INSTITUTE FOR SYSTEMS
AND COMPUTER ENGINEERING,
TECHNOLOGY AND SCIENCE

INESCTEC

INESC TEC
ACTIVITY PLAN
2022

Editorial Notes

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1.1 Profile, vision and mission

INESC TEC is a private, non-profit association with Public Interest status, 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. INESC TEC's sites are located in the cities of Porto, Braga and Vila Real. At the end of September 2021, INESC TEC's 13 R&D Centres hosted 743 integrated researchers (328 PhDs), including R&D employees, academic staff, grant holders and affiliated researchers. INESC TEC's team also includes technical and administrative support staff and trainees.

INESC TEC endeavours 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 generates new knowledge as part of its research, and leverages that knowledge in technology transfer projects, seeking impact through both value creation and social relevance.

The overarching mission of INESC TEC is to excel in research while looking for its social and economic impact, with a unifying commitment to the scientific and technological aspiration of fostering pervasive intelligence.

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

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 different technology transfer instruments (Figure 1.1).

Research at INESC TEC is undertaken in its 13 Research Centres and structured in four broad Scientific Domains: Computer Science (CS), Industrial and Systems Engineering (ISE), Networked Intelligent Systems (NIS), and Power and Energy (PE). The main technology market drivers express themselves internally through the TEC4 initiatives, currently TEC4SEA, TEC4HEALTH, TEC4AGRO-FOOD, TEC4ENERGY and TEC4INDUSTRY.

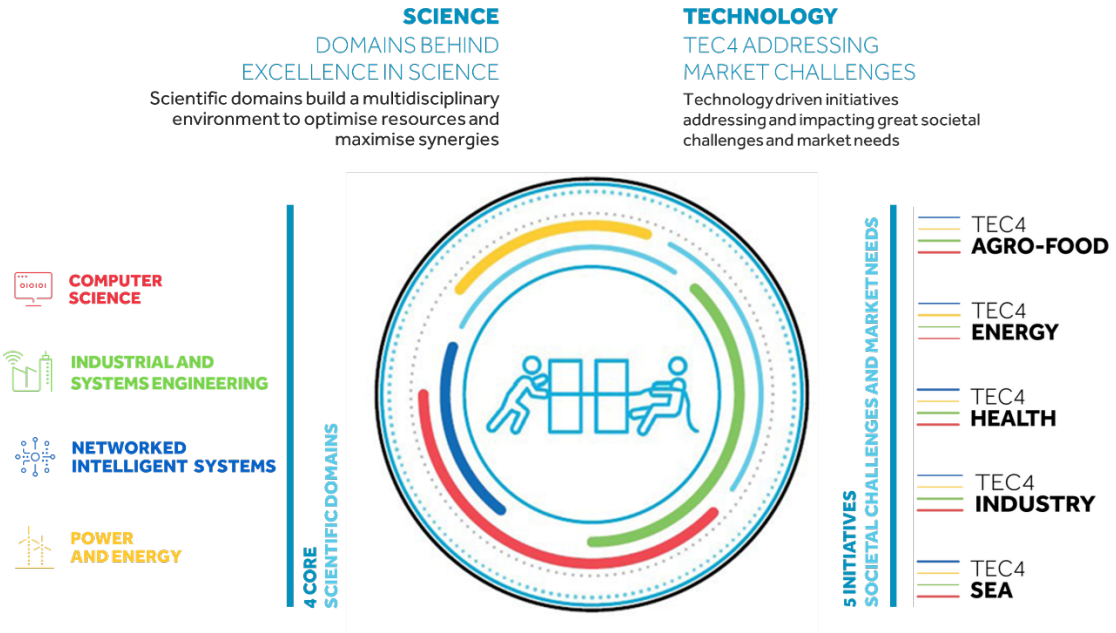


Figure 1.1 - Fostering pervasive intelligence

1.2 Organisational structure

Figure 1.2 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 five out of those nine members. The Boards act in close coordination with the Council of R&D Centres, meeting every other week with the Centre Coordinators and the Managers of the different Support Services. This ensures institution-wide coherence in vision, policy and operations, and joint responsibility and commitment in both strategic and operational management decisions.

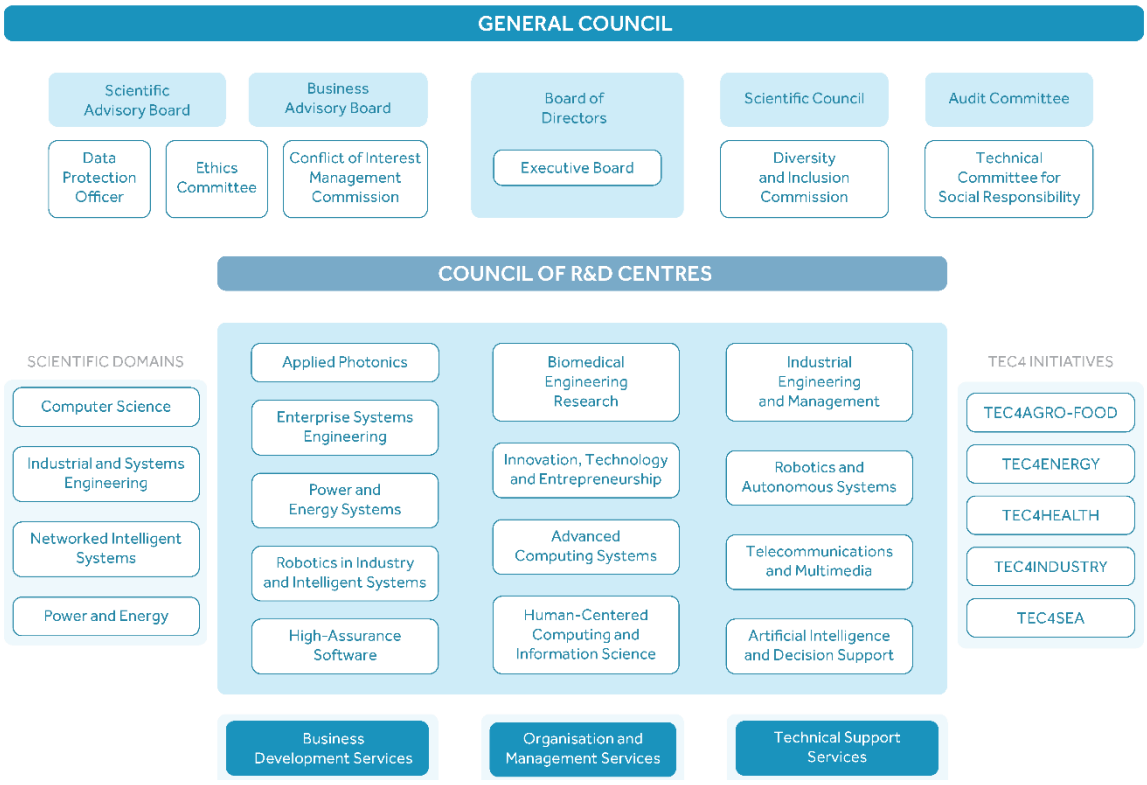


Figure 1.2 - Organisational structure

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

The Scientific Domains are meant to structure the institute's research competences and challenges facilitating strategic thinking, trajectory monitoring, and science communication.

The TEC4 initiatives articulate INESC TEC's activity towards major market sectors and address current societal challenges, defining market strategies and planning the interaction with major application areas. A TEC4 initiative establishes a network of external contacts and a dialogue with industrial and institutional partners and brings back major challenges and opportunities to multiple Centres.

The Scientific Advisory Board is composed of twelve internationally recognised scientists that support the institution in its search for continuous improvement and excellence, building a vision for future research through a valuable benchmark at international level. The external monitoring, orientation and evaluation of the technology transfer and innovation activities are entrusted to the Business Advisory Board, whose members have knowledge and experience in several economic sectors of relevance to INESC TEC. The Scientific Council is an internal body responsible for monitoring and guiding scientific and technical activities, and it includes one representative from each Centre and three additional members appointed by the Board of Directors.

The Conflict of Interest Management Commission and the Data Protection Officer are responsible for the implementation of the institute's Policy on Conflicts of Interest Management and the General Data Protection Regulation, respectively. The Technical Committee for Social Responsibility has the mission to incorporate social

responsibility in the institution organisational culture and practice. The Diversity and Inclusion Commission will thrive to encourage the organisation to implement practices that promote diversity and inclusion and develop long-term work in this field, by proposing and implementing a D&I Program for INESC TEC, including the issue of gender balance as one of the priorities. The Ethics Committee will implement the recently approved INESC TEC's Ethics Code. A new office will be created to promote and articulate the institution's contributions to public policies.

A streamlined and dynamic team of highly qualified technical and administrative personnel provides support to INESC TEC's activities, organised across the following areas: Business Development, Organisation and Management, and Technical Support.

1.3 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 multidisciplinarity;
- Scale and density;
- International visibility and presence;
- Ethics, social responsibility, gender equality, diversity and inclusion.

1.3.1 Excellence in research, talent development, and innovation

Knowledge generation at INESC TEC stems from a base of rigorous scientific research, and flourishes in a dynamic research environment that enables the institute to engage in and foster the development of excellent researchers. The involvement in PhD and Masters Programmes strengthens the institute's ability to attract and motivate young talent in conducting highly relevant research. The institute's focus on impactful research challenges, along with its culture of collaboration with industry thus, provides an ideal environment for innovators.

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

1.3.2 Full coverage of the knowledge value chain

INESC TEC creates new knowledge and technology and supports companies innovating products, processes, services and business models, contributing to their competitiveness and ensuring economic and social impact. The success of INESC TEC's managed science model relies on the ability to establish upstream and downstream flows along the knowledge value chain, punctuated by feedbacks at multiple levels. The interaction and collaboration with industry is essential for the identification of new research challenges and the valorisation of research results is key to the economic sustainability of the institute.

To excel in these dynamics and to be able to fully fulfil its mission, INESC TEC is increasingly challenged to ensure that individual researchers focus where they feel more comfortable to perform at their best. The Research Centres are where the diverse activities and personal contributions are balanced under an agreed strategy. All the work is project based and quarterly monitored, from both research outcomes and economic sustainability perspectives. The Centres are expected to reach the critical mass that allows knowledge to flow not only within each Centre, but also among Centres.

1.3.3 Integration and multidisciplinarity

INESC TEC pays constant attention to its integration dynamics, as the institution and its context undergo continuous changes, and its resources are accordingly renewed, strengthened, and recombined. The Scientific Domains 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-fertilisation, originating new science through fusion of knowledge and skills, and conducting 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. Other instruments, such as the Internal Seed Projects, which support inter-Centre research, junior researcher development, and proof-of-concept activities, also play a key infrastructural role in this purpose.

1.3.4 Scale and density

INESC TEC's ambitious vision and mission require a level of scale and density that is nurtured by its multi-institutional base model. The resource endowment collaboratively brought to INESC TEC by its associates 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 future key priorities is a consistent effort to widen its activities and attract leading researchers to further reinforce its human capital.

1.3.5 International visibility and presence

Excellence in science and technology requires nowadays collaboration and strong partnerships with leading international research institutions and companies. INESC TEC's international projects and activities are crucial to secure its status of an international player, ensuring the institution's effective participation and recognition in the global arena. INESC TEC permanently directs significant efforts to its international activities, so that they continue to play a major role, increasing the capacity to promote projects, secure funding, and attract human resources at an international level.

1.3.6 Ethics, social responsibility, and diversity and inclusion

Ethics is core to INESC TEC's multiple endeavours and for many different reasons. The institute's community has a shared interest in protecting its research, education, and innovation environments, that the recently approved Code of Ethics reinforces, through the formalisation of the ethical principles, commitments and procedures that must guide individual and institutional conducts, in order to affirm a culture based on rigour, competence, transparency and respect for others, both in research and in management.

As a whole institution, INESC TEC exists and operates on an implicit social contract with its community at large. As such, in addition to the desired outcomes for its associates and research and innovation partners, the institute's strategy and activity must also be aligned with the stakeholders strategy and outcomes. This shared realisation has been taking shape in the institute and has led to the appointment of a Social Responsibility Technical Committee and to the adoption of a plan aiming at the embedment of the values and concerns of social responsibility in INESC TEC.

Building on a practice of compliance with non-discrimination and equality rules, INESC TEC is now committing to a more pro-active approach to building a diverse and inclusive community, having recently signed the Portuguese Diversity Charter as a public commitment with this Policy. This approach is not only in line with the institute values and law requirements, but also with the value of well-established contributions to research and innovation outcomes. Gender equality, ethnic and cultural diversity and inclusion practices are among key priorities to be addressed by the recently appointed Diversity and Inclusion Commission.

1.4 Research and innovation

INESC TEC's vision for research and innovation is that of a society increasingly assisted by human-centred, trustworthy, sustainable, smarter and autonomous computing systems. The conveyed image translates into the

commitment to foster pervasive intelligence through the creation of new computer intelligence paradigms, their development and application. This is enabled by the institute's size, diversity and managed science model, fertile ground for multidisciplinary cooperation.

Current computer systems, pervading the society, in public administration, industry, earth observation, etc. and large scale critical systems such as utilities, healthcare, transportation, and finance, present new opportunities and challenges that demand competences and capacity across multiple scientific domains and in all technology readiness levels.

INESC TEC's researchers cover more than forty scientific disciplines structured around four scientific domains and cooperate towards meeting sixteen short- to medium-term research challenges. The latter include achieving machine perception, making communication systems context-aware, creating all sorts of human-empowering computing, improving the quality and key non-functional properties of information and industrial systems, increasing the autonomy of robotic systems, achieving full and resilient renewable energy systems, and achieving responsible and sustainable technology-driven innovation.

Research and development are complemented by knowledge valorisation and technology transfer activities, made credible by INESC TEC's sizeable portfolio of partners and customers. Currently, through TEC4 initiatives, business development focus on five socioeconomic areas: sea, healthcare, agriculture and food, energy, and industry.

1.5 2022 external context outlook

The macroeconomic scenarios underlying the outlook for 2022 remain marked by a context of uncertainty as a result of the COVID-19 pandemic. The projections of the Portuguese Ministry for Finance, when preparing the state budget for 2022, forecast economic 5.5% growth in 2022, estimating that the national public accounts deficit should remain at 3.2% of Gross Domestic Product (GDP), and also predicting that the Portuguese unemployment rate would fall to 6.5%, the lowest since 2003.

Despite the uncertainties of the current context, the expected growth rate of the Portuguese economy also driven by four European programmes along the decade - the PRR (Portuguese Recovery and Resilience Plan), PT2030, Horizon Europe and INvestEU 21-27 - constitute an opportunity for the development of INESC TEC's activity, with a special emphasis on the cooperation with companies.

The pandemic has nevertheless led to severe constraints in global supply chains and relevant changes in the demand leading to significant impacts at the supply level and imbalances in the labour market that amplify the risks of achieving reasonable precise macroeconomic scenarios projections. Therefore, the lack of raw materials, equipment and components will continue and, in parallel, there are other constraints affecting the supply chains. Examples are the lack of ships, containers and truck drivers, the Brexit, the energy costs and the increase in fuel prices which, combined with the market pressure on the recruitment of qualified staff, may jeopardise the expected macroeconomic evolution as well as limit the potential evolution of INESC TEC's activity.

Since March 2020, and according to an established contingency plan, INESC TEC has adopted the necessary measures to protect the health of both its researchers and staff, adopting the telework regime in an extended way with impact and adjustment in its operation. Since then, a set of measures were taken to follow up and monitor the activity, which have shown that most of the ongoing projects continued at a good pace of execution, even in the most critical phases of the pandemic, with the activity having maintaining a positive evolution in 2020 that is expected to continue towards the end of 2022.

1.6 Main initiatives for 2022

To fulfil its policy priorities and reach its objectives, for 2022 and beyond, INESC TEC is committed to a set of initiatives. These will enable the institute to strengthen its intervention capacity in the national and international areas, as well as its ability to carry out its mission for the benefit of society.

These initiatives are summarised below, under the following categories: excellence in research, managed science model, partnership with HEI, structural initiatives, internationalisation, contributions to public policy, openness to society, and support structure.

- Excellence in research
  (in line with the policy priority "Excellence in research, talent development, and innovation")
    - Preparation of the coming FCT R&D Unit Evaluation process, taking into account the review and discussion of the institute's scientific strategy and goals undertaken by the Scientific Advisory Board;
    - Reinforcement of the international recognition of researchers, through the encouragement of high quality publication profiles, and actions to support applications to international awards, and ACM and IEEE Fellowships;
    - Launching of the fourth call for Internal Seed Projects, aiming at supporting internal exploratory R&D projects (in the categories of inter-centre research, junior researcher development and commercialisation proof-of-concept);
    - Maintain INESC TEC's involvement in PhD and Masters Programmes, essential to its ability to attract and involve young talent in conducting and disseminating excellent research while leveraging the intervention of Higher Education Institutions (typically assisting more than 20 PhD programmes, and involving over 250 PhD students and 500 master's students);
    - Reinforcement of INESC TEC's research team with the recruitment of researchers for key strategic areas, in line with the institute scientific strategy;
    - Reinforce the implementation of research careers.

- Managed science model
  (in line with the policy priorities "Full coverage of the knowledge value chain" and "Integration and multidisciplinarity")
    - Review of INESC TEC's managed science model, by proceeding with the implementation of the new organisation of Research Domains and by fostering their closer strategic integration with the other two key internal R&D organisational units – Centres and TEC4s;
    - Reinforcing the Business Advisory Board for the forthcoming mandate.

- Partnership with Higher Education Institutions
  (in line with policy priorities "Excellence in research, talent development, and innovation" and "Scale, density, and critical mass")
    - Continued efforts to establish more detailed protocols with INESC TEC's Associate HEI as to frame the double assignment and sharing of human and material resources and regulates matters such as Intellectual Property;
    - Continued collaboration in the Advanced Studies Programmes running in several Associate HEI, to offer post-graduate training within the scope of R&D projects, both through a structured introduction to transferrable skills (innovation, entrepreneurship, leadership, and time management, among others) as well as through the specialisation in technological areas;
    - Further collaboration and sharing of good practices between INESC TEC and ISPUP - Institute of Public Health of the University of Porto in the area of data protection, with the implementation of screening instruments for R&D and Data Protection Impact Assessments (DPIA) of project proposals, with a view to establishing internal audit procedures;
    - New facilities and expansion of iiLab – Industry and Innovation Lab, a cross-Centre infrastructure covering areas such as Cyber Physical Systems (CPS) and Internet of Things (IoT), Business Intelligence and Decision Support Systems, Advanced Automation and Industrial Robotics, Mobile Robotics and Internal Logistics, Industrial Vision Systems for Inspection and Quality Control, to be located in a P.Porto building.

- Structural initiatives
  (in line with the policy priority "Ethics, social responsibility, and diversity and inclusion")

- Full operation of the newly created Ethics Committee, whose mission is to ensure the observance and promotion of standards of integrity, honesty and responsibility in research activities carried out by INESC TEC members, through the implementation of the Code of Ethics that establishes the principles that must guide individual and institutional conducts.
- Full operation of INESC TEC's Diversity and Inclusion Commission that will focus on three key areas: (1) Launching and promoting an enlarged advisory group for diversity and inclusion, in order to support and advise the D&I Commission. (2) Approving and implementing a Gender Equality Plan. The Board has established Gender Equality as one of the main priorities of the work in this area in the following years. The D&I Commission is preparing a Gender Equality Plan (GEP) with a diagnosis of the current situation in INESC TEC and an Action Plan towards gender equality for the next years. In 2022, the GEP will be approved, implemented and monitored in INESC TEC. (3) Setting the key D&I priorities for the following years. Supported on a diagnosis of the current situation and the validation and orientation of the internal and external advisory groups, INESC TEC will set the main priorities within the existing D&I dimensions or areas of action.
- Further implementation of social responsibility policies with the support of the Social Responsibility Technical Committee, enabling related concerns to be addressed throughout the institution, with activities that include external and internal dimensions. As the pandemic situation made it difficult to deploy all the previously defined activities, the intention is that in 2022 the social responsibility activities will be implemented taking into consideration the previously defined strategy and that includes, among other aspects, new human resources practices, the identification of activities with direct and indirect environmental impact, or even the development of marketing strategies associated with social causes.
- With the leadership of INESC TEC's Data Protection Officer (DPO) and the support of a multidisciplinary team, pursue the monitoring of the of the institute's General Data Protection Regulation (GDPR) compliance plan. Efforts in 2022 will be channelled, in particular, to: (1) Strengthening the training plan for staff members and researchers, including new resources and new modules in the existing online training courses; (2) Continuous cooperation and coordination efforts with ISPUP under the Protocol established in the field of Personal Data Protection, following the hiring of an additional team member. (3) Continuous cooperation with AG (Management Support Service) in the development of a document management policy for INESC TEC.

- Internationalisation
  (in line with the policy priority "International visibility and presence")
  - Full operation of INESC Brussels Hub, the Brussels representation of INESC TEC, INESC Coimbra, INESC ID, INOV INESC and INESC MN, set up 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;
  - After the recognition of several Digital Innovation Hubs, INESC TEC will participate in the preparation of applications for the Call for European Digital Innovation Hubs. Special highlight to the ATTRACT DIH (Digital Innovation Hub for ArTificial InTelligence and High-PeRformAnce CompuTing), coordinated by INESC TEC;
  - Monitoring of INESC TEC's strategy for successful participation in the European calls, especially in the scope of the Horizon Europe programme;
  - Active participation in projects and activities of the European Knowledge and Innovation Communities (KICs) EIT Raw Materials and EIT Manufacturing;
  - INESC TEC will carry on coordinating the UT Austin Portugal Program on the Portuguese side. In 2022, this International Partnership will celebrate its 15th anniversary with a communication plan evoking the Program's impact on Portugal's research and innovation landscape. INESC TEC remains fully committed to: 1) Supporting and monitoring the Partnership's exploratory and

strategic research projects, leveraging inter-collaboration between them and also with high-level national and international initiatives; 2) Organising advanced training programs for its transatlantic community across the five core knowledge areas; 3) Supporting the placement at UT Austin of researchers affiliated with Portuguese research organisations for advanced hands-on training; 4) Raising awareness of the Partnership's impact over the years through creation and dissemination of success stories; 5) Taking the Program's brand beyond UT-Portugal boundaries, evidencing Portugal's successful experience with transnational S&T partnerships; and 6) Implementing the recommendations of the Program's main governing bodies.

  - Strengthen participation as a member in international organisations (15+), in broadened geographies, and strengthening of the collaboration with international partners (Memoranda of Understanding, R&D contracts, researchers exchange programmes, etc).

- Contributions to public policy
  (in line with policy priorities "Full coverage of the knowledge value chain" and "Integration and multidisciplinarity")
  - Creation of a new organisational structure to coordinate contributions to public policy and follow-up on public policies in areas of expertise of the initiative by monitoring their instruments as well as the interventions of policy makers, regulatory bodies, interest associations and other stakeholders in the public space, at events, in Parliament, and in the media;
  - Continuous involvement in the update of the regional and national Smart Specialisation Strategies in the institute's areas of expertise;
  - Strong contribution to the CoLABs (Collaborative Laboratories) public policy objective through the development of the twelve institutions that INESC TEC participates in, with academic and business partners, in order to exploit knowledge created in research institutions and address major societal challenges;

- Openness to society
  (in line with policy priorities "Full coverage of the knowledge value chain" and "Integration and multidisciplinarity")
  - Organisation of the Autumn Forum, annual event seeking to actively make a contribution to the public policy debate, by inviting relevant actors to present and discuss their views on topics of relevance for the country;
  - Organisation of the renowned international conference PSCC'2022 – XXII Power Systems Computation Conference;
  - Launch of the 4th and 5th issues of the magazine "INESC TEC Science & Society" aimed at citizens interested in general knowledge about research, its possible applications and impact on society, as well as informed opinions on the public policies most influenced by technology;
  - Promotion of open days, organised by an increasing number of R&D Centres, 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.

- Support structure
  (in line with the policy priority "Excellence in research, talent development, and innovation")
  - Implementation of the new model for Human Resources management, with special focus on the areas of recruitment and selection, training, performance appraisal, career development and employee life cycle;
  - Expansion to the whole organisation of the use of the recently implemented Customer Relationship Management system;

- Launch of a major initiative to replace the current Accounting and Financial information system;
- Following COVID-19 pandemic impact, implementation of a new model of hybrid work where co-workers will alternate between telework and face-to-face activity.
    - During pandemic peaks – should they occur in 2022 - dedicated support lines will remain operational, including those aiming at supporting INESC TEC members in practical questions related with COVID-19, self-care and well-being; and measures to improve both external and internal communication will be further promoted.

1.7 Articulation with the detailed plan

The strategic priorities outlined in this initial section provide a high-level view of the more detailed plan that is presented in the remainder of the document.

Section 2 provides a quantitative aggregate perspective of the plan, bringing together the key activity indicators planned for 2022, namely regarding human resources, activity in projects, publications, Intellectual Property and dissemination.

The high-level research and innovation goals are developed in greater detail for the Scientific Domains in Section 3, the TEC4 initiatives in Section 4, and the Research Centres in Section 5.

The plans for the main Research Infrastructures and Laboratories, and for the Support Services, which also play a key role in many of the main initiatives foreseen for 2022, are presented in Sections 6 and 7, respectively.

2 MAIN INDICATORS FOR 2022

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 2022. The presentation of each R&D Centre and the detailed discussion of their objectives, activities and results are carried out in Section 5.

2.1 Human Resources

2.1.1 Global indicators

Table 2.1 and Figure 2.1 show the breakdown of INESC TEC's Human Resources by type of contractual link and the expected evolution for 2022. Table 2.1 also includes the number of PhDs (343 planned at the end of 2022).

Table 2.1 - Evolution of INESC TEC's Human Resources

Type of Human Resources			2020	2021	2022	Δ 2021-22	
Integrated HR	Core Research Team	Employees	152	160	179	19	12%
		Academic Staff	169	172	171	-1	-1%
		Grant Holders and Trainees	334	308	263	-45	-14%
		Total Core Researchers	**655**	**640**	**613**	**-27**	**-4%**
		Total Core PhD	**264**	**256**	**253**	**-3**	**-1%**
	Affiliated Researchers		77	75	68	-7	-9%
	Management, Administrative and Technical	Employees	94	101	112	11	11%
		Academic Staff	11	11	11		0%
		Grant Holders and Trainees	9	6	2	-4	-67%
		Total Manag, Admin and Tech	**114**	**118**	**125**	**7**	**2%**
	Total Integrated HR		**846**	**833**	**806**	**-27**	**-3%**
	Total Integrated PhD		**354**	**351**	**343**	**-8**	**-2%**

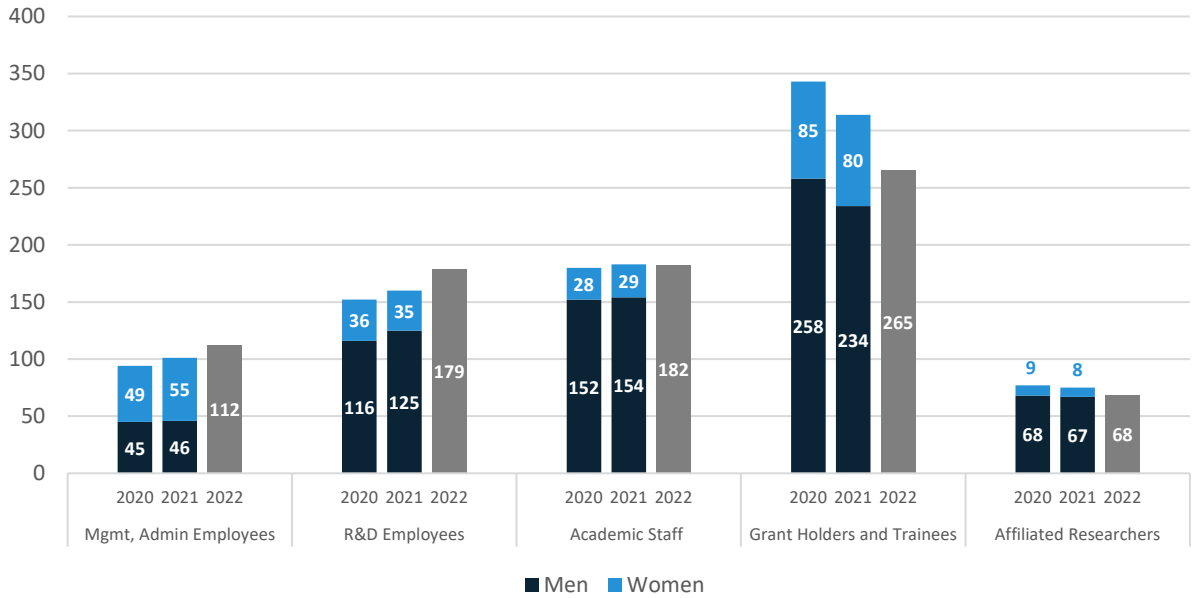


Figure 2.1 - Evolution of INESC TEC Human Resources

In Figure 2.1, the number of human resources planned for 2022 does not portray the gender distribution since it is not possible to foresee it in future hires. Nevertheless, INESC TEC has been monitoring closely some indicators related to dimensions of Diversity and Inclusion (D&I), namely those relating to gender balance.

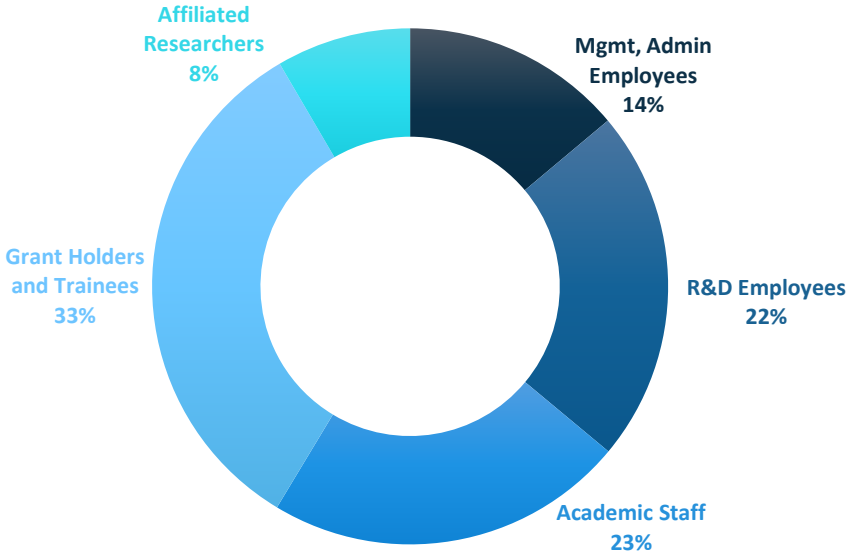


Figure 2.2 - Distribution of Human Resources (Plan 2022)

As highlighted in Figure 2.2, grant holders and trainees are still the largest group of human resources (33%) at INESC TEC, featuring, nevertheless, a new noticeable decrease in 2022, explained by two different sets of reasons. First of all, INESC TEC and its HEI associates are progressively adapting to the modified Research Grant Holder Statute that came into force in August 2019 and 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.

There is a decrease of 3% in the total number of integrated human resources. This contraction, mainly due to the reduction of the number of grant holders and trainees, is a conservative forecast, resulting from the fact that the numbers presented in the planning exercise for 2022 only consider ongoing projects and foreseen projects with a minimum level of certainty. The number of Human Resources, both grant holders and PhD employees, is therefore expected to increase along the year with the expected approval and launching of new projects.

In 2022, human resources in Support Services are planned to increase, namely in terms of employees. This is partly due to a shift from grant holders to employees and, on the other hand, to the need of supporting the continued growth of the institute's activity and the deployment of new strategic objectives.

2.1.2 R&D Centres indicators

The detailed Human Resources figures expected for the end of 2022 are given in Table 2.2 for each R&D Centre.

Table 2.2 - Human Resources by type and R&D Centre (Plan 2022)

Type of Human Resources			Total R&D Centres	R&D Centres												
				CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	HUMANISE	LIAAD	CRACS	HASLAB
Integrated HR	Core Research Team	Employees	**179**	11	12	20	7	56	21	15	5	5	12	4	1	10
		Academic Staff	**171**	13	8	12	6	10	4	11	18	2	27	23	17	20
		Grant Holders and Trainees	**263**	31	5	26	9	33	14	21	18		34	16	13	44
		Total Core Researchers	**613**	**55**	**25**	**58**	**21**	**99**	**39**	**47**	**41**	**7**	**73**	**43**	**31**	**74**
		Total Core PhD	**253**	**22**	**17**	**16**	**10**	**31**	**12**	**17**	**23**	**4**	**30**	**27**	**19**	**25**
	Affiliated Researchers		**67**	9	8		1	3	8	5	6	1	15	5		6
	Administrative and Technical	Employees	**20**	1	1	4	1	3	2	3	1		1	1		2
		Total Admin and Tech	**20**	1	1	4	1	3	2	3	1		1	1		2
	Total Integrated HR		**700**	**65**	**34**	**62**	**23**	**105**	**49**	**55**	**48**	**8**	**89**	**49**	**31**	**82**
	Total Integrated PhD		**317**	**31**	**23**	**16**	**10**	**34**	**20**	**22**	**29**	**5**	**45**	**32**	**19**	**31**

2.1.3 Support Services indicators

The Human Resources figures expected for the end of 2022 for the Board of Directors, the TEC4 teams, and the Support Services are provided in Table 2.3.

Table 2.3 - Human Resources by type and Service (Plan 2022)

Type of Human Resources		Total	Board and Advisors	Support Services															
						Organisation and Management Services					Business Development Services				Technical Support Services			
				TEC4	DPO	AG	AJ	CF	CG	RH	SAAF	SAL	SRI	SCOM	SRC	SIG	SAS	SGI
Integrated HR	Employees	90	11	6	2	2	3	9	12	6	3	3	5	7	3	7	6	5
	Academic Staff	11	8	3														
	Grant Holders and Trainees	2		1										1				
	Affiliated Researchers	1	1															
	Total Integrated HR	**104**	**20**	**10**	**2**	**2**	**3**	**9**	**12**	**6**	**3**	**3**	**5**	**8**	**3**	**7**	**6**	**5**
	Total Integrated PhD	**26**	**12**	**9**		**1**	**1**	**1**				**2**						

2.2 Activity in projects

2.2.1 Global indicators

Table 2.4 shows the breakdown of INESC TEC's funding sources and the expected evolution from 2021 Plan to 2022 Plan, presenting an increase in European programmes and an overall growth in activity of 4%. Table 2.5 then provides this information in greater detail, specifying the evolution of firm projects and the share of strategic programmes, namely FCT's pluriannual funding, the programmes for scientific employment (EEC) and to support Highly Qualified Human Resources (RHAQ), and the pluriannual funding for technology transfer activities (CIT).

Table 2.4 - Funding sources and planned evolution

Sources	Value (k€)		Δ (k€ / %)	
	2021	2022	2021-22	
National Programmes	11 976	12 013	37	0%
European Programmes	6 526	8 220	1 695	26%
R&D Services and Consulting	4 472	3 754	-718	-16%
Other Funding Sources	276	191	-84	-31%
Total Revenues	**23 249**	**24 179**	**930**	**4%**

Table 2.5 - Funding sources and planned evolution – Detail

Sources			Value (k€)		Δ (k€ | %)	
			2021	2022	2021-22	
Firm Projects	PN-FCT	National R&D Programmes – FCT	3 708	1 438	-2 270	-61%
	PN-PICT	National R&D Programmes - S&T Integrated Projects	0	181	181	
	PN-COOP	National Cooperation Programmes with Industry	2 195	3 377	1 182	54%
	PUE-FP	EU Framework Programmes	5 788	7 212	1 424	25%
	PUE-DIV	EU Cooperation Programmes – Other	405	410	5	1%
	SERV-NAC	R&D Services and Consulting – National	2 439	2 201	-238	-10%
	SERV-INT	R&D Services and Consulting - International	306	172	-134	-44%
	OP	Other Funding Programmes	1 082	2 331	1 249	115%
		Total Active Projects	**15 924**	**17 323**	**1400**	**9%**
Uncertain Projects			2 152	1 894	-258	-12%
National Strategic Programme – Pluriannual			2 649	3 023	374	14%
National Strategic Programme – RHAQ			580	561	-19	-3%
National Strategic Programme – EEC			478	523	45	9%
National Strategic Programme – CIT			616	302	-315	-51%
National Strategic Programmes – Other			628	367	-261	-42%
Other Revenues			223	186	-37	-17%
		Total Revenues	**23 249**	**24 179**	**930**	**4%**

Figure 2.3 illustrates the funding distribution for the active projects planned for 2022, and its comparison with the plan for 2021. The total revenue planned for 2022 grows 4% in comparison with 2021, with some variation per funding source, as explained below.

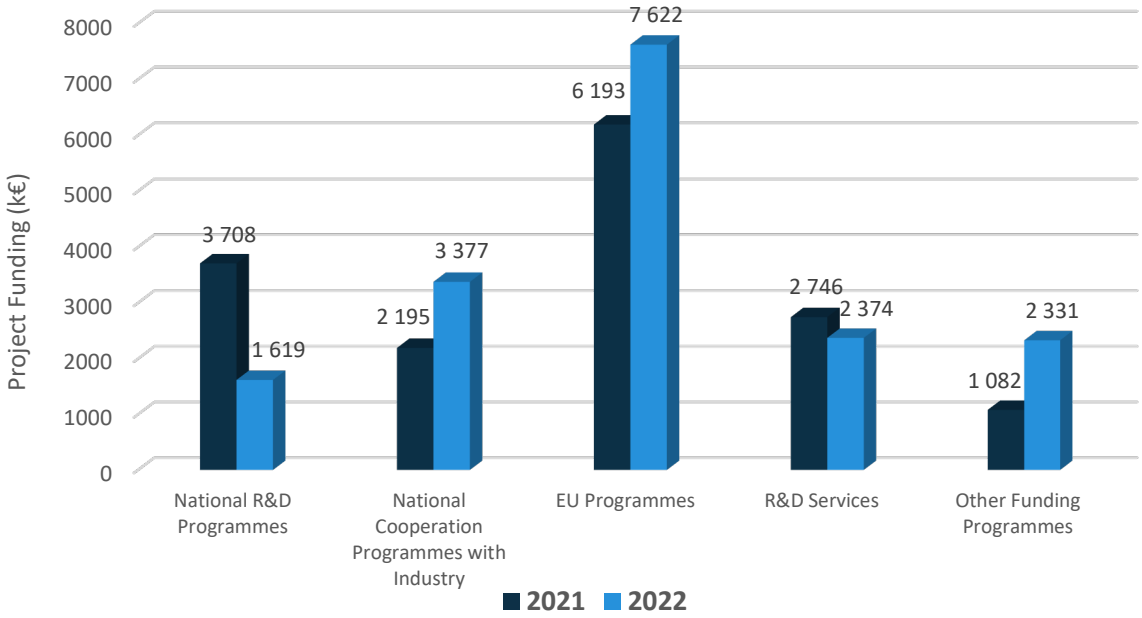


Figure 2.3 - Evolution of project funding by source (k€)

Figure 2.4 shows the funding distribution by source expected for firm projects, in comparison with that of the previous plan.

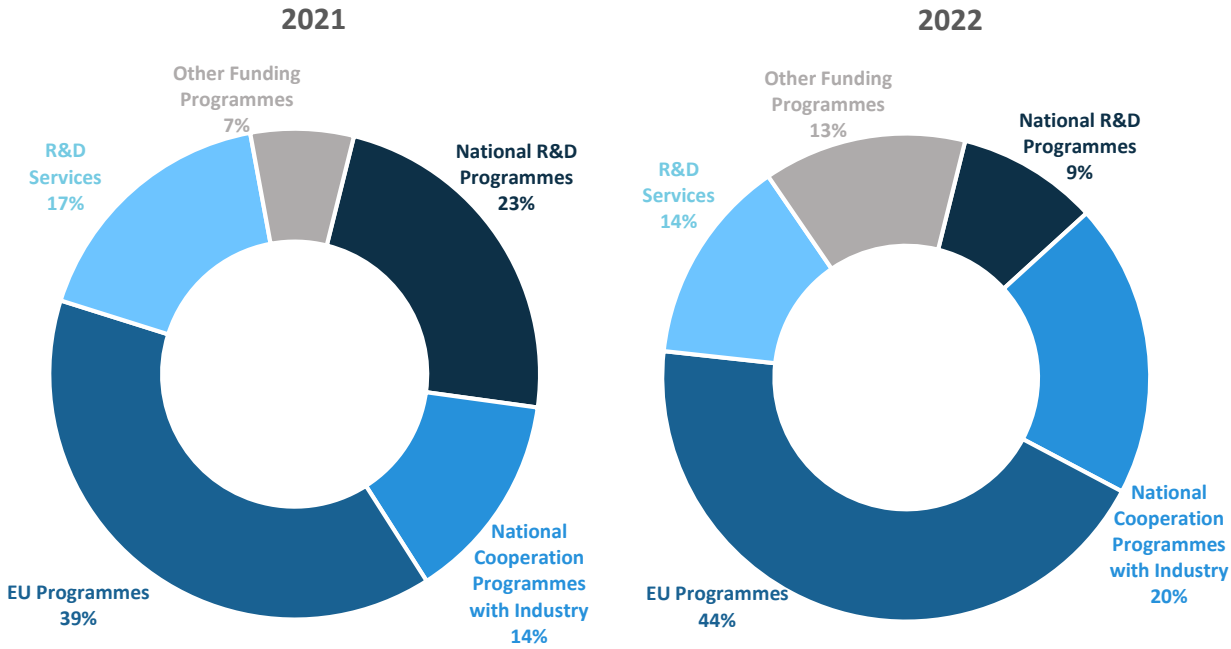


Figure 2.4 - Distribution of project funding by source - Plan 2021 (left) and Plan 2022 (right)

The number of active projects and the average funding per project by source is also of interest, and is shown in Table 2.6.

Table 2.6 - Number of active projects and average funding by source (Plan 2022)

Type of Project		Number of Active Projects		Δ	Average Funding (k€)	
		2021	2022	2021-22	2021	2022
PN-FCT	National R&D Programmes - FCT	49	32	-17	76	45
PN-PICT	National R&D Programmes - S&T Integrated Projects	0	1	1		181
PN-COOP	National Cooperation Programmes with Industry	26	45	19	84	75
PUE-FP	EU Framework Programmes	44	45	1	132	160
PUE-DIV	EU Cooperation Programmes - Other	12	12	0	34	34
SERV-NAC	R&D Services and Consulting - National	48	56	8	51	39
SERV-INT	R&D Services and Consulting - International	8	5	-3	38	34
OP	Other Funding Programmes	15	12	-3	72	194
	Total	**202**	**208**	**6**	**79**	**83**

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

- The total revenue planned for 2022 grows to 24 M€, that is 4% higher than in 2021;
- There are several changes in the evolution of the different funding sources from 2021 to 2022 (*c.f.* table 2.5), the most noticeable being the increase in the National Cooperation Programmes with Industry (54%), mainly related with the approval of several P2020 projects, namely Mobilisers and projects in consortia with companies. Also relevant is the increase in EU Framework Programmes (25%) due to the start of the last approved projects in the H2020 Programme, but also to the large project (Atlantis) with more than 1M€ of investment in 2022;
- The decrease in National R&D Programmes – FCT, though related to the specific conditions of the last two calls, is a source of concern as this is the most targeted funding to science, but it is also related with the end of the infrastructure projects financed through FCT;
- Due to the pandemic context and certainly due to industry holding back investments waiting for the PRR (Portuguese Recovery and Resilience Plan), contracted national and international R&D and Consulting Services are expected to decrease in relation to 2021, 10% and 44% respectively. Nevertheless, the shorter lifecycle of these projects and the conservative approach of this planning exercise mean that this value is expected to turn out larger than planned;
- The support from the "Pluriannual" National Strategic Programme, which includes funding related to the Associate Laboratory statute, has a great importance due to its flexibility and stability; though representing only 12.5% of the total funding, it is greatly leveraged by the institution in its activity;
- Although there is no guarantee of the continuity of the funding for technology transfer activities, "CIT", we have reasons to be optimistic about the new application to renew this funding, so a total revenue of about 300k€ was estimated which represents 1.2% of the total revenues. This is of particular importance to strengthen the institute's technology transfer capabilities.
- The growth in other funding programmes is mainly due to large investments foreseen in the project Sustainable HPC, which is funded through FAI and FEE. The funding Programmes for highly qualified Human Resources (RHAQ) and Infrastructures ("National Strategic Programmes - Other") are very relevant funding sources to materialise the Scientific Employment Policy, and combined represent 3.8% of the total revenues;
- National R&D Programmes - S&T Integrated Projects and EU Framework Projects are the largest in terms of volume while, at the opposite end, other EU Cooperation Programmes typically fund small projects

(with complex and often highly specific rules) and R&D and Consulting Services often feature short durations and are therefore expected to be below average funding per project;

- Funding from still uncertain projects represents 8% of the total funding, slightly lower than in 2021 (9%), the majority being R&D and Consulting Services, which have a much shorter contracting cycle, when compared with national and European funding programmes.

2.2.2 R&D Centres indicators

A detailed view of the total funding by source per R&D Centre is given in Table 2.7 and Figure 2.5. In comparison with the plan for 2021, some important changes can be highlighted:

- The most relevant variation is the already referred large decrease (-71%) in FCT funded projects, a major concern because this funding is primarily devoted to basic science, although the numbers are distorted by the values obtained by CRAS in relation with infrastructural funding;
- This decrease is partially compensated by the large increase in projects in cooperation and by the reappearance of integrated projects, setting the national funding for projects 15% below the planned for the previous year; the impact is not evenly distributed by the different Centres, with CPES and CESE displaying a significant increase and CTM and CEGI, besides CRAS, experiencing a strong decrease;
- In terms of European projects, the planned 23% increase is mainly due to the action of CPES, CRAS, HUMANISE, CRIIS, and CEGI; going downwards in this indicator we find CTM and CESE;
- National contract research and consulting is expected to increase by 5%, without fully considering the impact of projects possibly approved in the Program of Recovery and Resilience, with still very volatile results and thus not fully accounted in the 2022 Plan, except for the already running effort to secure more human resources to be able to manage future commitments; in the current exercise, some centres (CTM, CRIIS, CESE) are planning a robust increase in this indicator, while several others expect a slowdown;

Table 2.7 - Project Funding (k€) and Uncertainty Analysis (Plan 2022)

			R&D Centres														
		Total (k€)	CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	HUMANISE	LIAAD	CRACS	HASLAB	Special Projects
Projects	PN-FCT	**1 438**	111	87	543	85	98	88	1	84	0	98	103	0	140	0
	PN-PICT	**181**	81	0	0	0	100	0	0	0	0	0	0	0	0	0
	PN-COOP	**3 377**	248	183	528	82	645	737	272	117	8	180	163	0	216	0
	PUE-FP	**7 212**	131	263	1 935	117	2 311	235	661	480	115	720	40	0	204	0
	PUE-DIV	**410**	12	4	89	0	46	0	9	16	50	41	56	87	0	0
	SERV-NAC	**2 201**	336	30	0	18	789	196	327	40	0	104	60	20	282	0
	SERV-INT	**172**	29	70	0	0	18	45	0	0	0	10	0	0	0	0
	OP	**2 331**	64	0	0	0	1 523	0	1	0	0	1	0	0	103	639
	Total Projects	**17 323**	**1 013**	**637**	**3 095**	**302**	**5 530**	**1 302**	**1 270**	**738**	**173**	**1 152**	**422**	**107**	**944**	**639**
Uncertain Projects		**1 894**	**233**	**155**	**164**	**58**	**63**	**337**	**40**	**24**	**104**	**130**	**114**	**47**	**270**	**155**
Total Funding		**19 217**	**1 246**	**792**	**3 258**	**360**	**5 593**	**1 639**	**1 310**	**762**	**277**	**1 282**	**536**	**154**	**1 214**	**794**
Uncertain Projects		**10%**	19%	20%	5%	16%	1%	21%	3%	3%	38%	10%	21%	30%	22%	20%

Table 2.7 also shows that uncertain projects represent 10% of the total funding from projects, although the relative weight between uncertain and firm projects is quite variable across R&D Centres, as shown in Figure 2.5.

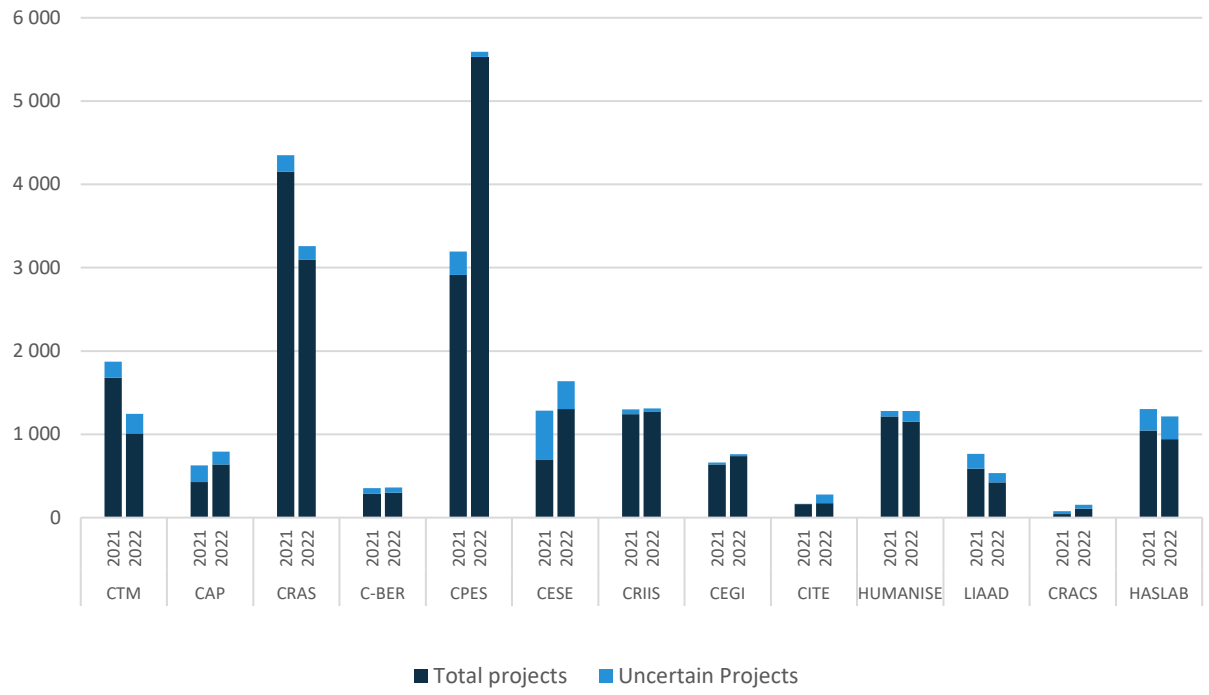


Figure 2.5 - Project funding and uncertainty analysis (k€) per R&D Centre (Plan 2021 vs Plan 2022)

2.3 Publications

2.3.1 Global indicators

Table 2.8 and Figure 2.6 show the number of INESC TEC publications and the expected evolution for 2022.

The number of publications for 2019 and 2020 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, but the institutional total removes repetitions of the same publication.

Values for 2021 and 2022 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 the same factor derived from 2020 publications (about 5% of the publications are authored by researchers from more than one Centre).

Table 2.8 - Number of INESC TEC Publications

Publication Type	2018	2019	2020	2021 (Forecast)	2022 (Plan)
Indexed Journals	312	381	422	391	390
Indexed Conferences	494	570	385	557	443
Books	7	6	2	8	14
Book Chapters	40	29	25	39	24
PhD Theses - Members	38	19	28	15	49

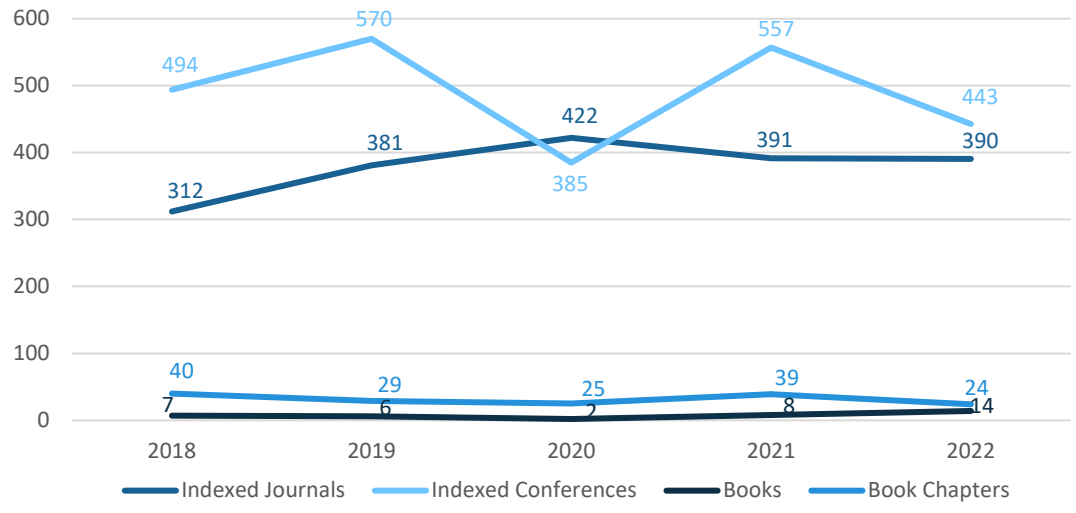


Figure 2.6 - Evolution of INESC TEC Publications

For 2022, INESC TEC plans to keep its scientific production stable in terms of articles in indexed journals, with a clear focus on journals classified by SCOPUS as first quartile. Moreover, since the maintenance of some restrictions caused by the pandemic is foreseen in 2022, despite a better adaptation of these events to online formats, INESCTEC R&D Centres opted for a conservative forecast in terms of publication activity in indexed conferences proceedings.

2.3.2 R&D Centres indicators

Figure 2.7 presents the number of indexed publications in journals and conferences per R&D Centre.

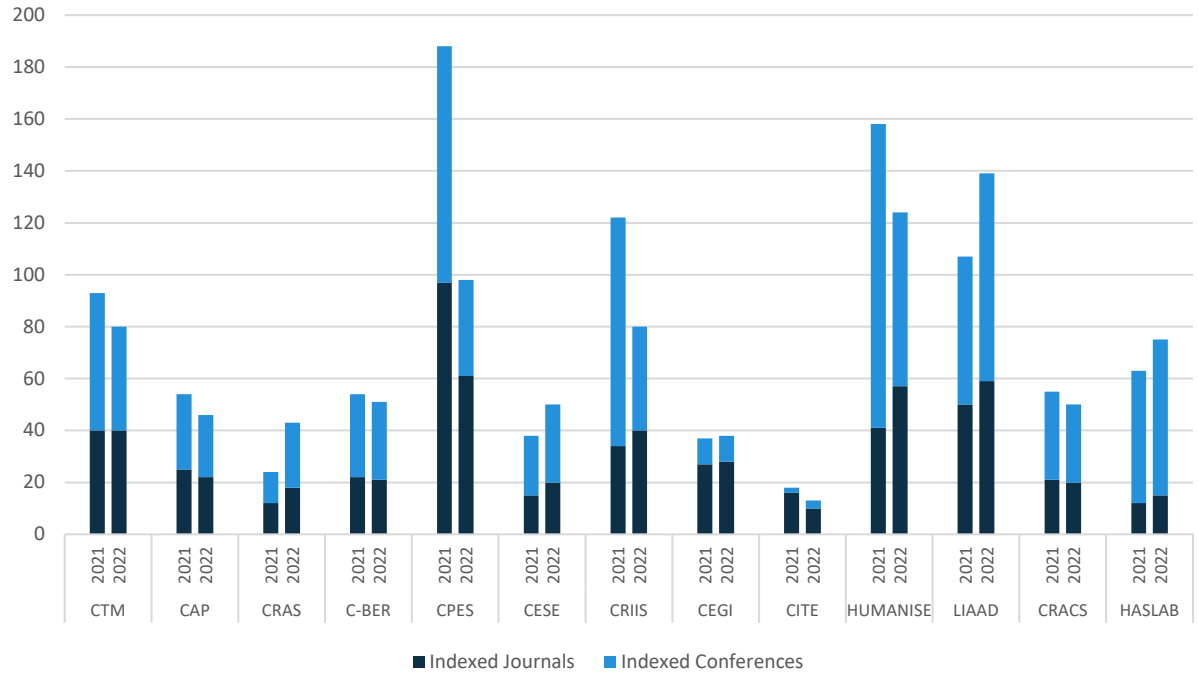


Figure 2.7 - Indexed Publications in Journals and Conferences (Forecast 2021 vs Plan 2022)

2.4 Knowledge transfer

Table 2.9 presents the number of INESC TEC's intellectual property (IP) results and the expected evolution for 2022.

Table 2.9 - Results related with Knowledge Transfer

Type of Result	2020	2021 (Forecast)	2022 (Plan)
Invention disclosures	26	32	29
Software copyright registrations at IGAC	6	1	10
Patent first priority filings (New inventions)	7	4	5
Patent applications (Internationalisation)	30	23	4
Commercial contracts – Licenses and Assignments	5	2	5
Spin-offs	3	3 [(1)]	2

[(1)] *two of them in development*

In 2022, the number of invention disclosures and software copyright registrations is expected to remain high, in part due to an initiative by INESC TEC's Technology Licensing Office. The initial communication phase has been simplified by introducing short disclosure forms but articulated with a selection funnel prone to a high-quality and lean IP portfolio.

The number of new inventions/technologies is now stabilising at few units per year, after a policy-driven earlier peak enabled by the combination of patent-related project performance criteria and the availability of public funding for international patenting. The IP strategy is now focusing on quality over quantity, so the number of international patents in the next years is expected to be about 50% of the new priority filings.

As for commercial contracts, an increase is foreseen with SAL reorienting part of its capacity from IP protection to the active scouting of both new technologies and business opportunities and exploitation of the IP portfolio.

Finally, in May 2021, INESC TEC's participation in UNEXMIN GeoRobotics was formalised while two spin-offs remained in a development phase, iLoF and WeSenss. Due to complex negotiations and formalities resulting from its international nature, INESC TEC's formal participation in iLoF is expected in 2022. Moreover, the creation of the spin-off "WeSenss" is planned for 2022, in association with the licensing of three patent families.

2.5 Dissemination activities

Table 2.10 illustrates the expected activity of INESC TEC members and R&D Centres in a variety of categories of dissemination activities.

Table 2.10 - Results related with dissemination activity

Type of Activity	2022
Participation as principal editor, editor or associated editor in journals	80
Conferences organised by INESC TEC members (in the organising committee or chairing technical committees)	61
International events in which INESC TEC members participate in the program committees	190
Participation in events such as fairs, exhibitions or similar	51
Conferences, workshops and scientific sessions organised by the R&D Centres	48
Participants in the conferences, workshops and scientific sessions organised by the R&D Centres	1791
Advanced training courses organised by the R&D Centres	24

Despite the effects of the Covid-19 Pandemic, still expected during 2022, INESC TEC's researchers plan to maintain a dynamic activity in scientific dissemination events and other formats. For this purpose, the virtual alternative provided in many of these events, as hybrid conferences or full remote participation, has been and will be decisive.

Besides its annual Autumn Forum, another event to be organised by INESC TEC and worth mentioning is PSCC'2022 – The XXII Power Systems Computation Conference, the international forum addressing the theoretical developments and computational aspects related to power systems applications from micro-grids to mega-grids. The event will be held late June 2022, in Porto, with an expected number of 500 participants.

INESC TEC will also have a strong involvement in the organisation of other relevant conferences such as <Programming> 2022 - The International Conference on the Art, Science, and Engineering of Programming, IFCS 2022 - The 17th conference of the International Federation of Classification Societies, FPG - the French German Portuguese Conference on Optimisation 2022 or NetSciX - The International School and Conference on Network Science, to name but a few.

3 INESC TEC SCIENTIFIC DOMAINS

Research at INESC TEC is structured in four Scientific Domains - Computer Science (CS), Industrial and Systems Engineering (ISE), Networked Intelligent Systems (NIS), and Power and Energy (PE) - presented in the following sections.

3.1 COMPUTER SCIENCE

Coordinator: Rui Oliveira
Assistant to the Domain Coordinator: Ana Alonso

3.1.1 Scope and vision

Computing became fully decentralised, mobile, increasingly ubiquitous, smarter, and autonomous.

Current computer systems, especially in critical realms such as utilities, health care, transportation, and finance, present new, and often unanticipated, sorts of risks that defy our best practices of software engineering and human-computer interaction and present hard and intricate challenges associated to interoperability, scalability, security, and criticality. Computer systems in organisations account for over 10% of all the global energy consumption and approximately 2% of global CO_2 emissions which makes the sustainability of much of our innovation also a major challenge.

The ever-increasing data generated present a never seen opportunity for real world data centred solutions to filter, curate, store, process, query and visualise unprecedented volumes of data from diverse sources and formats complying with demanding levels of privacy and liability pose enormous and new challenges for software systems and their engineering.

3.1.2 Research Challenges

Research in this domain is strategically focused on four main short- to medium-term challenges as described next. To this end, INESC TEC amasses a large group of researchers with competences in Artificial Intelligence, Computer Graphics, Cybersecurity, Human-Computer Interaction, Immersive Environments, Information Management, Information Systems, Mathematics of Computing, Parallel and Distributed Systems, Programming Languages, and Software Engineering.

Computing systems to empower human capabilities

The overarching goal is to advance the state-of-the-art of human-centred computing systems augmenting human capabilities at all levels: perception, understanding, reasoning, decision, interaction, and collaboration. This is to be pursued by:

- Improving the trustworthiness and transparency of AI systems, providing increased cognitive power, including the ability to link perceived language, images, sounds and other signals to larger bodies of knowledge, enabling causal inference; inventing AI systems with controlled autonomy having the ability to explain and trace their actions, as well as to safely interact with human agents and society and respecting human dignity and fairness; enabling AI systems to benefit from learned and human provided models to accelerate the safe application of AI.
- Improving information access based on automatic narrative building from news feeds and the corresponding visualisation; bridging logic, probabilities and learning into applications helping to better understand the process of transforming raw data into knowledge.
- Empowering humans with increasingly complete and immersive virtual environments aimed at training in high-risk and digital twinning environments.
- Integrating rigorous formal analysis and user-centred design practices in software design techniques and tools to enable both formally proving user-centred requirements during early design stages and prototype evaluation; improving software development methodologies and guidelines for helping developers enhancing usability and optimising user experience; empowering more people (e.g.,

children, non-tech-savvy, etc.) with simpler software development approaches and tools to enable them to design and build their own apps addressing their small scale personal and professional needs.

Methods and tools to boost the quality of future software systems

Future software systems will be even more technically complex and of unprecedented scale, with high integrity requirements, short time-to-market, developed under volatile, uncertain, complex, and ambiguous environments (VUCA), and running in heterogeneous computing platforms. We aim to devise new methods, techniques, and tools that advance the way software is designed, synthesized, and assessed, as follows:

- Improving structured requirements specification languages to diminish ambiguity and further automate software development processes; contributing to innovative concurrent high-level and domain-specific programming languages and compilers targeting the whole spectrum of parallel and distributed computing environments with emphasis on non-functional requirements.
- Inventing tools, and techniques to evaluate the interaction between developers and software development tools in next-generation development environments (low-code, no-code, visual programming languages); increasing the efficiency and effectiveness of software developers by creating new approaches and techniques to improve the developer experience.
- Contributing to static and dynamic automatic code analysis techniques and tools for checking non-functional aspects of code quality, such as maintainability, data protection and energy efficiency; inventing and improving techniques and tools to increase effectiveness and efficiency in software testing.
- Creating foundations and rigorous mathematical methods for Quantum Computer Science and Quantum Software Engineering and their application to strategic problem-areas.

Performance, interoperability, and dependability of critical information systems

Information systems are the cornerstone of any sizeable organisation and service making their stakeholders altogether dependent on their correct behaviour and availability. These became increasingly complex from the low-level infrastructure to the user interface. Scale, heterogeneity, geographic distribution, and versioning all concur to more capable, faster, ubiquitous, and more resilient systems while, at the same time, can easily and frequently be the source of unresponsive, unreachable, or altogether useless services. We focus on non-functional requirements of software and systems and contributions are planned to be achieved as follows:

- Improving the management of heterogeneous data sources and contributing to the development of linked data and semantic web technologies; improving and moving towards interoperable data exchange for data spaces and cross-sector data-centric applications.
- Improving the performance, scalability, dependability and security of data management systems serving data-centric applications, such as machine-learning, analytical, and database frameworks; improving the interoperability and performance of heterogeneous computing and data management systems; improving the dependability of critical information systems as these evolve towards distributed architectures, both in terms of data and control, powered by the increasing virtualisation of critical infrastructures; inventing custom computing architectures, techniques and tools that realise the potential of heterogeneous systems.
- Improving the scalability and usability of formal design techniques and tools to enable the verification of complex distributed protocols by non-experts in formal methods.

Trustworthy control of data confidentiality and provenance

We aim to address the contention between the enormous value that resides in data for the benefit of the whole society and the necessary qualities on that data that must be imposed to protect laws, regulations, and fundamental rights. The goal is to develop privacy-enhancing technologies, transparent data management and protection mechanisms that preserve information provenance and allow for fine-grained control of data integrity and consent information in a privacy preserving way. Our work will improve the technological support for empowering data owners in controlling the security of personal and organisational data lifecycles, including

secure storage, access control, data transfer and sharing, confidential computation, and secure preservation or erasure. This is to be achieved as follows:

- Improving the usability and scalability of emerging technologies such as computation over encrypted data, multi-party computation, and verifiable outsourced computation making privacy-preserving computation a commodity; inventing secure machine learning algorithms and systems; inventing post-quantum-secure alternatives that can be used as drop-in replacements matching the performance and assurance of existing techniques and guarantee security.
- Contributing to the accountability of data provenance ensuring authenticity and traceability.

3.2 INDUSTRIAL AND SYSTEMS ENGINEERING

Coordinator: João Claro
Assistant to the Domain Coordinator: Ricardo Zimmermann

3.2.1 Scope and vision

In the domain of Industrial and Systems Engineering (ISE), INESC TEC researches and innovates systems and services applied to the management of value streams. The goal is to lead complex decision-making in end-to-end, customer-centric, agile supply chains across different industries (e.g., manufacturing, retail, health and mobility). To improve business performance, innovation, productivity, and environmental and social sustainability, our intervention in this domain ranges from local optimisation of individual organisations to complex system optimisation of networks and chains. Our activities cover the design, implementation and improvement of systems for decision support, operations human-centred automation, management and intelligence, as well as innovation and technology management.

Our activity in this domain builds on the following main areas of competence:

- Asset Management, Collaborative Networks & Supply Chain Management, Factories Design, Logistics & Transportation Systems & Mobility, Production Planning & Scheduling;
- Decision Support Systems, Optimisation Solution Methods, and Performance Assessment;
- 2D/3D Visual Perception & Advanced Sensing, Collaborative Robots, Control of Dynamic Systems, Navigation & Control;
- Engineering & Public Policy, Entrepreneurship, Innovation Management, Service Design, Technology Adoption & Implementation;
- Data & Information Management, Digital Enterprise Architectures, Industrial Information Systems Design.

3.2.2 Research Challenges

Five main challenges are the strategic focus of our research in this domain for the upcoming years: Operations Management for Responsive, Resilient and Sustainable Systems; Operations Research for Decision Support in a Digitised World; Cognitive, Aware and Collaborative Robotic and Autonomous Systems; Responsible and Sustainable Technology Driven Innovation; Industrial Information Systems Supporting Circularity and Sustainability.

Operations Management for Responsive, Resilient and Sustainable Systems

This challenge focuses on the design, planning, control, and improvement of value-adding processes that lead to more efficient, effective and sustainable creation and delivery of goods and services, leveraging our deep applied research experience in different sectors; from Manufacturing and Retail to Health and Mobility. The most used research methods range from quantitative modelling to empirical studies, from operations research, artificial intelligence and statistics to social sciences and exploratory research.

The main topics addressed include flexible, responsive and sustainable operations and industrial systems; collaborative networks and supply chain design and management; asset management; production planning and scheduling; logistics, intelligent transportation systems and mobility; and marketing analytics (consumer behaviour, product line design, demand forecast, revenue management and product variety management).

The main thrusts of our research roadmap for this challenge are the following:

- Develop state-of-the art planning and scheduling systems to adequately handle the ready availability in quality and quantity of real-time and historic data from a system environment.
- Identify and tackle new problems (e.g., online order fulfilment) arising from digital services, that disclose new levels of complexity and variability, and may have different requirements.

- Design end-to-end processes that capture the complexity and relations within supply chains, while acknowledging an ever-empowered end customer.
- Outline methodologies, methods and techniques that ensure the optimal configuration of resources and processes to guarantee maximum efficiency in customised unit production environments.

To strengthen the research environment and outputs related to this challenge, our priorities are: fostering research in the scope of iiLab; proposing a mid-term plan for already identified researchers to become Fellows of related associations, e.g., EurOMA and POMS; and increasing the number of publications in 1st Quartile and FT Research rank (FT50) journals, such as Manufacturing & Service Operations Management, Production & Operations Management and Journal of Operations Management.

Operations Research for Decision Support in a Digitised World

This challenge seeks to contribute to the methodology of operations research and to the practice of decision-making, leveraging the science of optimal decision-making support, especially under uncertainty. It builds on a strong critical mass and deep involvement in national and international associations (e.g., APDIO, EURO and IFORS), the visibility of several researchers in the European Operational Research community, and the coordination of European projects such as TRUST-AI, which aims at developing next-generation explainable artificial intelligence methods.

The main research topics are: mathematical programming, constraint programming and metaheuristics; hybrid solution methods (Matheuristics, Simulation-Optimisation, Machine Learning and Optimisation); decision-making under uncertainty; policy learning methods and real-time decision making; multi-objective optimisation; decision support systems, and performance assessment.

The challenge's roadmap includes the following main drives:

- Tackle uncertainty in decision making processes at all levels, through the design and development of innovative solution approaches, e.g., hybridising optimisation with simulation or machine learning techniques.
- Develop agile and real-time decision-making processes, based on advanced models and analytical methods applicable in the real-world, and promote efficiency, flexibility and agility of industrial companies and networks.
- Develop decision support solutions that are more appropriate for SMEs, enhancing their simplicity, interpretability, modularity, and support to implementation.

The reinforcement of the challenge's research environment and outputs will focus on: proposing a mid-term plan for already identified researchers to become Fellows of related associations, e.g., INFORMS; increasing the submission of applications to ERC grant; increasing the number of publications in FT50 journals.

Cognitive, Aware and Collaborative Robotic and Autonomous Systems

The main focus of the research in this challenge is the design and implementation of innovative solutions within the areas of industrial robotics and intelligent systems, having at its core the development of cognitive, sensitive, collaborative and safe robotic-based and automated systems. The main research topics addressed are: Collaborative Robots; 2D/3D Visual Perception and Advanced Sensing; Navigation and Control and Control of Dynamic Systems.

The roadmap for the challenge comprises the following areas of advancement:

- Push the mobile manipulators systems closer to full production system.
- Sophisticated sensors for a correct and cost-effective monitoring and control.
- Tackle dynamic environments and robot accuracy limitations and part dimensional deviations leveraging 3D point-cloud based perception systems.
- 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.

- Human-Robot Collaborative Cells in production plants, addressing the unpredictability of human behaviour, which impact the speed of operation of these solutions.
- New robot programming techniques, both based on CAD and programming by demonstration techniques.
- Methodologies to balance autonomy and collaboration or human supervision in autonomous systems.
- Advanced safety systems and code verification to foster robotics adoption.

The key priorities for the enhancement of the challenge's research environment and outputs will be: developing a plan to have Fellows in related associations, e.g., IEEE and IFAC; increasing publications in top ranked journals, such as IEEE Transactions on Robotics, IEEE Transactions on Robotics & Automation, and Autonomous Robots.

Responsible and sustainable Technology Driven Innovation

This research challenge is concerned with the study and development of theories, methods and models to support technology enabled sustainable innovation. With this purpose, the methods used in this challenge include conceptual development, qualitative methods, quantitative methods, action research and design science research. The main research topics addressed are: Innovation management and the front-end of innovation; Service design for technology enable service innovation; Design for transformation toward sustainable service ecosystems; Co-creation and citizen engagement with sustainable transition; Technology management and policy; Technology adoption and implementation; Value chain strategies for emerging technologies; Technology-based business model design and entrepreneurship; and Technology transfer and exploitation.

For this challenge, the key research thrusts present in the roadmap are:

- Strengthen innovation management and the front-end of innovation towards a responsible and sustainable economy and society, with a focus on circular value chains and open innovation and co-creation practices.
- Designing human-centred and sustainable digital transformation processes.
- Advancing the conceptual and methodological foundations of service design and innovation, as key areas of service science.
- Understanding and designing for customer experience with new technology enabled services, such as smart services and data analytics.
- Designing for service system transformation and fostering citizen engagement with sustainable transitions.
- Strengthen technology management (planning to implementation), focusing on emerging enabling technologies.
- Characterise the factors that influence technology adoption and its impacts, including at the policy level.
- Strategic alignment of technology driven innovation through business model design.
- Understand the practices and conditions for the fostering and growth of technology-based entrepreneurship.
- Understanding the leveraging of research outputs for marketplace and society, including from a policy viewpoint.

Our priorities in reinforcing the challenge's research environment and outputs are: strengthening the research team's international collaborations and submission of European projects; increasing the publications in key outlets such as Journal of Technology Transfer, Technological Forecasting and Social Change, Technovation, Research Policy, Journal of Innovation and Knowledge, Journal of Manufacturing Technology Management, Journal of Service Research, Journal of Service Management, Journal of Cleaner Production, Journal of Business Research, Design Studies.

Industrial Information Systems Supporting Circularity and Sustainability

This research challenge aims to develop new concepts of information systems for industrial management, integrating emerging technologies and methods, aiming to support a sustainable transformation of industrial organisations. It also focuses on industrial data and information management models and systems addressing the challenges and opportunities of an industrial context characterised by data dependency and an intensive digital transformation. Furthermore, it pursues the design of theories to maximise the adoption and impact of new industrial information systems addressing the sustainability and circularity needs of industrial organisations, networks and chains. The research is conducted using, in particular, design science research, systems development methods and socio-technical systems design.

The main research topics addressed are: Digital enterprise architectures – Digital twin information models; Industrial reference models and architectures; IOT-based architectures; Industrial data & information management – Semantic information organisation & integration; Industrial data management (data spaces); Industrial data business models; and Design and impact of IIS – Design theory for industrial platforms; Industrial digital platforms adoption and impact; Socio-technical design theory.

Sustainability and circularity raise specific challenges to IIS such as trust, and confidentiality on one side, and systems adoption and user mobilisation on the other side. Accordingly, the key thrusts of the challenge's roadmap are:

- How to design inter-organisational information systems, particularly industrial digital platforms that support collaboration, information management and collective action to foster and implement circular and sustainable business strategies?
- How to manage industrial data and information in individual organisations and value chains and networks to foster knowledge and unlocking value creation from data?
- How to assess the impact and derive design propositions for information systems based on emerging technologies leading to the creation of organisational capabilities that foster competitiveness and sustainability?

To reinforce the challenge's research environment and outputs, we will focus on: increasing the number of (senior) researchers and research outputs (PhD theses, papers); expanding the publications in key outlets such as Business and Information Systems Engineering, Computers in Industry, Computers and Industrial Engineering, Journal of Information Technology, and International Journal of Information Management; fostering the cross-fertilisation between this research challenge and the Computer Science domain.

3.3 NETWORKED INTELLIGENT SYSTEMS

Coordinator: Aníbal Matos
Assistant to the Domain Coordinator: Andry Maykol Pinto

3.3.1 Scope and vision

The **Networked Intelligent Systems (NIS)** domain envisions to work "*towards autonomous networked intelligent hybrid systems enabled by ubiquitous sensing and processing of information*". These systems are obtained by interconnecting agents, which interact and communicate mainly over wireless networks. Intelligence is achieved by developing the capability of agents to sense, perceive, communicate, navigate, and learn from past experiences, in order to enhance the ability to meet objectives. Such systems are expected to be low power and locally intelligent, to act as reconfigurable networks, to be tolerant to external disturbance, allowing them to sense and operate under extreme conditions or environments.

To accomplish such goal, the domain gathers researchers with competences in instrumentation, optics, photonics, reconfigurable hardware, communications, electronics, biomedical engineering, artificial Intelligence, signal processing, computer vision, robotics, and control.

3.3.2 Research Challenges

Research activities within this domain are organised along four major research challenges: novel perception tools, beyond human vision, context-aware communication systems, and autonomy of robotic systems.

Novel perception tools

This challenge addresses the development of new sensing mechanisms and devices, together with signal processing to act as enablers of networked intelligent systems. Novel scientific approaches include combining smart spectroscopy, low power implantable sensing and neurostimulation microsystems, wearable and human implementable devices, imaging techniques, compressive sensing techniques, and its integration with hybrid microfabricated devices. Research activities are organised along the following lines:

- **Lab-on-a-fiber & lab-on-a-chip**, addressing the integration of optofluidic platforms with new sensing methodologies and advanced signal processing and analysis, towards miniaturised, implantable and ubiquitous sensing devices; tunable resonators for very high sensitivity detection; micromanipulation (optical tweezers, plasmonic nanotraps); smart (AI assisted) spectroscopy (scattering, absorption fluorescence) for reagent-less analytics; and real time modeling, analysis and classification of bio-entities (cells, exosomes, proteins,..);
- **Photonic solutions for extreme sensing**, addressing sensors with high sensitivity, challenging the measuring limits resolution using advanced interrogation system in physical sensors to increase their robustness; nanofibers, Fabry-Perots, fiber Bragg gratings, long-period fiber gratings, tapers and microsphere using fiber optic technology; interrogation systems for very high sensitivity measurements relying on interferometric techniques; and simulation of fiber sensors and 3D printing structures for Extreme environments;
- **Optical systems for quantum simulation and computing** addressing the use of nonlinear optical systems for the development and deployment of analog quantum simulation platforms; and reservoir computing solutions for the implementation of all-optical information processing devices, aiming for a seamless integration with the various optical sensing devices;
- **Biomedical instrumentation**, addressing research on smart-textile and integration of hardware and sensing capabilities in textiles using conductive fibres, seeking wearable devices with different form-factors and with different monitoring capabilities; low-power small hardware devices with the aim to achieve smaller, more comfortable and ergonomic wearable devices with mobile/web application for user interaction; embedded AI engines for future wearables, snap2skin and intra-body sensing; new health occupational strategies; and movement analysis and recognition using body kinematics analysis;
- **Neuro-Engineering**, addressing 3DVideo-EEG for neurological disease monitoring and supported diagnosis; deep brain stimulation new technologies to support surgical procedures; new

neurostimulation & neuro-sensing technologies; human-machine symbiosis for brain computer interface; fMRI neuroimaging analysis; and new multimodal deep-learning approaches that uses multiple bio-sources to achieve improved CAD systems.

Major competences required to pursue this challenge include instrumentation, optics, photonics, biomedical engineering, artificial intelligence, signal processing, and electronics.

Beyond human vision

This challenge addresses the development of computer vision architectures achieving functionalities and performances surpassing humans. The main research goals associated to this challenge are never ending learning capabilities, multi-objective perception, generic artificial vision, and causal models: from correlations to causality. Activities contributing to this challenge are organised along the following lines:

- **General Novel Computer Vision Approaches**, addressing compression and acceleration of Deep CV; explainable and uncertainty aware deep learning; multimodal learning; efficient annotation learning; open world learning; domain adaptation; and domain knowledge and data integration.
- **Medical Image Analysis**, addressing cancer management; ophthalmology; neurology; and thorax pathologies.
- **Forensics**, addressing liveness detection; recognition under domain drift; biometrics with security; and scene and human behaviour analysis.
- **Multimedia content understanding**, addressing brand recognition; intelligent media content annotation; automatic content creation; sentiment inference from content analysis; and human centric perception.
- **Autonomous vehicles**, addressing scene understanding; ego-motion estimation; in-vehicle analysis; occupant analysis; and driver assistance.
- **Perception of marine and underwater environments**, addressing underwater imaging; ego-motion estimation; and distributed perception.

Major competences required to pursue this challenge include biomedical engineering, artificial intelligence, and computer vision.

Context-aware communications systems

This challenge addresses the design communications systems able to dynamically adapt to the context, including physical environment, communicating peers, and users involved. To achieve this goal, research activities encompass the following topics:

- **Communications hardware adapted to the environment**, addressing self-adaptive baseband processing according to the environment (multi-standard, multi-mode support (e.g., radio, optical), free bands, interference patterns); array transceiver architectures for beamforming and spatial noise-shaping; and edge and neuromorphic computing.
- **Reconfigurable antennas for communications and positioning**, addressing reconfigurable antennas based on 2D materials (e.g. graphene) – enabling reconfigurability up to sub-THz; antennas on thin, flexible substrates embedded into environment (buildings, cars); and application of AI/ML on antenna characteristics and wireless communications signals for positioning.
- **Resilient and adaptive wireless communications**, addressing geometric/probabilistic constellation shaping – adaptive modulations constellation optimisation using AI/ML-oriented approaches; photonic integrated circuit design for mmWave communications and programmable photonics & QKD; and multi-parameter wireless link adaptation to changing channel conditions.
- **On-demand adaptive wireless networking**, addressing on-demand robotic-borne wireless networks using AI/ML and optimisation techniques – traffic-aware positioning, proactive routing and queue management, network slicing; and smart wireless link adaptation using AI/ML – playing with additional parameters – e.g., position of the nodes, number of nodes

- **Context-awareness and AI for simple-to-use multimedia applications**, addressing the use AI/ML to predict context for flexible, dynamic and simple-to-use multimedia applications; context-aware personalised multimedia management approaches in heterogeneous environments; automatic content understanding using AI/ML for adaptive multimedia services; and content-aware streaming and adaptation of new media contents.

Major competences required to pursue this challenge include reconfigurable hardware, communications, artificial intelligence, and electronics.

Autonomy of robotic systems

This challenge aims at making robotic and other autonomous systems able to operate in complex, unstructured and dynamic environments with increasing levels of autonomy, by enhancing their perception, understanding, reasoning, decision, and interaction capabilities. To achieve such goal, the following topics are addressed:

- **Positioning & navigation**, addressing positioning and navigation of autonomous systems in GNSS denied environments; underwater acoustic positioning systems and algorithms; simultaneous navigation and mapping; semantic navigation; environment aware navigation; transition between open area and close to features positioning;
- **Guidance & control**, addressing control of multibody and variable geometry robots; degraded modes of operation of autonomous systems; platform docking, including vehicle to vehicle docking; information aware path planning, including adaptive sampling; mobile manipulation and intervention; and multiple vehicle coordination;
- **Mapping & real time perception**, addressing hyperspectral, electro-optic, and acoustic image processing; multi modal data fusion and mapping; distributed perception; underwater acoustic mapping; and multi sensor 3D environment modelling;
- **Platforms & operations**, addressing the development of innovative robotic solutions; persistent robotic systems for ocean exploration; heterogeneous robotic teams; underwater docking stations; and underwater data and energy mules;
- **Human-machine symbiosis**, addressing advanced human sensing integration; explicit and implicit human machine symbiosis; virtual environments to train and test brain computer interfaces algorithms; robotic systems for surgery support; and human anatomic behaviour mimic systems.

Major competences required to pursue this challenge include instrumentation, artificial intelligence, signal processing, robotics, and control.

3.4 POWER AND ENERGY

Coordinator: Luís Seca
Assistant to the Domain Coordinator: David Rua

3.4.1 Scope and vision

The **Power and Energy (PE)** domain envisions to support the full and enduring decarbonisation of society, an overarching objective of EU, that intends to become the first climate neutral continent by 2050.

This transformation will only take place by adopting a multidisciplinary strategy that acts on the whole energy value chain, by planning and operating it across multiple energy carriers, infrastructures, and users, in an integrated, interconnected and digitalised energy market.

This strategy will be anchored on electrification of society, renewable energy sources massive integration and on energy efficiency, requiring the combination of physical representations and data-driven methods for modelling and optimising energy systems, leveraging from emerging technologies like AI, blockchain and interoperability. This requires significant advances in the state-of-the-art and a combination of new computational, hardware and regulatory solutions.

To accomplish this goal, the domain gathers researchers with competences in Energy analytics and forecasting, Energy economics and regulation, Industrial electronics, Static and dynamic analysis of power systems, Decision-aid and optimisation, Artificial Intelligence, Parallel and Distributed Systems, Asset Management and Cybersecurity.

3.4.2 Research Challenges

Research activities within this domain are organised along five major applicational research challenges: Massive RES integration through power electronic-based interfaces, Large-scale modelling and optimisation of energy systems, Data-driven methodologies for energy systems, Health Conditions of Electrical Assets under Smart Grid Operation and Cybersecurity and IoT for Electrical infrastructures.

Massive RES integration through power electronic-based interfaces

Research will focus 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.

The main challenge is therefore 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 explore end users availability to participate in the operation of the electrical system.

To address this challenge, a set of scientific research challenges (that incorporate a set of specific research topics) is established for the coming years:

Definition of grid stability monitoring and control strategies in 100% RES systems

- Define frequency control strategies in low inertia systems;
- Estimating and providing manageable virtual inertia to power systems;
- Promoting improved stability through smart transformers;

Unlocking the use of flexibility in smart grids

- Defining standardised flexibility services and products for DSO and TSO;
- Developing models and tools to promote the TSO-DSO coordination;
- Incorporating flexibility in network operation and planning tools;
- Promoting sector coupling flexibility through EV and H2.

Improving energy communities and grid resilience through microgrids

- Developing islanding and bottom-up blackstart strategies and tools;
- Detailed modelling of distributed energy storage technologies for energy optimisation problems;
- Developing power and energy management strategies for hybrid microgrids.

Large-scale modelling and optimisation of energy systems

This challenge is the basis for the development of the electrical system 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 optimisation tools.

This process involves a significant **use of computationally efficient algorithms that integrate different sources of uncertainty** given 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.**

Related to the development of optimisation techniques, **the solution of large-scale non-convex optimisation and learning problems with decomposition techniques and distributed computing** will be explored.

To address this challenge, the following scientific research challenges is established for the coming years:

Provision of system situation awareness while tracking system states at different and simultaneous levels of sensor signal time scales, by combining knowledge at different levels of granularity

- for human perception and closed loop control in a diversity of control room environments, including in a smart grid context;

Search for a systematic set of transforms or rules to build meaningful images from time-domain sensor signals (static and in data streams), maximising the preservation of extractible knowledge content, to achieve knowledge extraction by image processing tools

- for novelty detection, identification, diagnostic purposes, as well as for feeding AI tools;

Building of a self-adaptive method to conduct intelligent optimisation in large spaces via projections onto reduced feature spaces

- to deal with large-scale complex problems with population-based methods.

Data-driven methodologies for energy systems

The digitalisation of the energy sector **requires novel data-driven methodologies for forecasting, optimisation and prescriptive analysis**, which enables the creation of new services for end-users.

The 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.

The creation of **data marketplaces**, using blockchain and smart contracts technology, bearing in mind the creation 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.

These R&D results will be applied to different energy domains: **energy efficiency** (e.g., new energy services), **grid operation and electricity markets.**

To address this challenge, a set of scientific research challenges (that incorporate a set of specific research topics) is established for the coming years:

Hybridisation of AI-human-physics for the control rooms of the future

- Knowledge extraction from heterogeneous data sources;
- Novel data representations for knowledge extraction;
- Integration of forecast uncertainty in electrical grid management.

Energy and cross-sector data-driven services by leveraging on privacy-preserving federated learning and data marketplaces

- Improve predictability of renewable energy;
- Privacy-preserving protocols for data sharing in renewable energy and smart grids;
- Monetary and non-monetary incentives for energy data sharing;
- Unlock "hidden" value of smart metering data.

Health conditions of electrical assets under smart grid operation

The inclusion of new assets, with significant **uncertainty in life cycle**, together with completely **new operation strategies for more conventional assets**, makes this challenge fundamental for the operation of the electrical system of the future.

The development of new business models, that explore flexibility over all stakeholders in the electrical system, 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.

Development of **combined 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**.

To address this challenge, a set of scientific research challenges (that incorporate a set of specific research topics) is established for the coming years:

Combination of multiple information sources in different formats and timeframes to create accurate asset failure models

- Diagnostics via chemical, thermal, mechanical, electric, meteorological, maintenance data;

Address missing or misleading data when predicting remaining useful life

- Overcoming issues with censored/truncated data and survivability bias;

Imbed failure models in system-level reliability assessment algorithms and asset management techniques

- Include non-Markovian stochastic processes in the identification of important ageing infrastructure requiring preventive maintenance and/or replacement actions.

Cybersecurity and IoT for electrical infrastructures

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 challenge is focused on **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.

Research in IoT must **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.

To address this challenge, a set of scientific research challenges (that incorporate a set of specific research topics) is established for the coming years:

Combine distributed IoT with hybrid edge-cloud continuum processing

- Leverage IoT devices' distribution to address/bound privacy concerns and policies;
- Adopt new protocols to maximise data processing at the edge;

Address semantic knowledge extraction for autonomous preventive tasks

- Exploiting autonomous interoperability across IoT and Grid stakeholders;
- Adopt interoperable interfaces as a way to reduce risk vectors;
- Explore new methodologies to limit undesired behaviour when resorting to knowledge exploration.

4 TEC4 INITIATIVES

4.1 Overview

A TEC4 ("TEChnologies FOR …") is a new organisational 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-Domain 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 4.2 to 4.9 present a short description of the scope and objectives of the current TEC4 initiatives.

4.2 Current initiatives

The global TEC4 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
- A structure named TECPARTNERSHIPS, responsible for global coordination and support, to ensure the typical TEC4 functions to other application areas not covered 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, provides national companies an easy access to international partners and enables the attraction of foreign direct investment into the region and the country.

4.3 Methodology

Each TEC4 has an implementation plan addressing the following stages:

- 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.

4.4 TEC4INDUSTRY

Coordinator: Américo Azevedo
Business Developer: António Almeida

4.4.1 Scope and strategy overview

Both SMEs and large industrial companies recognise the importance of the digital transition as the key to leveraging and supporting their success in this new economy. The generalisation of these new industrial challenges has been promoting the creation of new types of consultancy and technology companies, with a strong innovative and disruptive mindset, capable of providing industrial companies with added-value and effective digital solutions. In this new reality, the TEC4Industry has the objective to leverage the science-based cross-sectoral innovation by promoting new added-value interactions and partnerships between INESC TEC and the industry, and INESC TEC and these new consultancy and technology companies, towards a more competitive and sovereign national industrial ecosystem.

In this sense, the TEC4Industry presents a double role, both internally within the INESC TEC ecosystem and externally for the national industrial ecosystem. At the internal level, the TEC4Industry must perform as the INESC TEC driver for added-value science-based research, promoting vision alignment between the 13 research centres and the industry needs. Externally, the Tec4Industry must promote a more vital national industrial ecosystem composed of added-value industrial companies and disruptive and unique technologies and consultancy companies.

The scope of the TEC4Industry cover the entire value chain, from the extractive and manufacturing industry to the distribution and retail industry, and also include the advanced manufacturing systems industry. From an industry sector perspective, the TEC4Industry covers the entire set of industrial sectors, with special attention to the more traditional and important ones, such as the automotive industry, metal and equipment production industries, textile and shoe industries, cork/wood and forest industries, plastic and mould industries, retail industry, and many others.

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.

TEC4INDUSTRY INTERVENTION MODEL

INESC TEC presents a unique combination of multidisciplinary knowledge, competencies, and resources, divided by 13 research centres with specific and comprehensive in-depth know-how and experience, a strong network of infrastructures, as well as an extensive network of partners. In this sense, TEC4Industry wants to take advantage of this unique combination to promote INESC TEC to the ideal position to develop added value applied research, based on science, in a targeted way and according to the domain-specific challenges.

This added value service to the market has been anchored in a history of successes, materialised in effective technology and knowledge transfer to companies, based on different formats:

- Important long-term partnerships with companies from different sectors from the manufacturing industry (e.g. Kyaia, Amorim, etc.);
- R&D partnerships with consultancy, technology and engineering services companies (e.g. Critical Manufacturing, Softi9, KIT-AR, etc.);
- Distinct consultancy projects targeted to support small, medium and large companies along with their digital transformation (e.g. GALP, Bulhosas, JC Ribeiro, etc.);
- Cooperation with national industry associations to foster the digital transformation (COTEC, AECOA, MOBINOV, etc.);
- Advanced training services, leveraged on the unique test and experimental facilities that INESC TEC has been developing (e.g. iiLab, Massive Lab and MACC - Minho Advanced Computer Centre);

- Promotion and execution of innovative 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.

On the other hand, the proximity with the national and regional governmental entities supports the creation and definition of national industrial agendas aligned with the industrial needs and ambitions. Specific in the context of PRR (Plano Recuperação e Resiliência), TEC4Industry promotes the interaction between academia, industry and technology providers to drive the development, demonstration and promotion of new Portuguese products, technology and services.

DRIVING FORCES

TEC4Industry promotes Portuguese industry competitiveness by supporting companies in building the foundations and tools that will allow them to take advantage of the current and future societal, environmental and economic landscapes, to create added value at an international level. In this sense TEC4Industry wants to take its role to promote:

- **a resilient Industry** with the ability to resist and react quickly to context changes with direct impact on business, which may be technological, natural, political or, as in the present case of the pandemic, public health
- **a digital Industry** with a strong commitment to digitalisation, taking advantage of all the potential of digital technologies to develop new products, services, processes and business models
- **a sustainable Industry** where industrial companies are active agents of Circular Economy, minimising the use of materials and other resources, namely energy, incorporation of recycled materials, capture and reuse of CO2, the introduction of new materials, extension of the life span of products or components, etc.
- **an industry with added value** where the application of specialised know-how and cutting-edge technical knowledge in the creation of products, production processes and associated services, will have a strong potential to guarantee sustainable growth and high economic value to Portugal.

4.4.2 Main objectives for 2022

The strategic lines that will drive TEC4INDUSTRY along 2022 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. In 2022, TEC4INDUSTRY will explore the INESC TEC alignment with the opportunities enabled by the Portuguese Resilience and Recovery Plan. Furthermore, we intend to leverage the potential of INESC TEC competencies and services, geared by the new iiLab infrastructure. 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) Explore internal assets (e.g. iiLab) to leverage new partnerships and value-added services;

c) 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 Research Domains and Centres to industrial associations and external R&D organisations, at the 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.

4.4.3 Action plan

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

Table 4.1 – TEC4INDUSTRY – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Visit and contact new potential clients in Portugal and eventually abroad	2.b 2.c 2.f	Increase INESC TEC network of partners and customers	Continuous Activity
Develop high level meetings with the management of large companies	2.a 2.b 2.d	Establish research-based contract programs	Continuous Activity
Participate on specific Summits and events promoted by European Commission, EU programmes/initiatives or others EU organisations	2.g	See the future of manufacturing from global experts and have visibility on EU initiatives and programs in order to influence EU manufacturing roadmap.	Continuous Activity
Visits to European and International institutes facilities	2.e 2.g	Benchmarking	Continuous Activity
Participation in National and International fairs	2.a 2.c 2.f	Disseminate and demonstrate the technologies and case studies developed in INESC TEC	Continuous Activity
Participation in International Conferences for education and manufacturing	2.e	Collect new ideas and technologies as well as challenge TEC4INDUSTRY innovation (IEEE EDUCON 2022, ICMR 2022 or FAIM 2022)	Continuous Activity
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	1st Quarter
To consolidate iILAB's value proposition and thus characterise and specify its service offering.	1.a 1.b 2.a 2.d	Structured service offer	1st Quarter
Re-think INESC TEC services portfolio: assess the current portfolio of services and identify clear overlaps and market opportunities	1.c 2.a	List of services provided by INESC TEC centres and market strategy	1st Quarter
Promote INESC TEC and Industry collaboration within the PRR	2.b 2.f	Support collaboration between INESC TEC, Technology companies and Industrial companies to submit innovative projects in PRR agendas.	1st Semester
Promote regular webinars oriented to hot-topics and workshops for training taking advantage from the iiLab infrastructures	1.c 2.a 2.d	Support Centres to promote blended events (online and iiLab based events) to promote INESC TEC services offer, expertise and know-how	Quarterly
Advanced Training Courses and Master Classes for target domains	1.b 2.d	Build flexible, multidisciplinary, and customised courses in the digital transformation domain	Continuous Activity
TEC4INDUSTRY Summit	2.a 2.e 2.f	TEC4INDUSTRY will bring together national/international companies and INESC TEC experts in industry 4.0 domain to address important topics for this industrial revolution	3rd Quarter

4.5 TEC4HEALTH

Coordinator: Miguel Coimbra
Business Developer: Carlos Ferreira

4.5.1 Scope and strategy overview

The Mission of TEC4HEALTH is to induce a market pull drive into R&D, targeting all the value chain actors and processes in the healthcare and wellbeing sectors. 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 competences, resulting into successful projects, contracts, and technology transfers.

Portugal is still small in the health technology market, but the country has been proving to be an excellent hub with regard to the development of prototypes and innovative projects with patients and healthcare providers. In the last 4 years, INESC TEC developed 54 health projects together with partners whether on the business or hospital side and whether with national or international relevance. Although it is not possible to cover the entire TRL range, usually between 1 and 6 due to the difficulty and time required for certification and clinical tests, INESC TEC has also adopted an intelligence strategy in this area with the launch of spin-offs (WeSenss, InSignals Neurotech, iLoF) to drive forward the growth and maturity of technologies.

Regarding R&D contributions, INESC TEC has a strong alignment on at least three application areas: cancer (lung, breast, colorectal, stomach, ovary and uteri), disease prevention/screening (chronic and pandemic diseases) and neuro/brain diseases (epilepsy, Parkinson, Alzheimer, autism and depression). The first two application areas are particularly relevant for the near future since cancer has been designated as one of the European Missions and chronic/pandemic diseases will continue to be societal challenges where technological solutions and public policies are required to emerge. Neuroengineering based solutions have been quite successful in terms of granted patents and launched spin-offs so the main support is to continue this positioning in the market.

INESC TEC's know-how in artificial intelligence, biomedical instrumentation, information systems, health management and medical robotics make it a very attractive research institute for any type of partner working in the health pipeline. However, the health technology business sector in Portugal is quite small with only one medium-sized company (Glintt). Only recently, large IT companies, traditionally operating for other sectors such as Microsoft, Altice, NOS, NTT or Vodafone, among others, have started to gain interest in healthcare and may become interesting partner companies to establish partnerships. On the other hand, the development of technological solutions for public hospitals is strongly influenced by a public software house (SPMS). Thus, currently our main partners have been research institutes (I3S, Fraunhofer AICOS, ISPUP, CINTESIS and Champalimaud), public hospitals in the North region (Hospital São João, Hospital Santo António, Hospital Vila Nova Gaia/Espinho and IPO Porto) and some international universities (LMU and CMU). With that in mind, our target will be to improve collaborative relations with Glintt and SPMS and to reinforce the investment to reach big international players in the digital health area (Siemens, GeHealthcare, Phillips and Medtronic), the largest Portuguese private health groups (Luz, Trofa, CUF and Lusíadas), relevant small companies in the sector (Plux, Neutroplast, B-Simple, Neadvance…) and patient associations. New types of industries will also be a target, with little or no interaction with INESC TEC so far, such as clinical analysis laboratories, pharmacies, pharmaceutical, in sports, nutrition or veterinary.

4.5.2 Main objectives for 2022

After a 2020 mainly dedicated to identifying internal strengths, 2021 was already a very good year in terms of approaching external partners. For 2022, the objective are as follows:

INTERNAL

A. Collect the researchers needs to meet target partners to pair on R&D projects;
B. Promote brainstorming meetings between researchers to better tackle research calls;
C. Map INESC TEC competences for expected calls of Horizon Europe (2023-2024) but also in other relevant European programs such as EU4Health, ERA4Health, Mission Cancer, EIT Health, Digital Europe and the Europe's Beating Cancer Plan;

D. Promote thematic discussions and sensitise for considerations that should be ensured in R&D health projects;

E. Present relevant news and research opportunities;

F. Extend research opportunities to centres that do not usually do research in health and strengthen those that usually do research.

EXTERNAL

A. Disseminate our technical oriented competences in health to relevant actors;

B. Establish new partnerships with relevant Portuguese entities in the health ecosystem;

C. Join other clusters and meeting organisations with national relevance;

D. Increase activity with already cooperating partners;

E. Cooperate in the technology transfer process in prototypes with TRL close to the market;

F. Increase representation and relations with international consortia.

4.5.3 Action plan

This year, TEC4HEALTH will design and/or implement the following actions:

Table 4.2 – TEC4HEALTH – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Organisation of internal meetings with INESC TEC Centres	1A), 1B), 1E)	Get feedback and needs within the research centres.	All year
Invited talks on relevant health concerns	1C)	Increase health literacy and improvements in the innovation pipeline	T2, T4.
Study and plan of European calls	1D), 2F)	Strategic plan with relevant European funding opportunities Submitted project proposals with strong possibility of approval	All year
International businesses visits	1D), 2A), 2F)	Establishment new partnerships Increased visibility of INESC TEC within the health technology area Preparation of new proposals and contracts	T2, T3.
National businesses visits	1D), 2A), 2B), 2D)	Establishment new partnerships Increased visibility of INESC TEC within the health technology area Preparation of new proposals and contracts	T1, T4.
INESC TEC participating in relevant networks	2C)	Presence in relevant networks New Opportunities	T3-T4.
Enhancing technologies	2E)	New Products and Spin-offs	All year
Participation in national and international fairs	1D), 2A), 2B), 2F)	Networking / Lobbying Market scouting (access to sectorial roadmaps)	All year
Develop new communication materials	2A)	Produce webinars, brochures, TEC4Health website and other promotional material	T1

4.6 TEC4ENERGY

Coordinator: João Peças Lopes
Business Developer: Nuno Campos

4.6.1 Scope and strategy overview

TEC4ENERGY is INESC TEC's innovation platform towards a Decarbonised Economy, that aims to stimulate power and energy (P&D) related industries to overcome the main challenges in their domain. TEC4ENERGY brings together R&D&I institutions, businesses, and associations, increasing synergies and developing critical mass, in order to contribute to innovative solutions, that bring value to the economy and society.

INESC TEC's R&D results are monitored in all the TRL (Technology Readiness Levels) spectrum, potentiating a market-pull valorisation, focused on applied research that can lead to products, processes and services transferable to all the P&E sector actors and/or valorised by start-ups, that mainly address emerging (or niche) market segments.

For accomplishing this, it is necessary to implement a technological and market surveillance, studying the activities within the P&E sector where business/technology necessities/limitations demonstrate a high potential for applying our competences, resources and experience, in order to accomplish successful projects, collaborations and technology/knowledge transfer, fostering transformation towards a decarbonised economy.

The main types of collaboration between TEC4ENERGY and the industry are advanced consultancy & training services, contract-based R&D and strategic partnerships, promoted both at national and international levels.

INESC TEC benefits form a strong recognised expertise in P&E Systems, with more than 20 years transferring research results to manufacturers, software vendors, electric utilities and large energy users, nationally and internationally.

We develop solutions that contribute to the Societal Challenges and Innovation Strategies for Smart Specialisation defined by EU policies. Specifically, the P&E sector will be heavily digitalised decentralised, under a user centric and market-based approach, involving a large-scale integration of renewable energy sources, requiring the conceptualisation and development of disruptive solutions

TEC4ENERGY identifies new potential projects with the industry and the society, through a multidisciplinary scientific based approach to overcome the limitations that stakeholders find in the existing market solutions, conveying these projects for further development to the R&D Centres closer to the technological requirements.

TEC4ENERGY is therefore expected to impact INESCTEC activity by fostering the generation of new contract programs and specific projects joining in this mission different competences and resources of the institution.

4.6.2 Main objectives for 2022

The main objectives of TEC4ENERGY for 2022 are the following:

1. Identify leads to involve in National and International R&D projects, Contract Programs, Advanced Consultancy & Advanced Training opportunities (external);
2. Promote the involvement of INESC TEC in the development of consultancy studies related with the verification of grid code compliance for new renewable power plants, including hybrid generation facilities, over-equipment and repowering solutions;
3. Promote the involvement of INESC TEC in renewable gases projects (H2 and biogases) regarding control of generation, transmission and distribution networks;
4. Promote the involvement of INESC TEC in projects related with the decarbonisation in industry (renewable self-consumption and improvement of energy efficiency in the industry);
5. Collaborate in the formation and preparation of new projects within the framework of Horizon Europe;
6. Consolidate and leverage collaborations with synergetic R&D Centres (internal);
7. Promote INESC TEC visibility and Excellence (external);

8. Participate in the main P&E events – conferences, workshops, exhibitions (external);
9. Network with Clusters and Industrial Associations (external);
10. Promote and increase the collaboration with the P&E CoLABs – SEL, HyLab, VG Lab (external);
11. Potentiate and promote the utilisation of INESC TEC laboratory infrastructures, mainly the SGEV Lab, when providing services to the industrial community (internal).

4.6.3 Action plan

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

Table 4.3 – TEC4ENERGY – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
National Business Visits/Meetings	1) 2) 3) 4) 5) 6) 10) 11)	New partners / Partnership consolidation	All year
		Generate Proposals / Future opportunities	All year
		Contract Programs	All year
International Business Visits/Meetings	1) 5) 6) 7) 11)	New partners / Partnership consolidation	All year
		Proposals / Future opportunities	All year
		Contract Programs	All year
Organisation of Events (e.g., PSCC - Power Systems Computation Conference 2022 - with Stand)	1) 5) 6) 7) 8) 11)	Potentiate future opportunities	All year
		Networking creation and market understanding refresh	All year
		Contribution to technological / Scientific roadmap	All year
		Promote INESC TEC	All year
Participation in Business Fairs and Events	1) 2) 3) 4) 5) 7) 8) 9)	Networking creation and market understanding	All year
		Promote INESC TEC	All year
Communication and Equipment	5) 6) 7) 10) 11)	Videos, flyers, equipment	All year
International and National Institutional Meetings	5) 7) 8) 9) 10)	Networking / Lobbying	All year

4.7 TEC4AGRO-FOOD

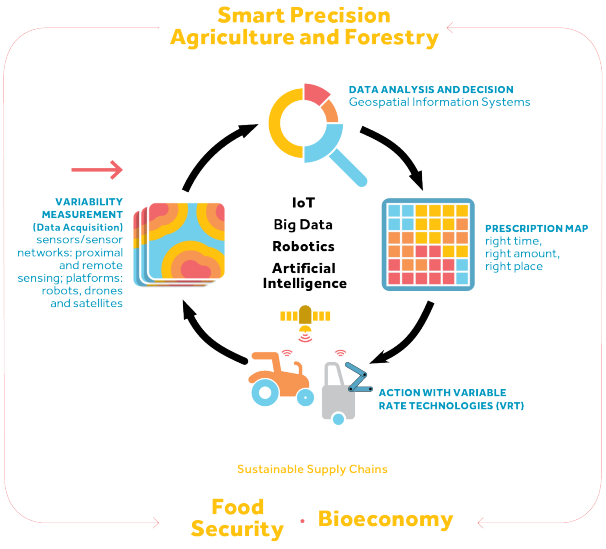
Business Developer: André Sá

4.7.1 Scope and strategy overview

TEC4AGRO-FOOD is INESC TEC's Initiative for Agro-Food and Forestry.

TEC4AGRO-FOOD's mission is co-shaping the digital (r)evolution in Agro-Food and Forestry through research and technological development in Digital Technologies and Robotics.

TECAGRO-FOOD's application areas are Smart (digitalisation) Precision ("right time, right amount, right place") Agriculture and Forestry, Food Security and Bioeconomy. TEC4AGRO-FOOD may 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.



TEC4AGRO-FOOD's current strategy is to consolidate the importance it has achieved at both national and European levels and to sustain the considerable growth verified in the last years, especially in the last five (since 2017). The presence in the relevant Collaborative Laboratories (CoLABs), Competitiveness Clusters (Clusters), National Competence Centres and Smart Specialisation Regional Platform Food and Environmental Systems (CCDR-N), the established partnerships, namely with INIAV, Herculano and complementary partners, and specially in what concerns Europe, the start or the strengthen of the participation in relevant European programmes/initiatives, as well as INESC BRUSSELS HUB's Work Group Agro, will be essential to implement the strategy. In the beginning of 2022, the TEC4AGRO-FOOD's Strategic Plan, which is being developed during 2021, will be concluded and consequently there could be changes regarding strategy, main objectives and action plan.

4.7.2 Main objectives for 2022

The main objectives of TEC4AGRO-FOOD for 2022 are the following:

- Full realisation of projects in portfolio (#1);
- Redouble efforts with companies (#2);
- Redouble efforts at the international level (#3);
- Increase internal knowledge about Agro-Food and Forestry (#4);
- Increase Researchers feeling of belonging to TEC4AGRO-FOOD and foster inter-R&D Centres collaboration (#5).

4.7.3 Action plan

In 2022, TEC4AGRO-FOOD will design and/or implement the following actions:

Table 4.4 – TEC4AGRO-FOOD – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Develop TEC4AGRO-FOOD's Strategic Plan	#1; #2; #3; #4	TEC4AGRO-FOOD's Strategic Plan	Beginning of the year
Start or strengthen participation in relevant European programmes/initiatives	#3	Participation/stronger participation in relevant European programmes/initiatives	TBD
Participate in kick-off meetings, demos 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
Establish 1 direct contract with Portuguese company	#2	1 direct contract with Portuguese company	TBD
Submit 2 applications for PRR Agendas	#2	2 applications for PRR Agendas	TBD
Submit 3 applications for PRR Agro-Food Initiatives	#2	3 applications for PRR Agro-Food Initiatives	TBD
Submit 1 application for Individual R&D Projects (National R&I FP)	#2	1 application for Individual R&D Projects (National R&I FP)	TBD
Submit 3 applications for Co-promotion Projects (National R&I FP)	#2	3 applications for Co-promotion Projects (National R&I FP)	TBD
Submit 3 applications for HEurope projects with INESC TEC as Coordinator	#3	3 applications for H2020 and HEurope projects with INESC TEC as Coordinator	TBD
Submit 5 applications for HEurope projects with INESC TEC as partner	#3	5 applications for H2020 and HEurope projects with INESC TEC as partner	TBD
Participate in relevant ecosystem activities (CoLABs; Clusters; National Competence Centres; Smart Specialisation Regional Platform (CCDR-N)	#2; #3	R&I projects	TBD
Participate as "R&D Partner" in AgroIN 2022	#2	National networking and notoriety	06/2022
Organise an TEC4AGRO-FOOD's Community Preferential Contacts Meeting/Social Event	#1; #2; #3; #5	Stimulate TEC4AGRO-FOOD's Community Preferential Contacts	TBD
Develop new communication materials	#1; #2; #3	Increase and improve TEC4AGRO-FOOD communication	TBD

4.8 TEC4SEA

Coordinator: Eduardo Silva
Business Developer: Carlos Pinho

4.8.1 Scope and strategy overview

TEC4SEA is the INESC TEC initiative towards the Blue Economy established and emerging sectors, aiming to stimulate related industries and partners to overcome the main future challenges in this domain. TEC4SEA brings together R&D+i Institutions, businesses, and associations, increasing synergies and critical mass, raising up a north based Ocean Engineering Excellence Network capable of leading international initiatives in the Sea Economy.

TEC4SEA monitors the internal results (TRL 1-9) but focuses on applied research leading to products, processes, and services (TRL 5-9) that can be transferred to companies and/or valorised by star-ups addressing emerging (or niche) market segments.

The multidisciplinary application-oriented solutions addressed by TEC4SEA cover a wide range of industries currently facing several changes and a considerable number of future challenges in the horizon. From specific national challenges in each of the Blue Economy sectors, to the European Green Deal objectives to 2030, the new European vision targeting 2050, up to global challenges. TEC4SEA in organising this outlook in three vectors:

a) Digitalisation.
b) Energy.
c) Robotisation and automation.

These vectors are aligned with the internal competencies and Research Lines, impacting both established and emerging Blue Economy sectors. Considering the strategic positioning defined by TEC4SEA, priority market sectors include Marine Living Resources (fishing and aquaculture), Marine Renewable Energies (including green hydrogen), Shipbuilding and repair, Deep Sea Mining, Ports, and the Maritime Defence.

4.8.2 Main objectives for 2022

TEC4SEA ambitions both “internal” (impacting the core teams of INESC TEC) and “external” (impacting stakeholders outside INESC TEC) objectives:

INTERNAL

1. Continue the consolidation with increasingly relevant centres (e.g., CPES, CESE and CEGI), and develop new initiatives to better engage other relevant centres for the Blue Economy (e.g., LIAAD, HASLAB and CRACS).
2. Strengthen the articulation with the work team to reduce barriers between the centres and the TEC4SEA as well as enable the execution of the several actions and tasks. Develop a continuous work of synchronisation, strategies, and priorities alignment, supported by a full year agenda previously booked.
3. Internal awareness and alignment with the medium-term strategy and action-plan (2030), fostering current and future funding opportunities (e.g., Horizon Europe, EITs, national programs, etc.).
4. Initiate the strategic awareness for the need of dedicated data storage solution for unique information gathered within Sea activities.

EXTERNAL

1. Explore and leverage INESC TEC involvement in the EMSO-PT and Tec4Sea infrastructures.
2. Promote and disseminate the resources and capacities of the Tec4Sea infrastructure, fostering R&D+i and subcontracting opportunities.
3. Develop and pursue national and international mechanisms to establish INESC TEC Sea domain as a Centre of Excellence.
4. Assume a position in the Ocean Renewable Energies test site (Aguçadoura's test site) and/or in other coastal areas of the country.

5. Continue to strengthen our relationship and collaboration mechanisms with national core players, such as: Fórum Oceano, IPMA, CIIMAR, INEGI, AIR CENTER, IBS, B2E and +Atlantic and widen the close collaboration mechanisms to entities in the autonomous regions (Azores and Madeira).
6. Strengthen the collaboration with entities in the entrepreneurial ecosystem to help revitalise a competitive and innovative Blue Economy in Portugal.
7. Request "Títulos de Utilização Privativa do Espaço Marítimo (TUPEM)" to support INESC TEC R&D+i in the Sea domain.
8. Pursue a close collaboration platform with the Portuguese Navy, following their initiatives and previous invitations.
9. Identify and establish close collaboration mechanisms/protocols with international leading organisations (e.g., Sintef Norway and GCE Ocean).
10. Foster the successful accomplishment of all the Sea related initiatives within the "Plano de Recuperação e Resiliência" – from bottom-up project proposals to top-down initiatives (Hub Azul Norte - Leixões).
11. Continue to consolidate international relations (Europe, Latin America, India, South Korea).
12. Contribute for the European establishment of the Portugal Blue Digital Hub, led by Fórum Oceano.

4.8.3 Action plan

This year, TEC4SEA will design and/or implement the following actions:

Table 4.5 – TEC4SEA – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
National Businesses visits	I3, I4, E1, E2, E3, E4, E5, E6, E8, E10, E12	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	All year
International Businesses visits	I3, I4, E1, E2, E3, E6, E9, E11	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	All year
Participation on Oceans 2022 in Virginia as visitors	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	2T (October 17-21)
Participation on Business2Sea with stand	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	4T
Conferences inscription	All objectives	• Scientific/market orientation • Develop SEA intelligence	All year
Communication material production	All objectives	• Marketing & Communication materials • Make the brand INESC TEC/TEC4SEA known	All year
Participation on Aquaculture Europe 2022 with stand (Italy)	I3, I4, E4, E5, E11	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	3T (September 27-30)
Promoting TEC4SEA Infrastructure	I3, I4, E1, E2, E3, E4, E5, E6, E7, E8, E9, E11, E12	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	2T

4.9 TECPARTNERSHIPS

Business Developers: Augustin Olivier, António Gaspar and José Nina de Andrade

4.9.1 Scope and strategy overview

The scope of TECPARTNERSHIPS is to 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. We will evaluate the possibility of INESC TEC transfer technology targeting those sectors, allowing companies to be internationally competitive with innovative products.

The goal for each sector is promoting INESC TEC as a technologic reference partner and to create and consolidate a scientific community inside the organisation and with relevant complementary scientific institutions.

In the strategic planning elaborated for Financial and Internet Market the following strategic actions were identified:

a. Be a reference in the Internet value chain

   We intend to develop a set of actions to position INESC TEC as an R&D reference in the Internet value chain. Conduct a survey of service providers. Organisation of the offer based in INESC TEC research lines and preparation of supporting documentation. Participation in networking events and fairs. Identification of funding opportunities in Horizon Europe and other public funding sources that include companies.

b. Scouting application areas

   We intend to develop a set of actions to position INESC TEC as an R&D reference in the others identified sectors. In that others, we will identify relevant events and founding opportunities.

c. Creating and consolidating a community

   We intend to create and consolidate an internal community of researchers from various centres and external, establishing partnerships with R&D entity/groups with complementary skills, and with technology companies.

Regarding the Defence and Security, Space, Mobility and Public Administration, the goal is to identify application areas, increase awareness of INESC TEC's competences, identify and link with potential partners and create Communities of Practice.

The following table presents the current status of the main areas/sectors under consideration.

Table 4.6 – TECPARTNERSHIPS– Main areas/sectors under consideration

Sector	Core Centres	Phase of implementation	Existing Network
Construction	CESE, LIAAD, CRAS, CRIIS	Startup	PCTP, BuiltColab
Defence and Security	CRAS, CTM	Study	AEDCP, EARTO
Space	CAP, CRAS, CTM	Study	AEDCP, EARTO
Internet Market	Computer Science, CTM, CESE, CEGI	Startup	NEM, TICE.PT
Finance	Computer Science, CTM	Startup	
Mobility	CEGI, CESE, CSIG, CTM	Study	AEDCP, PFP, ITS Portugal
Public Administration	Computer Science	Study	

4.9.2 Main objectives for 2022

The main objectives of TECPARTNERSHIPS for 2022 are the following:

1) Identify and structure INESC TEC offer: services and technologies, for new market segments
2) Identify the services providers and potential partnerships
3) Identify leads and explore potential research and services opportunities
4) Promote and communicate INESC TEC
5) Identify and participate in the main business events
6) Network with clusters and industrial associations
7) CRM implementation
8) TEC4 sub website review

4.9.3 Action plan

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

Table 4.7 – TECPARTNERSHIPS – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
National Businesses visits	2) -3) - 4)	• Proposals/ Future opportunities • Make the brand INESC TEC known • New partners/Partnership consolidation	All year
International Businesses visits	2)-3)-4)	• Proposals/ Future opportunities • Make the brand INESC TEC known • New partners/Partnership consolidation	All year
Participation on fair/event of with stand QSP Summit and AED Days	4)-5)	• Proposals/Future opportunities • Networking creation and market understanding • Contribution to technological/Scientific roadmap • Make the brand INESC TEC known	Second half of the year
Conference registration	2) -5)	• Networking creation and market understanding	All year
Workshop organisation	2)-3)-4)	• Attract main actors of market sector • Contribution to Technological/ Scientific roadmap • Networking creation • Proposals/Future opportunities • Make the brand INESC TEC known	Second half of the year
Strategic reflexion seminary	1)	New strategy	All year
Communication material production	4)	Videos, flyers, …	All year
Transversal activities			
International association meetings	2)-4)-6)	• Networking / Lobbying	All year
CRM	2)-3)-7)	Proposals/Future opportunities	All year
Web site TEC4	1)-2)-3)-8)	Make the brand INESC TEC known Proposals/Future opportunities	All year
Association fees	2)-4)-6)	• Make the brand INESC TEC known Networking / Lobbying	All year

5 RESEARCH AND DEVELOPMENT CENTRES

5.1 CTM - CENTRE FOR TELECOMMUNICATIONS AND MULTIMEDIA

Coordinators: Jaime Cardoso and Filipe Ribeiro

5.1.1 Scope, vision and activities

Centre scope and vision

The Centre for Telecommunications and Multimedia (CTM) consists of over 100 researchers working on scientific and technological challenges in the fields of telecommunications and multimedia. CTM is fully committed to the vision and mission of INESC TEC and specialises them as follows:

- Vision: A lively and sustainable world where networked intelligence enables ubiquitous interaction with sensory-rich content;
- Mission: To research and develop advanced systems and technologies that enable high capacity, efficient communications, media knowledge extraction, and immersive ubiquitous multimedia applications.

CTM fulfils its mission in the Networked Intelligent Systems scientific domain by organising its activities within four Main 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); Visual Computing and Machine Intelligence (VCMI, led by Hélder Oliveira). Research at CTM is organised in five Research Lines, which are detailed next.

Scientific activities

RL1. Optical/radio and electronics engineering

The main goal of this research line is to devise solutions for the communications, processing and sensing systems of the future, building on advanced skills in applied electromagnetics, photonics, as well as electronics and reconfigurable logic, and targeting applications in optical and wireless communication systems, human sensing and embedded computing. Research activities in applied electromagnetics include reconfigurable antennas using novel materials and antenna arrays up to sub-THz and signal processing techniques with a focus on localisation and beamforming. Research in photonics addresses the use of light signals for transporting information in optical fibre, wireless and underwater scenarios, as well as signal processing techniques and photonic integrated circuit design enabling the processing of microwave signals. Research in (micro)electronics addresses the design of electronic circuits in thin-films focusing particularly on ultra-low power neuromorphic architectures for computing at the edge and extreme edge, while research in reconfigurable devices and application-specific computing strive for improved power-performance tradeoffs, providing hardware acceleration at the edge combined with transparent adaptivity mechanisms. This research line contributes to the "Novel perception tools" and "Context-aware communications systems" INESC TEC's Research Challenges.

RL2. Wireless Networking

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 communications. This includes the design of novel algorithms and mechanisms and requires theoretical and simulation modelling, implementation, and experimental evaluation of wireless networks and their elements. The main research topics include network topology control, routing, radio resource management, and context-aware optimisation using cross-layer techniques and machine learning for networking. This RL expects to achieve several relevant scientific contributions aligned with such a vision including: 1) algorithms and mechanisms for optimal node positioning and radio resource allocation in flying networks; 2) novel reinforcement learning based algorithms addressing smart link adaptation in Wi-Fi networks and dynamic positioning of flying access points; 3) mechanisms and algorithms enabling novel wireless communications solutions for underwater environments; 4) new custom-

tailored simulation models enabling the creation of Digital Twins for accurate, cost-effective validation of wireless networking solutions. This research line contributes to the "Context-aware communications systems" INESC TEC's Research Challenge.

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, etc.), the development of new approaches for constructing different narratives, the use of enhanced data visualisation paradigms and Human-Media interaction mechanisms to enhance the quality of experience or the quality of the content produced. 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 and scene recreation. Such applications can provide added value in different domains and facilitate information management to be efficiently accessed and navigated. This research line contributes to the "Beyond human vision" and the "Context-aware communications systems" INESC TEC's Research Challenges.

RL4. Computer Vision

This line performs research in both fundamental and applied problems in computer vision, multimedia data processing, 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. We favour the adaptation of the solutions in several main areas: medical image analysis, biometrics and forensics, multimedia content understanding, agriculture and zootechnical, sports, arts and autonomous vehicles. The work on developing intelligent decision support systems combines audiovisual data understanding with any additional information, coming from sensors or other external sources, to improve flexibility and enhance the analysis and decision process. Our main activities are focused on developing computer vision architectures achieving functionalities and performances surpassing humans, centring on never-ending learning capabilities, multi-objective perception, generic artificial vision, and causal and explainable models. This research line contributes to the "Beyond human vision" INESC TEC's Research Challenge.

RL5. Cancer Image Analysis

CTM has been working in this RL for two decades and is considered a reference research group worldwide in cancer image analysis. We aim to continue contributing with approaches on computational pathology to assist the radiologist in the diagnosis, methodologies to facilitate surgery planning, computer-aided systems to perform aesthetic evaluation after treatment, and specifically for breast cancer survivors, serious games for rehabilitation. Furthermore, in cervical cancer screening, we will contribute mainly to colposcopic and histopathological image analysis, by developing methods for image quality analysis and support of diagnosis, and also on lung cancer on radiogenomics, pathomics and omics analysis. Our research also contributes to managing other cancer types, such as pancreatic, neuroblastoma and gastrointestinal. Our main activities are focused on interdisciplinary research, computational models on health data from multiple sources, models integrating clinical domain knowledge and transparent, causal and accurate algorithms for improving clinical outcomes. This research line contributes to the "Beyond human vision" INESC TEC's Research Challenge.

Innovation activities

INOV1 Design of planar antennas and microwave components addressing specific industrial requirements, characterisation of wireless systems in an anechoic chamber, and design of radio-based localisation systems. This innovation activity is aligned with TEC4INDUSTRY, TEC4HEALTH, TEC4AGRO-FOOD, and TEC4SEA initiatives.

INOV2.A Planning, design, and development of narrowband and broadband wireless networks capable of supporting different types of traffic, from raw data to multimedia applications and services (including video), in terrestrial and maritime environments. This Innovative activity is aligned with TEC4INDUSTRY, TEC4ENERGY, TEC4AGRO-FOOD, and TEC4SEA initiatives.

INOV2.B Planning, design, and development of multi-hop, on-demand wireless networks for network infrastructure extension in terrestrial and maritime environments. This Innovative activity is aligned with TEC4ENERGY, TEC4AGRO-FOOD, and TEC4SEA initiatives.

INOV2.C Design and development of wireless networks for autonomous vehicles (aerial, surface, and underwater) in terrestrial and maritime environments. This Innovative activity is aligned with TEC4INDUSTRY, TEC4ENERGY, TEC4AGRO-FOOD, and TEC4SEA initiatives.

INOV3.A Context-aware personalised multimedia applications in heterogeneous environments. This Innovative activity is aligned with TEC4INDUSTRY initiative.

INOV3.B Multimedia content management and visualisation techniques for large multimedia assets. This Innovative activity is aligned with TEC4Industry initiative.

INOV4 Solutions to demonstrate, test and validate AI models with respect to their utility, in the context of biometrics, forensics, media industries and autonomous vehicles areas of application. This Innovative activity is aligned with TEC4INDUSTRY initiative.

INOV5 Solutions to demonstrate, test and clinically validate AI models with respect to their utility, aiming for improving the standard-of-care. This Innovative activity is aligned with TEC4HEALTH initiative.

5.1.2 Main objectives for 2022

Research: Increase the publications' relevance, as measured by the number of 1st quartile publications and the weighted indexed publication metric adopted at INESC TEC.

Innovation: increase to 4 the number of IP protection results/FTE.

Advanced training: organise 2 advanced training Programs.

Dissemination: Co-organise 8 scientific events (as organising committee or chairing technical committees).

Internationalisation: increase of CTM international visibility by a) submitting at least 4 project proposals with international partners; b) publishing more than 10 publications within international collaborations; organise at least 6 scientific events with international cooperation.

5.1.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.1 - CTM – Main actions planned

Action	Expected Outcomes
Organisation of CTM Open Day 2022 and summer internships	Attraction of MSc and PhD students, increase number of publications
Maintain organisation of monthly informal centre meetings - CTMeet Up - focusing on promising/emerging topics; Maintain organisation of specific meetings between full-time PhDs and meetings involving all PhDs (RCU)	Increased internal articulation and creation of new joint research opportunities
Organise a centre-wide team-building event	Increased internal articulation and creation of new joint research opportunities
Promote internally high-quality venues for publication of key research results	Increased impact of the centre in the scientific community and higher international recognition
Maintain a CTM policy for the participation in high-quality conferences and international focused-events (summer/winter schools, workshops) by senior researchers	New joint research ventures, increase the participation in the technical committees of conferences and increase the chances of becoming organisers of top conferences
Establish an international scholar visiting program	Improved networking with international peers and increased chances of attracting high-quality international researchers

5.2 CAP - CENTRE FOR APPLIED PHOTONICS

Coordinators: Paulo Marques and Ireneu Dias

5.2.1 Scope, vision and activities

Centre scope and vision

CAP research activities objectives are grounded on fundamental physics and optical engineering, driven by the demonstration of practical solutions for demanding problems, and the development of intellectual property.

CAP develops its activity within the Novel Perception Tools Research Challenge, by directing its activities in four main areas of research: integrated optics and microfabrication, optical sensors, advanced optical imaging; quantum optical engineering. The overall objective is to work towards the incorporation of our sensors as novel perception tools, such as: imaging technologies enhancing the capabilities of AUV; analytical LIBS and UV VIS systems providing real time analysis tools for robots in hazardous environments; and optical sensing technologies enabling in situ and remote physical, chemical and biological parameters detection, in demanding application scenarios.

Scientific activities

The scientific activities are developed in four main areas of research, described below. In all areas, expansion and consolidation of national and international partnerships with complementary expertise required for the goals described will be actively pursued.

RL1. Integrated Optics and Microfabrication

Activities within this research line include:

- Upgrading the Bragg gratings fabrication set-up by introducing an extra degree of freedom in the sample positioning.
- Developing robust solutions based on integrated optics for excitation of whispery gallery modes to overcome the fragility of coupling these modes into fiber tapers (and similar structures), as well as devising other applications for suspended waveguides.
- Developing hybrid sensing devices that combine optical layers with fluids handling capabilities (opto-fluidics made by femto-etching); introducing laser welding for monolithic fabrication.
- Exploring 3D glass machining for the development of solutions for liquid biopsy.
- Machining and waveguiding writing in Ultra Low Expansion (ULE) glasses. Fabrication of reference cavities for development of very high sensitivity temperature sensors.
- Exploring glass poling for the fabrication of active devices fabricated by femtosecond. 3D metallic electrode fabrication.

RL2. Advanced Optical Imaging

Advanced Optical Imaging activities will pursue the reinforcement of its activities within the Novel Perception Tools Research Challenge, addressing and contributing to current monitoring challenges in Health, Space and Marine Sciences by:

- Reinforcing the laboratorial capabilities on using digital holography and turbid lens imaging principles;
- Reviving the development of compressive sensing principles to LIDAR 3D imaging.

RL3. Optical Sensors

Optical Sensors activities include:

- Study and development of nanofiber sensors for exploration of the Vernier effect for discrimination of physical parameters.
- Applications of the Vernier effect for giant sensitivity sensors of high-performance for space interferometry.

- Development of optical sensors embedded on 3D imprinted materials for applications in electrical transformers.
- Study and development of graphene and reduced graphene oxide devices for optical antennas fabrication by inkjet printing techniques.
- Distributed sensing using Fi-OTDR for high voltage and submarine cable applications. It is intended to explore the external effects as seismic detection or environmental applications.
- Application of the developed fiberscope for Raman spectroscopy in cancer specimens.
- Deploy the first laboratory studies within the complex challenge of measuring dissolved CO2 in blood flowing in extracorporeal circuits, pairing spectral detection with artificial intelligence.
- Implement a new modular optical tweezers setup to enable easy testing of new configurations (dual optical source, plasmonic nanotraps, among others) Expand the signal processing capabilities, including direct optical signal processing schemes for real time analysis. Implement new analytical strategies combining Optical tweezers, MIPS and smart scattering analysis.
- Identify strategic applications and partners (micro algae in environment and bioreactors, biomedical - liquid biopsy).
- Improve the current LIBS system by adding automation with imaging and advanced algorithms for adaptive mapping of samples.
- Expand reference data sets to improve signal processing ability and quantitative performance.
- Expand the applications to the full value chain of Lithium (going further than mineral characterisation, to analyse the products metallurgy, battery coating process, etc.).
- Explore the combination of acoustic and optical trapping to enable micro sampling.
- Improve library of functionalisation strategies of optical fiber sensors, using plasmonic nanomaterials optimised for the NIR and structured materials for excitation of Bloch waves.
- Develop low-cost interrogation systems and explore its application in the field (INESC TEC oceanographic buoy and boat).

RL4. Quantum optical engineering

Quantum optical engineering activities include:

- Nanophotonic sensing: to explore metamaterial-based solutions for sensing applications using novel sensing principles (e.g. anomalous absorption).
- Numerical simulation of quantum optical systems: use of high-performance computing solutions to develop scalable and research efficient numerical tools for the simulation of light-matter interaction and quantum phenomenology.
- Quantum simulations with quantum fluids of light: use of optical beams to create experimentally tunable analogs of complex quantum systems.
- Quantum Enhanced Artificial Intelligence with optical hardware: to explore how complex quantum systems could be used to augment the implementation and operation of artificial intelligence systems based on the concepts of the reservoir and neuromorphic computing applied to classification problems; use of digital quantum computers (e.g. IBM's quantum computer) to simulate complex quantum systems capable of data separation and classification and benefiting from parallelism and higher information density permitted by quantum information systems.

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 characterisation;
- Micro and nanofabrication techniques;
- Photonic systems implementation, test and characterisation.

5.2.2 Main objectives for 2022

Organisation, human and material resources

Two main objectives will be pursued: involvement in the Physics and Physics Engineering experimental classes to attract new MSc and PhD students to more practical subjects and research and the achievement of sustainability conditions concerning PhD researchers hired through the FCT Employment Stimulus program.

Research (including publications, communications, datasets, artefacts)

Publication in journals and presentations in international conferences of first quartile and higher impact factor will be aimed, even at the expense of reduced overall numbers.

Innovation (including knowledge valorisation and technology transfer)

CAP strategy aims at maintaining a good balance between more fundamental science, like involvement in new areas of research, and the development of technological applications driven by market pull as detected by the TEC4 platforms. The protection of registered intellectual property and support to the creation of new start-ups, like it was done some years ago with FiberSensing, and more recently with ILOF, is a long-term commitment, that has already become part of our DNA. Besides this, an increase in the number of technology transfer projects with local and international industry will be developed along two main vectors: novel technology solutions for technology takers and new application-oriented prototypes for industrial end-users. The Recovery and Resilience Plan will be an important instrument to fund and develop such projects.

Dissemination (including events organisation)

Of particular importance is the insertion of the Centre talks and other dissemination activities within the Department of Physics and Astronomy (DFA-FCUP) general program, with the aim of increasing the attractiveness of the Centre for new MSc and PhD students. Cooperation with other DFA-FCUP initiatives like Open Days, “Ciência Viva” and Physics Summer School, providing projects for short internships also contributes to such goal.

Internationalisation

An increase of internationalisation activities is sought, towards more European collaborations and projects, namely in the new Framework Program. This will be done by an increased participation in Photonics 21 platform and EPIC cluster activities: meetings, brokerage events and science-industry workshops.

CAP will maintain the involvement in COST Actions and bi-lateral cooperation projects with other countries.

5.2.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.2 - CAP – Main actions planned

Action	Expected Outcomes
EPIC Annual/topical meetings	Two proposals
Scholarships for last year students	Four undergraduate students
Active participation in TEC4s activities	One proposal
Integration of the Centre talks in the DFA program	One monthly talk
PRR proposals	Participation in two PRR proposals

5.3 CRAS - CENTRE FOR ROBOTICS AND AUTONOMOUS SYSTEMS

Coordinators: José Miguel Almeida and Nuno Cruz

5.3.1 Scope, vision and activities

Centre scope and vision

CRAS addresses challenges associated to activities in harsh, dangerous, complex, and dynamic environments. In these scenarios, the replacement of human presence by robotic systems avoids unnecessary risks, while providing room for improvement in mission performance. The Centre activities are driven by these challenges, both at the scientific and technological domains, as well as several trends and concerns, both from the societal and funding perspectives. This explains the broad range of TRL addressed by CRAS activities, from fundamental concepts to effective devices used in field operations. The Centre activities are aligned with major priorities and concerns at national to international levels, as addressed, for example, in:

- The Extension of the Portuguese Continental Shelf, and the national Plan for Recovery and Resilience.
- Horizon Europe Missions – 1) Adaptation to Climate Change, 2) Restore our Ocean and Waters, and 3) Climate-Neutral and Smart Cities.
- UN Sustainable Development Goals – Clean Water and Sanitation, Industry Innovation an Infrastructure, Climate Action, and Life Below Water, among others.

The Centre works towards a future where autonomous systems can operate proficiently in harsh environments, either isolated or in collaborative teams, with aggregated performance far exceeding human capabilities.

Scientific activities

CRAS activities are organised along the following research lines (RL):

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 localisation and navigation problems. Dynamic modelling of sensors and robotic behaviour, using either deterministic or stochastic approaches play a key role. 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, underwater and above water platform docking, and information aware path planning and trajectory tracking.

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. Perception 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 lies 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, and underwater acoustic positioning systems.

RL4. Platforms and operations

This RL addresses the development of innovative robotic platforms as well as novel concepts of operation. Core areas of work are command and control of multiple coordinated platforms, development of mobile beacons for underwater positioning and communication networks, and coordinated operations of heterogeneous platforms. These can be planned or supervised under new frameworks associated with the concept of digital twins. Coordinated mobile platforms are enablers for advanced solutions in multiples domains that lie within the scope of NIS domain activities. Relevant examples are 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.

Innovation activities

The CRAS innovation activities are the following:

INOV1. Robotics systems prototyping and upscaling

Based on previous projects results, CRAS will be upgrading the robotic prototypes for operations in flooded mines and deep waters. Dedicated solutions for inspection of infrastructures, both underwater and above water, will be prototyped and field tested within the scope of ongoing projects. Furthermore, a continuous update of existing robotic platforms used in tests and demonstrations will be pursued (ROAZ, GRIFO-X, EVA, MARES, DART, SHAD, among others).

INOV2. Navigation and mapping

This activity encompasses the development of solutions for specific challenges for which CRAS expertise is instrumental. Examples are the reconstruction and mapping of underwater environment, Eye-in-Hand manipulation strategies for underwater interventions, collision-free interactions in dynamic scenarios, BVLOS (Beyond Visual Line of Sight) operations or the navigation in GPS denied scenarios.

INOV3. Component development for robotics systems

Development of components for robotic systems that are expected to greatly increase the performance of the robotic solutions. Examples are the SLS (structured light system for underwater applications), real time detection of fiducial markers for very close-range navigation, or the MARESEYE underwater stereo vision system.

INOV4. Underwater acoustics for positioning, navigation and communications

This activity involves the research, development and deployment of underwater acoustic systems embedded in custom designed vehicles and platforms for the aquatic subsurface environment, to enable support for precise relative and absolute positioning, cooperative navigation and also communications. The ability to create innovative solutions in this domain, highly customised and flexible, is a key competence essential for going further on underwater autonomy.

5.3.2 Main objectives for 2022

Organisation, human and material resources

The majority of CRAS researchers are distributed in two separate locations, at FEUP and ISEP. Although the physical distance is short, the recent pandemic situation aggravated this separation and disallowed team building activities. These will be resumed as soon as possible, together with other actions to foster cohesion.

The number of human resources associated with CRAS has been growing slowly and reached a stable number around 70 elements. However, many senior members have taken different responsibilities at INESC TEC creating the opportunity for younger researchers to assume greater leadership in specific areas. The percentage of PhD researchers is still relatively low, and the Centre will provide conditions to advance ongoing programs, associate these programs to ongoing projects, and, at the same time, attract more faculty members. The Centre suffers from an imbalance in gender distribution, like the rest of INESC TEC. With this respect, the Centre will strongly support any initiatives to fight any preconceptions about the role of women in engineering, taking advantage of the current popularity of robotics.

The lab space is still a strong limitation to embark in new projects, but with the first phase of infrastructure projects completed in 2022 (e.g. TEC4SEA), the Centre will move part of the logistics to the new facilities in Leixões.

Research (including publications, communications, datasets, artefacts)

The Centre will increase all indicators relative to scientific production, particularly in what concerns journal papers and top-rated publications. With the pandemic situation being resolved and the outdoors activities being resumed to support field validation, we estimate a significant growth, and return to pre-pandemic levels.

Innovation (including knowledge valorisation and technology transfer)

The UNEXMIN spinoff (UGR) is still in an initial and critical phase of development, and the Centre will continue to support its consolidation, namely through the UNEXUP EIT RM project, developing the robots and the exploration services, and through new project submissions to include additional exploration tools.

Advanced training

All scientific areas related to robotics are very active, and the Centre will proceed with advanced training of human resources. In the scope of the DEEPFIELD project, for example, one thematic workshop is already scheduled for February, by Max Planck Institute, Germany ("Deep Reinforcement learning for UAV"), and two summer schools, by the University of Girona, Spain ("Underwater perception and manipulation") and Heriot-Watt University, United Kingdom ("Underwater SLAM").

Dissemination (including events organisation)

Many CRAS researchers have been actively involved in the organisation of scientific events. Some of these were suspended or converted to virtual editions during the pandemic but are likely returning to conventional formats in 2022. The same applies to the participation in technology fairs, like Oceanology International, or conference-related events, where the Centre will promote the flagship projects and main achievements. At local and national levels, the Centre will continue to participate in dissemination events. These activities will be coordinated with SCOM at INESC TEC to provide periodic update of the Centre activities, and for dissemination through institution means (newsletters and social media, for example).

Internationalisation

One priority for 2022 will be to revive existing MOUs and other interactions with international organisations, that were on hold during the pandemic. For example, the participation in the IEEE/MTS Oceans conference, in Chennai, India, will be a good opportunity to revive the relationships with Indian researchers established in 2019.

In general, the Centre will take the advantage of interchange opportunities to stimulate researchers to visit top-ranked institutions. This will directly benefit the researcher and the institution, strengthening existing contacts, fostering joint scientific publications, and building complementary teams to participate in projects. Simultaneously, the Centre will host invited researchers for short to medium term visits, with specific goals in mind, like the delivery of seminars, the participation in experiments, or the discussion of joint proposals.

5.3.3 Main actions planned for 2022

The Centre will carry out the following actions contributing to the above objectives towards its vision:

Table 5.3 – CRAS – Main planned actions

Action	Expected Outcomes
CRAS Open Day	Increased cooperation with other centres
FCT PhD scholarship application	4 new funded PhD students
Seminars by invited visitors	Advanced training and potential for collaboration
REPMUS 22 exercise	Increase cooperation with NATO Navies
Team building events	Encourage teamwork and cohesiveness within CRAS

5.4 C-BER - CENTRE FOR BIOMEDICAL ENGINEERING RESEARCH

Coordinator: João Paulo Cunha

Assistant to the Centre Coordination: Duarte Dias

5.4.1 Scope, vision and activities

Centre scope and vision

The mission of the Centre for Biomedical Engineering Research (C-BER) 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 Networked Intelligent Systems (NIS) domain. 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 strategic 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** internal synergies and strategic partnerships with other Centres of INESC TEC, clinical partners, research institutes, medtech companies & startups and foster international cooperation.

Scientific activities

C-BER has three Labs that share the same vision and objectives, creating a strong synergy and cooperation within Centre members in the biomedical engineering area. In order to organise scientific activities and specific areas of knowledge, these are divided in research lines (RL) that are directly connected to each Laboratory.

RL1. Biomedical Imaging Lab - Coordinator: Miguel Coimbra

Development of advanced image analysis and machine learning and deep learning methodologies, including generic approaches, applied to medical and biological images, with the aim of creating computer-aided diagnosis tools to support medical decision making, with the following scientific activities:

- Ophthalmology CAD: Analysis of different types of eye images, namely color retinal photographs and optical coherence tomography (OCT) and OCT-angiography (OCTA) images, to develop diagnosis support systems for prevalent eye disorders such as diabetic retinopathy and age-related macular degeneration;
- Lung CAD: Analysis of images from distinct imaging modalities (Chest X-Ray and CT images), possibly integrating supplementary data (analytical results and clinical report) for the implementation of second opinion CAD systems able to support radiologists in the early detection of lung lesions, as well as in the discrimination between normal and pathological cases, including the newest COVID-19 disease;
- Ultrasound CAD and point-of-care ultrasound (POCUS): Analysis and characterisation of ultrasound Images in 2D, 3D and 4D, for improving their application in different clinical environments;
- Gastroenterology CAD: Image & clinical video analysis and characterisation of digestive tract images for diagnosis & follow-up;
- Point-of-care cardiology screening (MultiScope): Cardiological diseases screening in point-of-care underprivileged environments making use of synchronised multimodal data.

RL2. BioInstrumentation Lab - Coordinator: Miguel Velhote Correia

Perform high-level R&D interdisciplinarity 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, Informatics, Computation, Physiology, Biomechanics, Physiotherapy and Sports science. Pursuit advances in smarter, more adaptable and reliable sensing and measurement technologies with novel embedded biosignal acquisition and processing methods, innovating on these areas and facilitating technology transfer to the high-tech market. The main scientific activities are:

- Research on smart-textile - integration of hardware and sensing capabilities in textiles using conductive fibres, seeking wearable devices with different form-factors and monitoring capabilities to gather physiological data;
- Explore the development of low-power small hardware devices with the aim to achieve smaller, more comfortable and ergonomic wearable devices with mobile/web application for user interaction;
- Embedded AI engines for future wearables, snap2skin and intra-body sensing;
- Explore new health occupational strategies;
- Movement analysis and recognition using body kinematics analysis and new sensing devices.

RL3. NeuroEngineering Lab - Coordinator: João Paulo Cunha

Perform high-level R&D interdisciplinarity in engineering and computational approaches applied to basic and clinical neuroscience, crossing several areas, such as Physics, Engineering (Electronics, Computation, etc.), Neurology, Neurosurgery, Neurophysiology, Neuroradiology and Neurobiology. The main scientific activities are:

- Deep brain stimulation new methodologies to support surgical procedures and therapy;
- New neurosensing technologies for symptoms quantification with the aim to support clinicians on patient diagnosis and follow-up;
- 3DVideo-EEG for neurological disease monitoring and supported diagnosis;
- Multimodal machine learning and deep-learning approaches that makes use of multiple bio-sources to achieve improved CAD systems for neurological diseases, namely Parkinson disease and Epilepsy;
- Human-Machine Symbiosis for brain computer interface.

Innovation activities

C-BER has been very active in converting scientific results into patents, focused in licensing these IP to "vehicles" (startups, SME, etc.) to take these results into the market. We are also very committed in creating new partnerships and infrastructures that will allows us have even higher capability to pursuit new research activities with high scientific standards. The planed innovation activities for 2022 are:

INOV1. WeSENSS spin-off: The WeSENSS-Wearable SENSors for Safety – will actively look for seed funding to be spin-offed in 2022. It is currently creating partnerships to perform pilot tests during 2022 with the aim to show its innovative potential and capability to enhance industry workers safety. The participation in a recently approved H2020 project will also push the system development to higher TRLs to support these pilot tests.

INOV2. Infrastructure Partnerships: C-BER will make and effort to try to create a new infrastructure in the area of NeuroEngineering in order to endorse the research activity in this area, creating new opportunities, new services and new tools to support clinicians. This push will be made at a national level and also at an European level with an effort to join EBRAINS community.

INOV3. New patents application preparation based on FCT project results: C-BER will work closely with INESC TEC licensing office to discuss and implement the strategy for the two patents planed for the CAGED project on computer assisted decision systems for endoscopy gastric cancer videos.

INOV4. PRR mobiliser project in the textile: Increase the TRL of the results obtained in the TexBoost project (patent request P856.1 PP 2020.01.26). This endeavour will pave the way for an easier technology transfer.

5.4.2 Main objectives for 2022

Organisation, human and material resources

C-BER plans to endorse its capacity on wearable devices R&D with the contract of a highly-skilled researcher with firmware & hardware skills. Two FCT projects of C-BER (THOR and CAGED) have started 2021 and were already able to bring two PhD students to the centre, that recently got their own scholarship to pursuit their PhD in the project area. Next year C-BER will try to repeat this cycle by recruiting two new PhD students to be included in these projects and support the ongoing research. For 2022 we already have several master theses students undergoing which is very beneficial to the Centre to explore very low TRL ideas and support PhD students. We aim to keep the same amount of master students, so we will make an effort to get closer to Biomedical Engineering students at FEUP in order to attract the best students to perform internship in the centre with the aim to pursuit their master thesis in the area.

Research (including publications, communications, datasets, artefacts)

Strive to obtain publications at the highest level, namely further enlarge the Q1 Centre publications.

Innovation (including knowledge valorisation and technology transfer)

C-BER has shown very positive results by launching two successful start-ups in the last two years. To maintain the same level of activity in technology transfer as in previous years (successful launch of 2 start-ups) C-BER will have an internal workshop to discuss and design an innovation roadmap to create value from research outcomes that are being achieved. Beside this, we aim to submit new patent applications and software registrations to approach med-tech players and companies for future technology adoption. An effort will also be made to look for seed funding for WeSENSS to try to be spin-offed in 2022.

Advanced training

Following successful funding applications, C-BER will hire and train at least three new PhD students associated with three of our research lines: Gastric cancer screening (CAGED), point-of-care cardiology screening (Multiscope), point-of-care ultrasound (POCUS). Efforts will also be made to host international students for training periods (Brazil, Italy, Spain), which were hindered in 2021 due to the pandemic situation.

Dissemination (including events organisation)

Members of C-BER will be actively involved on the IEEE EMBS Portugal Chapter bi-annual conference to be held in Porto in the autumn 2022, may the pandemic status allow its organisation. C-BER will also continue the dissemination activities performed in 2021 in the form of invited keynote talks in a variety of national and international events, especially within the framework of programs associated with a UP framing such as EUGLOH, CMU|Portugal and UTAustin|Portugal. In 2022, C-BER also aims to create an Expo of C-BER technologies to external partners, including companies, hospitals, research institutions, among others. This event has the aim to create new partnership and endorse C-BER network in our research field.

Internationalisation

The participation in a recently approved H2020-GreenDeal project with 36 partners will increase our European visibility, which is one of our main goals for 2022. We will try to keep the number of Horizon Europe proposals submissions (8 proposal in 2021 with 1 approved and 4 still waiting for answer), since they are a key instrument to create new international partnerships and increase our network (already 4-5 under preparation for 2022). We are also pursuing the integration on EBRAINS community and a joint Horizon Europe submission, endorsing our European network for further research on the NeuroEngineering area. C-BER will maintain the strong partnership with the Ludwig-Maximilians-University Munich (Munich, Germany) and Carnegie Mellon University (Pennsylvania and California, USA) with two new PhD students with co-supervisors from this institution. For 2022 we have already planned to further establish at least five new international R&D cooperations with 1) Real Hospital Português (Recife, Brazil) by planning new cardiology screening data collection and research collaborations within the rural area of Pernambuco, 2) Emory University (Atlanta, USA) for the purposes of the joint launch of a Physionet and Computers in Cardiology Society supported grand challenge on the area of PCG data analysis, 3) EPFL - École Polytechnique Fédérale de Lausanne (Switzerland), 4) Universiteit Twente (The Netherlands) and 5) Politecnico di Milano (Milan, Italy) to collaborate on the design of new Horizon Europe project proposal and in multimodal wearable devices signal analysis research.

5.4.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.4 – C-BER – Main planned actions

Action	Expected Outcomes
Internal workshop for IP strategy analysis at C-BER	Create internal awareness to IP protection importance to design technology exploitation roadmaps
C-BER technologies Expo	Get closer to industrial and clinical partners to create new partnerships
IEEE EMBS Portugal Chapter bi-annual conference	Promote Bioengineering and Biomedical Engineering research in Portugal and reinforce national cooperation between research groups and institutions in these areas

5.5 CPES - CENTRE FOR POWER AND ENERGY SYSTEMS

Coordinators: Manuel Matos and Ricardo Bessa

Assistant to the Centre Coordination: Jorge Pereira

5.5.1 Scope, vision and activities

Centre scope and vision

The Centre supports the decarbonisation of the energy system, to fight against GHG emissions through large-scale RES integration, electrification of the society and increased energy efficiency. This involves the combination of physical representations and data-driven methods for modelling and optimising energy systems, leveraging from emerging technologies like AI, blockchain and interoperability. Results include concepts, models, methodologies and tools useful for addressing the decision problems of citizens, communities, multi-utilities, system operators, regulators, policymakers and government bodies. Activities are developed in R&D national and international projects, under competitive funding and with direct contracts with industry that may include technology transfer. A laboratorial infrastructure (SGEVL) enhances the research and innovation capabilities of the Centre, by providing technological support for the validation of theoretical concepts.

Scientific activities

The Centre addresses the relevant scientific problems associated to its mission and vision, in the Power and Energy System, exploring its competences in energy analytics and forecasting, energy economics and regulation, static and dynamic analysis of power systems, decision-aid and optimisation and Industrial electronics. Low TRL activities are seldom left alone, but rather integrated in value chains where the new models and algorithms are tested, applied to pilots for demonstration and in some cases raised to higher TRL.

Innovation activities

The Centre emphasises the application of the research results as the prime motivation for its existence, being innovation the culmination of the R&D process and a stepstone for new research and technology transfer activities, that respond directly to society requirements. Innovation activities are thus related to the scope, mission and vision described earlier, but also result from interaction with companies that require solutions to respond to societal challenges.

5.5.2 Main objectives for 2022

Organisation, human and material resources

Considering the increase in the financed National and European projects during 2022, and anticipating future opportunities in Horizon Europe and Portuguese Recovery and Resilience and Plan, CPES is planning to expand the research team with the following human resources:

- 3 Post-Doctoral Contracted Researchers, with less than 3 years of Post-Doc experience, to work in real-time power system simulation, digital protection systems and decarbonisation of ports.
- 1 Post-Doctoral Contracted Researcher, with more than 5 years of Post-Doc experience, to coordinate the research team working in decarbonisation of the economy, green hydrogen and energy efficiency.
- 13 MSc Contracted Researchers to work in energy/grid optimisation, energy analytics, green hydrogen, electric vehicles smart charging, smart grids and power system dynamic simulation.
- 2 Post-Doctoral Research Grants to work in offshore renewable energy and forecasting.
- In order to train and engage BSc and MSc students in R&D activities, CPES will open, during 2022, at least 5 Research Initiation Grants, 2 Research Grants for MSc students and launch 2 PhD theses to tackle long-term challenges such as digital twin for production of green hydrogen and decarbonisation of ports.

Research (including publications, communications, datasets, artefacts)

The main research topics and objectives identified for 2022 are:

- Dynamic simulation models based on PHIL tests;

- Estimation and provision of manageable virtual inertia to power systems;
- Local energy and flexibility markets models;
- Incorporation of flexibility in network operation and planning tools;
- Power flow tracing for green electricity consumption characterisation;
- Models and algorithms for energy infrastructure integrated management;
- Detailed modelling of distributed energy storage technologies for energy optimisation problems;
- Integration of forecast uncertainty in electrical grid management;
- Improve predictability of renewable energy;
- Development of predictive algorithms for EV charging optimisation in car parks associated to tertiary buildings.

Innovation (including knowledge valorisation and technology transfer)
The main innovation topics and objectives identified for 2022 are:

- Development of electrical connection plan for offshore energy;
- Development of tools for flexibility needs assessment and activation based on sensitivity coefficients;
- Enhanced tool for market simulation;
- Development and demonstration of an integrated LV state estimation tool and PV envelope estimation;
- Development of LV network phase identification, topology mapping and estimation of electric characteristics;
- Development of optimisation algorithms for hybrid microgrids and energy communities;
- Updated version of PS-MORA;
- Development of an algorithm to optimise the operation of multi-energy infrastructures considering flexibility and network constraints;
- Characterisation of the port energy supply chains and potential designs of local energy markets;
- Development of an algorithm to help define the bids that aggregating entities should submit to energy markets.

Advanced training
EES-UETP course – September 2022 – "Towards 100 % renewables in islands"

Training at different levels for companies (in house), e.g. REN

Dissemination (including events organisation)
Organisation of the Power Systems Computation Conference 2022

Organisation of thematic webinars

Internationalisation
Coordination and participation in Horizon Europe ongoing and new projects, and organisation of new proposals with reliable consortia.

Development of the partnerships in Africa and Brazil

5.5.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.5 – CPES – Main actions planned

Action	Expected Outcomes
Development of electrical connection plan for offshore energy in the framework of EU-SCORES	RES integration enhancement
Power hardware in the loop (PHIL) tests of commercial PEM and alkaline electrolysers	Dynamic simulation models based on PHIL tests
Development of a decision-aid function for human operators' selection of flexibility options	Software prototype for flexibility management
Analysis of governance models of Renewable energy communities (REC)	Improvement of REC design
Research and development on P2P markets design and simulation	Local energy and flexibility markets models
Consultancy on REC developments	Support to real renewable energy communities in different sectors
Analysis and prototype of power flow tracing	Power flows tracing for "green electricity" consumption characterisation
Characterisation of the port energy supply chains and potential designs of local energy markets	Support to ports energy management
CEVESA MIBEL market simulator improvements	Enhanced tool for market simulation
Development of tools for flexibility needs assessment and activation based on sensitivity coefficients	New tools for flexibility management
Development and demonstration of an integrated LV state estimation tool	Contribution to commercial software for LV monitoring and control
Development of PV envelope estimation	Contribution to commercial software for LV monitoring and control
Development of LV network phase identification, topology mapping and estimation of electric characteristics	Software module ready to test with real data
Development of optimisation algorithms for hybrid microgrids and energy communities	Software module ready for integration in pilot
Implementation of new features in the PS-MORA tool	Updated version of PS-MORA
Development of an algorithm to optimise the operation of multi-energy infrastructures considering flexibility and network constraints	New tool for energy infrastructure integrated management
Development of an algorithm to help define the bids that aggregating entities should submit to energy markets	Tool for support multi-energy aggregators
Development of a model of ageing of BESS, heat pumps and electrolysers for different operating strategies	Model and algorithm for energy infrastructure integrated management
Development of predictive algorithms for EV charging optimisation in car parks associated to tertiary buildings	Support to new services that contribute to the decarbonisation of large cities
SW registry of the cloud-based energy management system	IP protection

5.6 CESE - CENTRE FOR ENTERPRISE SYSTEMS ENGINEERING

Coordinators: António Lucas Soares and Rui Rebelo

5.6.1 Scope, vision and activities

Centre scope and research lines

CESE's mission is to advance scientific knowledge in enterprise systems engineering, resulting in unique expertise in developing innovative systems and services for the management of industrial organisations. CESE produces high-quality research that results in a set of competencies recognised by industrial partners as improving competitiveness, sustainability, and resilience of their business processes and supply chains. To fulfil its mission, CESE pursues five research lines: Manufacturing Systems Design and Management, Supply Chain and Collaborative Networks Management, Industrial Information Systems, Technology Management in Industry, and Transportation and Logistics.

Scientific activities

RL1. Manufacturing Systems Design and Management. This research line aims to investigate and develop innovative methods and tools to support manufacturing organisations to (re)design sustainable production systems by integrating data management and analytics, AI, optimisation techniques and simulation. The impact of this RL will be directed, not only to the operational excellence, but also to sustainable and balanced human-centred manufacturing.

RL2. Supply Chain and Collaborative Networks Management. In this research line CESE addresses the design and management of digital supply chains and collaborative networks allowing companies to be more competitive by means of resilient networks and contributing to the development of a circular economy. Digital supply chain transformation has been emerging as a crucial approach to foster efficiency, flexibility, visibility, governance and other strategic choices in an ever-changing market environment.

RL3. Industrial Information Systems. This RL aims at developing new concepts of information systems for industrial management addressing a data-driven, sustainable and circular industry transformation. Research and develop proof of concepts of new industrial information systems supported in new digital architectures enabling the distributed, comprehensible, secure, and trusted data storage and data processing capabilities, along the organisational hierarchical layers and across the different life cycle stages and actors of the value chain. This data driven context leverages the introduction of new data driven services for manufacturing systems visibility, transparency, and predictability.

RL4. Technology Management in Industry. Deliver high quality research on Technology Management strategies with relevant contributions to both theory and practice. It focuses on studying the impact of the adoption and implementation of digital technologies on innovation, resilience, and sustainability of manufacturing companies and its value chains. RL4 addresses the design, adoption, and management of emergent technologies, allowing companies to face contemporary challenges and be more competitive by increasing efficiency, flexibility, visibility, and circularity.

RL5. Transportation and Logistics. Innovative and integrated solutions in transportation systems and logistics are fundamental to contribute to the uptake of the Circular and Green Growth Economy. This RL develops from a recognised know-how and experience in decision support systems, simulation, optimisation and information and knowledge management, to transportation and logistics, urban logistics and mobility, and Intelligent Transportation Systems.

Innovation activities

The above research lines feed the innovation activities that support the portfolio services (technology transfer, advanced consultancy) that the centre provides. These innovation activities are: IA1. Design and management of manufacturing systems, IA2. Planning and scheduling, IA3. Digital transformation and management, IA4. Industrial Data Driven Systems and Platforms, IA5. Transportation and logistic systems.

5.6.2 Main objectives for 2022

Organisation, human and material resources

CESE achieved an organisational milestone in 2021 by consolidating its R&D teams and launching the Research Lines coordination scheme. In 2022 the objective is to refine the articulation within RLs, aiming to maximise the scientific production of the centre. Concerning the management of competencies, we have the goal of updating the technical knowledge and skills of most researchers in the fields of Data Science and Artificial Intelligence (machine learning, deep learning, …) as this reveals to be instrumental for a major part of the research and innovation projects. The iiLab is pivotal for CESE in articulating research and innovation. 2022 will be the year of evolution towards the new iiLab space, fostering important research and development activities to support this evolution.

Objectives for RL1. Manufacturing Systems Design and Management. This RL aims to explore new forms of simulation-optimisation integration for planning/scheduling problems in industry. We are researching how real-time data can be integrated into optimisation-simulation tools and how optimisation algorithms can be combined with simulation models to manage the operations of manufacturing systems when facing unexpected events. The need to procure energy uses with cost-effectiveness at industrial companies, leads us to research multi-objective planning and scheduling tools that include energy efficiency as an objective (Green Scheduling), supported on digital twin, IIOT platforms and data analytics. Objective is to publish in the most relevant journals classified as Q1 in the domain of Decision Sciences, Management Science and Operations Research, fostering involvement in the most relevant scientific associations in the field, namely CIRP International, EUROMA European Operations Management Association, POMS Society, IEOM Society.

Objectives for RL2. Supply Chain and Collaborative Networks Management. The objective is to be internationally recognised as an emerging reference in the study of supply chain management and collaborative networks, especially in the study and development of digital technology-based solutions to increase resilience and sustainability of value chains. It is foreseen the publication of papers in Q1 journals such as Supply Chain Management: An International Journal, Industrial Marketing Management and International Journal of Logistics Management, and the participation in conferences such as the EurOMA conference. CESE will participate in the data collection for the 6th Global Manufacturing Research Group Survey.

Objectives for RL3. Industrial Information Systems. RL3 main goals are grouped in three areas. In digital enterprise architectures, we aim to develop an industrial systems reference architecture, based on open standards and open software tools, integrating legacy and novel industrial information systems. In industrial data and information management we are researching semantic models to abstract heterogeneous information (data sets, documents and other industrial content, multi-physics models, machine learning models) and to be part of a digital platform to manage product digital-twin instances. Finally, to develop a socio-technical framework to support the design of digital transformation processes based on product digital twin technologies. Focus in high impact journals such as Business & Information Systems Engineering, Computers in Industry, Computers and Industrial Engineering, and International Journal of Information Management.

Objectives for RL4. Technology Management in Industry. Continue to research the main drivers and barriers in Technology Management and innovation, namely those in the state-of-the-art, such as in digital twin, artificial intelligence, and data sovereignty technologies adoption and implementation. Additionally, the design of human centred and sustainable digital transformation processes will be supported by activities such as the development of an user/organisational experience framework for the implementation of industrial digital platforms. To develop frameworks and models to design new schemes for training and technology transfer in advanced manufacturing technologies and systems. Target high impact journals such as the Journal of Engineering and Technology Management, Journal of Manufacturing Technology Management, Technovation, or Technological Forecasting and Social Change.

Objectives for RL5. Transportation and Logistics. RL5's main goal is to develop models for the design and multi-criteria assessment of supply-chains, explicitly considering dimensions such as the environmental and social impacts — explore new forms of stakeholders' participation and (vertical and horizontal) collaboration in urban logistics (last mile). Other important goals are to develop decision support tools for supporting the design and management of urban logistics solutions and business models, and to design a conceptual framework to support decision-making, to foster synchro-modality in more sustainable and resilient transportation networks and

supply-chains. The main target journals are Transportation Research, Transportation Science, and the International Journal of Logistics Management.

Innovation (including knowledge valorisation and technology transfer). To innovate well-established services provided by the centre - design of flexible production systems, planning and scheduling in production systems, digital transformation and management - and to develop new services in the areas of industrial data-driven systems and platforms, and transportation and logistic systems. The main goals for this period are then to: (i) exploit the Advanced Plant Model in the BetterFactory RAMP Platform; (ii) develop new models and methodologies materialised in services to support companies in the adoption of innovative technologies, namely: Product and Process Digital Twin, IIoT Platforms and as Data Sovereignty Enabling Technology; (iii) refine and improve the industry 4.0 maturity assessment and roadmapping framework, towards a fully digital solution to support the respective services provided to companies, increase agility in delivering services; (iv) develop an innovative data-driven methodology for industrial processes continuous improvement that covers the entire journey from data sensing to information discovery, evolution and pro-action; (v) design a service framework to support companies to implement industrial data management strategies.

Advanced training

CESE has been active in the last years in providing and contributing to advanced training in Industry 4.0 . For this period, the goals are to further develop the portfolio of training materials and approaches, mainly supported on results from EIT Manufacturing projects, to provide customised and tailor made courses to companies. For that, a roadmap for the training actions using the educational and training contents developed in CESE (and in collaboration with other centres) will be developed. Furthermore, the iiLab will consolidate its role as the training hub for most of the advanced training provided by the centre. Other specific goals include: (i) design and launch a master class on advanced operations (data-driven manufacturing); (ii) develop advanced training in digital architectures for manufacturing.

Dissemination (including events organisation)

CESE will continue acting at academic, industrial, and societal levels to make the results of its activities well-known. The main journals for publication were defined for each research line, aiming at high impact outlets. In the same vein, international scientific conferences, most of them having industry participation and lively collaborative communities, were selected for the several research and innovation areas. Also, iiLab resources will be key to other strands of dissemination, while being demonstration-based. Finally, an increase in participation in fairs and industry workshops will be expected, as the limitations imposed by the pandemic clear out.

Internationalisation

CESE has a strong and diverse network of international partnerships, particularly European partners. Continue to focus on the Horizon Europe projects and try to better balance the proposals for research and innovation actions (RIA and IA). The other pillar of CESE internationalisation is the EIT Manufacturing programme and community, in which CESE already counts with a significant portfolio of approved projects to this period. One area needing improvement is the internationalisation of the services provided by the centre. Our goal is to identify (e.g., through EU tenders) EU companies that could benefit from added value services, in the scope of CESE's research and innovation activities.

iiLab

In 2022, several actions related to the implementation of the new infrastructure of iiLab (PORTIC) will take place, in cooperation with other INESC TEC Centres. Therefore, the main activities related to these actions are i) to explore and develop innovative activities under the new iiLab infra-structure, including new research project proposals, as well as advanced training and technology transfer activities based on the completed research projects results of the centres represented in the iiLab; to support iiLab Executive Committee (EC) in the definitions of a roadmap for technologies and technological concepts, as well as training actions, to be developed and implemented in 2022 for the iiLab (CESE, CRIIS and other INESC TEC Centres); Participation in the task force responsible to develop and to operationalise the rules and procedures for iiLab; Participation in charge of planning and implementation of the inauguration event of the new iiLab.

5.6.3 Main actions planned for 2022

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

Table 5.6 – CESE – Main actions planned

Action	Expected Outcomes
Research: Participation in the 6th Global Manufacturing Research Group Survey (1st semester)	Access to data from more than 30 countries related to supply chain management practices and submission to top journals
Develop a digital platform, implementing the technology adoption framework, to adoption of advanced technologies	Support to services addressing technology adoption and management
Develop services, models, and methodologies to support companies on the adoption of Digital Twin Technology	Support to services addressing Digital Twin Solutions adoption and management
Innovation: Develop services, models and methodologies to support companies on the adoption of IIoT Platforms and fully integrated Information and Operation Technology	Selling these services to companies and increase revenue
Design of innovative services in urban logistics	Services to provide new logistic solutions addressing new e-commerce challenges and current environmental concerns, more efficient, shared-connected and low-emission sustainable operations
Design a framework to support decision-making in intermodal freight operations and global supply-chains	Capability to provide services to support companies in synchro-modality in transportation networks and global supply-chains
Advanced training: Design a master class oriented to Advanced Operations (data-driven manufacturing)	Master classes provide a high visibility of the centre to the top management of industrial partners and are a source of income
3rd edition of the Industry 4.0 Advanced Program – "Systems Architecture and Integration"	The Industry 4.0 Advanced Program provides a high visibility of the Centre in the top management of our industrial partners and is a source of income
Coordination of master thesis on the domains of technology management and data sovereignty and interoperability of services applied to supply chain management	Disseminate the data spaces standards and models for the younger generation of graduates. Improve the technical and scientific competencies in the area
Identify CESE's strategic partnerships (companies, associations, clusters. digital innovation hubs) for education activities at iiLab	Strategic partnerships in the areas of R&D and training will help to build dynamic capabilities for impactful advanced and state-of-the-art training

5.7 CRIIS - CENTRE FOR ROBOTICS IN INDUSTRY AND INTELLIGENT SYSTEMS

Coordinators: António Paulo Moreira and Germano Veiga

5.7.1 Scope, vision and activities

Centre scope and vision

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.

Scientific activities

RL1. Navigation, Localisation and Coordination of Mobile Robots

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. 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. Main research challenges address semantic navigation, dynamic SLAM, mobile manipulation, distributed and cooperative mapping, coordination of multiple robots taking into account failures in communications and online deep learning for perception and navigation.

RL2. Intelligent Sensors and Control of Dynamical Systems

The main research challenges will be in Agriculture and Forestry (AF) in topics such as: i) innovative sensors, ii) modelling and decision support tools to reduce the dependence on fertilisers and hazardous pesticides used in agriculture to contribute towards zero pollution of water, soil and air as well as reducing contamination of fruits, iii) high-throughput robotic platforms for in-field, non-destructive plant physiology and omic-driven precision agricultural practices. These AF topics are aligned with the Farm-to-Fork Strategy and are a critical step towards sustainable agriculture in the context of climate change.

RL3. 2D/3D Visual Perception and Advanced Sensing

The flexibility of collaborative robotics is a composition of varied contributions, namely: simplified programming solutions, advanced systems interfaces, and new perception capabilities. In fact, the ability of robots to recognise, locate and carry out object picking and placement, using trajectories without collisions, is of fundamental importance to sustain their autonomy in the execution of operations. Several research works were presented, focusing on different problems: robotic picking of objects, trajectory planning of the robotic arm and respective control based on sensors, recognition of multiple objects and collection of deformable objects. The Centre will focus on the development of algorithms tailored for industrial and agricultural use, with special emphasis on multimodal sensor fusion, integrated artificial intelligence, active perception, digital twin representations, among others.

RL4. Advanced Human Machine Interfaces

Human machine interaction is a key element on the development of flexible production systems. The Centre will explore emergent technologies, such as virtual and augmented reality, and programming-by-demonstration of robotic systems, to develop novel and intuitive human machine interfaces, that will allow human operators to easily and intuitively interact with more and more complex production resources (including robotic systems). This system will be empowered with artificial intelligent methodologies to allow the system to adapt and evolve in time with the user experience.

RL5. Future Industrial Robotics and Collaborative Robots

Future industrial robotics will move from a robot centred perspective of a robotic 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 novel Human Robot interfaces (RL4), new advanced sensing systems (RL3), more intuitive programming methodologies, novel and not so restrictive safety systems, and the development of new AI based methods that allow the robotic system to recognise and autonomously adapt its behaviour, not only to changes in the operational environment, but also in accordance to the human operator.

RL6. Advanced Robotics and Automation for Industry 4.0

With the advent of Cyber-Physical Systems and their utilisation in an industrial context, it is of paramount importance to the added effectiveness of automated and collaborative production to make them fully interoperable with digital manufacturing systems. This research line focuses on continuing the development effort of digital twin-based infrastructure for the support, orchestration, monitoring, and integration of Cyber-Physical Systems, pursuing increased levels of practical industrial applications. It is expected to continue to augment the existing tools with added levels of interoperability with the Industrial Internet of Things (IIoT), vertical and horizontal integration, and artificial intelligence.

INNOVATION ACTIVITIES

INOV1. Agile 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 P2020 CoopWeld, H2020 ScaLABLE4.0 and H2020 FASTEN projects, whose industrial results are currently being transferred or commercially exploited by some of the companies involved in the project. 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 some of the Industry 4.0 best practices. Technologies, such as, advanced human-machine interaction systems, artificial intelligence, advance sensing, simulation and shop floor digitisation are being explored and combined to develop agile, collaborative and plug-'n'-produce robotic solutions. The 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.

INOV2. Inspection, Control and Embedded Systems

Machine vision is widely applied in quality control (non-conformity detection, dimensional control,...) coupled or not coupled to industrial robotic systems. Some successful projects have already been developed and applied in industry (e.g., CONTINENTAL, GISLOTICA and Rail-Inspect). This solid background and experience of the Centre will support the development of new reinforcement learning-based approaches, auto-reconfigurable and self-parameterizable, to solve the increasing complexity of challenges that the industry is facing in quality control operations, due to the variety of products being produced, highly customizable, and with short life cycles.

INOV3. Cloud-based Robotics

The emergence of cloud computing is undeniably expanding its reach to many practical applications, including industry and robotics. In recent months, through a partnership with Amazon AWS, CRIIS researchers are pursuing an innovation path focused on the development of cloud-based robotic solutions. This innovation path is materialising in three distinct innovative tracks: (i) the development of a continuous integration (CI) and continuous deployment (CD) solution for robotics, which leverages the power of cloud-based simulation as the final frontier of continuous software validation, powering a systematic CD infrastructure; (ii) a web-based robotic toolkit, which relies on cloud-based simulation to help developers to construct novel robotic behaviour, without the need to have direct access to hardware, by relying on representative and detailed simulations; (iii) the reliance on cloud scalability and processing power to assist robots in computationally-demanding tasks, such as machine learning methodologies for active perception and environment inference.

INOV4. Robotics and IoT for Agriculture and Forestry

In the scope of Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry, we aim to move AgIoT and AgRobVxx technologies towards TRL 8. In this innovation line, we are researching and developing cost effective visual-based sensors, manipulators and small machinery with advanced localisation, mapping, control and perception algorithms, considering the agricultural and forestry constrains and needs.

5.7.2 Main objectives for 2022

Organisation, human and material resources

Reinforcement of the coordination team to begin its renewal. Continue including contracts for RH in new projects (scholarships presently are not so attractive for who do not plan to do a PhD). Optimizse the use of material resources and equipment of the iiLab. To reinforce the responsibility of the coordinators of groups and research

lines. To encourage the continuous training and evolution of the members of the CRIIS. To support the participation in the elaboration of project proposals by more members of CRIIS. Stimulate and create incentives for top researchers to apply for high impact grants (e.g. ERC Grants).

Research (including publications, communications, datasets, artefacts)

Encourage the publication of scientific articles in journals of high merit positioned in the Top 5 of the bibliometric reference bases. In addition, encourage the publication of papers in the main international conferences in the area of robotics: ICRA and IROS. Encourage the creation of datasets resulting from the activity of ongoing projects. Making these datasets public to increase our visibility. Try to find more fundamental research lines for the future and promote new FCT projects. Optimise applied research by carefully choosing the type of projects and their partners. Trying to have fewer larger projects and concentrating on CRIIS core knowledge.

Innovation (including knowledge valorisation and technology transfer)

Find more partner companies (national and international) that will put our developments on the market and have the capacity to absorb the knowledge, take care of the future maintenance of the product, etc. Prospecting, listening, analysing and stimulating the protection and licensing of technologies developed within the different activities of CRIIS, with emphasis on their interoperability within the Centre's areas.

Advanced training

Plan, design and teach courses in several areas (Industria 4.0/5.0, IoT, VR, etc) that monetise the iiLab resources.

Dissemination (including events organisation)

Participate in the organisation of some international conferences (ROBOT- Iberian Robotics Conference, IEEE-ICARSC, CLAWAR, CONTROLO, ...) and national and international events like ROBOTICA, that position us, increase visibility and contact network. Holding "Open days" inviting renowned international speakers.

Internationalisation

Maintain and, if possible, increase the cooperation with international groups namely through European projects and exchange/internship of PhD students. In the Robotics and IoT for Agriculture and Forestry R&D line reinforce the collaboration with Wageningen University & Research, Institute of Robotics and Intelligent Systems (IRIS) from ETH Zurich, STEMS-CNR, EURECAT, CMU, MIT, Lincoln Agri-Robotics. Maintain and promote greater participation in national (SPR, APCA) and international (ROS-Industrial, euRobotics) working groups/associations of interest.

5.7.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.7 – CRIIS – Main actions planned

Action	Expected Outcomes
Promote the licensing of some of the technologies resulting from EU and/or national funded projects, namely in the area of: (1) projected augmented reality to assist human operation on assembly / cutting / welding operations, and (2) advanced sensing systems for industrial robotic system on the metalworking industry.	Knowledge valorisation trough software licensing contracts
Move AgIoT and AgRobVxx technologies towards TRL 8	Reinforce the relevance of "Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry". Increase the economic value and dissemination of AgIoT and AgRobVxx technologies. Make this technology easier to transfer to SME's. These platforms will be also useful for industrial logistics and surveillance applications.

5.8 CEGI – CENTRE FOR INDUSTRIAL ENGINEERING AND MANAGEMENT

Coordinators: Ana Viana and Pedro Amorim

5.8.1 Scope, vision and activities

Centre scope and vision

CEGI Research Centre (RC) 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., asset management).

The Centre has a vision of an ever-integrated and flexible value chain across different industries (e.g., manufacturing, retail, health and mobility). To fully address the challenges posed by this vision, the competences of the Centre in Operations Research and Operations Management, as well as in Service Engineering, will be crucial. Such vision will be materialised through research of new effective and efficient quantitative methods, which adequately handle the readily available data from a system perspective and provide robust solutions.

The contribution to society through knowledge transfer is also a central point of the activity of the Centre. Building up on its past experience, CEGI continues to provide the Energy Sector with updated asset management expertise. Aligned with the European agenda, it will also contribute to de-materialisation of processes and improvement of insights in the Health sector, and to sustainable operations of the supply chain in Retail.

Scientific activities

Operations Research / Operations Management: The Centre will continue to contribute to several sectors of activity, with main focus on Healthcare, Intelligent Transportation Systems and Mobility, and Industry and Retail. Main lines of contribution will be the proposal of new business models that incorporate new market challenges, and the development of hybrid optimisation methodologies, capable of extracting relevant information from an ever increasing quantity of data and of providing solutions robust to scenario changing.

Data Science / Data Mining: Main lines of research under this topic will include individual methods and techniques in knowledge acquisition and representation, and their application in the construction of recommendation systems. In particular, it will address Human-Computer Interaction, and Artificial Intelligence for markets such as Business, Education and Health Care.

Service Science / Design: The Centre will continue to promote research on service design, in B2C and B2B environments, as well as nonprofit services (education, and government). Illustrative topics include service strategy and customer experience, particularly the design of technology enabled services and complex service systems and value networks. In terms of methods the Centre has mainly worked with empirical analysis, and grounded theory building.

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 developments 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.

RL4.2 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. In recent years the Centre has had several requests to provide the market with highly qualified studies in this area. The group involved in this line of research was small to face all market requests and, therefore, the time available to contribute to the development of the state-of-the-art in this area was short. With two new PhD contracts starting in 2022, we expect to consolidate its scientific contributions with a couple of publications in highly ranked journals.

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 optimisation problems.

INNOVATION ACTIVITIES

INOV1. ENERGY

The energy application area is a core area for CEGI in terms of technology transfer. Asset management, decision support and prescriptive analytics have been used to significantly improve processes in this industry, particularly in the following two areas:

- Predictive and prescriptive maintenance;
- Power system planning, in particular in the development of tools for reliability analysis, for security of supply evaluation and reserves adequacy evaluation.

The Centre consistently provides consultancy services to the main Portuguese companies in this sector. Participation in European Projects XFLEX_HIDRO and EURO_SCORES provides now with the necessary exposition for international collaboration. These innovation activities are tightly related to TEC4 Energy.

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. This innovation line can now benefit from such results and start transferring knowledge to industry. In particular, in 2022 a large project with a leading fashion marketplace will be developed. In this project various methodologies developed during the last years (e.g., Genetic Programming) will be tested to orchestrate such a complex supply chain.

INOV2.2 Industry CEGI has a strong competence 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 establish innovation activities to start transferring the knowledge that has been developed (e.g., dynamic scheduling algorithms for collaborative human-robot production lines). Within the large EU project TRUST-AI a pilot with a leading glass-container industry will continue to be developed in 2022. These innovation activities are tightly related to 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 / Operations Management have contributed with best practices to this sector. Open collaborations target digitalisation of medical reports, towards development of Decision Support Systems that, based on data treatment and extraction, provide the clinician with useful information obtained through data inference. These innovation activities are tightly related to TEC4Health.

5.8.2 Main objectives for 2022

Organisation, human and material resources

The number of researchers of the Centre is expected to remain stable. The main initiative is to contract two PhDs to support the Asset Management team. We will also continue to help the hired researchers to improve their R&D development skills, motivate them to search for national and international funding, and to attract younger researchers through adequate mentoring and financial conditions. The aim is to help this layer of the Centre to gain scientific autonomy and contribute proactively to the persecution of the RC's objectives.

Research (including publications, communications, datasets, artefacts)

The Centre will continue to output high-impact scientific papers, targeting quality over quantity, to further consolidate its international positioning in the several research areas (e.g., operations management, operations research, service design). In 2022 several publications on outlets such as Management Science and Manufacturing Services and Operations Management are expected to emerge. This expectation brings extra visibility overseas to the work done internally. From 2016 to 2021 the Centre moved from a position where

European Projects had a negligible impact in its budget, to a 40% share. Participation in European Projects gives extra visibility and potentiates our research. We will now target projects that are mainly geared towards research (e.g., FET calls).

Innovation (including knowledge valorisation and technology transfer)

We will continue to develop the newly established field of health care logistics and text-mining by applying state-of-the-art machine learning tools to unstructured information and extracting clinical knowledge from past cases. Projects with retail leaders as the one mentioned above with a fashion marketplace will also be pursued. With the increase of FTEs associated to the Asset Management line of research we also expect to widen the areas of activity covered by this group.

Advanced training and PhDs

CEGI has a long traditional of hosting PhD students from FEUP doctoral program on Industrial Engineering and Management. We expect to keep that core strategy and continue to increase our influence in other PhD programmes such as the Doctoral Program in Engineering and Public Policy.

Dissemination (including events organisation)

CEGI has been extremely active in the organisation of scientific events, with several of its researchers acting as members of the Programme Committees of international conferences. The pandemics permitting, we will also continue organising invited sessions in conferences, and foster regular meetings of the European Working Groups that we lead.

Internationalisation

Leverage the independent opportunities brought by the European projects that started in 2020 to improve the international dimension of the Centre and get closer to strategic companies.

5.8.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives:

Table 5.8 – CEGI – Main actions planned

Action	Expected Outcomes
Promote sessions to present and discuss research papers prior to submission	Increase the chances of publishing in high-ranked journals. Increase peer-pressure for publication
Improve communication with hired researchers	Increase in the number of proposals submitted
Refocus multi-annual budget allocation to sponsor hired researchers on activities strategically relevant for the Centre	Retention of high-potential HR and establishment of key partnerships
Promote internal workshops to transfer built-in expertise on EU project proposal/participation	Increase overall participation in European Projects

5.9 CITE – CENTRE FOR INNOVATION, TECHNOLOGY AND ENTREPRENEURSHIP

Coordinator: Alexandra Xavier

5.9.1 Scope, vision and activities

Centre scope and vision

Vision: Strengthen Innovation towards a responsible and sustainable economy and society, by empowering researchers, public and private organisations in the process of Innovation and Technology Management and Entrepreneurship.

Scope:

- Research and Develop Theories, Methods and Models to support technology enable, sustainable innovation, with a particular focus on:
  - Innovation Management & Front End of Innovation;
  - Technology Management and Policy;
  - Technology Entrepreneurship with a focus in Business Model Innovation & Co-creation.
- Apply the state of the art of conceptual models and tools to Consulting Activities and Executive Training.
- Act as a transversal Centre for all Domains and TEC4, contributing with the development of methodologies, frameworks and tools to support the management and exploitation of R&D results developed in National and European projects.

Scientific activities

Having as main research challenge "Responsible and Sustainable Technology Driven Innovation", CITE develops its research lines to support innovation management, the front end of innovation and technology management, with a focus on responsible and sustainable technology driven innovation.

RL1. Innovation Management & Fuzzy Front-End of Innovation (FEI): Strengthening the conceptual and methodological foundations for the Innovation Management and Front-End of Innovation, towards a responsible, resilient and sustainable industry and society*:* An emphasis is placed on innovation management practices, tools, and metrics, building on a history of contributions to the Portuguese Standard for R&DI Management and an active participation in the ISO TC 279 – Innovation Management. FEI ensures companies do the right products for the right markets, and, for that reason, FEI activities are critical for Innovation Performance.

RL2. Technology Management and Policy: The research line comprises the study of the challenges of implementing and adopting new technologies, analyse how new technologies can foster industry transformation at the individual, organisational and ecosystem level, as well as explore how public policies can promote technology enabled transformation.

RL3. Business model innovation: The strategic alignment between emerging technologies and business model innovation are becoming more relevant for the competitive environment. Cross disciplinary approach to design business model innovation and new value chain strategies as well as exploring new challenges of circular economy and sharing economy namely in manufacturing, agri-food, energy and environment, health and well-being, and social innovation settings are the challenges for this research line.

RL4. Co-creation methodologies for customer centric innovations to support entrepreneurship: The research line covers methodologies and tools to foster users and customers as triggers to innovate in an open innovation ecosystem.

Innovation activities

INOV1. LET in, the Laboratory for Technology Entrepreneurship: is a proof of concept initiative, supported by open innovation and co-creation methodologies, that promotes Innovation labs, accelerator programs, executive training activities and offers mentoring, coaching, and business consultancy, with the main goals: 1) to develop entrepreneurial skills; 2) to facilitate the development of new technological enabled early stage entrepreneurial

projects; 3) to strength the innovation culture and to foster the development, adoption and implementation of new responsible innovations and business models in companies.

INOV2. Innovation and Technology Management Consulting & Executive Training Activities: Advanced consulting and training provides support in the assessment, implementation and improvements of Innovation Management Systems & Technology Management towards a strategic management of responsible and sustainable innovations.

INOV3. EEN Portugal 2022-2025: Since 2015, CITE runs the international projects EEN Portugal that aims to provide free advisory services to companies, to promote R&D and innovation capabilities and partnerships to support growth and expansion in international markets.

5.9.2 Main objectives for 2022

Organisation, human and material resources

- Intensify the internal and external collaboration:
    i. With Centres, Domains and Tec4 and SAL to identify opportunities for working together on the field of Innovation and technology management and valorisation. Develop, in collaboration with SAL, a work package to manage the value creation and exploitation of R&D projects;
    ii. With other national and European organisations, in order to promote and foster technological entrepreneurship by implementing accelerator programs target Portugal ecosystem;
    iii. With the CoLAB ForestWISE, to foster the development and adoption of innovative solutions in forestry sector;
    iv. As an active participant in SmartHealth4All, continue to cooperate to explore all the opportunities to develop projects and explore new business models in health domains;
    v. Continue to develop new projects with net value in order to ensure financial sustainability and reinforcement of the team;
- The Centre aims at strengthening its team by attracting at least 2 master students and 2 new PhD students, requiring, for this, an increase in internal investment.

Research (including publications, communications, datasets, artefacts)

- Submit 1 European project proposals led by a member of the Centre; integrate 2 European projects proposals led by other Centres
- Participate in 3 international conferences/workshops;
- Participate in the scientific committee of its 1st International Congress, under the theme: "Multidimensional sustainability: transitions and convergences". September 29 and 30, 2022
- Participate in the scientific committee of the International Conference on Entrepreneurship Education: the conference aims at sharing the best practices of Entrepreneurship Education in all levels of scholarship;
- Submit 10 papers to international peer-reviewed journal, increase the quality of the journals were the researchers of CITE publish;
- Submit 1 paper targeting practitioner audiences transferring knowledge developed in previous projects
- Conclude 1 PhD thesis under the topic “University Entrepreneurship: The process of knowledge-based value creation”;
- Participation as principal editor in the Journal of Innovation Management; the journal addresses the multidisciplinary nature of the innovation process, combining principles and concepts from social sciences to technology research and development areas. The journal is indexed by ProQuest as Scholarly Journal at ABI/Inform, under the Subject Business and Economics (Pub ID: 2046363).

Innovation (including knowledge valorisation and technology transfer)

- Develop and disseminate a set of case studies of good practices and lessons learned related to Technology and Innovation Management;
- Maintain an active participation in National and International Committee for Innovation Management Standards i) ISO TC2709 –Innovation Management; ii) Active participation in working group for the review of NP4457:2007–Innovation Management, under the CT169- Innovation Management Systems;
- To contribute for the sustainable intensification of R&D valorisation activities, by developing valorisation and exploitation plans of the technologies developed in INESC TEC projects, integrating formally European and national proposal - WP Dissemination and Exploitation.

Advanced training

- Develop and Implement 3 Advanced Training Programs on the topic of "Technology Adoption and implementation";
- Design and Implement at least 3 accelerator programs during 2022;
- Increase the Intrapreneurship capabilities of INESC TEC researchers by organising and launching an internal program, in collaboration with SAL, to support INESC TEC researchers in the process of technology valorisation;
- Follow European and national opportunities to development open innovation acceleration programs that allows the collaboration between new venture initiatives and INESC TEC towards an entrepreneurial society.

Dissemination (including events organisation)

- Organisation of the event "Digital opportunities for the future of agri-food, forestry and environment" with European experts in IT for Agrifood (April 2022);
- Use the presence in all networks already built (e.g., EEN, Smart Healthy Age-Friendly Environments, Porto4Aging), to communicate, disseminate and promote the team competences and project's results;
- Members of the Mobility and Women Entrepreneurship Sector Groups of the European Enterprise Network;
- IP Helpdesk Ambassadors, with the expert support of Daniel Marques Vasconcelos (SAL).

5.9.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.9 – CITE – Main actions planned

Action	Expected Outcomes
TURING	Develop and implement a training program in the topic of Technology Adoption and Implementation (deadline: December 2022)
GreenMA | Green Manufacturing Accelerator contribute to bringing the circular economy and Industry 5.0 vision	2 rounds of acceleration and support 30 early-stage companies (ca 15 in each round).
Teck2market - technology early stage Accelerator	50 technological results from R&D European projects - pave their way to the market
CT169 - Participating Experts	NP4457:2007 – 2nd edition (deadline: December 2022)
FIRE-RES	Assessment tool for responsible innovation; New methodology for co-creation programmes; design an Open innovation campaign for responsible innovations applying to forest sector
EIT Jumpstarter	Local Accelerator Training, - 5 projects, 15 participants form all EIT
Advisory services to clients, especially on Innovation. under EEN-PORTUGAL 2022-2025	20 Companies

5.10 HUMANISE – HUMAN-CENTRED COMPUTING AND INFORMATION SCIENCE

Coordinators: Ademar Aguiar and Artur Rocha

5.10.1 Scope, vision and activities

Centre scope and vision

The Human-Centred Computing and Information Science (HumanISE)) is an interdisciplinary Centre researching at the forefront of human-centred computing (HCC) with a wide and deep expertise in computer science (CS) and information science (IS). HumanISE engineers, scientists and designers focus on research and development of software systems, methods, and tools, capable of leveraging human abilities and practices within their communities and environments, involving high technical and managerial complexity, due to large scale, high heterogeneity, high uncertainty, high integrity, severe compliance to standards and legal frameworks, or domain-specific organisational issues.

HumanISE mission is to pursue high quality research, strongly linked to industrial partnerships, consultancy, and technology transfer, in five main research areas: Computer Human Interaction, Computer Graphics and Interactive Digital Media, Information Management and Information Systems, Software Engineering, and Large Scale and Special Purpose Computing Systems, Languages and Tools. HumanISE innovation activities are organised in four main application areas: Platforms and Methods for Personalised Health Research, Platforms and Methods for Earth, Ocean and Space Science, Geospatial Information Systems Engineering, and Information Systems and Applied Computing.

Furthermore, the Centre is also strongly committed to the training of young researchers and professionals, with a significant track record in the supervision of master and PhD students. Presently, its researchers originate from the University of Porto (UP), Polytechnic of Porto (IPP), University of Trás-os-Montes e Alto Douro (UTAD), Universidade Aberta (UAb) and University of Minho (UM).

Scientific activities

Computer Human Interaction. This research area seeks to understand how people interact with technologies and how technology changes society, by designing new interaction techniques and interfaces, following the mission of ACM SIGCHI. Major research topics concerning human factors for interactive systems include technology for persons with disabilities, active and healthy ageing, and cooperative systems. Research trends in accessibility and assistive technologies 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 research aims to enhance the relationship between seniors and technology, by personalising 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. Moreover, endeavours contextualised services, based on pervasive monitoring and prediction of users' interaction. Cooperative systems research focuses on groupware tools and crowd computing. Hybrid Human AI collaborations, committing to explore human factors in AI through cooperative and crowd empowered systems are current hot topics.

Computer Graphics and Interactive Digital Media. Computer Graphics is one of the main drivers for innovation in the IT sector, as an underlying layer on Extended Reality solutions (including VR and AR), Visualisation, 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 multi-sensory information to enhance the feeling of presence and immersion in Virtual Environments (VE). Serious Games (SG) can push their applications in Education, Tourism, and Professional Training taking advantage of these advances and on intuitive authoring tools. Both VE and SG require multidisciplinary teams to address challenges in Human-Computer Interaction (HCI). We focus on User Experience (UX), User Interaction (UI), Human Cognition, and Human perception. Within this area, Gameful and Playful Design are other approaches to improve UX in distinct processes, promoting behaviour change, and increased engagement. Pushing the borders of HCI into Human-data Interaction, Scientific Visualisation is also a definite necessity to explore and provide knowledge on Big Data.

Information Management and Information Systems. Information systems have evolved from specialised 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 and information access. This research area is committed to address some of the resulting challenges, selecting the topics where previous work can enable more significant results. It includes research in the areas of information management, information retrieval, information processing, digital preservation, and research data management. A current area of focus is research data management, which includes 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 (EOSC) provides a favourable context to deploy existing work. At national level, INESC TEC is currently coordinating the Portuguese node of the Research Data Alliance.

Software Engineering. The Software Engineering area aims to develop novel methods, techniques and tools that advance the way in which software is designed, constructed 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: requirements management, software architecture and design, model-driven development, cloud-based software engineering; (2) software testing: model-based testing, mobile testing, distributed systems testing, and IoT testing; (3) software process and tools: agile processes, process improvement, tools for collaboration and knowledge management; serious games in software engineering education.

Large Scale and Special Purpose Computing Systems, Languages and Tools. The research problems focused by the SPeCS area 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.

Innovation activities

[Platforms and Methods for] Earth, Ocean, and Space Science (EOSS). This area aims at supporting researchers and stakeholders in the EOSS 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, simulation and big data analysis are but a few examples of the undergoing trends and challenges. In terms of the research challenges of the computer science research domain, this innovation area encompasses several research challenges such as: *computing systems to empower human capabilities*, *methods, and tools to boost the quality of future software systems*, and *performance, interoperability, and dependability of critical information system*s.

[Platforms and Methods for] Personalised Health Research. This area focuses on empowering researchers in the health domain achieving evidence-driven science towards personalised treatments. It splits into two sub-areas: a) personalised Internet-based treatments; and b) human data storage, harmonisation, and controlled sharing. Important trends and challenges include collaborative tools and methods for health research, leveraging on the FAIR principles, security, and privacy preservation. This area is in line with the goals of the research challenge *computing systems to empower human capabilities*, by fostering distributed ML techniques, AI reproducibility and new visualisation paradigms. In addition, the challenges addressed under this innovation area overlap research challenges such as *methods and tools to boost the quality of future software systems*, and *trustworthy control of data confidentiality and provenance*.

Geospatial Information Systems Engineering. This area focuses on applied research leading to products and services. One branch aims to provide specialised and advanced consultancy, and in technology transfer and support in the adoption of good practices and emerging standards by companies and public administration entities. Another branch aims to help induce a market pull drive into research and technological development and generate a convergence of knowledge, competences and synergies to help produce solutions for Agro-Food, involving companies and 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.

Information Systems and Applied Computing. The ISAC area develops R&D activities centred on models, theories and conceptual frameworks that frame the use of information and information technologies that support organisational processes, including human, social, and organisational phenomena that involve access and availability of information, when computers and computer applications are used for the processing and availability of information. Its key areas are: Enterprise Computing; Data Management Systems and Applications; Digital Business.

5.10.2 Main objectives for 2022

Since mid-2020, the Centre has been refining and consolidating a new vision and objectives for the research and innovation activities, a vision firmly grounded on its long and diverse portfolio of expertise and projects, with the goal to leverage our researchers' motivation and scientific knowledge and competence.

Organisation, human and material resources

i) Repositioning of the centre with a new vision and identity as HumanISE, both internally in the Centre and INESC TEC, but especially to all our knowledge, research, and industrial partners. ii) Improving conditions to consolidate the research teams, including increasing talent attractivity, retention, and performance of young researchers, while reinforcing the existing culture of teams collaboration to achieve medium to long-term excellence in research and innovation.

Research (including publications, communications, datasets, artefacts)

i) Capitalise planned research projects' achievements and deliverables as publications, datasets, software prototypes, specifications, licenses, and other kinds of artefacts (e.g., in projects EPISA, iReceptor+, and ILIAD). ii) Pursue research in previous research topics, namely: Wikipedia information quality, health information retrieval, and the mutability of results in search engines. iii) Further explore techniques related to performance engineering (including energy usage reduction), as well as the potential of source-to-source compilation, in the areas of source code vulnerability detection and removal, and multi-language techniques. Overall, as a result, we expect to be involved in 3 books and 7 book chapters, to continue publishing more than 100 articles in indexed international journals and conferences.

Innovation (including knowledge valorisation and technology transfer)

i) Explore technology and know-how transfer in the context of research projects, namely consultancy projects, and specifications developed and software prototypes (e.g. the EPISA project, iReceptor+), resulting in a few more licensing of inventions and software copyright registrations.

Advanced training

Specialised training of experts in industry and public sector (e.g. EMPORDEF).

Dissemination (including events organisation)

i) Organisation of events related to research projects, ii) Organisation of conferences as general chairs (e.g., <Programming> 2022 - The Sixth International Conference on the Art, Science, and Engineering of Programming, Porto, Portugal) or involvement in organising committees and chairing technical committees (12); iii) Participation in program committees of international events (50); Participation in events such as fairs, exhibitions or similar (+10).

Internationalisation

Consolidation of participation in core scientific networks for our research (e.g. AIRR, RDA, EPOS).

5.10.3 Main actions planned for 2022

HumanISE will carry the following actions towards its vision and the above objectives:

Table 5.10 – HumanISE – Main actions planned

Action	Expected Outcomes
Organise HumanISE Seminars, HumanISE News, HumanISE Meetings with TEC4s, HumanISE Meetings with Centres (along the year)	Increased internal and external awareness over the centre core expertise and competences, and increased number of opportunities created for the centre via external partnerships and internal collaborations
Implementation of HumanISE Dashboard (by T2)	Increased internal awareness over all centre's activities and achievements
Disseminate and promote open positions of centre projects among Post-doc and PhD candidates	1 new Post-doc and 4 new PhD students
Mentor and support researchers to prioritise high-quality venues for publication of research results	Increase in number of high-quality publications
Identify, promote and focus on the stronger research areas of activity without losing the existing diversity	Decrease in number of projects and increase their impact
Plan and follow the value creation funnel, from ideas, research concepts and prototypes, to applied research and innovative services and products.	Increase in value added activities and respective results and impact

5.11 LIAAD – ARTIFICIAL INTELLIGENCE AND DECISION SUPPORT LABORATORY

Coordinator: Alípio Jorge

Assistant to the Centre Coordination: Ricardo Sousa

5.11.1 Scope, vision and activities

Centre scope and vision

LIAAD works on Intelligent and Adaptive Systems and Mathematical Modelling in Decision Support. Our scientific foundations are machine learning, statistics, optimisation and mathematics.

Our activity is motivated by three main vectors: 1) The growing amounts of collected data and the ubiquity of interconnected devices with sensing capabilities and/or processing power offering opportunities and challenges to scientists and engineers; 2) The increasing importance of complex and comprehensive models for objective decision support in multiple application domains; 3) The interaction of humans and the society with AI systems is growing in complexity and it is critical to assure safety, equity and transparency.

The overall challenge we take is to **Produce AI systems to empower human capabilities for a better society**, by improving the trustworthiness and transparency of AI systems, providing increased cognitive power, including the ability to link perceived language, images, sounds and other signals to larger bodies of knowledge, enabling causal inference. We aim to provide AI systems with controlled autonomy having the ability to explain and trace their actions, as well as to interact with human agents and society in safety and respecting human dignity and fairness. Enable AI systems to benefit from learned and human provided models to accelerate the safe application of AI.

Our strategy is to take advantage of the pervasive digitalisation and growing importance of AI systems by developing algorithms, methods and models that will help shorten the gap between collected data and useful data, offer diverse modelling solutions and promote a high level, high quality interaction between humans and AI. We pursue fundamental research in computer science and mathematics, with a strong basis of Faculty, junior PhD, PhD students and MSc students. We position ourselves in the international scientific communities of our areas, editing and publishing in the top journals and conferences, which we frequently organise. Our team is application ready by making research lines (push) meet market needs (pull) as much as possible, also supporting less applicational scientific domains.

Scientific activities

In **Machine Learning, AutoML and Human Artificial Intelligence** we work on the problems of data unbalance, complex networks, data stream mining and automated ML. These are some of our 2022 **challenges**:

- Improve causal inference from data using machine learning and Bayesian reasoning and use causal models for explainability and improve the explainability of black box fault models;
- Boosting for advancing the state of the art in the prediction of extreme values;
- Design ML techniques for imbalance data streams and obtain post hoc explanations for anomalies detected in predictive maintenance scenarios;
- Automatic data leakage detection in supervised learning.

In **Complex Data Analysis** we develop 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. Some of our main challenges:

- Find more efficient representations and algorithms of complex data;
- Improve data privacy guarantees, namely on the internet, and in official statistics;
- Devise a methodology for the aggregation of large surveys and their analysis at macro level, as well as for the combination of independent surveys.

In **User Modelling,** we work on algorithms and methods for stream-based recommender systems. In **NLP** we pursue the semantic and adaptive extraction of narrative structures from news, clinical records, business reports and tweets, their understanding and visualisation. Some important challenges:

- Improving online recommender systems with smart incremental ensemble models;
- Measuring and dealing with catastrophic forgetting in recommendation models;
- Improve semantic entailment using enriched language models;
- Design a methodology to increase the volume of NLP corpora in European Portuguese;
- Produce an operational pipeline for narrative extraction from text in Portuguese (news and tweets).

Modelling and Optimisation: Heuristic and exact methods are developed and applied to combinatorial optimisation problems in multiple fields, including scheduling, storage, and distribution. Agent-Based models are developed and used as computational tools in topics such as in Artificial Economics and Social Simulation.

- Develop metaheuristic methods to evaluate the impact of considering perishable/deteriorating goods on production and manufacturing schedules;
- Developing efficient heuristics for a new variant of the order scheduling problem;
- Improve the prediction of crisis and pandemics using agent-based learning resorting to conscious and non-conscious learning models;
- Forecasting crises using link prediction in multilayer bipartite networks (nodes representing countries and portfolio investment products).

Mathematical Modelling: We develop fundamental research on game theoretical modelling.

- Analyse the persistence of the Barrett paradox for quasi linear utilities;
- Explain the mechanism of price formation in the presence of positive network effects.

Innovation activities

Natural Language Processing. We will apply information extraction, narrative extraction and entity linking in knowledge transfer in the sectors of health, human resource intelligence, insurance, and media.

Predictive quality:

- Prediction: Development and application of Machine Learning predictive methods to anticipate the degree of non-conformant (defects) in products;
- Digital Twin: Digital Twin concept enhancement where Machine Learning models are used to represent object behaviour;
- Data Generation: Production of synthetic data with high fidelity of several formats (e.g., tabular data, time series) for relevant data lacking scenarios to pave the way to real data use.

Personalisation:

- Development of a recommender system for interior design materials, based on secure data exchange between supplier and retail traders.

Document summarisation and management

- Document summarisation, extraction of keywords, mentions of participants and of relevant events in the clinical domain and for a market intelligence company.

Software Engineering: Construction of an online learning framework for AIops including:

- Automatic causality tracking of software faults;
- Online software relevant fault event filtering.

Federated Learning and privacy preserving:

- Pilot with secure machine learning algorithms for insurance risk profiling and up-/cross-selling, able to learn from data with variable levels of encryption and/or obfuscation;
- Distributed network traffic analysis system based on federated learning for risk management in large communication networks.

5.11.2 Main objectives for 2022

Organisation, human and material resources

LIAAD will predictably maintain its RH numbers in 2022. Otherwise, our RH aims are the following:

1. Consolidate the contracts with two of the young PhD researchers who are very important in the activities of project proposal and project management.
2. Slightly increase the number of funded PhD students, who are ready for collaborating in projects and proposals.

In terms of organisation, Ricardo Sousa started his role as coordination assistant in 2021. Ricardo has the specific mission of providing an overall view of project and RH activity for LIAAD with the help of a customised tool. We will also foster the collaboration between PhD students of different research lines in an AI & DS PhD summit, including students from other centres. We also plan to identify outstanding PhD students and recognise them publicly.

Research (including publications, communications, datasets, artefacts)

We plan to perform a more refined analysis of scientific production, by researcher and by research topic to reach the number of 2 indexed publications by FTE, 1.5 publications in indexed journals and 2 in weighted indexed publications. The analysis will be shared and discussed with all LIAAD researchers to increase awareness.

We have a good activity of publishing software tools and data. In 2022 we plan to contribute with new datasets and resources in NLP for Portuguese within the internal seed project PT.Pump-up.

We plan to publish 1 book authored by LIAAD researchers and 3 other edited (4 books total).

Innovation (including knowledge valorisation and technology transfer)

NLP, decision support and predictive quality are promising areas for knowledge transfer in 2022. The domains of application will be health, industry, market intelligence and finance.

Advanced training

We foresee 8 concluded PhD theses: Daniel Loureiro, Manish Bhanu, Jian Jian Mou, Evelina Pereira, Guilherme Sette, Atefeh Afsar, Rita Nogueira and João Fernandes.

Dissemination (including events organisation)

LIAAD is strongly involved in the organisation of the following conferences:

- **IFCS 2022**, the 17th conference of the International Federation of Classification Societies;
- **FPG**, the French German Portuguese Conference on Optimisation 2022;
- **ISDG**, the International Symposium on Dynamic Games and Applications 2022.

We are also organising the usual collection of international scientific workshops associated with main conferences: **Text2Story**@ECIR, **LIDTA**@ECML/PKDD, **SoGood**@ECML/PKDD and **ORSUM**@RecSys. We are also involved in the **Datastreams** track at ACM SAC and in the Session "**Dynamics and Games**", International Conference on Mathematical Analysis and Applications in Science and Engineering – ICMA2SC'22.

Internationalisation

Besides organised scientific events, the following actions will contribute to a stronger international presence:

- **HumaneAI Network of Excellence**, promoting and participating in micro-projects with European partners.
- Presence in the **Dagstuhl** seminars.
- A **contract** with a New York based company.

5.11.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.11 – LIAAD – Main actions planned

Action	Expected Outcomes
A contract with a New York based company	Establish a relationship with the company; Internationalisation; Improved NLP tools; Industry track paper.
PhD AI and DS Summit	Increased collaboration and publication activity.
Organisation of international conferences, special tracks and workshops.	International networking, dissemination, increased influence in the scientific communities.
Project dashboard tool	More efficient project management; 1 distributable tool
Micro projects in HumaneAI and Dagstuhl seminars	International networking; increased influence in the scientific communities.
Knowledge transfer events on ML for financial applications and on predictive quality.	Contacts with companies, partners and potential partners. We expect to have at least 2 new contracts as a result.
A survey on existing fairness, bias mitigation, transparency evaluation metrics impact on model selection.	1 high impact paper
A survey on narrative extraction from text.	1 high impact paper
Book on "Analysis of Distributional Data". edited by Paula Brito et al. in Taylor and Francis.	1 book
A book on Agent based modelling edited by Pedro Campos (Springer).	1 book
Nuno Moniz and Rita Ribeiro will publish the book “Imbalanced Domain Learning with R” by CRC Press.	1 book
"Corruption, game theory and economics" (Elvio Accinelli, Filipe Martins, Bruno M. P. M. Oliveira, Alberto A. Pinto), to be published in Springer	1 book

5.12 CRACS – CENTRE FOR RESEARCH IN ADVANCED COMPUTING SYSTEMS

Coordinator: Ricardo Rocha

5.12.1 Scope, vision and activities

Centre scope and vision

CRACS pursues 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.

Scientific activities

Lock-Free Data Structures: extension of a Lock-Free Hash Trie design to support a set of new operations: the compact-on-removal operation, which allows the internal indexing data structures to be compressed upon removal of keys; the just-in-time indexing operation, which allows the internal indexing structures to expand optimally by dynamically adjusting keys as they are being inserted; and the ordered-indexing operation, which allows keys to be inserted by order.

Pattern-Matching: collaboration with IRIF at Université de Paris in the study of the semantics of pattern-matching through theoretical calculi equipped with built-in patterns. We aim at building a sustained study on the dynamic properties of pattern calculi (bounded and/or exact information about time and space) by using typing systems.

Quantitative Types and Linearisation: collaboration with the Universidade Federal de Goiás in the open conjecture that relates the set of terms for which there is a possible compilation into a linear term (this process is called linearisation) and the set of intersection typed terms. We are revisiting this open problem using quantitative types and, in particular, the notion of tight types, which was previously used in the context of the lambda-calculus to capture the notion of minimal typings. We aim at defining a linearisation procedure based on the notion of tight types, which is conjectured to terminate for strongly terminating terms.

Types for Events and Obligation Models: collaboration with King's College London in the transfer of knowledge available in the field of classical type-theory and rewriting to formal verification in applied areas such as CEP (Complex Event Processing) and access control systems. We developed an event language using polymorphic record calculus with flexible records that add extra flexibility to record based event-processing languages. This event language is used in our category-based obligation model using a set of axioms that specify the state of obligations. We aim at designing tools to define obligations attached to privacy policy specifications, and to analyse policies to be able to check their safety (i.e., whether a given policy ensures the expected effect).

Time Series Analysis: development of novel methods for the characterisation and classification of univariate and multivariate time series, leveraging the usage of different complex network mappings to offer a set of time series features based on the topology of those networks.

Complex Network Patterns: efficient detection of graph patterns, both at the node and subgraph level, capable of providing rich characterisation of networks. This includes the ability to incorporate extra node/edge features (e.g., temporal information, numeric weights, colors) and different network layers (e.g., multiplex networks).

Edge-Computing and Edge-Clouds: development of the JAY framework that allows users to implement different strategies for offloading tasks in hybrid topology clouds (infrastructure, cloudlet, femto, edge) and to evaluate their performance with respect to chosen metrics (e.g., execution time, energy consumption).

Fake News Detection: continuation of previous work focusing on the Twitter platform. Longitudinal understanding of the machine learning model's stability to quantify the volume of information needed with predicting power. Usage of deep learning models based on BERT and RoBERTa to identify best features for predictions. Generation of synthetic samples using GANs to promote balance and improve machine learning.

Fake Photos and Videos Detection: exploration of innovative ways to detect fake photos and videos subject to some kind of manipulation, such as copy-move or splicing, using machine learning techniques. The overall goal is to design and implement an external module for the "Autopsy - The Sleuth Kit" forensic tool.

Framework for Gamified Programming Education (FGPE project): definition of an integrated ecosystem to manage gamified programming exercises that could fit several educational and business scenarios. A new

Erasmus+ project, named FGPE Plus, started in mid-2021 with the aim of extending the FGPE ecosystem to allow learning management systems to play a central role in the launch and track of learning activities by teachers and students. Another new Erasmus+ project, named JuezLTI, aims to create a tool for the automatic assessment of computing exercises, namely markup languages, programming and databases exercises, taking advantage of the LTI standard to communicate with several online LMS such as Moodle, Sakai, and others.

Innovation activities

Crowd-Sensing and Crowd-Sourcing Applications: development of BioLens, a web portal that includes several deep learning models trained to identify animal taxa (currently Lepidoptera and Odonata) and are close to release a model for the Portuguese autochtone flora (a collaboration with the Portuguese Botanical Society and Parque Biológico de Gaia). Future plans include extending these models to more taxa with special interest in pollinators (collaboration with the MNHC at University of Porto). These tools are crucial for environmental monitoring in the light of current biodiversity loss. Software available at https://rubisco.dcc.fc.up.pt/biolens.

Safe/Smart Cities: collaboration with BOSCH Ovar with the aim of using edge-clouds of mobile devices to provide building security information in emergency situations, such as, fires, earthquakes, or terrorist attacks. We focused on the problem of indoor location for which we have developed a system that uses a network of Bluetooth beacons to estimate the locations of mobile devices. The system provides a back office that seamlessly manages and monitors the network of devices. Into this system we introduced new technologies such as UWB (Ultra Wide Band) and Computer Vision (that infers the position of a mobile device from photos or video taken with it, using deep learning). We are exploring the technologies in isolation and from a sensor fusion perspective. This system is running at the Galeria da Biodiversidade, part of the MNHC at University of Porto, and the collaboration includes colleagues from MNHC and FEUP that provide contents and multimedia.

Secure Clouds and Edge: collaboration with BOSCH Braga with the aim of creating secure solutions to support autonomous vehicles in a safe city environment. This includes secure cloud infrastructure, decentralised identity management, access control and storage, and privacy preserving approaches.

Google Chrome plug-in: to detect the fakeness level of multimedia content. Dataset of cyber bullying and hate speech for the Portuguese language. Classifier of hate speech for the Portuguese language, based on NLP.

5.12.2 Main objectives for 2022

Dissemination & Internationalisation

A key objective for 2022 is to maintain CRACS's international visibility, notoriety and publication output. In particular, we aim to maintain the number of publications by CRACS's members around a total of 50 publications in indexed journals and conferences. We also aim to maintain the number of international events organised by CRACS members, the number of participation as editor in international journals and the number of participations in program committees (we estimate the organisation of 4 events and the participation in 5 journals as editor and in more than 30 program committees). We also aim to be successful in new scientific projects, national and preferentially European, in order to increase our funding level, which was decreased significantly in the last years.

Scientific activities

Develop a generic high-level interface that efficiently implements synchronisation procedures for memory reclamation in lock-free data structures. This is an essential step to enable the wider usage of lock-free data structures in programming environments in modern multi-core CPUs where garbage collection is not available.

Continue efforts to build a sustained study of the dynamic properties of pattern calculi (bounded and/or exact information about time and space) by using typing systems. We will build this study starting from pattern calculi with matching modulo some equational theory. We will also focus on patterns having constructors with flexible arity. Finally, we will explore the dynamics of patterns with recursive definitions.

Continue work on defining a linearization procedure based on the notion of tight types.

Continue work on designing tools to define obligations attached to privacy policy specifications, and to analyse policies to be able to check their safety (i.e., whether a given policy ensures the expected effect). To combine privacy policies and obligations, we plan to combine the category-based data collection model with the category-

based obligation model. To check the safety of policies, we plan to use transition systems and reachability properties. Transition systems are a well studied mathematical tool to analyse the dynamic behaviour of a system. Type systems can be used to filter states to avoid state explosion.

Publish a software package for time series analysis using complex networks.

Develop and make available a labelled dataset composed of synthetic fake news samples to balance training of classification models based on random forests, decision trees and naive bayes classifiers.

Continue research and development of middleware for edge networks of mobile devices in the context of crowd-sourcing and crowd-sensing applications, potentially including collaboration with the Underwater Systems and Technology Laboratory at FEUP.

Extend the FGPE ecosystem to support the LTI specification. Define new types of validators to assist in the assessment of the JuezLTI main tool, namely XML validators.

Innovation activities

Continue the development of the BioLens project by adding new deep learning generated models for new taxa and exploring different neural network topologies and different techniques to handle imbalance in datasets such as image augmentation and “one shot learning”.

Continue the collaborations with BOSCH-Ovar, BOSH-Aveiro and MHNC in the development of new infrastructure, middleware and apps for energy aware, precise, indoor positioning systems.

Start collaboration with Centro de Astrofísica da Universidade do Porto (CAUP) with the goal of using deep learning techniques to tackle astrophysics problems, namely, the automatic spectral classification of stars and analysis of time series generated from radial velocity surveys in search for exoplanets.

Participation in Theia, a P2020 project with Bosch Braga.

Advanced training

Organisation of the International School and Conference on Network Science (https://netscix.dcc.fc.up.pt).

5.12.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.12 – CRACS – Main actions planned

Action	Expected Outcomes
Submit project proposals to national and European calls	Development of new projects and increase funding level
Organisation of international scientific events (we estimate the organisation of 4 events)	Reinforce expertise in the area and promote networking
Organisation of International School and Conference on Network Science	Reinforce expertise in the area and promote networking
Participation in project Theia with Bosch Braga	Reinforce expertise in the area and promote networking
Reinforce collaboration with institutions related to Nature conservation	Growth of the BioLens initiative and its use by amateur and the scientific community
Start collaboration with CAUP to tackle astrophysics problems	Growing expertise in machine learning applications to other scientific areas

5.13 HASLAB – HIGH-ASSURANCE SOFTWARE LABORATORY

Coordinators: Alcino Cunha and António Luís Sousa

5.13.1 Scope, vision and activities

Centre scope and vision

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.

To accomplish this mission, HASLab covers three main competences (research areas) within INESC TEC Computer Science domain — Cybersecurity, Distributed Systems, and Software Engineering — complemented by other competences such as Human-Computer Interaction, Programming Languages, or the Mathematics of Computing.

Scientific activities

The contributions of HASLab to these three main 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. In particular HASLab research focus on:

- **Software Engineering** – methods, techniques, and tools for rigorous software development, that can be applied to the internal functionality of a component, its composition with other components, as well as the interaction with the user. Research in this area is strongly aligned with the INESC TEC research challenge “Methods and tools to boost the quality and energy-efficiency of future software systems”.
- **Distributed Systems** – improving the reliability and scalability of software, by exploring properties inherent to the distribution and replication of computer systems. Research in this area is strongly aligned with the INESC TEC research challenge “Performance, interoperability, and dependability of critical information systems”.
- **Cybersecurity** – minimise the vulnerability of software components to hostile attacks, by deploying structures and cryptographic protocols whose security properties are formally proven. Research in this area is strongly aligned with the INESC TEC research challenge “Trustworthy control of data confidentiality and provenance”.

Innovation activities

Through a multidisciplinary approach that is based on solid theoretical foundations, HASLab aims to provide solutions — theory, methods, languages, tools — for the development of complete ICT systems that provide strong guarantees to their owners and users. Prominent application areas of HASLab research include the development of safety and security critical software systems, covering all phases of software development from requirement specification and validation to algorithm design and implementation, the operation of secure cloud infrastructures, including polyglot data management and “cloudification” services, and the privacy-preserving management and processing of big data.

5.13.2 Main objectives for 2022

Organisation, human and material resources

To better cope with the increasing load of research and development contracts, in 2022 we aim to hire at least one PhD and 2 MSc researchers/developers.

In the upcoming year we intend to start organising a short monthly *staff meeting* with all senior researchers to improve the communication with the centre’s coordination and to better monitor the progress in the execution of the annual plan, including the definition of mitigation plans if necessary.

To strengthen the collaboration between researchers, the centre is also planning to promote more internal informal scientific events and discussions.

Research (including publications, communications, datasets, artefacts)

In terms of number of publications, HASLab is experiencing some stagnation in the recent years, even with a slight increase in the number of collaborators. It is not entirely clear what are the reasons for that, and so a key action for next year is to perform a detailed analysis of the current publication patterns, identify under- and over-

performers, and identify reasons that can explain such low or high productivity, respectively. This analysis will mainly be conducted in the aforementioned monthly staff meetings, and will help the coordination define plans to increase the scientific productivity of the centre in the long term.

Apart from this long-term goal for the overall scientific productivity, in the medium term we intend to increase the number of publications in top conferences (CORE A* and A) and top journals. With that goal in mind, we will ask all senior researchers to define a publication plan that identifies research topics with potential to be published in such top venues, together with concrete submission deadlines to be met.

Finally, research in HASLab involves empirical studies and system evaluations that lead to large datasets that can be useful for other researchers around the world. However, it is still not common for HASLab researchers to release these datasets to the public domain, thus in 2022 we intend to raise awareness to the value of releasing these datasets to the public domain, and aim to have at least 2 new data sets released.

Innovation (including knowledge valorisation and technology transfer)

The bulk of technology transfer and industry contracts in HASLab have been mainly focused in a few specific competences (namely, privacy and cloud). In the upcoming year, we intend to identify other competences in the centre's portfolio with potential for valorisation and technology transfer. In particular, we will start with those related to Software Engineering and to the research challenge on "Methods and tools to boost the quality and energy-efficiency of future software systems". In the past years the centre had some contracts related to this topic, but not as much as could be expected given the prominence of Software Engineering in the national IT industry. Following this process, we intend to define a communication plan to promote these competences, including, among others, webinars or short videos in INESC TEC social media platforms.

Furthermore, knowledge valorisation in HASLab is often disregarded. As such, in the upcoming year we intend to raise the awareness for this topic, and in particular aim to have more invention disclosures (the first official recording of an invention that can help establish its irrefutable date and scope).

Advanced training

In 2022 we foresee the conclusion of 6 PhD theses.

The 2021 HASLab internship program, that offered BII grants to MSc students doing their theses in the Centre, was quite successful, with several of these students opting to pursue a PhD in the Centre. As such, since the number of PhD students in the Centre is still quite low, we intend to continue with this program in 2022.

In 2021 we also started a mentoring program for PhD students, where they meet with the Centre coordination board, and focusing on keeping the research plan on track and defining a high-quality publication plan. This program was very well received by students, and so it is planned to continue in the next year.

Dissemination (including events organisation)

In 2022, HASLab members will be involved in the organisation of at least the following international conferences and workshops:

- 8th International Conference on ICT for Sustainability, to be held in Plovdiv, Bulgaria.
- 26th International Workshop on Algebraic Development Techniques, to be held at University of Aveiro.
- 2nd Workshop on Quality and Reliability Assessment of Robotic Software Architectures and Components, to be proposed as a workshop at the 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems, in Kyoto, Japan.

Concerning conference organisation, it is worth mentioning that we recently submitted a proposal for organising INForum'23, the main national symposium in computer science. Also, following the successful organisation of top international conferences in recent years (namely, FM'19 and EuroSys'18), which brought high international visibility and recognition to the Centre, we also intend to define a medium-term plan to submit proposals for organising more top-level international conferences.

Concerning Summer Schools, the Centre will be involved on the organisation of the SusTrainable PhD School, to be held in Cluj, Romania, focused on sustainable software, and also intends to organise (in cooperation with INL) a Summer School on quantum computing targeting high-school students.

Finally, related to the recent release of Alloy 6, a formal software design language tool that now incorporates major contributions by members of the Centre, we also intend to publish a book about formal software design with Alloy 6, targeting an educational and industrial audience, and propose to organise a tutorial about this tool at a top-level international Software Engineering conference.

Internationalisation

Besides organising scientific events, the following actions are planned to promote the internationalisation of the Centre:

- Attract more international researchers to work in the centre, namely by disseminating opportunities for grants in relevant international forums and mailing lists.
- Increase the presence of HASLab members in IFIP Technical Committees, namely HASLab members are actively involved in the creation of a new TC related to quantum computing.
- Increase the presence of HASLab members in international professional societies, namely IEEE and ACM, namely promote the application to higher membership ranks.

5.13.3 Main actions planned for 2022

The Centre will carry the following actions towards the above objectives and as part of its continued activity towards its vision:

Table 5.13 – HASLab – Main actions planned

Action	Expected Outcomes
Hire new employees	1 new PhD employee and 2 new MSc employees
Organise monthly meetings with the senior researchers	11 meetings
Raise awareness for the value of releasing datasets to the public domain	2 new public domain datasets released
Promote HASLab Software Engineering competences for the national IT sector	1 communication plan
Raise awareness for knowledge valorisation	2 new invention disclosures
Continue with the HASLab internship program to attract MSc students, funded by BII grants	8 publications co-authored by master students, 6 new PhD students
Continue with the mentoring program for PhD students	Decrease mean time for PhD completion and increase the average number and quality of scientific publications per PhD thesis
Event organisation	3 workshops / conferences, 2 summer schools, 1 plan for submitting proposals for conference organisation
Formal software design with Alloy 6	1 book, 1 tutorial
Attract foreign researchers	2 new foreign researchers

6 RESEARCH AND TECHNOLOGY INFRASTRUCTURES

INESC TEC maintains more than twenty state-of-the-art laboratories that support both research and technology transfer activities, besides its active participation in several national Research Infrastructures (RIs). The main objectives and actions planned for the year 2022 of a selection of those research and technology infrastructures are presented below in this Section.

6.1 TEC4SEA Research Infrastructure

6.1.1 Main objectives and actions planned for 2022

The TEChnologies for the Sea (TEC4SEA – www.tec4sea.com) infrastructure, will finish the first implementation phase in April 2022. 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 trials. It aims to become a unique and pioneer platform in Europe to support research, development, and testing of marine robotics, telecommunications, and sensing technologies for monitoring and operating in the ocean environment. It shall be able to offer the first services to the academic and businesses players.

The main objectives for 2022 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.
- Validation of services – the definition of services is being finalised and a series of validation tests will be conducted before these services are offered to the community.
- Present itself to the world – the end of the first implementation phase shall be commemorated with a special event. Different stakeholders shall be invited, and the infrastructure resources presented and visited.

Building on the experience from the first implementation phase, INESC TEC will be strongly committed in the preparation of a successful plan for the second implementation phase. This includes an active participation in discussions and reporting of the first phase, and establishing priorities for the second implementation phase, to ensure a successful transition to the operational phase.

6.2 Laboratory of Microfabrication

6.2.1 Main objectives and actions planned for 2022

The Microfabrication laboratory explores non-traditional microfabrication techniques based on femtosecond laser direct writing processes. For example, microfluidics and optofluidics chips are produced to implement biosensors and 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.

- Besides the fabrication of integrated optics or optofluidic devices, identify other areas of application where the installed micromachining capabilities can add value due to its unique characteristics;
- Micromachining and laser welding of glasses;
- Machining and waveguiding writing in Ultra Low Expansion (ULE) glasses;
- Exploration of glass poling techniques for the fabrication of active devices fabricated by femtosecond;
- 3D metallic electrode fabrication.
- Fabrication of microfluidic and optofluidic devices using FLICE techniques for sensing applications;
- Fabrication of Bragg and long period gratings (first and higher order structures).

The fabrication capabilities are complemented with equipment available at CEMUP – MNTEC. The cleanroom is a service providing laboratory managed by University of Porto that was supported since its creation by INESCTEC which made its micro/nanofabrication equipment available on this infrastructure for widespread use.

6.3 Robotics and Autonomous Systems Laboratory

6.3.1 Main objectives and actions planned for 2022

The Laboratory of Robotics and Autonomous Systems has two physical locations within the ISEP and FEUP campuses. These dedicated facilities support R&D activities, technical training of human resources as well as advanced education programs. In fact, as a research lab in an academic environment it fosters undergraduate research, supports multiple engineering courses and academic activities.

The main objectives of the Robotics and Autonomous Systems Laboratory for 2022 are the following:

- **Upgrading laboratory equipment and tools** – the growing R&D activity and the expansion to new application areas requires up to date laboratory equipment and tools. Investments planned for 2022 will contribute to the maintenance and update of development equipment, make available fast prototyping equipment, as well as high performance systems allowing for the conduction of field experiments.
- **Training of technical staff** – in order to allow researchers to be more focused on innovation and research activities, an effort will be pursued on the training technical staff to support the conduction of experimental activities.
- **Consolidation of the technical support team –** Given the planned activities for 2022 there will be a strong demand for technological developments therefore there will be some efforts to increase the support team.
- **Integration with R&D Infrastructures –** take advantage of some of the services provided by the infrastructures (eg. TEC4SEA) to optimise logistics, simplify outsourcing, and accelerate development and testing of equipment.

6.4 EMSO-PT Research Infrastructure

6.4.1 Main objectives and actions planned for 2022

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 organise 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. INESC TEC involvement in EMSO-PT addresses the establishment of long-term non-fixed observatories. Such work is organised 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.

The main objectives for 2022 are the following:

- **Deployment of a Turtle node with an EGIM system** – The EGIM system assembled at INESC TEC will be integrated on a Turtle lander that will be deployed off the northern Portuguese coast.
- **Deployment of a glider network** – two operational gliders equipped with payload sensors will be deployed in cooperation with EMSO-PT partners to conduct several experiments.

Building on the experience from the first implementation phase, ending in 2022, INESC TEC will be strongly committed in the preparation of a successful plan for the second implementation phase. This includes an active participation in discussions and reporting of the first phase, welcoming and collaborating with new candidates for the infrastructure, and establishing priorities for the second implementation phase, to ensure a successful transition to the operational phase.

6.5 iiLab - Industry and innovation laboratory

The iiLab – Industry and innovation laboratory, established in 2019, is an experimentation and a prototyping space with advanced training and hands-on experiences for managers and operators of industrial and technology companies interested in implementing and developing technologies for manufacturing processes. The iiLab is a space to research, to demonstrate and to disclose concepts and advanced technologies in robotics, automation and industrial cyber-physical systems (also called Industrial Internet-of-Things, IIoT), as well as to exhibit INESC TEC's expertise to the industrial community.

6.5.1 Main objectives and actions planned for 2022

In 2022, several actions related to the implementation of the new infrastructure of iiLab (PORTIC) will take place, in cooperation with several Centres. The main objectives of these actions are i) to implement an efficient and attractive innovative laboratory for showroom and collaboration with private and public companies interested in testing, demonstrating, validating, and/or to implementing industry 4.0 enabling technologies (such as robotics, automation, digital twin, industrial internet-of-things, among other technologies); ii) to create and disseminate innovative and advanced training courses and educational programs, mainly for companies. For the year 2022, the actions planned are:

- Explore and develop innovative activities under the new iiLab infrastructure, including new research project proposals, as well as advanced training and technology transfer activities based on the completed research projects results of the centres represented in the iilab;
- Define a roadmap for technologies and technological concepts;
- A In accordance with the roadmap and taking into account the required material and equipment, plan, develop and implement training actions (CESE, CRIIS and other INESC TEC Centres);
- Define and implement a communication and dissemination plan for the iilab;
- Operationalise the rules and procedures;
- Monitor the construction and adaptation works of the new spaces in the PORTIC building. Installing and commissioning the equipment acquired;
- On the occasion of the inauguration of the new iiLab facilities, organise and hold events to promote the Laboratory's activities to the industry, research community and society;
- Promote partnerships with companies, such as technology providers, in order to make more efficient technology transfer activities;
- Participation in educational research projects, at a national and European level, to develop new approaches to training and education initiatives.

6.6 Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry

6.6.1 Main objectives and actions planned for 2022

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, profitability, and automation in three main environments: Permanent Crops (such as steep slope vineyards, olive groves, tree fruits), Forest biomass harvesting, Protected Cultivation (conventional and urban). For 2022 it was established the next main objectives:

- Develop the AgRob and AgIoT technology till TRL 8 and deploy this technology in full time pilots;
- Transfer our robotic technology for European companies;
- Organise two open days with our AgRob and AgIoT technology;
- Accomplish the coordination of one European project;
- Explore new R&D lines with lower TRLs, such micro-robotics and robotic algorithms in systems on chips;
- Increase the international cooperation with relevant institutions in EU, UK, Brasil, USA and Australia;
- Increase the number of publications (8 papers) in IEEE, Springer and Elsevier journals.

6.7 Laboratory of Computer Graphics and Virtual Environments

6.7.1 Main objectives and actions planned for 2022

We foresee the following objectives and respective actions:

- Integrate immersive learning environments with management and learning information systems;
    - Action: Prototype the Inven!RA platform for management of inventive activity plans in education and training.
- Enhance immersive solutions for training in Industry 4.0;
    - Action: Develop an online tool and framework to select the most adequate immersive training solution.
- Expand current state of the art in interaction and collaboration in Extended Reality.
    - Actions: Prototype case studies in the context of ongoing research of the PAINTER project applied to different collaborative content creation scenarios;
    - Propose funded project in Research Actions.
- Develop solutions that provide Virtual and Augmented Reality solutions to the market;
    - Action: Propose projects in Innovation Actions.
- Develop Game-based and Gamified solutions for behaviour change on process enhancement;
    - Action: Propose projects in Innovation Actions.
- Develop collaborative solutions for driver behaviour studies;
    - Action: Propose project for the driver simulator.

6.8 CLOUDinha Laboratory

The laboratory provides computational support to research and development activities of INESC TEC and University of Minho, providing bare metal, virtualisation capabilities, containers and security features such as trusted hardware.

The cluster is composed of different generations of hardware namely, Sandy Bridge, Ivy Bridge, Haswell and Kaby Lake. It is currently composed of 100 machines based on commodity hardware with Intel Core i3 CPUs, 16 GB of memory, and heterogeneous storage hardware including HDDs, SSDs, and NVMe devices. The servers are connected through either a 1 Gb or 10 Gb network.

The heterogeneous hardware nature of the cluster is important for supporting different research projects that may require specific hardware features (e.g., different storage or network technologies, access to trusted hardware capabilities).

6.8.1 Main objectives and actions planned for 2022

The main goal of the laboratory is to continue supporting research and development, by providing the necessary computational resources, for key computer science areas such as:

- Distributed systems and data management
- Storage systems and databases
- Privacy and security
- Blockchain and Internet of Things
- Software engineering

The laboratory will continue to provide access to bare metal servers, where virtualised resources can also be deployed on (e.g., virtual machines, containers), according to the need of the research work being conducted. Also, we plan to continue updating the cluster, by introducing new servers, if the demand for these is justified.

6.9 Smart Grids and Electric Vehicles Laboratory (SGEVL)

6.9.1 Main objectives and actions planned for 2022

- Create scientific based innovation focused on green hydrogen, namely power electronic converters, control, and grid integration. Implementation of a laboratory scale validation facility including PEM and Alkaline electrolysers (Horizon 2020 GREENH2ATLANTIC).
- Design solutions and prototype technology to implement a hybrid AC+DC microgrid with very low EMI content, as part of an energy supply solution for a novel telescope infrastructure (Portugal 2020 SmartGlow).
- Continue to create knowledge in PV plant modelling, specifically power electronic inverters, aiming to develop new O&M tools for future and existing PV pants (Portugal 2020/Eureka AI4PV).
- Conclude the implementation of a realistic and comprehensive V2G test bed with technology from partners and internally developed. This test bed will be used to implement and validate new control strategy and strengthen the relevance of SGEVL in electric vehicle charging area (Horizon 2020 POCITYF).
- Consolidate expertise in the grid automation and protections area, based on real-time simulation and interface with IEC 61850 compliant instruments, namely V/I amplifiers, network equipment and satellite-based time server (Portugal 2020 SCALE).
- Develop and implement interoperable solutions for EV charging smart appliance and energy management and validation using realistic microgrid test bed. (Horizon 2020 InterConnect).
- Development support and validation of novel fault detection and prediction methods for low voltage grids, based on real-time simulation and PHIL co-simulation. Final validation with real measurement and analysis equipment. (Direct Contract with Eneida - Portugal)
- Begin the operation of a synchronous generator emulator targeting realistic emulation of static and dynamic behaviour of electricity grids.
- Explore all the results in commercial and scientific aspects, with creation of new added-value services for industry and production of relevant publications and patents.
- Consolidate the SGEVL value proposition, in terms of human resources, facilities and offer to stakeholders, aiming to achieve the continuity of a relevance presence in *RNIE (Roteiro Nacional das Infrastruturas de Interesse Estratégico)*, with corresponding budget to continue as a key research infrastructure in the energy sector.
- Make efforts to increase the dissemination activities focused on attracting new clients and strategic partners based on the list of services developed. Dissemination of SEGVL website and production of additional support material.

6.10 Neuro-Engineering Lab – BRAIN Lab

Neuro-Engineering laboratory, named of BRAIN (Biomedical Research And INnovation) has a strong focus on researching new biomedical engineering methods for neurological diseases (e.g., Parkinson's, Alzheimer's, Autism and Epilepsy) namely neuroimaging, quantified movement semiology, Gait impairment analysis, Deep Brain Stimulation (DBS), brain connectivity, neuro-robotics, among others. This lab has largely contributed to some pioneering research achievements, being the most relevant:

1. Neurokinect installation at University of Munich Medical Center, managing around 7TB/day of data, leading to the creation of a unique labelled dataset. To the best of our knowledge, it is the world-largest and unique 3Dvideo-EEG dataset of epileptic seizures.
2. The creation of the start-up InSignals Neurotech focused on the intra-op real-time motor symptoms monitoring to support neurosurgical procedures of deep brain stimulation. After a 4 year of development with CHUSJ, a family of patents and relevant high-impact papers, the start-up has raised $120,000 to extend the number of clinical trials in Europe and initiate the medical device road to the market.
3. The iLoF (intelligent-Lab-on-Fiber) technology was born from this lab that joined forces with CAP Centre to explore novel ML approaches to photonics signals obtained from optical fiber tweezers usage on biofluids. It generated high-impact papers, a patent family and a spin-off startup that has raised $3M seed funding so far and focused in Alzheimer's neurologic disease.

BRAIN Lab also has a Stim-BRAIN Lab which we have an f-MRI simulator fully equipped with 64ch EEG medical systems from Micromed, wearable EEG devices, video cameras and pads MRI compatible and audio system to simulate f-MRI experiences and prepare stimulation sessions before going to a MRI at the CHUSJ or any other clinical centre. We also have a strong research line in the area of Brain-Computer Interfaces, in the area of psychophysiological states, among others

BRAINLab research group in the last academic year of 2020/2021 counted with 4 interns, 6 MSc Theses and 4 undergoing PhD theses.

6.10.1 Main objectives and actions planned for 2022

- Expand and share our knowledge and network at a European level in order to pursuit our research and innovative ideas in the Neuro-Engineering area;
- Pursuit the creation of a more advanced infrastructure to conduct new research projects and clinical trials, bringing researchers from different fields together with clinicians;
- Research and development of personalised brain medical treatments, therapies, autonomous and adaptive robotics, brain-computer interfaces, sensing system with edge-AI and decision-making capabilities, applying all the knowledge that our multidisciplinary team has at technology (signal processing, machine learning, computer vision, wearable devices and hardware development, e-health/m-health systems, …) and clinical levels (seizure semiology, Parkinson personalised therapeutics, neurosurgery, DBS implantation, …).
- Translate the achieved results in high-impact research papers in the Neuro-Engineering area concerning both engineers and clinicians' scientific communities.
- Attract more national and international student for internship programs and MSc and PhD Theses.

7 SUPPORT SERVICES

7.1 LEGAL SUPPORT SERVICE

Manager: Rita Barros

7.1.1 Main objectives and actions planned for 2022

The Legal Support, as a vital service to the pursuit of INESC TEC's objectives of achieving advancement in science and technology development and transfer, will keep ensuring compliance with International, European and National applicable legal frameworks, safeguarding the best practices in all relevant matters, such as human resources, institutional relations, contracts, public procurement and personal data protection, seeking, at all times, to give the most appropriate response to each problem raised, or advice requested.

In this sense, it will have the following objectives in 2022:

- Contracts: ensure internal training on contractual practices, in two sessions for Centre Coordinators and their Researchers, making them aware of the most common and sensitive issues;
- Public Procurement: increase of joint procurement in public procurement, in order to reduce its constraints in certain supply chains;
- Promotion of Internal Partnerships: promote greater synergy with the Services with which it most directly interacts, in order to optimise the joint response, ensuring presence in the various stages of project construction (applications) or proposals;
- Labour Law: assist in the review of employment contract templates and other related documents, ensuring that they are updated in the light of changes in labour matters, as well as adapting them to better respond to new challenges in the current social and economic context;
- Personal Data Protection: continuing the work of cooperation and coordination, ensuring a joint and updated response at each moment of project development;
- Awareness-raising on the subject of Dual Use, promoting the respective and appropriate training with the AT;
- Hiring of a new team member to ensure the timely response of the Service in contractual and other private law matters.

7.2 FINANCE AND ACCOUNTING SERVICE

Manager: Paula Faria
Assistant Manager: Libânia Caetano

The Accounting and Finance service is responsible for coordinating and executing the accounting activities, for fulfilling all fiscal obligations, 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.

7.2.1 Main objectives and actions planned for 2022

The main objectives and actions planned for 2022 are a result of the Accounting and Finance Service needs and challenges foreseeable for the near future:

- Consolidate the digital archive process;
- Increase efficiency on Fixed Assets Management;
- Enhance the organisation procurement process;
- Participate in the identification of requirements, procurement and implementation of a new ERP system;
- Reinforce continuous improvement activities and practices;
- Promote the development of the team skills and its optimal integration with the rest of the organisation.

7.3 MANAGEMENT CONTROL SERVICE

Manager: Vanda Ferreira
Assistant Manager: Bárbara Maia

7.3.1 Main objectives and actions planned for 2022

The service has the following main actions planned for 2022:

- Preparation of an internal manual of procedures;
- Collaboration in the search, selection and implementation of a new management information system (ERP);
- Complete the Digital project file, with all accounting documents that are necessary to instruct a payment request, created "automatically" according to each project type (invoices, transfers, bank statements);
- Improve the “proposals workflow” together with SIG and SAAF;
- Review of the procedure of opening a cost centre, together with SIG;
- Design, develop, and implement new tools for monitoring and managing Human Resources projects’ allocation, together with SIG and HR;
- Continue the dematerialisation of processes, namely invoicing, together with SIG.

In 2022, the Service plans to recruit a new team member to be dedicated to European projects, to face the increased number of projects and specifically the number and dimension of coordinated projects.

7.4 HUMAN RESOURCES SERVICE

Manager: Luís Seca

The current Human Resources service coordinates and executes all activities pertaining to human resources administrative management and to the development and implementation of HR related policies, according to the applicable law, internal regulations and guidelines provided by the Board. During the year 2022, the transformation that was initiated in 2020 will continue, both on operational and strategic HR activities, reconceiving and reconfiguring HR management strategies, policies and practices.

7.4.1 Main objectives and actions planned for 2022

Activities in the Strategic Development Area

One of the important goals for 2022 is to get INESC TEC co-workers to maintain work-life balance, an essential condition to ensure well-being, while **making the best use of their capabilities**. Following a decision from the Board of Directors, **a new model of hybrid work**, where co-workers will alternate between telework and face-to-face activity, will be designed. In detail, during the year 2022 the following activities will take place:

- **Design and implementation of the role and competences policy**: finish the job description process; structure the job description and competencies policy; elaborate, validate and implement the roles and competencies policy, as well as the job descriptions for all the positions and the respective competency catalogue.
- **Design and implementation of the career policy**: work on the strategic guidelines already produced and delivered to CE assessment; elaborate, validate and implement the career policy.
- **Review current model and structure a pilot of the new performance appraisal policy**: finish the ongoing expert working group (GTE) for the performance appraisal policy; elaborate the strategic guidelines, validate and develop the performance appraisal policy; structure a performance appraisal pilot.
- **Remodel and implementation of the new welcoming and onboarding policy**: review the existing institutional welcoming model; revisit the contents available to newcomers and welcome kit; elaborate, validate and implement this policy in each unit;
- **Make use of training pilots to improve the design and implementation of the training policy:** establish the expert working group (GTE); work on the results of the external training pilot that took place in 2021 and develop collaboratively an internal training pilot to achieve the best training policy; create a strategy to offer training as a complementary benefit, a differentiating factor, and a competitive advantage in attraction; ensure compliance with legal requirements; promote reskilling to avoid technical obsolescence.
- **Revision and design of the new recruitment and selection policy**: establish the expert working group (GTE); ensure planning and resource forecasting in a more integrated way; consider improvements on attraction mechanisms; rethink and elaborate the recruitment and selection process.
- **Develop wellbeing and occupational health actions and promote the existing support line:** develop and implement internal initiatives to build institutional capacities on occupational health and to promote workers wellbeing; endorse the existing support team to provide personal support and promote wellbeing.

Activities in the Operational Area

- Improvement of the intranet HR processes to reduce workload, time of processing and error occurrences;
- Promotion of information internal sessions, addressed to the Secretariat or other attendees, on changes in HR processes and new requirements;
- Process internal reorganisation;
- Revision of all HR documents available on INESC TEC's intranet, namely the document of the rights and duties of each kind of liaison of INESC TEC collaborators;
- Create HR Guide, to provide clarifications / information about internal rules and processes; administrative proceedings; Labour legislation and Scientific Employment (types of contracts); INESC TEC Grants Regulation; Applications INESC TEC; tuition fees.

7.5 MANAGEMENT SUPPORT

Manager: Isabel Macedo

7.5.1 Main objectives and actions planned for 2022

The Management Support Service will focus its activity for 2022 along its four main areas of activity: decision-making, direct support to the Board, information management and continuous improvement.

Besides its regular activities, the Service will also endeavour to achieve the following objectives:

- Assist in organisational changes as a result of the deployment of the new science model and contribute in the redefinition of the institutional performance indicators;
- Implementation of a document management policy at an administrative level and ensure the compliance of its guideline, while assisting in the reorganisation of the institutional archives and fostering archive digitisation;
- Assist and guide in the new disposal process of accumulated institutional documentation in accordance with the conservation periods established in the document management policy while ensuring legal compliance with the GDPR;
- Promote the certification of the INESC TEC research data repository, following the guidelines of the CoreTrustSeal Requirements;
- Design and improvement of data management services, among others by adopting data policies, improving metadata quality and supporting researchers to define Data Management Plans;
- Participation and contributions to the EOSC Future User Group which aims to provide a wide variety of research data services;
- Establish relationships with international institutions, namely by participating in the Research Data Alliance Communities of Practice in order to foster the adoption of data management best practices;
- Fuel incremental continuous improvement namely by promoting actions for current business processes' analysis and improvement and by supporting the implementation of newly identified ones.

7.6 SECRETARIAL COORDINATION

Managers: Grasiela Almeida and Ana Isabel Oliveira

The Secretarial team is responsible for effectively executing the tasks required for the development of the activities of the Board of Directors, Research Centres and Services they support, in accordance with INESC TEC´s internal rules and processes.

This team, composed by 18 employees, develops its work directly under the responsibility of a coordinator within a structure, Centre and Service, being also coordinated by one of the above-mentioned managers: Ana Isabel Oliveira manages the team of 3 Executive Assistants of the Board of Directors and Grasiela Almeida manages the team of 15 Assistants that support the Research Centres and Services.

Each manager supervises her corresponding team (assuring procedure compliance, providing training, giving feedback on performance, providing information on established partnerships and anticipating needs) while combining efforts to develop both teams along with the institution, being a part of the team with focus on continuous improvement.

7.6.1 Main objectives and actions planned for 2022

Apart from the main actions, as described in the previous section, the Managers will work on the following actions:

Work in Progress	1. finish the implementation of the digital archive with focus on the compliance with GDPR;
	2. design and implementation of a new Process for Event Management, following the state of the art analysis that has been previously developed, coordinated by the Board;
	3. produce a comprehensive guide with useful information for Assistants at INESC TEC;
	4. study, define and implement updated and accurate activity indicators applied to the team;
New Initiatives	5. organise necessary and identified training and networking initiatives (such as the MS Excel, MS PowerPoint, Event Management and “Assistant Day@INESCTEC” Workshop and the “Strategic Thinking - a Joint Vision”);
	6. develop the secretariat reorganisation process;
	7. explore the opportunity of evolution of the CRM towards an institutional contacts database.

7.7 FUNDING OPPORTUNITIES OFFICE

Manager: Marta Barbas

7.7.1 Main objectives and actions planned for 2022

The Funding Opportunities Office is crucial to support researchers submitting successful proposals and to search and identify the most suitable funding opportunities to support INESC TEC Research, Development and Innovation activities. In order to accomplish these objectives the service planned the following actions:

- Recruitment of a new resource to reinforce the team in order to meet new funding opportunities challenges and to respond to researchers' demands;
- Organisation of workshops to explain the procedures for preparing and submitting proposals to specific calls;
- Regular analysis on the results of proposals, in order to design a set of dedicated workshops that allow researchers to improve the quality of their proposals;
- Improvement of "proposals workflow" together with SIG;
- Implementation of a new area in the internal website for funding opportunities in order to guarantee the most effective dissemination.

7.8 TECHNOLOGY LICENSING OFFICE

Manager: Daniel Marques de Vasconcelos

7.8.1 Main objectives and actions planned for 2022

The INESC TEC Technology Licensing Office (TLO) aims **to boost the societal impact of the R&D results** generated at the institution. The TLO is a key player at national and European level with a **world-class practice in Intellectual Property (IP) Strategy and Technology Transfer** that in 2022 will be evolving to achieve the following objectives:

- **Formalise and promote INESC TEC exploitable outputs** by creating and implementing new user-friendly tools and policy for knowledge management and transfer;
- **Adopt a market-driven IP portfolio management focused on quality** to foster the economic valorisation of the R&D results, IP revenue and the creation of deep tech spin-offs;
- **More transparent and user-friendly internal TLO procedures for results and technology disclosure** to improve predictability and help INESC TEC researchers at dealing with IP;
- **Raise IP awareness and promote new IP-related KPIs and incentives** by offering hands-on workshops to help researchers with different profiles at having success by using IP;
- **A new market-driven team organisation** structured by technology managers fully aligned with industrial sectors addressed by TEC4s to exploit synergies, accumulated experience and networks. An operational manager or a new tech manager is likely required to support this broader and more complex mission of the TLO.

7.9 INTERNATIONAL RELATIONS SERVICE

Manager: Andreia Passos

7.9.1 Main objectives and actions planned for 2022

In 2022, the SRI will continue its work as a service supporting INESC TEC's international standing as a S&T player, 1) keeping track and disseminating information about the global setting in matters of interest to the institution's stakeholders; 2) helping spot and nurture high-level institutional collaborations with prospective and existing overseas partners; 3) helping foreign staff settle in, and 4) contributing to raising the institution's international profile.

For 2022, the SRI is set on the following actions and goals:

1. **Implementation of a survey to map active international research collaborations.** The results should help the service channel its efforts to support the evolution of individual collaborations into potentially relevant institutional ones; identify overlapping actions; and monitor geographic-specific opportunities. It is worthwhile remembering that given the uncertainty and disruption that still marked most of 2021, the service ended up not organising the workshops with all Domains to discuss their strategic approach to internationalisation using the supporting tool developed the year before. Additionally, feedback from the CS Domain on that tool led the service to step back and opt for a survey to map international collaborative relationships of INESC TEC's researchers. To assist the institution, the SRI needs to have a better understanding of its international standing. Individual-led collaborations often go unnoticed in conventional indicators, but they are many times at the basis of institutional partnerships and should, therefore, be tracked or at least known.
2. **Carry on assisting in bilateral and multilateral cooperation**, taking advantage of individual initiatives that may leverage international agreements and liaising with potential overseas institutional partners or relevant brokers (such as embassies) in areas deemed strategic for the institution. This also includes organising tailored training for our community on topics such as "trusted research" or "intercultural competencies in international research collaboration." At the same time, the service will continue to support FCT in coordinating and implementing the long-standing global partnership UT Austin Portugal, giving particular attention to planning the next funding cycle.
3. **Promote the institution's international profile through refreshed internal and external communication and new and improved indicators to best capture its performance in a global setting**. Preliminary work in this field started in 2020. Still, it was put on hold as the BoD wished to go for a more in-depth revision of current indicators, not limiting the discussion to the international dimension. Without appropriate indicators to measure internationalisation efforts and outcomes at INESC TEC, SRI's capacity to contribute towards the institution's goals will be limited, reactive, opportunistic, and lack strategic thinking. Regarding communication, the service intends to collaborate with SCOM on new content production for the website and institutional presentations. The website, in particular, lacks a section reflecting INESC TEC's international position and footprint (achievements and geographic coverage). Therefore, refinement of internationalisation indicators and improved communication of our international profile must go hand in hand.
4. **Carry on supporting inbound and outbound research mobility processes.** This entails:
    - Consistently improving documentation, workflows, indicators and established appointments;
    - Working closely with HR to help the institution expand its talent recruitment base abroad, taking into account the Centres' recruitment needs and requirements, INESC TEC's value proposition to new staff and key external factors affecting global recruitment and talent retention. The SRI would also like to get the BoD's buy-in to move forward with the set-up and implementation of an International Visiting Researcher Programme based on a preliminary proposal drafted in 2021.

7.10 COMMUNICATION SERVICE

Manager: Joana Coelho

7.10.1 Main objectives and actions planned for 2022

The Service's strategy for 2022 follows an approach based on Integrated Marketing Communication, therefore, comprehending a set of communication tools used to reach different target audiences and built on a holistic management approach.

The main objectives planned for 2022 are divided in two main axes:

- External communication, through four main actions:
    - A diagnosis of the institutional contents will be developed to guarantee a uniformisation between the contents, no matter the type of communication materials used. After this first step, the contents will be made available in several communication materials, considering the different objectives and target audiences to be achieved.
    - An investment in Science Communication will be reinforced. A strategy related to the number of Science Communication contents started in the last months of 2021 with the launch of new features in the newsletter and/or the adaptation of some materials already existent (ex: Science & Technology Magazine). Since the acceptance of this type of content – measured by the visitors and reactions – was high, the strategy will be strengthened in 2022.
    - An analysis, together with the Human Resources Service and the International Relations Service, will be done to develop communication strategies to help achieving the talent attraction goals of the institution. After this step, contents will be made available in different typologies of communication materials to attract new national and international talent.
    - A focus on new strategies aiming at promoting INESC TEC international impact, namely through closer collaboration with the Brussels Hub and other means, such as the dissemination of science across Europe through Alpha Galileo, the presence and organisation of strategic international events, among others.
- Internal communication, through two main actions:
    - A rethinking of the internal communication strategy to promote the level of awareness and knowledge of the collaborators about INESC TEC scientific and market activities and achievements.
    - New ways of engaging the collaborators in the daily life of the institution, namely by increasing the number of participations in internal events, activities, or campaigns. The objectives are two-fold: 1) a way of involving collaborators from different centres, geographies, or cultures in a more friendly environment and 2) retaining talent.

7.11 NETWORKS AND COMMUNICATIONS SERVICE

Manager: Gil Coutinho

The Networks and Communications Service is responsible for the operation and maintenance of INESC TEC's voice and data infrastructures, the implementation of network-based services, and for providing users the respective support.

The pandemic situation that we still live in, with foreseeable evolution from remote to (more demanding) hybrid working dynamics, drives the objectives of the service for the year 2022 to the continuous adaptation of infrastructures and support services, as well as to the reinforcement of security and resiliency mechanisms. A particular focus shall be given to cybersecurity of the IT environment as a whole.

7.11.1 Main objectives and actions planned for 2022

As was the case in the previous year, the pressure over SRC's team is continuously intensifying, both by the greater dynamics of the requirements over the infrastructure and by the increasing needs for technical support both by local or remote users. We strongly feel that the hiring of another member dedicated to the continuous activities of the team would improve overall results and response time, as well as release time for planning actions. Furthermore, we feel that the hiring of a team member dedicated exclusively to cybersecurity would allow a holistic approach to this crucial area, targeting not only the infrastructures (central or otherwise) but also processes and people.

Besides the continuous operation, administration, management of INESC TEC's communication infrastructures, its associated services and connections to external entities, the Networks and Communications Service's focus during 2022 will be to:

- Conclude the redundant connection to the Portuguese national research and education network (RCTS), and through it provide a communications solution to a disaster recovery and off-site backup location;
- Further simplify and streamline resource management procedures by integrating SRC's database and user interface in the intranet, thus paving a way for "self-service" creation and management of virtual machines;
- Participate in and support the design and implementation processes of laboratory infrastructures like e.g. iiLab;
- Define a cybersecurity strategy and plan for INESC TEC, and begin the implementation of some of its steps, towards an advanced protection of the infrastructure, namely assuring its availability, integrity and confidentiality of data.

7.12 MANAGEMENT INFORMATION SYSTEMS SERVICE

Manager: José Carlos Sousa

7.12.1 Main objectives and actions planned for 2022

The service strategy for 2022 is to improve the development and maintenance of INESC TEC's management information system. To cope with the currently increasing workload, the service plans to hire two collaborators, one replacement and one addition.

Besides the maintenance and continuous improvements of website, processes and the INESC TEC Research Information System (IRIS), next are highlighted the five main objectives and actions planned for 2022:

- Prepare the current ERP system replacement and its bulk data migration;
- Redesign the automation of the timecards process;
- Design and implement a visualisation system for research and management indicators;
- Integration of uONE application with IRIS projects to improve the project management capabilities such as planning and control execution;
- Re-engineering of the Project Proposals process, enhancing the user experience and better integration with CRM/Project database.

7.13 SYSTEM ADMINISTRATION SERVICE

Manager: Jaime Dias

7.13.1 Main objectives and actions planned for 2022

The SAS strategy for 2022 is to improve the helpdesk service, the computing infrastructures, the collaborative applications, DevOps platforms, the Disaster Recovery site, and continue to increase the overall security at both servers and users' computers.

The helpdesk service demand has been growing considerably over the last years, especially with the increase of remote/hybrid work. To deal with this, SAS will hire two first line support collaborators.

Besides the maintenance and continuous improvements of the infrastructures and services provided by SAS, and the INESC TEC Living Lab, next are highlighted the five main objectives and actions planned for 2022:

- Helpdesk. The two new first line support members will help reducing the support response and resolution times, but also help on implementing measures to reduce new helpdesk issues. SAS will extend the helpdesk and system administration services to the new iiLab infrastructures and end-users;
- Computing infrastructures. SAS will continue expanding and improving the computing infrastructures to deal with the growing demand in terms of both resources and technologies. The CCloud computing infrastructure will be improved to enable users to create and manage VMs directly on the management interface;
- DevOps. The DevOps ecosystem will continue to be extended and improved with new resources and functionalities. SAS will promote DevOps training sessions to researchers;
- Security. SAS will extend the Disaster Recovery site with new application services. SAS will also deploy scalable security patching solutions to help update end-user computers;
- SAS will continue assisting the Data Protection Officer on Data Protection Impact Assessments, system security audits and security policy definitions to enforce the deployment of the General Data Protection Regulation.

7.14 INFRASTRUCTURE MANAGEMENT SERVICE

Manager: Jorge Couto

The Infrastructure Management Service assures the support services necessary for the adequate management and maintenance of INESC TEC buildings infrastructures.

7.14.1 Main objectives and actions planned for 2022

After the COVID-19 pandemic, the organisation and condition of space requires specific action, so several actions to optimise and reorganise overall spaces in the different buildings will be put in place, bearing in mind the increase of comfort to all INESC TEC co-workers and the availability of the proper conditions for the foreseen hybrid model (face to face and remote work) to be adopted.

As for specific measures, the following can be outlined:

- Increase energy efficiency of buildings, by:
    - converting traditional lighting to controllable LED;
    - implementing a CMS – Central Management System - for effective management of HVAC, lighting, security, and protection systems in a single platform;
    - designing an electrical alternative to central heating of buildings, exploring available solar PV;
    - install additional solar PV panels to increase self-consumption.
- Improve the performance of the Rooftop Unit for Air Handling;
- Installation of DIN rail three-phase power & energy meters to support the accountability of electricity consumption in the A and B buildings, to foster future measures to increase efficiency;
- Carrying out a fire drill in buildings A and B to verify the fire safety conditions and validate the Self Protection Measures;
- Training in fire prevention and fire fighting in buildings;
- Training in first aid and basic life support;
- Promote preventive and corrective maintenance of the various security, electrical and mechanical equipment installed in the buildings;
- Installation of an Electrical Switchboard for the maintenance of low voltage transformer stations;
- Preventive maintenance of the electricity transformer stations in Buildings A and B, with cleaning and retightening of the transformer, and thermographic analysis of the transformers and Media voltage cells;
- Constant improvement of building conditions, including painting and rearrangement of several offices to improve working condition;
- Replacement of the insulating films on the façade windows of building A.