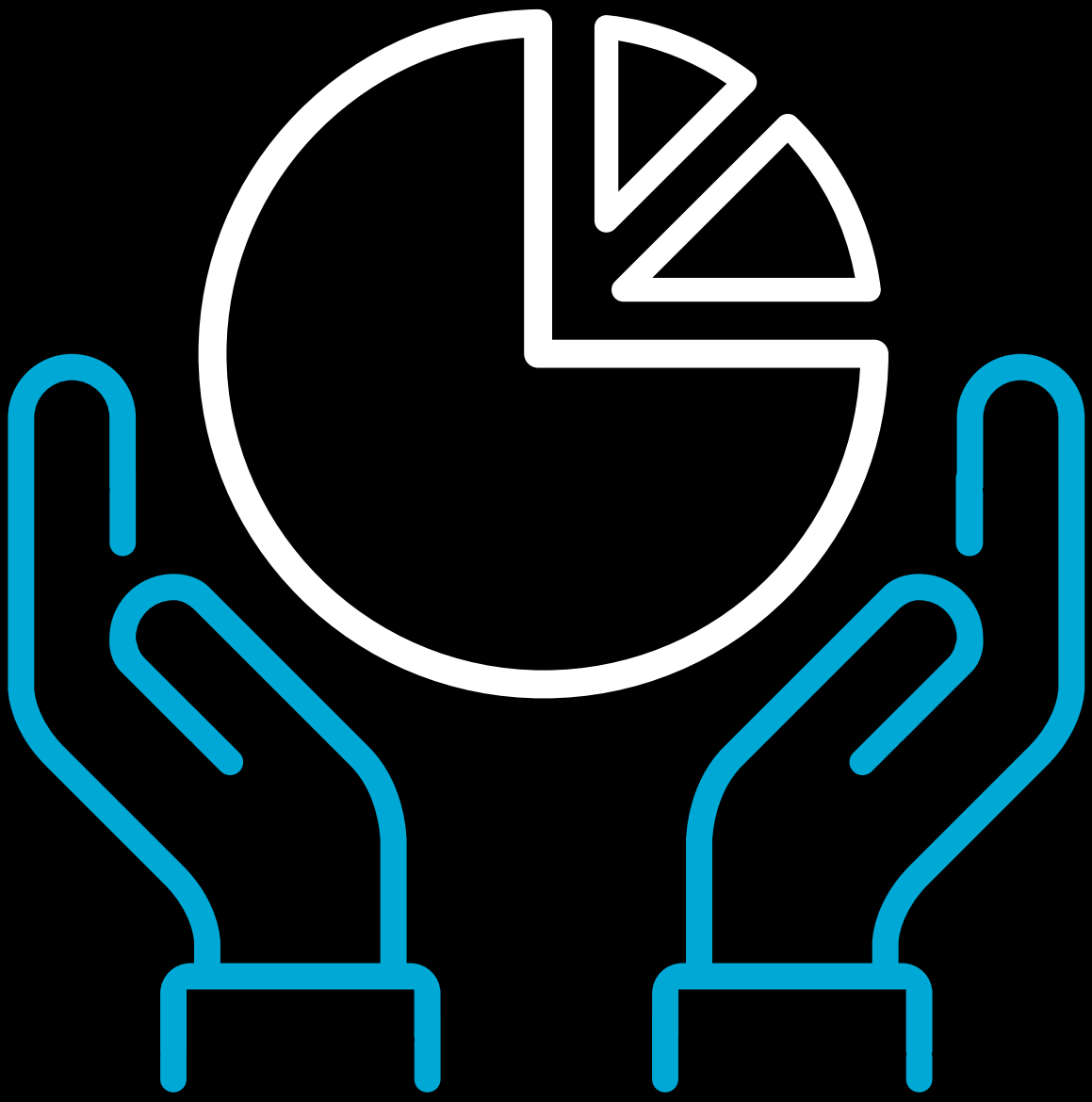
INSTITUTE FOR SYSTEMS
AND COMPUTER ENGINEERING,
TECHNOLOGY AND SCIENCE

INESCTEC



INESC TEC
ACTIVITY PLAN
2020

Editorial Notes

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December 2019

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1 INTRODUCTION

This document briefly presents INESC TEC Plan of Scientific and Technological Activities for the year 2020.

Section 2 offers a summarized presentation of INESC TEC profile, its vision, mission, organisational model, policy priorities, institutional objectives and research and innovation goals for 2020. Section 3 presents the institution main activity indicators planned for 2020, namely those regarding Human Resources, Activity in Projects and Publications.

Research at INESC TEC is developed in 13 Research Centres, organised in four stable structures denoted as Clusters: Computer Science (CS), Industrial and Systems Engineering (ISE), Networked Intelligent Systems (NIS), and Power and Energy (PE). Section 4 presents these four Clusters and their objectives for the short and medium term.

Section 5 focuses on the TEC4 initiatives, platforms that articulate INESC TEC's activity towards economic and societal impacts, presenting the high-level objectives for the ongoing initiatives in the following domains: ENERGY, INDUSTRY, AGRO-FOOD, SEA and HEALTH.

Section 6 presents the Scientific and Technological Activities planned by each of the 13 Research Centres for 2020, including their objectives, activity plan and activity indicators for 2020.

Section 7 presents INESC TEC main research infrastructures and laboratories.

Section 8 introduces one "special" project running at INESC TEC: the UT Austin Portugal Program, highlighting the contributions of the institute to public policies in education and science.

Finally, Section 9 presents INESC TEC Support Services, including the Business Development Services, the Management and Organisation Services and the Technical Support Services.

2 INESC TEC PRESENTATION

2.1 Profile, vision and mission

INESC TEC is a private, non-profit association dedicated to scientific research and technological development, technology transfer, advanced consulting and training, and pre-incubation of new technology-based companies.

The University of Porto, INESC, the Polytechnic Institute of Porto, the University of Minho and the University of Trás-os-Montes e Alto Douro are INESC TEC's associates. Presently, INESC TEC's main sites are located in the cities of Porto, Braga and Vila Real. By the end of September 2019, INESC TEC's 13 R&D Centres hosted 720 integrated researchers (329 PhDs), including R&D employees, academic staff, grant holders and affiliated researchers. INESC TEC's team also includes trainees and technical and administrative support staff.

INESC TEC's vision is to be a relevant international player in Science and Technology in the domains of Computer Science, Industrial and Systems Engineering, Networked Intelligent Systems, and Power and Energy.

As an institution operating at the interface between the academic and business worlds, bringing academia, companies, public administration, and society closer together, through its "managed science" model, INESC TEC leverages the knowledge and results generated as part of its research, in technology transfer projects, seeking impact both through value creation and social relevance.

The dual mission of INESC TEC is to excel in research, seeking social relevance and international influence, and to foster pervasive intelligence, contributing to the competitiveness and internationalisation of Portuguese companies and institutions.

The merit of INESC TEC in the accomplishment of its dual mission has been formally acknowledged by the Foundation for Science and Technology, with the institute's recognition as Associate Laboratory, and the Portuguese Ministry of Economy, with its recognition as Technology Interface Centre.

2.2 Managed science model

2.2.1 Knowledge value chain

INESC TEC's management and operational model implements the concept of end-to-end knowledge value chain, driving knowledge from its generation in research activities to its valorisation through a mix of processes of technology transfer.

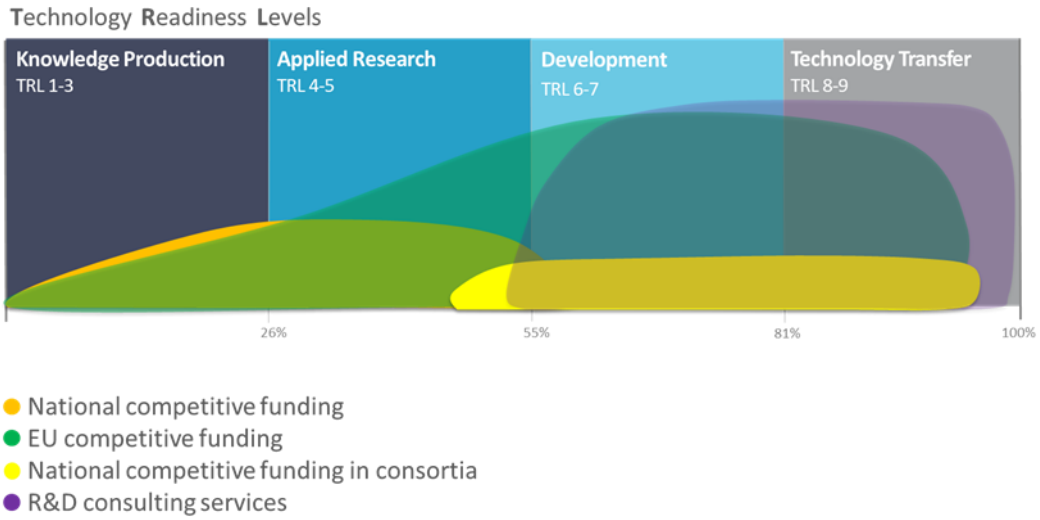


Figure 2.1 - End-to-end knowledge value chain: an integrated two-way pipeline

The concept is illustrated in a very simplified manner in the figure above, which presents a view of the knowledge value chain as a seamless integration of four stages – knowledge production, applied research, development, and technology transfer. Each is associated with a range of Technology Readiness Levels (TRLs) and major project and funding typologies. As with any model depicting a complex reality, the divisions between stages are fluid.

2.2.2 Centres, Clusters and TEC4s

Research at INESC TEC is undertaken by its 13 Research Centres, organised in four stable structures called Clusters: Networked Intelligent Systems (NIS), Power and Energy (PE), Industrial and Systems Engineering (ISE) and Computer Science (CS). The interaction with the main market application areas is articulated by five initiatives called TEC4: TEC4SEA, TEC4HEALTH, TEC4AGRO-FOOD, TEC4ENERGY and TEC4INDUSTRY.

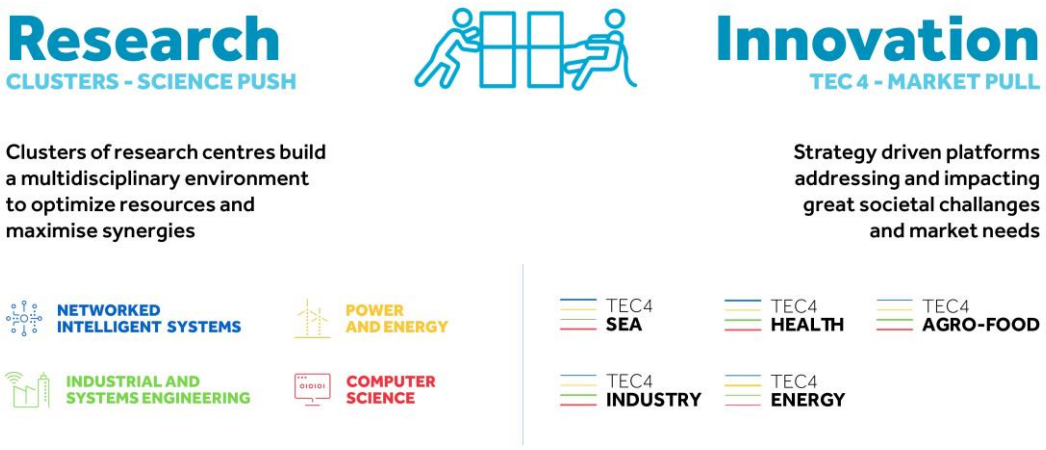


Figure 2.2 - Putting pervasive intelligence to work

The Centres are INESC TEC's R&D organisational base units, each focused in specific scientific and technological domains and responsible for its own planning, strategy and resources, and reports directly to the Board regarding its budget and performance indicators.

The Clusters bring together Centres in specific thematic domains, and are responsible for the research and development strategy and long-term planning in their domains. Performance indicators are consolidated at Cluster level to enable proper planning and accompaniment of the forthcoming periods. Each Cluster is directly coordinated by a Member of the Board, with the support of a Cluster Council, composed by the Centres' Coordinators.

The TEC4 initiatives articulate INESC TEC's activity towards the market, defining market strategies and planning the interaction with the main market application areas. A TEC4 initiative structures and provides coherence to INESC TEC's activity towards specific markets, integrating and articulating the competencies of the relevant Centres. A TEC4 is fundamentally driven by a market application domain perspective, where multidisciplinary interventions are usually necessary, instead of a science perspective. A TEC4 initiative establishes a network of external contacts and dialogue with industrial partners and brings back major challenges and the identification of opportunities to the multiple Centres. The TEC4s are flexible, evolving and adaptive to external conditions and internal response. While seeking impact of research in real world multidisciplinary environments, the TEC4 initiatives allow INESC TEC to address broad societal challenges. Each TEC4 initiative has a management committee, composed by its Coordinator, a Business developer and representatives of the relevant Centres. Each TEC4 reports directly to a Member of the Board.

2.3 Organisational structure

The figure below presents a simplified view of the institution's organisational structure. The high-level management of INESC TEC is undertaken by a Board of Directors, composed of nine members, and an Executive

Board, composed of four members from the Board of Directors. The Boards act in coordination with the Council of R&D Centres, meeting every other week with the Centre Coordinators and Service Managers. This ensures institution-wide coherence in vision, policy and operations, and joint responsibility and commitment in both strategic and operational management decisions.

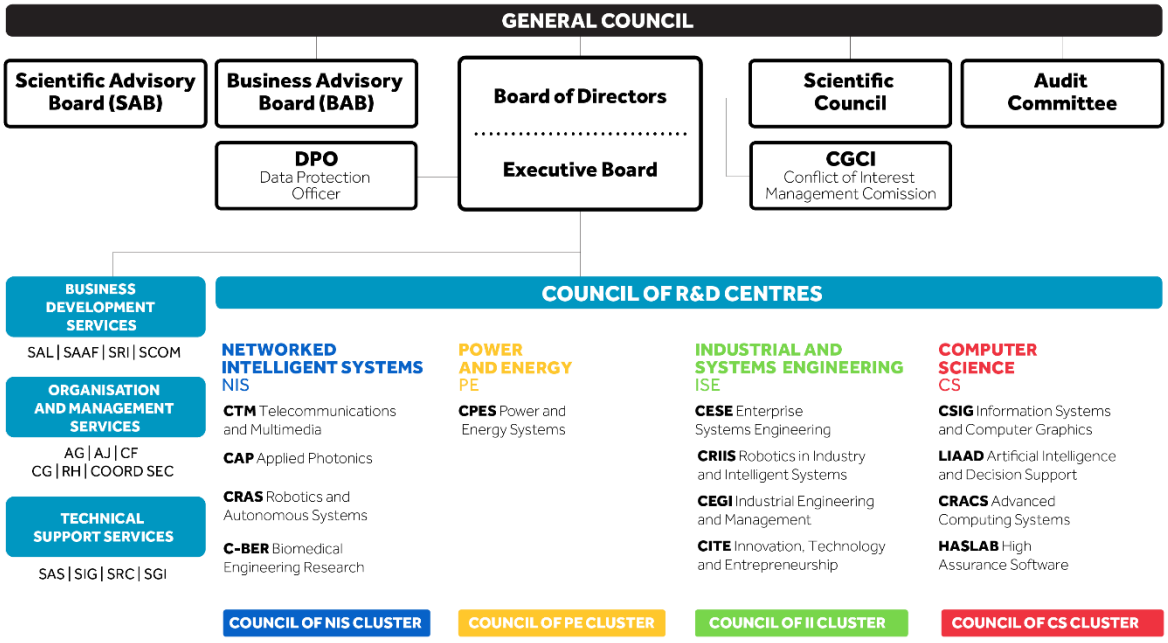


Figure 2.3 - Organisational Structure

The external Scientific Advisory Board is composed of internationally recognised scientists from prestigious institutions, experts in INESC TEC's fields of competence that support the institution in its search for continuous improvement and excellence, building a vision for future research through a valuable benchmark at an international level. The external monitoring, orientation and evaluation of the innovation and technology transfer activities are entrusted to the Business Advisory Board, where the economic sectors of relevance to INESC TEC are represented.

The Scientific Council is an internal body responsible for monitoring and guiding scientific and technical activities, and it includes one representative from each Centre's committee and three additional members appointed by the Administrative Board. The Conflict of Interest Management Commission is appointed by the Board to implement the institute's Policy on Conflict of Interest. The Data Protection Officer leads the implementation across INESC TEC of the General Data Protection Regulation.

A streamlined and dynamic team of highly qualified technical and administrative personnel provides support to INESC TEC's activities. A comprehensive set of support services, presented in the table below, is organised to support the R&D Centres across the domains of Business Development, Organisation and Management, and Technical Support. Furthermore, each research Centre has its autonomous administrative support, also with highly qualified staff.

Table 2.1 - Support Services

Business Development	Organisation and Management	Technical Support
SAL: Technology Licencing Office SAAF: Funding Opportunities Office SRI: International Relations Service SCOM: Communication	AG: Management Support AJ: Legal Support CF: Finance and Accounting CG: Management Control RH: Human Resources COORD SEC: Secretarial Coordination	SAS: System Administration SIG: Management Information Systems SRC: Networks and Communications SGI: Infrastructure Management

2.4 Policy priorities

To accomplish its mission, INESC TEC defines the following policy priorities:

- Excellence in research, talent development, and innovation;
- Full coverage of the knowledge value chain;
- Integration and multi-disciplinarity;
- Scale, density, and critical mass;
- International visibility and presence.

2.4.1 Excellence in research, talent development, and innovation

INESC TEC creates new knowledge and technology to improve products, processes, services and business models, contributing to the competitiveness of companies and institutions, and benefiting society. This knowledge is built upon a base of rigorous scientific research, and in a dynamic research environment that enables the institute to engage and foster the development of excellent researchers. The commitment to the reinforcement and internationalization of INESC TEC's research infrastructures is essential to ensure the competitiveness of this research environment. Initiatives such as the creation of a research data repository and the active participation in the Portuguese node of the Research Data Alliance, led by INESC TEC, contribute to strengthening the alignment with open science policies. The reinforcement of the international recognition of its researchers, through high impact publication profiles, international awards, or ACM and IEEE Fellowships, plays a major role in maximizing the impact of the institute's excellent research.

As part of its strategic partnerships with associated Departments, Schools, and Higher Education Institutions, INESC TEC seeks to continuously bring valuable contributions to their PhD and Masters Programmes. INESC TEC assists more than 20 PhD programmes, typically involving over 300 students, about 60 concluding their theses every year. Every year the institute's researchers supervise over 600 master's students. The strengthening of INESC TEC's involvement in PhD and Masters Programmes is essential to its ability to attract and involve young talent in conducting and disseminating excellent research while leveraging Higher Education Institutions intervention.

INESC TEC's focus on finding solutions to important problems, along with its culture of collaboration with industry, provides an ideal environment for innovators. On an international level, the build-up of its positioning as an interface organisation of excellence, is key to expanding the ability to partner with international organisations to provide them unique knowledge and relevant technology for innovation, generating and transferring socially relevant results. On a national level, the participation in initiatives such as CoLABs also contributes to this consolidation, while simultaneously allowing the strengthening of the collaboration with other national R&D organisations.

The reinforcement of its global dynamics of excellence is a permanent priority for the institution, whose expansion in recent years required a renewed attention to some of its fundamentals, in particular to its human resources management, science management and advanced training models, as well as to research ethics and gender equality policies.

2.4.2 Full coverage of the knowledge value chain

The success of INESC TEC's managed science model relies on the ability to easily enable flows from upstream to downstream along the knowledge value chain, and feedbacks in the reverse direction. In fact, the interaction and collaboration with industry is also essential for the identification of new research lines, and the valorisation of research results, through processes such as technology licensing, collaborative development, advanced consulting, training, and spin-off launching, is key to the economic sustainability of the institute.

In order to excel in this dynamics, INESC TEC is increasingly challenged to ensure that individual researchers focus where they feel more comfortable to perform at their best, while at the same time Centres develop the broad spectrum of activities and the critical mass that allows knowledge to flow not only within each Centre, but also between Centres, so that INESC TEC as a whole is able to fully accomplish its dual mission.

2.4.3 Integration and multidisciplinarity

INESC TEC pays constant attention to its integration dynamics, as the institution and its context evolve, and its resources are accordingly renewed, strengthened and recombined. The Clusters and the TEC4 initiatives are key instruments to support INESC TEC's policy for achieving institutional cohesion and maximising synergies, differentiation and impact. Overall, this policy seeks to strengthen the ties among Centres, by deepening cross-fertilization, originating new science by fusion of knowledge and skills, and conducting multidisciplinary research and innovation by truly multidisciplinary teams.

The institute strives to foster this meeting of different scientific disciplines, a key enabler of its impact in practice through science-based innovation. The implementation of initiatives that encourage and support the interaction among Centres is key to enable the integration of the institute's diversity of deep scientific knowledge into multidisciplinary solutions that transcend traditional technological divides. The Clusters and the TEC4 initiatives play a key infrastructural role towards this purpose, as well as other instruments, such as the Internal Seed Projects, which support inter-Centre research, junior researcher development, and proof-of-concept activities.

2.4.4 Scale, density, and critical mass

INESC TEC's ambitious vision and mission require a level of scale and density that can only be made possible through its multi-institutional base model. The resource endowment collaboratively brought to INESC TEC by its associates and privileged partners is continuously leveraged by the institute to sustain a level of growth and densification in the areas of knowledge that are critical for its activity, which is not only unique in the country, but also increasingly relevant in the international arena. One of the institute's key priorities for the future is a consistent effort to focus its activities and attract leading researchers to further reinforce its critical mass.

2.4.5 International visibility and presence

Excellence in science and technology nowadays requires collaboration and strong partnerships with leading international research institutions and companies. INESC TEC's international projects and activities are crucial to securing the status of international player, ensuring the institution's effective participation and recognition in the international arena. INESC TEC permanently directs significant efforts to its international activities, so that they continue to play a major role in the institution.

In this context, the first and foremost undertaking is the consolidation of the massive presence in European research and innovation, including the strengthening of collaborations with international companies. INESC TEC's active participation in the European Knowledge and Innovation Communities (KICs) – EIT Raw Materials, EIT Manufacturing and EIT Digital – has a highly relevant role in this domain. A second step is the strengthening of a base of operations outside Portugal, to increase the capacity to promote projects, secure funding, and attract human resources at an international level. The operation in Brazil, with the creation of INESC P&D Brasil and its recognition by the Brazilian Science and Technology agencies as a Brazilian ICT (Institution of Science and Technology), and the creation of INESC Brussels Hub and a service for international relations must be understood under this perspective. The India Office also aims to develop relevant bridges with important companies and public actors and support the attraction of students and post-docs. The continued involvement in the Portuguese Government's International Partnerships with MIT, CMU and UT Austin, and in particular the hosting at INESC TEC of the national leadership of the UT Austin Portugal Program, play a key role in the development of

collaborations with the United States. Other initiatives, such as the AIR Centre or the CENTRA network of excellence, foster the collaboration with partners from an even broader spectrum of geographies.

2.5 Main initiatives for 2020

Looking beyond from 2020, INESC TEC has committed to a set of critical institutional initiatives that will enable the institute to strengthen its intervention capacity in the national and international Science and Technology systems, and its ability to carry out its mission in the benefit of society in the forthcoming years.

These initiatives are summarized next, under the following categories: managed science model, structural initiatives, internationalisation, internal activities, support structure, infrastructures, large events, calls of strategic importance, and contributions for public policy.

- **Managed science model**
    - Strengthening of the institute's scientific strategy, driven especially by the strategic planning and management efforts carried out at Cluster level, under the new model of Cluster coordination by a Board member with the support from a senior researcher;
    - Implementation of the new TEC4 model, aiming at enhancing the articulation of INESC TEC's activities with its key markets, under the leadership of a coordinator and the support of a business developer for each TEC4, starting with the refinement and implementation of each TEC4's strategic agenda;
    - Improvement of the strategic integration of the key internal R&D organisational units – Centres, Clusters and TEC4s – and the institute's science and innovation activities, including the organisation of TEC4Clusters internal workshops;
    - Reinforcement of INESC TEC's research team with the recruitment of researchers for key strategic areas, in line with the government policy for scientific employment.
- **Structural initiatives**
    - Approval and implementation of a Code of Ethics, to publicly clarify and internally strengthen the ethical and deontological principles of the institute and its members, especially in R&D activities, and establishment of an Ethics Committee, following the ongoing open discussion of a draft proposal to be concluded in early 2020;
    - Implementation of gender balance policies, as the result of the activity of the Gender Equity Working Group, created in 2019;
    - Implementation of a set of social responsibility policies, following the assessment performed in 2019 by a group of INESC TEC volunteers, and the subsequent creation of the Social Responsibility Technical Committee in October 2019.
- **Internationalisation**
    - Entry into full operation of INESC Brussels Hub, the Brussels representation of INESC Coimbra, INESC ID, INOV INESC, INESC MN, and INESC TEC, set up in 2019 to reinforce the institutes' positions in European programmes, increase their visibility and credibility in key areas, represent them in European platforms, groups and structures, and provide their researchers a permanent physical space for support and representation;
    - Formalization of a new service to reinforce the management of International Relations, which will also integrate the Brazil and India offices and INESC Brussels HUB;
    - Consolidation of INESC P&D Brasil, with the formal entry of new associates;
    - Intensification of the participation in the European Knowledge and Innovation Communities (KICs) EIT Raw Materials, EIT Manufacturing and EIT Digital;
    - Continued hosting of the national leadership of the UT Austin Portugal Program by INESC TEC;

- Active participation in the AIR Centre (Atlantic International Research Centre), being INESC TEC a founding member and part of its Coordinating Committee, namely through the co-organization of two workshops in the USA, with UT Austin and UPenn, with a view to creating an AIR Centre hub in the USA, and the entry into operation of the data infrastructure AIRDataNet, coordinated by INESC TEC and Minho Advanced Computer Center (MACC);
- Implementation of a set of MoUs with research organisations from Japan (AIST and NICT) and India (NIO, NCPOR, IIT Goa, NIT GOA and TERI);
- Active participation of INESC TEC in EARTO (the European Association of Research and Technology Organisations) in its first full year as a member.

- **Internal activities**
  - Second call for Internal Seed Projects, again aiming at supporting internal exploratory R&D projects (in the categories of inter-centre research, junior researcher development and commercialization proof-of-concept), launched in late 2019 and with results to be known in 2020;
  - Visit of INESC TEC's new Scientific Advisory Board in October 2020 for the periodic review and discussion of the institute's scientific strategy.
- **Support structure**
  - Implementation of the new model for Human Resources management, aiming at reinforcing the strategic management and development of careers in the institute, following the recommendations of the diagnostics initiative carried out in 2019;
  - Strengthening of the institute's sponsored research pre-award function, reinforcing its team and leadership, and focusing namely on improving its strategic articulation with external stakeholders and internal processes all across the organization;
  - Launch of a major initiative to restructure the institution's information systems;
  - Systematisation of the institute's support to entrepreneurship and spin-off creation activities;
  - Refinement of the institute's data protection policy and practices, benefiting in particular from the innovative collaboration with ISPUP – Instituto de Saúde Pública da Universidade do Porto, under the Memorandum of Understanding signed in 2019.
- **Infrastructures**
  - Launch of the construction of a new technological infrastructure in the Industry 4.0 domain, aiming at expanding the already existing iiLab – Industry and Innovation Lab and covering areas such as Cyber Physical Systems (CPS) & Internet of Things (IoT), Business Intelligence & Decision Support Systems, Advanced Automation & Industrial Robotics, Mobile Robotics & Internal Logistics, Industrial Vision Systems for Inspection and Quality Control;
  - In addition to the continuous improvement of the existing laboratories, conclusion of the significant upgrades in the Energy and Sea infrastructures in the scope of projects SGEVL, TEC4Sea, and EMSO-PT.
- **Large events**
  - Celebration of INESC TEC's 35th anniversary, including the organization of a diversified range of commemorative initiatives, some more focused internally, in particular its special quinquennial get-together, and others more open to the exterior;
  - Active involvement in the celebration of INESC's 40th anniversary;
  - Organization of the Autumn Forum, in which the institute will again seek to actively make a contribution to public policy debate, by inviting relevant actors to present and discuss their views on topics of relevance for the country;

- Promotion of open days, organised by an increasing number of INESC TEC centres and clusters, inviting society, academia, industry and media to visit the institute and become acquainted with its main science and innovation contributions, following a tradition of openness and accountability;
- Hosting of the 2020 meeting of the CENTRA partnership, the first to be held in Europe.

- **Calls of strategic importance**
  - Submission of proposals in the last calls of H2020 and P2020, which will be of very high importance for the period of bridging to the new funding programmes;
  - New call for proposals from FCT, the first after 2017;
  - Participation in the call for renovation of the Associate Laboratory label and funding, following the FCT evaluation process – whose outcome was nonetheless considered a disappointment by the institute and was the object of a rebuttal.
- **Contributions for public policy**
  - Active involvement, in 2019 and 2020, in providing contributions to administrative simplification in the area of Science and Technology at a national level;
  - Continuing involvement in the update of the regional and national smart specialization strategies in the institute's areas of expertise;
  - Major developments likely in the eight CoLABs that INESC TEC is associated with, opening opportunities for the institute to expand its research in the CoLABs' areas of application, strengthen knowledge sharing and enhancement, contribute to the creation of highly qualified jobs for its young talent, and overall strengthen its position as an interface institution of excellence;
  - Technical coordination by INESC TEC, in partnership with University of Minho, in acquiring the EuroHPC supercomputer for the Minho Advanced Computer Center (MACC), Deucalion, the second largest computer in the world based on ARM processors, with a hybrid architecture, combining several avant-garde architectures, which will be installed by the end of 2020.

2.6 Research and innovation goals

The institution's scientific objectives defined for 2018-2022 are aligned with its vision and mission, and in particular with the commitment to **fostering pervasive intelligence**. This is enabled by the structures and processes put in place at INESC TEC to promote and facilitate multidisciplinary cooperation, which allow linking sensors, communications, hardware and software systems, data, knowledge, models, decision and action.
INESC TECs high-level scientific objectives, defined at Cluster level, are summarised below with each Cluster's vision and research priorities (more details can be found in the Clusters and Centres sections):

- NETWORKED INTELLIGENT SYSTEMS - For the next years the cluster envisions smarter and smaller collaborative systems, the convergence of deep learning and communications, and the ubiquity of computer vision. The cluster will continue addressing futuristic scenarios in which collections of networked systems - autonomous, carrying sensors, communications enabled - collect information in extreme environments such as the deep sea or the human body, and process it using artificial intelligence tools. Four main research lines will be active: sensing, communications, computer vision, and autonomous systems. The main expected outcomes for 2020 include the following: graphene-based sensors and antennas, optical and electrical sensing microdevices, CAD for cancer analysis, automatic audio-visual content manipulation, self-learning communications for extreme and immersive environments, autonomous system for underwater inspection, and a deep-ocean robotics observatory.
- POWER AND ENERGY - The Cluster's vision is aligned with the EU policies for digitalization, energy efficiency and increase in Renewable based Energy Sources (RES) integration, and includes as main challenges the transformation of the energy sector through synergies between advanced mathematical modelling and digital technologies, the full decarbonization of the power system with novel solutions, and the bridging of the gap between research results and industry business cases with a

multidisciplinary approach. The Cluster has defined the following main research lines: (1) towards 100% RES integration and massive integration of power electronics-based interfaces; (2) large-scale modelling and optimization of energy systems; (3) data-driven methodologies for energy systems; (4) asset management and predictive maintenance; (5) cybersecurity and Internet of Things (IoT) for critical infrastructures (electricity generation, transmission and distribution).

- INDUSTRIAL AND SYSTEMS ENGINEERING - The Cluster envisions a fully integrated supply chain across different industries (e.g., manufacturing, process industries, retail, health and mobility). The cluster will also consolidate the leadership in knowledge generation and technology transfer on digital transformation, advanced analytics and integration of advanced manufacturing technologies and new business models, helping companies to fully embrace the 4th industrial revolution. Customer-centric and real-time supply chain optimisation, as well the decentralized decision-making, will only be possible with highly flexible, realocable, adaptable and intelligent automation, control and robotics. The use of collaborative robots (mobile and manipulators), smart sensor networks, industrial vertical IoT-based information architectures and Human-robot interface and responsive collaboration plays an important role in these processes. Furthermore, the cluster will focus on the development and implementation of intelligent systems, automation, management and decision support systems, among other technological solutions, fostering the resilience, resource efficiency, competitiveness, circular economy and sustainability towards an effective bio-economy. The Cluster has defined the following strategic research lines: (1) Operations Management in manufacturing and services for responsive, sustainable and resilient operation; (2) Operations Research and Management Science for empowering decision support in a digitised industry; (3) operational and strategic architectures for a data-driven industry; (4) Human Robot Collaborative workstations; (5) Technology-enabled service design and innovation.
- COMPUTER SCIENCE: Computing became fully decentralized, mobile, increasingly autonomous, and ubiquitous reaching all appliances, devices and living beings. As a result, current information and communications systems present many hard and intricate challenges associated to scalability, security and criticality. The ever-increasing amounts of generated data embody a wealth of information that needs to be properly and timely mined and analysed. This challenges our capacity to filter, curate, store, process, query and visualise unprecedented volumes of data from diverse sources and formats. In addition, the economic value of the data, trade and state secrets, and individual rights require data manipulation to comply with demanding levels of privacy. Smarter and autonomous systems in critical realms such as utilities, health care, transportation and finance require dealing with new, and often unanticipated, sorts of risks that challenge the best practices of software engineering, network and information security and human-computer interaction.

These scientific objectives are complemented by knowledge valorisation and technology transfer targets, structured namely by TEC4 initiatives. Five initiatives are organised to address innovation challenges in the main target market domains in 2020:

- TEC4SEA - Bringing the digital world to a sustainable sea economy;
- TEC4AGRO-FOOD – Co-shaping the digital (r)evolution in agro-food and forestry;
- TEC4INDUSTRY – Collaborative value chains for an innovative, human-centred and sustainable industry;
- TEC4ENERGY – Decarbonization and digitalization of the energy sector;
- TEC4HEALTH – User-centred ICTs to improve health care and personal wellbeing.

The initiative TECPARTNERSHIPS is dedicated mainly to promote and support new projects in all other sectors and to explore new market segments and incubate new potential TEC4's until they reach a qualified maturity level.

3 MAIN INDICATORS FOR 2020

This section presents the main global indicators for INESC TEC, regarding human resources, activity in projects, scientific publications, IP protection, exploitation and technology transfer, and dissemination activities planned for 2020. The presentation of each Cluster and R&D Centre and the detailed discussion of their objectives, activities and results are carried out in Sections 4 and 6, respectively for Clusters and Centres.

3.1 Human Resources

3.1.1 Global Indicators

Table 3.1 and Figure 3.1 show the breakdown of INESC TEC's Human Resources by type of contractual link and the expected evolution for 2020. Table 3.1 also includes the number of PhDs (348 planned at the end of 2020).

Table 3.1 - Evolution of INESC TEC's Human Resources

Type of Human Resources			2018	2019	2020	Δ 2019-20	
Integrated HR	Core Research Team	Employees	102	122	142	20	16%
		Academic Staff	155	159	156	-3	-2%
		Grant Holders and Trainees	418	341	318	-23	-7%
		Total Core Researchers	**675**	**622**	**616**	**-6**	**-1%**
		Total Core PhD	**259**	**256**	**262**	**6**	**2%**
	Affiliated Researchers		70	73	73		0%
	Management, Administrative and Technical	Employees	80	86	88	2	2%
		Academic Staff	9	9	12	3	33%
		Grant Holders and Trainees	14	7	15	8	114%
		Total Manag, Admin and Tech	**103**	**102**	**115**	**13**	**13%**
	Total Integrated HR		**848**	**797**	**804**	**7**	**1%**
	Total Integrated PhD		**339**	**341**	**348**	**7**	**2%**

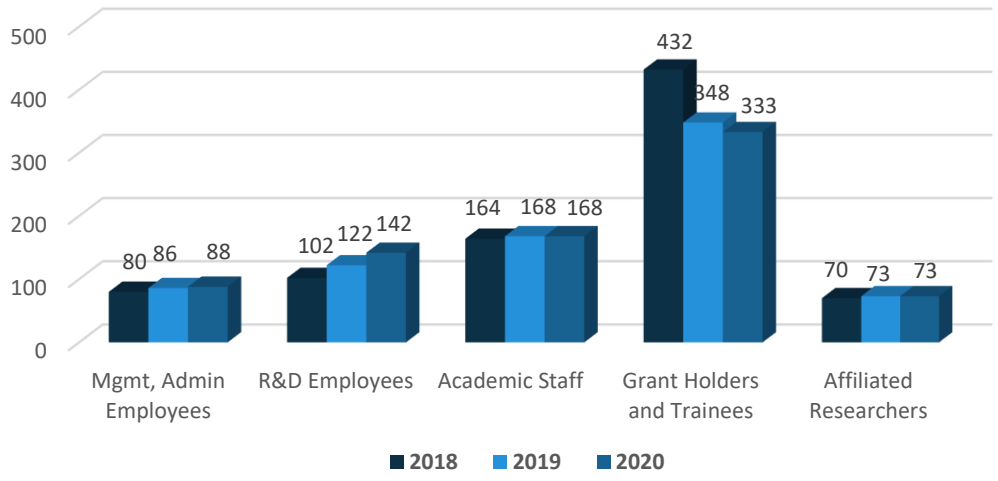


Figure 3.1 - Evolution of INESC TEC Human Resources

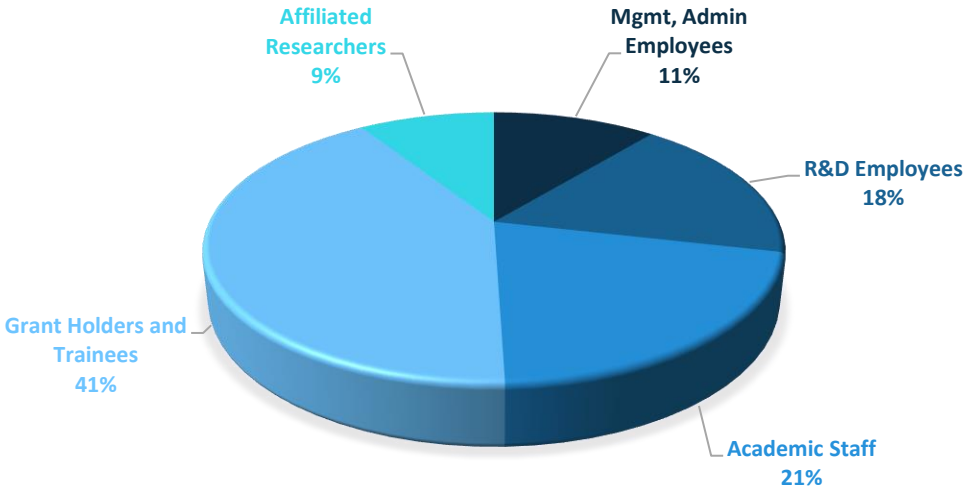


Figure 3.2 - Distribution of Human Resources (Plan 2020)

As highlighted in Figure 3.2, grant holders and trainees are still the largest group of human resources (41%) at INESC TEC, featuring, nevertheless, a noticeable decrease in 2020, which may be explained by two different sets of reasons. First of all, the modified Research Grant Holder Statute that came into force in August 2019 limits the award of grants to researchers who are enrolled in a higher education program. Secondly, as a result of the implementation of the Portuguese Government's policy for scientific employment, the number of R&D employees has been steadily rising, namely for PhD researchers.

The increase in Human Resources in Services aims at supporting the continued growth of the institute's activity and the operationalisation of new strategic objectives, such as the implementation of the new TEC4 model, the reinforcement of international relations management, and the implementation of a new model of human resources management.

Overall, the total number of integrated human resources remain stable between 2019 and 2020, as does the size of the academic staff.

3.1.2 R&D Clusters Indicators

This section presents an overwier of the relative size of the R&D Clusters planned for 2020.

Table 3.2 - Human Resources by Cluster (Plan 2020)

Type of Human Resources			Clusters			
			NIS	PE	I SE	CS
Integrated HR	Core Research Team	Employees	39	30	44	29
		Academic Staff	38	10	30	78
		Grant Holders and Trainees	85	49	75	110
		Total Core Researchers	**161**	**89**	**149**	**217**
		Total Core PhD	**63**	**26**	**66**	**107**
	Affiliated Researchers		13	6	19	34
	Administrative and Technical	Employees	7	2	6	3
		Grant Holders and Trainees	0	0	2	1
		Total Admin and Tech	**7**	**2**	**8**	**4**
	Total Integrated HR		**181**	**97**	**176**	**255**
	Total Integrated PhD		**76**	**31**	**86**	**137**

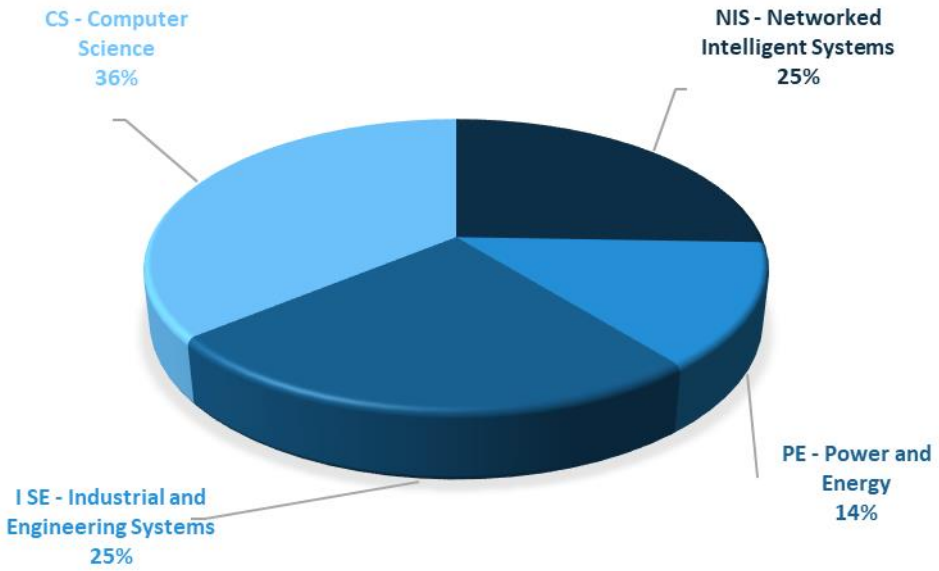


Figure 3.3 - Human Resources by Cluster (Plan 2020)

3.1.3 R&D Centres Indicators

The detailed Human Resources figures expected for the end of 2020 are given in Table 3.3 for each R&D Centre.

Table 3.3 - Human Resources by type and R&D Centre (Plan 2020)

Type of Human Resources			Total R&D Centres	R&D Centres												
				CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	CSIG	LIAAD	CRACS	HASLAB
Integrated HR	Core Research Team	Employees	**142**	12	7	17	2	30	20	11	10	3	15	5	1	8
		Academic Staff	**156**	14	8	10	6	10	4	12	13	1	25	22	15	16
		Grant Holders and Trainees	**318**	38	12	26	9	49	27	9	37	2	34	25	21	30
		Total Core Researchers	**616**	**64**	**27**	**53**	**17**	**89**	**51**	**32**	**60**	**6**	**74**	**52**	**37**	**54**
		Total Core PhD	**262**	**26**	**14**	**15**	**8**	**26**	**14**	**18**	**31**	**3**	**30**	**33**	**17**	**27**
	Affiliated Researchers		**72**	8	5			6	7	5	6	1	19	5	4	6
	Administrative and Technical	Employees	**18**	1	2	3	1	2	2	2	1	1	1		1	1
		Grant Holders and Trainees	**3**						1		1					1
		Total Admin and Tech	**21**	1	2	3	1	2	3	2	2	1	1		1	2
	Total Integrated HR		**709**	**73**	**34**	**56**	**18**	**97**	**61**	**39**	**68**	**8**	**94**	**57**	**42**	**62**
	Total Integrated PhD		**330**	**34**	**19**	**15**	**8**	**31**	**21**	**23**	**37**	**5**	**49**	**37**	**18**	**33**

R&D Centres:

CTM Centre for Telecommunications and Multimedia
CAP Centre for Applied Photonics
CRAS Centre for Robotics and Autonomous Systems
CBER Centre for Biomedical Engineering Research
CPES Centre for Power and Energy Systems
CESE Centre for Enterprise Systems Engineering
CRIIS Centre for Robotics and Intelligent Systems
CEGI Centre for Industrial Engineering and Management
CITE Centre for Innovation, Technology and Entrepreneurship
CSIG Centre for Information Systems and Computer Graphics
CITE Centre for Industrial Engineering and Management
LIAAD Laboratory of Artificial Intelligence and Decision Support
CRACS Centre for Research in Advanced Computing Systems
HASLAB High-Assurance Software Laboratory

3.1.4 Support Services Indicators

The Human Resources figures expected for the end of 2020 for the Board of Directors, the TEC4 teams, and the Support Services are provided in Table 3.4.

Table 3.4 - Human Resources by type and Service (Plan 2020)

Type of Human Resources		Total	Board and Advisors	Support Services															
					Organisation and Management Services						Business Development Services				Technical Support Services			
				TEC4	AG	AJ	CF	CG	DPO	RH	SAAF	SAL	SRI	SCOM	SRC	SIG	SAS	SGI
Integrated HR	Employees	70	8	4	2	3	9	11	1	6	1	3	4	5	2	3	4	4
	Academic Staff	12	8	4														
	Grant Holders and Trainees	12					1	2	1		1		3	1	1	2		
	Affiliated Researchers	1	1															
	Total Integrated HR	**95**	**17**	**8**	**2**	**3**	**10**	**13**	**2**	**6**	**2**	**3**	**7**	**6**	**3**	**5**	**4**	**4**
	Total Integrated PhD	**18**	**10**	**5**			**1**					**2**						

Support Services:

AJ	Legal Support
CF	Accounting and Finance
CG	Management Control
RH	Human Resources
AG	Management Support [1]
SAAF	Funding Opportunities
SAL	Technology Licensing
SRI	International Relations
SCOM	Communication
SRC	Networks and Communications
SIG	Management Information Systems
SAS	System Administration
SGI	Infrastructure Management

[1] *Includes Secretarial Coordination*

3.2 Activity in Projects

3.2.1 Global Indicators

Table 3.5 shows the breakdown of INESC TEC's funding sources and the expected evolution from 2019 to 2020. Table 3.6 then provides this information in greater detail, specifying the evolution of firm projects and the share of strategic programmes, namely the FCT Pluriannual, the programme for scientific employment (EEC) and the pluriannual funding for technology transfer activities (CIT).

Table 3.5 - Funding sources and planned evolution

Sources	2019	2020	Δ (k€ / %) 2019-20	
National Programmes	11 138	10 766	-372	-3%
European Programmes	4 729	6 288	1 559	33%
R&D Services and Consulting	3 732	4 292	560	15%
Other Funding Sources	205	265	60	29%
Total Revenues	**19 804**	**21 612**	**1 807**	**9%**

Table 3.6 - Funding Sources and planned evolution – Detail

Sources			Value (k€) 2019	Value (k€) 2020	Δ (k€ | %) 2019-20	
Firm Projects	PN-FCT	National R&D Programmes - FCT	5 128	4 940	-188	-4%
	PN-PICT	National R&D Programmes - S&T Integrated Projects	234	0	-234	-100%
	PN-COOP	National Cooperation Programmes with Industry	961	916	-46	-5%
	PUE-FP	EU Framework Programmes	3 737	5 822	2 085	56%
	PUE-DIV	EU Cooperation Programmes - Other	824	369	-455	-55%
	SERV-NAC	R&D Services and Consulting - National	2 114	1 865	-249	-12%
	SERV-INT	R&D Services and Consulting - International	396	218	-178	-45%
	OP	Other Funding Programmes	1 547	1 071	-476	-31%
		Total Active Projects	**14 941**	**15 201**	**260**	**2%**
Uncertain Projects			1 280	2 400	1 120	88%
National Strategic Programme - Pluriannual			2 527	2 451	-76	-3%
National Strategic Programme - CIT			540	983	443	82%
National Strategic Programmes - Other			367	394	27	7%
Other Revenues			148	182	34	23%
		Total Revenues	**19 804**	**21 612**	**1 807**	**9%**

Figure 3.4 illustrates the funding distribution for the firm projects planned for 2020, and its comparison with the plan for 2019. The total revenues planned for 2020 grow 9% in comparison with 2019, with some variation per funding source, as explained below.

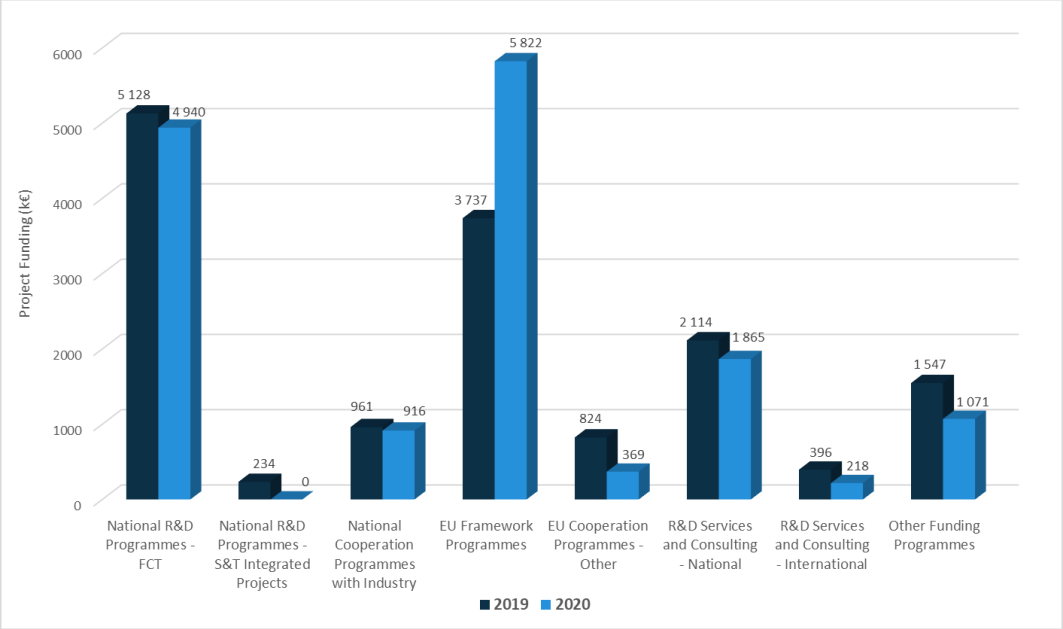


Figure 3.4 - Evolution of project funding by source (k€)

Figure 3.5 shows the funding distribution by source expected for firm projects, in comparison with the previous plan.

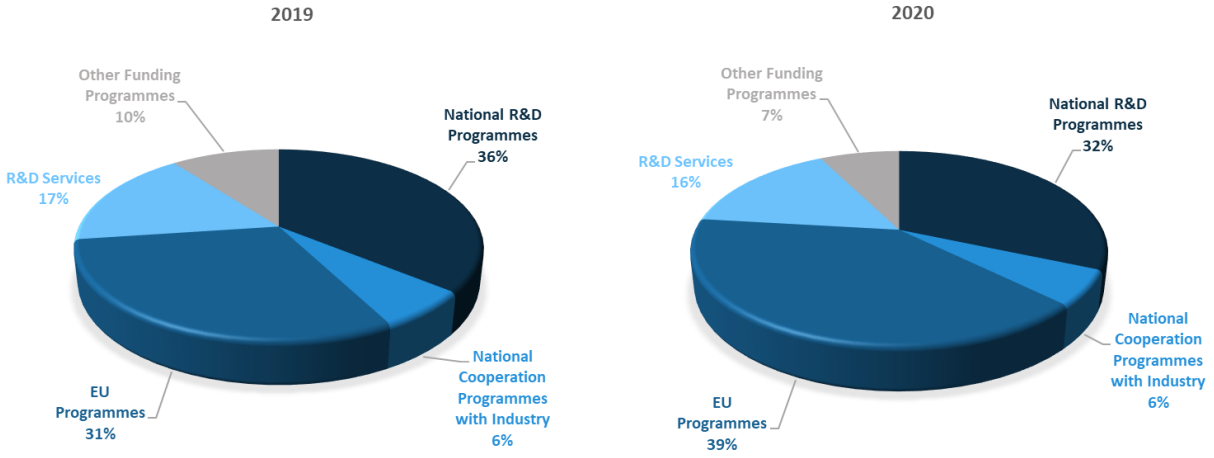


Figure 3.5 - Distribution of projects funding by source - Plan 2019 (left) and Plan 2020 (right)

The number of active projects and the average funding per project by source is also of interest, and is shown in Table 3.7.

Table 3.7 - Number of active projects and average funding by source (Plan 2020)

Type of Project		Number of Active Projects		Δ (%)	Average Funding (k€)	
		2019	2020	2019-20	2019	2020
PN-FCT	National R&D Programmes - FCT	73	62	-11	70	80
PN-PICT	National R&D Programmes - S&T Integrated Projects	8	0	-8	29	
PN-COOP	National Cooperation Programmes with Industry	17	17	0	57	54
PUE-FP	EU Framework Programmes	22	47	25	170	124
PUE-DIV	EU Cooperation Programmes - Other	18	12	-6	46	31
SERV-NAC	R&D Services and Consulting - National	48	44	-4	44	48
SERV-INT	R&D Services and Consulting - International	8	8	0	50	46
OP	Other Funding Programmes	21	18	-3	74	65
	Total	**215**	**208**	**-7**	**69**	**75**

The main conclusions that can be drawn from the global indicators summarized in the previous tables and graphs are the following:

- The total revenue planned for 2020 grows to 22 M€, 9% more than in 2019;
- There are several changes in the evolution of the different funding sources from 2019 to 2020, the most noticeable being the large increase in the EU Framework Programmes (56%), mainly justified by the institution's strategic efforts towards this type of projects;
- The conclusion of the National S&T Integrated Projects from NORTE2020 in 2019 represents a breakdown on national financing for lower TRL's activities;
- The R&D and Consulting Services is expected to grow to 4.2 M€, representing a 20% share in the total activity and a planned growth of 15% in relation with 2019;
- The support from the National Strategic Programme - "Pluriannual" - is an important source of funding due to its flexibility and stability. As a relatively small proportion of the total funding sources (11.3%), it is greatly multiplied by the institution in its activity;
- The base funding for technology transfer activities – "CIT" – is a new and very important funding source received since 2019 to strengthen technology transfer capabilities, and represents 4.5% of the total revenues;
- EU Framework Projects are the largest projects in terms of funding volume. At the opposite end, other EU Cooperation Programmes fund typically small projects (with complex and often highly specific rules). R&D and Consulting Services are often short duration projects and therefore expected to be below average funding per project.
- Funding from uncertain projects represents 9% of the total funding, this increase in comparison with 2019 (6%) is mainly explained by the anticipation of this planning exercise by two months, leading to a greater level of uncertainty. Also natural is the fact that the majority of uncertain projects comes from R&D and Consulting Services because these have a much shorter contracting cycle, when compared with national and European funding programmes.

3.2.2 Clusters Indicators

This section presents in Table 3.8 and Figure 3.6 the funding by source and Cluster, providing an overview of their relative size and expected results planned for 2020.

Table 3.8 - Activity in projects by Cluster and funding source (Plan 2020)

Funding Source			Clusters			
			NIS	PE	ISE	CS
Firm Projects	PN-FCT	National R&D Programmes - FCT	2 655	536	770	979
	PN-PICT	National R&D Programmes - S&T Integrated Projects	0	0	0	0
	PN-COOP	National Cooperation Programmes with Industry	511	42	290	74
	PUE-FP	EU Framework Programmes	1 898	1 942	1 233	748
	PUE-DIV	EU Cooperation Programmes - Other	282	0	37	51
	SERV-NAC	R&D Services and Consulting - National	261	786	239	807
	SERV-INT	R&D Services and Consulting - International	327	28	0	10
	OP	Other Funding Programmes	64	349	7	159
		Total Firm Projects	5 996	3 683	2 576	2 829
		Uncertain Projects	467	14	947	483
		Total Funding	**6 463**	**3 697**	**3 523**	**3 312**
		Uncertainty (%)	7%	0%	27%	15%

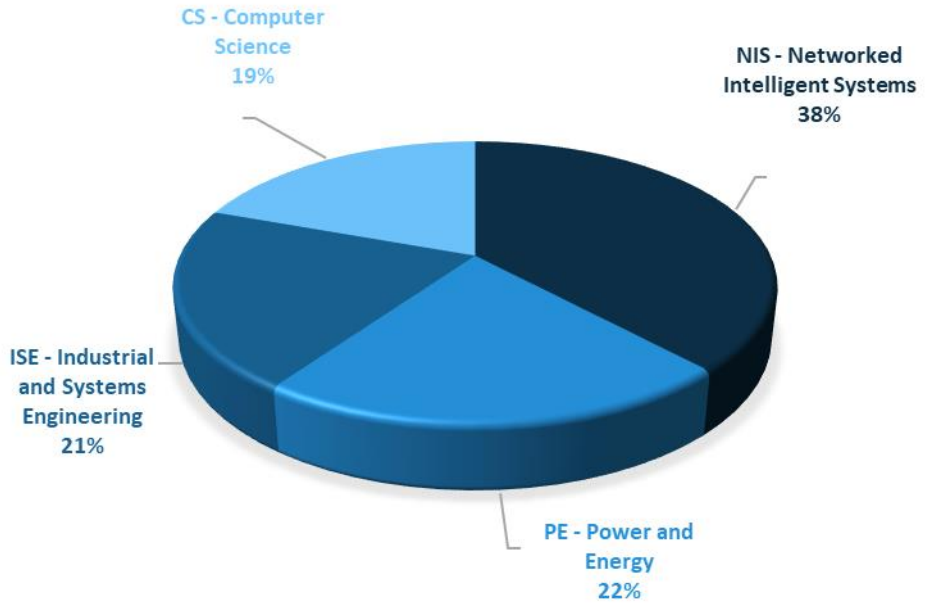


Figure 3.6 - Project Funding by Cluster (Plan 2020)

3.2.3 R&D Centres Indicators

A detailed view of the total funding by source per R&D Centre is given in Table 3.9 and Figure 3.7.

Table 3.9 - Project Funding (K€) and Uncertainty Analysis (Plan 2020)

Funding Source		Total (k€)	R&D Centre													
			CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	CSIG	LIAAD	CRACS	HASLAB	Special Projects
Firm Projects	PN-FCT	**4 940**	674	250	1 559	172	536	124	204	433	9	368	304	19	288	0
	PN-PICT	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PN-COOP	**916**	232	0	268	11	42	214	38	38	0	45	27	0	2	0
	PUE-FP	**5 822**	297	225	1 376	0	1 942	540	367	194	132	571	46	1	130	0
	PUE-DIV	**369**	0	78	204	0	0	0	20	1	16	33	0	18	0	0
	SERV-NAC	**2 093**	210	0	51	0	786	41	100	90	8	151	196	71	389	0
	SERV-INT	**365**	115	0	212	0	28	0	0	0	0	10	0	0	0	0
	OP	**1 171**	64	0	0	0	349	0	7	0	0	61	2	0	96	591
	Total Firm Projects	**15 675**	**1 592**	**552**	**3 670**	**182**	**3 683**	**919**	**737**	**756**	**164**	**1 238**	**576**	**109**	**905**	**591**
Uncertain Projects		**1 926**	**151**	**108**	**143**	**65**	**14**	**588**	**179**	**148**	**31**	**225**	**65**	**12**	**181**	**15**
Total Funding		**17 601**	**1 743**	**660**	**3 814**	**247**	**3 697**	**1 507**	**916**	**905**	**196**	**1 463**	**641**	**122**	**1 086**	**606**
Uncertainty (%)		**11%**	9%	16%	4%	26%	0%	39%	20%	16%	16%	15%	10%	10%	17%	2%

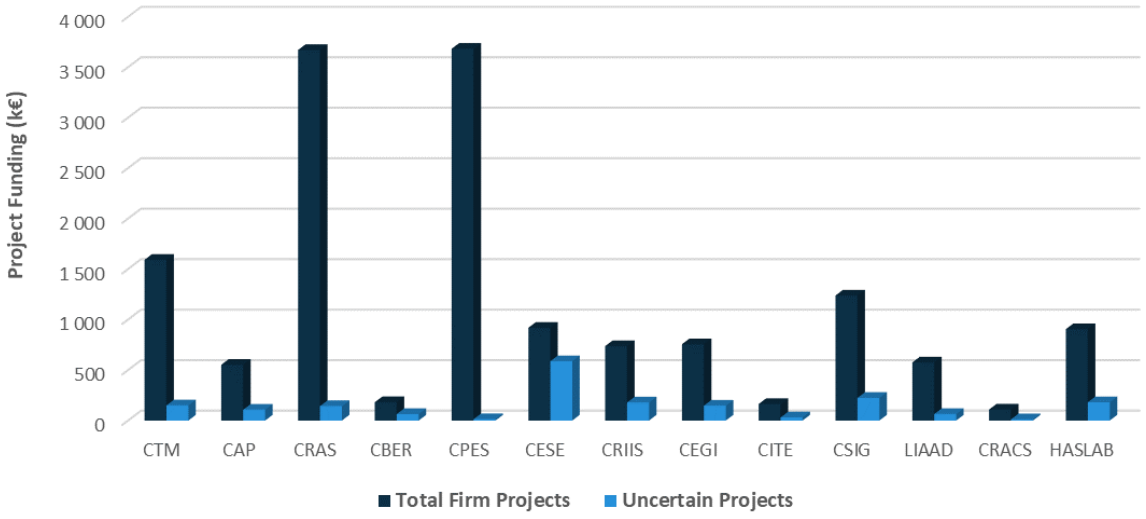


Figure 3.7 - Project Funding (K€) per R&D Centre (Plan 2020)

Table 3.9 shows that uncertain projects represent 11% of the total funding from projects, although the relative weight between uncertain and firm projects is quite variable across the R&D Centres, as shown in Figure 3.7 and Figure 3.8.

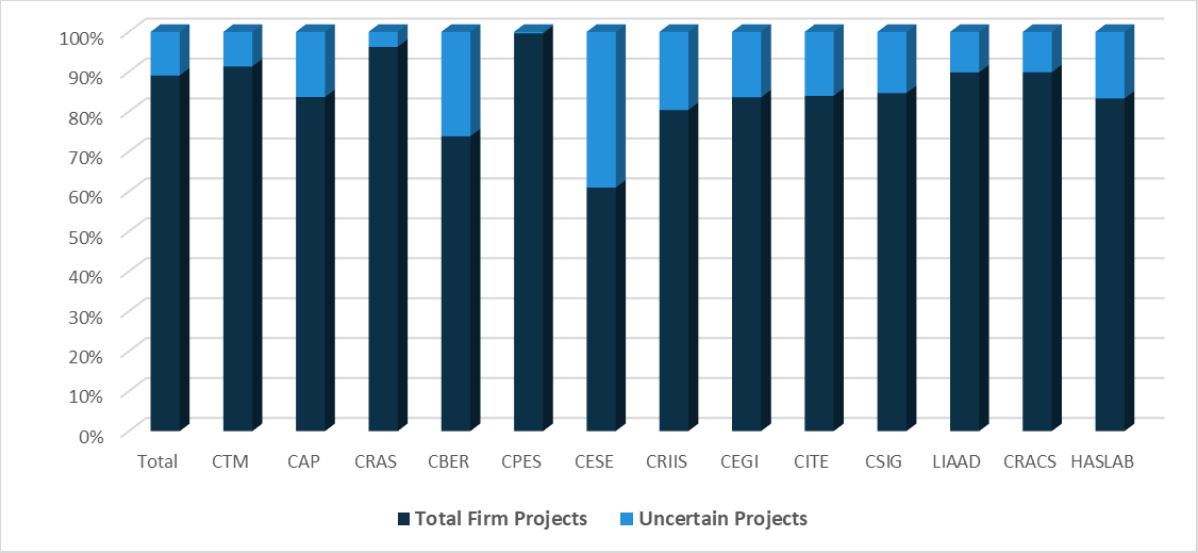


Figure 3.8 - Uncertainty Analysis by R&D Centre (Plan 2020)

3.3 Publications

3.3.1 Global Indicators

Table 3.10 and Figure 3.9 show the number of INESC TEC publications and the expected evolution for 2020.

The number of publications for 2018 has been obtained from different indexing sources (ISI, SCOPUS and DBLP) gathered by the Authenticus platform. Publications with authors from different Centres are counted individually in each Centre of the authors, but the institutional total removes repetitions of the same publication.

Values for 2019 and 2020 have been estimated using a bottom-up approach and need to be used with caution. Since it was not possible to remove potential duplicates, the totals obtained summing the values provided by each Centre were reduced by a same factor derived from 2018 publications (about 6% of the publications are authored by researchers from more than one Centre).

Table 3.10 - Number of INESC TEC Publications

Publication Type	2017	2018	2019	2020
Indexed Journals	318	312	310	346
Indexed Conferences	492	494	285	376
Books	1	7	6	6
Book Chapters	27	40	40	18

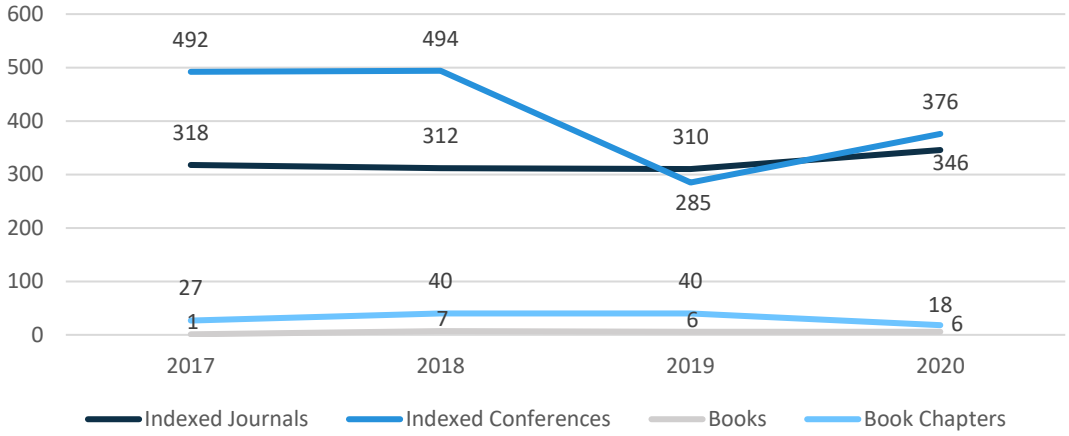


Figure 3.9 - Evolution of INESC TEC Publications

3.3.2 R&D Clusters Indicators

This section includes the Clusters main publication indicators, presenting an overview of their expected contributions planned for 2020.

Table 3.11 - Publications by Cluster and publication type (Plan 2020)

Publication Type	Clusters			
	NIS	PE	ISE	CS
Indexed Journals	101	60	77	131
Indexed Conferences	109	45	64	183
Books	1	0	1	4
Book Chapters	3	2	4	10

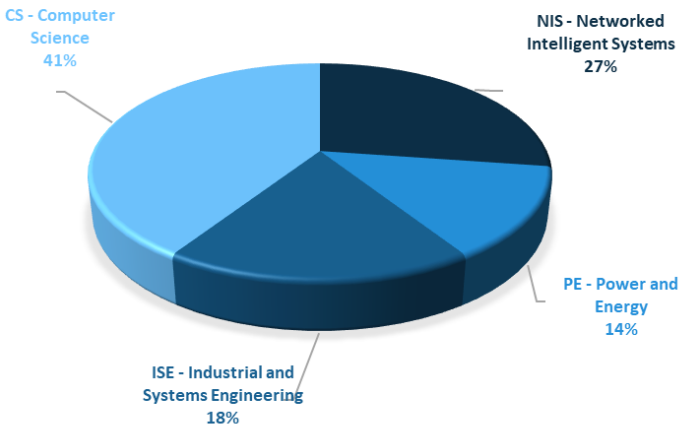


Figure 3.10 - Planned Indexed Articles by Cluster (Plan 2020)

3.3.3 R&D Centres Indicators

Figure 3.11 presents the number of indexed publications in journals and conferences per R&D Centre. The figures planned for 2020 are compared with previous figures in the presentation of each R&D Centre in Section 6.

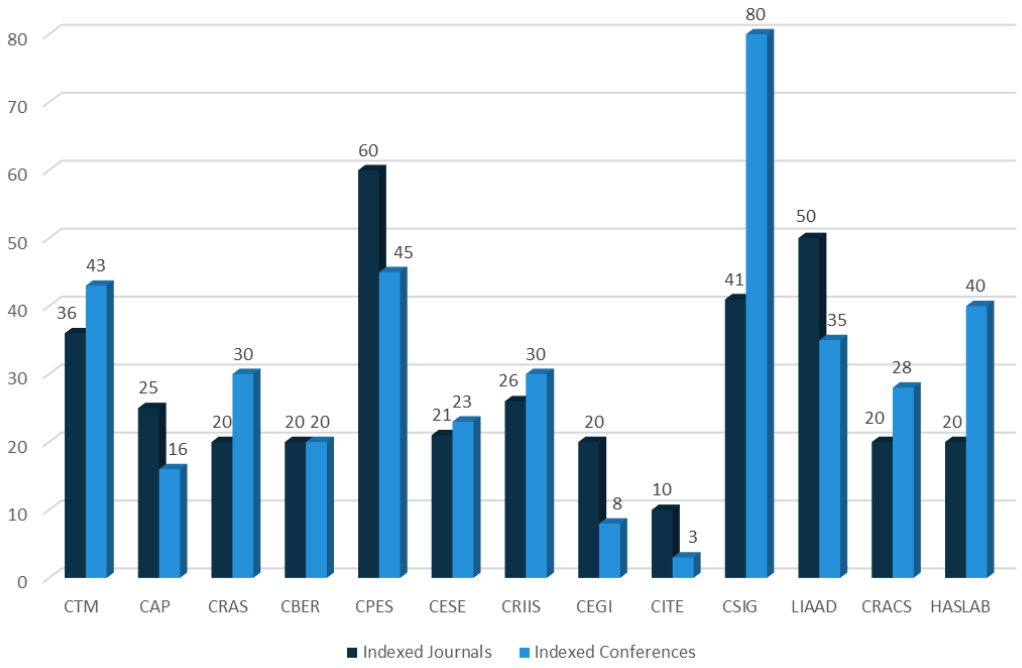


Figure 3.11 - Indexed Publications in Journals and Conferences (Plan 2020)

3.4 IP Protection, Exploitation and Technology Transfer

Table 3.12 - Results related with IP Protection, Exploitation and Technology Transfer

Type of Result	2018	2019	2020
Invention disclosures	15	9	15
Software copyright registrations	3	1	2
Patent applications	12	29	12
Licence agreements	1	1	7
Spin-offs	2	2	1

3.5 Dissemination Activities

Table 3.13 - Results related with dissemination activity

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	50
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	44
International events in which INESC TEC members participate in the program committees	198
Participation in events such as fairs, exhibitions or similar	45
Advanced training courses	28

Table 3.14 – Dissemination activities organized by INESC TEC's R&D Centres

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centres	33
Participants in the conferences, workshops and scientific sessions organised by the Centres	2 990
Advanced training courses organised by the Centres	28

3.6 R&D Clusters Activity Overview

Finally, Figure 3.12 presents an integrated overview about the dimension and activity of the four R&D Clusters - Networked Intelligent Systems (NIS), Power and Energy (PE), Industrial and Systems Engineering (ISE) and Computer Science (CS).

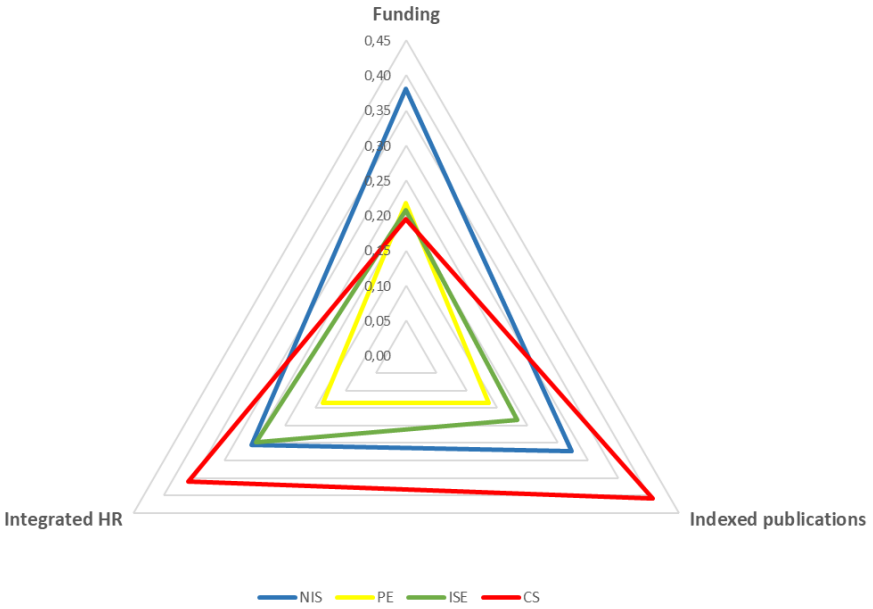


Figure 3.12 – Presentation of the R&D Clusters' dimension and activity (Plan 2020)

4 INESC TEC CLUSTERS

As mentioned in Section 2, research at INESC TEC is structured in four Clusters - Networked Intelligent Systems (NIS), Power and Energy (PE), Industrial and Systems Engineering (ISE) and Computer Science (CS), which are presented in the following sections.

4.1 NETWORKED INTELLIGENT SYSTEMS

Coordinator: Manuel Ricardo

Core Centres: Centre for Applied Photonics (CAP), Centre for Biomedical Engineering Research (C-BER), Centre for Robotics and Autonomous Systems (CRAS), and Centre for Telecommunications and Multimedia (CTM).

4.1.1 Presentation

The Cluster on **Networked Intelligent Systems (NIS)** envisions to work "*towards autonomous networked intelligent hybrid systems enabled by ubiquitous sensing and processing of information*". NIS plays an important role in scientific areas related to:

- **Networking**, by interconnecting agents which interact and communicate mainly over wireless networks;
- **Intelligence**, by developing the capability of agents to sense, perceive, navigate and learn from past experiences in order to enhance their ability to meet objectives;
- **Systems**, by aggregating sensing, computation, communications and navigation components into agents and interrelating agents so that they can inter-operate in environments such as the deep sea or the human body.

NIS consists of 4 INESC TEC research centres addressing complementary scientific domains:

- **CAP** addresses optical sensing, optical imaging, and microfabrication of devices;
- **C-BER** addresses bio-instrumentation, biomedical imaging, and neuro-engineering;
- **CRAS** addresses robotics and autonomous systems operating in complex environments for data gathering, mapping, inspection, surveillance, and intervention;
- **CTM** addresses electronics, radio and optical communications, communications networks, multimedia technologies, computer vision, and intelligent information processing.

NIS uses algorithms, statistics, simulation and machine learning to address problems related to both fundamental theory and systems implementation. The application domains of NIS scientific results include underwater robotics for environment protection and resource exploitation, flying or terrestrial robotics for surveillance of borders, distributed sensing for monitoring intelligent cities, multimedia content analysis, multi-sensor monitoring of human health, and distributed robotics for provisioning of adaptive telecom infrastructures. Therefore, the research activities of NIS are related to the field[2] of Engineering and Technology including the following: 2.2 - Electrical engineering, Electronic engineering, Information engineering; 2.6 - Medical engineering; 2.7 - Environmental engineering. The publications of NIS contribute to scientific fields related to Signal Processing, Electronics and Computers, Interfaces and Multimedia, Telecommunications, Intelligent Systems, and Control and Robotics.

The Cluster NIS Council is composed of the following members: Manuel Ricardo (coordinator), Andry Pinto (assistant coordinator), Aníbal Matos, Aurélio Campilho, Carlos Pinho, Eduardo Silva, Filipe Ribeiro, Hélder Oliveira, Ireneu Dias, Jaime Cardoso, João Paulo Cunha, Luís Pessoa, Paula Viana, Paulo Marques, and Rui Campos.

[2] *DSTI/EAS/STP/NESTI(2006)19/FINAL, Working Party of National Experts on Science and Technology Indicators, http://www.oecd.org/science/innovationinsciencetechnologyandindustry/38235147.pdf*

4.1.2 Context

The technology research is entering on an Era[3] where (1) public funding structure is being replaced by challenge–driven funding calls released by public organizations to foster science and innovation as a governmental response to grand challenges such as, climate change, energy and food scarcity, (2) an increasing focus on applied research motivated by commercial targets is predicted due to industry-funded research that will be soon a main source of R&D funding for universities and institutes, and (3) a state of hyper-competition where the pressure to demonstrate research impact will continue to rise.

The reports from the 'Future Today Institute'[4] and OCDE[5] confirm that emerging technology empowering digital experiences have steadily disrupted organizations, global markets and people's health, and it will likely influence business, government, education, media, and society in the coming years. Relevant research areas include the following:

- Computer vision appears in many forms, being identified as a key technology in a wide range of fields, such as recognition systems, agriculture, advertising, media industries, entertainment, broadcasting, health, transportation, or the defence and national security sector. Robotic's vision will play an important role in autonomous vehicles, allowing the interaction of the robots in human environments. But impact will be broader and affect other sectors of the society as the huge amount of multimedia information made available, together with the growing sensorization of the electronic gadgets and of the environment, creates new opportunities for the creation of context and semantically aware multimedia applications.
- Autonomous Underwater Vehicles (AUVs) are explicitly identified as a trend for a host of purposes, from environmental mapping to safety and security. Likewise, autonomous ships, autonomous land vehicles, and drones also play a key role in several domains, from construction, city planning, agriculture, defense, and national security, among many others. Autonomous vehicles are now a trend in the automobile industry, presenting relevant scientific challenges.
- Biosensors find a central role in bio-interfaces laminated onto our skin, and health technologies and wearables. Ultrathin electric mesh, pressure-sensitive fabrics, optical sensors, and bio-acoustic sensing arrays will soon provide a persistent window into our health.
- Biomedical engineering is a relatively new and interdisciplinary field. Sitting at the cross-section of medicine, biological science, and engineering, biomedical engineers design the advances in equipment, devices, and computer systems to improve human health. The future of medicine will mean personalised medicine, hand-held diagnostic platforms, wearable monitoring devices, and other technological advances to make healthcare more effective, cheaper and convenient.
- Communications have relevant challenges related to the design of networking solutions that address the exponential traffic growth in the Internet, namely video and bandwidth-hungry applications, and the emerging communication needs in remote environments, namely at sea. Softwarization of the communications networks, from the application down to the physical layer, will change the current networking paradigm. High flexibility and real-time reconfiguration of the communications network according to the context will become a must. As such, the novel networking solutions need to be smart and take advantage of Software Defined Networking, Network Function Virtualization, and machine learning techniques to make wireless networks context-aware and reconfigurable in real-time.

According to ESPAS' (European Strategy and Policy Analysis System) projections to 2030, the technological progress is expected particularly with regard to Internet of Things (IoT), AI, advanced robotics, wearables, 5G communications, and 3D printing. Moreover, The BOHEMIA study[6] is the main EU strategic foresight study in

3 Research futures, Drivers and scenarios for the next decade Full report, Published by Elsevier, February 2019, www.elsevier.com/connect/elsevier-research-futures-report

4 https://futuretodayinstitute.com/2018-tech-trends-annual-report/

5 OECD Science, Technology and Innovation Outlook 2016, https://www.oecd-ilibrary.org/docserver/sti_in_outlook-2016-5-en.pdf?expires=1572433337&id=id&accname=oid029566&checksum=0F65E3A701F36B52C9C7037E1EFFC62A

6https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/support-eu-research-and-innovation-policy-making/foresight/activities/current/bohemia_en

support of the Commission's proposal for Horizon Europe - the EU framework program for research and innovation 2021-2027. As part of its recommendations, the BOHEMIA study identified 19 likely future scenarios with disruptive implications and associated priority directions for EU research and innovation. They cover a variety of potential future scenarios including the desirable, challenges and threats.

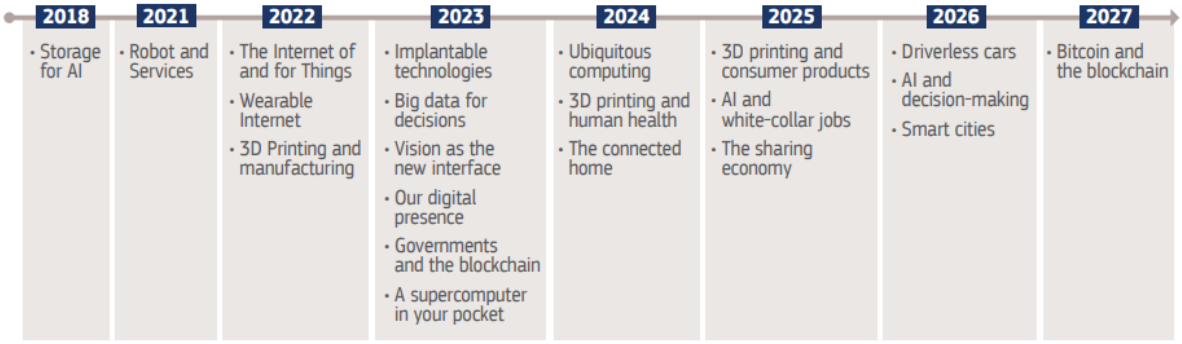


Figure 1- Technology tipping points. Source: World Economic Forum

Among those 19 scenarios, it is worth highlighting those, which are aligned with the NIS vision:

- **The electrosphere of sensors**. Miniaturization and energy self-sufficiency of microsensors allowing the generation of massive amounts of data. As also clear from the targeted scenario, *"The benefits of diverse sensors and networks across the key policy fields can hardly be overemphasized. Remote sensing is the front end of the big data revolution, a field of fierce international competition."*
- **Ubiquitous expert systems**. Expert systems used routinely to predict and manage all kinds of situations.
- **Precision medicine**. Using a variety of technologies to anticipate and cure illnesses.
- **Assisted living**. New services and technologies such as robot assistants, and virtual trainers.
- **Emotional intelligence online.** Data availability and the progress in processing capabilities have led to a qualitative leap in the understanding of emotions. Sophisticated emotion markers and the means to interpret them are widely available. They include many face/gesture-recognition devices embedded in personal systems, such as wearables and portable brain-reading helmets, as well as third party systems such as cameras and other scanners.
- **New Knowledge Systems.** Abundant data, real-time and historical, are easily accessible through AI devices. As knowledge becomes pervasive people lead more productive fulfilling lives.

4.1.3 Vision and contribution

4.1.3.1 Future vision of the domain

The Cluster NIS will work towards futuristic scenarios in which collections of cooperative systems, communications enabled and carrying advanced sensors, collect information also in extreme environments such as the deep sea or the human body, and process it by using artificial intelligent tools. The Cluster NIS research activities, for the next five years, will be dominated by 3 main vectors:

- **Smaller, long endurance, collaborative and intelligent systems.** For the coming years, several advances and breakthroughs are expected in the field of networked devices. It is expected that robots will sense, communicate in real-time, cooperate and enter into previously unreachable environments. Bio-sensing will evolve from macro to nano dimensions, smart peripherals will appear in large number, and medicine will become more personalized.
- **Ongoing convergence of deep learning and communications.** Besides transporting significant amounts of data, today's communications systems also generate huge amounts of data which can be used to enhance the design and management of communications networks, when combined with advanced machine learning methods. Furthermore, recently developed end-to-end training procedures offer new

ways to jointly optimize the components of a communications system. Also, in emerging application fields of the communications technology, such as smart cities or internet of things, machine learning methods are of central importance.

- **The ubiquity of Computer Vision.** The current wave is the integration of AI in many areas of our society. Computer vision, powered by deep learning, will reach an high level of maturity and integration. This will impact on the amount of information that can be provided and used by intelligent systems to detect, recognize and understand situations, events or threats, and to automatize preventive actions or interact with elements in extreme environments.

4.1.3.2 Cluster contribution

The **main research goals of NIS until 2025** are the following:

- **Graphene based devices and antennas.** To develop novel sensing devices and antennas integrating optics and graphene.
- **Optical and electrical microdevices for theranostics applications.** To combine diagnostic and therapeutics capabilities of novel devices for personalized health care.
- **CAD Cancer.** To develop decision support systems, with a performance similar to expert medical doctors, on the detection and diagnosis of breast and lung cancer.
- **Content Manipulation.** To devise methodologies and develop algorithms and tools for context-metadata-aware automatic content manipulation.
- **Self-learning Communications for Immersive and Extreme Environments**. To take advantage of Software Defined Antennas, Radios, Networks, context-aware applications, and Machine Learning and Artificial Intelligence techniques as major tools towards the holistic optimization of the communications stack.
- **Autonomous underwater inspection and intervention system.** To develop a multi-robot long term system for inspection and maintenance of underwater infrastructures.
- **Deep ocean robotic observatory.** To develop a deep ocean observatory based on robotic assets - landers, profilers, AUVs - and auxiliary devices.

The Cluster NIS is creating relevant experimental platforms which will help meeting some of the above goals:

- **The TEC4SEA**. It is a unique and pioneer infrastructure in Europe to support research, development, and test of marine robotics, telecommunications, and sensing technologies for monitoring and operating in the ocean environment. The first phase of the infrastructure implementation (specification, procurement, deployment and validation) will be completed in 2020, and includes back-office laboratories upgrade, underwater remote facilities (mobile robotic and fixed platforms) and support and control facilities (ocean, land-to-ocean, and on-shore operations support). This infrastructure will contribute to establish INESC TEC as an international reference in R&D technologies and solutions to address the deep-sea challenges, as well as empowering the Sea Economy through sustainable approaches for exploring and exploiting living and non-living ocean resources.
- **The ATLANTIS**. It is a pioneer pilot infrastructure capable of demonstrating key enabling robotic technologies for inspection and maintenance of offshore wind farms. ATLANTIS will be installed in Portugal from 2020 to 2023, and it will play an important role in connecting the market needs and user's expectation to robotic applications from the research, technology developers and system integrators, by accelerating the roll-out of maritime robotic technology to end-users through real-world demonstrations open to all communities. The emphasis of ATLANTIS will be on demonstrating and validating capabilities, which will provide a context and real data to support further developments related to all research lines of the Cluster NIS.

4.1.4 Cluster research lines

A Research Line in Cluster NIS can be characterized by a set of related research topics, each of them addressed by a group of researchers. The Clusters NIS has 4 main Research Lines: Sensing, Communications, Computer Vision, and Autonomous Systems.

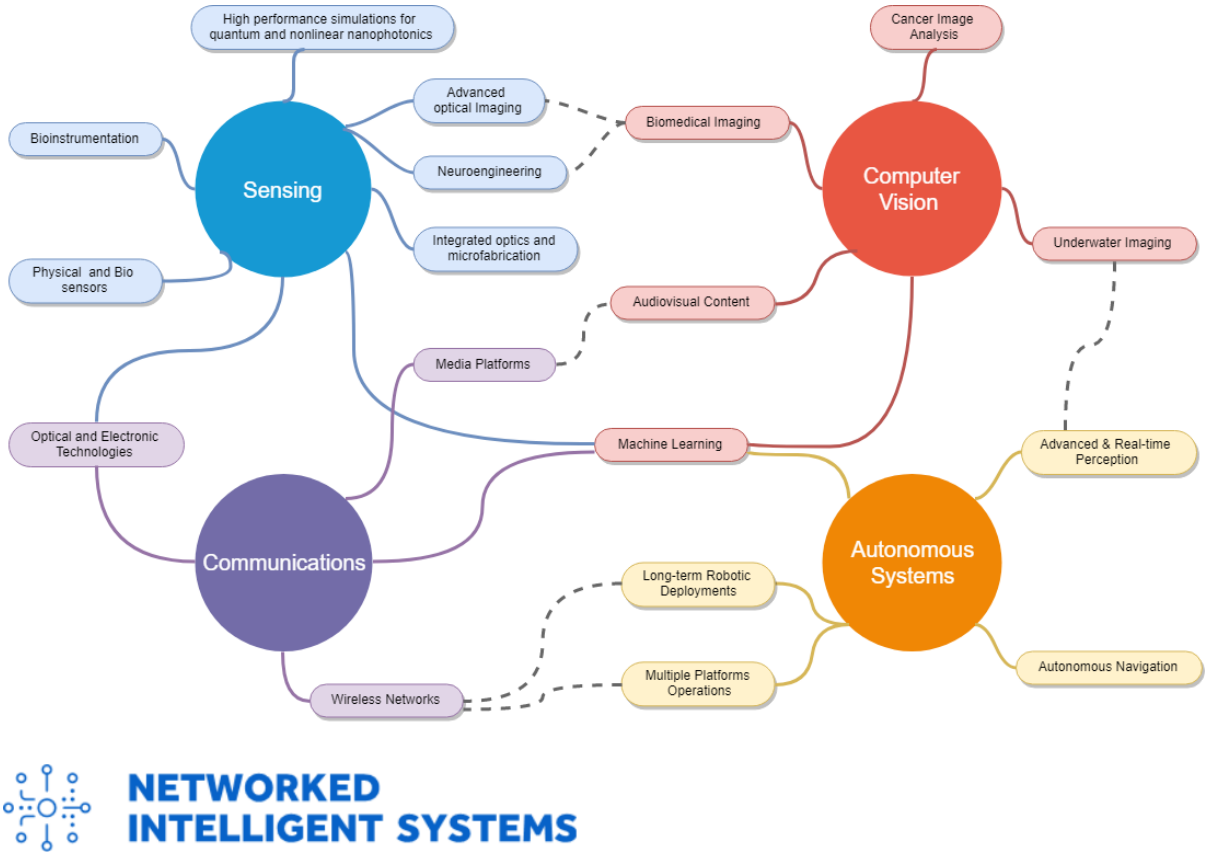


Figure 2 - The NIS Research Lines and their related Research Topics

RI1 - Sensing

Definition of the Research Line

This research line focuses on developing novel sensing solutions targeting ultra-high sensitivity sensors for structural health monitoring, biomedical and environmental applications. Novel approaches combining several principles and methods, smart spectroscopy (LIBS, UV-VIS coupled with artificial Intelligence algorithms), low power implantable sensing and neurostimulation microsystems, wearable and human implementable devices, various imaging principles and techniques (hyperspectral, digital holography, LIDAR 3D, turbid lens), compressive sensing techniques, with the potential of being integrated with hybrid microfabricated devices, are the core of the research line activity.

Alignment with the Cluster vision

The RL contributes to the Cluster vision by means of the novel sensing components, algorithms and its combinations that constitute advanced perception systems to interface with real-world systems operating in life and biomedical applications and extreme environments, providing new sources of information, relevant to Precision Medicine, Assisted Living, and Ubiquitous expert systems and autonomous systems.

Main research challenge

The main challenge is the design of multi-parameter sensing devices and systems based on multi-technology platforms, artificial intelligence and signal processing algorithms and applying various sensing and detection principles in a synergetic way.

Objectives for 2020

The main objectives of this RL are the following:

- **Optical-graphene-microphone.** To fabricate graphene oxide films in optical fibers by chemical processes and use these sensors for ultrasonic and optical microphones applications;
- **Optofluidics and sensing.** To fabricate hybrid devices that combine optical layers with fluids handling capabilities (made by femtoetching), tri-dimensional structures using multi-photon polymerization, structures supporting whispering gallery modes, together with functionalities such as micromanipulation and analysis of living cells. Other sensing mechanisms based on strong optical localization and quantum effects to increase sensing sensitivity will be pursued;
- **Low power micro sensor human implementable.** To develop low power implantable sensing and neurostimulation microsystems, wearable and human implementable devices, that enable personalized medicine as well as integrated diagnostics and therapeutics.

RI2 - Communications

Definition of the Research Line

This research line is focused on devising solutions for the communications systems of the future, from the physical layer to the networking layer to the application layer, considering both terrestrial and maritime environments. At the physical layer, it considers the development of miniaturized antennas and antenna arrays up to sub-THz, optical-wireless interfaces, signal processing techniques with a special focus on localization and beamforming, and embedded and adaptive systems based on dynamic reconfiguration and adaptive transparent acceleration. At the networking layer, this RL is focused on wireless networks and mobile communications, extending infrastructure networks and enabling the Internet of Everything in terrestrial and maritime environments, contributing to truly ubiquitous connectivity. This includes the design of novel algorithms and mechanisms and requires theoretical and simulation modelling, implementation, and experimental evaluation of communications networks and their elements. At the application layer, the RL aims to develop new strategies for capturing, producing, sharing and accessing information from users' own perspectives, in scenarios such as social media, creative environments, media industries, culture, sports, industrial systems, robotics, and wellbeing, including the delivery and access to content through different networks and distribution mechanisms, creating interactive, virtual, and immersive environments.

Alignment with the Cluster vision and contribution

The RL contributes to the Cluster vision by means of the hardware and wireless networking components that enable the sensing, computing, and communications subsystems forming the networked intelligent systems, and the new approaches to deal with multimedia content in heterogeneous environments, supporting different communications networks and devices.

Main research challenge

The main challenge is the design of self-learning communications systems that can support different types of services and data in Immersive and Extreme Environments, considering that the current learning algorithms in mobile and wireless systems are immature and inefficient.

Objectives for 2020

The main objectives of this RL are the following:

- **Novel antennas and optical-wireless interfaces.** Prototype demonstration of (1) antenna radiation pattern steering control through an FPGA implemented digital beamforming method using a 16-element

antenna array operating at 5 GHz, (2) sub-THz (300 GHz) 1x4 antenna array substrate integrated with Uni-Travelling Carrier Photodiode (UTC-PD) sources for high-speed optical-wireless interfaces and (3) electrical and optical modulation of a 10 GHz resonant tunnelling diode photodiode oscillator with 64QAM-OFDM modulation;

- **Flying Access Point Placement taking advantage of Machine Learning Techniques.** To develop novel algorithms and mechanisms enabling self-learning wireless networks in terrestrial and maritime environments, including a a multi-UAV placement algorithm based on deep reinforcement learning, a height optimization algorithm for aerial networks in maritime environment, and a flying gateway positioning algorithm for flying backhaul multi-hop networks;
- **Tool for automatic content creation.** Devise methodologies, algorithms, tools, and approaches for context-metadata-aware automatic content creation and multimedia data visualization and content navigation.

RI3 - Computer Vision

Definition of the Research Line

Computer Vision is a key technology in a wide range of fields. In the context of NIS, Computer Vision encompasses various fields including health, multimedia and robotics. In health, computer vision and machine learning, powered by deep learning, we will conceive and develop algorithms and architectures for the early detection, diagnosis and prognosis of different types of cancers. In multimedia, we will develop algorithms to enable multimedia content understanding, including identification and recognition of objets, regions of interest, relevant features and events that enable infering high level concepts from the content. In robotics, underwater imaging solutions and algorithms will be investigated for improving the reliability of perceptual 2D/3D information captured by AUV/ROV during tasks related with 3D mapping, object recognition and manipulation, and close-range navigation.

Alignment with the Cluster vision and contribution

Intelligent processing of image data is fully aligned with the Cluster vision allowing to make contributions in the fields of health, multimedia and robotics. In this RL we develop artificial intelligence methodologies, computer vision and multi-modality big data approaches. Data to be used in the different scenarios may include images, videos, audio, liquid biopsy, biological data and sensor data. This holistic view enables us to learn powerful features and understand relationships between multi-sensing and multi-modal settings.

Main research challenges

There are several research challenges in Computer Vision. Particularly within the NIS Cluster we face the following challenges: 1) Create explainable and uncertainty aware deep learning architectures; 2) Conceive and create intelligent computer vision architectures achieving functionalities and performances close to humans; 3) Conceive and create intelligent approaches to enable inferring high level concepts by using a multimodal approach.

Objectives for 2020

The main objectives of this RL are the following:

- **Cancer detection and diagnosis based on artificial intelligence and computer vision.** To develop AI and CV methods for the design of CAD systems for early detection, diagnosis and genotype cancer prediction.
- **Improving Multimedia content understanding for enhanced personalised access and re-purposing.** To develop methodologies and develop algorithms for multimedia content description that enable context-metadata-aware content access, manipulation and creation.
- **Improving the 3D visual information based on AI algorithms for underwater manipulation.** To develop AI methods for combining sparse 3D with texture information for enhancing both precision and accuracy of 3D perception obtained by a new version of MARESye imaging system, a innovative hybrid imaging system for 2D/3D visual acquisitions for harsh underwater environments.

RI4 - Autonomous Systems

Definition of the Research Line

This research line addresses the development of innovative robotics solutions for operation in complex environments – relevant examples are underwater environments, and particularly deep-sea water. Novel developments in multi-sensor perception, cooperative robotic systems, navigation, guidance and control, robotic autonomy, and data fusion are the main research topics included here. This research line also includes activities related to the development of key components of field going robotic platform addressing topics such as persistent operations, underwater robotic data and energy mules, operations in non-segregated space, or collaborative mapping and learning.

Alignment with the Cluster vision and contribution

The RL contributes to the Cluster vision in two different levels. Due to its integrating nature, autonomous robotic solutions require and benefit with the developments from the other NIS research lines. However, more significantly this RL has multiple connections with the other RLs in cutting edge research topics such as machine learning, advanced and real time perception or long term robotic developments.

Main research challenges

The main challenges are related to the design of autonomous robotic solutions capable of robustly operating in harsh and dynamic environments with great levels of efficiency and effectiveness. Such solutions require the development of novel perception algorithms, navigation and guidance solutions, as well as autonomous command and control systems.

Objectives for 2020

The main objectives of this RL are the following:

- **Autonomous navigation**. Development of navigation systems for operation in underwater confined volumes; development of short-range acoustic high precision positioning systems;
- **Long-term deployments**. Development and field-testing of docking systems for AUVs;
- **Platforms and operations.** Implementation of a robotic lander network; field-testing of the cooperative operation of surface and underwater vehicles for deep-water operations.

4.2 POWER AND ENERGY

Coordinator: Luís Seca

Core Centres: Centre for Power and Energy Systems (CPES)

***Associated Centres**: Centre for Industrial Engineering and Management (CEGI), Centre for Telecommunications and Multimedia (CTM), Artificial Intelligence and Decision Support Laboratory (LIAAD), Centre for Robotics Autonomous Systems (CRAS), Centre for Information and Computer Graphics Systems (CSIG), High-Assurance Software Laboratory (HASLab), Centre for Enterprise Systems Engineering (CESE).*

4.2.1 Presentation

The Cluster is focused on traditional and emergent areas of power and energy systems, for planning and operation purposes, with an emphasis on renewable energy sources (RES) integration, electric vehicles (EV) deployment, distributed energy resources (DER) management, demand response (DR), smart grids and energy analytics, through steady-state and dynamic network analysis, reliability models and tools, optimization, soft computing and data science.

CPES is the core Centre of the Cluster, as it is clearly, where the sector critical mass is concentrated, but the evolution of the energy system, particularly the electrical power system, has supported the involvement of other competences, held by associated Centres, due to the multidisciplinary nature of the problems and opportunities to address. There are already examples of this collaboration and joint projects, in the areas of information and communication technologies (CTM), data science (LIAAD), data platforms and hubs (HASLab), asset management (CEGI) and combined energy and process optimization in industry (CESE). More than sharing projects, the goal is to foster a multidisciplinary approach to support current applied research and technology transfer, but most of all, to design the scientific strategy for this particular domain, distributed among the different Centres of the Cluster, that will guarantee the creation of new knowledge to support the future challenges of a digital and decarbonized energy system.

The Cluster coordination was recently changed, and so the council is still under invitation, being the objective of the coordinator to start 2020 with a new team, including representatives from other centers to foster a truly multidisciplinary approach to the topic. To support the Cluster activity, David Rua (PhD from CPES) was invited to assist the coordinator.

4.2.2 Context

The European Energy Policy[7], in 2007, established four main goals: (1) **internal energy market** to ensure fair and competitive energy prices for consumers, fight energy poverty and promote cross-border trade, (2) **secure energy supply**, (3) **reduce greenhouse gas emissions** with investment in energy efficiency and RES and, (4) **develop energy technologies** according to the strategy outlined in the European Strategic Energy Technology Plan (SET Plan).

The SET Plan identified research, development and innovation (RD&I) priorities for public and private partnership in order to achieve EU climate and energy goals and to strengthen industrial competitiveness. In the past 10 years, RD&I achievements were observed across 14 low-carbon energy technology sectors the SET Plan covers[8], such as RES technologies, smart cities and communities, energy efficiency in buildings and industry, e-mobility. In September 2015, the European Commission (EC) published a Communication[9] defining the new European research and innovation strategy for the coming years, named integrated SET Plan. This document defined 10 actions to accelerate the energy system transformation and create jobs and growth. Some of these actions are: reduce the cost of key RES technologies; create technologies and services for smart homes; increase the

[7] An energy policy for Europe. COM(2007) 1 final - Not published in the Official Journal
[8] Quental, N., et al. (2017). The Strategic Energy Technology Plan. Luxembourg: Publications Office of the European Union
[9] Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation. C(2015) 6317 final

resilience, security and smartness of the energy system; make European industry less energy intensive and more competitive: increase competitiveness in the global battery sector to boost e-mobility.

In November 2016, the EC proposed an ambitious "Clean Energy for All Europeans" package[10] with three main goals: **priority to energy efficiency**, global **leadership in RES** and **consumer's empowerment**. The result was a legislative framework with eight proposals to facilitate the clean energy transition and that will define the European Union (EU) research agenda for a long-term horizon. **Energy efficiency** is recognised as a source of energy and a 30% binding target will be defined for 2030 at EU level (amendment of Directive 2012/27/EU). The "**Energy Performance of Buildings**" Directive (2010/31/EU) was also amended by 2018/844/EU to introduce targeted improvements with the vision of a decarbonized building stock by 2050, encouraging the use of information and communication technology (ICT) to optimize its operation and interact with the grid. For **RES**, a new Directive will set new and binding targets for 2030 of at least 32% and increase the level of ambition for the transport, heating and cooling sectors. The **electricity market design initiative** aims to adapt the current market rules to new realities (e.g., local flexibility management), whilst empowering consumers (e.g., local energy communities, new energy services) and extracting full benefits from cross-border competition.

As consequence of this EU energy policy, several countries are increasing RES integration significantly, which is leading to fundamental changes in European electricity markets and power systems, motivated by its variability and uncertainty, as well as by its decentralized nature. These characteristics require new and flexible rules for operating electrical grids and energy markets, which must enable a cost-effective and transparent deployment of these renewable based technologies.

In order to support this long-term vision, the EC promoted **Vision 2050**[11] elaborated by the European Technology and Innovation Platform of Smart Networks for Energy Transition, which identifies the following R&D challenges for the decades to come: (1) integrated energy systems (e.g., storage, power conversion, demand flexibility) with local/regional black-start and self-healing capabilities; (2) integration of mitigation measures in power system operation and planning under adverse weather and other hazards; (3) seamless operation through fully interoperable and networked sub-systems allowing the coupling of all energy carriers (e.g., electricity, heat, gas); (4) peer-to-peer transactions integrated with centrally and locally-controlled electricity grids.

The building blocks of this **Vision 2050** are:

a) **Cost-effective integration of the different energy networks** and using new infrastructures for mobility;

b) Higher degree of **automated management and control of all energy network** users;

c) **Efficient wholesale markets** in a context of nearly **100% RES** mix;

d) Development of **local energy markets** providing high quality and economical supply for local prosumers;

e) **Digitalization** to support the provision of **new services**, while ensuring **data privacy** and ownership for all stakeholders and **enhancing cybersecurity;**

f) **Development of infrastructures to accommodate high penetration of RES** with the associated power electronics, monitoring and control equipment and to exploit available pan-European grid capacities;

g) **Efficient use of energy in different sectors**: buildings, industry agriculture, transports.

This vision traces one core concept for the energy system of the future, which is **Digitalization**. In this logic, the Digital Single Market[12], adopted in May 2015, recognises the **major role of ICT in improving the energy efficiency and the impact on climate change**[13]. **Standardization** of solutions and the **interoperability** across services and

[10] Clean Energy for All Europeans, https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[11] Bacher, R., de Nigris, M., Peirano, E., et al. (2018). ETIP SNET Vision 2050. INTENSYS4EU Project and ETIP SNET.
[12] A Digital Single Market Strategy for Europe, COM/2015/0192 final
[13] Mid-Term Review on the implementation of the Digital Single Market Strategy A Connected Digital Single Market for All. COM(2017) 228 final

datasets are key concepts towards this economy. This digitalization priority is also highlighted by several European associations such as EDSO for Smart Grids[14], EURELECTRIC[15] and ENTSO-E[16].

In **Portugal**, investment in **energy efficiency** and **RES** remains a priority as specified in the National Research and Innovation Strategies for Smart Specialization (**RIS3**) and in the National Strategy for Energy (**ENE 2020**), that resulted in the establishment of the **PNAEE** (National Action Plan for Energy Efficiency) and the **PNAER** (National Action Plan for Renewable Energy). Recently, the renewable energy association (APREN) published a study showing that hydropower, onshore wind and solar PV, together with offshore wind, are a cost-effective solution in scenarios of higher decarbonization[17]. Moreover, the National energy sector is entering in a key stage with the impending roll-out of the smart metering infrastructure, concession of low voltage grids and pilots promoted by the Energy Regulator about dynamic network-use tariffs and flexibility from large consumers.

4.2.3 Vision and contribution

4.2.3.1 Future vison of the domain

The PE Cluster vision is aligned with the EU policies for digitalization, energy efficiency and increase RES integration, as described below in the following strategic research vectors. These vectors highlight the main challenges envisaged by the core Centre and define the requirements that other scientific competences, located in the associated Centres, need to develop to be able to respond to the future requirements of the sector.

TRANSFORMING THE ENERGY SECTOR THROUGH SYNERGIES BETWEEN ADVANCED MATHEMATICAL MODELLING AND DIGITAL TECHNOLOGIES

The digitalization of the energy sector requires a multidisciplinary approach and co-creation of new business models. Technology from other domains, namely internet-of-things (IoT), sensors, blockchain and big data platforms, need to be adapted and, in some cases, enhanced to comply with specific requirements and contribute to consumer empowerment, feasibility and replicability of new business models, smart grids and buildings. Digital solutions provide additional monitoring and control capabilities that create technical conditions for new business models, enable different stakeholders to create their value, and simultaneously maintain high levels of cybersecurity and data privacy in critical infrastructures like the electrical grid.

Nevertheless, digital technologies are only a fundamental infrastructure to integrate advanced mathematics[18], such as mathematical distributed optimization, data-driven optimization, hybridization of classical mathematical optimization, metaheuristics and/or machine learning, data assimilation and control theory. Basic research in this area will increase the competitiveness of the PE Cluster and its Centres and materialize the application of artificial intelligence (AI) in the energy domain, covering human-centric and grid-centric use cases. To maximize the R&D impact in a sector characterized by several cognitive bias from decision-makers and to have steep learning curves, R&D in data visualization, advanced training procedures for human operators (e.g. augment and virtual reality) and novel cost-benefit and multicriteria analysis methodologies for new technology, are essential. Finally, scalability is a critical barrier and should be tackled at low TRL, e.g. through high-performance computing, quantum programming and exploit distributed approaches with graphics processing unit (GPU).

CREATING A FULL DECARBONIZED POWER SYSTEM WITH NOVEL SOLUTIONS

The full and enduring decarbonization of the power system requires significant advances in the state-of-the-art and a combination of new computational, hardware and regulatory solutions. This future scenario is composed by a massive connection of power electronics interface generation, active participation of RES and consumers in ancillary services, integration of multi-energy carriers, cross-border exchange of energy and data.

The R&D needs will be identified by preliminary studies (simulating alternative operation scenarios) that will evaluate the electric power system behavior and anticipate the requirements that industry will have in the

[14] European Distribution System Operators for Smart Grids. Digital DSO' – a vision and the regulatory environment needed to enable it. Position Paper, 7 Jan. 2016.
[15] The power sector goes digital - Next generation data management for energy consumers. A EURELECTRIC report, May 2016.
[16] ENTSO-E R&I Roadmap 2017-2026. http://riroadmap.entsoe.eu/wp-content/uploads/2016/06/entsoe_ri_roadmap_2017-2026.pdf
[17] Renewable Electricity in the Portuguese Energy System until 2050. APREN – Portuguese Renewable Energy Association. May 2018.
[18] National Academies of Sciences, Engineering, and Medicine. (2016). Analytic research foundations for the next-generation electric grid. National Academies Press.

upcoming years. This should include new planning and operational methodologies for the electrical infrastructure, focused on distributed control architectures and expansion of pan-European grids. Moreover, it should consider ICT and mission-critical IoT to increase grid resilience under extreme weather and hazard scenarios and contribute with predictive strategies procedures for black-start, self-healing and islanding operations in systems dominated by grid inverter-based generation.

In a system with high RES integration, a paradigm shift from deterministic to stochastic approaches for both interconnected and isolated systems (e.g., islands) is mandatory. This will require new mathematical algorithms based on convexification and decomposition techniques and human-in-the-loop approaches, which provide fast and clear advices, and handle local technical problems that may be created by DRES.

BRIDGING THE GAP BETWEEN RESEARCH RESULTS AND INDUSTRY BUSINESS CASES WITH A MULTIDISCIPLINARY APPROACH

Concepts such as microgrids, multi-microgrids and active grid management have been implemented successfully in different pilots along Europe and technically supported by industrial actors (e.g., EDP, EFACEC, Siemens, GE). However, two main barriers remain to achieve replicability and scalability: (a) regulation has been a bottleneck for this paradigm to scale up; (b) cybersecurity and interoperability have also limited the implementation in the field of these innovative concepts.

In this context, new regulatory frameworks should be proposed to support disruptive models, such as peer-to-peer trading, but taking into consideration the fundamentals of the electrical system, i.e., to satisfy with the proper quality of service the end-user needs. This should cover different areas, such as power systems, economics and behavioral sciences. Combining domain knowledge from electric power systems with other areas, particularly cybersecurity and interoperability through ontologies and cross-domain IoT, will allow creating the market conditions for large-scale deployment and replicability of concepts developed by CPES in previous European and national projects.

4.2.3.2 Cluster contribution

One of the key objectives for the PE Cluster is to continue and improve the process of associating other Centres of INESC TEC, addressing the vision described previously, where the scientific competences of other Clusters will help to maximize the impact of the research and innovation in this field. The PE Cluster identified inside INESC TEC the following list of key competences to realize its Vision:

- O&M and asset management – CEGI
- Data mining, machine learning and deep learning – LIAAD, CTM
- Operations research – CEGI, CESE
- Blockchain, big data and human-computer interaction – HASLab, CSIG
- Cybersecurity – CRACS, HASLab, CTM
- Internet-of-things – CTM
- Robotic autonomous systems – CRAS
- Fiberoptic and non-intrusive sensors – CAP

4.2.4 Cluster research lines

The main multidisciplinary strategic research lines (RL) for the PE Cluster are summarized below.

RL1 - Towards 100% RES integration and Massive integration of power electronic-based interfaces

Definition of the Research Line

This Research line will explore the knowledge that has been internalized over the years in CPES on the impacts of integrating large shares of renewable based generation, particularly the challenges of operating a system that depends on variable resources and that is losing a very important characteristic, that is mechanical inertia. In fact, a network that has a significant part of its electricity generated by distributed power electronics inverters,

connected at different voltage levels, requires a completely different set of tools to allow a stable and resilient operation of the electrical system.

Alignment with the Cluster vision

This RL will design the functionalities that guarantee a very relevant part of the decarbonization of the power system, namely because it will explore alternative system operation that requires new technical and business models, where the competences from other research Centres will be fundamental.

Main research challenges

The main challenge for this research line is the design of the requirements for a safe connection of an all new set of distributed energy resources under a profound technological revolution, in addition to a flexibility that will mostly be set over end users availability to participate in the operation of the electrical system.

Objectives for 2020

For 2020, the Cluster will start by identifying the opportunities that recent advances in technology provide, from RES to electric mobility, to start designing new interconnection requirements that will foster the participation of all stakeholders in the electrical system in a safe way and finally to develop advanced control strategies and interfaces to include in power converters, that allow end users to provide ancillary services to the system without losing comfort and economical benefit.

RL2 - Large-scale modelling and optimization of energy systems

Definition of the Research Line

This RL is fundamental for the development of the electrical system since the unbundling of the system and will continue so in years to come, as the integration of distributed energy resources poses significant challenges for network planning and operation, that can only be anticipated by thoroughly designing models to support simulation and to design adequate optimization tools.

Alignment with the Cluster vision

The adequate modeling and optimization of the electrical system are basic conditions to this new operation paradigm, based on distributed energy resources. This process involves a significant use of computationally efficient algorithms that integrate different sources of uncertainty and that will benefit from the fundamental knowledge that other Centres will bring to the Cluster.

Main research challenges

The major challenges come from the lack of adequate information from manufacturers on the characteristics of emerging technologies, what constitutes a difficulty in the accuracy of the models to use under simulation. This will foster the use of data driven approaches, based on historical data (whenever available), and also a close interaction with manufacturers to allow a realistic representation of the system.

Objectives for 2020

For modeling purposes, a deep review on existing and upcoming technological solutions is mandatory to define the basis of new simulation models that will support representativeness of the network components. The Cluster will explore INESC TEC participation in some technological Colabs, by evaluating the capabilities of new resources such as electrochemical storage and solar photovoltaics. Still under this RL, related to the development of optimization techniques, the solution of large-scale non-convex optimization and learning problems with decomposition techniques and distributed computing will be explored.

RL3 - Data-driven methodologies for energy systems

Definition of the Research Line

The digitalization of the energy sector requires novel data-driven methodologies for forecasting, optimization and prescriptive analysis, which enables the creation of new services for end-users. Improvement of RES, load and market prices forecasting skill by developing distributed and privacy-preserving statistical learning algorithms that explore geographically distributed time series data.

Alignment with the Cluster vision

This RL is the step stone for the digitalization of the energy sector and requires a multidisciplinary approach and co-creation of new business models that will largely benefit from the presence of other research Centres (like CEGI and LIAAD) to improve knowledge and techniques that CPES has been exploring over the last 3 years.

Main research challenges

The main challenge for this research line is the lack of domain knowledge that other researchers from other Centres, that are fundamental for the implementation of some of these tools, have. This will require a significant cooperation effort between all researchers involved, being the first big challenge present in the H2020 Interconnect project, where 4 Research Centres will cooperate in what can be considered the most relevant EU project ever held by INESC TEC, with 51 partners and where data driven methodologies will anchor the expected developments.

Objectives for 2020

This work will involve the competences of HASLab, using blockchain and smart contracts technology to create data marketplaces, bearing in mind the creation of representative use cases for the energy sector. The further development of AI techniques, related to exploitation/exploration of knowledge from past experiences, i.e., decisions made by human operators, will also be enhanced together with LIAAD. This research will be focused on two core concepts: (a) quantification of similarity between system operating states and, (b) use of reinforcement learning to learn and improve from human actions, contributing to improve the acceptance of new methodologies by the end-user. These R&D results will be applied to different energy domains: energy efficiency (e.g., new energy services), grid operation and electricity markets.

RL4 - Asset management and predictive maintenance

Definition of the Research Line

Utilities are facing the need to improve asset management policies, in order to increase their availability and reduce CAPEX and OPEX. The inclusion of new assets, with significant uncertainty in life cycle, together with completely new operation strategies for more conventional assets, makes this RL fundamental for the operation of the electrical system of the future.

Alignment with the Cluster vision

The Cluster envisages the development of new business models that explore flexibility over all stakeholders in the electrical system. This flexibility will necessarily depend on assets condition and maintenance, so despite this digital transformation, with cutting-edge business models, explores digital platforms, it will have to run over existing and upcoming physical assets that will be the levers of this change. This makes this RL one of the most important to fulfill the Cluster vision.

Main research challenges

The main challenges come from the lack of data from many of the assets and lack of casuistic for the different scenarios to study, in a system under a profound change. These difficulties require the application of advances methodologies to guarantee representations and also the identification of the critical characteristics that sensors and measurements must assure.

Objectives for 2020

Joint research work between CEGI and CPES, combining data-driven and engineering-based methods for the descriptive and predictive analysis of asset condition, and studies to evaluate the impact of maintenance actions in assets' failure rate and degradation curves are foreseen. The software developed by CPES for long-term adequacy and reserves evaluation will be enhanced with the reliability models and maintenance policies developed by CEGI for each individual asset.

Assets inspection will be improved by distributed fiber optics sensing, combined with drones and visual images processing with deep learning methods for automatic classification, by combining the competences of CAP, CRAS, CTM and domain knowledge from CPES for problem formulation and results interpretation. Interoperable, plug-and-play, non-intrusive and cost-effective smart sensors technologies are also of key importance to extend the asset monitoring capabilities in low voltage levels (where most problems occur).

RL5 - Cybersecurity and IoT for critical infrastructures (electricity generation, transmission and distribution)

Definition of the Research Line

The increasing use of digital equipment and ICT exposes the electrical grid, a critical infrastructure, to cyberattacks which can cause massive and long-lasting power outages with enormous societal impact. This RL is focused in security architectures and measures to improve power system resilience, on the customers and on grid sides and to assess their effectiveness in different contexts, such as microgrids, substations and IoT.

Alignment with the Cluster vision

Towards a human-centric energy ecosystem, research in IoT should design an interoperable IoT solution between devices, systems and domains (e.g. buildings, digital platforms, smart grid) by making use of standards, ontologies and abstraction layers, as well as considering security and privacy-by-design practices.

Main research challenges

In this RL, the main challenge comes from the requirement that critical systems have in terms of security and interoperability. Many of the existing solutions use proprietary communications and technology, making some of the measures difficult to apply.

Objectives for 2020

For 2020, the activity in this RL will include topics such as: (1) development of methods to assess security risks to the electricity grid, from generation to consumption, considering dependencies between the different stakeholders (CTM, CRACS); (2) design of a security architecture that protects against future, sophisticated cyberattacks for different smart grid, generation and smart buildings use cases (CRACS, HASLab, CTM); (3) include the impact of cyberattacks in distribution operator training simulators (CPES, HASlab).

4.3 INDUSTRIAL AND SYSTEMS ENGINEERING

Coordinator: Bernardo Almada Lobo

Core Centres: Centre for Enterprise Systems Engineering (CESE), Centre for Robotics and Intelligent Systems (CRIIS), Centre for Industrial Engineering and Management (CEGI), Centre for Innovation, Technology and Entrepreneurship (CITE)

4.3.1 Presentation

The Cluster Industrial and Systems Engineering at INESC TEC (c_ISE@INESC TEC) aims to research and innovate in systems and services applied to the management of value streams, from the individual organisation to networks and chains. The activities of the c_ISE@INESC TEC cover the design, implementation and improvement of systems for decision support, operations automation, management and intelligence and in the provision of innovation management & technology transfer consultancy services in Industry, Retail, Healthcare, Energy, Mobility and Transports, Agriculture and Forestry. c_ISE@INESC TEC provides intellectual leadership in complex decision-making issues faced by different types of industries based on developing and advancing systematic modeling and solutions.

The C_ISE@INESC TEC wants to position INESC TEC internationally as a leading research Centre in industrial and systems engineering and as a first choice for supporting organisations to achieve high-levels of sustainable innovation and performance. It consists of four INESC TEC Centres addressing complementary scientific and technological domains:

- CESE, addressing Manufacturing and Services Operations Management, Enterprise and Industrial ICT, Collaborative Networks and Supply Chains and Manufacturing Intelligence;
- CRIIS, addressing of Industrial Robotics, Collaborative Robots, Mobile Robots and Intelligent Sensors and Dynamical Systems;
- CEGI, addressing Service Science and Design, Decision Support, Performance Assessment, Asset Management and Prescriptive and Predictive Analytics;
- CITE, addressing Innovation Management, Technology Management and Technology Entrepreneurship.

The four core Centres of C_ISE@INESC TEC undertake research, technology transfer, consultancy services and executive education in complementary research domains strongly coupled and coordinated.

The Cluster uses a range of research methodologies and approaches to fulfil its mission namely: Systems Design, Modelling, Mathematical Programming, Optimization, Simulation, Analytics, Information Management, Data Mining, Knowledge Discovery, Machine Learning, Model Based Predictive Control, 3D and Active Perception, Multimodal Sensor Fusion, Design Science and Explanatory Research, Creative Thinking and Problem Structuring.

4.3.2 Context

Future European industry has to combine high and widespread productivity with a high level of environmental and social sustainability. This will mean moving from local optimization – for individual factories or clusters of firms - to complex systems optimization, with major impacts on the way supply chains and factories are designed, on the technologies used, infrastructure and wider government policies.

This is being addressed by the movement Industry 4.0 which is revolutionizing the shop floor of manufacturing plants, but the same technologies are impacting all sectors (e.g., retail and health). The proper deployment of these technologies is paramount in the pursuit of many national and European priorities, particularly those related to sustained, inclusive and sustainable economic growth. Therefore, some of these technologies are being thoroughly studied from the lens of operations management and decision support, namely collaborative robots, machine learning and blockchain.

In order to make more supported and informed decisions, there is a need to conveniently extract knowledge from data that could be leveraged to increase efficiency and growth of businesses, and promote sustainability. Moreover, the next generation of robots is able, in a variety of degrees, to work side by side with humans. This poses a variety of new challenges to managerial decisions, such as task allocation, scheduling, plant layout, and

ultimately the acquisition of these robots. Robotics is also transforming industry/agriculture/forestry by automating processes, reducing the labor costs, human effort, and increasing the efficiency. Robotics Technology will become dominant in the coming decade. It will influence every aspect of work and home. Robotics has the potential to transform lives and work practices, raise efficiency and safety levels, provide enhanced levels of service and create jobs. Its impact will grow over time as will the interaction between robots and people. However, more research is needed to move robotics technologies to new contexts like industry 4.0 and agriculture/forestry 4.0 contexts, these technologies need to be more safer, modular, cost-effective, plug-and-play, smarter, and reliable.

Beyond the manufacturing operational aspects of industry 4.0, the digitalization of the economy is a global trend of major transformative character, comprising all areas of daily and professional life. Businesses, consumers and industry are increasingly using digital technology to grow, overhaul workflow, and to develop new products and services. Increased efficiency and scale from digitalisation will impact supply chains and potentially make certain layers redundant. Thus, digitalisation can lead to a new era of automation enhancing and augmenting relevant human capabilities with new technologies. This will clearly have disruptive effects on the labour market: a future-oriented and lifelong-learning employment and education strategy will be essential to re-train and up-skill people for the new jobs created by digitisation. Integration of an increasingly digital world, connecting the data streams from new product development and design (ET), including CAD and PLM systems, to the production and resource planning (IT), such as ERP and MES, and real-time analysis of manufacturing data from the shop floor (OT), IoT sensor and machine tool data, is an essential requirement for success in the competitive marketplace. However, this integration is far from trivial and new platforms that promise to ease the integration have yet to prove their capabilities. The agility of today's supply networks and flexible manufacturing systems makes companies and business units equipped with different systems and resources have to work together. However, in many large, as in some small and medium-sized, corporations this presents an internal challenge that needs to be addressed in order to really profit from the developments and promise of Industry 4.0.

The developments on the industrial side are accompanied by tremendous changes in the retail sector that will face a predicted growth of e-commerce — in the US in 2018 it reached $500 billion, rising from 13.8% in 2015 to 17.1% in 2020 in the UK. In this setting, more than half of incurred delivery costs are associated to last mile delivery and 1/3 to line haul. The remaining costs are associated to collecting and sorting items. While delivery costs are perceived by supplier and consumer, other externalities such as air and noise pollution or traffic congestion, resulting for the additional number of vehicles required for deliveries are perceived and have a negative impact on all the society. It is therefore crucial to address the new problems arising from this paradigm, both in terms of planning, scheduling and definition of new business models that capture the novelty. Most of the problems will be NP-hard, highly stochastic, dynamic and will request for treatment and analysis of paramount information to better understand customers demand. Related to this, mobility is a major challenge that must be addressed altogether. Shared mobility is a competitive market, where two main factors influence demand: fleet availability and pricing. In these systems pricing can be an effective demand management tool when integrated with fleet management. Despite a growing interest, research is still mostly segregated by specific issues, often not considering relevant realistic system requirements. Also, in urban mobility, the challenges are increasing very fast, fostered by the availability of huge volumes of data, produced by a variety of devices, sensors and ITS (Intelligent Transport Systems). Systems' interoperability and semantic integration of the data produced by the different systems is of major importance in order to extract relevant knowledge. Part of this knowledge is applied in the development of algorithms that aim to optimize the resources involved in the provision of the service and improve the quality of the service.

Along with these challenges, and deeply engrained in them, innovation plays a vital role in the global economy. Technological innovation is the process where an organisation embarks in a journey where the technology is the base of the innovation strategy and a critical success factor for sustainability and competitiveness. However, the full potential of technological innovations can only be achieved if technology is appropriately adopted and diffused.

New technology developments, such as digital technologies enable new value chain and business models. New business models provide opportunities to frame how value can be realized from existing assets and can also provide conceptualizations of new applications providing cross fertilization of the value. Business model thinking gained momentum, and now provides a means to address the new boundary and industry-spanning transformations. The strategic alignment between emerging technology enabled services and business model innovation must be promoted. A systematic promotion of innovation requires a comprehensive system

of management as well as an orchestration of an effective living systems on individual, organisational and ecosystem level. The configuration of Innovation & Technology Management Systems is a key factor for achieving organisations innovation goals and objective.

4.3.3 Vision and contribution

The Cluster has a vision of an ever-integrated supply chain across different industries (e.g., manufacturing, process industries, retail, health, mobility). The Cluster will also consolidate the leadership in knowledge generation and technology transfer on digital transformation, advanced analytics and integration of advanced manufacturing technologies and new business models, helping companies to fully embrace the 4th industrial revolution.

C_ISE will undertake multi-disciplinary, system-oriented research and technology development for the strategic and operational management of enterprises and networks. Its research will focus on connected and high customizable and sustainable transformation systems, helping companies from different sectors to achieve personalised and complex products and services, and to be flexible and resilient in their operations.

Customer-centric and real-time supply chain optimisation, as well the decentralized decision-making, will only be possible with highly flexible, realocable, adaptable and intelligent automation, control and robotics. The use of collaborative robots (mobile and manipulators), smart sensor networks, industrial vertical IoT-based information architectures and Human-robot interface and responsive collaboration (where robots respond in real time to the movement of the worker) plays an important role in these processes and are key aspects of the Vision of the Cluster. Furthermore, the Cluster will focus on the development and implementation of intelligent systems, automation, management and decision support systems, among other technological solutions, fostering the resilience, resource efficiency, competitiveness, circular economy and sustainability towards an effective bio-economy.

In order to achieve the plenitude of this vision the impact in the overall decision-making strategies has still to be analyzed. On one hand, focusing on the production link, the main contribution will be to evolve decision making tools that will have to deal with production technologies with high flexibility, capable of performing different tasks with minimum reprogramming, of sensing the environment and working in environments designed for human-use. This new paradigm represents a challenge for the traditional production process modelling techniques, where machines are almost static resources and the flexibility is completely provided by the human resources. On the other hand, focusing on the entire supply chain, the Cluster will explore the developments of the blockchain to address the new challenges brought up by on-demand external logistics.

Naturally, innovation has been recognised as a catalyst for future development of business and societies. However, in many cases, the question of a structured and supported process is left unanswered. From ideation to exploitation phase of innovation value chain, there is in fact a need to set up the right environment that supports a holistic culture of ideation and innovation within an organization. Clearly, technological innovation does not guarantee business success. The design of the strategies to ‘go to market' and 'capturing value' is a key factor for value creation. In the current context of rapid technological evolution, the Cluster ISE adopts a service design and innovation perspective to leverage technology to devise new service solutions as enablers of value co-creation for customers and other relevant actors in the service ecosystem. It is of paramount importance to conduct studies on how technology enabled service innovation leads to organizational change and how public policy can promote systemic transformation. For that end, the Cluster, follows a multidisciplinary approach, bringing together technology, management, marketing, and design with a service perspective, to cover the different facets of service design and innovation, from an in-depth understanding of customers and other relevant actors, to creating and testing innovative solutions, and to following their implementation in organizations and fostering service system transformation.

4.3.4 Cluster research lines

This Cluster reached a maturity level that can respond to the challenge of creating a high impact research program towards a sustainable supply chain paradigm, beyond productivity improvement. The following strategic research lines are transversal to the current and emerging demands regarding the major trends of digitisation of industry and Industry 4.0 in both manufacturing and services. The four Cluster Centres develop research along their own strategic research lines. Some of these research lines involve joint research activities

that converge into the cohesive research lines of the Cluster. The remaining research lines are more or less confined to the specific centres (centres research).

Cohesive strategic research lines (core)

RL1 – Operations Management (in manufacturing and services) for responsive, sustainable and resilient operations

Definition of the Research Line

This strategic line of research adopts a holistic and integrated view of operations that leads to more efficient or effective processes for the creation and delivery of goods and services. It studies innovative or traditional processes for the design, procurement, production, delivery, and recovery of goods and services. This research entails the control, planning, design, and improvement of these processes. Specific research topics include: factories design and layout planning; retail and production operations management; advanced production planning and scheduling; navigation, localisation and coordination of mobile robots, and real-time performance monitoring and optimization. This line develops inter-disciplinary research activities on the: (i) design of the technology, (ii) design of the human and organisational environment, (iii) task allocation and scheduling, (iv) operations planning, (v) socio-economic assessment and technology management, and (vi) sustainable business models.

Alignment with the Cluster vision

Research in this line is centred on intelligent manufacturing technologies and methodologies, developed on top of analytical modelling approaches.

Main research challenges

- To consider responsiveness, sustainability and resilience as meta-criteria for operations optimization;
- The myriad of sensors and other data collection technologies existing today, enable remote monitoring of production processes and should be the basis for real-time planning;
- The ready availability in quality and quantity of real-time and historic data from the shop-floor together with management data demand state-of-the art planning and scheduling systems;
- Digital products and services disclose new levels of complexity and variability.

Objectives for 2020

- New integrated predictive and prescriptive models for asset management and distribution planning;
- Evolve real-time planning and scheduling systems to work with: other data collection tools (e.g. MES) within an Internet of Things environment; tailored production processes, for small series, high-customization;
- Conduct research on emerging topics, such as automation, e-commerce and shared economy, and target top high-ranked Operations Management journals (e.g. M&SOM, POM, JOM, IJOPM).

RL2 – Operations Research and Management Science: decision support in a digitised industry

Definition of the Research Line

This research line contributes to the methodology of operational research and to the practice of decision making, leveraging the science of optimal decision making. Modelling techniques or creative algorithms drawn from the fields of mathematical optimization, statistics, simulation and computer science are proposed. In addition, integrated and innovative forms of Optimisation / Decision Support Systems (DSS) are also researched, that complement quantitative methods and algorithms with an active “participation” of human decision-makers. Interfaces design and other ways to address the human dimension in DSS development are an important topic towards a human-centred digital industry.

Specific research topics include: business analytics, optimisation methods, simulation tools, machine learning, model-based digital-twins, multi-criteria decision under uncertainty, soft operations research, modelling subjectivity/intuition, visual thinking, performance assessment through Data Envelopment Analysis and econometric and statistical techniques.

Alignment with the Cluster vision

To achieve the plenitude of the vision of the Cluster for an ever integrated customer-centric real-time supply chain, decision making strategies and tools need to be evolved. In this context Decision Support Systems play a very important role, taking advantage of the fast digitalisation of the manufacturing environments, exploring powerful quantitative models and algorithms, and fostering the active "participation" of human decision-makers. C_ISE has a long inter-disciplinary research and development experience in these areas, providing modern companies with integrated systems capable of modelling and solving the complex problems that emerge from this new reality.

Main research challenges

- Deal with uncertainty poses significant challenges for decision-making processes, either at a more strategic level (e.g., for digital supply-chain design) or at a more tactic or operational level, with planning or scheduling activities;
- Need for agile and real-time decision-making processes, based on sophisticated models and advanced analytical methods that promote efficiency, flexibility and agility of industrial companies and networks;
- SMEs find existing solutions still too complex and call for further developments towards simplification, modularity and implementation support tools.

Objectives for 2020

- New mathematical programming-based algorithms (matheuristics) closer to real-world needs that deal with uncertainty (robust optimization and stochastic optimization);
- Hybridize optimization and machine learning techniques and propose new integration schemes between these two streams;
- Cross-fertilize simulation and optimization techniques to address the increasing complexity and scale of decision-making.

RL3 - Operational and strategic architectures for a data-driven industry

Definition of the Research Line

Research on digital architectures and operational elements for industrial applications addressing the design and use of new (ICT) architectural concepts at the strategic and operational levels.

Alignment with the Cluster vision

The changing context of manufacturing requires new design knowledge to inform the development of management systems as well as execution systems in the context of the increasing adoption of data-driven manufacturing. This poses demands for architectural concepts involving the so-called cyber-physical systems and the industrial internet of things. One concrete example of this research topic completely aligned with the vision of c_ISE's is the design of architectures that are able to integrate factory's horizontal and vertical information flows. For instance, the success of industrial and mobile robotics application is heavily dependent on the integration with the connected factory of the future. In fact, the role of robotics in the Industry 4.0 is an open challenge that requires a change of approach from a work-cell integration to a factory or even inter-factory level integration. Therefore, in the mobile robotics sector, the approach will explore the concept of a robot as a mobile sensor that can dynamically populate the digital shadow of the manufacturing plant. Another example is the development of European wide digital platforms e.g., for large scale pilots. Large scale integration of heterogeneous architectural elements such as digital twins, process / workflow models, data models, and applications is a challenge in terms of design knowledge, infrastructure deployment (IoT, blockchain, big data architectures) and business model design.

Main research challenges

- Novel architectures for Cyber-Physical Systems and (Industrial) Internet-of-Things; the focus is on devising new ways of integrating computing and communication with physical and virtual elements (digital twins) and processes across all levels of production, from processes through machines up to production and logistics networks;

- Architectures for efficient large amounts of streaming data collected from machines and processes; combination of off-the-shelf big data technology and in-house developments to support different types of data sources, including IoT, as well as other decision support technologies, including analytics, optimization and simulation, delivered as part of enterprise and industrial systems;
- New concept and architectures for multi-organisation digital platforms; from traditional supply-chains to virtual markets, the Cluster intends to devise new ways of combining semantic, blockchain and machine learning technologies to improve existing and foster new business models.

Objectives for 2020

- Increase the research on data and information management to support the effective application of Advanced Manufacturing Technologies;
- Increase the research efforts on systems integration operations towards efficient manufacturing;
- Develop new architectural concepts involving cyber-physical systems and industrial internet of things.

RL4 - Human Robot Collaborative workstations

Definition of the Research Line

This research line addresses new challenges for Manufacturing and Smart Production Systems. It is focused on developing cognitive, sensitive, collaborative and safe robotic-based workstations. These advanced automation technologies for manufacturing applications will support agile production, digital transformation and smart sensing related with Human-Machine interaction.

Alignment with the Cluster vision

Customer-centric and production will only be possible with highly flexible, re-allocable, adaptable, collaborative and intelligent robotics. The use of industrial collaborative workstations with smart sensors, vertical integration and IoT-based information architectures plays an important role in these processes and are one of the several contributions of the Centre to the Vision of the Cluster. Furthermore, increased flexibility of Human Robot collaborative workstations presents a new set of challenges for the design and planning of future flexible production systems, and therefore provide new research lines for the others Centres in the Cluster.

Main research challenges

- New human-machine interfaces, both based on mixed augmented reality techniques and physical interaction, and on the development of new horizontal and vertical plug-n-play mechanisms that allow easy and fast deployment and reallocation of robotics solutions at the shop floor.
- New robot programming techniques, both based on CAD and programming by demonstration techniques. This research line will continue to focus on developing a skill-based programming solution, that creates an abstraction layer (both for the hardware and software) allowing the operator to program the industrial robot at the task level.
- Human-Robot Collaborative Cells will be key to Future production plants. Typical scenarios are those related to assembly lines. Despite already existing several collaborative robots deployed at the shop floor level, it is not yet possible to take full advantage of the collaborative factor, especially due to the unpredictability of human behavior, which limits the speed of operation of these solutions. Therefore, on of the main focus of this research line, and drawing on the experience gained during the execution of some research projects such as FlexCoating, COBOTIS and ColRobot, will be to develop tracking systems that allow perceiving the operator intentions and adapt the robot trajectory and behavior in accordance. Furthermore, this mechanism conjugated with other results already achieved, merged with standardized safety sensors, will allow pushing the current industrial solutions to a new level of collaboration and coordination between robots and operators.

Objectives for 2020

This line will continue to focus on the research for new robotic and industrial automation technologies, that are both aligned with the best practices of the Industry 4.0 initiative, and with the market demands, especially from SMEs, that yearn for the development of more agile, scalable and more interconnected manufacturing solutions. It is expected that some of the developed technologies can reach quasi-industrial TRLs and that they can be integrated into demonstrators arising either as direct results of research projects or direct contract services with enterprises (ScalABLE4.0, FASTEN, MANUFACTUR4.0, PRODUTECH-SIF, among others) or as CRIIS' own initiatives for technology dissemination through iiLAB. With this objective in mind, it is anticipated that the most focused research areas, related with robotic collaborative workstations, for 2020 will be:

- To improve robot interaction and collaborative capabilities, including the development of new decision-making strategies;
- To develop intuitive mechanisms for robot programming and task reconfiguration;
- To enhance the safety of human-robot collaboration.

RL5 - Technology-enabled service design and innovation

Definition of the Research Line

This research line focuses on concepts, theories and methods for service design and innovation in technology enabled contexts. This research lines adopts a service logic perspective, broadly defining service the application of competences to enable value co-creation, where the distinction between products and services is blurred as products can be viewed appliances for service provision. In the current context of rapid technological evolution, this research line therefore adopts a service design and innovation perspective to leverage technology to devise new service solutions as enablers of value co-creation for customers and other relevant actors in the service ecosystem. This research line also studies how technology enabled service innovation leads to organizational change and how public policy can promote systemic transformation.

This research line adopts a multidisciplinary approach, bringing together technology, management, marketing, and design with a service perspective, to cover the different facets of service design and innovation, from an in-depth understanding of customers and other relevant actors, to creating and testing innovative solutions, and to following their implementation in organizations and fostering service system transformation.

Within this scope, several areas are covered:

- Studying customer experience and customer/citizen engagement with new technology enabled service environments (e.g. such smart energy services). This is crucial to gain an in-depth understanding that feeds and inspires the design and innovation process, as well as to evaluate the impact of the new solutions;
- Studying the challenges of implementing new technology enabled service solutions and how it requires organizational and technological change towards achieving strategic and operational alignment between both;
- Advancing methods and tools for creating new technology enabled services, such as smart service solutions, technology enabled healthcare services, or service platforms for healthcare ecosystems;
- Analyzing how new technology enabled service can foster service system transformation at the individual, organizational and ecosystem level, as well as how to develop service design and innovation capabilities in organizations to promote ongoing transformation;
- Exploring how public policies can promote technology enabled service system transformation and institutional change at the individual, organizational an ecosystem level;
- Although not exclusive, this research line has had a particular focus on healthcare and the energy, as these are sectors going through dramatic service system transformation leveraged by technology.

Alignment with the Cluster vision

This research line adds the technology enabled service design and innovation and service system transformation to the ISE Cluster. This research line also brings service systems thinking and value-cocreation perspective.

Main research challenges

- Strengthening the conceptual and methodological foundations of service design and innovation, as key areas of service science;
- Understanding and designing for the customer experience and customer engagement with new technology enabled services, namely smart energy services;
- Leveraging technology paradigms shifts to envisioning and implementing new value co-creation service solutions, such as smart services and data analytics;
- From technology enabled service innovation to service system transformation at the individual, organizational, and ecosystem level;
- Promoting the strategic alignment between emerging technology enabled services and business model innovation;
- Innovating increasingly complex service systems, namely the design of service platforms for service ecosystems;
- Designing public policy for institutional change and service system transformation.

Objectives for 2020

- Strengthening the research teams' International collaborations, and foster the completion and start of new PhDs;
- Submission and funding of new European projects in this area;
- Publication in key outlets of service research and innovation management such as Journal of Service Research, Journal of Service Management, Creativity and Innovation Management, Research Policy, among others.

4.3.5 Structural actions planned for 2020

- Continue the implementation of the current iiLab. Throughout 2020, iiLab will have new demonstrators, higher number of visits from companies, new technology-transfer projects, high-level training and education programs;
- Starting of the new iiLab in cooperation with several Centres and in a new building (from September 2020 onwardS). The objective is to implement an efficient and attractive innovation laboratory to serve as a show room for private and public companies interested on the implementation of Robotics, Automation and Industrial Internet-of-Things technologies. Furthermore, the new iiLab will have to define and disseminate attractive and innovative training and education programs to be delivered to operators working with advanced manufacturing technologies in manufacturing context;
- Coordinate INESC TEC participation in EIT Manufacturing activities and iMan Norte Hub.

4.4 COMPUTER SCIENCE

Coordinator: Rui Oliveira

Core Centres: Centre for Research in Advanced Computing Systems (CRACS), Centre for Information Systems and Computer Graphics (CSIG), High-Assurance Software Laboratory (HASLab) and Laboratory of Artificial Intelligence and Decision Support (LIAAD)

4.4.1 Presentation

The mission of the Computer Science Cluster is to achieve international excellence in both fundamental and applied research, with strong emphasis on technology innovation and transfer that benefits society at large.

Our commitment encompasses many core areas from programming languages and rigorous software development to complex information systems, from data processing to large scale computing, from embedded systems to virtual environments, and from security to quantum computing, with the goal of bringing better intelligence into everything.

The Cluster addresses diversified, heterogeneous and yet complementary research areas. Its overarching research topics are:

- Artificial Intelligence
- Cybersecurity
- Parallel and Distributed Systems
- Information Management and Systems
- Software Engineering
- Computer Graphics and Virtual Environments

The Cluster is strongly involved in Technology Transfer activities, either as Advanced ICT Consulting or Innovative Systems Development, in areas such as Agriculture, Electronic Government, Energy, Healthcare, Earth and Ocean Observation, Industry, and Telecommunications.

4.4.2 Context

Computing is reaching all aspects of modern life. With the advent of the Internet of Things, it is expected that in the next years we will find computing devices embedded in all sorts of equipment and appliances. This trend will reach also living beings and particularly humans, giving rise to a potentially intense cyber-bio-physical interconnectivity and interplay.

The presence of all these sensors and computing devices produce enormous amounts of data, challenging the current information extraction tools and creating opportunities for new generation machine learning and data mining approaches and help shape the decision support instruments of the future.

On the other hand, the misuse of data poses risks to individual privacy and challenges society fundamentals, as seen recently in some social platforms and in election manipulation with fake news. Therefore, ensuring personal privacy, data security and information trustworthiness becomes a priority in our digital world.

Interaction between man and machine is changing and is becoming more immersive and inclusive, merging virtual and real worlds, a move seen at computer gaming, but that will reach other levels of society.

Society is reacting to this new digital world and efforts are being made to reap the benefits and minimize the risks. As a consequence, public funding is being structured accordingly.

The forthcoming Horizon Europe research program, for the period 2021-2027, will have a budget of €97.6 billion and will be organised in three pillars, the most relevant of which is the Global Challenges pillar. This pillar will support research related to societal challenges, setting EU-wide missions with ambitious goals organised in 5 different topics, each with intervention areas relevant to the Cluster, some of which are highlighted bellow:

- Health: tools, technologies, and digital solutions for health;
- Inclusive and secure society: cybersecurity;
- Digital and industry: artificial intelligence and robotics; digital technologies; next generation internet; high performance computing and big data; space;
- Climate, energy, and mobility: smart mobility;
- Food and natural resources: environmental observation;

Some examples of missions that have been proposed and that could be relevant to the Cluster are:

- Before 2030, 1000 cities in Europe should offer life contexts in a virtual city, including participation in science, culture and the arts, by using interactive and mobile technologies;
- By 2030, build an open inclusive and safe digital society, namely with public digital services better and more secure than private digital services;
- By 2030, build a universal quantum computer and place it on the cloud;
- Establish integrated data capture, analysis and visualization systems that enable prevention, interception and early treatment of diseases, which account for 80% of healthcare costs;

Besides Horizon Europe, in the period 2021-2027, there will be other EU funding programs that can be relevant to the Cluster, namely:

- The European Defence Fund, with an overall budget of €13 billion, that aims to boost Europe's ability to protect and defend its citizens, and that will offer EU funded grants for collaborative projects addressing emerging and future defence and security threats and aiming to bridge technological gaps;
- The new Digital Europe Program, with €9.2 billion, that aims to bring the benefits of the digital transformation to all European citizens and businesses, and that will boost investments in high-performance computing and data, artificial intelligence, cybersecurity and advanced digital skills;

The national and regional funding programmes are also aligned with the European strategy. For instance, the regional smart specialisation strategy EREI Norte 2020 selected several domains to foster regional development, namely:

- Healthcare and Life Sciences
- Culture, Creation and Fashion (*)
- Sea Resources and Economy (*)
- Human Capital and Specialised Services (*)
- Mobility and Environmental Industries
- Advanced Manufacturing Systems (*)
- Food and Agri-environmental Systems
- Symbolic Capital, Technologies and Tourism Services (*)

ICT are explicitly referred in most of them as enabling technologies (marked with asterisk). Nevertheless, ICT can also play an important role in other domains. Similarly, the national research and innovation strategy for smart specialisation ENEI, which aligns with regional and sectoral strategies, identifies ICT as one of the 15 smart strategic priorities.

All of these European, national and regional funding programmes open a wide variety of opportunities for Cluster intervention in its core research areas.

4.4.3 Vision and contribution

4.4.3.1 Future vision of the domain

Computing became fully decentralized, mobile, increasingly autonomous, and ubiquitous reaching all appliances, devices and living beings. As a result, current information and communications systems present many hard and intricate challenges associated to scalability, security and criticality. The ever-increasing amounts of generated data embody a wealth of information that needs to be properly and timely mined and analysed. This challenges our capacity to filter, curate, store, process, query and visualise unprecedented volumes of data from diverse sources and formats. In addition, the economic value of the data, trade and state secrets, and individual rights require data manipulation to comply with demanding levels of privacy. Smarter and autonomous systems in critical realms such as utilities, health care, transportation and finance require dealing with new, and often unanticipated, sorts of risks that challenge the best practices of software engineering, network and information security and human-computer interaction.

4.4.3.2 Cluster contribution

The Computer Science Cluster is in a unique position to address many of the technological and societal challenges mentioned above, due to the complementary competences of its core research Centres. In general, the Cluster contributes with the areas of Artificial Intelligence, Parallel and Distributed Systems, Information Management and Systems, and Computer Graphics to the scalability challenges, with the overarching area of Cybersecurity to the challenges of security, and by and large combining Software Engineering, Distributed Systems and Virtual environments to the development of critical systems and infrastructures.

This wealth of knowledge is often enriched with the contributions from the other three Clusters and leveraged through the market pull of all TEC4 initiatives that, albeit with different emphasis, depend on the Cluster's strategic research lines presented next.

4.4.4 Cluster research lines

The Cluster activities are focused on three main research lines described next. As will be clear, these naturally are fully aligned with the Cluster's vision.

Rl1 - Big Data and Machine Learning

This research line addresses the challenges of the management, analytics and visualisation of stationary and streamed data sets brought by the unprecedented volumes of information and the increasing pervasiveness of smart devices. Big Data and Machine Learning are nowadays prevalent topics in both current and forthcoming European framework programmes and central to any sizeable ICT project. This is also a research line strategic for all research centres of the Computer Science Cluster.

With respect to data management, the aim is to provide the next-generation of software-defined storage solutions that can automatically adapt to heterogeneous data-intensive workloads and their specific requirements in terms of efficiency, security and dependability. At the database level the goal is to combine the scalability of NoSQL systems with the functionality of relational and transactional database management systems favouring analytic workloads. At the analytics level the focus is on complex networks dynamics, multi-label classification for high speed data and self-tuning machine learning algorithms.

Rl2 - Privacy-Preserving Computing

This research line aims at devising new algorithms and techniques for computation that preserves the confidentiality/privacy of the data as well as, in some specific use cases, of the algorithms themselves. This is to be done considering several trade-offs balancing security, performance, scalability and power consumption. Since the adoption of the European General Data Protection Regulation (GDPR) that imposes several constraints on the manipulation of personal data most of the existing analytics algorithms and technologies over personal data become inappropriate and therefore useless. This has raised enormous challenges, as fundamental techniques such as computation over encrypted data, multi-party computation, and verifiable outsourced computation need to be made usable and scalable to complex multi-administrative domains, so that privacy preserving computation can be a commodity.

RI3 - Virtual Environments

This research line aims at developing novel methods and tools for intelligent immersive virtual environments, enabling advanced and inclusive HCI with multi-sensorial immersion in augmented and virtual reality. Within the Cluster's vision the target is threefold: advanced training, industrial digital twins and large-scale interactive data visualisation.

To this end , the approach to work on the integration of games in educational/training information systems, on the creation of software techniques for procedural content generation and better data analytics, on approaches for better human-computer interaction with games and e-Learning systems, like the use of multisensory VR and AR techniques, and on combination of these lines with novel pervasive technologies.

4.4.5 Structural actions planned for 2020

The Cluster's general R&D objectives for 2020 essentially carry from previous years and focus on the sustained growth of the Cluster's performance across the research to innovation value chain. This is to be assessed by i) the increased focus on first tier and high impact publication venues and broader international visibility and notoriety, ii) the continued leadership and participation in European research and innovation actions, and networks of excellence, and iii) a growth in the knowledge and technology transfer contracts with industry. To this end, a set of actions are planned:

- Organise international scientific events, participate in scientific societies, and make available online demonstrators, software packages, datasets and other resources of interest to the community in general;
- Increase the number of PhD students;
- Strengthen the collaboration with international universities and research institutions by means of the exchange of researchers, seed projects and joint project applications;
- Promote cross-cutting research initiatives, such as INESC TEC's Data Science Hub, in areas such as cybersecurity, green energy, and healthcare;
- Seek stable long-term technology transfer collaborations with international large ICT companies leading to high impact in real-world applications;
- Expand and reinforce the Cluster's participation in the Data Science Hub initiative.

5 TEC4 INITIATIVES

5.1 Overview

A TEC4 ("TEChnologies FOR …") is a new organizational approach aiming at structuring the market-pull innovation process, as opposed to the science-push that occurs naturally in the Research Centres. This supports the establishment of the adequate balance between the two opposing motivations and supports the full knowledge-to-value chain.

Each TEC4 targets a specific market and induces cross-Cluster multidisciplinary projects, promoting collaboration with business and producing solutions to be transferred to companies.

The performance of each TEC4 is measured mainly by the level of recognition and activity (namely direct contracts with the companies and other relevant stakeholders) in its market and the number of inter-Centre collaborations generated. The TEC4 are not involved in project development: once an opportunity is detected, negotiations occur with the relevant Centres and it is under these that the project is then managed and executed.

The TEC4 initiatives address regional, national or international challenges by mapping the short- and medium-term sector needs with INESC TEC scientific and technological competences. Typically, each TEC4 encompasses:

- A concrete market domain, represented by businesses and associations;
- A group of Centres with their multidisciplinary competences, dedicated to the challenges of that market domain;
- An R&D infrastructure that supports the scientific and innovation activities and provides added value services to businesses that cannot be found in the market.

Each TEC4 has its own strategic agenda, according to their market domain, addressing three pillars: the stakeholders perspective, a strategy and related technological roadmap and the R&D infrastructure evolution - to keep up with the state-of-the-art and support the roadmap.

The short-term objectives of the TEC4 initiatives are the creation of innovative solutions and services with high export potential, based on internationally competitive research and innovation capabilities, contributing to the resilience and growth of the Portuguese economy. Their long-term objectives comprise the identification of scientific and technical challenges, embracing multiple specialities, involving and exploiting the full potential of INESC TEC in application domains that are easily understood and incorporated by businesses. Creating and maintaining these virtuous innovation cycles within each TEC4 is the main medium to long-term challenge.

Sections 1.2 to 1.7 present a short description of the scope and objectives of the current TEC4 initiatives.

5.1.1 Current initiatives

INESC TEC is reformulating the strategy to impulse the impact effect on society and economy. The global TEC4s organisation is composed by:

- Five established TEC4s:
  - TEC4AGRO-FOOD: agro-food and forestry;
  - TEC4ENERGY: energy related activities and economy;
  - TEC4HEALTH: health and well-being related activities and economy;
  - TEC4INDUSTRY: production technologies, manufacturing, distribution, logistics and retail;
  - TEC4SEA: sea activities and economy;

  - TECPARTNERSHIPS, dedicated mainly to promote and support business in all other sectors and to explore new market segments and incubate new potential TEC4's until they reach a qualified maturity level.

TEC4s are dynamic organisation models that need to be periodically evaluated and adapted to the economic landscape.

The application areas addressed by the TEC4s are aligned with European, national and regional priority domains, developing and consolidating internal R&D competencies around socio-economic pillars. Furthermore, the attraction of international partners to the TEC4 initiatives, supports INESC TEC internationalisation strategy, facilitates the national companies an easy access to international partners and enables the attraction of foreign direct investment into the region and the country.

5.1.2 Methodology

Each TEC4 follows an implementation plan covering the following maturity states:

- Identification of market segments where INESC TEC competencies can create value;
- Identification of internal research lines with highest potential impact in business – based on the assessment of market needs;
- Identification of the R&D infrastructure (i.e., laboratories, equipment, demonstration facilities and other technical means) supporting the offer of added value services to businesses;
- Identification of new potential partners and stakeholders that can bring added value to the TEC and support its innovation cycle;
- Definition/alignment of the strategic agenda of each TEC4 and the creation of its advisory board;
- Establishment of collaboration plans with other institutions.

5.2 TEC4ENERGY

Coordinator: João Peças Lopes
Business Developer: Nuno Campos

5.2.1 Mission and positioning

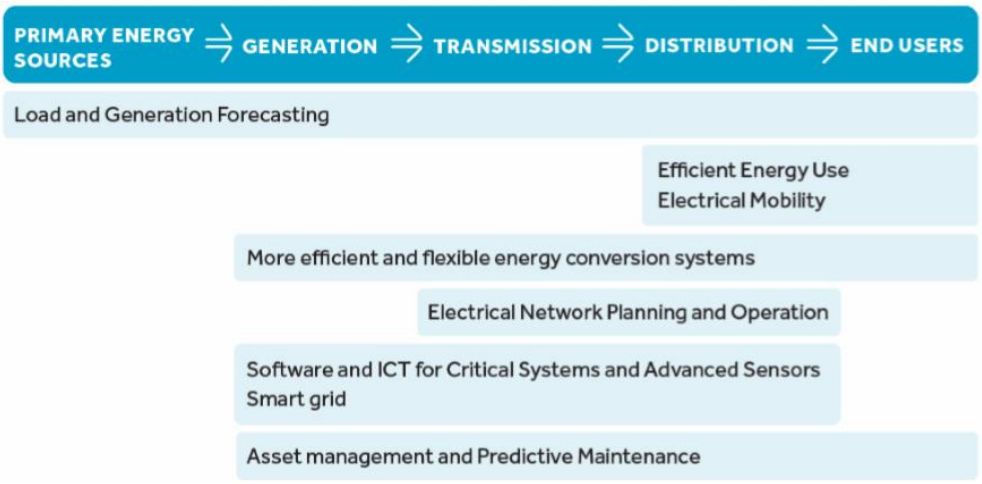
TEC4ENERGY is the leading innovation initiative that responds to the societal challenge "Secure, clean and efficient energy", addressing the major challenges of the sector, namely the ongoing digitalization, the large-scale integration of renewable based generation and massive deployment of electric vehicles and smart cities proposing a multidisciplinary scientific based approach to overcome the limitations that the different stakeholders find in the existing market solutions.

The INESC TEC competence in IoT, artificial intelligence, power systems, robotics, sensors, communications and big data will leverage a multidisciplinary capacity to generate innovative advancements. The focus will be on the implementation of optimised, intelligent and sustainable solutions, in software and hardware, for all agents (utilities, industry, transportation, retail) that operate in a broadly defined energy-concerned social structure, including water or waste management, with an intimate connection with energy, keeping in mind climate change and global warming challenges.

INESC TEC is a creator of research and technology transfer targeting this sector, allowing companies to be internationally competitive with innovative products.

5.2.2 Market

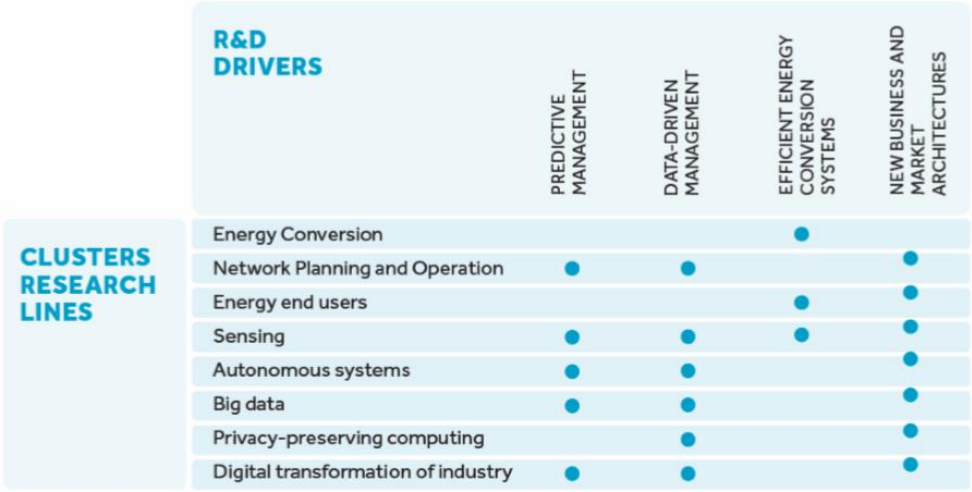
The TEC4ENERGY benefits from a strong recognized INESC TEC expertise in Power Systems, with more than 20 years transferring research results to manufacturers, software vendors, electric utilities and large energy users in Portugal, Europe and Brazil. This adds credibility to a broader effort, extended also to the fossil fuel sector, and encompassing from industry to transportation, buildings and energy efficiency.



5.2.3 Driving forces

The main drivers for the TEC4ENERGY initiative are the Societal Challenges and Innovation Strategies for Smart Specialization defined by EU policies: the energy sector will be heavily digitalized, under user centric and market based approach, requiring the conceptualization and development of disruptive solutions. At the same time, we are aiming at a very large decarbonization of the society and economy.

Considering the above challenges, the driving R&D lines in order to accomplish this are presented in the next figure.



This mapping describes the multiple cross participation of R&D research lines to TEC4ENERGY R&D drivers.

5.2.4 Innovation services

The following innovation services are provided by INESC TEC in the scope of TEC4ENERGY:

- **DMS/EMS and network automation:** specification, development and integration of advanced computational tools for network management systems for all voltage levels (transmission, distribution and island systems) and of new solutions for network automation, protection and control of distribution networks;
- **System planning and reliability:** tools and models within this area aim at supporting not only the operational planning but also the expansion of power systems. Naturally, this activity appeals to advanced optimization techniques and new stochastic models for the representation of the overall system behaviour;
- **RES & DER integration:** RES integration studies, and namely PV generation facilities integration studies, identification of system support functions/ancillary services from RES and the exploitation of new technologies for increasing the controllability and flexibility and coordination between transmission and distribution grids. This will involve dealing with transmission and distribution FACTS, energy storage systems and associated power converters, HVDC grids and converters and development of grid code requirements to allow the power system to cope with large-scale integration of RES. Some of these activities are supported by the laboratorial infrastructure of CPES (SGEVL);
- **User centric solution:** specification and development of energy management systems for home and building level in order to manage the local load consumptions (appliances, EV charging, thermal loads, etc), delivering services of flexibility to the grid and optimizing the usage of renewable generation and minimizing the electricity bill of the final end consumer. This involves also the engagement of consumers on this energy management solution via gamification or other approaches and the use of interoperable solutions;

- **Asset Management and predictive maintenance:** implementation of a risk-based maintenance strategy software for the distribution grids by analysing failure modes, consequences and decision maker's risk attitudes; estimation of power transformers condition and remaining useful life (RUL) by combining expert knowledge, engineering models and data analytics; fibre optic sensors to measure vibration and magnetic field for HV lines, and corrosion monitoring in off shore wind parks; drone with rotary wings o monitor electrical assets, such as, medium and high voltage support, substations and wind parks. This latter solution is innovative because it operates autonomously, making it possible to reduce risks and to optimise the inspection process that leads afterwards to definition of maintenance (and even repair) actions.

5.2.5 Associated Centres

The Centres involved with the TEC4ENERGY initiative are the following:

- CPES - Power and Energy Systems
- CAP - Applied Photonics
- CTM - Telecommunications and Multimedia
- CRAS - Robotics and Autonomous Systems
- CEGI - Management and Industrial Engineering
- LIAAD - Artificial Intelligence and Decision Support
- HASLab - High Assurance Software
- CESE - Enterprise Systems Engineering

5.2.6 External competencies and partners

The external competencies and partners relevant for TEC4ENERGY include the following:

- **Renewable Energy Sources**: feasibility studies on wind and solar photovoltaic potential for producing electricity – INEGI;
- **Power converter models**: development of transient stability models in PSS/E, provide plant controller modelling, with varied set of functionalities, enabling the performance of grid integration studies of plants with of advanced control for system support- IIT Comillas;
- **Power electronics**: Innovative EV Battery Charging Systems for Smart Homes and Smart Grids, Active Power Filters and Power Quality Analysis – GEPE/Uminho;
- **Electrochemical devices**: redox flow batteries integration in electrical grids, providing grid support functionalities to building advanced energy management systems – LEPABE/FEUP;
- **Advanced home energy management systems (HEMS)**: development of advanced home and building energy management systems to optimize (regarding the minimization of the bill of electricity and the maximization of the usage of local generation) the electrical consumption behind the meter and the provision of flexibility services to the grid operators – INESC Coimbra.

5.2.7 Objectives for 2020

The 5 main objectives of TEC4ENERGY for 2020 are the following:

1. **SGEV laboratorial infrastructure:** continue the support to the adaptation and improvement of the laboratory infrastructure to respond to new challenges in terms of testing and research capabilities, investing namely in the reinforcement of power hardware in the loop test beds and consumption monitoring;
2. **Strengthening the partnership with other Centres**: TEC4ENERGY will increase contacts with other Centres, namely the ones involved in projects and research concerning advanced fiber optic sensors,

new generation of telecommunication networks / standards (5G), data base governance, data mining and big data analytics;

3. **Seeking out new clients**: seeking for clients interested in the development of studies related with the grid integration of large number of PV generation facilities;
4. **Promoting, nationally and internationally, the image of INESC TEC**: by participating in exhibitions the capabilities of INESC TEC to deliver advanced consultancy studies and test of prototypes on new products and solutions targeting the support to the energy transition;
5. **Promoting enlarged external partnerships**: leading to Contact Programs in the Energy field.

5.2.8 Action Plan

This year, TEC4ENERGY will design and/or implement the following actions:

Action	Objective	Expected Outcomes	Calendar
Technological scouting in exhibition and conferences	1	Identification of new laboratory equipment to be installed at the laboratory.	Continuous action
Organization of internal meetings with INESC TEC Centres	2	Identification of synergies on the internal scientific and industrial outcomes developed by each Centre in order to serve the Energy domain	Continuous action
Visit and contact new potential clients in Portugal and eventually abroad Presentation of results from grid integration studies in Conferences and Exhibitions	3	Enlarge the portfolio of clients	Continuous action
Participation in the 2020 Utility Week in Milan	4	Promotion of the image and technical skills of INESC TEC on the Energy domain	TBD
Develop high level meetings with the management of large companies	5	Contract Programs	Continuous action
Development of a document about the energy sector and the positioning of INESC TEC on this domain	6	Identification of the most adequate approaches to deal with the promotion of TEC4ENERGY mature products to penetrate the market	TBD

5.3 TEC4INDUSTRY

Coordinator: Américo Azevedo
Business Developer: António Almeida

5.3.1 Mission and positioning

The MISSION of TEC4INDUSTRY is to foster transformation for an innovative, collaborative, human-centered and sustainable industry.

The TEC4INDUSTRY positioning in the market is completely aligned with INESC TEC purpose and track record, focused on streamline the interface between the academia and industry as well as drive sectors innovation through cross-fertilization.

TEC4INDUSTRY aims to monitor scientific results in the range TRL 1-9, induce a market pull drive into R&D, promote applied research leading to products, processes and services (TRL 5-9) and generate knowledge and solutions capable to be transferred to the retail and manufacturing Industries, covering end-to-end supply chain actors.

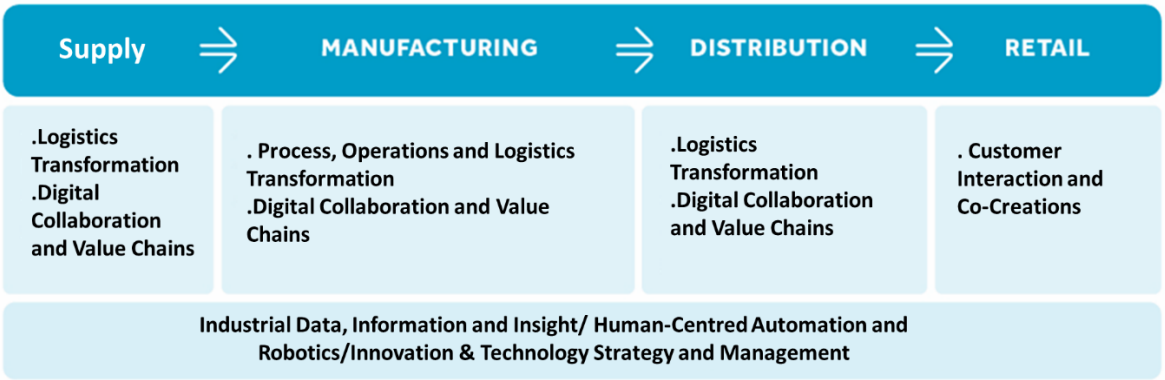
It should be noted that we identify a continuous activity under the scope of TEC4INDUSTRY. This bridging with companies from different industry sectors represents the core activities of INESC TEC, since its creation, and has been established based on different mechanisms: from advanced consultancy services to contract based R&D or even strategic & innovation partnerships, promoted both at a national and European level.

This added value service to the market has been anchored in a history of successes, materialized in effective technology and knowledge transfer to companies. Important partnerships with companies from the shoe industry (e.g. Kyaia), the distinct consultancy projects targeted to support companies along their digital transformation (e.g. GALP) or even the promotion and execution of innovate European projects, where INESC TEC has been involving Portuguese companies from the different sectors (e.g. automotive and wood industries) are examples of activities that TEC4INDUSTRY will continue to pursue and leverage.

Since the beginning of INESC's activity in Porto, several hundred projects have been carried out directly involving different types of companies and industrial organizations and totaling several dozen investments. As a frame of reference, considering the number of projects executed with Industry in the past ten years, it is possible to count more than 170 national projects and more 25 international projects, representing a direct income of more than 24 M€ for INESC TEC.

5.3.2 Market

TEC4INDUSTRY covers all the value chain actors and processes, and is committed to bringing unique knowledge and solutions to logistics, manufacturing industry, distribution, and retail.



5.3.3 Driving forces

The European and national strategic agendas, such as the FCT research and innovation agenda for manufacturing, were considered in the definition of the challenges of manufacturing, logistics and retail economic sectors.

Considering those challenges, the driving R&D lines were identified in order to accomplish them.

The focus on clients and the need to have quick response increases the value of personalizing manufacturing and services offered by companies. Digital process transformation and collaboration in the value chain are main requirement for operational efficiency increase. A better knowledge of the customer by business analytics techniques will induce new business models. Human centered industrial production based on robotics and intelligent manufacturing system will increase productivity and flexibility.

STRATEGIC AGENDAS ⇒	CHALLENGES ⇒	R&D DRIVERS
• Horizon 2020 • Horizon Europe • EFFRA • Portuguese Industria 4.0	• Focus on client • Quick response • Operational efficiency • Decision support • Business models	• Personalisation of manufacturing and services • Automatise and robotise • Digitise processes • Collaboration in the value chain • Business analytics

The Centres R&D research lines, together with TEC4INDUSTRY driving R&D lines, respond to the challenge of creating a high impact research program towards a sustainable production paradigm, beyond productivity improvement, assuring the digital transformation of industry enterprise sector.

CLUSTERS RESEARCH LINES	R&D DRIVERS: PERSONALISATION OF MANUFACTURING	AUTOMATISE AND ROBOTISE	DIGITISE PROCESSES	COLLABORATION	BUSINESS ANALYTICS
Sustainable production systems	●	●	●	●	
Digital transformation of industry	●	●	●	●	
Industrial robotics	●	●		●	
Innovation & technology management	●	●	●	●	
Computer vision		●	●		●
Sensing		●			
Big data, machine learning and data science			●	●	●
Privacy-preserving computing			●	●	●
Virtual environments		●	●		●

The mapping highlights the multiple cross participation of R&D research lines to TEC4INDUSTRY R&D drivers.

Personalization of manufacturing and process digitize are addressed by the defined R&D lines, such as digital transformation and sustainable production systems, assuring agile and real-time decision-making process, while incorporating conditions and constraints generated by the use of technology and, finally, by developing models that represent reality and exploit the digital twin/shadow concept, accelerating the creation of smart decision-support systems. This will also support the development of sustainable business models capable to reinforce the importance of the circular economy, focused on the industrial symbiose, efficient use of natural resources and the exploitation of green and renewal energy sources. Thus, research lines of Industry and Computer Science Clusters address collaboration activities, including all players in the supply chain, towards more added value chains.

Business Analytics drivers are developed in the objectives of research lines, addressing big data, artificial intelligence and machine learning, as well as computer science and privacy-preserving computing. Strong focus is placed on the interaction between Human and Information Systems, in order to leverage human cognitive capabilities to improve productivity and take smarter decisions, mainly in complex industrial contexts.

The challenges of automatization and robotization are considered in research lines of industrial robotics, addressing navigation, localization and coordination of mobile robots, intelligent sensors and control of dynamic systems, Human Robot Interfacing and Augmented Reality.

5.3.4 Innovation services

In order to support companies to face the challenges imposed by the current industry context, TEC4INDUSTRY will provide R&D services, advanced consultancy and training as well as support innovation on the following topics:

- **Digital Transformation for Customized Production** - Support companies along their digital transformation journey, from the initial maturity assessment and technical roadmap definition until the production system design, installation and setup, suitable to deal with the flexibility and scalability requirements imposed by this mass customization era. This transformation covers all aspects and levels of the production system, from the shop floor (with smart sensors, intelligent robots and cyber physical systems) to the data ubiquity (exploring the Industrial Internet of Things and secure cloud computing and storage) and cognitive decision support tools (leveraged by Big Data and Artificial Intelligence based algorithms;
- **Sustainable Business Models and Circular Economy** – Take advantage from the most recent digitalization mechanisms to support companies promoting new advanced services (servitization) as well as enable information management towards the product, production system and industrial processes.;
- **Factory Design and Operational Planning**. The work addresses simulation and optimization of the production lines through mathematical and simulation/digital twin models to design facilities and to plan and operate operations;
- **Intelligent Manufacturing Systems for Customized Production**. (cyber-security, horizontal and vertical integration, Cyber physical systems, smart sensors, robots);
- **Human centered industrial production** – Take advantage on big data and artificial intelligence algorithms and tools to generate knowledge and prescriptive insights in order to support human-machine interaction based on augmented reality (AR);
- **Future industrial robotics and Collaborative robotics** - Future industrial robotics will move from a robot centered perspective of a robotics work cell, to an integrated approach that involves perception, multiple sources of information, close collaboration with humans and continuous process learning;
- **Smart Logistics and Retail -** Development of intra and inter-organizational logistics systems. Services to enable companies to integrate IoT components and orchestrate manufacturing modules, such as planning, scheduling. New models and algorithms for optimizing the delivery of products purchased by online customers;
- **Predictive Maintenance and Consumer Forecasting**. Prediction of anomalous events and machine learning techniques to increase maintenance optimization and consumer forecast.

5.3.5 Infrastructures

TEC4INDUSTRY takes advantage of the following list of assets to provide advanced services to new and existing clients:

- iiLab
- Massive Lab
- Minho Advanced Computer Center (MACC)

5.3.6 Associated Centres

The Centres involved in TEC4INDUSTRY are the following:

- CESE – Centre for Enterprise Systems Engineering
- CEGI – Centre for Management and Industrial Engineering
- CRIIS – Centre for Industrial Robotics and Intelligent Systems
- CITE – Centre for Innovation, Technology and Entrepreneurship

- LIAAD – Laboratory of Artificial Intelligence and Decision Support
- HASLab – High Assurance Laboratory
- CSIG – Centre for Information Systems and Computer Graphics
- CTM – Centre for Telecommunications and Multimedia
- CAP – Centre for Applied Photonics

5.3.7 External competencies and partners

The external competencies and partners relevant for TEC4INDUSTRY include the following:

- **Product development -** Design of mechanical, pneumatic and hydraulic systems - INEGI;
- **Material technics** - New materials integrated in solutions - INEGI and INL Laboratório Ibérico Internacional de Nanotecnologia;
- **Minho Advanced Computing Centre (MACC)** – Access to a supercomputer that will allow research, development and innovation in different scientific domains, namely in the areas of digital simulation, data science and machine learning;
- **Produtech -** Articulated network of manufacturing technology providers capable of responding to both competitiveness and sustainability challenges and to the manufacturing industry's requirements with innovative, flexible, integrated and competitive solutions;
- **EIT (eit-Digital, eit-Manufacturing, eit-FlowMaterials)** – The European Institute of Innovation and technology focus on promoting and strengthening cooperation among leading business, education and research organizations;
- **Manufuture-EU –** European channel to propose, develop and implement a strategy based on Research and Innovation, capable of speeding up the rate of industrial transformation;
- **EFFRA** - Industry-driven association promoting the development of new and innovative production technologies;
- **EU Robotics -** Develop and implement a strategy and a roadmap for research, technological development and innovation in robotics;
- **Vanguard Initiative -** Developing interregional cooperation and multi-level governance for supporting clusters and regional eco-systems to focus on smart specializations in priority areas for transforming and emerging industries.

5.3.8 Objectives for 2020

The strategic lines that will drive TEC4INDUSTRY along 2020 will focus on the twofold mission of better understanding the market to influence INESC TEC technology, knowledge, and services evolution. This way, it will be possible to effectively target the Portuguese companies' needs and leverage their growth and international presence. Therefore, specific internal and external oriented objectives were defined:

1. TEC4INDUSTRY internal-oriented objectives
    a. Identify and consolidate problem-oriented technologies and research opportunities;
    b. Setup of best practice and guidelines for Centres and TEC4 relationship and cooperation;
    c. Explore internal assets (e.g. iiLab) to leverage new partnerships and value-added services;
    d. Identify and structure INESC TEC offer: services and technologies.
2. TEC4INDUSTRY external-oriented objectives
    a. Promote and communicate INESC TEC offer;

b. Establish long-term partnership agreements with relevant companies/institutes;

c. Identify leads and explore potential research and services opportunities;

d. Define and promote advanced training on new and emerging technologies;

e. Support the proximity between Clusters and Centres to industrial associations and external R&D organizations, at national or international level;

f. Identify opportunities for technology transfer to the market;

g. Consolidate INESC TEC contributions for European Commission policies influence and roadmap definition.

5.3.9 Action Plan

This year, TEC4INDUSTRY will design and/or implement the following actions:

Action	Objective	Expected Outcomes	Calendar
TEC4INDUSTRY market positioning and strategy		Define the boundaries of the sector, stakeholders and strategic partnerships	S1
Participate on specific Summits and events promoted by European Commission, EU programmes/initiatives or others EU organizations.	1.a	See the future of manufacturing from global experts and have visibility on EU initiatives and programs in order to influence EU manufacturing roadmap.	
Visits to European and International institutes facilities	1.a; 1.b; 2.b	Benchmarking	By Invitation
Promote quarterly meeting with Clusters for vision and roadmap alignment	1.b	Broadcast TEC4INDUSTRY vision through all INESC TEC Clusters and get information about new projects, technologies, and expertise developed.	Quarterly
INESC TEC matrix of competences for industry	1.d	Create a mapping between centres and services, expertise and technologies available	02/2020
Creation of dissemination material oriented to specific domains and specific white papers.	2.a	Produce videos, brochures and other promotional material for INESC TEC services and Tech dissemination	
TEC4INDUSTRY Website	2.a	New TEC4INDUSTRY channel where events information, services, recent use-cases and areas of expertise available and targeted for industry, will be available	08/2020
Participation in National and International fairs	2.a 2.c	Disseminate and demonstrate the technologies and case studies developed in INESC TEC	2 events
Participation in International Conferences for education and manufacturing	2.b 2.c	Collect new ideas and technologies as well as challenge TEC4INDUSTRY innovation (EDUCON 2020, IACEE2020 or ATINER)	2 events
Training Packages and Master Classes for target domains	2.d 1.c	Build flexible, multidisciplinary, and customized courses in the digital transformation domain	By request
TEC4INDUSTRY Summit	2.b; 2.c; 2.f; 2.g	TEC4INDUSTRY will bring together national/international companies and INESC TEC experts in industry 4.0 domain to address important topics for this industrial revolution	09/2020
Open technology days	1.a; 1.b 2.c	Bring companies/associations and INESC TEC experts together to explore relevant domains for the success of the digital transformation.	2 events
Start-ups meet research event	1.a; 1.b 2.d	Bring start-ups and INESC TEC Clusters together to facilitate and support the technology transfer to the market as well as accelerate new companies growth	Quarterly

5.4 TEC4AGRO-FOOD

Business Developer: André Sá

5.4.1 Mission and positioning

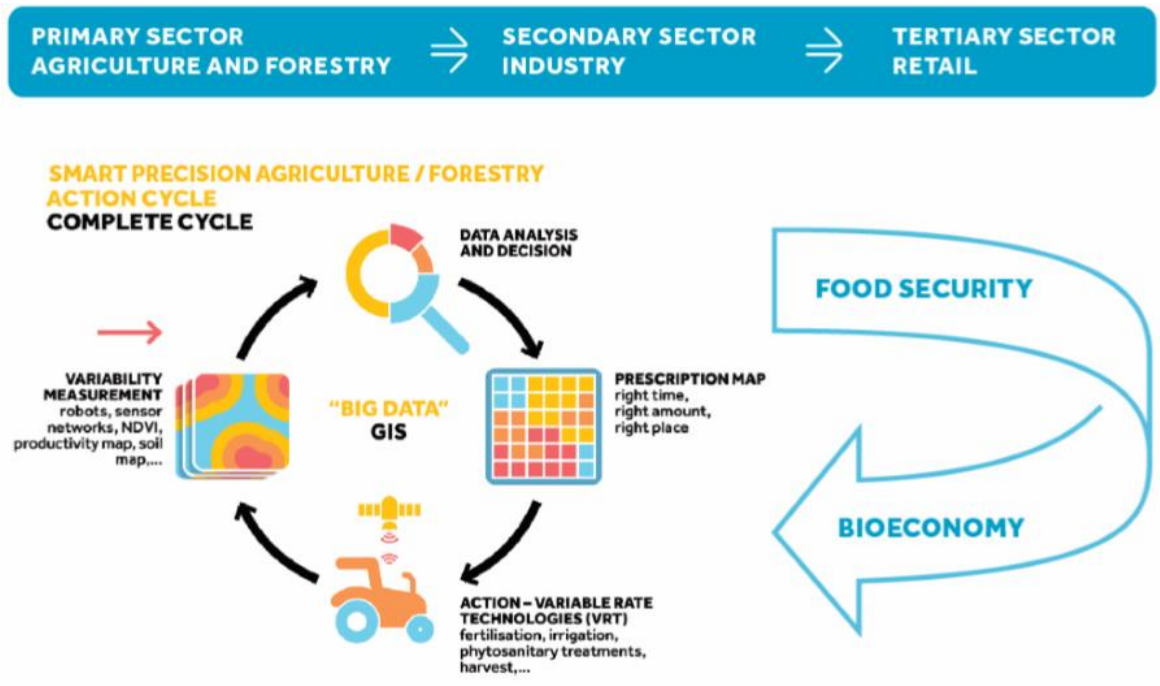
TEC4AGRO-FOOD is the INESC TEC Innovation Area to induce a market pull drive into research and technological development and generate a convergence of knowledge and competencies into producing solutions for Agro-Food and Forestry. TEC4AGRO-FOOD has competencies in the main technologies involved in the digital (r)evolution of Agro-Food and Forestry, i.e. IoT, Artificial Intelligence, Robotics and Big Data.

TEC4AGRO-FOOD follows-up results in the range Technology Readiness Level (TRL) 1-7 and focuses on applied research leading to products and services (TRL 5-7).

The mission of TEC4AGRO-FOOD is co-shaping the digital (r)evolution in Agro-Food and Forestry to tackle the productivity and sustainability societal challenges towards an effective Bioeconomy.

5.4.2 Market

TEC4AGRO-FOOD may and will act in all phases of the Smart Precision Agriculture/Forestry cycle, from Variability Measurement to Action with Variable Rate Technologies (VRT), encompassing Data Analysis and Decision and Prescription Map, as well as in what concerns Food Security and Bioeconomy.



5.4.3 Driving forces

TEC4AGRO-FOOD strategy is driven by societal challenges, such as Food Security, Sustainable Agriculture and Forestry and Bioeconomy, and by the contribution to the European goal of achieving leadership in enabling technologies, such as in Biotechnology, ICT & Robotics and Space.

Considering those challenges, R&D Drivers were identified.

STRATEGIC AGENDAS ⇒	CHALLENGES ⇒	R&D DRIVERS
• FCT • H2020 • SCAR • FAO	• Sustainable intensification of production • Climate change • Pests and Diseases • Rational use of resources	• Internet of Things (IoT) • Artificial Intelligence • Robotics and Automation • Big Data

Analysing the Clusters Research Lines and mapping it with TEC4AGRO-FOOD R&D Drivers, one can verify that they respond to the challenge of creating a high impact research program towards a Smart Precision Agriculture and Forestry, assuring the digital (r)evolution of Agro-Food and Forestry.

	R&D DRIVERS	INTERNET OF THINGS (IOT)	ARTIFICIAL INTELLIGENCE	ROBOTICS AND AUTOMATION	BIG DATA
CLUSTERS RESEARCH LINES	Sensing	●	●	●	●
	Big data	●	●		●
	Digital Transformation of Industry	●	●		●
	Industrial robotics	●	●	●	

The mapping shows the multiple cross participation of Clusters Research Lines regarding TEC4AGRO-FOOD R&D Drivers.

5.4.4 Innovation services

In the scope of TEC4AGRO-FOOD, INESC TEC provides innovation services of Consultancy, Studies and Research and Technological Development, in the following application areas:

- **Smart Precision Agriculture and Forestry**. This innovation service comprises all phases of the Smart (IoT, Artificial Intelligence, Robotics and Big Data) Precision ("right time, right amount, right place") Agriculture/Forestry cycle: Variability Measurement, Data Analysis and Decision, Prescription Map and Action with Variable Rate Technologies (VRT);
- **Food Security**. This innovation service deals with Food Security issues along the Agriculture and Forestry spply chains;
- **Bioeconomy**. This innovation service deals with Bioeconomy issues along the Agriculture and Forestry supply chains.

Through these innovation services, TEC4AGRO-FOOD contributes to the sustainability of Agro-Food and Forestry and promotes a circular economy.
TEC4AGRO-FOOD also embraces the challenge of providing Advanced Training to cope with the shortage of technicians with an Agro-Food or Forestry background and competencies in digital technologies.

5.4.5 Associated Centres

Although most of the activity related with TEC4AGRO-FOOD is pursued by the R&D Centres belonging to the Cluster Industrial and Innovation Engineering, there are others R&D Centres that have a relevant participation in projects related to the digital (r)evolution of Agro-Food and Forestry.

The Centres involved in TEC4AGRO-FOOD are the following:

- CPES - Power and Energy Systems
- CAP - Applied Photonics
- CTM - Telecommunications and Multimedia
- CESE - Enterprise Systems Engineering
- CEGI - Industrial Engineering and Management
- CRIIS - Robotics in Industry and Intelligent Systems
- CRAS - Robotics and Autonomous Systems
- CITE - Innovation, Technology and Entrepreneurship
- LIAAD - Artificial Intelligence and Decision Support
- CSIG - Information Systems and Computer Graphics
- HASLab - High Assurance Software
- C-BER - Biomedical Engineering Research

5.4.6 External competencies and partners

The external competencies and partners relevant for TEC4AGRO-FOOD include the following:

- Research in Agro-Food and Forestry:
  - ✓ INIAV - National Institute for Agrarian and Veterinarian Research;
  - ✓ CITAB - Centre for the Research and Technology of Agro-Environmental and Biological Sciences;
  - ✓ Instituto Superior de Agronomia (ISA), School of Agriculture;
  - ✓ GreenUPorto - Research Centre on Sustainable Agri-food Production;
- Development of innovation and excellence in Agro-Food and Forestry:
  - ✓ INOVISA
- Trailers and Machinery for Agriculture and Forestry:
  - ✓ HERCULANO

5.4.7 Objectives for 2020

The main objectives of TEC4AGRO-FOOD for 2020 are the following:

- Full realisation of projects in portfolio (#1);
- Redouble efforts with companies (#2);
- Redouble efforts at the international level (#3).

5.4.8 Action Plan

This year, TEC4AGRO-FOOD will design and/or implement the following actions:

Action	Objective	Expected Outcomes	Calendar
TEC4AGRO-FOOD's Intelligence and Positioning and Intervention Strategy Plan	#2; #3	Increase TEC4AGRO-FOOD's intelligence and evaluate its positioning and intervention strategy	S1
Start or strengthen participation in relevant European programmes/initiatives	#3	Start or strengthen participation in relevant European programmes/initiatives	All year
Participation in Demos/Open Days/Workshops/Kick-off and Closing Events of ongoing projects	#1	Contributing to full realisation of projects in portfolio	TBD
Continue efforts to transfer IPR of ongoing projects and continue with the identification of Technology Providers, namely Portuguese, and establishing contact with them	#1; #2; #3	Transfer IPR of ongoing projects. Identification of Technology Providers, namely Portuguese, and establishing contact with them	TBD
Participation in ADVID (CoLAB Vines&Wines) meetings/events	#2; #3	Projects in the scope of ADVID	TBD
Participation in CERVIM meetings/events	#3	Projects in the scope of CERVIM	TBD
Participation in national fairs (Agroglobal 2020; AgroIN 2020; AGRO INOVAÇÃO Summit 2020)	#2	National networking and notoriety	09/2020; 04/2020; 10/2020
Participation in international fairs (FIMA 2020; Agromek 2020; Vinitech-Sifel 2020)	#2; #3	International networking and notoriety	02/2020; 11/2020; 01-03/12/2020
Organise an INESC TEC TEC4AGRO-FOOD Community Preferential Contacts' Meeting	#1; #2; #3	Stimulate INESC TEC TEC4AGRO-FOOD Community	TBD
Develop new communication materials	#1; #2; #3	Increase and improve TEC4AGRO-FOOD communication	TBD

5.4.9 Infrastructures

TEC4AGRO-FOOD has at its disposal the following laboratories:

- Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry (FEUP *Campus*);
- Laboratory of Optoelectronics for Sensor Technologies (FCUP);
- Optical and Electronic Technologies Research Laboratory (INESC TEC Building, FEUP *Campus*);
- Laboratory of Computer Graphics and Virtual Environments (FEUP and UTAD *Campus*);
- Laboratory of Smart Grids and Electrical Vehicles (INESC TEC Building, FEUP *Campus*).

In the near future, a new laboratory will also be available: Remote Sensing Lab (UTAD *Campus*).

5.5 TEC4SEA

Coordinator: Eduardo Silva
Business Developer: Carlos Pinho

5.5.1 Mission and positioning

The MISSION of TEC4SEA is to induce a market pull drive into R&D activities targeting sea and deep-sea challenges towards a sustainable Sea Economy.

TEC4SEA is the INESC TEC initiative that brings together R&D&I Institutions, businesses and associations, increasing synergies and critical mass to address real world challenges related with the Sea Economy, raising up an Ocean Engineering Excellence Network capable of stimulating industries, who will act as the leading international counterpart.
INESC TEC Sea Research is aligned with UN Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development, promote the increasing scientific knowledge, research capacity and marine technology for exploration, exploitation and conservation of the oceans, committed with the safeguarding of marine and coastal ecosystems, preventing and reducing marine pollution and the impacts of ocean acidification by ensuring their sustainable use, improving ocean health.
During 2020, TEC4SEA shall continue its consolidation fundamentally in three centres: CRAS, CAP and CTM. Its most developed axis shall be the implementation of a technological infrastructure designated with precisely the same name, “Tec4Sea”, whose 1st phase of implementation will end during 2020. The engagement of additional centres is gaining momentum and the incorporation of CPES into this core is urgent, given the developments related with offshore energy businesses.
TEC4SEA monitors results in the range TRL 1-9 and focuses on applied research leading to products, processes and services (TRL 5-9) that can be transferred to companies.

5.5.2 Market

Quantifying and characterizing the Sea resources market remains quite complex - not even the most complete systematization studies, as was the report by the OECD on the outlook for growth of the ocean economy(19) was able to make this definition clear. However, they made significant progress on previous definitions considering not only the “ocean-based industries (such as shipping, fishing, offshore wind, marine biotechnology), but also the natural assets and ecosystem services that the ocean provides (fish, shipping lanes, CO2 absorption and the like)”. Since the two are inextricably inter-linked, many aspects of ecosystem services and ecosystem-based management have strong implications on the ocean-industry performance and growth.
Until now the majority of the countries only measure the ocean economy in terms of the ocean-based industries’ contribution to economic output and employment. The OECD report classifies the ocean-based industries in established and emerging, as presented in the following table.

19 OECD (2016), The Ocean Economy in 2030, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264251724-en

Next Table shows established and emerging ocean-based industries (adopted from the OCDE report):

Established	Emerging
Capture fisheries	Marine aquaculture
Seafood processing	Deep- and ultra-deep water oil and gas
Shipping	Offshore wind energy
Ports	Ocean renewable energy
Shipbuilding and repair	Marine and seabed mining
Offshore oil and gas (shallow water)	Maritime safety and surveillance
Marine manufacturing and construction	Marine biotechnology
Maritime and coastal tourism	High-tech marine products and services
Marine business services	Others
Marine R&D and education	
Dredging	

Regarding the characterization of the Portuguese Sea market, the most systematic and consistent work has been done by PwC, and the annual publication "HELM - PwC Economy of the Sea Barometer"(20) is a reference in terms of market characterization and analysis of the different sectors evolution, such as: shipbuilding and ship maintenance / repair; sea transportation; ports; logistics and shipping; fishing; aquaculture and fish industry; Portuguese State action at sea; entertainment; sports; tourism and culture; maritime insurance and maritime financing. It should be highlighted that the OCDE report considers an additional set of subsectors that may become relevant in the future; "including renewable energies, mineral resources and biotechnology that, despite having an enormous potential, will take time to gain economic relevance in the Portuguese economic framework".

The existing PWC reports don't characterize the sea-related R&D&I market as the OECD report does. Nevertheless, on the other side, it characterizes a very important subsector that is not mentioned in the OECD reports, which is the Portuguese State actions at Sea.

INESCTEC clearly contributes to worldwide R&D&I for the Sea Economy. The multidisciplinary application-oriented solutions addressed by TEC4SEA cover a wide range of both established (e.g., Ports management and autonomous ships) and emerging industries (e.g., seabed mining and offshore wind energy). It also contributes to the emergence and strengthening of new services and ecosystems in increasingly relevant areas, such as ocean health maintenance activities, by contributing to monitoring activities of biogeochemical variables, oil spill mitigation, among others.

5.5.3 Driving forces

TEC4SEA addresses some of the main societal challenges for the next years identified by INESC TEC Cluster's, such as NIS, and is completely aligned with the trends that influence its future research activities: "Smaller, smarter, long endurance, collaborative autonomous systems".

The Societal Challenges, European, National and Regional agendas and smart specialization strategies, and, more recently, the Global Goals for Sustainable Development where considered in the identification of the main challenges for the Sea Economy as well as the main R&D driver's for INESC TEC.

20 https://www.pwc.pt/en/publications/helm-portugal.html

STRATEGIC AGENDAS	CHALLENGES	R&D DRIVERS
• Horizon 2020 • European Societal challenges • The Global Goals for Sustainable Development • National Agendas and Strategies • Regional Smart Specialization agendas • Horizon Europe	• Sustainability • Safety • Automation • Autonomy • Digitalization	• Marine Robotics and Autonomous Systems • Fibre Optic Sensors and Imaging Systems • Broadband Wireless Communications Systems for ocean environments • Informatics Systems and Serious Games • Energy Management Systems

CLUSTERS RESEARCH LINES	MARINE ROBOTICS AND AUTONOMOUS SYSTEMS	FIBRE OPTICS SENSORS AND IMAGING SYSTEMS	BROADBAND WIRELESS COMMUNICATIONS SYSTEMS FOR OCEAN ENVIRONMENTS	INFORMATICS SYSTEMS AND SERIOUS GAMES	ENERGY MANAGEMENT SYSTEMS
Energy Conversion	●		●		●
Network Planning and Operation	●	●	●	●	●
Computer vision	●	●		●	
Sensing	●	●	●	●	
Autonomous systems	●	●	●	●	●
Big data	●	●	●	●	
Privacy-preserving computing	●	●		●	
Virtual environments	●			●	
Sustainable production systems	●	●	●	●	●
Digital transformation of industry	●	●	●	●	●
Industrial robotics	●	●	●	●	●

5.5.4 Innovation services

The following innovation services are provided by INESC TEC in the scope of TEC4SEA:

- **3D Mapping and data fusion in unstructured environments** - the services can involve several complementary technologies for 3D mapping and data fusion from heterogeneous sensors for air, ground and underwater environments.
- **Development of optical and bio-sensors** - the services include the conception, development and test of sensors for physical and chemical parameters monitoring.
- **Broadband communications solutions for marine environments** - the services provided cover the simulation, development test and validation of broadband communications solutions to be deployed above or underwater.
- **Data collection, processing and management** - conception, development and test of technological frameworks that ensure the integrity, organization, long-term preservation and accessibility of data as well as efficient data processing and visualization.

5.5.5 External competencies and partners

The external competencies leveraged by TEC4SEA include the following:

- **Marine and environmental knowledge** – knowledge and information about biological, physical and chemical dynamics in the marine environments as well as the impact of natural and human activities are fundamental in the technological development for these environments: CIIMAR, IPMA, EMSO

- **New materials** - new materials, information about their characteristics and behaviour in different environments and under different conditions is fundamental for new solutions: INEGI
- **Sea intelligence** - knowledge and information about strategic moves of different nations regarding the Ocean: AIR CENTER

5.5.6 Objectives for 2020

The objectives for 2020 can be classified as "internal" (with impact in the core teams of INESC TEC) and "external" (with impact in stakeholders outside INESC TEC):

Internal

1. Establish and consolidate a work team to reduce barriers between the centres and the TEC4SEA as well as enable the execution of several actions and tasks. The majority of the persons has already been identified, as they are deeply involved in the two National Roadmap infrastructures (Tec4Sea, EMSO);
2. Promote an internal activity that supports the production of a Sea Economy awareness report with the landscape characterization that impacts INESC TEC activities. The main goal is to help improving INESC TEC strategy for the development of Sea technology leadership fundamental for teaming submission;
3. Define a framework for INESC TEC's positioning and strategy for the sea economy;
4. Define an action plan aligned with Horizon Europe and also with each EITs;
5. Define the INESC TEC Sea Strategy for 2020-2030 and produce a reference document that reflects it.

External

1. Conclude the 1st implementation phase of the EMSO-PT and Tec4Sea infrastructures, promoting the new capacities in a public event;
2. Assume a corporate position in Aguçadoura's test zone;
3. Establish a stakeholder network to strengthen and reveal our initiatives;
4. Strengthen our relationship with national core players, such as: Forum Oceano, IPMA, CIIMAR, INEGI, AIR CENTER, IBS and, eventually, the two Colabs linked to the Sea;
5. Identify and establish collaboration protocols with international twinning organizations (e.g., Sintef Norway);
6. Consolidate international relations (Europe, Latin America, India, South Korea).

5.5.7 Associated Centres

The main centres involved in TEC4SEA are the following:

- CRAS - Robotics and Autonomous Systems
- CTM - Telecommunications and Multimedia
- CAP - Applied Photonics
- CSIG - Information Systems and Computer Graphics
- CPES - Power and Energy Systems
- LIAAD - Artificial Intelligence and Decision Support

5.5.8 Action Plan

The following table summarizes the main actions for 2020, identifying the main objectives of each action (i.e., regarding the previously presented "Internal" and "External" objectives) and expected outcomes.

Actions	Objective	Expected outcomes	Calendar
National Businesses visits	I2, I3, I5, E3, E4	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	all year
International Businesses visits	I5, E3, E5, E6	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	all year
Participation as Institutional delegate (air centre, …)	I4, I5, E4	• New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	all year
KIC RAWMATERIALS meetings	I4, I5, E3	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	all year
Participation in Oceans 2020 in Singapore with stand	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	Q2
Participation in Lisboamar with stand (event during 2nd UN conference in Lisbon)	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	Q2
Participation on Business2Sea with stand (event in VIGO - Spain)	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	Q4
Workshop organization during Business2Sea	All External objectives	• Project proposals/Future opportunities • Networking creation • Contribution to Scientific roadmap • Promote the brand INESC TEC/TEC4SEA	Q4
Conferences inscription	Scouting future	• Scientific/market orientation • Develop SEA intelligence	all year
Communication material production	All objectives	• Videos, flyers, …	all year

5.6 TEC4HEALTH

Coordinator: Miguel Coimbra
Business Developer: Carlos Ferreira

5.6.1 Mission and positioning

The Mission of TEC4HEALTH is to contribute to the improvement of the health of all individuals in the future by researching and developing technology. For accomplishing this, TEC4HEALTH aims to explore the activities within the health sector where technology needs and roadmaps indicate a high potential for applying INESC TEC's skills and research lines, resulting into successful projects, contracts and technology transfers.

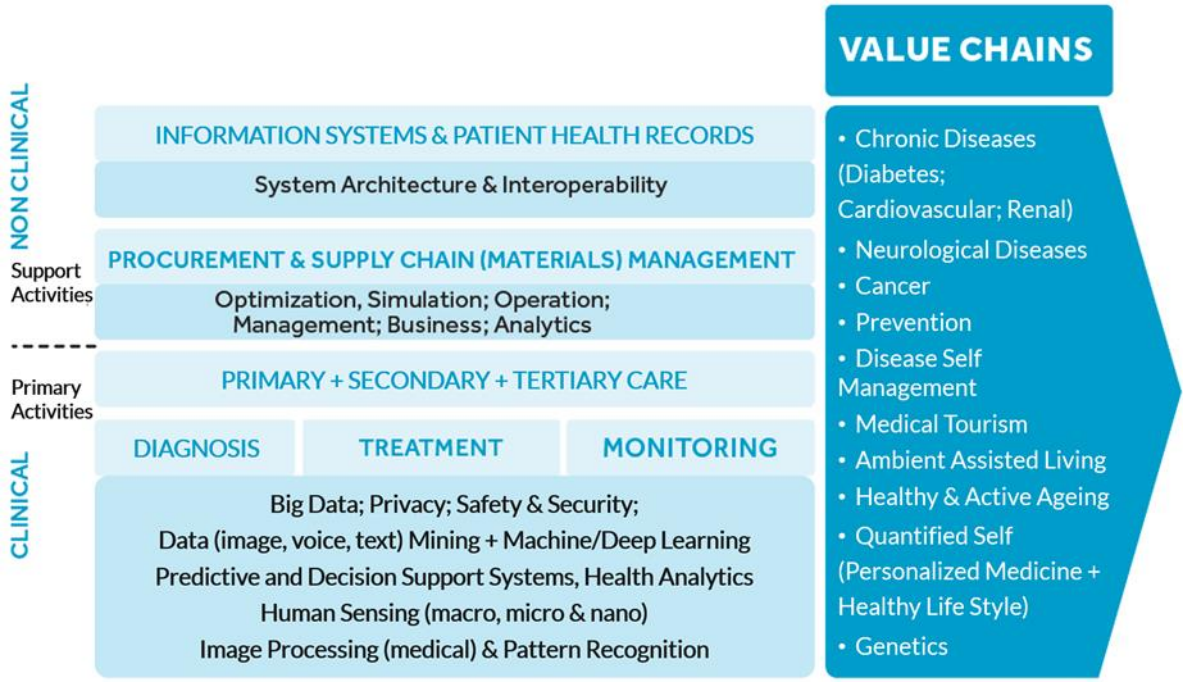
INESC TEC already has several examples of research, development and technology transfer of health technologies, in clinically relevant areas such as cancer, neuroscience or disease screening systems. TEC4HEALTH aims to:

- Create internal and external visibility of the profile and activities of INESC TEC in the area of health technologies.
- Promote the growth of the area of health technologies within INESC TEC, namely research, services and technology transfer activities.

INESC TEC aims to position itself as a disruptive research and development partner of health technologies, in which the excellence of its fundamental research associated with the intense collaboration with clinical partners creates new opportunities for products and services for companies operating in the health sector market.

5.6.2 Market

TEC4HEALTH aims to address all the value chain actors and processes in the health sector, and is currently very committed to bringing unique knowledge and technologies to solve challenges in mainly cancer, neurological diseases and disease screening.



INESC TEC already produces relevant research and development for some of these value chains, with a stronger emphasis on three: cancer (lung, breast, colorectal, stomach, esophagus, thyroid, cervix uteri), neurological diseases (epilepsy, Parkinson, Alzheimer) and disease screening (retinal disease, heart disease). The later involves a variety of different diseases such as retinopathy or cardiovascular, but is unified by the concept of technologies

for mass cost-effective screening the global population. All three are strongly aligned with current health challenges identified in the strategic agendas of H2020, WHO and FCT.

STRATEGIC AGENDAS ⇉	CHALLENGES ⇉	R&D DRIVERS
• H2020; Horizon Europe – Societal Challenge: Health, demographic change and wellbeing • WHO – Global action plan for Healthy Lives and Well-being for All • EIP_AHA – Blueprint to innovate health and care in Europe • PT2020/RIS3 • FCT Research and Innovation Thematic	• Cancer (lung, breast, colorectal, stomach, esophagus) • Neurological diseases (epilepsy, Parkinson, Alzheimer) • Disease screening (retinal disease, heart disease)	• Health Information Systems (security, privacy, interoperability) • Computer Vision (deep learning) • Signal Processing (deep learning) • Biomedical Instrumentation (optical sensors, inertial sensors) • Machine Learning (reinforcement learning, explainable artificial

R&D drivers for addressing these challenges can be divided into five groups, as depicted in the diagram above: Health Information Systems, Computer Vision, Signal Processing, Biomedical Instrumentation, Machine Learning. All these drivers map into a variety of research lines from at least three different Clusters of INESC TEC: Computer Science, Networked Information Systems, Industrial and Systems Engineering.

CLUSTERS RESEARCH LINES	R&D DRIVERS	Health Information Systems	Computer Vision	Signal Processing	Biomedical Instrumentation	Machine Learning
COMPUTER SCIENCE	Big Data and Machine Learning		●	●		●
	Privacy-preserving Computing	●				
	Virtual Environments	●			●	
NETWORK INTELLIGENT SYSTEMS	Sensing				●	
	Communications				●	
	Computer Vision		●	●		●
	Autonomous Systems				●	
INDUSTRY AND INNOVATION	Innovation and Development of new Products/Services	●	●	●	●	●
	Information Management and Knowledge Discovery	●				
	Robotics				●	
	IoT and Cyber-Physical Systems			●	●	

5.6.3 Innovation services

A stronger external image of INESC TEC as a highly competent innovator in the area of health technologies is needed in order to fully explore the potential of providing these services. Four core competences have already been identified, which will form more solid structured offers in the future:

- Artificial intelligence for healthcare studies;
- Artificial intelligence for computer-aided screening and diagnosis;
- Information systems for healthcare;
- Novel sensor-based devices for healthcare.

5.6.4 Associated Centres

In a first analysis, Centres involved in technologies for healthcare activities are (L – low, M – Medium, H – High):

Centre	TEC4HEALTH	AI	Inf. Syst	Instrum.
CAP – Centre for Applied Photonics	M	To be studied during the first Quarter of 2020		
CTM – Centre for Telecommunications and Multimedia	H			
CRAS – Centre for Robotics and Autonomous Systems	M			
C-BER – Centre for Biologics Evaluation and Research	H			
CITE – Centre for Innovation, Technology and Entrepreneurship	M			
CESE – Centre for Enterprise Systems Engineering	M			
CEGI – Centre for Management and Industrial Engineering	M			
CRIIS – Centre for Industrial Robotics and Intelligent Systems	M			
CRACS – Centre for Advance Computer Systems	M			
CSIG – Centre for Information Systems and Computer Graphics	H			
LIAAD – Laboratory of Artificial Intelligence and Decision Support	M			
HASLab – High Assurance Laboratory	M			
CPES – Centre for Power and Energy Systems	M			

5.6.5 External competencies and partners

The external competencies and partners relevant for TEC4HEALTH will be systematically identified and contacted during the planned activities of 2020. A sample of both current and regionally relevant partners include the following:

- Research Partners: Fraunhofer AICOS, CINTESIS, I3S, IT, INESC INOV, INESC MN, INESC-ID, INESC Coimbra;
- Hospitals: Hospital São João, Hospital Santo António, Hospital Santos Silva, Hospital Pedro Hispano;
- Private Health Groups: José de Mello Saúde, Luz Saúde, Lusíadas, Trofa Saúde;
- Companies: Glintt, Critical, First Solutions, Siemens, Philipps, Medtronic, GE Healthcare, Olympus, Fuji, Pfizer.

5.6.6 Objectives for 2020

The 2 main objectives of TEC4HEALTH are the following:

- Create internal and external visibility of the profile and activities of INESC TEC in the area of health technologies;
- Promote the growth of the area of health technologies within INESC TEC, namely research, services and technology transfer activities.

The specific objectives for 2020 can be divided as either focused on Objective 1 or Objective 2. The most crucial specific objectives for 2020 are associated with the creation of both the infrastructure and the relevant workflows within INESC TEC that enable the sustainable addressing of these main objectives in the future. This includes the identification of all projects, activities, and interested research groups in this area within INESC TEC (Objective 1). It also includes the regular presence of INESC TEC in events and networks more strongly associated with the area of health technologies (Objective 1). The most relevant efforts for the growth of the activities in this area (Objective 2) will be in the area of European funding, namely the last calls of H2020, and the preparation of the new Horizon Europe framework program. This is a key fundamental step, to later enable the growth of services and technology transfer activities in the future.

5.6.7 Action Plan

During 2020, the following actions will be implemented:

Actions	Objective	Expected outcomes	Calendar
Meetings with associated TEC4HEALTH Centres	1	Mapping of all projects, activities, needs and interested research groups in this area within INESC TEC	Q1
Promote meetings between different associated Centres to establish internal collaborations	1	Increased number of projects and activities in this area involving more than one INESC TEC centre	All year
Increase INESC TEC visibility by participating in relevant events and networks	1	Presence in relevant events Presence in relevant networks	All year
Creation of promotional materials	1	Flyers Videos	All year
National Businesses visits	2	Establishment of new partnerships Increased visibility of INESC TEC within the health technology area Preparation of new proposals and contracts	All year
International Businesses visits	2	Establishment of new partnerships Increased visibility of INESC TEC within the health technology area Preparation of new proposals and contracts	All year
Support to the last funding opportunities of the H2020 program	2	Submitted project proposals with strong possibility of approval	Q1
Study and planning of Horizonte Europa calls	2	Strategic plan with relevant European funding opportunities Submitted project proposals with strong possibility of approval	Q2, Q3, Q4

5.7 TECPARTNERSHIPS

Coordinator: Augustin Olivier

Business Developer: José Nina de Andrade

5.7.1 Mission and positioning

Our mission is to promote and support market activity in all other sectors (not covered by the previous TEC4) and explore new sectors of activity in the market where technology needs and roadmaps indicate a high potential for applying INESC TEC's skills and research lines. The viability and sustainability of the sectors being explored will allow, after incubation, for an eventual transformation into a TEC4 specific to the respective sector or integration into one of the existing ones.

INESC TEC is a leader of research and technology transfer, allowing companies to be internationally competitive with innovative products, services, processes and business models.

The working methodology to explore new application/market areas is structured in three steps and, in 2020, will address the following domains:

1. **Scouting the market**

Scouting opportunities, understanding potential INESC TEC role.

Continuous work, aiming at identifying new areas with potential for INESC TEC intervention.

2. **Study phase**

Mobility: sector where there has been unstructured intervention, so a market analysis will be developed in view of national challenges and European agendas, and consequent establishment of INESC TEC's positioning.

The objective of the analysis will be to target market segments with their players (technological and end users, partners and competitors) where INESC TEC can bring a recognized value, in line with the institution's research lines, and create a first level of structured intervention.

Media: although INESC TEC already had a TEC4MEDIA initiative, the ongoing transformation of this sector, regarding technologies, players and their role in the value chain led us to revise the all strategy, thus positioning the process in this study phase.

3. **Startup phase**

In this phase, two sectors were studied during 2018 and 2019, which allowed to build some solid foundations and to associate INESC TEC brand:

Financial sector: currently in a restructuring period due to the entry of new players and the need to digitize by exploiting the available data. Some contacts with banks were established, resulting in a contract and leads that confirmed the receptivity of the sector to INESC TEC intervention.

Construction sector: low productivity sector, lagging behind digitization, which is expected to have a relevant impact from its increase. During 2018 and 2019, contacts were established resulting in the creation of the BUILT Colab, where INESC TEC is a founding member and will be responsible for the digitalization agenda, and also the launch of the mobilizing collaborative program proposal "**REV@CONSTRUCTION - DIGITAL CONSTRUCTION REVOLUTION**".

5.7.2 Market

1. **Study phase**

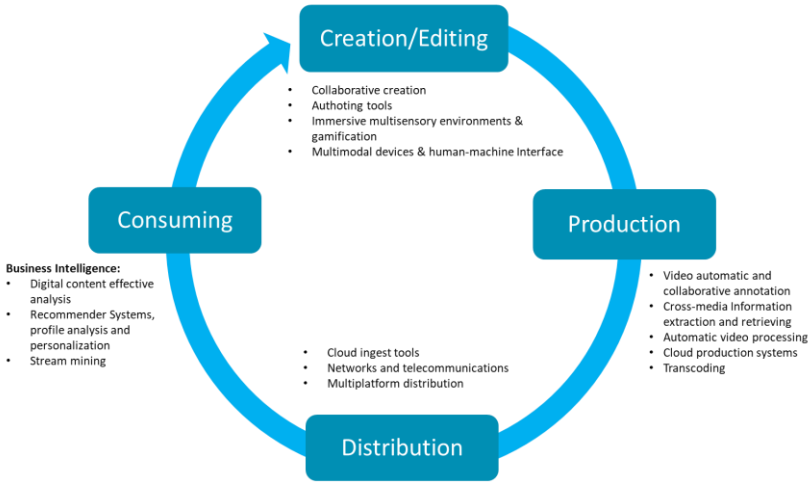
a) Mobility

In a first approach, this area will be looking for the aspects related with passengers transportation (land, air, water), metropolitan areas traffic planning and communication networks associated to the Smart City concept.

b) Media

The content value chain below shows the current intervention of INESC TEC on the creative industry sector.

During 2020, the goal will be to focus this thematic on the most promising market segments, aligned with the evolution of the sector and INESC TEC related research lines.



2. Startup phase

a) Financial Sector

Our focus will be concentrated in final users of the following segments:

- Financial service activities;
- Insurance, reinsurance and pension funding;
- Activities auxiliary to financial services and insurance activities;
- Legal and accounting activities; activities of head offices; management consultancy activities.

With economical activities identified with the NACE code K64, K65, K66, M69 and M70.

The following NACE code activities identify the technological partners in:

- J58.2 - Software publishing;
- J62 - Computer programming, consultancy and related activities;
- J63 - Information service activities;

At this first step, we focus on the final users that have the capability to absorb R&D&I solutions without intermediary technological third party.

b) Construction sector

Our focus will be concentrated in final users of the following NACE code activities;

- F41 - Construction of buildings;
- F42 - Civil engineering;
- F43 - Specialized construction activities;

At this first step, we focus on the final users that have the capability to absorb R&D&I solutions without intermediary technological third party and technological partners with the same NACE code activities identified for the financial sector.

The construction value chain below shows the main activities related where INESC TEC intervention will be defined.

5.7.3 Driving forces

The definition of the challenges of the analyzed sectors consider the Sustainable Development Goals (SDG) defined by the United Nations, and also the European, national and sectorial strategic agendas.

Considering those challenges, the preliminary R&D drivers were identified in order to accomplish them. The R&D drivers will be use to define the R&D research lines involved in the thematic.

a) Mobility sector

The SDG 9 "Industry, Innovation, and Infrastructure" (target 9.1) and SDG 11 "Sustainable cities and communities" (targets 11.2 and 11.6) are the goals where it is possible to contribute including the waste management (SDG11.6) considering the global management of the transports in the city.

STRATEGIC AGENDAS ⇒	CHALLENGES ⇒	R&D DRIVERS
• Horizon Europa – cluster "Climate, Energy and Mobility" • EU - WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system • EU - Guidelines for developing and implementing a sustainable urban mobility plan • ACEA- The 2030 Urban Mobility Challenge • PAMUS - Plano de Ação de Mobilidade Urbana Sustentável	**TO BE REVIEWED** • Sustainable urban mobility • Public transport planning • Urban freight distribution systems • Urban private transport policies • Coordination of all stakeholders • Connectivity and data collect • New mobility business • Waste collection mangement	**TO BE DEFINED**

b) Media sector

Driving forces for the TEC4MEDIA are, at the present time, the following:

STRATEGIC AGENDAS ⇒	CHALLENGES ⇒	R&D DRIVERS
TO BE REVIEWED • H2020/ICT • NEM SRIA – Strategic Research & Innovation Agenda • ECDG CNET – Communications Networks , Content and Technology: Data Applications and Creativity, Media Convergence and Social Media , Media Policy • PT2020/RIS3	**TO BE REVIEWED** • Economy and digital marketing • Content personalization • Media Convergence and Social Media • Access and navigation in large repositories • Content digitalization, restauration and preservation • Gamification Strategies • Production and reuse of content on multiple platforms	**TO BE REVIEWED** • New techniques and tools for storytelling • Immersive environments/ experience creation • Recommender systems and profiles analysis • Metadata(creation and management) • Content agile management and distribution • Cryptography in IoT.

c) Financial sector

The financial sector is crucial to reach all 17 Sustainable Development Goals (SDG) defined by the United Nations and it's a main concern for a world healthy economy and contribute to a sustainable world by financing "greener" activities.

In this thematic, INESC TEC want to contribute to the Goal 8 "Economic Growth" (target 8.2 and 8.10)

STRATEGIC AGENDAS ⇒	CHALLENGES ⇒	R&D DRIVERS
• Horizon Europa - cluster "Digital, Industry and Space" • EU strategy on sustainable finance • BCE - FINANCIAL SECTOR STRATEGY 2016 – 2020 • Banking_trends_2017 (Cap Gemini) • Commercial-banking-top10-trends-2018-1 (Cap Gemini) • Payments-trends_2018 (Cap Gemini) • Retail-banking-2020-evolution-or-revolution (PWC)	• New business models • Productivity • Digitalization • Interoperability of solutions and platforms • Cybersecurity • Green Finance	FIRST APPROACH • Big data • Machine learning • Artificial Intelligence • Criptography

d) Construction sector

Like the financial sector, this sector is transversal to all SDG, with a direct contribution to SDG 8 "Economic Growth" (target 8.2), SDG 9 "Industry, Innovation, and Infrastructure" (target 9.1) and SDG 11 "Sustainable Cities and Communities" (target 11.1).

The main concern is the productivity and the Construction and demolition waste (CDW) management.

The productivity rate consists in a flat value along the last 20 years compare with the manufacturing industries, that multiplied this rate by 1,7 during the same period.

CDW accounts for approximately 25% - 30% of all waste generated in the EU.

CDW arises from activities such as the construction of buildings and civil infrastructure, total or partial demolition of buildings and civil infrastructure, road planning and maintenance.

CDW has been identified as a priority waste stream by the European Union.

INESC TEC is determined to contribute to reach EU objectives.

STRATEGIC AGENDAS	CHALLENGES	R&D DRIVERS
• COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL "Strategy for the sustainable competitiveness of the construction sector and its enterprises". • Horizon Europa – cluster "Digital, Industry and Space" • Horizon Europa – cluster "Climate, Energy and Mobility" • Plano Estratégico de Inovação e Competitividade 2030 para o Setor AEC, Deloitte 2018 • European Powers of construction, Deloitte, 2016 • Mckinsey Global Institute, Reinventing Construction: A Route to Higher Productivity, Feb 2017	• Productivity • Digitalization • Interoperability of solutions and platforms • Digital Twin • Construction and Demolition Waste management	FIRST APPROACH • Modelization • Machine learning • Big Data • IoT • Interoperability • Prevision • Circular economy

5.7.4 Innovation services

Not applicable in this context

5.7.5 Associated Centres

In a first analysis, Centres involved in thematic sectors are the following (C indicate core centres):

Centres	Construction	Finance	Media	Mobility
CAP – Centre for Applied Photonics	V			
CTM – Centre for Telecommunications and Multimedia	C	C	C	C
CRAS – Centre for Robotics and Autonomous Systems	C			C
C-BER – Centre for Biologics Evaluation and Research	V			V
CITE – Centre for Innovation, Technology and Entrepreneurship	V	V	V	V
CESE – Centre for Enterprise Systems Engineering	C			C
CEGI – Centre for Management and Industrial Engineering	V			
CRIIS – Centre for Industrial Robotics and Intelligent Systems	V			
CRACS – Centre for Advance Computer Systems		V	V	V
CSIG – Centre for Information Systems and Computer Graphics	C	C	C	C
LIAAD – Laboratory of Artificial Intelligence and Decision Suppor	C	C	C	C
HASLab – High Assurance Laboratory	V	C	C	C
CPES – Centre for Power and Energy Systems	V			V

5.7.6 External competencies and partners

The external competencies and partners relevant for Mobility and Media sectors will be defined during 2020.

The external competencies and partners relevant for financial sector include the following:

- **Partners** – FEP – Faculdade de Economia do Porto

The external competencies and partners relevant for Construction sector include the following:

- **Production –** New construction technics - FEUP;
- **Partners** – PCTP and BUILT Colab

5.7.7 Objectives for 2020

Main objectives for 2020 are the following:

1. Obtain the "Approval organization" seal for the French research tax credit;
2. Identify leads and explore potential research and services opportunities;
3. Identify and structure INESC TEC offer: services and technologies, for new market segments;
4. Promote and communicate INESC TEC and its offer;
5. Establish long-term partnership agreements with relevant stakeholders (particularly with companies);
6. Network with clusters and industrial association;
7. INESC TEC market positioning in new segments;
8. Identification of the most relevant European programs / initiatives.

5.7.8 Action Plan

During 2020, the following actions will be designed and/or implemented:

Actions	Objective	Expected outcomes	Calendar
Application for Approval organization for the French research tax credit	1) - 2) - 4) - 5)	• Proposals/Future opportunities • Make the brand INESC TEC known in the new market	Q1
Market positioning for construction and financial sector	3) - 7)	• Internal document	S1
Identification of the most relevant EU programs / initiatives	8)	• Internal document	S1
National Businesses visits	2) -3) - 5)	• Proposals/ Future opportunities • Make the brand INESC TEC known • New partners/Partnership consolidation	all year
International Businesses visits	2) -3) - 5)	• Proposals/ Future opportunities • Make the brand INESC TEC known • New partners/Partnership consolidation	all year
Clusters / others organizations meetings	2) - 4) - 6)	• Networking / Lobbying • Market scouting (access to sectorial roadmaps)	all year
Participation on fair/event of a new market segment with stand	2) - 3) - 4)	• Proposals/Future opportunities • Networking and market understanding • Contribution to technological/Scientific roadmap • Make the brand INESC TEC known	TBD

Actions	Objective	Expected outcomes	Calendar
Workshop organization (partnership FEP): Financial sector (by invitation)	2) - 3) - 4)	• Attract main actors of the financial market sector and/or financial functions of businesses • Contribution to Technological/ Scientific roadmap • Networking creation • Proposals/Future opportunities • Make the brand INESC TEC known	Q1
Workshop organization (partnership PTPC): Construction sector (by invitation)	2) - 3) - 4)	• Attract main actors of the construction market sector • Contribution to Technological/ Scientific roadmap • Networking creation • Proposals/Future opportunities • Make the brand INESC TEC known	Q2
Workshop organization: AI applied to audiovisual archives	2) - 3) - 4)	• Attract main actors of the audiovisual archive market sector • Contribution to Technological/ Scientific roadmap • Proposals/Future opportunities • Make the brand INESC TEC known	Q1
Strategic reflexion seminary	3)	• New strategy for the “Mobility” thematic (1 seminary) • New strategy for the “Media” thematic (2 seminaries)	TBD
Communication material production	4)	• Videos, flyers, …	all year

6 RESEARCH AND DEVELOPMENT CENTRES

6.1 CTM - CENTRE FOR TELECOMMUNICATIONS AND MULTIMEDIA

Coordinators: Jaime Cardoso and Filipe Ribeiro

6.1.1 Presentation

The Centre for Telecommunications and Multimedia (CTM) consists of 100+ researchers addressing scientific and technological challenges related with the fields of telecommunications and multimedia. CTM is fully committed and aligned with the vision and mission of INESC TEC and specializes them as follows:

- Vision: A lively and sustainable world where networked intelligence enables ubiquitous interaction with sensory-rich content;
- Mission: Research and development of advanced systems and technologies enabling high capacity, efficient communications, media knowledge extraction, and immersive ubiquitous multimedia applications.

CTM accomplishes its mission, within the Cluster NIS – Networked Intelligent Systems, by directing its activities towards 4 main areas of research: Optical and Electronic Technologies (OET); Wireless Networks (WiN); Multimedia and Communications Technologies (MCT); Information Processing and Pattern Recognition (IPPR).

6.1.2 Context

There is an ongoing convergence of key technologies that are poised to transform the ecosystem where CTM develops its activity. Those technologies include artificial intelligence, data analytics, wireless networks, media management and the Internet of Things (IoT). The combination of these technologies will create opportunities to significantly enhance user experiences in multiple domains such as communications, health, transports, and digital multimedia content.

Artificial Intelligence (AI) is increasingly integrated into many areas including Internet search, entertainment, content optimization, health and well-being, and robotics. The long-term prospect for AI is that it will become embedded in many different technologies and provide autonomous decision making on behalf of humans, both directly and indirectly, through processes, products, and services. AI is having an ever-increasing role in ICT including both traditional telecommunications as well as many communications-enabled applications and digital commerce.

When it comes to wireless networks, the relevant challenges are related to the design of networking solutions that address the exponential traffic growth on the Internet, namely video and bandwidth-hungry applications, and the emerging communication needs in remote environments, namely at sea. Softwarization of the communications networks from the application down to the physical layer will change the current networking paradigm. High flexibility and real-time reconfiguration of the network according to the context will become necessary. As such, the novel networking solutions need to be smart and take advantage of Software Defined Networking, Network Function Virtualization, and machine learning techniques to make wireless networks context-aware and reconfigurable in real-time. The design of smart networks is being assumed as a priority for the next framework programme in Europe (Horizon Europe) 2021-2027, namely by the ETP Networld2020, which periodically defines strategic agendas within the telecommunications domain and has been working with the European Commission to consider this a major underlying research and innovation topic for Horizon Europe. On the other hand, autonomous ships, the expected increase in maritime transportation traffic in European waters, and the increasing activity at sea (e.g., offshore aquaculture, deep sea mining) will require new communications solutions, both above water and underwater. According to two recent reports from the European Union and OECD, the Ocean Economy in 2030 will bring up global value added in the order of trillions of dollars. This is drawing international attention and is expected to drive research and innovation in this domain in the next decade. Wireless communications will be at the centre to support all these activities conveniently, in a cost-effective way, and enable human remote presence at the harsh ocean environment.

It is also worth emphasizing the role computer vision is expected to have – powered by artificial intelligence – in the next years, as acknowledged in several reports analysing emerging technology trends that will influence business, government, education, media industry, entertainment and society in the coming years (21 22, 23). Computer Vision is a quickly growing field, with the ability to completely change and improve different applications such as advanced driver assistance systems, medical imaging, industrial systems, precision agriculture, retail, advertising, broadcasting, media streaming services, security, surveillance, unmanned vehicles and robotics. The huge amount of multimedia information made available not only by professionals but also by common users, together with the growing sensorization of the electronic gadgets and of the environment, creates new challenges for the efficient management, access and merge of this valuable content but also new opportunities for the creation of context and semantically aware and personalised multimedia applications capable of creating more immersive and adaptable experiences. This new environment and innovative technologies for content creation and management are also contributing to an integrated ecosystem that is expected to increase revenue for content owners and creators. The integrated and holistic expertise and long-term experience of CTM on multimedia technologies provides the right environment for answering the new emerging challenges in the area, making it a core activity within the Centre. Also, medical imaging and medical image analysis have attracted increasing attention in recent years due to its vital component in healthcare applications and are a core expertise at CTM. The trend is on the integration of multimodal information carried out from different diagnostic imaging techniques, essential for a comprehensive characterization of the body part under examination. A key application of this research is the development of deep learning-based algorithms to recognise cancer at a level comparable to trained physicians, also a central activity at CTM.

6.1.3 Contribution to the Vision of the Cluster

CTM strongly contributes to the NIS vision of autonomous networked intelligent hybrid systems enabled by ubiquitous sensing and processing of information. CTM contributes to the research in new sensors, which are low power or nanoscale to enable the envisioned “electrosphere of sensors”. CTM is responsible for the communications aspects of NIS; CTM has focused its activities on wireless communications for dynamic and challenging scenarios, well aligned to the NIS vision. The CTM’s expertise in machine learning and audiovisual data interpretation and management provides the means to make sense of the acquired data; the semantic knowledge built from the integration of the network of sensors will allow acting over the environment as well as over the content.

Through NIS to other Clusters, CTM’s work can be an input to other scientific and development activities in INESC TEC. CTM’s work on the fundamentals of Artificial Intelligence on novel algorithms for Machine Learning can be used by all Clusters. Also relevant for the CS Cluster is CTM unique expertise on multimedia, including the manipulation of new media formats such as Multiview, panoramic, 3D and 360˚ audio and video, the semantically and context-aware management and handling of media content and the development of personalised and adaptable multimedia services. Its unique communications line at the institute provides the fundamentals to any digital transformation in any application at any environment, the capacity to transmit high volume of data and ways to contextualize it. For the PE Cluster, solutions to transmit metering data from millions of smart meters and other utilities resources with critical requirements; for the ISE Cluster, solutions to support massive machine to machine type communication required by the industry IoT; for CS cluster, ways to tag and to wirelessly transmit massive volumes of data required by the multimedia applications.

6.1.4 Centre research lines

RL1. Optical and Electronic Technologies

The main goal of this research line is to devise solutions for the communications and intelligent systems of the future, based on the integration of advanced skills in applied electromagnetics, electronics and programmable logic, targeting mainly applications in optical and wireless communication systems as well as in dedicated

[17] https://futuretodayinstitute.com/2018-tech-trends-annual-report/
[18] https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/support-eu-research-and-innovation-policy-making/foresight/activities/current/bohemia_en
[19] https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2019/

computing. Specific scenarios of interest are in the maritime (above and underwater), GPS-negated and earth-space environments.

Research activities in applied electromagnetics include miniaturized antennas and antenna arrays up to sub-THz, optical-wireless interfaces, and signal processing techniques with a focus on localization and beamforming. Research in (micro)electronics addresses the design of analogue, mixed-signal and digital electronic circuits in silicon-monolithic substrates, printed circuits, spanning from low frequency to radio frequency, while research in programmable logic addresses dedicated computing applications in reconfigurable logic, embedded systems, and implementing adaptive systems based on dynamic reconfiguration and adaptive transparent acceleration.

This research line contributes to the vision of the NIS Cluster through the hardware component that enables the sensing, computing and communications subsystems of autonomous networked intelligent systems.

RL2. Wireless Networks

The main goal of this research line is to investigate new wireless networking solutions for extreme environments such as aerial and maritime, in alignment with the international and European strategic agendas. The focus is on wireless networks and mobile communications, extending infrastructure networks and enabling the Internet of Everything in terrestrial and maritime environments, contributing to truly ubiquitous connectivity. This includes the design of novel algorithms and mechanisms and requires theoretical and simulation modelling, implementation, and experimental evaluation of communications networks and their elements. The main research topics include network topology control, routing, radio resource management, and context-aware optimization using cross-layer techniques and machine learning for networking.

This research line contributes to the vision of the NIS Cluster through the wireless networking component that will ultimately enable the creation of autonomous networked intelligent systems. This RL expects to achieve several relevant scientific contributions aligned with such a vision including: 1) algorithms and mechanisms for topology control and routing in flying networks; 2) machine learning based models addressing topology control and routing in flying networks; 3) mechanisms and algorithms to enable higher throughput and longer-range maritime communications; 4) mechanisms and algorithms enabling novel wireless communications solutions for underwater environments; 5) new simulation models enabling the reproduction of real experiments for accurate, cost-effective validation of wireless networking solutions.

RL3. Media platforms and audiovisual content management

This research line aims to develop new strategies for capturing, producing, sharing and accessing information from users' own perspectives, in scenarios such as social media, creative environments, media industries, culture, sports, industrial systems, robotics or wellbeing. This includes the integration of different media formats (High-definition, 3D, 360º, panoramic, multi-view content), the development of new approaches for constructing different narratives, the use of enhanced data visualization paradigms, Human-Media interaction mechanisms to enhance the quality of experience or the quality of the content produced or the possibility of delivering and accessing content through different networks or distribution mechanisms, creating interactive, virtual and immersive environments with the ability to engage multiple senses.

We aim to make critical and tangible advances in the digital media sector, the scientific community and in media-related application areas or markets. For that purpose, we will investigate and develop a comprehensive set of methodologies and algorithms that will foster the creation of enhanced multimedia applications with realistic and dynamic immersion, interaction and participatory capabilities. Such applications can provide added value in different domains and facilitate information management so that they can be efficiently accessed and navigated. This research line contributes to the vision of the NIS Cluster by addressing the need to provide new approaches to deal with multimedia content in heterogeneous environments, supporting different communication networks and produced by several devices in several environments.

RL4. Machine Learning, Computer Vision, Audiovisual Content Analysis

This line performs research in both fundamental and applied problems in computer vision, multimedia (image, video, and audio) processing, pattern recognition, machine learning, and decision support systems. The focus is on the development of intelligent systems, which combine content-understanding capabilities with any available additional information to enable sophisticated recognition. Built on the same scientific background, under these topics, we favour the adaptation of the solutions to several specific domains: medical decision support, well-

being, biometrics, biological imaging, autonomous driving, advanced driver help systems, video analytics systems, entertainment, media industries, sports, and arts. Our work on machine learning cares mostly with the adaptation of learning to the challenging conditions presented by audio-visual data. The work on the development of intelligent decision support systems combines audio-visual data understanding with any available additional information, coming from sensors or other external sources, to enhance the analysis and the decision process as well as the efficient handling of the large amounts of data produced.

This research line contributes to the vision of the NIS Cluster by developing and adapting ML algorithms able to process different types of data and, through information fusion approaches, develop more intelligent decision support systems able to infer additional information from the content.

RL5. Cancer Image Analysis

This research line performs research in image analysis for breast cancer screening and diagnosis, surgery planning, rehabilitation and quality of life assessment. CTM has been working in this line of research for two decades, considered as a reference research group over the world, by doing research on computer vision and machine learning. Examples of recent relevant contribution include tools to assist the radiologist in the diagnosis, tools to facilitate surgery planning, computer-aided system to perform an aesthetic evaluation results result after treatment, or serious games for rehabilitation of breast cancer survivors. In the planning of reconstruction surgery area, we were granted a European patent, for a software to analyse and characterise the vessel network in the abdominal patient region. Furthermore, we are also becoming a worldwide reference in cervical cancer screening, mainly in colposcopic image analysis. We will research methods for image quality analysis and support of diagnosis. Additionally, we have been performing research on other cancer types, such as lung, gastro-intestinal and colon cancer.
This research line is strongly in line with the Computer Vision research line of the NIS Cluster, particularly associated with human health scenarios.

6.1.5 Innovation activities

INOV1. Optical and Electronic Technologies

In the optical and electronics area, CTM is able to transfer technology and provide consulting services on:

- **INOV1.A Design of radio/microwave systems**, including compact/in-package multi-band planar antennas as well as planar/coaxial to waveguide transitions and waveguide antennas, including characterisation in anechoic chamber, with applications in wireless communications systems (TEC4SEA, TEC4INDUSTRY);
- **INOV1.B Design of (micro)electronic systems**, including semi/full-custom designing and testing of analogue, digital and mixed (A/D) circuits and digital systems based on microprocessors and reconfigurable logic, targeting mainly biomedical applications and wearable systems (TEC4HEALTH, TEC4AGRO-FOOD).

INOV2. Wireless Networks

In the wireless networks area, CTM is able to transfer technology and provide consulting services on:

- **INOV2.A Planning, design, and development of narrowband and broadband wireless networks** capable of supporting different types of traffic, from simple data to multimedia applications and services (including video), in terrestrial and maritime environments;
- INOV2.B Planning, design, and development of multi-hop, on-demand wireless networks for network infrastructure extension in terrestrial and maritime environments;
- **INOV2.C Design and development of wireless networks for autonomous vehicles** (aerial, surface, and underwater) in terrestrial and maritime environments.

These innovation activities are related to the following TEC4: TEC4SEA, TEC4AGRO-FOOD, and TEC4INDUSTRY.

INOV3. Multimedia Communication Technologies

In the Multimedia Communication Technologies area, CTM is able to transfer technology and provide consulting services on:

- INOV3.A Context-aware personalised multimedia applications in heterogeneous environments;
- INOV3.B Content streaming and adaptation; Broadcasting and new media technologies;
- INOV3.C Multimedia Content Management;
- INOV3.D Data visualization techniques for large multimedia assets;
- INOV3.E Computer Vision and AI based solutions for multimedia-based applications, including cross-media knowledge extraction.

INOV4. Information Processing and Pattern Recognition

In the information processing and pattern recognition area, CTM is able to transfer technology and provide consulting services on:

- **INOV4.A** Integrated vision systems and the application of machine vision to problems of real-world importance.
- **INOV4.B Solutions to medical decision support systems**, well-being systems, biometrics, biological systems, autonomous driving, advanced driver help systems, video analytics systems, perception systems, and communication networks.

These innovation activities are related to the following TEC4: TEC4HEALTH and TEC4INDUSTRY.

6.1.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CTM - Table of relationships between the Centre research lines and the innovation activities

Centre research lines	Innovation activities (*)										
	INOV1A	INOV1B	INOV2A	INOV2B	INOV2C	INOV3A	INOV3B	INOV3C	INOV3D	INOV4A	INOV4B
Optical and Electronic Technologies	H	H	H	M	M						
Wireless Networks			H	H	H						
Media Platforms and audio-visual content management						H	H	M	M		
Machine Learning, Computer Vision, Audio-visual, Content Analysis						M	M	H	H	H	M
Cancer Image Analysis										M	H

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.1.7 Main objectives for 2020

CTM General Objectives

OBJ1. **High-quality publications**. CTM aims at (1) maintaining the number of articles published in journals and, in particular, (2) increasing the number of articles published in the journals classified by SCOPUS as first quartile.
OBJ2. **Provide research services to the community.** In 2020, CTM will have a relevant number of researchers involved in basic research (low TRLs). Besides publishing our scientific results and protecting our intellectual property, CTM will also focus on strong and stable partnerships with industry with the purpose of enabling the transference of the new results to strategic partners.
OBJ3. **Increase international visibility and reputation**. The increase of CTM international visibility will also be pursued, either by participating in international fora or by organizing international conferences, with the purpose of facilitating the formation of new and strong European consortia or helping the publication of new scientific results in top-ranked journals. We will also continue the effort of increasing the number of IEEE Senior Members.
OBJ4. **Increase CTM research capacity / talent and recruitment.** Consolidate an on-the-job training program for CTM Members.

OET Objectives
OBJ1: Design of novel neural network architectures in analogue electronics based on memristors.
OBJ2: Design and development of novel solutions for transparent acceleration of algorithms with run-time support and efficient processing of long short-term memory in embedded reconfigurable systems.
OBJ3: Design and hardware implementation of adaptive digital beamforming architectures for satellite communications.
OBJ4: Consolidate recognition in the emerging area of underwater optical communications, wireless power transfer and energy harvesting through prototype demonstrations.
OBJ5: Design and evaluate novel indoor localization solutions based on Bluetooth Low Energy and advanced signal processing techniques.
OBJ6: Design and implementation of novel micro-wave/millimeter-wave antennas/devices and optical/wireless interfaces, including building expertise in Photonic Integrated Circuit design.
OBJ7: Investigate theoretically the existence of stable dissipative solitons in 3-level media and wave stability in highly dispersive media.
OBJ8: OET laboratory upgrade and modernization, through new infrastructure such as new illumination, water supply, electric installation, technical tables and racks, implementation of access control, and purchase of new equipment.

WiN Objectives
OBJ1. Development of flying networks including the design of topology control, routing, and gateway positioning algorithms.
OBJ2. Development of long-range, broadband maritime networks, including the use of short-range radio communications and Autonomous Underwater Vehicles (AUV) as data mules for underwater communications and novel MAC and routing protocols enabling ship-to-shore communications.
OBJ3. Design of new simulation models addressing the reproduction of real wireless experiments using Network Simulator 3 (ns-3).
OBJ4. Increase the number of PhD students by 33% and maintain the number of scientific publications in conferences and journals achieved in 2019.

MCT Objectives
OBJ1: Devise methodologies and develop algorithms and tools for context-metadata-aware automatic content creation.
OBJ2: Devise methodologies and develop algorithms for multimedia content description.

OBJ3: Design and implement new approaches for multimedia data visualization and content navigation.
OBJ4: Investigate and develop approaches for emotion-aware content analysis.
OBJ5: Consolidate the reputation of the area within the international landscape.
OBJ6: Increase the interaction and cooperation between PhD students.
OBJ7: Design and develop algorithms for pose and activity analysis.

IPPR Objectives
OBJ1: Improve our in-house fingerprint recognition system, aiming for the MINEX3 certification.
OBJ2: Improve decision support systems for oncological diseases, focusing in breast cancer, cervical cancer, lung cancer and gastro-intestinal cancer.
OBJ3: Improve our algorithms on biometrics research line: face analytics, face biometrics, electrocardiogram biometrics, driver drowsiness and driver emotions.
OBJ4: Consolidate the recent research lines in IPPR: advanced driver help-systems, autonomous driving, lower-limb amputees and capilar surgeries.
OBJ5: Improved machine learning algorithms. Novel weakly supervised learning algorithms; algorithms for explainable machine learning; new deep learning architectures for computer vision.

6.1.8 Main actions planned for 2020

This year, CTM will implement the following actions:

Table 6.2 - CTM – Main actions planned

Action	Objective	Expected Outcomes	Calendar
Submission of FCT scholarship application and Summer Internship Proposals (as part of the CTM Summer Internships Program)	CTM-OBJ4	At least 4 new PhD students	Aug. 2020
Organize CTM Open Day	CTM-OBJ3	Create new partnerships with industry, new joint research ventures, reach to the public.	May 2020
Organize CTM “Open Days”, through the establishment of a schedule of open days with laboratory visits and demonstration of prototypes.	CTM-OBJ4	Attract new students and researchers	June 2020
Establish a CTM policy for the participation in high quality conferences and international focused events (summer/winter schools, workshops) by senior researchers	CTM-OBJ3; stimulate the research along the centre’s research lines	Create new partnerships with industry, new joint research ventures, increase the participation in the technical committees of conferences and increase the chances of become organizers of top conferences.	March 2020
Actively participate in the ongoing project meetings	MCT-OBJ5	Consolidate partnerships and boost new project submissions	
Develop prototypes to be used as a proof of concept	MCT-OBJ1,2, 3,5	Proof-of-concept prototypes and 3 papers submitted	Dec 2020

Action	Objective	Expected Outcomes	Calendar
Engage students in research activities to exploit new scientific areas	OET-OBJ4,7 WIN-OBJ4 MCT-OBJ3,4, OBJ7; IPPR-OBJ4,5	9 MSc theses	Set 2020

6.1.9 Centre Organisational Structure and Research Team

The Centre for Telecommunications and Multimedia is coordinated by Jaime Cardoso and Filipe Ribeiro and is organised in 4 areas: Optical and Electronic Technologies (OET), led by Luís Pessoa; Wireless Networks (WiN), led by Rui Campos; Multimedia and Communications Technologies (MCT), led by Paula Viana; Information Processing and Pattern Recognition (IPPR), led by Hélder Oliveira. The Secretariat is supported by Renata Rodrigues. The Coordination Council of CTM includes the Coordinators, Area Leaders and the Administrative Assistant. The Scientific Council of CTM includes most of the PhD Members of the Centre. The CTM representatives in INESC TEC Scientific Council are Henrique Salgado and Paula Viana.

Table 6.3 - CTM - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	10	13	12	-1
		Academic Staff	14	14	14	0
		Grant Holders and Trainees	53	43	38	-5
		Total Core Researchers	**77**	**70**	**64**	**-6**
		Total Core PhD	**25**	**26**	**26**	**0**
	Affiliated Researchers		9	8	8	0
	Administrative and Technical	Employees	1	1	1	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**1**	**1**	**1**	**0**
		Total Integrated HR	**87**	**79**	**73**	**0**
		Total Integrated PhD	**34**	**34**	**34**	**0**

6.1.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CTM - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	329	608	674	65
PN-PICT	National R&D Programmes - S&T Integrated Projects	261	33		-33
PN-COOP	National Cooperation Programmes with Industry	309	316	232	-83
PUE-FP	EU Framework Programmes	195	259	297	38
PUE-DIV	EU Cooperation Programmes - Other				
SERV-NAC	R&D Services and Consulting - National	226	374	210	-164
SERV-INT	R&D Services and Consulting - International	17	76	115	39
OP	Other Funding Programmes	29	30	64	34
Uncertain Projects		168	89	151	62
	Total Funding	**1 534**	**1 784**	**1 743**	**-42**

Table 6.5 - CTM - Summary of publications bymembers of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	26	32	36	4
Indexed Conferences	43	40	43	3
Books				
Book Chapters		8	1	-7

Table 6.6 - CTM - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	3	3
Software copyright registrations	0	0	0
Patent applications	2	12	2
Licence agreements	0	0	0
Spin-offs	0	0	0

Table 6.7 - CTM - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	3
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	1
International events in which INESC TEC members participate in the program committees	38
Participation in events such as fairs, exhibitions or similar	8
Advanced training courses	1

Table 6.8 - CTM - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	6
Participants in the conferences, workshops and scientific sessions organised by the Centre	300
Advanced training courses organised by the Centre	2

Table 6.9 - CTM - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	AUTOMOTIVE	Ana Maria Rebelo	01/10/2018	30/09/2021
PN-FCT	Blueenergy	Manuel Cândido Santos	01/10/2018	31/03/2020
PN-FCT	CLARE	Jaime Cardoso	01/07/2018	30/06/2021
PN-FCT	CompMash	Matthew Davies	01/10/2017	30/11/2021
PN-FCT	ENDURANCE	Luís Manuel Pessoa	01/07/2018	29/06/2020
PN-FCT	EVOXANT	André Marçal	15/06/2016	15/06/2020
PN-FCT	GROW	Rui Lopes Campos	01/10/2018	31/12/2020
PN-FCT	HELP-MD	Matthew Davies	01/10/2018	30/09/2021
PN-FCT	LUCAS	Hélder Filipe Oliveira	26/07/2018	25/07/2021
PN-FCT	NeurOxide	Vítor Grade Tavares	01/10/2018	30/09/2021
PN-FCT	PEPCC	João Canas Ferreira	01/10/2018	30/09/2021
PN-FCT	S-MODE	Hélder Filipe Oliveira	01/07/2018	30/06/2021
PN-FCT	TEC4SEA-1	Rui Lopes Campos	01/09/2017	30/08/2020
PN-FCT	XPERIMUS	Rui Penha	26/11/2018	25/11/2021
PN-COOP	5G	Manuel Ricardo	01/01/2018	31/12/2020
PN-COOP	BCCT.Plan	Hélder Filipe Oliveira	01/11/2016	31/10/2019
PN-COOP	CHIC	Paula Viana	01/10/2017	30/09/2020
PN-COOP	STRx	Luís Manuel Pessoa	01/05/2019	30/04/2022
PUE-FP	EuConNeCts4	Rui Lopes Campos	01/06/2019	01/12/2021
PUE-FP	FotoInMotion	Maria Teresa Andrade	01/01/2018	31/12/2020

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PUE-FP	InterConnect-1	Filipe André Ribeiro	01/10/2019	30/09/2023
PUE-FP	RESPONDRONE	Rui Lopes Campos	01/05/2019	30/04/2022
PUE-FP	TERAPOD	Luís Manuel Pessoa	01/09/2017	31/08/2020
SERV-NAC	ESCUDO	Filipe André Ribeiro	01/04/2019	01/06/2020
SERV-NAC	Evo3DModel	Hélder Filipe Oliveira	01/02/2019	31/12/2019
SERV-NAC	TenisApp2	Pedro Miguel Carvalho	01/01/2019	30/09/2019
SERV-NAC	UGREEN	Rui Lopes Campos	01/10/2017	30/09/2019
SERV-NAC	v-CardID3	Ana Maria Rebelo	01/12/2018	31/12/2019
SERV-INT	NFCAD	Filipe André Ribeiro	01/07/2019	30/09/2019
SERV-INT	SIMBEDplus	Rui Lopes Campos	01/05/2019	31/03/2020

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.2 CAP - CENTRE FOR APPLIED PHOTONICS

Coordinators: Paulo Marques and Ireneu Dias

6.2.1 Presentation of the Centre

CAP accomplishes its mission within the Cluster NIS - Networked Intelligent Systems, by directing its activities towards 3 main areas of research: optical sensors, integrated optics and microfabrication, and advanced optical imaging. In this arrangement, optical sensors comprise chemical, biosensors and physical sensors.

This organisation is non-hermetic and the development of new solutions implies multi-disciplinary and cooperative work. A good example is microfabrication, which will explore traditional top-down microfabrication techniques, and non-traditional based on laser direct writing processes to support the activities of other areas. For example, microfluidics chips will be produced to implement biosensors and micro and nanostructures; Bragg gratings will be made by laser direct writing to implement new sensing heads that will lead to the development of better and more reliable sensing heads.

CAP has a task force devoted to R&D outreach activities, which deals with news related to the CAP research activities, the organisation of scientific meetings, the collaboration with the Department of Physics and Astronomy (DFA) of the Faculty of Science of University of Porto, and the scientific dissemination to the general public.

6.2.2 Context

The global photonics sector[24] is growing twice as fast as the global GDP with European Photonics leading the world in Production Technology (50%), Measurement and Automated Vision (35%), Optical Components and Systems (32%), Medical Technology and Life Sciences (28%), Defense and Security (26%), and Lighting (24%). This position is achieved with a fast growing SME base with about 5000 companies, contributing to the societal challenge of qualified employment.

According to the Photonics21 Vision Paper towards FP925, Photonics is a key digital technology for a relevant set of global markets and challenges, including the following:

- Life sciences and Healthcare: instant diagnosis of major diseases and “theranostics” contributing to a healthy and fit ageing population;
- Safe, nutritious and affordable food, from farm to fork through field and soil monitoring, integrated machine operation and sustainable water management reducing the environmental footprint of agriculture, fisheries and aquaculture;
- Accident and congestion-free road transport through multimodal transport, automated driving, driver assistance, traffic monitoring and photonics-based imaging solutions (e.g. LIDAR) even for adverse weather conditions;
- Truly circular economy: zero emission, less waste through the use of intelligently networked pollution detectors enabling real-time detection of toxic substances, helping to reduce the depletion of resources by managing material streams in a circular economy, reducing energy consumption in buildings and public spaces, creating efficient industrial processes, developing the next generation of photovoltaics, enabling smart mobility and monitoring our environment in real time, reducing the carbon footprint of the Internet;
- Empowering Industry 4.0: a million new jobs through the undergoing photonics revolution, with earlier generations of factory machinery increasingly giving way to lasers and sensors, usually in conjunction with robots, enabling fast, green and flexible factories, a fully digital value chain from supplier to customer birthing new forms of collaboration and customization (e.g. laser-based additive

[24] https://www.photonics21.org/download/ppp-services/photonics-downloads/Photonics21_Advocacy_Paper_C1.pdf
[25] https://www.photonics21.org/download/ppp-services/photonics-downloads/Photonics21-Vision-Paper-Final.pdf

manufacturing), new services, and new business models (on-demand manufacturing) – all of which strengthening Europe's industrial base;

- A new quality of urban life: smart homes and liveable cities, photonic technologies enabling us to live and work in attractive, secure and productive environments tailored to our individual needs, like human-centric lighting for health (more effective prevention and treatment of mood disorders, mental disease and any condition with a psychosomatic component) and productivity;
- Building our digital society: Photonics for a secure and resilient IT infrastructure towards a zero downtime in a terabit economy, through emerging shift to high-performance optical and quantum computing (a step comparable to the transition from conventional electronics to microelectronics in the 1960s);
- Linking big ideas: Photonics as a driver of the digital knowledge society, a flagship science for innovation, a pillar and driver of the knowledge society, playing an instrumental role in the creation and dissemination of knowledge and ideas.

6.2.3 Contribution to the Vision of the Cluster

CAP produces sensing technology to enable detection of physical, chemical and biological signals and parameters. These are essential perception tools for the advanced system produced by other centres of NIS.

In this context, CAP will consolidate the tendency of the recent years, cooperating with the other members of the NIS Cluster in the incorporation of sensors as perception tools for more advanced systems. Relevant examples of this cooperation include the following:

- Imaging Lidar technologies for enhancing the imaging capabilities of AUV and other vehicles;
- Analytical LIBS and UV VIS system to provide real time analysis tools for incorporation in robots exploring hazardous environments;
- Fiber optic remotely interrogated sensors to provide monitoring awareness of critical facilities (e.g., strain, temperature, corrosion monitoring of on shore and offshore facilities and vehicles).

6.2.4 Centre research lines

RL1. Integrated Optics and Microfabrication

The major expected scientific contributions of this research line include the following:

- Enhancement of tri-dimensional laser direct writing station based on a femtosecond fiber laser system (second and third harmonics), including the improvement of third axis and software control of the apparatus;
- Monolithic integrated optic devices in pure silica mainly for integrated sensors and communications. Other materials, such as chalcogenide glasses, Lithium Niobate and applications such as astronomical interferometry, quantum cryptography will be considered as exploratory areas of work;
- Hybrid devices that combine optical layers with fluids handling capabilities (opto-fluidics made by femtoetching) for sensing. The fabrication of tri-dimensional structures using multi-photon polymerization or suspended cores within channels will be investigated;
- Structures supporting whispery gallery modes are very interesting for sensing but coupling to these structures is typically based on fragile fiber tapers or similar. Alternative robust solutions based on integrated optics for excitation of whispery gallery modes will be developed;
- Implementation of a second apparatus for specialized Bragg grating fabrication mainly on optical fibers, including possibility of handling special fibers;
- Fabrication of Bragg and long period gratings and also explore "fiber-integrated optics", i.e. using the fiber cladding as the media to write waveguides and devices.

RL2. Advanced Optical Imaging

The main research activities of this research line include the following:

- Explore medical and bio-sciences applications of optical imaging using high resolution imaging techniques, digital holography, and turbid lens imaging principles, to be combined with hybrid microfabricated devices and small size optical devices;
- Develop the application of compressive sensing principles to LIDAR 3D imaging, targeting security and defence, automotive and submarine applications;
- Integrate (hyper)spectroscopic channels in 3D LIDAR, Pharmaceutics, and Astronomical imaging systems, and implement AI techniques for information handling and classification.

RL3. Physical Sensors

The physical sensors research line will target ultra-high sensitivity sensors. Active devices will be designed in order to improve the precision of physical parameters measurement and to apply them in new platforms. The research areas include the following:

- Fabrication and characterization of nano/microfibers through micro-furnace fabrication techniques;
- Exploration of Vernier effect for physical parameters for simultaneous measurement of physical parameters;
- Applications of Vernier effect for ultra-high sensitivity and high-performance sensors;
- Study and development of refractometer sensors for chemical and pharmaceutical applications;
- Development of Microfiber Knot Resonators as Sensors for gas sensing;
- Development of nano-tapers targeting very high resolution and accuracy employing metamaterials and SPR;
- Development of optical sensors for medical instrumentation;
- Distributed sensing based on OTDR for the detection of anomalous movements in high power cables;
- Development of optical sensors embedded on 3D imprinted for high power transformers.

RL4. Biosensors

The main goals in the chemical and biosensor research line focus on some core technologies that are explored in different applications. Recent development in the group lead to the exploitation of the potential of coupling established spectroscopy techniques like UV-vis and LIBS, with advanced signal processing methods, including AI. We have demonstrated this combination leads to smart spectroscopy enabling analytical performance of complex samples with no need for labelling chemistry. Presently there is a consolidated prototype based on Laser Induced Breakdown spectroscopy that is being explored in different areas. The main research activities of this research line include the following:

- Characterize complex mineral samples from mining activities (core drills and other samples from prospection activity for Lithium minerals, which are fully characterized by ICP-Ms), to train the smart-Libs system to automatically characterize complex ores;
- Explore fiber lasers technology to develop new LIBs methodologies for underwater applications (multi-pulse and high repetition rates in different combinations);
- Improve automatic adjustment of the system settings (laser and detection parameters) according to sampling scenario;
- Expand the activities of Libs to other areas: medical (dentistry and blood analytics); environmental (contaminants and fertilizers in soil, water and air);
- Similar concepts where AI is used to extract analytical information from complex spectral data are being explored in environmental, agriculture and health applications.

RL5. Quantum engineering

This research area explores current trends in applied photonics associated with the miniaturization of devices into scales of tens to hundreds of nanometers, in combination with other domains such as material sciences and quantum information theory, to explore quantum and nonlinear effects as base stones for new ultra-high sensitivity sensing technologies and optical information processing. The plan for the next five years is centered in combining research in base sciences with the development of high-performance simulation toolboxes that can assist in the exploration of these fundamental processes, while anticipating and supporting the other strategic research lines, from integrated optics and microfabrication to the design of sensing devices, as well as produce exploratory work in novel research topics, including quantum optical technologies and cross-field fertilization. The main research activities of this research line include the following:

- Exploit and further develop the strong background in quantum, nonlinear optics and ultrafast optics to investigate at a fundamental level the interaction of light and quantum matter out of equilibrium, with emphasis to quantum gases and their use in developing optical and quantum analogues for physical/optical simulation;
- Development of high-performance simulation toolboxes (typically based on GPGPU supercomputing and artificial intelligence) that model interaction between light and matter at a quantum and atomic scales and can be applied in the design the design and engineering of functional optical metamaterials, nanostructured optical fiber sensors, integrated optics, plasmonics and many other related topics. This activity will be complemented with the develop in-house know-how in new techniques of high-performance computation for scientific engineering calculation (mainly artificial intelligence and quantum computing) via training and exploratory work;
- Design, fabricate, test and optimize nanoscale optical devices, including plasmonic and optical metamaterials for optical sensing, quantum sensing and new generation fiber optical sensors;
- Promote cross-field fertilization, by considering adaptations of our simulation models to other fields, from fundamental physical sciences to finance.

6.2.5 Innovation activities

INOV1. Electronics and Photonics Integration

In the electronics and photonics area, CAP is able to transfer technology and provide consulting services on:

- Electronic PCB design, implementation, test and characterization;
- Micro and nanofabrication techniques;
- Optoelectronics assembly and packaging;
- Photonic systems implementation, test and characterization.

6.2.6 Knowledge valorisation chain

The following table presents the contribution of the "Research and Technology" areas to the "Technology Transfer" areas, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1-CAP – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities*
	Electronics and Photonics Integration
Integrated optics and Microfabrication	M
Advanced Optical Imaging	M
Physical Sensors	H
Biosensors	H
High performance simulations for quantum and nonlinear photonics	F

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.2.7 Main objectives for 2020

OBJ1. **Recruitment of new researchers.** In order to interest potential new researchers, the Centre intends to keep a policy of awarding scholarships for last year students so they can get acquainted with the research activity. This policy has proven to be fruitful in the past and it will be continued. A dedicated laboratory already in place with advanced photonics projects will attract also younger students.

OBJ2. **Submission of Horizon2020 proposals**. The shortcoming of a fragile participation in H2020 projects will be mitigated by an increased participation in Photonics 21 platform and EPIC cluster activities: meetings, brokerage events and science-industry workshops.

OBJ3. **Projects with industry**. A careful and detailed attention will be given in finding new R&D contracts with industry.

OBJ4. **Development of proof-of-concept laboratory demonstrations**. Optical-graphene-microphone. Hybrid devices with optofluidics and sensing capabilities

6.2.8 Main actions planned for 2020

This year, CAP will design and/or implement the following actions:

Table 6.2 - CAP – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
EPIC Annual General Meeting 2020 Radisson Blu Hotel Lietuva	**OBJ1**	two potential proposals	15-17 April 2020
EPIC Roundtable on Quantum Optronics at OPTRO Paris, France	**OBJ2**	one potential proposal	30 January 2020
Scholarships for last year students	**OBJ2**	Four undergarduate students	Throughout the year

6.2.9 Centre Organisational Structure and Research Team

The Centre for Applied Photonics is coordinated by Paulo Marques and Ireneu Dias and is organized around the following strategic lines of research and its leaders:

- Integrated optics and Microfabrication: Paulo Marques
- Advanced Optical Imaging: Carla Rosa
- Physical Sensors: Orlando Frazão
- Biosensors: Pedro Jorge
- High performance simulations for quantum and nonlinear photonics: Ariel Guerreiro

Table 6.3 - CAP – Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	8	9	7	-2
		Academic Staff	7	8	8	0
		Grant Holders and Trainees	17	13	12	-1
		Total Core Researchers	**32**	**30**	**27**	**-3**
		Total Core PhD	**15**	**15**	**14**	**-1**
	Affiliated Researchers		5	5	5	0
	Administrative and Technical	Employees	2	2	2	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**2**	**2**	**2**	**0**
		Total Integrated HR	**39**	**37**	**34**	**-1**
		Total Integrated PhD	**20**	**20**	**19**	**-1**

6.2.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CAP - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	263	396	250	-146
PN-PICT	National R&D Programmes - S&T Integrated Projects	180	46		-46
PN-COOP	National Cooperation Programmes with Industry				
PUE-FP	EU Framework Programmes			225	225
PUE-DIV	EU Cooperation Programmes - Other	69	69	78	8
SERV-NAC	R&D Services and Consulting - National				
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes				
Uncertain Projects		106	135	108	-27
	Total Funding	**618**	**647**	**660**	**14**

Table 6.5-CAP - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	22	23	25	2
Indexed Conferences	12	4	16	12
Books				
Book Chapters		2		-2

Table 6.6 - CAP - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	2	1	5
Software copyright registrations	0	0	2
Patent applications	3	4	3
Licence agreements	0	0	0
Spin-offs	0	0	0

Table 6.7 - CAP - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	6
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	3
International events in which INESC TEC members participate in the program committees	3
Participation in events such as fairs, exhibitions or similar	1
Advanced training courses	0

Table 6.8 - CAP - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	1
Participants in the conferences, workshops and scientific sessions organised by the Centre	300
Advanced training courses organised by the Centre	0

Table 6.9 - CAP - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	ENDOR	Orlando Frazão	01/06/2018	31/05/2021
PN-FCT	FLAPSYS	Pedro Jorge	01/03/2018	28/02/2021
PN-FCT	GreenNanoSensing	Ariel Guerreiro	01/07/2018	30/06/2021
PN-FCT	MetBots	Rui Costa Martins	26/07/2018	24/07/2020
PN-FCT	SolSensors	Luís Carlos Coelho	01/05/2018	30/04/2021
PN-FCT	TEC4SEA-2	Pedro Jorge	01/09/2017	30/08/2020
PUE-DIV	AGRINUPES-1	Pedro Jorge	01/04/2017	30/06/2020
PUE-DIV	SAFEWATER	Pedro Jorge	03/04/2018	02/04/2021
PUE-FP	INSite-1	Pedro Jorge	01/01/2020	01/01/2023

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.3 CRAS - CENTRE FOR ROBOTICS AND AUTONOMOUS SYSTEMS

Coordinators: Aníbal Matos and Eduardo Silva/José Miguel Almeida (replacement foreseen during 2020)

6.3.1 Presentation

The Centre for Robotics and Autonomous Systems (CRAS) aggregates more than 40 researchers addressing scientific and technological topics associated to field robotics and autonomous systems. CRAS aims at becoming a worldwide reference in field robotics and autonomous systems and is already internationally recognised for its innovative robotics solutions for operation in complex environments – relevant examples are underwater environments, and particularly deep-sea water.

CRAS has a special scientific focus in the multi-sensor perception, navigation, positioning, and sensor fusion competences. Within the Cluster NIS - Networked Intelligent Systems, CRAS accomplishes its mission, by directing its activities towards 4 main areas of research: autonomous navigation and exploration; long term deployments and autonomy; sensing, mapping, and intervention; multiple platform operations.

CRAS activities are mainly positioned within RL levels 5-8, associated with design, development and integration of robotic platforms with increasing degrees of autonomy. These activities have contributed to the deployment of innovative solutions in multiple application domains, such as safety security and defence, underwater mining, deep sea exploration and infrastructure inspection.

6.3.2 Context

The activities of CRAS are driven by several challenges, both at the scientific and technological domains, as well as several trends and concerns, and from societal and funding perspectives. In a broad sense, CRAS addresses challenges associated to activities in harsh, complex, and dynamic environments where automatic data collection and processing as well as autonomous operation are key factors in the design and development of new technologies.

CRAS activities are driven by major priorities established at European, national or regional level, expressed by: 1) European societal challenges: Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and Bioeconomy; Secure, Clean and Efficient Energy; Smart, Green and Integrated Transport; and Climate Action, Environment, Resource Efficiency and Raw Materials; 2) Portuguese National Ocean Strategy 2013-2020; and 3) Norte 2020 – Regional Smart Specialisation Strategy.

In these priorities, technological trends include the increasing digitalization and automation of activities, the development of novel paradigms of human-machine interactions, as well as longer-term and higher autonomy levels of robotic based operations.

The "2018 Tech Trends Report"[26] from the 'Future Today Institute' identifies a wide range of technology trends for the coming years. Directly related to the research activities of CRAS, this report identifies trends in areas such as Security, Advanced Robotics, or Transportation. An increase in the use of drones for multiple applications (surveillance, mapping, good delivery, establishment of communication networks) is a well identified trend. Furthermore, autonomous underwater vehicles are also described as playing a key role in domains such as safety, security, or environmental mapping. Also, autonomous ships and autonomous cars are emerging technologies that will contribute to revolutionize the transport industry.

CRAS is also strongly involved in the implementation of the research infrastructures TEC4SEA and EMSO-PT, both integrating the national research infrastructures roadmap.

26 https://futuretodayinstitute.com/2018-tech-trends-annual-report/

6.3.3 Contribution to the vision of the Cluster

The NIS Cluster joins a set of Centres with complementary competences, enabling it to develop several futuristic scenarios encompassing autonomous systems, innovative communications and sensors, collecting and transmitting information that can be processed using artificial intelligent tools.

Due to its development and integration of robotic platforms capabilities, CRAS has this unique position and responsibility, within Cluster NIS, to pursue and drive the achievement of new scientific and technological breakthroughs. One of the contributions to the Cluster is the support and integration of new sensors and communications. For this contribution line, within the next 5 years, CRAS aims to push the results of Coral project to be integrated within robotic platforms, such as: sensors for monitoring gamma radiation, remote fibre sensors, biosensors, chemical sensors, sensing probes, imaging, DNA bio sampler, underwater radio communications, underwater wireless optical communications, wireless energy transfer, LIBS real time grade assessment.

Regarding computer vision, a new automatic image processing system (adapted from the health domain) could be developed and integrated in robotic platforms in order to process analysis of microbial life in real-time.

CRAS itself aims at enabling/supporting the other Centres to access deep-sea. For this purpose, it is CRAS objective, by 2022, to operate in the deep sea with its own vehicles, where new sensors and new subsystems for navigation will be integrated, together with broadband wireless communications and wireless energy transfer underwater. Cooperation between robots and the challenges associated to miniaturized robotics will also be addressed. Also, the continuous miniaturization of robotic platforms is an objective for CRAS.

6.3.4 Centre research lines

CRAS research activities area organized along four research lines (RL). Activities encompassed by each RL are expected to produce low RL (typically 1-5). Nonetheless, the nature of several CRAS activities pushes further some of these results by integrating them in field going prototypes. These four research lines contribute to a major research goal addressing higher autonomy levels of robotic systems, which is directly linked to the NIS Cluster research line on autonomous systems.

RL1. Navigation and control

This RL addresses the navigation of autonomous systems in environments where global positioning aiding systems are not available. At its core lie methodologies for multisensory data fusion applied to localization and navigation problems. Dynamic modelling of sensors and robotic behaviour, using either deterministic or stochastic approaches play a key role here. This RL also tackles challenges associated with the design and implementation of time efficient data processing algorithms enabling their implementation in real field going robots. Specific problems addressed include the following: algorithms for simultaneous navigation and mapping, semantic navigation, control of multibody/variable geometry robots, degraded modes of operation, environment aware navigation, guidance and control, seamless transition between open area and close to features operations. Due to the widespread use of visual or visual like data acquisition systems, this RL directly contributes to the NIS research line on computer vision.

RL2. Interaction with environment

This RL addresses challenges motivated by the operation of robots in environments or scenarios where explicit interaction with objects or features is required. Relevant examples are autonomous intervention from floating bases (AUVs, ASVs, drones), object placing or picking from surface or sea bottom, or vehicle docking into another vehicle. Methodologies and algorithms are sought to deal with obstacles (greater accuracy required to handle objects as compared to avoiding them, need to assess and mitigate risks – collision, imprisonment, or dead-locks, for example), to address control problems related to mobile intervention (end effectors mounted on moving platforms), and to deal with cooperative intervention.

RL3. Sensing and mapping

Traditionally, mobile robots operate as data collectors with limited onboard data processing capabilities. This paradigm is shifting to robots with heavy onboard data processing capabilities allowing for high level onboard decision making. This RL addresses the new challenges posed for such scenarios. At its core lie the development of computer vision techniques and algorithms, sensing strategies for single or multiple robotic systems, adaptive

sampling techniques, multi sensor data fusing for underwater or overwater mapping, hyperspectral, electro-optic and acoustic image processing, as well as underwater acoustics for positioning. This RL is core to the NIS Cluster research line Sensing. The development of advanced sensor processing methodologies together with novel sensing technologies puts NIS at the forefront of the development of innovative sensing devices (e.g. underwater LIBS and LIDAR).

RL4. Platforms and operations

This RL addresses the development of innovative robotic platforms as well as novel concepts of operation possibly associated to such platforms. Core areas of work are command and control of multiple coordinated of multiple platforms, development of mobile beacons for underwater positioning and communication networks, and coordinated operations of underwater, surface, and aerial platforms.

Coordinated mobile platforms are enablers for advanced solutions in multiples domains that lie within the scope of NIS Cluster activities. Relevant examples area the use of multiple airborne robots for the establishment of non-permanent wireless communication networks, or the use of coordinated robots to simultaneously map time and space variations of a given phenomenon. The design of efficient propulsion systems for underwater or surface vehicles, the development of long-range navigation algorithms, the development of energy harvesting systems for robotic platforms, and the development of auxiliary systems for long term deployments (e.g. docking stations, energy transfer systems) are also addressed by this research line.

6.3.5 Innovation activities

The CRAS innovation activities are the following:

INOV1. Robotics systems prototyping and upscaling

This activity addresses the prototyping and/or upscaling of robotics solutions. Based on previous projects results (VAMOS and UNEXMIN) CRAS will be upgrading the robotic prototypes for operations in flooded mines. Dedicated solutions for inspection of infrastructures, both underwater and above water, will be prototyped and field tested within the scope of ongoing projects.

INOV2. Navigation and mapping

This activity encompasses the development of solutions for specific challenges for which CRAS expertise is instrumental. Examples are the mapping of underwater environment or the navigation in GPs denied scenarios.

INOV3. Component development for robotics systems

This activity addresses the development of components for robotic systems that are expected to greatly increase the performance of the robotic solution of that are essential to their operation. Examples are the SLS (structured light system for underwater applications), the MARESYE underwater stereo vision system, or the short-range acoustic positioning system.

6.3.6 Knowledge valorisation chain

The following table presents the contribution of the Centre research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CRAS – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)		
	Robotic systems prototyping	Navigation and mapping	Component development
Navigation and control	M	H	
Interaction with environment	H	M	
Sensing and mapping		H	H
Platforms and operations	H		M

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.3.7 Main objectives for 2020

General objectives

OBJ1. Scientific publications. Increase the number of papers published in first quartile journals.

OBJ2. Partnerships. Strengthen already established partnerships with CAP and CTM through activities in the ongoing joint research project and also explore other possibilities of cooperation promoting the joint participation in new project proposals. Promote joint research initiatives with other INESC TEC centres in areas where CRAS technologies can be with other competences. Deepen scientific cooperation with top research groups in CRAS core areas but also in areas where the application of CRAS know how is a key factor in the development of innovative systems. Continue to deepen relationships with industrial partners in order to promote the transfer of high TRL technologies developed by CRAS. Increase the number of industrial partnerships.

OBJ3. Leadership and visibility. Participate in international technological exhibitions, by the organization of international events (such as special sessions in relevant international conferences) and by the organization of summer schools on robotics. Promote short term exchanges of researchers with partner institutions. Promote the participation in international fora INESC TEC researchers are involved with: Kick-Raw Materials, EU ROBOTICS, Air Centre, EMSO ERIC. Increase the participation of CRAS researchers as journal editors.

OBJ4. Human resources. Increase the number of MSc and PhD students in CRAS. Promote joint supervision of PhD students with researchers from other INESC TEC centres. Allow younger senior CRAS researchers to enrol in training activities related to project management, proposal preparation, and team management.

OBJ5. Laboratory infrastructure. Continue the implementation of the two research infrastructures CRAS is involved in – TEC4SEA and EMSO-PT. Continue the establishment of a top-quality laboratory infrastructure with distinctive and unique capabilities.

Specific scientific objectives

- Development of navigation systems for operation in underwater confined volumes;
- Development of short-range acoustic high precision positioning systems;
- Development and field testing of perception and control systems for underwater docking;
- Development of efficient methods for underwater acoustic mapping;
- Development of efficient methods for autonomous underwater exploration and 3d mapping with visual and acoustic sensor data;
- Implementation of a robotic lander network;
- Development of perception methodologies for autonomous underwater manipulation;
- Development of deep-learning based methodologies for navigation in GPS denied environments.

6.3.8 Main actions planned for 2020

This year, CRAS will implement the following actions:

Table 6.2 - CRAS – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
FCT PhD scholarship application	OBJ4	3 new PhD students	March 2020
Organization of CRAS openday	OBJ3	New partnerships with industry	July 2020
Participation in exhibitions and conferences	OBJ2 & OBJ3	New partnerships with top research groups and industrial partners	several
Participation in project calls	OBJ2 and OBJ3	New partnerships with top research groups and industrial partners	several

6.3.9 Centre organisational structure and research team

The Centre for Robotics and Autonomous Systems is coordinated by Aníbal Matos and Eduardo Silva/José Miguel Almeida. The centre has a coordination council (CRAS Coordination Council) composed by the centre coordinators and by Alfredo Martins, Carlos Pinho, José Almeida/Eduardo Silva, José Carlos Alves, and Nuno Cruz. This council is responsible for the discussion, definition, and implementation of the centre research, development and innovation strategy.

The Centre research team present composition and planned evolution is presented in Table 5.3.

Table 6.3-CRAS - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	11	12	17	5
		Academic Staff	11	11	10	-1
		Grant Holders and Trainees	22	22	26	4
		Total Core Researchers	**44**	**45**	**53**	**8**
		Total Core PhD	**14**	**14**	**15**	**1**
	Affiliated Researchers		0	0	0	0
	Administrative and Technical	Employees	4	4	3	-1
		Grant Holders and Trainees	1	0	0	0
		Total Admin and Tech	**5**	**4**	**3**	**-1**
		Total Integrated HR	**49**	**49**	**56**	**0**
		Total Integrated PhD	**14**	**14**	**15**	**1**

6.3.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CRAS - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	920	1 444	1 559	116
PN-PICT	National R&D Programmes - S&T Integrated Projects	71			
PN-COOP	National Cooperation Programmes with Industry	164	140	268	128
PUE-FP	EU Framework Programmes	523	210	1 376	1 166
PUE-DIV	EU Cooperation Programmes - Other	115	179	204	25
SERV-NAC	R&D Services and Consulting - National	33	84	51	-33
SERV-INT	R&D Services and Consulting - International	125	150	212	62
OP	Other Funding Programmes		8		-8
Uncertain Projects		76	61	143	83
	Total Funding	**2 027**	**2 275**	**3 814**	**1 538**

Table 6.5 - CRAS - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	8	16	20	4
Indexed Conferences	27	25	30	5
Books				
Book Chapters	1			

Table 6.6 – CRAS - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	2	1	5
Software copyright registrations	0	0	2
Patent applications	3	4	3
Licence agreements	0	0	0
Spin-offs	0	0	0

Table 6.7– CRAS - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	2
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	3
International events in which INESC TEC members participate in the program committees	10
Participation in events such as fairs, exhibitions or similar	10
Advanced training courses	2

Table 6.8 - CRAS - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	2
Participants in the conferences, workshops and scientific sessions organised by the Centre	60
Advanced training courses organised by the Centre	1

Table 6.9 - CRAS - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	BIOREM	André Dias	01/06/2018	31/05/2021
PN-FCT	DIIUS	Andry Maykol Pinto	26/07/2018	25/07/2021
PN-FCT	EMSO-PT	Aníbal Matos	01/07/2017	29/06/2020
PN-FCT	ENDURANCE-1	Nuno Cruz	01/07/2018	29/06/2020
PN-FCT	GROW-1	Eduardo Silva	01/10/2018	31/12/2020
PN-FCT	QuALTOS	Nuno Cruz	01/01/2020	01/01/2022
PN-FCT	TEC4SEA	Eduardo Silva	01/09/2017	30/08/2020
PN-COOP	FEEDFIRST	Eduardo Silva	01/01/2018	31/12/2020
PN-COOP	HiperSea	Eduardo Silva	01/07/2018	30/06/2021
PN-COOP	NESSIE	Aníbal Matos	01/01/2019	31/12/2021
PUE-DIV	INTENDU	Aníbal Matos	01/03/2018	28/02/2021
PUE-DIV	Nettag	Aníbal Matos	01/01/2019	31/12/2020
PUE-DIV	Prince	Aníbal Matos	01/01/2019	31/12/2021
PUE-DIV	PROTOATLANTIC	Eduardo Silva	01/11/2017	31/10/2020
PUE-FP	ATLANTIS	Andry Maykol Pinto	01/12/2019	01/12/2022
PUE-FP	DEEPFIELD	Diana Viegas	01/10/2019	30/09/2022
PUE-FP	INSite	Diana Viegas	01/01/2020	01/01/2023
PUE-FP	Mine_Heritage	Eduardo Silva	01/01/2019	31/12/2021
PUE-FP	SPRING	Aníbal Matos	01/08/2019	31/07/2023
PUE-FP	UNEXUP	Ana Cristina Pires	01/01/2020	31/12/2022
SERV-NAC	Modulmar	Aníbal Matos	01/01/2019	31/12/2020
SERV-INT	AutoMon	Aníbal Matos	01/04/2017	31/03/2019
SERV-INT	SantoAntonio	Aníbal Matos	01/01/2019	31/12/2019

Type of Project:

PN-FCT National R&D Programmes - FCT
PN-PICT National R&D Programmes - S&T Integrated Projects
PN-COOP National Cooperation Programmes with Industry
PUE-FP EU Framework Programme
PUE-DIV EU Cooperation Programmes - Other
SERV-NAC National R&D Services and Consulting
SERV-INT International R&D Services and Consulting
OP Other Funding Programmes

6.4 C-BER - CENTRE FOR BIOMEDICAL ENGINEERING RESEARCH

Coordinators: Aurélio Campilho and João Paulo Cunha

6.4.1 Presentation

The mission of C-BER – Centre for Biomedical Engineering Research is "to promote scientific knowledge excellence through fundamental and applied research, advanced training and innovation in Biomedical Engineering". C-BER activities are aligned with the vision of the Cluster on Networked Intelligent Systems (NIS). To accomplish its mission, C-BER is organised in three Labs (Biomedical Imaging Lab, BioInstrumentation Lab and NeuroEngineering Lab), and is guided by the following goals:

- To create interdisciplinary knowledge enabling the innovation and technology transfer with economic impact;
- To develop bioengineering methods, products and tools for the prevention, early detection and diagnosis of different types of diseases, aging-related impairments, rehabilitation, occupational health and wellness;
- To contribute to the development of advanced neuro-technologies at the frontier of engineering and neuroscience;
- To promote strategic partnerships with other Centres of INESC TEC, clinical partners, research institutes and foster international cooperation.

6.4.2 Context

The world is facing new and serious challenges in the health sector due to the ageing of the population, the rise of noncommunicable diseases (NCDs), and the extremely high costs of health care. According to World Health Organization (WHO) "NCDs kill 41 million people each year equivalent to 71% of all deaths globally". The mortality of NCDs like cardiovascular diseases, cancer, respiratory diseases and diabetes account for over 80% of all premature NCD deaths, being the detection, screening and treatment the key components to face these pandemics. This is in line with the current EU 3rd Health Programme, particularly in the thematic priority that includes the chronic diseases such as cancer, age-related diseases and neurodegenerative diseases, as will be considered a priority in the future. This is also in line with the Portuguese Health Programme Priorities identified by the Portuguese Health Service (Serviço Nacional de Saúde). At a regional level, Life Science and Health is one of the domains in the intelligent specialization strategy for the North Region of Portugal.

At the same time, the last decade saw the emerging of technologies influencing or with a great potential of influencing the health sector. Examples are in the Wearables, Precision Medicine, Telemedicine, 3D Printing, Multifunctional Radiology, Digital Histopathology and Artificial Intelligence (AI). AI, in particular advanced machine learning, as deep learning, play a key role in early disease detection, accurate diagnosis and good predictive power, achieving performance levels comparable to human experts.

Biomedical Imaging and medical image analysis are central in many healthcare departments, and are areas of CBER expertise, one of the main focus of the Biomedical Imaging Lab. Lesion detection, pathology diagnosis, image-based screening operations are targets of C-BER researchers applied in clinical or screening environments, using advanced state-of-the-art image analysis and computer vision technologies for addressing many of the challenges in the health sector, posed by the rise of NCDs. Bioinstrumentation, such as wearables and other advanced human sensing technologies enable more continuous and precise monitoring of different human conditions, enabling early diagnosis, more personalized therapies and more efficient management of chronic diseases, having a large potential to contribute to the above mentioned goals. Finally, Neuroengineering approaches, from macro to nano dimensions, are promising several breakthrough advances in neuroscience and our Centre is exploring several avenues with expected impact in this frontier area between engineering and neurosciences.

Wearable devices are currently a major trend that is expected to significantly impact the health sector in the near future. According to the WHO's Global Action Plan on Physical Activity 2018-2030, regular physical activity is proven to help prevent and treat noncommunicable diseases (NCDs), as well as it helps to prevent hypertension, overweight and obesity and can improve mental health, quality of life and well-being. Wearable

devices can pave the way for a disruptive path in how healthcare will be provided in the future. By the continuous long-term monitoring of physiological and activity signals, health wearables will contribute towards increasing the consciousness and self-awareness of one's health and physical condition and will enable and promote the concepts of personalized health, self-management of chronic conditions, as well as self-rehabilitation scenarios. C-BER can contribute with novel and more reliable technologies for smarter and adaptable sensing and monitoring systems with embedded advanced signal and information processing.

6.4.3 Contribution of the Vision of the Cluster

NIS established, for the medium term, four main research lines: Sensing, Communications, Computer Vision, and Autonomous Systems. In the Sensing and Computer Vision research lines, C-BER has important contributions to be made in the five years' horizon, in cooperation with other Centres and within the Centre itself. In Sensing, we investigated and continue to develop research in Optical Fiber Trapping (Tweezers) and Back-Scattered AI Signal Analysis in collaboration with CAP. Particularly relevant was the proposed method to differentiate cancer cells trapped by a polymeric lensed fiber tip. Results suggest that it can be a valuable contribution for early cancer identification and for other diseases. A patent and several Journal papers have been published. C-BER is strongly in line with the Computer Vision research line, particularly associated with human health scenarios. We are following and continue to follow artificial intelligence methodologies, machine learning and computer vision approaches for NCDs, such as cancer, respiratory diseases and diabetes, by developing research on prediction, early detection or diagnosis of pathologies in hospital or large screening scenarios. We will take as case studies different types of diabetic complications as diabetic retinopathy or diabetic macular oedema, or several case studies of cancer, affecting different organs as the lung, the breast, the thyroid, and the ovary and uterus. We will adopt holistic approaches by considering multi-modal and multi-sensor data. Data to be used in the different scenarios include images of different types, as ultrasound images, computed tomographic images or microscopic images of digital pathology slides. Other complementary data will be used as from liquid biopsy, or from patient metadata.

C-BER also contributes to bring autonomous networked intelligent systems into medicine, biology and human health, by pursuing R&D in biosensors, resilient, smarter and more reliable sensor technologies and systems.

6.4.4 Centre research lines

RL1. Biomedical Imaging Lab

The main focus of the Biomedical Imaging Lab is the development of advanced image processing and analysis methodologies, particularly for medical and biological images, with the aim of creating computer-aided diagnosis tools to support medical decision making. The research activities at the Lab use several imaging modalities addressing different clinical departments including Ophthalmology, Neurology, Radiology, Gynecology, Obstetrics and Gastroenterology. The Biomedical Imaging Lab is organized in four main lines of research: Ophthalmology CAD, Lung CAD, Ultrasound CAD, Endoscopy CAD and Cardiology CAD.

Ophthalmology CAD. The research activities under this line are the following: a) Screening of Diabetic Retinopathy, including the automatic detection of image quality, the automatic detection of images with pathology and the grading of retinopathy. Advanced image analysis and machine learning methodologies, including generic approaches are/will be used; b) Analysis of eye fundus images for early detection of prevalent eye pathologies, including diabetics and hypertension. It involves the detection and segmentation of main anatomical structures and its characterization in order to derive image-based biomarkers. Advanced image analysis methodologies, including generic approaches, are/will be used; c) Screening and computer-aided diagnosis of glaucomatous papilla. Development of advanced machine learning methodologies for the screening of glaucomatous papilla and embedding them in low-cost technologies to be introduced in current clinical practice and screening programs; d) Analysis of optical coherence tomography (OCT) and optical coherence tomography-angiography (OCTA) images for the diagnosis and follow-up of diabetic retinopathy and age-related macular degeneration. These analysis methodologies aim at the extraction of disease biomarkers which will be used for discriminating healthy from pathological eyes and for assessing the disease progression or the effectiveness of therapeutic approaches.

Lung CAD. The research activities under this line are the following: a) Segmentation of lung structures, as lung lobes, airways and vasculature network; b) Early detection of lung pathologies in chest CT scans, with a reduced number of false positives; c) Segmentation and characterization of lung lesions; d) Computer-aided diagnosis of lung cancer and prediction of malignancy likelihood; e) Predictive modelling for relating CT scans image features (phenotype) to genotype signatures (radiomic approach), and evaluation of the contributions of liquid biopsy in lung cancer characterization; f) Digital pathology. In this field, a project was proposed aiming at the development of a system that, given a stained histology whole-slide image from a biopsy or surgical lung specimens, predicts a set of genetic and molecular markers associated with cancer.

Ultrasound CAD. The research activities under this line are the following: a) Characterization of ultrasound Images in 2D, 3D and 4D, using raw radio-frequency data or B-mode data, and its application in clinical environments, including Gynecology and Obstetrics; b) Other clinical areas of application of ultrasound images will be considered, namely for the analysis of the thyroid or for the characterization of vascular diseases.

Endoscopy CAD. The research activities under this line are the following: a) Development of a Computer-aided Diagnosis (CAD) system for the diagnosis of intestinal tract lesions based on videos produced by endoscopic capsules; b) Location of the anatomical regions in the gastrointestinal tract (GT); c) Detection, characterization and classification of abnormalities in the GT.

Cardiology CAD. This research line focuses on the processing of a variety of medical signal and image modalities for point-of-care screening of cardiac disease. Current challenges include: a) Segmentation of heart sound signals (PCG) into its fundamental sounds; b) Classification and description of murmurs present in heart sounds signals (PCG); c) Multi-modal analysis of heart sound (PCG) and electrocardiogram (ECG) signals; d) Processing of echocardiogram videos for cardiac disease screening.

RL2. NeuroEngineering Lab

The main goal of the NeuroEngineering Lab is to perform high-level interdisciplinary R&D in engineering and computational approaches applied to basic and clinical neuroscience, namely crossing several areas, such as Physics; Engineering (Electronics, Computation, etc.), Neurology, Neurosurgery, Neurophysiology, Neuroradiology and Neurobiology. Furthermore, we also aim to innovate and facilitate tech-transfer to the high-tech market.

The main research activity lines in this lab are the following: a) Brain imaging (&signals); b) Man-machine symbiosis (e.g. Brain-Computer Interfaces); c) Quantified Movement analysis in neurological diseases; d) Neurosurgery Aiding Systems; e) From Macro-to-nano bio-neuro-sensing.

RL3. BioInstrumentation Lab

The main goal of the BioInstrumentation Lab is to perform high-level interdisciplinary R&D in engineering and computational approaches applied to rehabilitation, occupational health, wellness and sports performance, crossing knowledge from several scientific areas, such as Physics, Electronics Engineering, Computation, Physiology, Biomechanics, Physiotherapy and Sports science. By pursuing advances in smarter, more adaptable and reliable sensing and measurement technologies with novel embedded biosignal acquisition and processing methods, the lab also aims to innovate and facilitate technology transfer to the high-tech market.

The main research activity lines in the lab are the following: a) Smart sensing technologies and advanced biosignal processing methods; b) Wearable devices and monitoring systems for human physiology and movement analysis.

6.4.5 Innovation activities

C-BER has been very active in converting scientific results into patents (6 patents in 4 years, one accepted and 5 pending in different stages), focused in licensing these IP to “vehicles” (startups, SME, etc.) to take these results into the market. Five out of the above mentioned six patents will be licensed to two spin-off start-ups created in 2019 and one that is planned to be created in 2020, namely:

INOV1 - inSignals Neurotech. In partnership with UK based FrontierIP Group plc (http://www.frontierip.co.uk/), we created a spin-off startup to explore a patent generated at our Neuroengineering lab on quantification of articulatory rigidity for intra-op Deep Brain Stimulation surgery optimization (Patent PT108366/ WO2016166702 - WRIST RIGIDITY ASSESSMENT DEVICE FOR USE IN DEEP BRAIN STIMULATION SURGERY). During 2020 we will

engage several international Neurology centers to perform a multi-center evaluation study of the developed neurotechnology.

INOV2 - iLoF-Intelligent Lab on Fiber. This spin-off startup plans to license the patent PCT/IB2019/059371 - DEVICE AND METHOD FOR DETECTING AND IDENTIFYING EXTRACELLULAR VESICLES IN A LIQUID DISPERSION SAMPLE resulting from a cooperation with CAP and i3S and won the largest EU medtech innovation prize EIT Health Wild Card of 2M€. In 2020 C-BER will establish a R&D program contact with this spin-off and will engage in future H2020 projects in partnership.

INOV3 - WeSENSS – Wearable SENsors for Safety. Plan to license three patents – one on wearable bioinstrumentation (Patent PT109596/WO2018037389 - MEDICAL DEVICE WITH ROTATIONAL FLEXIBLE ELECTRODES) and two other on advanced signal processing methods for biometrics (Patent PT109357/WO2017187422 - BIOMETRIC METHOD AND DEVICE FOR IDENTIFYING A PERSON THROUGH AN ELECTROCARDIOGRAM (ECG) WAVEFORM) and stress/fatigue detection (Patent PT110584/ WO PCT/IB2018/056558 - METHOD AND DEVICE FOR DETECTING STRESS USING BEAT-TO-BEAT ECG FEATURES), aiming at the mission-critical professionals such as first responders, air traffic controllers or oil&gas potentially hazardous procedures operators. This startup is planned to be created in 2020.

INOV4 - Mixed-Signals BUS Management. The following patent was granted in 2018 in several designated countries: “Control module for multiple mixed-signal resources management”, patent US9921835 (B2), JP6321221 (B2), KR101842540 (B1), EP3123348 (B1), CN106471483 (A) published 2018. It discloses a mixed-signal resources management infrastructure for test and measurement, targeting independent or inter-dependent scenarios such as multi-sensor and process/component sharing. It provides for initialization, mixed-signal analog bus scheduling, synchronization and group addressing as part of a flexible long-term solution for monitoring, self-calibration, built-in self-testing, measurements and individual or group synchronized core task management dependent strategies.

INOV5 - Biomedical Imaging. Although we do not yet sense a large demand for Biomedical Imaging services in the Portuguese market, C-BER will entail during 2020 a search for opportunities of technology transfer and consulting services in the sub-areas of speciality below: a) Planning and design Ophthalmology CAD, particularly involving image analysis of eye fundus and OCT/OCTA images; b) Ultrasound (US) image analysis techniques in order to develop tools for image enhancement, lesion detection, biomarkers measurements from 2D, 3D and 4D US images; c) Planning and design Lung CAD for early detection and characterization of lung pathologies in chest CT scans; d) 3D markerless human motion quantification for Neurological Diseases. We will continue to invest into turning high-impact scientific results into IP that may be licensed or spin-off to the market in the future. We have already two more patents under preparation.

6.4.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1-CBER – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)				
	INOV1	INOV2	INOV3	INOV4	INOV5
Biomedical Imaging Lab	L				H
BioInstrumentation Lab	H	H	H	H	
NeuroEngineering Lab	H	H	M		M

(*) Types of relationships:
“blank” – no direct relationship / contribution
L – Low or weak relationship / contribution;

M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.4.7 Main objectives for 2020

- New man-autonomous vehicle symbiosis developments in cooperation with CMU-Silicon Valley and Naval Postgraduate School, Monterrey, CA;
- Establish R&D contract programs with recent startups that licensed our patents – iLoF and inSignals;
- Novel neuro-data-fusion deep-learning approaches with clinical knowledge transfer to neural architectures;
- Novel deep learning approaches for detection and grading of ophthalmological and pulmonary pathologies;
- Submission of a patent on detection of diabetic retinopathy (DR) and/or refer DR for treatment in a screening environment;
- Organize an international challenge for automatic classification of patient follow-up recommendation from CT lung nodule findings;
- Active fund raising for the next R&D cycle (namely H2020 and Horizon 2030);
- Scientific&IP indicators improvements, even with less resources;
- Equipment updates and improvements funding;
- Active participation on dissemination activities including organization of one international conference;
- Evolve the current PCG research line into a multi-modal approach to cardiac signal processing by including simultaneous ECG in a variety of clinical situations (screening in underprivileged scenarios, surgery, others);
- Explore the potential of ultraportable ultrasound technologies, when enhanced by artificial intelligence algorithms, for the screening of disease in underprivileged scenarios such as Northeast Brazil and Africa.

6.4.8 Main and actions planned for 2020

This year, C-BER will implement the following actions:

Table 6.2 - CBER – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Participation JIFX in California, with CMU-Silicon Valley & Naval Postgrad School partners	1	Evolution of our man-autonomous vehicle symbiosis systems	May, 2020
Establish R&D program contracts with spin-offs	2,8	Contracts and direct funding for early low/medium TRL outcomes aligned with spin-offs objectives	January/February, 2020
H2020 project on AI and photonics	2,7	Proposal for New AI and photonics approaches to micro&nano biosensing	March, 2020
R&D period at LMU (Munich)	3	Evolution of neuro-data-fusion algorithms for neurological diseases	February, 2020
H2020 project on Motion & Neurologic Diseases	3,7	Project proposal	May, 2020

Action	#Objective	Expected Outcomes	Calendar
Develop deep learning methodologies in radiology and ophthalmology	4	Prepare and Submit two PhD thesis	December 2020
Prepare a Patent on the SCREEN-DR project	5,8	Submission of a patent	March 2020
Organize a Bioimaging Challenge	6	Evaluate Challenge results and submit a challenge journal paper	June/October 2020
Active participation in proposals of H2020 projects	7	Submission of two H2020 projects	April 2020
Raise the impact factor of our scientific publications	8	Raize the citations track-record (we have raized 30% between 2017 and 2018 and want to continue this trend)	Jan-Dec, 2020
Apply for new funding and diversify sources, namely H2020	7,9	New projects	Jan-Dec, 2020
Organize an International Conference	10	ICIAR 2020 – International Conference on Image Analysis and Recognition	June 24-26, 2020
Explore current PCG signal processing expertise.	11,7	Project on screening pulmonary hypertension in different scenarios (urban, remote).	May, 2020
Explore the potential of ultraportable ultrasound technologies	12,7	Project proposal on AI for the screening of disease in underprivileged scenarios such as Northeast Brazil and Africa	Jan-Dec, 2020

6.4.9 Centre organisational structure and research team

The Centre research team present composition and planned evolution is presented in Table 5.3.

Table 6.3 - CBER - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	2	2	2	0
		Academic Staff	6	7	6	-1
		Grant Holders and Trainees	19	14	9	-5
		Total Core Researchers	**27**	**23**	**17**	**-6**
		Total Core PhD	**11**	**9**	**8**	**-1**
	Affiliated Researchers		0	0	0	0
	Administrative and Technical	Employees	1	1	1	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**1**	**1**	**1**	**0**
		Total Integrated HR	**28**	**24**	**18**	**-1**
		Total Integrated PhD	**11**	**9**	**8**	**-1**

6.4.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 – CBER - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	281	290	172	-119
PN-PICT	National R&D Programmes - S&T Integrated Projects	243	42		-42
PN-COOP	National Cooperation Programmes with Industry	1	15	11	-5
PUE-FP	EU Framework Programmes				
PUE-DIV	EU Cooperation Programmes - Other				
SERV-NAC	R&D Services and Consulting - National	30			
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes				
Uncertain Projects		17	41	65	24
	Total Funding	**571**	**388**	**247**	**-141**

Table 6.5 – CBER - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	19	18	20	2
Indexed Conferences	32	20	20	
Books	1		1	1
Book Chapters	1	4	2	-2

Table 6.6 – CBER - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	2	2	1
Software copyright registrations	2	0	0
Patent applications	2	8	1
Licence agreements	0	0	2
Spin-offs	0	1	1

Table 6.7 – CBER - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	1
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	2
International events in which INESC TEC members participate in the program committees	9
Participation in events such as fairs, exhibitions or similar	3
Advanced training courses	1

Table 6.8 - CBER- Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	2
Participants in the conferences, workshops and scientific sessions organised by the Centre	250
Advanced training courses organised by the Centre	1

Table 6.9 – CBER - List of projects

Type of Project	Short Nme	Leader	Starting date	Ending date (planned)
PN-FCT	LUCAS-1	João Paulo Cunha	26/07/2018	25/07/2021
PN-FCT	PERFECT-1	João Paulo Cunha	01/07/2018	29/06/2020
PN-FCT	SCREEN-DR	Aurélio Campilho	01/04/2016	31/03/2020
PN-FCT	WalkingPAD	Miguel Velhote Correia	01/01/2020	01/01/2022
PN-COOP	TexBoost	Miguel Velhote Correia	01/07/2017	30/06/2020
PN-FCT	LUCAS-1	João Paulo Cunha	26/07/2018	25/07/2021

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.5 CPES - CENTRE FOR POWER AND ENERGY SYSTEMS

Coordinators: Manuel Matos and Ricardo Bessa

Assistant to the coordination: Jorge Pereira

6.5.1 Presentation

The Centre for Power and Energy Systems (CPES) is the core centre of the Cluster Power and Energy. Within this Cluster, CPES holds specific expertise in power systems analysis (steady-state and dynamic), probabilistic and fuzzy modelling, reliability, optimisation and decision-aid, computational intelligence, energy analytics and forecasting, with special focus on large scale integration of Renewable Energy Sources (RES), Distributed Energy Resources (DER) operation, Electric Vehicles (EV) deployment and Energy and Flexibility management, under the Smart Grid paradigm, towards an electrified carbon-free society.

CPES activity is organised in six areas:

- DMS/EMS and network automation
- System planning and reliability
- RES & DER integration
- Electricity markets
- X-energy management systems
- Multi-energy networks

Part of the activity of the group is developed in its Smart Grids and Electric Vehicles Laboratory (SGEVL) that supports real environment, testing and validation of major developments.

Over the last years, this Centre has made several contributions to electrical network planning and operation, namely the inclusion of DER in forecasting and network optimization tools embedded in different voltage levels, aligned with the Smart Grid concept. Relevant steps were taken on the inclusion of computational intelligence in control algorithms that were tested and demonstrated under real conditions in several pilots.

This Centre is a world reference in large scale integration of RES and DER. CPES has two IEEE Fellows (one in the IEEE Distinguished Lecturer Program) and is a strong player in EU H2020 (coordinator in some projects) and contracts with national and international companies, with a robust track record in technology transfer and consulting. One researcher received the IEEE PES Renewable Energy Excellence Award 2103. Another received a recognition award 2013 from CIGRE. Yet other researchers won the 2014, 2017 and 2018 IEEE PES competitions in meta-heuristics applications to difficult power systems problems. Several post-graduate students won the Portugal best MSc thesis prizes attributed by: the Portuguese TSO (REN) in 2015-17; the Portuguese association of renewable GENCO (APREN)- in 2015 and 2016 and by the Portuguese pattern recognition association (APRP) in 2017. Because of this expertise, INESC TEC won the recognition of best 2016 innovation partner of EDP (the major player in the Portuguese wholesale and retail markets, besides including the DSO).

The research results produced by CPES cover a large range in the technology readiness level (TRL), ranging from level 2, where fundamental research is carried out, to level 8, where prototyping and demonstration of technology is performed.

Members of CPES are in the board of several Societies and Steering Committees responsible for organizing some of the most important worldwide conferences in power systems (IEEE PowerTech, PSCC, ISAP, PMAPS, IREP, SEST). They are also part of the Editorial Board of top Elsevier and IEEE journals.

6.5.2 Context

The European Energy Policy[27] established, in 2007, four main objectives: internal energy market to ensure fair and competitive energy prices for consumers and fight energy poverty; secure energy supply; reduced greenhouse gas emissions with investment in energy efficiency and RES; develop energy technologies according to the strategy outlined in the European Strategic Energy Technology Plan (SET Plan). In November 2016, the EC proposed an ambitious "Clean Energy for All Europeans" package[28] with three main goals: priority to energy efficiency, global leadership in RES and empowerment of consumers. More recently, Vision 2050[29] elaborated by the European Technology and Innovation Platform of Smart Networks for Energy Transition (ETIP SNET) and the Digital Single Market[30], adopted by the EC in May 2015, recognizes the major role of digitalization in improving the energy efficiency and the impact on climate change.

In this context the next paragraphs present the background in each CPES area of activity.

DMS/EMS and network automation: The electrification of transport and heating/cooling sectors supported by a RES-based electricity system will require a change of paradigm in distribution networks towards a more flexible, efficient, resilient and reliable grid. The new actors together with the need of improved cooperation with TSO and interaction with energy markets and other new market platforms will require, the identification of alternative control architectures and distributed control concepts. The development of preventive network management tools integrating the uncertainty of RES power generation and loads are required, enabling the mobilization of flexibility and a more secure and efficient operation[31]. Besides a preventive approach, the increased complexity of operation also requires enhanced real-time control strategies. Although smart grid technologies have improved the monitoring and control capabilities of distribution networks, particularly at the LV level, innovative data-driven algorithms are required for ensuring the observability of the system. At the same time, the digitalization trend together with deployment of Artificial Intelligence (AI) also promises to change utilities operation paradigm[32].

System planning and reliability: The progressive integration of RES into power systems together with the decommissioning of fossil-fuelled power plants and the upcoming end-of-life of nuclear units will create numerous challenges to the adequacy and the security of bulk supply. Future power systems will be planned and operated with an unprecedented degree of uncertainty, which must be adequately modelled and incorporated into planning tools. More specifically, advanced models for modelling the equipment wear-out, for the progressive deployment of storage capacity, for the coordinated operation and planning of transmission and distribution networks, for cross-border reserves sharing, and for the mitigation of the cyberattacks threats are seen as pressing worldwide research topics for the years to come in the area of planning and reliability[33].

RES & DER integration: The adoption of RES in European power systems is a mean for progressively achieve the power sector de-carbonization. Recent figures point towards a target established by the EC of 32% of renewable electricity through RES integration by 2030. This area of activity intends to assure the safe and secure integration of this new RES associated with the overlapped disconnection of conventional power generation (especially thermal ones). In this area, there is a need to anticipate research on how future power system will behave with reduced inertia levels and loss of controllability inherent from the loss of dispatchable power plants within the electricity mix. The identification of power system scarcities will be one of the activities and will lead to the development of innovative system services that partially will be provided by RES & DER. Thus, there will be the need of investigating and designing associated controllers as well as coordinating the existing assets towards the attainment of power system robustness on scenarios of high level of RES.

Electricity markets: The energy transition for decarbonisation has important implications in power sectors and electricity markets challenges. One key aspect is converging to a level playing field for all potential market

[27] An energy policy for Europe. COM(2007) 1 final - Not published in the Official Journal
[28] Clean Energy for All Europeans, https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[29] Bacher, R., de Nigris, M., Peirano, E., et al. (2018). ETIP SNET Vision 2050. INTENSYS4EU Project and ETIP SNET.
[30] A Digital Single Market Strategy for Europe, COM/2015/0192 final
[31] Soares, T., et al. (2017). Active distribution grid management based on robust AC optimal power flow. IEEE Transactions on Smart Grid.
[32] Li, F., & Du, Y. (2018). From AlphaGo to Power System AI: What Engineers Can Learn from Solving the Most Complex Board Game. IEEE Power and Energy Magazine, 16(2), 76-84.
[33] Gómez-Expósito, A., et al. (2018). City-Friendly Smart Network Technologies and Infrastructures: The Spanish Experience. Proceedings of the IEEE, 106(4), 626-660.

players, efficiently promoting the participation of the RES generation and demand of all sizes, considering their specific challenges due to their small size, local distribution network constraints, and their own operating constraints. Challenges are therefore many. They include market pricing mechanisms, spatial and temporal granularity, complex bids and efficient pricing, energy and reserves markets coordination, reserve requirements reflecting scarcities, balance responsibilities and market inefficiencies, imbalance pricing, markets liquidity, generation reliability and capacity mechanisms[34]. In this context, EU is also actively legislating towards EU markets integration, and promoting a more competitive, consumer-centric, flexible and non-discriminatory EU electricity market, where consumers and energy communities should play an important role[35]. More precisely, the engagement of consumers in the energy management is a trend that will boost the EU's electricity markets in the upcoming years. A more consumer-centric electricity market can empower small consumers and producers to share energy among each other within energy communities, encouraging the energy efficiency and investing in renewable technologies to increase local sustainable production.

X-energy management systems: The use of energy from the customer side is gaining attention with the integration of intelligence (data analysis) that allows the exploitation of energy efficiency actions and the use modulation techniques to be employed so that controllable loads (or industrial processes) and flexible generation can adapt to different operational and economical contexts. Strategies for the articulation and participation of buildings is one of the key aspects in supporting smart (energy) cities and communities. Smart devices and systems are providing additional information and in some cases the ability to be remotely controlled, which is triggering smart building/process automation, like the case of lighting, HVAC systems and processes in industry 4.0. Virtual and augmented reality can be exploited to expedite and enhance the characterization of energy consumption. Communications and information exchange mechanisms are the supporting infrastructure for devices, systems and buildings. The use of interoperability schemes is fundamental in allowing the integration of different devices and systems but at the same time a challenge as different vendors are looking for ways to keep their business and monetize over existing solutions.

Multi-energy networks: Multi-energy systems provide appropriate services to citizens and help to ensure the security of supply, maximize the primary energy efficiency and deliver a high share of RES. These systems will have to cope with a fundamental transformation in the coming years, responding to actual drivers, such as the increasing uptake of renewables, the boosting digitalization and associated business models, together with users' empowerment. The main challenges and research trends in this area are related with the integration of electric mobility networks in city/local energy systems, exploitation of synergies between energy networks to increase overall efficiency of the energy system, widespread deployment of power-to-gas and power-to-heat technologies and utilization of multi-energy systems flexibility in energy markets[36].

6.5.3 Contribution to the Vision of the Cluster

CPES is the core Centre of the Power and Energy Cluster, therefore its research lines and areas of activity are fully aligned with the vision of the Cluster. CPES is conducting research in advanced mathematical modelling for optimization of electrical grids and energy consumption, as well as large-scale time series forecasting. The decarbonisation of the energy sector is a key goal in the Centre research agenda and is being handled at the software and hardware level and using the laboratorial infrastructure for testing and validation. Finally, the Centre in 2018 identified a set of INESC TEC competences that can leverage pre-existing know-how and help to materialize concepts such as microgrids, e-mobility and smart energy systems (cybersecurity, internet-of-things (IoT), interoperability, data platforms/hubs and blockchain).

The area of activity of CPES in energy management systems can contribute to push energy efficiency in industrial consumers beyond traditional actions (e.g., investment in more efficiency equipment such as LED lights) and integrate data collected from IoT platforms (aligned with industry 4.0) in data-driven energy optimization schemes. Moreover, opportunities generated by dynamic tariffs for both energy and network-use also create regulatory conditions to explore flexibility from industrial processes and contribute to decrease energy costs. Finally, another contribution from CPES is decision-aid methods and new business models for industrial

[34] Ignatio Pérez-Arriaga et al (2016). Utility of the Future, An MIT Energy Initiative response to an industry in transition.
[35] Gregor Erbach (2018). Common rules for the internal electricity market. Briefing EU Legislation in Progress, European Parliamentary Research Service.
[36] Mancarella, P. (2014). MES (multi-energy systems): An overview of concepts and evaluation models. Energy, 65, 1-17.

consumers that consider the role of renewable energy and participation in different types of electricity markets (e.g., ancillary services, capacity markets). This also covers the agriculture sector, where its seasonal activity is the perfect case to apply demand-side management and business models based on digital solutions (e.g., peer-to-peer, variable contracted power). This contribution fits the Vision of two other Clusters: Network Intelligent Systems and Industrial and Systems Engineering.

The energy analytics and forecasting and decision-aid and optimization scientific domains from CPES can also contribute to the Computer Science Cluster, namely in meta-heuristics optimization, uncertainty modelling and forecasting and data-driven optimization with reinforcement learning. CPES has been developing basic research in these areas, which have a broad application in other domains.

6.5.4 Centre research lines

CPES is organized in five scientific domains (or research lines - RL) that produce results in low RL, which are further exploited in combination with the innovation activities areas described in section 0.

RL1. Energy analytics and forecasting

This RL applies statistical learning techniques to power system related problems, electricity markets and energy end-users . The core concepts are the development of time series forecasting algorithms for electric load, renewable energy based generation and electricity prices. These techniques are the basic framework to tackle new problems like distributed and data-driven optimization strategies and knowledge extraction from different power system data, such as phase measurement units, smart meters data and other sensors. The final goal is to integrate extracted knowledge in decision-aid methods problems under risk and create new paradigms for power system control, market participation and planning.

It will contribute with data-driven methodologies for the PE Cluster and support the digitalization of the energy sector, e.g. new approaches for network operation and control based on AI; data-driven control of industrial processes for energy optimization. This should involve collaboration with other centres for the design and development of an architecture for large-scale multi-domain data exchange, management and fast processing (including edge computing) in the electricity sector. Finally, one goal is to continue the development of a data analytics toolbox to accelerate the development of research studies and TEC4 solutions, such as advanced forecasting tools, provision of innovative energy services and safe and effective operation of grids.

RL2. Energy economics and regulation

This RL is divided in three topics: (1) re-design of existing market mechanisms or design of new ones to integrate flexible resources like storage, EV and demand response; (2) long-term transmission expansion planning; (3) new economic and regulatory frameworks. The first topic is focused in local reactive power markets, peer-to-peer energy markets, participation of DER in ancillary services, remuneration of conventional technologies and the adaptation of current market designs to the large integration of infra marginal technologies such as wind and PV. The second topic aims at studying the impact of the increasing integration of RES on the multi-period transmission expansion planning and its consequences for the network-use tariffs' setting mechanisms, including large-scale modelling of RES spatial-temporal uncertainty. The third topic consists in designing new economic and regulatory frameworks for smart grids, namely incentive schemes associated to the quality of service, dynamic tariffs for energy and network-use and participation of storage in multiservice.

This line is well integrated in the vision of the Cluster namely in terms of the development of models to frame the expansion of transmission grids and redesign of electricity markets so that the dissemination of RES (with integration levels above 50%) is enabled while maintaining the high reliability levels of power systems.

RL3. Industrial electronics

The following thematic lines have been defined for this RL: (1) materialization of the next-generation of grid-tied inverters, which involves the development of power converters with power circuit and coordination control between RES and energy storage; (2) enhancing the capability of exploiting energy storage systems, which requires fundamental research on power converters, including their topologies, multi-cell and multi-level converters, and its control methodologies with fault tolerance and diagnosis; (3) research and development for the electric mobility solutions of the future, including advanced technical solutions for the ultra-fast charging of

electric vehicles, solid-state transformers, control of vehicular systems and enhance control systems for hybrid energy storage systems for different applications.

This RL takes advantage of the laboratorial infrastructure (SGEV). Moreover, it develops new hardware and control solutions that can be further explored by TEC4ENERGY in high TRL and contribute to one key goal of the PE Cluster, i.e. the decarbonization of the energy sector.

RL4. Static and dynamic analysis of power systems

The economy decarbonisation trend dictates the increasing share of RES in electric power systems as well as an increasing share of grid-connected inverter-based generators.. Therefore, a key research line lies on the identification and development of innovative contributions within the scope of the future grid scenario, with up to 100% shares of RES where the active contribution of inverter-based generators connected from the low voltage distribution grids, up to the transmission grid resiliency and stability, becomes necessary. This includes research activities addressing the development of innovative on-line Dynamic Security Assessment, the identification of minimum inertia/dispatching system inertia, in order to operate power system with large-scale RES integration, advanced control strategies for the provision of ancillary services through non-conventional power plants, and advanced control concepts for inverters connected to large scale batteries for assuring proper grid stability conditions. Moreover, addressing system protection concepts in low inertia power systems brings together the grid stability and protection domains, that deserve a specific attention. On the distribution grid segment, the recent developments on the Smart Transformer and hybrid AC/DC distribution grid concepts requires new control approaches in order to increase grid resiliency, through the operation of cluster of microgrids autonomously. The expected results will have a strong scientific value but also relevant market value, constituting solutions to be exploited by the TEC4ENERGY initiative, for instance in consultancy studies.

Finally, this RL is also improving the observability of electrical grids by combining data assimilation, deep learning and information theoretic learning. The main goal is to develop novel state estimation algorithms that exploit heterogeneous data (in quality, temporal resolution and number of variables) from different sensors.

RL5. Decision-aid and optimization

This RL incorporates classic and emerging optimization methods with applications to energy systems, methodologies for multi-criteria decision aiding, including risk models and methodologies based on metaheuristics and evolutionary computation for optimization and decision making. This RL also includes the definition, development and specification of new advances in multi-criteria decision-aid methods with user friendly inputs, namely through swing weights, the acceptance of multiple trade-offs and the use of fuzzy inference systems (value machines and utility machines). In order to ease the integration of uncertainty in decision-aid situations, this RL will promote a reflection on the interpretation of probabilistic results for direct use from operators in an online environment and identification of fuzzy methods' challenges, with emphasis in the interpretation of results in natural language, but also in the associated optimization methods.

This RL is core for the PE Cluster vision since it will develop core algorithms for problem such as co-optimization of multi-energy networks to increase overall efficiency of energy systems, decision-aid tools for portfolio optimization of multi-energy aggregators and multi-period optimization in electrical grids with storage.

6.5.5 Innovation activities

INOV1. DMS/EMS and network automation

The main focus of this area is the specification, development and integration of advanced computational tools for network management systems for all voltage levels (transmission, distribution), both for interconnected and islanded systems, and also new solutions for network automation, protection and control of distribution networks. EMS/DMS and network automation area holds a privileged position in technology transfer, with TRLs between 3 and 7, mainly due to its long collaboration with EFACEC and most recently with demonstration activities in the context of national and European projects (e.g., H2020 SENSIBLE, H2020 InteGrid, H2020 EU-SysFlex). It has been responsible for the development of advanced tools for Advanced Distribution Management Systems (ADMS) and for the specification and development of innovative tools for the operation of LV networks in a smart grid context. Extending the area competences to network automation, protection and control allows

the coordination of local and centralized operation strategies, required to deal with future network operation challenges.

INOV2. System planning and reliability

The system planning and reliability area is concerned with the R&D activities and studies that allow evaluating the performance of the power system, aiming to achieve optimized decisions, not only for the use of the existing equipment, but also for the decommissioning and installation of new ones. Hence, the tools and models within this area aim at supporting not only the operational planning but also the expansion of power systems. Naturally, this activity within the area appeals to advanced optimization techniques and to new stochastic models for the representation of the overall system behaviour. Over the past 20 years, CPES has accumulated important knowledge in power system reliability assessment, which lead to the development of two software applications, the RESERVE and MORA tools, currently used by the Portuguese TSO. The System Planning and Reliability Area will continue to improve and expand such tools to foster new contracts and services for other agents in power systems.

INOV3. RES & DER integration

The central focus of the RES & DER integration Area is the steady state, dynamic and transient modelling, analysis and control of interconnected and isolated electric power systems with increasing shares of RES. The main activities are related to RES integration studies, identification of system support functions/ancillary services from RES and the exploitation of new technologies for increasing the controllability and flexibility of transmission and distribution grids, such as transmission and distribution FACTS, energy storage with associated power converters and HVDC). These activities are supported by the laboratorial infrastructure of CPES (SGEVL) where reduced-scale models can be implemented and extensively tested in a power-hardware-in-the-loop set-up. The work developed in this area has been largely carried out in collaboration with industry, not only through consultancy services and applied research, but also through national and European public research bodies, whose financial support enables the developed of fundamental R&D activities.

INOV4. Electricity markets

The Electricity Markets Area aims at the analysis and modelling of electricity markets to help understanding the advantages, difficulties and opportunities of the ongoing energy transition, under a context of low-carbon energy generation, high penetration of renewable generation, electrification of the energy consumption, etc. Understanding current electricity markets and price formation is essential to support industry and new market players to adapt their strategies to be more efficient and competitive. However, this transition also poses many challenges (see section 6.5.2) and needs a re-evolution of markets to increase stakeholders participation and maintain system flexibility, by re-thinking existing markets or designing new ones (as for example new locally distributed markets to profit from distributed resources and consumers empowering). Different market models (based on advanced classic and metaheuristic optimization) will be needed to help in the design of new market structures, and to address the challenges of the existing ones. These models will progressively be adapted and expanded to cope with broader objectives (long-term decisions, integrated EU market, different market products, etc.).

INOV5. X-energy management systems

This area is recent (created in November 2018) and as such it does not have any technology transfer yet. However, given the potentially high levels of TRL associated to its activity, it is expected that to have such output in the coming years. The development lines of this area are focused on the articulation of several tools, computationally based, such as energy models, optimization algorithms, decision making strategies, and modular automation platforms for buildings in general. The technology transfer potential is mainly related to the provisioning of SW tools, developed from the ground up to fulfil specific energy management requirements or to be integrated in existing systems. Energy related models and algorithms may be subjected to licensing to allow further exploitation by technological partners. Given the associated energy efficiency measures that can be exploited by the energy management platforms, consultancy activities will be carried out in the scope of energy efficiency audits (including industrial processes) and economic exploitation of existing and newer business models. Retrofitting strategies are being used to allow technology updates in buildings, considering the related investments and exploitation costs, to support newer energy and non-energy services.

INOV6. Multi-energy Networks

One of the goals of the multi-energy networks area is the specification and development of advanced models of loads, generation technologies, energy converters, storage devices and networks in a "multi-energy vector" perspective. These models will cover electricity, gas, heating/cooling and transportation technologies and networks and will later be used to develop optimization tools for multi-energy aggregators' participation in energy markets (electricity and gas) and for real-time management of clients' infrastructures. The models will also be used to optimize the coordinated operation and planning of multi-energy networks, at multiple scales: building, neighbourhood, cities, regions and countries. For the lower scales, i.e. buildings and neighbourhoods, solutions for the operation of multi-energy networks will be designed to be compatible with multiple architectures, such as microgrids and energy communities, and to maximize energy efficiency.

6.5.6 Knowledge valorisation chain

The following table presents the contribution of the Strategic Research Lines to the "Technology Transfer" areas, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CPES – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)					
	DMS/EMS and network automation	System planning and reliability	RES & DER integration	Electricity markets	X-energy management systems	Multi-energy networks
Energy analytics and forecasting	H	H	M	H	H	F
Energy economics and regulation		H	L	H	F	M
Industrial electronics	M		H		F	
Static and dynamic analysis of power systems	H	M	H			F
Decision-aid and optimization	H	M	L	M	H	H

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.5.7 Main objectives for 2020

The main objectives of CPES for 2020 are listed by activity area and by research line:

ACTIVITY AREAS

DMS/EMS and network automation

1. Identify distribution network control and automation architectures to integrate future network control strategies;
2. Develop data-driven network operation tools to enable decentralized control ;
3. Develop new protection and decentralized control strategies for smart secondary substations, including self-healing strategies compatible with high RES integration scenarios.

System planning and reliability

1. Develop models and tools for emerging reliability problems;
2. Consolidate the topic of coordinated operational planning of the TSO and the DSO;
3. Reduce significantly the execution time of security of supply evaluation tools.

RES & DER integration

1. Increase the technology transfer potential

Electricity markets

1. Extension of CEVESA MIBEL market simulator (in collaboration with IIT Comillas);
2. Develop advanced simulation tools for local flexibility markets;
3. Develop a local energy-related market platform based on blockchain technology.

X-energy management systems

1. Define models and tools associated to load flexibility management;
2. Define strategies for the provision of new network services.

Multi-energy networks

1. Develop models and tools to support to multi-energy aggregators in their participation in energy markets;
2. Develop methods to maximize energy efficiency in multi-vector infrastructures.

RESEARCH LINES

Energy analytics and forecasting

1. Interact with climate experts for assessment of the impact of climate changes on power systems;
2. Identify research directions associated to emergent AI and related techniques with potential to address power systems emerging problems;
3. Provide tools to energy communities for optimizing their operation;
4. Promote the internationalization and visibility of CPES in the Energy Resources forecasting topic.

Energy economics and regulation

1. Develop a new market design to deal with the foreseen dramatic changes in the generation mix;
2. Develop optimization models for multiyear expansion planning of the transmission system;

Industrial electronics

1. Research on condition monitoring and fault-diagnostic systems for DC/DC converters;
2. Develop soft-switching techniques in the context of intelligent inverters and battery interfaces;
3. Address emergent topics of IE in power systems.

Static and dynamic analysis of power systems

1. Master the control of the autonomous operation of hybrid AC/DC microgrid clusters enabled through smart transformers:
2. Develop new protection strategies for low inertia electric power systems;
3. Develop models for the predictive dispatch of system inertia and reserve requirements, for power systems with high shares of renewables while coping with multiple disturbances.

Decision-aid and optimization

1. Organise the information about models, methods, tools and platforms used in CPES for optimisation and decision-aid, with emphasis in the methodologies created and developed at INESC TEC;
2. Improve the internal literacy regarding optimisation and decision-aid;
3. Promote the interaction of OR and AI approaches.

6.5.8 Main actions planned for 2020

This year, CPES will design and/or implement the following actions:

Table 6.2 - CPES – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Development of battery storage energy optimization and life cycle estimation algorithms	#1, #3	Integration of the algorithms in EFACEC commercial storage management solution	May 2020
Definition of a roadmap for the future architectures for distribution network control and automation	#1	Roadmap to support future consultancy and research projects with the DSO	Mar 2020
Development of an AI based event and alarm management system for distribution network substations	#2	Transfer of system for supporting distribution network operators based on AI	Dec 2020
Extend present adequacy assessment of bulk power systems tools to integrate demand response effects	#4	New module for the PS-MORA tool	Mar 2020
Implementation of the Sequential Monte Carlo Simulation method in a distributed environment (parallel processing using Graphic Processing Units or other architecture)	#6	Parallel version of the PS-MORA tool	Dec 2020
Conclusion of HEAD project	#4	New models and tools for Assets Management	Mar 2020
Disseminate the work developed in the framework of EU-SYSFLEX project and corresponding results	#7	Deployment of flexibility-hub on the field for the Portuguese Demo of EU-SYSFLEX	November 2020
Increase and update team skills regarding specialised simulation tools	#7	Stronger team	December 2020
Collaboration with SGEVL to incorporate lab-scale tests for both industrial clients and research projects	#7	Offer of new services	December 2020
Integration of Portugal power system in CEVESA (currently only Spain is modelled)	#8	Full MIBEL market simulator for medium and long term strategic analysis	Jan 2020
Integration of a simplified EU energy market modelling in CEVESA	#8	EU market simulation tool	Sept 2020
Market platform simulator for local flexibility markets for TSO and DSO services and coordination mechanisms testing	#9	Flexibility market simulator for distributed resources	Apr 2020
Development of a local energy-related market platform based on Ethereal on top of blockchain technology.	#10	Market platform simulator for local energy-related products, for economic and regulatory research on business models and energy communities	Nov 2020
Development of cognitive models for load flexibility management	#11	New models for load flexibility management	May 2020
Definition of energy efficiency technical strategies for articulation with electric mobility	#12	New global approach	Nov 2020
Development of bid optimization algorithms for multi-energy aggregators	#13	Algorithms to maximize the profit of multi-energy aggregators	Oct 2020

Action	#Objective	Expected Outcomes	Calendar
Development of methodologies to maximize energy efficiency in multi-vector infrastructures	#14	Portfolio of actions to improve energy efficiency	Dec 2020
Participation in the activities of the Cigré WG C6/C1.33	#13, #14	Knowledge exchange with international experts	Dec 2020
Research on long-term wind forecasting (up to 7 days) based on data-driven techniques and attention-aware approaches.	#16	New models for wind forecasting	Apr 2020
Research on Generative Adversarial Networks (GAN)	#16	New insight and research guidelines	May 2020
AI to process HV/MV substations alarms	#16	Operator support	Nov 2020
Develop a framework to facilitate the organization of real-based forecasting competitions	#18	Forecasting competition platform	July 2020
Analyse the impact of Feed-In Tariffs in the total generation cost and in market adequacy	#19	Report	Sep 2020
Organize and protect the tools for multi-year expansion planning of the transmission system	#20	Dossier for CPES discussion on software valorisation	June 2020
Experimental validation of the inversion-based approach for fault diagnosis	#21	Validation of the approach	April 2020
Study and development of soft-switching techniques and innovative circuit design to optimize the filter passive elements with EMI requirements EMI filters	#22	Innovative power control and filter circuit to enhance the efficiency of inverters	Dec 2020
Development of control-allocation methods to tackle the power allocation and battery balancing of hybrid energy storage systems.	#23	Algorithms to maximize the efficiency of hybrid energy storage systems through model-predictive power allocation	Sep 2020
Development of methodologies for emulation of inertia with power converters	#23	Scientific material for CPES discussion	July 2020
Develop and advanced simulation tool for hybrid microgrids	#24	Dynamic simulation tool	June 2020
Adapt PHIL platform existing in the lab	#25	PHIL platform capable of testing protections systems in low inertia power system environment	June 2020
Incorporate simulation platforms for low inertia systems	#26	Simulation available in a new environment (DiGSILENT)	Dec 2020
Produce a report on models, methods, tools and platforms used in CPES for optimisation and decision-aid	#27	Report	Dec2020
Organise Lab Meetings on optimisation and decision-aid	#28, #29	Increased literacy on optimisation and decision-aid and their relation with AI	Dec 2020

6.5.9 Centre organisational Structure and Research Team

The Centre for Power and Energy Systems is coordinated by Manuel Matos (coordinator), Ricardo Bessa (assistant coordinator), Jorge Pereira (assistant to the coordination) and is organised in the following Activity and Business Areas:

- DMS/EMS and network automation. Responsible: Clara Gouveia
- System planning and reliability. Responsible: Leonel Carvalho
- RES & DER Integration. Responsible: Bernardo Silva

- Electricity markets. Responsible: José Villar
- X-energy management systems. Responsible: David Rua
- Multi-energy networks. Responsible: Filipe Joel Soares

Research in low TRL is organized in the following Scientific Domains:

- Energy analytics and forecasting Responsible: Nuno Fidalgo
- Energy economics and regulation. Responsible: João Tomé Saraiva
- Industrial electronics. Responsible: Rui Esteves Araújo
- Static and dynamic analysis of power systems. Responsible: Carlos Moreira
- Decision-aid and optimization. Responsible: Manuel Matos

The SGEVL research infrastructure is transversal to all areas and scientific domains and the responsible is Miguel Miranda.

The Centre research team present composition and planned evolution is presented in Table 5.3.

Table 6.3 - CPES – Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	18	21	30	9
		Academic Staff	10	10	10	0
		Grant Holders and Trainees	53	48	49	1
		Total Core Researchers	**81**	**79**	**89**	**10**
		Total Core PhD	**25**	**26**	**26**	**0**
	Affiliated Researchers		6	7	6	-1
	Administrative and Technical	Employees	1	1	2	1
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**1**	**1**	**2**	**1**
		Total Integrated HR	**88**	**87**	**97**	**0**
		Total Integrated PhD	**30**	**32**	**31**	**-1**

6.5.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CPES – Project funding

Funding Source		Total Income (k€)			
		2018	2019 (Forecast)	2020 (Plan)	Δ 2019-2020
PN-FCT	National R&D Programmes – FCT	573	602	536	-67
PN-PICT	National R&D Programmes - S&T Integrated Projects	21			
PN-COOP	National Cooperation Programmes with Industry	61	35	42	7
PUE-FP	EU Framework Programmes	841	1 054	1 942	888
PUE-DIV	EU Cooperation Programmes – Other	226	70		-70
SERV-NAC	R&D Services and Consulting - National	1 125	973	786	-187
SERV-INT	R&D Services and Consulting - International	141	67	28	-39
OP	Other Funding Programmes	20		349	349
Uncertain Projects		113	21	14	-7
	Total Funding	**3 122**	**2 822**	**3 697**	**876**

Table 6.5 - CPES– Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	71	73	60	-13
Indexed Conferences	73	11	45	34
Books				
Book Chapters	8	5	2	-3

Table 6.6 - CPES – Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	4	1	4
Software copyright registrations	0	0	0
Patent applications	1	2	1
Licence agreements	0	0	0
Spin-offs	0	0	0

Table 6.7 - CPES – Summary of participation in dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	5
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	1
International events in which INESC TEC members participate in the program committees	2
Participation in events such as fairs, exhibitions or similar	3
Advanced training courses	2

Table 6.8 - CPES - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	1
Participants in the conferences, workshops and scientific sessions organised by the Centre	300
Advanced training courses organised by the Centre	2

Table 6.9 – CPES - List of projects

List of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	ESGRIDS	João Peças Lopes	01/01/2017	31/12/2019
PN-FCT	SGEVL	Luís Seca	01/07/2017	29/06/2020
PN-FCT	UNiTED	João Catalão	01/06/2018	31/05/2021
PN-COOP	GPDER	Ricardo Jorge Bessa	01/08/2019	28/01/2022
PUE-FP	AmBIENCe	Nilufar Neyestani	01/06/2019	30/11/2021
PUE-FP	ATTEST	Filipe Joel Soares	01/09/2019	01/09/2022
PUE-FP	EMB3Rs	Tiago André Soares	02/09/2019	01/09/2022
PUE-FP	EUniversal	Bernardo Silva	01/09/2019	01/03/2023
PUE-FP	EU-SysFlex	Bernardo Silva	01/11/2017	31/10/2021
PUE-FP	FEEdBACk	Filipe Joel Soares	01/11/2017	31/10/2020
PUE-FP	InteGrid	Ricardo Jorge Bessa	01/01/2017	30/06/2020
PUE-FP	InterConnect	David Emanuel Rua	01/10/2019	30/09/2023
PUE-FP	POCITYF	Nilufar Neyestani	01/10/2019	30/09/2024
PUE-FP	Smart4RES	Ricardo Jorge Bessa	01/11/2019	30/04/2023
PUE-FP	TDX-ASSIST	Leonel Magalhães Carvalho	01/10/2017	30/09/2020
PUE-FP	XFLEX	Carlos Moreira	01/09/2019	31/08/2023
SERV-NAC	AI4Substation	Clara Sofia Gouveia	01/01/2019	01/01/2020
SERV-NAC	AO_Perdas	Luís Seca	01/01/2018	31/12/2019
SERV-NAC	EFACEC-DMS	Jorge Correia Pereira	15/04/2001	31/12/2030
SERV-NAC	EstinvestQoS	José Nuno Fidalgo	01/12/2017	31/12/2019
SERV-NAC	FlexAgg	Ricardo Jorge Bessa	01/05/2019	30/11/2019
SERV-NAC	FLEXERGY	Clara Sofia Gouveia	01/09/2018	31/03/2020
SERV-NAC	FlexOPlan	Ricardo Jorge Bessa	01/05/2019	01/11/2020
SERV-NAC	FlutuacoesPV	Helena Vasconcelos	21/03/2019	21/07/2019
SERV-NAC	GEST_STORAGE	Clara Sofia Gouveia	02/04/2018	31/12/2019
SERV-NAC	GridPlan	Filipe Joel Soares	01/10/2019	01/10/2020
SERV-NAC	HEAD-1	João Peças Lopes	01/01/2018	30/09/2019
SERV-NAC	IeM_QST	José Nuno Fidalgo	16/08/2019	16/06/2020
SERV-NAC	INFRA_PT	João Peças Lopes	20/07/2017	06/11/2019
SERV-NAC	LossPD	José Nuno Fidalgo	02/05/2019	31/03/2020
SERV-NAC	LPVAnalytics	Ricardo Jorge Bessa	01/06/2018	30/06/2020
SERV-NAC	MUKI_nordeste_solar	Bernardo Silva	01/10/2019	01/02/2020
SERV-NAC	NazaréSustentável	Luís Seca	10/01/2019	31/12/2019
SERV-NAC	Perfis_Perdas_2020	José Nuno Fidalgo	21/05/2019	21/12/2019
SERV-NAC	ProtTerrasR	João Peças Lopes	01/07/2019	30/06/2020
SERV-NAC	RedeDistDigital	Clara Sofia Gouveia	17/10/2018	31/12/2019
SERV-NAC	Sglab_MA	Luís Seca	01/01/2019	30/09/2019
SERV-INT	PredAdvisor	Ricardo Jorge Bessa	01/05/2019	01/09/2019
SERV-INT	SECRETS	Luís Seca	01/12/2013	31/05/2019
OP	VEARREN2030	João Peças Lopes	01/06/2019	30/09/2020
OP	PSCC2020	João Peças Lopes	01/04/2019	01/10/2020

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.6 CESE - CENTRE FOR ENTERPRISE SYSTEMS ENGINEERING

Coordinator: António Lucas Soares

6.6.1 Presentation

CESE mission is to advance the scientific knowledge in enterprise systems engineering, providing unique expertise targeting complex industrial organisation challenges that foster high impact management and ICT systems and generate innovative services for industrial organisations. CESE wants to position as a leading research Centre focused on connected, sustainable and customizable production systems through the engineering of innovative enterprise systems. It aims to become the first choice in helping industrial organisations to improve competitiveness and sustainability of their supply chains and achieve high-performance levels of their inner business processes.

CESE accomplishes its mission, within the Cluster ISE – Industrial and Systems Engineering, by undertaking multi-disciplinary, system-oriented research and technology development for the strategic and operational management of industrial enterprises and networks. It uses the knowledge generated in research to provide high value-added niche services to the industrial enterprises in areas such as Manufacturing Systems Design, Manufacturing Systems Planning and Management, Collaborative Platforms, Supply Chain Strategy, Manufacturing Intelligence, Logistics and Technology Management.

CESE core competencies are Systems Design, Operational Research (including Modelling, Optimization and Simulation), Information Management and Analytics, Design Science and Explanatory Research, and Creative Thinking and Problem Structuring.

6.6.2 Context

Future European industry has to combine high and widespread productivity with a high level of environmental and social sustainability. This will mean moving from local optimisation – for individual factories or clusters of firms - to complex system optimisation, with major impacts on the way factories are designed, the technologies factories use, infrastructure and wider government policies. The following challenges are to be taken also as opportunities to foster and frame the research and innovation strategy of the Centre for Enterprise Systems Engineering.

Challenges as opportunities

1. Manufacturing as networked and dynamic socio-technical systems. In what concerns to value creation networks, manufacturing can be viewed as a networked and dynamic socio-technical system. It goes far beyond factories and refers to networked and dynamic value creation systems, which can be organised in multifaceted ways. The coincidence of various value creation systems, which are adapted to specific needs and framework conditions, contribute to a resilient European manufacturing system in a dynamically changing and uncertain world. We can envision four archetypal types of value creation networks that companies may configure or even combine to target different markets or product lines: (i) Highly Integrated Global Supply Networks, (ii) Regional Value Creation for Global Markets, (iii) Local Value Creation for Local Markets, and (iv) Dynamic Virtual Value Networks.

2. Digital Transformation. Digitalisation is a global trend of major transformative character, comprising all areas of daily and professional life. Businesses, consumers and industry are increasingly using digital technology to grow, overhaul workflows and generate efficiencies and to develop new products and services. Increased efficiency and scale from digitalisation will impact production chains and potentially make certain layers redundant. Thus, digitalisation can lead to a new era of automation enhancing and augmenting relevant human capabilities with new technologies. This will clearly have disruptive effects on the labour market: a future-oriented and lifelong-learning employment and education strategy will be essential to re-train and up-skill people for the new jobs created by digitisation.

3. An ecosystem of Information, Operations, Technologies and People. Integration of an increasingly digital world, connecting the data streams from new product development and design (ET), including CAD and PLM systems, to the production and resource planning (IT), such as ERP and MES, and real-time analysis of manufacturing data from the shop floor (OT), IoT sensor and machine tool data, is an essential requirement for

success in the competitive marketplace. However, this integration is far from trivial and new platforms that promise to ease the integration have yet to prove their capabilities. The agility of today's supply networks and flexible manufacturing systems makes companies and business units equipped with different systems and resources have to work together. However, in many larger but as well in some small and medium-sized corporations this presents an internal challenge that needs to be addressed in order to really profit from the developments and promise of Industry 4.0.

4. Data-Driven Manufacturing. Increasing interconnectivity and availability of data will create a new reality for smart manufacturing at their core. Having access to and being able to utilise large amounts of data opens up many significant opportunities across all manufacturing and leadership functions in an enterprise. An indication on how valuable resource manufacturing data is considered already is the tendency to specify access, usage and ownership of (manufacturing) data in new contracts. Managing data is a challenge, in particular in a noisy, non-stationary environment, with rapidly changing conditions which characterise manufacturing. Furthermore, some processes produce terabytes of data every minute and hosting, analysing and maintaining the data infrastructure requires increasing resources and adds to the hidden cost of machine learning. Another important challenge is to design new data-centric business models, integrating existing and emerging product-service models.

Sources:

THE 2018 WORLD MANUFACTURING FORUM REPORT: Recommendations for the Future of Manufacturing. World Manufacturing Foundation.

ManuFUTURE VISION 2030: COMPETITIVE, SUSTAINABLE AND RESILIENT EUROPEAN MANUFACTURING. Report from ManuFUTURE High-Level Group, November 2018.

RE-FINDING INDUSTRY. Report from the High-Level Strategy Group on Industrial Technologies. Conference Document. European Commission, DG Research & Innovation, February 2018.

6.6.3 Contribution to the Vision of the Cluster

CESE undertakes multi-disciplinary, system-oriented research and technology development for the strategic and operational management of industrial enterprises and networks. CESE research focuses on connected and high customizable and sustainable transformation systems, helping companies, from different sectors, to achieve personalised and complex products and services, being flexible and resilient in their operations. CESE will direct its research strategy on these areas complying at the same time with the requirements of resource efficiency and circular economy implementation, as well as trying to achieve an optimal balance and integration between humans and machines. CESE will also consolidate the leadership in knowledge and technology transfer on digital transformation, integration of advanced manufacturing technologies and new business models, helping companies to fully embrace the 4th industrial revolution.

The research strategy of CESE is aligned with the strategic research lines of the Cluster Industrial and Systems Engineering.

6.6.4 Centre research lines

CESE core RLs

RL1. Design and management of manufacturing systems

Manufacturing companies are rapidly adopting a new customer-focused manufacturing paradigm in order to deal with the increasing demand for personalized products. The adjustment from low product variety and high production volume to high mix and low volume poses many important challenges. Therefore, manufacturing firms need to rethink their production systems to more rapidly respond to customer requirements and to better manage production capabilities towards high levels of sustainability covering all value chain. Hence, this implies a continuous and dynamic change of product design tools, production planning and control approaches, supply chain strategies and operations and adopting practices that allow to maximise value from products and materials and to minimise the resource consumption and the environmental impact via re-using, re-manufacturing and recycling. CESE research activities in this strategic line address applied research in operations management focusing in responsive and high efficient operating models addressing high variety and low volume (mass

customization) environments. The research encompasses Factories Design and Operation, Orders and Production Management and Optimizing and Scheduling. The research generates knowledge and tools in modelling, simulation and optimization, combined with support for decision-making in close collaboration with industry.

RL2. Collaborative networks and digital value chains as socio-technical systems

The adoption by companies of collaborative value chains strategies seeking global efficiency gains, implies a significant and robust interaction and integration upstream and downstream. In fact, the creation of these dynamic and digitally integrated value chains raise more complex to production networks and turns decision-making increasingly difficulty. Furthermore, a key priority is to consider Human capital as the most valuable resource of these collaborative production systems, namely through human-centred workplaces, where the technical equipment and tools support the humans, make their job attractive and eventually improve their performance. Complex digital value chains can unleash its potential only if technology and human work are jointly designed and optimised in the framework of socio-technical systems. CESE research activities in this strategic line address the design of collaborative and supply networks, network business models and processes and the study and design of information and knowledge management in collaborative networks.

RL3. Digital architectures for data-driven manufacturing

Research on digital architectures and operational elements addresses the design and use of ICT in industrial organisations and networks along the instrumental, architectural and impact dimensions. The changing context of manufacturing requires new design knowledge to inform the development of management systems — performance, information, supply-chain, business processes — as well as execution systems — manufacturing operations management in the context of the increasing adoption of data-driven manufacturing. This poses demands for architectural concepts involving the so called cyber-physical systems and the industrial internet of things that are opportunities for research. Data-driven manufacturing is, in-fact, a source of research problems, being the most relevant for CESE the industrial data management and governance. There is here an opportunity for joint research between CESE and LIAAD. Finally, technological development should be informed by empirical research on technology assessment.

RL4. Mobility for the Circular Economy

Globally distributed industrial organisations and networks require new logistics solutions, as a way to address the challenges posed by the 'on demand economy' and by shared-connected and low-emission logistics operations. These innovative, integrated solutions are fundamental to contribute to the uptake of the Circular Economy. In close collaboration with CEGI and marginally with other centres, CESE has developed three strongly inter-disciplinary research lines. These lines are based on the application of a recognised know-how and long experience in decision support systems, simulation, optimization and information and knowledge management, to transportation systems and logistics, urban logistics and mobility, and Intelligent Transportation Systems.

CESE common SRLs

RL5. Decision Support in a digital manufacturing context (with CEGI)

Manufacturing activities and supply chains are typically characterized by high levels of complexity and variability and by the frequent occurrence of disturbances. Dealing with uncertainty poses significant challenges for decision-making processes, either at a more strategic level (e.g. for network design) or at a more tactic or operational level, with planning or scheduling activities. In this context Decision Support Systems (DSS) along with Performance Management Systems (PMS) can play a very important role, taking advantage of the fast digitalization of the manufacturing environments, exploring powerful quantitative models and algorithms, and fostering the active “participation” of human decision-makers. CESE has a long inter-disciplinary research and development experience in these areas, providing modern companies with integrated systems capable of modelling and solving the complex problems that emerge from this new reality. Such systems effectively support agile and real-time decision-making processes, based on sophisticated models and advanced analytical methods that promote efficiency, flexibility and agility of industrial companies and networks.

RL 6. Technology adoption and management for inclusive manufacturing (with CITE)

The changes brought about by the digital revolution in the process of transformation and creation of value are radical and represent a real challenge for companies and in particular for SMEs. However, digital transformation is not just about advanced technology. The use of new technologies and the acquisition of new knowledge, through the selective treatment of information, will inevitably lead to new types and ways of working. In that context, human behaviour, perceptions, emotions, consumer preferences and design, as well as social aspects related to the desirable society structure for Europe and globally, the relationships between stakeholders, etc., require approaches that will combine technical aspects as well as humanities and social sciences. Identification and adoption of proper and efficient enabling technologies at all levels (basic to cutting-edge) which reduce drudgery while creating new jobs hence fostering and sustaining inclusive innovation in manufacturing. CESE research activities in this strategic line encompass two sides: from the one side it aims at creating empirical knowledge that can help companies to better manage their technology and digital transformation roadmaps, processes, organization and competencies and, from the other side, this knowledge will help CESE to better align its systems engineering research and services provision with the real challenges of manufacturing organisations. Research methods include qualitative studies on adoption and use of advanced manufacturing technologies, development of maturity models, methods for roadmap creation, methods for change management.

6.6.5 Innovation activities

An important part of the centre's mission is dedicated to provide innovative, high value-added technology based services to industrial companies and networks. These services are sustained by the research activities described above. A major priority of CESE is to transfer to IT companies - technology up takers - the knowledge and technology resulting from the RTD activities undertaken in the scope of the research domains. For this purpose, the collaborative projects commonly include at least one technology up taker company with interest in the commercial exploitation of the research results generated in the project. However, additional actions are needed for successful transfer of the technology related with manufacturing systems planning, including:

- New collaborative research projects to produce market-ready products based on CESE research results;
- New commercial agreements with technology up takers, foreseeing the royalties schema related with the CESE property rights over the exploitable results;
- Support to the commercialization efforts of our partners technology up takers, including the parameterization of the CESE developed modules to new clients/end-users as pre-selling initiatives; or adapting the CESE modules to evolving needs of existing end-users. An example is the long-lasting relationship with developers of ERP systems that incorporate our research results and gives us access to large final clients; partnerships with MES/MOM providers are also being done; and
- initiatives to disseminate research results and seek for new partnerships with technology up takers and end-users, including the participation in sectorial associations, such as Produtech and AIFF and the participation in national and international fairs and seminars.

The most active areas of knowledge and technology transfer, and provided services are the following:

INOV1. Production Systems Management

Consultancy services in Manufacturing Systems Design include the conceptual and functional design of resource-efficient factories, the modelling and simulation of manufacturing systems and resource-constrained production processes, and the development of ICT solutions for designing and managing high-performance manufacturing systems. Business Processes Management, as well as Information Systems specification and implementation project management are also important services provided in this area.

INOV2. Logistics Systems

The centre develops intra and inter-organisational logistics systems. Concerning the former, CESE provides services to enable companies to integrate IoT components and orchestrate manufacturing modules, such as planning, scheduling and balancing with internal logistics in order to increase the flexibility of the manufacturing systems. With respect to the inter-organisational logistics systems, novel methods for transportation/distribution planning, combined with other upstream and downstream supply chain processes. Examples of applications can be found in biomass and wood-based products distribution across forest-based supply chains. CESE also develops multi-disciplinary approaches (based on advanced decision support tools) to

design transport networks or inter-modal logistic solutions, integrated in broader distributed manufacturing systems. This stream includes problems such as fleet sizing and management, vehicle routing planning (for product distribution or collection) and the design of logistic networks.

INOV3. Digital platforms for networks and supply chains

Levered in the research conducted on Networked and dynamic value chains as socio-technical systems, the centre is providing consultancy and development services on digital platforms for managing several types of collaborative networks. Contracts are established with enterprise associations and sectorial clusters to develop collaborative platforms for managing information, communication and collaboration together with networks and collaboration governance models. The distinctive aspect of the centre's offer is the integrated approach to network governance and digital platform development.

INOV4. Digitalisation and Industry 4.0 roadmapping

The ability to analyse the prevailing organizational structure, culture and the patterns of operation is fundamental for the successful implementation of a Digital Transformation strategy. A structured approach is a key point. One of the first actions is to evaluate the maturity of organization. Assessing maturity means to conceptualize and measure the maturity of an organization regarding some specific target state (aligned with the overall strategy of the organization). CESE will keep successfully helping industrial companies to assess the maturity and roadmapping for advanced manufacturing technologies in the frame of Industry 4.0. This will continue in 2020, expanding to a more strategic level regarding operations and technology management. An example was a strategic roadmap for Industry 4.0 developed for a sectorial association.

6.6.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1-CESE – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Manufacturing Systems Management	Logistics Systems	Digital platforms for networks and supply chains	Digitalisation and Industry 4.0 roadmapping
RL1. Design and management of manufacturing systems	H	H		
RL2. Collaborative networks and digital value chains			H	M
RL3. Digital architectures for data-driven manufacturing				H
RL4. Decision support in a digital manufacturing context	H	H		
RL5. Mobility for the Circular Economy		M		
RL6. Technology adoption and management for inclusive manufacturing	M	M	M	H

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.6.7 Main objectives for 2020

The centre main objectives for 2020 are organized in three dimensions: scientific, innovation and management.

Scientific:

1. Rethink the scientific strategy: the Centre needs to refocus its research lines and align them those of the Cluster ISE and market pull strategies of TEC4INDUSTRY;
2. Adopt fully the Circular Economy paradigm deploying its principles in impact goals for every research activity in the Centre; the Centre needs to raise the standards of its impact on society;
3. Increase the research efforts on systems integration operations and energy management, towards energy efficient manufacturing;
4. Increase the research on data and information management to support the effective application of Advanced Manufacturing Technologies;
5. Develop a service-oriented architecture to support the research and development activities of the Centre, enabling the agile development of proof-of-concepts in research (as well as in consultancy);
6. Improve the scientific performance (quality and quantity of the publications), aiming to achieve 90% of Q1 journal publications, 100% of indexed conference publications and a minimum of 1 journal paper per PhD per year;
7. Consolidate and expand the network of European partners in projects and increase joint publications with them;
8. Increase the success rate of European projects applications;

Innovation:

1. Define a model of advanced services to strategic partners of the Centre, based on contracted research;
2. Improve the articulation between Centre core activities and the ones developed at iiLab; ther is a need to develop a model for dissemination, demonstration, and training in the scope of the iiLab; articulate activities with the iMan Norte Hub;
3. Systematise the emergent technologies assessment supporting research, consultancy in the iiLab and iMan Norte Hub;

Management:

1. Improve the efficiency and effectiveness of system development, through a reorganization of the teams and the adoption of adequate methodologies;
2. Rethink the Centre's human resources strategy in the context of the new regulations;

6.6.8 Main actions planned for 2020

This year, CESE will design and/or implement the following actions:

Table 6.2 - CESE – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Redefine scientific strategy, aligning research lines with the Cluster and TEC4INDUSTRY	1,2,3,4,6	Scientific strategy for the next 3 years	02/2020 07/2020
Develop the base platform and main services (IIOT) of the SOA	4,5	SOA architecture to support R&D activities	01/2020 12/2020
Implement a new structure, methods and tools for software development	9, 12	Reorganised software development team	01/2020 12/2020
Develop a technology scouting process	11,12	Technology Roadmap for R&D	01/2020 07/2020
Coordinate INESCTEC participation in EIT Manufacturing activities	7,8	Successful participation in EIT	01/2020 12/2020
Coordinate the activities of the and services offer of the iMan Norte Hub	9,10	Effective synergy between the Centre and the DIH	01/2020 12/2020
Prepare and submit 4 EU project proposals (coordinating 1)	7,8	2 EU projects approved	01/2020 09/2020

6.6.9 Centre organisational structure and research team

The Centre research team present composition and planned evolution is presented in Table 5.3.

Table 6.3 - CESE - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	17	21	20	-1
		Academic Staff	7	5	4	-1
		Grant Holders and Trainees	37	30	27	-3
		Total Core Researchers	**61**	**56**	**51**	**-5**
		Total Core PhD	**12**	**15**	**14**	**-1**
	Affiliated Researchers		6	7	7	0
	Administrative and Technical	Employees	2	2	2	0
		Grant Holders and Trainees	0	0	1	1
		Total Admin and Tech	**2**	**2**	**3**	**1**
		Total Integrated HR	**69**	**65**	**61**	**0**
		Total Integrated PhD	**16**	**22**	**21**	**-1**

6.6.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CESE - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	199	169	124	-44
PN-PICT	National R&D Programmes - S&T Integrated Projects	108	6		-6
PN-COOP	National Cooperation Programmes with Industry	378	298	214	-84
PUE-FP	EU Framework Programmes	521	641	540	-101
PUE-DIV	EU Cooperation Programmes - Other	42	17		-17
SERV-NAC	R&D Services and Consulting - National	412	211	41	-170
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes				
Uncertain Projects		15	61	588	527
	Total Funding	**1 674**	**1 402**	**1 507**	**105**

Table 6.5 - CESE - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	14	10	21	11
Indexed Conferences	26	2	23	21
Books				
Book Chapters	3	2	2	

Table 6.6 - CESE - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	0	0
Software copyright registrations	0	0	0
Patent applications	0	0	0
Licence agreements	1	0	0
Spin-offs	0	0	0

Table 6.7 – CESE - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	2
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	2
International events in which INESC TEC members participate in the program committees	4
Participation in events such as fairs, exhibitions or similar	4
Advanced training courses	2

Table 6.8 - CESE- Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	4
Participants in the conferences, workshops and scientific sessions organised by the Centre	120
Advanced training courses organised by the Centre	3

Table 6.9 – CESE - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	DM4Manufacturing-1	César Toscano	01/11/2016	31/10/2020
PN-FCT	opti-MOVES	Tânia Daniela Fontes	26/07/2018	24/01/2021
PN-FCT	StoSS	Ana Maria Rodrigues	15/10/2018	14/10/2021
PN-FCT	Tec-FEL-1	Alexandra Sofia Marques	04/04/2018	03/04/2021
PN-COOP	ADIRA_I4.0	António Correia Alves	01/09/2016	28/02/2020
PN-COOP	CrossLOG	Luís Guardão	01/11/2019	31/10/2022
PN-COOP	FAMEST	Rui Diogo Rebelo	01/11/2017	31/10/2020
PN-COOP	GOTECFOR-1	Alexandra Sofia Marques	01/01/2017	31/12/2020
PN-COOP	PRODUTECH_SIF	António Correia Alves	01/10/2017	30/09/2020
PUE-FP	ConnectedFactories2	Vasco Bernardo Teles	01/12/2019	30/11/2022
PUE-FP	DigTrafoRIS	Ana Cristina Barros	01/01/2020	01/01/2021
PUE-FP	DIVA-1	Alexandra Sofia Marques	01/04/2018	31/03/2021
PUE-FP	EIT_M_RIS_Hubs	Ana Cristina Barros	01/01/2020	01/01/2021
PUE-FP	Fasten	César Toscano	01/11/2017	31/10/2020
PUE-FP	M_NEST_RIS	Ana Cristina Barros	01/01/2020	01/01/2021
PUE-FP	MANU-SQUARE	António Lucas Soares	01/01/2018	31/12/2020
PUE-FP	ScalABLE4.0-1	César Toscano	01/01/2017	30/06/2020
PUE-FP	UP4Legacy	António Correia Alves	01/01/2020	31/12/2020
PUE-FP	ZeroDefects40	Alexandra Sofia Marques	01/01/2020	31/12/2020
SERV-NAC	ACCMES40III	Rui Diogo Rebelo	31/05/2019	31/03/2020
SERV-NAC	T4CDTKC	Américo Azevedo	01/09/2019	31/03/2020

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.6.11 Annex: Details of the strategic research lines

RL1 detailed

Factories Design and Operation: Industries of the future must be driven by adaptability of the factory design and of its processes strategically aligned with high level goals. This requires innovative and multidisciplinary approaches to address the increasing complexity and scale of decision-making. CESE research in this line is centred on intelligent manufacturing technologies and methodologies, developed on top of analytical modelling approaches such as simulation and optimization. The research efforts are aimed at (i) the conceptual factory design and layout planning (manufacturing and assembly); (ii) integrated design and operation of smart manufacturing systems; (iii) virtual commissioning and operators training; and (iv) real-time performance monitoring and optimization.

Orders and Production Management, Optimizing and Scheduling: This line is a major research area of CESE over the past 15 years, and stills a challenge, most relevant in the context of demands for increased agility and

resiliency. It involves the development of planning and scheduling methods and IT tools for complex production processes. Application areas include footwear, metalwork, and forestry. Two specific topics are envisioned:

- to advance existing optimization models and heuristics to deal with tailored production processes, for small series, high-customization; this is particularly important in the case of new installed footwear assembly lines demand a sophisticated planning of resources, namely in what concerns the balancing of mixed model lines and the real-time sequencing of operations. Related with this, optimize the allocation of multi skilled teams allocation to operations, for instance considering a specific mix of assembly to order and project client orders;
- to evolve planning&scheduling tools to work with other data collection tools within an Internet of Things environment. In fact, the myriad of sensors and other data collection technologies existing today, enable remote monitoring of production processes and should be the basis for real-time planning. Furthermore, the ready availability in quality and quantity of real-time and historic data from the shop-floor together with management data, will foster a research line on planning and scheduling systems integrating ML and optimisation techniques.

RL2 detailed

Design of Collaborative and Supply Networks: The design of collaborative networks involves determining which structural governance forms would be most appropriate for network success, implementing and managing the structure and recognizing when structure should change based on network and participant needs. Digital platforms have a strong role in shaping the behaviour and sustainability of collaboration in the network. One research line along these needs is to create design knowledge on how digital platforms can be used instrumentally to transform networks in sustainable collaborative networks. Another research line is focused on global supply networks. Current research includes information management for risk management in supply-chains and the design supply networks towards increasing the technological capabilities of regions.
Knowledge and Collaboration Management in collaborative networks: Successful management of enterprise networks strongly depends on the ability of the network members to collaborate towards solving increasingly complex problems. If it is consensual that collaboration is a means to an end, it is not the case in what concerns to how collaboration should be governed within a network. Collaboration nowadays is intertwined with powerful information and communication (digital) platforms whose diversity poses demanding problems of socio-technical optimisation. The research topics addressed in this line are (i) new concepts for the design of collaborative spaces for decision making involving complex information and sense making; (ii) new concepts, models, methods and tools for information and knowledge management in collaborative networks and (iii) to explain information behaviour and knowledge representation processes in collaborative networks.
New Business Models and Processes Design: The sharing economy enabled the creation of new business models that leveraged scattered knowledge and spare capacities linked through websites. The objective of this research line is to extend this concept to industry, by studying novel business models for product-services systems that tap into the under-utilized prototyping and manufacturing capacity. The implementation of these business models requires enhanced collaboration and information exchange among the members of the extended value chain to map the existing technology infrastructure, spare capacity, and scattered knowledge.

RL3 detailed

Design knowledge for industrial information systems: In the instrumental dimension, research is focused on the creation of design knowledge for industrial information systems; this is materialised in innovative design concepts and prototypes that cover the upper decision-making levels — performance management, information management, supply-chain management, business process management — as well as the lower levels — manufacturing operations management (including, among-others, production planning systems and manufacturing execution systems).
Digital architectures and operational elements: The architectural dimension addresses research along two lines: (i) novel architectures for Cyber-Physical Systems and (Industrial) Internet-of-Things; the focus is on devising new ways of integrating computing and communication with physical and virtual processes across all levels of production, from processes through machines up to production and logistics networks; (ii) architectures for efficient large amounts of streaming data collected from machines and processes; combination of off-the-shelf big data technology and in-house developments to support different types of data sources, including IoT, as well

as other decision support technologies, including analytics, optimization and simulation, delivered as part of enterprise and industrial systems.
Industrial data management: The adoption of Industry 4.0 by industrial/manufacturing companies will create data in quantity and quality never seen before, fostering an enormous potential for their businesses. These companies are now becoming conscious of this reality but lack competencies and resources to deploy a continuous strategic process of data management and governance. Nevertheless, only a very small percentage of industrial data is currently used in a way that makes sense or adds value. Several approaches to assess maturity and define roadmaps regarding Industry 4.0 are today proposed both in research and practice, yet none of them addresses explicitly and in detail the Industry 4.0 data strategy and governance required to explore the full potential of this movement. Research in this line aims to develop a systematic approach to support industrial/manufacturing companies to deploy a strategic data management process, specially in the context of Industry 4.0 implementation. An effective and strategic data management process will provide companies with data awareness and data maturity, enabling an effective data-driven approach to their decision making.

RL4 detailed

Performance Management Systems: There is an increasingly important challenge for manufacturing organizations to find the strategic decisions that best fit the underlying organization complexity, and the need to evaluate the impact that the strategic decisions will have in the future performance. Research in this line addresses the exploitation of model-based digital-twin/shadow and development of hybrid methods for improved performance management, focusing on approaches to predict the operational performance, namely for quantifying the impact of operational decisions in the future system's performance. Digital-Twin and hybrid approaches, with combined qualitative and quantitative methods, allow for a better understanding of the past operational choices made by the manufacturing organization and of the decisions the organization intends to make in the future. These approaches also help to predict how future operational choices will impact the system's performance.
Decision Support Systems: he ever-growing utilization of advanced business analytics and digital-twins, along with more sophisticated optimization and simulation tools, has naturally been the basis for the development of more integrated and powerful forms of Decision Support Systems (DSS). At a more strategic level (e.g. for network design, layout reconfiguration, or process selection) or at a more tactic or operational level (with planning or scheduling activities), a DSS will hopefully complement quantitative models and algorithms with an active "participation" of human decision-makers. Interfaces design and other ways to address the "human dimension" in DSS development is still an important research topic that is a key component for the deployment of true multi-criteria decision making frameworks. These frameworks integrate multiple stakeholders, and explicitly take into account their different perspectives. Moreover, another important related research topic is the use of DSS for collaborative planning and decision-making processes, allowing a fair distribution of the costs and the benefits associated to collaboration. CESE is well known for the activity in some of these areas, with particular emphasis in combinatorial optimization and meta-heuristics (as fundamental tools for tackling many problems in operations management and logistics) and also in advanced simulation-optimization approaches. Current research challenges for decision-making in manufacturing that are of the interests of CESE can be found in areas such as Soft Operational Research, multi-criteria decision-making with unclear/uncertain facts, modelling subjectivity, intuition and emotions, creative problem solving, or visible/visual thinking.

RL5 detailed

Transportation Systems and Logistics: Modern manufacturing and supply networks are becoming more and more complex, geographically distributed and fragmented. This is the natural result of the increasing complexity of products and the benefits of specialization associated with new, more efficient forms of collaboration. Sophisticated, complex products involve quite disperse manufacturing and logistic actors, with a huge component of moving raw materials, parts and components, and therefore with a higher role of transportation systems and logistics. Due to this complexity, research in this area is obviously of a multi-disciplinary nature, and with quite dynamic demand patterns, uncertainty (at different levels and with different sources) becomes an important factor to consider in the design or operation of logistic services.
Urban Logistics and Mobility: Mobility of people in urban and metropolitan areas has an enormous importance in the organization of cities and in the quality of life. Huge costs are involved in daily commuting, with a large weight for private cars. Environmental impacts of transport in cities are also at an unacceptable level. Better designing and operating transport services is therefore critical, especially in a time when demand patterns are

more and more diverse, and when inter-modality is the basis of urban mobility. Still in the city context, in urban logistics multiple interesting research topics have emerged, to design more efficient services and to better manage operations.
Intelligent Transportation Systems: Embedded “intelligence” in vehicles and in transportation systems has since a long time been an important topic of research, from different perspectives and in various scientific disciplines. However, recent, extraordinary technological advances have created a still more promising landscape for multi-disciplinary research, particularly concerning urban mobility systems. Sensors networks, the co-creation of knowledge, information sharing, big data, or the Internet-of-Things paradigm, are creating the ground for new, promising research projects, strongly aligned with the interests and competences of CESE.

RL6 detailed

Technological evaluation: Current trends in technology and communication are driving companies to a new level of industrial automation. Manufacturing machines are now able to communicate among themselves and with information systems, negotiating and reconfiguring their activities for a flexible production of multiple items. The integration of technologies such as Cyber-Physical Systems (CPS), Additive Manufacturing (AM), Internet of Things (IoT) and Cloud Computing, among others, into an autonomous, knowledge - and sensor-based - self-regulating production system implies the characterisation of the available architectures, technologies and solutions covering the MOM domain (including MES); evaluation of the different possibilities around integration technologies for Industrial Information Systems; and the development of frameworks for the selection and implementation of information systems in enterprises and supply chains. The integration of new technologies to existent manufacturing units may face internal barriers. In order to incorporate the concept of industry 4.0, companies need to engage both strategic and operational sectors, reducing chances of technological and cultural resistance. Furthermore, there is an increasing demand for comprehensive frameworks that help to scope and evaluate their i4.0 activities, presenting their current implementation level and what is necessary to upgrade such status.
Socio-technical studies of industrial ICT: The adoption of technologies by companies is a complex process and impacts in several aspects of the organization management practices. The factors that influence the decision to adopt a technology, the assessment of the social impacts of the technologies adoption, the planning and management of the technologies adoption and implementation process, and the design of technologies that consider aspects related to human well-being, among others, should be explored in empirical studies in order to improve the organization’ benefits arising from the adoption of the advanced manufacturing technologies. These are research themes with great interest to CESE, and to organizations, as far as they complement the current focus on technology development of CESE, improving the value created to both parts. The current and future projects on the design and implementation of advanced manufacturing technologies in industrial organisations and networks by CESE offers a golden opportunity to research on these themes

6.7 CRIIS - CENTRE FOR ROBOTICS IN INDUSTRY AND INTELLIGENT SYSTEMS

Coordinators: António Paulo Moreira and Germano Veiga

6.7.1 Presentation

The Robotics and Intelligent Systems Centre designs and implements innovative solutions within the areas of industrial robotics and intelligent systems. The Centre works in close cooperation with companies, other INESC TEC Centres and other Institutes and Universities, following the lemma from Research and Development to Innovation, passing through Design, Prototyping and Implementation.

6.7.2 Context

The society faces big challenges where cost-effective and novel robotics and intelligent systems are needed. The three challenges that drive CRIIS R&D are:

- Bring industries (4.0) to the developed countries and upgrade existing industry towards 4.0 concept;
- Manage resources in efficient way and produce more in a sustainable way;
- Automate processes to make elderly people more active (aging society) and increase development.

Robotics and Artificial Intelligence is transforming industry/agriculture/forestry by automating processes, reducing the labour costs, human effort, and increasing the efficiency. Robotics Technology will become dominant in the coming decade. It will influence every aspect of work and home. Robotics has the potential to transform lives and work practices, raise efficiency and safety levels, provide enhanced levels of service and create jobs. Its impact will grow over time as will the interaction between robots and people [Robotics 2020 Strategic Research Agenda for Robotics in Europe].

However, more research is needed to move robotics, automation and artificial intelligence technologies to new contexts such as industry 4.0 and agriculture/forestry 4.0 contexts. These technologies need to be safer, modular, cost-effective, plug-and-play, smarter, and reliable. The CRIIS R&D is aligned to the existing (2020) and future (2030) main National, European and Worldwide agendas, namely:

- Manufacturing 2030 Vision and the strategic objectives of the FoF PPP;
- Robotics 2020 Multi - Annual Roadmap (https://eu-robotics.net/sparc/upload/about/files/H2020-Robotics-Multi-Annual-Roadmap-ICT-2016.pdf;
- Robotics 2020 Strategic Research Agenda for Robotics in Europe (https://www.eu-robotics.net/cms/upload/topic_groups/SRA2020_SPARC.pdf);
- 2016 US robotics roadmap (http://jacobsschool.ucsd.edu/contextualrobotics/docs/rm3-final-rs.pdf);
- Agendas Temáticas de Investigação e Inovação – FCT.

From these agendas CRIIS selected and is highly involved in the following strategic research lines:

- Navigation, Localization and Coordination of Mobile Robots;
- Intelligent Sensors and Control of Dynamical Systems;
- 2D/3D Vision and Advanced Sensing;
- Human Robot Interfacing and Augmented Reality;
- Future Industrial Robotics and Collaborative Robots;
- Vertical Integration, IoT, Industry 4.0.

6.7.3 Contribution to the Vision of the Cluster

Customer-centric and production optimisation in real time, as well the decentralisation of decisions will only be possible with highly flexible, re-alocable, adaptable and intelligent automation, control and robotics. The use of

industrial collaborative robots (mobile and manipulators); smart sensor networks, Industrial vertical IoT-based information architectures and Human-robot collaboration and interface plays an important role in these processes and are the main contribution of the Centre to the Vision of the Cluster.

Furthermore, our contributions and activities in the Cluster focus on the development and implementation of intelligent systems, automation, management and decision support systems, among other technological solutions in the areas of agriculture, forest and livestock in an integrated approach, fostering - the resilience, efficiency, competitiveness and sustainability of these areas towards an effective bio-economy.

6.7.4 Centre research lines

RL1. Navigation, Localization and Coordination of Mobile Robots

This research line addresses mobile robots, Automated Guided Vehicles (AGVs) and navigation solutions for indoor and outdoor environments. The Centre for Robotics and Intelligent Systems (CRIIS) develops mobile robotic systems that can be applied in industry, indoor and outdoor environments.

During the last years, the Centre had a strong focus on the development of Mobile Manipulators. These robotics systems present high flexibility and are particularly adapted to the needs of existing production systems, where layout reconfigurations are difficult. The application of such systems extend from internal logistics to novel applications, such as on-site construction. This research line has been developed with extensive international collaborations in the context of 3 European projects (FP7 - CARLoS, FP7- STAMINA and H2020 ColRobot), with reference end-users such as PSA - Peugeot Citroen, Renault or Thales-Alenia Aerospace. For the upcoming years, the goal is to push the mobile manipulators systems closer to full production systems, either through the development of basic technologies, or the development of higher TRL projects, namely through the application of the previous developments industrial settings.

RL2. Intelligent Sensors and Control of Dynamical Systems

Research in Dynamics and Control can be applied in several systems from robots to industrial process and is crucial to the efficient control and design of complex and optimized systems. Using the mathematics and physics laws, we build model based approaches, namely model based predictive controllers, and apply them to a wide range of systems from process control to robotics and industrial production lines. To have a correct and cost-effective monitoring and control the use of sophisticated sensors is mandatory. The development of smart-sensors, software-sensors and networked sensors is also a main research topic for CRIIS.

RL3. 2D/3D Industrial Vision and Advanced Sensing

Sensing is a key component on modern industrial robotics systems. The advent of 3D point-cloud based perception systems opens a wide variety of opportunities to deal not only with dynamic environments, where parts are placed in unknown places, but also with robot accuracy limitations and part dimensional deviations. Furthremore, the widespread use of different sensing technologies, including force-sensing, laser range finders or sonar, for example, are key elementd in the development of upcoming robotics systems. The research line followed by the centre is focused on the development of algorithms tailored for industrial use, robotics in particular, with special emphasis on multimodal sensor fusion, integrated machine learning, active perception among others.

RL4. Human Robot Interfacing and Augmented Reality

Together with machine vision, human robot interfacing is a key element on the development of flexible robotics systems. Although a topic of extensive research in the past, also by the Centre, the potential of applications unleashed by the human intervention in robotic systems is still very significant. The approach will explore previous developments on Programming-by-demonstration, CAD based programming but will put a strong emphasis on techniques for uncertainty handling on robotic systems, namely through the combination of augmented reality (projection mapping) in which the Centre has proven expertise.

RL5. Future Industrial Robotics and Collaborative Robots

Future industrial robotics will move from a robot centred perspective of a robotics work cell to an integrated approach that involves perception, multiple sources of information (either sensors of IT support systems), close collaboration with humans and continuous process learning. This requires a multidisciplinary work that includes

the above-mentioned development of Human Robot interfaces and advanced 2D 3D sensing, but also depth evaluation of the strengths and weaknesses of the use of safe collaborative robots.

Collaborative robotics are commonly evaluated as a game-changing technology in the future of industrial robotised operations. However, for these robots to be used spread out in industry, there is still the need for applied research applications that would show the success of the concept. The research approach will be the development of accessing tools that include the safety analysis according to the ISO technical standard 15066 and the related ISO 10218-1norms, and also on the economic analysis of the use of such systems.

RL6. Vertical Integration, IoT, Industry 4.0

The success of industrial and mobile robotics application is heavily dependent on the integration with the connected factory of the future. In this regard the unit will further develop the use of integration tools with a network of partners, namely within INESC TEC with the CESE and CEGI centres. The role of robotics in the Industry 4.0 is an open challenge that requires a change of approach from a work-cell integration to a factory or even inter-factory level integration. In a connected factory scenario, advanced mobile robots play a differentiated role from other Industry 4.0 actors, namely due to the advanced sensing capabilities, CPU/GPU processing power inherent to the robot. Therefore, in the mobile robotics sector, the approach will explore the concept of a robot as a mobile sensor that can dynamically populate the digital shadow of the manufacturing plant. Concerning collaborative robots, the approach will explore the impact of such systems in the upper layers of the connected factory, namely through the development of decision-making strategies that consider the new capabilities/limitations of collaborative robots and their balance with the human operators. The Centre previous experience in vertically integrated projects, namely the STAMINA project, is the foundation for Centre offer of consultancy services.

6.7.5 Innovation activities

INOV1. Internal Logistics

The Centre has a strong activity in internal logistic systems that goes from the development of simple AGV systems in partnership with Portuguese companies, to the development of advanced mobile manipulators in Flagship European projects, such as STAMINA and ColRobot. The Centre offers consultancy services for the installation of existing and mature robotics systems, such as the LeanAGV, but is also capable of developing novel robotics systems, namely mobile manipulators for high flexible logistics operations. The Centre developed a well-proven network of competences, both internally at INESC TEC as well as with external companies that allows the Centre to provide complete logistics systems that vertically integrates the robotic system in the production environment.

INOV2. Robotics for Agriculture and Forestry

The Agriculture and Forestry R&D line has a 10-year road-map, considering the Portuguese reality (needs and desires) and the European Robotics agenda. It is focused on three application topics: Vineyards (Steep Slope), Forest biomass harvesting, and Greenhouses (urban and traditional). Our main efforts are concentrated to develop cost effective visual-based sensors, manipulators and small machinery with advanced localization, mapping, control and perception algorithms (where we believe that can occur technology transference). This R&D line will build on two active national projects in co-promotion with national companies/associations (Tekever, ADVID, Prodfarmer, Herdade do Esporão, Herdade Maria da Guarda) and 2 international projects in co-promotion with international companies/associations (Wageningen University & Research, Aveleda, isardSAT, AIB University, IMAMOTER). In addition to these ongoing projects, other ones with reference institutions/companies (INIAV, Forestis, CTAG, ENERMETER, FERTIPRADO, WHITUS, HIDROSOPH, CERSUL, INCREASE and ELAIA 2) are being evaluated under P2020, POCTEP, and PDR2020 programs. We are working together with Pulverizadores Rocha, Herculano Alfaias Agrícolas, Aveleda and WiseCrop in order to set new goals and common projects.

INOV3. Flexible Production using Robotics

The Centre presents a proven track record of successful robotics based flexible production systems that were installed and transferred to the market. It is worth highlighting the SIIARI and P2020 CoopWeld projects, whose industrial results are currently being commercially exploited by some of the companies involved in the projects consortium.

The use of Industrial robotic systems on SME's is a strong demand on the Portuguese and European markets, and requires novel approaches that combine Advanced sensing, human machine interfacing, high level programming, simulation and off-line programming, augmented reality among others. The centre accumulated expertise in the different scientific/technological areas and a well-established network of partnerships, gives the Centre a large set of tools to answer to the most demanding challenges.

INOV4. Inspection, Control and Embedded Systems

Machine vision is widely applied in quality control (non-conformity detection, dimensional control,...) using or not industrial robotics systems. Some success projects have already been developed and applied in the industry (CONTINENTAL, GISLOTICA and Rail-Inspect).

The application of the control theory for Dynamics Systems is now used in a wide range of different systems, from classic process control systems to production lines and logistic systems all using similar dynamical models. With these models we use model based predictive controllers (project FOCUS).

To the efficient control, modelling and monitoring of complex and optimized systems it is mandatory the acquisition of large amounts of information (sensors data and inputs from operators) and so the development of the appropriate devices that facilitates the integration with the connected factory of the future is under progress, following the paradigms of the Industry 4.0.

INOV5. New challenges in Robotics

The Centre has a strong track record on the development of novel robotics systems for new application sectors, such as Surveillance (RobVigil), Architecture and construction (RobArc), the health sector (TriHo) or outdoor logistics (Galp 4.0). The Centre broad range of expertise allows multidisciplinary approaches for the development of software and hardware customized for specific applications.

6.7.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CRIIS - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)				
	Internal Logistics	Rob. for Agriculture and Forestry	Flexible Production using Robotics	Inspection, Control and Embeded Systems	New challenges in Robotics
Navigation, Localization and Coordination of Mobile Robots	H	H	H	L	M
Intelligent Sensors and Control of Dynamical Systems	L	H	M	H	M
2D/3D Industrial Vision and Advanced Sensing	L	H	H	H	H
Human Robot interfacing and Augmented Reality	L	M	H	M	H
Future Industrial Robotics and Collaborative Robots	M	L	H	M	H
Vertical Integration, IoT, Industry 4.0	H	M	H	H	H

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.7.7 Main objectives for 2020

Strategic Objectives, Main initiatives / actions planned

- Improve the alignment between basic research, applied research and consultancy.
- Maximise the impact of the Centre's activity in the companies and promote the valorisation of results.
- Establish strategic partnerships with international research key players, industries and stakeholders, allowing the alignment of the research activities with future industrial projects.
- Improve internal competences by developing the motivation of human resources and creating conditions for attracting high level national and international researchers
- Improve the Centre's external visibility, through the organisation and participation in key national and international scientific and industrial events
- Diversification of funding namely European Projects and direct contracts.
- Consolidation of the strategic communication plan, that includes the establishment of Centre's dedicated website, youtube channel in articulation with the communication strategy of INESC TEC.
- In terms of sources of funding the Centre will try to keep the balance between fundamental (FCT), applied research (P2020 – Co-promotion), European funded projects (H2020) and direct contracts. The goal is to have 40-50% of the latest two (H2020 and direct contracts).
- Team - The objective is to increase the permanent research staff and minimize the number of scholarships (very difficult to attract), and restructuring the non-research contracts. In detail, the focus will be sharing or the centralising of resources with other units that have specific needs in technical support.
- To implement joint strategies to attract high quality PhD students and scholarship holders;
- Increase the number of financed PhD students by external programmes, FCT, N2020, MIT, CMU and others.
- Significant development of the activities under the iiLab umbrella, including new research project proposals, advanced formation and technology transfer.
- Develop new partnerships with national and international research organizations, leaders in fields near or complementary to the Centre's activity
- Maintain/Increase the Centre participation and the visibility in European projects.
- Consolidate partnerships with international research key players, industries and stakeholders and continue direct contact with large number of companies, in Portugal and abroad.
- Promote an internal regular discussion on research opportunities and project organization.
- Define plans for the valorisation of the intellectual property of the Centre.
- Support and promote the activity of the several laboratories already existent at CRIIS: iiLab Industry and innovation lab; Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry; Laboratory of Mobile Robotics and Internal Logistics; Laboratory of Industrial Robotics and Automation; Laboratory of Modelling, Control and Intelligent Systems and iRSlab: Remote Sensing Laboratory

Future research

- Control of mobile manipulators for non-logistic processes. The focus will be on the integrated kinematics development, safety and process control.
- Multi robot coordination methodologies for automatic generation of mission plans; supervision of autonomous platform operations; cooperative operation of multiple platforms in hard communications environments.

- Concerning vision based real time sensors: perception systems as a sensor for on board sensing; real time stereo, and 3D point-cloud sensing for mapping, self-localization and objects detection; low latency and robust feature extraction in semi controlled environments.
- In the field robotics area: modelling and control of mobile robots; navigation and localization in out-door semi structured environments (using natural and artificial landmarks);
- Industrial robotic manipulators: vision and manipulator coordination; advanced sensing: measurements and testing of features; rapid teaching and programming interfaces;
- Intelligent control and smart sensors: control algorithms for complex dynamic systems. New sensing strategies.

6.7.8 Main actions planned for 2020

This year, CRIIS will design and/or implement the following actions:

Table 6.2 - CRIIS – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Continue the implementation of the actual iiLab in cooperation with the Enterprise Systems Engineering (CESE-INESCTEC)	1	New demonstrators , visits from companies, new technology-transfer projects, high-level training and education programs	Jan-Dez 2020
Starting the new iiLab in cooperation with several Centres and in a new building	2	The objective is to implement an efficient and attractive innovation laboratory to serve as a show room for private and public companies interested on the implementation of Robotics, Automation and Industrial Internet-of-Things technologies. Also define and disseminate attractive and innovative training and education programs to be delivered to operators working with advanced manufacturing technologies in manufacturing context.	Set-Dez 2020

6.7.9 Centre Organisational Structure and Research Team

The Centre for Robotics and Intelligent Systems is coordinated by António Paulo Gomes Mendes Moreira / Germano Veiga and is organised in the following Areas:

- Navigation, Localization and Coordenation of Mobile Robots - Responsible: Paulo Costa / Héber Sobreira
- Intelligent Sensors and Control of Dynamical Systems - Responsible: J. Boaventura / Filipe Santos
- 2D/3D Industrial Vision - Responsible: Manuel Silva / Luís Rocha
- Human Robot Interfacing - Responsible: Germano Veiga / Rafael Arrais
- Future Industrial Robotics and Collaborative Robots - Responsible: Luis Rocha / Germano Veiga
- Vertical Integration, IoT, Industry 4.0 – Responsible: Hélio Mendonça / Rafael Arrais

The Centre research team present composition and planned evolution is presented in Table 6.3.

Table 6.3 – CRIIS - Research team composition

Type of Human Resources			2018	2019 (Forecast)	2020 (Plan)	Δ 2019-2020
Integrated HR	Core Research Team	Employees	6	8	11	3
		Academic Staff	12	12	12	0
		Grant Holders and Trainees	23	22	9	-13
		Total Core Researchers	**41**	**42**	**32**	**-10**
		Total Core PhD	**15**	**18**	**18**	**0**
	Affiliated Researchers		5	5	5	5
	Administrative and Technical	Employees	3	2	2	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**3**	**2**	**2**	**0**
		Total Integrated HR	**49**	**49**	**39**	**0**
		Total Integrated PhD	**20**	**23**	**23**	**0**

6.7.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CRIIS – Project funding

Funding Source		Total Income (k€)			
		2018	2019 (Forecast)	2020 (Plan)	Δ 2019-2020
PN-FCT	National R&D Programmes - FCT	177	233	204	-29
PN-PICT	National R&D Programmes - S&T Integrated Projects	34	1		-1
PN-COOP	National Cooperation Programmes with Industry	143	69	38	-31
PUE-FP	EU Framework Programmes	363	378	367	-11
PUE-DIV	EU Cooperation Programmes - Other	223	172	20	-152
SERV-NAC	R&D Services and Consulting - National	297	97	100	3
SERV-INT	R&D Services and Consulting - International	13	7		-7
OP	Other Funding Programmes		18	7	-11
Uncertain Projects		33	74	179	106
	Total Funding	**1 283**	**1 049**	**916**	**-133**

Table 6.5 - CRIIS – Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	29	24	26	2
Indexed Conferences	46	26	30	4
Books			1	1
Book Chapters	9	9	2	-7

Table 6.6 - CRIIS – Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	1	1
Software copyright registrations	0	0	0
Patent applications	2	1	1
Licence agreements	0	0	1
Spin-offs	0	0	0

Table 6.7 - CRIIS – Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	0
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	2
International events in which INESC TEC members participate in the program committees	6
Participation in events such as fairs, exhibitions or similar	9
Advanced training courses	2

Table 6.8 - CRIIS - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	3
Participants in the conferences, workshops and scientific sessions organised by the Centre	920
Advanced training courses organised by the Centre	0

Table 6.9 - CRIIS – List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	COBOTIS	António Paulo Moreira	01/06/2018	31/05/2021
PN-FCT	DM4Manufacturing	António Paulo Moreira	01/11/2016	31/10/2020
PN-FCT	MetBots-1	Filipe Neves Santos	26/07/2018	24/07/2020
PN-FCT	SAFER-1	Filipe Neves Santos	01/07/2018	30/06/2021
PN-COOP	CrossLOG-2	Manuel Santos Silva	01/11/2019	31/10/2022
PN-COOP	FDControlo	Filipe Neves Santos	02/01/2018	31/12/2021
PN-COOP	GOTECFOR	Filipe Neves Santos	01/01/2017	31/12/2020
PN-COOP	PRODUTECH_SIF-1	António Paulo Moreira	01/10/2017	30/09/2020
PUE-DIV	AGRINUPES	José Boaventura	01/04/2017	30/06/2020
PUE-DIV	BIOTECFOR	Filipe Neves Santos	01/01/2017	31/12/2019
PUE-DIV	MANUFACTUR4.0	Luís Freitas Rocha	17/04/2017	31/12/2019
PUE-FP	AgRoBoFood	Filipe Neves Santos	01/06/2019	31/05/2023
PUE-FP	CPPS101	Marcelo Petry	01/01/2020	31/12/2020
PUE-FP	DEMETER	Filipe Neves Santos	01/09/2019	28/02/2023
PUE-FP	Fasten-1	Rafael Lírio Arrais	01/11/2017	31/10/2020
PUE-FP	ScalABLE4.0	Germano Veiga	01/01/2017	30/06/2020
SERV-NAC	Smart-Fertilizers	Filipe Neves Santos	01/01/2019	30/11/2020
SERV-NAC	T4CDTKC-1	António Paulo Moreira	01/09/2019	31/03/2020
OP	SAFE	António Paulo Moreira	01/01/2019	31/12/2020

Type of Project:

PN-FCT National R&D Programmes - FCT
PN-PICT National R&D Programmes - S&T Integrated Projects
PN-COOP National Cooperation Programmes with Industry
PUE-FP EU Framework Programme
PUE-DIV EU Cooperation Programmes - Other
SERV-NAC National R&D Services and Consulting
SERV-INT International R&D Services and Consulting
OP Other Funding Programmes

6.8 CEGI – CENTRE FOR INDUSTRIAL ENGINEERING AND MANAGEMENT

Coordinators: Ana Viana and Pedro Amorim

6.8.1 Presentation

CEGI integrates the Cluster Industrial and Systems Engineerig (ISE). This Research Group (RG) is an international reference in business analytics through decision support systems for service and operations management, contributing also in data science, service science, and other emerging topics (e.g., blockchain and asset management).

Operations Research is at the core of CEGI, having several researchers acting as editors of international journals (e.g., European Journal of Operations Research, International Transactions in Operational Research), the coordination of three EURO Working Groups in the fields of Retail Operations, Production Planning and Cutting Problems, and the vice-chairing of a COST Action line. Recently, a group of CEGI researchers was finalist of the "Wagner Prize award", for Excellence in Operations Research Practice, by The Institute for Operations Research and the Management Sciences.

Within the domain of business analytics, the goal of the RG is to conveniently extract knowledge from data that could be leveraged to increase, for example, revenues of a business. In terms of descriptive and predictive analytics, the challenges placed by large data sets lead to a redefinition of the processes of data analysis to find patterns and relationships between data elements in large and noisy data sets. Regarding prescriptive analytics the RG is particularly focused on addressing challenges related to dynamic optimization under uncertainty. A new challenge, also associated to the increasing quantity of available data, is to couple Machine Learning and Optimization, in order to make more supported and informed decisions.

In the service science area, a CEGI member is the executive member of a global and cross-disciplinary team that defined the "Service research priorities 2015".

Core areas of application/innovation of CEGI include Retail/Industry, Mobility and Healthcare, with significant contributions also in the Energy Sector through a strengthened collaboration with CPES. CEGI includes the Portuguese delegate to the European Union Horizon 2020 committee on Smart, Green and Integrated Transport.

This RG originated from the area of industrial engineering and its integration in INESC TEC generated powerful synergies with RGs holding expertise in technologies and industrial processes.

The research outputs of CEGI are in the range of TRL 2-9. With this knowledge, CEGI was involved in the launching of a complementary spin-off (LTPlabs), a boutique management consultancy company.

6.8.2 Context

CEGI's research has always been driven by problems and challenges identified in different sectors of Industry and Services. Besides contributing to the evolution of state-of-the-art, a main concern of the RG outputs is to provide Industry and Services with specialized tools /policies that position them as more competitive and sustainable entities in the market. Main challenges currently investigated by the research team are linked to the different areas of application:

1. **Industry and Retail**

   - **Industry 4.0:** Industry 4.0 is revolutionizing the shop floor of manufacturing plants, but the same technologies are impacting all sectors. The proper deployment of these technologies is paramount in the pursuit of many national and European priorities, particularly those related to sustained, inclusive and sustainable economic growth. Therefore, some of these technologies are being thoroughly studied from the lens of operations management and decision support, namely collaborative robots, machine learning and blockchain. For example, regarding the collaborative robots technology, the next generation of robots is able, in varied degrees, to work side by side with humans, which pose a variety of new challenges to managerial decisions, such as task allocation, scheduling, plant layout, and ultimately the acquisition of these robots.
   - **Retail:** Predicted growth of e-commerce in the US in 2018 is $500 billion, from 13.8% in 2015 to 17.1% in 2020 in the UK. More than half of incurred delivery costs are associated to lastmile delivery and 1/3

to line haul. The remaining costs are associated to collecting and sorting items. While delivery costs are perceived by supplier and consumer, other externalities such as air and noise pollution or traffic congestion, resulting for the additional number of vehicles required for deliveries are perceived and have a negative impact on all the society. It is therefore crucial to address the new problems arising from this paradigm, both in terms of planning, scheduling and definition of new business models that capture the novelty. Most of the problems will be NP-hard, will be highly stochastic, dynamic and request for treatment and analysis of paramount information to better understand customer demand.

2. **Mobility and Transports**

- **Shared mobility:** In shared mobility systems, a fleet of vehicles is shared by a pool of users. Either operating within an urban scope - such as car sharing - or inter-urban scope - such as car rental, these systems face akin challenges regarding fleet management, including fleet size and deployment decisions. Car rental is an established yet still growing sector: in 2015, Portuguese car rental companies acquired 31% more cars than the previous year. This business is critical for the tourism sector, due to its potential to increase the geographical scope of foreign visits and is at the same time highly impacted by tourist flows. This is a competitive market, where two main factors influence demand: fleet availability and pricing. Car sharing is a more recent system, growing significantly in Europe and North America. Its concept, focused on urban mobility, is in itself an attempt to reduce the environmental impact of passenger transportation, representing an actual alternative to car ownership. In these systems, pricing can be an effective demand management tool when integrated with fleet management. Despite a growing interest, research is still mostly segregated by specific issues, often not considering relevant realistic system requirements.
- **Urban mobility:** The challenges related to mobility and transports are increasing very fast, fostered by the availability of huge volumes of data, produced by a variety of devices, sensors and ITS (Intelligent Transport Systems). Systems' interoperability and semantic integration of the data produced by the different systems is of major importance in order to extract relevant knowledge. Part of this knowledge is applied in the development of algorithms that aim to optimize the resources involved in the provision of the service, and improve the quality of the service. Smart cities are closely related with this topic since they enable a seamless integration of technologies in order to promote, among other things, urban mobility. In terms of H2020 priorities, the work in this area is tightly related to the topic on "Transformative impact of disruptive technologies in public services".

3. **Healthcare**

- Due to the ongoing ageing of the population, health spending is expected to grow considerably in all developed countries. This may come at a cost to other sectors so as to offset the additional resources diverted into health care. In alternative, access to good health care services may be hindered, as few resources exist to satisfy increasing needs. Therefore, all R&D oriented towards increasing efficiency, productivity and overall quantity and quality of the healthcare services is critical to minimize the impact. Being a labor-intensive sector, doing so also implies understanding how new roles in health care may contribute to more health care delivery. In this vein, both operations research/management science, machine learning and service science may help to address some of the most pressing issues likely to affect the health care sector.

6.8.3 Contribution to the Vision of the Cluster

The Cluster has a vision of an ever integrated supply chain across different industries (e.g., manufacturing and process industries). This vision materializes in a powerful production link that embeds Industry 4.0 concepts and transportation flows that are capable of using sensor information and customer information to replan daily activities. The Cluster has been working on the hardware and operating systems that will advance manufacturing technologies with high flexibility, such as robotics. Nevertheless, to achieve the plenitude of this vision the impact in the overall decision making strategies still has to be analyzed. In particular, the operations research / management science and the operations management capabilities of the Centre will be crucial to address such challenges.

On one hand, focusing on the planning layer, the main contribution of the Centre will be to evolve decision-making tools that will have to deal with production and distribution technologies with high flexibility, capable of

performing different tasks with minimum reprogramming, capable of sensing the environment and working in environments designed for human-use. This new paradigm represents a challenge for the traditional process modeling techniques, where resources are almost static. To that end new dynamic algorithms / mathematical approaches for routing and scheduling that have good performance under uncertain settings are to be developed.

On the other hand, these supply chains will have a customer centric approach. To that end the approaches brought by service design will be paramount to understand customer preferences towards the different options available. On a more quantitative perspective, data-mining and econometric models (usually used in operations management communities) will be developed / applied to understand, at scale, the preferences and utility functions of customers, who should govern the different activities of the supply chain.

6.8.4 Centre research lines

RL1. Operations Research / Management Science

The RG publishes research in established areas of Operations Research/Management Science such as inventory management, production and distribution planning, service operations, supply chain management, workforce staffing and performance assessment. The RG seeks to promote research on emerging topics such as automation, e-commerce, emerging country operations, and the shared economy.

In terms of research methodologies, the RG uses both analytical and empirical methods. Analytical work uses modeling techniques or creative algorithms drawn from the fields of mathematical optimization, statistics, and simulation. The goal is to provide substantive academic contributions and practically relevant insights and algorithms.

The diversity of topics that fall within this is illustrated by the different ongoing reseach projects that aggregate several researchers.

Regarding integrated planning problems under uncertainty, in the new project DeltaC&P - Uncertainty in Cutting and Packing problems: robust planning and optimized replanning in manufacturing and transportation", the main R&D objectives in this area will be the development of algorithms closer to real-world needs, based on advanced optimization techniques (based on mathematical programming models, metaheuristics and their hybridization).

Concerning distribution planning there are two projects that help framing this research stream: LASTMILE and TEC-FEL. Both projects will investigate new models and algorithms for optimizing the delivery of products purchased by online customers. In particular, the concept of crowdsourcing is exploited in which, in addition to professionals, ordinary citizens are invited to participate in the delivery process.

In the project SiuSMS - Smart (inter)urban shared mobility systems: integrating pricing and fleet management for a sustainable mobility planning future, pricing decisions are tackled. Pricing decisions influence and are influenced by the availability of the fleet, which is dependent on fleet occupation and fleet size and deployment. This project aims for innovative solution methodologies that will be able to provide profitable, sustainable and useful solutions within reasonable time.

RL2. Data Science / Data Mining

The RG performs research in the various domains of the vast research field of data science, data mining and visualization, mainly with an application perspective. This includes individual methods and techniques in knowledge acquisition and representation, and their application in the construction of recommendation systems.

In terms of the application areas, the RG covers Human-Computer Interaction, and Artificial Intelligence for the new and growing markets for these technologies, such as Business, Education and Health Care.

To illustrate some of the activities that will be addressed in this RL there is project OPTI-MOVES - Quality management of intermodal public transport services: diagnosis and optimization. The main objectives of this project related to this RL are the following:

- To understand and to study urban mobility patterns using massive data provided by ITS and other information systems; to understand mobility patterns will help to create better mobility services and improve the existing ones (for example, promoting intermodality).

- To define and calculate a set of performance indicators that will allow the decision agents to understand and measure the performance of the system during time. This will involve the digestion and processing of huge volumes of data and the development of innovative and interactive visualization tools.

RL3. Service Science / Design

The RG fosters novel and relevant ideas about service design and/or service innovation, in B2C, B2B, as well as nonprofit services (education, and government). Illustrative topics include service strategy (focus, competitive capabilities and competencies, business models), The focus has been on service design and in particular on the:

- Design and engineering of complex service systems and value networks, creating new services in the context of distributed and interconnected value co-creating actors, such as health care.
- Design for the customer experience, pursuing a holistic understanding of the customer experience and a human-centered design approach that continuously feeds the service design process with customer experience input.
- Design and engineering of technology enabled services, integrating multiple disciplines such as ICT (Information and Communication Technologies), Human Computer Interaction, Service Design and Service Management, to support the transition from technology development to creation of innovative services that create value for customers and organizations, particularly in the areas of mobile services, smart services, and social networks.

In terms of methods the RG has mainly worked with empirical analysis, and grounded theory building.

RL4. Emerging topics (Blockchain, Asset Management, Machine Learning and Optimisation)

RL4.1. Blockchain

Focusing on the entire supply chain, the main goal is to explore innovative uses of the blockchain technology in this context. Recent development turned blockchain into a safe, trustable, decentralised, and immutable chain of encrypted transactions, opening up a whole new realm of applications once deemed unfeasible. Notwithstanding its success in digital (or crypto) currencies, its usefulness is underlined by its potential of application in diverse fields. One such problem is coordinating a flat, global and distributed supply chain. Although market players use prices to signal scarcity and coordinate themselves, operational diligence is still a necessity. The Centre will contribute with a proof-of-concept of a blockchain tailored to address supply chain coordination, specifically worldwide procurement supported by a decentralized network.

RL4.2 Asset Management

Focusing on the emerging area of asset management, the main goal is to develop new integrated (predictive and prescriptive) models and algorithms to tackle challenges such as: (i) the integration of multiple failure modes, (ii) the incorporation of operating conditions in the failure time projections and (iii) the creation of holistic decision models for a portfolio of diverse assets as most of the literature considers one asset (or asset type) at a time. This research will be leverage by participating in EU financed projects and increased focus on developing the research background by increasing the publication count and the number of PhD and MSc students in the area.

RL4.3 Machine Learning and Optimisation

The main goal of this topic is to improve well established research of the Centre in Optimisation by coupling it with Machine Learning (ML) techniques. Indeed, data for parameterising a problem's instance has often to be inferred from observations, which is commonly done with the help of ML algorithms. In some situations, data is expensive to collect; in these cases, decisions concerning where and when to gather data are themselves optimization problems. How to integrate such subproblems with the main optimization process is an important, cutting-edge research area, with many applications in situations involving optimisation in stochastic settings.

6.8.5 Innovation activities

Techonology transfer of the Centre has been mainly directed to three areas of activity: Energy, Retail/Industry and the Healthcare sector.

INOV1. ENERGY

The energy application area is a core area for CEGI in terms of technology transfer. Both asset management, decision support and prescriptive analytics have been used to significantly improve processes in this industry. CEGI core competences on asset management and reliability can be divided in the following two areas:

- Predictive maintenance and asset management.
- Power system planning, in particular in the development of tools for reliability analysis, for security of supply evaluation and reserves adequacy evaluation.

CEGI has been involved in several R&D projects with utilities companies (EDP Distribuição, EDP Produção, REN) in asset management, and will continue in 2020. These innovation activities are tightly related to the TEC4 Energy. Furthermore, activity will be spread to other sectors, with several projects being negotiated.

INOV2. RETAIL AND INDUSTRY

INOV2.1 Retail

Over the last years there were a set of PhDs focused on developing empirical and analytical methods for better decision making in both offline and online retail settings. In 2020 we expect to consolidate this knowledge and establish innovation activities with companies, such as Sonae MC. A first approach will be related to helping retailers to fine tune the parameters of delivery subscription services. Another approach will be towards designing new delivery models based on crowdsourcing.

INOV2.2 Industry

CEGI has a strong competences in Industry 4.0 related concepts framework. In particular: (1) advanced production planning and scheduling algorithms, (2) blockchain protocols over the supply chain, (3) improved asset management. Through the ongoing research projects we expect to start establishing innovation activities to start transfering the knowledge that has been developed (e.g., dynamic scheduling algorithms for collaborative human-robot production lines).

These innovation activities are tightly related to the TEC4 Industry.

INOV3. HEALTHCARE

The healthcare area has evolved due to the close collaboration between CEGI and several entities of the public sector, namely hospitals and central regulatory entities. Both Service Design and Operations Research / Management Science have contributed with best practices to this sector

In the field of health care logistics, a partnership with two of the biggest Portuguese medical supplies/pharmaceuticals distributors is to be pursued in order to study the impact of outsourcing logistics in hospitals to third-party logistic partners. Also in this field, in 2020 we expect to continue developing an intelligent dashboard capable of informing decision-makers in inventory management and hospital planning with a flagship software company and two hospitals.

Another project about to initiate, again in partnership with a large oncological hospital, aims to use *text mining* to extract thousands of health records written in free text form. The objective is to apply state-of-the-art machine learning tools to this structured information to extract clinical knowledge from past cases, in this way assisting physicians in the clinical decision-making process.

These innovation activities are tightly related to the TEC4HEALTH.

6.8.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CEGI - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)		
	Energy	Retail/Industry	Health
Operations Research / Management Science	H	H	M
Data Science / Data Mining	L	M	M
Service Science / Design			M

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.8.7 Main objectives for 2020

The year of 2020 will be a consolidation year for the Centre due mainly to four factors: (1) The Centre earned several research projects in 2018 related to the different strategic research lines and in 2020 the main outputs of these projects are expected to emerge; (2) There is a considerable number of structural projects (e.g. DM4Manufacturing) that will close this year and, therefore, there is room to accommodate new proposals; (3) The RG has, for the first time, full time senior researchers who are paid from public funds that can further help to consolidate the position of the Centre; and (4) from a financial perspective, the Centre is 2020 has an interesting balance between FCT and European projects, but there is the need to grasp new technology transfer projects.

In line with the objectives of 2019, the objectives for 2020 aim to address this context.

Objective 1 (R&D): a) Output high-impact scientific papers with a balance between quantity and quality, strengthening the position of the Centre in the several research areas (e.g., operations management, operations research, service design). In recent years the RG has been able to sustain similar scientific production levels to previous years, while increasing the quality and reputation of the outlets it is able to publish (e.g., EJOR, OMEGA, Journal of Service Research, Mathematical Programming). One of the goals is to submit more papers to some of the 50 journals used in the FT Research Rank (https://www.ft.com/content/3405a512-5cbb-11e1-8f1f-00144feabdc0) (e.g., Journal of Operations Management, Management Science, Operations Research, or Production and Operations Management). b) Increase participation in H2020 projects, by participation in the following calls, aligned with the research vectors of the Centre: ICT-38-2020 - Artificial intelligence for manufacturing, ICT-12-2020 - AI for the smart hospital of the future, MG-2-11-2020 - Network and traffic management for future mobility and MG-4-8-2020 - Advanced research methods and tools in support of transport/mobility researchers, planners and policy makers.

Objective 2 (Partnerships): Leverage the independent opportunities brought by the projects that started in 2019 to improve the international dimension of the Centre and get closer to strategic companies. Most of the projects that are currently being pursued have the involvement of relevant world-class research institutions (e.g., CMU is co-leading the development of the blockchain prototypes), and the participation of important companies in the Portuguese ecosystem (e.g., Sonae MC is helping to define the e-commerce requirements for the next years which will feed the retail-related research). This objective aims to take this relationship to a further development stage to increase the chances of subsequent projects.

Objective 3 (Human resources development and recruitment): Continue to help the newly hired researchers to improve their R&D development skills, motivate them to search for national and international funding, and to attract younger researchers. The fact that there are several full time senior researchers in the group is to be leveraged through this objective. The idea is to give adequate mentoring and financial conditions to help this

(fundamental) layer of the Centre to gain scientific autonomy and contribute proactively to the persecution of the RG's objectives. Up to 2019 CEGI has never had such type of HR and, therefore, this new reality will require an extra focus of the RG in retaining and motivating these researchers for the upcoming years.

Objective 4 (Relevance and impact): Continue the path of occupying high-relevant positions in the scientific editorial world to further improve the chances of steering the scientific domains. As aforementioned, several researchers act as editors of international journals (e.g., European Journal of Operations Research, International Transactions in Operational Research, Logistics Research), as well as on the the coordination of three EURO Working Groups in the fields of Retail Operations, Production Planning and Cutting Problems, and the vice-chairing of a COST Action line. In 2020 we expect to further expand this influence by, for example, editing a special issue in Retail Operations in the European Journal of Operations Research and another on Healthcare in the International Transactions in Operational Research, or participating in several program committees (e.g. POMS-International 2020, IFORS 2020). Objective 4 should follow naturally from the individual goals of each researcher.

6.8.8 Main actions planned for 2020

This year, CEGI will design and/or implement the following actions:

Table 6.2 - CEGI – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Promote sessions to present and discuss research papers prior to submission	1	Increase the chances of publishing in high-ranked journals. Increase peer-pressure for publication.	1 quarter
Improve communication with hired researchers	3	Increase in the number of proposals submitted	1 quarter
Refocus plurianual budget allocation to sponsor hired researchers on activities strategically relevante for the Centre	2 and 3	Retention of high-potential HR and establishment of key partnerships (e.g., CMU and Sonae MC)	N/A

6.8.9 Centre Organisational Structure and Research Team

The Centre for Industrial Engineering and Management is coordinated by Ana Viana and Pedro Amorim and has a project oriented structure that gives responsibility to the different senior researchers in developing their research interests. In 2019 the Centre had, for the first time, a considerable number of hired PhD researchers that are now ready in 2020 to be working a full pace.

Table 6.3 - CEGI – Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	4	8	10	2
		Academic Staff	13	13	13	0
		Grant Holders and Trainees	30	27	37	10
		Total Core Researchers	**47**	**48**	**60**	**12**
		Total Core PhD	**27**	**26**	**31**	**5**
	Affiliated Researchers		7	6	6	0
	Administrative and Technical	Employees	1	1	1	0
		Grant Holders and Trainees	0	0	1	1
		Total Admin and Tech	**1**	**1**	**2**	**1**
	Total Integrated HR		**55**	**55**	**68**	**6**
	Total Integrated PhD		**33**	**32**	**37**	**5**

6.8.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CEGI– Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	224	345	433	88
PN-PICT	National R&D Programmes - S&T Integrated Projects	188	10		-10
PN-COOP	National Cooperation Programmes with Industry	33	7	38	30
PUE-FP	EU Framework Programmes		57	194	138
PUE-DIV	EU Cooperation Programmes - Other			1	1
SERV-NAC	R&D Services and Consulting - National	104	50	90	40
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes	8	4		-4
Uncertain Projects		114	131	148	18
	Total Funding	**672**	**604**	**905**	**301**

Table 6.5 - CEGI – Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	30	20	20	
Indexed Conferences	13	8	8	
Books				
Book Chapters	2			

Table 6.6 - CEGI – Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	0	0
Software copyright registrations	0	0	0
Patent applications	0	0	0
Licence agreements	1	0	0
Spin-offs	0	0	0

Table 6.7 - CEGI – Summary of participation in dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	5
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	3
International events in which INESC TEC members participate in the program committees	6
Participation in events such as fairs, exhibitions or similar	1
Advanced training courses	1

Table 6.8 - CEGI – Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	0
Participants in the conferences, workshops and scientific sessions organised by the Centre	0
Advanced training courses organised by the Centre	0

Table 6.9-CEGI – List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	ASAP	Maria Antónia Carravilla	01/06/2018	31/05/2021
PN-FCT	DeltaC&P	José Fernando Oliveira	26/07/2018	25/07/2021
PN-FCT	DM4Manufacturing-2	Pedro Amorim	01/11/2016	31/10/2020
PN-FCT	DoubleChain	Pedro Amorim	01/09/2018	29/02/2020
PN-FCT	LASTMILE	João Pedro Pedroso	26/07/2018	25/07/2021
PN-FCT	opti-MOVES-1	Teresa Galvão	26/07/2018	24/01/2021
PN-FCT	SiuSMS	Maria Antónia Carravilla	26/07/2018	25/07/2021
PN-FCT	Tec-FEL	Pedro Amorim	04/04/2018	03/04/2021
PN-COOP	CrossLOG-1	Elsa Marília Silva	01/11/2019	31/10/2022
PUE-FP	FIN-TECH-1	Pedro Amorim	01/01/2019	31/12/2020
PUE-FP	InteGrid-4	Pedro Amorim	01/01/2017	30/06/2020
PUE-FP	MANU-SQUARE-1	Mário Amorim Lopes	01/01/2018	31/12/2020
PUE-FP	POCITYF-1	Lia Patrício	01/10/2019	30/09/2024
PUE-FP	XFLEX-1	Armando Leitão	01/09/2019	31/08/2023
SERV-NAC	HEAD	Luís Guimarães	01/01/2018	30/09/2019

Type of Project:

PN-FCT National R&D Programmes - FCT
PN-PICT National R&D Programmes - S&T Integrated Projects
PN-COOP National Cooperation Programmes with Industry
PUE-FP EU Framework Programme
PUE-DIV EU Cooperation Programmes - Other
SERV-NAC National R&D Services and Consulting
SERV-INT International R&D Services and Consulting
OP Other Funding Programmes

6.9 CITE – CENTRE FOR INNOVATION, TECHNOLOGY AND ENTREPRENEURSHIP

Coordinator: Alexandra Xavier

6.9.1 Presentation

The Centre for Innovation, Technology & Entrepreneurship (CITE) aims to foster a vibrant ecosystem for the development of responsible technology based innovations. By working with researchers, businesses, governments, innovators, and citizens, CITE aims at contributing to the development of an economy based on responsible R&D and innovation that are restorative and regenerative by design.

The overarching objectives of the Centre are:

- To create and disseminate interdisciplinary research-based knowledge in the area of Innovation & Technology Management and Technology Entrepreneurship that influences education, practice and policy;
- To use the knowledge and expertise to engage researchers, business, government and society, and to contribute and promote entrepreneurial approaches, new responsible technology innovations and new business models in order to address socio-economic challenges;
- To foster an entrepreneurship mindset in research communities and society that embraces creativity, critical thinking, imagination, risk-taking and the bold experimentation with new ideas in a climate of honesty, collaboration, transparency, responsibility and openness.
- To accelerate the transition for a circular management of R&D and innovation activities, contributing for "eliminating unused" and "extending the use" of the R&D results, engaging science and innovation to accelerate a global transformation to sustainability through collaboration and by empowering researchers and external organizations in the process of innovation management and technology valorization.

CITE accomplishes its objectives, within the Cluster ISE – Industrial and Systems Engineering by carrying out R&D, advanced consulting and executive education fostering a cross-cutting approach to all INESC TEC's Clusters researchers, Entrepreneurs, Private and Public organizations and Society. As a result, CITE develops studies, conceptual frameworks, methodologies and tools that apply in their all activities.

CITE operates the LET-in (Laboratory for Technological Entrepreneurship of INESC TEC) contributing for the embrace of an innovation, entrepreneurship and intrapreneurship culture.

6.9.2 Context

For a long time, many have emphasized that environmental and climate change, demographic issues, technology, emerging social challenges inevitably lead to changes in the business environment and competitive advantage.

Innovation plays a vital role in the ways in which people and institutions respond to these changes.

More and more actors (individuals, public authorities, non-profit organizations, and companies) are changing their views in order to deliver sustainable innovations in a digitalized world.

The Digital vision of Europe 2025 is "A *Europe where digital technologies, innovation, and artificial intelligence can provide Europe's people with competitive jobs, better health, and better public services*"[37]. New technology developments have the potential to contribute for better lives (Badawy, 2009)[38]. However, that potential can only be achieved if technology is appropriately diffused, after being adopted (Leonard-Barton, 1988). The success

37 "A stronger digital Europe, our call to action towards 2025"- download 29/10/2019 from https://www.digitaleurope.org/wp/wp-content/uploads/2019/02/DIGITALEUROPE-%E2%80%93-Our-Call-to-Action-for-A-STRONGER-DIGITAL-EUROPE.pdf
38 Badawy, A. M. (2009). Technology management simply defined: A tweet plus two characters. Journal of Engineering and Technology Management, 26(4), 219-224

of the implementation of new technologies and the development of new concepts to apply such technologies is an organizational challenge.

The configuration of Innovation and Technology Management Systems are a key factor for achieving organizations' goals and objectives. Another field is the adoption and implementation of new technologies in organizations and networks of organizations, which research focuses specially on the efforts for overcoming misalignments between the technology and the application adopters.

In addition to 'new' discoveries, business models provide opportunities to frame how value can be realized from existing assets, and can also provide conceptualizations of new applications providing cross fertilization of the value. Business model thinking gained momentum, and now provides means to address the new boundary and industry-spanning transformations.

Technology entrepreneurship, lies at the heart of many important debates related to launching and growing firms, regional economic development, selecting the appropriate stakeholders to take ideas to markets, and educating managers, engineers, and scientists. Technology entrepreneurship is a vehicle that facilitates prosperity in individuals, firms, regions, and nations and is mandatory for the sustainability of research organizations by fostering the exploitation of R&D results.

Based on this background, CITE's research group aims to consolidate and develop novel methods, frameworks and tools to promote sustainable innovations supported by innovative business models.

Internal Context:

The CITE was created in 2007 to consolidate the significant investments and experience of INESC Porto in the development of internal processes and tools to manage R&D results, and organize the resulting knowledge and competences in order to enable a higher level of responsibility and leadership of the process of knowledge valorisation. In this context, the main goal of the research team at the time of its creation was to develop and promote innovation management practices, acting directly in the internal processes, and supporting entrepreneurship activities helping business development as well as incubation.

The last years growing strategy of INESC TEC embraces new challenges in terms of organizational issues:

- New structural services have been launched to embrace INESC TEC Vision and Mission; however, some duplication and unclear responsibilities emerged;
- The increasing number of Centres and Clusters provokes a dispersion of competences with a risk of loss of critical mass and knowledge cross-fertilization;
- A significant share of technology innovation comes from hard-core geeks in Centres and Clusters. However, generally there is a lack of knowledge on how to bring a technology to the market, assess its viability, and develop a strategy for value creation;
- The quality of results developed by INESC TEC researchers are high, however, the maximum potential of valorization is not explored what promotes waste of results and longer time to market cycles;
- The majority of researchers of INESC TEC are specialized in science and engineering, having a lack of skills in economics, innovation management, business model generation, technology management and technology exploitation.

Challenges:

In order to pursue with the mission and vision embraced by INESC TEC, "from knowledge production to science-based innovation", the **empowerment of researchers** in the process should be mandatory. Thus, some important challenges emerge:

- A well-run intrapreneurship program can unlock an innovation culture and value opportunities;
- A problem-solving approach that could match technology market pull with multi-domains technology push could allow synergies between research groups and external partnerships;
- Exploratory long-term industrial collaborations in an openness environment reinforces INESCTEC contribution to the society;

- A transition for a circular management of R&D and innovation activities, contributing for "eliminating unused" and "extending the use" of the R&D results, leveraging the results exploitation.

6.9.3 Contribution to the Vision of the Cluster

CITE aims at intensifying the cooperation within the Industrial and Systems Engineering Cluster and all its Centres, but also across the remaining Clusters and Centres of INESC TEC, supporting services for R&DI Management and Technology Valorization in order to:

- Leverage research outputs for marketplace & society benefit;
- Foster the development and adoption of innovative solutions to accelerate sustainable and responsible transformations within industrial and society partnerships;
- Improve the strategic innovation management practices.

Acting as Let In Coordinator, CITE also aims to:

- Develop entrepreneurial skills among research community and organizations;
- Support technology entrepreneurship initiatives;
- Improve the understand internal and external factors that influence the technology entrepreneurship initiatives.

By continuing research on the topics of Innovation and Technology Management and Technology Entrepreneurship, CITE aims to continue to provide methodologies and tools to better manage innovation with a circular perspective in all types of projects. Technological innovation does not guarantee business success – new product development effort open new approaches for the entire business model, the design of the strategies to 'go to market' and 'capturing value' is a key factor for value creation. Business models often act as the bridge between technology and the ability to deliver a compelling customer value proposition. A special focus will be taken concerning the R&D exploitation methodologies and the evolution of business models of technology based academic spin-offs.

CITE aims to contribute with "user centered and problem solving design" approaches to generate more sustainable and responsible innovations as well as "new business model development" that complement the technological developments of INESC TEC Centres and Clusters. Therefore, CITE aims to act as a transversal Centre for all Clusters acting in the areas of:

- Innovation and technology management
- Technology adoption and exploitation
- User centered and problem solving design for generate responsible innovations
- Business model innovation

6.9.4 Centre research lines

CITE addresses Innovation Management, Technology Management & Policy, and Technology Entrepreneurship research areas by consolidating and developing novel methods, frameworks and tools to maximize the value realized from R&DI activities in all types of organizations.

RL1. Innovation Management

"Innovation management" refers to handling of all the activities needed to "introduce something new", which in practice means things such as coming up with ideas, developing, prioritizing and implementing them, as well as putting them into practice, for example by launching new products, or by introducing new internal business processes. Over the last few decades, the interest to do research on innovation management has been growing

and also the immediate effect on the competitive edge of companies worldwide.[39] Four major fields for future research in innovation management theory and practice will be pursued:

- **Customer oriented innovations**: Mainly through new technologies and the merging of several fields in information processing, it becomes easier to collect data and know more about customer needs than ever before. We aim to research on methodologies and tools to foster users as helpers to innovate and take a closer look at user innovativeness and the customer's goodwill derived from innovation.
- **Business model innovation**: Aspects of business model innovations are becoming more relevant for the competitive environment. Teece (2010, p. 172) states, "Without a well-developed business model, innovators will fail to either deliver – or to capture value from their innovations."[40] Concepts as the flexibility and scalability of business models are important for strategic responses to rapid changes of the firm's environment. Business model innovation has to be customer based, creating more sustainable value for the customer and not only for the company[41].
- **Sustainable Innovation and Digitalization**: The scarcity of resources and the demographic and climate changes, leads us to the conclusion that innovations have to be developed with a maximum level of sustainability, little needs in resources and with less hazardous emissions. Companies, society as well as individual customers embrace act as responsible[42].
- **Innovation roadmapping**: Investigating how innovation is organized developed and commercialized is a key critical factor to accelerate the sustainable transformation. An emphasis is placing on innovation management practices, tools, and innovation metrics, building on a history of contributions to the Portuguese Standard for R&DI Management and for the ISO TC 279 – Innovation Management. Study how to apply the concept of "circular economy" for R&D activity is an emerging topic that CITE embraces in order to promote the maximization of the potential use of research results.

RL2. Technology Management and Policy

In this research line, CITE aims to create a body of knowledge in policies, strategies and management practices for the adoption and implementation processes of new technologies in organizations.

RL3. Technology Entrepreneurship

Recent literature emphasizes, "*Technology entrepreneurship is about creating and capturing value for the firm through projects that combine specialists and assets to produce and adopt technologies*[43]". In this research line, CITE aims at:

- Improving the knowledge to develop frameworks, methodologies and tools needed to support the entrepreneurial mindset and initiatives within the community of researchers and society;
- Contributing for the creation of an entrepreneurial awareness through the organization by developing training actions, development of tools, and providing direct support to entrepreneurs in the process of turning ideas and technologies into business.

6.9.5 Innovation activities

INOV1. LET in, the umbrella project for Technology Entrepreneurship

[39] Christian Horn, Alexander Brem, (2013) "Strategic directions on innovation management – a conceptual framework", Management Research Review, Vol. 36 Iss: 10, pp.939 – 954.
40 Teece, D. J, (2010), "Business models, business strategy and innovation.", Long Range Planning, Vol. 43 No. 2/3, pp. 172-194.
41 Zott, C., Amir, R. and Massa, L., (2011), "The Business Model: Recent Developments and Future Research", Journal of Management, Vol. 37 No. 4., pp. 1019-1042.
[42] Christian Horn, Alexander Brem, (2013) "Strategic directions on innovation management – a conceptual framework", Management Research Review, Vol. 36 Iss: 10, pp.939 – 954.
[43] Bailetti, T; "Technology Entrepreneurship: Overview, Definition, and Distinctive Aspects", Technology Innovation Management Review, February 2012 (Download 31/10/2019 in: https://timreview.ca/sites/default/files/article_PDF/Bailetti_TIMReview_February2012.pdf)

In order to promote academic entrepreneurship, LET-in, INESC TEC's proof of concept and innovation lab, has grown from an internal service into an encompassing programme providing a set of services and projects targeting actors beyond INESC TEC's community.

LET-In is a service promoted by CITE that offers mentoring, coaching, technological and business consultancy, supporting the development of technology-based entrepreneurial projects related to the institution's core areas, with the following main goals:

- To create entrepreneurial awareness through the organization by implementing training actions, seminars and workshops and giving direct support to entrepreneurs in the process of turning ideas and technologies into business;
- To develop methodologies and tools directed to the entrepreneurial empowerment trough technology, namely addressing the gender equity problem;
- To develop and use case studies to disseminate creative entrepreneurship projects that will be examples for emerging new entrepreneurial projects;
- To implement accelerator programmes supported by new methodologies and tools to facilitate the development of new technological early stage projects.

INOV2. Innovation Management dissemination

CITE continues to organize t**he Conference on Entrepreneurship Education.** The CEE'2017 was the 1st step towards its internationalization, by opening the conference to the Spain and the Iberian American community. The conference aims to share the best practices of Entrepreneurship Education in all levels of scholarship. Furthermore, it will keep upscaling the Journal of Innovation Management launched (and still edited) by one of its core members.

The Journal of Innovation Management encourages the submission of papers addressing the multidisciplinary nature of the innovation process combining principles and concepts originating from a myriad of scientific areas, from social sciences to technology research and development. The journal encompasses all phases of the process of technological innovation from conceptualization of a new technology-based product/service process through commercialization. This Journal is Indexed by ProQuest as Scholarly Journal at ABI/Inform, under the Subject Business and Economics (Pub ID: 2046363).

Executive programmes

CITE's R&D activities related to innovation & technology management and technology entrepreneurship result in the design of new conceptual frameworks, tools, and executive programs to be provided internally and to private and public organizations.

INOV3. Consulting and Innovation Labs

CITE's R&D activities related to innovation management result in the design of new conceptual framewor ks and tools to be applied by our consulting team to private and public organizations. Advanced consulting provides support in managing the implementation processes of new technologies, and to develop recommendations and frameworks to address public policy concerns and plan public policy agendas.

In addition, CITE will organize Innovation Labs for companies interested in strengthening their innovation culture and fostering the development of new responsible innovations and business models.

INOV4. EEN Portugal and EEN Innovation Journey and Diva Project

CITE is partner of the Enterprise Europe Network since 2015. On behalf of the Network, CITE runs 2 international projects focused on innovation management and technological entrepreneurship with a special focus on societal and environmental well-being entrepreneurial projects.

On the other hand, the ongoing DIVA project aims at providing support to the emergence and development of new industrial digitech value chains with applications to the agro-food, forestry and environment sectors.

6.9.6 Knowledge valorisation chain

The following table presents the contribution of the "Research and Technology" areas to the "Technology Transfer" areas, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CITE - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)						
	Let In	Executive programs	EEN	Innovation Labs	Consulting	The Journal of Innovation Management	Conference on Entrepreneurship Education
Innovation Management	L	H	H	H	H	H	
Technology Management	H	H	M	L	H	H	
Technology Entrepreneurship	H		H	H	L	H	H

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.9.7 Main Objetives for 2020

The main general objectives for 2020 are:

- Researching on user centered innovation methodologies and tools to support responsible innovations and new business model approaches, engaging potential clients, end users and other stakeholders, in order to mitigate risks and considering the world challenges regarding societal and environmental well-being;
- Initiate research on a circular approach to R&D and Innovation Management to foster the flow and re-use of the resulting knowledge and competences;
- Developing multidisciplinary approaches to enabling the Front End of Innovation for both companies and entrepreneurs. This endeavor is being pursued in two ways: 1) organizing knowledge by the creation of conceptual frameworks that build on the literature and on best practices; 2) the development of tools, supported by those frameworks that may be tested and used by entrepreneurs and innovators alike, in the development of new sustainable and innovative concepts, and business models;
- Researching and exploring the role of business model innovation connecting new technology with the market in order to deliver new responsible societal and environmental value propositions;
- Studying strategies and policies for the use and control of the technology for the benefit of communities; priority will be given to the design of complex networked infrastructures with flexibility, to enhance their performance in relation to uncertain future conditions of operation, and to improving methods for the design of engineering systems in a multidisciplinary way, integrating engineering, management and social sciences.

Internally, CITE aims at contributing for the sustainable intensification of R&D activities by organizing and launching an internal program to support INESC TEC researchers in the process of knowledge and technology valorization. The proposed internal program will consist of four actions:

- A1|Competence Network Model in Innovation and technology Management;
- A2|Let In Catalyst – Support for proof of concepts Seed Project Labs;
- A3|Let In Catalyst - Intrapreuneurship Training Program;
- A4|Circular Management of R&D projects – methodologies & tools.

In the topic of Innovation Management, CITE aims to:

- Intensify the cooperation with EASME and the National Consortium of European Enterprise Network. CITE runs the next two years program;
- Provide support to company's benefits from SME Instrument, under the EEN Innovation Journey Project;
- Implement Innovation Management audits into at least 20 SMES, under the EEN Innovation Journey Project;
- Participate in ISO-TC279 for Innovation Management and research on the impact of the outcomes on the innovation management practices;
- Design and implement a transversal work package to manage the value creation and exploitation of R&D projects.

In the topic of Technology Entrepreneurship, CITE aims to:

- Manage the second edition of DIVA grants to support new technological solutions applying in the agro-food sector;
- Follow European and national opportunities to development accelerate programs that allows the collaboration between new venture initiatives and INESC TEC and that contribute for a more entrepreneurial society

Concerning Technology Management, CITE aims to:

- Reinforce the team working in these fields and the number of published papers and participation in conferences;
- Submit a proposal for a scientific project focused on the concerns mentioned above;
- Develop new training programs focused on the adoption and implementation of technology.

Resources and partnerships:

CITE aims to reinforce in 2020 the team with a senior researcher to intensify the research capacity of the Centre and to increase the opportunities for participate in European projects as well as provide scientific consulting services.

Explore and reinforce partnerships in order to give access to new European projects, with EASME, EIT- Digital, EIT- Manufacturing and EIP_AHA.

Continue collaborating with the CoLAB ForestWISE to foster the development and adoption of innovative solutions in forestry sector.

6.9.8 Main actions planned for 2020

This year, CITE will design and/or implement the following actions:

Table 6.2 - CITE – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Workshops organization on "Turning technologies into responsible innovations"	2 workshops	Foster in INESC TEC researchers an exploitation mindset Foster circular R&D projects mind-set; result exploitation strategies definition; Competence Network Model	2 semesters
Participate in European initiatives, namely coordinating/participation in action groups (EIT Digital; EIT Manufacturing; EIP_AHA)	4 meetings	Foster the cross-border adoption of digitally-driven marketable solutions; foster development of new European projects	1 annual per group
Participation in European consortia	3 Submissions	Strengthen participation in technology-based innovation projects within European partnerships	April; September
Participation in training courses: "Technology & Innovation Management"	1 course- 2 persons	Learn the state-of-the art of Technology & Innovation Practices; establishing links with academic and international network at IFM	March 3800€ + viagens
Design and Implement a program in cooperation with seed projects at INESC TEC	3 workshops & mentorship	Increase the potential of valorization of the projects	Quarter
Innovation consulting activities with industrial partners	10 companies	Services to be developed under EEN consortium	end 2020
Innovation Management consulting	20 companies	Services to be developed under EEN Innovation Journey consortium	end 2020
Innovation consulting activities for tourism sector with share economy business models	4 companies	Services to be developed under TourismShare consortium	29-02-2020
2nd call for solutions within DIVA project	6 portuguese applications; 2 projects funding	Foster new technological entrepreneurial projects applied to agro-food, forestry and environment sectors	30-12-2020
Finished the incubation process of ForestWISE by INESC TEC	Launch of ForestWISE	Research agenda, partnership agreements, project management, recruitment, marketing communication	31-01-2020
Development of projects for ForestWISE	3 projects	Policy insights Risk communication	31/12/2020
PLIS – "Plataforma de interoperabilidade do SGIFR"	2 sub - projects	Diagnosis of the actual system (As-Is) Design of the PLIS architecture	31/12/2020
Firefighting Report	Report	Diagnosis of the forest fires suppression campaign in 2019	29/02/2020
ISO56008 Nominated and Participating Experts	Participation in Innovation Measurement - ISO 56 008 , 2 meetings	Development a ISO technical guide for measure the impact of innovation	31/12/2021
Participation in training courses for Horizon Europe proposal writing	2 px	Improve the capacity of the Centre to participate in European projects	End 2020

6.9.9 Centre Organisational Structure and Research Team

The Centre for Innovation, Technology and Entrepreneurship is coordinated by Alexandra Xavier and is organized in the following Areas:

- Innovation Management - Responsible: Alexandra Xavier & João José Pinto Ferreira
- Technology Management - Responsible: João Claro
- Technology Entrepreneurship - Responsible: Alexandra Xavier & João Claro
- Internal Projects - Responsible: Cristina Machado Guimarães

Table 6.3 - CITE– Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	3	3	3	0
		Academic Staff	1	1	1	0
		Grant Holders and Trainees	4	4	2	-2
		Total Core Researchers	**8**	**8**	**6**	**-2**
		Total Core PhD	**3**	**3**	**3**	**0**
	Affiliated Researchers		1	1	1	0
	Administrative and Technical	Employees	0	1	1	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**0**	**1**	**1**	**0**
	Total Integrated HR		**9**	**10**	**8**	**0**
	Total Integrated PhD		**4**	**5**	**5**	**0**

6.9.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CITE– Project funding

Funding Source		Total Income (k€)			
		2018	2019 (Forecast)	2020 (Plan)	Δ 2019-2020
PN-FCT	National R&D Programmes - FCT	20	18	9	-9
PN-PICT	National R&D Programmes - S&T Integrated Projects	51	1		-1
PN-COOP	National Cooperation Programmes with Industry				
PUE-FP	EU Framework Programmes	107	64	132	68
PUE-DIV	EU Cooperation Programmes - Other	75	88	16	-72
SERV-NAC	R&D Services and Consulting - National	9	19	8	-11
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes	12	2		-2
Uncertain Projects		13	3	31	28
	Total Funding	**286**	**196**	**196**	

Table 6.5 - CITE – Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	10	10	10	
Indexed Conferences	3		3	3
Books	1			
Book Chapters	5			

Table 6.6 - CITE – Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	0	0	0
Software copyright registrations	0	0	0
Patent applications	0	0	0
Licence agreements	0	0	0
Spin-offs	0	0	0

Table 6.7 - CITE - Summary of participation in dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	1
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	1
International events in which INESC TEC members participate in the program committees	1
Participation in events such as fairs, exhibitions or similar	3
Advanced training courses	3

Table 6.8 - CITE – Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	1
Participants in the conferences, workshops and scientific sessions organised by the Centre	80
Advanced training courses organised by the Centre	1

Table 6.9 - CITE – List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	DigEcoBus	Vânia Guiomar Gonçalves	03/07/2018	02/07/2021
PUE-DIV	PROTOATLANTIC-1	Alexandra Xavier	01/11/2017	31/10/2020
PUE-DIV	TouriSMEShare	Alexandra Xavier	15/12/2017	30/11/2019
PUE-FP	DIVA	Alexandra Xavier	01/04/2018	31/03/2021
PUE-FP	EENINNOVATION	Alexandra Xavier	06/01/2020	05/01/2021
PUE-FP	EENPortugal	Alexandra Xavier	05/01/2020	05/01/2022
SERV-NAC	IMSGIDI	Alexandra Xavier	15/03/2019	15/09/2019

Type of Project:

PN-FCT National R&D Programmes - FCT
PN-PICT National R&D Programmes - S&T Integrated Projects
PN-COOP National Cooperation Programmes with Industry
PUE-FP EU Framework Programme
PUE-DIV EU Cooperation Programmes - Other
SERV-NAC National R&D Services and Consulting
SERV-INT International R&D Services and Consulting
OP Other Funding Programmes

6.10 CSIG – CENTRE FOR INFORMATION SYSTEMS AND COMPUTER GRAPHICS

Coordinators: António Gaspar and Ângelo Martins

6.10.1 Presentation

The Centre for Information Systems and Computer Graphics (CSIG) is integrated in the Computer Science Cluster. Its mission is to pursue high quality research, strongly linked to industrial partnerships, consultancy and technology transfer, in five main areas: Computer Graphics and Virtual Environments, Information Management and Information Systems, Software Engineering, Accessibility and Assistive Technologies and Embedded/Special Purpose Computing Systems.

The Centre is particularly well positioned to address complex and difficult engineering problems faced by industry as it has the expertise to analyse, design, mine and implement large information systems, using best software engineering practices for design, development and testing, and provide the visual and user interaction components such a solution may require. To this effect, it has 3 transversal application areas: Platforms and Methods for Earth and Ocean Observation Science, Platforms and Methods for Personalised Health Research, Public Administration Business Area.

Furthermore, the Centre is also strongly committed to the training of young researchers and professionals, regularly graduating more than 10 PhD students per year.

Presently its researchers originate from the University of Porto, Polytechnic of Porto, University of Trás-os-Montes e Alto Douro, Universidade Aberta and University of Minho.

6.10.2 Context

6.10.2.1 Scientific/Research Areas

Computer Graphics and Virtual Environments (CG&VE)

Computer Graphics is one of the main drivers for innovation in the IT sector, as an underlying layer on Mixed Reality solutions (including VR and AR), Visualization, Digital Games, and Interactive multimedia applications. The high-performance hardware and new algorithms push global illumination rendering to real-time, particularly in the digital games area and 3D movies production. Virtual and Augmented Reality applications can also take advantage of high performance and affordable hardware for distinct applications, particularly with the industry 4.0 paradigm, providing new tools for planning, supervision, and operation. A significant trend is the integration of multisensory information to enhance the feeling of presence and immersion in VE. Serious Games (SG) can push their applications in the area of Education, Tourism, and training taking advantage of these advances. Both VE and SG require multidisciplinary teams to address challenges in the area of Human-Computer Interaction (HCI). We focus in particular in User Experience (UX), User Interaction (UI), Human Cognition, and Human perception. Within this area, Gameful design is another approach to improve UX in distinct processes, providing behaviour change, and increased engagement. Pushing the borders of HCI into Human-data Interaction, Scientific Visualization is also a definite necessity to explore and provide knowledge on Big Data.

Software Engineering (SE)

The Software Engineering area aims to develop novel methods, techniques, and tools that advance the way in which software is designed, synthetized and assessed. It aims to ensure that the research results have a lasting impact in software development practice, and to contribute to improve the competitiveness of the industry. The main research lines are: (1) Software requirements, design and construction – Patterns and paradigms; Architecture and cloud computing; requirements maintenance; (2) Software Testing – Model-based testing; Mobile testing; IoT testing; (3) Software Process and knowledge management – Software Process Improvement; Knowledge management in software engineering; serious games in software engineering education.

Accessibility and Assistive Technologies (AAT)

According to the WHO about 15% of the world's population have some form of disability, and this number is rising, with advances in medical care and population growth. The UN Convention on the Rights of Persons with Disabilities states that technology design should take into account accessibility and usability features for the

protection and promotion of the human rights of persons with disabilities, in all policies and programmes. Research trends in accessibility aim to apply computing and information technologies to empower individuals with disabilities and older adults by eliminating the gap between the average user and those with special needs, promoting equal rights and opportunities for all.

Active ageing is conditioned by many factors mainly aimed at maintaining autonomy and control of the contiguous environment, in particular the physical and social surrounding context. The frailties associated with aging and the necessary care for maintaining the autonomy is crucial for their independence and are increasingly supported by information and communication technologies that require active interaction with older adults, as well as with people with special needs, namely the blind, the deaf, patients with Parkinson's disease (etc.). Recent studies aim to enhance this relationship between these users and technology, by personalizing their user experience and adapting the interaction to the context and the user profiles. This contextual availability of information triggers user motivation and highlights the benefits of the use of technology in daily life. Research trends in this domain aim to provide contextualized services, based on pervasive monitoring and prediction of users' interaction.

Information Management and Information Systems (IMIS)

Information systems have evolved from specialized systems operating on curated data managed at the institutional level to pervasive structures, incorporating different technologies and data from multiple sources. This evolution brings new technical and social challenges to information management. The Information Management and Information Systems area is committed to address some of the resulting challenges, selecting the topics where previous work can enable more significant results.

Research data management has significant challenges in the required tools and in the workflows that incorporate them in research processes. The considerable investment being made in the European Open Science Cloud provides a very favourable context to deploy existing work at the InfoLab and the results of the TAIL project. At national level, INESC TEC is currently coordinating the Portuguese node of the Research Data Alliance.

Embedded/Special-Purpose Computing Systems (ES/SPeCS)

The research problems focused by the SPeCS group are considered very relevant by the international communities as they are focused on software tools and compilers to map computations to the new and future generation of computing systems (e.g., as basis of the "to compete we must compute" idea). Those tools and compilers can enable computations in devices with strict restrictions (such as the mobile and handheld devices), but also can contribute to more efficient computing solutions (e.g., in terms of Energy consumption and other performance requirements) providing either the possibility to companies be more competitive and the innovation and research findings in many areas.

6.10.2.2 Application Areas

Platforms and Methods for Earth and Ocean Observation Science

This area aims at supporting researchers and stakeholders in the EOOS field in achieving evidence-driven science, by providing systematic and collaborative methods, assisted by data science tools to address important societal challenges such as climate change or the sustainable management of the environment and its resources. Semantic interoperability, IoT, real time data stream processing and big data analysis are but a few examples of the undergoing trends and challenges.

Platforms and Methods for Personalised Health Research

This area focuses in empowering researchers in the health domain achieving evidence-driven science towards personalized treatments. It splits into two sub-areas: a) personalized Internet-based treatments; and b) human data storage, harmonization and controlled sharing. Important trends and challenges include collaborative tools and methods for health research leveraging on the FAIR principles, security and privacy preservation.

Public Administration Business Area

This area focuses on applied research leading to products and services. One branch aims to provide specialized and advanced consultancy, and in technology transfer and support in the adoption of good practices and emerging standards by public administration entities. Another branch aims to help induce a market pull drive into research and technological development and generate a convergence of knowledge, competencies and

synergies to help producing solutions for Agro-Food, involving public entities. We are pushing for the adoption of ICT solutions using geospatial information systems based on OGC (Open Geospatial Consortium) standards and Spatial Data Infrastructures.

6.10.3 Contribution to the Vision of the Cluster

Researchers from the Computer Science Cluster, together with partners from companies and other institutions, cooperate to bring the state-of-the-art in computing methodologies to problems with high social relevance, managing and processing their data in an ethical and responsible manner. CSIG has a central role in this endeavour, leading the Cluster's contribution in the thematic lines TEC4HEALTH, TEC4SEA and TEC4AGRO.

6.10.4 Centre research lines

RL1. Computer Graphics and Virtual Environments

The goal is to create novel technologies for creation and deployment of serious games and learning technology, aiming to enable their widespread use. This aim is targeted by focusing on integration of games in educational/training information systems, on the creation of software techniques for procedural content generation and better data analytics, on approaches for better human-computer interaction with games and e-Learning systems, like the use of multisensory VR and AR techniques, and on combination of these lines with novel pervasive technologies. Main results will be new and improved authoring tools for virtual multisensorial environments, including the support of immersive e-Learning and training.

RL2. Software Engineering

One research line very active is software testing, especially, test automation. This area aims to develop methods and approaches that help to test in a more efficient way. Model based testing allows to generate test cases automatically from models of the software under test. The construction of this models may require some effort, so there are approaches that infer part of these models from a reverse engineering process. Also, there are some research work in which there is a catalogue of behaviour to test. This catalogue is predefined, works as a model, and may be applied to test several applications after a configuration step. In addition, there is the need to assess the quality of the existing testing tools. This may be done my using mutation testing. In particular, the mobile world has some specificities that most of the tools available do not test. Building mutation operators specific for the mobile world is also a necessity.

RL3. Information Management and Information Systems

The "open science and open data" research line pursues activities related to open science, namely in what concerns the identification of complex research workflows, the definition of domain-specific strategies for data organisation, data description and data publication, the specification, development and deployment of data curation tools, and the training of research managers and researchers by means of actual data management tasks in their projects.

Scientific contributions are envisaged with respect to data management tools and workflows, the design of metadata models, and the user studies that evaluate the success of their combination with the institutional, national, international, or disciplinary data repositories.

Open data encompasses data that are generated or used in scientific contexts, but also extensive collections that are kept for cultural, historical, or administrative purposes. Data created outside the scientific processes also raises concerns related to access, preservation, and interoperability. Contributions in each of these aspects are expected: 1) with access in mind, new services are provided for end-users and for data creators; 2) preservation requires robust infrastructures that must be kept technologically up to date; 3) linked-open-data-friendly models for data and metadata favour

RL4. Embedded and Special-Purpose Computing Systems

Focuses on mapping applications to embedded and special-purpose computing systems, using hardware accelerators (e.g., GPUs) and reconfigurable computing technology (e.g., FPGAs), and on Domain-specific languages (DSLs) and compiler techniques for high-performance embedded systems.

RL5. Accessibility and Assistive Technologies

The focus is on enhancing the quality of life of people with special needs, physical rehabilitation, e-health, active ageing and social participation. Thus, main research activities will be focused on: predictive interfaces, capable of combining user preferences and behaviour with contextual information; exploring pervasive technologies and IoT to minimize interaction and gather environment data; hybrid solutions, combining human computation with artificial.

These research lines have direct application and/or are integrated in the tech lines the Centre participates in: TEC4HEALTH, TEC4SEA and TEC4AGRO-FOOD.

6.10.5 Innovation Activities

INOV1. Computer Graphics and Virtual Environments

The main technology transfer area in the CG&VE area is the development of special purpose training and certification systems, based on Serious Games, VR and AR, integrated in LMS (learning Management Systems). Another area is the development of intuitive and multimodal authoring tools to deliver multimedia content.

INOV2. Platforms and Methods for Personalized Health Research

This area focuses in empowering researchers in the health domain achieving evidence-driven science towards personalized treatments. It splits into two sub-areas: a) personalized Internet-based treatments; and b) human data storage, harmonization and sharing. In the first sub-area, we develop flexible platforms that are used to support large scale randomized controlled trials, collecting a wealth of data and performing analysis towards the delivery of treatments that are tailored to individuals. The second sub-area aims at storing duly curated human data, across the life span of individuals, support harmonization across different repositories and performing distributed analyses, thus fostering cooperative hypothesis-driven research. Besides software adaptiveness, other important trends in this area result from the dichotomy in implementing FAIR Data principles, while preserving the privacy of individuals according to regulations such as the GDPR, which results in new paradigms for collaborative research as well as the methods and tools to support them.

This area has 3 active H2020 Research an Innovation projects in 2020, in application domains ranging from epidemiology (RECAP Preterm, EUCAN-connect) to immunogenetics (iReceptor Plus), playing key roles, which is a clear international recognition of merit. In addition, the Moodbuster platform continues to be explored and enhanced in the scope of European partnerships to foster collaborative research on personalized Internet-based treatments.

INOV3.Platforms and Methods for Earth and Ocean Observation Science (EOOS)

This area focuses in empowering researchers in the EOOS domain in achieving evidence-driven science by providing generalizable tools and methods to manage streams of data (from sensors or collected by humans), to process them and integrate them, thus deriving value-added outputs (so-called “products”) and support services based on analysis and forecasts. Tendency is that EOOS relies now more on continuously acquired data, rather than in “snapshots” taken periodically in the scope of scientific campaigns, yet both coexist and pose challenges. Semantic interoperability, IoT, real time data stream processing and big data analysis are but a few examples of the undergoing trends and challenges.

This area has an on-going H2020 project (MELOA), a line of 5 successive cross-border INTERREG projects (RAIA Observatory, currently focused on climate changes with the MarRISK project), a National Research Infrastructure project (C4G) and the respective European Research Infrastructure (EPOS) with a newly approved H2020 project to start in 2020.

INOV4. Public Administration

The public administration was an area where we have had an important intervention for many years. Both in the specialized and advanced consultancy, and in technology transfer and support in the adoption of good practices and emerging standards by public administration entities. Moreover aims also to help induce a market pull drive into research and technological development and generate a convergence of knowledge, competencies and synergies to help producing solutions for Agro-Food, involving public entities. We are pushing for the adoption of ICT solutions using geospatial information systems based on OGC (Open Geospatial Consortium) standards

and Spatial Data Infrastructures, at local, regional and national public institutions, as well as to partner with companies that develop business with these institutions.

6.10.6 Knowlege valorisation chain

The following table presents the contribution of the "Research and Technology" areas to the "Innovation Activities", giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CSIG - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)			
	Computer Graphics & Virtual Environments	Personalized Health Research	Earth and Ocean Observation Science	Public Administration
Computer Graphics and Virtual Environments	H	M		F
Software Engineering		H	M	L
Information Management and Information Systems		H	H	M
Accessibility and Assistive Technologies	M	F	L	
Embedded/Special Purpose Computing Systems		F	F	

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.10.7 Main objectives for 2020

The centre's main objectives for 2020 are in line with centre's reengineering strategy, focusing on high added value research and services. The recent changes in FCT scholarship rules will have a strong impact in the way the centre will hire talent in the future, further stressing the need to focus on high added value research and services.

Refocusing activity into high added value projects and services. The current very aggressive market for IT talent and current scholarship rules makes it very difficult for the centre to retain and attract enough human resources, both in terms of quantity and quality. Therefore, the centre must scale back its activity and focus only on high added value projects and services.

Retaining CSIG research capacity/talent and recruitment. The CSIG capacity of retaining current talent and recruiting new one relies on the capability to offer motivating challenges and excellent research conditions. To this effect, CSIG will act to be more attractive to Master and PhD students, one of the few areas in which can be competitive with IT companies.
Furthermore, a continuous on-job advanced training strategy and a plan will be defined in order to improve the skills of current human resources.

High-quality publications. CSIG aims at increasing the number of articles published in journals, especially in those classified by SCOPUS as first quartile.

Increase international visibility and reputation. The increase of CSIG international visibility will also be pursued, either by participating in international fora or by organizing international conferences, with the purpose of facilitating the formation of new and strong European consortia or helping the publication of new scientific results in top-ranked journals.

Computer Graphics and Virtual Environments

In the area of Serious Games, the H2020 BEACONING project is entering its final year providing a system to design, develop and manage pervasive games for learning. Another relevant area is gamified platforms to reduce the energy costs in buildings, some of them being tested at the INESC TEC Porto facilities in the scope of H2020 Feeback project. The link of Serious Games and e-Learning platforms for Health will be continued in projects like H2020 RECAP and P2020 SIMPROVE, but also will be pushed forward as the results of recent applications. This area will have several active FCT and P2020 projects, the later mainly involving the MASSIVE lab.

Software Engineering

We will continue the work on automated scenario-based testing of distributed and heterogeneous systems. Decentralized algorithms will be developed to fully automate the scenario-based integration testing of distributed systems, following an adaptive model-based testing strategy, with a minimum communication overhead between test components, and with application examples in the e-health domain.

We will also consolidate and extend the work on automated software process performance analysis and improvement recommendation, in order to support the automated assessment of adherence to agile practices and take further advantage of data mining, crowdsourcing and gamification techniques.

IMIS

Converging with the Open Science and Open Data research line, two initiatives contribute to its international dimension. The first is the involvement of INESC TEC as a node of the EUDAT CDI, the Common Data Infrastructure that is being implemented at the European level. The node is part of the plan submitted to the FCT funding by INESC TEC. The second is the Portuguese node of the Research Data Alliance, RDA-pt, that runs from February 2019 to May 2020 and is managed by a board of representatives from 8 organisations. RDA-pt is creating a Portuguese community in RDA and making the link between RDA and FCT for the sustainability of the Portuguese presence in the global RDA.

In the context of the TAIL project, the collaboration with research groups and research institutes will continue in 2020, delivering datasets that are identified, described and deposited. In a follow-up of the work on the INESC TEC repository, an activity for enabling the repository with CoreTrustSeal certification has been proposed in the context of the FAIRsFAIR European project.

The collaboration with the Portuguese National Archives will also continue within the EPISA project, with the University of Évora and the DGLAB as partners. The project will result in the first migration model to be tested, and a prototype knowledge graph for linked open data.

In the context of health information retrieval, we will proceed with the study of the impact of health literacy in users information seeking behaviour. We will begin a collaboration with Centro Hospitalar de São João.

AAT

The creation of a public demonstrator of blind navigation technology is one of the core objectives. The public demonstrator will allow conduction small scale pilots and the exploitation of the technology through users, community and partners.

Smart interfaces for accessibility and active ageing has been a core research topic of the area in the past years. The developed technologies allowed the establishment of a research framework for the study and evaluation of impact of smart interfaces in different usage scenarios for active ageing and inclusion of people with special

needs. Main contributions aim to exploit the developed research framework. A specific context for its application is the use of smart interfaces in human computation scenarios, where human intelligence tasks are delivered according to each participant best capabilities (physical, cognitive, and contextual).
The application of collaborative technologies and computational motivation models for wellbeing and the study of its impacts in the daily life of older adults are also in the objectives, aiming contributions on the treatment compliance levels, and quality of life.

Platforms and Methods for Personalized Health Research
The establishment of a formal agreement for the exploitation and continued development of the Moodbuster platform leveraging the development of new personalized treatments encompassing an Internet-based component is an objective for this area.
As the implementation of the H2020 projects on Personalized Health Research progresses, more publishable results will emerge. The reinforcement of the number of theses and publications effectively aligned with the research topics enclosed in these projects is a major objective.
Increasing the number of federated repositories including curated human health related data and having these repositories, along with privacy-preserving research tools integrated in global health research ecosystems effectively used by the respective research communities to formulate and validate personalized health research questions is a priority.
The area will also aim at organizing and attending more events as a form of achieving further engagement with the targeted research communities, which is expected to result in broadening lines and topics for future collaborative research.
Further Research and Innovation Actions in H2020 and other programmes will be sought.

Platforms and Methods for Earth and Ocean Observation Science (EOOS)
Given the maturity of the projects in this area, resulting in more elaborate research platforms, encompassing more data and the tools to process it, attaining a higher level of publications aligned with these projects is a major objective.
The area will aim at strengthening the bonds with specific communities in the EOOS, organizing and attending events in the scope of on-going initiatives, with the aim of broadening lines and topics for future collaborative research projects.
Further Research and Innovation Actions in H2020 and other programmes will be sought.

Public Administration Business Area

Increase the permanent staff allocated to this area;
Reinforce the area position by exploring the outcomes from the ongoing projects;
Reinforce the collaboration with the EOOS Area;
Participate in, at least, one strong H2020 proposal;
Reinforce the collaboration with the Laboratory of robotics and IOT for smart precision agriculture and forest;
Reinforce the collaboration with the Remote Sensing Laboratory.

6.10.8 Main actions planned for 2020

This year, CSIG will design and/or implement the following actions:

Table 6.2 - CSIG – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Collaboration with the Portuguese National Archives in the EPISA project	1	First migration model to be tested, and a prototype knowledge graph for linked open data.	2nd semester 2020
Enabling the INESC TEC repository with CoreTrustSeal certification has been proposed in the context of the FAIRsFAIR European project.	2	INESC TEC repository with CoreTrustSeal	2nd semester 2020
H2020 BEACONNG project prototype	3	Prototype	1st semester 2020
H2020 Feeback project protype	4	Prototype	1st semester 2020
Hiring of a distinctive international senior researcher for the Platforms and Methods for Personalized Health Research area	5	New hiring	1st semester 2020
Hiring of a new junior post-doctoral researcher for the CG&VE area, to replace one leaving at the end of 2019	6	New hiring	1st semester 2020
Reinforce the collaboration with the Laboratory of robotics and IOT for smart precision agriculture and forest	7	New national and European projects	End 2020

6.10.9 Centre Organisational Structure and Research Team

The Centre for Information Systems and Computer Graphics is coordinated by António Gaspar and Ângelo Martins and is organized in 5 research areas and 3 multidisciplinary application areas, each one lead by an area coordinator:

- Research areas
    - Computer Graphics and Virtual Environments – António Coelho
    - Software Engineering – Ana Paiva
    - Accessibility and Assistive Technologies – João Barroso
    - Information Management and Information Systems – Sérgio Nunes
    - Embedded/Special-Purpose Computing Systems – João Paiva Cardoso
- Application areas
    - Platforms and Methods for Personalized Health Research – Artur Rocha
    - Platforms and Methods for Earth and Ocean Observation Science – Artur Rocha
    - Public Administration Business Area – Lino Oliveira

The existence of so many areas is both a plus and a limitation. On one hand, the Centre has a diverse team of researchers, which allows it to address complex and difficult engineering problems faced by industry as it has the expertise to analyse, design, mine and implement large information systems. On the other hand, there is a clear fragmentation of the team and effort. The geographical dispersion of the team further aggravates this problem, contributing to a lower cohesion.

Table 6.3 - CSIG - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	13	14	15	1
		Academic Staff	24	25	25	0
		Grant Holders and Trainees	50	39	34	-5
		Total Core Researchers	**87**	**78**	**74**	**-4**
		Total Core PhD	**31**	**30**	**30**	**0**
	Affiliated Researchers		18	19	19	0
	Administrative and Technical	Employees	1	1	1	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**1**	**1**	**1**	**0**
		Total Integrated HR	**106**	**98**	**94**	**0**
		Total Integrated PhD	**49**	**49**	**49**	**0**

The number of grant holders and employees is very difficult to estimate in the scope of the new regulation for scholarships and scientific employment. The trend appears to be a sharp reduction of grant holders in 2021 and 2022, as current projects finish.

6.10.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CSIG – Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	214	473	368	-105
PN-PICT	National R&D Programmes - S&T Integrated Projects	224	30		-30
PN-COOP	National Cooperation Programmes with Industry	183	82	45	-37
PUE-FP	EU Framework Programmes	401	383	571	188
PUE-DIV	EU Cooperation Programmes - Other	47	55	33	-23
SERV-NAC	R&D Services and Consulting - National	121	67	151	84
SERV-INT	R&D Services and Consulting - International			10	10
OP	Other Funding Programmes	152	68	61	-7
Uncertain Projects		332	508	225	-283
	Total Funding	**1 673**	**1 667**	**1 463**	**-204**

Table 6.5 - CSIG - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	34	35	41	6
Indexed Conferences	113	83	80	-3
Books	1	2	1	-1
Book Chapters	6	5	4	-1

Table 6.6 - CSIG - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	2	0	0
Software copyright registrations	0	0	0
Patent applications	1	1	0
Licence agreements	0	0	0
Spin-offs	1	0	0

Table 6.7 - CSIG - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	9
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	12
International events in which INESC TEC members participate in the program committees	49
Participation in events such as fairs, exhibitions or similar	3
Advanced training courses	5

Table 6.8 - CSIG - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	6
Participants in the conferences, workshops and scientific sessions organised by the Centre	500
Advanced training courses organised by the Centre	1

Table 6.9 – CSIG - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	C4G	Artur Rocha	15/06/2017	13/06/2020
PN-FCT	eCSAAP	Hugo Paredes	01/09/2018	29/02/2020
PN-FCT	EPISA	Cristina Ribeiro	01/01/2019	31/12/2021
PN-FCT	Icarefordepression	Artur Rocha	01/06/2016	29/02/2020
PN-FCT	M2S	António Coelho	01/07/2018	30/06/2021
PN-FCT	MoST	Alexandre Carvalho	01/06/2018	27/11/2020
PN-FCT	PAINTER	Rui Silva Nóbrega	01/07/2018	30/06/2021
PN-FCT	PERFECT	Maximino Bessa	01/07/2018	29/06/2020
PN-FCT	PromoTourVR	Maximino Bessa	26/07/2018	25/07/2021
PN-FCT	SCReLProg	Leonel Morgado	01/10/2018	30/09/2021
PN-FCT	WalkingPAD	Hugo Paredes	01/01/2020	01/01/2022
PN-FCT	Wex-Atlantic	João Barroso	20/07/2018	19/07/2021
PN-COOP	FDControlo-1	Lino Oliveira	02/01/2018	31/12/2021
PN-COOP	INFRAVINI	Lino Oliveira	01/07/2019	30/06/2021
PUE-DIV	MarRisk	Artur Rocha	01/07/2017	30/06/2020
PUE-DIV	RADARONRAIA	Lino Oliveira	01/01/2018	31/12/2021
PUE-FP	EUCAN_CONNECT	Artur Rocha	01/01/2019	31/12/2023
PUE-FP	INCLUDING	Maximino Bessa	01/08/2019	31/07/2024
PUE-FP	InteGrid-2	António Gaspar	01/01/2017	30/06/2020
PUE-FP	iReceptor+	Artur Rocha	01/01/2019	31/12/2022
PUE-FP	MELOA	Artur Rocha	01/12/2017	28/02/2021
PUE-FP	RDA-pt	Cristina Ribeiro	15/02/2019	31/05/2020
PUE-FP	RECAP	Artur Rocha	01/01/2017	31/03/2021
PUE-FP	TIPES	Susana Alexandra Barbosa	01/09/2019	31/08/2023
SERV-NAC	ARQNET	José Correia	26/10/2016	31/01/2020
SERV-NAC	ICON	Gabriel David	13/05/2019	13/03/2020
SERV-NAC	PalacioDaAgua	António Gaspar	01/06/2018	31/05/2020
SERV-NAC	RUTE-1	Ana Cristina Paiva	01/10/2018	29/02/2020
SERV-NAC	VRTrainingIndustry	Miguel Correia Melo	13/02/2019	12/02/2021
SERV-INT	MBIntervention	José Pedro Ornelas	20/12/2018	19/07/2019
SERV-INT	MBSupport	José Pedro Ornelas	18/10/2018	17/12/2020
OP	AmbiVideo360	Rui Pedro Rodrigues	01/09/2019	01/09/2020
OP	HDR4RTT	Maximino Bessa	30/09/2016	30/03/2020
OP	RADCAMIN	Susana Alexandra Barbosa	01/01/2019	01/01/2021

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.11 LIAAD – ARTIFICIAL INTELLIGENCE AND DECISION SUPPORT LABORATORY

Coordinator: Alípio Jorge

6.11.1 Presentation

LIAAD accomplishes its mission within the Computer Science Cluster focusing on Intelligent and Adaptive Systems and Mathematical Modeling in Decision Support.

LIAAD aims to produce high quality cutting-edge research, to be in the international forefront of our research areas and promote transfer of knowledge and technology. This Centre started as a Machine Learning Research Group in 1991 and has since been in the area of Data Science, which has a growing importance in the world and is critical to all areas of human activity. The huge amounts of collected data (Big Data) and the ubiquity of devices with sensors and/or processing power offer opportunities and challenges to scientists and engineers. On the other hand, the demand for complex models for objective decision support is spreading in business, health, science, e-government and e-learning, motivating our investment in different approaches to modeling. Currently, the growing awareness of the impact of Artificial Intelligence (and in particular of Machine Learning) in our lives demands a finer attention to bringing the human to the AI loop. Our overall strategy is to take advantage of the data flood and data diversification and invest in research lines that will help shorten the gap between collected data and useful data, offering diverse modeling solutions, as well as bringing more transparency and meaning to Artificial Intelligence.

The scientific foundations of LIAAD are machine learning, statistics, optimisation and mathematics. LIAAD has currently 56 members, 27 senior researchers and 29 young researchers, most from the University of Porto.

6.11.2 Context

Machine Learning is nowadays at the centre of the new Artificial Intelligence revolution. The widespread availability of data brought by corporate databases, the World Wide Web and ubiquitous sensors enable the analysis of information-rich scenarios as well as the constant monitoring of processes. Data can now be collected, related, crunched and abstracted through visualization and modelling at quantitative and qualitative levels that never existed before. Data is presented in static form or flows in multi-dimensional and multi aspect depictions that boost the possibility for its relatively deep algorithmic understanding. As a result, Data Science has emerged as the scientific field that brings together and articulates the different layers of data processing, from collection to analytics, with a strong flavour of statistics. It provides also the most important toolkit for modern decision support and automation, from small data to big data.

- **Machine learning** is the hottest research topic and currently the core element of Artificial Intelligence. As different data types are combined with increasing resolution and volume, new algorithms and new paradigms are required. The pervasive application of machine learning algorithms in operational scenarios demands for new parameterizations, development methodologies, efficient processing and systematic evaluation. It also requires models, algorithms and interfaces that are both effective and human-inclusive.
- **Statistics** provides much of the foundations for machine learning algorithms and can help provide answers for new challenges. It is of fundamental importance for evaluation and the establishment of sound scientific evaluation methodologies.
- **Data Streams** analysis puts machine learning algorithms and statistics to the next level of continuous processing, even if with limited computational resources.
- **Natural Language Processing**, **Information Retrieval**, **Recommender Systems, Computer Vision** and other approaches within the realm of Machine Learning/Statistics that deal with complex and rich data share principles and abstract sub-problems such as representation learning, convergence, efficiency and robustness. Many of these problems have been tackled by structured complex approaches that generally fit under the umbrella of Deep Learning. This is a very important field where the interaction between people and computers is played.
- **Meta learning** is the application of machine learning methods and principles to machine learning problems themselves. It therefore enables the automation of machine learning, which is known as

AutoML. The proliferation of machine learning installations will demand decision support and automation for the Data Scientist throughout the data processing cycle, including data pre-processing, choice of algorithms and parameters and reuse of existing models (Transfer Learning).

- **Autonomous systems** are a growing trend enabling increased complexity of Artificial Intelligence applications. User/client/patient management systems, cyber security systems, autonomous vehicles and other cyber physical systems, intelligent industrial production lines (including power plants) and many other systems require a data-driven smart management of the continuous processes they manage, with automatic machine learning, self-monitoring, self-healing and human-machine communication abilities.

Despite the domination of data, decision support still has important model-driven dimensions, mostly fulfilled by mathematical approaches and classical artificial intelligence techniques such as multi agent modelling.

- **Optimization** can play an important role in finding a best solution or at least a very good one for complex decision problems, taking available resources such as time or budget into account. Problems can be modelled solely on the grounds of theoretical findings but also using empirical models elicited by machine learning approaches.
- **Game Theory** models the interactions of decision makers in competitive scenarios and can be used to model complex systems using background knowledge as well as empirically models learned from data.
- **Dynamical systems** theoretically model processes along a temporal dimension. The formulation of such mathematical models can itself be obtained/refined using data, or they can be validated with data.
- **Multi agent systems** are a computational approach that allows the representation of complex societies even with only a shallow understanding of their inner working, enabling modeling, simulation and prediction. Agents are algorithmic entities that can learn from data.

The current open and forthcoming calls for Horizon 2020[44] on Artificial Intelligence and Machine Learning focus on sustainability, circular economy, cyber security, secure and robust manufacturing, data markets, big data for quality of life monitoring and AI for public services. For the Data Mining keyword there are calls that include the processing of data for the observation of the ocean and the seas. The revised work programme 2018-2020[45], wrt AI, focuses on:

- Applications of AI/ML to Cooperative Robotics and Quantum Simulation (FET),
- New Generation Internet, AI-on-demand platform, Cyber-physical systems, autonomous systems, software development, semantics technologies, cyber-attacks management (Information and Communication Technologies)
- Massive information processing, real-time, autonomy, cooperative robotics (Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing)
- Ground systems with massive processing (Space)
- Health status monitoring and quality of life, reducing cyber risks in hospitals and care centers, Smart and healthy living at home (Health, demographic change and wellbeing)
- ICT-enabled agri-food systems (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy)
- Innovative grid-services and small scale generation (Secure, clean and efficient energy)
- Automated road transport, mobility (Smart, green and integrated transport)
- Water distribution smart solutions (Climate action, environment, resource efficiency and raw materials)

[44] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home
[45] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/reference-documents

- Disruptive technologies in public services (Europe in a changing world – Inclusive, innovative and reflective societies)
- Fight cyber-crime and terrorism, enhance border surveillance (Secure societies - Protecting freedom and security of Europe and its citizens)

6.11.3 Contribution to the Vision of the Cluster

Computing is becoming ubiquitous, decentralised and mobile, reaching all devices, appliances and beings, in real time, producing enormous amounts of data, which can produce a wealth of information if properly mined, challenging individual privacy and society fundamentals. More intelligent and autonomous systems will change the way we live and work. New interfaces will enable more immersive and inclusive interactions among humans and machines, blurring real and virtual environments.

Machine learning and decision support are at the Centre of the vision of the Cluster. LIAAD adds skills in these central areas that are related to data processing, pervasive intelligence, autonomous systems and intelligent interfaces.

- The processing of big and small data, from storage to analytics, is an important vector of the Cluster. LIAAD concentrates on the analytics layer. Machine learning and statistics are important to automatically produce operational abstractions of data (models). Optimisation, Mathematical modelling and simulation complement the use of models for effective and balanced action deployment. Many algorithmic challenges lye here, from data stream processing to complex and varied data analysis, ubiquitous and situation-aware machine learning. Meta learning / AutoML have a growing importance in these areas.
- The Cluster has a strong strategy in cyber-privacy and security, where machine learning and decision support are playing a fundamental role. Additionaly, cyber-security concerns apply to machine learning/artificial intelligence installations.
- Intelligent interfaces and immersive environments require real time user interaction with a strong demand on human-machine collaboration.
- There is a growing importance of human-centric approaches to machine learning and artificial intelligence. This requires a strong interplay between AI algorithms, interfaces and computational systems.

6.11.4 Centre research lines

RL1. Large Scale Machine Learning

This research line aggregates core research in machine learning, including the treatment of continuous and voluminous streams of evolving data. Areas of applicability include sensors data, internet-of-things, industry 4.0, intelligent transportation systems, and Web mining.

RL2. Complex Data Analysis

This line aims at developing statistical and machine learning approaches for the representation and analysis of complex data, arising from the aggregation of large amounts of open/collected/generated, or directly available in a structured or unstructured form, in particular taking inherent variability into account.

RL3. User Modelling and NLP

The growth of the size and importance of the Web and social networks, the ubiquitous digitalization of processes and the increasing variety of contents require increasing data analysis capabilities of huge and complex data that enable powerful applications in the areas of user modelling, recommender systems, customer behaviour prediction, human resources management, (including: information extraction, sentiment analysis, information retrieval, recommender systems, social network analysis).

RL4. Metalearning / AutoML

LIAAD pioneered in metalearning, contributing to the foundations since 1994. This is an area that will soon show its importance in the automated machine learning arena, also known as AutoML.

RL5. Modelling and Optimization

This line aggregates core research in Heuristics, Modelling and exact methods. On the one hand, heuristic and exact methods are developed and applied to combinatorial optimization problems in multiple fields, including scheduling, storage, and distribution. On the other hand, Agent-Based models are developed and used as computational tools in topics such as in Artificial Economics and Social Simulation. The methods developed are capable of obtaining optimal or good quality solutions for difficult and relevant problems, thus helping decision makers to optimize the use of their resources.

RL6. Mathematical Modelling

We model mathematically problems from several fields and explore different solutions. Namely, vaccination game theoretical models will be explored to analyse people decisions regarding vaccination in different diseases; duopoly and oligopoly economic models will be introduced to search for optimum strategies; problems proposed by other research lines will be modelled and analysed using dynamical systems and game theoretical methods.

6.11.5 Innovation activities

INOV1. Recommender systems, personalization and behavior modeling

We have extensive experience in recommender systems and personalization: the algorithms and the applications. We are able to put recommendation algorithms to work in production in various domains such as music recommendation, e-learning, commerce and health. The variety of data about products, customers, consumers coming from web browsing, shopping and movement can be exploited to understand and predict user behavior as well as to support users in coping with vast amounts of choices.

INOV2. Data science in action

Data mining and machine learning are our core areas. We can help businesses and services to make sense of the growing pools of data they collect to improve their actions. We have experience in algorithm development and evaluation, data transformation and system deployment. We help companies and institutions to integrate data science and machine learning into their production flow and Business Intelligence from Business Understanding to Deployment. We currently work in domains such as telecommunications, agriculture, commerce, urban transports, smart software development and power management, using a variety of data mining algorithms and techniques.

INOV3. Consultancy in Data science

We are able to help companies and institutions in their effort to develop their own data science teams. We can advise on hiring specialized personnel and in help in the supervision of the data science team. We are able to identify opportunities for data valorization and provide recommendations on the best practice to follow.

INOV4. Surveys and Data Analysis

We have competencies in statistical data analysis, including survey design, data collection, data cleaning and understanding, exploratory data analysis, development of predictive models and reporting. These are particularly useful for market studies, analysis of treatments and to measure any specific set of indicators.

INOV5. Extracting information from text

Much of the data in companies and services is stored as text. People express their views as consumers and citizens on social networks. Relevant information emerges everyday in news, reports, scientific articles and on the Web. We are able to extract information from texts, including named entities, topics, relevant dates and sentiment. This information can be integrated in the data science workflow, exploited for decision making processes or used for producing new content.

INOV6. Event and Anomaly detection, Predictive maintenance

We develop algorithms for the detection of events and anomalies. We are able to design and deploy solutions in domains such as predictive maintenance, commercial fraud, telecommunications, smart cities, ecological systems and water management.

6.11.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - LIAAD - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)				
	Personalization	Information Extraction	Data Science in action	Consultancy in Data Science	Anomaly detection / Predictive Maintenance
Large Scale Machine Learning	M	M	H	H	H
Complex Data Analysis	H	M	H	H	M
Meta Learning	F	F	F	F	F
User Modelling and NLP	H	H	H	H	L
Modelling and Optimization			M	M	M
Mathematical Modelling			L	L	L

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.11.7 Main objectives for 2020

Scientific Excellence:

1 Be part of AI Network(s) of Excellence.
2 Participation in scientific projects with international collaboration, in particular H2020 where a FET proactive proposal on Narratives and AI has been submitted.
3 Increase the number of FCT projects led by members of LIAAD to promote fundamental research.
4 Increase number of publications in journals Q1 and Q2.
5 Increase participation in top conferences (e.g. Core A and A*).
6 Organize special issues in top scientific journals.

Knowledge Transfer and Funding

1 Set-up a NLP team with good scientific production that can also respond to knowledge transfer requests.
2 Steadily increase the participation in knowledge transfer projects.
3 Maintain financial sustainability and increase margin.
4 Build-up ready to deploy toolboxes in ML, NLP and Personalization.

Visibility

1 Production and maintenance of high visibility demos and programming packages.
2 Organization of national and international events (Meet-ups, Conferences, Workshops, Tutorials and Summer Schools)

Environment

1 Promote scientific team building actions, with focused thematic internal events.
2 Promote joint research actions between different lines in LIAAD.
3 Improve quality of open space and offices.
4 Promote and participate in internal social events.

6.11.8 Main actions planned for 2020

This year, LIAAD will design and/or implement the following actions:

Table 6.2 - LIAAD – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Promote scientific team building events mostly centered around LIAAD but possibly including other Centres. Events will be focused on research lines but may promote cross research line interaction.	4	More project proposals and more scientific articles.	Each trimester
Promote social events within LIAAD	4	Better atmosphere and increased collaboration	Each trimester
Develop NLP toolbox in projects Text2Story and IPO	6	More knowledge transfer projects in NLP	Month 9
Develop ML toolbox joining efforts from different projects and Data Science Hub	6	More knowledge transfer projects in ML	Month 9
Organize a Humane AI meeting in Porto	1	Increase networking with European partners	Month 4
Hire a PhD in NLP and two new PhD students	5	An NLP team, more publications, demos and innovation projects	Month 1
Participate and promote dissemination events for companies	3	Get more contracts	Each semester

6.11.9 Centre Organisational Structure and Research Team

The Centre research team present composition and evolution is presented in Table 6.3.

Table 6.3 – LIAAD - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	3	3	5	2
		Academic Staff	22	22	22	0
		Grant Holders and Trainees	24	26	25	-1
		Total Core Researchers	**49**	**51**	**52**	**1**
		Total Core PhD	**30**	**29**	**33**	**4**
	Affiliated Researchers		4	5	5	0
	Administrative and Technical	Employees	0	0	0	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**0**	**0**	**0**	**0**
		Total Integrated HR	**53**	**56**	**57**	**4**
		Total Integrated PhD	**34**	**34**	**37**	**3**

6.11.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 – LIAAD - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	58	236	304	68
PN-PICT	National R&D Programmes - S&T Integrated Projects	189	14		-14
PN-COOP	National Cooperation Programmes with Industry	39		27	27
PUE-FP	EU Framework Programmes	92	96	46	-50
PUE-DIV	EU Cooperation Programmes - Other				
SERV-NAC	R&D Services and Consulting - National	178	147	196	49
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes	4		2	2
Uncertain Projects		94		65	65
	Total Funding	**655**	**493**	**641**	**147**

Table 6.5 – LIAAD - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	44	44	50	6
Indexed Conferences	59	35	35	
Books	4	1	1	
Book Chapters	6	4	4	

Table 6.6 –LIAAD - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	0	0
Software copyright registrations	0	0	0
Patent applications	1	0	0
Licence agreements	0	0	1
Spin-offs	0	0	0

Table 6.7 – LIAAD - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	10
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	2
International events in which INESC TEC members participate in the program committees	15
Participation in events such as fairs, exhibitions or similar	3
Advanced training courses	5

Table 6.8 – LIAAD - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	5
Participants in the conferences, workshops and scientific sessions organised by the Centre	100
Advanced training courses organised by the Centre	2

Table 6.9 – LIAAD - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	FailStopper	Rita Paula Ribeiro	01/12/2018	30/11/2020
PN-FCT	FAST-manufacturing	Dalila Fontes	01/07/2018	30/06/2021
PN-FCT	MaLPIS	Paula Brito	01/10/2018	30/09/2021
PN-FCT	MDG	Alberto Pinto	01/10/2018	30/09/2021
PN-FCT	NITROLIMIT	Luís Torgo	01/10/2018	30/09/2021
PN-FCT	Text2Story	Alípio Jorge	14/11/2019	13/11/2022
PN-COOP	SKORR-1	João Gama	01/09/2019	01/01/2022
PUE-FP	FIN-TECH	Alípio Jorge	01/01/2019	31/12/2020
PUE-FP	Humane_AI	João Gama	01/03/2019	29/02/2020
PUE-FP	RECAP-1	Rui Camacho	01/01/2017	31/03/2021
SERV-NAC	PELICAN	João Gama	01/09/2019	03/02/2020
SERV-NAC	RISKSENS	João Mendes Moreira	01/07/2019	01/05/2020
SERV-NAC	RUTE	Alípio Jorge	01/10/2018	29/02/2020
OP	DSAA2021	João Gama	01/01/2020	01/01/2022

Type of Project:
PN-FCT National R&D Programmes - FCT
PN-PICT National R&D Programmes - S&T Integrated Projects
PN-COOP National Cooperation Programmes with Industry
PUE-FP EU Framework Programme
PUE-DIV EU Cooperation Programmes - Other
SERV-NAC National R&D Services and Consulting
SERV-INT International R&D Services and Consulting
OP Other Funding Programmes

6.12 CRACS – CENTRE FOR RESEARCH IN ADVANCED COMPUTING SYSTEMS

Coordinators: Luís Antunes and Ricardo Rocha

6.12.1 Presentation

CRACS integrates the Computer Science Cluster with the mission of pursuing scientific excellence in the areas of programming languages, parallel and distributed computing, information mining, security and privacy, with a focus on scalable software systems for challenging multidisciplinary applications in Engineering, Life Sciences, Social Networks and the Internet of Things (IoT). The core research team is currently composed by 39 members, of which 15 are senior researchers, mostly faculty members at the CS department at FCUP. The research environment is enriched with talented junior researchers that together with senior researchers build the necessary critical mass and scientific competences to fulfill our mission.

6.12.2 Context

The CRACS research group has a world leading role on the design and implementation of sequential and parallel LP and ILP systems, with YAP Prolog being their flagship system. It has been enriched to support large-scale parallelism, probabilities, negation and tabling towards Data Science and Big Data applications. Considerable progress was made in these areas, with work on large datasets for author identification, semantic relatedness, sentiment discovery, motifs discovery and medical diagnosis, by using new techniques in complex networks, processing sensor data streams and high-throughput genomics data.

Research focused also on mobile edge computing and sensor networks, towards IoT. DSLs, VMs and middleware were developed to harness the combined resources of large networks of mobile devices and sensors. The ubiquity of such devices introduces new opportunities for game-changing applications but also privacy and security issues. Techniques and tools were developed, for scalable context-aware identity management in large networks and for lightweight secure autonomous communication, and new policies and mechanisms at application and services level that ensure an adequate level of privacy and user empowerment.

It is clear that our main research strengths are in line with the challenges identified for the Europe 2030 program. In particular, high performance computing for data analytics and exploitation of artificial intelligence capabilities, and cybersecurity and privacy enhancing techniques to leverage the fundamental rights, that took centuries to conquer, to this new challenging digital world.

6.12.3 Contribution to the Vision of the Cluster

CRACS activity is in line with some of the major challenges for Europe2030, namely mobile computing, data science, and cybersecurity and privacy. Given our past research and collaborations in health sciences and smart cities, CRACS can leverage some societal challenges in real world scenarios, thus contributing to the vision of the CS Cluster, namely in the research areas of:

- Mobile computing: mobile devices have become ubiquitous and traditionally viewed as thin clients or edge devices that serve primarily as user-input devices. More recently, with their increased computing and storage capabilities, their potential is now viewed as thick clients, and going even further, as thin servers. Given the proliferation and enhanced capabilities of mobile devices, it is now a real possibility for a wireless cloud of nearby smartphones to pose an interesting-enough collective computational/storage resource.
- Data science: computing is becoming ubiquitous, decentralised and mobile, generating never-ending amounts of data daily. Developing methods, systems and applications that better understand the process of transforming raw data into knowledge is a competitive advantage that most organisations have identified as the key to being successful and competitive in today's world.
- Cybersecurity and privacy: the ever-increasing volume of data produced by the internet-of-Things (IoT) undermines some of the fundamentals privacy principles: informative self-determination, data minimization, consent and the rights to individual access. Nowadays, large sets of data are collected and used without respect for these international rights for privacy. Therefore, it is mandatory to find mechanisms to ensure an adequate level of privacy protection, user empowerment, through new

applications and services based on access to personal information. In particular, techniques allowing online preprocessing of data streams as close as possible to the source (e.g., smartphones) in order to significantly avoid information linkage.

Addressing these challenges is a key factor in the development of the Digital Single Market, and the large scale data economy envisioned by the EU.

6.12.4 Centre research lines

The strategic research lines of CRACS are grouped as follows.

RL1. Languages and Distributed Computing

This research line focuses on the design of (i) high-level programming languages that integrate logical and probabilistic reasoning, supporting negation, tabling, concurrent data-structures and parallelism; (ii) programming languages and middleware frameworks for mobile wireless networks and for the Internet of Things (IoT); (iii) cloud-computing and edge-computing; and (iv) innovative crowd-sensing and crowd-sourcing applications. Our main intervention areas are:

- Programming Languages
- Concurrent Data-Structures
- Parallel and Distributed Computing
- Edge-Computing and IoT
- Middleware and Applications

RL2. Security and Privacy

This research line focuses on algorithms and methodologies to improve the usability of privacy and security in software and systems. Applications include: (i) user-controlled identity management systems that respect user privacy and protect personally identifiable information; (ii) secure identity cards and authentication mechanisms with a view to ensure access control to physical locations or networks, as well as to enable identity verification in online transactions or governmental services communications to guarantee its data integrity and non-repudiation properties; (iii) specialized algorithms and tools for sharing sensitive data while preserving privacy; and (iv) ethical hacking and penetration testing for pre-emptive vulnerability detection. We have been collaborating with the Portuguese Data Protection Commission as consultants in national projects and with Portuguese National Security Agency on auditing systems and developing solutions to secure mobile communications. Our main intervention areas are:

- Identity Management Systems
- Secure Tokens for eID
- Privacy Enhancing Technologies
- Secure Edge Computing and Streaming
- Distributed intrusion detection systems

RL3. Knowledge in a World of Data

This research line focuses on the bridge between logic, probabilities, data structures and learning. Our focus is on applications that tie our work together with domains such as author identification, semantic relatedness, sentiment and emotion discovery, complex networks, motifs discovery, sensor data streams, medical records data, and high-throughput genomics data. Our main intervention areas are:

- Machine Learning and Discovery
- Big Data Applications
- e-Learning Environments and Tools

6.12.5 Innovation activities

INOV1. YAP Prolog

Our group has a leading role on the implementation of sequential and parallel logic programming systems. Yap Prolog is a highly regarded system in the research community, especially for machine learning, being distributed with the Fedora Linux distribution. It supports just-in-time compilation, multiple forms of parallelism, multithreading, tabling, constraints handling, probabilistic inductive logic programming, among many other features and independent packages. Recently it has been extended with Python, Android and R interfaces, and with a Jupyter kernel. It is widely used as a teaching, research and development tool.

INOV2. Logtalk

Logtalk is a declarative object-oriented logic programming language that extends and leverages the Prolog language with modern code encapsulation and code reuse mechanisms while also providing improved predicate semantics. Implemented as a trans-compiler in highly portable, extensively tested, and well documented code, it can use most modern and standards compliant Prolog implementations as a backend compiler. As a multi-paradigm language, it includes support for modules, prototypes, classes, protocols (interfaces), categories (components and hot patching), event-driven programming, and high-level multi-threading programming. Distributed under a commercial friendly license, it includes full documentation, portable libraries, portable developer tools, and a large number of programming examples. It is used in academic teaching, academic research, and in industry. Recent developments include improved support for parametric objects, an extended linter, improved compilation of Prolog modules as Logtalk objects, a new tutor learning tool for helping new users understand compiler warning and error messages, an updated documenting tool capable of generating API documentation in Sphinx format, a new website, an improved diagrams tool with extended support for generating diagrams for Prolog module applications, improved QuickCheck support, new and improved libraries, and improved installers.

INOV3. Edge-Computing and Edge-Clouds

Our group has expertise in the development of middleware for edge computing and for building innovative proximity-aware applications that pool nearby devices data and processing power to construct edge-clouds. We have designed, implemented and licensed a publicly available middleware that provides mobile devices with support for automatic network formation and registration as well as point-to-point communication among nearby peers. The middleware also provides several high-level services for distributed computing, storage and sensing. In its development or final form the middleware has been used as the backbone for several research projects. We are starting a collaboration with BOSCH Ovar, with the goal of using edge-clouds of mobile devices to provide building security information for firemen and for their users, e.g., in case of a fire, gas leak or other emergency situations.

INOV4. Crowd-Sensing and Crowd-Sourcing Applications

We have expertise in the development of crowd-sensing/sourcing applications for several mobile contexts. One example is the Ramble platform. Ramble uses the aforementioned middleware to form ad-hoc networks of mobile devices and cloudlets and allows the capture and sharing of sensor, text, video, audio data for first-response teams in the context of intelligence gathering in the aftermath of, or during, natural or humanitarian catastrophes. Another example is StopCortaderia, an app designed to provide real-time sightings and monitoring of contention works for the highly invasive species *Cortaderia selloana*, a collaboration with Câmara Municipal de Gaia. Finally, in collaboration with the rectorate of the University of Porto, we are developing an application and service infrastructure for providing improved visiting experience to the university museums, including multimedia, augmented reality and virtual reality, using the mobile devices of visitors.

INOV5. Cloud Computing Services

Our group has experience in the design and deployment of reliable cloud infrastructures using OpenStack and Ovirt, comprising both storage and infrastructure-as-a-service (IaaS). We were responsible for the setup of INESC TEC Cloud-CA, a cloud comprising 280 computing cores, 1.5TB of main memory and 16TB of storage that was built to be fully redundant and fault tolerant from the network to the service layers. We are currently acting as consultants to EFACEC in their effort to migrate their workload and solutions to the public clouds.

INOV6. Privacy and eID

We have a long history of collaboration with the Portuguese Data Protection Authority, exemplified with the C3Priv project whose main goal was to return the control of the data to the users, and the Break-the-Glass work that originated a PhD thesis that won the Fraunhofer best PhD thesis with practical application, later its implementation on the second largest hospital won the CNPD privacy prize. Some of our researchers collaborate on the International Working Group on Data Protection in Telecommunications and were actively involved in the new European General Data Protection Regulation. A startup was created in 2018, whose business model is based on providing platforms that enhance the activity of Data Protection Officers.

INOV7. Privacy Preserving IoT Middleware

In more recent work, we started addressing the security and privacy of IoT devices, namely identity management of the devices, trust and privacy, enhancing technologies to express consent in IoT. As a result of this research, a novel secure live-streaming system was developed and is currently being patented.

INOV8. Relevance Detection in Social Networks

Our group developed a ground-breaking system for relevance detection in Social networks, which provides journalists and the general public with a self-feed machine learning and user interface system for the detection of potentially relevant content on Social Networks. This unique system automatically predicts whether a Twitter post is relevant or not. Current work involves the use of Word2Vec embeddings and neural networks to help create new features and predict relevance. The system also features a pool of trained models and a selection mechanism which identifies the best model to use according to the type of post/message to analyse. CRACS is hosting and maintaining this system.

INOV9. Authenticus

Our group developed the Authenticus national repository of scientific publications metadata authored by researchers from Portuguese institutions. The system automatically uploads publications from multiple indexing databases, automatically associates publication authors with known researchers and institutions, provides specialized interfaces to researchers and institutions to confirm or dismiss proposed associations, allows interoperability with other CRIS systems, provides synchronisation with ORCID, both for import and export, among many other functionalities. Currently, Authenticus aggregates publications data from: SCOPUS, Scholar, ISI Web of Science, Crossref, DBLP and ORCID. It already reached more than 350,000 authorship validations from users. The number of active users is currently above 4600 users. Authenticus has been supported by FCT, University of Porto and INESC TEC.

6.12.6 Knowledge valorisation chain

The following table presents the contribution of the research lines to the innovation activities, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - CRACS – Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)								
	Yap Prolog	Logtalk	Edge-Computing and Edge-Clouds	Crowd-Sensing and Crowd-Sourcing Applications	Cloud Computing Services	Privacy and eID	Privacy Preserving IoT Middleware	Relevance Detection in Social Networks	Authenticus
Languages and Distributed Computing	H	H	H	H	M				L
Security and Privacy			M	M	M	H	H	M	L
Knowledge in a World of Data	H		L	L	L	M		H	M

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.12.7 Main objectives for 2020

The main objectives of CRACS are focused on increasing our international visibility, notoriety and publication output, and on continuing strengthening our core research areas, in particular the ones that are strategic for the Computer Science Cluster, namely mobile edge computing, big data, security and privacy. These are also areas that connect well with other research lines of competence within INESC TEC to tackle application areas with high societal impact, namely in health, climate change, oceans, and energy.

For 2020, we plan to consolidate our international visibility by organizing or chairing more international events (we forecast 7) and by participating in more than 20 program committees of international conferences. We also aim to be successful in at least 2 new projects, preferentially 1 European, in order to increase our funding level, which was decreased significantly in the last two years.

Regarding R&D objectives, we set up the following key research directions:

- Logic-based systems: (i) progress in the development of type systems for Logic Programming (LP) using the YAP Prolog system as the base research platform; (ii) improve the integration of LP in foreign programming environments; and (iii) advance in the integration of Inductive Logic Programming and Deep Neural Networks.
- Lock-freedom: implementation, proof and evaluation of novel methods for the efficient removal and memory reclamation of nodes in branching lock-free data structures. The ultimate goal is to develop a generic high-level interface that efficiently implements the required synchronization procedures for memory reclamation in lock-free data structures.
- Edge-clouds: (i) continue development of middleware features for networks of mobile devices, e.g., computational and load-balancing services with different optimization metrics (e.g., time, energy, cost); (ii) integration of advanced computer vision features in crowd-sourcing applications for object identification and as an alternative for indoor location (e.g., museum or buildings in general); (iii) continue development of applications for mobile platforms to support environmental protection and

territorial management (e.g., mapping and monitoring invasive species) as well as safety (e.g., helping civilians and firefighters in building fires).

- Gamified programming education: provide a framework for application of gamification to programming education, including the necessary specifications (of the gamification scheme and the exercise definition format), collection of gamified exercises (for popular programming languages) and software (a toolset for editing the exercises and an interactive learning environment providing them to the students). The target group of the project are programming instructors and students learning programming (also self-teaching).

6.12.8 Main actions planned for 2020

This year, CRACS will design and/or implement the following actions:

Table 6.2 - CRACS – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Promote join research meetings within CRACS	Foster internal awareness of on-going work	Submit proposals to FCT call for projects	1st sem
Extend our consulting efforts to future project proposals within the P2020 scope	Submit proposals within the P2020 scope	Get, at least, one proposal accepted	1st sem
Collaborate with DM/ML group at Dalhousie University, Canada	Reinforce and improve existent collaboration in Data Mining and Machine Learning areas	Write 1-2 joint papers	1st sem
Propose collaboration with UP-Tecnologias Educativas & UP Digital	Create a system capable of predicting student failures based on their interaction with Moodle	Access to Moodle courses from several different Faculties	2nd sem

6.12.9 Centre Organisational Structure and Research Team

The Centre for Research in Advanced Computing Systems is coordinated by Luís Antunes and Ricardo Rocha and is organised in three main research areas:

- Languages and Distributed Computing – Coordinator: Luís Lopes
- Security and Privacy – Coordinator: Rolando Martins
- Knowledge in a World of Data – Coordinator: Álvaro Figueira

The Centre research team present composition and planned evolution is presented in Table 6.3.

Table 6.3 – CRACS - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	1	1	1	0
		Academic Staff	14	15	15	0
		Grant Holders and Trainees	37	20	21	1
		Total Core Researchers	**52**	**36**	**37**	**1**
		Total Core PhD	**21**	**18**	**17**	**-1**
	Affiliated Researchers		0	3	4	1
	Administrative and Technical	Employees	1	1	1	0
		Grant Holders and Trainees	0	0	0	0
		Total Admin and Tech	**1**	**1**	**1**	**0**
	Total Integrated HR		**53**	**40**	**42**	**0**
	Total Integrated PhD		**21**	**19**	**18**	**-1**

6.12.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 - CRACS - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	107	76	19	-57
PN-PICT	National R&D Programmes - S&T Integrated Projects	220	23		-23
PN-COOP	National Cooperation Programmes with Industry				
PUE-FP	EU Framework Programmes	89	96	1	-95
PUE-DIV	EU Cooperation Programmes - Other		14	18	5
SERV-NAC	R&D Services and Consulting - National	47	65	71	6
SERV-INT	R&D Services and Consulting - International				
OP	Other Funding Programmes				
Uncertain Projects		65	4	12	8
Total Funding		**529**	**278**	**122**	**-156**

Table 6.5 - CRACS - Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	11	11	20	9
Indexed Conferences	41	20	28	8
Books		3	2	-1
Book Chapters	1	2	2	

Table 6.6 – CRACS - Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	1	1	1
Software copyright registrations	0	0	0
Patent applications	1	2	1
Licence agreements	0	0	1
Spin-offs	0	0	0

Table 6.7 – CRACS - Summary of dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	3
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	7
International events in which INESC TEC members participate in the program committees	25
Participation in events such as fairs, exhibitions or similar	2
Advanced training courses	3

Table 6.8 - CRACS - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	0
Participants in the conferences, workshops and scientific sessions organised by the Centre	0
Advanced training courses organised by the Centre	0

Table 6.9 – CRACS - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	CRADLE	Vítor Santos Costa	15/06/2018	14/06/2021
PUE-DIV	FGPE	Ricardo Queirós	01/09/2018	31/05/2021
SERV-NAC	Authenticus19_20	Luís Filipe Antunes	01/09/2019	01/01/2020
SERV-NAC	EFA-Cloud	Luís Filipe Antunes	01/01/2019	31/12/2020
SERV-NAC	PGODISSEIA	Manuel Eduardo Correia	24/07/2018	31/12/2019

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

6.13 HASLAB – HIGH-ASSURANCE SOFTWARE LABORATORY

Coordinators: Alcino Cunha and António Luís Sousa

6.13.1 Presentation

HASLab is focused on the design and implementation of high-assurance software systems: software that is correct by design and resilient to environment faults and malicious attacks. HASLab accomplishes its mission within the Computer Science Cluster, anchoring its research on a rigorous approach to three areas of Computer Science: Software Engineering, Distributed Systems, and Cryptography and Information Security.

The contributions of HASLab to these areas range from fundamental research on formal methods and algorithms, to applied research on developing tools and middleware that address real-world demands stemming from long-term collaborations with industry.

HASLab has currently 91 members, 41 senior researchers and 50 young researchers from University of Minho and University of Porto.

6.13.2 Context

Despite the high confidence that society has in software, the vast majority of ICT systems are currently maintained by low assurance software. The fundamental rights of individuals, including safety, privacy and health, can only be a reality if the technological building blocks that support them provide high assurance of their correctness, security and availability. Unfortunately, today this is not the case.

How can we make sure that the software we use actually is trustworthy? HASLab's answer to this question is based on a rigorous approach to three technological pillars: Software Engineering, Distributed Systems and Cryptography and Information Security. Through a multidisciplinary approach that is based on solid theoretical foundations we aim to provide solutions—theory, methods, languages, tools— for the development of complete ICT systems that provide strong guarantees to their owners and users.

6.13.3 Contribution to the Vision of the Cluster

Prominent application areas of HASLab research include the development of safety and security critical software systems, the operation and security of cloud infrastructures, and the privacy-preserving management and processing of big data. These are key enablers for pervasive intelligence and will continue to be the focus of the group in 2020.

6.13.4 Centre research lines

RL1. Software Engineering

HASLab's research on Software Engineering area focuses mainly on developing formal methods for system design and program verification, in order to achieve high-quality software. In particular, we develop formal languages and tools for specification, verification (model checking), and design of complex systems, including stochastic, continuous, and systems where human-computer interaction plays a central role. This work is supported by a strong research line on the structural and foundational aspects of Computer Science area and a recent but important strategic investment on Quantum Computing. We also develop static and dynamic automatic analysis techniques for checking several software quality aspects, for example execution safety or energy consumption, and for automatic testing and debugging, namely fault localization.

For the next five years, the main scientific contributions and publication outcomes for this research line are expected to come from:

- Formal design of safety-critical systems, such as medical devices or the software controlling next-generation robots;
- Static and dynamic code analysis techniques for checking execution safety and energy consumption;

- Formal methodologies and tools aiding in the conception, validation, verification, and construction of quantum programs.

RL2. Distributed Systems

HASLab's work on Distributed Systems focuses on dependable data management for cloud computing and data science environments. In particular, we aim at providing the next-generation of software-defined storage solutions that can automatically adapt to heterogeneous data-intensive workloads and their specific requirements in terms of efficiency, security and dependability. Moreover, we are interested in combining the scalability of NoSQL systems with the functionality of relational and transactional database management systems. Our contributions encompass the development of new techniques and mechanisms for data replication and distribution, including conflict-free approaches to eventual consistency with conflict-free replicated data types, query processing focused on analytic workloads, secure data processing in untrusted infrastructures, and operational management of performance and reliability. The main challenge is thus to make novel data management technologies as safe and usable as the well-known and trusted SQL technologies.

The support of scalability is grounded on efficient dissemination protocols and data collection. This is based on topologies that are both resilient and effective in dissemination speed and load, and when appropriate, in stochastic data aggregation techniques that reduce the communication load while providing a global view of the system with controlled accuracy.

For the next five years, the main scientific contributions and publication outcomes for this research line are expected to come from:

- Dependable data management for cloud computing and data science support;
- Dissemination and aggregation protocols for very large geographically distributed systems (IoT and edge computing);
- Programmable software-defined storage systems for heterogeneous data-intensive cloud computing and big data;
- Interoperable Solutions Connecting Smart Homes, Buildings and Grids.

RL3. Cryptography and Information Security

HASLab's work in Cryptography and Information security covers both fundamental and applied topics, and also the challenge of bridging theory and practice. At the theoretical level we conduct research in provable security and machine-assisted cryptography, where the goal is both to develop the theoretical foundations of rigorous security analysis of cryptographic protocols, and to design formal verification techniques that permit verifying security proofs. At the applied level we focus on high-efficiency and high-security implementations of cryptography, with an emphasis on providing high-assurance to the functional and non-functional properties of cryptographic implementations. A major challenge that we address at this level is to provide domain-specific languages and tool support that guarantee the preservation of theoretically proven properties from high-level specifications to low-level implementations. Privacy enhancing technologies for securely storing data and computing in the cloud are the most prominent application scenarios we have recently addressed.

For the next five years, the main scientific contributions and publication outcomes for this research line are expected to come from:

- Provable security and formal verification of cryptographic protocols, namely for secure outsourcing of data storage and processing;
- Efficient and secure implementation of cryptographic software, harnessing architecture-specific features for high-speed and side-channel security;
- Privacy-enhancing technologies, targeting emerging challenges in edge computing and industry 4.0.

6.13.5 Innovation activities

INOV1. Requirement specification and validation

Early validation of requirements is key to ensure the success of a software project. HASLab has members with a vast experience on using formal methods to specify and validate requirements (and on reliable system design methodologies in general) that can provide early feedback to all stakeholders about potential inconsistencies and critical scenarios. We can also provide consultancy in the process of developing domain specific languages and tools for requirement elicitation and validation. Finally, one important technology transfer area is the analysis of security requirements in software applications, namely those involving complex trust models, such as those arising in the cloud, and the use of cryptography for more than securing communications and data at rest. These are particularly important in safety and mission critical innovation areas, namely in TEC4HEALTH, TEC4AGRO-FOOD and TEC4ENERGY, where application have a direct impact on humans, and TEC4SEA where property understanding the requirements of systems that will operate autonomously is critical to avoid mission failures that could result in their loss.

INOV2. Algorithm design and implementation

HASLab can provide consultancy in the design of algorithms for several complex and critical domains, for example, distributed data synchronization and aggregation, secure implementations of high-speed cryptographic modules for embedded devices, and complex implementations of advanced privacy enhancing protocols for the cloud. We can also provide implementations of such algorithms with high correctness and efficiency guarantees, and, when applicable, implementations that are correct-by-construction obtained by refinement of formal specifications. Such specialized algorithms are quite relevant in domains where energy and time efficiency are fundamental, for example, to be deployed in autonomous exploration systems in the TEC4SEA area or IoT and wearable devices in TEC4ENERGY and TEC4HEALTH applications.

INOV3. Evaluation of critical software components

HASLab has expertise on evaluating the implementation of critical software components in order to check their conformance to functional and non-functional requirements, for example, security, execution safety, energy consumption, scalability or usability. We can also provide consultancy in the process of software certification required in several safety critical domains, for example in the TEC4HEALTH and TEC4INDUSTRY areas, where software operating medical devices or robots in industrial environments is required to conform to strict standards. In the area of cryptographic software development, we can provide independent validation of correctness and non-functional properties such as the deployment of side-channel countermeasures. Again, this is critical for privacy preserving applications in the TEC4HEALTH domain, but also to help secure large public utility infra-structures, for example in the TEC4ENERGY area.

INOV4. Polyglot data management

The use of multiple data management technologies side-by-side is increasingly common in practice. Besides the traditional SQL database management systems, applications rely on novel systems such as MongoDB or HBase for storage, and on Hadoop or Spark for query processing. In particular, the technologies based on the Hadoop stack have been proven useful in a variety of application domains. HASLab has experience in deploying and operating these systems and can provide support in their implementation in new scenarios and the optimization of existing applications. Moreover, we have experience in integrating and combining multiple technologies in the scope of the same application. Such polyglot data management is fundamental in applications generating large volumes of data, for example, in the TEC4ENERGY area.

INOV5. Cloudification services

The deployment of applications on today's technological landscape is moving towards the cloud. The industry largest companies have started to migrate their infrastructure to a cloud environment, seeking to reduce the operational costs and reaping the benefits of resource allocation on demand. Whether the transitions is made to a public service provider, a private cloud or a hybrid-model there is always the problem of integrating an application on the cloud environment. It is not simply a matter of deploying an application on a virtualized environment, there are always concerns regarding the application’s configuration, components interaction, resource monitoring and automatic resource allocation. From years of research and by collaborating with the industry, we gathered the experience required to accelerate the transition of applications to the cloud. This

transition is particularly relevant in large public services, for example in public health, video streaming, or energy distribution platforms typical of the TEC4HEALTH and TEC4ENERGY domains.

6.13.6 Knowledge valorisation chain

The following table presents the contribution of the "Research and Technology" areas to the "Technology Transfer" areas, giving some insight into the operation of the knowledge valorisation chain relevant to the Centre.

Table 6.1 - HASLab - Table of relationships between the Centre research lines and the innovation activities

Centre Research Lines	Innovation Activities (*)				
	Requirement Specification and Validation	Algorithm Design & Implementation	Evaluation of Critical Software Components	Polyglot Data Management	Cloudification Services
Software Engineering	H	M	H	L	L
Distributed Systems	L	H	M	H	H
Cryptography and Information Security	M	H	M	L	M

(*) Types of relationships:
"blank" – no direct relationship / contribution
L – Low or weak relationship / contribution;
M – Medium relationship / contribution;
H – High or strong relationship / contribution;
F – Future predicted relationship / contribution

6.13.7 Main objectives for 2020

1. Increase the publication outcome, namely in high profile venues
2. Increase the research funding dedicated to lower level TRLs;
3. Increase the number of PhD students;
4. Move from prototype-level high-assurance software development tools to production-level open-source tools with a significant user-base and high-profile real-world applications;
5. Consolidate stable long-term technology transfer collaborations with international giants in ICT such as Amazon, Google, IBM that guarantee high-impact in real-world applications for mature research contributions;
6. Upgrade the CLOUDinha laboratory, in order to improve its capacity as testbed for privacy preserving computation as well as distributed deep learning.

6.13.8 Main actions planned for 2020

This year, HASLab will design and/or implement the following actions:

Table 6.2 - HASLab – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Increase the funding dedicated to fundamental research projects	1,2	5 new proposals for fundamental research projects	Dez
Launch an HASLab internship program to attract master students for conducting fundamental research-oriented thesis in the centre, funded by BIC grants	3	6 new PhD students	Jan
Promote tool demos and tutorials at high-visibility events	4	A 100% increase in the social statistics (used by, watches, stars, etc) of the github repositories of the main HASLab tools	Dez
Establish a new partnership with an international ICT giant	5	A new project or consultancy project with an international ICT giant	Dez
Purchase equipment to improve our CLOUDinha research lab	6	A substantial improvement in the capacity of CLOUDinha	Mar

6.13.9 Centre Organisational Structure and Research Team

The High-Assurance Software Laboratory is coordinated by Alcino Cunha and António Luís Sousa and is organised in the following areas:

- Software Engineering;
- Distributed Systems;
- Cryptography and Information Systems.

Table 6.3 – HASLab - Research team composition

Type of Human Resources			2018	2019	2020	Δ 2019-20
Integrated HR	Core Research Team	Employees	6	7	8	1
		Academic Staff	14	16	16	0
		Grant Holders and Trainees	49	32	30	-2
		Total Core Researchers	**69**	**55**	**54**	**-1**
		Total Core PhD	**30**	**27**	**27**	**0**
	Affiliated Researchers		7	6	6	0
	Administrative and Technical	Employees	0	1	1	0
		Grant Holders and Trainees	3	1	1	0
		Total Admin and Tech	**3**	**2**	**2**	**0**
	Total Integrated HR		**79**	**63**	**62**	**0**
	Total Integrated PhD		**37**	**33**	**33**	**0**

6.13.10 Activity indicators for 2020

The following tables present the main indicators of the activity planned for 2020 – participation in projects under contract, scientific production, IP valorisation and knowledge dissemination.

The income from projects presented in Table 6.4 includes signed contracts listed in Table 6.9 and new projects to be signed during the year.

Table 6.4 – HASLab - Project funding

Funding Source		Total Income (k€)			Δ (k€)
		2018	2019	2020	2019-20
PN-FCT	National R&D Programmes - FCT	23	237	288	51
PN-PICT	National R&D Programmes - S&T Integrated Projects	176	28		-28
PN-COOP	National Cooperation Programmes with Industry	24		2	2
PUE-FP	EU Framework Programmes	611	499	130	-368
PUE-DIV	EU Cooperation Programmes - Other				
SERV-NAC	R&D Services and Consulting - National	60	17	389	372
SERV-INT	R&D Services and Consulting - International	5	96		-96
OP	Other Funding Programmes	139	231	96	-135
Uncertain Projects		25	140	181	41
	Total Funding	**1 063**	**1 248**	**1 086**	**-161**

Table 6.5 - HASLab – Summary of publications by members of the Centre

Publication Type	Total Publications			Δ
	2018	2019	2020	2019-20
Indexed Journals	15	15	20	5
Indexed Conferences	39	30	40	10
Books				
Book Chapters		1		-1

Table 6.6 - HASLab – Summary of IP protection, exploitation and technology transfer

Type of Result	2018	2019	2020
Invention disclosures	0	0	0
Software copyright registrations	1	0	0
Patent applications	0	0	1
Licence agreements	0	0	0
Spin-offs	0	1	0

Table 6.7 - HASLab - Summary of participation in dissemination activities

Type of Activity	2020
Participation as principal editor, editor or associated editor in journals	3
Conferences organized by INESC TEC members (in the organizing committee or chairing technical committees)	5
International events in which INESC TEC members participate in the program committees	30
Participation in events such as fairs, exhibitions or similar	2
Advanced training courses	1

Table 6.8 - HASLab - Summary of dissemination activities organised by the Centre

Type of Activity	2020
Conferences, workshops and scientific sessions organised by the Centre	2
Participants in the conferences, workshops and scientific sessions organised by the Centre	60
Advanced training courses organised by the Centre	15

Table 6.9 - HASLab - List of projects

Type of Project	Short Name	Leader	Starting date	Ending date (planned)
PN-FCT	DaVinci	José Paiva Proença	26/07/2018	25/07/2021
PN-FCT	HADES	Manuel Barbosa	01/10/2018	30/09/2021
PN-FCT	KLEE	Luís Soares Barbosa	01/06/2018	31/05/2021
PN-FCT	MaLPIS-1	Ricardo Morla	01/10/2018	30/09/2021
PN-FCT	SAFER	Alcino Cunha	01/07/2018	30/06/2021
PN-COOP	SKORR	Paulo Jorge Azevedo	01/09/2019	01/01/2022
PUE-FP	InteGrid-1	Manuel Barbosa	01/01/2017	30/06/2020
PUE-FP	InterConnect-2	Fábio André Coelho	01/10/2019	30/09/2023
SERV-NAC	INCMchaves	José Bacelar Almeida	15/04/2019	15/10/2019
SERV-NAC	MobileID	João Marco	01/10/2019	01/04/2021
SERV-NAC	OLM2	José Creissac Campos	01/05/2019	29/02/2020
OP	FM'19	José Nuno Oliveira	01/08/2018	31/03/2020

Type of Project:

PN-FCT	National R&D Programmes - FCT
PN-PICT	National R&D Programmes - S&T Integrated Projects
PN-COOP	National Cooperation Programmes with Industry
PUE-FP	EU Framework Programme
PUE-DIV	EU Cooperation Programmes - Other
SERV-NAC	National R&D Services and Consulting
SERV-INT	International R&D Services and Consulting
OP	Other Funding Programmes

7 RESEARCH INFRASTRUCTURES

7.1 Laboratory of Sound and Music Computing (SMC)

Contact Person: Gilberto Bernardes

7.1.1 Presentation

The mission of the SMC lab is to develop assistive technology to aid users of all levels of expertise to engage in creative musical tasks. To this end, we are engaged in devising novel means for interacting with musical content which sit at the intersection of digital signal processing and music theory.

The Laboratory hosts 11 researchers from INESC TEC's Centre for Telecommunications and Multimedia and from the Department of Informatics Engineering of the Faculty of Engineering of the University of Porto.

Research areas

The laboratory addresses the following main areas of research in the field of Sound and Music Computing

- Interactive Music Systems (Human-Computer Musical Interaction)
- Automatic Music Generation and Procedural Music
- Music information retrieval
- Immersive audio
- Audio signal processing
- Music robotics

Location: FEUP Campus, Porto

7.1.2 Associated Centres

- CTM – Telecommunications and Multimedia

7.1.3 Objectives for 2020

- Leverage a research line based on new interfaces for musical education
- Define strategic partnerships (e.g. Matosinhos Municipality)
- Reinstate the international projection of the lab by submitting applications to host relevant conferences
- At the management level, reorganize the occupation of the lab and the involvement of the collaborators by aligning them into clustered research topics

7.2 Optical and Electronic Technologies Research Laboratory

Contact Person: Luís Pessoa

7.2.1 Presentation

The Optical and Electronic Technologies (OET) Research Laboratory enables the test and characterisation of optoelectronic devices, RF/microwave circuits/waveguides and electronics components and systems up to 110 GHz in frequency. The laboratory includes the capability for characterizing Ground-Signal-Ground probed circuits in the DC-50 GHz and 75-110 GHz bands, wire bonding of integrated circuits, anechoic chamber characterization of planar and waveguide based antennas up to 110 GHz, and a glazed test tank for underwater optical communications research. The laboratory includes an independent space for PCB assembly/re-work, as well as mechanical workshop and 3D printing for building electronics test fixtures and antenna test supports.

The laboratory contains equipment for electrical and optical spectrum analysis, including real-time spectrum analysis up to 160 MHz of instantaneous signal bandwidth, vector network analysis of 4-port and optoelectronic circuits, real-time sampling oscilloscope with 20 GS/s capability, arbitrary waveform generator with 12 GS/s capability and a 3D electromagnetic simulation software with license for commercial projects.

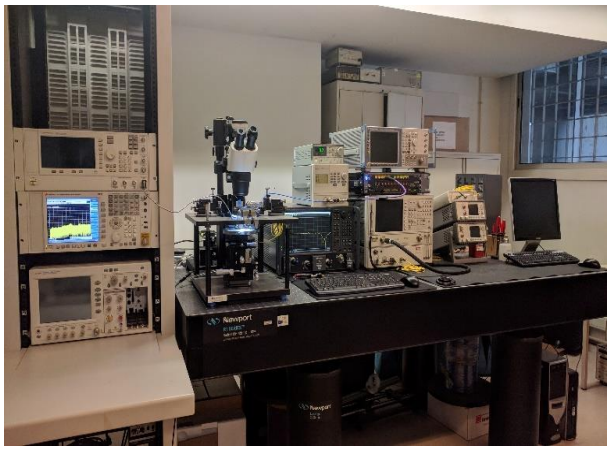
The laboratory was created in 2007 and is used for research purposes by 25 collaborators from the Centre for Telecommunications and Multimedia (CTM).

Research Areas

The researchers working at the Laboratory address major general topics of research in the field of Optical and Electronic Technologies:

- Optical-wireless interfaces
- Microwave circuits and antennas
- Signal processing
- (Micro)-electronics
- Programmable logic

Location: INESC TEC Building, FEUP Campus, Porto



7.2.2 Associated Centres

- CTM –Telecommunications and Multimedia

7.2.3 Objectives for 2020

- Laboratory infrastructure upgrade and modernization, including:
  - ✓ Replacement of luminaires with new LED models, for better illumination of the workspace;
  - ✓ Build of new water supply point, to facilitate and support underwater communications experiments;
  - ✓ Revised electric installation including UPS backup;
  - ✓ Replacement of the wall between mechanical workshop and laboratory space by a new fully glazed wall supported in a stainless-steel frame structure;
  - ✓ Implementation of RFID access control.
- Installation of new technical tables and racks, for modernization and improving usability.
- Installation of new PC for data acquisition, controlling and interfacing with the laboratory equipment.

7.3 Imaging Laboratory

Contact person: Carla Carmelo Rosa

7.3.1 Presentation

The Imaging Lab focuses on the development and improvement of optical measurement and imaging techniques.

The systems we develop target the applications where microscopy is unable to provide an acceptable response, either due to the requirement for sample preparation (dicing, contact, accessibility) or to cost/performance constraints when depth discrimination is paramount.

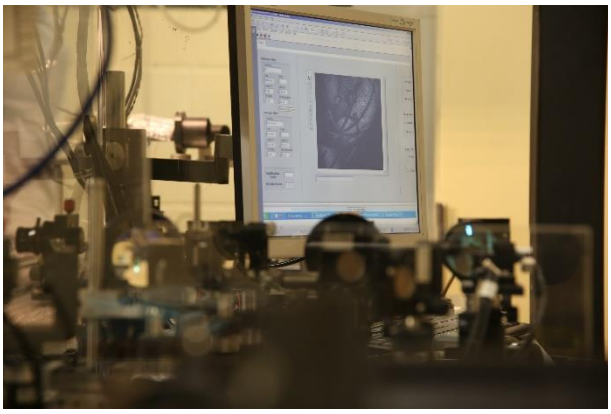
The techniques we explore aim at achieving high spatial resolutions and non-invasiveness when probing samples.

The expertise acquired has been demonstrated in different fields of application, ranging from optical inspection of industrial products to quality control and biological tissues.

Research areas

- Single fiber imaging systems
- Optical tweezers and cell manipulation
- Improvement of LIDAR techniques

Location: FCUP Campus, Porto



7.3.2 Associated Centres

- CAP –Applied Photonics

7.3.3 Objectives for 2020

- Consolidate the knowledge on the fusion of compressive sensing with lidar imaging
- Hardware implementation and assessment of compressive sensing approaches in hyperspectral imaging

7.4 Laboratory of Microfabrication

Contact person: Paulo Vicente Marques

7.4.1 Presentation

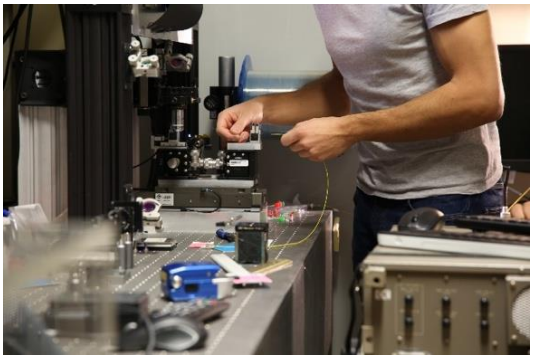
The Microfabrication laboratory explores traditional top-down microfabrication techniques and non-traditional based on femtosecond laser direct writing processes to support the activities of other areas of research.

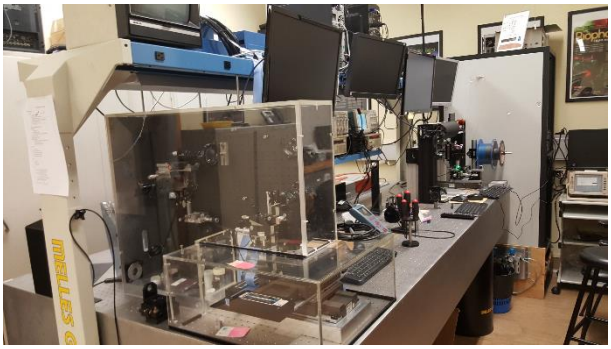
For example, microfluidics and optofluidics chips are produced to implement biosensors, micro, and nanostructures. First order Bragg gratings are made by laser point-by-point direct writing to implement new sensing heads that will lead to the development of better and more reliable sensing heads.

Research areas

- Three-dimensional direct inscription of waveguides and complex integrated optical devices;
- Fabrication of Bragg and long period gratings (first and higher order structures);
- Fabrication of microfluidic devices using FLICE techniques;
- Fabrication of optofluidic devices for sensing applications;
- Micromachining.
- High resolution 3D photopolymerization

Location: FCUP Campus, Porto





7.4.2 Associated Centres

- CAP –Applied Photonics

7.4.3 Objectives for 2020

- Characterization of the new installed system for laser direct writing
- Development of integrated plasmonic optofluidic devices
- Fabrication of high resolution tridimensional structures in polymeric and hybrid materials by multiphoton absorption

7.5 Biomedical Imaging Laboratory

Contact person: Aurélio Campilho

7.5.1 Presentation

The main focus of the Biomedical Imaging Lab (BIL) is the development of advaced image processing and analysis methodologies, particularly medical and biological images, with the aim of creating Computer-aided Diagnosis (CAD) tools to support medical decision making.

The research activities at the Lab use several imaging modalities addressing different clinical departments including in Ophthalmology, Neurology, Radiology, Gynaecology, Obstetrics and Gastroenterology.

RESEARCH LINES

Presently, the Biomedical Imaging Lab is organized in the four main research lines described below. These research lines are described in the medical application or medical imaging dimensions. However, C-BER and in particular the Biomedical Imaging Lab, associates to each one of these RLs, the conceptual and methodological dimension, as Medical Image Analysis, Computer Vision and Machine Learning methodologies.

RL1: Ophthalmology CAD

The research activities under this research line are:

Screening Diabetic Retinopathy - The main goal of this research activity is the Screening of Diabetic Retinopathy (DR) in digital color photographs of the retina. It includes the automatic detection of image quality, and removal of low quality images, automatic detection of non-pathological cases, and grading of DR for reflecting the disease severity. For this purpose, advanced image analysis and machine learning methodologies, including generic deep learning approaches, are being developed. These activities are developed in the framework of a CMU|Portugal research project and two PhD theses. In particular, in 2020, we will address the following topics:

- Detection of microaneurisms and hemorrhages offering an alternative and focused methodology for the detection of these lesions, that are the first signs of DR.
- Grading DR providing an interpretable framework to support the algorithm decisions, and uncertainty – aware, providing the prediction uncertainty to allow an ophthalmologist to evaluate the degree of confidence on the grading result.
- Evaluate on site the methodologies developed so far for interpretable Image Quality detection, DR detection and DR grading. Create a pilot to be installed at the ARSN (Administração Regional de Saúde do Norte), allowing an evaluation for a large set of cases.

CAD and follow-up of prevalent eye diseases using OCT/OCTA images: In this line of research, automated methodologies based on optical coherence tomography (OCT) and OCT angiography (OCTA) will be developed in order to provide a second opinion to the ophthalmologists on pathology detection and diagnosis tasks. Dedicated methods will be developed for the extraction of disease biomarkers from OCT and OCTA images, which will be used for pathology detection on eyes with DR or age related macular degeneration (AMD) and for assessing the disease progression or the effectiveness of a therapeutic approach. These activities are to be developed in the framework of a PhD thesis and other training activities.

New biomarkers for a prospective analysis of age-related macular degeneration progression: The main goal of this project is the automatic detection of patients with referable AMD, as well as the assessment of the 5-year risk of progression to the advanced forms of the disease. For this purpose color eye fundus images will be used. The project will study the temporal evolution of AMD in order to identify biomarkers that can be associated with the risk of progression to more advanced AMD stages, corresponding to more severe forms of advanced neovascular or nonneovascular stages of the disease. These activities are planned to be developed in the framework of a proposed PhD thesis and other training activities.

RL2: Lung CAD

The Lung CAD has several research activities, all contributing to the development of CAD tools summarized below.

Lung nodule detection, characterization and classification: Segmentation of lung anatomical structures, as lung lobes, airways and vasculature network, in order to have reference location structures and guide the detection and diagnosis tools. These activities are developed in the framework of a FCT research project, two PhD theses, and several research training activities. In particular, in 2020, we will address the following topics:

- Evaluate a lung detection and nodule and segmentation tools in large-scales and assess the potential of using gaze information for integrating automatic detection systems in the clinical practice. For that purpose, several radiologists were involved in detection tasks while being monitored by an eye tracker device and an automatic lung nodule detection system previously developed.
- Embed in the detection system the interpretation of the predictions, taking into consideration the clinical applicability of the system should not only be reliant on its detection quality but also on the method used for exposing the decision reasons to the radiologists, thus removing the black box issue that is common in available CADe systems currently on use.
- Large scale validation of the nodule detector to prove the effectiveness of the system prior to its implementation in clinical settings.
- Design a computer-aided diagnosis system by providing a patient label based on the LUNG-RADSTM guidelines, for patient treatment and follow-up based on the measurement of calcification, texture and size characteristics of the findings.

Lung cancer screening: As a continuation of the research activities for lung nodule detection, characterization and segmentation described before, this new line of research aims to push CAD systems to a more objective, both qualitative and quantitative tumor characterization, i.e., a radiomic approach to describe and to create predictive models relating image phenotypes to genomics signatures. These activities are developed in the framework of an FCT research project, and several research training activities. In particular, in 2020, we will address the following topics:

- Development of lung cancer gene mutation prediction models. For this purpose, we will identify and extract features from the differents lung tumor structures and develop predictive models for predicting lung cancer semantic features. We will use public datasets and a private dataset under assembling.
- Continuing assembling the private lung cancer dataset.

AI in Chest radiography analysis: Chest radiography (CXR) is one of the most common imaging examinations globally, playing an essential role in screening, diagnosis and disease management. Nevertheless, CXR interpretation is a challenging and time-consuming task, representing a major burden for radiologists. As such, the development of automated tools for the detection of multiple pathologies could play an important role in reducing the burden on radiologists and decrease variability in image interpretation. We plan to develop a Chest X-Ray detection system that advances the state-of-the-art by providing explanations not only based on reports but also through visual maps, together with Chest X-ray-based Metrics of AI-interpretations at image level. These activities are planned to be developed in the context of a research project proposed recently. In particular, in 2020 the following activities are foreseen:

- Start collecting image data.
- Design an annotation software to provide a standardized radiological report.

RL3: Ultrasound

Ultrasonography is a commonly used imaging modality for the examination of several pathologies due to its non-invasiveness, affordability and easiness of use. The Biomedical Imaging Lab is using ultrasound (US) imaging techniques in two lines of developments, applications in Ginaecology and Obstetrics, the Gyn-US and open a new field of research in echocardiography. These two are were or will be object of proposal of research projects, and if funded the following activities will be addressed in 2020:

- Gyn-US -Gyn-US aims to provide a quantitative and accurate CAD system for the diagnosis of ovarian and uterine pathologies, using B-mode and radio-frequency (RF), 2D and 3D US images. Techniques for improvingthe characterization of the different tissues present within the ovary (stroma and follicles) will be investigated, in order to allow an early diagnosis of ovarian cancers, namely, novel techniques based on Convolution Neural Networks.

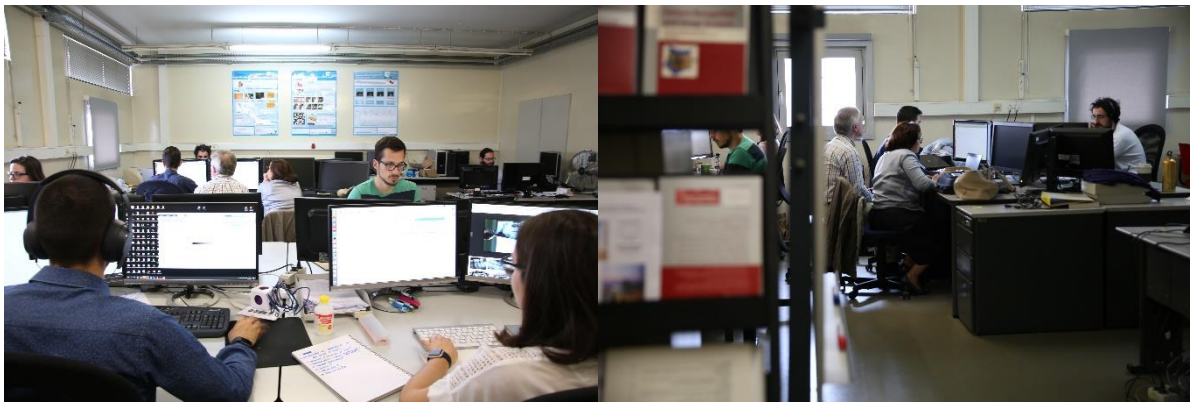
RL4: Capsule endoscopy

Capsule endoscopy is nowadays the imaging modality used to study and diagnose small bowel pathologies since it allows viewing inaccessible regions with the traditional endoscope with greater patient comfort. However, analyzing the long-videos produced is a time-consuming and challenging task and prone to distracting errors. We plan to develop CAD methods and assemble a tool to assist clinicians in revising videos of wireless capsule endoscopy. These activities are developed in a PhD and several research training activities, and they will be the object of a proposal of research project. In particular, in 2020, we will address the following topics:

- Detection and classification of abnormalities in full videos of wireless capsule endoscopy. For this purpose, will be used deep learning approaches and trained and evaluated on public datasets and a large private video dataset previously assembled.
- Continue collecting of the private video dataset.

Currently Biomedical Imaging Lab has 17 researchers.

Location: FEUP Campus, Porto



7.5.2 Associated Centres

- C-BER –Biomedical Engineering Research

7.5.3 Objectives for 2020

- Improve and/or validate decision support systems for ophthalmic, pulmonary, cardiac and gynaecological pathologies;
- Improve machine learning algorithms using novel weakly supervised, explainable and uncertainty aware systems to support medical decision.

7.6 Neuroengineering and Advanced Human Sensing Laboratory

Contact person: João Paulo Cunha

7.6.1 Presentation

The main goal of the NeuroEngineering & Advanced Human Sensing lab is to perform high-level interdisciplinary R&D in engineering and computational approaches applied to basic and clinical neuroscience & human sensing, namely crossing several areas, such as Physics; Engineering (Electronics; Computation; etc.); Neurology; Neurosurgery; Neurophysiology; Neuroradiology and Neurobiology.

Furthermore, the lab also aims to innovate and facilitate tech-transfer to the high-tech market.

Currently the lab has 19 members, all from the INESC TEC Centre C-BER.

Research areas

- Brain imaging (&signals)
- Man-computer symbiosis (e.g. Brain-Computer Interfaces)
- Movement disorders in neurological diseases
- Neurosurgery Aiding Systems
- Macro-to-nano biosensing

Location: INESC TEC Building, FEUP Campus, Porto

7.6.2 Associated Centres

- C-BER –Biomedical Engineering Research

7.6.3 Objectives for 2020

- New man-autonomous vehicle symbiosis developments in cooperation with CMU-Silicon Valley and Naval Postgraduate School
- Establish R&D contract programs with recent startups that licensed our patents – iLoF and inSignals
- Novel neuro-data-fusion deep-learning approaches with clinical knowledge transfer to neural architectures
- Active fund raising for the next R&D cycle (namely H2020 and Horizon 2030)
- Scientific&IP indicators improvements, even with less resources
- Equipment updates and improvements funding

7.7 Robotics and Autonomous Systems Laboratory

Contact persons: Anibal Matos, José Miguel Almeida, Eduardo Silva

7.7.1 Presentation

The Laboratory of Robotics and Autonomous Systems has two physical locations within the ISEP and FEUP campus. These dedicated facilities support R&D activities, technical training of human resources as well as advanced education programmes. In fact, as a research lab in an academic environment it fosters undergraduate research, supports multiple engineering course and academic activities.

The mission of the laboratory is the research of excellence in Autonomous Systems enabling the observation and operations in complex, unstructured and harsh environments. The multiple-purpose robotic operations include data gathering, inspection, mapping, surveillance, and/or intervention. The impact in the economic and social fabric development is also part of the objectives - by contributing to the performance, competitiveness and internationalization of Portuguese companies and institutions.

Research areas:

- Navigation and control;
- Sensing, mapping, and intervention;
- Interaction with environment;
- Multiple platform operations.

Locations: ISEP and FEUP campus

7.7.2 Associated Centres

- CRAS – Robotics and Autonomous Systems

7.7.3 Objectives for 2020

The main objectives of the Robotics and Autonomous Systems Laboratory for 2020 are the following:

- **New laboratory equipment and tools** – the growing R&D activity and the expansion to new application areas requires new laboratory equipment and tools. New investments planned for 2020 will create essential conditions to address these challenges.
- **Create privacy conditions within the Labs** – current R&D contracts with industry are very demanding in terms of privacy and associated penalties. During 2020 new privacy conditions shall be created in both Labs to become compliant with current demands.

7.8 TEChnologies for the Sea (TEC4SEA)

7.8.1 Mission and Positioning

The TEChnologies for the Sea (TEC4SEA – www.tec4sea.com) infrastructure, will finish the first implementation phase during 2020. This research infrastructure will enable full validation and evaluation of technological solutions designed for the ocean environment, allowing researchers to evolve from simulation/lab experiment to field trial. It aims to become a unique and pioneer platform in Europe to support research, development, and test of marine robotics, telecommunications, and sensing technologies for monitoring and operating in the ocean environment, shall be able to offer the first services to the academic and businesses players.

The scientific objectives of the TEC4SEA are:

- To become a reference on experimentally-driven, multidisciplinary research on technology for the ocean;
- To support research, development, and testing of new technologies;
- To support the specification and testing of draft standard technologies for the ocean environment;
- To support research in other scientific areas;
- To integrate with international infrastructures;
- To support technical training of human resources as well as advanced education programmes.

TEC4SEA has poles in Porto and Faro, two major coastal cities of Portugal. Additionally, a maritime wireless network composed by two land station and eight sea nodes located offshore the Porto metropolitan area are also available. The TEC4SEA geographic location (North Atlantic Ocean) enables fast deployments in deep sea.
This RI shall provide support and services to the scientific and industrial ecosystems, generating revenue through contracted services or indirectly by supporting R&D funded initiatives.

7.8.2 Management Structure and team

The TEC4SEA is currently under implementation. This implementation phase is coordinated by Paulo Mónica as Principal Investigator. The implementation management team also includes Agostinho Oliveira, Aníbal Matos, António Silva, Eduardo Silva, Manuel Ricardo, Maria Barbosa, Marta Barbas, Pedro Jorge and Sérgio Jesus.

7.8.3 Objectives for 2020

The main objectives of RI for 2020 are the following:

- **Conclude the first investment phase** – current investment plan and deadlines are very challenging. Concluding this plan within the timeline will enable the infrastructure to become active and start offering differentiated services to the stakeholders.
- **Refresh the website** – communication to the outside world is a fundamental piece of dissemination and promotion of the infrastructure, it's capacity and services. Approaching the end of this 1st implementation phase, the website shall be revisited and updated with the new capacities and services.
- **Present itself to the world** – to end of the 1st implementation phase shall be commemorated with a special event. Different stakeholders shall be invited, and the infrastructure resources presented and visited.

7.9 European Multidisciplinary Seafloor Observatory – Portugal (EMSO-PT)

Contact persons: Aníbal Matos, Eduardo Silva

7.9.1 Presentation

EMSO-PT is a research infrastructure lead by IPMA (Instituto Português do Mar e da Atmosfera) and involving 15 other research institutions working on ocean science or technology, including INESC TEC.

The ultimate goal of EMSO-PT is to organize the Portuguese contribution to the EMSO-ERIC network, a large-scale European Research Infrastructure, networking fixed point, deep sea multidisciplinary observatories, with the scientific objective of real-time, long-term monitoring of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere. It is a geographically distributed infrastructure at key sites in European waters, spanning the Arctic, the Atlantic, and the Mediterranean, up to the Black Sea. It will be in place by the end of the decade.

EMSO identifies eight main scientific questions where advances are foreseen: 1) Dynamics of tectonic plates and magmatic systems; 2) Climate and greenhouse gas cycling; 3) Ocean productivity and ocean dynamics; 4) Marine mammal and fish stocks; 5) Non-renewable marine resources; 6) Episodes, events and catastrophes; 7) Origins and limits of life; 8) marine ecosystems dynamics. All these topics are dependent on long-term, continuous observations, able to capture significant episodes as they occur.

So far, the Portuguese participation in EMSO has been focused on the Azores and Cadiz nodes, in cooperation with France (Azores) and Italy (Cadiz) using two of the few available technological solutions for long term seafloor monitoring (ASSEM and GEOSTAR). Within the scope of EMSO-PT two sites will be considered close to the mainland: a deep water one, located in the Gulf of Cadiz, and another shallow water, located off North Portugal. The later one will also be a test bench for emerging monitoring strategies.

EMSO-PT observatories will merge “off-the-shelf” technology, which will ensure that they will meet the international standards, with novel approaches (based on networked, autonomous observation platforms) that will contribute to more sustainable monitoring operations and will create the basis for the development of new marine products and services, creating value and qualified jobs.

INESC TEC involvement in EMSO-PT addresses the establishment of long-term non-fixed observatories. Such work is organized along two complementary lines: relocatable nodes and long-endurance mobile platforms. In the first case, INESC TEC is building an EGIM (EMSO Generic Instrument Module) for integration and use in a Turtle relocatable node. In the second one, INESC TEC is implementing a network of underwater gliders for collection of oceanographic data.

While the goal of the EMSO-PT infrastructure is the implementation of a network of ocean observatories for data gathering, the underlying activities are aligned with CRAS research line associated with long term deployments.

INESC TEC core research team associated with this infrastructure includes Eduardo Silva, Aníbal Matos, Hugo Ferreira and Nuno Abreu.

7.9.2 Associated Centres

- CRAS – Robotics and Autonomous Systems

7.9.3 Objectives for 2020

The main objectives regarding the involvement of INESC TEC in the EMSO-PT RI for 2020 are the following:

- Conclude the first investment phase:
    - **Finalise the implementation of an EGIM –** INESC TEC is developing a prototype of an EGIM according to the specification developed within the scope of the H2020 EMSODEV project. This module is composed by a set of different sensors for oceanographic data collection. The ultimate goal is its integration in a Turtle lander to make part of the North Portugal EMSO-PT node.
    - **Finalise the establishment of a glider network –** INESC TEC is acquiring a second glider in order to be able to perform simultaneous operations with multiple gliders. Further activities include

the development and establishment of operational procedures and auxiliary tools to store and post-process gathered data.

- Demonstrate the operationality of assets: taking advantage of partnerships and participations in several research projects, field trials with the EMSO-PT assets are planned to take place off the Portuguese coast.

7.10 Smart Grids and Electric Vehicles Laboratory (SGEVL)

Contact person: Luís Miguel Miranda

7.10.1 Presentation

The Smart Grid and Electric Vehicle Laboratory (SGEVL) constitutes a physical space integrating systems and equipment designed to support the development and testing of solutions and pre-industrial prototypes, promoting active and intelligent management of electric grids in scenarios with a progressive integration of microgeneration together with other distributed energy resources including and Electric Vehicles (EV). Proof-of-concept and experimental validation, which includes pre-prototyping processes for physical devices and/or software and equipment modules, are performed to support functional/technical specification of solutions for microgeneration, active demand response solutions and EV integration in distribution grids. It allows individual and in integrated test of control concepts, communication solutions in normal and emergency modes of operation.

This RI has a unique integrated capacity to simulate, prototype and test the electrical system of the future, providing support and services to the scientific and industrial ecosystem, generating revenue through those direct services or indirectly by supporting R&D funded initiatives.

The main benefit of this RI, in comparison with other infrastructures with commercial purposes, is the fact of being neutral in terms of commercial interest, which is also an opportunity. Other main advantage of SGEVL is the staff, which has a professional behavior as it can be expected from certification laboratories, but at the same time is very active in research activities which brings an updated and scientific approach to these works. This can be particularly interesting to companies needing a support in the initial stage of development and not only for advanced prototypes that require testing for pre-certification. It can be also useful to offload some development and research which is not possible to perform in house due to time and human resource limitations.

The laboratory facility has a significant flexibility that are easily configured to a specific project, to provide quick and reliable results. Most of the test laboratories have a very rigid infrastructure which requires for the equipment under test to be adapted to the laboratory, which we believe is a major weakness. Finally, and of great relevance, we can give a detailed analysis and feedback reporting, considering not also the results of the tests, but going deep into the technological solution.

Research areas

- Directly associated: Smart Grids
- Other areas: Forecasting, DMS/EMS - Distribution Management Systems / Energy Management Systems

The SGEVL is intended to support research and validation activities for the scientific community and companies that develop products in the energy sector, supporting top-level research and innovation in their respective fields.

Having in mind the range of activities in the referred domains, the infrastructure intends to provide professional support to the research activities, taking also advantage of INESC TEC expertise in these domains. But more than that, these developments are usually supported and supervised by academic staff, namely Professors, which are not fully dedicated to these activities. In SGEVL a new researcher is quickly integrated in an active R&D environment where they can work side-by-side with senior researchers with solid experience on the same topics, which has proven to motivate the new researchers and accelerates the development considerably. This acceleration allows then to go deeper in the topics within the same time frame.

The RI has a professional management team (since November 2018, is an area of CPES and coordinated by Luis Miguel Miranda.), with competences in innovation and research funding management, that guarantees the implementation of an action plan and the accomplishment of the specific aims defined, with an efficient and transparent internal management of resources. This managements structure is also responsible for the implementation of specific procedures to grant access by national and international researchers that are external to the infrastructure.

7.10.2 Associated Centres

- CPES – Power and Energy Systems
- CTM - Telecommunications and Multimedia

7.10.3 Objectives for 2020

Full deploy of an upgraded PHIL test platform with 100kVA amplifier and three time more real time computation capacity. Perform of tests with a real industrial equipment (EFACEC/NextStep) to validate the platform and produce key results for dissemination activity.

Finish the implementation of a novel electric vehicle charger with ISO 15118 compliance (smart EVSE). Start the research and development of the advanced functionalities allowed by this standard, mainly the ones regarding smart grid integration.

Support a research work base on inertia emulation in power electronics converters with a novel method and produce the experimental results to enable a potential patent application.

Find an industrial partner and start the first design stage of a power converter for energy storage with the use of second life batteries from road vehicles within the scope of Horizon 2020 POCITYF project.

Exploit the knowledge in cybersecurity, specific in self-healing of security issues, and encourage a young researcher (Frederico Lopes) to share is academic work in this topic, for us to have the first steps on the area and understand how this valuable knowledge can be applied in future electricity grids.

Make efforts towards the possible technology transfer of the equipment, as a whole or in parts, developed in the InteGRID project, which was designed to target residential prosumers.

Build-up of a laboratorial platform for field-validation of load desegregation techniques specifically focused on electric vehicles charging (direct contract with Eneida).

Upgrade the laboratorial facilities to test interoperability of control and communication solutions for energy management with integration of equipment from several makers with distinct protocols. (Horizon 2020 InterConnect project).

7.11 iiLab – Industry and innovation lab

Contact person: António Paulo Moreira

7.11.1 Presentation

The Industry and innovation lab, located at INESC TEC - Campus Asprela, is quasi-industrial space designed to foster the collaboration between industrial and academic communities through experimentation, prototyping and advanced training, specially geared towards industrial companies that use and develop technologies. iiLab's mission is to demonstrate and to disclose concepts and advanced technologies for the digitalisation of production including robotics, automation, simulation, virtual and augmented reality, decision support and cyber-physical systems.

To disclose the state-of-the-art in advanced production technologies through the demonstration of research, experimentation and advanced training results. iiLab supports technology-based innovation in public and private organisations, thus contributing to the development of their skills in the development, adoption and implementation of advanced production technologies, leading to a sustainable competitiveness in the circular economy context.

Demonstration of concepts and advanced technologies in the areas of robotics, automation, industrial cyber-physical systems (Internet of things) in the form of a show-room.

Dissemination of INESC TEC's expertise for the industry and the community in general

Experimentation and prototyping space for technological companies

Tailor-made training for senior managers and senior executives of industrial companies

Created in 2019, the laboratory hosts 14 researchers from CRIIS.

Research areas

- Cyber Physical Systems & Internet of Things
- Advanced Automation & Industrial Robotics
- Mobile Robotics & Internal Logistics
- Industrial Vision Systems for Inspection and Quality Control
- Projected, Augmented and Virtual Reality for Industrial applications

Location: Centro Empresarial Hipercentro, Rua Dr. Eduardo Santos Silva, 261

7.11.2 Associated Centres

- CRIIS – Robotics in Industry and Intelligent Systems
- CESE – Enterprise Systems Engineering

7.11.3 Objectives for 2020

1. During 2020, iiLab will serve as the emulated industrial environment to sustain the final stretch of development for two H2020 projects coordinated by INESC TEC (H2020 ScalABLE4.0 & H2020 FASTEN). The laboratory will host a multiproduct assembly line where robotic system will work side-to-side with human operators to pick and pack a set of different plastic components, as to mimic the scenario that the H2020 ScalABLE4.0 development team will encounter during its final Test Sprint in Simoldes Plásticos. Also, the laboratory will be equipped with a mock-up of an automated vertical warehouse, to reproduce the one located at an industrial plant of Embraer Portugal S.A., where the H2020 FASTEN development team will integrate a mobile manipulator for kitting operations currently in development. As both projects will be finalized by the end of 2020, it is to be expected that both laboratorial demonstrators will remain functioning after the projects' conclusion, to be included in the iiLab showroom, highlighting the technologies developed on the scope of each R&D initiative.
2. In 2020, the iiLab will strengthen its position as a technology showroom for digital manufacturing, aiming to be a reference location in the region. Two main objective lines are associated with this premise: on one hand, ongoing R&D projects of national and international scopes where INESC TEC is a participant (DM4MANUFACTURING, MANUFACTUR) will use the iiLab showroom to host their final demonstrators not only to the projects' consortia and evaluators, but also to invited members of the scientific and industrial areas. On the other hand, past projects and ongoing working prototypes and proof-of-concepts will be permanently assembled and ready for demonstration in the showroom. This characteristic will allow the organization of a set of thematic visits by industrial parties of different domains of manufacturing (automotive, aerospace, shoes and clothing, etc.), with the macro objective of leveraging the creation of partnerships for upcoming R&D projects where INESC TEC would be on of the participants.
3. As a mean to disclose the state-of-the-art in advanced production technologies iiLab will start offering training and education programs at the beginning of 2020. The first program has COTEC Portugal as a partner and will offer qualification to senior executives and engineers regarding the foundations, concepts, methodologies, technologies, and tools related to Industry 4.0. Other Postgraduate courses expected to be launched during 2020 include the Digital Transformation Management and the Advanced Manufacturing Technologies.
4. In 2020, the iilab will strengthen its role in order to support and promote initiatives to disseminate and to exploit the knowledge and technologies developed at INESC TEC. Additionally, in order to leverage INESC TEC intellectual property as well as to promote research and business worlds bridging for knowledge and technology transfer, process innovation management capabilities will be developed.

7.12 Laboratory of Mobile Robotics and Logistics

Contact person: Héber Sobreira

7.12.1 Presentation

Created in 2009, the Laboratory of Mobile Robotics and Logistics develops innovative algorithms in the field of mobile robotics (navigation, localization, perception of the environment), as well as real transportation solutions in challenging environments, indoor and outdoor, adapting robotic systems to logistics, surveillance, monitoring and other problems that can be addressed by mobile robots.

The Laboratory hosts 10 permanent researchers from INESC TEC's Centre for Robotics and Intelligent Systems (CRIIS).

Research areas

- Robotic localisation and navigation
- Multi-robot coordination and control
- Trajectory planning
- Sensor fusion and environment perception
- Special solution for load transport
- Motion control of mobile robots
- Mobile Manipulators

Location: FEUP Campus, Porto

7.12.2 Associated Centres

- CRIIS – Robotics in Industry and Intelligent Systems

7.12.3 Objectives for 2020

- Increase the Technology readiness levels (TRLs) by the deployment of the laboratory's solutions at several real application scenarios;
- Find an industrial partner to guide our roadmap in the market needs direction

7.13 Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry

Contact person: Filipe Baptista Neves dos Santos

7.13.1 Presentation

The Laboratory of Robotics and Internet-of-Things (IoT) for Smart Precision Agriculture and Forestry was established in 2013, with the mission of developing robotics, automation, and IoT based solutions, to improve the levels of smart precision ("right time, right amount, right place") agriculture and forestry, profitably, and automation in three main environments: Permanent Crops (such steep slope vineyards, olive groves, tree fruits), Forest biomass harvesting, Protected Cultivation (conventional and urban).

This laboratory is developing its RTD activities based on a multiple of 10-year roadmap, primarily aligned to European reality (societal challenges), European agendas (euRobotics, FCT Research and Innovation Thematic Agenda for Agrofood, Forestry and Biodiversity, strategic approach to EU agricultural research & innovation), FAO's agricultural agenda (Food and Agriculture Driving action across the 2030 Agenda for Sustainable Development), and to the TEC4AGRO-FOOD Innovation Area agenda (TEC4AGRO-FOOD is INESC TEC's Innovation Area for Agro-Food and Forestry). This laboratory has more than 13 researchers.

Research areas

- Outdoor localization and mapping;
- Outdoor Artificial Vision (Perception and Monitoring);
- Planning and controlling trajectories in irregular terrains;
- Grasping and Manipulation in advanced robotics tasks (such pruning and harvesting);
- Internet of Things (IoT) and digitalization for existing agricultural/forestry implements/machinery/irrigation systems;
- Collaborative and Safety Robotics (Advanced Man-Machine Interfaces)

Location: FEUP Campus, Porto



7.13.2 Associated Centres

- CRIIS - Robotics in Industry and Intelligent Systems
- LIAAD - Artificial Intelligence and Decision Support
- CSIG - Information Systems and Computer Graphics
- CAP - Applied Photonics

7.13.3 Objectives for 2020

- Reinforce the laboratory position by exploring the outcomes from the ongoing projects;
- Develop a multi-annual cooperation program with relevant Technology Providers (two);

- Lead two H2020 proposals for agricultural robotics and participate in other four strong H2020 proposals;
- Build an informal scientific advisory board and increase scientific network;
- Develop a multi-annual cooperation program with relevant Technology Providers;
- Increase the permanent staff allocated to this RTD line;
- Increase the number (by the factor of two) of direct contracts with companies;
- Promote results in four relevant and international events/conferences;
- Promote 2 PhD thesis and 3 MSc theses.

7.14 Laboratory of Modelling, Control and Intelligent Systems

Contact person: José Boaventura

7.14.1 Presentation

The Laboratory of Modelling, Control and Intelligent Systems (MCIS) incorporates researchers from the fields of Modelling, Automatic Control, Industrial Control Systems, Artificial Intelligence and Intelligent Systems. The MCIS mission is to develop research and development activities based on the aforementioned areas within the CRIIS and INESC TEC strategy. The MCIS has laboratory facilities located mainly at the INESC TEC pole of UTAD, but also with activities at ISEP and FEUP.

The main intervention areas are industrial control systems, modelling and control using artificial intelligent based techniques, agroforestry systems and precision agriculture.

Research areas

- Modelling of dynamic control systems;
- Modelling of discrete based systems;
- IoT platforms and DSS
- Intelligent based Control Systems;
- Industrial Automation;
- Control Engineering Education;
- Natural Computing.

Researchers:

- António Valente
- Eduardo Solteiro Pires
- José Boaventura Cunha
- Paulo Moura Oliveira
- Tatiana Pinho
- Samir Mehmeti
- António Paulo Moreira
- Paulo Gomes da Costa
- Manuel Silva
- Pedro Gomes da Costa
- Hélio Mendonça
- J. Magalhães Lima

7.14.2 Associated Centres

- CRIIS –Robotics in Industry and Intelligent Systems

7.14.3 Objectives for 2020

- Lead and/or participate in consortiums of H2020 proposals
- Workshop and meetings with stakeholders to promote R&D and Knowledge transfer
- Promote PhD thesis and MSc theses.

7.15 iRSlab: Remote Sensing Laboratory

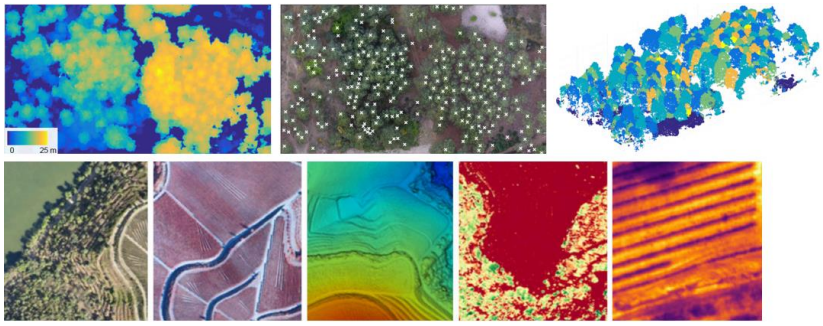
Contact persons: Raul Morais e Joaquim João Sousa

7.15.1 Presentation

The INESC TEC Remote Sensing Lab (**iRSlab**) brings together scientists from fields related to the earth observation and environment, but also electronics, robotics, image processing and artificial intelligence (AI). This multidisciplinary is crucial in an era where rapid advances in sensor technology, field robotics, unmanned aerial systems (UAS), and computing power led to an exponential growth of remote sensing applications. Nowadays, any RS application generates a huge amount of data, making processing and analysis a very complex task. Indeed, the need for integration of multiscale and multidimensional data acquired from UAS, satellites and field sensors is becoming quite common, increasing the difficulty to summarize and visualize the data for agricultural and environmental assessments.

iRSlab explores the numerous opportunities and challenges with broader usage of multi-sensor remote sensing data, mainly related to the development of algorithms to handle and interpret (ultra) high resolution imagery, and the ample spectral and spatial data converting it in useful information to support the decision-making process. This way, AI appears as a crucial field seeking to replace human brain system for automatic analysis and interpretation of huge amount of data.

iRSlab created the mySense environment (MSE), an innovative data integration platform specifically created and continuously developed to provide solutions to specific problems. MSE relies on a cloud-based infrastructure that supports the development of particular solutions based on static, mobile, proximity or remote static sensors. Simultaneously, machine learning algorithms are used on data from these sources, aiming the implementation of decision support tools.



Research/intervention areas

- Research in the areas of RS and geo-information;
  - ✓ Agriculture and forestry;
  - ✓ Water levels and quality monitoring;
  - ✓ Land subsidence;
  - ✓ Structures monitoring;
  - ✓ Archaeology
- Applied research towards improved understanding, management, and monitoring of natural resources and infrastructures;
- Expert and specialized services and products of excellence in line with the latest developments in RS and related geospatial technologies or other high-tech tools;
- Processing services including cloud-based infrastructure, integration platforms, and data storage;
- Analysis services including model selection, application, validation, and interpretation using modern machine learning and data science methods;

Location: iRSlab is located at UTAD Campus, Vila Real, Portugal, and is equipped with a number of remote sensing instruments including a fleet of unmanned aerial systems, hyperspectral, thermal, multispectral and LiDAR sensors, a hand-held spectroradiometer, etc.

People:

André Dias (Robotics - CRAS)
António Cunha (Artificial Intelligence)
António Sousa (Image Processing, Computer Vision and Machine Learning)
Emanuel Peres (infield data Gateway)
Filipe Santos (Robotics, Image Processing and IoT)
Joaquim João Sousa (satellite and drone RS, GIS and Cartography)
Lino Oliveira (Geospatial Information Systems, based on OGC (Open Geospatial Consortium) standards)
Mário Cunha (Agricultural applications)
Raul Morais (Proximity sensors)
Sérgio Madeira (Positioning and navigation and satellite RS)
Telmo Adão (Algorithms)

7.15.2 Associated Centres

- CRIIS – Robotics in Industry and Intelligent Systems
- CRAS – Robotics and Autonomous Systems

7.15.3 Objectives for 2020

- Submission of new research projects proposals, together with relevant partners (companies and academic/research institutions);
- Increase **iRSlab**'s visibility through the participation of its members in remote sensing fairs and conferences;
- Move to new facilities at UTAD Campus, increasing the ability to act in the various areas of interest;
- Apply for funds for **iRSlab**'s re-equipment.

7.16 Laboratory of Industrial Robotics and Automation

Contact person: Luís Freitas Rocha

7.16.1 Presentation

The Industrial Robotics and Automation Laboratory: New Challenges for Manufacturing and Smart Production is focused on developing cognitive, sensitive, collaborative and safe robot-based automation solutions, and advanced automation technologies for manufacturing applications, which support agile production, digital transformation, smart sensing, and Human-Machine interaction, and advanced control initiatives in the industry. Created in 2010, the laboratory hosts 15 researchers, 9 on a permanent basis, from INESC TEC's research Centres, CRIIS and CESE.

Research areas

- Collaborative Robotics Cells;
- Autonomous Mobile Manipulators;
- Artificial Vision (Robot Perception, Process Monitoring, and Quality Control);
- Intuitive Robot Programming (CAD-based Programming, Programming by demonstration, and others);
- Advanced Human-Machine Interfaces (Virtual, Augmented and Mixed Reality);
- Cyber-Physical Systems (Advanced Sensing and Embedded Systems);
- Industrial Internet of Things (IIoT) (Vertical and Horizontal Integration);
- Additive Manufacturing;
- Intelligent Automation;
- Modular Robotic Cells Design and Simulation;

Location: FEUP Campus, Porto

7.16.2 Associated Centres

- CRIIS – Robotics in Industry and Intelligent Systems

7.16.3 Objectives for 2020

For 2020, the Industrial Robotics and Automation Laboratory will continue to focus on the research for new robotic and industrial automation technologies, that are both aligned with the best practices of the Industry 4.0

initiative, and with the market demands, especially from SMEs, that yearn for the development of more agile, scalable and more interconnected manufacturing solutions. It is expected that some of the developed technologies can reach quasi-industrial TRLs and that they can be integrated into demonstrators arising either as direct results of research projects or direct contract services with enterprises (ScalABLE4.0, FASTEN, MANUFACTUR4.0, PRODUTECH-SIF, among others) or as CRIIS' own initiatives for technology dissemination through iiLAB. With this objective in mind, it is anticipated that the most focused research areas for 2020 will be:

1. **To improve robot interaction and collaborative capabilities:** In future manufacturing applications, the robot needs to be able to closely collaborate and interact with operators, other automation equipment and other systems within the production environment. To address this challenge the laboratory will focus its activity on the development of new human-machine interfaces, both based on mixed augmented reality techniques and physical interaction, and on the development of new horizontal and vertical plug-n-play mechanisms that allow easy and fast deployment and reallocation of robotics solutions at the shop floor. These developments will be built on top of the results of some research projects, such as SCALABLE4.0, FASTEN, and MANUFACTUR4.0, that are currently running at the laboratory.
2. **To develop intuitive mechanisms for robot programming and task reconfiguration**: The manufacturing process is more and more oriented for the production of both customized products and in small lot sizes and therefore in reducing the time and skill needed to reconfigure an adapt system to new processes. Therefore, the laboratory of Industrial Robotics and Automation will continue to develop new robot programming techniques, both based on CAD and programming by demonstration techniques, building on top of recent successful projects, SIIARI and ADAPTPACK. Also, the laboratory will continue to focus on developing a skill-based programming solution, that creates an abstraction layer (both for the hardware and software) allowing the operator to program the industrial robot at the task level.
3. **To Enhance robot manipulation capabilities:** One of the most important capabilities for robots in smart factories is their ability to respond to changes in the operating environment. In this context, the laboratory has been working for the past 10 years, on the development of object recognition and pose estimation framework that allows the robot to detect the pose of an object in the environment and manipulate it in accordance with the production goal. For 2020, the focus will now be directed for the development of new grasping approaches based on CAD and Artificial Intelligence, to allow the robot to self-learn the grasping positions of new objects (both rigid and flexible). These developments will be incorporated in the SCALABLE and FASTEN demonstrators at the iiLAB.
4. **To enhance the safety of human-robot collaboration:** Human-Robot Collaborative Cells will be key to Future production plants. Typical scenarios are those related to assembly lines. Despite already existing several collaborative robots deployed at the shop floor level, it is not yet possible to take full advantage of the collaborative factor, especially due to the unpredictability of human behaviour, which limits the speed of operation of these solutions. Therefore, the main focus of this laboratory for 2020, and drawing on the experience gained during the execution of some research projects such as FlexCoating, COBOTIS and ColRobot, will be to develop tracking systems that allow perceiving the operator intentions and adapt the robot trajectory and behaviour in accordance. Furthermore, this mechanism conjugated with the results achieved in point 1 and 3 presented earlier, merged with standardized safety sensors, will allow pushing the current industrial solutions to a new level of collaboration and coordination between robots and operators.
5. **IoT and Cyber-Physical Production Systems:** The Industry 4.0 initiative is materializing into practical applications in manufacturing environments through the foreseen introduction of Cyber-Physical Production Systems as well as concepts not originally associated with the movement, such as the widespread of IoT-enabled devices. Designing and experimentally trialling the first generation of Cyber-Physical Production Systems combined with these unforeseen technological advancements triggered a reconsideration of the principles upon which digital manufacturing systems are designed. With this goal and supported by the experience acquired by the coordination and participation in leading R&D initiatives (ScalABLE4.0, FASTEN), in 2020 this laboratory will focus on continuing developing and expanding the Open Scalable Production System (OSPS), a reference manufacturing software stack resulting from a carefully selected set of design principles abiding by this new age of digital manufacturing. The OSPS is currently being applied in a multitude of industrial use-cases worldwide, and in 2020 it is expected to reach a more advanced TRL.

6. **To develop machine vision systems for product inspection and quality control:** Product inspection and quality control are still nowadays one of the most important processes in the production environment. The laboratory has received more and more requests from the market for this type of solution, especially from textile SMEs. Hence, the laboratory will continue to focus on the development of artificial vision solutions combined with artificial intelligence techniques, expecting to embrace new projects with Portuguese companies at the beginning of 2020.

7.17 Laboratory of Software Engineering

Contact person: Ana Cristina Paiva

7.17.1 Presentation

Software is increasingly present in our lives, covering diverse areas such as navigation systems, control systems, service support systems, teaching support systems, etc. In this context, software quality is a critical aspect that should be seriously considered. Software Engineering is concerned with ensuring that the software is built in a systematic, rigorous, measurable, timely, cost-effective and specification-driven manner.

The laboratory belongs to the Department of Informatics Engineering of FEUP. It is located in the I Building (122). The senior researchers that work in this lab are associated with INESC TEC's Centre for Information Systems and Computer Graphics (CSIG), in the area of Software Engineering. Some master and doctoral students and research grantees of FEUP, not associated with INESC TEC, also work in this lab.

Our mission is:

- To develop new methods, techniques and tools that promote the way software is designed, synthesized and evaluated;
- To ensure that the results of our research have a lasting impact on software development practice;
- To provide students with an education that prepares them to take a leading role in complex software development projects; and
- To contribute to improving the competitiveness of the industry.

Research areas

- General areas:
  - Software Engineering
- More specific areas:
  - Software testing
  - Software patterns
  - Software process improvement
  - Knowledge management in software engineering
  - Software requirements evolution
  - Serious games for software engineering education
  - Agile methods

Location: FEUP Campus, Porto

7.17.2 Associated Centres

- CSIG – Information Systems and Computer Graphics

7.17.3 Objectives for 2020

In 2020, this lab aims to foster the design and development of methodologies, techniques and tool to improve the quality of the software. The results achieved should be published in international conferences and journals. This lab also aims to continue working with students, including them in research project teams, as a way to prepare them to take a leading role in complex software development projects.

7.18 CLOUDinha Laboratory

Contact person: Rui Miguel Ribeiro

The laboratory acts as a computational support to research and development activities of INESC TEC and UMinho, providing bare metal, virtualization, containers and security features such as SGX.

7.18.1 Presentation

Created in 2014, the laboratory is located at the Informatics Department of University of Minho, in Braga, and is shared by UMinho and INESC TEC.

The cluster is composed of several different generations of hardware namely, Sandy Bridge, Ivy Bridge, Haswell and Kaby Lake. It is currently composed of 108 machines based on commodity hardware with Intel Core i3 CPUs, 16GB of memory and 256GB HDD and SDD capacity and 10GbE, and it serves the research community with bare metal, virtualization containers and SGX security features.

Research areas

- Distributed Systems
- Cryptography
- Software Engineering
- Computer Science Education

Location: UMinho Campus, Braga

7.18.2 Associated Centres

- HASLab - High-Assurance Software

7.18.3 Objectives for 2020

- Target new application areas in the domains of privacy preserving computation and distributed deep learning.
- Add 16 new servers to increase the overall processing and storage capacity, namely to enable the above new application areas.

8 SPECIAL PROJECTS

8.1 UT Austin

Coordinators: José Manuel Mendonça and Rui Oliveira

The UT Austin Portugal Program is a partnership program in Science and Technology between the Portuguese Foundation for Science and Technology and the University of Texas at Austin, supported by the Ministry of Science, Technology, and Higher Education in close collaboration with the Council of Rectors of the Portuguese Universities.

Launched in 2007, the partnership was renewed in 2018, towards a new decade until 2030. The UT Austin Portugal Program addresses a number of **transformative knowledge areas** (Nanotechnologies; Advanced Computing; Medical Physics; Space-Earth Interactions; Technology, Innovation and Entrepreneurship) under which scientists and companies in Portugal engage with the University and other institutions in Texas in multidisciplinary research and technology transfer and commercialization. The vision is to **develop knowledge-based society, and foster science and innovation-based companies to help Portugal face future challenges that are predominantly global**.

Since 2018, the Program is headquartered in Porto, at INESC TEC. José Manuel Mendonça and Rui Oliveira are the National Director and the National Co-Director of the Program, respectively. They are backed up by a team of six whose competencies span across six functional areas: Project Management; Communication; Training and Events; Analytics for Monitoring and Evaluation; Administrative and Finance.

After a slow take off in 2018, 2019 was a pivotal year for the Program to leverage its presence within the academic, research and business communities through a series of research and education activities but also thanks to a reinvigorated communication and outreach strategy which shall start bearing fruit next year. 2020 will be a year to go on consolidating the Program's alignment towards the preestablished 2030 goals and to build on this years' lessons learnt and achievements, both from a strategic and operational standpoint.

Should the level of funding granted by FCT remain similar to that of 2019, a number of diverse activities will take place from January to December 2020, thus, contributing to make the Program's brand stronger and grow the community of stakeholders in Portugal and at UT Austin. Planned activities include:

- **The launch of a research exchange mobility scheme**, under which researchers from Portugal will have the chance to benefit from an up to 3-month stay at UT Austin to engage in high-level research activities in collaboration with UT Austin's researchers;
- **Competitive funding for high-risk/high rewarding exploratory research projects** involving researchers at UT Austin and Portuguese researchers. **Not only a second call for projects is on next year's calendar**, but also the 2019's exploratory research projects will be kicking off and are expected to lead up to promising results by the end of 2020.
- Although a new call for co-promotion projects is not in the 2020 funding roadmap, the projects awarded funding 2019 will be starting. **Throughout 2020, the Program will work to maintain a close relationship with funded consortia so as to monitor project progress and alignment with the Program's goals.**
- **Advanced training activities covering topics of the five knowledge areas of the Program**, jointly led by top-notch experts from UT Austin and Portuguese organisations. To this end, the Program is planning to open a call for workshop proposals aimed at supporting workshops, seminars and masterclasses with the scientific coordination of, at least, one researcher in and another at UT Austin.
- **New entrepreneurial initiatives,** through UTEN, to prepare Portuguese researchers and innovators for scientific readiness for commercialisation success.
- **The Governing Board and ERC meetings**. Both governance bodies will be convening at different occasions to review and comment on the Program's progress and give appropriate guidance to the Board of Directors. To this end, the executive team has been and will go on working to establish and

implement an overarching dashboard of indicators and supporting tools that can be used to track the progress of the Program against its expected goals and objectives, evaluate the impact of its initiatives throughout the years and inform the Program's governance.

- **The 2nd Annual Conference since 2018**. The Program intends to repeat the 2019 Annual Conference's formula, where Masterclasses were the highlights of the event agenda. In 2020, the areas of Earth-Space Interactions and Medical Physics should be in the foreground of the thematic Maseterclasses.

9 SUPPORT SERVICES

9.1 LEGAL SUPPORT SERVICE

Manager: Maria da Graça Barbosa

Table 9.1 - AJ - Service team composition

	Type of Human Resources	2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	2	2	3	1
	Academic Staff				
	Grant Holders and Trainees				
	Affiliated Researchers				
	Total Integrated HR	**2**	**2**	**3**	1
	Total Integrated PhD				

9.1.1 Presentation of the Service

The Legal Support service provides legal advice and appropriate action on most of the legal matters emerging within the INESC TEC universe, namely in the areas of human resources, institutional relations, project contracts and public procurement of goods, services and works. The service is committed to always defend the institution's best interests, not only preventively, ensuring that the institution is compliant with national, European or other applicable legal frameworks, but also in order to repair any damage or minimize its costs.

9.1.2 Main actions planned for 2020

- Study of the legal implications and monitoring of the application of the legal framework for the upcoming Horizon Europe Programme;
- Definition and permanent update of the internal procedures for application of the Public Procurement Code and complementary or special legislation for R&D activities, as well as launching of open tenders for acquisition of several services and goods. Definition of environmental criteria for acquisitions, in line with Ethics Code goal;
- Reporting of all the public procurement procedures observed in several acquisitions, to ensure accountability to the financing entities;
- Legal support to the ongoing process of transformation of Human Resources management policies and procedures;
- Legal support to the formalization of operations related to INESC TEC's participation in associations and companies, namely collaborative laboratories and spin-off companies, as well as the design and implementation of the licensing models associated to such operations in close collaboration with SAL;
- Legal support to the negotiation and drafting of licensing deals in close collaboration with SAL;
- Legal support to the drafting and negotiation of Consortium Agreements and other contractual instruments in the framework of European Projects already approved;
- Continued participation in the multidisciplinary Data Protection Team, appointed to support and monitor the implementation and compliance with the European General Data Protection Regulation (Regulation EU 2016/679) and complementary national legislation, namely through:
    - Direct involvement in the implementation of several actions and tasks assigned to the Data Protection Team, e.g., meetings with staff and researchers, awareness initiatives, seminars on data protection and research, and early identification and monitoring of research projects with potential privacy and data protection implications;

  - Contribution to the preparation and design of data protection management plans, data protection policies for contract templates, including in public procurement, and other data protection related documentation, as well as participation in the negotiation and drafting of data sharing and data processing agreements;
  - General legal counselling related to data protection matters and permanent legal support to the activity of the appointed Data Protection Officer (DPO).
- Proposal of a Confidentiality Guarantee Policy ("Chinese walls");
- Organization of awareness and information internal sessions, addressed to different audiences, on legal subjects with relevant or high impact on INESC TEC, namely:
  - Scientific employment;
  - Recruitment of foreign nationals (entry and stay procedures; academic degrees recognition process);
  - State aid and related rules for participation in R&D consortia, especially in the scope of the Portugal 2020 Programme;
  - Public Procurement rules and procedures, especially concerned with R&D activities;
  - Bullying and harassment at work;
  - New Industrial Property Code and related procedures (in collaboration with SAL);
  - New Research Grant Holder Statute.
- Preparation of templates, available in the intranet, for the most frequent types of contracts and other frequently requested documents;
- Participation in the implementation of the Intellectual Property Regulation, namely to ensure its translation into appropriate provisions in the contracts with personnel and with other entities, as well as the recommendation of updates to its provisions as required to comply with the new Industrial Property Code;
- Participation in the workgroup on gender equality/parity;
- Participation in in the implementation of the INESC TEC Ethics Code.

9.2 FINANCE AND ACCOUNTING SERVICE

Manager: Paula Faria

Table.9.1 - CF - Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	8	9	9	
	Academic Staff				
	Grant Holders and Trainees	2		1	1
	Affiliated Researchers				
	Total Integrated HR	**10**	**9**	**10**	1
	Total Integrated PhD	1	1	1	

9.2.1 Presentation of the Service

The Accounting and Finance service is responsible for coordinating and executing the accounting activities, for fulfilling all fiscal obligations and for managing INESC TEC´s cash flow and ensure the availability of enough funds to meet the payments due. In this context, the service acts as a mediator between the institute and external parties, according to the guidelines provided by the Board. From an administrative perspective, it is also responsible for the purchasing and travel processes and for managing the institute insurances and fixed assets.

9.2.2 Main actions planned for 2020

The main objectives and actions planned for 2020 reflect the Accounting and Finance service needs and are aligned with the continuous pursuit of excellence that drives INESC TEC, including:

- Electronic billing implementation;
- Foster awareness and promote the implementation of new practices and technological solutions towards a paper-free office;
- Promote the development of the team skills and its optimal integration with the rest of the organization;
- Reinforce the continuous improvement practices and activities.

9.3 MANAGEMENT CONTROL SERVICE

Manager: Marta Barbas
Assistant Manager: Vanda Ferreira

Table 9.1-CG – Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	10	11	11	
	Academic Staff				
	Grant Holders and Trainees	1		2	2
	Affiliated Researchers				
	Total Integrated HR	**11**	**11**	**13**	2
	Total Integrated PhD				

9.3.1 Presentation of the Service

The Management Control service is responsible for coordinating and executing the activities inherent to budgetary planning and control, and also to produce, coordinate and disseminate management information in order to ensure that all resources are obtained and used effectively and efficiently to fulfil the purposes of the institution. The service is also responsible for continuous reporting to funding agencies of financial reports and the reimbursement of expenses, monitoring funded projects for compliance with funding agencies terms and conditions by working closely with researchers and providing training whenever necessary.

9.3.2 Main objectives and actions planned for 2020

- Implementation of monthly budget control.
- Improvement of “proposals workflow” together with SIG and SAAF.
- Review of the procedure of opening a cost center, together with SIG.
- Conception, development and Implementation of new tools for monitoring and managing Human Resources projects’ allocation, together with SIG and RH.
- Dematerialization of processes, namely invoicing, together with SIG.
- Organisation of regular meetings with projects’ Principal Investigators about managing projects and funding rules.
- Organisation of regular meetings with the Centres managers and/or secretaries and other organization and management services about funding rules and internal procedures.
- Drafting of a strategic plan for the Service.
- Periodic reporting about active projects (eg number of projects, budget and funding) to assist evaluation and support decision-making.
- Restructuring of the Service, namely of responsibilities of middle managers.

9.4 HUMAN RESOURCES SERVICE

Manager: Implementation Committee *interim*

Assistant Manager: tbd

Table 9.1-RH – Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	4	5	6	1
	Academic Staff				
	Grant Holders and Trainees				
	Affiliated Researchers				
	Total Integrated HR	**4**	**5**	**6**	**1**
	Total Integrated PhD				

9.4.1 Presentation of the Service

The current Human Resources Service coordinates and executes all activities pertaining to human resources administrative management and to the implementation of HR related policies, according to the applicable law, internal regulations and guidelines provided by the Board.

During the year 2020, a deep transformation will be carried out, both on functional and strategic HR activities, reconceiving and reconfiguring HR management strategies, policies and practices.

9.4.2 Main objectives and actions planned for 2020

For 2020, the main objective for the service is the inclusion of complementary dimensions, namely collaborator life cycle and the implementation of HR strategies and practices. The overarching objective is to guarantee that **people achieve satisfaction through work**, while making the **best use of their capabilities**, assuring that the expectations are aligned with both the institution and themselves.

Implementation of a New Human Resources Management model

In 2019, a comprehensive assessment of the current situation of human resources in the institution was made. It became clear that INESC TEC HR service is making an effort in responding promptly to day-to-day operations, facing constant overwork, intensified by a poorly responsive information system, thus underperforming as a result. Also, several initiatives emerge spontaneously and are held disconnected, making it difficult to manage them centrally. In addition, although some progress has been made, it is essential to systematize the development of several strategic HR areas that urgently need attention. This results in a current functional and reactive model, which clearly limits the capacity and scope of a fundamental area in the institution.

The main goal in 2020 will represent the second stage of the reconfiguration process, based on the results of the assessment. Considering the complexity of the operation and the sophistication of the organization itself, an implementation committee will be created to ensure the transition in a first phase, putting into action the transformational change that is required.

The implementation, still to be discussed with the committee, will definitely include 2 new dimensions: working through the entire life cycle of the collaborator, together with line managers; and developing and implementing HR strategies and practices, while achieving more agile communication mechanisms and giving voice to the concerns of the collaborators. The implementation committee will work together as a team to guarantee the day-to-day operations while the new management model starts to take place. A detailed action plan will be developed, prioritizing the action lines already identified in the diagnostic phase.

9.5 MANAGEMENT SUPPORT

Manager: Isabel Macedo

Table 9.1-AG – Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	1	2	2	
	Academic Staff				
	Grant Holders and Trainees	1			
	Affiliated Researchers				
	Total Integrated HR	**2**	**2**	**2**	
	Total Integrated PhD				

9.5.1 Presentation of the Service

The Management Support Service facilitates effective decision-making in the following governing bodies of INESC TEC: General Council, Board of Directors, Executive Board and Council of R&D Centres.

In addition to its operational focus, it also assists the Board of Directors and the Executive Board in streamlining internal strategic initiatives. With a cross-cutting perspective, it ensures institution-wide coordinated information management, and seeks to improve current processes and procedures, namely by developing data-driven recommendations and solutions.

Areas of Activity	Operational	Strategic
Decision-making process	Prepares and operationalizes decision-making processes at multiple levels (General Council, Board of Directors, Executive Board and Council of R&D Centres)	
Direct support to Management (Board of Directors and Executive Board)	Supports action planning and follow-up Assists with internal and external communication	Streamlines strategic initiatives based on the priorities of the Board of Directors and the Executive Board Monitors organisational priorities, goals and metrics Collaborates in the drafting of strategic plans and reports
Information management	Coordinates institution-wide information management Ensures liaison with FEUP Library	Assists in the validation and maintenance of institutional strategic indicators Identifies knowledge gaps and assists in addressing them
Continuous improvement	Analyses and follows up on improvement ideas received in the Intranet suggestion box	Provides analytical support and data-driven recommendations and solutions to the Board of Directors and the Executive Board

9.5.2 Main actions planned for 2020

- Guarantee effective information management at INESC TEC
    - Initiate a study and integration of information quality management standards towards the definition and implementation of an information management policy;
    - Deploy an Open Access policy;
    - Foster archive digitization through the institution, supporting the progressive abandonment of paper-based filling systems;
    - Ensure overall information management in the new Intranet;
    - Undertake data curation of INESC TEC's RDM (Research Data Repository), guaranteeing some standardization with other internal repositories;
    - Redefine and automatize processes and procedures under the liaison with FEUP library.

- Fuel incremental continuous improvement at INESC TEC
    - Following the new Intranet's launch, promote actions for current business processes' analysis and improvement; support the implementation of newly identified ones;
    - Develop new visual tools in order to widen the interpretation of the institutional strategic performance indicators, meanwhile guaranteeing internal data quality and an automatized gathering of new types of indicators;
    - Maintain benchmarking routines towards international RTOs, namely on decision-making processes, business intelligence and information management.

9.6 SECRETARIAL COORDINATION

Managers: Grasiela Almeida and Ana Isabel Oliveira

9.6.1 Presentation of the Service

Executive Assistants and Administrative Assistants are responsible for effectively executing the tasks required for the development of the activities of the Board o Directors, Research Centres or Services they support, in accordance with INESC TEC processes.

Ana Isabel Oliveira manages the team of Executive Assistants of the Board of Directors. Grasiela Almeida manages the team of Assistants that support the Research Centres or Services.

Each manager coordinates and supervises its corresponding team, providing feedback to the Board on performance and anticipating any needed intervention.

9.6.2 Main objectives and actions planned for 2020

In the scope of the presented mission, the Manager's goal s are the following:

- to guarantee that all internal rules and procedures are coherently followed in close collaboration with organization and management services;
- to cooperate in the team's assessment process;
- to contribute to the implementation of a Training Plan;
- to schedule assistants to accommodate absence periods;
- to constantly review the established corporate protocols necessary for the current activity of the team (hotels, renting companies, travel agencies, etc) and to create new protocols, if necessary;
- continuously contribute to the improvement of INESC TEC's procedures and tools.

In addition to the development of these goals, in the year of 2020, the Managers will work on the following actions:

- cooperate with Management Support in bi-weekly meetings with the purpose of achieving the continuous improvement of processes at INESC TEC;
- normalize the processes that are mandatory for an Administrative or Executive Assistant at INESC TEC, through a comprehensive guide;
- implement the digital archive, gradually ending with paper support;
- implement the activity annual planning of the Executive Assistants of Board of Directors;
- implement the networking of the Executive Assistants of Boards of Directors;
- create a tool to register and track activity indicators related to the team's work (conference and event organization, schedule management as well as other defined indicators). These would provide additional administrative indicators and thus a more profound assessment of the team's activity;
- promote team meetings, with the purpose of general improvement of the service and satisfaction of its clients, as well as the team itself;
- promote better work conditions;
- promote coaching sessions conducted by the main services at INESC TEC;
- evaluate and propose training solutions, including the organization of the Workshop "Assistant Day@INESCTEC", an initiative designed with the purpose of refreshing concepts and developing team building activities to increase the service's efficiency;

- maintain the Directory of Useful Information at Secr-Drive: residences or renting agencies for scholars or visiting fellows, bus companies or other transports, venues for events, catering companies, IT suppliers and many others.

It is the service suggestion, that Management Control should issue a Periodic Report regarding Travel and Purchase processes in PLONE to give each centre feedback regarding the approval or rejection of expenses, within the rules of eligibility and according to the feedback from Funding Agencies. This report should be issued with the necessary frequency that would allow the team to learn from work pattern and correct it, improving global Indicators and, ultimately, obtaining a budget optimization by increasing the rate of approval of expenses.

9.7 FUNDING OPPORTUNITIES OFFICE

Manager: Marta Barbas

Table 9.1-SAAF – Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	1	1	1	
	Academic Staff				
	Grant Holders and Trainees			1	1
	Affiliated Researchers				
	Total Integrated HR	**1**	**1**	**2**	1
	Total Integrated PhD				

9.7.1 Presentation of the Service

The Funding Opportunities Office aims at identifying the relevant funding opportunities to support INESC TEC Research, Development and Innovation activities, always aligned with the mission and objectives of the Institute. This service will also support and supervise the development and submission of proposals to different funding programmes, always in collaboration with the R&D Centres and with the other Business Development Services.

9.7.2 Main actions planned for 2020

- Recruitment of a trainee for the reinforcement of the team in order to meet present and new framework programme funding challenges and to respond to researchers' demands;
- Regular organization of workshops to explain the procedures for preparing and submitting proposals to specific calls;
- Monthly presentation (@ CCI and Intranet) of open calls and proposals submission;
- Improvement of "proposals workflow" together with SIG;
- Creation of a new website, together with SIG, for funding opportunities in order to guarantee the most effective dissemination.

9.8 TECHNOLOGY LICENSING OFFICE

Manager: Catarina Maia

Table 9.1 - SAL - Service team composition

	Type of Human Resources	2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	2	3	3	
	Academic Staff				
	Grant Holders and Trainees	1			
	Affiliated Researchers				
	Total Integrated HR	**3**	**3**	**3**	
	Total Integrated PhD	1	2	2	

9.8.1 Presentation of the Service

The mission of the Technology Licensing Office is to protect and license technology developed at INESC TEC. To carry out its mission, the office works in close collaboration with the Legal Support Service and the Industrial Partnerships Service. The office's responsibilities consist of establishing and managing INESC TEC's processes related to: internal scouting and dissemination of research results that can be protected by Intellectual Property (IP) rights; market and state of the art assessment; definition of IP strategy; technology licensing; negotiation and monitoring of licensing contracts.

9.8.2 Main actions planned for 2020

The office's main activities planned for 2020 include:

- technology scouting;
- market research and business development for licensing opportunities, namely through suitable brokers;
- manage the current Compete 2020 patent funding projects;
- develop and maintain INESC TEC's technology offers in our website;
- actively monitor open innovation platforms for technology calls that can be met by INESC TEC's technologies;
- engage in INESC TEC's spin-offs' support, following up on the projects and reporting to INESC TEC's Board of Directors;
- support INESC TEC's technology negotiation and transfer activities;
- represent INESC TEC in the TTO Circle and ASTP;
- staff involvement in the execution of European projects exploitation plans;
- develop a new, dedicated software disclosure form;
- increase open source licensing awareness and close relationship with INESC TEC's software repository.

The service will continue to provide support on IP matters to INESC TEC researchers through:

- meetings and workshops for IP knowledge dissemination;
- support in contracts negotiation and background identification;
- patent landscapes searches;

- support to patent drafting;
- the preparation of applications for public funding of patent processes.

The service will continue to provide support on IP matters to INESC TEC's Board of Directors, namely:

- evaluation of invention disclosures;
- INESC TEC's Intellectual Property Guidelines and Regulation;
- draft and implementation of spin-off policies;
- licensing to spin-offs;
- support INESC TEC's presence in trade fairs;
- continue to support INESC TEC's researchers in regards to open science;
- report on IP key performance indicators for stakeholders.

9.9 INTERNATIONAL RELATIONS SERVICE

Manager: Andreia Passos

Table 9.1 - SRI - Service team composition

	Type of Human Resources	2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees		4	4	
	Academic Staff				
	Grant Holders and Trainees	1	3	3	
	Affiliated Researchers				
	Total Integrated HR	**1**	**7**	**7**	
	Total Integrated PhD				

9.9.1 Presentation of the Service

A stepping-stone to the professionalization of internationalization support activities at INESC TEC, the **International Relations Service (SRI)** was established in the fourth quarter of 2019 to support the Board of Directors (BoD) **in the conception, implementation and monitoring of the organisation's overall internationalization strategy.** The support provided by the service, which reports directly to the BoD, intends to be manifold and to bring new breadth and depth to INESC TEC's commitment to active global presence. SRI's activities spread across **three operational areas**:

International Cooperation: This area encompasses working closely with the BoD to identify and develop new or strengthen existing international institutional partnerships; reviewing, assessing (proposals for) and monitoring overarching international partnership agreements, commonly designated as Memoranda of Understanding; liaise with external contacts to prospect relevant internationalization opportunities aligned with INESC TEC's competencies, assets and priorities; manage international S&T partnerships on behalf of third parties | **International Mobility:** This area includes both the induction of foreign staff and the assistance to staff wishing to spend some time abroad in a host organization with the purpose of acquiring new knowledge, forging new research collaborations, conducting and / or participating in lectures or courses or taking part in joint research activities | **International Culture:** This area involves activities aimed at embedding internationalization in the organization's mindset and valuing cultural diversity. The service also works to educate Centres / TEC4s and Clusters to keep the records of their international activities up-to-date for monitoring, reporting and profile-raising purposes.

The SRI will accommodate the current three INESC TEC's international-oriented offices (Brazil, India and Brussels). The offices will rely on the processes and procedures that delimitate the SRI's operational areas, while benefiting from a backup team in Portugal that should allow them to keep focused on the prospection and development of strategic partnering opportunities in their addressed markets. The leadership of these offices reports directly to INESC TEC's BoD in relation to strategic matters regarding performance in such markets, not to the SRI.

9.9.2 Main objectives and actions planned for 2020

In 2020, the SRI will begin to operate according to the vision set out for the service and stemming from the service handbook. Over the course of 2020, the service will test and refine, as needed, the procedures, templates, tools and indicators proposed during service conceptualization and collaborate with other services of the organization in order to effectively contribute to enhancing INESC TEC's global presence and global presence at INESC TEC.

Besides the day-to-day operation, the SRI will be particularly committed in 2020 to:

- Assisting the BoD in the formulation and dissemination of an internationalisation strategy utilising the developed conceptual framework for designing an internationalisation strategy;
- Mapping, analysing and reporting on live/ active international MoUs so as to effectively understand their level of progress and actual or expected impact;
- Mapping, analysing and reporting on the internalisation profile of INESC TEC's core R&D structures (opt either for TECs, Clusters or Centres as units of analysis);
- Establishing a Cultural Ambassadors' Network and an internal Internationalisation Committee.

9.10 COMMUNICATION SERVICE

Manager: Sandra Pinto

Table 9.1 - SCOM - Service team composition

	Type of Human Resources	2017	2018	2019 (Plan)	Δ 2018 - 2019
Integrated HR	Employees	5	5	5	
	Academic Staff				
	Grant Holders and Trainees	1	2	1	-1
	Affiliated Researchers				
	Total Integrated HR	**6**	**7**	**6**	-1
	Total Integrated PhD				

9.10.1 Presentation of the Service

The Communication Service collaborates with the Board in order to define the institution's communication strategy and image. Its main activities are planning, implementing, organising and coordinating both internal and external communication in accordance to the regulations and procedures established, promoting the image and prestige of the institution.

9.10.2 Main objectives and actions planned for 2020

The Communication Service has been defining its strategies in accordance with the principles of integrated marketing communication, which involves a number of tools, such as Public Relations (events, media advisory), digital marketing (social media management), sponsorships, exhibitions and fairs. The goal is that these tools can complement each other in a coordinated way in order to bring more recognition to INESC TEC's brand.

9.10.2.1 New actions planned

- In 2020, the Communication Service will coordinate all the initiatives of the 35th anniversary celebration. In this regard, an internal event will be organised, with playful and team building activities for collaborators and families, aiming at promoting a sense of belonging and strengthening the cohesion. An edition of the Autumn Forum - Special 35 years, targeted to companies and society, will be held in Porto. Also within the context of the 35th anniversary, other smaller initiatives will be organised, always aiming at increasing the recognition of INESC TEC's brand and state the position of INESC TEC with its stakeholders.
- Considering that the video marketing remains one of the main trends in the digital communication strategies and continuing to focus on video production for the several channels of INESC TEC, a new multi-purpose institutional video will be produced and launched in 2020. This video should be suitable for several audiences and versatile for the different platforms (website, social networks, events and institutional presentations).
- Taking advantage of the 35th anniversary celebration, an intervention of the entrance hall of building A is planned to redesign the space to reflect an image associated with innovation, excellence and ambition.
- Concerning INESC TEC's corporate image, new communication supports will be created, such as new leaflets, roll-ups and Powerpoint presentations. The goal is to give visibility to the organisation in Clusters and TEC4.
- The Communication Service will also undertake actions, together with the Human Resources Service, to improve the attraction and retaining talent, with a special focus on the reception of multicultural and transparent aspects. In this context, should be highlighted the role of the Communication Service in the

process of providing support to events, mostly organised by students, to attract new talent to INESC TEC.

9.10.2.2 Standard and enhanced actions planned

- Concerning to Public Relations, it is worth mentioning the events organised by INESC TEC, such as Seminars, Workshops and Open Days, the participation in international events such as the European Utility Week and the role of INESC TEC in other renowned events. These initiatives allow INESC TEC to attract public and media attention and to increase brand awareness.
- It is also important to stress the support that the Communication Service provides to INESC TEC's R&D Centres with the dissemination of work packages in European projects such as InterConnect, FEEdBACk and Ambience, as well as to the EEN network and project CHIC. The support of the Service in the writing of proposals (communication and dissemination actions) for new projects should also be highlighted.
- Regarding media advisory, the Communication Service will continue to communicate in international media, using the new platform Medium to foster international dissemination of INESC TEC's achievements. Furthermore, to broaden more visibility, the less active R&D Centres in the media will be encouraged to communicate more.
- The regular communication activities are also worth mentioning, namely: national media advisory, promotional project videos, organization of Science Communication initiatives, production of the institution's bilingual monthly newsletter (BIP), oversight of visits to INESC TEC, photo and video coverage of events.
- Concerning the presence of INESC TEC on social media, we will continue the strategy of increasing the social media's community and the awareness of INESC TEC collaborators during this year. Moreover, the Board and Coordinators will be encouraged to play an active role in social media.
- Regarding internal communication, initiatives such as the "Strategic Meeting for senior researchers" and the "INESC TEC on foot" (hiking for all collaborators) will be organised. The "INESC TEC on the move" (Team Building for all collaborators) can eventually be integrated into the initiatives of the 35th anniversary.
- A training session entitled "Improve your public speaking skills" is also planned for researchers, aiming at preparing themselves to present their projects more appealingly and engagingly. It is also worth mentioning the usual media and social media training sessions.
- Finally, other usual internal events will be organised, such as photo competitions, "Magusto" and the multicultural party, as well as monthly welcome sessions for new collaborators.

9.11 NETWORKS AND COMMUNICATIONS SERVICE

Manager: Gil Coutinho

Table 9.1 - SRC - Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	2	2	2	
	Academic Staff				
	Grant Holders and Trainees			1	1
	Affiliated Researchers				
	Total Integrated HR	**2**	**2**	**3**	1
	Total Integrated PhD				

9.11.1 Presentation of the Service

The mission of the Networks and Communications Service is to provide for the communication needs of INESC TEC's community. This service manages INESC TEC's voice and data infrastructures and is responsible for the implementation and maintenance of network-based services, as well as for providing the respective support.

9.11.2 Main actions planned for 2020

Besides the continuous operation, administration, management, provision and troubleshooting of INESC TEC's local area network, its associated services and connections to external entities, the Networks and Communications Service will in 2020:

- Continue the upgrade process of the switching infrastructure, providing access speeds of 1 Gigabit/s to workstations;
- Further upgrade the existing videoconferencing infrastructure, namely by extending its usability to other rooms;
- Decommission and replace the outdated VoIP infrastructure, and start the modernization process of VoIP terminals;
- Reformulate the network-based printing and scanning solution, namely by starting an upgrade process of the equipment and simultaneously outsourcing the provisioning of supplies and support;
- Simplify and further automate the network's access granting procedures to new devices and users.

9.12 MANAGEMENT INFORMATION SYSTEMS SERVICE

Manager: José Carlos Sousa

Table 9.1 - SIG - Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	4	3	3	
	Academic Staff				
	Grant Holders and Trainees			2	2
	Affiliated Researchers				
	Total Integrated HR	**4**	**3**	**5**	2
	Total Integrated PhD				

9.12.1 Presentation of the Service

The Management Information Systems Service is in charge of the development and maintenance of INESC TEC's management information system.

9.12.2 Main actions planned for 2020

- Maintenance of INESC TEC Website;
- Continuous improvement of processes;
- Implementation of the Projects Database and interconnection with the uONE project management tool;
- Complete the systematic collection of all institutional indicators and improvement of its visualization;
- System for reporting research results to the Associates and FCT;
- Establishment of a CRM system, interoperable with the INESC TEC information system;
- Interoperatibility between Ciência Vitae and INESC TEC publications system;
- Integration of Eletronic Invoicing with the INESC TEC information system.

9.13 SYSTEM ADMINISTRATION SERVICE

Manager: Jaime Dias

Table 9.1 - SAS - Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	3	3	4	1
	Academic Staff				
	Grant Holders and Trainees				
	Affiliated Researchers				
	Total Integrated HR	**3**	**3**	**4**	1
	Total Integrated PhD				

9.13.1 Presentation of the Service

The System Administration Service is responsible for managing servers, computer systems and common applications, and for providing support to end-users, administrative staff as well as research and development teams. This Service is also responsible for managing the INESC TEC Living Lab, in collaboration with Research Centres and other Services, to enable INESC TEC's building and infrastructures as real-life testbeds while promoting R&D results.

9.13.2 Main objectives and actions planned for 2020

Besides the helpdesk service, the maintenance and continuous improvements of the infrastructures and services provided by SAS, next are highlighted the main objectives and actions planned for 2020.

SAS will continue expanding and improving the storage and computing infrastructures to deal with the growing demand in terms of both resources and technologies.

The HPC-GGPU cluster will be improved with a new multi-tenancy platform to increase cluster usage efficiency.

The DevOps platform will be extended with new computing resources and functionalities, from software development to application/service production. SAS will promote DevOps training sessions to researchers.

SAS will continue assisting the Data Protection Officer on system security audit and security policy definition to enforce the deployment of the General Data Protection Regulation.

SAS will maintain the Identity Provider service at INESC TEC, which allow INESC TEC collaborators to access the services, provided by RCTSaai and eduGAIN, and, when required, will enable the federated authentication and authorization on services provided by INESC TEC to the academic community.

The INESC TEC Living Lab initiative will continue. The INESC TEC Living Lab aims at promoting and enabling the exploitation of INESC TEC R&D results, and use the INESC TEC building and infrastructures as a laboratory testbed for experiments with real people and real scenarios. The promotion shall exploit the "WOW Effect", increase researcher's inspiration and creativity, and help attracting new customers and researchers. Centres will have a central role in the definition of the testbeds and on the selection of the R&D results to be promoted. Some of the planned equipment are Smart Displays, which will allow the presentation of news, promotion of INESC TEC R&D results, access to remote testbeds and equipment in real-time, and possibly to building telemetry.

9.14 INFRASTRUCTURE MANAGEMENT SERVICE

Manager: Jorge Couto

Table 9.1 – SGI - Service team composition

Type of Human Resources		2018	2019 (Forecast)	2020 (Plan)	Δ 2019 - 2020
Integrated HR	Employees	4	4	4	
	Academic Staff				
	Grant Holders and Trainees				
	Affiliated Researchers				
	Total Integrated HR	**4**	**4**	**4**	
	Total Integrated PhD				

9.14.1 Presentation of the Service

The Infrastructure Management Service guarantees the support services necessary for adequate management and maintenance of INESC TEC's building and infrastructures.

9.14.2 Main actions planned for 2020

- Develop a set of maintenance actions in the buildings' electrical infrastructure (transformer substation, main and partial switchboards);
- Schedule maintenance of electrical equipment (transformer substation, switchboards, water pumps, etc.);
- Continue actions to prevent and fight building fires;
- Schedule and register technical verifications of equipment installed at INESC TEC to detect and fight building fires;
- Continue the painting works using internal resources and eventually outsource if necessary;
- Improve the floor of the backyard patio on B Building, allowing more adequate emergency exit for people with reduced mobility and for transporting heavy loads;
- Improve the conditions of lunchrooms and bar;
- Use as frequently as possible internal resources in the different maintenance and support tasks;
- Change the financial model of corporate cars, replacing the oldest ones by renting contracts, preferably full electric or plug-in hybrid cars;
- Improve the image and environment inside the buildings with natural plants;
- Improve the outside environment by creating a rest zone in the garden;
- Improve the documentation of the service processes and equipment;
- Increase the level of usage of tickets for services to be provided;
- Incorporate the measures outlined by the Social Responsibility Commission.