HSR system.*  
Another important research area is *generalized global risk assessment*. The notion of an integrated approach to studying risks of various sorts, including safety, security, financial, technological and market risks, is an opportunity to make a significant contribution to the understanding of the issues and opportunities associated with HSR in Portugal as well as internationally.

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### First Year Program Plan for the Transportation Systems Focus Area

The first year of the transportation systems focus area of the Portugal program at MIT is intended to provide a fast start for the education and research programs, laying a strong foundation for many years of future collaboration.

Our first priority in the first year program is to begin development of the educational activities, focused especially on the MSc in transportation. As noted earlier, the theme of this MSc program is “*Complex Transportation Infrastructure Systems: Conceiving, Designing, Integrating and Operating the Transportation Enterprise.*”

This will be developed as a joint venture of MIT and three Portuguese universities, the Instituto Superior Técnico (IST), the University of Coimbra, and the University of Porto. During the first three months of the program, as a *pilot project*, we plan to have a major workshop in Portugal on the development of the MSc program. This workshop will focus on developing the structure of the MSc program and the content of several of the core subjects within it. We will assess the existing activities at all the participating universities, ascertain what can be effectively utilized in the new international MSc program, and outline the new content that needs to be developed. The plan is that prototype versions of several of the new subjects will be offered on an experimental version in the year preceding start up of the program.

A further outcome of the workshop will be a plan for assessing the international market for the MSc program. We will aim at understanding the competition in the marketplace for international students, and to ascertain what the characteristics of an attractive MSc program would be. At the same time, we are committed to developing deep intellectual content and a program that will be of value to in the Portugal education market.



As the kick-off event for the transportation systems focus area, this workshop will be a high-profile event involving MIT and Portuguese participants from academia, industry, government and research laboratories.

We also plan important activity on the *research* side of the transportation focus area in the first year program. The first priority will be to establish the coordinating research program, as previously noted, entitled "*Strategic Planning for the Regionally-Scaled Integrated Transportation Intermodal Enterprise: Toward Sustainable Development.*"

This research program is parallel to the MSc educational program as a integrating element of the overall transportation systems focus area. It will create an integrating framework for the three domain areas of research, ITS, airports, and high-speed rail. Initial research emphasis will be on the development of an intermodal platform for the Portuguese transportation system. Further, we will reach out to other focus areas in the MIT-Portugal collaboration and especially the energy and EDAM focus areas, to identify opportunities for coordinated research. An outcome of this initial integrated research will be a work plan of research activities to be conducted in the three domain areas, which we expect to initiate early in the first year, working in cooperation with Portuguese organizations.

In summary, then, for the first year we plan an active program in both education and research, with our initial efforts being on the *integrative elements* of the transportation systems focus area, the **MSc in Transportation** with the theme *Complex Transportation Infrastructure Systems: Conceiving, Designing, Integrating and Operating the Transportation Enterprise* –with a major workshop in Portugal during the first three months of the program as a *pilot project*– and **research** in *Strategic Planning for the Regionally-Scaled Integrated Transportation Intermodal Enterprise: Toward Sustainable Development*. We will branch early in the first year into the deep study of the three domain areas we have selected in the transportation systems field, ITS, Airports and HSR. We will work to assure the effective integration of research and education, as is classic in the development of strong intellectual programs in academia and to assure our work in education and research will be of value to transportation stakeholders in Portugal.

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## **Appendix C: Sustainable Energy Systems**

### ***Introduction***

Energy security and long-term environmental management are only two of the many emerging long-term challenges facing today's energy infrastructures for which novel research on integrated energy systems, including renewables and energy efficiency, will be highly beneficial to Portuguese, EU, and other stakeholders. Portugal, which imports most of its energy as fossil fuels, must devote particular attention to energy efficiency, by designing future energy systems tailored to the nation's specific needs for energy services. These efforts, aimed at the long-term transformation of the energy infrastructure also include such issues as aging infrastructure components, shifting investment responsibilities under competitive energy markets, and the need to identify—and protect—vulnerable energy system nodes and modes. In addition to novel, detailed, and transferable knowledge on future sustainable energy systems, society and industry will need individuals well educated in these areas.

### ***Overview of the Sustainable Energy Systems Focus Area***

While there is much quality work on various components along the energy supply chain—work on individual technologies for example—to develop policies with beneficial long-term impacts a new generation of tools which allows us to evaluate the diverse impacts of alternative energy strategies, or pathways, is needed. The suite of research and educational initiatives proposed for the Sustainable Energy Systems Focus Area focuses directly on these challenges.

The research and education program will involve numerous departments and laboratories at MIT, in collaboration with several Portuguese universities, including the Instituto Superior Técnico (IST), the Faculdade de Engenharia da Universidade do Porto (FEUP), the Universidade Técnica de Lisboa (UTL) and the Universidade de Évora. We anticipate that other universities, and national laboratories will join these lead organizations as the program of research and educational activities develops.

To successfully address these challenges, Sustainable Energy System Focus Area participants will work on the development and integration of new energy system simulation and design methodologies, including educational programs which disseminate this knowledge. Research activities will include the dynamics among energy services and supplies, including opportunities for combined heat and power and renewables in the distribution network. To the extent possible, these new approaches will be tested through real-world case studies.

As part of their research and educational activities, MIT will collaborate with Portuguese counterparts on the formation of a “Portuguese Energy Institute” that will bring together interested faculty and students from across Portugal to pursue focus area activities. The activities of the energy systems focus area will be overseen and coordinated by co-directors in Portugal and at MIT. Professors Paulo Ferrão (IST) and David Marks (MIT), and Stephen Connors (MIT) and have indicated their willingness to be the initial co-directors in the energy area.

### ***Energy Systems Education***

Energy systems research is not only a fertile area for scholarly research, but an area for which there is anticipated high demand for well trained and educated individuals, such that large scale design and deployment of sustainable energy systems can occur. As such there is a great need to transfer new methods from research into curriculum. MIT will work collaboratively with Portuguese faculty to develop graduate education programs in energy systems at the DFA, DEA and PhD levels, as well as professional

short courses. These will be closely aligned with Sustainable Energy Systems research activities to ensure that the curriculum represents “best practices” in energy research.

### ***Energy Systems Research***

Several complementary areas of research have been identified, which collectively cover a broad range of important energy systems topics encompassing local and regional energy systems, development and integration of novel energy supply technologies, and the design and assessment of economic and environmental incentives for sustainable energy.

Working titles for these research activities, which will be adapted and refined during the first year of the program include:

- *Energy Networks: Management of Distributed Generation Through Virtual Power Plants*  
This topic focuses on the dynamic management of electricity generation, storage and end-uses within a local or regional power grid, such that distributed/renewable resources can be used to the maximum extent possible without any degradation in power quality and reliability. This includes market-based implementation for the coordination and control of network resources in the real, near-, and medium-term time horizons.
- *Industrial Ecology: Urban Metabolism*  
This research topic will look at the energy/environmental footprint of a city, including energy and waste flows. Urbanization is one of the main challenges facing the world today, however its impact on the sustainability of our planet is largely unknown. The Urban Metabolism project aims at identifying and mapping the main flows of energy, materials and products in the city, in the context of its built environment. This effort will focus on creating a multidisciplinary model of the built environment of the city, including its impact on energy use in buildings and public spaces, energy generation within the fabric of the city, quality of outdoor urban spaces, and issues of material sustainability, building life cycle assessment, and pollution.
- *Sustainable Energy Development at Regional and Urban Scales — Portuguese Case Study*  
Development of an integrated modeling capability for decentralized energy planning, including externality evaluation and policy assessment is a crucial need if a variety of local energy resources are to be tapped to meet a region’s unique energy service needs. In addition to power generation, regional energy needs include thermal energy services (heating and cooling) in residential, commercial and industrial contexts. Thermal energy (process steam, etc.) is also necessary for many large industrial and agricultural enterprises. Fuel for transportation is also a critical social need. Understanding the degree to which renewable (and non-renewable) energy resources can be tapped to meet these energy needs—over time—is a major analytic and intellectual challenge.
- *Sustainable Energy Systems Planning: Systems Integration in Energy Supply, Delivery and Use — African Case Study*  
This project focuses on the development of a toolkit for use by developing nations to assess energy infrastructure alternatives employing domestic energy resources, and infrastructure limitations over the medium-to-long-term. Ongoing interactions between academic and government agencies in Portugal and in Angola provide the basis for a good initial case study for developing the information and tools.
- *Greenhouse Gas Reduction Policy Assessments*  
With increasing frequency, large portions of the energy infrastructure’s growth and transformation is being left to the private sector through market mechanisms. Policy instruments, such as emissions taxes and cap-and-trade systems, to influence both the investment in, and operation of, energy

facilities are increasingly being relied on to affect these changes. Recent history has shown that these systems must be designed and implemented well—over the long term—if the desired results in terms of substantial and sustained reductions in greenhouse gas and other emissions are to be achieved.

➤ *Marine Energy*

Portugal has a great opportunity to exploit marine energy resources. These come in various forms, in both wave and tidal energy. Understanding both the size and dynamics of wave/swell and tidal resources not only informs the Portuguese government, and technology and project developers, how much attention they should pay to marine energy, it is also critical in the establishment of design criteria for marine energy technologies, from survivability through cost-effectiveness, to integrated energy system benefits.

The above topics in sustainable energy systems technologies, policies, and design and analysis, cover a broad range of existing and potential methodologies. Due to the inherent synergy among research topics, a certain amount of the research activity should be devoted to cross-cutting research in engineering systems design, across the requisite ranges of geographic scope, time steps and duration, and degree of resolution. The research program is to be designed not only to achieve excellence in the development and application of energy systems tools and methodologies, but to develop metrics, and methods of communication, such that the products of the research can be put to use by decision makers and others in Portugal and beyond.

The initial phases of the program will take a comprehensive, systematic look at the core analytic needs and primary knowledge products of a well coordinated Sustainable Energy Systems suite of activities, in order to lead to a rapid, focused, launch of the energy systems research and education program.

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## First Year Program Plan for the Sustainable Energy Systems Focus Area

### ***Coordination and Scope***

Development and launching of a large-scale, multinational, integrated research and education program is a daunting task. The period Sept-Dec 2006 of the Sustainable Energy Systems program will focus on identifying topics, audiences, personnel, and available models and data sources. This will feed the remainder of the first year's "formative research" tasks and the identification of key educational targets. By taking a comprehensive, systematic look at the core analytic needs and primary knowledge products a well coordinated Sustainable Energy Systems suite of activities will be identified.

### ***Program Initiation, Formulation and Leveraging***

It is recommended that the program begin with a workshop in Portugal in early Fall involving the major participants where key research and educational goals and challenges will be discussed, and the near-term, principally cross-cutting, research needs will be identified. Via this workshop and subsequent discussions, specific research projects—drawn in part from those described in the Assessment Report—will be refined and grouped or clustered into two or three sub-topics to provide additional leverage and cohesion within the Sustainable Energy Systems research and education program. Synergies with other focus areas such as Transportation and the Engineering Systems Anchor Program will be part of the workshop as well.

Past experience has shown that large multi-disciplinary research projects which build upon best practice methodologies, and test innovative approaches using real world case studies, require significant coordination and data collection at the front end. This coordination commonly takes three forms. First, identifying, collecting and verifying detailed information which represents both the baseline characteristics

of the case study and the primary input data for the methodologies under development. Second, collecting, assessing, and coordinating the initial set of modeling tools that will be used and expanded upon via the program's research. And, third, refine the initially very broad set of research criteria, identifying key metrics, both among the research team and of prime relevance to the user community (stakeholders, decision-makers, etc.)

It is anticipated that many of the proposed Sustainable Energy Systems research projects will draw from the same data sources, as well as some analytic tools, and so the first year's "formative research" will establish this foundation of information and models—thereby saving time, money, and increasing the synergy and comparability of research activities. Identification of core modeling tools and techniques will also help identify key topics for inclusion into the educational program.

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## Appendix D: Engineering Design and Advanced Manufacturing, EDAM

### *Introduction*

The major desired impacts of the MIT/Portugal EDAM focus area are to make progress toward:

- Significantly improved educational programs in design, product development, and technological leadership
- Development of a cadre of innovation leaders educated not only in the fundamental elements of technology and management, but also trained in the practical exploitation of those core skills in the leadership and formation of knowledge-based creative enterprises.
- Educationally coupled research results that set a foundation for improving the capabilities to design, to manufacture and to market **high-value products and integrated systems** in order to reinforce the Portuguese and European techno-industrial capabilities

In order to make progress towards these objectives, EDAM will establish an integrated program of educational and research activities as well as strong industry interactions with the research and education objectives and results.

### *Portuguese Institutions Role in EDAM*

The EDAM research and educational programs will involve collaborative work between MIT and three Portuguese Universities: the University of Minho School of Engineering (UMinho), University of Porto (FEUP) and the Instituto Superior Técnico, Universidade Técnica de Lisboa (IST). Progress towards the objectives will only occur if the support for the EDAM agenda within these institutions stays at the high level that has been apparent during the assessment period. These universities will also orchestrate the interaction with interface institutions that will participate in the research and industrial outreach activities. Key interface institutions include CEIIA (and the REDIA network of design studios), PIEP, INEGI, INESC-Porto, and INESC-MN. The commitment of these and other Portuguese universities, institutions, and companies to collaborate with MIT, and their performance in their portions of the collaborative projects, will be critical to the success of the projects.

It is anticipated that INTELI (a Portuguese non-profit organization) will also play a significant role, particularly working with industrial firms and in other networking roles. A key feature of the EDAM focus area will be to build upon university-industry interactions in three important sectors: medical devices, aeronautics, and automotive. We aim to involve companies from these three areas in executive seminars and to engage some companies more deeply in the educational and research activities. These activities are intended to involve European companies such as EADS-CASA and VW-Autoeuropa as well as Portuguese companies such as Simoldes, Inapal Plásticos, Inapal Metal, CaetanoBus, Iberomoldes, Plasdan, Pouzada. MCG, Vangest, TMG, Coindu and the DMF group of Medical Devices Companies.

The academic collaborators, namely MIT and Portuguese Universities, will interface with industrial collaborators and R&D Centers / Design Studios, in order to:

- Identify the areas of education and knowledge development with highest potential for achieving the vision and objectives of the agenda;
- Establish knowledge-based development opportunities.

These two aspects will be continuously updated and will serve as input for determining the specific content in the components of the Focus Area discussed below.

***HCD (Human Capital Development) and Education Initiatives***

Human resources development is the most critical dimension to fulfill the objectives of the EDAM focus area agenda. The emphasis will be on the following set of initiatives:

***A. New post-graduate initiatives***

- *Advanced Course: Technology Management Enterprise (TME)*: This initiative is seen as an advanced courses leading to a European 3rd Cycle of Higher Education Diploma (post-master level). The preliminary curriculum design, to be collaboratively undertaken by MIT and three Portuguese universities, will have ten courses in the areas of product development (including customer assessment, quality, and platforms strategy); innovation management and evaluation; materials and technology selection and economics; management for engineering; and engineering systems. The courses will be offered and the diploma will be granted jointly by the three Portuguese universities involved and will require a learning effort of 90 ECTS (European credit system);
- *PhD program: Leaders Technical Industries - Europe (LTI)*: This educational initiative consists of a PhD degree which will be jointly granted by the three Portuguese universities. LTI PhD graduates are expected to manage extensive product development programs involving emerging technological areas and industrial enterprises innovation strategies. This PhD program will have 42 months duration, including two industrial internships and seven academic semesters: four coursework semesters and three final semesters devoted to the thesis. The coursework will fall in three areas: foundations (research methods, economics etc.); integration (operations, product development, lean thinking, etc.); and leadership and change management. The thesis will be developed in parallel with the curricular semesters and the industrial internships. The curriculum materials will be jointly developed by MIT and the three Portuguese universities.

***B. Short Courses and prospective seminars***

- *Executive seminar series (ESS)*: This series of short industrial symposia will target executive staff of European companies. The seminars will last for two to three days with English as the working language. They may be conducted within academic facilities (if the use of demonstration equipment will be needed) or in a resort in order to accentuate the importance of effective group dynamics between attendees and academic staff. The main objective is to analyze and to discuss, under a cooperative and informal environment, new trends and emerging solutions in product development, advanced manufacturing, supply chain management and innovation strategies. It is also of interest as a mechanism to engage companies in the initiative as collaborators for the research and education initiatives.
- *Research seminar series (RSS)*: This series is aimed at potential researchers/students (post-graduate level). Seminars will last for six to 12 days. The main objective is to analyze and to discuss emerging topics and opportunities for research and innovation activity in product development, advanced manufacturing and supply chain management, under an integrated engineering systems approach. The RSS seminars also aim to attract students of high quality and high potential to the EDAM initiatives. The typical structure of the seminars will combine an intensive lecture program (five to six hours/day) and an individual or small group project utilizing the lecture material.

***Educationally Coupled Research***

In order to attain the initiative goals of innovative, globally-appealing curricula and innovative opportunities for the larger research initiatives with possible short-term impact, research priorities need to be defined and integrated with appropriate human resources development.

Numerous potential opportunities for research projects have been identified and grouped by strategic “pillars” that support the industries and technological areas (design, innovative manufacturing, product

development, supply chain management, aeronautics, automotive and medical devices) that are core to the EDAM initiative. As the assessment progressed, preliminary concepts and potential Portuguese and MIT collaborators have been identified; other areas have been even further developed. A few are listed below but the list will not be finalized until the EDAM process has developed a full slate of opportunities for high quality research programs that can become part of the program.

- Eco-Efficient Materials Systems Design
- Economics of Micro-Electronics/Photonics Components
- Improved Metrics for Evaluating Product Development Programs
- Methods for Defining Product Architecture Decompositions
- Lean Product Development processes

The research projects will be selected according to the following criteria within the objectives of EDAM Agenda:

- Consistency with the objectives of EDAM
- High potential for beneficial impact on the curricula
- High potential for fostering sustainment of existing companies or entrepreneurial formation of new ones
- Existence of research capability at both MIT and Portuguese universities (preferably with more than one Portuguese university).
- Degree of industrial involvement

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## **First Year Program Plan for the EDAM Focus Area**

### ***Overview***

The first four months of the EDAM agenda work will focus on establishing some initial activities while also pursuing deeper sustaining knowledge essential for the ongoing educational and research initiatives. In both the research and educational areas, we will start systemic processes for establishing strong foundations for the activities. In both areas, we will also run selected launching projects and activities.

In the remainder of the first year we will continue to refine both the research and educational plans based upon learning from the results of launching activities and based on learning from the systemic processes. It is believed that this “action plus reflection” approach will lead to the best short and long term potential for EDAM to achieve its ambitious objectives.

### ***HCD (Human Capital Development) and Education Initiatives***

#### **A . Systemic “Market Research” Activities relative to HCD and Education Programs**

The TME initiative will best achieve the EDAM objectives if it attracts students from beyond Portugal . We believe that to do this a number of potential students from outside of Portugal need to be interviewed (possibly in professionally run focus groups) before making decisions about how to communicate and advertise this initiative. Such market research could explore:

- the attractiveness of Portugal,
- the importance of the MIT connection,
- the tradeoff between making this a second masters (as would be done in the US) rather than a diploma,
- the attractiveness of the continuing education model,



- the strengths and weaknesses of the envisioned multiple Portuguese university approach.

This research could also be useful in finding ways to enhance the offering. It is important that such research be done and the initiative and communication adjustments be made before launching this beyond Portugal.

The LTI-Europe will also best fulfill the EDAM objectives if it can attract experienced engineers and a significant number from outside of Portugal (EU and beyond). We believe that to do this a number of companies that might hire potential students from outside Portugal need to be interviewed in some depth before making decisions about how to communicate and advertise this initiative. Such market research could explore similar issues as outlined above. The interviews should also explore the potential of companies to sponsor internships and help contribute in other ways. It is important that such research be done and the initiative and communication adjustments made before launching this program.

### **B. Launching Activities Relative to HCD and Education Initiatives**

**Research Seminar Series (RSS) Launch:** For potential post-graduate students (and researchers). Tentative topic: Fostering knowledge-based manufacturing (focus on automotive, aeronautics and medical device). The first of the RSS is conceived as an active learning experience (project-based initiative) based on a preliminary evaluation of the business potential (specific development plan, possible products and services, business plan) of selected research opportunities. These research opportunities would be defined beforehand by the faculty from FEUP, UMinho and IST with appropriate MIT participation. The students would work in small groups to assess and develop action plans relative to their selected research opportunity. They would be instructed to learn about the industry they are trying to affect (market opportunity, competition, etc.).

Tentative scheme:

- Two days of lectures on reducing research opportunities to practice;
- One day for project selection, team building and project planning;
- Parallel lectures and project development work for four and a half sessions;
- Final report out to a wide variety of Portuguese faculty (including possibly those whose research the students are trying to further develop for practical benefit).

### ***Educationally Coupled Research (ECR)***

#### **Establishing a systemic process for achieving a strong research agenda**

As detailed in the technical annex, the EDAM initiative intends to foster potentially widespread industry interaction. Interactions with these companies will receive strong emphasis during the first year of the program in particular to help develop the research program. A systematic and structured decision process will be developed to carry out this approach. The development of mechanisms for fostering interaction among MIT and the three Portuguese universities' educators and researchers will be accomplished. Time will also be spent developing the EDAM management process. At this time, we plan to explore launching an EDAM Executive Committee (EC) (reporting to the overall Portugal-MIT Collaboration structure), involving five members: two from MIT (one of whom will be the President of EC) and three from Portugal (one member from each university, including the Executive Chairman). The main tasks of the EC are:

- to manage the EDAM agenda assuring the high quality execution of the planned actions;
- to assure the active involvement of both MIT and Portuguese universities' staff;
- to promote the effective interaction between EDAM initiatives and the Portuguese and European industrial communities;
- to induce a continuous flow of ideas within the EDAM framework and the integration of the HCD and ECR areas; and

- to implement an ongoing process to look for new opportunities in the EDAM related technical and scientific areas.

***Pilot Research Project Launch:***

Objectives: to evaluate the potential of alternative technologies (materials, manufacturing technology and wireless communications) for a selected automotive system; to induce cooperative research work between institutions involved in the EDAM Agenda.

Targeted system: a Autoeuropa case study will be used to define requirements and specifications.

Comparison between 3 material and technological solutions:

- Metallic (steel and aluminum) – IST
- RTM composites - FEUPorto
- Molded LFT – UMinho

Analysis:

- Performance, cost evaluation and environmental issues;
- Development of cost models and selection procedures;
- Evaluate the opportunity to introduce wireless and fiber optical communications (based in microsystems) as alternative to cable systems;

Partnership: MIT/ESD, UMinho (IPC/Algoritmi/PIEP), FEUP (INEGI/INESC-Porto/IDMEC/), IST (ICEMS/IN+), CEIIA/REDIA Network/Inteli, and Portuguese firms (Autoeuropa, AIS, Celoplás, Iber-Oleff, Inapal Metal, Inapal Plásticos, MCG, Plasdan, Simoldes Plásticos, Sunviauto and TMG)

Time frame: July 2006 to September 2007

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## Appendix E: Bio-Engineering Systems

### ***Introduction***

This program will be run in a collaboration of MIT with a consortium of three Portuguese Universities (Technical Lisbon, Nova Lisbon and Minho as lead institutions), with possible future collaborations with other universities and associated research laboratories (i.e., Porto and Coimbra). Embracing the theme of developing future leaders and innovators in Bio-Engineering, the main foci of the collaboration will be on Innovation in Bio-Engineering, Cell and Tissue Engineering, and Bioprocess and Computational Biosystems Engineering. MIT faculty will help develop the curriculum materials with the Portuguese institutions and will offer to teach at some of the class meetings at the Portuguese institutions. The participation and performance of the Portuguese institutions will be critical to the ability of MIT to perform its part.

The bioengineering field in Portugal has acquired expertise and critical mass in several sub-areas in the last ten years. Skills have been developed, for instance, in bioreaction engineering, molecular biology, bioseparation, animal cell technology, and enzyme engineering, while expertise is still lacking in other emerging areas. Creating a Portuguese Bio-Engineering Systems degree program that is offered jointly between Portuguese universities is a new approach; by adding the essential areas of technical innovation and leadership development, it can realize the highest quality multidisciplinary education and research in bioengineering.

Life Sciences and Biotechnology are areas that the MIT assessment found to be in healthy development in Portugal, and it would be impossible to include the whole spectrum of on-going activities in one single program. The assessment identified a few biotechnology start-ups that are being launched, but there is little experience in many areas of capability beyond technical capacity that are essential to successful ventures. This area was identified as one where collaboration with MIT could have a significant impact for Portugal. The focus of the search for collaborators was therefore turned to bio-engineering groups with close ties to start-ups, and groups in these areas belonging to Centers of Excellence were identified. The three main objectives of the Bio-Engineering Systems focus area are to:

- Promote new inter-institutional post-graduation training and opportunities, aimed at educating a new generation of leaders in bio-engineering technical innovation in Portugal;
- Create new knowledge through R&D, targeting strong participation in the European Framework Research Program, FP7 (2007-2013); and
- Promote industrial, health-care and environmental biotechnology education and research that makes it possible for new start-ups, which implement new models of interaction between universities and enterprises, government, and society.

### ***Education***

The Bio-Engineering Systems focus area consists of an Advanced Studies one-year Course (1<sup>st</sup> year toward a PhD or an Advanced Certificate upon completion) and a PhD research program (3 to 4 additional years) offered jointly by the collaborating Portuguese universities. The Bio-Engineering Systems PhD program will attract the highest-performing students and involves possible exchanges with MIT faculty and their laboratories.

The specific emerging technologies targeted to complement and enhance the existing Portuguese biosciences and technology excellence include education and research in: tissue engineering, biomaterials, computational and synthetic biosystems, drug development, neuroscience, biomedical devices and technologies, health and environmental systems, and innovation and leadership for future bioengineers.

*MIT Participation:* MIT faculty collaborators and their associated research laboratories participating in the Bio-Engineering effort are from the Engineering Systems Division [including the Program on Emerging Technologies PoET], the Department of Chemical Engineering, the Harvard–MIT Health Sciences and Technology Program, the Picower Institute of Learning and Memory, the Biological Engineering Division, the Deshpande Center for Technological Innovation, and the Sloan School of Management.

*Portuguese Universities and R&D Centers:* Three Portuguese Universities lead the program and will confer joint degrees:

- Universidade Técnica de Lisboa / Instituto Superior Técnico (UTL/IST);
- Universidade Nova de Lisboa (NOVA); and
- the Universidade do Minho (UM).

The Portuguese University collaboration might grow in the future to include the University of Porto, in order to allow the participation of research groups from Universidade do Porto including INEB that have on-going collaborations with MIT faculty. Additional expertise and collaboration with colleagues in Coimbra at the Laboratório Associado, Centro de Neurociências e Biologia Celular (CNBC) has also been identified. Initially, the core research centers involved in the program are the Associate Laboratories (Laboratórios Associados<sup>1</sup>): Instituto de Tecnologia Química e Biológica (ITQB); REQUIMTE, Associate Laboratory for Green Chemistry; and Institute of Biotechnology and Bioengineering (IBB).

In addition to these core collaborators, other research centers will be invited to collaborate. In particular, in the areas of Innovation Studies and Entrepreneurship, contributions and collaborations with the School of Economics of NOVA and IN+ of IST will work closely with MIT faculty from the Deshpande Center and the Sloan School of Management.

The support of Portuguese companies is being actively sought in the biopharmaceutical, pharmaceutical, nutraceutical, healthcare and medical devices areas. The participation and performance of the Portuguese institutions will be critical to MIT's ability to perform its part of the work.

#### Advanced Studies Course Program

The Advanced Studies Course is designed as a first-year PhD lecture course + innovation training + lab visit. It consists of one semester of courses and one semester for research initiation, partnerships and placement. Each student follows six curricular modules (two weeks each, intensive). Four of these modules are core, mandatory modules (Innovation in Bioengineering; Bioprocess Engineering; Computational Biosystems; and Cell & Tissue Engineering), and the two remaining requirements are electives from a selection of modules (Nanobiotechnology; Biomaterials; Neuroscience; Biomedical Devices and Technologies; etc.). MIT and the Portuguese institutions will jointly develop the curriculum materials, which the Portuguese institutions will be responsible for offering. MIT faculty will teach certain portions of the curriculum.

#### **Research**

The doctoral program will accommodate extensive training periods at MIT for selected Portuguese students. MIT host laboratories with joint projects with Portuguese research groups have been identified to host about eight to ten Portuguese students in steady state. A unique educational component of the doctoral program is a required doctoral student seminar entitled "Bioengineering Systems: Idea to Innovation." The following research topics/areas have been identified for collaborative Portuguese and MIT faculty and student research projects.

- Innovation and Emerging Technologies
- Biomolecular Science and Bioprocess Engineering
- Nanobiotechnology
- Cellular and Tissue Engineering
- Computational and Systems Biology and Engineering

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<sup>1</sup> The Laboratório Associado status is granted by the Ministry of Science to research centers of excellence, and it involves contracts with additional research funding

Biological Systems Imaging  
Brain and Cognitive Sciences and Biology

Workshops and Symposia

The joint development and offering of workshops and symposia constitute an important aspect of the collaboration that came out of the Bio-Engineering Systems Assessment. Three initial workshops that could be offered during the first and second years include: a workshop on “Business/Government Interfaces in Biosciences and Engineering;” an intensive weeklong workshop on leadership development; and workshops on synthetic biology.

The Bio-Engineering Systems focus area is a partnership of MIT with a consortium of Portuguese Universities (Technical Lisbon, Nova Lisbon and Minho as lead institutions with possible future collaborations with other universities and associated research laboratories, i.e., Porto and Coimbra). The vision of this collaborative initiative is to develop future leaders and innovators in the bio-engineering field for Portugal.

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**First Year Program Plan for the Bio-Engineering Systems Focus Area**

1. Curriculum development (finished by the end of April)
  - Mandatory core course development
  - Electives for Fall 2007
  - i-teams – Spring 2007 - 3 Portuguese Faculty members (one from each university) attend the i-team course at MIT
  - Deliverables: Syllabus, Reading List / Materials, Teaching / Learning Methods, Faculty Staffing Plan, Assessment Tools
2. Steering Committee Meetings
  - Monthly by video/teleconference
  - In person in January (kick off, Lisbon) and April (Boston)
3. Student recruitment
  - Announcements starting October 2006; Interviews during February and March; Selection finished by 15 April 2007
  - Students arrive beginning of September 2007; Advanced Studies Program is implemented
4. Symposia and workshops
  - Kick-off Symposium (January 2007)
  - 2-day workshop on Innovation teams with local businesses (possible pilot project for Fall 2006)
  - The Business / Government interface in Biosciences and Engineering (early June 2007)
  - Leadership Development 4-day workshop offered (possible pilot project for Fall 2006)

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## Appendix F: Engineering Systems – “Anchor Program”

The Anchor program of the MIT-Portugal Collaboration is based in Engineering Systems and has the following multiple objectives:

1. Build a community of scholars and practitioners cutting across the individual projects, in order to develop stronger methodology and systems fundamentals that can apply across Focus Areas.
2. Bring the research communities on ‘both sides of the Atlantic Ocean’ into close contact on a regular basis utilizing modern methods of communication.
3. Establish a set of research goals and tasks focusing on systems fundamentals and systems methodology that cut across the individual project areas.
4. In anticipation of a future workforce that will have to “think differently,” create educational material on engineering systems that can be taught in Portuguese schools and that can be incorporated in the educational initiatives underway in the separate focus areas.

With regard to items 1, 2 and 3 above, we seek to periodically motivate researchers working in a particular research area to expand their thinking beyond their Focus Area to think about the broad themes and to seek fundamental results that can be extracted and applied elsewhere. We will also initiate use of key technical methodologies in all Focus Areas in order to further our learning about the methods, principles and fundamentals that cut across the areas. These cross-cutting methodology studies will be joint activities between Focus Area researchers and Anchor Program researchers. Also, by creating an open collaborative community, we hope to bring some of the MIT and Portuguese faculty members and students not directly involved in Portugal collaborative research into the program as well, perhaps providing lateral thinking or novel solutions to difficult problems. With regard to item 4, we anticipate the challenges that will face tomorrow’s workforce and the need to prepare today’s students with new perspectives and skills. We need to educate them in the principles and methods of engineering systems so they can assume leadership positions in Portugal and the world. Our students must become expert in the integrated analysis of systems incorporating engineering with management and social sciences. If we are successful, Engineering Systems may indeed become a transformative mechanism for approaching the design and operations of complex systems.

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### First Year Program Plan for the Engineering Systems Anchor Program

#### ***Engineering System Seminars***

Periodic live research seminars will be presented that examine the research projects in the Focus Areas. These seminars will be viewed by program participants in Portugal and MIT and they can be accessible to a wider audience. They would not only explore aspects of a particular research project, but also discuss how it relates to the overall Focus Area and Program in a broader context. The Power Point slides or other residual intellectual content of each seminar (e.g., working papers) would be posted on a project-based password-protected web site for sharing and commenting.

#### ***Engineering System Fundamentals***

Research will be performed on the fundamentals of engineering systems. This research will build upon the results of the Focus Area research projects. It will examine fundamental issues in engineering systems including complexity, uncertainty, emergence and system architecture of large-scale engineering systems. Particular attention will be directed toward the non-traditional properties or goals of systems (often called “ilities”). These usually arise from taking a long-term or life cycle view of systems. They include: flexibility, robustness, scalability, safety, security, durability, sustainability, reliability, quality, recycle ability, and maintainability. The research will reflect an enterprise-level holistic perspective recognizing the relationships and interdependencies of the system and subsystem components and it will utilize new methodological approaches in such areas as real option theory, network analyses and agent based modeling. At the appropriate time we may publish a book and/or present a symposium based on the results of the research studies.

#### ***Engineering Systems Curriculum Development***

Subjects would be developed on the fundamentals of engineering systems. These subjects would be utilized in the educational initiatives underway in the focus area so that Portuguese universities would be early users. This activity could also serve to integrate the educational initiatives in the focus areas and thus could serve as the foundation of a strengthened ESD-like educational program in Portugal. There is currently no such program within Europe and the development of a stronger than existing entry would insure Portugal a lead role. If Portugal created such an activity it could attract students from Europe much as the creation of Technology Policy (University of Cambridge) and the Zaragoza Logistics programs have done, which were developed collaboratively with MIT faculty. These educational initiatives would be complimentary to the academic programs being created in the focus areas.

#### ***Leadership***

The Engineering Systems Anchor Program will be lead by Professors Daniel Roos at MIT and Professor Paulo Ferrao in Portugal. They are the Directors of the overall collaboration between Portugal and MIT and therefore are in the best position to lead this integrative program.