CMU-PORTUGAL COLLABORATION:

BUILDING-UP A JOINT "INFORMATION AND COMMUNICATION TECHNOLOGIES INSTITUTE", ICTI

PROGRAM OVERVIEW
OCTOBER 2006

1. The Portuguese Government, through the Ministry of Science, Technology and Higher Education, is entering into a long-term collaboration with the Carnegie Mellon University (CMU) focusing on basic research and education. The objectives, framework and structure of the collaboration were developed during a six month assessment study conducted by CMU between March and September 2006, which concluded that the excellence of the research identified in Portuguese research centers throughout the assessment exercise recommends that CMU foster collaborations with Portuguese institutions. It refers that "…CMU has recognized from the beginning the goals of the Portuguese government and of the Portuguese Universities and Research Institutions, their quality and international reputation, as well as the excellence of their faculty.…we recognize that Universities and Research Institutions in Portugal are of high quality and are internationally recognized, and their faculty includes first-rate researchers. Our assessment also identified structural shortcomings and inadequate practices that constraint the activity of the faculty and limit the impact of these institutions. The success of the CMU-Portugal initiative will depend very much in recognizing these insufficiencies and confronting them directly. The administrations of several Portuguese Schools and Universities that we contacted consistently reassured us that they are prepared to address any identified deficiencies."

2. The CMU-Portugal Program will set-up a new international virtual institution, the **Information and Communication Technologies Institute (ICTI)**, which will be focused on Information and Communication Technologies, with two poles: ICTI@CMU, resident at CMU, and ICTI@Portugal, resident in Portugal. The Institute has a unified administration: a Board of Directors, an External Review Committee, and the directors of each pole.

3. The Portuguese Government intends to strengthen the country's knowledge base at an international level through a strategic investment in people, knowledge and ideas and the CMU-Portugal Program has been designed together with other international partnerships with renowned research and education institutions worldwide to contribute adequate funding to support the development of basic research and education and to foster a set of new and diversified institutional partnerships. It should also be noted that the goals of the overall operation include launching and promoting new research-based consortia at a national level and the CMU-Portugal Program contributes for this effort by involving 12 different universities, 8 schools of higher education, together with a large number of research centres and 4 Associated Laboratories. From CMU, there are 6 Colleges, 8 Departments, and 6 Research Centers and Institutes that have direct involvement in this Program.

4. The CMU-Portugal Program is organized in three dimensions: advanced degree programs, doctoral programs, and research projects. The advanced degree programs and the doctoral programs are dual degree programs, i.e., the graduates of these programs receive two degrees – one awarded by Carnegie Mellon University and one awarded by the Portuguese Partner University. As such, the programs are structured to satisfy the degree requisites required by Carnegie Mellon University and the Portuguese University awarding the degree. The advanced degree programs are delivered by Carnegie Mellon University in partnership with a Portuguese University. There are three such programs: i) Software Engineering, to be launched in partnership with Universidade de Coimbra, with faculty from other Portuguese Institutions; ii) Information Technology with focus on Information Security, to be launched by

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Faculdade de Ciências da Universidade de Lisboa, with faculty from other Portuguese Institutions; and iii) Information Networking, to be launched by Universidade de Aveiro in collaboration with Instituto de Telecomunicações, with faculty from other Portuguese Institutions. Doctoral degree programs include PhDs in Computer Science, Electrical and Computer Engineering, Language Technology, Mathematics, and in the area of Technological Change and Innovation. The research projects are in a number of areas and they complement well the educational programs.

5. The program will also involve CMU and Portuguese faculty, graduate students, post-doctoral associates and research staff. Visiting appointments of faculty at CMU and in Portuguese institutions will enrich the collaboration. Portuguese graduate students will spend time at CMU as visiting students and Portuguese students will be encouraged to apply to CMU for graduate degrees. The collaboration will involve opportunities for a significant number of professionals as shown in Attachment.

6. To develop the program in Portuguese institutions it is expected, besides the involvement of their faculty, the establishment of new contracts with invited professors and postdoctoral researchers with recognized merit in international basis, in a way that reinforces their education and research capability, involving a total of around 11 new professorships and 14 post-docs annually in the program. The program will also involve around 80 new PhD students and about 180 new professional master students over the 5 years.

7. The program envisages the collaboration of students, researchers and professors of Portuguese institutions with research teams at CMU, where the "ICTI@CMU" will be developed, involving around 40 professors, and 80 graduate students at CMU annually. All CMU professors, researchers and PhD students will have a co-affiliation with a Portuguese Institution.

8. The anticipated total public budget for the first 5 years of the CMU-Portugal partnership amounts to around 56 Million Euros (70 Million USD), from which 28 Million Euros are to fund activities at CMU (35 M.USD) and other 28 Million Euros are public funding to Portuguese institutions. In addition, private funding will be used to support activities in industrial affiliates and to support advanced professional education programs.

9. The Program will involve a new companion effort, "CMU-Portugal Industrial affiliates" with the goal of fostering new research consortia in collaboration with CMU and Portuguese research groups, leading to new frontiers of transatlantic collaboration in science and technology, as listed in Annex. Companies that, from the start, have a major role in the CMU-Portugal Program include the incumbent operator (i.e., PT: Portugal Telecom, SGPS), major national companies (Novabase) and multinationals operating in Portugal (including Siemens Networks Portugal) and a set of technology-based firms, including Critical Software, SkySoft Portugal, Altitute Software, Mulitcert, and Priberam Informática,among others. In addition, technology-based firms associated to INOVA-RIA (Associação de Empresas para uma Rede de Inovação em Aveiro) are also committed to participate in the Program.

10. The CMU Program Director is José Moura, Professor of Electrical and Computer Engineering. The Portuguese Program Director will be identifies in the coming months.

ANEXO I – "Technical Annex"

INFORMATION AND COMMUNICATION TECHNOLOGIES INSTITUTE
(ICTI)

A PORTUGAL-CARNEGIE MELLON UNIVERSITY PARTNERSHIP

List of Contents:

I.   Introduction

This *Technical Annex* summarizes the main research and educational activities and identifies the main partners associated with the preparation of the CMU-Portugal Program. It follows the detailed analysis described in the *Assessment of the CMU-Portugal Cooperation*, in the sequel simply referred to as *Assessment*.

From March to August 2006, following the signing public ceremony of the *Memorandum of Understanding* (MoU) between CMU and the Government of Portugal (see the *Assessment*) on March 11, 2006, numerous Portuguese researchers took the initiative to contact other researchers at CMU and discuss potential collaborations. This process involved a number of informal and formal contacts between Portuguese and CMU researchers and educators that occurred during this 6 month period coordinated by the CMU´s Assessment team, with most of them established based on the results derived from previous international research evaluations carried out by FCT. As a result, and after consolidation of their efforts, teams of Portuguese researchers and educators submitted a number of proposals of collaborations (as described in Volume II of the *Assessment).* The research and educational activities described in this Annex and that are the basis for the initial CMU-Portugal Program configuration were arrived at by this *bottom-up* approach.

The CMU-Portugal Program is open to new ideas and projects to be proposed by both Portuguese and CMU researchers, subject always to their critical assessment under the framework established by the Portuguese Government, through FCT and CMU.

As a result of the assessment phase, the CMU-Portugal partnership focus on ***information and communication technologies*** and, within this broad area, several education and research programs were identified by the CMU´s Assessment team to be of critical relevance to both CMU and Portugal. Now that the program areas were defined, <u>a new period of up to 3 months is open to define the terms of the consortia of Portuguese institutions to be involved, as well as to identify Principal Investigators and Program Coordinators for the various areas selected</u>.

Institutions that did not actively participated in the assessment phase, but have the necessary scientific capacity and human skills to be able to contribute for the success of this partnership, are welcome to develop new proposals and join the CMU-Portugal Program, subject to their critical assessment under the framework established with CMU and budget constraints.

In addition to this initial phase of identification of new potential partners in Portugal, the program will be <u>continuously open</u> to new ideas and the participation of scholars that may present their own proposals for evaluation on a yearly basis.

The goals of the CMU-Portugal Program are detailed in Part II. They include developing excellence, internationalization, and adoption of best practices at Portuguese Universities.

There are numerous Portuguese Universities and Research Institutions that have partnered with CMU in this Phase of the Program; these are listed in Part III. These include 12 Higher Education Institutions (including 11 Universities and 1 Polytechnic), 8 Faculties and Schools, 4 Associate Laboratories, 1 Applied Research Institute and 2 Governmental Agencies. From CMU, there are 6 Colleges, 8 Departments, and 6 Research Centers and Institutes that have direct involvement in this Program. These show the breadth of the CMU-Portugal Program and the high degree of enthusiasm demonstrated by the researchers and faculty in Portugal and at

CMU. Beyond these, a program of industrial affiliation has been planned and Portugal Telecom, the main Telecom operator in Portugal, together with other major national and multinational companies and a number of technology-based firms (e.g. Critical Software), has committed to the Program and in helping to define its strategy and direction.

Part V describes the four areas in which the main theme of Information and Communication Technologies is divided, namely: i) information networking and processing, that includes software engineering, information infrastructures security and dependability, language technology, and information networking; ii) critical infrastructures and risk assessment, that includes sensor networks, distributed decision making, distributed fusion, actuation, hardware, middleware, and software platforms, several relevant applications, and a major test bed, the "sensed campus;" iii) technology, innovation, and policy, that includes technical change and innovation and engineering and public policy in network and software industries; and iv) basic sciences, in particular, mathematics.

Part VI describes the institutional framework, namely, the virtual organization, the *Information and Communication Technologies Institute* (ICTI) that houses the CMU-Portugal Program. ICTI has two poles, one residing in Portugal, ICTI@Portugal, and the other residing at CMU, ICTI@CMU.

Part VII summarizes this Annex. The Appendix presents the description of the specific programs presented by the Portuguese Institutions.

II.   Goals

ICTI and the CMU-Portugal Program holds the promise of great impact on the educational and research system in Portugal. The CMU-Portugal Program has the following overall goals:

1. Create in Portugal first rate, internationally recognized, education and research programs in areas of great interest to the Portuguese society, including information technology, critical infrastructures, risk assessment, technology, innovation, and policy, as well as selected basic sciences, in particular, applied mathematics;
2. Promote in Portugal a new generation of technology-based companies, involving telecom operators, software companies and related institutions able to foster new economic activities at an international scale;
3. Recruit in the national and international arena a large number of students, post-docs, faculty, and researchers to join the education and research programs in Portugal;
4. Increase significantly the number of advanced degree graduates in a short period in highly relevant areas. Over 5 years, this collaboration will involve directly close to 300 post-graduate students (some 215 at the advanced degree level and 85 at the doctoral level);
5. Immerse the Portuguese institutions in a symbiotic environment with a leading international research institution;
6. Leverage the research carried out in Portugal with the research carried out at CMU in the context of these collaborations with a corresponding multiplicative effect;
7. Promote change and adoption of best practices by Portuguese Universities to make them nimble, to rapidly recognize and respond to new challenges and opportunities.

8. Establish a productive working relation between Universities and research Institutions and high technology companies.

III. Portuguese and CMU Partners

There are numerous Departments, Colleges, and Research Centers and Institutions at CMU and in Portugal involved in the CMU-Portugal Program. Faculty and researchers involved are drawn from the following (not necessarily complete) list, which will be completed during the course of the Program.

Portuguese Institutions at the launching phase:
a) Higher Education Institutions, including Universities and Polytechnics (12):
IPP: Instituto Politécnico do Porto
UA: Universidade de Aveiro
UALG: Universidade do Algarve
UBI: Universidade da Beira Interior
UC: Universidade de Coimbra
UCP: Universidade Católica Portuguesa
UL: Universidade de Lisboa
UMad: Universidade da Madeira
UM: Universidade do Minho
UNL: Universidade Nova de Lisboa
UP: Universidade do Porto
UTL: Universidade Técnica de Lisboa

b) Faculties and Schools (8):
EEUM: Escola de Engenharia da Universidade do Minho
FCEE/UCP: Faculdade de Ciências Económicas e Empresariais, UCP
FCTUC: Faculdade de Ciências e Tecnologia da Universidade de Coimbra, UC
FCUL: Faculdade de Ciências da Universidade de Lisboa, UL
FCTUNL: Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, UNL
FEUP: Faculdade de Engenharia da Universidade do Porto, UP
ISEP: Instituto Superior de Engenharia do Porto, IPP
IST: Instituto Superior Técnico, UTL

> **These faculties and schools integrate various research centres involved in the CMU-Portugal Program, including the following:**
> CAMGSD: Centro de Análise Matemática, Geometria, e Sistemas Dinâmicos
> CEMAPRE: Centro de Matemática Aplicada à Previsão e Decisão Económica, ISEG
> CISTER: Centro de Investigação em Sistemas Confiáveis e de Tempo-Real
> CISUC: Centro de Informática e Sistemas da Universidade de Coimbra
> CLUL: Centro de Linguistica da Universidade de Lisboa
> HULTIG: Center for Human Language Technology and BioInformatics, UBI
> IN+: Center for Innovation, Technology and Policy Research
> ISR Porto: Instituto de Sistemas e Róbotica do Porto
> L2F: Laboratório de Lingua Falada

c) Associate Laboratories (4)
INESC-ID: Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento
INESC PORTO: Instituto de Engenharia de Sistemas e Computadores do Porto,
ISR LISBOA: Instituto de Sistemas e Róbotica de Lisboa
IT: Instituto de Telecomunicações

d) Institutes of Applied Research (1)
ISQ: Instituto de Soldadura e Qualidade

e) Governamental Agencies (2):
FCCN: Fundação para a Computação Científica Nacional
UMIC: Agencia para a Sociedade Conhecimento

In addition to the above, companies that, from the start, have a major role in the CMU-Portugal Program include the incumbent operator (i.e., PT: Portugal Telecom, SGPS), major national companies (CTT: Correios de Portugal, S.A.) and multinationals operating in Portugal (including SIEMENS S.A. – Portugal) and a set of technology-based firms, including Critical Software S.A., SkySoft Portugal – Software e Tecnologias de Informação S.A., Altitude Software S.A., Priberam Informática S.A.. In addition, technology-based firms associated to INOVA-RIA (*Associação de Empresas para uma Rede de Inovação em Aveiro*) are also committed to participate in the Program. These companies will launch a program of "Industrial Affiliates" with ICTI, which will certainly attract other companies during the coming years.

CMU's Colleges, Departments, and Research Institutions at the launching phase:

Colleges (6):
CIT: Carnegie Institute of Technology, the College of Engineering at CMU
Heinz: Heinz School of Public Policy
HSS: Humanities and Social Sciences College
MCS: Mellon College of Science
SCS: School of Computer Science
Tepper: Tepper School of Business

Departments (8)
CEE: Department of Civil and Environmental Engineering, CIT
CS: Department of Computer Science, SCS
ECE: Department of Electrical and Computer Engineering, CIT
EPP: Department of Engineering and Public Policy, CIT
DMath: Department of Mathematics, MCS
INI: Information Networking Institute, CIT
ISRI: International Software Research Institute, SCS
LTI: Language Institute Technology, SCS
SDS: Department of Social & Decision Sciences, MCS

Research Centers and Institutes (6)
CEIC: Carnegie Mellon Electricity Industry Center
CenSCIR: Center for Sensed Critical Infrastructures Research, ICES, CIT
CyLab: CyberSecurity Lab
CTTEC: Center for Technology Transfer and Enterprise Creation
ICES: Institute of Complex Engineered Systems, CIT
ITRI: International Taiwan Research Institute

Programs (10)
MSE: Master of Software Engineering, ISRI, SCS
MSIN: Master of Science in Information Networking, INI, CIT
MSIT: Master of Science in Information Technology, INI, CIT
MSIT: IS: MSIT in Information Security, INI, CIT
PhD in CS: PhD in Computer Science, CS, SCS
PhD in ECE: PhD in Electrical and Computer Engineering, ECE, CIT
PhD in Engineering and Public Policy, EPP, CIT
PhD in LTI: PhD in Language Technology, LTI, SCS
PhD in Math, DMath, MCS
SETChange: Program in Strategy, Entrepreneurship and Technological Change

IV.   Information and Communication Technology: Main Themes

The major theme for the CMU-Portugal Program is *Information and Communication Technologies* (ICT). ICT has a major impact in the economic development and employment growth of the country. The impact of innovations in information and communication technologies cuts across not only industries such as computers and software, but many other sectors, as organizations in every area of activity adopt ever more sophisticated information and communication technologies. The CMU-Portugal Program on information and communication technologies is divided in four main areas: i) information processing and networking; ii) critical infrastructures and risk assessment; iii) basic sciences; and iv) technology, innovation and policy. In turn, these areas divide in several subareas. The areas and subareas are briefly described next.

Table 1 lists the main Portuguese Higher Education Institutions and research groups that are involved in the programs in the four areas, as well as the main Colleges, Departments, and Research Institutions involved from CMU with each major area. Table 2 refines the four areas into relevant sub-areas.

Area	Main Portuguese Schools, Associate Laboratories and Governmental Organizations at launching phase	CMU Departments and Research Centers at launching phase
Information Processing and Networking (IPN)	FC (UL), FCCN, FCT (UC), FCT (UNL), FEUP, INESC-ID, IST(UTL); IT, UA, UALG, UBI, FCCN, UMIC	ECE (CIT), CS (SCS), ISRI (SCS), LTI (SCS), INI (CIT), EPP (CIT), CenSCIR (CIT), CyLab
Critical Infrastructures and Risk Assessment (CIRA)	FEUP, INESC-ID, INESC Porto, ISEP(IPP), IST(UTL), ISR, ISQ	ECE (CIT), CS (SCS), EPP (CIT), CenSCIR (CIT), CyLab, Heinz, Tepper
Basic Sciences	FC (UL), FCT (UNL), IST(UTL)	Math (MCS)
Technology, Innovation, and Policy (TIP)	FCEE (UCP), IST(UTL), UM, UMIC, FCCN	ECE (CIT), EPP (CIT), SDS (HSS), Heinz, Tepper

Table 1 Information and Communication Technology: Main contributors to each major area of collaboration at the launching phase

Area	Sub-areas
Information Processing and Networking (IPN)	1. Software Engineering 2. Information Security 3. Information Networking 4. Language Technology
Critical Infrastructures and Risk Assessment (CIRA)	1. Sensing technologies and networks 2. Risk Assessment and management
Basic Sciences	1. Applied Mathematics
Technology, Innovation, and Policy (TIP)	1. Technological Change and Innovation 2. Engineering and Public Policy for network and software industries

Table 2 Information and Communication Technology: Main Areas and sub-areas

The following paragraphs briefly describe each of the main four areas.

1. **Area on Information Processing and Networking**.

This area includes several methodologies underlying the area of *Information Processing and Networking*, namely, information networking, language technology, software engineering, and information infrastructures security and dependability. This area involves partnerships of several CMU Departments and Research Centers and several Portuguese Universities and Research Institutions, as expanded next briefly.

Information Networking. Information networking is an area of great impact. The CMU-Portugal Program will partner Carnegie Mellon faculty drawn from CyLab, CenSCIR, ECE, and CS and several Portuguese research groups, including those at Universidade de Aveiro, INESC-ID, IT, and Universidade de Coimbra. There will also be a strong involvement with companies in the Portugal Telecom group. In a relatively short time, the Internet has evolved from a small research network used by researchers into a critical infrastructure that delivers a wide variety of services to hundreds of millions of users. Looking forward, we see a number of trends that are

likely to cause a similarly dramatic transformation in the next ten to fifteen years. First, while the Internet initially connected fixed, wired, computers, current trends suggest that in the near future, the vast majority of users will use wireless, mobile devices to access Internet services. These personal devices will be complemented by large numbers of non-computational devices, including sensors, actuators, and I/O devices, most of which will also be wireless. This means that wireless will be pervasive as an access network technology. At the same time, the service infrastructure is evolving from simple client-server applications into a sophisticated, highly distributed, highly resilient software platform that delivers personalized services to users. These trends suggest a number of important research areas in information networking. For brevity, we illustrate by focusing on research in wireless networking and the delivery of electronic and pervasive computing services.

The pervasiveness of wireless networks creates a number of challenges. A first challenge is at the network architecture level, where mobility, device heterogeneity, and variable network properties will require new architectural paradigms for access networks that can maintain high service quality for mobile users. These will include new proxy architectures, security and authentication mechanisms, naming and addressing mechanisms, and bandwidth provisioning techniques. At a lower level, the high demand for wireless bandwidth will put pressure on a scarce resource, namely the spectrum. This will require improved efficiency at all layers of the wireless protocol stack. This can be achieved by "autonomic" networking techniques that automatically optimize the network based on wireless channel conditions, traffic load, and node properties – manual network configuration and control will be impractical because of network complexity and dynamics. At the same time, architectural solutions such as spectrum-agile networking, in which nodes opportunistically and dynamically use available spectrum, can be used to increase network capacity.

In order to have impact, this wireless networking research agenda will have to be executed in a realistic, forward-looking broader systems context. The research will have to be driven by aggressive applications, such as high quality video stream and interactive games, and highly mobile users, including car-based wireless networks. Results will have to be evaluated using both large testbeds that combine a variety of devices and applications in a realistic way, and emulation techniques that allow a more controlled quantitative evaluation of individual techniques.

Another key challenge in information networks is the development of a scalable infrastructure that can deliver personalized electronic services in a resilient and secure fashion. Examples of such services include information retrieval, e-commerce, and video conferencing, but also more aggressive services such as virtual reality, remote medicine, and interactive games. Three factors combine to make the delivery of such services a very challenging problem: the complexity of services themselves, the dynamics and unreliability of the underlying hardware infrastructure (network, servers, storage), and the variable user demand.

This infrastructure will require a highly modular approach in which services are constructed from basic building blocks. Not only does this maximize the potential for software reuse, but it also opens the door for the automated configuration and optimization of network services using closed-loop control systems. The service infrastructure will include a set of monitoring probes that can quickly detect failures, changes in load, performance problems, and

intrusions. The output of these probes feeds into a diagnostic module that can identify the cause of the problem and formulate an automated response. This will require research of both an experimental and formal nature in a variety of areas, including distributed systems, software engineering, formal methods, and security.

Besides the delivery of the above-mentioned "electronic" services, we also envision a dramatic growth in the delivery of "physical" services that leverage the rapid deployment of sensors, actuators, and I/O devices. Examples of such "pervasive computing" services include location- and context-aware services, automated control of the user's physical environment (heat, light...), and personalized entertainment. The requirements in this area are similar to those mentioned above for the electronic services infrastructure: how can we deliver personalized services in a resilient and secure fashion. However, because of the localized nature of the services and the tight coupling to the physical world, the challenges are different. Questions include: how to manage the large volume of data, how to translate noisy, dynamic sensor data into useful information, how to engineer applications that continuously adapt to the user's context, and how to maintain privacy and security in this device rich environment.

Addressing these challenges requires an architecture that separates the responsibility of the different players using well-defined interfaces. At the lowest layer, we need techniques for the configuration and management of the sensor networks so they can deliver the sensor data to a set of information services in a timely fashion. The sensor data will be filtered and combined with data from other sources (e.g. calendar and other databases) to create context information that will be tagged with meta-data, e.g. to time stamps, precision, etc. This will effectively create a distributed database of context information that can be used by a variety of applications. If designed right, this architecture and its component can be reused in many environments, e.g. office, home, etc. This pervasive computing infrastructure can be built, deployed, and maintained by commercial service providers, similar to the electronic services infrastructure.

The CMU-Portugal Program includes an advanced degree program, a Professional Master of Science in Information Networking, to be offered in partnership by the University of Aveiro and the INI at CMU. Other potential partners, namely for research activities, should be defined during the first 3 months of the Program. A PhD and a research component to be pursued in partnership with the ECE Department at CMU complement this program.

Language Technology. The CMU-Portugal Program on language technology involves a consortium of Portuguese Research Centers and Universities and the Language Technology Institute (LTI) at CMU. The LTI formed about 20 years ago, first as a research center, and then as an academic department in the School of Computer Science, is the leading center in language technologies in the world. The consortium in Portugal, which we will refer to as the L2F consortium, includes the Laboratório de Sistemas de Lingua Falada (L2F) (language to speech) at INESC-ID, IST, the Center of Linguistics of Universidade de Lisboa (CLUL), the group of linguistics of Universidade do Algarve (UALG), and the Center for Human Language Technology and Bioinformatics (HULTIG) of the Universidade of Beira Interior (UBI). In addition, a close cooperation is expected with the LINGUATEC network established in Portugal through FCCN (i.e., the national foundation for scientific computation, through the "Centro de Recursos Distribuído para o Processamento Computacional da Língua Portuguesa"). The collaboration between L2F and CLUL dates back to the early nineties, forming the basis for a

truly interdisciplinary cooperation (engineering/linguistics). The cooperation with UALG and HULTIG is much more recent and, despite their much smaller size in terms of human language technologies, is also very active.

There are a number of areas of strong common interest that will be pursued: computer aided language learning (CALL), speech-to-speech machine translation (S2SMT), speech recognition, speech synthesis, dialogue systems, summarization, and topic detection and tracking. In particular, the CMU-Portugal Program will pursue two very important multilingual research projects: in computer aided language learning (CALL); and speech-to-speech machine translation (S2SMT). These projects will involve at least two languages, one of them being Portuguese, the target language for the CALL system to be developed and either the source or target language (or both) for the MR system. The other language is either English or Chinese (Mandarin) or both. Chinese is of particular interest to both parts, because of the existing expertise at LTI with language technologies for Chinese and the great demand from China for products involving Portuguese.

The CALL research project will involve the development of a Portuguese version of the REAP project (Reader-Specific Lexical Practice for Improved Reading Comprehension), currently in progress at LTI at CMU, and research in the associated topics. This research involves a variety of language technologies to help native or non-native students learning to read. Examples include searching for appropriate authentic documents for students to read according to reading level, topic, vocabulary list, and other teacher-specific criteria, with a search engine that finds text passages satisfying very specific lexical constraints, selects materials from an open-corpus, thus satisfying a wide range of student interests and classroom needs, and models an individual's degree of acquisition and fluency for each word in a constantly-expanding lexicon so as to provide student-specific practice and remediation. The challenges posed by such a system enable research on a wide range of very difficult reading comprehension topics.

The speech-to-speech machine translation (S2SMT) research area, one of the most strategically relevant areas for the Portuguese consortium, will investigate a Portuguese-to-English/Chinese translation system (or vice-versa) that deals with one of the two challenges of current S2SMT systems: the need for disfluency removal on the speech input side, or the inadequacy of current translation systems to produce text that is fit for a synthesizer, i.e., that can be read in a naturally sounding way. We will investigate the use of statistical based machine translation approaches, but also a hybrid approach, developed by LTI, that starts from a relatively small parallel elicitation corpus and uses rule induction. Research in S2SMT is crucially dependent on several core technologies from speech recognition to machine translation, to text-to-speech synthesis, including voice morphing.

These two projects provide a focus for the proposed research; through them the collaboration will explore the main core areas in language technology.

The CMU-Portugal Program includes a PhD degree component offered in partnership between IST (DEEC and DEI) and LTI at CMU, and research projects in language technologies between the L2F consortium and LTI. Other potential partners in Portugal will be defined during the initial 3 months of the Program.

Software engineering. Today's world of rapidly changing software technology underscores the need for software engineering research and education to deal with new methods, tools, platforms, user expectations, and software markets that address the large scale problems that dominate current relevant applications. The programs envisaged in this CMU-Portugal cooperation target the further development of the educational and research programs at Portuguese Universities in IT and software engineering, namely, with Universidade de Coimbra, through its Faculdade de Ciências e Tecnologia, among other Portuguese schools. These programs hold the potential for a significant impact on traditional large companies consumers and producers of software (e.g., Portugal Telecom) and its associates but also on the nascent Portuguese software industry. In the last decade, several software related companies (e.g., Critical Software SA, Wit-Software, Flor-de-Utopia, Insert-Solutions, Netvita, Bookmark, to name a few) have initiated their activity around the University of Coimbra, their Centro de Informática e Sistemas da Universidade de Coimbra (CISUC), and Instituto Pedro Nunes.

The CMU-Portugal Program will include an advanced educational program, the Professional Master of Software Engineering offered in partnership by the University of Coimbra and ISRI at CMU, as well as research projects in software engineering. Other potential partners in Portugal, namely for research activities, will be defined during the initial 3 months of the Program.

Information infrastructures security and dependability. Dependability and security are very important fields in information technology. Dependability attempts to keep systems working correctly despite the occurrence of accidental faults or defects, while security addresses problems arising from malicious hazards, attacks, or intrusions. Because systems are increasingly so complex, dynamic, and interdependent, it is no longer possible to consider these two problems, security and dependability, independently. In a modern perspective, security and dependability are concerned with both information and infrastructure. Of particular interest, are critical information infrastructures, their pervasive interconnection, and the progressive intertwining of "normal" and embedded systems.

The Internet has been transformed by the proliferation of embedded, inconspicuous, and often mobile devices that cluster and un-cluster in ad-hoc fashion. Many are connected to physical artifacts, like in smart homes or ambient intelligence. This reality includes wifi-enabled small computers, wireless sensor and actuator devices, network-enabled embedded gadgets that are present in every day life, but also large scale systems like the telecom network, or the power grid that are permeated with computers that introduce digital control. This new reality poses major challenges from a security, dependability, and resiliency points of view against threats that are not known à priori. These threats include accidental hazards or faults and malicious attacks or intrusions. Given the complexity of these modern large scale infrastructures, the educational and research program on security and dependability will pursue the development of rigorous design methodologies for fault and intrusion prevention, tolerance, and detection.

The proposed educational and research program will address both security and dependability on an equal footing. The collaboration between CMU and Portuguese Universities, in particular, as envisaged with Faculdade de Ciências da Universidade de Lisboa, FCUL, involves coordinated education and research components to address dependability and security in these critical information infrastructures. Of significance is an advanced degree, a Professional

Master of Science in Information Technology: Information Security, to be offered in partnership by FCUL and FCUC, among other potential partners in Portugal, and INI at CMU. This program is complemented by a PhD program offered in partnership between FCUL and FCUC, among others, and the Departments of ECE and CS at CMU, and research projects in the areas of security and dependability. Other potential partners in Portugal, namely for research activities, will be defined during the initial 3 months of the Program. In particular "FCCN – Fundação para a Computação Científica Nacional," the national foundation for scientific computation, will actively participate in this area, working in close collaboration with university groups.

2. **Area on Critical Infrastructures and Risk Assessment**.

The CMU-Portugal Program will pursue research initiatives and a PhD program between a consortium of research institutions in Portugal with strong interests on critical infrastructures and risk assessment and CenSCIR at Carnegie Mellon. CenSCIR is an interdisciplinary Center with faculty drawn from ECE, CEE, EPP, and the Tepper School at Carnegie Mellon. The initial consortium in Portugal includes ISR Lisbon, INESC-ID, both involving faculty at IST (UTL), CISTER at ISEP (IPP), and ISQ. Besides the main effort integrated in a single proposal, see Appendix, this area includes a second effort on static and mobile sensor networks involving faculty from FEUP/UP, as well as faculty from CenSCIR, CS, and the Robotics Institute at CMU. This effort will be closely coordinated with the overall effort on critical infrastructures and risk assessment. The participation of INESC Porto and other faculty at FEUP is also expected, among the potential active involvement of other leading Portuguese research institutions.

Infrastructures are of major significance in the economy of a country. For example, infrastructures like bridges, airports and harbors, water distribution systems, water treatment plants, power distribution systems, telecommunication network systems, commercial and industrial facilities, among many others run into the hundreds of billions of dollars. In spite of these enormous investments and their importance to the economy, countries are not good stewards of their infrastructure, letting it degrade often unchecked with major disasters leading to loss of human life and grave economic consequences. Recall the Hintze Ribeiro bridge collapse on March 4, 2001, in Entre-os-Rios, where 59 people died. Just in the year of 2003, on August 14, in less than 8 minutes, a blackout, twice as large as any in the US history, affecting 250 power plants and 62 Gigawatts of generating capacity, left over 50 million people in the US Northeast and Canada without electrical power (*Conservation Update*, Sep-Oct 2004). Quoting from the skyscraper city website, two weeks later, on August 28, a vast blackout blew out a fifth of London's power for half an hour during evening rush hour; the British electricity network provider called this its worst failure in more than 10 years. About 4 weeks later, on September, a broad power blackout striked southern Sweden and eastern Denmark, crippling industry, airports, trains and bridges. According to official estimates, the outage may have hit up to five million consumers, including one to two million in Sweden and between two and three million in Denmark. Five days later, a power cut crippled most of Italy in one of its worst blackouts. Only the island of Sardinia and small pockets of the mainland escaped the outage. At its peak infection rate the MyDoom internet virus affected 1 in 12 e-mails, and it is estimated that internet viruses cost businesses 55 Billion dollars a year in 2003, up from 20 and 13 billion in 2002 and 2001,

respectively (*Computer World*, January 2004). Recent developments have heightened the security concerns of critical infrastructures from airports, to harbors, to water distribution systems, to public transportation systems.

Instrumented infrastructures: sensor networks. Recent technological developments in large-scale electronics and RF integration make it feasible and practical to address the security, continuous monitoring, and rationale management of these critical infrastructures, by making very cost effective to fabricate sensing platforms that are autonomous, and have computing, sensing, and wireless communications transceivers capabilities. These inexpensive platforms are easily deployable to form ad-hoc wireless sensor networks that can be used to instrument the highly distributed, geographically extensive infrastructures like, for example, the highway system, power grids, cities, airports, as well as impromptu spaces in urgent need of surveillance or monitoring. These ad-hoc wireless sensor networks pose new problems and challenges to traditional information technology systems and telecom service providers. These challenges include: telecommunications infrastructure (issues like network protocols or quality of service in ad-hoc networks); security (integrity of information collected – is a sensor reliable or has it become compromised); on the fly network topology design and reconfiguration; distributed software validation and fault tolerant design; network traffic estimation under constraints; or distributed decision making (how to make sense from the vast amounts of information collected). All these issues are to be dealt with under power constraints and scarcity of other resources (like bandwidth, computing power, multiple access channel rate constraints).

Distributed fusion, inference, and actuation. Massively instrumented infrastructures collect vast amounts of data, but several factors at the sensing platforms including energy scarcity, limited processing capability, and bandwidth constraints impose the need to distribute the decision making and the actuation across the network instrumenting the infrastructure. New types of distributed inference algorithms that can uncover global behavior from local noisy data and local dynamics need to be developed.

Mobile and robotic sensors. The sensor platforms instrumenting the infrastructure may be mobile, in particular, heterogeneous multi-robot systems. A highly relevant problem is to explore combining several different types of robots, each featuring unique sensing capabilities, with the goal to act as a unified, mobile, and intelligent sensor network. Challenges include fast detection and action within the sensor network, coordination of static and mobile sensors towards a hierarchical heterogeneous approach to multi-sensor communication, active information gathering through mobile sensor navigation.

Most sensed campus. Beyond the concepts, theories, and algorithms in distributed decision making, actuation, privacy, and security; beyond the platforms (HW and SW) design and implementation; beyond the networking issues; and beyond new sensing technologies and the sensors themselves, the CMU-Portugal Program on Critical Infrastructures and Risk Assessment will build a large scale sensor network that can support a broad range of applications. This is the goal of the *most sensed campus* concept that will be deployed in one of the University campus, as a cooperative effort. This testbed will have, in the first phase, several hundred and then, in a second phase, several thousand sensing platforms.

Applications. This area will explore several important applications. One of the members of the Portuguese consortium, ISQ, is committed to identifying and actively engage potential industrial

and service companies in Portugal to develop relevant applications of sensor networks. Of particular interest are, for example, networked distribution systems like water distribution, power grid, surveillance and security of large spaces, tracking of goods, or transportation networks like an urban subway system.

Risk analysis and assessment. For a comprehensive program on critical infrastructures, we need to analyze and assess the risk of each possible methodology for monitoring or preventing disaster. Minimum risk decision systems must rely on adequate technological infrastructures, which have to be designed in accordance to well defined criteria, e.g., minimum cost subject to a given level of expected protection. Therefore, systems analysis, risk analysis, and behavioral decision theory form the fundamental core of a balanced and complete approach to the design of infrastructure systems, and play a key role in the definition of strategies of communication to systems' operators and users and in public perception management.

Main subareas. This joint unique research initiative between CenSCIR and the Portuguese Consortium will bring together interdisciplinary teams of experts that can address effectively and efficiently the problems of critical infrastructures and their risk assessment. The research project will consider all the relevant subareas in Critical Infrastructures and Risk Assessment, including the following: Wireless sensor networks; HW platforms and sensing technologies; Software and middleware; Mobile and robotic heterogeneous sensors; Navigation; Decision making; Fusion Algorithms; Actuation; Security; Privacy; Risk Assessment. The CMU-Portugal Program will have several research projects within the research initiative that will pursue a research agenda in all these subareas and PhD educational programs.

3. Area on Technology, Innovation, and Policy

Technological change and innovation are at the heart of regional and national economic growth and firm performance. Thus, while Portugal needs to develop new knowledge and technologies, it is critical for the nation to be able to apply them in the market for the successful creation of new products, processes, and services. The development of strategies and policies to guide such innovative activity at the national, regional and organizational levels is thus an imperative for productivity and employment growth. This is particularly relevant in the areas of information and communication technologies. ICTs are at the core of the innovation process, not only in industries such as computers or software, but across all sectors, as organizations in every area of activity adopt ever more sophisticated ICT systems.

This innovation process is characterized by complex phenomena that have science or technology at their core, but where social, economic, and organizational forces also play critical roles. Thus, the collaboration program integrates a set of research and education efforts that aim to complement and extend the technical effort, focusing on the development of the analytical lenses and tools needed to study and understand the critical social and economic dimensions of innovation phenomena, especially those associated with ICTs. This collaboration between Carnegie Mellon and research institutions in Portugal, including Universidade Técnica de Lisboa (UTL), Universidade Católica Portuguesa (UCP) and University of Minho (UM), will pursue research and education of highly qualified people, capable of leading research, education and policy with this integrated perspective. Application to improve understanding of public actions

and to help designing public policies for the information society will be established through UMIC.

The main subareas encompassed in the program are: a dual Ph.D. program that aims at providing students with substantive skills for academic research and for high level business/corporate strategy and public policy formulation in technological change and innovation dynamics; and a research program in engineering and public policy. The latter subarea has three main focuses, namely telecommunications management and policy, public policy for power grids, and engineering and policy applied to the software industry.

Technical Change and Innovation. Innovation and technical change are nowadays the main engines of economic and social development. Thus, the development of strategies and policies to guide innovative activity in countries, regions and organizations is essential for the re-structuring and renewal of market economies, an imperative challenge for productivity and employment to grow. As the process of change accelerates, entrepreneurship is also becoming increasingly prominent. As a result, achieving excellence in education and research in the areas of technological innovation and policy has become essential for the competitiveness of firms, regions and countries.

The foundation to this collaboration is a dual Ph.D. program proposed by CMU, UCP and UTL. The program aims at providing students with substantive skills for academic research and for high level business/corporate strategy and public policy formulation. The target audiences for this program are post-graduate students from engineering, technology, economics, business, and social sciences willing to pursue a career in academia and/or strategic leadership and policy-making in industry or in government. The program should be aiming to attract students from all over the world, with particular emphasis on Europe and developing countries.

The education of highly qualified people in the aforementioned areas should be a priority for Portugal. The Portuguese model of economic development is at a crossroads. The productivity gains arising from public investment in physical infrastructure and development of financial services and real estate markets seem to be tailing off. The transition towards a knowledge-based, entrepreneurial model of development requires the education of high quality human resources that can teach, research and work at high level private sector and public administration positions in technology commercialization and the strategic management of technology. Through their future role as educators and leading experts in these areas, these human resources could significantly influence the development of Portugal. Moreover, these topics have gained increasing importance in Europe and developing countries during the last decade. Thus, the establishment of a strong collaboration with Carnegie Mellon University in these areas has the potential to give Portugal a specialized academic structure that would figure at the top of European higher education institutions, attracting high quality human resources from a variety of geographic origins.

This collaboration is also to be considered as an integral part of the overall association platform between Carnegie Mellon University and Portugal centered in the areas of information and communication technologies (ICTs). Portugal needs to go beyond the development of new knowledge and technologies in these areas, and also lean to effectively apply them in the market, either through established firms or start-ups. The proposed collaboration in Technology, Innovation, and Policy will help promote strategic visions for public and private ventures and

develop the necessary skills to help developing partnerships for innovation at an international level in these areas.

Engineering and Public Policy Applied to Network and Software Industries: This subarea considers three main themes for research. First, it considers telecommunications management and policy. This is because digital convergence is dramatically changing the technology, services and competitive environment faced by telecommunications carriers around the world. Portugal is no exception. Separate infrastructures tightly tied to specific services, such as telephone and cable, are giving way to generic IP based infrastructures providing a wide gamut of services, including voice, data and video. This transformation impacts industry structure, competition and regulatory policy. Critical questions range from: Is the diffusion of broadband best realized by a monopoly provider of infrastructure, or should telephone, cable and wireless based infrastructures be provided by independent entities, each competing for the customer? To should municipalities take responsibility for building new wireless or fiber-based infrastructures in the same way that they build roads or sewer systems, leaving private sector companies to compete only in the provision of services?

This research, proposed by EPP at CMU in collaboration with IST/UTL and UMIC will focus on two main issues. The first concerns questions of industry structure and regulation. Portugal, as elsewhere in the EU, must decide whether and how traditional open access policies should be carried forward onto new Fiber To The Home (FTTH) networks. The decision rests on choosing the appropriate balance between incentives for investment in infrastructure and facilitating innovative entry and competition in the delivery of services. The second issue concerns the role of individual communities in promoting broadband diffusion and adoption. Cities and towns can take a range of actions varying from direct investment in infrastructure, such as conduits or fiber, to demand stimulation through education and outreach programs. At the same time the national government is wrestling with how to support and orient municipal efforts. Comparing efforts currently underway or proposed in Portugal and in the rest of Europe with U.S. experience in comparable small towns and rural communities can provide valuable insight.

Second, this subarea will also consider "Public Policy for Power Grids". The development and management of electric power grids and advanced low-carbon uses of coal, other fossil fuels, and the integration of intermittent renewables are key problems that will shape the future development of the electricity industry. This research collaboration between Carnegie Mellon faculty and graduate students with investigators and students in Portugal will include, among other, looking at technical, economic, regulatory and risk-related studies of distributed energy systems, micro-grids, and advanced information technologies for integrating and controlling such systems in conventional electric power systems; research on advanced methods for the instrumentation and control of electric power transmission and distribution systems in the face of normal operations, and risks from natural disruptions and terrorist events; studies of technology innovation in energy and environmental technologies, its relationship to government actions (both "carrots" and "sticks") and its implications for policy and energy systems development.

Finally, this subarea will also incorporate research on "engineering and policy applied to the software industry". Software and software-related industries are now considered to be critical

industries by many developing economies, and inordinate amounts of resources are being expended to develop these industries. This proposal intends to address the sustainable development of the Portuguese software and software-related industries by understanding their current characteristics, both in what concerns the technological products and associated services. Understanding the seminal R&D context that might have given origin to each novel Portuguese software company is also relevant. Furthermore, it is also important to understand the role of formal R&D activities undertaken in Portuguese research centers and universities dedicated to software engineering subjects. This characterization will allow an in-depth observation of the organizational capability of the Portuguese software industry. This study will promote, within the Portuguese software industry, the need to adopt an increasing involvement with innovation projects to seek better software of a higher quality, on time, in the best way and at a lower cost.

The lead proponent on the Portugal side for the theme on "engineering and policy applied to the software industry" is University of Minho. Yet, as a result of its multidisciplinary and research nature, this proposed collaboration will be linked to other initiatives within the Area of Technology, Management and Public Policy, in particular the proposed PhD effort in Technological Change and Innovation involving UCP and UTL as well as existing Ph.D. programs at CMU. Other potential partners in Portugal should be defined before January 2007. At CMU, the Department of Engineering and Public Policy (EPP), the Heinz School and the School of Computer Science by means of their Software Industry Centre (SWIC) will be involved. Collaborations with the Institute for Software Research International (ISRI) and the Software Engineering Institute (SEI) are also envisioned. This program will strongly involve the Portuguese software companies, by promoting the systematic adoption of industrial-driven PhD dissertations in the context of R&D initiatives with both CMU and in Portugal (namely at University of Minho). The establishment of a Portuguese *Software and Systems Process Improvement Network* (SPIN) and the creation of a non-profit centre to contribute to the development of the Portuguese software industry might be considered as a potential initiative of the *Information and Communication Technology Institute* (ICTI), in particular collaboration with the University of Minho.

4. Area on Basic Sciences

This area considers a doctoral program in Applied Mathematics involving a consortium proposed and to be launched with the three Mathematical Departments at the three public Universities in Lisbon, namely, Universidade Técnica, through IST, Universidade de Lisboa, through Faculdade de Ciências, and Universidade Nova de Lisboa, through Faculdade de Ciências e Tecnologia, and the Math Department at CMU. Other potential partners in Portugal include the Department of Mathematics and Engineering at the University of Madeira and will be defined during the initial 3 months of the Program.

The work program defined for this area will reinforce the scientific and educational programs at the three Portuguese Universities in Applied Mathematics, stimulate mobility and scientific interactions among graduate students, researchers, and post-docs, and attract strongly motivated students that are able to integrate advanced research in Mathematics and applications.

V. Partnership Programs

1.   **Carnegie Mellon University-Portugal partnerships**. As described in Part III, the CMU-Portugal Program is organized in three main types of programs: Advanced post-graduate programs; PhD programs; and research programs. We describe briefly each of these.

A. **Advanced post-graduate degrees**. These are 3rd-cycle level programs, post 2nd-cycle programs in the Bologna agreement, that correspond to advanced degrees offered in collaboration with Portuguese Partner Institutions; these programs are Professional Masters Degrees, using a US nomenclature. They correspond to post-Master programs in the Bologna agreement. These programs serve multiple purposes from educating and training high quality professionals in high technological areas whose career goal is to enter the work force upon their completion of the program, to launching new doctoral programs by providing the course work and required background for prospective doctoral students in these new areas. These programs are an essential building block that will help Portuguese Universities to offer first rate quality programs and build their capacity to offer doctoral programs in the forefront of research in the information technology areas covered by the CMU-Portugal Program.

The three Professional Masters' programs to be offered by a partnership between CMU and a Portuguese University are:

i. *Master of Software Engineering (MSE)* to be offered by the International Software Research Institute (ISRI) of the School of Computer Science at CMU in partnership with the Department of Computer Science at the Faculdade de Ciências e Tecnologia, Universidade de Coimbra (FCTUC), but also involving faculty from other potential Portuguese institutions to be defined (namely the Faculdade de Ciências, Universidade de Lisboa, FCUL).

ii. *Master of Science in Information Networking (MSIN)* to be offered by the Information Networking Institute of the Carnegie Institute of Technology at CMU in partnership with the University of Aveiro and *Instituto de Telecomunicações*, IT, but also involving faculty from other potential Portuguese institutions to be defined.

iii. *Master of Science in Information Technology, Information Security (MSIT:IS)* track, to be offered by the Information Networking Institute of the Carnegie Institute of Technology at CMU in partnership with the Department of Computer Science at the Faculdade de Ciências, Universidade de Lisboa (FCUL), but also involving faculty from other potential Portuguese institutions to be defined (namely the Faculdade de Ciências e Tecnologia, Universidade de Coimbra, FCTUC).

These are dual degree programs, the students will receive the corresponding degree from CMU and an advanced degree from the Partner Portuguese University. Each of the above programs is dimensioned for a annual class size of 15 students for a total of about 210 students over five years (the programs are planned to start in the second year). Each program lasts four semesters, the students entering on a Fall term and terminating the

program at the end of the following Fall. Details on delivery of the Program are described in the *Assessment* and in the proposals included in Section VI.

B. **Doctoral programs**. These are dual degree programs – a PhD awarded by a CMU College and a PhD awarded by the Portuguese partner University(ies). As dual degrees, the students will satisfy all the requirements of both institutions, the CMU College granting degree and the partner Portuguese University(ies). These programs will achieve several important goals. They will launch strong doctoral programs that will achieve immediate international recognition in areas identified as of primary relevance to Portugal and to the Portuguese Universities. They will graduate in a relatively short period a significant number of doctoral professionals that will strengthen the faculty of Portuguese Universities or the Portuguese labor force with highly trained experts. They will develop a sustainable level of research activity in pivotal areas. Finally, they will put in place dynamic doctoral programs that reproduce the best practices of such programs in US Universities. The dual doctoral programs will be structured so that students spend part of their time at CMU and at the Portuguese partner Institution. In addition, whenever it makes sense, besides the CMU advisor, the student will have as a co-advisor a faculty member at the partner Institution. The CMU planned degrees include:

    i. *PhD in the area of Electrical and Computer Engineering* to be offered by the Department of Electrical and Computer Engineering at CMU and by several Portuguese partners. These include: 1) the Department of Computer Science at Faculdade de Ciências e Tecnologia da Universidade de Coimbra; 2) the Department of Computer Science at Faculdade de Ciências da Universidade de Lisboa; 3) the Department of Electrical and Computer Engineering at Instituto Superior Técnico, Universidade Técnica de Lisboa; 4) Department of Telecommunications and Electronics at Universidade de Aveiro and 5) the Department of Electrical and Computer Engineering at Faculdade de Engenharia da Universidade do Porto. Faculty to involved from other potential Portuguese Universities is to be defined before January 2007 for the launching phase.

    ii. *PhD in in the area of Computer Science* to be offered by the Department of Computer Science, School of Computer Science, at CMU and the Department of Computer Science at Faculdade de Ciências da Universidade de Lisboa), but also involving faculty from other potential Portuguese Universities (to be defined before January 2007 for the launching phase).

    iii. *PhD in the area of Language Technology* to be offered by the Language Technology Institute of the School of Computer Science of CMU and by the Department of Electrical and Computer Engineering or the Department of Informatics at Instituto Superior Técnico (Universidade Técnica de Lisboa), but also involving faculty from other potential Portuguese Universities (to be defined before January 2007 for the launching phase).

    iv. *PhD in the area of Technical Change and Innovation* to be offered through the SETChange Program at CMU. At CMU, it involves the Department of Engineering and Public Policy, the Department of Social and Decision Sciences, the Heinz School, and the Tepper School, and is offered by the Portuguese Partners

Universidade Técnica de Lisboa, led by Instituto Superior Técnico and Universidade Católica Portuguesa, directed by Faculdade de Ciências Económicas e Empresariais, FCEE/UCP. Faculty to be involved in the launching phase from other potential Portuguese Universities will be assessed by CMU before January 2007.

v. PhD in in the area of Mathematics to be offered by the Department of Mathematics at CMU and by the Departments of Mathematics at Instituto Superior Técnico (Universidade Técnica de Lisboa), Faculdade de Ciências (Universidade de Lisboa), and Faculdade de Ciências e Tecnologia (Universidade Nova de Lisboa). Faculty to be involved in the launching phase from other potential partners will be assessed by CMU before January 2007.

As mentioned, these are dual degrees. The students will also be awarded a corresponding PhD degree from the Partner Portuguese University.

The teaming Departments will work out the exact details of the PhD programs leading to these degrees. For illustrative purposes, a generic template, whose particulars are to be adjusted and modified to fit the specifics of each program, is the following:

o Average duration of the PhD dual degree program: 4 to 5 years.

o 1st year at the Portuguese University, taking relevant courses and starting research.

o 2nd year and 3rd year (or fraction) at CMU completing various requirements, e.g., qualifier, breadth course requirements, teaching requirement, continuing research program, and possibly presenting PhD thesis proposal.

o 4th year and 5th year (if necessary) at the Portuguese University with visits to CMU.

o PhD thesis defense at CMU or at Portuguese University.

C. **Research initiatives**. Research initiatives will complement both the advanced post-graduate degrees and the doctoral programs, these collaborations providing often the themes and the context for the projects in the advanced degrees and for the doctoral theses. Teams at CMU *and* Partner Institutions in Portugal will carry out jointly these projects, which will involve frequent visits by team members of one pole to the other pole. Besides faculty, they involve post-docs and PhD graduate students receiving their doctoral degree at either CMU or a Portuguese Partner University(ies) but working in the context of a Information Communication Technology research project. These post-docs and graduate students will be recruited in the international market.

VI.   Framework of the CMU-Portugal Program

1.   **Information and Communication Technologies Institute: Framework of partnership**. The Program has been planned to be governed by a single virtual institution, ***the***

Information and Communication Technologies Institute (ICTI), with two poles: ICTI@CMU, resident at CMU, and ICTI@Portugal, resident in Portugal. The Institute has a unified administration: a Board of Directors (BoD), an External Review Committee (ERC), and the directors of each pole.

2.　　**Board of Directors**. This Board includes the following members (minimum of 6):

- o The President of the *Fundação para a Ciência e Tecnologia* (FCT), or a representative, who <u>chairs the Board</u>;

- o A representative of the Portuguese Minister for Science, Technology and Higher Education, MCTES;

- o The President of CMU, or a representative;

- o The Dean of CIT, the College of Engineering at CMU;

- o The Director of ICTI@Portugal;

- o The Director of ICTI@CMU;

- o Representatives of major companies sponsoring the program (above 1 Million Euros per year), including the coordinator of the industrial affiliates program and/or following any additional rules fixed by the Board of Directors.

The Board exercises its responsibilities by reviewing and approving the report on the activities of the Institute, its next year plan of activities, its annual budget, and proposals for potential new areas of collaboration. The Board has final arbitration over all matters regarding the Institute.

The Board should meet <u>at least</u> twice a year, with one face-to face meeting and other by video conferencing. The two directors (i.e., the Director of ICTI@Portugal and the Director of ICTI@CMU) form a *Directorate* that meets frequently for the daily running of ICTI.

3.　　**External review committee (ERC)**. The External Review Committee (ERC) nominated by the President of the Fundação para a Ciência e Tecnologia (FCT) reviews annually the activities of the Information and Communication Technologies Institute suggesting possible changes to the Institute's programs, including the launching of new programs or the cancelling of existing programs.

4.　　**ICTI: internal organization.** The activities of ICTI are divided in two major groups: Research activities that include the research and PhD programs, and the educational activities that include the different advanced degree programs. The two Directors of ICTI (in Portugal and at CMU) appoint Research Directors and Education Directors at each pole to head ICTI's research activities and educational activities. The Research and Education Directors help the two Directors to run the Institute's educational and research programs.

The two Directors, as well as Research Directors and Education Directors, may be advised by Advisory Boards that help define the research and educational agenda of the Institute.

The members of the Advisory Boards are chosen among the Research Directors, Education Directors, Coordinators, and PIs of the Institute's areas and programs. It also includes members of companies and institutions involved with the activities of the Institute.

5.   **Fellows**. Faculty, graduate students, and post-docs associated or supported by the Institute will receive an appointment as "CMU-Portugal Fellows" with the corresponding rights and responsibilities, namely, in terms of a co-affiliation with a Portuguese University. As a best practice, given that faculty are periodically reviewed in US Universities, the Institute will establish mechanisms for the periodic review of "CMU-Portugal Fellows". This review will be activity and curriculum based.

6.   **Industrial affiliates program.** The Fundação para a Ciência e Tecnologia (FCT) in close collaboration with the Directors of the two poles of ICTI will establish an industrial affiliates program to promote the active participation of Portuguese and multinational companies in defining its research and education agenda. The degree of involvement can vary, but the criteria are to be defined by the Board of Directors. Companies can be expected to fund graduate students in the advanced degree programs, to be involved in the studio components (namely of the Master of Software Engineering, among others to be established) and to provide internships to projects in the other Master of Science programs, tying the students' projects to real firm needs. Companies can fund doctoral students. Companies are also expected to support research projects of common interest to ICTI Partners and the Company. Finally, all the companies to be affiliated to the CMU-Portugal Program (and, therefore, to ICTI) are expected to make their own compromise to strengthen their investment in R&D and to help increasing the business expenditure in R&D (i.e., BERD) in Portugal, as measured by international standards (namely EUROSTAT and the OCDE). This should include the compromise of employing every year qualified experts and doctorates.

Following the *Assessment*, Portugal Telecom (PT) is expected to coordinate the industrial affiliate program, at least in the launching phase of the Program and in the terms described in the contract signed by PT and the Fundação para a Ciência e Tecnologia (FCT).

7.   **Links with governmental organizations**. Besides the involvement with private corporations, the CMU-Portugal Program and ICTI will establish partnerships with other Institutions and Agencies. In particular, two governmental agencies have been recognized as main partners of ICTI, namely: "UMIC - The Agency for the Knowledge Society"; and "FCCN – Fundação para a Computação Científica Nacional", the national foundation for scientific computation.

Other national agencies and governmental departments in Portugal are expected to be involved in the program. In particular the national telecom regulatory authority, ANACOM, is expected to join an institutional affiliation program.

VII. Conclusion

The CMU-Portugal Program will set-up a new international virtual institution, the **Information and Communication Technologies Institute** (ICTI), which will be focused on *Information and Communication Technologies* (ICT). ICT is at the heart of regional and national economic growth and firm performance. The development of strategies and policies for strengthening the educational and research infrastructure in ICT activity in Portugal is imperative for Portugal's economic, productivity and employment growth. Information and communication technologies are at the core of the innovation process, not only in industries such as computers and software, but across all sectors, as organizations in every area of activity adopt ever more sophisticated information and communication technologies.

The ICT theme is organized in four main areas: i) *Information processing and networking*, including software engineering, information security and dependability, language technology, and information networking; ii) *critical infrastructures and risk assessment,* which includes research programs in static and mobile sensor networks, distributed inference, adaptation, security and privacy, hardware, software and middleware platforms, applications to large scale networked systems, and a large site testbed "*sensed campus*;"; iii) *technology, innovation, and policy,* which includes education and research programs in the areas of technical change and innovation and research in engineering and public policy for network and software industries; and iv) *basic sciences*, in particular, applied mathematics. These areas involve several subareas and several specific potential collaborations. The collaborations involve several Colleges, Departments, and Research Centers at Carnegie Mellon University, including, the College of Engineering (ECE, CEE, EPP, CenSCIR, INI), School of Computer Science (CSD, LTI, ISRI), CyLAB, H&SS (SDS), Heinz School, and Tepper School of Business. The Portuguese Institutions involved include 12 Higher Education Institutions (including 11 Universities and 1 Polytechnic), 8 Faculties and Schools, 4 Associate Laboratories, 1 Applied Research Institute and 2 Governmental Agencies. The program will be developed together with a diversified set of Industrial Affiliates and Portugal Telecom, and its associate companies, will launch the coordination of the industrial partners of the Program.

The CMU-Portugal Program is organized in three dimensions: advanced degree programs, doctoral programs, and research projects. The advanced degree programs and the doctoral programs are dual degree programs, i.e., the graduates of these programs receive two degrees – one awarded by Carnegie Mellon University and one awarded by the Portuguese Partner University. As such, the programs are structured to satisfy the degree requisites required by Carnegie Mellon University and the Portuguese University awarding the degree. The advanced degree programs are delivered by Carnegie Mellon University in partnership with a Portuguese University. There are three such programs: i) Software Engineering, to be launched in partnership with Universidade de Coimbra, with faculty from other Portuguese Institutions; ii) Information Technology with focus on Information Security, to be launched by Faculdade de Ciências da Universidade de Lisboa, with faculty from other Portuguese Institutions; and iii) Information Networking, to be launched by Universidade de Aveiro in collaboration with IT, with faculty from other Portuguese Institutions. Doctoral degree programs include PhDs in Computer Science, Electrical and Computer Engineering, Language Technology, Mathematics,

and in the area of Technological Change and Innovation. The research projects are in a number of areas and they complement well the educational programs.

To attain the desired goals for the partnership and maximize the return on investment, the institutional form of the partnership is simple and dynamic, with a clear management structure through the *Information and Communication Technologies Institute* (ICTI), a CMU-Portugal Partnership, with two poles, ICTI@Portugal residing in Portugal and ICTI@CMU residing at Carnegie Mellon University. Each pole will be managed by a Director and the overall governance of the Institute will be guaranteed by the Directors of the two poles. ICTI has a Board of Directors that has overall responsibility over all matters concerning the CMU-Portugal Program and ICTI. An External Review Committee is appointed by the Fundação para a Ciência e Tecnologia (FCT) to review the activities of the Program and ICTI. Research and Education Directors head the research and education activities for each area at each pole. Every program has a Principal Investigator in Portugal and another at Carnegie Mellon University.

Appendix: Area Project Descriptions

1. Information Processing and Networking

Sub-areas:

Software Engineering
Information Infrastructure Security and Dependability
Information Networking
Language Technology

Software Engineering

Main Proponent: FCT (UC), in collaboration with FC(UL)

João Gabriel Silva, jgabriel@dei.uc.pt

Executive Summary

Goals. This action aims at offering in Portugal two joint CMU-University of Coimbra degrees, the Master of Software Engineering (MSE) degree, widely recognized in the world, and the Master of Science in Information Technology - Software Engineering Track (MSIT-SE), a shorter version of MSE, accompanied by advanced research projects. Other potential partner institutions in Portugal will be defined before January 2007.

The offer in Portugal of the MSE/MSIT-SE programs is a fantastic opportunity to introduce a quantum leap in the way Portuguese Universities fulfil their role, and to give European-wide visibility to Portugal in this area.

It can also influence the economic fabric of the country in a decisive way, as the growth of the Portuguese software industry critically needs highly qualified people that are able to successfully manage projects of ever increasing size, complexity, and market stress on quality and timing. Portugal needs to be able to educate the extremely valuable and critical people that are at the technical top of those endeavours. Just like MBAs are a requirement for solid economic management, MSEs are needed for solid growth of the software industry. Without them Portugal will be largely relegated to the position of a subcontractor, competing based on little more than cheap hourly rates, a situation that is particularly fragile in view of competition from eastern and Asian countries, as Portugal has learned the hard way in several other areas.

Moreover, the time seems to be ripe for this kind of offer to appear in Europe. There is no similar competing offer in any European University, and the need appears to be there. Portugal can become central in fulfilling that need. The MSE/MSIT-SE should also deeply influence how Universities in Portugal, and the University of Coimbra in particular, organize their advanced programs, as world class degrees like the MSE are run quite differently from the way that master programs are organized currently in Portugal.

Partners. On the CMU side the involved units are the School of Computer Science (SCS), the Institute for Software Research International (ISRI) and the Software Engineering Institute (SEI). On the Portuguese side, the program will be launched by the Department of Informatics Engineering, Faculty of Science and Technology, University of Coimbra. Potential collaborations are expected from other leading Portuguese Schools, namely the Department of Informatics at the Faculty of Science of the University of Lisboa, among others (to be defined by January 2007).

Main researchers. João Gabriel Silva at the University of Coimbra and Paulo Veríssimo, at University of Lisboa. On the CMU side, David Garlan, Director of the Professional Programs in Software Engineering at CMU.

The participants on the CMU side are the team of the MSE/MSIT-SE programs (among others Jonathan Aldrich, Jim Herbsleb, Anthony J. Lattanze, Priya Narasimhan, Dave B. Root, Mel Rosso-Llopart, Mary Shaw, Gil Taran). On the University of Coimbra side, a non exhaustive list includes Henrique Santos Madeira, Luis Moura e Silva, Marco Vieira, Paulo Marques and Paulo Rupino. The research projects will be lead on the Portuguese side by Henrique Madeira and Paulo Marques, and on the CMU side by Roy Maxion and Phillip Koopman.

Specific form of collaboration. This action encompasses a MSE/MSIT-SE joint CMU-UC offering, and two main research projects.

The joint CMU-UC MSE/MSIT-SE programs will last for an initial five years. Due to the long preparation time that each cycle requires, this amounts to 4 cycles of 4 trimesters each, for a global duration of slightly more than 5 years: September 2006 to December 2011. The start on September 2006 is required for the first students to start in late August 2007, in sync with the Pittsburgh program. The MSE program must aggressively target an international audience, with the main focus in Europe. It shall not be restricted to Portuguese students. The number of students to admit each year is 15. This is an elite program, to nurture agents of change, the leaders of tomorrow in the software industry.

Due to the very demanding admission conditions of MSE, the companion MSIT-SE degree shall also be offered. It has less demanding admission requirements, particularly in what regards previous industrial experience of the candidates. Their graduates should be excellent single project managers, while the MSE graduates should be excellent multi-project managers. This double offering opens a larger scope of possible candidates, with very little additional effort as the courses are all common, just the global duration is different (4 semesters for MSE and 3 semesters for MSIT-SE), and the Studio work of MSE is substituted by the significantly shorter Practicum of MSIT-SE.

All students in both programs are required to stay in Pittsburgh for one semester, probably the Summer semester (mid May to mid August), as it is the one with more intensive activity in studio/practicum, and thus with the higher potential for that stay to be beneficial.

The admissions requirements shall be the same as those of the Pittsburgh CMU MSE programs.

The MSE program is heavily based on a studio, which lasts the whole program, as it follows a hands-on approach, where students deal with real problems from industry.

Many of the courses will be progressively delivered locally at Coimbra. Coimbra faculty members are expected to train at CMU, during the first four years of the contract.

Since there is no world class education without world class research associated with it, there are two research projects to be held together with the MSE/MSIT-SE program. They were chosen to have the highest multiplicative potential within the University of Coimbra, having a very clear emphasis on the research method, that should be up to the most demanding requirements.

One of them aims at developing security benchmarks for key components of internet-based systems (and for the whole system in general). Security benchmarks can be used for two main purposes: i) quantifying system or component behavior in the presence of malicious faults (attacks) and ii) compare alternative solutions concerning security.

The other one aims at investigating new methodologies to quantify safety properties in embedded systems, with particular emphasis on experimental approaches. Our thesis is that quantification of safety properties should be analysed in conjunction with the actual specification of the safety requirements that must be met by the system.

Description of Collaboration

Influence on the economic fabric of the country
The MSE/MSIT-SE programs are essential to the further development of the Portuguese software industry, that has had a big development in the last years. It is by no chance that many of the companies that are described as the innovation leaders in Portugal, bearing the hope for a more developed society and having the potential to compensate for the decline of the traditional Portuguese industries, are largely connected with software. But as in any other area, that growth critically needs highly qualified people that are able to successfully manage projects of ever increasing size, complexity, and market stress on quality and timing. Portugal needs to be able to educate the extremely valuable and critical people that are at the technical top of those endeavours. Just like MBAs are a requirement for solid economic management, MSEs are needed for solid growth of the software industry. Without them Portugal will be largely relegated to the position of a subcontractor, competing based on little more than cheap hourly rates, a situation that is particularly fragile in view of competition from eastern and Asian countries, as Portugal has learned the hard way in several other areas.

Internationalization of the Portuguese Universities
The CMU Master of Software Engineering program is widely recognized as the best in the world. Offering it at the University of Coimbra (UC) is an enormous opportunity for the UC to get a sharp visibility in the area of software in particular, and computer science/engineering/technology in general. Moreover, the time seems to be ripe for this kind of offer to appear in Europe. There is no similar competing offer in any European University, and the need appears to be there. For instance, the current tendency to outsource software construction, mainly to Asian countries, but certainly away from the companies technical headquarters, as well as the growing complexity of software, require the high level skills to manage software products that the MSE graduates have (and, to a lesser extent, also the MSIT-SE graduates). Some even say that one of the main roots of why Europe is not in the forefront of the software market is the lack of sufficient high level software engineers and of a strong software engineering culture.

Influence on the internal organization of Portuguese Universities
First, the MSE (and MSIT-SE) are professional degrees. They are not meant for those that want to follow a research career, but instead target people with years of professional experience that wish to get to significantly higher positions in industry. Second, the quality assessment methods of the courses, the rules for admission, the goals and organization of the projects included in the program, the requirements to have real customers for them, the grading rules, the intensive teaching methods, all add up to very significant organizational differences to the current rules

of the University of Coimbra. Third, the governance model at CMU is quite different from the Portuguese universities. The University of Coimbra will have to adapt many of its regulations.

Why the University of Coimbra?

Being in the small group of the founding fathers of the European University, thanks to having been established in 1290, the University of Coimbra already has a very good international visibility. In the area of software development, Coimbra also has a long tradition. It introduced a Master Program in Informatics back in 1983, and an undergrad program in 1984. There have always been very strong connections to industrial projects, from the first computer designed and commercialy offered in Portugal back in 1982, a Coimbra design, to e.g. the development of embedded systems for Portuguese paper mills, or the system in use today to control fishing quotas in the Portuguese maritime area, among many, many others. Many of these collaborations with industry went through the Instituto Pedro Nunes, that also includes the most successful high technology company incubator in Portugal. Many UC spin-off companies started there, among them the most Quality-Certified Portuguese software company, Critical Software SA, that e.g. very recently obtained CMMi level 3 certification from the Software Engineering Institute of CMU, a level that no other Portuguese company has yet attained. Critical Software is a strategic partner of UC in the endeavour of offering the MSE in Portugal. Portugal Telecom has also formally stated its interest in participating in the program, and we expect other companies to do the same. The University of Coimbra contributes also with its faculty members of international standing. The research groups most directly associated with this project have received an "Excellent" rating by the international evaluation board of the Foundation of Science and Technology (FCT), and the Research centre as a whole (CISUC - Informatics and Systems Research enter of the University of Coimbra) was classified as "Very Good". Still, some additional Faculty recruiting will be needed.

Project duration and scope

The goal is to hold the joint CMU-UC MSE/MSIT-SE programs for five years. Due to the long preparation time that each cycle requires, this amounts to 4 cycles of 4 trimesters each, for a global duration of slightly more than 5 years: September 2006 to December 2011. The start on September 2006 is required for the first students to start in late August 2007, in sync with the Pittsburgh program. Renewal of the program is a clear possibility, but will have to be decided upon at a later stage, based on the actual experience with this project and the availability of adequate funding.

The MSE program must aggressively target an international audience, with the main focus in Europe. It shall not be restricted to Portuguese students. The number of students to admit each year is 15. This may seem a low number, but it is important to notice this program has very demanding admission conditions, and its graduates are meant for the very top of technical/managing positions in the software industry. This is an elite program, to nurture agents of change, the leaders of tomorrow in the software industry.

Due to the very demanding admission conditions of MSE, the companion MSIT-SE degree shall also be offered. It has less demanding admission requirements, particularly in what regards previous industrial experience of the candidates.This double offering opens a larger scope of

possible candidates, with very little additional effort as the courses are all common, just the global duration is different (4 semesters for MSE and 3 semesters for MSIT-SE), and the Studio work of MSE is substituted by the significantly shorter Practicum of MSIT-SE.

All students in both programs are required to stay in Pittsburgh for one semester, probably the Summer semester (mid May to mid August), as it is the one with more intensive activity in studio/practicum, and thus with the higher potential for that stay to be beneficial.

Admission

The admissions requirements shall be the same as those of the Pittsburgh CMU MSE programs. A first selection shall be made in Coimbra, with the final selection being made by a mixed CMU-UC committee. Those requirements are compatible with the current Portuguese legislation, and the University commits to make the necessary changes to its internal regulations.

Software Engineering Studio

The MSE program is heavily based on a studio, which lasts the whole program, as it follows a hands-on approach. The students must work with real industry projects, which should not be a problem. Still, we see a weakness in the size and capability of the current supporting technical staff, which will have to be strengthened for this project. We see it as clearly viable that in some projects the interested companies will assign some of their employees to support them. The help of PhD students and post-doc researchers will also be sought.

Delivery model

Many of the courses will be progressively delivered locally at Coimbra. We expect to buy 10 courses from CMU, including the 5 core courses, and 5 electives, yet to be chosen. We also expect to train and certificate at CMU five Coimbra faculty members. This will not happen all at the same time; we expect it to happen during the first four years of the contract.

Until then, the courses will be delivered mostly asynchronously, where each student receives the complete packet, including a DVD with all the lectures recorded, that he/she is supposed to study on his own, with frequent contacts to faculty at CMU and Coimbra, both to discuss issues that may arise and to handle the very frequent assignments. Still, at least one course per semester will be delivered synchronously from CMU, as the 5 time-zone difference clearly allows it.

The programs are very intensive. The MSE program lasts for only 16 months, but corresponds to 120 ECTS credits, that normally would correspond to two full years. the MSIT-SE last for only 12 months, but corresponds to 100 ECTS credits.

Communication Strategy

The program will have to be supported by a consistent, targeted, promotional campaign done by UC. The main target will be companies involved in software development in Europe, because the audience for the MSE program are mainly young professionals, and because the program will be much stronger if it is able to build good partnerships with many companies, that can promote the program among it's employees, sponsor projects, and later hire the graduates. The name of Carnegie Mellon University is a central stone for this campaign, as it is quite well known in Europe in the area of Software Engineering, mainly because of the CMM

models and the SEI. All promotion materials involving the CMU name will have to be accepted by the CMU.

Industrial partners
Contacts have already been started with industry to gather support for this program, some of them with large transnational companies. Critical Software and Portugal Telecom, the strategic partners of this project, will be very helpful in this respect.

Governing model
The joint CMU-UC master program will have a Director on the UC side, that will be responsible for the program and all its logistics on the UC side. It will always work is close cooperation with the CMU program directors. Thus UC will not make changes to the program unilaterally; all decisions will have to be met with the CMU side, that has veto power.

Success metrics
The success of the program will be measured by two main criteria:
- The number of non-Portuguese students of the MSE program;
- The employment ratio of the graduates and the positions occupied by them.

Plans of Study
The plans of study will be exactly the current ones in the CMU MSE/MSIT-SE programs, except for the list of electives, that will have to be negotiated and will include several offering from the CMU and others from the UC side, as well as some courses offered by other Portuguese universities. An example will most certainly be a computer security course offered by the Informatics Department of the University of Lisboa.

Research Projects
Two research projects were chosen to have the highest multiplicative potential within the University of Coimbra, having a very clear emphasis on the research method, that should be up to the most demanding requirements. The researchers from CMU are world class researchers, very well known in their fields, and the projects require very careful experimentation and modelling. Roy Maxion, the CMU responsible for one of them, will even run a seminar at UC, open to every researcher in Portuguese Universities, about research methods in Computer Science, building on the ground breaking new course that he is introducing in CMU in the Fall of this year. We expect these two projects to have a very enduring influence on how research is done in Portugal, and in Coimbra in particular.

One is about **Security benchmarking**. It aims at measuring security properties by the use of security benchmarks for key components of internet-based systems (and for the whole system in general). Security benchmarks can be used for two main purposes: i) quantifying system or component behavior in the presence of malicious faults (attacks) and ii) compare alternative solutions concerning security.

The project is structured according to three work packages: Security benchmarking concepts and approach, Security benchmark specification and components (measures, workload, and attackload), and Security benchmark experimentation, validation, and consolidation

The other one is on the **Specification of provable safety requirements of embedded systems.** Many embedded systems have safety requirements. However, unlike what happens in functional requirements, where verification and validation (V&V) techniques, as well as certification, are normally used to give some guarantee that the system complies with its specified requirements, proving that safety requirements of embedded systems are met is a very hard problem. Our goal is to investigate new methodologies to quantify safety properties in embedded systems, with particular emphasis on experimental approaches. Our thesis is that quantification of safety properties should be analysed in conjunction with the actual specification of the safety requirements that must be met by the system. The project is structured in four workpackages: State of the art on safety evaluation , Safety measures and experimental evaluation approaches, Case-studies and Consolidation.

Conclusion

This action involves a joint CMU-UC professional master double offering: the MSE and MSIT-SE. It has the potential to change the landscape of software development in Portugal, and be very visible in Europe, along with strongly influencing practices at Portuguese universities. Two ambitious research projects complement the master courses, with emphasis on methodology.

Information Infrastructure Security and Dependability

Main Proponent: FCUL (UL), in collaboration with FCT(UC) and UA
Other potential partners: FCCN
Paulo Veríssimo, pjv@di.fc.ul.pt

Executive Summary

Goals. This initiative features an ambitious plan of setting up a joint-venture which, as a criterion of success, expects to become internationally visible as a distributed centre of excellence for its results in state-of-the-art scientific research and advanced education, in the field of *Information Processing and Networking*, and more specifically in *Information and Infrastructure Security and Dependability*. This project differentiates itself by addressing such difficult issues as the Internet and the Critical Information Infrastructures of the future, and their interpenetration: the dramatic security and dependability problems posed the inevitable fusion between classical Internet and embedded and computer control systems justify per se the existence of an effort focused on this theme. This proposal tries to give some contribution to its study and its solution, through a coordinated set of initiatives: education at the level of MSc and PhD, and joint research.

Partners. On the CMU side, this initiative draws mainly from programs and faculty from both the *College of Engineering (CE)*, and the *School of Computer Science (SCS)*, namely the Departments of Electrical and Computer Engineering (CE-ECE) and the Department of Computer Science (SCS-CS). From the Portuguese side, there is the major involvement of the University of Lisboa Faculty of Sciences (FCUL), through the Department of Informatics, and the collaboration of researchers from two other main universities, namely the University of Coimbra Faculty of Sciences and Technology (FCTUC), through the Department of Informatics, and the University of Aveiro (UA), with the Instituto de Engenharia Electrónica e Telemática de Aveiro. Other faculty from other potential partners in Portugal should be defined before January 2007.

Main researchers. Paulo Veríssimo from FCUL, Henrique Madeira from FCTUC and André Zúquete from UA. Key personnel from FCUL involved in the program, both at the education and research level, are António Casimiro, Miguel Correia, Nuno Neves and José Rufino. From CMU, key personnel involved in the program are David Garlan, Phil Koopman, Bruce Krogh, Roy Maxion, Priya Narasimhan, Raj Rajkumar, Mike Reiter, and Jeannette Wing.

Specific form of collaboration. The initiative will encompass the following three activities, which will involve the participating institutions in several ways: Master of Science in

Information Technology – Information Security (MSIT-IS). Carnegie Mellon PhD degree-granting program. Joint Research program.

INI's MSIT-IS is believed to constitute an excellent means of fulfilling the objectives established above: train young graduates and professionals, with a slant to the Portuguese ICT circuit, including personnel from institutions affiliated with FCUL or participating to the CMU-Portugal project as a whole, in the area of information security and its applications.

The Carnegie Mellon PhD degree-granting program constitutes an opportunity to confer the seal of outstanding quality of the CMU departments involved (CE-ECE and SCS-CS) to a set of high-quality students and demanding thesis research programs. This activity is expected to attract a critical mass of very high-quality candidates not only from Portugal but also from other European countries.

The Joint Research program aims at contributing to create long-term, mutually fruitful relationships between the US and Portuguese groups, which may leverage the international visibility of the associated Portuguese universities. Specifically, the program is designed to take advantage of the complementarities of research made on each side, and/or to create critical mass by reinforcing hot areas where both sides have strong positions in the international research arena, in the areas of Information and Infrastructure Security and Dependability.

Description of Collaboration

Main goals for Carnegie Mellon University-Portugal cooperation.

This initiative aims at setting up a joint-venture which, as a criterion of success, expects to become internationally visible as a distributed centre of excellence for its results in state-of-the-art scientific research and advanced education, in the field of *Information Processing and Networking*, and more specifically in *Information and Infrastructure Security and Dependability*. This proposal however, addresses such difficult issues as the Internet and the Critical Information Infrastructures of the future, and their interpenetration. Dependability and Security are two very important fields of computer science and engineering which have until recently been concerned with complementary aspects of system trustworthiness: accidental faults, defects or bugs; and malicious hazards, attacks or intrusions. The purpose of this proposal is to address both security and dependability on an equal foot. This proposal tries to give some contribution to the study and solution of the above-mentioned problems, through a coordinated set of initiatives: education at the level of MSc and PhD, and joint research.

Why a Carnegie Mellon University partnership.

This initiative is an opportunity to take advantage from the experience and excellence of CMU in the area of Information Processing and Networking, to train young graduates and professionals, with great importance for the Portuguese ICT circuit, including participating institutions such as Portugal Telecom. It will also constitute an opportunity for joint teaching and research experiences between CMU and Portuguese faculty, expected to create enduring relationships, and long-lasting and interdisciplinary record of research between teams on both sides of the Atlantic. In the end, we expect that this initiative

will contribute to create in Portugal first rate, internationally recognized, education and research programs in an area of significant relevance, such as Information and Infrastructure Security and Dependability.

Description of the initiative.

The initiative will encompass the following three activities, which will involve the participating institutions in several ways:

- Master of Science in Information Technology – Information Security (MSIT-IS)
- Carnegie Mellon PhD degree-granting program.
- Joint Research program.

A.   Master of Science in Information Technology – Information Security (MSIT-IS)

The program will be launched by the FCUL in Lisboa-Portugal, and will take advantage of the excellent distance learning capacities of INI, combined with the participation of the Portuguese adjunct faculty, and eventual short-length stays in Portugal of CMU faculty involved in the PhD and/or research programs. The program confers the corresponding CMU MSc degree. FCUL will vet the program through the usual internal and official mechanisms and bodies, in order to be able to confer an analogous MSc degree from the University of Lisboa Faculty of Sciences. The number of openings will be defined on a yearly basis.

The program structure will follow the MSIT-IS established structure in general. *A complete description can be found in the final assessment report*. The core courses will be supplemented with electives aimed at addressing the specific field of information and infrastructure security and dependability. The structure of the program is: 5 core courses or 60 units; 3 restrictive electives or 36 units; 1 free elective or 12 units; and a masters project/thesis with 36 units; for a total number of units of 144. The core courses are Introduction to Computer Security, Fundamentals of Telecommunication Networks, Embedded Systems, Network Security, and Secure Software Systems. The first three are given remotely from CMU, whereas the last two can be given either remotely or on site by local faculty. Restricted electives are picked from a subset of the global electives list. Free electives can be picked from CMU programs, or from electives offered by Portuguese faculty. The project or thesis, comprising 36 units worth of work, is to be performed locally. It may be defined by CMU and/or by Portuguese faculty, and may be part of research projects.

The teaching scheme will be largely based on the current mould of CMU programs abroad. In detail: At least 4 courses per incoming class, 3 of which core, are imperatively given from CMU. Fundamentals of Telecommunication Networks and Embedded Systems will imperatively be given in synchronized mode (in real-time from CMU), with starting time between the 8:30-9:30 time range (Pittsburgh time), to help synchronize with Portuguese time. All the other courses may be given in non-synchronized way, to help optimize the program schedule. As for the remaining core and electives, arrangements will be made for them to be taught either by CMU or by accredited Portuguese faculty. Human resources will be foreseen on the Portuguese side to assure: co-instruction of all remotely broadcast courses; locally offered courses; student hours; grading assignments and exams; advising thesis and final projects.

The professors potentially involved in the starting phase of the program are as follows. CMU- to be adjusted as needed, in coordination with INI. Portugal: António Casimiro; Miguel Correia; Nuno F. Neves; José Rufino; Paulo Veríssimo; Henrique Madeira; André Zuquete.

Relevant implementation details follow. Openings: a tentative target number of 15 admissions per year, internationally advertised. Enrollment is performed at FCUL and then centralized in CMU's academic management system. Selection of candidate students will be performed by selection committees according to CMU practice, in coordination with FCUL. Proposed start date: August/September 2007.

Financial items (Portugal side): Additional investment in technical infrastructure (upgrade of FCUL's video-conferencing facilities and laboratories to INI's quality standards). Additional investment in administrative infrastructure (program office). Additional exploitation costs of technical infrastructure (networking, system administration staff, maintenance). Additional exploitation costs of administrative infrastructure (administrative staff, running costs). Additional promotion and marketing costs. Additional teaching staff (lectures, co-instructing, grading, student hours, project/thesis advising).

B.   Carnegie Mellon PhD degree-granting program.

The program will work in the FCUL premises in Lisboa and in the CMU premises in Pittsburgh. *A complete description can be found in the final assessment report.* Students will have stays in both sites during the program. The structure and execution of the program will follow, in the way possible, the rules of the CMU college/department involved. Theses will be co-advised, by CMU faculty and CMU-accredited Portuguese faculty, with eventual short-length stays in Portugal of CMU faculty involved in the PhD program, and vice-versa (to be coordinated with the CMU departments involved). Definition of co-advised theses will be made easier by the synergies created by the joint research program. The program confers the corresponding CMU PhD degree, according to the college/department involved (CE/ECE, SCS/CS). FCUL, on their side, will vet the program through the usual internal and official mechanisms and bodies, in order to be able to confer candidates an analogous PhD degree from the University of Lisboa.

The professors having shown an interest to participate in the starting phase of the initiative are listed next, a list that may evolve with time. US side: David Garlan, Phil Koopman, Bruce Krogh, Roy Maxion, Priya Narasimhan, Raj Rajkumar, Mike Reiter, and Jeannette Wing. Portuguese side: António Casimiro, Miguel Correia, Nuno F. Neves, José Rufino, and Paulo Veríssimo.

Relevant implementation details follow. Openings: the target number of thesis openings is 8 admissions. Target thesis work duration (for planning purposes) depends on the Department concerned, may range from 4-5 years. Theses will be proposed as CMU and FCUL faculty define a theme, and names of co-advisors, for each. Thesis will be co-proposed from ECE or CS depending on the affiliation of the CMU co-advisor. The announcement and application process follow the usual procedure. Selection of candidate students will be performed by selection committees according to CMU involved Departments' practice, in coordination with FCUL. Proposed start date: August/September 2007.

A time-chart prototype is tentatively defined as follows, subject to further trimming between FCUL and CMU Departments involved. It is aimed that students spend a balanced time between both institutions. After being selected, the student starts to work at CMU for an extended period, where he/she should go through all the necessary qualifiers. During this period, the Portuguese co-advisor will visit as appropriate. Then the student comes to Lisbon for an extended period where he makes progress in his research. During this period, the CMU co-advisor will visit as appropriate. The student will be back at CMU for a period of a few months to synchronize intensively with the CMU-side co-advisor, and then back to Lisbon for another extended period, until he/she practically concludes the thesis. During this period, the CMU co-advisor will visit as appropriate. Finally, he/she comes back to CMU, to finalize, deliver and discuss the dissertation. During these periods, visits of co-advisors to the site where the student currently is will allow joint discussions on the progress of work. These visits may very well occur in synergy with the joint research program activities.

Financial items (Portugal side): Additional investment in technical infrastructure (PhD student labs). Additional investment in administrative infrastructure (program office). Additional exploitation costs of technical infrastructure (networking, system administration staff, maintenance). Additional exploitation costs of administrative infrastructure (administrative staff, running costs). Additional promotion and marketing costs. Additional travel costs professors (short-duration travels for PT advisors). Additional travel costs students (temporary relocations in CMU).

C.   Joint Research program.

The program has a duration of 5 years, divided in two phases. *A complete description can be found in the final assessment report.* Besides community building actions, two *exploratory projects* are defined for the first phase, which will serve to: address perceived research problems; establish research relationships and trust relations; better organize global discussions and braining-storming; and promote the definition of more structured ideas leading to *focused projects* in the second phase. Relevant implementation details follow. Projects are described, together with the faculty PIs having already shown interest in the initiative.

Phase 1: Community building and exploratory research. Duration: 2 years

Community Building – structured in two working groups: WG1 – Security and Dependability of Large-scale Computer Systems; WG2 – Secure Systems of Embedded-Systems.

- Duration: 24 months, Yr1 to Yr2. Number of working groups: 2. Supported items: The program supports the relevant trips to all involved PIs: one trip across the ocean, allowing for a total of two workshops. Work plan, month 1 to 24: Inaugural workshop, month 1-2; Interim remote bilateral contacts; Final workshop, month 22-23. Deliverables: Workshop reports, 1 and 2 – Community Building Chapters – asap. Phase 1 conclusions and self-assessment – Community Building Chapters - month 24. Contribution to Phase 2 plan – month 24.

Exploratory Research – structured in two projects: P1 – Security and Dependability of Large-scale Computer Systems, P2 – Secure Systems-of-Embedded-Systems.

- Project 1 – Task 1 – Ultra-resilient IP-based systems

Teams: Miguel Correia, Priya Narasimhan, Nuno F. Neves, Mike Reiter, Paulo Veríssimo

- Project 1 – Task 2 – Modeling and experimental assessment of threats to distributed computer information and control systems

Teams: Henrique Madeira, Roy Maxion, Nuno F. Neves, Paulo Veríssimo, Jeannette Wing

- Project 2 – Task 1 – Trustworthy dynamic Systems-of-Embedded-Systems (SoES) architectures

Teams: António Casimiro, Phil Koopman, Bruce Krogh, Raj Rajkumar, José Rufino, Paulo Veríssimo

- Project 2 – Task 2 – Dependable Adaptation for Survivability

Teams: Luís Almeida, António Casimiro, David Garlan, Paulo Veríssimo

- Duration: 24 months, Yr1 to Yr2. Number of projects: 2. Manpower estimate (total): 128 pm. Supported items: Additional to the community building support, the projects support: 1 additional short trip across the ocean for each PI involved; 1 mid-duration trip per PI for a junior researcher to spend time in the other side; a moderate amount of grant money per PI for manpower support. Work plan, month 1 to 24: Inaugural workshop, month 1-2. Interim remote bilateral contacts and personal visits. Final workshop, month 22-23. Deliverables: Workshop reports, 1 and 2 – Exploratory Research Chapters – asap. Report on Security and Dependability of Large-scale Computer Systems – month 12. Report on Secure Systems of Embedded-Systems – month 12. Phase 1 conclusions and self-assessment – Exploratory Research Chapters - month 24. Contribution to Phase 2 plan – month 24.

Phase 2: Focused Projects. Duration: 3 years

- Number of projects: 4 (tentative). Manpower estimate (total): 420 pm. Supported items: Additional Manpower, Travel, Additional equipment, as needed for the cooperation. Duration: 36 months, Yr3 to Yr5. Work plan: TBD in the plan. Deliverables: TBD in the plan.

Financial items (Portugal side): Additional investment in technical infrastructure (research labs). Additional exploitation costs of technical infrastructure (networking, system administration staff, maintenance). Additional exploitation costs of administrative infrastructure (administrative staff, running costs). Additional research-assistant grant support Portuguese side. Short-duration travel expenses for PIs Portuguese side. Medium-duration travel expenses for Portuguese junior researchers' temporary relocations in CMU.

Potential industrial partners

Portugal Telecom has explicitly expressed an interest on the program, to be involved at least in the MSc activity, and potentially in the others. Companies with a potential interest on the program, to be confirmed and pursued further, are Critical Software, SkySoft and Siemens.

Conclusion

The development of the proposal has had the active participation of several faculty from the ECE and CS Departments. The combined expertise of the CMU and Portuguese researchers assembled spans some of the most relevant topics in Information and Infrastructure Security and Dependability. Results of this effort are expected to be beneficial to all institutions, not only throughout the initiative duration, but also under the perspective of future relations.

The MSc program (MSIT) will constitute an opportunity for joint teaching experiences between CMU faculty and adjunct faculty from the Portuguese institutions involved. The PhD program, set up around co-advised theses, is yet another pillar to the creation of long-lasting connections. A mix of affinities and complementarities of research agendas in the right combination characterizes the research program, jointly proposed by CMU and Portuguese researchers.

Information Networking

Main Proponents: UA and IT

Paulo J. S. G. Ferreira, pjf@det.ua.pt
José Ferreira da Rocha,frocha@det.ua.pt

Executive Summary

Goals. *Internationalization*: The collaboration in Information Processing and Networking will help Portuguese institutions to establish themselves as international leading institutions in this area of great strategic importance for them, and in which they have gained a solid national reputation in telecommunications.

Recruiting: One of the goals is to attract students from around the world, and to recruit the best candidates in the international arena.

Advanced education: The Master of Science in Information Networking, targeted at industry personnel, will allow addressing specific aspects of great importance for the telecommunication professionals, aspects that the existing programs do not cover with the desirable emphasis.

Collaboration: The dual-degree doctoral program and the associated research program will foster a culture of collaboration and exchange between the partner institutions, carried out in collaboration with the Portuguese telecommunications industry.

Within years, the number of international students enrolled in the Masters and PhD programs is expected to *surpass* the number of Portuguese students.

Main Partners. The main partner institutions in Portugal include Universidade de Aveiro (UA) and the Instituto de Telecomunicações (IT). Other potential partners should be defined before January 2007. The CMU Units involved are the Information Networking Institute (INI) and the Electrical and Computer Engineering Department (ECE). Details about these institutions can be found in the assessment documents.

Main researchers. Paulo J. S. G. Ferreira and José Ferreira da Rocha, with a number of faculty at UA and IT (tentative names include R. Aguiar, A. Almeida, C. Belo, A. Borges, N. Borges, J. Brazio, J., Cunha, P. Monteiro, J. Neves, A. Pinho, A. Pinto, J. Sobrinho, R. Valadas, A. Zúquete, among others). At CMU, the collaboration will involve the INI and faculty from the ECE department.

Specific form of collaboration. The collaboration CMU-UA/IT has three components: (i) Professional Master in Information Networking (ii) Doctoral program in Electrical and Computer Engineering / Information Processing and Networking (iii) Research program in Electrical and Computer Engineering / Information Processing and Networking.

The selection of the area of Information Processing and Networking is consistent with the strategic objectives of UA/IT, which rank telecommunications high in their list of priorities, and which have built a solid reputation in the area. It is also in agreement with the spirit of the

Memorandum of Understanding and the conclusions of the Assessment Committee. Last, but not the least, it is consistent with the interests of our industrial partners.

The Master of Science in Information Networking (which is a post-Masters program in the Bologna agreement) is in fact targeted at industry personnel, and will address aspects of great importance for the telecommunications professionals, aspects that the existing programs do not cover with the desirable emphasis. At the end of the course, the student will receive a Professional Masters degree from CMU, and a *Diploma de Estudos Avançados* from UA.

The doctoral program is a dual-degree program, in the area of Information Processing and Networking (either wired, optical or wireless). The CMU will award the degree of PhD in Electrical and Computer Engineering, whereas the UA will grant the degree of Doutor in Engenharia Electrotécnica.

The research initiative in Information Processing and Networking will feed on the Professional Masters and the doctoral program. The research will be carried out jointly by teams at UA/IT and CMU, and may involve, in addition to PhD students and faculty, post-docs. These post-docs, and of course the PhD students, will be recruited in the international market.

The mutual benefits of collaboration between industry and academia have been recognized by all academic partners and industry. The syllabus of the Professional Masters course is the result of dialog involving not only the academic partners, but Portugal Telecom as well. Potential research themes have already been proposed and discussed in the Workshop of July 24, in Portugal Telecom (Aveiro).

Description of Collaboration

Main goals. The main goals are closely related to the following key aspects: (i) Internationalization (ii) Recruiting (iii) Advanced education (iv) Collaboration.

Internationalization. In the national context, the UA/IT have built a strong reputation in the area of telecommunications. The proposed collaboration in Information Processing and Networking will help Portuguese institutions to establish themselves as leading institutions in this area, at the international level.

Recruiting. The collaboration will help UA and IT evolve, and will increase their international visibility in the area. This will help UA to attract good graduate students from around the world. As the international visibility of the university increases, and the doctoral and research programs grow in momentum, the university will greatly benefit from the possibility of recruiting post-docs and eventually faculty in the international market, helping to increase the proportion of graduate students and to reduce the degree of inbreeding.

Advanced education. The Master of Science in Information Networking, targeted at industry personnel, is an advanced course (post-Masters in the Bologna agreement) that will address aspects of great importance for the professionals, aspects that the existing programs do not cover with the desirable emphasis. The syllabus is the result of dialog with the industry partners (Portugal Telecom). Within years, the number of international students enrolled is expected to surpass the number of Portuguese students.

Collaboration. The dual-degree doctoral program and the associated research program will foster a culture of collaboration and exchange between the partner institutions, to be carried out in close collaboration with the telecommunications industry. The research program will involve, in addition to faculty, post-docs and graduate students, which will be recruited in the international market. The steady exchange of ideas and the adoption of best practices will help UA to reach a higher level in research and impact.

Best practices. Bottlenecks often noted in reference to Portuguese universities include the evaluation period for undergraduate courses, which is much longer than in the USA, and the much larger burden with administrative meetings and tasks. *These problems cannot be solved by the faculty alone.* It is up to the administrations of the universities to take steps to correct these problems. Solving these issues would allow the faculty to focus on teaching and research.

Why a partnership. Why Aveiro, and why the area of Information Processing and Networking?

o The UA already has an excellent reputation in Portugal for undergraduate and graduate education in Electronics and Telecommunications Engineering. Telecommunications is already a trademark of the UA. If an investment in Information Processing and Networking has to be made, then investing in Aveiro will maximize the return on investment, while minimizing the time necessary to see significant results.

o The potential of the faculty at the Departamento de Electrónica, Telecomunicações e Informática reflects in the recognized quality and sustained demand of the courses that it teaches, as well as in research.

o UA is closer to the telecommunications industry than perhaps any other Portuguese university. The city of Aveiro has become a centre of excellence in Telecommunications, where Portugal Telecom has had a strong presence since the beginning. Siemens has located its R&D facilities in Aveiro. The presence of other industrial partners and associations such as INOVA-Ria show the privileged position that Aveiro occupies in the national arena.

o The Institute of Telecommunications (IT) has been created in 1993 and its main mission is to create and disseminate scientific knowledge in the field of telecommunications. It has 345 researchers from five Portuguese institutions (three universities, one telecom operator and one industrial partner). Due to its relevance, IT has been granted the status of Public Interest and is an Associate Laboratory to the Ministry of Science and Technology, a status awarded only to Portuguese institutions graded 'excellent' by international evaluation panels.

o Collaboration with the telecommunications industry has always been a characteristic of UA. Portugal Telecom and Siemens are among the partners of Instituto de Telecomunicações (IT), and IT has had a long and profitable experience in this collaboration.

Description of program. It has three components: The Professional Masters in Information Networking, and the doctoral program and research initiative. The structure of the Professional Masters, which may start with about 15 students, is the following:

Core Course Requirements	72 units
Restricted Electives	48 units
Free Electives	12 units
Project	39 units
Total	171 units

The core course requirement, in turn, consists of the following three requirements:

Networking and Systems Requirement	48 units
Management Requirement	18 units
Database Requirement	6 units

The courses in each of these requirements are the following:

Networking and Systems Requirement		48 units
Fundamentals of Telecommunications Networks		
Or		
Packet Switching	UA	12 units
Embedded Systems	CMU	12 units
Distributed Systems	CMU	12 units
One course from (i) to (vii)	UA	12 units

Management Requirement		18 units
Managerial Economics	CMU	6 units
Business Management	CMU	6 units
Information Systems Modeling	UA	6 units

Database Requirement		6 units
Database Applications	UA	6 units

The restricted electives are the following:

Restricted Electives		48 units
Any four of the following:		
(i) Telecommunication Technology and Policy	CMU	12 units
(ii) Introduction to Computer Security	CMU	12 units
(iii) Wireless Networks	UA	12 units
(iv) Optical Networks	UA	12 units
(v) Network Security	UA	12 units
(vi) Multimedia Comm., Coding Syst., & Networking	UA	12 units
(vii) Principles of Broadband Networks	UA	12 units
Introduction to Computer Systems	CMU	12 units
Operating Syst. Design & Implementation	CMU	12 units

The course Introduction to Computer Systems is a prerequisite for Operating Syst. Design & Implementation. The Free Elective can be any course offered by UA or CMU.

The Project course consists of a research-based or development-based project, in which the students work individually or in teams of two (seldom three). The assignment of the students to faculty will proceed as follows: (i) the faculty offer a list of topics, which will include projects of interest to the industrial partners (ii) The student selects a topic and discusses it with the faculty (iii) The student prepares a proposal , which should be ready by the end of the second semester. The proposal (3-4 pages) will describe the goals of the project, identify the deliverables, and contain a time-line. At the end of the semester the student will deliver a written report, and will make a presentation in front of the other students.

The doctoral / research program in Electrical and Computer Engineering / Information Processing and Networking is a dual-degree program, granted by both CMU and UA. The number of admissions is expected to evolve so that in steady state the number of PhD students is six (suggestion: 2+2+1+1). An effort will be made to engage in research that will be also of interest to our industry partners (the topics have been defined in the workshop hosted by Portugal Telecom in July 24). The following areas have been identified for collaboration:

* Wireless Networks (self-organizing, reward-oriented, clean slate design, multiple access and routing for wireless mesh networks, multicast in wireless, metro ethernet, FPGA based network design and verification, sensor networks, waveform design by time reversal)

* Network Optimization across OSI Layers

* Scalable Ethernet technology for wide area networks

* Router-Assisted Congestion Control

* Network monitoring (network traffic estimation, traffic modeling, internet measurement)

Potential industrial partners. The research and development branch of Portugal Telecom, PT Inovação, is located in Aveiro and has already shown a great deal of interest in the program. Other potential partners include Siemens and INOVA-Ria.

Resources. The Professional Masters course requires a room with capacity for about 20 students, equipment (video cameras, microphones, projection equipment, smart board, etc.) and software. An Internet connection capable of 2 to 4 Mbits/s is required. The operation of the software during the classes requires the permanent presence of a trained technician. The presence of another person, to assist teacher or students with the equipment, is highly recommended.

Regarding human resources, the seamless integration of the teaching staff at UA and their adaptation to the practices and standards of CMU requires stays in the USA of one semester. These stays are *required,* unless in exceptional cases (those already familiar with the CMU procedures, such as former faculty or graduate students). Because of this strict requirement, the UA will not be able to count with one of its faculty, per semester. Hiring one full-time professor is a necessary condition to render the stays, and the program, possible.

The faculty of the UA is already overloaded with their present commitments. As a result, the involvement of the required number of professors in the Professional Masters of Information Networking is only possible if an equivalent number of new professors is hired.

Conclusion

The collaboration has three components: The Professional Masters in Information Networking, and a doctoral program and research initiative. Aimed at 15 students per year, and targeted to industry personnel, the Professional Masters course fills a gap in the existing courses, and will enable recruiting students in the international arena. At the end of the course, the student gets a Professional Masters degree from CMU, and a Diploma from UA. Other potential partner institutions will be identified before January 2007.

The doctoral program in Electrical and Computer Engineering / Information Processing and Networking is a dual-degree program, granted by both CMU and UA. The number of admissions is expected to evolve so that in steady state the number of PhD students is six (suggestion: 2+2+1+1). An effort will be made to engage in research that will be also of interest to our industry partners (topics have been identified in the workshop hosted by Portugal Telecom in July 24). The following is a tentative list of areas of collaboration: Wireless Networks (self-organizing, reward-oriented, clean slate design, multicast in wireless, metro Ethernet, multiple access and routing, FPGA based network design and verification, sensor networks, waveform design by time reversal), Network Optimization across OSI Layers, Scalable Ethernet technology for wide area networks, and Network monitoring (network traffic estimation, traffic modeling, internet measurement).

It is hoped that this collaboration will help the Portuguese groups involved to establish themselves as leading institutions in Information Processing and Networking at the international level, and that the flow of ideas and best practices will make a positive lasting impact in UA/IT, helping to better prepare them for the challenges ahead.

Language Technology

Main Proponents: L2F (INESC-ID and IST, UTL), CLUL (UL), UALG and UBI, in cooperation with Linguateca and FCCN

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Executive Summary

Goals. This proposal falls within the area of *Information and Communication Technology* (ICT), identified as the main theme of the potential CMU-Portugal partnership. Within this theme, the main topic is (Human) Language Technology. The proposal will significantly contribute towards the progress of HLT in Portugal, given the opportunity to cooperate closely with an institute that is among the top in the world in this domain. In fact, Pittsburgh is the city with the largest number of people working in this area per capita in the world.

Main Partners.

The Portuguese partners include 4 different research centers, which have been for some time cooperating together: L2F, CLUL, UALG and UBI. This joint team is headed by L2F, the lab which includes as invited researchers representatives from the 3 other centers. Although only these 4 centers are explicitly mentioned in this proposal, the cooperation with LTI should be extended to cover other centers working on HLT in Portugal, namely those currently represented in the Linguateca network.

Main researchers. Isabel Trancoso, IST/INESC-ID (Speech recognition, synthesis and coding); M. Céu Viana, CLUL (Phonetics and phonology, speech synthesis); Jorge Baptista, UALG (Corpus linguistics, information retrieval, linguistic resources, representation of lexical-semantic knowledge for various NLP applications); Gaël Dias, UBI (NLP, namely automatic extraction of collocations from corpora).

Other Senior Researchers from the Portuguese Team:
Diamantino Caseiro, IST/INESC-ID, (Automatic speech recognition, speech-to-speech machine translation); Luísa Coheur, IST/INESC-ID (Question answering, dialogue systems, machine translation); David Martins de Matos, IST/INESC-ID (Natural language generation, summarization, question answering); Nuno Mamede, IST/INESC-ID (Natural language interfaces to databases, spoken dialogue systems); João Paulo Neto, IST/INESC-ID (Speech recognition, speaker-adaptation, spoken dialogue systems); Luís Caldas de Oliveira, IST/INESC-ID (Speech synthesis, voice quality, expressive speech synthesis), António Serralheiro, Military Academy/INESC-ID (Speech recognition, fractional system modelling, microphone arrays); Christian Weiss, INESC-ID (Speech synthesis, audio-visual synthesis, statistical learning); Palmira Marrafa, FLUL/CLUL (Computational lexical syntax and semantics, machine translation, question answering); Ana Isabel Mata, FLUL/CLUL (Phonetics and phonology, and

educational linguistics); M. Amália Mendes, *CLUL* (Corpus compilation and annotation, corpus-driven development of lexical resources).

Main Researcher at CMU (LTI): Jaime Carbonell, Director LTI (Artificial intelligence, natural language processing, machine learning / translation).

Other Senior Researchers from the CMU Team:
Alan W. Black, CMU/LTI (Speech synthesis, speech-to-speech machine translation, spoken dialog systems); Jamie Callan, LTI (Information retrieval, adaptive information filtering, text data mining); Maxine Eskenazi, LTI (Computer-aided language learning, speech processing, speech recognition); Robert Frederking, Director of Graduate Programs LTI (Speech-to-speech MT, rapid development wide-coverage MT, question answering); Alon Lavie, LTI (Machine translation, spoken language understanding, machine learning); Lori Levin, LTI (Minority languages, machine translation, interlingua representation, lexicons); Tanja Schultz, LTI (Speech recognition, human-human communication, human-machine communication); Richard Stern, LTI (Robust automatic speech recognition, auditory perception, signal processing).

Specific form of collaboration.

This proposal involves two main forms of cooperation: a dual degree doctoral program and a complementary joint research program, in which the doctoral students will be involved in one of two projects aimed at building real HLT systems. The joint doctoral program will involve 1 or 2 new PhD students from the Portuguese team every year, for the duration of the 3-year program, with a target of 5 students. Each project will involve the equivalent of 2 full time researchers from the Portuguese team during the 3 years, and the equivalent of 9 person-month from the LTI staff side. One or two of the members of the Portuguese team will be the doctoral students involved in the program, who will dedicate half of their time to research during the first 2 years.

Description of Collaboration

Main goals for Carnegie Mellon University-Portugal cooperation.

The main goals of this cooperation proposal are to boost the progress and the internationalization efforts of Portuguese Universities in the Human Language Technologies area, by a joint doctoral program and a joint research program with LTI. The doctoral students will be integrated in real research projects that will result in the development of much needed HLT systems, within a 3-year time frame. These prototype systems will be in the topics of CALL (Computer Aided Language Learning) and S2SMT (Speech-to-Speech Machine Translation), two multilingual topics with very strong synergies between them, where LTI's research is undoubtedly one of the best at world wide level. The language specific expertise of the Portuguese research teams will complement this know-how.

Why a LTI / Portuguese team partnership?

As explained below, the cooperation takes two complementary forms: joint doctoral program and joint research projects. Concerning the first form, the main advantages are:

Opening the possibility of Portuguese students to take PhD level courses at CMU would guarantee that they have access to a wide range of courses which are more specific than the typical PhD level courses that can be found at the Portuguese Universities. The fact that these courses are taught by top ranking experts in these specific topics is also very important, as is the possibility of using a wide range of high performing language technology components in lab classes.

The joint supervision of doctoral students will also significantly contribute to boosting the internationalization efforts of Portuguese Universities.

- A PhD CMU granted degree combined with the cooperation in research initiatives would have the potential advantage of attracting more students to the area of human language technologies in Portugal.

Concerning the second form, the main advantages are:

- The cooperation with a prestigious group such as LTI would be of a great importance to foster the internationalization efforts of the Portuguese teams. Participating in international projects has been very difficult recently. On one hand, Portuguese is not typically recognized as a strategically important language in joint European projects, especially since the addition of new Eastern languages to the Community. On the other hand, the support of Portuguese industry in European projects is still very scarce.

- The areas in which the partnership would be most fruitful are CALL and S2SMT, two multilingual topics with very strong synergies between them, where LTI's research is undoubtedly one of the best at world wide level.

Description of program.

Joint Doctoral Program

The proposed joint doctoral program will involve 1 or 2 new PhD students from the Portuguese team every year, for the duration of the 3-year program, with a target of 5 students. Each student will get a dual degree from LTI and the Portuguese University, being co-supervised by one advisor from each institute, and spending approximately half of the 5-year doctoral program at each institute.

Ideally, the academic part of the PhD program should be done at LTI, during the first 2 years. The remaining 3 years of the doctoral program will be dedicated to research, supervised by the two advisors. Although most of this time will be spent at the Portuguese institute, at least one or two visits to CMU per year should be planned, roughly amounting to one extra semester at CMU, during the last 3 years. The thesis topic will be in one of the research areas of the cooperation program, defined by the two advisors. It is expected that sometime at the end of the third year, the student will present the dissertation proposal. Although this proposal outlines the ideal framework of spending half the time at each institute, adjustments are possible, in terms of percentage of time and number of courses taken at each institute.

Courses at LTI

In order to get an LTI degree, the students must complete a minimum of 8 courses selected in consultation with their advisors. At least one course must be selected from each focus area

(Linguistic, Computer Science, Statistical/Learning, Task Orientation). All students must also enrol for a minimum of two sections in the Language Engineering laboratory, which includes hands-on work in four different modules (Speech, Machine Translation, Information Retrieval, Natural Language Analysis). Each lab counts as one half of a course. In order to encourage PhD students to focus on research, PhD students are normally only permitted to register for 24 units of actual coursework per semester, which roughly allocates half of a student's time to research. Hence, the course part of this doctoral program typically extends for 4 semesters. Besides the successful completion of the set of 8 courses (minimum B level), and the program of research culminating in a Ph.D. thesis, the doctoral program also requires mastery of certain proficiencies demonstrated in the course of graduate study, as described in the LTI Policies & Procedures: writing (e.g. conference paper), presentation (e.g. conference presentation), programming, and teaching (satisfied by assisting in the teaching of two classes, in the Portuguese University).

Courses at Portuguese Universities

The doctoral programs in Portuguese universities are currently undergoing a profound restructuring, as a result of the transition to the common European Bologna model. Traditionally, however, the students that did their PhD in HLT chose one of three major courses equivalent to ECE (*Engenharia Electrotécnica e de Computadores*, at IST), CS (*Engenharia Informática e de Computadores*, at IST) or (Computational) Linguistics. The ECE degree was more common among the students working on speech technology; the CS degree was more common among the NLP (Natural Language Processing) students; the Linguistics degree was more common among the students without an engineering background. The interdisciplinary nature of the human language technology area is similarly reflected in the profiles of the Portuguese and LTI researchers, which include all 3 different backgrounds. Hence, for instance, a student applying for a joint degree could either apply for an ECE or CS degree at IST, depending on his/her background. The choice of the courses should also reflect the major focus.

At a Master's level, one can find several courses in Portuguese Universities similar to the ones taught at LTI, although at a more generic level (e.g. 1 instead of 2 semesters), and covering only the less advanced topics. This lack of specific HLT courses is mainly due to the relative small number of students who choose HLT as their PhD area. So, a subset of the 8 courses could be done in Portugal, but given that most IST students from that area would take such courses during their Master Course, the current offer would typically not allow them to take more than 2 local courses in this area at a post-graduate level.

Joint Research Program

The two multilingual topics around which the potential projects have been defined are CALL and S2SMT. The projects involve at least 2 languages, one of them being Portuguese: the target language for the CALL system to be developed, and either the source or target language (or both) for the S2SMT system. The other language will be either English or Chinese (Mandarin) or both. Chinese was chosen not only because of its importance as one of the most spoken languages of the world, but also because of the existing expertise of LTI researchers with language technologies for Chinese, and the great demand from China for products involving Portuguese.

Each project will involve the equivalent of 2 full time researchers from the Portuguese team during 3 years (72 person-month), and the equivalent of 9 person-month from the LTI staff side. One of the members of the Portuguese team will be a doctoral student who, as explained, will dedicate only half of his/her time to research during the first 2 years (total of 24 pm during the 3-year project). Ideally, each project should involve 2 doctoral students, but this target may be difficult to achieve. In this case, a post-doc should be involved as well (36 pm). The other members of the Portuguese team will be faculty members (12 pm). The involvement of post-doc researchers will also contribute to renovate the Portuguese team, where restrictions in terms of hiring faculty members are one of the most difficult problems faced by the research community. Whereas students with a CS background will probably prefer to be integrated in the CALL project, students with an ECE background will probably be more suited to the S2SMT project. All projects will have 4 milestones:

M1 (Month 6) – Defining and collecting the necessary linguistic resources.
M2 (Month 12) – Development of the first full system integrating all the components.
M3 (Month 24) – Development of a 2nd version of the system that is comparable with the state of the art, and corresponding evaluation, according to internationally recognized metrics.
M4 (Month 36) – Development of a 3rd version of the system, integrating novel features.

Project 1 (CALL) – This project will involve the development of a Portuguese version of the REAP project (Reader-Specific Lexical Practice for Improved Reading Comprehension), currently in progress at CMU, and research in the associated topics. The project uses a variety of HLTs to help native or non-native students learning to read. It searches for appropriate authentic documents for students to read according to reading level, topic, vocabulary list, and other teacher-specific criteria. The core ideas of the project are i) a search engine that finds text passages satisfying very specific lexical constraints, ii) selecting materials from an open-corpus, thus satisfying a wide range of student interests and classroom needs, and iii) the ability to model an individual's degree of acquisition and fluency for each word in a constantly-expanding lexicon. In addition, the project will explore the use of techniques such as topic detection and summarization in the search for documents that are more motivating for the students.
The main researchers at LTI to be involved in this cooperation project will be: J. Callan, M. Eskenazi, L. Levin. The main Portuguese researchers involved in this cooperation project will be: D. Matos, N. Mamede, L. Coheur, I. Trancoso, J. Baptista, G. Dias, C. Viana, A.I. Mata.

Project 2 (S2SMT) – The goal of this speech-to-speech machine translation project will be to design a Portuguese-to-English/Chinese translation system (or vice-versa) that, besides dealing with the problems of textual machine translation, also deals with the two challenges of current S2SMT systems: the need for disfluency removal on the speech input side, and the inadequacy of current translation systems to produce text that is fit for a synthesizer, i.e. that can be read in a naturally sounding way. Most S2SMT systems currently use statistical based machine translation approaches. The LTI team is also using a hybrid approach that starts from a relatively small parallel elicitation corpus and uses rule induction.
The main researchers at LTI to be involved in this cooperation project will be: A. Black, T. Schultz, R. Stern, R. Frederking, A. Lavie, J. Carbonell. The main Portuguese researchers involved in this cooperation project will be: D. Caseiro, L. Coheur, C. Weiss, I. Trancoso, L. Oliveira, J. Neto, A. Serralheiro, C. Viana.

Conclusion

This cooperation proposal involves several research teams with a very strong synergism between them: a consortium of Portuguese research teams (L2F, CLUL; UALG, UBI, in close collaboration with the Linguatec network and FCCN) and the Language Technologies Institute of CMU. The proposal will significantly contribute to boost the progress and the internationalization efforts of the Portuguese Universities/research centers in the Human Language Technologies area, by a joint doctoral program and a joint research program with LTI (namely in the areas of CALL and S2SMT).

2. Critical Infrastructures and Risk Assessment

Main Proponents: INESC-ID; ISEP/IPP; ISR Lisboa; ISQ
Other potential partners: FEUP and INESC Porto

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PART A. CRITICAL INFRASTRUCTURES AND RISK ASSESSMENT

Executive Summary

Goals. The main goal of the partnership is to contribute to promoting the development of the Portuguese scientific and technological capabilities necessary for both the operation and performance assessment of **public risk minimization systems**. This will rely on an integrated research and educational (PhD) program in the area of Critical Infrastructures and Risk Assessment, specially focused on Networked Sensor, Communication, and Decision Systems, which are important and very actual topics in Information and Communication Technologies (ICT). Those topics include the sub-areaas wireless sensor networks, HW platforms and sensing technologies, software and middleware, decision making, actuation, security, privacy, applications, and risk assessment.

Partners. The partnership has been launched in Portugal with ISR-Lisbon, INESC-ID, CISTER/ISEP, and ISQ, but it is expected to bring together other leading Portuguese institutions, including INESC Porto and FEUP. The following CMU Units are involved: Center for Sensed Critical Infrastructure Research (CenSCIR), Electrical and Computer Engineering (ECE) Department, Computer Science (CS) Department, Engineering and Public Policy (EPP) Department, and Tepper, the CMU Business School.

Main researchers. Victor Barroso (ISR-Lisbon, IST/UTL); Augusto Casaca (INESC-ID, IST/UTL); Eduardo Tovar (CISTER, ISEP/IPP); and Manuel Cruz (ISQ).

Other researchers involved in the program are: António Pascoal, Carlos Bispo, Carlos Silvestre, João Paulo Costeira, João Xavier, José Santos-Victor, Maria Isabel Ribeiro, Paulo Oliveira, Pedro Aguiar, and Pedro Lima, all from ISR-Lisbon; António Grilo, Carlos Ribeiro, and Mário Serafim Nunes from INESC-ID; Bjorn Arne Andersson , Luís Miguel Pinho, and Mário Jorge Andrade Ferreira Alves from CISTER; Elói Trindade from ISQ.

Potential faculty members of CMU participating in the program are: José Moura, Kumar, Marija Ilic, Priya Narasimhan, Raj Rajkumar, Adrian Perrig, and Tsuhan Chen, all from the ECE Department; Hoon Sohn, Jeanne Van Briesen, Jim Garret, and Scott Mathews from the Civil and

Environmental Engineering (CEE) Department; Manuela Veloso from the CS Department; Granger Morgan from the EPP and ECE Departments, and Michael DeKay from EPP.

The participant researchers, from the Portuguese partners and from CMU, form a multidisciplinary team that cover all the sub-areas identified in the CIRA area.

Specific form of collaboration. This is a collaborative scientific program in the general area of CIRA, promoting joint research initiatives, integrating the capabilities of the Portuguese research units and of CMU, and including a dual doctoral program in ECE to be granted by IST – UTL and CMU, the main focus of which being on Networked Sensor, Communication, and Decision Systems. The possibility of extending this doctoral program to FEUP is under active consideration. Other potential partner universities in Portugal should be defined before January 2007. The research objectives in this collaboration cover the sub-areas listed in point 2 (wireless sensor networks, HW platforms and sensing technologies, software and middleware, decision making, actuation, security, privacy, applications, and risk assessment), and other technological/ scientific related topics such as: static and mobile sensors; data, image, and video processing; distributed information fusion and perception; computer vision; optimization; cooperative planning and decision making. This research activity will be strongly connected to the doctoral program in ECE, although in some specific cases it may support students involved in other doctoral studies directly related with the objectives of this partnership.

The doctoral program is designed to take up to five years to complete. Students are required to fulfill course requirements covering fundamentals and applied topics in ECE and in other relevant areas, such as risk analysis and decision support methods. Typically, each student will spend the first year in Portugal taking the courses on fundamentals. The next 1½ /2 years are spent at CMU to complete the course requirements and the qualifying examination. The final 1½ /2 years are spent in Portugal. Since the beginning, the student will be involved in research activities related with the theme of his/her thesis. Thesis proposal and defense will take place at CMU or in Portugal, as agreed in a case by case basis by the respective Advisory Committee.

In general, in recognition of completion of the course of studies and successful defense of a doctoral thesis, it is expected that IST – UTL and CMU will confer to the student their own PhD degrees: "Doutor em Engenharia Electrotécnica e de Computadores" conferred in the terms of article 42º of "Decreto-Lei" nº 74/2006 of March 24, and Ph.D. in Electrical and Computer Engineering, respectively. For some specific situations, CMU will confer to the involved students the Ph.D. in Computer Science or the Ph.D. in Risk Assessment.

Description of Collaboration

Goals. This collaboration aims at strengthening innovation in the Portuguese society, by achieving scientific and institutional improvements in research and advanced training in the particular area of Critical Infrastructures and Risk Assessment (CIRA). The consortia in Portugal involve ISR-Lisboa, INESC-ID, CISTER and ISQ, as well as faculty from FEUP. Other potential partner institutions in Portugal should be defined before January 2007.

The partner institutions in Portugal also expect to reinforce their international visibility and recognition. This will contribute to increase the attractivity to students, and to facilitate

recruiting/ placing the best candidates, from researchers to faculty members, from/ in the most reputed institutions around the world. For the success of process improvement in Risk Assessment, Risk Communication and Risk Management, it is of paramount importance the involvement, since the earlier stages, of the companies and critical infrastructures' owners and managers. This partnership fosters this kind of collaboration through the involvement of ISQ as an institution that bridges fundamental research agents and the economic tissue, e.g., acting as the interface between university researchers and the critical infrastructures owners.

ISR-Lisbon and CISTER have a tradition of scientific collaboration with some CMU Units such as the ECE, CS, and EPP Departments. These collaborations have included bilateral research initiatives and Ph.D. studies of Portuguese researchers at CMU, some of which are now faculty members of IST. The success of those past collaborations together with the common interests on the CIRA area have facilitated the establishment of this partnership. The Portuguese partners see this partnership has an opportunity to develop/ create in Portugal first rate, internationally recognized, doctoral and research initiatives in ICT/ CIRA, an area of great interest to the Portuguese Society. The partnership with CMU will also benefit the academic/ research Portuguese partners in terms of attractivity of the best students and post-docs from the best institutions all over the world.

Program description - research. This is a collaborative scientific program in the area of Critical Infrastructures and Risk Assessment and in a dual doctoral program in ECE, to be granted by IST – UTL and CMU (other universities in Portugal to be defined, namely the potential involvement of University of Porto), the main focus of which being on Networked Sensor, Communication, and Decision Systems.

This program focuses on critical infrastructures and risk assessment. We make use of recent developments in the technology of highly integrated, cost effective, sensing platforms that are autonomous, inexpensive, and have computing, sensing, and wireless communications transceivers capabilities. These platforms, easily deployable, form ad-hoc wireless sensor networks that instrument highly distributed, geographically extensive systems – for example, highways, power grids, cities, airports, or other critical infrastructures, as well as impromptu spaces in urgent need of surveillance or monitoring. These ad-hoc wireless sensor networks pose new problems and challenges to traditional information technology systems and telecom service providers. These challenges include: telecommunications infrastructure (issues like network protocols or quality of service in ad-hoc networks); security (integrity of information collected – is a sensor reliable or has it become compromised); on the fly network topology design and reconfiguration; distributed software validation and fault tolerant design; network traffic estimation under constraints; distributed decision making (how to make sense from the vast amounts of information collected). All these issues are to be studied and dealt with under power constraints, time constraints, and scarcity of other resources (like bandwidth, computing power, multiple access channel rate constraints). This proposal and the activity it will spawn expands to the next level traditional telecommunication infrastructures and will prepare telecom companies to provide the new services of the future.

To address Critical Infrastructures and Risk Assessment, as well as related issues on security, safety, and reliability, a broad expertise is needed within the partnership, requiring the participation of different universities and departments. The program involves, also, a number of

technological areas and their interaction such as sensors, data collection and transmission, data analysis, decision making, and event prediction.

Risk analysis and assessment is an important dimension to this partnership. Minimum risk decision systems must rely on adequate technological infrastructures, which have to be designed in accordance to well defined criteria, e.g., minimum cost subject to a given level of expected protection. Therefore, systems analysis, risk analysis, and behavioral decision theory form the fundamental core of a balanced and complete approach to the design of infrastructure systems and play a key role in the definition of strategies of communication to systems' operators and users and in public perception management.

To validate and transition to market the technologies developed, applications with industrial partners are planned to be designed and implemented. Test beds at the consortium and at the critical infrastructures partners will be implemented. In particular, the consortium plans as testbed a unique infrastructure that will instrument the IST campus with several hundred wireless polyvalent sensors in a first phase and will extend to several thousand of wireless sensors in a second phase. This testbed will support several applications, for example: 1) monitoring mass transit transportation systems, 2) water supply systems, and 3) monitoring campus physical infrastructure.

Program description – doctoral program. The doctoral program aims at a dual doctoral degree in ECE with a focus on Networked Sensor, Communication, and Decision Systems. It is expected to attract post-graduate students from reputed institutions around the world. The students are expected to acquire state-of-the-art knowledge and background on the multidisciplinary aspects of sensor networks and risk analysis, so that they can play a key role in research activities in problems related to information processing, communication, and control, and in the design of complex sensing, monitoring and decision systems.

Admission to the doctoral program will be granted only to those applicants who show convincing evidence of high-order analytical skills, intellectual curiosity, and the ability to work independently in pursuing scholarly research. The admission criteria will be based upon the requirements of CMU and IST programs.

The program is designed to take up to five years to be completed. Students in the doctoral program must take a total of 8 ECE courses at CMU and IST – UTL in a total of 48 ECTS. At least 4 of these 8 courses must be graduate courses on fundamentals in ECE relevant for the networked sensor, communication, and decision systems subject. Each student must take at least 3 courses chosen from both the Breath Areas defined by the ECE Department of CMU or the list of similar courses offered by IST. A student can only take up to 1 ECE undergraduate course at the "segundo ciclo" level or the equivalent at CMU to fulfill the course requirements. Areas of concentration of courses on fundamentals will differ across students, depending on the specific research area they want to focus on. Required first-year courses (typically, courses on fundamentals) will be offered at IST in Lisbon. During the second-year, students are required to go through the qualifying examination, and encouraged to complete the course requirements at the CMU campus. They will also have to defend successfully a doctoral thesis proposal and then complete the doctoral thesis. The thesis proposal discussion and the thesis defense can take place in either Lisbon or Pittsburgh, with the previous agreement of their Advisory Committees.

In terms of the Portuguese partners, teaching and supervising faculty are selected from the involved research and academic institutions. This does not exclude the possibility of involving faculty from other academic units. Mobility of faculty between Pittsburgh, Lisbon, and Porto should also be greatly encouraged whenever contributing to the pursuit of research collaborations.

Conclusion

With this collaboration, the Portuguese partners aim at achieving scientific and institutional improvements in research and advanced training in the area of Critical Infrastructures and Risk Assessment, and at bridging fundamental research agents and the economic tissue.

This collaboration is expected to contribute to start structural changes in the practices of the Portuguese higher education system, particularly in what respects the management of faculty members. On this matter, the best international practices, as those of the best American Universities, must be considered by instituting a system of short-term incentives and recognize explicitly teaching and research excellence as critical criteria.

This collaborative program in the area of Critical Infrastructures and Risk Assessment includes research initiatives and a dual doctoral program in ECE, granted by CMU and IST – UTL, the main focus of which being on Networked Sensor, Communication, and Decision Systems.

The research initiatives are focused on the sub-areas: wireless sensor networks, HW platforms, and sensing technologies, software and middleware, decision making, actuation, security, privacy, applications; risk assessment; static and mobile sensors; data, image, and video processing; distributed information fusion and perception; computer vision; optimization; cooperative planning and decision making.

The doctoral program aims at a dual doctoral degree in ECE with a focus on Networked Sensor, Communication, and Decision Systems. The students, which are expected to be attracted from reputed institutions around the world, will acquire state-of-the-art knowledge and background on the multidisciplinary aspects of sensor networks and risk analysis, so that they can play a key role in research activities in problems related to information processing, communication, and control, and in the design of complex sensing, monitoring and decision systems.

Applications that are relevant to industrial and service companies in Portugal will be actively pursued. These may include networked systems like water distribution or subway networks, power grid, surveillance and security monitoring of large physical spaces with sensor networks integrating both static and mobile sensors. ISQ, and the other consortium partners, are committed to engaging and interfacing with interested potential companies.

This collaboration program on Critical Infrastructures and Risk Assessment will contribute to accomplish two main objectives of the Portuguese Government: the development of the scientific and technological capabilities necessary for both the operation and performance assessment of public risks minimization systems; and the increase of the number of doctors with expertise in the area.

Executive Summary

Goals. The main goals of this collaboration are to contribute fast mobile detection and action within a sensor network. We propose to research the coordination of static and mobile sensors towards a hierarchical heterogeneous approach to multi-sensor communication and active information gathering through mobile sensor navigation. Our work fits into the Critical Infrastructure and Risk Assessment area.

Partners. Faculdade de Engenharia da Universidade do Porto (FEUP)–Departamento de Engenharia Electrotécnica e de Computadores – and Computer Science Department at CMU.

Team. Researchers from FEUP involved in this project include Antonio Paulo Moreira, Paulo Costa (FEUP), and Armando Souda. From CMU they include Manuela Veloso (CS, CMU), and possibly Paul Rybski both from the Robtics Institute (RI) at CMU. All of these faculty have extensive experience in mobile teams of robots, where robots are equipped with multiple sensors, including vision, ultrasound, infrared and laser.

Specific form of collaboration. This effort will be a research collaboration with 1-2 PhD students candidates, possibly for a joint dual degree awarded by CMU and by FEUP.

Description of Collaboration

We propose a mobile sensor network, based on a heterogeneous multi-robot system. We would like to explore the idea of combining several different types of robots, each featuring unique sensing capabilities, with the goal to act as a unified, mobile, and intelligent sensor network.

Challenges and Benefits. We would especially like to focus on the notion of heterogeneity in this robotic sensor network. Since we are dealing with mobile robots, heterogeneity does not only mean that we can expect various kinds of sensor input, but furthermore suggests that our system should be able to operate with any mix of different underlying robotic platforms which each have their own unique properties and capabilities. We can point out a few examples where we can expect heterogeneous aspects within our suggested system:

Robot Size, Speed, and Mobility. These properties are of particular interest, because we can imagine to construct a network containing robots of various different sizes. Smaller robots have the advantage of operating at relatively high velocities while being able to explore very complex and narrow spatial configurations. Having a large set of smaller robots clearly allows to quickly cover a great amount of the sampling space. Larger robots on the other hand might tend to be slower, but are also often more capable. They might be able to carry a greater payload, and thus more sensory equipment. Furthermore, their size can also be an advantage when doing localization tasks or when performing human-robot interactions.

Sensor Types and Coverage. Our system should explore how to best combine the input from various types of sensor data. We can for example imagine the smaller robots to perform simpler sensory tasks, such as collecting light, acoustic noise, flame/smoke or temperature data, while the larger robots might be able to collect real-time depth and video data. Our goal would be to create a world model which can use and accommodate data coming from various different (and possibly moving) sources. We would especially like to analyze the tradeoffs between a centralized approach of a single shared world model, and the ad-hoc approach of having many individual models which synchronize through limited data-exchange.

Manipulative Capabilities. We would like to emphasize that we are not only dealing with a static sensor network, but rather with actively engaged robots. As such, we are not only limited to gather data from the current state of the world, but we are also able to actively modify it. These manipulative capabilities can range from simple manipulations through collisions (such as pushing an obstacle out of the way) to much more sophisticated abilities (such as kicking a soccer-ball or flipping a light-switch). Being able to plan, to model, and to observe our actions will certainly play a significant role in creating a robotic sensor network that is able to operate in a realistic domain.

Looking at all of the above, we can quickly recognize that there lies an inherent advantage within the heterogeneous aspect of our proposed robotic sensor network: every robot can have its own unique strengths and weaknesses for every one of the properties mentioned above. In theory, this should allow us to cover a much broader range of sensory problems than what we could ever hope to achieve with a simple homogeneous approach. The real challenge however, lies in exploiting all of the robots' differences while still working in unison towards a single goal.

Navigation. Heterogeneity adds complexity to the robot navigation task, especially since we cannot expect all of the robots to be equipped with complete localization sensors. We suggest a hierarchical approach to navigation in which a localized robot can act as a "guide" for the robots without inherent localization capabilities. A particular example would be that one of the larger robots with an omnidirectional vision system might be able to see and localize the smaller robots. It can then share this information with the smaller robots' world model. A problem obviously occurs when a smaller robot becomes "lost" in a way that it cannot localize itself and it cannot be found by any of the other robots. In this case, it might have to rely on its own internal world model and its limited prediction and sensing capabilities to reach a state where it can be seen again. The first approach could be to backtrack its last movement until it reaches a point where it did not use to be lost. If this does not help it might be able to attempt a more random exploration pattern. The last resort could be that the other robots with localization capabilities will attempt to further explore the space in order to re-localize the lost robot in a "search and rescue"-like fashion.

More generally however, we can say that localization should be treated as a shared sensing capability. That is, each robot should be able to make use of any other robots' localization results. If we are to implement a single shared-world model then it is very likely that we can increase absolute localization precision by combining partial localizations of various robots.

Infrastructure and Sample Applications. For an initial implementation we would suggest combining a small set of "CMassist" robots with a larger set of RoboCup "Small Size" robots.

CMassist is a very flexible robotic platform which was originally designed to act as an assistive robot in a human home-like environment for the "RoboCup@Home" competition. The robot is approximately 4ft tall and has a base of 2x2 ft. Its current sensing capabilities include a 4-way omnidirectional camera, a separate stereo depth-camera, and 3-4 distance sensors (for collision avoidance). Its physical properties allow it to move at relatively low speeds by using a differential drive system. Another alternative is the MSL compliant robots developed by the FEUP team (80 cm tall, occupying a 50 by 50 cm2 area). These "5dpo-MSL" robots feature an catadioptric omnidirecnional vision system and also an omnidirectional driving system. They have an on board PC capable of more demanding computational tasks and storage capabilities. The "Small Size" robots on the other hand are fairly small in size (18cm in diameter, 15cm height) and can move at very high velocities. Since their original design was intended to play robotic soccer, they feature special sensors and manipulators to perform dribbling and kicking of golf-balls. Small Size robots however, do not feature any inherent localization capabilities and are therefore dependent on some sort of external localization and control.

Map of Temperatures/ Acoustic Noise Level/ Light Intensities. A simple sample application for the above described infrastructure would be the objective to obtain a complete 2D temperature Acoustic Noise Level/ Light Intensities map of a room. One could assume temperature sensors on board of the Small Size robots which will then explore and map the room while being localized and guided from the Cmassist/5dpo-MSL robots. This task becomes particularly interesting with configurations where the Small Size robots might temporarily lose localization from their guides (e.g. when they have to drive underneath a table). A good world model and prediction will be required to deal with these kinds of scenarios.

Distributed Vision System. Another sample application could be a Distributed Vision System where the Small Size robots carry a wireless camera. These cameras could be used to obtain images from positions inaccessible to bigger robots. The 5dpo-MSL have wireless capabilities and could gather and process the images from the other robots A generalized image of the room could be assembled where the images from all the robots would be fused in a high resolution/multi angle picture of the surrounding world. This could be a preliminary task, giving a rough map of the environment, to some other sensory gathering tasks.

Team Cleanup Manipulative Task. A more sophisticated application would not only involve sensing, but also manipulation of the world state. We could for instance imagine a room full of randomly placed golf balls of two different colors, with the goal to be sorted into two piles, one for each color respectively. This task would entail complex planning, collaboration, and manipulation of objects. It is particularly interesting because the Small Size robots themselves are only able to detect golf-balls from very short distances (through an array of IR-sensors) and will need to rely on the Cmassist/5dpo-MSL robots to localize them globally. Furthermore, the Small Size robots will not be able to recognize the balls' colors on their own, but instead might need to deliver a ball into the field of visibility of a Cmassist/5dpo-MSL guide for identification purposes, before being able to deliver it to the correct pile.

In summary, our project will enable a collaboration between FEUP and CMU/CS,RI to contribute active mobile sensors to collaborate with static sensors for the design of critical infrastructures.

3. Basic Sciences: Mathematics

Main Proponents: IST (UTL), FCUL (UL), FCTUNL (UNL)
Other potential partner: UMad

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Executive Summary

Goals. The main goal of this project is to develop advanced programs of research and education in specific areas of mathematics of common interest and expertise between faculty of CMU and from Portuguese Universities.

Main Partners. The program as been proposed to establish cooperation between IST (UTL), FCUL, FCTUNL and the Department of Mathematical Sciences of CMU. Other potential partners in Portugal include the Univesity of Madeira (UMad).

Main researchers. José Matias (IST), Ana C. Barroso (FCUL) and Luísa Mascarenhas (FCTUNL). Other researchers include: Pedro Girão, Diogo Gomes, Carlos Rocha, Adélia Sequeira (IST), Manuel Marques, Miguel Ramos (FCUL)

CMU researchers include: Irene Fonseca, Giovanni Leoni, David Kinderlehrer, Robert Pego, Dejan Slepcev (CMU),

Specific form of collaboration. The project establishes a program of graduate studies in Mathematics. In particular, it sets up an internationally attractive graduate program leading to a dual degree in Mathematics and promotes matching between members of CMU and members of the Portuguese Universities in order to ensure good scientific interaction and top research work.

A student enrolled in the program should be involved in research activities as soon as possible, in order to benefit from the matching between researchers.

Description of Collaboration

Main goals for Carnegie Mellon University-Portugal cooperation.

Without excluding other possible projects, the main goal is to establish a common program of graduate studies in Mathematics, between IST (UTL), FCUL, FCTUNL and the Department of Mathematical sciences of CMU. Other potential partners in Portugal, including the University of Madeira, should be defined before the end of January 2007. This program is intended to be internationally attractive and of top quality. In order to ensure this, a student enrolled in it must

satisfy the requirements from all the Universities involved. Therefore, upon completion of these requirements, the student will be awarded a PhD degree in Mathematics by CMU and a doctoral degree in Mathematics by the three Portuguese Universities involved, in association (joint degree). In case one of these three Universities is unable to confer the degree, it will be awarded by the others.

At the same time, the program aims to take advantage of viable matchings between faculty from CMU and from the Portuguese schools, in order to promote good scientific interaction and top research work in pivotal areas.

Best practices.

The Portuguese partners are all the public Universities in Lisbon. With this program we intend to promote cooperation between these institutions and effective internationalization of the above.

At the same time, one aims to optimize resources and to strengthen the research conducted in the Portuguese Universities.

Also, since the project will set up a dynamical doctoral program that reproduces the best practices of such programs in US Universities, we expect it will contribute to effective changes in the Portuguese University.

Why a Carnegie Mellon University-Portugal partnership in Mathematics?

There is a long history of scientific interactions between the Department of Mathematical Sciences of CMU and their Portuguese counterparts, namely in the areas of Applied Mathematics, Calculus of Variations and Partial Differential Equations. These are areas were good intellectual matching between members of CMU and members of the Portuguese Universities is possible. The following are examples of effective research partnerships:

> Irene Fonseca and Giovanni Leoni (CMU) with Ana C. Barroso, Manuel Marques (FCUL), José Matias (IST) and Luísa Mascarenhas (FCTUNL);
>
> David Kinderlehrer (CMU) with Pedro Girão and Diogo Gomes (IST);
>
> Robert Pego (CMU) with Carlos Rocha and Adélia Sequeira (IST).

The program aims to take advantage of this history of interactions, both by graduating in a relatively short period a significant number of professionals that will strengthen the faculty of the Portuguese Universities and by promoting research interaction in these specific areas of Mathematics.

Description of program.

The program, whose typical duration is four to five years, will consist of up to two years of courses, followed by up to three years of thesis preparation with possible advanced coursework. Taking into account the desired mobility of both graduate students and researchers, the student is expected to spend the first year in Lisbon, the second and third years at CMU, and the fourth year in Lisbon. In year five, the time spent in each country will be decided on an individual basis, depending on the demands of the research schedule. At the end of year two the student should be in position to select a scientific advisor from CMU and one from Lisbon. Since one of

the main goals of the program is to reinforce research interactions between Portuguese and CMU faculty, during the third year of the program the Portuguese advisor should join his/her student at CMU for a period of up to a semester´s length, in order to engage in a research collaboration with his/her CMU colleagues. The CMU advisor is also expected to visit Portugal for a short term during years four or five.

The number of students in the program should be proportional to the number of CMU´s and Portuguese faculty involved.

Conclusion

This program aims to take advantage of the long history of interactions between Portuguese and CMU´s faculty in specific areas of mathematics, in order to:

- o Set up an internationally appealing program of graduate studies that is able to attract to the involved Universities strongly motivated students who are able to integrate advanced research programs in mathematics and applications;

- o Reinforce the scientific and learning capabilities in Portugal, as well as promote the internationalization of the graduate programs of the aforementioned Portuguese Public Universities;

- o Explore possible partnerships (and contribute to set up new ones), in order to stimulate mobility, reinforce scientific ties and develop a sustainable level of research activity in pivotal areas;

- o Enable a close monitoring of the student´s progress by both advisors (one from CMU and one from the Portuguese Universities) and make sure that the student is involved in research activities as soon as possible, in order to benefit the most from the matching between researchers;

- o Contribute to an effective change in the Portuguese University, by putting in place a dynamical doctoral program that reproduces the best practices of such programs in US Universities.

4. Technology, Innovation, and Policy

Sub-areas:

Technical Change and Innovation

Engineering and Public Policy Applied to Network and Software Industries

Technical Change and Innovation

Main Proponents: IST (UTL), FCEE-Católica (UCP),
in cooperation with ISEG (UTL), ISA (UTL), ESB-Católica (UCP)

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Executive Summary

Goals: Technological change and Innovation are the main engines of economic and social development throughout the world. The development of strategies and policies to guide innovative activity in regions and organizations is essential for economic re-structuring and renewal, which is imperative for productivity and employment to grow. The main objective of this collaboration is therefore to educate highly qualified people who can teach, perform research, and work at high level private sector and public administration positions in technology development and commercialization, as well as science and innovation policy and strategy. The education of these professionals is particularly relevant in areas of Information and Communication Technologies (ICTs). Nowadays, ICTs are at the core of the innovation process across all sectors, as organizations adopt ever more sophisticated ICT systems. Portugal needs professionals at the forefront of knowledge in ICTs, but also those that can become leaders in understanding how to develop and apply such technologies successfully in the marketplace, either through established firms or start-ups. The proposed collaboration focuses particularly on research into the positive effects of technological innovation on development and competitiveness, and on how specific strategies and policies may enhance such effects. ICTs will be at the core of this proposed effort.

Main Partners: The main Portuguese partners launching this initiative include the Technical University of Lisbon (UTL) and the Catholic University of Portugal (UCP). IST is the coordinating institution within UTL, while the participation of UCP will be headed by FCEE-Católica. The program will also benefit from the participation of other schools within UTL and UCP. Other schools within UTL include Instituto Superior the Economia e Gestão (ISEG) and Instituto Superior de Agronomia (ISA). UCP's Escola Superior de Biotecnologia (ESB-Catolica) is also part of this collaboration. Four academic units from CMU are involved in this collaboration: Engineering and Public Policy (EPP); Social and Decision Sciences (SDS); the H. John Heinz III School of Public Policy and Management (Heinz); and the Tepper School of Business (Tepper).

Main researchers. Rui Baptista (innovation, entrepreneurship, and industry dynamics); Fernando Machado (technical change and valuation of non-market goods). Other faculty at UTL include Pedro Ferreira (telecom policy), João Santos Silva (econometrics and research methods), and Ana Póvoa (technology, operations and supply chain modeling). Other Católica faculty include David Patient (organizational behavior and managerial communication), Fernando Branco (technology adoption and competition under uncertainty), and Pedro Oliveira

(operations, technology and innovation management). Faculty at CMU include Steven Klepper (technological change and industry evolution), Granger Morgan (technology policy, regulation and risk), Francisco Veloso (technology and innovation policy), Ashish Arora (economics of technical change), Robert Lowe (technology transfer and entrepreneurship).

Specific form of collaboration. The main foundation of this collaboration is a double degree interdisciplinary Ph.D. program in the area of Technological Change and Innovation, aiming to provide students with substantive skills for academic research and high level business or public decision making. The targets of this program are post-graduate students from any area in engineering, technology, economics, business, and social sciences, willing to pursue a career in academia and/or leadership in industry or government. The scope of the double degree Ph.D. program is strongly international, aiming to attract three to five top students per year from all over the world. Students must acquire rigorous, state of the art knowledge in core areas of technological change, innovation, public policy, industry dynamics, and research methodologies, starting with one year of coursework pursued in Lisbon, followed by a second year at CMU. Concurrently with coursework, students must develop significant research leading to a paper and thesis proposal which are part of the qualifying requirements to be filled at the end of the second year. Students will work under joint supervision of collaborating academic advisers from CMU and the Portuguese partner institutions, and are expected to pursue a substantial part of their thesis work in Portugal. Research collaboration between faculty and students from all partner institutions is of primary importance. The collaboration will also include the pursuit of select joint research projects between faculty members from CMU and the Portuguese universities without the aim of a double PhD. There will be a special effort to develop research topics that are of relevance to other universities and research units also active in the Portugal–Carnegie Mellon ICT collaboration framework, in order to increase leverage of the overall collaboration and maximize its benefits to the Portuguese economy and science base.

Description of Collaboration

Introduction: background and goals

Achieving excellence in education and research in the areas of innovation and technological change has become essential for the competitiveness of firms, regions and countries. There are very few structured doctoral and research programs in Europe which are dedicated to these largely multidisciplinary topics. Addressing this gap was the main purpose of the pursuit of contacts leading to a partnership between Portuguese higher education institutions and Carnegie Mellon University (CMU). The main objective was to establish a doctoral and research collaboration in with a significant emphasis on topics exploring policies, firm strategies, and market and entrepreneurial dynamics associated with the development, commercialization, implementation and diffusion of innovations – with a special emphasis on ICTs – as well as their impact on industrial re-structuring and economic development. CMU has established an interdisciplinary doctoral program in these areas that provides an excellent model and unique opportunity for what could become a leading initiative in Europe. This is precisely the ultimate goal of this collaboration, establishing Portugal as leading location for education and research in these critical domains.

Technological change and innovation are the main engines of economic and social development throughout the world. The development of strategies and policies to guide innovative activity in countries, regions and organizations is essential for the re-structuring and renewal of market economies, which is imperative for productivity and employment to grow. The main objective of this collaboration is therefore to educate highly qualified people who can teach, perform research, and work at high level private sector and public administration positions in technology development and commercialization, as well as science and innovation policy and strategy. The education of these professionals is particularly relevant in areas of Information and Communication Technologies (ICTs) , the focus of the overall CMU collaboration. Nowadays, ICTs are at the core of the innovation process across all sectors, as organizations adopt ever more sophisticated ICT systems. Portugal needs professionals at the forefront of knowledge in ICTs, but also those that can become leaders in understanding how to develop and apply such technologies successfully in the marketplace, either through established firms or start-ups. The proposed collaboration focuses particularly on research into the positive effects of technological innovation on development and competitiveness, and on how specific strategies and policies may enhance such effects. ICTs will be at the core of this proposed effort.

Collaboration structure and organization

The main foundation of this collaboration is a double degree interdisciplinary Ph.D. program in the area of Technological Change and Innovation, aiming to provide students with substantive skills for academic research and high level business or public policy decision making. The targets of this program are post-graduate students from any area in engineering, technology, economics, business, and social sciences, willing to pursue a career in academia and/or strategic leadership and policy-making in industry or government. The scope of the double degree Ph.D. program is strongly international, aiming to attract three to five top students from all over the world. Students must acquire rigorous, state of the art knowledge in core areas of innovation, technological change, public policy, industry dynamics, and research methodologies.

During its first stages of development, the program will build upon and reinforce the resources of the institutions involved, with particular reference to the Ph.D. program in Strategy, Entrepreneurship, and Technological Change (SETChange) at CMU and the Master of Science in Engineering Policy and Management of Technology at IST, as well as the research and education programs offered by FCEE-Catolica. Over time, the Portuguese institutions involved intend to reinforce their capabilities in the scientific areas focused in this proposal, such that the program may continue as a stand alone endeavor in the future, yet maintaining a close working relationship with Carnegie Mellon University.

The first year curriculum will be offered in Lisbon. Second year coursework will be pursued at the CMU campus in Pittsburgh. In addition to obtain approval in all courses in the curriculum, students are required to fulfill qualifying requirements that include presenting and defending a research paper and successfully completing a qualifying exam. During the third and fourth years of the program, students are required to successfully defend a doctoral thesis proposal and then complete a doctoral dissertation. Students will work under supervision of collaborating academic advisers from CMU and the Portuguese partner institutions, and are expected to pursue a substantial part of their thesis work in Portugal. Research collaboration between faculty and

students from all partner institutions is of primary importance. The collaboration will also include the pursuit of select joint research projects between faculty members from CMU and the Portuguese universities without the aim of a double PhD. There will be a special effort to develop research topics for students that are of relevance to other universities and research units also active in the Portugal–Carnegie Mellon ICT collaboration framework, in order to increase the leverage of the overall collaboration and maximize its benefits to the Portuguese economy and science. The following table summarizes the structure of the double degree Ph.D. program:

First Year	1st Semester	Location	2nd Semester	Location
Coursework	Advanced Topics in Microeconomics	Lisbon	Modeling Firm Decision Making and Industrial Competition	Lisbon
	Quantitative Research Methods I	Lisbon	Quantitative Research Methods II	Lisbon
	Advanced Topics in Organization Theory	Lisbon	Entrepreneurship Theory	Lisbon
Research	**Work on Research Paper**			
2nd Year	1st Semester	Location	2nd Semester	Location
Coursework Requirements	Economics of Technical Change	CMU	Industry Evolution and Technological Change	CMU
	Technological Change and Entrepreneurship Elective	CMU	Technological Change and Entrepreneurship Elective	CMU
	Research Methods Elective	CMU	Research Methods Elective	CMU
End 3rd Sem.	**Presentation of Research Paper to Faculty (*location*: CMU)**			
End 2nd Year	**Qualifier Exam (*location*: CMU)**			
3rd Year	**Presentation and Defense of Thesis Proposal**			
4th Year	**Presentation and Defense of Final Dissertation**			

One of the main benefits of the proposed collaboration is providing Portuguese higher education institutions with the possibility to internalize the best practices – with regard to teaching and research – pursued by an institution – CMU – whose multidisciplinary approach to issues concerning the role played by technology in society and the economy is unique and has been widely acclaimed. Enabling students to pursue coursework and research at the CMU campus is an integral part of this vision, which represents the ultimate goal of the present collaboration.

Conclusion

Technological change and Innovation are the main engines of economic and social development throughout the world. The development of strategies and policies to guide innovative activity in regions and organizations is essential for economic re-structuring and renewal, which is imperative for productivity and employment to grow. The main objective of this collaboration is to educate highly qualified people who can teach, perform research, and work at high level private sector and public administration positions in technology development and commercialization, as well as science and innovation policy and strategy. The education of these professionals is particularly relevant in areas of ICTs, the focus of the CMU collaboration.

The main foundation of this collaboration is a double degree interdisciplinary Ph.D. program in the area of Technological Change and Innovation, aiming to provide students with substantive skills for academic research and high level business or public decision making. The scope of the double degree Ph.D. program is strongly international, aiming to attract three to five top students per year from any area in engineering, technology, economics, business, and social sciences, from all over the world. Students must acquire rigorous, state of the art knowledge in core areas of technological change, innovation, public policy, industry dynamics, and research methodologies, starting with one year of coursework pursued in Lisbon, followed by a second year at CMU. Concurrently with coursework, students must develop significant research leading to a paper and thesis proposal which are part of the qualifying requirements to be filled at the end of the second year. Students will work under joint supervision of collaborating academic advisers from CMU and the Portuguese partner institutions, and are expected to pursue a substantial part of their thesis work in Portugal.

There are very few structured doctoral and research programs in Europe which are dedicated to these multidisciplinary topics of technological change and innovation. This program will address this gap. Carnegie Mellon University has established an interdisciplinary doctoral program in these areas that provides an excellent model for what can become a leading initiative in Europe. Through this collaboration, Portuguese universities with have the possibility to internalize best practices – with regard to teaching and research pursued by CMU, whose multidisciplinary approach to issues concerning the role played by technology in society and the economy is unique and has been widely acclaimed. Enabling students to pursue coursework and research at the CMU campus is an integral part of this vision.

Engineering and Public Policy Applied to Network and Software Industries

Main Proponents: IST (UTL), ISR-Lisboa, IT, UAveiro, UMinho, UMIC;,
in collaboration with FCCN, FCEE(UCP)
Other potential partners: FEUP, INESC Porto,

Pedro Ferreira, pedro.ferreira@umic.pt

PART A. TELECOMMUNICATIONS MANAGEMENT AND POLICY

Executive Summary

Goals: The widespread use of IP based networks to provide secure and advanced services such as voice, data and video will surely have a determinant impact on the future structure of the industry, the competitive landscape and the challenges that regulatory policy faces. Several competing technologies can provide broadband access. Yet, access can be provided by a monopoly provider of infrastructure or, alternatively, by competing players each favouring a specific suit of technologies. What approach yields more and better access? What role should municipalities play in this regard? How will competition among services providers shape the future of the industry in the near future? Will the diffusion of broadband be driven by computers, and the demand for information services, or by entertainment, such as gaming and video over IP? What will be impact of the introduction of Quality of Service (QoS) in the network? By addressing complex questions that bring together all the dimensions of the issues at stake, the institutions engaged in this proposed research effort will certainly contribute to a more dynamic development of research and education activities targeted at the telecommunications industry in Portugal, which can spill over to society at large and result in accelerated growth and quality of live through a more productive use of information and communications technology.

Main Partners: This proposal sets forth a specific research agenda in the field of telecommunications policy and management that focuses on questions that go beyond the technological aspects to encompass the analysis of complementary issues of business and public policy and thus requires combining skills from telecommunications engineering, management and policy analysis under a framework for multidisciplinary research. This proposal is therefore a joint effort involving the Institute for Systems and Robotics (ISR) and the Center for Innovation, Technology and Policy Research at Instituto Superior Técnico (IST) and the Department of Engineering and Public Policy (EPP), who will certainly contribute to establish enduring research links across disciplines and schools within Portugal and between Portugal and CMU. This program will also benefit from the participation of other schools and institutions, namely the Department of Electrical Engineering and Telecommunications (DET) at the

University of Aveiro (UA), the Instituto de Telecomunicações (IT), the School of Economics and Management (FCEE) of the Catholic University of Portugal (UCP) and the Fundação para a Computação Científica Nacional (FCCN), who manages the National Research and Education Network in Portugal. At CMU, the department of Electrical and Computer Engineering (ECE) and the Tepper School of Business (TSB) are also engaged in this research agenda.

Potential Industrial Affiliates: the Portuguese government, network operators and service providers must consider establishing the right mechanisms to absorb the knowledge generated in the scope of the joint research programs with CMU. Henceforth, the current proposal seeks to provide the adequate pool of knowledge that both governmental institutions and firms can use to best inform decision-making. Portugal Telecom (PT) has expressed an interest in being involved in these programs in terms and levels that are to be further detailed in the future. It is expected that other telecommunications companies and other research institutions, with interest in the telecommunications industry, will join this research program.

Potential Institutional Affiliates: In addition, the program also includes activities aimed at promoting the involvement of institutions such as the Portuguese Telecommunications Regulator in ways that will allow them to effectively benefit from the research performed.

Main Researchers: At the launching phase, the key contact faculty in Portugal for this program is Pedro Ferreira (technology policy and management and on computer network architectures). Other researchers include the team led by Francisco Vaz, Univ. of Aveiro (signal processing, communication systems and computer networks), and Pedro Oliveira at FCEE-UCP (technology and innovation policy). Key faculty at CMU include Marvin Sirbu (telecommunications management and policy analysis), Jon M. Peha (technology and policy issues of computer networks) and Adrian Perrig (information and systems security with a focus on broadband networks).

Specific Form of Collaboration. The proposed program is a research joint effort between CMU and several Portuguese higher education institutions and companies that tackles major issues in the field of telecommunications policy and management and thus will also include participation from the Government, namely through UMIC and FCCN. The program provides scope for active research by two Ph.D. students per year that want to specialize in this area. Such students can engage, for example, in existing programs such as the Ph.D. in EPP, at CMU, and the Ph.D. in Electrical Engineering and Computers (EEC), at IST. Telecommunications policy is also likely to be an elective topic within several of the proposed masters and doctoral joint programs between CMU and Portuguese institutions, such as the M.Sc. degree in Information Networking or the Ph.D. degree in the area of Technological Change and Innovation. Existing courses at CMU will provide a model for faculty in Portugal to develop similar courses in Portugal and in the context of these other programs.

It is paramount for Portugal, and for Europe, to train people in such programs with the multidisciplinary approach needed to address all the issues that currently shape the development

of the telecommunications industry. Only a deep understanding of the technological questions, as well as of the legal and socio-economic issues associated with the development of the industry can provide the underlying framework needed to successfully manage telecommunications assets, either private or publicly owned. The program proposed here establishes the right conditions to develop research in such a multidisciplinary environment and across disciplines, thus bringing an element of integration across programs between Portugal and CMU for those who want to delve into research issues related to how technological waves shape the dynamic structure of the telecommunications industry and how such developments can have an impact in and for Portugal.

Description of Collaboration

Digital Convergence is dramatically changing the technology, services and competitive environment faced by telecommunications carriers around the world. Portugal is no exception. Separate infrastructures tightly tied to specific services, such as telephone and cable, are giving way to generic IP based infrastructures providing a wide gamut of services, including voice, data and video. This transformation impacts industry structure, competition and regulatory policy.

Initial collaborations will focus on two main issues. The first concerns questions of industry structure and regulation. Portugal, as elsewhere in the EU, must decide whether and how traditional open access policies should be carried forward onto new Fiber To The Home (FTTH) networks. The decision rests on choosing the appropriate balance between incentives for investment in infrastructure and facilitating innovative entry and competition in the delivery of services. The second issue concerns the role of individual communities in promoting broadband diffusion and adoption. Cities and towns can take a range of actions varying from direct investment in infrastructure, such as conduits or fiber, to demand stimulation through education and outreach programs. At the same time the national government is wrestling with how to support and orient municipal efforts. Comparing efforts currently underway or proposed in Portugal and in the rest of Europe with U.S. experience in comparable small towns and rural communities can provide valuable insight.

The government and firms acting in the telecommunications industry should be able to appropriate the knowledge generated by realizing the activities in this research agenda. To this end, this proposal sets up a plan for interaction with the government and firms to exchange knowledge, practices and experiences and to discuss new topics to target. On the government side, the Public Agency for the Knowledge Society (UMIC) emerges as a partner for this interaction, namely through projects that promote the widespread deployment of broadband throughout the country and foster the development of robust and secure advanced information services over broadband, as privileged ways to include more of the less qualified citizens in the information and knowledge society.

The Portuguese telecommunications regulator (ANACOM) is yet another institution that would benefit from being associated to a program such as the one proposed here. This research agenda will tackle a set of issues that will have a major impact on the structure of the industry that must be fully understood and anticipated by the telecommunications regulator in an era of increased digital convergence. In fact, it is likely that, very soon, the Portuguese regulator will be

evaluating most of the issues that our research agenda addresses and thus the importance of a rapid and productive exchange of scientific knowledge and information on these issues.

Conclusions

The widespread use of IP based networks to provide secure and advanced services such as voice, data and video will surely have a determinant impact on the future structure of the industry, the competitive landscape and the challenges that regulatory policy faces. Several competing technologies can provide broadband access. Yet, access can be provided by a monopoly provider of infrastructure or, alternatively, by competing players each favoring a specific suit of technologies. What approach yields more and better access? What role should municipalities play in this regard? How will competition among services providers shape the future of the industry in the near future? Will the diffusion of broadband be driven by computers, and the demand for information services, or by entertainment, such as gaming and video over IP? What will be impact of the introduction of Quality of Service (QoS) in the network? What sort of pricing models for integrated Internet services can best realize the potential benefits associated with QoS? In this context, the program includes activities aimed at promoting the affiliation of institutions such as the Portuguese Telecommunications Regulator in ways that will allow them to effectively benefit from the research performed.

In addition, the Portuguese government, network operators and service providers must consider establishing the right mechanisms to absorb the knowledge generated in the scope of the joint research programs with CMU. Henceforth, the current proposal seeks to provide the adequate pool of knowledge that both governmental institutions and firms can use to best inform decision-making. Portugal Telecom (PT) has expressed an interest in being involved in these programs in terms and levels that are to be further detailed in the future. It is expected that other telecommunications companies and other research institutions, with interest in the telecommunications industry, will join this research program.

PART B. PUBLIC POLICY FOR POWER GRIDS

Executive Summary

Goals: The development and management of electric power grids and advanced low-carbon uses of coal, other fossil fuels, and the integration of intermittent renewables are key problems that will shape the future development of the electricity industry. The collaboration with investigators and students in Portugal will raise the opportunity to add a European (and especially Portuguese) dimension to previous work developed at CMU on these issues. At the same time, Portuguese faculty and graduate students will have access to a variety of advanced analytical tools, to North American perspectives and problems, and to CMU's expertise and unique interdisciplinary approach to problem formation and analysis. Areas of collaboration will include:

1. Technical, economic, regulatory and risk-related studies of distributed energy systems, micro-grids, and advanced information technologies for integrating and controlling such systems in conventional electric power systems;

2. Advanced methods for the instrumentation and control of electric power transmission and distribution systems in the face of normal operations, and risks from natural disruptions and terrorist events;

3. Studies of technology innovation in energy and environmental technologies, its relationship to government actions (both "carrots" and "sticks") and its implications for policy and energy systems development.

4. Engineering-economic, policy analytic and risk-related studies of advanced fossil fuel technologies with carbon capture and geological sequestration;

Main Partners: This research proposal will be carried out jointly at UMIC, Instituto Superior Técnico (IST) and the department of Engineering and Public Policy (EPP) at CMU, namely through the CMU Electricity Industry Center (CEIC) which in turn has strong working ties with the Electric Power Research Institute, the U.S. Department of Energy's National Energy Technology Laboratory (located near Pittsburgh) as well as with a number of major power companies. It is also expected a strong contribution from the University of Oporto, particularly from INESC-Porto.

Main Researchers Involved: At the launching phase, the key contact faculty in Portugal for this program is Pedro Ferreira (technology policy and management). Other researchers include the team led by Paulo Ferrão (energy and environmental policy). Key faculty at CMU include Granger Morgan (distributed energy systems, carbon management and climate policy, integrated assessment with uncertainty in policy analysis and in R&D policy), Ed Rubin (modelling and assessment of energy and environmental systems including advanced low-carbon system and CCS), Sarosh Talukdar (dynamic behaviour and control of electric power transmission systems), Prof. Marija Ilic (large-scale systems modelling and power systems instrumentation, control and pricing algorithms), Jay Apt (electricity generation, storage, renewables, transmission, distribution and electricity markets), Lester Lave (economics of electric power system, risk analysis of management and on product and process design for the environment, including life-

cycle analysis) and David Hounshell (technological and organizational innovation, technology policy, industrial research and development).

Specific Form of Collaboration. CMU and our Portuguese collaborators will jointly identify and recruit at least one PhD student (preferably with a European background) to pursue an EPP PhD at CMU in each jointly identified area of collaborative research. These students will have an engineering background (at the level, for example, of the new IST post graduate programs in sustainable energy systems or in risk analysis). In each area of collaboration, CMU will identify at least one Portuguese faculty member who will be appointed as an adjunct faculty member at Carnegie Mellon and be involved in the supervision of both CMU and Portuguese students working in the area. In most cases, both CMU and our Portuguese collaborators will also recruit one or more students working in the same general problem area. Portuguese collaborators (faculty and students) will make periodic visits to CMU and faculty on both sides will engage in joint planning and student supervision.

Description of Collaboration

Research collaboration between CMU and Portugal in the fields of energy policy and power grid may include the following four aspects:

1. Technical, economic, regulatory and risk-related studies of distributed energy systems, micro-grids, and advanced information technologies for integrating and controlling such systems in conventional electric power systems. Studies which could include: Design and evaluation of alternative active intelligent control strategies for incorporating distributed resources into utility distribution systems in a way that allows intelligent islanding; Technical, economic, and regulatory assessment of the potential for microgrid applications in several different parts of the EU; Analysis of the optimal ownership arrangements, business model, locus of system control, etc. for DG and micro-grid systems as a function of location (national setting, climate regime, etc.); Assessment of the opportunities of industrial development and hardware and system innovation in the area of DG and micro-grid systems (e.g. what are the opportunities to develop a manufacturing and supply industry in Portugal; what would be Portugal's comparative advantages and disadvantages).

2. Advanced methods for the instrumentation and control of electric power transmission and distribution systems in the face of normal operations, and risks from natural disruptions and terrorist events. Future work could include: Development of improved information displays and intelligent support for power system operators; Development and demonstration of advanced methods for power-system instrumentation, data acquisition and control; Assessment of the value and cost of selective use of flexible AC control technology and DC back-to-back converters to improve the reliability and stability of power systems (e.g. should all of the EU, or all of the Eastern interconnect in the U.S., be run as a single synchronous system, or would there be economic, reliability and security benefits to operating these as several separate synchronous systems with asynchronous interconnections?); Development of very low cost instrumentation for phase measurements in the AC distribution system (e.g. this might allow students to monitor

power system state all over an extended region and thus make their own independent inferences about the state and operation of the system); Assessment of the opportunities of industrial development, hardware and system innovation and operator training in the areas of power system operations (e.g. what are the opportunities to develop a manufacturing and supply and operator training industry in Portugal; what would be Portugal's comparative advantages and disadvantages?).

3. Studies of technology innovation in energy and environmental technologies, its relationship to government actions (both "carrots" and "sticks") and its implications for policy and energy systems development. The collaborative projects proposed here will substantially improve the capability of policy-related models to characterize the nature and rates of innovation for energy and environmental technologies. This work will build upon a substantial body of experience at Carnegie Mellon, led by Professors Ed Rubin and David Hounshell, to understand and characterize the effects of government actions on technological innovation to address environmental issues associated with energy production and use. Through a series of retrospective case studies, we will seek quantitative representations of the changes in technology cost and performance over time as a function of pertinent variables, both technical, economic and policy-related. Insights from case studies will be used to better predict the impacts of proposed energy and environmental policies, such as proposals to address global climate change.

4. Engineering-economic, policy analytic and risk-related studies of advanced fossil fuel technologies with carbon capture and geological sequestration. A range of models and software tools have been developed at Carnegie Mellon to assess the performance, emissions and cost of alternative fossil fuel power systems as a function of the plant design, fuel characteristics, financial factors and emission constraints. In addition to the engineering economic work that has been done at Carnegie Mellon, there is also a strong background in risk assessment, risk management, and public perceptions of risk to begin a series of studies of these issues. This body of previous work lays a firm foundation for future studies which could include: Use of modeling tools to study power plant emission control options, costs and policies for Portugal; Development and application of the virtual engineering environment as a modeling tool for use in the Portuguese and/or EU context for analysis and design of advanced power systems; Perform analysis of the strengths and weaknesses of alternative regulatory frameworks for CCS, and assess their potential for a future coalescence of national regimes into an international regime.

Conclusions

The development and management of electric power grids and advanced low-carbon uses of coal, other fossil fuels, and the integration of intermittent renewables are key problems that will shape the future development of the electricity industry. The collaboration between Carnegie Mellon faculty and graduate students with investigators and students in Portugal will raise the opportunity to add a European (and especially Portuguese) dimension to previous work developed at CMU on these issues. At the same time, Portuguese faculty and graduate students will have access to a variety of advanced analytical tools, to North American perspectives and

problems, and to CMU's expertise and unique interdisciplinary approach to problem formation and analysis.

PART C: ENGINEERING AND POLICY APPLIED TO THE SOFTWARE INDUSTRY

Main Proponent: UMinho

Ricardo Machado. rmac@dsi.uminho.pt

Executive Summary

Goals. The software and software-related industries are now considered to be critical industries by most economies, and inordinate amounts of resources are being expended to develop these industries. The Indian software industry is a well-known example that is inspiring many countries desiring to 'leapfrog' to intellectual-based work and high value added export capabilities. This begs the question of what characteristics should this industry take the form of. This proposal intends to address the sustainable development of the Portuguese software and software-related industries. This study expects to promote, within the Portuguese software industry, the need to adopt an increasing involvement with innovation projects to seek better software of a higher quality, on time, in the best way and at a lower cost. As a longer term vision for this initiative, an early assessment phase should be used to support the creation of joint education programs in software engineering to leverage the industry in its professional competency. Additionally, a non-profit centre capable of assisting the technological, methodological and managerial needs of the Portuguese software industry might be created as a means to help foster a sustainable software industry in Portugal.

Main Partners. This proposal sets forth a specific research agenda in the field of software development capabilities that focuses on questions that go beyond the technological aspects to encompass the analysis of complementary issues of business and policy and thus requires combining skills from software engineering, management and policy analysis under a framework for multidisciplinary research. The lead proposer institution in Portugal is University of Minho. Because of its multidisciplinary and research nature, this proposed collaboration will be linked to other initiatives within the Area of Technology, Management and Policy, in Particular the proposed PhD effort in the area of Technological Change and Innovation. At CMU, the Department of Engineering and Public Policy (EPP) of the College of Engineering will certainly contribute to establish enduring research links across disciplines and between Portugal and CMU. This program will also benefit from the participation of the Heinz School of Public Policy and Management and the School of Computer Science by means of their Software Industry Centre (SWIC). Collaborations with the Institute for Software Research International (ISRI) and the Software Engineering Institute (SEI) are also envisioned.

Main Researchers. The main contact for this program is Ricardo J. Machado (software engineering, embedded software and pervasive information systems). Other researchers include Luis S. Barbosa (formal methods applied to software engineering with a particular emphasis on component-based development). The key faculty at CMU include Francisco Veloso (technology and innovation policy) and Ashish Arora (economics of technical change), and who is Co-Director of Software Industry Center. The proposal will also further explore collaborations with David Garlan (software architecture) at IRSI.

Specific Form of Collaboration. This proposal will study the sustainable development of the Portuguese software and software-related industries. It will first understand the current characteristics, both in what concerns the technological products and associated services. This characterization will allow an in-depth observation of the organizational capability of the Portuguese software industry, by assessing its software process maturity in accordance with several standards. Understanding the seminal R&D context that might have given origin to each novel Portuguese software companies will also relevant. It is then of further importance to understand the role of formal R&D activities undertaken in Portuguese research centers and universities dedicated to software engineering subjects. As it enfolds, this work hopes to identify major issues in the field of software development and provides scope for M.Sc. training and Ph.D. research, potentially in existing programs such as the Ph.D. in Software Engineering at ISRI/CMU. Software policy is also likely to be an elective topic within several of the proposed masters and doctoral joint programs between CMU and Portuguese institutions, including the Ph.D. degree in Technological Change and Innovation. The establishment of a Portuguese *Software and Systems Process Improvement Network* (SPIN) and the creation of a non-profit centre to contribute to the development of the Portuguese software industry might also be considered as a joint initiative of ICTI and the University of Minho.

Description of Collaboration

This proposal intends to address the sustainable development of the Portuguese software and software-related industries by understanding their current characteristics, both in what concerns the technological products and associated services. This characterization will allow an in-depth observation of the organizational capability of the Portuguese software industry, by assessing its software process maturity in accordance with several standard referencials, such as the Capability Maturity Model Integration (CMMI), the ISO/IEC 15504 Guidance on Use for Process Improvement and Process Capability Determination, or the ISO/IEC 20000 IT Service Management. Understanding the seminal R&D context that might have given origin to each novel Portuguese software company is also relevant to the study of the Portuguese software industry. It is intended to devise the extent to which the current state-of-practice adopted in the Portuguese software industry results from explicit efforts in R&D government institutions and universities. It is finally important to understand the role of formal R&D activities undertaken in Portuguese research centers and universities dedicated to software engineering subjects.

This study will promote, within the Portuguese software industry, the need to adopt an increasing involvement with innovation projects to seek better software of a higher quality, on time, in the best way and at a lower cost. As a longer term vision for this initiative, an early assessment phase should be used to support the creation of joint education programs in software engineering to leverage the industry in its professional competency. One should note that currently there is no education program in Portugal exclusively dedicated to the multidisciplinary nature of the software engineering body of knowledge. This entails the incorporation of a diversity of competencies from a wide variety of different disciplines such as Computer Engineering, Computer Science, Management, Mathematics, Project Management, Quality Management, Software Ergonomics, and Systems Engineering. Additionally, a non-profit centre capable of assisting the technological, methodological and managerial needs of the Portuguese

software industry might be created as a means to attain a sustainable software industry in Portugal.

By addressing complex questions that bring together all the dimensions of the issues at stake, the institutions engaged in these research projects will certainly contribute to a more dynamic development of research and education activities targeted at the software industry in Portugal, which can spill over to society at large and result in accelerated growth and quality of live through a more productive use of ICT. It is paramount for Portugal, and for Europe, to train people in such programs with the multidisciplinary approach needed to address all the issues that currently shape the development of the software industry. Only a deep understanding of the technological questions, as well as of the socio-economic issues associated with the development of the industry can provide the framework needed to successfully manage software assets. The program proposed here establishes the conditions to develop research in such a multidisciplinary environment and across disciplines, thus bringing an element of integration across programs between Portugal and CMU for those who want to delve into research issues related to how technological waves shape the dynamic structure of the software industry and how such developments can have an impact in and for Portugal.

Another effective impact for the Portuguese software industry might be to contribute to the strengthening of a Portuguese community of software engineering professionals continuously trained and engaged in the establishment of a Portuguese *Software and Systems Process Improvement Network* (SPIN). Within ICTI activities and with the specific support of SEI/CMU and together with a variety of national institutions, a Portuguese SPIN could gather the support of several key national software companies to promote the creation of a non-profit centre capable of assisting the technological and managerial needs of the Portuguese software industry. The mission of this centre should be to contribute to the development of the Portuguese software industry and increase industry competitiveness, by means of knowledge, innovation, continuous improvement and the promotion and dissemination of software technology and methodologies, as well as investigating emerging trends in the economics, technology and management of the global software industry. An initial group of Portuguese companies that have expressed their potential interest in subscribing these initiatives include Critical Software, Primavera Software, and Matakiterani, as well companies at the Software clurster of Minho, and also Outsystems, F3M Software, and the Software Department of Blaupunkt.

Conclusions

The software industry is now considered to be critical by many economies, and large amounts of resources are being expended to develop such industries. This collaborative proposal intends to address the sustainable development of the Portuguese software and software-related industries. Thus, it sets forth a specific research agenda that focuses on questions that go beyond the technological aspects to encompass the analysis of complementary issues of business and policy and thus requires combining skills from software engineering, management and policy analysis under a framework for multidisciplinary research.. As it enfolds, the proposed program will tackle major issues in the field of software development and provides scope for education and research for in existing programs at CMU or being created through the joint CMU-Portugal program. It will further consider the possibility to establish a Portuguese *Software and Systems Process Improvement Network* (SPIN) and the creation of a non-profit centre to contribute to the

development of the Portuguese software industry might be considered as joint initiatives within ICTI. These initiatives will contribute to the increase of industry competitiveness, by means of knowledge, innovation, continuous improvement and the promotion and dissemination of software technology and methodologies, as well as investigating emerging trends in the economics, technology and management of the global software industry.

ANEXO II

COMPOSIÇÃO, COMPETÊNCIA E FUNCIONAMENTO DO CONSELHO DE
REPRESENTANTES DAS INSTITUIÇÕES NACIONAIS

Conselho de Representantes das Instituições Nacionais, CRIN

1. É da competência do CRIN:

   o Analisar e emitir parecer sobre o Plano Anual de Actividades e o Orçamento Anual;

   o Informar o "Board" sobre o desenvolvimento do Programa nas várias Instituições;

   o Solicitar ao ERC, através do Presidente da FCT, a análise de qualquer aspecto específico, assim como o acompanhamento e avaliação de um projecto em particular.

2. O CRIN é composto pelo Presidente da FCT, que preside, e pelos Presidentes/Directores de todas as instituições nacionais, ou seus representantes.

3. O CRIN integra, ainda, um representante de cada Parceiro Empresarial e Institucional ("ICTI Industrial Affiliate")

3. O CRIN reúne ordinariamente duas vezes por ano, podendo reunir extraordinariamente sempre que tal for convocado pelo seu Presidente.

4. O CRIN pode organizar-se por programas, caso em que é presidido pelo Director do respectivo programa de educação ou investigação, e onde pode ser conferido a um Parceiro o estatuto de líder dos Parceiros Empresariais e Industriais desse programa.

5. O parecer sobre o plano anual de actividade e o orçamento anual deve ser emitido até 29 de Abril de cada ano.