Scientific Advisory Board Report

The visit was conducted March 6 & 7, 2017 at INESC-TEC Porto, Portugal.

The INESC-TEC Scientific Advisor Board is composed of:

Dr. José Carlos Principe
Dr. Faramarz Farahi
Dr. James C. Spohrer
Dr. John O'Reilly
Dr. José A. B. Fortes
Dr. José Luíz Fiadeiro
Dr. Leonardo Chiariglione
Dr. Max Viergever
Dr. Steven P. Nichols
Dr. Tomaz Goméz
Dr. Volker Stich
Dr. Pere Ridao
Dr. Pedro Larrañaga
Dr. Bruno Siciliano
Dr. Christian Cachin

The meetings were coordinated by Dr. José Principe. Drs. Spohrer, O'Reilly, Viergever, Siciliano were absent. This report is an effort of all the remaining members.

This report is divided into two major parts:

- I- The overall scientific review of INESC-Porto.
- II- Reports for individual Center activities.

I- Overall Scientific Review of INESC-Porto

I.1. General Comments

INESC-TEC has changed its internal structure to better manage its increased size and portfolio of activities. At the base, it is structured in 13 R&D Centers: Power and Energy Systems (CPES), Innovation, Technology and Entrepreneurship (CITE), Enterprise Systems Eng. (CESE), Industrial Eng. And Management (CEGI), Robotics in Industry and Intelligent System (CRIIS), Applied Photonics (CAP), Telecommunications and Multimedia (CTM), Biomedical Eng. (C-BER), Robotics and Autonomous Systems (CRAS), Information Systems and Computer Graphics (CSIG), Artificial Intelligence and Decision Support (LIAAD), Advanced Computing Systems (CRACS), and High-Assurance Software (HASLAB). Each R&D Center was born and grew independent of the others in a bottom up fashion, therefore they possess very different profiles, goals and perspectives to exploit the local and short-term niches in the Portuguese market. At the same time, it represents a challenge to design a coherent, long-term plan for the overall Institute. Therefore, INESC-TEC further organized these R&D Centers in four Clusters: Power and Energy, Industry and Innovation, Networked Intelligent Systems, Computer Science to foster multi-disciplinarity, flexibility, synergies and strategic alignment.

INESC-TEC has the vision to become an international player in the Science and Technology Arena, with the mission to contribute to the performance, competitiveness and internationalization of Portuguese companies and institutions by creating and transferring technology from the highly skilled University environment to a mostly traditional and technology "challenged" Industry, Services and Public Administration. INESC-TEC organization was enhanced since the last visit. The Board of Directors has more members (9), the Services have been diversified to include Business Development and Technical Support Offices, there is a new Business Advisory Board, and the Council of R&D Centers. Each Center has between 5 and 30 Ph.Ds., a varying number of University Professors and graduate students and low number of staff. The Scientific Council remains the same, where each Center has a scientific coordinator, who integrates the INESC TEC Scientific Council representing all the faculty members in the institution. Each Center has a coordinator, who along with the scientific council coordinator interacts with a Board of Directors.

INESC-TEC continues to grow at an increasing pace. In 2012 the Institute had an annual budget of 10 million euros with 600 members (200 with Ph.Ds., approximately 50 staff), while in 2017 it grew to 18 million with 725 researchers (350 with Ph.Ds.) and 75 support staff. Currently it has 154 on-going projects with 33% of funding from international sources, and an equal amount from R&D and consulting activities. INESC-TEC has now five distinct facilities in Northern Portugal, and with the external collaborators it is at the threshold to be considered a large size research/technology institution at the EU level (1,000 members).

The Scientific Advisory Board (SAB) was very impressed with the progress. First, the evaluation of Excellent in the last FCT review puts INESC TEC in the top tier of research organizations in Portugal. The management of INESC TEC is developing new tools to quantify the activities in the INESC world to enable management and reward. This is not an easy task because of the diversity of activities and partners, which range from science production metrics, to technology transfer, and their corresponding impacts. The idea of implementing a performance metric for the Institute based on the technology readiness level (TRL) scale is novel and makes a lot of sense because it covers rather well the INESC TEC foot print of science based technology innovation. The vision of INESC TEC and its Centers in terms of the integrated value chain is very interesting and tells a lot about the diversity of the Institute. However, this metric needs calibration since readiness level has not been applied before for such a purpose.

Another innovation in the organization are the Clusters, to facilitate synergies amongst the Centers. The SAB praises the move for scientific management due to the large scope of the Centers, and the increase in EU funding during the past years may have been already due to the multidisciplinarity that the Cluster's existence brought to INESC TEC. However, the Clusters may add one more layer to the decision process in INESC TEC which may have negative impact. Moreover, the profile of some clusters need clarification as we will discuss latter.

The final change in the organization are the TEC4. The SAB believes that the TEC4 are the most innovative piece since the last visit, and which distinguishes INESC TEC from similar technology transfer Institutes. They basically are designed to transiently "pull" together scientific expertise to respond to external needs (industrial or services). This is a very versatile way to maximize use of scientific expertise and also effectively respond to evolving market needs that require multiple engineering disciplines. TEC4s are being organized in large strategic areas that are important for Portugal, and because of its short history there is not a lot of data to support their usefulness for INESC TEC. The bottlenecks will be to find leaders who can rally researchers in each Center, and also to implement effective relationships with the Industrial Council to make the Industry needs heard in the organization and planning of strategic activities.

Overall INESC TEC presents a solid and healthy performance growth since the last SAB meeting, by increasing all the funding sources (national, international, and R&D). It is creating consistently more than 40 Ph.Ds. per year, it is producing 700 scientific publications per year (journals and conference proceedings), it is mentoring more than 100 entrepreneurial projects, incubating 9 spin-off companies, transferring 230 professionals (34 Ph.D.) to the market, and protecting IP (21 patents since 2008). INESC TEC has an international reach, exporting its model to Brazil, being part of international programs with MIT, CMU and U. of Texas at Austin, attracting students from 30 nationalities, engaging in EU initiatives (EFFRA and Manufuture-EU), participating in 45 ongoing EU projects, and improving the international competitiveness of Portuguese companies. These activities are an engine for the Portuguese economy and are on par with the best Institutes in Europe.

I.2. Centers' Scientific Performance

CPES has a long tradition within INESC-TEC, it is internationally recognized, and is the center with the highest economic contribution to INESC sustainability with a remarkable success rate in obtaining European projects and transfer to the service sector. Its productivity in publications should still be improved. The positioning of CITE in the Cluster I&I is perhaps too specific, but promising, through the developed conceptual framework of methodologies, tools and programs. However, its impact in the other Centers is still unfulfilled. The CESE is an established backbone of the Cluster I&I, with a well-defined road map as it is pursuing a multidisciplinary, system-oriented research and technology development. Its impact in the Portuguese Industry is a reference point. The Center for Industrial Engineering and Management (CEGI) is well positioned with six fields of expertise, a solid scientific performance, and a strong relation with National funding but much less EU funding. CRIIS has a very good research agenda divided in 8 fields of competencies with a good level of publications and high relevance demonstrated by the number of international research projects. CAPS has been very strong in fiber sensors and reached maturity in microfabrication, with evident synergisms between the areas. The optical imaging group reduced its activities and is finding new directions. The publication record continues to be very strong. CTM's scientific performance is in line with the expectations, but the center research portfolio is too broad. CBER is dedicated to three important areas in biomedical engineering, namely bioimaging, neurotechnology, and bioinstrumentation. The center is recent, and the leaders are well respected researchers who publish in very good journals. However, tech transfer should increase as well as funding. CRAS is very successful in attracting projects and raising funds. It is remarkable the number of highly competitive international projects in which they are involved coming from diverse and heterogeneous national and international programs. CSIG is a unique center because it can be viewed as doing "End-to-End Systems" design and development, but at the same time the cumulative scientific performance of the Center is quite good and has been steadily improving for the last five years. LIAAD presents excellent productivity in terms of journal and conference publications with a good balance between both. Their publications have received a large number of citations, especially those related to data streams. The degree of internalization is very high and they have been very active and successful in getting grants from national and international agencies. CRACS has consistently generated high-quality research outputs with an average number of publications per member with a PhD of around three per year, with a significant increase in research funding. The international visibility of its researchers continues to be very good and increasing, with numerous international collaborations with institutions in Europe, Brazil and the USA. The High-Assurance Software Laboratory (HASLAB) has achieved excellent results in basic science, engineering, and applied research, with research results presented at some of the most prominent and internationally visible venues rated at the highest level world-wide.

I.3. Balance Depth / Breadth

CPES has consolidated its leadership in five areas and has achieved a high level of maturity and technology transfer. The challenge now is to widen the scope within the Cluster of Power & Energy and create a story line aligned with the EU's announced major challenges in the energy area. Until now the Cluster strategy is based on an internal proposal from CPES to the potential associated centers, but in the SAB opinion, a top-down external high-level approach would be preferred to compose within the story line, contributions from the other INESC associated centers. CITE has three different accelerator programs implemented in 2017, but what is missing is a clear and simple roadmap, how partners are addressed, in which situation partners can rely on CITEs expertise or how partners can stay in a continuous exchange with CITE. This shows that there is wide breadth and a low depth, which might not reflect the real potential of the center. CESE tends to overstretch its human resources to stay in a good balance between science and industry for so many fields of competencies. Nevertheless, the management team consists of very experienced people, who seem to know exactly how to run efficient and effective processes, but the high turn around is of concern. CEGI tends to stretch too much as well, because with a relative small core group it will be hard to cover 5 application areas and be relevant in all. Nevertheless, the team achievements are very impressive. CRIIS is addressing all Industry 4.0 relevant topics in the shop floor but it will be necessary to align the broad scale of expertise and to consolidate in a subset to achieve depth and impact. CTM is spread over a number of areas that can all be represented as "Telecommunications and Media", but bioimaging does not fit. The Center succeeds in achieving sufficient depth in selected areas and produce excellent results there. However, these appear to be more due to individual local efforts than the result of coordinated and harmonized efforts that leverage on the synergy of those areas. As it is indicated above CAPS covers a broad range of topics, in which in the area of Optical Sensor is excellent, in the area of micro-fabrication has the potential to excel and in the area of Optical Imaging is trying to find itself. Other competing international groups have more focus that CAPS. C-BER is addressing very broad areas in biomedical engineering with few human resources. There are good results in a few of the selected areas, but there are improvements to be made to capitalize on the effort done in each project. The linkage with bioinstrumentation should be also clarified. CRAS covers successfully a large spectrum of marine robotics research lines (surface, underwater and aerial robotics). However, they should choose the most promising ones and reinforce them for international recognition. CSIG’s breadth is extensive but not necessarily a problem if it is leveraged for research and technology transfer on “End-to-end Systems”. The addition of experimental capabilities in the human-computer interaction domain has great potential for many innovative research and tech transfer projects. LIAAD research portfolio covers a large number of machine learning topics, but the visibility seems to be concentrated in data streams. It will be good to capitalize on it and diversify. CRACS has kept over the years a distinctive and strong scientific profile with high international visibility in computer science, and more recently into more data-centered areas. The SAB supports this expansion, but it would be important to ensure that these areas continue to develop in depth and with collaborations with other INESC TEC centers. Overall, HASLAB balance is good, however expertise should be more uniformly distributed within each domain spanned by the center. HASLAB might broaden its educational effort for or direct involvement in projects of other centers, ensuring that INESC TEC overall delivers more scalable, safe, and secure ICT systems. It is time to host high-profile scientific events in Portugal (such as conferences sponsored by ACM, IEEE, or similarly prominent organizations), potentially with other INESC TEC Centers to show the internal strength of computer science.

I.4. Gaps in Expertise

CPES should increase the number of published papers by faculty and PhD students. In addition, it seems that the new PhD research staff recently incorporated in the Center do not have a clear definition of their professional career at INESC. In the long term, this issue is crucial to ensure sustainability and sharing of responsibilities between faculty and research staff. CITE could play an important role for other INESC centers, but the mechanism to gain voluntary partnership with other centers need clarification. It could be helpful to address the topic Innovation more specifically and linked to the business activities. CESE should intensify the “Horizontal” and “Vertical” approach of integrated SCMs in relation to the market driven Business software, that traditionally is very fragmented. This would raise the regional visibility in large organizations like IKEA. The “Service design” research area of CEGI needs a recalibration in relation to the state of the art in other countries, by combining with “decision support” and “business intelligence”. We could not evaluate CRIIS in detail due to lack of expertise (SAB member absent). It is difficult to identify gaps in CTM when efforts are spread over so many areas. For sure the personnel is flexible enough to adapt to new research areas, but either areas should be merged or synergies with other centers/clusters identified. In general, CAPS does not seem to suffer from shortage of expertise except in the Optical Imaging activities, where it benefits from collaborations on signal processing and pattern recognition. C-BER is spread too thin, so it needs to create a clear vision where to invest or where to capitalize on expertise inside INESC TEC. No significant gap in expertise is observed in CRAS. Nevertheless, it would be good to intensify certain research lines to be more recognizable internationally. CSIG should consider strengthening its “Embedded computing/special-purpose computing systems” coverage, so important for “pervasive intelligence”. This CSIG gap is also an INESCTEC gap, while the required expertise may already exist camouflaged in other centers/ clusters. An intensification of the adaptation component in machine learning methods on big data scenarios can be of interest for LIAAD. The strength in data streams can be easily morphed in time series analysis which is critical for the industry and IoT. An increase in CRACS’s critical mass in Security& Privacy and Knowledge in a World of Data should be done identifying complementarities and gaps with other Centers. Some vulnerabilities exit in the technical competences related to code optimization. The mission of HASLAB to focus on "high-assurance software" is comprehensive, but it would be interesting to place a bigger focus on system security jointly with CRACS. This field is practically relevant and could also be a good opportunity for technology transfer to local companies.

I.5. Balance between R&D and Tech Transfer

CPES enjoys a healthy situation regarding income from R&D and technology transfer contracts. The Laboratory for Smart Grids has demonstrated its capabilities to create value and new possibilities for experimentation and can play a central role in the organization and demonstration of new projects within the Cluster. Therefore, it should be included within the formal structure of the Cluster. CITE should lead an initiative to combine all Cluster knowledge and turn it into “Money for qualification”. Some of the bigger EU Universities have started this business and are very successful. CESE technology transfer is very relevant as the portfolio of projects and clients show. Contract based research with customers like IKEA shows the visibility, but be careful, such large projects are extremely time and resources consuming. CEGI obviously succeeded in building up an excellent network in both, scientific and business partners. CEGIs activities in collaboration with other INESC Centers like CTM, CESE, CPES, CSIG should be intensified. Although most of CRIIS projects come from national and international programs, the center already has some tech/transfer contracts. This part has potential to grow in the future. CAPS developed and successfully transferred a *current sensor* technology to Brazil, and spectroscopy and chemical sensors are reaching maturity. CTM has shown to be able to produce excellent research but also solutions with opportunities of exploitation. But this aspect needs to be continuously monitored because of the center profile. C-BER is doing technology transfer, but it is unclear if there is a master plan to capitalize on these efforts. CRAS carries out a lot of research and development. This is one of its strong points, and what makes the center internationally recognizable. CSIG has demonstrated consistently that it can be very effective in tech transfer. CSIG and INESCTEC should identify credible indicators for high TRLs to help set goals of CSIG’s activity. LIAAD technological transfer activities have increased significantly since the previous evaluation and the development of industrial PhDs with a co supervision from academic and industry should be encouraged. CRACS profile is now more balanced at 60% research vs 40% development, which is similar to that INESC-TEC as a whole. This change of profile is reflected in a number of high visibility and high impact projects (VcardID), as well as in the increase of collaborations with other centers. Another important component is Open Source software systems and tools that are used throughout the world, which adds to its international (and national) prestige. However, this component does not appear in any of the INESC TEC institutional presentations of technology transfer. HASLAB can improve its participation in research and technology transfer, making it more visible overall, which can also motivate new smaller projects funded by FCT or from the local industry to enable better connections to the local businesses.

I.6. SWOT Analysis

Strengths

- Continued meteoric expansion since 2012
- Excellent success in EU project awards.
- Healthy budget with research projects and R&D components
- People Assets – vibrant mature and young researchers
- High international visibility and good rate of attracting international scholars
- Efficient Management + Support Services

Weaknesses

- Absence of a multiyear plan of activities

- Lack of institute wide scientific coordination and strategic planning at the BoD and Cluster levels
- BoD organization and execution needs improvement because it should be shared by all its Directors
- Uneven quality of research. Some Centers still need more (new) focus+ critical mass
- Scientific productivity still needs further improvement
- External visibility can still be improved
- No perceived policy or action plan to address the lack of representation of women, especially in leadership roles

Opportunities

- INESC TEC should explore other EU funding mechanisms, such as ERC Grants
- More systematic management approach to tie fundamental & applied research to respond to the pull of the market (Clusters and TEC4)
- TEC4 benefits from closer ties to the Business Advisory Board
- INESC TEC should explore strategic alliances with top EU research organizations
- INESC TEC management model of science based innovation should be properly formalized
- Can the example of INESC TEC Brazil be duplicated in other parts of the world?
- TRLs can serve as a ranking criterion for INESC TEC activities once properly validated

Threats

- Portuguese economic situation
- Organization bottlenecks (information flow and response time)
- Fluid relation with the University partners to access person-power
- Fast pace of high technology industry
- No financial reserves for investment in initiatives

II- Individual Centers' Reports

Cluster Power and Energy

CPES - Power and Energy Systems

Cluster of Industry and Innovation

CITE - Innovation, Technology and Entrepreneurship
CESE- Enterprise Systems Engineering
CEGI - Industrial Engineering and Management
CRIIS- Robotics in Industry and Intelligent Systems

Cluster of Networked Intelligent Systems

CAP- Applied Photonics
CTM - Telecom. and Multimedia
C-BER - Biomedical Engineering
CRAS - Robotics and Autonomous Systems

Cluster of Computer Science

- **CSIG -** Information Systems and Computer Graphics
- **LIAAD -** Artificial Intelligence and Decision Support
- **CRACS -** Advanced Computing Systems
- **HASLab -** High-Assurance Software

II.1. Center: Power and Energy Systems (CPES)

II.1.1. Evaluation of Center's scientific performance

CPES has already long tradition within INESC-TEC, international recognition, and is the center with the highest economic contribution to INESC sustainability.

Since 2012, the center has grown keeping the same number of faculties but hiring new researchers. The number of grant holders and trainees is quite stable between 40 and 50 changing with the years and funded projects.

The Center is organized in 5 technical areas well interconnected and with a flexible structure. In some of these areas new PhD research staff have been appointed as area leaders. The Center coordination is shared by Prof. Matos and Mr. Seca who has been recently incorporated giving added value to the management and organization tasks.

As it has been said the number of PhD students and also the number of concluded PhD theses along these years in average remain the same as in the past. Probably this can be the reason why the scientific productivity measured in publications has not increased in the last years. The number of publications in indexed journals is in average stabilized in between 15 and 20 papers per year.

On the other hand, it is remarkable the success rate of the Center in obtaining European projects financed by EU research programs (EU FP7 and H2020). These European funds account for almost 50% of the total incomes of the Center.

The Center counts also with a Laboratory for Smart Grids which provides added value for experimentation and integration with other INESC disciplines, such as telecommunications, power electronics, and control. Those lab assets are fundamental for increasing competences in the kind of interdisciplinary projects that are needed in this area of power systems of the future.

II.1.2. Balance between depth and breadth

CPES has consolidated its leadership in the area of Power Systems and integration of renewable and smart grids. The applications and techniques already included in its five areas have a high level of maturity and technology transfer.
The challenge now is to widen the scope forming what it has been called the INESC Cluster of Power and Energy.

It seems that until now a bottom up incremental approach centered on a proposal from CPES to the potential associated centers has been followed to create this Cluster. In the SAB opinion, a top-down high-level approach would be complementary to achieve better results including more balance contributions from the other INESC associated centers.
In addition, a storyline aligned with the major challenges in the energy area would benefit the visibility and understanding of the main focus of the Cluster; for instance, climate challenges lead to integrated energy-climate solutions, with future totally decarbonized power systems, where all the research lines and applications in the Cluster can be situated and interrelated.

II.1.3. Gaps and required expertise

The number of PhD students in CPES devoted to projects is almost stable, however the scientific production remains low. It seems that the published papers by faculties and PhD students should increase. One possibility is to define a target of a minimum number of papers published before the thesis defense. On the other hand, it is important that the faculties and new research staff incorporate in their duties this obligation when they supervise PhD students.

In addition, it seems that the new PhD research staff recently incorporated to the Center, and who are not faculties, do not have a clear definition of their professional career at INESC. In the long term, this issue is crucial for ensuring sustainability and future leadership by sharing responsibilities between faculties and research staff in the functioning of INESC.

II.1.4. R&D tech/transfer

CPES enjoys a healthy situation regarding income from R&D and technology transfer contracts. It is expected that this continues in the next future with a diversified portfolio of European projects and services and consulting contracts. In addition, the creation and consolidation of the INESC Cluster of Power and Energy is an excellent opportunity to reinforce this trend and find new application for tech transfer.

The Laboratory for Smart Grids has demonstrated its capabilities to create value and new possibilities for experimentation. However, this Lab is neither included in the formal structure of CPES nor in the Cluster of Power and Energy. The Lab can play a central role in the organization and demonstration of new projects within the Cluster. Therefore, a recommendation is to include the Lab within the formal structure of the Cluster and report periodically about its added value and indicators of activity.

II.1.5. SWOT Analysis

Strengths

- CPES is well consolidated and enjoys national and international recognition.
- High rate of success in projects financed by the EU H2020 research program.

- Continuous financial growth ensured by incomes from R&D projects and services and consulting.
- New contracted PhD research staff with high scientific and management qualities and potential growth.

Weaknesses

- Research publications in journals are still low.
- No clear definition of the professional career within INESC for the new contracted PhD staff.
- Research excellence and PhD supervision tasks are not explicitly recognized.

Opportunities

- The creation and consolidation of the INESC Cluster on Power and Energy with real integration of and a shared agenda with the other associated centers.
- The full integration of the Laboratory of Smart Grids in the structure and organigram of the Center and the Cluster with a central role in organizing experimental research and integrating multidisciplinary research.
- Align Cluster and Tech4 initiatives in Energy with the European Climate and Energy Agenda. That will provide visibility and recognition of INESC as one of the main reference centers in energy in Europe.
- Continue international cooperation with projects in Brazil, USA and Europe.

Threats

- Economic situation could negatively affect research national funds.

II.1.6 Recommendations

- Define the professional career for permanent INESC research staff who are not faculty members.
- Define area coordinator responsibilities. They should play a more strategic role at scientific and project management levels.
- Promote the consolidation of the INESC Cluster on Power and Energy with real integration of and a shared agenda with the other INESC associated centers.
- Include the Laboratory of Smart Grids in the formal structure of CPES and in the Cluster of Power and Energy and periodically report added value for the center and indicators of activity.
- Align Cluster and Tech4 initiatives in Energy with the European Climate and Energy Agenda.
- Continue international cooperation with projects in Brazil, USA and Europe.
- Increase the number of publications in journals. Establish an annual control of published papers by PhD students and set a target for the number of published papers in journals before the PhD defense for those PhD theses conducted at INESC.

II.2. Center for Innovation, Technology and Entrepreneurship (CITE)

II.2.1. Evaluation of Center's scientific performance

The positioning of CITE in the Cluster II is specific, but promising. This center should carry out advanced consulting and executive education in areas like innovation management, entrepreneurship and technology management. Therefore, the group has developed a conceptual framework of methodologies, tools and programmes. It`s evident, that such an approach could not be measured under the normal scientific performance indicators (see List of publications) and PhD thesis. Nevertheless, the center must intensify the "portfolio" of propositions and base this portfolio on scientifically approved methods and approaches.

II.2.2. Balance between depth and breadth

CITE is going to have three different accelerator programmes for 2017, that include mentorship and education: IN&OUT, BIP and LET IN, but what is missing minimally is a clear and very simple roadmap, how partners are addressed, in which situation partners can rely on CITEs expertise or how partners can stay in a continuous exchange with CITE.

Summarizing, there is wide breadth and a low depth, which might not reflect the real potential of the center.

II.2.3. Gaps and required expertise

The Center could play an important role for the other INESC centers, it should clarify its position to gain voluntary partnership from other centers.

Concerning the actual, international debate on digitalization it could be helpful to address the topic Innovation in an "innovative manner": Innovation and Venture capital, Innovation and Startups, Innovation and IOT, Innovation and Disruptive business models. Up to now, the Center hasn`t seen such an approach with related experience.

II.2.4. R&D tech/transfer

Reading the chapter 5.9.3 Technology transfer and following the discussion during the meeting it appears possible to discuss a "school of management" approach, which combines all Cluster knowledge and turns it into "Money for qualification".

Some of the bigger EU Universities have started this business and are very successful, because this kind of transfer generates different potentials:

- Institutions force themselves to identify and conceptualize content for professionals
- Through this experience, one is always very close to the actual, relevant topics for research formulated by industry
- European credit points for certified courses count much higher than consultancy and project

II.2.5. SWOT Analysis

Strengths

- Good positioning of the Center
- High potential to get closer to industry
- Already 10 years of experience on management level

Weaknesses

- Hard to understand the Centers real supporting areas
- What is meant by “Fuzzy Front End of Innovation”
- Talk “industry language”

Opportunities

- Global interest in different aspects of digitalization
- Innovation and Disruption is a new place to position the center

Threats

- Not being able to bind partners on their journey towards Industry 4.0 and digitalization

II.2.6. Recommendation

CITE should rethinks on intensifying

- Innovation & VC, Innovation & Startups, Innovation & Digitalisation/ IOT, Innovation & “Disruption”
- Interdisciplinary (research) projects should be increased.
- The Center would benefit from more collaborations among the Cluster’s members.
- Think about a “school” approach, like school of management, which combines all Cluster knowledge and turns it into “Money for qualification” perhaps even INESC Approach for “school of…” is thinkable
- Think about an Industrial Affiliate Program as detailed next:
    - Industrial Affiliates (IA) could be developed in several areas of INESC TEC to provide long term (multi-year) funding for research topics of medium and longterm interest of industrial members while also providing stable funding for research staff and students.
    - Affiliates programs can also provide graduates of the program who are capable of knowledge and capability transfer to industry
    - IA can also enable rapid response to research funding opportunities requiring university/industrial collaboration.
    - IA Allows significant long term industrial funding for problems/opportunities facing industrial concerns not possible with single company funding sources (Potentially multi-million euro source over time.)
    - IA’s “inform” Academic communities of significant problems facing industry.

II.3. Center for Enterprise Systems Engineering (CESE)

II.3.1. Evaluation of Center's scientific performance

The Center CESE is an established backbone of the Cluster I&I, as it is undertaking since long time a multidisciplinary, system-oriented research and technology development.
The research road map shows the broad expertise, that CESE was able to build through the recent decade:
Collaboration Networks and SCM, Enterprise ICT, Manufacturing and Service operations management, business analytics and decision support systems, Transportation, logistics and Mobility.
CESE was always able to perform in several EU funded projects, it shows a significant spread of different funding schemes throughout the types from FCT, S&T, National Services and Consulting.
The Center has published 2 books and different chapters in books, the publication ratio is ok. In terms of PhD theses concluded or supervised, this rate is actual pretty low in relation to the overall number of Integrated PhD. The total level of publications could be higher, this will attract scientific staff, which obviously is a bottleneck.
The given report to the reviewers addresses very clearly relevant research activities per research field (see 5.6.2) and explains convincingly the "Why" and "What".

(Remark: Naming Transport, Logistics and Mobility a **NEW** domain research at CESE (See page 79) seems a bit exaggerated ☺)

II.3.2. Balance between depth and breadth

This balance tends to be overstretched, it might be hard for the management team, to stay in a good balance between science and industry for so many fields of competencies on the one hand and on the other hand to get new and high skilled researcher to work with.
Nevertheless, the management team consists of very experienced people, who seem to know exactly how to run efficient and effective processes at CESE.
It is necessary, to keep the knowledge internally the whole team due to constant changes and new team members, which form the core working force.
The reviewers are asking, if the mentioned research approaches (see 5.6.1) to fulfill the centers mission are really known in depth and actively used for the project work.

II.3.3. Gaps and required expertise

Because of the center's long experience with the Portuguese shoe industry, a white paper on "Future challenges in shoe industry under digitalization" is expected and it would be very relevant to report INESC TEC successes in this important industrial area.
Furthermore, the Center should intensify in the "Horizontal" and "vertical" approach of **integrated** SCMs in relation to the market driven Business software, that companies have installed, but due to historical reasons show very fragmented ICT Systems Integration.
This would level up the visibility regional wide and in large organizations like IKEA.

II.3.4. R&D tech/transfer

The enumeration of industry driven projects and clients and partners show the relevance of CESE's work in the applied area. Contract based research with customers like IKEA show the acceptance of the Centers competencies in praxis, but be careful, such large projects are extremely time and resources consuming and hinder researches that lead to publications or PhD thesis.
Under 5.6.3 the Center explains its expertise in technology transfer and the competencies to exchange with partners market ready products, new commercial agreements a.s.o., but were are training courses and education skills mentioned?
These could play a very interesting role in getting actual problems back from industry in order to solve them through research projects and then give back the applied and relevant research results to industry again.

II.3.5. SWOT Analysis

Strengths

- high reputation throughout a long period
- both, research and industry are to be addressed through long-term professionals
- good and relevant topics form the agenda of CESE

Weaknesses

- Very broad approach and competencies, hard to keep high level working
- Clarification in the area of business analytics is needed between CESE and CEGI, there should only be one "king of data science"

Opportunities

- Strengthen the direction of Industry 4.0 and Smart Connected industry
- Actual or expected calls from EU will go in the heart of CESE's competencies

Threats

- Stay with the critical mass of high skilled collaborators
- Possible cannibalization with CEGI and other centers around getting IT/ ICT approved collaborators

II.3.6. Recommendations

CESE is the strong backbone of the Cluster, with a highly motivated group of professionals

- Think about an approach in the field of "Industrial Analytics" to foster on Industry 4.0
- After such a large expertise in the shoe industry, a white paper on "Digitalisation of shoe industry " is missing
- What about enlarging the Centers expertise in Industrial business software versus Platforms and multilayer approaches for further digitalisation in its core business areas

- Actual opportunity through networked industries of the future should be underlined by appropriate activities, perhaps the Center needs some new branding like:
    - horizontal and vertical integration of SCs
    - new technologies for linked industries
- Rethink and possible reconfigure the future research guidelines, i.e. business analytics and decision support in relation to CEGIs positioning

II.4. Center: Industrial Engineering and Management (CEGI)

II.4.1. Evaluation of Center's scientific performance

The Center for Industrial Engineering and management (CEGI) is positioned with six fields of expertise:
-Service design, Decision support, Performance Assessment, Asset management, Business intelligence and prescriptive Analytics in four main domains.
This gives CEGI an excellent starting point for both, scientific approaches and industrial relevance.
Five main areas of application such as Retail, Healthcare, manufacturing, Mobility and energy complete the positioning of the Center.
The centers scientific performance is OK, as shown by the numbers of concluded PhD theses by own members and those supervised by members of the center.
The breakdown of funding projects shows a strong relation with National funding and low EU funding, the total number of publications is medium, but of acceptable high level like indexed publications.

II.4.2. Balance between depth and breadth

The center tends to stretch too much, with a relative small core group it will be hard to cover 5 application areas and to develop an accepted position as relevant player in all five areas.
Obviously, there are some good results through projects in the field of asset management. It might be good, to start from here and capitalize in *maintenance* explicitly in order to enlarge the portfolio continuously through preventive and predictive maintenance competencies.
Wind energy, Hydro power, gas distribution, these all are very promising branches for services and optimization of their assets.
Concerning the Center depth it is acknowledged that the team achievements (see list) are very impressive

II.4.3. Gaps and required expertise

The "Service design" research area perhaps needs a recalibration in relation to the state of the art in other countries, especially an approach on "Smart Services" or "Data driven Services" could help to line out, why the combination with "decision support" and "business intelligence" is so fruitful and actually a relevant topic to invest in.

II.4.4. R&D tech/transfer

CEGI obviously succeeded in building up an excellent network in both, scientific and business partners, this gives a good opportunity to focus the Center's core competencies along with these partners. CEGIs activities in collaboration with other INESC Centers like CTM, CESE, CPES, CSIG are very well accepted and should be intensified through further collaboration and exchange of knowledge. This gives speed and focus.

II.4.5. SWOT Analysis

Strengths

- Good relation with partners in science and business
- Very good alignment of research areas
- Actual topics addressed like decision support and business analytics
- Intensive team activities on a high level (see team achievements)

Weaknesses

- Broad area of application

Opportunities

- Smart services in relation with Industry 4.0 play an increasing role for scientific as well as industry related topics
- Relatively few players are able to combine service design with business analytics

Threats

- Only a small group of contracted people, try to get for a critical mass
- Speed up, others don`t wait ☺

II.4.6. Recommendations

- The Center has an excellent starting point for actual recommendations in Research and industry, but it should focus more in order to not lose control on its own spread of competencies
- The field of "service design" needs calibration with the international state of the art
- CEGI has a profound potential to collaborate with other Centers, if it focuses on its expertise around big data and data science.
- Foster the expertise on predictive and preventive maintenance, this area keeps a lot of potential in both, scientific and industry research
- Keep an eye on the EU activities around block chain and data driven services
- Possibly reduce the application areas,
  RETAIL, HEALTHCARE, MANUFACTURING, MOBILITY & ENERGY is too large to be recognized as an expert group (without enough contracted people)

II.5. Center: Robotics in Industry and Intelligent Systems (CRIIS)

II.5.1. Evaluation of Center's scientific performance

The Center CRIIS results originally from the former CRO. It has a very good research agenda divided in 8 fields of competencies (see 5.7.2. P 87) with a good level of publications, 1 patent and 1 invention disclosure.
The number of international research projects show the high relevance of what the center is undertaking in the research area. The graduation rate seems a bit low.
Obviously CRIIS is trying to strengthen its position through a number of publications, and initiatives such as principal editor, international events and advanced training courses.

II.5.2. Balance between depth and breadth

CRIIS is addressing all Industry 4.0 relevant topics in the shop floor, like sensors, 2D/3D, robots and especially collaborative robots and human robot interfacing.
It will be necessary to align the broad scale of expertise and to consolidate what CRIIS is standing for in depth and especially.
Four expert domains are already hard to cover and to stay in, the center is additionally thinking about health and architecture to get in there. Think about focusing.

II.5.3. Gaps and required expertise

(Not able to evaluate, I am no Robot specialist, sorry)

II.5.4. R&D tech/transfer

Although most of their projects come from national and international programs, the center already has some tech/transfer contracts. This part has potential to grow in the future. The transfer activities seem to be very active and relevant for industrial partners, may be in agriculture, logistics, forestry or production

II.5.5. SWOT Analysis

Strengths

- Good and reliable expertise
- Actual a lot of industry related questions need to be researched scientifically
- Covering 4 different, but relevant domains like agriculture, forestry, logistic and production

Weaknesses

- What is the USP, that explains the proximity at Cluster II with the other three centers
- No clear focus on what belongs to basic research, applied research and pure consultancy

Opportunities

- Right time to work on these topics, because industry needs solutions

Threats

- Low external awareness due to the fact belonging to the Clusters II portfolio
- Overlapping with other Robot specific domains at INESC

II.5.6. Recommendations

- Some question need to be answered: Why, besides history purposes is CRIIS belonging to this Cluster, what is it`s USP for the Cluster?
- How to avoid cannibalizing the other INESC TEC activities in this field
- There is a possible USP in the area of industrial Logistics, but this should be clarified
- Possible strength in localisation, sensing and mobile manipulation could help on focusing
- …and even rethink a possible allocation in the Robot specific domains, to get more speed through focalisation
- For the FCT Review it would be good to differentiate the scope of CRIIS w.r.t. CRAS as well as why they are in different clusters

II.6. CAP

II.6.1. Evaluation of Center's scientific performance

CAP has three distinct activities, Optical fiber Sensors, Micro-fabrication and Integrated Optics, and Optical Imaging.

<u>Optical Fiber Sensors:</u> CAP has been and still is very strong in the areas of fiber sensors, physical parameters, and since our last meeting it has developed significant resources in the chemical and biological sensors.

<u>Microfabrication:</u> In this area CAP has reached to a maturity level and recent growth in this area has been noteworthy. Although still with modest track record, but one can observe the formation of a consolidated team that has started to make valuable scientific contributions. The synergy between the traditional strength of the group, sensors, and microfabrication team is evident, and can bring about positive outcomes in the near future and in the long-term.

<u>Optical Imaging</u>: There has been a reduction in research activities in the area of optical imaging. Recently, there has been a renewed interest in compressive imaging and its application in LIDAR. Some industrial projects in the area of OCT are being carried out. There are also a few new projects that are emerging among them a project in Optical

Tweezers, but at this point the impact of this new direction in activities related to Optical Imaging cannot be assessed.

In general, the CAP publication record is very strong and collaborations between members of the center are very good as evident by the number of joint PhD students. There are also productive collaborations with CRAS (Robotics) and CBER (biomedical) Centers, which are very positive.

II.6.2. Balance between depth and breadth

As it is indicated above CAP covers a broad range of topics, in which in the area of Optical Sensor is excellent, in the area of micro-fabrication has the potential to excel and in the area of Optical Imaging is trying to find itself.

Other competing international groups have more focus that CAP.

II.6.3. Gaps and required expertise

In general, the center does not seem to suffer from shortage of expertise except in the Optical Imaging activities. It is debatable if CAP should invest more in that area before more progress is made with the existing members in this area.

One area of expertise is signal processing and pattern recognition that can help all CAP's activities.

II.6.4. R&D tech/transfer

INESC TEC has successfully transferred a *current sensor* technology to Brazil. This technology was developed in CAP.

Currently, there is a technology that has reached to its advanced stage (spectroscopy and pattern recognition) that should be commercialized soon.

There are some potential commercialization opportunities in the area of chemical sensors.

II.6.5. SWOT Analysis

Strengths

- High competency and strong expertise in the area of optical sensors
- Very good micro-fabrication and characterization facilities
- Very good expertise in the area of micro-fabrication

- Very good theoretical and modeling expertise
- Good collaborations between CAP's members
- Good collaboration with other centers

Weaknesses

- CAP's visibility relative to its expertise and productivity is modest.
- CAP's would benefit from more permanent staff.
- CAP lacks expertise in the area of signal processing.

Opportunities

Collaborations with CRAS and CBER Centers are two examples that show how INSEC TEC can benefit from the strong expertise that CAP has and at the same time provide new funding opportunities for CAP as well as raising the TRL of CAP research and development activities.

The same could be said about the micro-fabrication facilities of CAP that should be considered an INESC TEC resource. This could galvanize a new series of mutual collaborative projects.

Due to CAP's unique characteristics and its place at INESC TEC, it is prudent that INESC TEC provide sufficient support to CAP with the understanding that CAP is able to support many other centers achieving their goals.

Threats

Lack of diversity of funding sources and channels can provide challenges along the way. CAP should be aware of this and mitigate this by expanding its research collaborations with other centers within INESC TEC while acquiring funds to support fundamental research that keep the center at the forefront of this field.

II.6.6. Recommendations

- The Center would benefit from more collaborations among the center's members.
- The Center would benefit from more collaboration with other center's within the INESC.
- The Center would benefit from targeting large European projects for funding and collaboration with researchers in other countries to increase it chance of success.

II.7. Center: Telecom. and Multimedia

II.7.1. Evaluation of Center's scientific performance

The Center's scientific performance is in line with the expectations.

Publications in indexed journals is almost constant, while publication in conferences is decreasing, a fact that is reported to be an INESC TEC decision.

II.7.2. Balance between depth and breadth

The Center is spread over a number of areas that can all be represented as "Telecommunications and Media". The Center succeeds in achieving sufficient depth in selected areas and produce excellent results there. However, these appear to be more the effects of individual local efforts than the result of coordinated and harmonized efforts that leverage on the synergy of those areas.

II.7.3. Gaps and required expertise

It is difficult to identify gaps when efforts are spread over so many areas. For sure the personnel is flexible enough to adapt to new research areas. Gaps can be treated in two different ways: by acquiring or increasing the expertise in areas where it is insufficient or – recommended – by trying and reassembling areas and expertise in different centers or even clusters.

II.7.4. R&D tech/transfer

The Center has shown to be able to produce excellent research but also solutions with opportunities of exploitation.

II.7.5. SWOT Analysis

Strengths

- Excellent personnel capabilities
- Ability to address new areas effectively
- Unique (sometimes almost personal) expertise in some areas
- Ability to create project specific bonds across organisational boundaries

Weaknesses

- Spread over too broad an area spanning the entire protocol stack
- Concentrated over too many topics

Opportunities

- Exploit the weakness of spanning the entire protocol stack (where opportunities exist)
- Create critical mass by combining expertise in neighboring areas belonging to different organizations
- Develop knowledge abstracted from but exploitable in applications
- Exploit cultural diversity within and outside of the Centre
- Institute a method by learning from how projects have delivered successful results

Threats

- New technologies may unseat traditional image processing (no intention of riding the hype)

II.7.6. Recommendations

- CTM needs to develop a more strategic view of where to invest
- Absent of more structural interventions, CTM should develop ever closer contacts with CSIG, specifically in Computer Graphics, to stay relevant in multimedia

II.8. C-BER

II.8.1. Evaluation of Center's scientific performance

The center was recently created (2014) and it is divided in three laboratories, namely Bioimaging, NeuroEngineering and BioInstrumentation. They cover a small portion of the bioenginnering and Health informatics domain. The connection of two methodology strong laboratories with bio instrumentation makes sense, and may help cover the spectrum of research development and applications, but there is insufficient information if the linkage is being done (not reported).

In the two research areas (bioimaging and neurotech), there is solid work on methods and novel approaches, but the two labs are different: Bioimaging is more dedicated to algorithm development and validation for important clinical applications, while neurotech is more exploratory and interested in pushing the envelope, perhaps because of the different maturity of the two domains.

In the fact sheet, C-BER lists 9 prof (4 from UTAD), 5 Ph.D., 8 researchers, 2 contracts and one technician. The 11 papers published during 2014-2016 is below expectations for the group, however, some of the publication venues are top journals in the field. The ratio of prof to Ph.d. is also below expectation if we consider the UTAD researchers, and marginal otherwise. The total budget for the period is 800 k, which is less than 100k/Prof, should also be increased, although there is a solid ramp up of funding in 2016. The source of funding are exclusively National Programs, which is a pity because some of the research topics are very current and the lab directors are well known researchers. It is unclear if the two research labs collaborate, and how they are linked to the bio-instrumentation lab. Apparently, the latter has no direct funding.

II.8.2. Balance between depth and breadth

The Center has a huge breadth for the size. To be competitive in any of the labs there is a need for much higher number of leaders and researchers. The bioimaging lab is well establish in each of its 3 areas, but it seems that the students are developing algorithms very close to the application, so there is little acquired knowledge that can be transferred across the domains. This can be mitigated, if there was the interest in studying new classes of algorithms exploiting some new approach that could then be configured to each of the applications. This would create more cohesion within the lab, and very likely also across labs. The topics of the neuroengineering lab are seeking new ways of formulating solutions, which is appropriate because of the recent interest in neurotechnology and understanding the brain. However, there is only one leader pushing and so he is overstretched. Creating a pyramid is very important for this lab. The report for the bio-instrumentation lab, is too brief so there is no indication how it works internally and how it relates to the other 2 labs. Although we think it makes sense for C-BER to have a dedicated bio-instrumentation, these relationships need to be clarified.

II.8.3. Gaps and required expertise

It is difficult to pin point specific gaps because the areas are so broad, but the man power is insufficient, and relationships with other INESC Centers should be pursued to mitigate gaps. The research lab leaders are experts in the domains of activity, so they just need to create hierarchical groups. Postdoc can help bootstrap this process.

II.8.4. R&D tech/transfer

The tech transfer is mostly done through bioimaging and bioinstrumentation, which makes sense. The bio instrumentation laboratory has 4 patent disclosures and one patent submitted for the period, which is a good number. However, we do not know if the disclosures have been pursued. The table of areas and their interest for each group is a good way to organize the activities of Tech transfer. Because algorithms are difficult to patent, the algorithms developed in bioimaging should at least be copyrighted before being distributed to the community.

II.8.5. SWOT Analysis

Strengths

- lab leaders are well known
- areas of activity are important
- scientific publications are in good journals
-

Weaknesses

- the linkage between the labs needs improvement
- the size of the group is below critical mass in any of the areas
- there are too many topics for the size of the teams
- no EU projects are listed
- reporting needs improvement

Opportunities

- Collaborations for EU projects should be pursued.
- Collaboration with UTAD should be strengthened
- This group can provide inside expertise for other INESC TEC projects in Health informatics
- There are many opportunities for tech transfer in this domain

Threats

- Too much dependent upon National funding
- Little internal cohesion

II.8.6. Recommendations

The Center's knowledge of the field/understanding of the problems is an institutional resource that should be used to develop

- Major research programs in collaboration with sensor activities,
- Major research programs in collaboration with researcher in the areas of imaging and image processing,
- Understanding of commercialization efforts/challenges in the area of biomedical devices.

II.9. Center: Robotics and Autonomous Systems (CRAS)

II.9.1. Evaluation of Center's scientific performance

The center is very successful in attracting projects and rising funds, being remarkable the number of highly competitive international projects in which they are involved coming from diverse and heterogeneous national and international programs.

The research work of the center is mostly focused in applied research (high TRLs) although basic research (low TRLs) is also addressed in cooperation with other centers. This, is actually a good example of synergy within the cluster, where this sort of cooperation is actually happening.

The number of conference publications is adequate for the dimension of the center. It is recommended that the team makes an effort to increase the number of journal publication. Their work in these highly competitive projects deserves publication in journals. Probably they only have to re-orient some of their current publications in high level conferences to journals.

II.9.2. Balance between depth and breadth

The center covers a high spectrum of marine robotics research lines (surface, underwater and aerial robotics). It shows a strong experience in mechatronics, system integration, and field operations. While they are targeting a wide number of research lines, they are recommended to choose the most promising ones and reinforce them in order to promote an easy international recognition of the center based on their excellency.

II.9.3. Gaps and required expertise

No significant gap in expertise is observed. Nevertheless, as told above it would be good to intensify certain research lines to be more recognizable internationally.

II.9.4. R&D tech/transfer

The Center carries out a lot of research and development. This is actually one of its strong points, and probably what makes them currently internationally recognizable.

II.9.5. SWOT Analysis

Hereafter the SWOT analysis provided by the center is reported. The reviewer comments expanding their analysis appears in italics:

Strengths

1. Team with strong background in field robotics
2. Vast experience in collaborative projects. *High capability to attract new projects*
3. Good experience in field trials.

Weaknesses

1. Lack of diversity in backgrounds of researchers
2. Reduced number of full time PhD researchers. *This can be addressed by contracting PostDocs in projects instead of MSc.*
3. Strong bias towards high TRL project.
4. I*t would be good to intensify certain research lines to increase international visibility. Try to answer the following question, what can CRAS do much better than the rest of the world?*

Opportunities

1. Available funds for maritime related research
2. (Marine) Robotics is an expanding area

Threats

1. Most innovation calls demand self-funding
2. Low funding available for PhD grants and science projects
3. Non-competitive grants/salaries reduce possibility of recruitment

II.9.6. Recommendation

- The centre has potential to increase the number of journal publications (i.e. forwarding some contributions to journals instead than to high impact conferences).
- It is recommended to re-inforce some of their research lines to be more easily recognisable internationally (What is CRAS excellent at?)

II.10. Center: CSIG - Information Systems and Computer Graphics

II.10.1. Evaluation of Center's scientific performance

CSIG is a unique center with regard to:

1. Technical scope: Center has identified five main areas of activities, namely

- Computer Graphics and Virtual Environments
- Information Management and Information Systems
- Software Engineering
- Special Purpose Computing Systems
- Accessibility and Assistive Technologies.

This is a relatively broad scope but the SAB believes this is good as long as the researchers in different domains leverage each other's work. This Center can be viewed as doing "End-to-End Systems", understanding that such systems either aggregate or provide data or information from/to people, need to be managed, process information and need to be properly engineered. This aspect of CSIG is readily apparent in its e-Health "Horizontal Area".

The cumulative scientific performance of the Center is quite good according to quantitative indicators and has been steadily improving for the last five years.
In 2016 CSIG produced approximately 100 publications, of which approximately 30 were journal papers. In the same year, it produced 8 theses and had a project budget of over 1.4 Million Euros. These numbers are significantly better than they were during the last EAB review. There is also improved scientific quality, as evidenced by, for example, six best paper/presentation awards, invitations to researchers, and quality awards for CSIG projects.

The "per investigator" quantitative indicators, considering only PhD CSIG members, are slightly over 2 publications and 30 Thousand Euros per investigator for the year of 2016. These numbers are respectable but possibly conservative and under-representative of the ratio of scientific output and scientific funding as explained below. Future evaluation of CSIG performance should have a more precise methodology to evaluate different types of productivity versus the corresponding types of funding. In particular, the ratios per investigator should account only for investigators funded by research funds (vs. funds from non-research sources such as services and technology transfer projects).

CSIG has impressive technology transfer projects. See III.3.4.

2- Distribution of activities in TRL spectrum: the Center's funding portfolio is quite broad and balanced, showing similar percentages of funding from national sources, international agencies, services and "other" providers of funding. This breadth is also reflected on the TRL distribution of projects, covering from TRL3 to TRL9, including 12 and 15 projects for TR3 and TR4, respectively, and an average of 6 projects for each of TRL5 to TRL9. This distribution is atypical of research-only institutions but it is quite well suited for the INESCTEC mission and for the "End-to-End Systems" view of CSIG.

II.10.2. Balance between depth and breadth

CSIG's breadth is extensive but not necessarily a problem if it is leveraged for research and technology transfer on "End-to-end Systems". The depth is not uniform across the above listed areas of activity and there is room for improvement in some of them. The continued tracking, rewarding and encouragement of research publications by CSIG's leadership is a good mechanism to improve and/or demonstrate depth. The EAB found that there is a good combination of established researchers with a long track record of activity and publications in their areas and technologists who complement these researchers. The addition of experimental capabilities in the human-computer interaction domain has great potential for many innovative research and tech transfer projects, if properly integrated with other CSIG and INESCTEC expertise.

II.10.3. Gaps and required expertise

CSIG should consider strengthening its "Embedded computing/special-purpose computing systems" coverage, which now only has one investigator (João Cardoso). This CSIG gap is also an INESCTEC gap. This area is essential for "pervasive intelligence" and presents many opportunities for integration with other work within CSIG (e.g. virtual environments and assistive technologies) as well as within INESCTEC (e.g. embedded AI). The required expertise can be "recruited" within and outside CSIG and INESCTECH leveraging the existence of a computer science cluster.

II.10.4. R&D tech/transfer

CSIG has demonstrated consistently that it can be very effective in tech transfer. vCardID, 3 PORT, DIW2020 and the Leixoes Harbour are all excellent examples of technically effective and broadly impactful technology transfer projects. Technology transfer should be viewed as "first-class citizen" within the broad TRL spectrum of INESCTEC activities. In order to continue to excel in this area, CSIG and INESCTEC should consider the identification of credible quality and quantity indicators that can be used to characterize the value of this aspect of CSIG's activity. This a differentiating factor of CSIG versus other centers.

II.10.5. SWOT Analysis

CSIG has provided its own SWOT analysis with which the EAB partially agrees. What is shown below reflects the combination of CSIG's analysis and the above considerations.

Strengths

Excellent tech transfer capability
Broad "end-to-end system" R&D skills
Complementary research and technology competence
Healthy financials

Weaknesses

Geographical dispersion of researchers needing further integration
Multiple research areas needing further integration

More publications needed
Need to create a marketable center image

Opportunities

Leverage virtual environment research facilities to pioneer unique end-to-end user-centered systems
Amplify activities in embedded systems
Build upon past success to create center image and get additional tech transfer projects
Work with computer science cluster to design collaborative end-to-end system projects
Increasing national and international demand for ICT systems
Increased engagement of INESCTECH in national and international initiatives

Threats

Competition from industry
Competition for funding
Decreasing human resource availability

II.10.6. Recommendations

- Good strategic goals addressing current weak aspects of center
    - Improve research impact, publications, cooperation, balance and sustain tech transfer
- Emphasize center strength and unify activities: production systems that are
    - End-to-end
    - Robust and
    - User-centered
- Increase TRL1 and TRL2 activity
- Leverage rich virtual environments research facilities to pioneer unique end-to-end user-centered systems
- Leverage and amplify activities in embedded systems
    - Naturally associated with virtual environments but so far unexplored
    - A rich target for software engineering methods
    - A current gap in the Inesctec scientific portfolio
    - A timely area with many opportunities (IoT, smart cities, smart sensing, pervasive intelligence!! …)

II.11. Center: LIAAD Artificial Intelligence and Decision Support

II.11.1. Evaluation of Center’s scientific performance

LIAAD presents excellent productivity in terms of journal and conference publications with a good balance between both. Their publications have received a large number of citations, especially those related to data streams. The degree of internalization is very high and they have been very active and successful in getting grants from national and international agencies.

II.11.2. Balance between depth and breadth

-Their topics of research cover a large number of machine learning topics, i.e., data streams, anomaly detection, inductive logic programming, text mining, …
-Data streams is the topic where LIAAD shows the highest level of excellence

II.11.3. Gaps and required expertise

- An intensification on the adaptation of machine learning methods on big data scenarios can be of interest for LIAAD
- The recent inclusion of staff with a solid statistical background should provide excellent opportunities to develop new approaches, for example exploiting synergies between data streams and time series

II.11.4. R&D tech/transfer

- Technological transfer activities have increased significantly since the previous evaluation
- The development of industrial PhDs with a co supervision from academic and industry should be encouraged

II.11.5. SWOT Analysis

Strengths
- Excellence in publication records including some relevant papers on machine learning reviews
- Incorporation of new researchers with a strong background on statistics should strengthen LIAAD

Weaknesses
- The “data mining” section of LIAAD depends very much on the topic of “data streams”

Opportunities
- To provide data science advice, expertise and assistance to the rest of centers when needed
- To offer short introductory courses in machine learning and in advanced statistics to industrial patterns
- Adaptation of machine learning methods to big data scenarios

Threats

- The rest of the centers are also working in the application of machine learning methods in several projects. LIAAD vision and expertise should be considered in this regard

II.11.6. Recommendations

- The "data mining" section of LIAAD depends very much on the topic of "data streams". Try to avoid this situation
- Provide data science advice, expertise and assistance to the rest of centers when needed
- Adapt machine learning methods to big data scenarios
- Offer short introductory courses in machine learning and in advanced statistics to industrial patterns

II.12. Center: Center for Research in Advanced Computing Systems(CRACS)

II.12.1. Evaluation of Center's scientific performance

CRACS has consistently generated high-quality research outputs; according to the metrics that we were given, 70% of the journal publications during the 2014-16 period are Q1 or Q2, 32% of the conference publications are CORE A and 44% are CORE B. The total number of publications decreased in 2016, even if the 5 extra journal papers that were accepted in 2016 are accounted for. The average number of publications per member with a PhD was around three per year, which is not spectacular and undoubtedly reflects the high overhead incurred by the senior members due to their university commitments. We would expect the increase in the number of post-docs to improve the publication ratio.

The number of PhD students has remained stable at 16, which the team recognizes not to be ideal but difficult to increase due to the strong competition from industry for talented graduates. Otherwise, the SAB noted that the team hosts or has hosted two PhD students engaged in the dual-degree scheme with CMU, and the participation of the team in the teaching of PhD and MSc programmes.

The SAB also acknowledges the significant increase in research funding, from 523K€ in 2014 to 857K€ in 2017, to a total of over 2.6M€ for the period. Funding has been kept diversified, which is very healthy. The team have been particularly good at attracting funds from the N2020 scheme, which also reflects a strong involvement in the local economy and, more generally, the increase in the proportion of applied research and of development in the center's profile.

Finally, the international visibility of CRACS researchers continues to be very good and increasing, with numerous international collaborations with institutions in Europe, Brazil and the USA.

II.12.2. Balance between depth and breadth

CRACS has kept over the years a distinctive and strong scientific profile with high international visibility, initially built around Languages and Distributed Computing, which has expanded into Security and Privacy (Identity Management Systems and Privacy Enhancing Technologies), and more recently into more data-centered areas, including Machine Learning, Statistical Relational Learning, Complex Networks, Bioinformatics, and E-Learning Environments and Tools.

The SAB supports this expansion, which is well aligned with INESC-TEC's global strategy in meeting the challenges of pervasive intelligence, and both complements and intersects with competencies available in other centers. The publications, grant portfolio and network of collaborators indicate that the newer areas are now established in their own right, but it would be important to ensure that these areas continue to develop in depth. Over the period, the center has also shown excellent progress in engaging in collaborations with other centers INESC-TEC, which should continue to be incentivized and built into the operational structure and practices of the CRACS.

II.12.3. Gaps and required expertise

CRACS continues to rely on a highly qualified team of experts in its core research areas. The number of senior members has increased from 12 to 14 since 2014, and the number of post-docs from 5 to 7, thus increasing the critical mass available. More generally, the increased levels of collaboration with other centers help mitigate any lack of specific expertise required for a project.

CRACS intends to further increase their critical mass in the new areas – Security& Privacy and Knowledge in a World of Data. However, it would be important to use the experience gained in working with other centers to identify complementarities and gaps that could be filled through an alignment of research strategies, especially in relation to cybersecurity and Big Data.

Although no obvious gaps can be found in the scientific competences of CRACS, the increase in the weight of development and tech transfer of its profile (discussed below) has exposed some vulnerabilities in the technical competences of the team, for example in relation to code optimization, which have been key to the success of recent projects; the perceived threat here concerns the ability to hire researchers outside the university system, i.e., without a faculty position.

Another threat is the massive increase in student numbers at DCC/FCUP without any corresponding expansion in academic staff, which implies that senior staff at CRACS are even more stretched than they were in 2012. Having said this, ways could perhaps be found to use the increase in the number of post-docs to help offset the high overhead incurred by the senior members due to their university commitments.

II.12.4. R&D tech/transfer

Our 2012 report noted that CRACS activities in the knowledge-to-value production chain were tilted towards basic knowledge and applied research (80%) versus development and tech transfer (20%). The profile is now more balanced at 60% vs 40%, which is similar to that INESC-TEC as a whole. At around 40%, applied research is the strongest followed by development, which means that CRACS now occupies a comfortable middle ground for R&D tech/transfer.

This change of profile is reflected in a number of high visibility and high impact projects, as well as in the increase of collaborations with other centers. A notable recent example is *VcardID – A fingerprint biometric solution for the Portuguese Citizen Card,* which was a joint project with three other centers, leading to what is now the new national biometric solution adopted by INCM. Together with current activities with GSN around a secure communication app for governmental use, and the on-going contacts with VisionBox, it is clear that CRACS is achieving impact with a very wide reach.

The exhibits and documentation made available during the visit also confirm that CRACS continues to develop impressive software systems and tools that are used throughout the world, which adds to its international (and national) prestige. It also became clear that there are now more synergies with other centers, inside and outside the Computer Science cluster, which helps leverage the expertise and capabilities of CRACS.

It would now be important to follow-up on the opportunities that the engagements mentioned before have created for higher levels of TRL (spin offs, patents, and commercialization of research outputs) and to strengthen the competencies of the team at those levels.

II.12.5. SWOT Analysis

Strengths

- Languages and Distributed Computing continues to be an area of international excellence
- Very strong competencies in Security&Privacy and in Big Data related techniques
- Diversified sources of funding
- Cohesive team that delivers relevant research with wide-reach impact
- Balanced profile across the knowledge-to-value production chain
- Synergies developed with other centers of INESC-TEC
- Wide network of international collaborators

Weaknesses

- Insufficient human resources for continued growth and new initiatives
- Low number of PhD students
- Vulnerability in relation to competencies that are not held by established staff

Opportunities

- Strong demand for applied research in Security&Privacy and in Big Data in the economic sector, government and public administration
- Demand for competencies in Security&Privacy and in Big Data within INESC-TEC
- New legislation for employing post-docs

Threats

- Increase in the overhead incurred by the senior members due to the inability of the university to hire more staff
- Competition from the industrial sector for hiring young talented graduates
- New legislation for employing post-docs

II.12.6. Recommendations

- Continue to produce excellent research and strengthen the publication record.
- Follow-up on the opportunities that the engagements mentioned before have created for higher levels of TRL (spin offs, patents, and commercialisation of research outputs) and to strengthen the competencies of the team at those levels.
- Use the experience gained in working with other centres to identify complementarities and gaps that could be filled through an alignment of research strategies, especially in relation to cybersecurity and Big Data.
- Use the increase in post-docs to help offset the high overhead incurred by the senior members due to their university commitments.

II.13. Center: High-Assurance Software Laboratory (HASLAB)

II.13.1. Evaluation of Center’s scientific performance

The High-Assurance Software Laboratory (HASLAB) has achieved excellent results in basic science, engineering, and applied research. HASLAB's mission is to "design and implement high-assurance software systems, software that is correct by design and resilient to environment faults and malicious attacks". The team of HASLAB interprets this mission broadly and the work addresses three domains: Software Engineering, Distributed Systems, Cryptography and Information Security. These roughly correspond to different organizational units at the corresponding "home institutions".

Overall the research results from HASLAB are presented at some of the most prominent and internationally visible venues, which are rated at the highest level world-wide. HASLAB occupies a top position in this respect across the CS cluster and perhaps also across INESC TEC. For instance, the focus on journals like IEEE Transactions on Software Engineering or the papers appearing in ACM Computing Surveys, Usenix Security Symposium, and IEEE Security & Privacy Symposium belong to this category.

On the other hand, these excellent publications appear to originate from a subset of the center only; the center could aim at a more uniform representation of all its domains in the future. The review observed that the overall visibility could be strengthened if all three domains, and most researchers within those domains, focused on achieving similarly high scientific excellence.

II.13.2. Balance between depth and breadth

Overall the balance is good, however it might be more uniformly distributed within each domain spanned by the center.

II.13.3. Gaps and required expertise

According to the mission of HASLAB to focus on "high-assurance software" the center would span all areas of dependable systems, computer security, cryptography, formal methods in software engineering and more. Among the topics, it would be interesting to place a bigger focus on system security, spanning topics such as: malware, intrusion detection, ethical hacking and more. This field is practically relevant and could also be a good opportunity for technology transfer to local companies.

Furthermore, the HASLAB-specific expertise (especially: distributed data, cryptography and computer security) is today needed in most parts of ICT. From the Internet of Things, sensors, to big data, fintech innovations, and autonomous systems, big data and security are key topics, or enablers, respectively. HASLAB might broaden its educational effort for or direct involvement in projects of other centers, ensuring that INESC TEC overall delivers more scalable, safe, and secure ICT systems. This might require allocation of additional positions that take up such internal technology transfer.

For growing the international visibility of the teams, the review recommends to host high-profile events in Portugal (such as conferences sponsored by ACM, IEEE, or similarly prominent organizations). Several members of the center have already successful past experience with this.

II.13.4. R&D tech/transfer

The strong participation in EU-funded FP7 and Horizon 2020 programs demonstrates that the center performs very well in the area of advanced research and innovation on the European level. Furthermore strong participation in FCT-funded projects is visible.

Again, as stated under "scientific performance", the participation in research and technology transfer might be changed to be more uniform overall. This will benefit the teams that have so far been oriented more locally and give them broader exposure, increasing their technology depth. For the teams oriented towards (and succeeding in) international research excellence, please keep doing that! But observe that smaller projects with funds from Portugal (FCT) or from the local industry may give better connections to the local businesses. Do not overlook this opportunity. This would help accomplish INESC TEC's mission of supporting the Portuguese economy.

II.13.5. SWOT Analysis

Strengths
-Deep technology expertise in certain domains
-Some world-class research
-Good connections to local industry

Weaknesses
-Center shows internally a small imbalance in distribution of long-term versus short-term research (resp. orientation on the TRL scale)
-Some projects with low impact on local economy

-Opportunities
-Aim at a more uniform technology depth across the internal domains
-Increase internal communication and collaboration to achieve overall better results

-Threats
-Internal geographic dispersal across sites
-Internal segregation into isolated topics of expertise

II.13.6. Recommendations

- Continue with a strong scientific record
- Invest in international visibility (through events)
- But consider also impact on local industry, via initiative like a new TEC4 for ICT, in digital services/finance/insurance
    - More consistency in TRL-balance across topics of Center

Engage/align with other centers though the HASLAB-specific expertise (distributed data & cryptography/security)

Signature Page

The Scientific Board Members

Dr. José Principe

___________________________________ Date ______________

Dr. Leonardo Chiariglione

___________________________________ Date ______________

Dr. Faramarz Farahi

___________________________________ Date ______________

Dr. Tomas Gomez

___________________________________ Date ______________

Dr. James C. Spohrer

___________________________________ Date ______________

Dr. José A. B. Fortes

___________________________________ Date ______________

Dr. John O'Reilly

___________________________________ Date ______________

Dr. José Luíz Fiadeiro

___________________________________ Date ______________

Dr. Max Viergever

________________________________ Date ____________

Dr. Steven P. Nichols

________________________________ Date ____________

Dr. Volker Stich

________________________________ Date ____________

Dr. Pere Ridao

________________________________ Date ____________

Dr. Pedro Larrañaga

________________________________ Date ____________

Dr. Bruno Siciliano

________________________________ Date ____________

Dr. Christian Cachin

________________________________ Date ____________