



ASSESSMENT OF AN MIT-PORTUGAL COLLABORATION  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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## *TABLE OF CONTENTS*

Acknowledgements .....	3
Assessment Overview.....	4
Appendix A: Transportation Focus Area.....	18
Appendix B Energy Focus Area.....	33
Appendix C: Engineering Design and Advanced Manufacturing (EDAM) Focus Area.....	47
Appendix D: Bio-Engineering Focus Area.....	57
Appendix E: Management Focus Area.....	69
Appendix F: Engineering Systems Anchor Program .....	74
Appendix G: Schedule of Visits by MIT Faculty to Portugal.....	78
Appendix H: Schedule of Visits by Portugal University and Government Representatives to MIT. ....	94
Appendix I: Private Firms that Have Been Involved in or Contacted During the Assessment.....	114

## *ACKNOWLEDGEMENTS*

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Bio-Engineering Systems: Dava Newman (MIT); Manuel Nunes da Ponte, Joaquim Cabral, and Manuel Mota (Portugal)

Management Systems: Paul Osterman and Simon Johnson (MIT)

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### Additional Acknowledgements

Coordination and Production of Report: Renee J. Robins and Beverly Kozol-Tattlebaum

Assistance with Preparation of Budgets: Su Chung

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## Portugal-MIT Assessment Report – Overview

### **1. Assessment Background & Objectives**

MIT is deeply committed to working in a global context. International relationships are beneficial to both our students and faculty and the excellence of the research identified in Portuguese research centers throughout the assessment exercise recommends that MIT foster joint ventures with Portuguese institutions. Also, the commitment of the Portuguese Government to strengthening science and technology and to 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 joint ventures in the emerging knowledge-based, globalized economy.

These relationships enable us to enrich our educational programs and to engage in basic research on critical problems of international importance. Each proposed relationship must be carefully evaluated and structured since MIT has a limited number of faculty and cannot respond positively to the many requests it receives from countries around the world. MIT has found it of great value for both the potential host country and the Institute to undertake an assessment prior to entering into a long-term relationship with another country.

Accordingly, this assessment study was initiated in order to assess the potential for a relationship between MIT and Portuguese research and higher education institutions and to explore the many considerations that are essential in developing and executing the relationship. It was agreed in February of 2006 that MIT and the Government of Portugal would explore and assess the intellectual program objectives that each would have for such an initiative, as well as the options for structuring a relationship, the feasibility and scope of a relationship, and the other terms that would govern a relationship those focus areas.

During a five-month assessment period from February 15 to July 15, 2006, faculty and representatives of MIT had discussions and visits with various Portuguese research, higher education institutions, industrial companies and government agencies to exchange information and ideas with the goals of determining mutually desirable focus areas and the requirements to frame successful projects and identify key institutional, operational, financial, legal and technical issues to be resolved. The assessment explored basic research initiatives focusing on system thinking in intellectual areas relevant to problems in Portugal and of interest to MIT, and education programs including the PhD, one-year professional master's degrees and short courses.

### **2. Approach**

The strategy for developing the relationship has relied heavily on interactions at the faculty level. Both MIT and Portuguese leaders recognize the importance of enlisting professors and researchers early in the process of building a relationship between MIT and Portuguese universities. Based on initial discussions and on the understanding of existing relations between MIT faculty and Portuguese scholars, a set of initial Focus Areas were tentatively identified for the assessment exercise. This process has also benefited from the analysis of the international

evaluations of research centers carried out in previous years by the Portuguese Government, through the Portuguese Science and Technology Foundation (FCT). This allowed us to identify existing research skills in Portugal and to confirm the level of excellence of those Portuguese groups previously identified on the basis of existing collaborations with MIT faculty. Any of the original Focus Areas would have been dropped if there had been a lack of interest on the part of MIT faculty or our faculty partners in Portugal.

Most MIT international collaborations have utilized a diffusion strategy where we work initially with a single university in the host country. Over time, the results of that collaboration are transferred to other universities in the country. However, in the particular case of Portugal, we have understood the requirement imposed by the Portuguese Government in terms of the need to involve various institutions and research centers in any potential collaboration with MIT. Consequently, we have agreed to follow a different approach in Portugal where we will work with national consortia in each of the focus areas. Since Portugal is a relatively small country, many university research groups in the focus areas are below critical size. By forming Portuguese consortia, we can bring together the best researchers and research groups from the universities and research institutes throughout the country. However, we need to recognize that it will be more complex for MIT to interact with a consortium than with a single university. The consortia that have been formulated for the assessment may be restructured once the work plan has been finalized to reflect the initiatives that will be pursued. We must ensure that the best Portuguese organization, or combination of organizations, is selected for each initiative. Therefore, for potential future projects to be considered in addition to the initial launching areas of collaboration, it might be advisable to invite several Portuguese organizations to submit proposals which will be evaluated for technical excellence to determine which organization is selected.

Many faculty members in Portugal and at MIT have expressed interest in participating in this collaboration and have suggested additional research projects and focus areas. An example of such proposals is a preliminary tentative project on “e-planning.” The start-up strategy to limit the number of initial focus areas has precluded including additional projects or focus areas during the first year. We anticipate that new initiatives can be proposed in the annual plans submitted in subsequent years. Those new initiatives can occur at several different levels. Seed research and planning studies can be utilized to study the feasibility of a new project that does not relate to an existing focus area. Some of these planning studies will evolve into new projects, whereas others will not go beyond the planning stage. In addition, new focus areas can also be implemented by the Governing Committee (See Section 1.F). Therefore, the overall relationship consists of a spectrum of initiatives ranging from seed research to individual projects to focus areas to anchor programs.

Although we have received suggestions about many potential projects and focus areas, we mention “e-planning” initiatives in particular because we have received many expressions of interest from faculty in Portugal and MIT. We suggest that the “e-planning” initiatives should be the subject of further analyses during the coming year after the launching of the initial program.

### 3. Criteria and Identification of Focus Areas

A range of criteria have been used throughout the assessment discussions to evaluate the merits of potential collaborative projects and programs. They include:

- Intellectual benefit to Portugal and to MIT
- Inclusion of both research and education components
- Recognition of the implications of globalization to Portugal
- Achievable goals within budgetary constraints
- Content that is appropriate to pursue in achieving the focus area objectives
- Ability to build on existing and previous faculty relationships
- Commitment of key faculty
- Involvement of different Portuguese universities
- Industrial interest

In addition, it was agreed that an uncoordinated collection of unrelated projects was not considered to be of great value to either side. MIT experience with other international relationships strongly suggests limiting the initial number of focus areas, particularly during the startup phase of the relationship. Projects in each focus area should be part of an overall systematic framework rather than many smaller unconnected projects.

Based on these criteria, together with the insight gained by the MIT faculty that have participated in the assessment exercise, numerous challenges and opportunities were clearly identified for Portugal that are areas for potential collaboration with MIT. These involve the need to strengthen engineering systems thinking and practice, with particular emphasis on critical sectors in Portugal that have based their development during the last few decades in very traditional approaches and clearly require modernization. These include manufacturing, transportation and energy, which are sectors that have received attention by MIT in recent years for the development of new and emerging concepts associated with engineering systems. We expect a major long term impact of this strategy for small countries, such as Portugal, and MIT is committed to the challenge of developing engineering systems to help reform the Portuguese economy. The role of Portuguese Universities and research centers in reforming these sectors and the country's economy should be explicitly acknowledged in any public and private strategy; MIT's recommendation is that specific Focus Areas be established for these three sectors, with a systems orientation.

It is clear that this strategy requires the joint commitment of Portuguese research centers and engineering schools and we recommend that a formal national consortium be formed around the theme of engineering systems. The commitment of the Portuguese Government is acknowledged here, but the success of any collaboration with MIT depends on the explicit institutional commitment at the Portuguese university and research levels.

In addition, we recognize the extent of public investment in Portugal during the last decade in Bio-Engineering Systems and related technologies, and the resulting need to further strengthen existing research capacity through institutional collaborations at an international level. Again, these are areas of major developments at MIT, and we recommend that the MIT-Portugal

relationship include a Focus Area centered in bio-engineering systems in order to build on the existing collaborations between Portuguese researchers and faculty at MIT. Bio-engineering systems are changing the economic structure of many regions throughout the world and, again, we believe Portugal may play a relevant role in the international scene by means of strong institutional collaborations.

Beyond the areas mentioned above, it was clear from the assessment exercise that Portuguese research and advanced education do require a major effort in order to strengthen the existing capacity in management, which should be oriented towards reforming the various sectors mentioned before. MIT experience with other international relationships suggest the need for a clear commitment of leading management schools towards this goal, which represents a major challenge in the case of Portugal due to existence of many, but rather small, programs without a clear international visibility. Again, the commitment of the Portuguese Government to change this situation is acknowledged and MIT has indicated interest in collaborating in a major operation to reform advanced education and research in management in Portugal in the event that a clear joint commitment of the leading Portuguese management schools is made towards this goal. In addition, MIT has relevant experience in bringing together management and engineering, which appears to be of major relevance for Portugal at the present time.

As a result, the following specific fields were identified as the initial Focus Areas for the MIT Portugal relationship:

- *Engineering Design and Advanced Manufacturing*: aimed to emphasize development of design as a key academic field. This will further enable the development of a cadre of innovative leaders 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 leadership and formation of knowledge-based creative enterprises.
- *Transportation Systems*: to be developed with the ultimate goal of promoting 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*: aimed to go far beyond traditional energy research and be focused on the dynamics among energy services and supplies, including opportunities for combined heat and power and renewables in the distribution network;
- *Bio-Engineering Systems*: aimed to be based on the research capacity existing in Portugal and consider emerging aspects of bio-engineering, cell and tissue engineering, and bioprocess and computational biology;
- *Management*: aimed to emphasize the need to reform advanced education and research in Portugal in the area of management, bringing together the leading management schools towards a unique (and large) global MBA program, as well as strengthening entrepreneurship education and research in close collaboration with a leading engineering school.

We recommend that engineering systems should serve as the overall framework for the MIT Portugal relationship and the Engineering Systems Division should be the lead unit at MIT to coordinate the assessment and we recommend that it continue in this role in the implementation of the collaboration. MIT created the Engineering Systems Division in 1998 recognizing the

growing importance of engineering systems in an increasingly complex and technology-driven economy.

Engineering systems knowledge is of strategic importance for Portugal since it will be a fundamental tool for economic and social development in the twenty first century. In a recent speech to the U.S. National Academy of Engineering, MIT President Emeritus Charles M. Vest emphasized the importance of engineering systems as he spoke of “a frontier with larger and larger systems of great complexity, and generally, of great importance to society. This is the world of energy, environment, food, manufacturing, product development, logistics and communication. This frontier addresses some of the most daunting challenges to the world”

Engineering systems are difficult to plan and design on budget, on time, and in a manner that satisfies the objective of many different stakeholders. Their development and operation requires more than technical expertise. They call for an interdisciplinary perspective that integrates technology with management/organization issues, such as supply chain design, and considerations rooted in social science, such as sustainability. Countries that aspire to compete in today’s global economy need to develop expertise in this newly emerging field.

To reinforce the engineering system framework we recommend developing engineering systems anchor programs as an important component of the overall relationship. These anchor programs in engineering systems will serve as an integrating mechanism bringing together faculty participating in the various focus areas. They will provide a systematic approach for the overall program.

Also, the proposed activities in each Focus Area should be pursued in a systematic manner. Interaction between the Focus Areas is also encouraged. For example, a potential project on materials recycling that is being discussed in the design and manufacturing focus area involves researchers who are also engaged in discussions with the energy focus area, and opportunities to link these efforts are under consideration. The Focus Area Leaders at MIT have met periodically during the assessment and have shared ideas about structuring and supporting the relationship in order to achieve a level of integration across the programs. The proposed governance structure, further detailed below, purposefully involves the Focus Area Leaders in a Program Operating Committee in order to further generate and support opportunities for integration.

#### **4. Process**

In January and February, preliminary visits to MIT were made by Manuel Heitor, Secretary of State for Science, Technology, and Higher Education (twice), and Carlos Zorrinho, (once) National Coordinator of Lisbon Strategy and the Technological Plan. These visits included meetings with MIT senior administration (Chancellor Phillip Clay, Provost Rafael Reif, Senior Council Jamie Lewis Keith) and faculty leaders from two central academic units (Daniel Roos and Daniel Hastings, both prior Directors of the Engineering Systems Division, and Joel Moses,



Acting Director of ESD; and Steven Eppinger, Deputy Dean of the Sloan School of Management). Numerous other faculty members and researchers participated in these visits.<sup>1</sup>

In February, Professor Daniel Roos and Chancellor Phillip Clay traveled to Portugal to discuss and sign the Letter of Agreement Assessing a Potential Research and Educational Collaboration of MIT and Portugal. In addition to Carlos Zorrinho and Manuel Heitor, they met with Prime Minister Jose Socrates, and with Fernando Teixeira, the Minister of Finance, and Mariano Gago the Minister of Science, Technology and Higher Education.

The Focus Area Leaders on the Portugal and MIT sides were selected to coordinate the assessment discussions in each focus area. The Focus Area Leaders are identified in Table 1. With the formal assessment having begun, the focus area leaders from Portugal in four of the initially designated areas made visits to MIT, engaging over 50 MIT faculty members and researchers (see Appendix H for the visit agendas). The faculty members who have been involved in assessment discussions represent all five schools at MIT (Engineering; Science; Sloan School of Management; Humanities, Arts and Social Sciences; and Architecture and Planning). In Portugal, the area leaders engaged faculty members and experts from various Portuguese universities and leading enterprises in advance of their trips to begin assessing interests and capabilities. These initial visits were followed by a visit to Portugal by the MIT Focus Area leader and in some cases other MIT faculty members representing each Focus Area (Appendix G contains these visit agendas).

## 5. The Focus Areas and Related Consortia

Beyond the clear involvement of leading Portuguese faculty and researchers, the institutional enthusiasm of leading Portuguese engineering schools was identified throughout the assessment exercise. In the Focus Areas related with engineering design, energy, transportation systems and bio-engineering systems, it is particularly important to acknowledge the institutional willingness to form national consortia among leading Portuguese schools, in a way that will facilitate achieving the goals of the overall MIT-Portugal Program. The following consortia have been successfully identified:

- Engineering Design and Advanced Manufacturing:
  - School of Engineering, University of Minho (UM)
  - Instituto Superior Tecnico, Technical University of Lisbon (IST)
  - School of Engineering, University of Porto (FEUP)

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<sup>1</sup> Prof. Thomas Allen (Sloan, ESD); Dr. Kirkor Bozdogan (CTPID); Prof. John Carroll (Sloan, ESD); Prof. Joel Clark (ESD, MSE); Dr. Joseph Coughlin (CTPID); Dr. Joel Cutcher-Gershenfeld (ESD, Sloan); Prof. Richard de Neufville (ESD, CEE); Prof. Oliver de Weck (ESD, AA); Dr. Frank Field (CTPID, TPP); Ms. Sharon Gillett (CTPID); Prof. Randy Kirchain (ESD, MSE); Prof. Stuart Madnick (Sloan, ESD); Prof. William Mitchell (Arch, MAS); Dr. Donald Rosenfield (Sloan, ESD); Ms. Renee Robins (ESD, TPP); Dr. Richard Roth, (CTPID); Prof. David Simchi-Levi (ESD, CEE); Prof. Joseph Sussman (ESD, CEE); Prof. Fred Moavenzadeh (ESD, CTPID, CEE); Prof. Dava Newman (ESD, AA, TPP, HST); Prof. Yossi Sheffi (ESD, CEE, CTL); Prof. Ernest Moniz (ESD, Physics, LFEE); Dr. Christopher Magee (ESD, ME)  
Full agendas are copied in Appendix H.

AA: Aeronautics and Astronautics; Arch: Architecture; CEE: Civil and Environmental Engineering; CTL: Center for Transportation and Logistics; CTPID: Center for Technology, Policy and Industrial Development; EECS: Electrical Engineering and Computer Science; ESD: Engineering Systems Division; HST: Harvard-MIT Division of Health, Sciences and Technology; LFEE: Laboratory for Energy and the Environment; MAS: Media Arts and Sciences; ME: Mechanical Engineering; MSE: Materials Science and Engineering; TPP: Technology and Policy Program.

- Transportation Systems:
  - Instituto Superior Tecnico, Technical University of Lisbon (IST)
  - School of Engineering, University of Porto (FEUP)
  - School of Sciences and Technology, University of Coimbra (FCT/UC)
- Energy Systems:
  - Instituto Superior Tecnico, Technical University of Lisbon (IST)
  - School of Economics, Technical University of Lisbon (ISEG)
  - School of Engineering, University of Porto (FEUP)
  - School of Sciences and Technology, University of Lisbon (FCT/UL)
- Bio-Engineering Systems:
  - School of Sciences and Technology, New University of Lisbon (FCT/UNL)
  - Instituto Superior Tecnico, Technical University of Lisbon (IST)
  - School of Engineering, University of Minho (UM)
  - School of Sciences and Technology, University of Coimbra (FCT/UC)
  - School of Engineering, University of Porto (FEUP)

MIT considers particularly important that the various consortia are coordinated and implemented through the Research Centers associated with the various university schools, as recognized and evaluated by the Portuguese Science and Technology Foundation (FCT). This will guarantee the full involvement of the leading Portuguese research community in the overall management and implementation of the collaborative effort. The serious commitment of the research centers is particularly important to guarantee the highest level of excellence of the post-graduation activities under planning and, in particular, of the doctorate degrees to be considered under the MIT-Portugal Program. The various Research Centers involved are listed in Appendix I of this report.

In addition, it also important to note that the assessment exercise involved visits and discussions with leading enterprises and technology centers in Portugal, which have shown a considerable interest in the collaborative framework. The Portuguese institutions involved in the various Focus Areas should be engaged in promoting consortia with companies in Portugal, Europe and elsewhere.

The Focus Area of “Engineering Design and Advanced Manufacturing” considers a primary emerging challenge worldwide to foster “engineering design” as a major discipline and research area in engineering schools. In this respect, the leading experience of the “IST Design Studio” at Instituto Superior Tecnico should be acknowledged and it is strongly suggested that the University of Minho and the School of Engineering at the University of Porto, FEUP, follow that initiative and develop their own design studios. It is clear that this strategy will help Portuguese engineering schools achieve the Bologna objectives and foster a leading position in Europe, although it requires a major effort of all the schools in promoting engineering design practice. A possible network of those three university design studios (i.e., the recently announced REDIA network) with faculty and students at MIT should be promoted in close collaboration with industry and, in particular, through the involvement of the *Center for Excellence and Innovation in the Auto-Industry*, CEIA. The facilities of this engineering center are of the greatest relevance for the activities under planning and CEIA will gain from its involvement with university groups and the MIT-Portugal Program.

The collaboration of CEIA was particularly discussed and considered of critical interest, together with that of leading companies in Portugal, such as Simoldes, Auto-Europa, and INAPAL Plasticos, among others. From the various discussions organized during the assessment exercise, as well as based on the previous involvement of faculty from MIT in the analysis of the Portuguese auto-industry (i.e., the work developed in 1998-2001 under the leadership of Prof. Joel Clark), it is clear that INTELI (a Portuguese non-profit organization) should play a significant role in our collaborative effort in order to guarantee the necessary networking procedures and helping achieving the ultimate goals of the MIT-Portugal program. Their leading role in prospective studies for the auto industry and in launching CEIA should be acknowledged and will certainly be of major interest for the success of future initiatives in “Engineering Design and Advanced Manufacturing.”

It should also be noted that the EDAM Focus Area has been planned as centered around the auto-parts industry, which is well justified by the emerging challenges of this sector worldwide and, in particular, in Portugal. Current trends worldwide in the automotive industry, namely at the level of OEMs, include the outsourcing of design skills for auto-parts companies and this requires Portuguese companies to build their own design capacity in order to compete globally. Again, the role of CEIA in fostering this strategy and in promoting industry-science relationships is acknowledged and should be supported. However, it is also clear that the EDAM Focus Area should be implemented beyond the auto-parts sector and include a diversified strategy, broadening potential applications, including aeronautics and medical devices. This will help Portugal explore new opportunities in emerging global markets.

The Focus Area of “Energy Systems” is focused on the integration of renewable systems and in energy economics. It should consider the involvement of major corporations and energy players, and the discussions with the National Energy Network, REN, should be extended to other enterprises. In addition, the various discussions organized during the assessment exercise have elicited interest in involving the renewable energy group at INETI, as well as the Center for Wave Energy. In particular the involvement of the energy group at INETI should be planned under the current reform of State Laboratories. In general, the experience and the excellence of the work developed by the faculty of IST (namely in the area of industrial ecology, energy economics, and wave energy) is acknowledged and will be of major relevance for the success of the MIT-Portugal Program in the area of sustainable energy systems.

For the Focus Area of “Transportation Systems,” the involvement of BRISA is of particular interest. Their technical achievements should be acknowledged and their network of contacts with Portuguese research centers is of major relevance for the MIT-Portugal Program. In addition, the Government of Portugal should develop the necessary efforts in order to guarantee the involvement of the national rail network, as well as of the public organizations that will lead the implementation of the TGV system in Portugal. Also, the future enrollment of the national airport authorities and, in particular, of the public entities involved in the design and planning of the new Lisbon airport, are of particular relevance to the MIT-Portugal Program.

The Focus Area of “Bio-Engineering-Systems” involves leading Portuguese groups and the previous collaborations among faculty of IST and of MIT will certainly facilitate the

implementation of the project. The involvement of young entrepreneurs and recently established start-ups (e.g. Alfama, Biotecnol, among others) should be considered as a matter of priority, but a major effort should be considered by the university groups in order to raise the interest of major Portuguese and European sectors regarding the potential applications of Bio-Engineering Systems.

The process for the Focus Area of “Management Systems” has differed slightly since there were different proposals for collaboration and a single integrated project from Portugal could not be identified at the initial stage. MIT has engaged in separate discussions with representatives of all the schools that have expressed interest for collaboration with the MIT Sloan School of Management. These included four different management schools in Portugal, namely: the Faculty of Economics and Business at the Portuguese Catholic University (FCEE/UCP); ISCTE Business School (ISCTE); the Economics Faculty at Universidade NOVA de Lisboa (FE/UNL); and the School of Economics and Management at the Technical University of Lisbon (ISEG/UTL). Representatives of two of these schools visited MIT, and Deputy Dean Paul Osterman and Professor Simon Johnson of the Sloan School of Management traveled to Portugal to visit all the schools. Following these discussions it became apparent that the management assessment would require more time to complete than the other focus areas. Therefore, the present report includes a preliminary assessment of potential collaborations in the area of management and any detailed work plan should be submitted at a later date. In fact, the Sloan School of Management has expressed its interest to work with leading Portuguese institutions in a global context and to establish international relationships that are beneficial to both our students and faculty. Among many brief proposals for collaboration that have been presented by the four schools to Sloan, a few potential subjects of collaboration have been carefully identified in the preliminary report included as Appendix F to this report and should be subject of detailed proposals by the Portuguese institutions to Sloan. Only after that process is considered will Sloan be in a position to decide upon a joint agreement with Portuguese institutions and the Government of Portugal.

Prior scheduling commitments of key participants at MIT and in Portugal in some of the focus areas constrained when visits could be made. The discussions in the transportation and bio-engineering systems focus areas occurred later than the discussions in the other two focus areas. As a result, there has not been as much time to refine the recommended projects in those two focus areas. In all the focus areas continued refining of the specific projects and activities in each focus area will extend into the beginning of the program.

As faculty discussions in the focus areas were progressing, discussions were also held with MIT senior administration including the Deans’ Council and Academic Council. The Engineering Systems Division devoted two faculty meetings and part of a semi-annual offsite to address the progress of the Assessment.

Professor Daniel Roos, Assessment Director, met on a number of occasions to update the MIT Dean of Engineering, and also held weekly phone conferences with Professor Manuel Heitor. Professor Roos and Renee Robins traveled to Portugal in early June to meet with Professor Heitor and the Portuguese focus area leaders. Professor Roos also met with Alfred Hoffman, Jr.,

the United States Ambassador to Portugal and discussed the program in Washington, DC with Dr. George Atkinson the Science and Technology Advisor to the U.S. Secretary of State.

**Table 1: Portugal and MIT Focus Area Leaders for 5-Month Assessment**

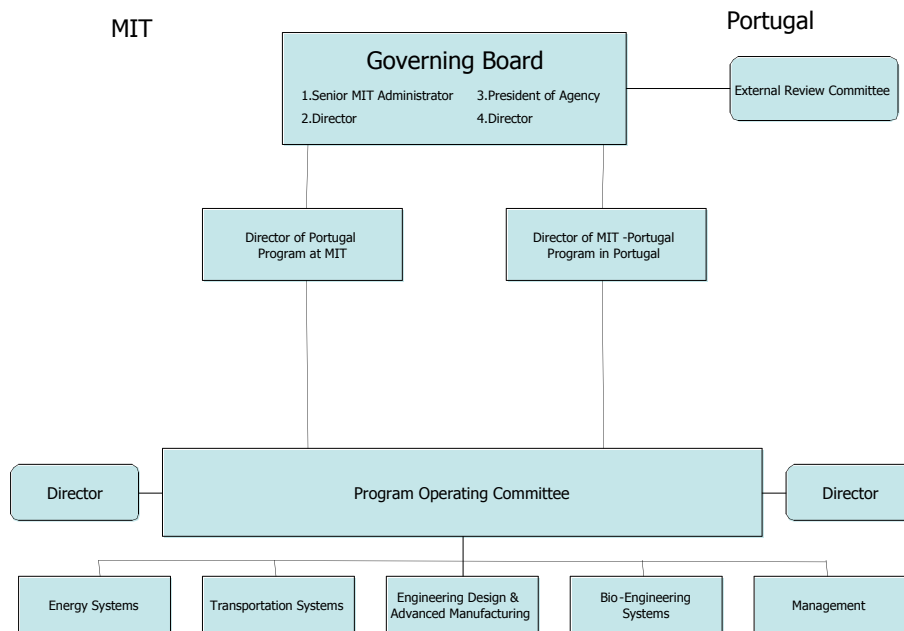
Focus Area	MIT Leader	Portugal Leader
Engineering Design and Advanced Manufacturing (EDAM)	<b>Joel Clark</b> , Professor of Materials Science and Engineering and Engineering Systems (Manufacturing) and <b>Christopher Magee</b> , Professor of the Practice of Mechanical Engineering and Engineering Systems (Design)	<b>Antonio Cunha</b> , Full Professor, Dean of the School of Engineering, University of Minho, and co-Director of CEIA, the Center for Excellence and Innovation in the Auto-industry
Energy Systems	<b>David Marks</b> , Professor of Civil and Environmental Engineering and Engineering Systems and Director, Laboratory for Energy and the Environment	<b>Paulo Manuel Cadete Ferrao</b> , Associate Professor at Instituto Superior Tecnico, Technical University of Lisbon and Director, Center for Innovation, Technology and Policy Research
Transportation Systems	<b>Joseph Sussman</b> , Professor of Civil and Environmental Engineering and Engineering Systems	<b>João Bento</b> , Member of the Board, Brisa-Auto-Estradas de Portugal and President, ASECAP. Also, invited Professor at Instituto Superior Tecnico
Bio-Engineering Systems	<b>Dava Newman</b> , Professor of Aeronautics and Astronautics and Engineering Systems, and Director, Technology and Policy Program	<b>Manuel Nunes da Ponte</b> , Full Professor, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Former Director of ITQB
Management Systems (MBA and technology entrepreneurship)	<b>Paul Osterman</b> , Professor and Deputy Dean, Sloan School of Management	Contacts established with 4 schools: <b>Fátima Barros</b> , Dean, FCEE/UCP; <b>António Gomes Mota</b> , Dean, ISCTE; <b>Jose F. Machado</b> , Dean, FE/UNL; <b>Jose L. Cardoso</b> , President, Scientific Council, ISEG/UTL

## 6. Proposed Governance Structure for the MIT-Portugal Collaboration

The Collaboration will be based on a contractual arrangement between MIT and the Portuguese Science and Technology Foundation. It is important for an effective collaboration that bureaucratic constraints be minimized. If this is not possible given a structure based on direct oversight by the Science and Technology Foundation, MIT recommends the creation of a new agency or organization to oversee the university collaborations that won't be subject to the same constraints. Maximum flexibility is vital to the success of the program. Either in the Portuguese

Science and Technology Foundation or a new agency, there will be a “Director of the MIT-Portugal Program” who reports to the Agency or Foundation President and who will direct all of the activities that the Agency agrees to undertake and/or support with MIT. The Portugal Program at MIT will be led by an MIT faculty member who serves as “Director,” and will typically hold an appointment in the Engineering Systems Division, which is serving as the lead unit at MIT.

The program governance structure includes a Program Governing Board 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 Board 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 each Portuguese institution that is committing to collaborate with MIT on a project or program. Figure 1 shows a schematic of the program governance structure.



**Figure 1. Schematic of the governance structure**

The four-member Program Governing Committee, which will meet annually consists of the two Program Directors (one in Portugal and one at MIT), the President of the Agency in Portugal and a senior MIT administrator. The Portugal Agency President will chair the Governing Board.

The membership of the Program Operating Committee will be determined by the two Directors (who will also serve on the Committee), and is expected to include, at least initially, the MIT

faculty members leading each of the Focus Areas (appointed by the MIT Director) and the Portuguese Focus Area Leaders (appointed by the Portugal Director). The Governing Board will have authority to change the size of the Program Operating Committee and its membership to reflect changes in the overall program. The Program Operating Committee will meet four times a year, and will be responsible for coordination and integration across the different focus areas, and for reviewing and giving preliminary approval to the initiative and associated budgets in each focus area set out each year in an Annual Plan. The Director of the Portugal Program at MIT will chair the Committee.

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 make sure the overall objectives of the MIT-Portugal Program are achieved.

Great care must be exercised by the various governing bodies not to place excessive nonproductive demands on the faculty with respect to reporting requirements. We want the faculty and Focus Area Leaders to concentrate on the educational and research projects, rather than constantly responding to inquiries from various committees.

## **7. Leadership**

MIT's experience in other international collaborations has shown the critical role of faculty leadership, both for the focus areas and most importantly for the overall program. We are very pleased with the selection of the Portuguese leaders in each of the focus areas. They combine the necessary characteristics of technical expertise, management experience, and respect by their colleagues, both at Portugal and MIT.

The selection of the Portuguese Program Director is a particularly important decision, and MIT recommends that Paulo Manuel Cadete Ferrão be appointed to that position. We have been very impressed by all our interactions with him during this assessment period and as Director of the Center For Innovation, Technology, and Policy Research at Instituto Superior Técnico, Technical University of Lisbon, he has the best knowledge of the overall objective of developing engineering system programs in Portugal. Also, Dr. Ferrão's connection to IST is particularly important. All of the universities involved in the assessment have faculty and research groups of high quality participating in the various focus areas. However, we were particularly impressed by the overall excellence of IST, so it is very important that the collaboration between IST and MIT be effective.

In general, we expect IST and the other schools involved in the overall MIT-Portugal Program to explicitly acknowledge their institutional commitment to the overall MIT-Portugal relationship and to provide all the necessary support to the Portuguese Program Director. In particular, IST should guarantee direct support to the Program Director. We also expect IST to work in close collaboration with the other schools involved and promote the international visibility of the various operations under planning. The Dean of IST, together with the Deans of the other schools involved, are invited to visit MIT and the Engineering System Division in order to

discuss details and make sure the governance of the MIT Portugal Program is properly implemented. In addition, we strongly recommend the following actions to guide the correct implementation of the program governance and leadership:

- First, we recommend that the various activities and the coordination of the various Focus Areas are implemented through the Research Centers associated with the various university schools, as recognized and evaluated by the Portuguese Science and Technology Foundation (FCT). As noted above, the serious commitment of the research centers is particularly important to guarantee the highest level of excellence of the post-graduation activities under planning and, in particular, of the doctorate degrees to be considered under the MIT-Portugal Program.
- Second, formal national consortia should be formed by the agency in Portugal among the university schools involved in the program. Again, we note that by forming Portuguese consortia, we can bring together the best researchers and research groups from the universities and research institutes throughout the country and help build the necessary critical masses for succeeding at an international level. It should be noted that other national consortia of technical universities and engineering schools are emerging in Europe (e.g., in The Netherlands) and we strongly recommend that the schools involved in the MIT-Portugal Program develop joint research and education agendas around the themes considered. This strategy will help Portuguese engineering schools to strengthen their international reputation and visibility.

## **8. Focus Area Assessments**

The assessments for each focus area are included in Appendices B-F. The format utilized for each focus area is different because the assessments were conducted in a decentralized bottom-up fashion, and the issues and considerations are different in each of the focus areas.

It is important to differentiate between the assessment study and the work plan to be undertaken by MIT and Portuguese institutions. The assessment study serves as background and input for determining the work plans, but not all initiatives identified in the assessment study will be pursued. As noted in this report a process has been established where the work plan is developed and approved on an annual basis. The MIT and Portugal Directors should both prepare complementary annual plans.

The educational and research projects will be specified in a contract of the Foundation or Agency with MIT and separate contracts of the Foundation or Agency with the Portuguese institutions. The MIT contract will focus on those activities that MIT will undertake, while the Portuguese contracts will focus on the Portuguese activities. This approach will be followed since there are many Portuguese institutions involved in each Focus Area. Since most projects involve both MIT and Portuguese institutions, the successful execution of joint activities will require each side to carry out their contractual responsibilities.

To ensure this takes place we suggest that each Portuguese institution involved in the Program enter into a written commitment with the Foundation or Agency to participate in the MIT-



Portugal Program through collaborations with MIT in the Focus Areas and to specify how that institution will contribute to the overall program in general and specified projects in particular. Part of the commitment should be for the Portuguese institution to enter into a process to develop an Annual Plan of projects and programs in the Focus Areas in the MIT-Portugal Program in parallel with MIT's Annual Plan (under the committee structure that the agreement between MIT and the Agency establishes). This should be done in a manner that will ensure that the activities, sequence of activities, payment schedule for sponsor funding, and other relevant matters under MIT's Annual Plan and Agreement with the Foundation or Agency and the Portuguese institution's Annual Plan with the Foundation or Agency and agreement with its funding sponsor are consistent and coordinated so that the two institutions are able to successfully deliver the project or program with each doing its intended part. The Foundation or Agency acting through the Director of the MIT-Portugal Program should serve as the coordinating organization for all Portuguese work activities. If a Portuguese institution receives funding from any organization other than the Foundation or Agency, that institution should enter into a companion agreement with the Foundation or Agency to commit that the sponsor's agreement with the Portuguese institution is consistent with its Annual Plan with the Agency and with MIT's Agreement with the Foundation or Agency and the Annual Plan.

Changes in the work plans are anticipated and encouraged. Past experience has demonstrated that collaborative faculty groups gain insight as their work progresses. This frequently leads to new perspectives requiring shifts in focus. The overall program needs to ensure flexibility at the project and Focus Area levels as well as providing flexibility for the Program Directors. This approach will produce the maximum payoff from the Program.

In conclusion, MIT would like to thank our many colleagues and friends in Portugal who were so helpful and supportive during this assessment study. It has been a very rewarding experience to see the faculty groups from MIT and Portugal in each focus area come together so effectively. Collaborations of this type are not easy to accomplish, so it is very encouraging how well faculty from both MIT and Portugal have worked together in formulating possible research and educational initiatives.

*APPENDIX A*

*THE PORTUGAL-MIT TRANSPORTATION SYSTEMS PROGRAM*

*MIT: JOSEPH SUSSMAN*  
*PORTUGAL: JOÃO BENTO*

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## Objectives and Vision

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.

The vision for the transportation component of the MIT/Portugal program is the design of an **integrated, technology-intensive, intermodal transportation system** considering all of the above not as independent modally-oriented transport elements, but rather as an integrated whole. Addressing the transportation system in this manner yields significant opportunities for leverage in investments, operations, and market development.

When considering the system as an integrated whole, we must think about the interconnections between transportation and other major societal subsystems, including the economic development system, the environmental system and the land-use system. This integrated view creates important opportunities, but also major design, implementation and institutional challenges. The set of transportation research and education programs we will establish within the Portugal-MIT program will be designed overall to address these challenges.

The strategic multi-decade goal is the development of a *world-class transportation system for passengers and freight for Portugal that can serve as a model for the rest of Europe*. The deployment of such a system will require the effective integration of new technology and new institutions, and will further require the development of human resources to support this endeavor. Once created, this technology/institutions/human resources system can provide a substantial boost to economic development in Portugal, and in addition can provide exportable transportation models and expertise that can help position Portugal in the world market. The centrality of transportation to social goals and economic and industrial development makes it an vital area to pursue in the MIT/Portugal Program.

Achieving the goals of the transportation systems focus area requires the development of both education and research programs. MIT will work in close cooperation with universities, industrial companies and research laboratories in Portugal. A full commitment of these Portuguese organizations is a critical factor for the success of this venture.

The following sections describe (1) the assessment process MIT undertook, and (2) the programs under consideration.

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## Assessment Process

In May 2006, Dr. João Bento of BRISA visited MIT to discuss the transportation focus area, which had already been identified by Manuel Heitor, Secretary of State for Science, Technology and Higher Education as an important area of potential cooperation. We had a very valuable set of meetings, which included a discussion of the overall focus area with Professor Daniel Roos and Professor Joseph Sussman (the designated MIT lead for the transportation focus area).

In addition, Dr. Bento met with a number of other MIT faculty and staff members in areas that had been identified as of interest to both MIT and Portugal. This included:

- Professor Hari Balakrishnan (Intelligent Transportation Systems- ITS)
- Professor Moshe Ben-Akiva (Intelligent Transportation Systems- ITS)
- Professor Richard de Neufville (Airports)
- Professor Joseph Ferreira (Urban Studies and GIS)
- Carl Martland (High-Speed Rail)
- Dr. Ichiro Masaki (Intelligent Transportation Systems- ITS)
- Professor Joseph Sussman (Intelligent Transportation Systems- ITS, High-Speed Rail, Risk Assessment)
- Professor Daniele Veneziano (Rail, Risk Assessment)
- Professor Nigel Wilson (Public Transportation and MIT's Master of Science in Transportation Program)
- Professor Fred Moavenzadeh (Institutional Aspects, Public Policies)
- Professor Joel Moses (Engineering Systems)

These meetings were very successful in identifying a number of areas of mutual interest that could become successful collaborative research and education activities involving MIT and various Portuguese organizations.

Dr. Bento also had a valuable meeting with members with the MIT Portuguese Students Association.

Subsequently, Professor Sussman traveled to Portugal for a three-and-a-half day set of meetings (June 26<sup>th</sup> through 29<sup>th</sup>) to continue the assessment. During his visit, which was well-organized and coordinated by Dr. Bento, Professor Sussman had opportunities to visit a number of transportation-oriented organizations.

He visited three academic institutions: the Instituto Superior Técnico (IST), where he met with the Chair of the transportation group, Professor José Manuel Viegas; the University of Coimbra, where he met with the head of the transportation group, Professor Luís de Picado Santos and also Professor Alvaro Seco; and the University of Porto, where he met with the head of the program Professor Álvaro Costa and Professors Maria Teresa Galvão Dias and Maria Antónia Carravilla. Each of these universities has transportation programs with different areas of emphasis. Both IST and Porto have Master of Science in Transportation programs. IST's has been in place for about twenty years; Porto's is much newer. Faculty from all three universities were very interested in the opportunity of working together with MIT and the other universities to develop academic programs as well as collaborating in various areas of research.

Professor Sussman had the opportunity to meet with representatives with the National Laboratory of Civil Engineering (LNEC). Among the people he met with were António Lemonde de Macedo (Head of the Transportation Department), Dr. Carlos Pina (Executive Vice President and Head of the Concrete Dams Department), and Elisabete Arsénio (member of the Transportation Department). LNEC is closely linked with many Portuguese universities (students from those universities may do their doctoral research at this laboratory). LNEC is working in some areas of transportation of interest to the MIT-Portugal program, especially including sustainable transportation and sustainable development.

In addition to the academic and research institutions, Professor Sussman met with other transportation organizations. He was hosted by representatives of the wholly state-owned Portuguese railroad infrastructure operator, REFER, and from RAVE, which is responsible for the proposed Portuguese high-speed rail system. Representatives included Carlos Fernandes, who is a member of the board of both REFER and RAVE. Also at the meeting were Francisco Melo Parente (International Affairs), Fernando Ribeiro Vendas (New Technologies Manager), and José M. Costa de Freitas (Deputy Operations Director). Mr. Fernandes presented a set of eight research topics for potential cooperation between REFER, MIT, and organizations in Portugal, and he expressed strong interest in participating in the Portugal-MIT program.

Professor Sussman had the opportunity to visit three industrial firms. He visited BRISA, where Portugal coordinator Dr. Bento is a member of the board. Dr. Bento arranged for a valuable demonstration of BRISA's ITS work and gave a useful overview of BRISA's concessions for roadways in Portugal. Jorge Sales Gomes, Head of Innovation and Technology, also participated in these meetings and presented some of the technological concepts that BRISA has developed within its network of R&D collaborators. Again the opportunities for coordination between BRISA and the Portuguese universities and MIT were of interest to this company. BRISA has considerable technical capability and has achieved a great deal in the ITS field. They can provide a strong platform for the Portugal Program at MIT.

Professor Sussman visited Siemens Portugal where he was hosted by the General Manager of Transportation Systems Manuel Nunes. Siemens' activities in various areas of technologies concerned with telecommunications and related concepts were presented by Pereira de Oliveira, the Director of Innovation Initiatives. Professor Sussman further had the opportunity to meet with the Managing Director of Siemens Portugal, Carlos de Melo Ribeiro and João Picoito, a member of the Board and CEO for Siemens Infocommunications Portugal. These senior executives of Siemens presented a valuable vision for various futures at Portugal, and how the Portugal-MIT program might relate to those concepts and expressed interest in the focus areas of the Portugal-MIT program in addition to transportation.

In addition, Professor Sussman met with members of another industrial company, EFACEC, including Mario A. Rosario Barbosa (Executive Director) and Pedro Moreira de Silva (Transport and Logistics Solutions Management Committee), who presented various technologies and solutions that EFACEC has provided to the transportation industry. EFACEC does work in many areas of interest to the Portugal-MIT program including rail and ITS where they provide hardware and software systems to those industries, working closely, for example, with REFER.

As a result of these meetings, as well as the initial meeting in May at MIT, Professor Sussman and Dr. Bento were able, on the final day of Professor Sussman's visit, to agree upon an overarching framework for the transportation research and education program, which is described later in this assessment. MIT thanks Dr. Bento for his effective job in arranging a very useful series of meetings for Professor Sussman during his visit and for his insights about future areas of collaboration. These meetings were very helpful in structuring a program we believe will be of value to our colleagues in Portugal and for MIT.

In addition to these meetings, there have been extensive email communication between Professor Sussman and Dr. Bento, and since the meeting to Portugal, between Professor Sussman and several of the people he had the opportunity to meet during his visit. We believe the basis is in place for sound cooperation between MIT and the various Portuguese organizations in academia, in industry, in government and research labs. The Portuguese organizations show commitment to the transportation focus area and have important strengths that can support our goals.

### **Assessment Report Criteria**

Various criteria have been used in this assessment to evaluate potential collaboration in the several focus areas. The following is our assessment of the transportation focus area according to these criteria.

➤ *Intellectual Benefit to Portugal and to MIT*

The field of transportation is of interest in Portugal from an economic development as well as from an environmental perspective. Given transportation's interconnections to other socio-technical systems, the ability to effectively capitalize on technological and other advances in the field is of great importance to Portugal. This is also an area of vital interest to MIT with its ongoing programs in the transportation area. Clear intellectual benefit is present.

➤ *Inclusion of Both Research and Education Components*

The program includes development of educational programs. Initially a Master of Science (MSc) program in Transportation will be developed, with a PhD program building on the MSc to be developed over the longer term. These educational programs will be coupled with broad and deep programs of research spanning a number of vital areas in the transportation field.

➤ *Recognition of the Implications of Globalization to Portugal*

The effectiveness and efficiency of Portugal's transportation system is vital to its position in the global economy. Efficiency of movement, for both people and freight, is key to the ability of Portugal to compete on an international scale.

➤ *Achievable Goals Within Budgetary Constraints*

The goals of the transportation systems focus area are achievable within the budget constraints.

➤ *Content That is Appropriate to Pursue When Achieving the Focus Area Objectives*

The content that has been identified is entirely consistent with establishing a first-rate educational program in Portugal in collaboration with MIT and collaborative in-depth and broad areas of research in the transportation sector.

➤ *Ability to Build on Existing and Previous Faculty Relationships*

Transportation faculty in Portugal were well known to MIT before this initiative. As part of the assessment a set of new relationships have been established. We are confident we can build upon these relationships to create a valuable program.

➤ *Commitment of Key Faculty*

The research and educational programs that have been identified are at the heart of the interests of MIT faculty. Further, this assessment has identified a number of faculty members in Portugal with expertise in and interests in these areas. Highly qualified faculty on both sides of the Atlantic are committed to the effort.

➤ *Involvement of Different Portuguese Universities*

This assessment involved visits to three major Portuguese universities, IST, Coimbra, and Porto. To achieve success in this focus area, it is vital that these universities work in close collaboration with each other and with MIT. In the future, we expect that additional universities will be identified. The universities contacted thus far are deeply interested in participation.

It is important that that these university commitments be formalized through a written statement submitted to the Portuguese Agency established for the Portugal Program at MIT.

➤ *Industrial Interests*

There is very active interest in the transportation sector in various Portuguese industries. The assessment visit involved meetings with three important industrial companies, directly concerned with transportation, BRISA, Siemens Portugal, and EFACEC. Interest in participating in the MIT-Portugal program was indicated by each. They see the cooperation between MIT and the Portuguese universities working toward the creation of an intellectual community that can advance the transportation field.

Again, it is important that that these industry commitments be formalized through a written statement submitted to the Portuguese Agency established for the Portugal Program at MIT.

## 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.

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## Overview of Transportation Focus Area: Education and Research Elements

The Portugal-MIT program is intended to be a coordinated and integrated set of education and research activities. The structure is shown in Figure 1 below.

The program is composed of *horizontal, integrating* elements, and *vertical, domain-specific* elements intended to operate in an coordinated manner. We believe there are considerable benefits to be derived through this approach. The whole of the transportation systems focus area should be more than the sum of its parts. Of course, there will be substance in each individual program element as well.

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## Education

The initial focus of the educational program is the 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 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.

This program will build on the current Master of Science in Transportation (MST) program at MIT, internationally recognized as a leader, with more than four decades of educational experience, as well as Masters programs at IST, Porto and Coimbra in Portugal, which, although newer, have already attained distinction.

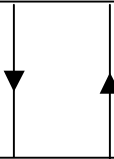


**FIGURE 1**

**TRANSPORTATION SYSTEMS FOCUS AREA**

**EDUCATION**

- MSc in Transportation
- Complex Transportation Infrastructure Systems: Conceiving, Designing, Integrating, and Operating the Intermodal Transportation Enterprise
- Short courses and Executive Courses
- PhD in Transportation



**RESEARCH**

Strategic Planning for the Regionally-Scaled Integrated Transportation Intermodal Enterprise: Toward Sustainable Development

<p>ITS</p> <p>ITS: Understanding the Benefits and Costs</p> <p>New Methods Related to Understanding, Valuing and Deploying ITS</p>	<p>Airports</p> <p>Airports as Complex Systems: Dealing with Uncertainty</p>	<p>High-Speed Rail</p> <p>Modal, Intermodal Connectivity and Competitive Issues in HSR</p> <p>Generalized Global Risk Assessment: Financial Risks Market Risks Technology Risks Safety and Security</p>
<p><i>High-Speed Rail/Airport Relationship</i></p>		
<p>Real Options Analysis</p>		
<p>Design Structure Matrices</p>		

*Cross-Cutting Methods:*

The idea is to create an international program presenting a systems perspective in the transportation field coupled with classes in various specialized modes. The focus of the program is the concept of an integrated transportation system interconnected with other important societal systems, including economic, environmental, and energy foremost among them. The program will teach technological- and systems-related quantitative approaches to understanding the transportation enterprise as an intermodal integrated system, but will also consider institutional, organizational and political factors in the deployment and operation of transportation systems.

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. To that end, the subjects will be taught in English, and will draw on best practices from MIT and Portuguese universities.

In addition to the MSc degree program, we 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, along the lines of BP's "Projects Academy," could also be part of the collaboration.

While the initial educational focus on the Portugal-MIT program will be the Master's 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.

The educational activity is planned as an early initiative in the transportation systems focus area. A workshop involving all the universities will be held in order to establish the goals and structure of the MSc and how it relates to the existing programs at MIT and the Portuguese universities. We will also be concerned with understanding the international market for the MSc and how our program design relates to various market issues. We also will involve other Portuguese collaborators in government, industry and the research community in order to understand their human capital development needs and how the MSc can contribute. Prototype versions of selected subjects are anticipated to be offered in the early stages of the program to gain experience in working together and to develop some visibility and market feedback for the program.

Further details of the early activities in the educational program are provided in the section entitled *Portugal/ MIT First Year Program in Transportation Systems Focus Area* at the end of this report.

As noted above, we recommend a written commitment to this endeavor from MIT and the Portuguese universities, submitted to the appropriate Portuguese Agency.

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## Research

### Coordinating Research

As seen in the figure above, the research program has both horizontal and vertical elements. Paralleling the MSc program, we plan a *horizontal 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, develop general methods in support of the strategic planning process for the transportation enterprise.

MIT, the Portuguese universities, LNEC, REFER/RAVE, BRISA and other industrial firms related to the transportation sector in Portugal all recognize the need to consider the role of the transportation system in achieving sustainable development, properly balancing environmental impacts, economic growth and social equity, and the need to do so at a regional scale in order to effectively compete in the global economy. There is strong interest in this perspective as an integrating theme for the research and a supporting theme for the transportation educational program. This research and the domain research described below will be a cooperative venture of academia, industry, government and research labs including those organizations mentioned earlier in this report.

Again, as was described in the educational program, this research will consider both issues of technology—from the point of view of innovation and deployment—as well as the institutional factors that govern the way in which transportation systems are conceived, designed and deployed to support societal goals.

In addition to the integrated strategic planning research activity, there will be three “vertical” 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)

Portuguese Universities and research laboratories and MIT all have focused on Intelligent Transportation Systems (ITS) as an important new component in surface transportation introduced over the last several decades. Further, from an industry perspective, BRISA has established itself as a major innovator in ITS. Its capabilities will be of great value in the ITS research area. We can build on the capabilities of all these organizations with ITS 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. We will build on network simulation models such as MITSIM and DYNAMIT developed at MIT to study network methods to predict congestion and evaluate strategies for enhancing network performance. Further, approaches to improving safety and the relation of ITS to environmental considerations will be developed within this research element.

Looking at the urban scale we anticipate studying ITS in support of highway networks and public transportation, and particularly bus systems, as a strategy for both reducing congestion and reducing environmental impact of urban surface transportation.

➤ *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. *Real options analysis* is an important engineering concept pioneered by the faculty in the Engineering Systems Division at MIT and its application to the ITS domain can build on studies of Houston, Texas. Portuguese collaborators and MIT will explore applying this idea in the Portuguese context.

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. Initial applications of this concept to the Seattle, Washington region have created new insights into structuring institutional relations; we will explore this concept in the Portuguese context.

The Government of Portugal should work to guarantee the cooperation and involvement of the universities, government agencies, the public entities and the concessionaires involved in the design and planning of and research in connection with ITS applications in Portugal. This will be vital to the success of the ITS research thrust.

## Airports

➤ *Airports as Complex Systems: Dealing with Uncertainty*

Building a major new international airport in the Lisbon region has been on the public agenda for some time. Clearly the development of this complex engineering system will have significant importance in the economic development of Portugal and to its relationship to the rest of Europe and the European community. This is surely a complex systems problem, and faculty at MIT and in the Portuguese universities are interested in the systemic issues in airport design, including the development of facilities in an era of rapid change and high degrees of uncertainty. Studying the potential new 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 may yield significant benefits in the planning and design of new facilities. Indeed real options

analysis is a cross-cutting theme; we noted its use in ITS in the Houston study, and this method will be useful in the airport's research topic as well. This airport research will be linked to the high-speed research activity, as described below.

The Government of Portugal should work to guarantee the cooperation and involvement of the universities, national airport authorities and the public entities involved in the design and planning of and research in connection with the new Lisbon airport. This will be vital to the success of the airport research thrust.

## High-Speed Rail

Another major infrastructure development on the public agenda 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*  
This research will explicitly consider 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. Currently, the plan is for the high-speed rail system going north of Lisbon to stop at the proposed new airport in OTA, 50 kilometers north of Lisbon. The interconnections between those two modes can be of vital importance in terms of providing intermodal services to and from Portugal with possible international linkages. This is an excellent example of the intermodal, integrated perspective we anticipate taking in this transportation systems focus area.

Further, how Portugal will integrate with a European system of high-speed rail, both technologically and institutionally, is very important and will be considered in the research element as well.

- *Generalized Global Risk Assessment of the HSR system.*  
This is an area specifically identified by REFER and of interest at MIT and the Portuguese universities. MIT has conducted a safety-oriented global risk assessment for the East Japan Railway Company. Portuguese universities (and MIT) are interested in additional dimensions of risk including financial risk, market risk, and technical (R&D) risk. Risk associated with security in this contemporary world must be considered as well. The notion of an integrated approach to studying risks of various sorts—that is, a *generalized global risk assessment*—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. Building this methodology and applying it will build on significant strengths at MIT and the Portuguese educational, research, and industrial organizations and is of great potential benefit to the organizations in Portugal ultimately responsible for the deployment of HSR.

The Government of Portugal should work to guarantee the cooperation and involvement of the universities, national rail network, as well as the public organizations that will lead the implementation of and research in connection with the TGV system in Portugal. This will be vital to the success of the HSR research thrust.

### **The Participation of Private and State-owned Companies**

As mentioned throughout this report, a number of Portuguese private and state-owned companies have been clearly involved in the preparation for initiating the research aspect of the Transportation Systems focus area of the MIT-Portugal Program. These organizations have shown interest and commitment.

First, there is the vital involvement of Brisa with their prominent role in ITS and with Dr. Joao Bento serving as the lead of the Portugal side.

In addition, Siemens Portugal and EFACEC – two major players in the transportation systems area in the country – have shown a great level of commitment, suggesting their willingness to participate actively in various lines of activity.

Furthermore, the involvement of both RAVE and REFER is clear, given the fruitful discussions that have already taken place.

Both the ITS and HSR aspects exhibit, therefore, a solid chance of good participation of important agents from industry and government.

However, so far, organizations in the airports aspect of this focus area have not been engaged. Therefore, it is an important priority to raise the interest of, at least, ANA (Aeroportos e Navegação Aérea), the civil airports operator, and of NAL (Novo Aeroporto de Lisboa), the entity responsible for the development of the new Lisbon airport. We fully expect that these organizations and others will see the advantages of participation in this program, as have their counterparts in ITS and HSR.

We are counting on the support of the government to assure the involvement and full cooperation of major companies, involved in the transportation sector in Portugal. The participation of these organizations, in applications including ITS, airports and HSR and potentially other areas, will be vital to the success of the Transportation Systems focus area.

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## Summary

Above we have described an integrated program of education and research, as is the classic approach. The watchword is *integration*. The program will be managed as an interconnected and mutually supportive group of intellectual endeavors.

There are several integrating mechanisms for this transportation systems focus area. The MSc program is an important integrator for the transportation systems focus area, tying together the intellectual fabric of various elements of work.

Parallel to this will be an integrating research project dealing with strategic planning for the transportation system in Portugal, considering it as an integrated, intermodal system operating at the regional scale, and focused on the long-term goal of sustainable development. This strategic planning project will integrate the results of in-depth domain studies of *Intelligent Transportation Systems (ITS)*, *Airports and High-speed Rail (HSR)*, each of which will have several related projects.

We further intend to take full advantage of cross-cutting concepts among these domain studies. We have noted the relationship between high-speed rail and the new airport. In addition, we expect advances in design methodology, such as real option analysis, and advances in institutional analysis, such as design structure matrices, to cut across the three domain areas as well.

Portuguese institutions, together with MIT, have an opportunity to make a profound contribution in the field of transportation, creating a distinguished educational activity that can attract people internationally. We will create research content that will support the sustainable economic development of Portugal and, we believe, can have international impact as well. The notion of building on the MIT Engineering Systems Division's idea of *systems thinking in complex environments* for the purpose of producing valuable research results and creating human capital is the touchstone of our transportation activity.

We also see this transportation program to be directly connected to other focus areas of the Portugal-MIT program, and especially those in energy and EDAM. Every attempt will be made to create connections across those focus area boundaries as well.

Finally we note the importance of strong cooperation between MIT and the various Portuguese organizations discussed above. This program is envisioned as truly joint in nature. To that end, it is important that MIT and the Portuguese organizations fully commit themselves to this undertaking in writing to the appropriate Portuguese Agency as specified elsewhere in this assessment report.

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### Addendum: Portugal/MIT First Year Program in 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. 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 with inputs provided by our Portuguese collaborators in industry, government, and the research laboratories, including BRISA, Siemens Portugal, EFACEC, REFER/ RAVE and LNEC. 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 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 horizontal 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. The organizations mentioned above in academia, industry, government and research labs will participate in our research ventures.

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. At the same time, we will work with our industrial, government and laboratory collaborators to assure our work in education and research are consistent with their interests and will be of value to transportation stakeholders in Portugal.

*APPENDIX B*

*RESEARCH AND EDUCATION IN  
SUSTAINABLE ENERGY SYSTEMS*

*MIT: DAVID MARKS, STEPHEN CONNORS  
PORTUGAL: PAULO MANUEL CADETE FERRÃO*

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## Energy Systems – Objectives and Vision

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 this context “energy systems” refers to the entire supply-chain of energy provision to ultimate end-use consumption. This encompasses detailed understanding the dynamics of energy resources—both fossil and renewable; the dynamics of current and potential future demand for energy services; and the structure of integrated networks which transform and transport energy resources to consumers. When approached from a regional context, where local energy resources as well as energy service needs can be addressed in detail, energy systems research becomes synonymous with studies of how various energy technology and policy options affect the transformation of the regional energy infrastructures.

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.

To successfully address these challenges, the development and integration of new energy system simulation and design methodologies must be developed. This includes the dynamics among energy services and supplies, including opportunities for combined heat and power and renewables in the distribution network. Furthermore, these new topologies must be tested for real-world situations, including the realities of less than complete system characterization (e.g. incomplete information), and multiple jurisdictions—both public and private—which affect strategy development, acceptance, and implementation.

Key to the successful development of new technologies and methodologies will be the ability to extend the range of metrics, which opens design and negotiation space among energy infrastructure stakeholders. With additional metrics on life cycle performance, and improved reliability, robustness and resilience of energy networks, novel energy technology and policy options can be developed. These challenges are embodied in MIT's recent activities which include the formation of the Engineering Systems Division, the merger of multidisciplinary research centers into the Laboratory for Energy and the Environment, and called for in the May 2006 report of the MIT Energy Research Council.

Fundamental to these new approaches will be the ability to incorporate uncertainty into the design process, whether it be from changes in consumer behavior, the variability arising from a greater reliance on renewable resources, or boom-bust investment dynamics associated with increased competition in energy markets. This includes assessing the potential impact of new technologies, which may be deployed to upgrade and/or expand the energy network. The ability to address the retrofit vs. replacement of infrastructure components will be another key aspect of tools to be developed.

Below is an overview of the Assessment Process that MIT has undertaken in the area of energy systems research, followed by an overview of the key areas where we think a suite of related energy systems research and education would be beneficial to both Portugal and MIT.

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## Assessment Process

### Overview of Activity

In late March, Paulo Ferrão of IST visited MIT where the focus area of Sustainable Energy Systems was initially discussed in detail. This was followed by a reciprocal visit by Marks and Connors to Lisbon in late May. Portuguese participants at that two-day activity included P. Ferrão (IST), E. Fernandes (FEUP), A. Martins (ISEG), A. Falcao (IST), and A. Vallera (UL). In addition to these meetings, in the area of marine energy, Prof. C. Mei of MIT visited IST and Prof. Gato (IST) visited MIT. In addition to face-to-face meetings there have been numerous phone and email conversations regarding MIT and Portuguese university participation on various research and educational topics.

The research and education programs described below will involve numerous departments and laboratories at MIT, in collaboration with several Portuguese universities and their associated research centers. These Portuguese institutions include the Instituto Superior Técnico (IST) and its Center for Innovation, Technology and Policy Research (IN3) and Centre for Wave Energy; the Faculdade de Engenharia da Universidade do Porto (FEUP) and its Power Systems Group and the Unit of Advanced Studies on Energy in the Built Environment; the Universidade Técnica de Lisboa (UTL) and its Instituto Superior de Economia e Gestão (ISEG); and the University of Évora. We anticipate that other universities, research centers and national laboratories will join these lead organizations as the program of research and educational activities develops. We also expect cooperation with the renewable energy group at INETI, particularly in the context of the Portuguese National Laboratories reform, including the formation of a new Energy and Geology National Laboratory. In general, the experience and the excellence of the work developed by faculty of IST (namely in the area of industrial ecology, energy economics, and wave energy) is acknowledged and will be of major relevance for the success of the Portugal-MIT Collaboration in the area of sustainable energy systems.

In the long run we expect that a new structure will be instituted allowing all these universities to cooperate in building new education and research programs among themselves and with MIT. The focus area of “energy” should consider the involvement of major corporations and energy

players, and the discussions with the National Energy Network (REN) should be extended to other enterprises.

### Relevance to Assessment Report Criteria

- *Intellectual Benefit to Portugal and to MIT*

The intellectual benefit to both MIT and Portugal is great. This area of research is of high social and intellectual merit to MIT as reported by the MIT Energy Research Council in its May 2006 report to the president. Discussions with Portuguese faculty indicate this is equally true in Portugal, especially given national obligations to address climate change.
- *Inclusion of Both Research and Education Components*

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. This has been incorporated into the Sustainable Energy System focus area's plans.
- *Recognition of the Implications of Globalization to Portugal*

The need to develop these tools for the benefit of Portugal, within the EU, and globally is well recognized. Tools and methods developed and tested via Portuguese case studies are directly transferable to other regions of the globe.
- *Achievable Goals Within Budgetary Constraints*

The size of the program is sufficient to make good progress on the proposed topics. Care must be taken to ensure that the program's impacts are greater than the sum of its parts.
- *Content That is Appropriate to Pursue in Achieving the Focus Area Objectives*

The range of proposed projects covers the requisite range of needs, in terms of geographic scope and regional detail. Testing of project output with Portuguese stakeholders will ensure the relevance of techniques developed to the needs of society.
- *Ability to Build on Existing and Previous Faculty Relationships*

Several existing relationships exist among MIT and Portuguese faculty, through prior research, international organizations, and prior student-faculty relationships. These will help accelerate the formulation and start-up of several program components.
- *Commitment of Key Faculty*

The topic is of great interest to leading MIT and Portuguese faculty. With the proposed size and duration of the MIT-Portugal Collaboration, many key faculty have stepped forward.
- *Involvement of Different Portuguese Universities*

The proposed projects have generated interest from numerous Portuguese universities. Care must be taken to ensure interest and collaboration among Portuguese universities remains high. The recommendation for a 'unifying research center' focuses directly on this topic.
- *Industrial Interest*

Energy sector interest is expected to be high, as is interest from numerous local, national and regional governmental agencies and non-governmental organizations. Stakeholder dialogues in the research process, and results synthesis and outreach steps should help entrain them further into the work.

By definition, multidisciplinary energy research, involving detailed case studies with local stakeholder participation, must interact with governmental agencies and industry. Which specific groups will participate in Sustainable Energy Systems research and educational activities will be developed during the initial phases of the program. It is anticipated that companies for which activities of the Sustainable Energy Systems Focus Area could be of interest includes: REN

(Rede Eléctrica Nacional); EDP (Energias de Portugal); GALP Energia; EFACEC; SIEMENS Portugal; Tejo Energia; Turbogás; Enersis; Alstom; Generg; Bioeléctrica; Valorsul; Climaespaço; Martinfer; Lisboa Gás; and AGNI Inc. Participation by additional Portuguese, EU and global companies is welcome.

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## Overview of Sustainable Energy System Program – Topics and Structure

### Program Overview

We discussed a research theme around energy security and long-term environmental management which are only two of the many emerging long-term challenges facing today's energy infrastructures. From this will flow innovative research on integrated energy systems, including renewables and energy efficiency. These are very active areas of research, globally as well as within our respective universities, and so a well tailored program that adds value to both our schools and to the area of energy systems needs to be carefully crafted.

Past efforts have identified the need to be not only “topically” innovative, but also focus on the fundamental challenges where university-led research can provide insights and tools to decision makers in industry and government at national and local levels. This includes looking hard at which new and refined models and methods would be most beneficial, including the data requirements and institutional implications required to the successful deploy these techniques. Care must be taken to ensure that the “prescriptive knowledge” provided by this next generation of tools can be effectively transferred to firms, government agencies, and the public-at-large. New methodologies and key insights provide the foundation for high value educational initiatives both within our universities, and tailored to professionals.

Below is a description of prospective educational and research activities of interest to Portuguese and MIT participants. Once the contract is formalized, we will have a workshop in Portugal to flesh out additional participants and refine individual and coordinated research projects. We have budgeted for eleven faculty participants from MIT with ten research assistants, with additional staff to ensure coordination of both research and educational activities. Collectively the MIT research effort will work closely with Portuguese colleagues on the focused research topics, research integration, and associated educational elements described below. The purpose of this research is to help establish Portugal as a leader in research and education in large-scale energy systems. From this will flow new methods for analysis and planning, as well as a cadre of educated graduates able to work on these topics, both in Portugal and internationally.

### Establishment of a Unifying Portuguese Research and Educational Center

MIT recommends the formation of a Portuguese institution that will bring together students and some faculty from all over Portugal to work on these methods and applications, design educational materials, and help to develop educational short courses and new fields of study. The possible location for this institute will be assessed during the start-up year of the Portugal-MIT Collaboration. Additionally, in the context of the Portuguese National Laboratories reform, we encourage a strong interaction between the energy systems focus area and the new Energy

and Geology National Laboratory. We also expect Portugal-MIT energy activities to include a consortium of local industries and governments to interact with the projects and to serve as a means of outreach on findings and trends.

### **Educational Activities**

Sustainable energy systems is not only an innovative area for 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 integrated energy systems can occur. As such there is a great need to transfer methods required by, and developed through, the Portugal-MIT Collaboration from research into curriculum.

The main educational goals are twofold. The first, oriented towards energy system technological and economic performance, will promote new inter-institutional post-graduate courses aimed at educating a new generation of sustainability aware leaders in energy systems and their economic implications. The second, oriented to the design of sustainable energy policies, focuses on developing interactions among universities, businesses, government, and society to identify and implement sustainable energy policies and technological innovations.

The possibilities being considered for advanced energy systems education in Portugal include:

*Diploma of Advanced Education (DFA)*: This program, intended to provide new knowledge in Sustainable Energy Systems is oriented at practitioners and professionals coming from the energy sector, including companies and other institutions. This DFA will provide professional training towards the analysis and design of integrated energy systems, considering their technological, environmental, and economic components. This program can be offered as a 12 month course with a total of 60 ECTS credits, i.e., a total of 10 courses.

*Diploma of Advanced Studies (DEA)*: This program represents the curricular step towards a PhD in “Sustainable Energy Systems,” and is consistent with the EU’s goals towards greater transparency and transferability in European post-graduate education. It can be offered as a 12 month course with a total of 30 ECTS credits, i.e., a total of 5 courses.

*PhD in “Sustainable Energy Systems”*: After completing the DEA, students are required to develop a thesis on a selected research topic. Such PhD topics should be designed such that training periods at MIT in line with ongoing research can be easily undertaken. The main goal of this program is to educate new researchers with the capacity of conception and analysis of energy systems, considering their combined technological, environmental, economic and social components.

MIT recommends and expects that the different Portuguese academic institutions may combine their efforts to promote joint Portuguese degrees on “Sustainable Energy Systems,” as a way to enhance cooperation between them and with MIT. At this stage, by promoting an initial joint degree between IST and ISEG, an engineering and economics school from the same university (Technical University of Lisbon), the educational program can advance quickly.

## MIT Contribution to Portuguese Educational Initiatives

There are several ways in which MIT can enhance Portugal's development of these education programs related to energy systems. These include:

*Visits by Portuguese Faculty and Students to MIT.* Portuguese faculty will work closely with their MIT counterparts during their visits to formulate curricula for the DFA, DEA and PhD programs. For example, faculty may sit in on subjects to gain an appreciation of how new subjects are taught. They will then use MIT's 'OpenCourseWare' and other resources to gain additional teaching materials. Numerous students associated with Portugal-MIT research activities may come as non-degree candidates and sit in on classes.

*Assistance with the Energy Systems Advanced Certificate Program (DFA).* This would be a one year program after the five year EU masters degree that would draw heavily on existing and newly created subjects at MIT and participating Portuguese universities. MIT's contribution would help to build a strong curriculum with projects that tie into the overall energy systems research being carried out through the Portugal-MIT Collaboration.

*Research Symposia.* MIT and Portuguese colleagues will work to hold in Portugal a yearly research symposia to show progress on the work being done in this area as well as other important advances. This is seen as mainly an academic focused activity with MIT faculty and students attending along with their counterparts and members of industry, government and public groups. MIT faculty will also visit their counterpart groups for research purposes which would include research seminars.

*Detailed Technical Short Courses.* Should Portugal wish to hold these they will contract directly with outside experts to organize such courses, and so they are not reflected in the program's budget. MIT will advise on potential candidates, themes and topics.

## Governance and Institutional Leadership

A Portuguese Faculty committee headed by P. Ferrão of IST and by D. Marks of MIT will serve as a governing board to help in framing research themes, selecting projects and participants, allocating resources and evaluating results. We would expect this committee, once started up, to meet quarterly mostly in Portugal but occasionally at MIT or by video conference. Additional leadership from across Portuguese universities and within MIT will be through participation in research and educational activities.



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## Energy Systems Research Topics

Below is the list of the energy systems topics currently under consideration. These projects integrate expertise both at MIT and with our Portuguese colleagues, and if developed properly will provide significant benefits at MIT and in Portugal in the areas of research and graduate education.

These research topics have been developed with consideration to the major energy systems challenges facing Portugal, such as long-term energy security of supply and environmental performance. Significant efforts must be made to develop alternative energy systems coupling energy supply and demand, and which incorporate more renewable and domestic energy resources, such as marine and solar energy. These alternatives require the simultaneous development of distributed energy networks capable of handling a greater diversity of supplies, while still improving overall energy system efficiency. These are essential if substantial and sustained reductions of greenhouse gas (GHG) emissions—in accordance with Portugal's Kyoto obligations—are to be achieved in concert with Portuguese efforts to reduce dependence on external energy supplies (mainly fossil fuels). These efforts can only be carried out through a rational exploration and design of the nation's potential future energy systems, using innovative concepts such as energy as a service, moving energy supplies closer to energy demands, and promoting the efficient use of energy with special attention to residential and services sectors, where energy consumption has increased significantly in recent years.

Additionally, this effort should contribute to the development in Portugal of a competence in this critical field; one that could be exported to other countries, such as those with whom Portugal has a long-standing relationships, namely Portuguese Official Language African Countries (PALOP). We envision strong collaboration on each of these projects, including faculty and student exchanges of varying duration, and the ability to test new methodologies' performance via numerous Portuguese focused and other cases studies.

### **Energy Networks: Management of Distributed Generation Through Virtual Power Plants**

Portuguese Lead: E. Fernandes (FEUP), J. Pecas Lopes (FEUP)

MIT Collaborators: J. Kirtley (EECS), R. Larson (ESD/CEE)

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.

Distributed generation as a future topology for the electric power network has been discussed for several years now. The distributed nature of renewable power generation, especially wind, solar, agriculturally-sourced biomass, and micro-hydro has recently raised the interest in distributed generation. From a network coordination perspective (including power system protection and power quality assurance), the realization of numerous, quasi-autonomous generators is not so

straightforward. Distributed generation may have stricter operational constraints than central station generation since it may rely more on non-dispatchable renewable resources (solar, wind), difficult to ramp generation such as a biomass power plants with a 'biorefinery' on its front end, or combined-heat and power facilities with independent thermal energy service obligations.

With or without electrical energy storage to balance supply with demand, new coordination and control approaches need to be designed and tested. These "operational protocols" also need to be evaluated in the context of network topology and the local electricity and energy markets, thereby requiring a multi-level synthesis of analytic approaches.

At MIT, Prof. James Kirtley has been leading research into the technological integration of distributed power equipment to meet energy and reliability needs of consumers. In the more broadly defined energy systems area Prof. Richard Larson's interest in the coordination of energy networks, principally through pricing mechanisms, remains high. Collaborating with similar Portuguese academics, like Prof. Eduardo Fernandes, to bring these concepts to a testable level, within a Portuguese context, is exciting.

Early definition of the scope, key metrics, and region for case study evaluation will be necessary for the scale of this topic to be managed appropriately. A catalogue of in-hand and desired models and methodologies is also in order.

### **Industrial Ecology: Urban Metabolism**

Portuguese Lead: P. Ferrão (IST), L. Caldas (IST)

MIT Collaborators: J. Ferreira (DUSP), L. Norford (Architecture), R. Kirchain (ESD/DSME)

Building upon IST's Life-Cycle Analysis (LCA) capabilities, this project would look at the energy/ environmental footprint of a city's (primarily) building stock, including energy and waste flows. This fits in well with the MIT Energy Report calling for innovative research on "giga-cities." This area requires significant methodology development, and so needs to be tested and benchmarked via a quality case studies to address real world data availability and metrics development.

Urbanization is one of the main phenomena characterizing the world today. Nevertheless, the actual scope of its impact on the sustainability of our globalized planet is largely unknown, despite forecasts that by 2050 three-quarters of the human population will live in cities. The city is one of the human artifacts of higher complexity, and its functioning is not well understood or controlled by any single entity. Urban growth is largely an emergent phenomenon, where the interaction of variables has been too large to capture in an encompassing model. There are now powerful computational methods and models that may be applied to try to capture some of its complexity.

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. Departing from the metaphor of the city as an organism of great complexity, it is the project's goal to create a method for understanding present-day cities, and new tools for designing more sustainable urban

configurations. This project 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.

The urban metabolism approach aims at managing over diverse space and time scales integrated biophysical and social components, incorporating uncertainty, and identify prospective flexible institutions for the management of urban systems. It is anticipated that these tools would help visualize and identify planning problems using novel tools and methods and help identify trade-offs and synergies for decision makers and the public. Although at an initial stage the model will be focused on the built environment, it is anticipated that future refinements would include topics related to transportation, logistics, industry, services and others.

The project will have two main axes of development: a diagnosis tool and a project tool. The diagnosis tool will capture some aspects of the complexity of existing cities, so that the interactions between urban elements become better understood, and successful patterns are identified. The output from the diagnosis tool would provide input to the project tool for exploring urban design alternatives.

## **Sustainable Energy Development at Regional and Urban Scales**

Portuguese Lead: E. Fernandes (FEUP)

MIT Collaborators: D. Wallace (ME/ESD), S. Connors (LFEE)

Development of an integrated modeling capability for decentralized energy planning, including externality evaluation and policy assessment is 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.

Furthermore, the benefits, disbenefits, and risks associated various mixes of local and imported energy sources need to not only be identified, but communicated to local decision makers. This is a critical extra level of research, since failure to communicate value and challenges associated with local energy system transformations will limit the extent to which they are implemented.

At MIT, Prof. David Wallace has been working with the AGS and the LFEE for the past several years on an internet-based model integration and analytic capability. Recent work extends this detailed linking of modeling tools and their associated databases to a more generalizable web framework, extending its utility to less skilled users.

In this prospective project, the DOME (Distributed Object-based Modeling Environment) suite of integration tools will be used to develop and test a distributed modeling environment allowing regional Portuguese and other potential users to explore not only novel energy supply and

demand options, but how they act collectively as greater numbers are deployed over time, and the energy infrastructure continues to grow and evolve.

### **Sustainable Energy Systems Planning: Systems Integration in Energy Supply, Delivery and Use — Angola Case Study**

Portuguese Lead: P. Ferrão (IST), A. Martins (ISEG)

MIT Collaborators: S. Connors (LFEE)

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. IST has some ongoing interactions with academic and government agencies in Angola that would make for a good initial case study for developing the information and tools.

This project overlaps with several of the others to offer a solid portfolio of energy system analytic tools that cover a range of detail, geographic scope, and duration. In developing nation contexts, detailed information is usually absent. However, beginning infrastructures are often small or limited. This project will develop a set of tools more focused on long-term energy sector evolution, including a strong educational component, as well as tools for visioning by the governmental agencies, NGOs, and the public-at-large. Angola represents an initial case study, but the goal is to structure the modeling environment such that it can be used by a diverse range of developing countries and regions.

### **Greenhouse Gas Reduction Policy Assessments**

Portuguese Lead: A. Martins (ISEG)

MIT Collaborators: D. Ellerman (CEEPR), J. Parsons (CEEPR)

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.

Working in concert with the more technologically oriented energy system projects, this project will do a comparative assessment of long-term GHG reduction policy and technology options, such as the EU emissions trading system (ETS), looking at fiscal policy, economic and demand impacts initially for Portugal. The goal would be to look at the macro and micro-economic impacts of alternative arrangements in order to inform the Portuguese government and public about how best to pursue long-term greenhouse gas reductions.

### **Marine Energy**

Portuguese Lead: A. Falcao (IST), L. Gato (IST)

Potential MIT Collaborators: C. Mei (CEE), D. Yue (Eng), M. Triantafyllou (ME)

With its coastline exposed to the Atlantic Ocean, 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.

A strong team among MIT and Portuguese engineers has already been put together to develop topics in the area of marine energy, who will collaborate with the Centre for Wave Energy and others in Portugal.

### **Discussion of Energy Projects and Programs**

The above proposed projects/topics in sustainable energy systems technologies, policies, and design and analysis, cover a broad range of existing and potential methodologies. As the research and education programs evolve, faculty at both MIT and Portuguese universities should take care to not only avoid over duplication (although some overlap to produce synergy is beneficial), but to identify under-represented areas in the project portfolio. Through case studies, including interactions with local and national stakeholders, such gaps will be identified. The program should encourage comments on these and other issues, and modify its research activities to address them.

For this reason and others, 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. This needs to be done in close coordination with the more focused, topical projects involving detailed case studies.

The research program is also 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.

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First Year Annual Program Plan in the Sustainable Energy Systems Focus Area  
(Sept. 2006 – Aug. 2007)

### **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, leading to a rapid, but focused, launch of the energy systems research and education program.

### **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 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.

### **Graduate Student Research Scale-Up**

Since new students arrive in the fall, it is proposed that the MIT side of the program begin with half the number of budgeted research assistantships (5 of 10) to collect information and other resources, and assist MIT and Portuguese faculty with defining the individual research projects, including where they leverage one another as well as the educational program. Selecting some students in August/September will ensure that access to students with superior qualifications related to the energy systems occurs. The remainder of the students will be identified over the course of the fall semester, and will begin the formative work associated with energy systems projects in January 2007.

*APPENDIX C*

*RESEARCH AND EDUCATION IN  
ENGINEERING DESIGN AND ADVANCED MANUFACTURING*

*MIT: JOEL CLARK AND CHRISTOPHER MAGEE  
PORTUGAL: ANTONIO CUNHA*

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## Engineering Design and Advanced Manufacturing General Assessment

### **Engineering Design and Advanced Manufacturing Systems – Objectives and Vision**

The Focus Area of “Engineering Design and Advanced Manufacturing” addresses an emerging worldwide challenge to foster “engineering design” as a major discipline and research area in engineering schools. In this respect, the leading experience of the “IST Design Studio” at Instituto Superior Tecnico should be acknowledged and it is strongly suggested that the University of Minho and the School of Engineering at the University of Porto, FEUP, follow that initiative and develop their own design studios. It is clear that this strategy will help Portuguese engineering schools achieve the Bologna objectives and foster a leading position in Europe, although it requires a major effort of all the schools in promoting engineering design practice. A possible network of those three university design studios (i.e., the recently announced REDIA network) with faculty and students at MIT should be promoted in close collaboration with industry (e.g. leading companies such as Simoldes, Auto-Europa and INAPAL Plasticos) and, in particular, through the involvement of the *Center for Excellence and Innovation in the Auto-Industry*, CEIA. The facilities of this engineering center will be important for the planned activities and CEIA can benefit from working with the four universities.

From the various discussions organized during the assessment exercise, as well as based on the previous involvement of faculty from MIT in the analysis of the Portuguese auto-industry (i.e., the work developed in 1998-2001 under the leadership of Prof. Joel Clark), it is clear that INTELLI (a Portuguese non-profit organization) should also play a significant role. Their leading role in prospective studies for the auto industry and in launching CEIA should be acknowledge and will certainly be of major interest for the success of future EDAM initiatives. INTELLI will be important in our collaborative effort, particularly working with industrial firms and other networking processes.

It should also be noted that the EDAM Focus Area has been planned as centered around the auto-parts industry, which is well justified by the emerging challenges of this sector worldwide and, in particular, in Portugal. Current trends worldwide in the automotive industry, namely at the level of OEMs, include the outsourcing of design skills for auto-parts companies and this requires Portuguese companies to build their own design capacity in order to compete globally. Again, the role of CEIA in fostering this strategy and in promoting industry-science relationships is acknowledge and should be supported. However, it is also clear that the EDAM Focus Area should be implemented beyond the auto-parts sector and include a diversified strategy, broadening potential applications, including aeronautics and medical devices. This will help Portugal explore new opportunities in emerging global markets.

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.

### **Assessment Process and Considerations**

Following the terms of the letter between the PT Government and MIT, signed in February 2006 an assessment was conducted of the potential for collaboration between Portugal and MIT in the area of Engineering Design and Advanced Manufacturing (EDAM). The assessment specifically identified two post-graduate educational programs and research focused on three selected sectors, automotive, aeronautics and medical devices as explained above. During the assessment, the EDAM Portuguese leader has made two multi-day visits to MIT to discuss various possibilities for structured interaction between MIT and the Portuguese universities. On the second visit, he was accompanied by multiple faculty members and research institute leaders from the three involved Portuguese Universities: UMinho, FEUP (Porto) and IST. Similarly, there have been two separate visits by MIT faculty who will be involved in the EDAM initiative to Portugal and both included meetings at each of the three Portuguese universities and at CEIIA. There have also been electronic comments on various drafts of long reports from which only some of the material is extracted in the summary given in the technical annex.

The assessment identified opportunities for MIT collaboration involving the Portuguese industry and scientific system. The assessment leaders agree that there are many opportunities for high quality research and development of advanced educational programs. We also agree on flexible processes to allow program evolution in a manner that can maximize the potential for the collaboration to be successful with respect to the mission, vision and objectives of the EDAM agenda. All of us also recognize that taken as a whole the mission, vision and objectives (see EDAM work plan) are very challenging and depend upon transformative actions throughout the Portuguese university system and wider society. Moreover, we do not believe there are foolproof methods to achieve such transformations for different contexts and cultures. Nonetheless, we believe these are the appropriate mission, vision and objectives for a Portugal-MIT EDAM agenda at this time and that with determination and persistence, much progress can be made towards the overall objectives of the MIT-Portugal Collaboration.

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### **General Program Overview**

The program is structured in two main areas:

- Human capital development (HCD)

- Educationally Coupled Research (ECR),

These two aspects of the program will be developed in parallel but under a very high degree of integration. As already mentioned, the EDAM program will be supported and developed by a large and multidisciplinary platform involving MIT, a group of Portuguese universities (UMinho, FEUP and IST), Portuguese R&D centers and Design Studios, and industrial companies from the EU and USA.

Although the envisioned education and research initiatives will benefit product and manufacturing industries in general, the program will be focused on three target sectors: automotive, aeronautics and medical devices.

### **Governance and Leadership**

The EDAM initiative is planned for a ten-year time frame and will be followed by specific management and evaluation schemes whose aim is to keep the program focused on the mission and objectives and to continuously integrate the two components of the program.

A systematic and structured decision process is critical to carry out this approach. The Academic partners, namely MIT and Portuguese universities, will interface with industrial partners 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;
- Establish knowledge-based development opportunities.

These two objectives will be continuously updated and will serve as input for determining the specific content in the two main program areas noted above. The EDAM agenda will be managed by the EDAM Executive Committee (EC) (reporting into the overall Portugal-MIT program 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 in the initiative 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 initiatives;
- to implement an ongoing process to look for new opportunities in the EDAM related technical and scientific areas.

The EC will maintain constant interaction with the Portuguese EDAM chairs.

## HCD and Education Initiatives:

Human resources development is perhaps the most critical dimension to fulfill the objectives of the agenda. It will involve the following set of integrated initiatives:

- a) New post-graduate initiatives
  - Advanced Course: Technology Management Enterprise (TME)
  - PhD program: Leaders Technical Industries - Europe (LTI)
- b) Short Courses and prospective seminars
  - Executive seminar series (ESS)
  - Research seminar series (RSS)
- c) Research-based PhD programs
- d) Research chairs
- e) Research opportunities for students (student exchange)
- f) Technology management fellowships
- g) Joint curricula development
- h) EDAM professorships

The most challenging of these initiatives, those in categories a) and b), are described further below.

## Technology Management and Entrepreneurship (TME)

The new post-graduate initiative in Technology Management and Entrepreneurship consists of advanced courses leading to a European 3rd Cycle of High Education Diploma (post-master level). The diploma will be granted jointly by the 3 Portuguese universities involved and will require a learning effort of 90 ECTS (European credit system):

### *TME Structure*

The TME Diploma will require coursework and a final report (or small thesis), in accordance to the following structure:

- 12 month program
- Two academic semesters (15 weeks each) – 60 ECTS
- Thesis (or final report) – 30 ECTS
- (could include an internship – industrial or at MIT)

### *TME Curriculum*

The curricular component will be based on 10 courses (6 ECTS each) on the following subjects:

- Product development (including customer assessment, quality, platforms strategy) - 2 (1)
- Innovation management and evaluation - 1 (0.5)
- Materials and technology selection and economics - 2 (1)
- Management for engineering - 2 (1)
- Engineering systems - (1)
- Additional topics (specific to each university) – 2

*Note: The number of subjects in each area follows the dash and the potential MIT effort for each area is given in the brackets.*

### **Assessment of TME**

The Portuguese faculty participants feel that this program would best fulfill its objectives if it can attract experienced engineers including a significant number from outside of Portugal (EU and beyond). 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 program. 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 multiple Portuguese university approach envisioned, as well as to be useful in finding ways to enhance the offering. It is important that such research be conducted and the program and communication/advertising strategy be adjusted accordingly before launching this beyond Portugal.

The MIT involvement indicated in the work plan is quite extensive and how this would be managed (video vs. on-site staff vs. short visits etc.) has not been determined.

### **Leaders for Technical Industries-Europe (LTI)**

This educational offering would be a PhD degree jointly granted by the three Portuguese universities. LTI PhD holders are expected to manage extensive product development programs involving emerging technological areas and industrial enterprises' innovation strategies.

The program should have between 10 and 15 students per year, with English as the working language. Each student will be associated with a company (European or American) involved in the program. The PhD dissertation will be developed under joint supervision of a MIT and a Portuguese academic staff member and will be influenced by an industrial tutor.

Candidates would be expected to have a European masters degree or a 1st cycle degree and relevant industrial practice (to be specified by the MIT-PT Education Committee). These courses will attract candidates with different prior education, so bridging courses in specific areas may be offered for students with specific needs.

### **LTI Structure**

This PhD program will have an expected duration of 42 months duration, with seven semesters:

- 4 semesters of coursework
- 2 industrial internships
- 3 final semesters devoted to the thesis
- The thesis will be developed in parallel with the curricular semester and the industrial internships.

### **LTI Curriculum**

The curriculum will be based on the following subjects, involving three main areas:

Foundations: (55% - 4 courses)

- Engineering (materials, processing technologies, ...) – 1 to 2 (1)

- Applied mathematics (incl. modeling and statistical) - 0 to 1
- Research methods – 1 (0.5)
- Informational – 0 to 1 (0.5)
- Economics - 0 to 1 (0.5)

#### Integration (35% - 3 courses)

- Operation management – 0 to 1
- Operation strategy – 0 to 1
- Managerial & Organizational – 0 to 1
- Product/Process development – 0 to 1 (0.5)
- Lean manufacturing – 0 to 1
- Plant visits
- Research oriented internship (to get acquainted with the industrial problem, collecting data and validating information/results)

#### Leadership and change management (10% - 1 course) – 1(0.5)

*Note: The number of subjects in each area follows the dash and the potential MIT effort for each area is given in the brackets.*

The students will be able to choose specific courses following guidelines to be defined (the curricular plan for each student will be approved by the LTI scientific committee).

#### **Assessment of LTI**

This program is also thought to best fulfill objectives if it can attract experienced engineers including 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 of Portugal need to be interviewed in some depth before making decisions about how to communicate and advertise this program. Such market research could explore the attractiveness of Portugal, the importance of the MIT connection, the desirability of a doctorate degree dedicated to large scale enterprise technology management, the attractiveness of the continuing education model, and the strengths and weaknesses of the multiple Portuguese university approach envisioned. It could also be useful in finding ways to enhance the program. The interviews should also explore the potential of companies to sponsor internships and contribute in other ways. It is important that such research be conducted and adjustments to the program and communication strategies be made before launching this program.

The MIT involvement shown in the work plan is quite extensive and how this would be managed (video vs. on-site staff vs. short visits etc.) has not been determined.

#### **Executive Seminar Series (ESS)**

These 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 program as partners for ECR initiatives.

Examples of potential topics for ESS are:

- technological trends and opportunities in automotive industry;
- new generation medical devices; and
- new challenges for supply chain management

### **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 project developing an integrated analysis of a selected opportunity towards a business plan.

The first seminar is planned for September 2006 and the assessment of it is given in the “launching actions” section of this report.

Examples of potential topics for RSS are:

- Advanced manufacturing solutions
- Translating research to practice
- Engineering design research
- Modeling manufacturing processes
- Lean manufacturing
- Systems change
- Innovation management

### **High Quality Research (HQR)**

In order to attain the program 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 human resources development. During the assessment, numerous potential opportunities for research projects have been identified and grouped by strategic “pillars” that support the industries and technological areas that are core to the EDAM initiative (design, innovative manufacturing, product development, supply chain management, aeronautics, automotive and medical devices). As the assessment progressed, preliminary concepts and potential Portuguese and MIT partners 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

These programs will be described in more detail in the workplan.

The research projects will be selected according to the following criteria

- 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 PT universities (preferably with more than one Portuguese university)
- Industrial participation

The project selection will be decided by the EDAM Executive Committee working within the overall MIT-Portugal Collaboration.

### **EDAM Launching Actions**

These initiatives are to be started in the short term to promote the EDAM agenda, attract potential students, as well as to develop and evaluate cooperative procedures between the participants in the EDAM consortium. In general, these actions are designed to give the Portugal-MIT EDAM program a running start at its official inception.

The launching initiatives are intended to take place during the last trimester of 2006 and will include two actions, an initial meeting of the Research Seminar Series (RSS) and a pilot research program. Each of these is described in the following sections.

#### ***Research Seminar Series (RSS) Launch***

The tentative topic for the first seminar is “Fostering knowledge-based manufacturing” with a focus on automotive, aeronautics and medical device industries. The target audience is potential post-graduate students (and researchers).

This first seminar 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 developed 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.). The tentative scheme consists of:

- 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; and
- 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).

### *Assessment of Research Seminar Series (RSS) Launch*

The assessment team believes this kind of active learning seminar could be very effective in launching the Portugal-MIT EDAM projects among Portuguese students and faculty. It is recognized that trying to achieve the entire agenda in a long week is not risk-free but the potential benefits of increasing overall confidence in the research and educational agenda are great enough to make the risks worthwhile. Successful completion of this seminar could lead to student and faculty word-of-mouth that would be invaluable to the program. However, as with all launching actions, poor execution could leave the program with an undeserved bad reputation and thus issues must be identified and addressed soon if the November event is to be conducted with sufficiently high quality. Some critical issues are: achieving sufficient participation of high quality students, finding a highly-functional site (with break out rooms, lecture room, social interaction space for informal interaction, library and high-speed Internet access), obtaining sufficient faculty involvement (particularly for the final-day presentations), obtaining funds to support the staff needed to achieve high productivity teams as part of the event, and getting started soon. A first step would be to agree on Portuguese and MIT chairs for this activity (Chris Magee or Joel Clark are possible MIT leads).

### *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: Rear lift gate (using Sharan 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 communications (based in microsystems) as alternative to cable systems;

Partnership: MIT, UMinho (IPC/Algoritmi/PIEP), FEUP (INEGI/IDMEC), IST(ICEMS/IN+), CEIIA, REDIA Network, and EU (Autoeuropa, Siomoldes) and USA (GM) companies.

Time frame: July 2006 to September 2007



*APPENDIX D*

*BIO-ENGINEERING SYSTEMS*

*MIT: DAVA NEWMAN*

*PORTUGAL: MANUEL NUNES DA PONTE, JOAQUIM CABRAL, AND  
MANUEL MOTA*

*Uses 8/28 RR/DN edited version*

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## 1. Summary and Technical Justification

This program will be run as 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. 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. 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. Fortunately, many of these groups already had established collaborations with MIT research groups, and these faculty-to-faculty relations serve as the basis to initiate the PT-MIT Bio-Engineering Systems focus area.

The specific emerging technologies targeted to complement and enhance existing Portuguese capabilities in biosciences and technology 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.

The three core Portuguese Universities in this program have a substantial share of all research being conducted in Portugal in bioengineering. Their graduate programs produce more than 50% of the new PhDs in the field. Moreover, the quality of the graduate students in the bioengineering area is one of the highest in all fields of engineering in the country. In fact, over the past few years, biological engineering and related undergraduate courses have consistently attracted the students with the best marks in the national University Entrance application contest for engineering, possibly among the 10% best students for all subjects. The three Portuguese Universities will offer a joint degree, enhanced by MIT collaboration in teaching and research. This program is expected to be able to enroll students of the highest quality. The three core research centers / Associate Laboratories involved in the program have a track record of strong cooperation with each other.

A small number of start-up, innovative companies is emerging from these research centers, but there is a feeling that opportunities are not being completely exploited due to lack of expertise outside of the laboratory. A program combining the best state-of-the-art information on bioengineering and related areas, with training in innovation management and bridging the gaps between ideas and implementation is sorely needed.

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## 2. Objectives

- Promoting new inter-institutional post-graduation training and opportunities, aimed at educating a new generation of leaders in bio-engineering technical innovation in Portugal.
- Creating new knowledge through R&D, targeting strong participation in the European Framework Research Program, FP7 (2007-2013).
- 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.

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## 3. The Collaboration and Leadership

### **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, or 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. Prof. D. Newman is leading the multi-faculty effort.

## Portuguese Universities and R&D Centers

The Portuguese Bio-Engineering Systems effort is lead by Prof. M. Nunes da Ponte. Three Portuguese Universities lead the program and will confer joint degrees:

- Universidade Técnica de Lisboa / Instituto Superior Técnico (UTL/IST) lead by Prof. J. Cabral.
- Universidade Nova de Lisboa (NOVA) lead by Prof. M. Nunes da Ponte.
- Universidade do Minho (UM) lead by Prof. M Mota.

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 Faculdade de Engenharia and INEB (M. Barbosa), that have on-going collaborations with MIT faculty (I. Yannas, R. Langer). The assessment will continue during the initial phase of the program.

The core research centers involved in the program are three Associate Laboratories (Laboratórios Associados<sup>2</sup>):

- *Instituto de Tecnologia Química e Biológica (ITQB)*

ITQB is an institute for graduate studies in chemistry and biology of Universidade NOVA, associated with two private research centers, the Gulbenkian Institute of Science (IGC), owned by the Gulbenkian Foundation, and IBET (Instituto de Biologia Experimental e Tecnológica), a platform for University-Industry collaboration.

- *REQUIMTE, Associate Laboratory for Green Chemistry*

REQUIMTE is an association between the Chemistry Department of Universidade NOVA and a research center of the University of Porto. Its core subject is sustainable chemistry. Its Chemical Engineering Division has a strong research record in Bioengineering.

- *Institute of Biotechnology and Bioengineering (IBB)*

IBB is a newly formed Associate Laboratory. Its core members are research centers of IST / Technical University of Lisbon and of University of Minho, with a history of close cooperation.

Additional expertise and collaboration with colleagues in Coimbra at the Laboratório Associado, Centro de Neurociências e Biologia Celular (CNBC) has also been identified. The CNBC and might also join the PT consortium in the future if/when resources allow. This possibility will be strengthened in 2007 when a Portuguese investigator currently at MIT returns to Portugal (L. Ferreira).

Other key collaborations have also been identified 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 (C Cooney) and the Sloan School of Management (T Allen, S Madnick, F Murray).

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<sup>2</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

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.

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#### 4. Description of the proposed program

The three Portuguese universities in the program enroll close to 300 students in biological engineering or related undergraduate courses each year. These are 3+2 year courses, awarding an M. Eng. Degree. These students will form a sound recruitment base, to which students from other national and foreign universities may be added.

The assessed Bio-Engineering Systems program has four components that are listed and detailed below (sections 4.1-4.4) including:

- 1 – *Advanced Studies Course (1<sup>st</sup> year)*
- 2 – *PhD program (entire curriculum and research)*
- 3 – *Joint Workshops and Symposia*
- 4 – *Mobility of students, research and teaching staff*

##### **4.1. 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. 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.

The goal is for 30 students per year to be admitted, with entrance exams and interviews. Each student follows six curricular modules (two weeks each, intensive). Four of these modules are core, mandatory modules, and the two remaining requirements are electives from a selection of three to four modules, which may change from year to year. Teams of lead faculty (typically one Portuguese and one MIT) have been identified and are listed below for curriculum development and teaching; numerous other colleagues have been suggested as lecturers/participants as well. The assessment recommends development and delivery of four core modules described below.

##### **4 mandatory core modules:**

###### ***M1. Innovation in Bioengineering (C Cooney / JA Girão FE/UNL)***

The class will consider the stages of innovation in biomedical technologies from generation of ideas, transfer to laboratory bench, commercialization, evaluation and dissemination.

Perspectives to be considered include natural science, engineering, management sciences and business development. A successful model and practice of innovation teams, or i-teams, will serve as the basis for teaching innovation. I-teams are teams of students working with selected technologies and focusing on building strategies for their commercialization. Identifying the

best path for commercializing a breakthrough technology is an iterative process, so the class is designed with checkpoints. Students will put forth hypotheses, test them, then go back and revise them based on customer inputs or other validations. At several points, teams will have the opportunity to present snapshots of their progress, receive feedback, and refine assumptions and plans. The goal of the class is to explore, identify and analyze the path “from idea to impact” for a chosen emerging technology. At the end of the course, teams will have identified the market(s) and application(s) with the most promise.

*M2. Bioprocess Engineering (Daniel Wang / Joao Crespo)*

Enzyme bioreactors; culture medium engineering; regime analysis; scale-up and scale-down; multiphase bioreactors; microbioreactors; bioprocess modeling and control; down-stream processing; integrated bioprocessing.

*M3. Computational Biosystems Science & Engineering (MIT faculty, Martha Gray / Eugenio Ferreira)*

Introduction to computational biology, emphasizing the fundamentals of nucleic acid and protein sequence and structural analysis, also including an introduction to the analysis of complex biological principles. Covers principles and methods used for sequence alignment, motif finding, structural modeling, structure prediction, and network modeling. This course is based on a multi-disciplinary approach for obtaining, modeling, organizing and managing large volumes of data, obtained experimentally or computationally. The central objective is to educate students in the techniques required to carry out research in this area.

*M4. Cell & Tissue Engineering (Robert Langer & Lino Ferreira / Joaquim Cabral)*

To give theoretical fundamentals on cell biology and bioreactor technology for animal and human cell culture and processing. Eight areas will be covered: 1. cell biology; methods for cell study; intracellular transport of proteins and secretion; cell adhesion and communication. 2. cell differentiation; regulation of gene expression in eukaryotes; transcriptional control; cell signaling; cell cycle; differentiation and development. 3. immune system: innate and adaptive systems. 4. animal cell culture; cell line immortalization; hybrid mass culture. 5. embryonic and adult stem cells; human cell processing; stem cells and tissue engineering. 6. bioreactors for animal cell culture; suspension and adherent cells; growth kinetics; bioreactors type. 7. tissue culture; cell expansion and differentiation in tissues. 8. biomedical applications.

*Elective modules*

The Assessment also recommends developing and offering a number of elective modules over the first two years of the program. Students would be required to take two electives. In any year three to four selected electives will be offered from a longer list of six to eight elective courses to be developed throughout the program. The electives might be jointly offered between Portuguese and MIT faculty lecturers and/or a Portuguese lead with MIT faculty providing a few lectures in person or via distance education technology. The assessment resulted in interest in the following:

*E1. Nanobiotechnology (HST faculty, Lino Ferreira (MIT/CNBC)<sup>3</sup>/ Joao Conde)*

The learning objective is for students to understand and apply the scientific and technological basis of nanotechnology. Areas of application that will be studied include: micro- and nanofabrication, MEMS and NEMS, microreactors, lab-on-a-chip systems, micro-total-analysis systems, carbon nanotubes, nanowires, AFM atomic and molecular manipulation, molecular motors, biological factories, nanoparticles, nanobiosensors and molecular electronics.

*E2. Biomaterials (Paula Hammond/ Rui Reis)*

Materials with special properties: structural materials with optimized mechanical properties, high performance hydrogels, materials responding to external stimuli, and materials with controlled biodegradation. Design for biomedical purposes.

*E3. Neuroscience: Molecular to Systems Neurobiology and Brain Diseases (S Tonegawa / A Coutinho)*

The proposed format is for two faculty to offer a two-week intense course (one week each) in neuroscience in Portugal (during January – MIT's between-semester Independent Activities Program). The subfields covered might include molecular and cellular neurobiology; systems neuroscience and brain diseases; and developmental neurobiology.

*E4. Biomedical Devices and Technologies (Dava Newman, Steve Massaquoi / Higinio Correia)*

The course allows students develop an understanding of the future potential and limitations of categories of medical devices and technologies. Topics include a mix of implantable devices, prosthetics, therapeutics and therapeutic delivery technologies, and the process of creating and transferring new medical technology from research to actual use.

*EX. Principles and Practice of Drug Development (Tom Allen / Manuel Carrondo)*

This module would likely be offered as a distance course from MIT to Portugal. Details for MIT faculty leads and compensation must be worked out during 2007 for possible delivery in the fall of 2007 or the fall of 2008.

Description and critical assessments of the major issues and stages of developing a pharmaceutical or bio-pharmaceutical. Drug discovery, preclinical development, clinical investigation, manufacturing and regulatory issues considered for small and large molecules. Economical and financial considerations of the drug development process. Multidisciplinary perspectives from faculty in clinical, life and management sciences, as well as industrial guests.

*EX. Strategic Decision Making in the Biomedical Business (Fiona Murray (distance learning possibility)/ PT*

Key strategic decisions faced by managers, investors and scientists at each stage in the value chain of the life science industry. Aims to develop students' ability to understand and effectively assess these strategic challenges. Focus on the biotech sector, with additional examples from the pharmaceutical and medical device sectors. Case studies, analytical models and detailed quantitative analysis. Intended for students interested in building a life science company or working in the sector as a manager, consultant, analyst or investor. Provides analytical

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<sup>2</sup> Laboratório Associado, Centro de Neurociências e Biologia Celular (CNBC), Coimbra

background to the industry for biological and biomedical scientists, engineers and physicians with an interest in understanding the commercial dynamics of the life sciences or the commercial potential of their research.

*EX. Functional Genomics and Bioinformatics (MIT BioEngineering?\* / Isabel Sá Correia), CSBi, CEnv.Health Unit (CEHS); New Tools for Genomics, Functional Genomics*

Experimental functional genomics, structural genomics, computational prediction of gene function, and models of complex biological systems. The course focuses on contemporary problems in functional genomics and systems biology, providing appropriate methods, in particular computational tools, to solve them. The underlying biological approach is characterized by large scale molecular profiling of living cells. The principles and methods used for sequence alignment and motif finding could be covered.

*EX. Molecular & Cell Therapies and Translational Medicine (HST? / Miguel Prazeres or Paula Alves)*

### *Second semester*

The second semester might best be used for short laboratory introductions and placements, to be chosen by students and advisors according to the student's professional interests; for conducting advanced studies sequential to lecture courses; and/or for continued participation in innovation teams (i-teams). These are teams of students working with selected technologies and focusing on building a go-to-market strategy for breakthroughs emerging from academic labs. Each team is guided by laboratory principal investigators, other faculty and mentors from the local business community.

## **4.2. The Doctoral PhD Program**

Eight to ten students will be selected for a PhD program in specific MIT / Portugal joint projects, with qualifying exams required. This part of the program will continue for 36–48 months past the Advanced Studies Course, and the doctoral program will accommodate extensive training periods at MIT (~ 12-18 months). MIT host laboratories with joint projects with Portuguese research groups have been identified to host about eight to ten Portuguese students in steady state. The intellectual areas as well as MIT host laboratories identified to date as promising for joint projects are listed below (D2-D8) with a goal of possibly hosting one to two students per lab. Depending on student interest and expertise, other lab placements are possible on an individual basis. Many MIT faculty have expressed interest in hosting Portuguese students and/or faculty visitors as well as performing joint research projects. A unique educational component of the doctoral program is a required doctoral student seminar entitled “Bioengineering Systems: Idea to Innovation” (D1 below).

### *D1. Bioengineering Systems: Idea to Innovation*

A capstone educational experience that serves as a requirement for the PhD program is recommended in the Assessment. This integrating bioengineering seminar would serve to add further depth and to motivate innovation and industrial practice in the Bio-Engineering focus

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\* Please note: All question marks (“?”) denote MIT faculty identified as collaborators by the assessment team, but the ? denotes that full participation and commitments of those MIT faculty are pending and must be finalized.



area. (MIT faculty member, Stan Finkelstein + / Manuel Carrondo + Joaquim Cabral).

Curriculum ideas for the “Integrating Bioengineering Concepts Seminar”

- Critical Literature Readings of bio-engineering, cells-through-systems, bioprocesses and medicine
- Health Care and Environmental Systems
- Technology Evaluation including scientific, technical, and business development decision-making
- Biomedical technologies and devices
- Others to be suggested and developed

### ***D2. Research in Innovation and Emerging Technologies***

J. Girão et al. (FE NOVA, FE/UNL)

MIT: Deshpande Center, Sloan POPI/CAMP (Consortium for the Advancement of Manufacturing Pharmaceuticals - Charles Cooney, Fiona Murray, Stuart Madnick (Sloan/ESD), collaboration with PoET (the Program on Emerging Technologies - Bioinformatics and Synthetic Biology, Ken Oye partnering with Drew Endy; Biomedical Devices and Technologies/Bioastronautics (Dava Newman, MIT Man Vehicle Laboratory; Neuroengineering, Steve Massaquoi)

### ***D3. Research in Biomolecular Science and Bioprocess Engineering***

Cláudio Soares, Helena Santos, Cecília Roque, Maria Carrondo (NOVA), Ângela Taipa (UTL), Miguel Gama (UMinho); *Bioreaction Engineering*: Susana Barreiros, Ascensão Reis (NOVA), António Cunha (IBET), Luís Fonseca, Manuela Fonseca (UTL), José Teixeira, António Vicente (UMinho); *BioSeparation, Purification and BioProcess Design*: Raquel Barros (UTL), João Crespo (NOVA), Manuel Mota, Armando Venâncio (UMinho)

MIT: Daniel Wang (MIT Institute Professor); Kristala Jones Prather (ChemE and BE) specializing in metabolic engineering, bioprocess engineering and synthetic biology

### ***D4. Research in Nanobiotechnology***

*Micro- and Nano-devices, BioMEMs*

Paulo Freitas, João Conde, Miguel Prazeres (UTL), Abel Oliva (NOVA)

MIT: Hammond Lab (Chem E) specializing in nanoscale design of biomaterials; HST-affiliated laboratories

### ***D5. Research in Cellular and Tissue Engineering***

*Vectors for gene therapy and vaccination*

Manuel Carrondo, Ana S. Coroadinha (NOVA), Miguel Prazeres, Gabriel Monteiro (UTL), Joana Azeredo (UMinho)

*Stem cells and regenerative medicine/ Cell and Tissue culture*

Joaquim Cabral (UTL), Rui Reis (UMinho)/Rosario Oliveira (UMinho), Paula Alves (NOVA)

*Drug delivery and targeting*

Raquel Barros (UTL), Miguel Gama (UMinho), Catarina Duarte (IBET)

MIT: Langer Lab, Lino Ferreira Institute Professor Robert Langer: performs research at the interface of biotechnology and materials science for drug delivery and tissue engineering.

### ***D6. Research in Computational and Systems Biology and Engineering***

#### *Computational and Predictive Models/ Expert Systems/Biosystems Engineering*

Francisco Lemos, Jose Menezes (UTL), Rui Oliveira, Joao Xavier, J.P. Mota (NOVA), Eugenio Ferreira, Antonio Vicente, Isabel Rocha (UMinho)

#### *Systems Biology/ Bioinformatics and Functional Genomics*

Isabel Sá-Correia, Arlindo Oliveira, Ana Teresa Freitas (UTL)

#### *Analysis of natural and artificial ecosystems*

Madalena Alves (UMinho)

MIT: Harvard-MIT Health, Sciences and Technology (HST) integrates science, engineering, and medicine to solve problems in human health; M. Gray, F. Bowman Bioengineering Division (BE). Doug Lauffenburger (?), Chair; other colleagues from BE and the CSBi (Center for Systems Biology) Bioastronautics, space life sciences and ecosystems D. Newman, L. Young (Man-Vehicle Laboratory)

### ***D7. Research in Biological Systems Imaging***

Ulrich Scheven, Regina Nogueira, Manuela Fonseca

MIT: Harvard-MIT HST (Martha Gray), Athinoula Martinos Center was established to foster biomedical imaging research that spans disciplines from basic research to clinical. Its mission is to build the next generation of functional imaging tools.

### ***D8. Research in Brain and Cognitive Sciences and Biology***

António Coutinho et al. (IGC)

MIT: Susumu Tonegawa (Picower Institute for Learning and Memory) The lead faculty of the Neuroscience module (E3 above) will also serve as research hosts for the Portuguese students under the research aspect of the Portugal-MIT program where the students will be at MIT for 1-2 years pursuing their doctorate jointly with their Portuguese faculty supervisor and university. Short lab rotations for students (during their first year) might also be possible in one of these labs.

## **4.3. 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. Lead faculty/instructors have been identified to develop the workshops during the first year.

***W1. The Business / Government Interface in Biosciences and Engineering***

Stan Finkelstein / Joaquim Cabral

This workshop will focus on decisions made by business in response to government regulations or to needs and opportunities to interact with the legal system. Prominent topics will include the European and American systems of pharmaceutical and medical device approval and registration; health care coverage and pricing of medical technologies and practices; and intellectual property policies. Faculty will offer a multidisciplinary perspective including life sciences, bioengineering, clinical medicine and health policy.

***W2. Leadership Development workshop***

MIT Dava Newman with possible collaboration with Sloan (Colleagues from MIT's Leadership Center)

The Leadership Development workshop will offer faculty and students a unique opportunity to develop leadership capabilities. An initial Outward Bound experience builds trust, teamwork and communications. Lectures and seminar sessions emphasize the characteristics of great leadership. Discussions explore leadership development for global citizens and emphasize creativity. The leadership learning experience will culminate in a personal leadership plan.

***W3/S. Synthetic Biology***

Planned workshops at MIT and in the US to which Portuguese faculty and students would be invited to participate. This theme also ties in with W1 above and we seek synergies among the workshops. (K Oye et al.)

**4.4. Mobility of Faculty and Students in the Bio-Engineering Systems Program**

Frequent exchanges of faculty and students will be required for course preparation, lecturing and research collaboration.

The goals for a steady state program include:

- 6 MIT researchers/professors visiting Portuguese Universities/year and others participating in lectures at MIT or to PT via videoconference
- 6 Portuguese researchers/professors visiting MIT/year
- 8-10 PT students at MIT/year (PhD + research partnerships)
- 4-6 MIT students visit Portuguese Universities/year

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**Bio-Engineering Systems Work Plan: Summary of activities 2007**

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 (possibly early June 2007)
    - Leadership Development 4-day workshop offered
  5. Evaluation/Review Committee
    - Membership to be nominated: Daniel Vasella, CEO of Novartis,  
Proposed nomination from MIT: Professor Torsten Wiesel, Nobel Laureate and former President of Rockefeller University; Professor and Chair, Robert Lowey, Georgia Institute of Technology, Dept. of Aerospace Engineering; Professor and Chair, Peter Cavanagh, Bioengineering Dept., The Cleveland Clinic Foundation

*APPENDIX E*

*EDUCATION IN MANAGEMENT*

*MIT: PAUL OSTERMAN, SIMON JOHNSON*

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## Assessment of MIT Collaboration in Education in Management in Portugal

The purpose of this report is to describe the results of the visit to Portugal of June 6 to June 9 by Professor Simon Johnson and Dean Paul Osterman both of the MIT Sloan School of Management. The goal of the visit was for the MIT delegation to meet with the Secretary of State for Science, Technology and Higher Education, Manuel Heitor, and with senior leadership in the four Portuguese business schools that have expressed their interest in the assessment to be performed by Sloan School of Management under the overall framework of the agreement signed in February 2006 between MIT and the Portuguese Government. The conversations centered on the possibility of joint projects between MIT Sloan and the universities in Portugal. This section reports the results of those conversations and it should be understood that it is in no way intended to be an evaluation of the schools or their programs. It refers exclusively to the potential for their collaboration with MIT Sloan School of Management.

The MIT Sloan School is deeply committed to its international character, both with respect to the origins and interests of its students and faculty as well as with respect to the content of its research and teaching. MIT Sloan has therefore found it to be rewarding and stimulating to work with universities throughout the world and the possibility of collaboration with Portugal is very attractive. In addition, MIT Sloan has found that when these engagements are properly structured it is able to add value to the educational and research missions of the international institutions with which it works.

For their part, the senior authorities in Portugal expressed an interest in collaboration with MIT Sloan as part of a broader collaboration with MIT in order to further enhance the teaching and research agendas of business and engineering education. The Portuguese Government emphasized to us their view that any successful collaboration would require the building up of critical mass and institutional links at a national level (i.e., involving at least two Portuguese universities) and that the content of the collaboration should be innovative in a way to have international visibility and be a major driver to attract students, researchers and corporate partners at an international level.

Over the course of the visit Professor Johnson and Dean Osterman met with the leadership (and in some cases faculty, students, and alumni) at the four institutions of higher education that contacted MIT Sloan previously, namely: the Faculty of Economics and Business at the Portuguese Catholic University (FCEE/UCP); ISCTE Business School (ISCTE); the Economics Faculty at Universidade NOVA de Lisboa (FE/UNL); and the School of Economics and Management at the Technical University of Lisbon (ISEG/UTL). In each case we were warmly received and in each case we found our visit to be informative and stimulating. We are very grateful to each of the institutions for the care that they put into organizing our visit.

On the basis of the visit we reached several tentative conclusions about what would make the most sense to consider in terms of a possible collaboration. These conclusions are described below. It is important to be clear, however, that these are tentative conclusions and from the MIT Sloan perspective no commitment is yet possible. (Similarly, we expect that no

commitment is yet possible from the Portuguese side). In order to move these conclusions forward MIT Sloan would need to take several substantive and several procedural steps. On substantive side we would need to identify specific faculty members who would be responsible for each of these possible initiatives and those faculty members would need to explore in greater depth the opportunities and challenges that would be involved. From the procedural side, MIT Sloan would need to go through some internal steps that we employ to gain faculty approval of any international initiative and then the precise terms of the agreement would need to be developed.

Attention is focused in this brief report on potential collaborative efforts that were considered of interest to both MIT Sloan and Portugal. No particular reference is made to proposals that were presented during the visits, but considered out of the scope of MIT Sloan. With these considerations in mind, our conclusions are the following:

We were impressed with many aspects of the schools with which we visited. The schools are proud of what they have achieved, and they are right to feel that way. However, in our view the best option would be for two or more of the leading business schools in Portugal to combine their MBA programs and work with MIT Sloan to develop a world-class international MBA. This proposal was clearly presented to all schools and particularly addressed with the Faculty of Economics and Business at the Portuguese Catholic University (FCEE/UCP) and the Economics Faculty at Universidade NOVA de Lisboa (FE/UNL). The reason for this conclusion is scale. Each of the schools in Portugal are anxious to improve their international profile, raise their quality, and achieve greater recognition. However, each MBA program is very small, and it is very difficult to build an internationally recognized high quality program that includes only forty or so MBA students and a correspondingly small faculty. Size alone limits impact and recognition, and it also limits quality in terms of breadth of faculty and of electives.

Despite what we believe are the clear advantages of such a merger we were given to understand by virtually all parties that for a set of historical and institutional reasons such a merger is not possible. We think that this is unfortunate but assuming that this is the case we identified three other good possibilities for collaboration with MIT Sloan.

First, people with whom we spoke indicated their interests in the fields of innovation in services, product development, and entrepreneurship. These substantive interests point towards a design with which MIT Sloan has considerable experience: joint programs between a business school and a school of engineering. There are several such programs underway at MIT. Based on our conversations we believe that a joint professional masters program is promising and worth further exploration. The Faculty of Economics and Business at the Portuguese Catholic University (FCEE/UCP) expressed an interest in launching such a program with Instituto Superior Tecnico (i.e., the School of Engineering of the Technical University of Lisbon). This should be explored as well as other possible relationships between other business schools and other schools of science and technology. The program should be targeted to a wide audience, including:

- i) Managers who want to promote an entrepreneurial spirit and innovative atmosphere within their companies;

- ii) Engineers and technology researchers who, in the course of their research projects, have developed new ideas with a high potential of commercialization and are looking for the skills needed to bring those ideas to the market and build strategic frameworks for growth;
- iii) High technology entrepreneurs who are striving to create a company, or to make their current company grow, but lack the skills and knowledge to move ahead;
- iv) Professionals from public or private institutions, such as incubators, R&D labs, university technology transfer offices, and science parks who want to significantly increase their skills in technology management and commercialization.

The exact nature of the program obviously requires more work as well as does the specifics of its auspice, but there are complementary strengths between the institutions and opportunities for creating an innovative design.

As noted above, before MIT Sloan proceeds interested faculty need to be identified and the administrative details of the collaboration need to be determined. However, it would also be useful for interested institutions in Portugal to develop a written proposal for collaboration among themselves and with MIT Sloan and to send that proposal to MIT Sloan. With this in hand arrangements could be made for a visit to MIT to discuss and develop the program.

Second, there is also broad interest in improving the quality of PhD management education. We do not believe that it makes sense at this point for MIT Sloan to get involved directly in a PhD program in Portugal. However, we do think that it would be stimulating and intellectually valuable for both sides to establish joint seminars in which cutting edge research was presented and discussed. A formal series of Research Seminars could be established, involving faculty, researchers and doctoral students from the various schools and research centers, in a way that would lead to further collaborative efforts among them. Finance is an obvious topic for such a seminar series (several of the schools are strong in this area) but there are others including Organizational Behavior and Entrepreneurship. These seminars would be jointly organized by faculty from Portugal and MIT and would be designed in such a way as to lead to useful next steps or continuing discussions. In order to raise the profile of Portugal in these areas, faculty from other countries might be invited as would Portuguese doctoral students. There may be opportunities to take advantage of distance learning technology in such an endeavor.

Again, with the appropriate caveats regarding MIT Sloan's procedural needs, it would be useful for interested Portuguese institutions to work together to develop a proposal for discussion with MIT Sloan.

Finally, Portuguese universities are currently in discussion with one or more units at MIT regarding initiatives in the field of bio-engineering and bioscience enterprise. MIT Sloan has a number of faculty with interests in the translation of scientific innovations in this area into products, as well as with the related public policy issues. In addition, MIT Sloan is an active participant in the MIT Center for Biomedical Innovation. There are, therefore, good possibilities for MIT Sloan to participate in the broader bio-engineering and bioscience enterprise project, depending on how it comes to be defined.



In conclusion, it is our view that there are important opportunities for collaboration between MIT Sloan and Portuguese higher education institutions. As indicated, this report is only the first step in determining whether such a collaboration is feasible, but we were very gratified with the warmth of our welcome and the quality of ideas and possible colleagues.

*APPENDIX F*

*ENGINEERING SYSTEMS ANCHOR PROGRAM*

*MIT: DANIEL ROOS*

*PORTUGAL: PAULO MANUEL CADETE FERRÃO*

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## Introduction

The engineering profession today faces a series of unprecedented challenges, many of them reflecting the changed context in which engineers practice. The converging forces of increased system complexity, and the social impact of technology – with the related need for increased leadership by engineers – call for a redefinition of engineering education and practice. Engineers today need to consider technological elements as part of a larger system, which means using approaches that significantly extend those based on the traditional engineering science paradigm.

Today, with products and systems increasing in size, scope and complexity, change is everywhere. Individual companies are developing production facilities at sites around the world, and relying on sophisticated supply chains to compete in the global marketplace. Production schedules are growing even shorter. Energy costs are increasing and security threats require companies to develop contingency strategies. Environmental concerns including global warming, air pollution, and recycling requirements are affecting the design of both products and processes. The Internet, meanwhile, is totally changing how engineers conceive, design and deliver systems, products and services.

The upshot of such changes is an era of unprecedented technological opportunity, with technology affecting all aspects of economic and social development, including large-scale systems for communications, transportation, health care, energy, and housing. These large-scale systems not only have critical technological components, but they also have significant enterprise and socio-technical level interactions that call for engineers in leadership positions to have training that goes beyond traditionally defined engineering disciplines. They are increasingly difficult to design and manage, to deliver on time and on budget, and to satisfy the multiple requirements of different stakeholder groups. And, after delivery they evolve over time; their behavior is emergent.

An engineering systems toolset and framework that encompass the enterprise and socio-technical aspects are needed to properly design, transform and operate these large-scale systems. For future engineers to succeed, they will need to be thoroughly versed in the principles and methodologies of engineering systems. Therefore, engineering systems knowledge is of strategic importance for Portugal, since it will be a fundamental requirement for economic and social development in the twenty-first century.

The Focus Area programs in the MIT Portugal relationship reflect an engineering systems perspective utilizing an integrative holistic approach. A similar integrative approach will be utilized not only in each Focus Area, but also across focus areas.

The Engineering Systems Anchor program provides a mechanism to explore these interdependencies and extend the methodological approaches in the various Focus Areas. The Anchor Program will examine frameworks and methodologies that cross cut the Focus Areas as well as new methods and research tools beyond those currently used in engineering. The anchor program initiatives will not only benefit Portuguese engineering education and practice, but they

will serve as a model for all of Europe. Portugal and MIT will work together developing engineering systems as a new field of study.

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## Objectives

The Anchor program 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 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 periodically to bring those working solely on one research project out of their Focus Area to think about the ‘big picture’ 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 simultaneously to accelerate 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 project researchers. Also, while a significant number of MIT and Portuguese faculty members and students will be involved in focused research, many more will not be directly involved. By creating an open collaborative community, we hope to bring some of them into the project as well, perhaps providing lateral thinking or ‘out of the box’ 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 design and operations of complex systems

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## Program Components

The following three initiatives are planned as initial components of the Anchor project.

*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 should consider publishing a book and/or presenting 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.

The Engineering Systems Anchor Program will be lead by Professors Daniel Roos at MIT and Professor Paulo Manuel Cadete Ferrão 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.

*APPENDIX G*

*SCHEDULE OF VISITS BY MIT FACULTY TO PORTUGAL*

***MIT-Portugal Assessment of Manufacturing and Design Collaboration***

***April 17-19, 2006***

***Visit to Portugal by***

**Joel Clark, Professor of Materials Science and Engineering Systems**

**Richard Roth, Director of Materials Systems Laboratory and Research  
Associate, Center for Technology, Policy, & Industrial Development**

***Hosted by***

**António Cunha,**

**Dean of Engineering, Universidade do Minho**

**Monday, April 17, 2006**

General Meeting

Antonio Cunha, Joel Clark, Richard Roth

Visit to FEUP (Univ. of Porto)

*Presentation of research programs at FEUP*

*Discussion led by Antonio Torres Marques*

*Numerous other researchers from FEUP, including representatives from INEGI, IDMEC, IBMC, INEB & INESC-Porto*

Tour of CEIIA – CE (Engineering Center)

**Tuesday, April 18, 2006**

Visit to University of Minho

*Presentation of research programs*

*Discussion led by António Cunha*

*Numerous other researchers from UMinho, including representatives from Polymer Engineering Department, Systems Engineering/Department of Productions and Systems (DPS) and Electronics Department*

Visit to Simoldes

*Discussion led by Julio Grilo, Director of Engineering Department*

*Also attended by Luis Reis (Inteli)*

Opening Ceremony for CEIIA – CE

**Wednesday, April 19, 2006**

Visit to Instituto Superior Tecnico, Lisbon (IST)

*Presentation of research programs*

*Discussion led by Prof. Manuel Freitas*

*Numerous other researchers from IST including representatives from various research groups within the Mechanical Engineering Department*

Visit to INAPAL

*Tour and Discussion led by Eduardo Matos, Industrial Director*

*Also attended by Luis Reis (Inteli)*

Executive Meeting with Manuel Heitor

*Also attended by António Cunha, Joel Clark and Richard Roth*



***MIT-Portugal Assessment of Energy Collaboration***

***May 17-18, 2006***

***Visit to Portugal by***

**Chiang Mei, Ford Professor of Engineering,  
Department of Civil and Environmental Engineering**

***Hosted by***

**Professor Antonio Falcao, Instituto Superior Technico,  
Lisbon, Portugal**

**Wednesday, May 17, 2006**

Lunch

*Professors Falcao, Sarmiento and Dr. Teresa Pontes (Director of INETI (Institute of Innovative Technologies))*

Meeting at Instituto Superior Technico

Overview of Wave Energy Research (1980-present) in Portugal and Europe  
*Professor Antonio Falcao, Professor Luis Gato, and Professor Antonio Samento (Director Wave Energy Center)*

Additional talks

*Professor Sarmiento and Professor Jose Sa da Costa .*

Discussions about potential MIT contributions to prediction of nonlinear interactions of wave power devices with large-amplitude waves

Dinner

*Professors Falcao and Sarmiento.*

**Thursday, May 18, 2006**

Seminar

“Long-period oscillations in harbor due to random and short incident waves with implications on wave power problem”  
*Chiang C. Mei, MIT Department of Civil Engineering*

Lunch at National Laboratory of Civil Engineering (LNEC)

*Dr. Francisco Carvalho, Director of LNEC*

Tour of the National Laboratory of Civil Engineering

Presentations on coastal engineering projects in Portugal including wave power *Dr. Rafaela Matos and others*

Preliminary discussion of collaboration

*Professors Paulo Ferrao, A. Falcao A. Sarmiento and L. Gato*

Dinner

*Professor Falco (IST) and Dr. Teresa Pontes (INETI).*

***MIT-Portugal Assessment of Energy Collaboration***

***May 21-22, 2006***

***Visit to Portugal by***

**David Marks, Morton and Claire Goulder Family Professor of Engineering Systems and Civil and Environmental Engineering and Co-Director, Laboratory for Energy and the Environment**

**Stephen Connors, Director, Analysis Group for Regional Electricity Alternatives, Laboratory for Energy and the Environment**

***Hosted by***

**Paulo Manuel Cadete Ferrão**

**Associate Professor, Center for Innovation, Technology and Policy Research, and Director, Section of Environment and Energy, Mechanical Engineering Department, Instituto Superior Técnico, Technical University of Lisbon**

Additional Portugal Participants: *Eduardo Oliveira Fernandes, Álvaro Martins, António Vallêra, António Falcão, Manuel Collares Pereira, Victor Santos, João Peças Lopes*

**Sunday, May 21, 2006**

10 am	Introductions
	MIT Energy research Presentation by <i>Dave Marks</i> and discussion of the MIT Energy Research Council Report
	Portuguese Consortium on “Sustainable Energy Systems” R&D strategies Presentation by <i>Paulo Ferrão</i>
	Discussion
Lunch	
1 pm	Discussion of future energy research in the context of the “Portugal- MIT Sustainable Energy Systems Institute” including potential niche areas, comparative strengths, research resources, needs, etc.
	Discussion of specific research/case study candidates for collaboration

6 pm           Adjourn

7:30 pm       Dinner

**Monday, May 22, 2006**

9:30 am       Strategies for preparing and educational program on “Sustainable Energy Systems”  
Presentation by *Paulo Ferrão*

Discussion

Discussion of the governance model to be adopted in the “Portugal- MIT Sustainable Energy Systems Institute”

12:30 pm      Lunch

2:15 pm       Meeting with the Secretary of State of Science, Technology and Higher Education, at the Ministry (Wrap up; next steps)

4:00 pm       Depart

***MIT-Portugal Assessment Progress and Contract Discussions***

***June 5-8, 2006***

***Visit to Portugal by***

**Daniel Roos, Japan Steel Industry Professor of Engineering Systems and Civil and Environmental Engineering and Founding Director, Engineering Systems Division**

**Renee Robins, Director of Special Projects,  
Technology and Policy Program**

***Hosted by***

**Manuel Heitor,**

**Secretary of State for Science, Technology and Higher Education**

**Monday, June 5, 2006**

- 9 am-12:30 pm Meeting with *Manuel Heitor and Carlos Zorrinho* (after 11.00am)  
Ministry of Science, Technology and Higher Education
- 12:30 pm Transportation Focus Area discussion – *João Bento (Coordinator of the Project)*  
Lunch and Visit at BRISA
- 2:45 pm Biotechnology Focus Area discussion – *Manuel Nunes da Ponte*  
ITQB
- 4:30 pm Manufacturing Focus Area site visits – *António Cunha*  
Visit to AUTOEUROPA site:  
- Bentley – Automotive Metallic Components  
- Inapal – SMC Composites
- 6:30 pm Dinner hosted by *António Cunha*

**Tuesday, June 6, 2006**

- 10 am Energy Focus Area discussion – *Paulo Ferrão*  
IST

1 pm                    Lunch with *Manuel Heitor*, Hotel Tivoli  
                              Joined by *Profs. Paul Osterman and Simon Johnson, MIT*

3 pm                    Meeting with *Manuel Heitor*  
                              Ministry of Science, Technology and Higher Education

**Thursday, June 8, 2006**

10 am                   Meeting with the United States Ambassador to Portugal  
                              USA Embassy

***MIT-Portugal Assessment of Management***

***June 6-9, 2006***

***Visit to Portugal by***

**Paul Osterman, Deputy Dean and NTU Professor of Human  
Resources and Management**

**Simon Johnson, Ronald A. Kurtz Professor of Entrepreneurship,  
Sloan School of Management**

**Tuesday, June 6, 2006**

Lunch with *Manuel Heitor, Ministry of Science, Technology and Higher Education, Daniel Roos, and Renee Robins*

Afternoon meeting with *António G. Mota, Dean, ISCTE Business School (and other colleagues)*

**Wednesday, June 7, 2006**

Meeting with *Fátima Barros, Director/Dean of the School of Economics and Management, FCEE-Católica Universidade Católica Portuguesa (and other colleagues)*

**Thursday, June 8, 2006**

Morning meeting with *José A. F. Machado, Dean, Professor of Economics, Faculdade de Economia, Universidade NOVA de Lisboa (and other colleagues)*

Afternoon meeting with *Vítor da Conceição Gonçalves, President of Executive Council Professor of Management. ISEG ^ Instituto Superior de Economia e Gestão, Universidade Técnica de Lisboa (and others)*

**June 9, 2006**

Executive Meeting with *Manuel Heitor*

Departure to the airport

***MIT-Portugal Assessment of Manufacturing and Design Collaboration***

***June 18-20, 2006***

***Visit to Portugal by***

**Christopher Magee, Professor of the Practice of Engineering Systems  
and Mechanical Engineering, and  
Director, Center for Innovation in Product Development**

**Warren Seering, Weber-Shaughness Professor of  
Mechanical Engineering and Engineering Systems**

**Randolph Kirchain, Professor of Materials Science and Engineering  
and Engineering Systems**

**Richard Roth, Director of Materials Systems Laboratory  
and Research Associate, Center for Technology, Policy,  
& Industrial Development**

***Hosted by***

**António Cunha**

**Dean of Engineering, Universidade do Minho**

**Sunday, June 18, 2006**

Delegation arrives at Francisco Sá Carneiro Airport

Transport to Guimarães

6 pm Meeting with University of Minho (EENG) and FEUP EDAM coordinators

8 pm Joint Dinner

**Monday, June 19, 2006**

8 am Departure from the Hotel

9 am Christopher Magee will give, at FEUP, an opening presentation at the IDDRG  
2006 Conference

9.30-10:30 am Visit to CEIIA

9:30 am Departure to INEGI



- 10.45-11.45 am Visit to INEGI
- 11.45 am Departure to INESC
- Noon-1 pm Visit to INESCPORTO
- 1.15-3.45 pm Snack – lunch, at room I105, during which formal presentations will be made as follows:
- Dean of FEUP (Carlos Costa)*
- Cluster Biomedical Engineering (Fernando Jorge Monteiro)*
- Cluster Electronics, Sensors, Networks and Supply Chain (José Manuel Mendonça)*
- Cluster Product Development and Engineering Design (António Torres Marques)*
- Discussion about Technology Management Enterprise Advanced Course with representative group of FEUP (Carlos Costa, António Torres Marques, José Manuel Mendonça, Luís Filipe Malheiros, João Falcão e Cunha, Alicibiádes Paulo Guedes, João José Ferreira)*
- Discussion about LIDAME PhD Program with representative group of FEUP (Carlos Costa, António Torres Marques, José Manuel Mendonça, Luís Filipe Malheiros, João Falcão e Cunha, Alicibiádes Paulo Guedes),*
- 3.45 -5.15 pm Parallel meetings as follows:
- Design for function and performance, manufacturing, pleasure and Eco-design, Product Design and Development management MIT delegation (Carlos Costa, António Augusto Fernandes, António Torres Marques, José Manuel Mendonça, Adélio Mendes, António Ferreira, Jorge Seabra, Renato Natal, Lia Patrício, José Sampaio, Adélio Mendes)*
- Aeronautic Solutions (Warren Seering with Pedro Camanho, Mário Vaz, António Ferreira, António Torres Marques, José Sampaio, Pedro Bandeira, Gil Gonçalves, Fernando Lobo Pereira, Adélio Mendes, Marcelo Moura, Lucas Silva)*
- Mobility concepts (Randolph Kirchain with José Manuel Mendonça, José António Ruela, Manuel Ricardo, João Tavares)*

Supply Chain Management (*Chris Magee with Alcibíades Paulo Guedes, José António Cabral, Ana Camanho, João Falcão e Cunha, José Carlos Caldeira, Jorge Pinho de Sousa, Américo Azevedo*)

5.30-6.30 pm Brief visit to specific laboratories at FEUP

7.30 pm Dinner offered by the Dean of FEUP

9.30 pm Departure to Guimarães

## Tuesday, June 20, 2006

MIT Engineering System Division representatives visit to UMinho School of Engineering

8:40 am Pick-up of MIT Delegation at Pousada da Oliveira

9 am Welcome and Institutional presentation of the School of Engineering  
*António M. Cunha* Eng. Mtg. Rm. A2-38

9:30 am Presentations of the Groups to be involved in the EDAM Agenda  
Eng. Mtg. Rm. A2-38  
DEP (IPC), *José Covas*  
DEP (3Bs), *Rui Reis*  
DEI (Algoritmi), *Higino Correia*  
DPS (Algoritmi), *J. Valério de Carvalho*

11:30 am Visits to department facilities and PIEP Departments

1 pm Lunch Room A2-35

2 pm Bilateral Meetings

4 pm Educational projects to be developed Eng. Mtg. Rm. A-38

5:15 pm Concluding Remarks Eng. Mtg. Rm. A-38

5:45 pm Departure to the airport

***MIT-Portugal Assessment of Transportation Collaboration***

***June 24-29, 2006***

***Visit to Portugal by***

**Joseph Sussman, JR East Professor of Civil and Environmental  
Engineering and Engineering Systems**

***Hosted by Dr. João Bento, Brisa-Auto-Estradas de Portugal,  
Member of the Board  
ASECAP, President***

**Monday, June 26, 2006**

- 9 am Pick-up at Hotel Tivoli and trip to Brisa headquarters
- 9:30 am–12:30 pm Meeting at Brisa with *Dr. João Bento and Jorge Sales Gomes, Director of Innovation and Technology*  
Visit to CCO – Centre for Operations' Coordination
- 1–2:30 pm Lunch with *Dr. João Bento* at Varanda do Ritz
- 3–6 pm Visit to IST, Dept. Civil Engineering & Architecture, Transportation Group  
Meeting with *Professor José Manuel Viegas*  
Visit to facilities and projects

**Tuesday, June 27, 2006**

- 8:30 am Pick-up at Hotel Tivoli and trip to REFER/RAVE  
(Rail and HSR Infrastructure Operator)
- 9–10:30 am Meeting with *Carlos Fernandes, Board Member (IST Faculty on leave of absence at REFER/RAVE), Francisco Melo Parente, International Affairs; Fernando Ribeiro Vendas, New Technologies Manager; and Jose M. Costa de Freitas, Deputy Operations Director*
- 10:30–10:45 am Trip to Siemens Portugal
- 11 am–12:30 pm Visit to facilities and projects with *Manuel Nunes, Head of Transportation, and Pereira de Oliveria, Director of Innovation Initiatives*

- 1–2:30 pm Lunch at Siemens Portugal with *Manuel Nunes, Carlos De Melo Riberro, Managing Director of Siemens of Portugal, and João Picoito, Senior Administrator*
- 4:30–6 pm Visit to LNEC, National Laboratory of Civil Engineering  
Meeting with *Dr. Carlos Pina, Head of the Concrete Dams Department; António Lemonde de Macedo, Head of the Transportation Department; and Elizabete Arsenio, Member of the Transportation Department*  
Visit to facilities and projects
- 8:30 pm Dinner with *Professor and Mrs. Henri-Ann Sussman, Dr. João and Professor Rita Bento* at Pestana Palace

**Wednesday, June 28, 2006**

- 8 am Pick-up at Hotel Tivoli and trip to Faculty of Sc.&Tech., University of Coimbra
- 10 am–12:30 pm Meeting with *Prof. Luís Picado Santos and Alvaro Seco, University of Coimbra*  
Visit to facilities and projects with sandwich lunch
- 12:45–2:30 pm Trip to Faculty of Eng., University of Porto
- 2:30–3:45 pm Meeting with *Professor Álvaro Costa, Coordinator of the Master in Transportation Program and Professors Maria Teresa Galvao Dias and Maria Antonia Carravilla*
- 4:00–5:30 pm Visit to EFACEC, Polo da Maia  
Meeting with *Mr. Mário Barbosa, Administrator, and Mr. Pero Moreira de Silva, Transport and Logistics Solutions Management Committee*
- 5:30–8:30 pm Return to Lisbon

**Thursday, June 29, 2006**

- 8–9:30 am Breakfast meeting with *Dr. João Bento and Professor JM Viegas*  
Hotel Tivoli
- 9:30 am Departure to Airport

***MIT-Portugal Assessment of Bio-Engineering Collaboration***

***June 27-28, 2006***

***Visit to Portugal by***

**Dava Newman, Margaret MacVicar Faculty Fellow,  
Director, MIT Technology and Policy Program, and Professor of Aeronautics  
and Astronautics and Engineering Systems**

***Hosted by Prof. Manuel Nunes da Ponte, Department of Chemistry, Faculdade  
de Ciencis e Tecnologia, Universidade Nova de Lisboa***

**Tuesday, June 27, 2006**

5-7 pm Bioengineering Focus Area Discussion

- Agenda Setting
- Remaining Issues
- Latest update on PT-MIT discussions

*Manuel Nunes da Ponte, Joaquim Cabral, Manuel Mota, Dava Newman*

8-11 pm Working Dinner

From Portugal: *Profs. Manuel Nunes da Ponte, Joaquim Cabral, Manuel Mota, Jose Girão (Professor of Economics), and Jose Girão (Professor of Economics and Vice-Rector, Universidade Nova de Lisboa)*

From MIT: *Profs. Dava Newman and Stuart Madnick and Dr. Stan Finkelstein*

**Wednesday, June 28, 2006**

9 am-4 pm Continued discussions

- Unresolved Issues
- Education Program
- Research placements

*Manuel Nunes da Ponte, Joaquim Cabral, Manuel Mota, the Dean from Univ. of Nova, Dava Newman, and Stan Finkelstein*

Noon-1 pm Working lunch

- Teleconference with *Prof. Charles Cooney and Ken Zolot of the Deshpande Center, MIT*
- Teams discussion

1-4 pm Concluding discussions focusing on Education, Research, Workshop, Final suggestions, and writing of Bio-Engineering Annex

*APPENDIX H*

*SCHEDULE OF VISITS BY  
PORTUGAL UNIVERSITY AND GOVERNMENT REPRESENTATIVES  
TO MIT*

**January 28-30, 2006**  
**Visit to MIT by**  
**Professor Manuel Heitor, Secretary of State for Science,**  
**Technology and Higher Education**

**Professor Carlos Zorrinho, National Coordinator of**  
**Lisbon Strategy and the Technological Plan**

**Sunday, January 29, 2006**

- 1-2:30 pm      Lunch  
*Richard de Neufville, Professor of Civil and Environmental Engineering and Engineering Systems*
- 2:30-4:30 pm      Advanced Materials  
*Joel Clark, Professor of Materials Science and Engineering Systems*  
*Randy Kirchain, Professor of Materials Science and Engineering and Engineering Systems*  
*Frank Field, III, Senior Research Associate, MIT Center*  
*Center for Technology, Policy and Industrial Development,*  
*Director of Education, Technology Policy Program,*  
*Senior Research Engineer, Senior Lecturer in Engineering Systems*  
*Richard Roth, Director of Materials Systems Laboratory and Research Associate, Center for Technology, Policy, & Industrial Development*
- 6 pm              Dinner  
*Daniel Roos, Japan Steel Industry Professor of Engineering Systems and Civil and Environmental Engineering and Founding Director, Engineering Systems Division*  
*Daniel Hastings, Dean for Undergraduate Education and Professor of Engineering Systems and Aeronautics and Astronautics*  
*Henk Sol, Prof.Dr., Professor of Systems Engineering and Founding Dean, Groningen University, the Netherlands*

**Monday, January 30, 2006**

- 8:30-10 am      Engineering Systems Division  
*Joel Moses, Institute Professor, Professor of Computer Science  
and Engineering Systems, and Acting Director,  
Engineering Systems Division*  
*Daniel Roos*
- 10-10:30 am      Media Laboratory  
*Bill Mitchell, Professor of Architecture and Media Arts and Sciences*
- 10:30-11 am      Sloan School of Management  
*Steve Eppinger, Deputy Dean, MIT Sloan School of Management and General  
Motors LFM Professor of Management Science and Engineering Systems*
- 11-12:30 pm      Leaders For Manufacturing/System Design and Management  
*David Simchi-Levi, Co-Director, Leaders for Manufacturing and System  
Design and Management Programs and Professor of Civil and  
Environmental Engineering and Engineering Systems*  
*Thomas Allen, Margaret MacVicar Faculty Fellow, Co-Director, Leaders for  
Manufacturing and System Design and Management Programs and  
Howard W. Johnson Professor of Management and Professor of  
Engineering Systems*  
*Donald Rosenfield, Director, Leaders For Manufacturing Fellows Program  
and Senior Lecturer, MIT Sloan School of Management*  
*Patrick Hale, Director, System Design and Management Fellows  
Program*
- 12:30-2 pm      Lunch  
*Daniel Roos*  
*Thomas Allen*  
*David Simchi-Levi*  
*Stuart Madnick, Professor of Information Technology and Engineering  
Systems and Co-Director, PROFIT Program*  
*Joel Cutcher-Gershenfeld, Senior Research Scientist, MIT Sloan School of  
Management and Executive Director, Engineering Systems Learning  
Center*  
*Joseph Sussman, JR East Professor of Civil and Environmental Engineering  
and Engineering Systems*  
*Joseph Coughlin, Director, Age Lab/Director New England UTC, Center for  
Transportation and Logistics*  
*Olivier de Weck, Robert N. Noyce Career Development Associate Professor of  
Aeronautics and Astronautics and Engineering Systems*  
*Donald Rosenfield, Director, Leaders For Manufacturing Fellows Program  
and Senior Lecturer, MIT Sloan School of Management*



*Kirkor Bozdogan, Principal Research Associate, Center for Technology,  
Policy, & Industrial Development*  
*John Carroll, Professor of Behavioral and Policy Sciences and Engineering  
Systems and Co-Director, Lean Aerospace Initiative*  
*Sharon Gillet, Executive Director & Principal Research Associate, Center for  
Technology, Policy, & Industrial Development*  
*Renee Robins, Director of Special Projects, Technology and Policy Program*

2–2:30 pm      *Lean Aerospace Initiative*  
*Kirkor Bozdogan*  
*John Carroll*

3–4 pm          *Phillip Clay, Chancellor*

4:15–5 pm      *Joel Moses and Daniel Roos*

5 pm            *David Marks, Morton and Claire Goulder Family*  
*Professor of Engineering Systems and Civil and*  
*Environmental Engineering and Co-Director, MIT Laboratory*  
*for Energy and the Environment*

**March 19-20, 2006**  
**Visit to MIT by**  
**Professor Manuel Heitor, Secretary of State for Science,**  
**Technology and Higher Education**

**Monday, March 20, 2006**

- 8-8:45 am      Breakfast  
*Richard de Neufville, Professor of Civil and Environmental  
Engineering and Engineering Systems*
- 9-9:30 am      *Provost Rafael Reif*
- 10-11 am      *Joel Clark, Professor of Materials Science  
and Engineering Systems*
- 11-11:45 am    *Joseph Sussman, JR East Professor of Civil and  
Environmental Engineering and Engineering Systems*  
*Fred Moavenzadeh, James Mason Crafts Professor,  
Professor of Civil and Environmental Engineering,  
Director, Center for Technology, Policy  
and Industrial Development, Director, Technology and  
Development Program*
- 11:45-1 pm     Lunch  
*Dava Newman, Margaret MacVicar Faculty Fellow,  
Director, MIT Technology and Policy  
Program, Professor of Aeronautics and Astronautics  
and Engineering Systems*
- 1-2 pm         *Yossi Sheffi, Professor of Civil and Environmental  
Engineering and Engineering Systems  
Director, Center for Transportation and Logistics  
Director, MLOG Program*
- 2-2:30 pm      *Christopher Magee, Professor of the Practice of Engineering  
Systems and Mechanical Engineering, Director, Center  
for Innovation in Product Development*
- 2:30-3 pm      *Joel Moses, Institute Professor, Professor of Computer  
Science and Engineering Systems,  
and Acting Director, Engineering Systems Division*

3-4 pm            *Ernest Moniz, Professor of Physics and Engineering  
Systems, Director of Energy Studies, Laboratory  
for Energy and Environment*

**Student Participation:**

*João Castro      Engineering Systems Division, PhD student*

*Marcus Dahlem    President of the Portuguese Student Association*

***MIT-Portugal Assessment of Manufacturing and Design Collaboration******March 23-24, 2006******Visit to MIT by******Prof. António Cunha,******Dean of Engineering, Universidade do Minho*****Thursday, March 23, 2006**

- 10:30 am      *David Simchi-Levi, Co-Director, Leaders for Manufacturing and System Design and Management Programs and Professor of Civil and Environmental Engineering and Engineering Systems*
- Noon            Lunch  
*Christopher Magee, Professor of the Practice of Engineering Systems and Mechanical Engineering, Director, Center for Innovation in Product Development*  
*Daniel Whitney, Senior Research Scientist, Center for Technology, Policy and Industrial Development, Senior Lecturer in Engineering Systems*
- 1:45 pm      *Marcus Dahlem, President of the Portuguese Student Association*
- 3 pm            Engineering Systems Division  
*Joel Moses, Institute Professor, Professor of Computer Science and Engineering Systems, and Acting Director, Engineering Systems Division*
- 4 pm            *Yossi Sheffi, Professor of Civil and Environmental Engineering and Engineering Systems and Director, Center for Transportation and Logistics Director, MLOG Program*
- 5 pm            *João Castro, Engineering Systems Division, PhD student*
- 6 pm            Dinner  
*António Cunha, Full Professor and Dean of the School of Engineering, University of Minho*  
*Kirkor Bozdogan, Principal Research Associate, Center for Technology, Policy, & Industrial Development*  
*João Castro, Engineering Systems Division, PhD student*

**Thursday, March 24, 2006**

- 9 am *Renee Robins, Director of Special Projects, Technology and Policy Program*
- 9:30-11:30 am *Randolph Kirchain, Professor of Materials and Engineering Systems*  
*Frank Field, III, Senior Research Associate, MIT Center for Technology, Policy and Industrial Development, Director of Education, Technology Policy Program, Senior Research Engineer, Senior Lecturer in Engineering Systems*
- 11:30-1 pm Working Lunch  
*Donald Rosenfield, Director, Leaders For Manufacturing Fellows Program and Senior Lecturer, MIT Sloan School of Management*  
*Patrick Hale, Director, System Design and Management Fellows Program*  
*Thomas Allen, Margaret MacVicar Faculty Fellow, Co-Director, Leaders for Manufacturing and System Design and Management Programs and Howard W. Johnson Professor of Management and Professor of Engineering Systems*
- 1-2 pm *Warren Seering, Weber-Shaughness Professor of Mechanical Engineering and Engineering Systems*  
*Eric Rebentisch, Research Associate, Center for Technology, Policy, & Industrial Development*  
*Donna Rhodes, Principal Research Engineer, Center for Technology, Policy, & Industrial Development*
- 2-2:30 pm Engineering Systems Division  
*Daniel Roos, Japan Steel Industry Professor of Engineering Systems and Civil and Environmental Engineering and Founding Director, Engineering Systems Division*

***MIT-Portugal Assessment of Energy Collaboration***

***March 30 – April 2, 2006***

***Visit to MIT by***

**Paulo Manuel Cadete Ferrão**

**Associate Professor, Center for Innovation, Technology and Policy Research,  
and Director, Section of Environment and Energy, Mechanical Engineering  
Department, Instituto Superior Técnico, Technical University of Lisbon**

**Thursday, March 30, 2006**

- 3 pm                      Engineering Systems Division  
*Daniel Roos, Japan Steel Industry Professor of Engineering Systems and  
Civil and Environmental Engineering and  
Founding Director, Engineering Systems Division  
Renee Robins, Director of Special Projects, Technology and  
Policy Program*
- 4 pm                      *David Marks, Morton and Claire Goulder Family  
Professor of Engineering Systems and Civil and  
Environmental Engineering and Co-Director, MIT Laboratory  
for Energy and the Environment*

**Friday, March 31, 2006**

- 9-9:30 am              *Chiang Mei, Ford Professor of Engineering, Department  
of Civil and Environmental Engineering*
- Noon-2 pm              *Luncheon and Presentation by  
Professor Paulo Manuel Cadete Ferrão, entitled, “Energy  
and Industrial Ecology Research in Portugal”  
for the Technology and Policy Program Faculty and Students*
- 2 pm                      *Frank Field, III, Senior Research Associate, MIT Center  
Center for Technology, Policy and Industrial Development,  
Director of Education, Technology Policy Program,  
Senior Research Engineer, Senior Lecturer in Engineering  
Systems  
Renee Robins*
- 3:30 pm                      *Ernest Moniz, Director of Energy Studies, Laboratory*

*for Energy and Environment, Professor of Physics  
and Engineering Systems*

4:15 pm

Engineering Systems Division  
*Joel Moses, Institute Professor, Professor of Computer  
Science and Engineering Systems,  
and Acting Director, Engineering Systems Division*

***MIT-Portugal Assessment of Management Collaboration***

***April 8-11, 2006***

***Visit to MIT by***

**Fernando Branco, Vice-Reitor**

**and**

**Professor Fátima Barros,**

**Dean of the School of Economics and Management**

**Universidade Católica Portuguesa**

**Tuesday, April 11, 2006**

- 9-10:30 am      *Daniel Roos, Japan Steel Industry Professor of Engineering Systems and Civil and Environmental Engineering and Founding Director, Engineering Systems Division*  
*Renee Robins, Director of Special Projects, Technology and Policy Program*  
*Steven Eppinger General Motors LFM Professor of Management Science and Engineering Systems Deputy Dean, Sloan School of Management*  
*Paul Osterman, Deputy Dean and NTU Professor of Human Resources and Management*  
*Simon Johnson, Ronald A. Kurtz Professor of Entrepreneurship, Sloan School of Management*  
*Fernando Branco, Vice-Reitor*  
*Professor Fátima Barros, Dean of School of Economics and Management*
- Noon-1:30 pm      Lunch  
*Simon Johnson*  
*Fernando Branco, Vice-Reitor*  
*Professor Fátima Barros, Dean of School of Economics and Management*
- 2 pm              Engineering Systems Division  
*Daniel Roos*



***MIT-Portugal Assessment of Transportation Collaboration***

***Friday, May 12, 2006***

***Visit to MIT by***

***João Bento***

***Brisa-Auto-Estradas de Portugal, Member of the Board  
ASECAP, President***

**Friday, May 12, 2006**

- 8:30-10 am      *Daniel Roos, Japan Steel Industry Professor of Engineering Systems and  
Civil and Environmental Engineering and  
Founding Director, Engineering Systems Division  
Renee Robins, Director of Special Projects, Technology and  
Policy Program*
- 10-11 am        *Air  
Richard de Neufville, Professor of Engineering Systems  
and Civil and Environmental Engineering*
- 11 am-noon      *Rail  
Joseph Sussman, JR East Professor of Civil and  
Environmental Engineering and Engineering Systems  
Carl Martland, Senior Research Associate, Department of  
Civil and Environmental Engineering  
Daniele Veneziano, Professor of Civil and Environmental Engineering*
- Noon-1:30 pm   *Lunch  
Moshe Ben-Akiva, Edmund K. Turner Professor of Civil and  
Environmental Engineering  
Joseph Sussman, JR East Professor of Civil and  
Environmental Engineering and Engineering Systems  
Hari Balakrishnan, Professor of Electrical Engineering  
and Computer Science  
Dan Roos  
Renee Robins  
Joseph Ferreira, Jr., Professor of Urban Studies and Planning*
- 2-3 pm           *Education  
Joseph Sussman, JR East Professor of Civil and  
Environmental Engineering and Engineering Systems  
Nigel Wilson, Professor of Civil and Environmental Engineering*

3-3:30 pm           Infrastructure  
*Fred Moavenzadeh, James Mason Crafts Professor of Engineering, Director, Center for Technology, Policy and Industrial Development, Director, Technology and Development Program*

3:30-4 pm           *Ichiro Masaki, Director of Intelligent Transportation Research Center, Microsystems Technology Laboratories*

4-5 pm               Engineering Systems Division  
*Joel Moses, Institute Professor, Professor of Computer Science and Engineering Systems, and Acting Director, Engineering Systems Division*  
*Daniel Roos*

*Renee Robins* will be at all meetings.

7 pm                 Dinner  
*Richard de Neufville and spouse*  
*João Bento, Brisa-Auto-Estradas de Portugal, Member of the Board ASECAP, President*

**Saturday, May 13, 2006**

9:30 am             Breakfast  
*João Castro, Engineering Systems Division, PhD student*  
*Marcus Dahlem, President of the Portuguese Student Association*

**MIT-Portugal Assessment of Manufacturing and Design Collaboration**

**May 14 –16, 2006  
Visit to MIT by  
EDAM Delegation**

**Sunday, May 14, 2006**

6:30 pm            *Dinner*

*Joel Clark, Professor of Materials Science and Engineering Systems*

*Frank Field, III, Senior Research Associate, MIT Center*

*Center for Technology, Policy and Industrial Development,*

*Director of Education, Technology Policy Program,*

*Senior Research Engineer, Senior Lecturer in Engineering*

*Systems*

*Richard Roth, Director of Materials Systems Laboratory and Research*

*Associate, Center for Technology, Policy, & Industrial Development*

**EDAM PT Delegation**

*António M. Cunha, Full Professor and Dean of the School of Engineering,*

*University of Minho*

*António Moreira, Assistant Professor, Technical University of Lisbon,*

*Instituto Superior Técnico*

*António Torres Marques, Full Professor and Head of department of*

*Mechanical Engineering and Industrial Management, University of*

*Porto*

*Carlos Bernardo, Full Professor, University of Minho*

*Fernando Jorge Monteiro, Full Professor, University of Porto & INEB*

*(Institute for Biomedical Engineering)*

*João F. Mamo, Assistant Professor, University of Minho*

*José H. Correia, Associate Professor, University of Minho*

*José Manuel Mendonça, Full Professor and President of the Board of*

*Directors of INESC Porto, University of Porto*

*Manuel Freitas, Full Professor and President of the Mechanical Engineering*

*department, Technical University of Lisbon, Instituto Superior Técnico*

**Monday, May 15, 2006**

8:30–10 am

*Breakfast*

*Christopher Magee, Professor of the Practice of Engineering*

*Systems and Mechanical Engineering, Director, Center*

*for Innovation in Product Development*

*Joel Clark*

10–11 am

*Yossi Sheffi, Professor of Civil and Environmental Engineering*

*and Engineering Systems, Director, Center for Transportation*

*and Logistics, Director, MLOG Program*

Noon-2 pm	Lunch
2-4 pm	<p><i>Frank Field, III, Senior Research Associate, MIT Center Center for Technology, Policy and Industrial Development, Director of Education, Technology Policy Program, Senior Research Engineer, Senior Lecturer in Engineering Systems</i></p> <p><i>Richard Roth, Director of Materials Systems Laboratory and Research Associate, Center for Technology, Policy, and Industrial Development</i></p> <p><i>Randolph Kirchain, Professor of Materials Science and Engineering and Engineering Systems</i></p>
4 pm	<p><i>Judith Tendler, Professor of Political Economy, International Development &amp; Reg. Planning Group, Department of Urban Studies and Planning</i></p>
6 pm	<p>Dinner</p> <p><i>EDAM PT Delegation</i></p> <p><i>Christopher Magee</i></p> <p><i>Thomas Allen</i></p> <p><i>Daniel Whitney</i></p> <p><i>Joao Castro</i></p> <p><i>Marcus Dahlem</i></p>

**Tuesday, May 16, 2006**

9-10 am	<p>Breakfast</p> <p><i>EDAM PT Delegation</i></p> <p><i>Christopher Magee</i></p> <p><i>Joel Clark</i></p>
10am-Noon	<p><i>Warren Seering, Weber-Shaughness Professor of Mechanical Engineering and Engineering Systems</i></p> <p><i>Daniel Whitney, Senior Research Scientist, Center for Technology, Policy and Industrial Development, Senior Lecturer in Engineering Systems, Research Staff</i></p>
Noon-1 pm	Engineering Systems Division Faculty Luncheon
1-2 pm	<p><i>Christopher Magee</i></p> <p><i>Joel Clark</i></p> <p><i>Daniel Roos</i></p>

*Joel Moses*

2-4:30 pm

Educational Programs

*Joel Clark, Professor of Materials Science and Engineering Systems*

*Daniel Roos, Japan Steel Industry Professor of Engineering Systems and  
Civil and Environmental Engineering and*

*Founding Director, Engineering Systems Division*

*Thomas Allen, Margaret MacVicar Faculty Fellow, Co-Director, Leaders for  
Manufacturing and System Design and Management Programs and*

*Howard W. Johnson Professor of Management and Professor of  
Engineering Systems*

*Donald Rosenfield, Director, Leaders For Manufacturing Fellows Program  
and Senior Lecturer, MIT Sloan School of Management*

*Dava Newman, Margaret MacVicar Faculty Fellow, Director, MIT  
Technology and Policy Program, Professor of Aeronautics and*

*Astronautics and Engineering Systems*

*Yossi Sheffi, Professor of Civil and Environmental*

*Engineering and Engineering Systems*

*Director, Center for Transportation and Logistics*

*Director, MLOG Program*

*Richard de Neufville, Professor of Civil and Environmental Engineering and  
Engineering Systems*

*Renee Robins, Director of Special Projects, Technology and Policy Program*

***MIT-Portugal Assessment of Management Collaboration***

***May 22, 2006***

***Visit to MIT by***

**ISCTE Business School**

**António Gomes Mota, Dean**

**Prof. Miguel Ferreira, Department of Finance and Accounting,  
Vice-President (CEMAF/ISCTE – Finance Research Center)**

**Monday, May 22, 2006**

- 11 am            *Daniel Roos, Japan Steel Industry Professor of Engineering Systems and  
Civil and Environmental Engineering and  
Founding Director, Engineering Systems Division  
Renee Robins, Director of Special Projects, Technology and  
Policy Program*
- Noon             Lunch  
*Paul Osterman, Deputy Dean and NTU Professor of Human  
Resources and Management, Sloan School of Management  
Simon Johnson, Ronald A. Kurtz Professor of  
Entrepreneurship, Sloan School of Management  
Renee Robins*
- 2 pm             *John Cox, Nomura Professor of Finance, Sloan School  
of Management*

**MIT-Portugal Assessment of Bio-Engineering Collaboration**

**June 6-8, 2006**

**Visit to MIT by**

**Manuel Nunes da Ponte, Department of Chemistry, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa**

**Joaquim Cabral, Technical University of Lisbon**

**Manuel Mota, University of Minho**

**Wednesday June 7, 2006**

10 am            *Dava Newman, Margaret MacVicar Faculty Fellow, Director,  
MIT Technology and Policy Program, Professor of  
Aeronautics and Engineering Systems  
Lino Ferreira, Post Doctoral Fellow, Department of Chemical  
Engineering  
Stan Finkelstein, Senior Research Scientist, Engineering  
Systems Division  
Charles Cooney, Professor of Chemistry and Biochemical  
Engineering, Department of Chemical Engineering  
Kenneth Oye, Associate Professor of Political Science and  
Engineering Systems  
Stuart Madnick, Professor of Information Technology and Engineering  
Systems and Co-Director, PROFIT Program*

Noon             *Lunch  
Thomas Allen, Margaret MacVicar Faculty Fellow, Co-Director, Leaders for  
Manufacturing and System Design and Management Programs and  
Howard W. Johnson Professor of Management and Professor of  
Engineering Systems  
Dava Newman  
Lino Ferreira  
Stan Finkelstein  
Charles Cooney  
Kenneth Oye*

1-3 pm          *Dava Newman  
Lino Ferreira  
Charles Cooney  
Kenneth Oye*

6:30 pm            Dinner  
*Lino Ferreira, Post Doctoral Fellow, Department of Chemical Engineering*  
*Stan Finkelstein, Senior Research Scientist, Engineering Systems Division*  
*Dava Newman, Margaret MacVicar Faculty Fellow, Director, MIT Technology and Policy Program, Professor of Aeronautics and Engineering Systems*  
*João Castro, PhD Student, Engineering Systems Division*  
*Marcus Dahlem, President of the Portuguese Student Association*  
*Manuel Nunes da Ponte, Universidade Nova de Lisboa*  
*Joaquim Cabral, Technical University of Lisbon*  
*Manuel Mota, University of Minho*

**Thursday, June 8, 2006**

8 am                Breakfast Meeting  
*Susumu Tonegawa, Director, Center for Learning and Memory, Professor of Biology, Picower Center for Learning and Memory*

9 am                *Frederick Bowman, Senior Academic Administrator, Lecturer, Mechanical Engineering, Harvard-MIT Division of Health Sciences and Technology*

10:30 am          *Robert Langer, Institute Professor, Germeshausen Professor, Chemical Engineering and Biomedical Engineering*

11:30 am          Lunch  
*Joel Moses, Institute Professor, Professor of Computer Science and Engineering Systems, and Acting Director, Engineering Systems Division*

1-4:45 pm        Technology and Policy Program 30<sup>th</sup> Anniversary Symposium



***MIT-Portugal Assessment of Energy Collaboration***

***June 6-7, 2006***

***Visit to MIT by***

**Professor Luis Gato,  
Department of Mechanical Engineering,  
Instituto Superior Technico**

**Tuesday, June 6, 2006**

Full-Day Meeting with *Professor Chiang Mei, Ford Professor of Engineering, Department of Civil and Environmental Engineering, Dick K.P. Yue, Associate Dean of Engineering, Professor of Hydrodynamics, Michael Triantafyllou, Professor of the Department of Mechanical Engineering*

9am-noon      Description of Portuguese efforts on wave energy

Lunch            (joined by *Stephen Connors, Director, Analysis Group for Regional Electricity Alternatives, Laboratory for Energy and the Environment*)

1-5 pm          Presentations by MIT faculty  
*Dick K.P. Yue, Michael Triantafyllou, and Chiang Mei,*  
Discussions were joined by *Dr. Yuming Liu, Principal Research Scientist,*  
*Department of Mechanical Engineering*

7 pm             Dinner at Chiang Mei's home.

**Wednesday, June 7, 2006**

Professor and Mrs. Gato attended MIT's graduation ceremonies.

*APPENDIX I*

*SUMMARY OF PORTUGUESE PUBLIC AND PRIVATE ORGANIZATIONS  
THAT HAVE BEEN INVOLVED IN OR  
CONTACTED DURING THE ASSESSMENT*

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## List of University Groups and Industry

In the scope of the **Engineering Systems** program, each one of the four thematic areas will integrate, from the Portuguese side, partnerships among several institutions of higher education. In addition, the companies listed below were identified during the assessment process.

- **Engineering Design and Advanced Manufacturing:**
  - Escola de Engenharia, Universidade do Minho (UM)
  - Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - Faculdade de Engenharia da Universidade do Porto (FEUP)

The project also includes the participation and interest of the following companies and institutions:

- VW Autoeuropa
- Simoldes
- INAPAL Plásticos
- Grupo DMF (medical devices)
- CEIA; Centro de Engenharia

The need to guarantee the involvement of EADS-CASA (from Spain) was also identified, as a way to stimulate the development of aeronautical components industries in Portugal;

- **Transportation Systems:**
  - Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - Faculdade de Engenharia da Universidade do Porto (FEUP)
  - Faculdade de Ciências e Tecnologia, Universidade de Coimbra (FCT/UC)

The project also includes the participation and interest of the following companies and institutions:

- BRISA
- EFACEC
- REFER; RAVE
- Siemens Portugal
- LNEC

The need to guarantee the involvement of ANA was also identified, as well as the process of development of the new airport of Lisboa;

- **Energy Systems:**
  - Instituto Superior Técnico, Universidade Técnica de Lisboa (IST)
  - Faculdade de Engenharia da Universidade do Porto (FEUP)
  - Instituto Superior de Economia e Gestão, Universidade Técnica de Lisboa (ISEG)
  - Faculdade de Ciências, Universidade de Lisboa (FCT/UL)

The project also includes the participation and interest of the following companies and institutions:

- REN
- AGNI Portugal
- BP Portugal
- Energy research groups from INETI, to be confirmed in the scope of the ongoing reform
- Centro de Energia das Ondas (Wave Energy Center)

The need to guarantee the involvement of EDP and GALP Energia was also identified, as well as a set of other companies such as EFACEC, Siemens Portugal, Tejo Energia, Turbogás, Enersis, Alstom, Generg, Bioelétrica, Valorsul, Climaespaço, Martinfer, Lisboa Gás;

• **Bio-Engineering Systems:**

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

The project also includes the participation and interest of the following companies and institutions:

- IBET/ITQB
- Instituto Gulbenkian de Ciência, IGC
- Alfama
- BIAL
- Biotecnol