Carnegie Mellon

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Date: 10/24/2006
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Information Communication Technology Institute
A Portugal-Carnegie Mellon University Partnership

Report on the Assessment of Portugal-Carnegie Mellon University Potential Collaborations

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I. Executive Summary

1. **Background**. This report assesses potential opportunities for educational and research collaborations between Carnegie Mellon University (CMU) and Portuguese Universities and Research Institutions. This assessment was carried out at the request of the Government of Portugal as foreseen in the Memorandum of Understanding (MoU) signed on March 10, 2006 by the Minister of Science, Technology, and Higher Education, Prof. José Mariano Gago, and CMU's Provost, Prof. Mark Kamlet. Between March 10 and July 24 there were numerous contacts between CMU and Portuguese Universities' faculty and administrators, including visits to Portugal and to CMU by interested parties, as detailed in section II.

2. **Goals**. Since the 1970's, science policy makers in Portugal consistently recognized the need for strengthening national Universities through internationalization. Until the 1990's, the dominant strategy in this effort was to fund a number of fellows every year so they could pursue their doctoral studies abroad. This policy has had a major impact as measured, for example, by the number of faculty in Portuguese Universities holding a PhD, the launching of graduate programs, or the routine awarding of PhD degrees. In the 1990's, a new dimension was added to this policy. While pursuing significant investments in research infrastructure, the founding of new research centers and institutes, and the systematic calls for proposals and programs to award fellowships for PhD education, the Government of Portugal also instituted the principle of periodic evaluation of all funded research efforts and institutions by teams of international experts. These policies led to significant quantitative and qualitative increases of the research output of Portuguese institutions as evaluated by international standards. Despite this important evolution, there remain significant barriers associated to the Portuguese research and education system that limit its full potential. The MoU with CMU, and similar efforts with others, pursues a new very innovative dimension – partnerships between Portuguese and leading foreign Universities. The partnership with CMU provides the opportunity to educate a large number of post-graduates and doctoral candidates in targeted areas of high impact in a short period with programs that are resident in Portugal or split between Portugal and CMU. A critical dimension is that the partnership involves active sharing between teams on both sides of the Atlantic, so that, not only scientific knowledge, but also organizational best practices are exchanged and learned. The synergies created will accelerate change within Portuguese organizations and will increase significantly their international presence and impact, while generating research results that benefit the Portuguese society. Section III expands on these issues.

3. **Partners**. This assessment identified as major potential partners, see sections IV and V, the following Portuguese Universities: Universidade de Aveiro; Universidade de Coimbra (Faculdade de Ciências e Tecnologia); Universidade de Lisboa (Faculdade de Ciências); Universidade Técnica de Lisboa (Instituto Superior Técnico); and Universidade Católica Portuguesa (Faculdade de Ciências Económicas e Empresariais). Potential partner Research Institutes and Centers identified include Center of Mathematical Analysis Geometry and Dynamical Systems at IST, Center for Innovation, Technology, and Policy Research (IN+) at IST, Center for Informatics and Systems Research at Universidade de Coimbra, INESC-ID, Instituto de Sistemas e Robótica de Lisboa, Instituto de Telecomunicações de Aveiro, Instituto Superior de Qualidade, CISTER, Centro de Linguística da Universidade de Lisboa, and linguistic research groups at Universidade do Algarve and at Universidade da Beira Interior. The

collaboration also potentially entails the involvement of leading Portuguese companies, in particular, Portugal Telecom, as well as start-up firms such as Critical Software and others.

4. **Information and Communication Technology**. The assessment identified *Information and Communication Technology* (ICT) as the main theme of the potential CMU-Portugal partnership. Innovation in ICT cuts across most industries and services and are at the root of economic development and employment growth. Within this theme, important topics are at the level of technologies, methodologies, applications, and support sciences, as well as associated issues of managing technological change and development of related public policies.

We organize the Information and Communication Technology theme into four broad areas, see Table 1 for pertinent details: Information Processing and Networking; Critical Infrastructures and Risk Assessment; Basic Sciences; and Technology Management and Policy. These areas are further divided in sub-areas as detailed in Sections IV and V.

Area	Program	Portuguese Partner	CMU Partner
Inf. Proc. & Networking (IPN)	Software Engineering (Adv. Degree, Res.)	FCTUC	ISRI, ECE, CS
	Security & Dependability (Adv Deg, PhD, Res.)	FCUL	INI, CS, ECE
	Information Net. (Adv. Deg., Res.)	U Aveiro	INI, ECE
	Language tech. (PhD)	IST (INESC-ID), CLUL, UALG, UBI	LTI
Critical Infrast. & Risk Ass.	Critical Infrastructures (PhD, Res. in ECE, CS)	ISR (IST,UTL), ISQ, INESC-ID (IST,UTL), CISTER (IPP)	CenSCIR, ECE, EPP, Tepper
	Risk Assessment	IST (UTL)	EPP, ECE
Basic Sciences	Mathematics	IST (UTL), FCUL, FCUN	Math
Tech. Manag. & Public Policy	Technological Change & Innov. (PhD)	IST(UTL) and FCEE (UCP)	EPP, SDS, Heinz, Tepper
	Power Grid (Research)	IST (UTL)	EPP
	Telecom & Public Policy (Research)	ISR (IST,UTL)	EPP

Table 1 Information and Communication Technology: Main areas (for a list of acronyms, see Appendix 2.)

Table 1 identifies three types of potential partnerships: advanced post-graduate degree programs; PhD programs; and research projects. The first two lead to a degree awarded by CMU and a degree awarded by the Portuguese Partner University, see Section V.

5. **Information Communication Technology Institute**. An important component to the CMU– Portugal partnership lies in its institutional framework. The assessment recognizes that all the activities launched under the auspices of this collaboration should be within a single (virtual) institution, which we will refer to here as the Information Communication Technology Institute. The Institute sets its educational and research agenda in collaboration with all involved partners through specific education and research programs and projects. The Institute has two poles, one at CMU, the other in Portugal, but has a single Board of Directors, integrated management, and advisory board structure. To involve Portuguese companies in defining the Institute Agenda, the Institute will develop an Industrial Affiliates Program, see item 25 in Section VI. The Portuguese Government funds the Institute's core budget in a rolling window of 5 years, subject to annual adjustments. Section VI expands on this topic.

II. INTRODUCTION

6. **Final Report**. This Final Report assesses the potential for collaborations between CMU and research institutions in Portugal.

The assessment is the result of numerous, face-to-face meetings and visits, conference calls and e-mails, discussions and interactions held by multiple CMU faculty and members of the CMU assessment committee with Secretary of State Manuel Heitor, Minister Mariano Gago, and numerous Portuguese Universities administrators, researchers and faculty members. Appendix 1 lists some of the visits to CMU and Portugal of different teams.

7. **Assessment committee**. The assessment was lead by Prof. Pradeep Khosla (Dean of CIT, CMU)[1] and Prof. José M. F. Moura (ECE. CMU). Prof. Moura chaired an assessment committee established at CMU to manage the specific day-to-day activities of the assessment. Besides Prof. Moura, this assessment committee included at various times Prof. Granger Morgan (ECE and EPP, EPP Department Chair), Prof. Ed Schlesinger (ECE Department Head), Ms. Dena Tsamitis (INI Director), and Prof. Francisco Veloso (EPP).

8. **Process**. Appendix 3 describes briefly the history and the process of the assessment. Appendix 4 includes the preliminary report of the Assessment Committee dated June 15/ 2006, submitted after the visits of May 23-26/ 2006 of this Committee to Portugal[2]. While in Portugal, the committee met the representatives of various interested Portuguese research groups who submitted a preliminary proposal as well as several University Presidents (Rectors), Vice-Rectors, Deans, Department Heads, and Research Institute Directors. Appendix 5 is a partial list of faculty members and other senior personnel from CMU and Portugal that were involved in this assessment exercise.

9. **Examples of Carnegie Mellon University international cooperation**. CMU is a private University covering most fields of knowledge in the seven colleges at its Pittsburgh campus. CMU is highly committed to international cooperation in education at both the undergraduate and graduate levels, as well as in research. We provide some illustrative examples. CMU opened a new undergraduate campus in Doha, Qatar, with the first freshman class entering in the Fall of 2004. CMU has also collaborations in several countries in different continents at the advanced degree Master of Science and Engineering levels that award CMU degrees. In Athens, Greece, CMU has partnered with the Athens Information Technology (AIT) to offer a Master of Science in Information Networking (MSIN). In Kobe, Japan, CMU collaborates with the Hyogo Institute of Information Education Foundation to offer a Master of Science in Information Technology, Information Security track. In Daejeon, Korea, together with Information and Communication University, CMU offers a Master of Software Engineering (MSE) and a Master of Science in Information Technology, Software Engineering track. Other examples include undergraduate agreements with École Polytechnique Federale de Lausanne (EPFL) at Lausanne, Switzerland, and with the National Chiao Tung University (NCTU) in Taiwan.

At the research level, CMU has several international partnerships. For example, CyLab Korea, is a joint venture between CMU and the Korea Information Security Agency (KISA) and the Ministry of Information and Communication (MIC) of the Government of the Republic of

[1] For a list of acronyms, see Appendix 2.
[2] The dates of the visits are listed in the preliminary report erroneously as occurring in June when they occurred in May/2006.

Korea, and CyLab Japan is a collaboration with the Hyogo Prefectural Government. In Taiwan, CMU has several collaborations including iCAST, a program focusing on a wide variety of security issues and the ITRI Lab@CMU, a joint research Center between CMU and the Industrial Technology Research Institute (ITRI). In Singapore, CMU teamed with A*STAR, the Agency for Science, Technology, and Research of Singapore and the National University of Singapore (NUS) to offer graduate education and research programs in Electrical and Computer Engineering.

10. **Carnegie Mellon University model for international cooperation**. The above examples illustrate the model used by CMU in establishing its international collaborations. By granting its own degrees, CMU makes no distinction between graduates of its programs at the Pittsburgh campus or at any other location, be it at Doha, Athens, Kobe, or Daejeon. For example, graduates receiving their degree in MSIN at CMU in Pittsburgh or at AIT in Athens will have fulfilled exactly the same degree requirements, taken courses that have been scrutinized by the same CMU curricula committees, and interacted with faculty that have been similarly vetted by the same recruiting committees. To guarantee this identical level of quality, CMU submits all its programs to the same measures of quality assurance and to the same stringent evaluation criteria, and subjects them to the same pre- and post-assessment exercises. CMU recruits and evaluates with comparable criteria the faculty involved in its education and research programs and expects them to perform according to similar high standards. This holds also with faculty from partner institutions involved in these collaborations that usually acquire CMU adjunct faculty status. Prior to assuming teaching responsibilities on CMU's programs, these faculty go through training, for example, by team co-teaching a similar course at the Pittsburgh campus. Regarding existing research collaborations, they team researchers from CMU with the researchers from the partner institution in joint projects. These entail engaging joint teams in defining and developing projects of common interest, with frequent interactions and extended visits (e.g., semester to year long, sometimes even longer) of personnel from the partner institution to the CMU campus.

In simple words, CMU's strategy for international collaborations is to work closely with partner institutions to jointly *develop*, *implement*, and *deliver* jointly educational and/ or research programs, and then *award*, when it makes sense, a CMU degree. This represents a level of commitment that goes well beyond common practice and is starkly different from CMU faculty delivering at a distance or locally a few isolated courses.

CMU is proud of the success and quality of its existing international collaborations. In turn, given its limited human, financial, and space resources, CMU is acutely aware that it can only engage in a small number of these international relations. To guarantee their success, CMU is particularly selective in their choice, Svigilantly procures the necessary resources, and carefully evaluates the commitment of its partners.

III. Goals of Carnegie Mellon University-Portugal Partnership

11. **Success of partnership**. The success of cooperations in which CMU is involved lies in the close working relationship between CMU and the partnering institutions and by jointly developing a common understanding of the goals and aspirations for the cooperation. CMU does not bring one single model solution to these international partnerships. Within the constraints of its own human and physical resources, CMU attempts to develop with their partners the best approach to the desired relationship. In the case of Portugal, CMU has recognized from an early stage 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. The collaborations identified in this assessment clearly reflect the concern of CMU in best accommodating these goals of the partnering institutions. For example, several Portuguese Universities identified Advanced Degree Programs (3^{rd} cycle in the Bologna agreement) and Research Programs as clearly desirable collaborations. Beyond these programs, CMU and the Portuguese Universities also recognized the opportunity for dual PhD degrees awarded by CMU and by partner Institutions. These degrees, to be offered in several scientific and technological areas by various Departments, represent a dimension that is novel to this CMU Portugal cooperation and that, up to now, was not yet available in CMU's existing international programs.

12. **Main goals for Carnegie Mellon University-Portugal cooperation**. From the discussions with the Secretary of State Manuel Heitor and Minister Mariano Gago, and, as we wrote in the preliminary assessment report, see Appendix 7, we understand the goals of the CMU-Portugal initiative to include the following:

A. **Internationalization**: Develop programs that will significantly and qualitatively impact the internationalization of Portuguese Universities and research Institutions and that will help establish Portuguese Universities as international leaders in fields perceived to be of strategic importance to Portugal and Europe

B. **Seeds of change**: The programs should be exemplary and create opportunities for the Institutions of Higher Education in Portugal to evolve and become highly dynamic and internationally recognized.

C. **Highly educated professionals**: To promote the rapid education of highly trained professionals at the post-licenciatura level (post 2^{nd}-cycle in the Bologna agreement)– advanced professional degrees and PhDs–in the areas referred to in 12.F, below.

D. **Recruiting**: To promote a culture of recruiting and placing the best candidates from (post-) graduate students, to post-doctoral associates, to faculty members, in the international arena.

E. **Collaboration**. The partnership should foster a culture of collaboration and exchange among Universities, Research Institutions, and Companies in Portugal and abroad.

F. **Areas of interest**: The initiative is to include collaborations in: (i) Electrical Engineering and Computer Science, in particular, Information Technology, Telecommunications, Software Engineering, Security, Robotics, Critical Infrastructures; (ii) Business and Public Policy, namely, Technology Policy, Technological Change and Entrepreneurship, and Risk Assessment; and (iii) Basic Sciences, including Applied Mathematics.

13. **Best practices**. As mentioned before, our assessment recognizes that many Universities and Research Institutions in Portugal are of high quality and are internationally recognized, and

their faculty include first-rate researchers. We also identified structural shortcomings and inadequate practices that constrain 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 and overcoming these insufficiencies. The administrations of the Portuguese Schools and Universities that we contacted consistently reassured us that they are prepared to promote change and institutionalize best practices when they make sense to resolve any identified deficiencies. Some of these practices may require action at a higher level.

As repeatedly noted by others, we concur that a major constraining factor in the higher education system in Portugal is the high teaching and administrative load overwhelming faculty. We offer several examples though recognizing that most of these are either anecdotal or derived from anecdotal evidence. As a first example, a young assistant professor told us that he taught three or four courses per year, where at least one course per semester had several hundred students. This faculty member taught alone with no helpers – no teaching assistants or graders – because he had to have a minimum of nine contact hours per week. This stands in stark contrast with faculty at research Universities in the US where a faculty member will teach a small course and at most a large course per year, often co-teaching with other faculty, and helped by a team of teaching assistants and graders. The final exam of each undergraduate course in a Portuguese University is usually offered three times per year with a reading period of several weeks. In US Universities, all final exams occur in the immediate two weeks after the last day of classes. The net effect is that there is no single three or four month period where faculty (and students) in Portugal are free of all teaching activities and can focus on their research. Possibly, at the expense of (post-) graduate level offerings, the undergraduate course offerings in Portuguese Universities, even at the basic level, seem too rich, often, slight variations of the same subject existing as different courses. As a generic observation, it seems that faculty at Portuguese Universities are overburdened with meetings, administrative tasks, and student evaluations. These examples point to a system that seems inefficient and expensive where the precious time of faculty is wasted with busy, but intellectually ineffective, activities.

Another aspect that affects performance is the lack of incentives and recognition that hardworking research faculty have. Several faculty noted that there is no tangible direct benefit that accrues to faculty who bring external research grants, work with industry, or develop a strong research group. Rather than investing the extra effort to setting up a high-level research environment it becomes almost more rewarding to take up extra teaching in another university or doing consulting work. To counter this state of affairs, it is important to institute a system of short-term incentives and recognize explicitly teaching *and* research excellence as critical criteria. Teaching load (quantity rather than quality) and "service to the department or school" should be used in a compensatory system only (if more today, less tomorrow) so that excellence is the overriding factor in career progression. Two practices used by US Universities may be of interest in addressing some of these issues. The first is concerned with Summer salary. Most US research universities adopted a system of summer support by which faculty who bring external research grants can earn up to 3 summer months of salary to complement their base salary. The second is a flexible system that makes it possible for a faculty to "buy out" from a teaching assignment, i.e., getting a reduced teaching load, from the Department by "charging" part of their salary to research grants, or having some other "charge-off" mechanism that weighs research grants or research supervision. This practice brings direct rewards for faculty active in research and recognizes explicitly research excellence. These practices make quality education and research impact to be the definite measures to promote and tenure faculty, by heavily basing

these decisions on a large number (typically 10) of letters from reputed researchers around the world attesting to the quality and impact of the faculty being considered for promotion.

A third dimension that is important to foster is the role of external visiting or evaluation committees. So far in Portugal, such committees play an important role for research units funded by the Ministry of Science, Technology, and Higher Education. Yet, visiting committees are critical instruments for reflection and improvement in top US schools at every level, Departmental, Program, College and University itself. They make university administrators more accountable and force them to open and work with the community in a joint search for excellence, be it in teaching, research, or contribution to the community.

There are other dimensions, including, the degree of inbreeding, recruitment policies, student-faculty ratios, balance of undergraduate class sizes versus graduate class sizes, number of undergraduate degrees offered by Universities and Departments that need careful attention.

The programs established between CMU and Portuguese Universities can provide important examples and work as seeds of change for Portuguese schools. By adopting some of these best practices they will be helping to disseminate them and contribute for Portuguese Universities to reach a much desired level of internationally recognized excellence and impact.

14. **Why a Carnegie Mellon University-Portugal partnership**. Portugal has sent through the years many talented individuals to pursue their doctoral programs at the best Universities in the World. This policy has been systematically followed since the early 1970's with much success. For the most part, these graduates returned and transformed the Portuguese Universities. They started master and doctoral programs, formed research centers, supervised new master and doctoral students, to the point where most Universities now have a professional, full time faculty holding a doctoral degree. In the 1990's, the Ministry of Science and Technology supported the founding of new research institutions with large research infrastructure programs, instituted annual calls for research funding opportunities, and increased significantly the number of available doctoral fellowships. In the mid nineties, the Ministry and the then brand new Fundação de Ciência e Tecnologia (FCT) instituted the evaluation of all research programs and research institutions by international panels. These policies had a major impact and transformed the landscape of research institutions in Portugal, bringing many of them closer to the top tier international institutions in their areas. Still, Portuguese Institutions recognize structural weaknesses and the need to move forward rapidly in specific areas. Other countries, from the UK to Ireland or Australia, have recently started initiatives to strengthen their own research infrastructure. While considering similar activities, the Government of Portugal is now proposing to add to the current portfolio new educational and research initiatives in partnership with a leading foreign university. These definitely hold the promise of great impact on the educational and research system in Portugal. The CMU-Portugal collaboration aims at the following:

i) 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, management of technology and public policy;
ii) 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;
iii) 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 (225 at the advanced degree level and 75 at the doctoral level);

iv) Immerse the Portuguese institutions in a symbiotic environment with a leading international research institution;
v) 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;
vi) Promote change and adoption of best practices by Portuguese Universities to make them nimble, to rapidly recognize and respond to new challenges and opportunities.

IV. Theme, Areas, and Teams of Partnership

15. **Proposals received**. Table 2 shows the proposals received.

#	Area	Title (Abbreviated)	Portuguese Inst.	PI (bold) & Co-PIs	Main CMU Dep.
1	Technological Change & Entrepreneurship	PhD Program in Technological Change and Entrepreneurship	IST & UCP	R. Baptista, P. Oliveira	EPP, SDS, Tepper
2	IT: Language Techn.	Collaboration Proposal with LTI	IST (INESC-ID), CLUL, UALG, UBI	I. Trancoso	LTI
3	IT: Information Networking	Collaboration CMU-UA/IT	Univ. Aveiro	**P. Ferreira**, J. Rocha	INI
4	IT: Inform. Security	CMU-Portugal Inf. And Infrastr. Secur. & Depend.	FCUL	P. Verissimo	INI, CS, ECE
5	Basic Science	LCMath – PhD Program Lisbon/ CMU in Mathematics	IST, FCUL, FCTUNL	**J. Matias** and A. Barroso	Math
6	IT: Software Eng.	Software Engineering	FCTUC	J. G. Silva	ISRI, CS, ECE
7	Crit. Infrast. & Risk Assessm.	Critical Infrastructures and Risk Assessment[1]	ISR (IST), ISQ, CISTER (IPP), INESC-ID (IST)	**V. Barroso**, M. Cruz, E. Tovar, A. Casaca	CenSCIR, ECE, EPP
8	Public Policy	Energy Systems: Carbon Control; Power Grid	IST	**P. Ferrão**	EPP, CenSCIR
9	Public Policy	Telecommunications Policy	ISR (IST)	**P. Ferreira**	EPP
10	Crit. Infrast. & Risk Assessm.	Assessment of Techn. and Natural Risks	IST	C. G. Soares	EPP
11	Business	Intern Inst. Bus. & Inf. Ethics[2]	UCP	J. C. Neves	Tepper

1 – This proposal is the consolidation of three pre-proposals: Networked Sensor, Communication, and Decision Systems (ISR(IST), ISQ, and CISTER (IPP)); Risk Management Institute for Critical Infrastructures (ISQ); and CMU-Portugal MoU (Manifest of Interest, INESC-ID (IST))

2 – This proposal was a manifest of interest, eventually not pursued further.

Table 2 Summary of Proposals Received

16. **Information and Communication Technology: Main areas and teams of cooperation**. From proposals 1 through 10, the assessment identified a major theme: *Information and Communication Technology (ICT)*. The proposals address this theme from several highly relevant dimensions. Some focus on specific cyber and software related issues, others address networking, fixed line and wireless; still other proposals consider these topics in the context of applications. A set of proposals concentrates on the integrative aspects of technological change and public policy. One proposal, representing a consortium of several Portuguese Universities, is on basic sciences, applied mathematics to be specific.

The Information and Communication Technology theme is divided into four major areas because of their transformational potential impact and because of the synergisms among partners at CMU and in Portugal: (1) Information Processing and Networking (IPN); (2) Critical Infrastructures and Risk Assessment (CIRA); (3) Basic Sciences; and (4) Technology Management and Policy (TMP). Table 3 lists the Portuguese Universities and Research Institutions and CMU Departments and Colleges primarily associated with each major area.

Area	Leading Port. Univ. & Res. Inst.	CMU Dep. or Res. Center
Information Processing and Networking (IPN)	UC (FCT), UL (FC), UA, INESC-ID (IST, UTL), UALG, UBI	ECE (CIT), CS (SCS), ISRI (SCS), LTI (SCS), INI (CIT), EPP (CIT), CenSCIR (CIT), CyLab
Critical Infrastructures and Risk Assessment (CIRA)	ISR(IST, UTL), ISQ, INESC-ID (IST, UTL), CISTER (IPP)	ECE (CIT), CS (SCS), EPP (CIT), CenSCIR (CIT), CyLab, Heinz, Tepper
Basic Sciences	Math Dep. at IST (UTL), UL(FC), UNL(FCT)	Math (MCS)
Technology Management and Policy (TMP)	UCP(FCEE), UTL(IST)	EPP (CIT), SDS (CHSS), Heinz, Tepper

Table 3 Information and Communication Technology: Contributors to each major area of collaboration

Tables 2 and 3 show that about 16 different Portuguese Universities, Research Institutions, and Departments and Research Groups within Institutions are involved in proposed partnerships, while 5 Colleges, 7 Departments, and 2 Research Institutions are included on the CMU side. Their emphasis on Information and Communication Technology represents a very meaningful effort of cooperation among the Portuguese and CMU partners. Discussions held already led to the consolidation of distinct proposals into single coherent research and educational programs. A recent Workshop hosted by Portugal Telecom Inovação at the end of July (see Appendix 6) with participation from most Portuguese teams, CMU researchers, and representatives of Portugal Telecom and associated companies showed a strong interest in pursuing the many synergistic opportunities that exist among the different programs.

Table 4 refines the 4 areas into relevant sub-areas and Figure 1 shows the overlap among the areas in which we subdivide the theme of Information and Communication Technology.

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. Wireless sensor networks 2. HW platforms and sensing technologies 3. Software and middleware 4. Decision making 5. Actuation

	6. Security 7. Privacy 8. Applications 9. Risk Assessment
Basic Sciences	Applied Mathematics
Technology Management and Policy (TMP)	1. Technological Change and Entrepreneurship 2. Telecom Policy 3. Energy Systems: Carbon Control; Power Grid 4. Risk assessment

Table 4 Information and Communication Technology: Main Areas and sub-areas

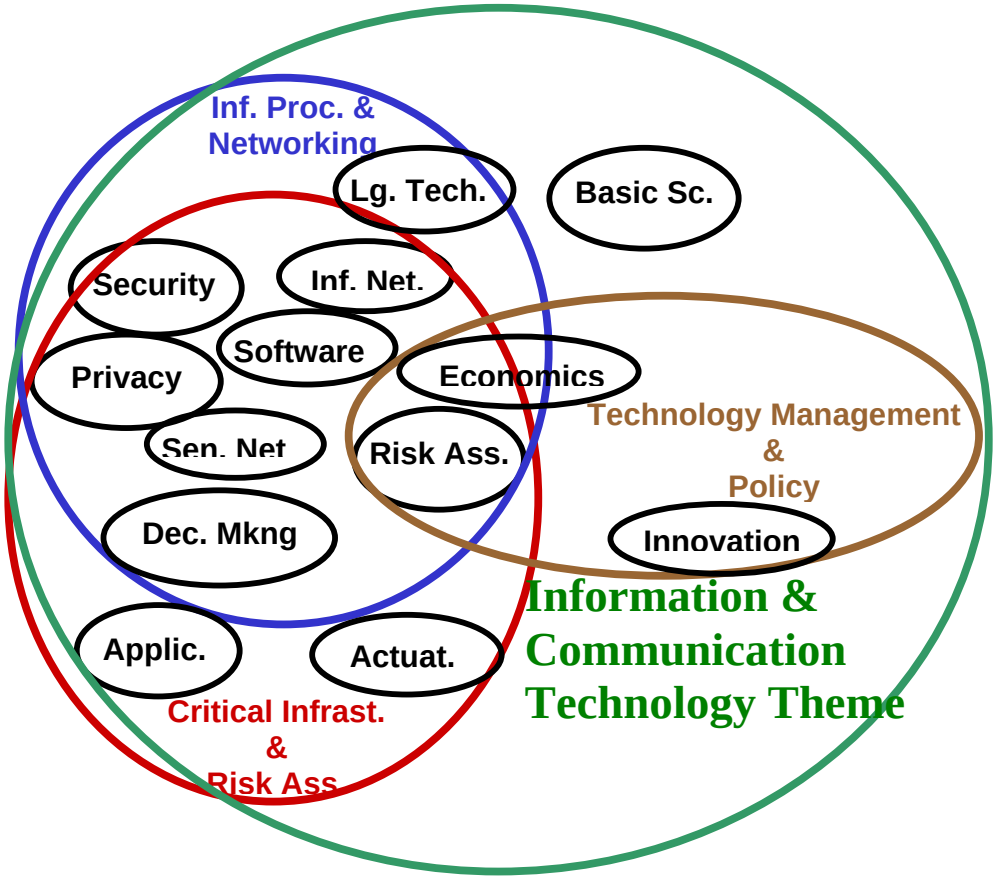

Figure 1 Information and Communication Technology: Overlaps between main areas of collaboration.

For example, the two areas, IPN and CIRA, share many sub-areas, from interest in several applications, e.g., the internet or other information networks, to software and networking technologies, or to privacy. Risk assessment is clearly relevant to areas IPN, CIRA, and TMP. We comment briefly on each of the areas and some of the subareas, liberally quoting from the proposals (without further specific attribution). For more details, see Appendix 8 that expands on the content of each area.

Area 1 Information Processing and Networking. We include in this area several methodologies underlying the theme of Information and Communication Technology, namely, software engineering, security and dependability, information networking, and language technology. This area involves partnerships of several CMU Departments and Research Centers and several Portuguese Universities and Research Institutions, see Table 3. We expand briefly in the sub-areas of this area.

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 and hold the potential for a significant impact 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. Prof. João Gabriel Sousa, the Dean of FCTUC organized a visit of Ministro Mariano Gago and of the CMU Assessment Committee to Critical Software SA, a very successful and promising spin-off from CISUC. The discussions held with Critical Software SA top management showed the strong interest of Critical Software SA, and by extension, of the many other software companies in Portugal, on strong advanced, post-Master, educational programs and research projects in software engineering.

Information security. 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 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 collaboration between CMU and Portuguese Universities, in particular, as envisaged with FCUL, involves a number of coordinated education and research components to address dependability and security in these critical information infrastructures.

Language technology. The assessment identified an excellent synergism between a consortium of Portuguese Research Centers and Universities, namely the L2F consortium led by INESC-ID at IST, and including CLUL, UALG, and UBI, see Appendix 9, and the Language Technology Institute at CMU. Two areas of strong interest in both teams are computer aided language learning (CALL) and speech-to-speech machine translation (S2SMT), involving at least two languages, one of them being Portuguese, and the other English or Chinese (Mandarin). Chinese is of particular interest given the expected great demand from China for language translation and education products involving Portuguese. This partnership will take the form of a dual degree doctoral program.

Information networking. In a relatively short time, the internet evolved from a small research network into a critical infrastructure that delivers a wide variety of services to hundreds of millions of users. A number of trends will likely cause a similarly dramatic transformation in

the next ten to fifteen years. Current trends suggest that the vast majority of users will use wireless, mobile devices to access the Internet. Large numbers of non-computational wireless devices, including sensors, actuators, and I/O devices will complement these personal devices. Predictably, wireless will be pervasive as access network technology. Simultaneously, the service infrastructure is evolving from simple client-server applications into a sophisticated, highly resilient software platform that delivers personalized services to users. The assessment has identified a number of potential collaborations between CMU teams of researchers and Portuguese research groups at Universities and Research Institutions addressing many relevant aspects connected to these issues on information networking and critical infrastructures from both the technological, engineering and computer science dimensions, and the policy dimensions. We envision advanced education programs and a dual degree doctoral program.

Area 2 Critical Infrastructures andRrisk Assessment. This area applies sensor networks to critical systems. This consolidates several relevant technologies within the Information Communication Technology theme. The assessment identified a strong consortium of four research institutions in Portugal, ISR(IST), ISQ, INESC-ID (IST), and CISTER (IPP). The interests of the consortium on critical infrastructures and risk assessment mirror those of CenSCIR at CMU and of several CMU Departments including ECE, CS, EPP, and Tepper, the CMU Business School. Infrastructures are of major significance in the economy of a country. They include transportation systems (from bridges, to roads and highways), airports and harbors, water distribution systems (for example, 40% of the water is lost in between the source and the user), water treatment plants, power generation and distribution, telecommunication networks, commercial and industrial facilities, large building and campus facilities. The collaboration between CMU and the Portugal team plans a strong doctoral component complemented by a strong research component on technology (e.g., ad-hoc wireless sensor networks, network protocols, sensor devices, HW and SW platforms, decision algorithms, actuation algorithms), security and privacy, as well as risk assessment and policy issues.

The partnership focuses on critical infrastructures and risk assessment. It makes 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; or distributed decision making (how to make sense from the vast amounts of information collected). These issues are studied under power constraints and scarcity of other resources (e.g., bandwidth, computing power, access channel rate). This partnership has the potential to expand traditional telecommunication infrastructures to the next level and to prepare telecom companies for 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.

Area 3 Technological Management and Policy are at the heart of regional and national economic growth and firm performance. The development of strategies and policies to guide innovative activity in Portugal and for different regions and Portuguese organizations, is imperative for productivity and employment growth. This is particularly relevant in the areas of the theme Information and Communication Technology identified by the assessment. ICT is 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 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. The assessment has identified education of highly qualified people that are capable of leading research, education and policy with this integrated perspective as a priority for Portugal. The proposed collaboration between CMU, in particular, EPP, Heinz, SDS, and Tepper, and UTL (IST) and UCP (FCEE) in Portugal recognizes this dimension. 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. Thus, the proposed collaboration 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 innovation and communication technologies.

There are three main subareas with related programs. The first is 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 entrepreneurship. The second is a research program in telecom policy, looking at questions of industry structure and regulation in telecom infrastructures, as well as the role of individual communities in promoting broadband diffusion and adoption. Finally, the third is a research

program that will address technology, engineering-economic, policy analytic, and risk-related studies of energy systems with emphasis on electric systems. In particular, it will consider advanced methods for the instrumentation and control of electric power systems and study the role of technology innovation in energy and environmental technologies as well as its relationship to government actions. This program involves at CMU EPP, ECE, and Tepper and IST in Portugal.

Area 4 Basic Sciences. This is a doctoral program in Applied Mathematics involving a consortium of 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. It will reinforce the scientific and educational programs in at the three 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

17. **Carnegie Mellon University-Portugal partnerships**. The partnerships described in Part IV of this assessment involve three main types of potential programs:

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; we refer to these in this assessment as Professional Masters Degrees, using a US nomenclature, but we stress that these are post-Master programs in the Bologna agreement. These programs serve multiple purposes from educating and training high quality professionals in the high technological areas identified in the assessment 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 this assessment.

The organization of these programs parallels other equivalent CMU collaborative Professional Masters programs; their graduates are undistinguishable from any other CMU graduate from the same program run by CMU at the Pittsburgh campus. In particular, our assessment identified three potential Professional Masters' programs to be offered by the partnership between CMU and a Portuguese University and that will strengthen the partner Portuguese Universities in the areas of software engineering, information security, and information networking:

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).

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.

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).

Appendix 8 details these three programs.

B. **Doctoral programs**. These represent a new dimension in CMU's international collaborations. They will be dual degrees – a PhD awarded by a CMU College and a PhD awarded by the Portuguese partner University. As dual degrees, the students will satisfy all the requirements of both institutions, the CMU College granting degree and the partner Portuguese University. 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. Planned degrees include:

i. PhD in 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).

ii. PhD in 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).

iii. PhD in 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 Electrical and Computer Engineering at Instituto Superior Técnico, Universidade Técnica de Lisboa; 2) the Department of Computer Science at Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa; and 3) Department of Telecommunications and Electronics at Universidade de Aveiro.

iv. PhD in 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.

v. PhD in Technological Change and Entrepreneurship to be offered by the SETChange Program. It involves at CMU 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.

Appendix 9 details some of these areas and programs.

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:

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

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

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.

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

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

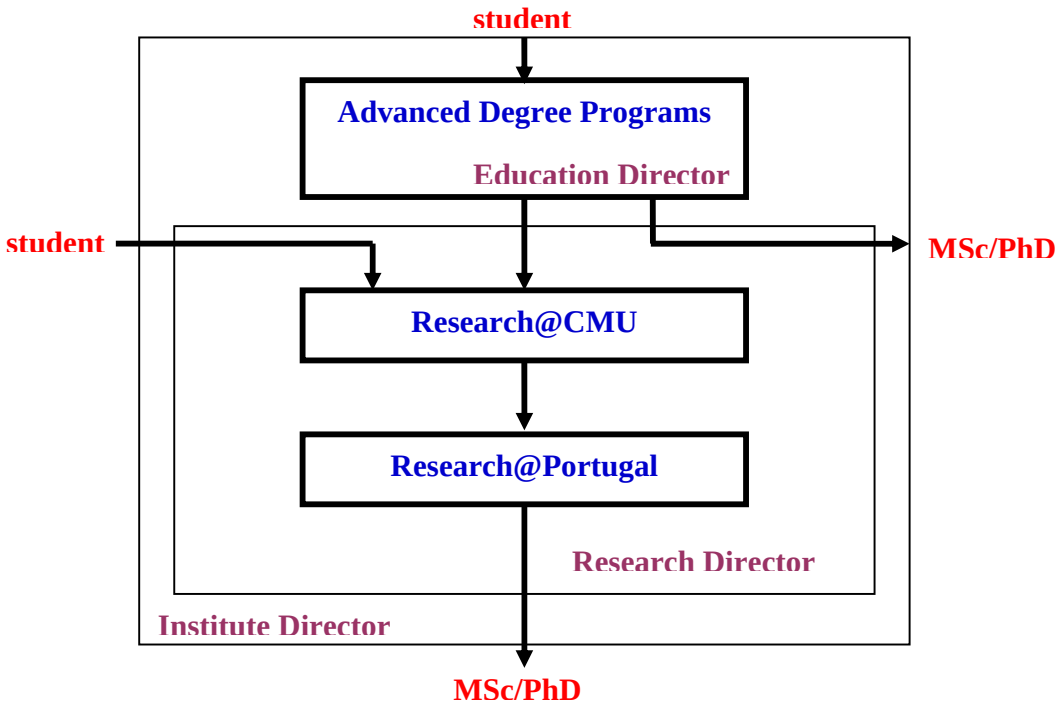

Figure 2 Advanced degree programs and research programs (PhD and research)

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 but working in the context of a Information Communication Technology Institute research project. These post-docs and graduate students will be recruited in the international market.

Figure 2 shows how these three programs interact. The advanced degree programs feed into the research activities, the PhD program and the research initiatives. As will be explained in the next item, the education and research programs have at least an education and a research director at each pole.

VI. Information Communication Technology Institute: A CMU-Portugal Partnership

18. **Information Communication Technology Institute: Framework of partnership**. We discuss briefly a format for the CMU-Portugal partnership. We propose a single Institution, the Information Communication Technology Institute (ICTI)[3], a CMU-Portugal Partnership, with two poles: ICTI@CMU, resident at CMU, and ICTI@Portugal, resident in Portugal. As illustrated in Figure 3, this Institute has a unified administration of one Institute Director and one Co-Director, residing at different Poles.

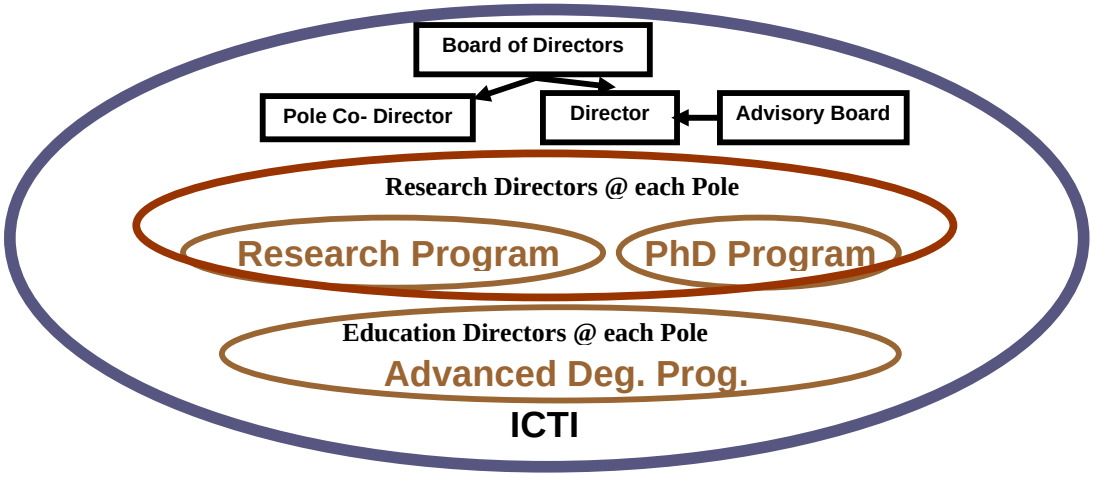

Figure 3 Information Communication Technology Institute: Structure and Main Programs

19. **Board of Directors**. At the top, there is a Board of Directors. This Board includes the following members: the President of CMU, or a representative; the Dean of CIT, the College of Engineering at CMU; the President of the Fundação para a Ciência e Tecnologia (FCT), or a representative, who chairs the Board; a second representative of the Fundacão da Ciência e Tecnologia; the Director; and the Co-Director. The Board may include participation of representatives of major companies involved in the program.

[3] The name of this Institution, here referred to as the Information Communication Technology Institute, as well as its two poles, ICTI@CMU and ICTI@Portugal, will be chosen at a later stage.

20. **External review committee (ERC)**. Following the standard policies of the Minister of Science, Technology, and Higher Education in Portugal, an External Review Committee (ERC) nominated by the Minister reviews annually the activities of the Information Communication Technology Institute. The External Review Committee writes a report on their evaluation. This report may suggest changes to the Institute's programs, including proposing the launching of new programs or the cancelling of existing programs, and modifications to the annual budget.

21. **Board of Directors: Functions**. The Board appoints the Director and Co-Director and reviews the activities of ICTI. The Board meets twice a year, once by conference call. The Board of Directors, with the exception of the Director and Co-Director, appoints the Director and the Co-Director of ICTI for a period of three years. After taking into account the report by the External Review Committee, the Board of Directors exercises its responsibilities annually by: 1) reviewing and approving the report on the activities of the Institute; 2) approving the plan of activities and the budget for the following year; and 3) evaluating proposals for potential new areas of collaboration. The Board of Directors may determine changes to the programs, including the launching of new programs or the cancelling of existing programs. The Board has final arbitration over all matters regarding the Institute.

22. **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 Director of ICTI appoints Research Directors and Education Directors at each pole to head ICTI's research activities and educational activities. The Research and Education Directors help the Director and Co-Director to run the Institute's educational and research programs. The Director and Co-Director are advised by an Advisory Board that helps define the research and educational agenda of the Institute. The members of the Advisory Board 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.

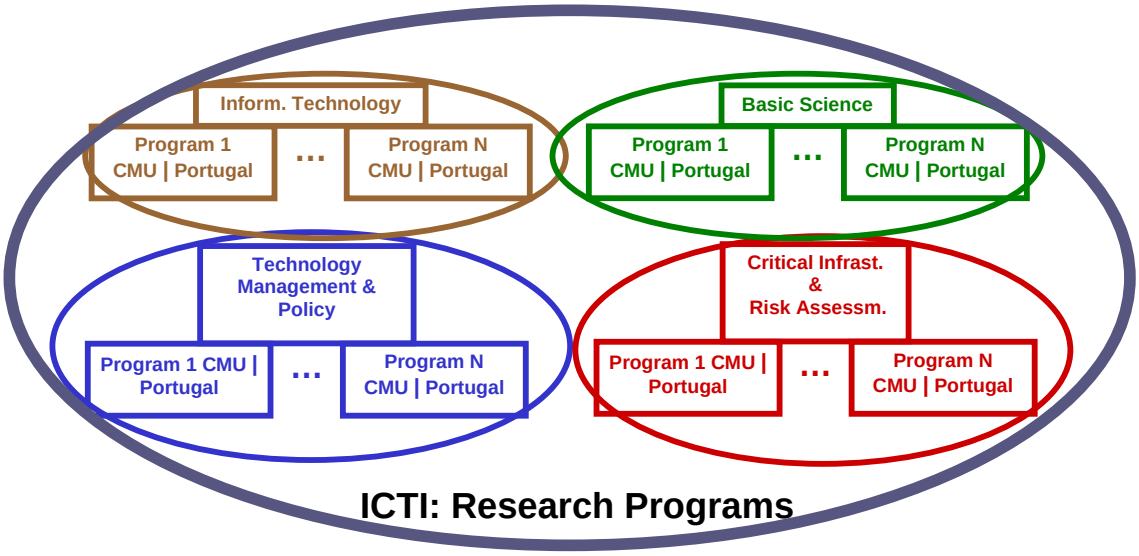

Figure 4 Information Communication Technology Institute: Research Programs

Figures 4 to 6 show the organization of the Institute programs.

With respect to Figure 4, within the Information Communication Technology Institute there are different areas of technological and scientific interest, as mentioned before, currently four: Information Technology, Basic Sciences, Technology Management and Policy, and Critical Infrastructures and Risk Assessment. A generic framework within each area can be the following. In each area there are several programs, say numbered from 1 to N. Each of these programs has two components, one at CMU and the other in Portugal, and there will be a single PI for each of the components of each of these programs, and an overall PI. Each area will have a single area coordinator in each pole of the Institute, and an overall coordinator. This allows for an integrated management structure. The Institute will set similar evaluation criteria and performance metrics, similar working conditions, and similar expectations for all areas and programs within each area. In time, if the program is successful, researchers, Universities, and research Institutions will be proud of being associated with the Institute. The success and impact of any component will translate into the success and impact of the Institute. In turn, the success of the Institute will mean the success of each partner institution.

Figure 5 shows several of the potential dual PhD programs. Like the research programs,

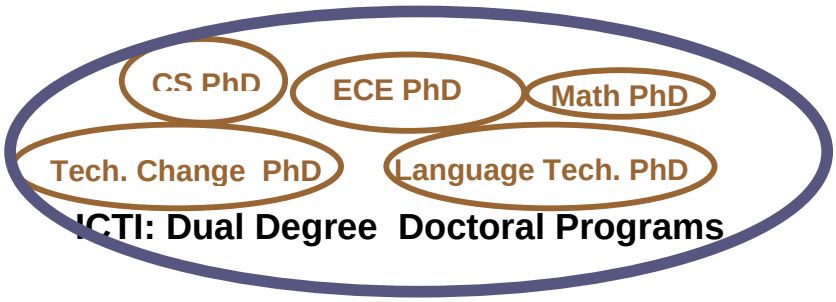

Figure 5 Detail of PhD Degrees in Information Communication Technology Institute

each doctoral program will have a Principal Investigator (PI) in each pole, and an overall PI. For example, the Technological Change & Entrepreneurship PhD program will have as PI at the ICTI@CMU pole the PhD program coordinator of the corresponding program. The PI at the ICTI@Portugal pole will be the parallel PhD program coordinator at the Portuguese Partner Institution. One of these PIs will be the overall PI of this program.

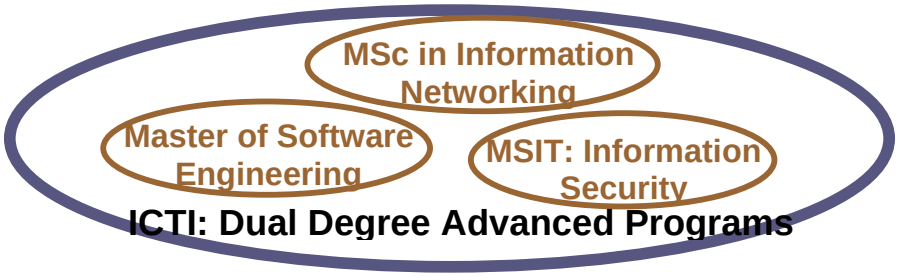

Figure 6 Advanced Degrees in Information Communication Technology Institute

Figure 6 shows the advanced degree programs in the Institute's educational agenda, of which there are three: one in Software Engineering, one in Information Security, and one in Information

Networking. Each program will have a coordinator at CMU and a coordinator at the Portuguese Partner Institution, one of which will be the overall coordinator. Details on the framework for each of these three programs will be fully defined by the CMU responsible unit and the Portuguese Partner Institution.

23. **First Director and first Co-Director**. After consultation with the Government of Portugal and specific discussion with Prof. Manuel Heitor, the Dean of CIT, Prof. Pradeep Khosla, with he consent of the CMU Higher Administration, proposes that: 1) Prof. José M. F. Moura be the first Director of the Information and Communication Technology Institute; 2) the Director once installed, and no longer than three months after the contract between the Portuguese Government and CMU has been signed, forwards to the Board of Directors the name of the Co-Director of the Portugal pole of the Institute; and 3) the Director and Co-Director inform the Board of the names of the Research and Education Directors of both poles as soon as possible thereafter.

24. **Fellows**. Faculty, graduate students, and post-docs associated or supported by the Institute will receive an appointment as 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 Portugal Fellows. This review will be activity and curriculum based.

25. **Information Communication Technology Institute and Partner Institutions**. The Institute, through the Fundação de Ciência e Tecnologia or any other Portuguese Government Agency empowered for that effect by the Minister of Science, Technology, and Higher Education, will establish contractual agreements with Portuguese Partner Universities and Research Institutions. These agreements will spell out the specific educational and research programs to carry out in partnership, who is involved, the costs, and the best practices that the different institutions will have to hold to.

26. **Industrial affiliates program.** The assessment emphasizes that the active participation of companies in Portugal will be extremely valuable to the potential CMU-Portugal partnership. This can take several forms. In particular, we discuss here the possibility of an industrial affiliates program for the Information Communication Technology Institute.

A. **Portugal Telecom**. During the assessment, there were several high level contacts with Portugal Telecom. On May 25, the CMU assessment committee met with members from the administration of Portugal Telecom (PT) at the PT Headquarters in Picoas. On June 22-23, a delegation from the administration of PT visited CMU. On July 24, Portugal Telecom hosted a Workshop at PT Inovação in Aveiro where most Portuguese teams, faculty from CMU, and members from PT, PT Comunicações, and PT Inovação discussed the content of several potential programs in this partnership and potential research projects. From all discussions held, it is clear that all parties, including PT and associated companies, recognize the enormous benefit resulting from the active involvement of PT with the several educational and research programs being discussed.

B. **Other industrial affiliates**. Besides PT, the assessment has recognized the potential to involve other companies. ISQ has identified several potential industrial partners. UC has contacts with several software companies. The assessment visited Critical Software when Minister Gago visited the company. The Information Communication Technology Institute

will establish an industrial affiliates program to promote the active participation of Portuguese companies in defining its research and education agenda. Companies can be expected to fund graduate students in the advanced degree programs, to be involved in the studio component of the Master of Software Engineering, and to provide internships to projects in the other Master of Science programs, tying the students' projects to real firm needs.

27. **Links with governmental organizations**. Besides the involvement with private corporations, the assessment has also recognized the potential to involve governmental organizations, namely with the Unidade de Missão, Inovação e Conhecimento, "UMIC- The Agency for the Knowledge Society." UMIC's goals are promote the use of ICT´s and, in general, the information society in Portugal. The involvement of UMIC should comprise at least two different forms. First, association with the research tasks on telecom policy and the overall research activity in technology management and policy, in a way that guarantees the impact of the CMU-Portugal partnership in designing and adapting public policies in Portugal. Second, association with the various education and research programs to maximize their potential in Portugal.

In addition, it is expected that ANACOM, the national telecom regulatory authority, will also be closely involved with the CMU-Portugal partnerships in terms of designing and testing regulatory measures, and in the education programs for training their own staff.

28. **Budget.** Each pole of the Institute has its own budget. These two budgets are contracted directly with the Government of Portugal, or the Institution charged by the Government to oversee this partnership. These budgets will support all programs related to the activities of the Institute. The Institute budget is contracted for a rolling window of 5 years, with minor annual adjustments. The Institute, through the Fundação de Ciência e Tecnologia or any other Portuguese Government Agency empowered for that effect by the Minister of Science, Technology, and Higher Education, will contract out with Portuguese Partner Institutions the budgets supporting their Institute related activities.

VII. Conclusion

This Report describes the assessment itself. The Government of Portugal requested this assessment to Carnegie Mellon University; see the Memorandum of Understanding signed by the Minister of Science, Technology, and Higher Education José Mariano Gago and the Carnegie Mellon University Provost Mark Kamlet on March 10, 2006.

The assessment was carried out in the period March 10 through July 31, 2006. It involved several face-to-face meetings between numerous faculty and administrators from Carnegie Mellon University and from Portuguese Universities and Research Institutions. This entailed several visits to Portugal of teams from Carnegie Mellon University and to Carnegie Mellon University from Portuguese teams.

The assessment identified a major theme: ***Information and Communication Technology*** (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.

From the 11 initial manifestations of interest (pre-proposals), some already the result of a consolidation effort, we organize the ICT theme into four main areas of potential collaboration: Information technology; critical infrastructures and risk assessment; technology management and policy; and basic sciences. These areas involve several subareas and several specific potential collaborations. Tables 1, 2, and 3 present information on the proposals, areas, and subareas. These potential 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 Universities and Research Institutions involved include the Universidade de Coimbra (FCTUC), Universidade de Aveiro, Universidade Técnica de Lisboa (IST), Universidade de Lisboa (FCUL), Universidade Católica Portuguesa (FCEE), Universidade Nova de Lisboa (FCTUNL), Universidade do Algarve, and Universidade da Beira Interior, as well as ISR, INESC-ID, ISQ, CISTER (IPP), CISUC, IN+, CAMGSD, and CLUL. There were intensive discussions with two Companies – Portugal Telecom and Critical Software. On July 24, a Workshop hosted by Portugal Telecom provided the opportunity for a discussion among most Portuguese potential partners, faculty from Carnegie Mellon University, and personnel from Portugal Telecom, as well as PT Comunicações, and PT Inovação.

The potential collaborations are 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. Potentially, there are three such programs: Software Engineering in partnership with Universidade de Coimbra; Information Technology with focus on Information Security with Faculdade de Ciências da Universidade de Lisboa; and Information Networking with Universidade de Aveiro. These programs have raised strong interest from Portugal Telecom and several software companies in Portugal, e.g., Critical Software. The research projects are in a number of areas and they complement well the educational programs, see paragraph 16 and Appendix 8 for a brief discussion of these areas.

To attain the desired goals for the partnership and maximize the return on investment, the institutional form of the partnership must be simple and dynamic, with a clear management structure. The assessment report discusses in section VI and item 18 the proposed Information Communication Technology Institute (ICTI), a CMU-Portugal Partnership, with two poles, ICTI@Portugal residing in Portugal and ICTI@CMU residing at Carnegie Mellon University. This Institute has a Director, and a Co- Director. It has an Advisory Board that advises the top management on the strategic directions. A Research Director and an Education Director head the Research and Education activities at each pole. Every program has a Principal Investigator in Portugal and another at Carnegie Mellon University. Likewise, every area has a coordinator in each pole.

The Institute will establish, through the Fundação de Ciência e Tecnologia or any other Portuguese Government Agency empowered for that effect by the Minister of Science, Technology, and Higher Education, a contractual partnership with each Portuguese partner. Each pole has its own budget that is directly negotiated with the Government of Portugal, or with the Institution charged by the Government to oversee this partnership.

There are superior goals to the partnership between Carnegie Mellon University and Portuguese Universities and Research Institutions. Carnegie Mellon is firmly committed to make sure that this partnership strengthens Portuguese Universities and their Research Institutions. We will work together with our counterparts in Portugal to: build their capacity to offer education and research programs of the highest quality in the areas of this assessment; foster their internationalizing by recruiting graduate students, post-docs, researchers, and faculty in competition with the best international academic centers; and transforming them through adoption of “best practices.”

Appendix 1

Visits to Portugal and to Carnegie Mellon (Partial List of Face to Face Meetings)

1. March 11: Signature of MoU, visit to Portugal by M. Kamlet (Provost), P. Khosla (CIT, Dean), and J. Moura (ECE Professor). Discussions held with Deputy Minister Prof. Manuel Heitor and Minister Prof. Mariano Gago. Meeting of Khosla and Moura with delegation from Instituto de Telecomunicações (Profs. Carlos Salema, Afonso Barbosa, and José Neves, and Eng. Vasco Lagarto). Brief encounter with Prof. Helena Ramos, Rector of University of Aveiro. Brief encounter with Prof. João Gabriel Silva (Dean, Faculty of Science and Technology, Universidade de Coimbra).
2. April 26-27: Visit to CMU of Profs. Pedro Oliveira and Rui Baptista where they met several faculty and CMU's assessment committee. This group is leading, from the Portugal side, the SetCHANGE collaboration effort.
3. May 18: Meeting of Moura with Prof. Paulo Ferreira (Universidade de Aveiro) and Prof. Victor Barroso (Instituto de Sistemas and Robótica, Instituto Superior Técnico) and brief meeting with Prof. Isabel Trancoso. These meetings occurred in Toulouse, France, where all parties attended an international meeting.
4. May 25-26: Visit by Prof. Isabel Trancoso to CMU, held meetings with Profs. Richard Stern (Electrical and Computer Engineering), and Alan Black and Tanja Schultz, both from the Language Technology Institute.
5. May 24-27: Visit to Portugal of CMU Assessment Committee (Moura, Schlesingher, Tsamitis, and Veloso). Also, accompanied for part of the visit by Prof. Michael DeKay. The schedule of meetings held is included in Appendix 1 to the Preliminary Report of the Assessment Committee.
6. June 22-23: Visit to CMU of Mr. Rodrigo Costa, Engs. Paulo Nordeste and Nuno Carvalhosa from Portugal Telecom. Meetings with Khosla, Schlesinger, Moura, Kim, Steenkiste, and Ferguson.
7. June 26-27: Visit to IST by Granger Morgan and Edward Rubin that included discussions of energy system research interests with Paulo Ferrão and Manuel Heitor.
8. June 30-Jul 4: Visit to CMU of Profs. José Matias and Ana Barroso from the Department of Mathematics, Instituto Superior Técnico and Faculdade de Ciências da Universidade de Lisboa, respectively. Meetings with Moura, and with Department of Mathematics Professors Fonseca, Kindlehrer, Pego, Leoni, Slepcev, Nicolaides (Head, Department of Mathematics), and Hrusa (Director of Graduate Studies, Department of Mathematics).
9. Jun 28-30: Visit to CMU of Prof. Paulo Verissimo. Meetings with various faculty from the Department of Electrical and Computer Engineering and the Department of Computer Science, including Maxion, . Meeting also with Moura.
10. July 5-6: Visit to CMU of Prof. Isabel Trancoso. Meetings with Moura and various faculty from the Language Technology Institute including Carbonnel (Director of LTI), Frederking (Director of Graduate Studies), Callan, Eskenazi, Balck, Lavie, Levin, aas well as Stern (ECE).
11. Jul 5-6: Visit to CMU of Prof. João Gabriel Silva, Dean of Faculdade de Ciências e Tecnologia, Universidade de Coimbra. Meetings with Assessment Committee (Moura, Schlesingher, Tsamitis), and with Garlan (by Conference Call), and Rosso?? and Miller, from the Master of Software Engineering (MSE) Program. Meetings also with Koopman (ECE) and Maxion (CS).

12. Jul 7: Profs. Paulo Ferreira and José Rocha from Universidade de Aveiro. Meetings with the Assessment Committee (Moura, Schlesinger, and Tsamitis). Meetings also with Tsamitis, Ghandi, and Wang from the Information Networking Institute and with Griffiths from the Department of Physics.
13. Jul 13-14. Visit by Prof Sirbu (EPP) to Portugal. Meetings with Profs. Pedro Fereirra (IST) and Rui Batista (UCP); with senior executives of PT including: Alfredo Baptista, Luis Filipe dos Santos Alveirinho, Salas Pires, Nuno Gonçalves, and Rodrigo Costa; and with Secretary of State Manuel Heitor.
14. Jul 13-15: Visit by Profs. Isabel Ribeiro (ISR, IST), Victor Barroso (ISR, IST), Eduardo Tovar (CISTER, IPP, ISEP), and Miguel Pinho (CISTER, IPP, ISEP), and Engs. Manuel Cruz (ISQ) and Elói Trindade (ISQ). Meetings with Assessment Committee (Moura and Schlesingher), and Profs. Perrig (ECE, CyLab, represented by one of his students), M. Veloso (CS), Ilic (ECE and EPP), RajKumar (ECE, CyLab, CenSCIR), Narasimha (ECE, CyLab, CenSCIR), Kumar (ECE, CyLab, and CenSCIR), Morgan (ECE, EPP), Garrett (Civil and Environmental Engineering Department Head and Co-Director of CenSCIR), Mathews (CEE and CenSCIR), VanBriesen (CEE and CenSCIR), Sohn (CEE and CenSCIR), Kim (ECE, CyLab Korea, CenSCIR), and Chen (ECE, ITRI, and CenSCIR).
15. Jul 23-24: Working visit to Portugal Telecom and Portugal Telecom Inovação of Moura (ECE, CenSCIR), Kim (ECE, CyLab Korea, and CenSCIR), RajKumar (ECE, CyLab, and CenSCIR), Steenkiste (ECE, CS, CyLab), and Sirbu (EPP and CenSCIR) to meet with several PT and PTI personnel and researchers, as well as with several of the Portuguese researchers, see Appendix for the agenda of this meeting.

Appendix 2

List of Acronyms and Affiliations

Carnegie Mellon University (CMU):
CEE: Civil and Environmental Engineering Department
CEIC: Carnegie Mellon Electricity Industry Center
CenSCIR: Center for Sensed Critical Infrastructures Research, ICES, CIT
CyLab: CyberSecurity Lab
CIT: Carnegie Institute of Technology, the College of Engineering at CMU
CS: Department of Computer Science, SCS
CTTEC: Center for Technology Transfer and Enterprise Creation
ECE: Department of Electrical and Computer Engineering, CIT
EPP: Department of Engineering and Public Policy, CIT
Heinz: Heinz School of Public Policy
ICES: Institute of Complex Engineered Systems, CIT
ITRI: International Taiwan Research Institute
INI: Information Networking Institute, CIT
ISRI: International Software Research Institute, SCS
LTI: Language Institute of Technology, SCS
MSE: Master of Software Engineering, ISRI, SCS
MSIN: Master of Science in Information Networking
MSIT: Master of Science in Information Technology
MSIT: IN: MSIT in Information Networking
MSIT: IS: MSIT in Information Security
MSIT: SE MSIT in Software Engineering
SCS: School of Computer Sciences
SDS: Social & Decision Sciences Department
SETChange: Program in Strategy, Entrepreneurship and Technological Change
Tepper: Tepper School of Business

Portuguese Institutions:
ANACOM: Autoridade Nacional de Comunicações
CAMGSD: Centro de Análise Matemmática, Geometria, e Sistemas Dinâmicos
CEMAPRE: Centro de Matemática Aplicada à Previsão e Decisão Económica, ISEG
CISTER: Research Unit of IPP
CISUC: Centro de Informática e Sistemas da Universidade de Coimbra
CLUL: Centro de Linguistica da Universidade de Lisboa
DMAT: Departamento de Matemática
DMath: Department of Mathematics
DET: Departamento de Electrónica e Telecomunicações, UA
FC: Faculdade de Ciências
FCEE: Faculdade de Ciências Económicas e Empresariais, UCP
FCT: Faculdade de Ciências e Tecnologia; also Fundação da Ciência e Tecnologia
FCTUC: Facudade de Ciências e Tecnologia da Universidade de Coimbra, UC
FCTUNL: Facudade de Ciências e Tecnologia da Universidade Nova de Lisboa, UNL
FCUL: Facudade de Ciências da Universidade de Lisboa, UL

HULTIG: Center for Human Language Technology and BioInformatics, UBI
IN+: Center for Innovation, Technology and Policy Research
INESC-ID: Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento, IST
INOVISA: Associação para Inovação e Desenvolvimento Empresarial, ISA
IPP: Instituto Politécnico do Porto
ISA: Instituto Superior de Agronomia, UTL
ISEG: Instituto Superior de Economia e Gestão, UTL
ISEP: Instituto Superior de Engenharia do Porto
ISQ: Instituto de Soldadura e Qualidade
ISR: Instituto de Sistemas e Róbotica, IST
IT: Instituto de Telecomunicações, IT, UA, UC
IST: Instituto Superior Técnico, UTL
L2F: Laboratório de Lingua Falada, INESC-ID, IST
PT: Portugal Telecom
PTC: Portugal Telecom Comunicações
PTI: Portugal Telecom e Inovação
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
UMIC: Unidade de Missão, Inovação e Conhecimento
UNL: Universidade Nova de Lisboa
UMIC: Agência para a Sociedade do Conhecimento
UTL: Universidade Técnica de Lisboa

CMU-Portugual Partnetrship:
ICTI: Informatioin Communication Technology Institute
ICTI@Portugal: INCTI Pole at Portugal
ICTI@CMU: ICTI Pole at CMU

Appendix 3

Process

1. In the Fall of 2005, Prof. José M. F. Moura was invited by Deputy Minister Manuel Heitor to meet with him and Minister José Mariano Gago to discuss their interest in exploring potential collaborations between Carnegie Mellon University (CMU) and Portuguese Institutions of Higher Education. These collaborations were to be part of the strategy of the Portuguese Government to strengthen the internationalization of Portuguese Universities and Research Institutions. This meeting was held at the Ministério da Ciência, Teconologia, e Ensino Superior (MCTES), in Lisbon on December 23, 2006. Prof. Heitor explained the interest of the Government of Portugal in establishing relations with American Universities, and, in particular, with CMU. Prof. Moura described several of CMU's educational international programs, e.g., CMU at Qatar, the INI program in Athens, the MSIT in Kobe, Japan, the MSIT in Korea, as well as several research collaborations, in particular, CyLab Korea, and ITRI with Taiwan. Potential areas of collaboration that were advanced included information networking, telecommunications, critical infrastructures, software engineering, computer engineering, robotics, other areas in electrical and computer engineering and computer science, as well as management of technological innovation and basic sciences in engineering.

2. This meeting was followed by a working visit of Prof. Manuel Heitor to CMU on January 31, 2006. Prof. Heitor met with, among others, CMU President Jared Cochon, CIT Dean Pradeep Khosla, EPP Head Granger Morgan, ECE Head Ed Schlesingher, INI Director Dena Tsamitis, and Profs. Moura (ECE) and Francisco Veloso (EPP). Prof. Heitor described the interests of the Portuguese Government in a CMU and Portugal collaboration. President Cochon explained CMU's strategic vision on internationalization and how it is developed over the years.

3. These initial meetings were followed by several discussions between Profs. Heitor and Moura and Dean Khosla, among others, which led to a Memorandum of Understanding (MoU) signed by Provost Mark Kamlet and Minister José Mariano Gago in Aveiro, Portugal, on the 10th of March, 2006, at the *1st Forum para a Sociedade da Informação*. At the Forum, Profs. Khosla and Moura were invited to give two talks on Cyber Security and Critical Infratsructures, respectively. The Forum provided the opportunity for the CMU delegation (Kamlet, Khosla, and Moura) to meet with Prime Minister José Socrates, who attended the signing ceremony, and who expressed the commitment of the Portuguese government to the internationalization of Portuguese Universities and Research Institutions as one of the means to foster the technological development of Portugal.

4. At the Forum, there was also the opportunity for a 1st formal meeting between Prof. Manuel Heitor, Dean Khosla, and Prof. Moura with the executive committee of Instituto de Telecomunicações (IT) represented by Prof. Carlos Salema (IT Director), Prof. Afonso Barbosa, Prof. José Neves, and Eng. Vasco Lagarto. Tere were also very brief meetings with Prof. Isabel Ribeiro (ISR Director, IST), Prof. José Gabriel Silva (Dean FCTUC, UC) and Prof. Helena Nazaré, Rector of University of Aveiro.

5. After the Forum, and during March through mid May, there were frequent meetings and contacts between Prof. Manuel Heitor and many Portuguese research groups, as well as these groups and Prof. Moura. The result of this activity were several white papers that gave rise to 10 pre-proposals, see the preliminary assessment report of 11 June/ 2006. Dean Khosla nominated an Assessment Committee to organize the day-to-day activities of the assessment. This

committee included Profs. Granger Morgan, José Moura, Ed Schlesinger, Francisco Veloso, and INI Director Dena Tsamitis.

6. On May 23-26, the assessment committee visited Portugal and met with all the groups that submitted a pre-proposal. The committee also met with Prof. Manuel Heitor, Minister Gago, visited a company Critical Software, and met with several members of the administration of Portugal Telecom.

7. On June 11, the assessment committee submitted to Prof. Manuel Heitor its preliminary assessment report. This report included specific recommendations to the different groups on how to proceed. In particular, several groups were invited to visit CMU and meet with CMU faculty and finalize their proposed collaborations.

8. These visits occurred between the June 28 and July 15, see Appendix 6 for a partial list of such meetings. These visits were prepared by several conference calls among the Portuguese visitors and Prof. Moura to identify relevant CMU collaborators, to structure the collaboration, and set the goals for the visit. Usually, at CMU, the visits were preceded by a meeting of Prof. Moura with interested CMU parties where the MoU was described, the Portuguese Government goals with the proposed collaborations were explained, and where the details of potential collaborations were discussed. A typical visit to CMU lasted for two to three days, started with an initial meeting with the assessment committee to set the goals for the visit and an initial discussion of the proposed collaboration. This was followed by intensive meetings of the Portuguese visitors with CMU interested faculty and Department Heads. Finally, the visitors produced a draft of their proposal outlining the proposed collaboration, and presented it at a closing meeting with the assessment committee.

Appendix 4

(Partial) List of Faculty Involved in the Assessment Exercise

The following is an incomplete list of faculty and other individuals that have been directly involved, with discussion meetings and/ or visits in exploring the collaborations between CMU and Research Institutions and Universities in Portugal. Additional faculty is involved in the proposed collaborations, see the specific proposals.

Carnegie Mellon University faculty and staff:
Jay Apt, Professor of EPP and Tepper Business School
Ashis Arora, Heinz
VijayaKumar Baghavatula, Professor of ECE
Alan Black, Professor of LTI
Jamie Callan, Professor of LTI
Jaime Carbonell, Professor of LTI, Director of LTI
Tsuhan Chen, Professor of ECE, Director of ITRI, CenSCIR
Michael DeKay, Professor of Heinz School and EPP
Maxine Eskenazi, Professor of LTI
William Ferguson, CyLab Director of Executive Education and Corporate Relations
Irene Fonseca, Professor of Mathematics
Robert Frederking, Professor of LTI, Director of Graduate Studies, LTI
David Garlan, Professor of CS and ISRI, Director of MSE
James Garrett, Professor of CEE, CEE Department Head, Co-Director of CenSCIR
Rajeev Ghandi, System Scientist, ECE and INI
Robert Griffiths, Professor of Department of Physics
David Hounshell, History and SDS
William Hrusa, Professor of Mathematics, Director of Graduate Studies, Department of Mathematics
Marija Ilic, Professor of ECE, CenSCIR
Pradeep Khosla, Dean of CIT, Director of CyLab, Leader of the Assessment
Hyong Kim, Professor of ECE, CenSCIR , and Director CyLab Korea
David Kinderlehrer, Professor of Mathematics
Steven Klepper, Professor of SDS and Tepper
Phil Koopman, Professor of ECE, CyLab
Bruce Krogh, ECE Associate Department Head, CenSCIR
Alon Lavie, Professor of LTI
Giovanni Leone, Professor of Mathematics
Lori Levin, Professor of LTI
Robert Lowe, Professor of SDS and CTTEC
Scott Matthews, Professor of CEE
Roy Maxion, Professor of CS
Don McGillen, CyLab Director
Jane Miller, MSE Managing Director
Granger Morgan, Professor of ECE and EPP, EPP Department Head
José M. F. Moura, Professor of ECE, Leader of the Assessment, Chair of the Assessment Committee, Co-Director of CenSCIR

Priya Narasimhan, Professor of ECE, CenSCIR, and CyLab
Roy Nicolaides, Professor of Mathematics, Math Department Head
Robert Pego, Professor of Mathematics
Andrew Perrig, Professor of ECE and EPP, CyLab
Raj RajKumar, Professor of ECE, Director of GM Lab, CenSCIR, and CyLab
Mel Rosso-Lopart, MSE Co-Director
Ed Rubin, Professor of CEE and EPP
Tanja Schultz, Professor of LTI
Ed Schlesinger, Professor of ECE, ECE Department Head
Marvin Sirbu, Professor of EPP, Tepper, and ECE
Dejan Slepcev, Professor of Mathematics
Hoon Sohn, Professor of CEE
Richard Stern, Professor of ECE
Dena Tsamitis, Director of INI
Jeanne VanBriesen, Professor of CEE
Francisco Veloso, Professor of EPP
Manuela Veloso, Professor of CS
Tina Wang, Professor of INI
Jannette Wing, Professor of CS, CS Department Head

CMU Admnistration:
Jared Cohon: President
Mark Kamlet: Provost
Pradeep Khosla: CIT Dean

Portuguese faculty and staff:
Rui Baptista, Professor, IST
Afonso Barbosa, Professor of ECE, Vice-President for Scientific Affairs, IST, Executive Committee IT (Lisbon)
Fátima Barros, Dean, FCEE-Católica
Ana Barroso, Professor of DMAT, FCUL
Victor Barroso, Professor of ECE, IST, ISR
Fernando Branco, Vice-Rector, UCP
Paulo Correia, Chair, Department of Engineering and Management Studies, IST
Manuel Cruz, Director of ISQ
Carlos Ferrão, Professor MECHE, IN+, IST
Carlos Matos Ferreira, Dean of IST
Paulo Ferreira, Professor of DET, UA
Pedro Ferreira, Professor ECE, IST, UMIC
Manuel de Freitas, Chair, Department of Mechanical Engineering
Pedro Girão, Professor of DMAT, IST
Diogo Gomes, Professor of DMAT, IST
Vasco Lagarto, IT
João Miranda Lemos, Professor of ECE, IST, ECE Department Chair
Francisco Lima, Professor, IST

Fernando Machado, Associate Dean, FCEE-Católica
Nuno Mamede, Professor of ECE, IST, INESC-ID
Manuel Marques, Professor of DMAT, IST
Luísa Mascarenhas, Professor of DMAT, FCTUNL
José Matias, Professor of DMAT, IST
Helena Nazaré, Rector UA
João Neto, Professor of ECE, IST, INESC-ID, L2F
José Neves, Professor of DET, UA, IT
Arlindo Oliveira, Professor of ECE, IST, INESC-ID, Director INESC-ID
Luís Oliveira, Professor of ECE, IST, INESC-ID, L2F
Pedro Oliveira, Professor, FCEE-Católica, UCP
Miguel Pinho, Professor, IPP, ISEP, CISTER
Miguel Ramos, Professor of DMAT, FCUL
Isabel Ribeiro, Professor of ECE, IST, Director of ISR
Carlos Rocha, Professor of DMAT, IST
José Rocha, Professor of DET, UA
Adélia Sequeira, Professor of DMAT, IST
António Cruz Serra, Professor of ECE, Vice-President for Admnistrative Affairs, IST
José Gabriel Silva, Dean, FCTUC, UC
Carlos Guedes Soares, Professor of Risk Assessment, IST
Eduardo Tovar, Professor, IPP, ISEP, and Director CISTER
Isabel Trancoso, Professor of ECE, IST, and INESC-ID
Elói Trindade, ISQ
Paulo Verissimo, Professor of CS, FCUL

Portugal Telecom members:
Nuno Carvalhosa, Advisor, PT
Rodrigo Costa, Executive Vice-President, PT, PTC
Paulo Nordeste, President, PTI
Francisco Padinha, Senior Director, PR
Critical Software, several members including:
João Carreira, VP Business development
Diamantino Costa, VP Business development

Portuguese Government members:
José Mariano Gago, Minister of Science, Technology, and Higher Education
Manuel Heitor, Deputy Minister of Science, Technology, and Higher Education

Appendix 5
Schedule of Visits
January 31, 2006
Deputy Minister Prof. Manuel Heitor's Visit to CMU

9-11:00 am: Dean of Engineering, Pradeep Khosla, ECE Department Head Ed Schlesinger, EPP Department Head Granger Morgan, INI Director Dena Tsamitis, EPP Professor Francisco Veloso, ECE Professor José M. F. Moura.

Apresentação do interesse do Governo de Portugal em parcerias com Universidades do US e em particular com a CMU. Apresentação de programas da CMU. Discussão.

11-noon: ECE Department Head Ed Schlesinger, INI Director Dena Tsamitis, ECE Professor José M. F. Moura.

Apresentação de programas de investigação envolvendo os alunos internacionais e visita à sala de ensino à distancia.

12-1:00pm: ECE Department Head Ed Schlesinger, EPP Department Head Granger Morgan, INI Director Dena Tsamitis, ECE Professor José M. F. Moura

Discussão durante almoço de next steps e wrap-up..

1:30-2:15pm: President, Jerry Cohon, ECE Prof. José M. F. Moura.

Manifestação do Governo de Portugal de interesse em parcerias com Universidades US e em particular com a CMU. Discussão do interesse da CMU em colaborações internacionais.

2-2:45pm: ECE Prof. José M. F. Moura

Wrap-up

2:45pm: Limousine para o aeroporto.

PhD Program in Technological Change and Entrepreneurship

Visit of Pedro Oliveira (FCEE-UCP) and Rui Baptista (IST-UTL) to CMU
April 25-27, 2006

4/25 7h30 Dinner with Francisco Veloso (Engineering and Public Policy - EPP).
4/26 8h30 Granger Morgan (EPP & ECE) and Steven Klepper (SDS & Tepper)
4/26 11h30 Lunch with SETChange Graduate Students
4/26 1h00 David Hounshell (SDS & History)
4/26 2h30 Jay Apt (EPP & Tepper)
4/26 3h00 Marvin Sirbu (EPP & Tepper & ECE)
4/26 4h00 Steven Klepper (SDS & Tepper)

4/27 11h00 Ashish Arora (Heinz School)
4/27 12h00 Lunch with Robert Lowe (SDS)
4/27 13h00 Fonseca Moura (ECE), Ed Schlesinger (ECE), Dena Tsamitis (INI)

Visit of Steven Klepper and Francisco Veloso to IST and FCEE-Católica
May 23-24, 2006

Meetings with –
- Fátima Barros, Dean, FCEE-Católica
- Fernando Machado, Associate Dean, FCEE-Católica
- Carlos Matos Ferreira, President, IST
- Pedro Oliveira, FCEE-Católica
- Rui Baptista, IST
- Manuel Heitor, Deputy Minister for Science, Technology and Higher Education

Discussion of Granger Morgan, Ed Rubin and Francisco Veloso with IST on occasion of the TMP Doctoral Consortia – Focusing Energy Collaboration
June 26-27, 2006

Meetings with Paulo Ferrão, IST; Rui Baptista, IST and Manuel Heitor, Deputy Minister for Science, Technology and Higher Education

PhD Program in Technological Change and Entrepreneurship

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4/26 1h00 David Hounshell (SDS & History)
4/26 2h30 Jay Apt (EPP & Tepper)
4/26 3h00 Marvin Sirbu (EPP & Tepper & ECE)
4/26 4h00 Steven Klepper (SDS & Tepper)

4/27 11h00 Ashish Arora (Heinz School)
4/27 12h00 Lunch with Robert Lowe (SDS)
4/27 13h00 Fonseca Moura (ECE), Ed Schlesinger (ECE), Dena Tsamitis (INI)

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- Rui Baptista, IST
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PROGRAMME FOR THE ASSESSMENT VISIT TO PORTUGAL
24-26 MAY 2006

José M. F. Moura (Chair)
Ed Schlesinger
Dena Tsamitis
Francisco Veloso
Michael DeKay

24 May - Wednesday (Lisboa)

10h45 – Departure from the Hotel Marriott to Instituto de Engenharia de Sistemas e Computadores (INESC)

11h00-12h00: Isabel Trancoso (INESC), Luis Caldas de Oliveira (INESC), João Paulo Neto (INESC)

Venue: INESC Lisboa

12h00-14h30: Carlos Matos Ferreira and Rui Baptista (IST, UTL) and Fernando Branco (Universidade Católica Portuguesa), Fátima Barros and Pedro Oliveira (FCCE, Universidade Católica Portuguesa)

Venue: IST, including lunch

14h45-16h15: Fernando Branco (Universidade Católica Portuguesa), Fátima Barros and Pedro Oliveira (FCCE, Universidade Católica Portuguesa)

Venue: UCP

16h30-18h00: MCTES – Secretary of State, Manuel Heitor

18h00-22h00: Paulo Veríssimo (Faculdade de Ciências, Universidade de Lisboa)

Venue: FC-UL, including dinner

25 May - Thursday (Coimbra e Aveiro)

8h00 – Departure from the hotel to Coimbra

10h00-13h00: João Gabriel Silva (FCT, Universidade de Coimbra)

Venue: FCT - U.Coimbra

13h30- 15h30: CRITICAL SOFTWARE (João Carreira)

Venue: CRITICAL SOFTWARE – *Coimbra;*

including visit and lunch with Minister José Mariano Gago

16h30- 21h00: Maria Helena Nazaré and Paulo Ferreira (Universidade de Aveiro), Carlos Salema (IT)

Venue: U. Aveiro, including dinner

26 May - Friday (Lisboa)

9h00 – Departure from the hotel to ISQ, in Oeiras

9h30-11h00: Manuel Cruz (ISQ)

Venue: ISQ

11h30-12h30: Carlos Guedes Soares (IST)

12h30-14h00 - Isabel Ribeiro (IST), Eduardo Tovar (Oporto Polythecnic), Manuel Cruz (ISQ),

Venue: IST (ISR), including lunch

14h00- 15h15: Carlos Rocha and José Matias (IST); also with members from FC-UL

Venue: IST – Department of Mathematics

15h30- 16h30: Rodrigo Costa, Board of Directors, Portugal Telecom, F. Padinha, N. Carvalhosa

Venue: PORTUGAL TELECOM

16h45- 20h00: MCTES – Secretary of State, Manuel Heitor

20h30: Dinner with Secretary of State, Manuel Heitor

Reservations:

HOTEL MARRIOTT in Lisbon:

http://marriott.com/property/propertypage/LISPT

José M. F. Moura (From 23-27 May)
Ed Schlesinger (From 23-27 May)
Dena Tsamitis (From 23-26 May)
Michael DeKay (From 25-27 May)

Transportation:

One seven seats van with driver will be available during the visits.

Arrivals (May 24):

Dena Tsamitis: TAP FLT 104 Newark-Lisbon, 6h05 am (in Lisbon)

José Fonseca de Moura: Continental CO 64 Newark-Lisbon 8h15am (in Lisbon)

Ed Schlesinger: TAP FLT 104, Newark-Lisbon, 6h05 am (in Lisbon)

Arrival (May 25):

Michael DeKay: Continental CO 64 Newark-Lisbon, 8h15 am (in Lisbon)

Portugal Telecom Visit to CMU

Thursday and Friday, June 22 and 23 2006

Visitors:

- Mr. Rodrigo Costa, Executive Vice-President, Portugal Telecom (PT)
- Eng. Paulo Nordeste, Director of PT Inovacao (PTI, the PT Research Laboratory)
- Eng. Nuno Miguel Pereira D de F. Carvalhosa, Advisor

Thursday, June 22

Note: All meetings in the CyLab Conference Room (CIC 2101) unless noted otherwise

7:00	Visitors picked up at airport and taken to hotel (Sheraton Station Square, need early check-in)
2:00	Visitors picked up at hotel and driven to CIC
2:30-3:10	CyLab overview (Don McGillen, CyLab Executive Director)
3:10-4:00	Hyong Kim
4:00-4:40	The Grey System: Device-enabled Authorization (Lujo Bauer)
4:45	Visitors taken back to hotel
6:20	Visitors picked up and taken to Monterey Bay
6:30-9:00	Drinks and dinner at Monterey Bay
9:00	Visitors taken back to hotel

Friday, June 23

8:15	Visitors picked up at hotel
8:45-10:45	Meet with Pradeep Khosla, Ed Schlesinger, José Moura, Hyong Kim (Meeting in Dean's Office, Scaife Hall)
10:45-11:00	Walk to CIC for presentations in CyLab Conference Room
11:00-11:40	Peter Steenkiste
11:40-12:40	Lunch (catered in)
1:2:40-1:20	Tsuhan Chen
1:30	Visitors taken to the airport

Visit of Prof. Paulo Verissimo
June 28 – 30/ 2006

Prof. Verissimo met several ECE and CS faculty including Roy Maxion (CS), BVruce Krogh (ECE), Raj Kumar (ECE), Priya Narasimhan (ECE), Jeannette Wing (Head, CS Department).

3:00-4:00pm, June 30: José Moura, ECE

Visit of Prof. José Matias and Prof. Ana Barroso
June 30 – July 4/ 2006

11:00-12:30pm, June 30: José Moura (ECE)
1:30pm- 4:00pm: David Kinderlehrer (Math), Giovanni Leoni (Math), Bill Hrusa (Math), Bob Pego (Math)

1:30pm – 5:00pm: Nicolaides (Math Department Head), Bill Hrusa (Math Director of Graduate Studies), Bob Pego (Math), David Kinderlehrer, Giovanni Leoni (Math), Irene Fonseca (Math).

Visit to CMU by Prof. Isabel Trancoso
July 5, 6/ 2006

9:00-10:00AM, July 5: Jaime Carbonell (LTI Director), Robert Frederking (LTI, Director of Graduate Studies), José Moura (ECE).

July 5 and 6: In addition to the above three, Prof. Trancoso held working meetings with: Richard Stern (ECE), Alan Black (LTI), Tania Schultz (LTI), Maxine Eskenazi (LTI), Jamie Callan (LTI), Alon Lavie (LTI), Lori Levin (LTI), Eric Nyberg).

4:00-5:00pm, July 6: Jaime Carbonell and Robert Frederking.

Visit to CMU by Prof. João Gabriel Silva
July 5, 6/ 2006

11:00-12:00 noon, July 5: José Moura (ECE), Ed Schlesingher (ECE Department Head), Dena Tsamitis (INI Director)

Noon-5:00pm, July 5: David Garlan (ISRI, CS, Director of MSE) (by conference call), Mel Rosso-Lopart (MSE Co-Director), Jane Miller (MSE Managing Director).

10:00-11:00AM, July 6: Phil Koopman (ECE)
11:00-noon, July 6: Roy Maxion (CS)
Noon-4:00pm, July 6: Mel Rosso-Lopart (MSE Co-Director), Jane Miller (MSE Managing Director).
4:00-5:30pm, July 6: José Moura (ECE), Ed Schlesingher (ECE Department Head), Dena Tsamitis (INI Director)

Visit to CMU by Prof. João Gabriel Silva
July 5, 6/ 2006

9:00-10:30, July 6: José Moura (ECE), Ed Schlesingher (ECE Department Head), Dena Tsamitis (INI Director), Tina Wang (INI), Rajeev Ghandi (INI)
10:30AM-3:30pm: Dena Tsamitis (INI Director), Tina Wang (INI), Rajeev Ghandi (INI)
3:30-4:00PM: Robert Griffiths (Physics)
4:00-5:30pm, July 6: José Moura (ECE), Ed Schlesingher (ECE Department Head), Dena Tsamitis (INI Director), Tina Wang (INI), Rajeev Ghandi (INI)

Visit of Marvin Sirbu to Lisbon
July 13-14, 2006

Meetings with Rui Baptista, IST; Pedro Ferreira, IST; Portugal Telecom; Manuel Heitor, Deputy Minister for Science, Technology and Higher Education

Critical Infrastructures CMU@Portugal Collaboration

Schedule July 13 and 15/2006

Meeting place: PH B34

Administrative Assistant: Ms. Carol Patterson, carol@ece.cmu.edu, (412)268-7286

Visitors from Portugal and their affiliation:

1) Instituto Superior Técnico (IST) (Eng. School of Univ. Técnica de Lisboa): Instituto de Sistemas and Robótica (ISR) http://www.isr.ist.utl.pt
    a. Prof. Isabel Ribeiro (Director)
    b. Prof. Victor Barroso
2) Instituto de Soldadura e Qualidade (ISQ): http://www.isq.pt/
    a. Eng. Manuel Cruz (Director)
    b. Eng. Elói Trindade
3) ISEP and IPP, CISTER: http://www.cister.isep.ipp.pt/
    a. Prof. Eduardo Tovar
    b. Prof. Luís Pinho
4) Instituto Superior Técnico (IST) and INESC-ID: http://www.inesc-id.pt/
    a. Prof. Augusto Casaca (not sure if coming)

Most CMU faculty below is also associated with **CenSCIR** (Center for Sensed Critical Infrastructures Research)

Thursday Jul 13:
10-11:15am: José Moura
11:15-11:45am: Mark Luk (security)
11:45-1:00pm (lunch provided): Manuela Veloso (SCS and CSD) (mobile and robotic sensors)
1-2:00pm: Marija Ilic (ECE and EPP) (power grid application)
2-3:00pm: Raj Rajkumar (ECE) (Wireless sensor networks: system infrastructures, HW and SW)
3-4:00pm- Priya Narasimhan (ECE) (Tools and distributed SW infrastructures (middleware) for sensor networks)
4-5:00pm: Kumar (ECE) (Video monitoring: Biometrics)

Friday July 14:
9-10:00am: José Moura
10-11:00am Granger Morgan (EPP and ECE) (EPP's Office) (Risk assessment)
11-noon: Tsuhan Chen (ECE) (ITRI Lab) (Video monitoring: Distributed video)
noon-1:30pm (lunch provided): Civil and Environmental Eng. Faculty to discuss water and campus wide maintenance applications: Jim Garrett (Dep. Head, Co-Director of CenSCIR), Scott Matthews, Jeanne VanBriesen (Director of Water-QUEST), Hoon Sohn
1:30-2:15- Hoon Sohn (CEE) (Pipeline sensing)
2:15-3:00pm- Hyong Kim (ECE) (CyLab Korea) (Networking)
3-4:00pm: Visitors time
4:30-5:30: Wrap-up with Assessment Committee (Ed Schlesinger (ECE Dep. Head) and José Moura (Chair, Assessment Committee))

Friday July 15:
9:00AM-6:00PM: Working period and brief meetings with José Moura

Visit to Portugal Telecom
Aveiro
July 24/ 2006
Schedule

Contact person: Nuno Miguel Pereira D de F. Carvalhosa
nuno-m-carvalhosa@telecom.pt

1. **09:00-09:45 AM**: Introduction and overview of Group PT, PT Inovação, and INOVARIA, Paulo Nordeste
2. **09:46-10:45 AM**: Visit to PT Inovação Labs
3. **10:45-11:00 AM**: Coffee break
4. **11:00-noon** : Network Engineering, brief intro (~15 min) by Peter Steenkiste followed by discussion moderated by Jorge Rodrigues and Francisco Fontes
5. **12:00-13:00 PM**: Information Security, brief intro (~15 min) by Hyong Kim followed by discussion moderated by José Alegria and Eduardo Silva
6. **13:00-14:00 PM: Lunch**
7. **14:00H-14:30 PM**: Brief presentations of Master Programs:
    a. Master in Software Engineering (MSE), João Gabriel Silva
    b. Master of Science in Information Technology: Information Security, Paulo Verissimo
    c. Master of Science in Information Networking, Paulo Ferreira
8. **14:30-15:30 PM**: Critical Infrastructures, brief intro (~15 min) by Raj Rajkumar followed by discussion moderated by Fino Gomes and Pedro Carvalho
9. **15:30-16:30 PM**: Policy, Technological Change and Entrepreneurship brief intro (~15 min) by Marvin Sirbu followed by discussion moderated by Marcelino Pousa and Nuno Miguel Carvalhosa
10. **16:30-16:45 PM**: Language technology, Isabel Trancoso
11. **16:45-17:30 PM**: Wrap-up discussion and concluding remarks

Hotel Meliá Ria (25 rooms single)
Dead line for reservation: July/ 20/2006
Cais da Fonte Nova, Lote 5
3810-200 Aveiro
Tel: 234 401 000, Fax: 234 401 009
E-mail:melia.ria@solmeliaportugal.com
Entrada: 23/07/06
Saída: 24/07/06
Rate per room : 60,00€, Breakfast included
Payment: indicate type of payment

Tentative list of participants:
José Alegria, jose.alegria@telecom.pt PT Comunicações
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Pedro Ferreira, pedro.ferreira@umic.pt

Appendix 6
Preliminary Assessment Report

Electrical & Computer ENGINEERING
Pittsburgh, PA 15213-3890
ph: 412.268.6341 • fax: 412.268.3890
http://www.ece.cmu.edu/

Memorandum

To: Prof. Manuel Heitor, Secretário de Estado da Ciência, Tecnologia, e Ensino Superior
From: José M. F. Moura, Ed Schlesinger, Dena Tsamitis, and Francisco Veloso
Date: 10/24/2006
Subject: 1st Draft of Assessment of Portugal-Carnegie Mellon University Potential Collaborations

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1. This Report is a first assessment of potential collaborations between Carnegie Mellon and research groups in Portugal. It is the result of discussions held with Prof. Manuel Heitor and the Portuguese groups that we met during our June 24-26 visit to Portugal. The Carnegie Mellon team included:

Prof. José M. F. Moura (ECE, Committee Chair), Prof. Ed Schlesinger (ECE Department Head), Ms. Dena Tsamitis (INI Director), and Prof. Francisco Veloso (EPP). The team was joined on the last day, June 26th, by Prof. Michael DeKay (EPP).

2. The schedule of the visit was arranged by the Secretaria de Estado and is enclosed as Appendix 1. The visits began and ended with meetings with Prof. Manuel Heitor where we had the opportunity to discuss the goals of the visit as well as the groups visited and the potential collaborations associated with them. In addition to our meetings with potential university collaborators, our schedule included meetings with three potential non-university partners, as highlighted below.

3. On Thursday June 25th, together with the Minister of Science, Technology, and Higher Education (MCTES), Prof. Mariano Gago, we visited Critical Software, a spin-off company from the Computer Science Department of Universidade de Coimbra. This visit gave us the chance to learn about the product line of Critical Software and their current and future needs in terms of highly educated professionals in the areas of information technology, software engineering, and security. The discussions held with Minister Gago helped to clarify the MCTES' goals regarding the cooperation between Carnegie Mellon and Portugal.

4. On Friday June 26th, we had the opportunity to meet with a delegation representing Portugal Telecom (PT) that included Executive Vice-President Rodrigo Costa, Director Padinha, and Advisor Nuno Carvalhosa. This was a very enlightening discussion that showed the interest of PT in promoting and supporting initiatives in the areas of telecommunications, information networking, software engineering, and security. This interest includes educating professionals

with post-graduate advanced degrees and establishing collaborative research programs with Portugal Telecom Inovação.

5. On Friday June 26th, we also visited Instituto de Soldadura and Qualidade (ISQ), a university-industry interface institution, where we met the Vice-president and member of Board of Directors Manuel Cruz and several other high level ISQ staff members. ISQ emphasized their interest in enlarging their scope to different aspects of critical infrastructures and risk assessment and in doing so in collaboration with Carnegie Mellon and Portuguese universities.

6. From the discussions with the Secretary of State Manuel Heitor and Minister Mariano Gago, we understand the goals of the Carnegie Mellon-Portugal initiative to include the following:

A. **Internationalization**: Develop programs that will significantly and qualitatively impact the internationalization of Portuguese Universities and research Institutions and that would help establish Portuguese Universities as international leaders in fields perceived to be of strategic importance to Portugal and Europe

B. **Areas of interest**: The initiative is to include collaborations in: (i) Electrical Engineering and Computer Science, in particular, Information Technology, Telecommunications, Software Engineering, Security, Robotics, Critical Infrastructures; (ii)Business and Public Policy namely, areas related to Management of Technology and Risk Assessment; and (iii) Basic Sciences, including Applied Mathematics.

C. **Seeds of change**: The programs should be exemplary and create the opportunity for the Institutions of Higher Education in Portugal to evolve and become highly dynamic and internationally recognized.

D. **Highly educated professionals**: To promote the rapid education of highly trained professionals at the post-licenciatura level (post 2nd-cycle in the Bologna agreement)– advanced professional degrees and PhDs--in the areas referred to in 6.b.

E. **Recruiting**: To promote a culture of recruiting and placing the best candidates from (post-) graduate students, to post-doctoral associates, to faculty members, in the international arena.

7. Based on our visits, we believe that potential collaborations between Carnegie Mellon and groups from Portugal should develop along the following three basic dimensions:

a. **Professional advanced degrees**: These are post 2nd-cycle in the Bologna agreement and correspond to advanced degrees to be offered in collaboration with Portuguese Partner Institutions; we refer to these as Professional Masters Degrees as they are generally intended for individuals who intend to enter the work force upon completion of this program. Their organization parallels any other equivalent Carnegie Mellon collaborative Masters programs; their graduates are undistinguishable from any other Carnegie Mellon graduate from the same program run by Carnegie Mellon at the Pittsburgh campus.

b. **Doctoral programs**: These are Carnegie Mellon PhD granted degrees and as such students will satisfy all the Carnegie Mellon and the degree granting College requirements. They will be structured so that students spend part of their time during the doctoral program at Carnegie Mellon and at the Portugal partner Institution. In addition,, whenever it makes sense, the student will be co-advised by faculty members from Carnegie Mellon and the partner Institution. Ph.D. degrees from Carnegie Mellon will be awarded and, as such,

students will satisfy all the corresponding Carnegie Mellon degree granting College requirements.

c. **Research initaitives**: These are to be carried out jointly between teams at Carnegie Mellon and Partner Institutions and may include one or more projects, extended stays of researchers from the partner Institution at Carnegie Mellon and visits by Carnegie Mellon researchers to the partner Institution.

8. We visited 10 groups while in Portugal. These groups submitted preliminary proposals prior to our visit and, in many cases, engaged in extensive dialogue and interaction with members of the Carnegie Mellon team and other faculty. The face to face meetings were very helpful to clarify many issues and provided us with an opportunity to gauge the level of commitment of the group, their University, College, and/ or partner Research Institution. These discussions demonstrated the high level of interest of both Portuguese and Carnegie Mellon faculty to engage in meaningful and productive collaborations.

9. A summary of potential collaborations follows:

a. **Prossional Master of Science in Information Technology**: (MSIT) with potentially three tracks (point of contact in parentheses):

i. Information Networking and Telecommunications with the University of Aveiro (Prof. Paulo Ferreira) and Instituto Telecomunicações (IT; Prof. Ferreira Jorge and Carlos Salema), with potential involvement and support from Portugal Telecom and other IT companies located in Aveiro (namely through the network of companies INOVA RIA);

ii. Software Engineering with the University of Coimbra (Prof. João Gabriel Silva), with potential involvement and support from Portugal Telecom, and Critical Software;

iii. Security with the University of Lisbon (Faculdade de Ciências da Universidade de Lisboa, Prof. Paulo Verissimo);

b. **Information Networking**: a Master program (see 9.a), a Carnegie Mellon PhD degree granting program, and a research initiative with Universidade de Aveiro (Prof. Paulo Ferreira), IT (Prof. Ferreira Jorge and Carlos Salema), and PT Inovação, as well as other companies at Aveiro (e.g., INOVA RIA). The PhD program and the research initiative need to be better defined.

c. **Software Engineering**: a Master program (see 9.a), a Carnegie Mellon PhD degree granting program, and a research initiative with Universidade de Coimbra (Prof. João Gabriel Silva), with possibly involvement of Portugal Telecom and Critical Software.

d. **Security**: a Master program (see 9.a), a Carnegie Mellon PhD degree granting program, and a research initiative, with Faculdade de Ciências da Universidade de Lisboa (Prof. Paulo Verissimo), as well as the potential involvement of FCCN (National Foundation for Scientific Computation), which holds a CERT certification. The three components of this collaboration need to be better defined, as well as the faculty involved in each Institution.

e. **SetChange**: A PhD program and a research intitaitive on technological change and entrepreneurship with Instituto Superior Técnico of the Technical University of Lisbon (IST,

Prof Rui Baptista) and the School of Economics and Management of the Faculdade Católica Portuguesa (UCP, Prof Pedro Oliveira).

f. **Critical infrastructures**: a research initiative, with a Carnegie Mellon PhD degree granting program, on large scale infrastructures with strong emphasis on integration of relevant technologies (e.g., HW and SW platforms, sensor networks, communications and networking, security), risk assessment and management, and applications, involving IST, Instituto de Sistemas e Robótica (ISR), CISTER, Instituto de Soldadura e Qualidade (ISQ), INESC-INOV, with Prof. Isabel Ribeiro (IST and ISR), Eng. Manuel Cruz (ISQ), CISTER, Prof. Augusto Casaca (INESC-INOV). The role of ISQ should be emphasized as an interface institution facilitating the connection to potential industrial or service provider partners. The role of the several Institutions involved needs to be better defined.

g. **Language Technology**: a research initiative to be further developed with INESC-ID and IST, as well as other research centers (Prof. Isabel Trancoso, INESC-ID). This is a potential collaboration that is currently under discussion and at a preliminary stage.

h. **Applied Mathematics**: a Carnegie Mellon PhD degree granting program with the Departments of Mathematics of the three Public Universities in Lisbon, namely IST (Prof. José Matias), Faculdade de Ciências da Universidade de Lisboa (Miguel Ramos) and Faculdade de Ciencias e Tecnologia da Universidade Nova de Lisboa (Luísa Mascarenhas). There have been initial contacts and a statement of interests but the exact terms of the collaboration need to be better defined.

i. **Risk Management**: a Carnegie Mellon PhD degree granting program with IST (Prof. Carlos Guedes Soares). This is currently at the initial stage of discussions. There is the potential to connect this program with the "Critical Infrastructures" initiative described in 9.f.

10. Table 1 below summarizes the proposals received, i.e., the information in point 9., and a 1st assessment regarding the status of each proposal (last column). We note that the entry regarding "Critical Infrastructures" consolidates three different proposals (ISR+CISTER, ISQ, and INESC-ID). This will have to be agreed upon by the proponents. The entry terms in the last column, "Status," have the following meaning:

a. **Finalize**: The goals of the proposal are relatively well defined. We need now to follow-up with the proponents of the proposal(s) to write in a document the goals, the work statement, and the milestones.

b. **Develop**: These efforts need further work to better clarify several issues including the terms of the proposed activity, how it achieves the goals of MCTES (internationalization, impact on the Portuguese Institution, and not just the research group), the CMU partners.

Entries where both terms appear mean that while some components of the proposed activity are well defined ("Finalize"), other components need further work ("Develop").

Collaborations	Partner	Others	Contact	Activity	Status
Inf. Netw.	**UA+IT**	**PT and other companies involved in INOVARIA**	**P. Ferreira** (with F. Jorge, C. Salema, IT, **and P. Nordeste,**	**MSIT: IN, PhD, Res. Initiative**	**Finalize + Develop**

			PT)		
SW Engineering	**FCT/UC**	**PT+Critical SW (and other companies involved in INOVARIA)**	**J.Gabriel Silva** (with J Carreira, CS, **and P. Nordeste, PT)**	**MSIT: IN, PhD, Res. Initiative**	**Finalize**
Security	**FC/UL**	**FCCN (to be confirmed)**	**P. Verissimo**	**MSIT: IN, PhD, Res. Initiative**	**Develop**
SETChange	**IST + FCEE/UCP**		**R. Baptista, P. Oliveira**	**PhD, Res. Initiative**	**Finalize**
Critical Infrastructures	**ISR/IST + ISQ**	**CISTER, INESC-ID**	**I. Ribeiro, Manuel Cruz**	**PhD, Res. Initiative**	**Finalize**
Language Tech.	**INESC-ID /IST**	**Other related centers**	**I. Trancoso**	**Res. Initiative**	**Develop**
Applied Math.	**IST, FC/UL, FCT/UNL**		**J. Matias,** Miguel Ramos, L. Mascarenhas	**PhD**	**Develop**
Risk Assessment	**IST**		**C. G. Soares**	**PhD**	**Develop**

Table 1

11. To complete the assessment by July 15th, 2006, individuals representing a proposed collaboration will be invited to visit Carnegie Mellon between now and the 1st week of July to finalize or further develop the proposed activity. Prof. Moura will contact each group with a follow-up e-mail to schedule these visits between June 19th and July 3rd. These visits should define clearly who are the CMU partners and the terms of the collaboration. With respect to each dimension of the potential collaboration, the final proposal should clearly state the following:

a. **Carnegie Mellon Professional Masters granting degree programs**: governance, structure, tracks, credits, courses, course contents, courses to be taught at Carnegie Mellon and at the partner institution, process to identify and select instructors and teaching assistants for courses lectured in Portugal, class size, students recruitment and selection, marketing, infrastructure to house the program (including lecture halls, faculty and students' offices, computing and networking infrastructure), expected number of students, costs, audio-visual infrastructure, pre- and post-assessment, schedule, calendar of activities to launch the program, and several other specifics concerning the program and its implementation.

b. **Carnegie Mellon PhD granting degree program**: governance, structure, degree requirements like breadth and depth course sequences, qualifier, proposal, and thesis, co-advising, infrastructure to house the program (including lecture halls, faculty and students' offices, computing and networking infrastructure), expected number of students, students recruitment and selection, costs, typical plan for the full PhD program (3 to 5 years), schedule, calendar of activities to launch the program, and several other specifics concerning the program and its implementation.

c. **Research initiative**: governance, scope, goals, specific project(s), team(s) involved, timetable, milestones, budget, infrastructure to house the program (including Lab space if

needed, faculty and students' offices, computing and networking infrastructure), and several other specifics concerning the initiative and its implementation.

12. The contract to be signed between Carnegie Mellon and the Government of Portugal will include mechanisms for the continual periodic evaluation of existing programs, as well as mechanisms to launch new initiatives or programs or to sunset current programs. Collaborations described in Table 1 that are not ready to be included in the initial launch, will be reevaluated and included as soon as it makes sense and resources are available.

13. The structure and governance of the Carnegie Mellon-Portugal program is currently under discussion among the partners. A current draft, subject to complete modification, is along the following lines. Funding is provided through an Agency for International Cooperation in S&T to be set by the Government of Portugal with FCT and other public stakeholders. This Agency will have a President supported by a light administrative infrastructure and oversees the several international programs. The Carnegie Mellon program will have a Governing Board advised by an External Review Committee, and managed by two Directors, one appointed by Carnegie Mellon and the other by the Portuguese Agency. The Director in Portugal may be supported by a Research and Academic Program Coordinator and managing a Program Operating Committee, which in turn oversees the different existing collaborative programs. The Program Operating Committee will be chaired by the Director of the Program at CMU.

The Governing Board is composed of the President of the Agency, who will chair, the President of CMU (or his representative) and the two Directors (one appointed by Carnegie Mellon and the other by the Portuguese Agency).

Each Director will have direct oversight responsibilities of the activities of the CMU-Portugal Program at CMU and at Portugal, respectively. Working under their oversight is a Research and Academic Program Coordinator and a Program Operating Committee (POC). POC has direct oversight of the different programs.

14. **A word of appreciation**: for the hospitality we received from all the groups we visited and the personnel from the Secretaria de Estado. Thanks to Prof. Manuel Heitor for hosting us.

Appendix 7
Advanced Degree Programs

Advanced degree program: Master in Software engineering. In today's world of rapidly changing software technology, engineers must deal with new methods, tools, platforms, user expectations, and software markets. This changing environment underscores the need for software engineering research and education. Education teaches engineers current technologies, trains them to adapt quickly to new technologies and trends, and allows them to anticipate and exploit emerging opportunities to improve their products and processes.

The typical engineering education keeps engineers abreast of technological advances by offering courses in new techniques and tools. This is fine while the engineers are in school, but it does not necessarily prepare them for future challenges. A better approach is to provide engineers with models, skills, and analytical techniques that can be used throughout their career to evaluate emerging technologies and then successfully adapt appropriate ones to their organization's needs. These engineers act as Agents of Change.

Since 1989, Carnegie Mellon University has delivered its advanced degree professional Master in Software Engineering Program with the express intention of developing technical leaders in software engineering practice. The Program continues to develop and refine its curriculum – one that differs from that of a traditional software engineering program – to include practical hands-on project experience and allowance for one's specialization within the discipline. The result is a novel approach that aims to cultivate future leaders in software engineering. It combines a long-term, mentored software development project with an unusual core curriculum that stresses broad-based models and problem-solving skills.

The Master of Software Engineering (MSE) Program has three basic components:

1. Core curriculum – these courses develop foundational skills in the fundamentals of software engineering, emphasizing design, analysis, and the management of large-scale software systems.

2. Software Development Studio – throughout the duration of the Program, students plan and implement a significant software project for an external client. As in design projects for architecture programs, students work as a team under the guidance of faculty advisors to analyze a problem, plan the software development effort, execute a solution, and evaluate their work.

3. Specialty tracks – the elective tracks allow students to develop deeper expertise in one of several specialties, including real-time systems, human-computer interfaces, management, security, and software process improvement.

Student growth and performance is evaluated in three key areas: teamwork, application of core concepts, and quality of outcomes, as these criteria mirror the principal objectives of the MSE Studio Project.

Given that the goal of the Master of Software Engineering Program is to provide students with an understanding of not only the best of current practice, but also of the future trends in technology, it is critical that such professional education in software engineering be informed by advanced research in software engineering. Research determines the horizon of opportunity, and helps define how to bridge the gap between theory and practice in software development. As the world moves to larger and larger software systems, spanning the globe, and given the size and

complexity of the worldwide web, new techniques, theories, tools, and processes are critical to the future of the discipline.

Information Networking. Advances in computer and communications technologies have formed the basis for global and economic growth and an increase in our standard of living for more than two decades. We rely on information technology in all aspects of our daily life more than we ever have in the past, and this reliance will continue to grow. With this increased reliance comes the need to make information systems more secure, trustworthy, sustainable, and available in the face of both intentional attacks and accidental faults. The very technologies that enabled unprecedented growth and now underpin our economy and way of life also increase the vulnerability of our information infrastructure, which in turn threatens our ability to sustain IT-driven prosperity.

In order to manage this growth, there is an urgent need for professionals who possess a comprehensive knowledge of the technologies, economics and policies of secure communication networks - professionals with enriched skill sets, who are able to design solutions, manage teams and lead enterprises, while protecting this infrastructure we rely on so heavily.

It is up to our institutions of higher education to produce these individuals while supporting the significant initiatives of the Portuguese Government's MCTES Ministry in the diverse areas of information and communication technologies (ICT). By partnering with Carnegie Mellon University and the Information Networking Institute (INI), the universities of Portugal can offer top-quality programs that can produce the next generation of innovative information networking professionals.

This partnership will offer two unique 16-month professional graduate degree programs: The Master of Science in Information Networking (MSIN) program, in partnership with the Universidade de Aveiro, and the Master of Science in Information Technology - Information Security (MSIT-IS) program, in partnership with the Faculdade de Ciências da U. Lisboa. Both of these programs have been offered successfully for over 15 years at Carnegie Mellon.

A vital part of these curricula is the graduate project, which provides students with another way to explore their areas of interest. Recent research projects have explored a wide variety of networking issues, including improving the robustness of networks by increasing diversity and using wireless networks to locate users. Research projects can be done in conjunction with Portuguese companies and government, who can then implement the results in their own networking systems.

Additionally, this partnership will create an opportunity to conduct global research activities with Carnegie Mellon and our current partners, Athens Information Technology (AIT) and CyLab Japan, to further research and education in information networking, security, and dependability globally.

These relationships will not only fulfill the strategic objectives of the universities, but will also meet the business needs and interests of the supporting Portuguese industrial partners. The programs will be a great boon to Portugal's companies because graduates of the program will be able to make an immediate impact in these companies, especially in the information networking and telecommunications sectors.

The Information Networking Institute

The INI was established by Carnegie Mellon in 1989 as the United States' first research and education center devoted to Information Networking. The INI now offers graduate programs in information networking (MSIN) in both Pittsburgh and Athens, Greece; information security technology and management (MSISTM) in Pittsburgh; and information technology - information security (MSIT-IS) in Kobe, Japan.

The programs in Athens and Kobe have become the model for international and distance-learning programs at Carnegie Mellon and around the world. Students engage in a mix of courses taught remotely from Pittsburgh by Carnegie Mellon faculty using the latest videoconferencing technology and courses taught locally on-site by INI-affiliated faculty members. Such a model takes advantage of the expertise on both sides of the international partnership and creates a cross-cultural experience for students that is invaluable in today's global economy.

Additionally, the INI is the education partner of Carnegie Mellon CyLab, a university-wide, multidisciplinary initiative involving over 200 faculty, students, and staff at Carnegie Mellon that builds on more than two decades of Carnegie Mellon's leadership in information technology. This partnership will advance the position of Carnegie Mellon, the Universidade de Aveiro and the Faculdade de Ciências da U. Lisboa as distributed centers of excellence for state-of-the-art scientific research and advanced education in the fields of information networking, information and infrastructure security and dependability.

The Information Networking Institute Master of Science in Information Networking Program (MSIN)

The MSIN program provides a strong technical foundation in the field of information networking and telecommunications, and additionally introduces students to management, strategic thinking, and policy, with the opportunity to study each of these areas in greater depth through electives. MSIN students are well-positioned to pursue leadership, technical, and management positions in a variety of sectors.

Specifically, the program is designed to prepare students to:

- Design, implement and manage complex networks and systems
- Measure, model and assess performance of complex networks and systems
- Make informed decisions during the entirety of the technology product development process, considering factors from technical, business and marketing perspectives
- Equip themselves for life-long learning and professional growth in information networking disciplines

The diversity of the MSIN curriculum allows students to specialize in different areas of networking, such as wireless networking, optical networking, sensor networks, broadband networks, etc. Some students also focus on the management issues of telecommunications networks and choose their electives to reflect their interests. This program is able to leverage the strong background and investment in information networking of the Universidade de Aveiro to provide students with an international perspective on information networking.

The Portugal MSIN program will be a great boon to the information networking and telecommunications industries, especially Portugal Telecom, whose employees can attend the program and then return to their companies with the networking and security expertise that they

have gained. In general, graduates of the MSIN program, regardless of whether they worked before the program, can make immediate contributions and impacts in Portugal's IT companies.

The Information Networking Institute Master of Science in Information Technology - Information Security Program (MSIT-IS)

The curriculum of the MSIT-IS has been designed to provide students with a core set of courses in security technology and management and a variety of technology and management electives to further enhance their knowledge of information security.

By selecting from a variety of management and technical courses, students can customize their studies depending on their background and career aspirations. The curriculum provides background, insights, and general and technical coverage of key elements of information security, while equipping students with the analytical methods and management practices to succeed as managers and technologists in the growing and rapidly changing field of information security.

Specifically, the program is designed to prepare students to:

- Assess the information security risks faced by an organization
- Understand the technological and human problems linked to these risks
- Evaluate technological tools and protocols available to protect against these risks, mitigate system vulnerabilities, and restore services
- Manage the development, acquisition, and evolution of a secure information infrastructure
- Assess the impact of information security policy, legal environment, and market developments on complex systems and organizational objectives
- Equip themselves for life-long learning and professional growth in information security disciplines

This program will provide students with the knowledge, skills and abilities to address the difficult issues of dependability and security from a unified perspective. These are two very important fields of computer science and engineering that have until recently been treated as different aspects of system trustworthiness. However, with the growing complexity of computer systems, these two issues can no longer be treated separately. Security needs to be included in the design of systems from the very beginning, not added in as an afterthought, because security needs to work together with every part of the system. By implementing such a comprehensive perspective on networking and security, this program will put Portugal at the forefront of the field of information security.

Appendix 8
Information and Communication Technology: PhD and Research Programs

Information and Communication Technology

The assessment has identified a major theme for the CMU-Portugal potential partnership: information and communication technology (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 cut across not only in 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 assessment grouped the several collaborations proposed into four areas within ICT: information processing and networking; critical infrastructures and risk assessment; basic sciences; and technology management and policy. We expand on these four areas.

1. **Information Processing and Networking**.

Information Networking. Information networking is an area of great impact. We recognize the potential for synergetic collaboration between Carnegie Mellon faculty drawn from CyLab, CenSCIR, ECE, and CS and several Portuguese research groups at IST, Universidade de Aveiro, INESC-ID, IT, and Universidade de Coimbra. We see also potential research collaborations with several companies, in particular, 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. In this report we focus 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.

Language Technology. We identified an excellent and strong synergism between a consortium of Portuguese Research Centers and Universities, which we will refer to as the L2F consortium, 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 L2F consortium in Portugal is led by the Laboratório de Sistemas de Lingua Falada (L2F) (language to speech) at INESC-ID, IST. It groups L2F with 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). 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. This assessment has identified a number of areas of strong common interest: 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 assessment has identified two very important multilingual research projects in computer aided language learning (CALL) and speech-to-speech machine translation (S2SMT) involving 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 groups because of the existing expertise at LTI with language technologies for Chinese and the great demand from China for products involving Portuguese.

This CALL research collaboration 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 L2F 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.

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

We have identified a strong consortium of four research institutions in Portugal whose interests on critical infrastructures and risk assessment mirror those of CenSCIR at Carnegie Mellon. CenSCIR is an interdisciplinary Center with faculty drawn from ECE, CEE, EPP, and the Tepper School at Carnegie Mellon. The consortium in Portugal is led by ISR at IST and includes INESC-ID at IST, CISTER at IPP, and ISQ.

Infrastructures are of major significance in the economy of a country. For example, the bridges, airports and harbors, water distribution systems, water treatment plants, power distribution systems, telecommunication network systems, commercial and industrial facilities, etc. runs 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 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. 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).

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, a challenging research project is to 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 deploy in a University campus, as a cooperative effort, in the first phase, several hundred and then, in a second phase, several thousand sensing platforms.

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.

We have determined that there is a tremendous opportunity for a joint unique effort between CenSCIR and the Portuguese Consortium led by ISR to bring together interdisciplinary teams of experts that can address effectively and efficiently the problems of critical infrastructures and their risk assessment.

3. **Technology Management and Policy**

Technological change and innovation are at the heart of regional and national economic growth and firm performance. The development of strategies and policies to guide innovative activity in countries, regions and organizations 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.

The 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. The education of highly qualified people that are capable of leading research, education and policy with this integrated perspective should therefore be a priority for Portugal. This collaboration proposal between Carnegie Mellon and research institutions in Portugal recognizes this dimension. 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. Thus, the proposal 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.

The main areas encompassed in the program are: first, 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 entrepreneurship. The second area is a research program in telecom policy, looking at questions of industry structure and regulation in telecom infrastructures, as well as the role of individual communities in promoting broadband diffusion and adoption; finally, the third is a research program in energy systems and policy that will focus specifically on: studies of advanced fossil fuel technologies with carbon capture and geological sequestration; studies of distributed energy systems, micro-grids, and advanced technologies for integrating and controlling such systems in conventional electric power systems; advanced methods for the instrumentation and control of electric power systems in the face of normal operations, and risks from natural disruptions and terrorist events; and, 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.

i. Technological Change and Entrepreneurship. Innovation and technological 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 change and entrepreneurship has become essential for the competitiveness of firms, regions and countries.

The foundation to this collaboration is a dual Ph.D. program organized by Carnegie Mellon, Universidade Católica Portuguesa and Universidade Técnica de Lisboa . This 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 would be strongly international, 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 therefore 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 that is being pursued by the current government (as purported by the "*Plano Tecnológico*") 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 seen 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). While Portugal needs the development of new knowledge and technologies in these areas, it is also critical to apply them in the market, either through established firms or start-ups. In today's world 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. The proposed collaboration in Technological Change and Entrepreneurship will have a significant emphasis on ICTs, helping to promote strategic visions for public and private ventures and developing the necessary skills to help developing partnerships for innovation at an international level.

ii. Telecommunications and Policy. Digital Convergence is dramatically changing the technology, services and competitive environment faced by telecommunications carriers around the world; Portugal and Portugal Telecom are 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. 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? 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? 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? As the services provided over a common infrastructure become more varied and diverse, how can Portugal Telecom, or new competitors become more entrepreneurial and better at the identification of user needs and the rapid development and deployment of new services? How will the introduction of QoS capabilities in the network, and a shift away from flat rate pricing affect competition and the ability of new entrepreneurial firms to develop Internet services?

Addressing these issues requires research that combines telecommunications engineering, computer science, business and policy expertise. It will demand collaboration among researchers from CMU in EPP, ECE and Tepper with researchers in Portugal from institutions as diverse as IST, FCEE, IT and PTI.

We see initial collaborations focusing on two 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. A related key issue is the appropriate pricing framework for infrastructure services provided to service providers. Infrastructure investors must be able to recoup their investments, but inappropriate pricing strategies can cripple the deployment of new 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, fiber or wireless mesh networks, 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 with U.S. experience in comparable small towns and rural communities can provide valuable insight.

iii. Energy Systems and Policy. As noted above, four broad areas will be explored via collaborative research under this heading. They are:

1. Engineering-economic, policy analytic, and risk-related studies of advanced fossil fuel technologies with carbon capture and geological sequestration.
2. Technical, economic, regulatory and risk-related studies of distributed energy systems, micro-grids, and advanced technologies for integrating and controlling such systems in conventional electric power systems.
3. Advanced methods for the instrumentation and control of electric power systems in the face of normal operations, and risks from natural disruptions and terrorist events.
4. 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.

Details on the proposed doctoral research collaboration will need further elaboration.