INESCTEC

INESC TEC
ACTIVITY PLAN 2023

Editorial Notes

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TABLE OF CONTENTS

1 STRATEGIC PRIORITIES FOR 2023

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 the third quarter of 2022, INESC TEC's 13 R&D Centres hosted 813 integrated researchers (334 PhDs), including academic staff, R&D employees, 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 and Innovation Centre.

INESC TEC's operational and management 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 1.1.1).

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 TEC4AGRO-FOOD, TEC4ENERGY, TEC4HEALTH, TEC4INDUSTRY and TEC4SEA.

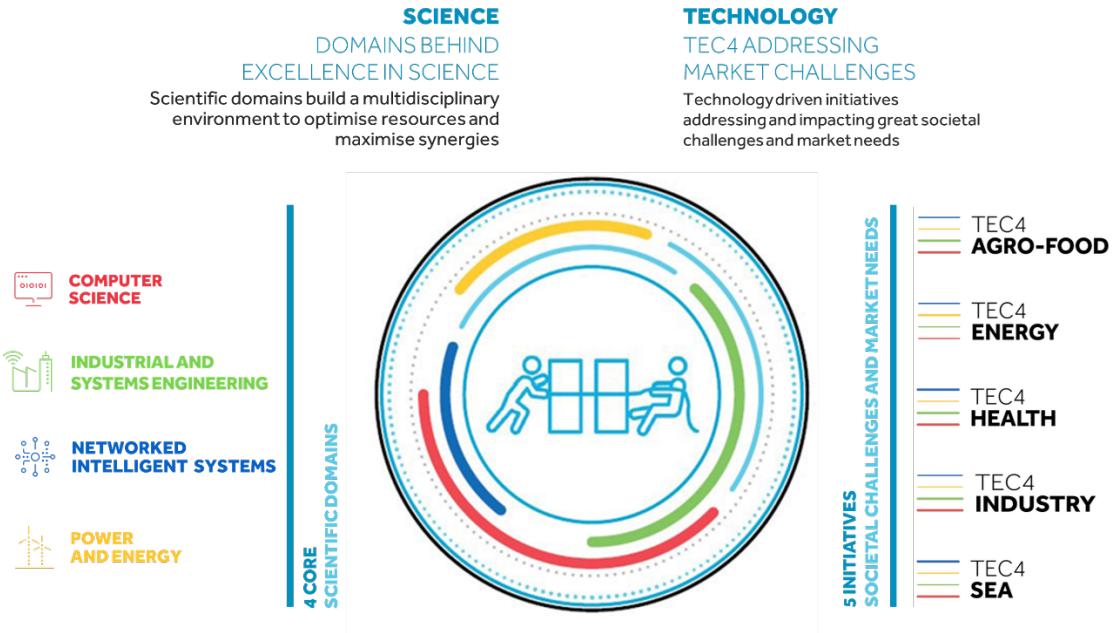

Figure 1.1.1 - High-level structure of science and innovation at INESC TEC

1.2 Organisational structure

Figure 1.2.1 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.

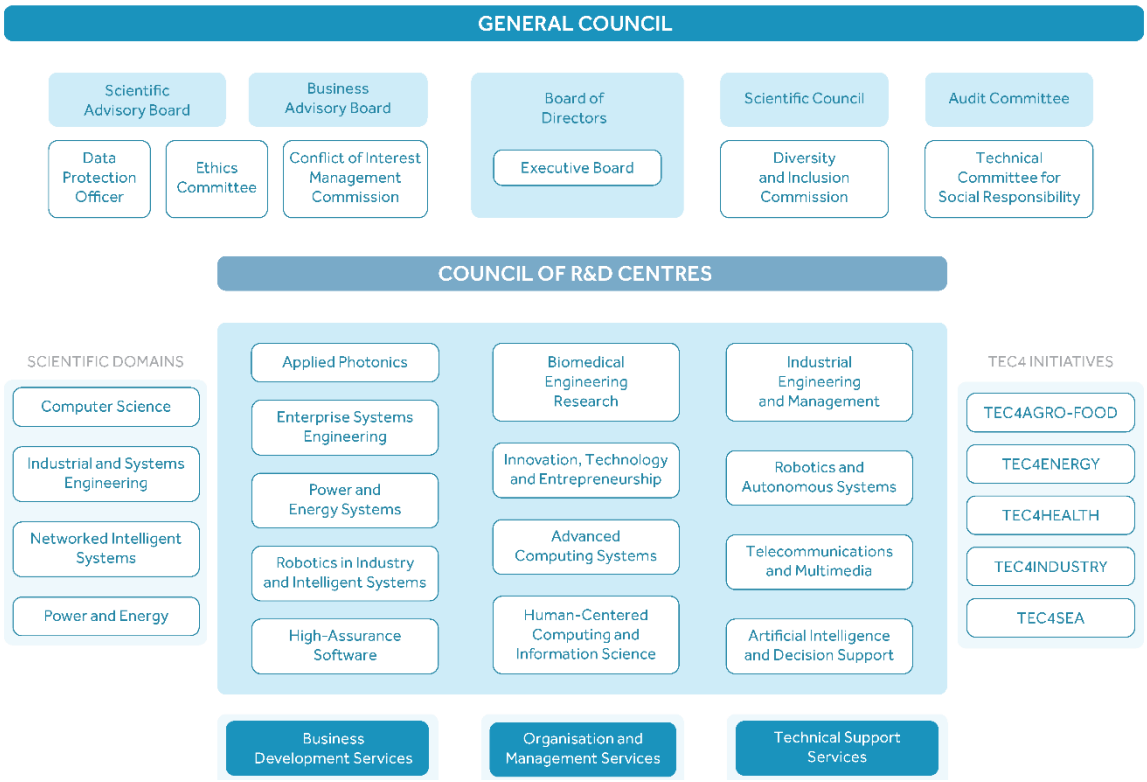

Figure 1.2.1 – INESC TEC organisational structure

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 currently 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 Audit Committee includes a ROC and oversees and validates the financial behaviour of the Institute.

Five non-statutory bodies are in charge of aspects that INESC TEC particularly values. The Ethics Committee ensures the observance and promotion of standards of integrity, honesty and responsibility in research activities carried out by INESC TEC's members, through the implementation of the institution's Code of Ethics. The Conflict of Interest Management Commission (CGCI) 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 Compliance Officer will be responsible for the implementation of the Compliance Programme for the prevention of corruption, in articulation with other relevant organisational units. The Technical Committee for Social Responsibility has as its mission the incorporation of social responsibility in the institution's organisational culture and practices. The Diversity and Inclusion Commission thrives 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 gender balance as a major priority, namely by implementing the Gender Equality Plan recently approved. A new office is being set up 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 human resources management, research careers, and 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 the structures 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 encounter of different scientific disciplines, certainly a key enabler of its actual impact 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 both scale and density, these being nurtured by its multi-institutional base model anchored in four major high-education institutions. 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 as 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 challenge the research teams, 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 common interest in protecting its research, education, and innovation environments, this being reinforced by its Code of Ethics 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 its 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 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, People with disabilities inclusion, ethnic and cultural diversity are the key priorities being addressed by the Diversity and Inclusion Commission, in line with the results of the D&I Survey.

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 concept translates into the commitment to foster pervasive intelligence through the creation of new computer intelligence paradigms, their development and application. This is favoured by the institute's size and diversity, as well as by its managed science model, creating fertile ground for multidisciplinary cooperation.

Current computer systems pervading society, in areas such as public administration, industry, earth observation, and large-scale critical systems, including utilities, healthcare, transportation, and finance, among others, 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 in four broad scientific domains and cooperate towards meeting sixteen major short- to medium-term research challenges. Examples include challenges such as achieving machine perception, making communication systems context-aware, creating a diversity of forms of human-empowering computing, improving the quality and key non-functional properties of information and industrial systems, increasing the autonomy of robotic systems, achieving fully and resilient renewable energy systems, and incorporating responsibility and sustainability in technology-driven innovation.

Research and development are complemented by knowledge valorisation and technology transfer activities, conducted with a sizeable and ever-expanding portfolio of partners and customers. Currently, through the TEC4 initiatives, business development at INESC TEC has its major focus on five socioeconomic/market areas: agriculture and food, energy, healthcare, industry and sea.

1.5 2023 external context outlook

The macroeconomic scenarios underlying the outlook for 2023 are marked by the war in Ukraine, the persistence of inflationary pressures and a tightening monetary policy, as well as by the continuation of the reversal of the measures associated with the mitigation of the COVID-19 pandemic.

The projections of the Portuguese Ministry of Finance, underlying the preparation of the state budget for 2023, forecast 1.3% of economic growth and 3.6% of investment growth in 2023, under a still moderately high inflation rate of 4.0%, estimating that the national public accounts deficit should lower to 0.9% of the Gross Domestic Product (GDP), and also predicting that the Portuguese unemployment rate would fall to 5.6%, the lowest since 2003.

Business investment growth will undoubtedly be impacted by increased uncertainty, rising financing costs and the continued impact of restrictions in global production and distribution chains on the costs and supply of materials and equipment. Those, combined with higher energy costs, the increase in fuel prices and the market pressure on the recruitment of qualified staff, may jeopardise the expected macroeconomic evolution and constraint the evolution of INESC TEC's activity.

Despite the uncertainties in the current context and the expected slowdown of the Portuguese economy, four major programmes – PRR (Portuguese Recovery and Resilience Plan), PT2030, Horizon Europe and InvestEU 21-27 – which will be key for the development of INESC TEC's activity along the decade, with a special emphasis on the cooperation with the most innovative economic fabric.

1.6 Main initiatives for 2023

To fulfil its policy priorities and reach its objectives for 2023 and beyond, INESC TEC is committed to a set of initiatives. These will enable the institute to strengthen its intervention in the national and international arenas, as well as its ability to better carry out its mission for the benefit of society.

These initiatives are summarised below, under the following lines of action: 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 a new 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);
- Maintaining 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;
- Reinforcing the implementation of research careers;
- Initial steps under the "Agreement on Reforming Research Assessment" subscribed by several entities at European level, and of which INESC TEC is also a signatory, that will commit the institution to a set of principles, initiatives and time horizons to implement changes in the way it conducts the assessment of research activities.

- Managed science model
  (in line with the policy priorities "Full coverage of the knowledge value chain" and "Integration and multidisciplinarity")
  - Conclusion of the preparation of INESC TEC's Strategic Plan for 2023-2030, that will allow for the integration, alignment and planning of different components of the institution's strategy that have been developed in a more localised manner, namely at the level of science, innovation, infrastructures and human resources, among others, and that will be instrumental to address INESC TEC's increasing dimension and complexity, as a result of the strong growth experienced in recent years, as well as the intensification of external interventions in response to stakeholders' requests and expectations;
  - Conclusion of the 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 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 HEIs, framing the assignment and sharing of human and material resources and regulating 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 hands on learning of transferable skills (innovation, entrepreneurship, leadership, and time management, among others) and 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, under construction in a P.Porto building.

- Structural initiatives
  (in line with the policy priority "Ethics, social responsibility, and diversity and inclusion")
  - Implementation and enforcement of INESC TEC's compliance programme for the prevention of corruption, that will include a risk prevention and management plan, a code of conduct, a training programme, and a reporting channel, to be accompanied by the appointment of a compliance officer to ensure and control its application;
  - The Ethics Committee will continue its mission of supporting INESC TEC researchers to ensure high ethical standards in their activities. It has become a regular practice for the project PI to respond to questionnaires containing questions relating to ethical issues that may be raised by the project, which the Ethics Committee analyses and, when necessary, interacts with. The Ethics Committee also responds to questions raised by PI's concerning projects dealing with human beings and personal data as well as those involving artificial intelligence, that may require a formal opinion and validation. Finally, the Ethics Committee will keep discussing and preparing actions to debate and alert INESC TEC researchers to ethical and deontological issues specific to their activity.
  - Full operation of INESC TEC's Diversity and Inclusion Commission, which will focus on raising awareness, developing skills, monitoring the D&I landscape, and promoting events in three priority areas: 1) Gender equality - The D&I Commission will focus on engaging the institution to implement the approved Gender Equality Plan for 2022-2026. It will promote the proactivity of all responsible units and the involvement of the overall community, and ensure a continuous effort to monitor and assess the implementation of the plan. 2) Interculturality - The Commission will work with the responsible units to implement actions to raise awareness for issues arising in an intercultural environment, and to decrease cultural barriers in all INESC TEC activities. 3) Accessibility - Universal accessibility and the inclusion of people with disabilities will be pursued with a strong focus on raising awareness for these often-hidden issues. Also, the Commission will strive for universal access in all INESC TEC activities, communications and platforms;
  - The Social Responsibility Technical Committee was restructured at the end of 2022. For 2023, the team will revise its diagnosis and evaluate the pertinence of developing some activities that were impossible to implement during the years of pandemic. Nevertheless, an effort will be made to guarantee the dynamization of activities that include external and internal dimensions. An alignment of those activities with the Sustainable Development Goals proposed by the UN will also be assessed;
  - With the leadership of INESC TEC's Data Protection Officer (DPO) and the support of a multidisciplinary team, the highlights in 2023 will be: (1) Strengthening of the internal awareness-raising initiatives, including the assignment of responsibilities within the organization, thereby contributing to the dissemination of a data protection compliance culture; (2) Strengthening of the training plan for staff members and researchers, including new resources and new models in the existing online training courses; (3) Continuous cooperation and coordination efforts with ISPUP under the Protocol established in the field of Personal Data Protection; (4) Cooperation with AG (Management Support Service) in its implementation of the document management policy; (5) Contribution to external awareness-raising and policy making initiatives, in close cooperation with international networks/ associations like Metared or the INESC Brussels Hub.

- 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;
- New edition of the INESC TEC International Visiting Researcher Programme, which provides researchers from institutions abroad the opportunity to conduct research activities at INESC TEC for up to three months while maintaining their affiliation with their home institutions;
- After the recognition of several Digital Innovation Hubs (Digital Innovation Hubs, DIH), INESC TEC will actively participate in the DIH approved in the European DIH Call: ATTRACT DIH (Digital Innovation Hub for ArTificial Intelligence and High-PerformAnce CompuTing), coordinated by INESC TEC, DigitalBuilt and PRODUTECH DIH;
- 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;
- On behalf of FCT, INESC TEC will continue coordinating the UT Austin Portugal Program on the Portuguese side. The Program is entering the last year of the current funding cycle. Therefore, INESC TEC Leadership will remain committed to not only bringing this cycle to a good end but also setting the stage for a potential partnership renewal after 2023. The main activities to be proposed to the Program's Governing Board in early 2023 include: 1) Supporting and monitoring the Partnership's ongoing exploratory and strategic research projects as they near their completion; 2) Assisting FCT in the organisation of the evaluation panel of the 2022 Call for Exploratory Research Projects; 3) Giving visibility to the new batch of projects selected through the 2022 Call for Exploratory Research Projects and helping them throughout the execution of their work plans; 4) Meeting with relevant stakeholders in Portugal and at UT Austin to finalise the drafting of a strategic document with the Program's vision and roadmap for a new funding cycle. The document should be presented and discussed with FCT and the Minister of Science, Technology and Higher Education to obtain their green light and the required funding. 5) Organising a new edition of the UT Austin Portugal Short-Term Research Internships initiative; 6) Organising advanced training for the Program's transatlantic community across its core knowledge areas; 7) Implementing the recommendations of the Program's main governing bodies, most notably the Governing Board and the External Review Committee. 8) Building awareness of the Partnership's impact over the years through the creation and dissemination of success stories; 9) Taking the Program's brand beyond UT-Portugal boundaries, evidencing Portugal's successful experience with transnational S&T partnerships;
- Strengthening of the participation as a member in international organisations (15+), in broadened geographies, and 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")
  - Launch of the new organisational structure to advance the involvement of the institute's community with public policies, promoting the effective use of scientific evidence resulting from INESC TEC research by public bodies and policy makers;
  - 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 active engagement in the development of the thirteen 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, INESC TEC's major 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 and co-organisation of several international conferences, namely the EMSLIBS2023 event, Euro-Mediterranean Symposium on Laser-Induced Breakdown Spectroscopy, in September 2023, and the ENBENG 2023 - 7th Portuguese Meeting on Bioengineering, in June 2023.
  - Launch of two new 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 talks and 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;
  - Expansion of current infrastructures and implementation of new laboratories integrated in the National Roadmap of Research Infrastructures of Strategic Interest (RNIE) to be funded until 2027;
  - Launch of a major initiative to replace the current Accounting and Financial information system;
  - Following COVID-19 pandemic impact, maintenance of a new model of hybrid work where co-workers can alternate between telework and face-to-face activity.

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 2023, 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 2023, are presented in Sections 6 and 7, respectively.

2 MAIN INDICATORS FOR 2023

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 2023. 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 2.1.1 and Figure 2.1.1 show the breakdown of INESC TEC's Human Resources by type of contractual link and the expected evolution for 2023. Table 2.1.1 also includes the number of PhDs (366 planned at the end of 2023).

Table 2.1.1 - Evolution of INESC TEC's Human Resources

Type of Human Resources			2021	2022	2023	Δ 2022-23	
Integrated HR	Core Research Team	Employees	159	190	271	81	43%
		Academic Staff	174	183	184	1	1%
		Grant Holders and Trainees	324	327	325	-2	-1%
		Total Core Researchers	**657**	**700**	**780**	**80**	**11%**
		Total Core PhD	**255**	**269**	**294**	**25**	**9%**
	Affiliated Researchers		67	64	52	-12	-19%
	Management, Administrative and Technical	Employees	102	115	121	6	5%
		Academic Staff	11	10	10		0%
		Grant Holders and Trainees	6	6	4	-2	-33%
		Total Manag, Admin and Tech	**119**	**131**	**135**	**4**	**3%**
	Total Integrated HR		**843**	**895**	**967**	**72**	**8%**
	Total Integrated PhD		**342**	**355**	**369**	**14**	**4%**

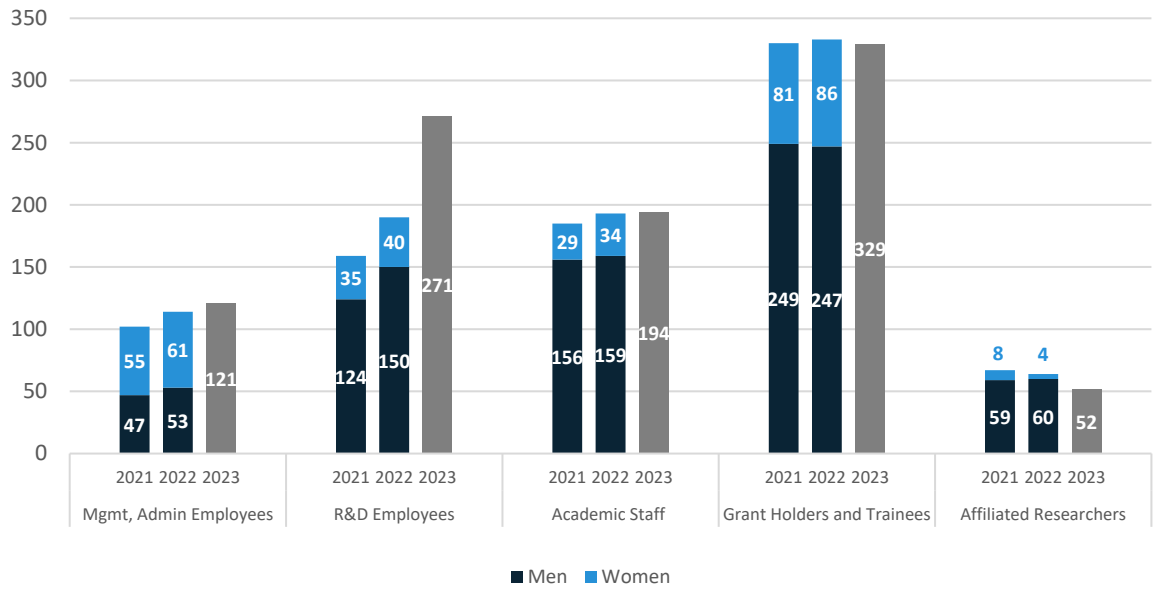

Figure 2.1.1 - Evolution of INESC TEC Human Resources

In Figure 2.1.1, the distribution of human resources planned for 2023 does not address gender distribution, which is not the object of planning in future hires. Nevertheless, INESC TEC is closely monitoring indicators related to dimensions of Diversity and Inclusion (D&I), namely those relating to gender balance, in practices such as recruitment, among several others.

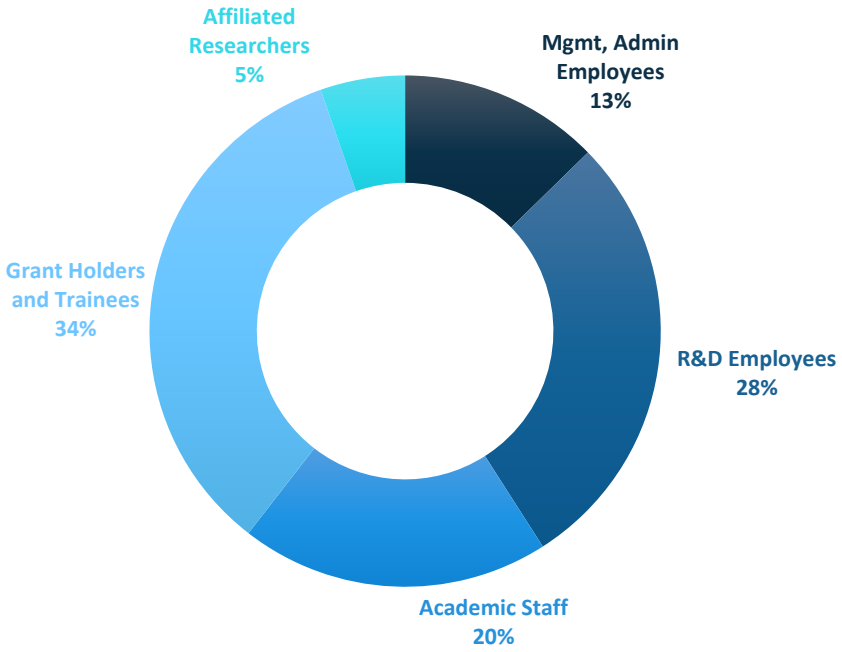

Figure 2.1.2 - Distribution of Human Resources (Plan 2023)

As highlighted in Figure 2.1.2, grant holders and trainees are still the largest group of human resources (34%) at INESC TEC, showing some stabilisation in its number following a significant decrease in previous years. This is explained by the fact that INESC TEC and its HEI associates progressively adapted to the modified Research Grant Holder Statute that came into force in August 2019 and limited the award of grants to researchers who are enrolled in a higher education program. As in previous plans, the number of grant holders and trainees, is a conservative forecast, resulting from the fact that the numbers presented in the planning exercise for 2023 only consider ongoing projects and foreseen projects with a minimum level of certainty.

A significant increase in the number of R&D employees is planned, with a foreseen growth of 43%, explained by two different sets of reasons. First of all, it is a result of the implementation of the Portuguese Government's policy for scientific employment, that has been strongly fostering the hiring of researchers with contracts. On the other hand, the execution of the projects approved in PRR (the Portuguese Recovery and Resilience Plan) and in the EU programmes will require a substantial addition to the workforce.

In 2023, human resources in Support Services are planned to increase by 3%, 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 to support 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 2023 are given in Table 2.1.2 for each R&D Centre.

Table 2.1.2 - Human Resources by type and R&D Centre (Plan 2023)

Type of Human Resources			Total R&D Centres	R&D Centres														Special Projects
				CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	HUMANISE	LIAAD	CRACS	HASLAB	
Integrated HR	Core Research Team	Employees	271	17	12	27	4	84	32	27	16	7	19	8	1	17	
		Academic Staff	184	14	8	12	6	10	8	13	20	2	29	23	16	23	
		Grant Holders and Trainees	325	64	12	24	14	46	7	28	30	4	25	19	14	38	
		Total Core Researchers	**780**	**95**	**32**	**63**	**24**	**140**	**47**	**68**	**66**	**13**	**73**	**50**	**31**	**78**	
		Total Core PhD	**294**	**28**	**17**	**18**	**8**	**38**	**17**	**24**	**26**	**5**	**35**	**30**	**17**	**31**	
	Affiliated Researchers		51	10	3			2	5	2	4		12	6	1	6	
	Administrative and Technical	Employees	20	1	1	4	1	2	2	2	1		1	1		4	2
		Total Admin and Tech	**20**	1	1	4	1	2	2	2	1		1	1		4	2
	Total Integrated HR		**851**	**106**	**36**	**67**	**25**	**144**	**54**	**72**	**71**	**13**	**86**	**57**	**32**	**88**	**2**
	Total Integrated PhD		**345**	**38**	**20**	**18**	**8**	**40**	**22**	**26**	**30**	**5**	**47**	**36**	**18**	**37**	**1**

2.1.3 Support Services indicators

The Human Resources figures expected for the end of 2023 for the Board of Directors, the TEC4 teams, and the Support Services are provided in Table 2.1.3.

Table 2.1.3 - Human Resources by type and Service (Plan 2023)

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	99	13	6	2	2	3	9	13	9	3	3	7	8	4	6	5	6
	Academic Staff	10	7	3														
	Grant Holders and Trainees	4		1												3		
	Affiliated Researchers	1	1															
	Total Integrated HR	**114**	**21**	**10**	**2**	**2**	**3**	**9**	**13**	**9**	**3**	**3**	**7**	**8**	**4**	**9**	**5**	**6**
	Total Integrated PhD	**23**	**12**	**5**		**1**	**1**	**1**		**1**		**2**						

2.2 Activity in projects

2.2.1 Global indicators

Table 2.2.1 shows the breakdown of INESC TEC's funding sources and the expected evolution from the 2022 plan to the 2023 plan, presenting an increase in European programmes and National Cooperation Programmes with Industry and an overall growth in activity of 30%. Table 2.2.2 then provides this information in greater detail, specifying the evolution of firm projects and the share of strategic programmes, namely FCT's multi-annual funding, the programmes for scientific employment (EEC) and to support highly qualified human resources (RHAQ), and the multi-annual funding for technology transfer activities (CTI).

Table 2.2.1 - Funding sources and planned evolution

Sources	Value (k€)		Δ (k€ / %)	
	2022	2023	2022-23	
National Programmes	12 013	19 054	7 041	59%
European Programmes	8 220	9 449	1 229	15%
R&D Services and Consulting	3 754	2 634	-1 120	-30%
Other Funding Sources	191	276	84	44%
Total Revenues	**24 179**	**31 414**	**7 235**	**30%**

Table 2.2.2 - Funding sources and planned evolution – Detail

Sources			Value (k€)		Δ (k€ | %)	
			2022	2023	2022-23	
Firm Projects	PN-FCT	National R&D Programmes – FCT	1 438	1 448	10	1%
	PN-PICT	National R&D Programmes - S&T Integrated Projects	181	113	-68	-38%
	PN-COOP	National Cooperation Programmes with Industry	3 377	11 955	8 578	254%
	PUE-FP	EU Framework Programmes	7 212	8 514	1 302	18%
	PUE-DIV	EU Cooperation Programmes – Other	410	573	163	40%
	SERV-NAC	R&D Services and Consulting – National	2 201	1 537	-664	-30%
	SERV-INT	R&D Services and Consulting - International	172	101	-71	-41%
	OP	Other Funding Programmes	2 331	618	-1 713	-74%
		Total Active Projects	**17 323**	**24 859**	**7 535**	**43%**
Uncertain Projects			1 894	1 535	-359	-19%
National Strategic Programme – Multi-annual			3 023	3 469	446	15%
National Strategic Programme – RHAQ			561	235	-326	-58%
National Strategic Programme – EEC			523	706	183	35%
National Strategic Programme – CTI			302	0	-302	-100%
National Strategic Programmes – Other			367	390	23	6%
Other Revenues			186	220	35	19%
Total Revenues			**24 179**	**31 414**	**7 235**	**30%**

Figure 2.2.1 illustrates the funding distribution for the active projects planned for 2023, and its comparison with the plan for 2022. The total revenue planned for 2023 grows 30% in comparison with 2022, with variations per funding source, as explained below.

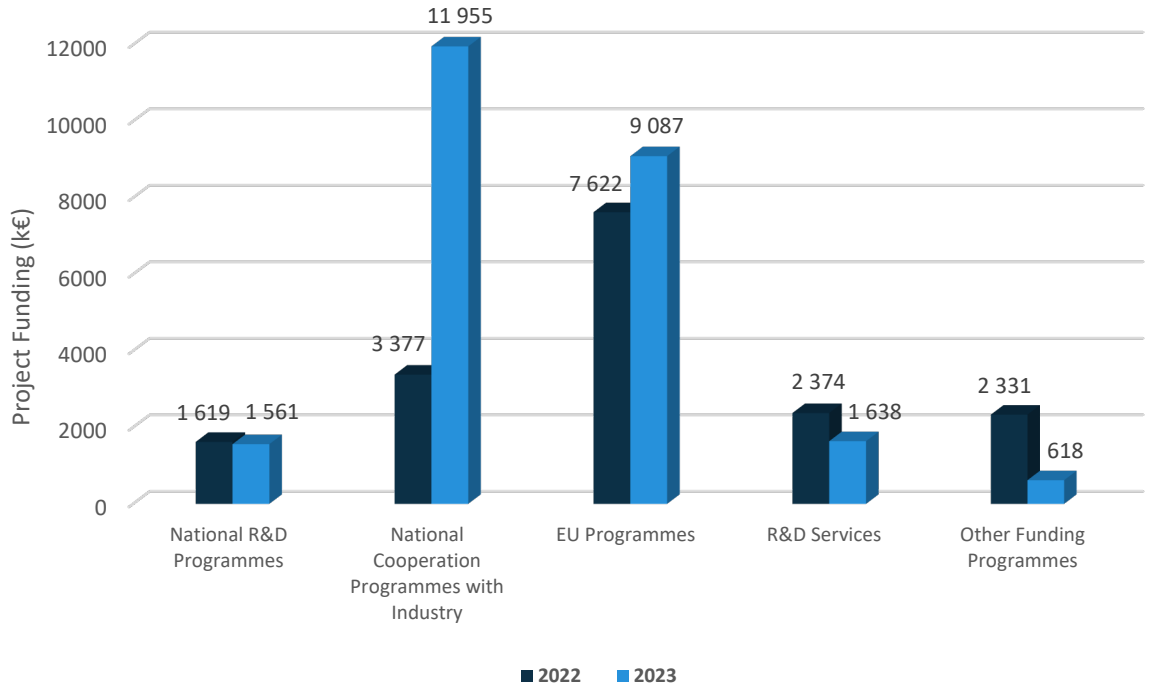

Figure 2.2.1 - Evolution of project funding by source (k€)

Figure 2.2.2 shows the funding distribution by source, expected for firm projects, in comparison with that of the previous plan.

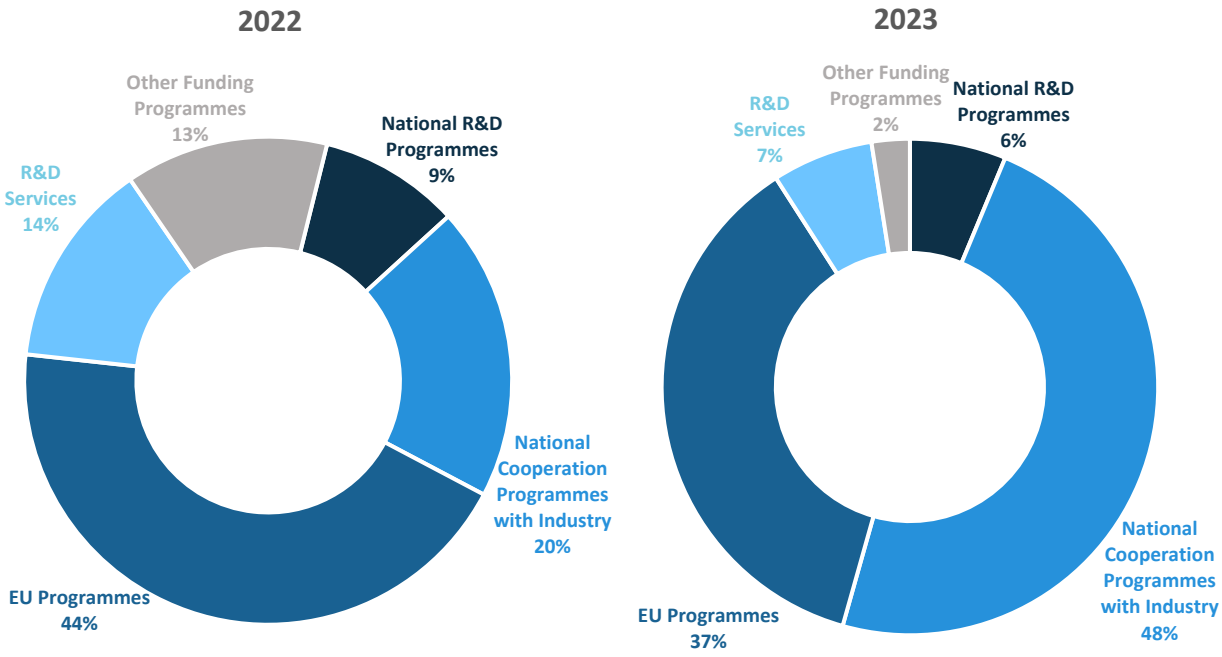

Figure 2.2.2 - Distribution of project funding by source - Plan 2022 (left) and Plan 2023 (right)

The number of active projects and the average funding per project by source is also of interest, as shown in Table 2.2.3.

Table 2.2.3 - Number of active projects and average funding by source (Plan 2023)

Type of Project		Number of Active Projects		Δ	Average Funding (k€)	
		2022	2023	2022-23	2022	2023
PN-FCT	National R&D Programmes - FCT	32	28	-4	45	52
PN-PICT	National R&D Programmes - S&T Integrated Projects	1	1	0	181	113
PN-COOP	National Cooperation Programmes with Industry	45	63	18	75	190
PUE-FP	EU Framework Programmes	45	63	18	160	135
PUE-DIV	EU Cooperation Programmes - Other	12	14	2	34	41
SERV-NAC	R&D Services and Consulting - National	56	38	-18	39	40
SERV-INT	R&D Services and Consulting - International	5	4	-1	34	25
OP	Other Funding Programmes	12	7	-5	194	88
	Total	**208**	**218**	**10**	**83**	**114**

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 2023 grows to 31.4 M€, which is 30% higher than it was in the 2022 activity plan;
- There are several changes in the evolution of the different funding sources from 2022 to 2023 (*c.f.* table 2.2.2), the most noticeable being the increase in the National Cooperation Programmes with Industry (254%), mainly related with the approval of projects supported by the Portuguese Recovery and Resilience Plan (PRR), with a total funding of 10 M€. Overall, an increase of 70% in national funding is foreseen for 2023, mainly related with new PRR projects, but also with the end of all the P2020 projects, namely Mobilisers and projects in consortia with industry related with the closure of the P2020 framework program.
- Also relevant is the increase in EU Framework Programmes (18%) due to the 27 projects already approved in the Horizon Europe Programme, which represent 41% of European funding;
- With regard to the R&D and consulting services, a global 30% reduction is expected, resulting from factors such as the high involvement of many companies in the PRR agendas, as well as the delay in starting the P2030 which, as has already happened in previous framework programs, leads companies to postpone some R&D projects subcontracted to INESC TEC;
- The support from the multi-annual 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 11% of the total funding, and is greatly leveraged by the institution in its activity;
- Although optimistic about the application to renew the funding for technology transfer activities, “CTI”, that is currently under evaluation, no revenues were estimated for 2023, as a precaution. Nevertheless, this funding is of particular importance to strengthen the institute’s technology transfer capabilities;
- The decrease in other funding programmes is mainly due to a more precautious estimation related to the project Sustainable HPC, which is funded through FAI and FEE;
- National Cooperation Programmes with Industry (mainly PRR projects) and EU Framework Projects are the largest in terms of volume while, at the opposite end, R&D and Consulting Services often feature short durations and are therefore expected to be below average funding per project;
- The degree of uncertainty in this budget, measured by the income from projects that do not yet have a signed contract, is reduced by three percentage points, when compared with the plan for 2022, representing 5% of total income, in a total volume of 1.5 M€.

2.2.2 R&D Centres indicators

A detailed view of the total funding by source per R&D Centre is given in Table 2.2.4 and Figure 2.2.3. In comparison with the plan for 2022, some important changes can be highlighted:

- The most relevant variation is the already referred large increase (254%) in National Cooperation Programmes with Industry, resulting from the projects approved in the PRR (the Portuguese Recovery and Resilience Plan) and with a reflection across all the R&D Centres;
- In terms of European projects, the planned 15% increase is mainly due to the action of CPES, CRAS, CTM, and CRIIS; and a reduction in CAP and HumanISE;
- National contract research and consulting is expected to decrease by 36%; nevertheless, in the current exercise, some centres (CRAS, CESE, CEGI, HumaISE, CRACS and HASLab at national level, and CPES at international level) are planning some increase in this indicator, while the remaining expect a slowdown;

Table 2.2.4 - Project Funding (k€) and Uncertainty Analysis (Plan 2023)

			R&D Centres													
		Total (k€)	CTM	CAP	CRAS	CBER	CPES	CESE	CRIIS	CEGI	CITE	HUMANISE	LIAAD	CRACS	HASLAB	Special Projects
Projects	PN-FCT	1 448	179	172	426	113	84	15	21	188	0	44	84	0	122	0
	PN-PICT	113	41	0	0	0	73	0	0	0	0	0	0	0	0	0
	PN-COOP	11 955	1 009	373	953	205	3 500	1 521	1 844	468	181	861	491	0	550	0
	PUE-FP	8 514	1 199	68	1 550	115	2 591	479	715	478	167	547	155	82	368	0
	PUE-DIV	573	24	4	242	0	0	4	2	0	49	120	23	33	72	0
	SERV-NAC	1 537	239	0	25	0	327	174	155	46	0	153	29	99	290	0
	SERV-INT	101	0	0	0	23	42	37	0	0	0	0	0	0	0	0
	OP	618	0	0	0	0	0	0	1	0	0	0	0	0	119	496
	Total Projects	**24 859**	**2 690**	**617**	**3 197**	**456**	**6 615**	**2 230**	**2 740**	**1 180**	**397**	**1 726**	**782**	**214**	**1 521**	**496**
Uncertain Projects		**1 535**	**64**	**134**	**125**	**79**	**344**	**89**	**0**	**31**	**76**	**30**	**275**	**0**	**176**	**111**
Total Funding		**26 394**	**2 753**	**751**	**3 322**	**535**	**6 959**	**2 319**	**2 740**	**1 211**	**473**	**1 756**	**1 057**	**214**	**1 696**	**608**
Uncertain Projects		**6%**	2%	18%	4%	15%	5%	4%	0%	3%	16%	2%	26%	0%	10%	18%

Table 2.2.4 also shows that uncertain projects represent 6% 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 2.2.3.

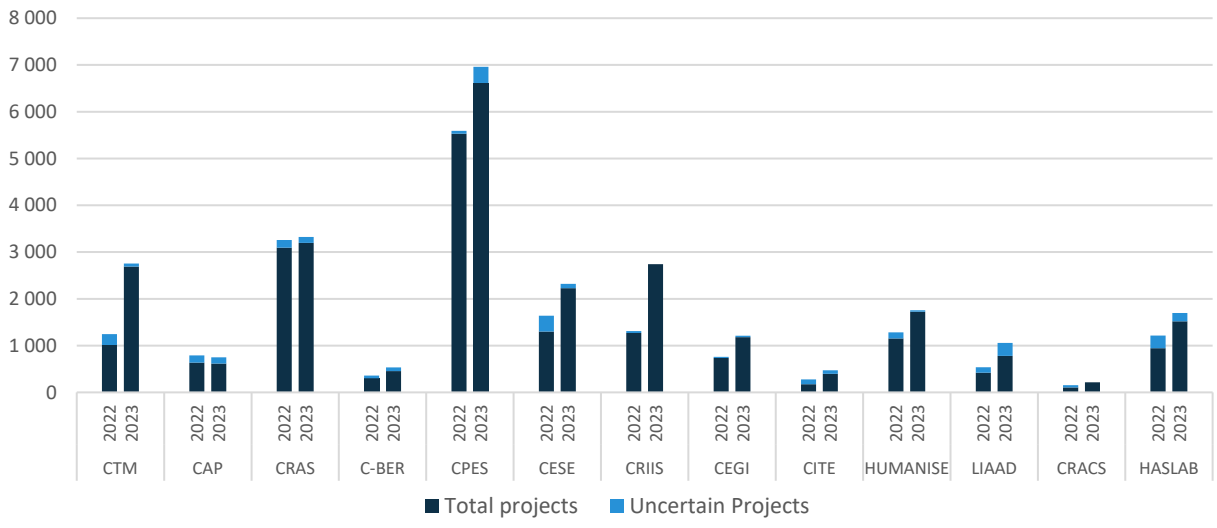

Figure 2.2.3 - Project funding and uncertainty analysis (k€) per R&D Centre (Plan 2022 vs Plan 2023)

2.3 Publications

2.3.1 Global indicators

Table 2.3.1 and Figure 2.3.1 show the number of INESC TEC publications in 2019, 2020 and 2021 and the expected evolution towards 2023.

The numbers for past publications have 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 2022 and 2023 have been estimated using a bottom-up approach and need to be regarded 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 2021 publications (about 8% of the publications are authored by researchers from more than one Centre).

Table 2.3.1 - Number of INESC TEC Publications

Publication Type	2019	2020	2021	2022 (Forecast)	2023 (Plan)
Indexed Journals	381	444	451	417	314
Indexed Conferences	570	413	471	256	305
Books	6	2	4	5	7
Book Chapters	29	25	33	37	15
PhD Theses - Members	19	28	30	37	38

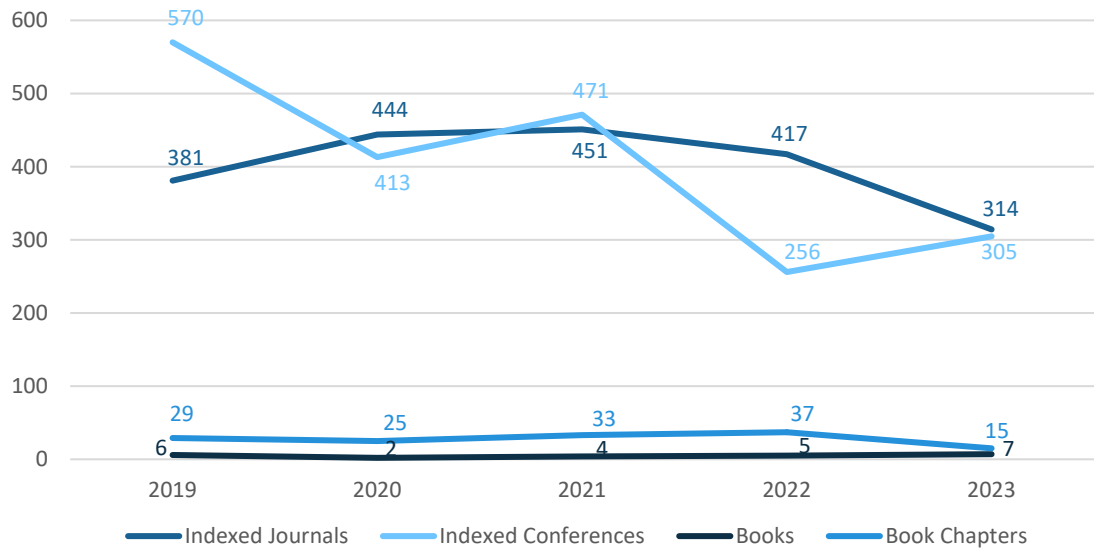

Figure 2.3.1 - Evolution of INESC TEC Publications

For 2023, scientific production in terms of articles in indexed journals is expected to decrease due to a clear focus on journals classified by SCOPUS as first quartile. Moreover, with the reversal of measures associated with the mitigation of the pandemic of COVID-19, and the resumption of international conferences to conventional formats, INESC TEC R&D Centres presented a more optimistic forecast in terms of publication activity in indexed conferences proceedings.

2.3.2 R&D Centres indicators

Figure 2.3.2 presents the number of indexed publications in journals and conferences per R&D Centre.

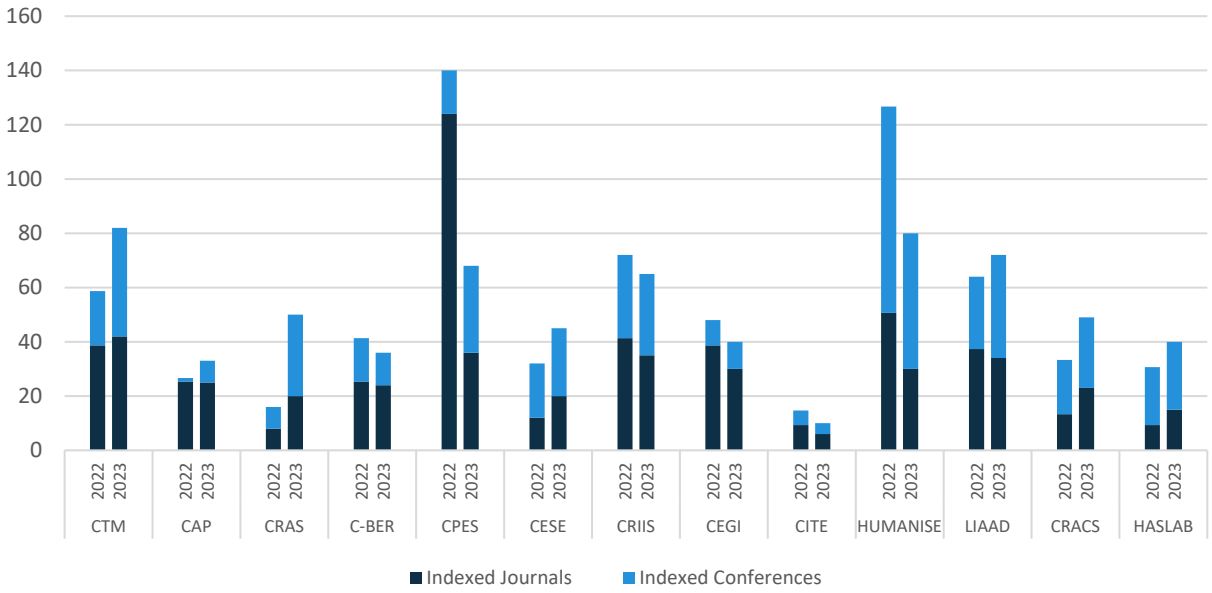

Figure 2.3.2 - Indexed Publications in Journals and Conferences (Forecast 2022 vs Plan 2023)

2.4 Knowledge transfer

Table 2.4.1 presents the number of INESC TEC's intellectual property (IP) results and the expected evolution for 2023.

Table 2.4.1 - Results related with Knowledge Transfer

Type of Result	2021	2022 (Forecast)	2023 (Plan)
Pre-disclosures	30	14	26
Invention disclosures	8	13	13
First Priority Patent Applications (New inventions)	5	5	6
First Patents Internationalisation	25	2	4
Commercial Contracts (Licences, Options, Assignments)	3	1	10
Spin-offs	1	2 (1)	2

(1) *in development*

In 2023, the number of new R&D results mapped at INESC TEC (pre- and technology disclosures) is expected to exceed for the first time 50, in part due to the strategic scouting initiative designed by the INESC TEC's Technology Licensing Office. The initial communication phase has been simplified by introducing pre-disclosure forms but articulated with a selection funnel favouring a representative, high-quality and lean IP portfolio.

The number of new patented inventions has stabilised at 5 to 10 applications per year, positioning INESC TEC as a top patent applicant both at domestic and European levels, 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 portfolio strategy is now market-driven or high-quality high-risk inventions, focusing on quality over quantity. Therefore, the number of international patents and grants in the next years is expected to reflect this lean approach.

As for commercial contracts, an increase is foreseen by the Technology Licensing Office due to the ongoing progress in specific-market networking, pricing and negotiation tools, identification of suitable channels in the market and maturity of specific INESC TEC's intangible assets.

Finally, two spin-offs remain 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 2023. Moreover, the creation of the spin-off "WeSenss" is planned for 2023, in association with the licensing of three patent families.

2.5 Dissemination activities

Table 2.5.1 illustrates the expected activity of INESC TEC members and R&D Centres in a variety of categories of dissemination activities.

Table 2.5.1 - Results related with dissemination activity – Plan 2022 vs Plan 2023

Type of Activity	2022	2023
Participation as principal editor, editor or associated editor in journals	80	80
Conferences organised by INESC TEC members (in the organising committee or chairing technical committees)	61	49
International events in which INESC TEC members participate in the program committees	190	181
Participation in events such as fairs, exhibitions or similar	51	56
Conferences, workshops and scientific sessions organised by the R&D Centres	48	70
Participants in the conferences, workshops and scientific sessions organised by the R&D Centres	1 791	2 350
Advanced training courses organised by the R&D Centres	24	24

With the reversal of measures associated with the mitigation of the pandemic of COVID-19, INESC TEC's researchers plan to resume a dynamic activity in scientific dissemination through events and other formats. Thus, the number of conferences, workshops and scientific sessions organised by the R&D Centres is planned to increase.

The list of conferences and other events to be organised or co-organised by INESC TEC researchers is presented in detail in Section 5, for each R&D Centre. To name but a few, the EMSLIBS2023 event, Euro-Mediterranean Symposium on Laser-Induced Breakdown Spectroscopy, will take place in September with a foreseen participation of around 220 researchers. The ENBENG 2023 - 7th Portuguese Meeting on Bioengineering, to be held in Porto in June at the Fundação de Serralves, is considered the main national congress in Bioengineering in Portugal.

Besides scientific events, INESC TEC researchers will resume participation in technology fairs and other exhibitions to promote flagship projects and main achievements.

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 and 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, Embedded Systems, 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 optimizing 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 virtualization 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 Digitized World; Cognitive, Aware and Collaborative Robotic and Autonomous Systems; Responsible and Sustainable Technology Driven Innovation; and 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 feature 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 customized 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-Optimization, Machine Learning and Optimization); decision-making under uncertainty; policy learning methods and real-time decision making; multi-objective optimization; 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., hybridizing optimization 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 grants; and 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 sustainable technology enabled 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 transitions; 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 its 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; and 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; Design and impact of IIS – Design theory for industrial platforms; Industrial digital platforms adoption and impact; and 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 mobilization 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; and 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, 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.

Research Challenge 1 – 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:

- **Photonic based platforms for environmental monitoring, medical diagnostic and industrial applications,** addressing the development of photonic based devices that allow monitoring and analysis of specific targets, using label free and reagent free sensing technologies, aiming for miniaturization, handling simplicity, speed of operation and long-term stability; activities include: advanced fabrication techniques for integrated optics, gratings, optical waveguides, and optofluidic systems; plasmonic based sensors; optical tweezers systems for detection of nanovesicles; light-activated cap for catheters sterilization;
- **Photonic solutions for extreme sensing,** addressing the development of modular sensors for permanent deployment in extreme environments using optoelectronic systems as measurement tools: interrogation systems for demanding space applications that require μK resolution, Distributed Acoustic Sensing (DAS) technology implemented in intercontinental submarine cables, methodologies to real time monitoring of metal's corrosion and the degradation of concrete structures using optical fiber sensors combined with nano structures, and optical sensors for gas leak detection and quantification, as hydrogen and methane, aiming the implementation in industrial natural gas distribution systems, following the energy transition strategy;
- **Optical systems for quantum simulation and computing,** addressing the development of accessible and versatile analog quantum simulators and all-optical processing systems using tabletop optical experiments, including the deployment of an experimental system working as an all-optical extreme learning machine and the upgrade of the existing experimental system for analogue quantum simulations by increasing the effective simulation time using wavefront shaping techniques;
- **Biomedical instrumentation**, addressing research in smarter, more adaptable, and reliable sensing and measurement technologies with novel embedded bio-signal acquisition and processing methods,

including wearable devices, applied to rehabilitation, occupational health, wellness, and sports performance assessment;

- **Neuro-Engineering**, performing high-level interdisciplinary research in engineering and computational approaches applied to basic and clinical neuroscience, addressing brain imaging (&signals), man-machine symbiosis with edge-AI, quantified movement multimodal analysis in neurological diseases, neurosurgery aiding systems, and from macro-to-nano bio-neuro-sensing.

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

Research Challenge 2 – 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 the application of machine perception techniques to different stages of a clinical process (diagnosis, treatment planning, surgery, and follow-up); research activities address different use cases: research cancer management, ophthalmology, neurology, gastroenterology, cardiovascular disease, thorax pathologies, and capsule endoscopy;
- **Forensics**, addressing liveness detection, recognition under domain drift, biometrics with security, and scene and human behaviour analysis;
- **Multimedia content understanding and management**, addressing the definition of strategies and the development of solutions for capturing and accessing real-world audio-visual and other sensory data and for extracting meaning from it, targeting the creation of applications with enhanced and adapted content that provide added value to diverse remote audiences in varied situations and purposes; tackled problems include: 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.

Research Challenge 3 – 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 1) circuit design and modelling with the integration of memristors and transistors using thin-film substrates, exploring applications in neuromorphic computing, and 2) design of reconfigurable devices and application-specific computing systems striving for improved power-performance trade-offs, providing hardware acceleration at the edge combined with transparent and adaptive mechanisms;
- **Transmission technologies,** addressing 1) design of reconfigurable antennas and intelligent surfaces using novel materials up to sub-THz, and signal processing techniques with a focus on localisation and

beamforming, and 2) characterization of transmission of light waves in optical fibres and unconventional media (e.g. water and biological tissues);

- **Wireless networking,** addressing the development of networking solutions towards autonomous and robotic-borne communications systems. The focus is on wireless networks and mobile communications, extending infrastructure networks and enabling the Internet of Everything in terrestrial and non-terrestrial environments; relevant scientific contributions are: algorithms and mechanisms for obstacle-aware optimal node positioning and radio resource management in robotic-borne networks, novel reinforcement learning based algorithms addressing smart link adaptation and dynamic positioning of flying nodes, mechanisms and algorithms enabling wireless communications solutions for underwater environments, network digital twins for accurate, cost-effective validation of wireless networking systems, and algorithms and mechanisms for energy-efficient communications;
- **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.

Research Challenge 4 – 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.

Research activities are organised along the following lines:

- **Positioning & navigation**, addressing the navigation of autonomous systems in dynamic environments where global positioning aiding systems are not available; specific research activities include 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 the dynamic modelling of sensors and robotic behaviour and the development of algorithms for the guidance and control of robotic systems, with applications to 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 the development strategies for single or multiple robotic systems, adaptive sampling techniques, multi sensor data fusion for underwater or overwater mapping, hyperspectral, electro-optic and acoustic image processing, underwater acoustic mapping, and multi sensor 3D environment modelling;
- **Platforms & operations**, addressing the development of innovative robotic platforms as well as novel concepts of operation, including coordinated operations of heterogeneous platforms, which 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, such as 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 development of auxiliary systems for long term deployments (e.g. docking stations, energy transfer systems suitable for underwater operation) is also tackled here;
- **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 decarbonization 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 digitalized 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 optimizing 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 Steady-state and dynamic power system operation and control, Electricity markets modelling and simulation, Distributed energy resources modelling and aggregation, Sector coupling modelling, Power electronics, Modelling and real-time simulation of cyber-physical systems, Reliability analysis of energy systems, Artificial intelligence, Optimization and decision-aid, Micro-grids and nano-grids, Aerial robots, Cybersecurity, Data modelling for interoperability, Distributed ledger technologies, Human-machine interaction.

3.4.2 Research Challenges

Research activities within this domain are organized along four major applicational research challenges: Cost-effective decarbonization and digitalization of integrated energy systems, Evolving and de-centralizing energy-driven business models and markets, Resilience and reliability of energy systems to natural and man-made threats, Smart control centres of the future.

Cost-effective decarbonization and digitalization of integrated energy systems

The main objectives for 2023 to address with this research challenge are:

- Definition of optimal operation strategies of electrolyzers in order to use electricity from renewable sources;
- System services provided by electrolysers as flexible loads;
- P2P solutions associated with seasonal energy storage to guarantee security of supply;
- Management and control of NG networks with integration of renewable gases;
- Operation of electricity, natural gas and renewable gases production and consumption aggregators;
- Optimisation of the operation of multi-energy networks.

Evolving and de-centralizing energy-driven business models and markets

The main objectives for 2023 to address with this research challenge are:

- Market equilibrium formulation and computation of local electricity pool-based markets with flexible resources: formulation and computation of an iterative or a one-step optimization problem for a local post-delivery pool market (based on [1], [2]), where the energy of the bids is the energy actually delivered by the market agents that dispatch their flexible resources according to the expected market price.
- Market equilibrium formulation and computation of real time (Walrasian) local electricity markets: Formulation and computation of a real time Walrasian-based market design for local electricity trading (based on [3]), based on based on consecutive auctions for very short delivery periods, where the

auctioneer defines a price for each of the delivery periods to which peers react by generating and consuming accordingly.

- Business models for self-consumption and flexibility provision with shared assets and benefit sharing mechanisms for the engagement of final customers in the energy system and the provision of flexibility, [4], [2].
- Algorithms and tools for the instantiation, assessment and operation of energy communities, and operationalization of an energy communities' operation platform with advanced energy sharing and settlement mechanisms (based on [4], [5]).
- Market equilibrium formulation and computation of a multi single-price-area market with coordination and optimal interconnection allocation of energy and reserve commodities, to be implemented in CEVESA MIBEL market model, [6], [7], [8].
- Development of transmission expansion planning models considering the larger presence of wind and solar units and the impacts of climate change. [9], [10].

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Resilience and reliability of energy systems to natural and man-made threats

The main objectives for 2023 to address with this research challenge are:

- Exploitation of local grid flexibilities for maximizing the continuity of supply during contingency events

This topic consists on assessing the long-term contribution of distributed and flexible resources to the continuous supply of critical loads in distribution networks during events that result in single or multiple failures. In addition, probabilistic tools for operational planning to preventively allocate and coordinate resources (e.g. emergency generators, repair crew, etc.), reserve flexibility (e.g. storage), and/or form islands are also envisioned to enhance the ability of the Distribution System Operator (DSO) to deal with extreme events.

- Long-term power system adequacy assessment under climate change and extreme weather

The long-term security of energy supply is becoming a major issue in Europe. The goals for the decarbonization of the sector require more integration of endogenous renewable power sources or other low emission technologies. Naturally, the migration from fossil-fueled units towards this new paradigm increases the exposure of the electric sector to severe climate variations since the primary energy resources are not possible to be easily stored. Extreme climate events can affect the system in different ways:

  - thermal power plant derating due to rising water temperature or lack of water in rivers;
  - lack of hydro power due to low water inflows;
  - photovoltaic power unavailability for several days or weeks when there are dense dust clouds in the atmosphere;
  - lack of wind power resulting from persistent low wind regimes or during storms;
  - variation in the demand due to extreme cold or heat waves or the uptake of electric vehicles as a way to curb rising CO2 emissions.

In a changing climate the frequency and duration of extremes is not adequately represented in historical data. For example, climate models predict intensification of drought conditions in the Iberia peninsula, thus management of hydro power availability based on past historical information alone fails to consider the increase in frequency and duration of drought conditions in current and future climates. In addition to model results, the analysis of station and reanalysis data shows significant changes in the data distributions in the past decades, for example for the temperature in the Iberia peninsula, leading to significant changes in corresponding extreme heat events. Consequently, the frequency and duration of extreme events serving as input to assess the security of power supply need to be obtained not only from historical data but also via accurate climate models appropriately adjusted to the geographic region and the time horizon.

From the above, new models for the availability of electricity supply components (generation, storage and demand) and their capacity variation when such extreme phenomena occurs are required. These models are imbedded in Monte Carlo Simulation, which can simulate the operation of power systems in a chronological way, hence capturing the transition between normal weather and extreme conditions and the ensuing change in the state of the electrical system components. The role of storage, either large scale or distributed, will also be incorporated in the analysis to mitigate possible power shortages. The main novelty consists in a) models for the generating capacity deficit or load variation due to climate changes, b) power system performance assessment in changing climate conditions, and c) new knowledge regarding the cost-effective investment options necessary to keep current continuity of supply standards.

Smart control centres of the future.

The main objectives for 2023 to address with this research challenge are:

- Finalize the development in Smart4RES project of a novel risk-aware decision-making methodology for grid and DER flexibility activation to solve voltage and congestion problems under load and renewable energy forecast uncertainty. Moreover, new methodologies and metrics will be proposed to evaluate human decision quality under uncertainty;
- Graph-based representation and knowledge extraction from power system alarm data to support human operators real-time and post-mortem analytics of grid events;
- AI-based solutions addressing critical systems (electricity, railway, and air traffic management) modelled by networks that can be simulated, and are traditionally operated by humans, and where AI systems complement and augment human abilities. The strategic goal is to develop the next generation of decision-making methods powered by supervised and reinforcement learning, which aim at trustworthiness in AI-assisted human control with augmented cognition, hybrid human-AI co-learning and autonomous AI, with the resilience, safety, and security of critical infrastructures as core requirements;
- Dynamic multi-level state estimation and situation awareness, harmonizing data from different voltage levels in real-time recognition of dynamic events assisting intelligent automated preventive and remedial tools.

4 TEC4 INITIATIVES

4.1 Overview

A TEC4 ("TEChnologies FOR …") is an 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-Cluster multidisciplinary projects, promoting collaboration with business and producing solutions to be transferred to companies.

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

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

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

Each TEC4 has its own strategic agenda, according to their market domain, addressing three pillars: the stakeholder's 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.

Next sections 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
- And 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 TEC4AGRO-FOOD

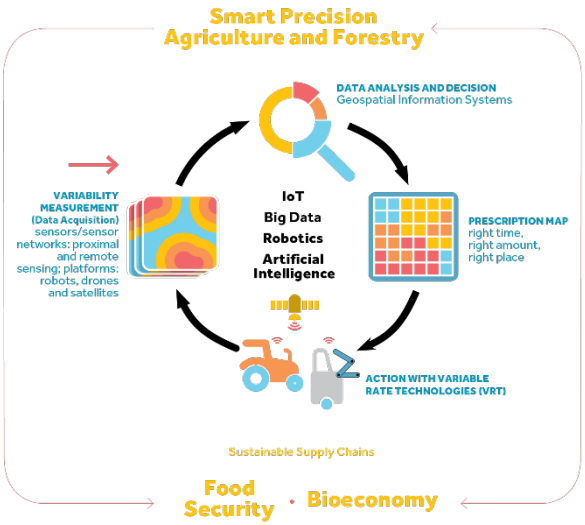
Coordinator: Filipe Santos
Business Developer: André Sá

4.4.1 Scope and strategy overview

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

TEC4AGRO-FOOD's mission is co-creating the digital (r)evolution in agro-food and forestry through research and technological development in digital technologies and robotics for the creation of long-term value for INESC TEC from customers, markets, and relationships.

TEC4AGRO-FOOD has as main application areas 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:



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 since 2017. The presence in the relevant Collaborative Laboratories (CoLABs), Competitiveness Clusters (Clusters), National Competence Centres (Competence Centres) and Smart Specialisation Regional Platform Food and Environmental Systems (CCDR-N), the established partnerships, namely with INIAV, Herculano, Sogrape Vinhos 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. The TEC4AGRO-FOOD's Strategic Plan, recently concluded, characterised the megatrends and agro-Food and forestry specific trends, elaborated an internal diagnosis of INESC TEC and an external sector diagnosis and defined a medium-long term action plan, within the scope of the TEC4AGRO-FOOD initiative.

4.4.2 Main objectives for 2023

The main objectives of TEC4AGRO-FOOD for 2023 are the following:

- Full implementation of projects in portfolio (#1);
- Redouble efforts with companies (#2);
- Redouble efforts at the international level (#3);
- Increase knowledge about the activities and results of TEC4AGRO-FOOD internally at INESC TEC (#4).

4.4.3 Action plan

In 2023, TEC4AGRO-FOOD will design and/or implement the following actions:

Table 4.4.1 – TEC4AGRO-FOOD – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
Continue to implement TEC4AGRO-FOOD's Strategic Plan	#1; #2; #3	Implementation of TEC4AGRO-FOOD's Strategic Plan.	All year
Participate in kick-off meetings, external events and closing events of projects in portfolio	#1	Contribute to the full implementation of projects in portfolio.	All year
Continue efforts to transfer IPR of projects in portfolio and continue with the identification of Technology Providers, namely Portuguese, and the establishment of contact with them	#1; #2; #3	Increase the level of exploitation of R&D results and also the portfolio of partners, particularly technology/solution providers	All year
Establish direct contracts with companies	#2	3 applications for Individual R&D Projects. 1 direct contract with a company.	All year
Submit applications for European R&D Framework Programmes	#3	3 applications for HEU projects, of which 1 with INESC TEC as coordinator.	All year
Participate in relevant national ecosystem activities (CoLABs; Clusters; Competence Centres; CCDR-N; established partnerships)	#2	More R&I projects	All year
Strengthen or start participation in relevant European programmes/initiatives and strengthen/establish contact with the "champions" of coordinating European projects	#3	Stronger participation/participation in relevant European programmes/initiatives and strengthen/establish contact with the "champions" of coordinating European projects	All year
Approach Wageningen University & Research and Volcani Centre to establish partnerships	#3	Partnerships with Wageningen University & Research and Volcani Centre.	All year
Participate in World FIRA 2023	#2; #3	International networking and notoriety. Robotics and IoT technologies exhibition. R&I projects.	Q1
Participate as "RTD Partner" in AgroIN 2023	#2	National networking and notoriety. R&I projects.	Q2
Participate in AGROGLOBAL 2023	#2	National networking and notoriety. Digital and robotics technologies exhibition. R&I projects.	Q3
Organise an internal TEC4AGRO-FOOD event at an INESC TEC's living lab	#4	Increase knowledge about the activities and results of TEC4AGRO-FOOD internally at INESC TEC.	Q2 or Q3
Develop new communication materials	#1; #2; #3; #4	Increase and improve TEC4AGRO-FOOD communication.	All year

4.5 TEC4ENERGY

Coordinator: João Peças Lopes
Business Developer: Nuno Campos

4.5.1 Scope and strategy overview

One of the main challenges of the energy sector is the need to act in response to the decarbonization of the society and economy. Within this framework, TEC4ENERGY focuses on the Societal Challenges and Innovation Strategies for Smart Specialization defined by EU policies - the energy sector will be heavily digitalized, decentralized, under a user-centric and market-based approach, involving a large-scale integration of renewable power sources and the development of a smart grid infrastructure that requires the conceptualization and development of disruptive solutions.

TEC4ENERGY leverages INESC TEC's resources, competencies, and technologies in order to develop and transfer innovative solutions to the energy sector, addressing current societal challenges and the specific needs of our energy partners. This value proposition is attained by establishing a continuous dialogue with industry, developing fruitful collaborations that address the energy sector challenges and needs.

The main application domains that TEC4ENERGY fosters are:

- Power Systems Management
- Energy Analytics
- Forecasting Techniques for Energy Systems
- Large Scale Integration of Renewable Energy Sources
- Distributed Energy Resources Operation
- Electric Mobility
- Energy and Flexibility Management
- Smart Grids
- Multi-Energy Systems
- Robotics for Intelligent and Autonomous Energy Asset Inspection
- Electrical Assets Health Condition Management
- Photonic for Energy Sensoring
- Energy Operators Health and Security Sensoring
- Immersive Training and Certification of Energy System Operators
- Smart Metering Deployment
- Cybersecurity and IoT for Electrical Infrastructures

4.5.2 Main objectives for 2023

The main objectives of TEC4ENERGY for 2023 are the following:

1. Identify leads interested in collaborating in National and International R&D projects, Contract Programs, Advanced Consultancy & Training;
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 creation and preparation of new projects within the framework of Horizon Europe;
6. Consolidate and leverage collaborations with synergetic INESC TEC's R&D Centres;
7. Promote INESC TEC's visibility and reputation;
8. Participate in the main Power & Energy events – conferences, workshops, exhibitions;
9. Network with Clusters and Industrial Associations;
10. Promote and increase the collaboration with the Power & Energy CoLABs – *"Smart Energy Lab"*, *"Vasco da Gama CoLab - Energy Storage"*, *"Green Hydrogen Collaborative Laboratory"*;
11. Structure and foster the potential of INESC TEC laboratory infrastructure (e.g., Smart Grids and Electric Vehicle Lab) for providing services to industry.

4.5.3 Action plan

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

Table 4.5.1 – 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 project proposals / Potentiate future opportunities	All year
		Contract Programs	All year
International Business Visits/Meetings	1) 3) 5) 6) 7)	New partners / Partnership consolidation	All year
		Generate project proposals / Potentiate future opportunities	All year
		Contract programs	All year
National and International Institutional Meetings	5) 7) 8) 9) 10)	Networking / Lobbying	All year
Events Organisation and Participation	1) 2) 3) 4) 5) 6) 7) 8) 11)	Potentiate future opportunities	All year
		Networking and market understanding	All year
		Technological surveillance	All year
		Promote INESC TEC	All year
Communication	1) 5) 6) 7) 8) 10) 11)	Videos, flyers, dissemination materials	All year

4.6 TEC4HEALTH

Coordinator: Miguel Coimbra
Business Developer: Carlos Alexandre Ferreira

4.6.1 Scope and strategy overview

TEC4HEALTH induces a market pull drive into R&D, targeting all the value chain actors and processes in the healthcare and well-being sectors. To accomplish 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 competencies, seeking to promote synergies with its partners and leading to the development of successful projects, contracts and technology transfers.

In the last 4 years, INESC TEC developed 67 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 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. Although traditionally our main partners have been research institutes, public hospitals in the North region and some international universities, in recent years we have managed to involve some small and medium-sized Portuguese companies operating in the health sector in our projects. The aim of the next year will be to get closer to health ministry companies, the four largest Portuguese private hospital groups, multinational players, patient associations and large IT companies, which used to operate in other sectors but have started to gain interest in healthcare. New types of industries will also be a target, with little or no interaction with INESC TEC so far, such as health equipment, clinical analysis laboratories, pharmacies, pharmaceutical and in sports.

4.6.2 Main objectives for 2023

After a 2020 mainly dedicated to identifying internal strengths, 2021 and 2022 were years that allowed good approaches to national and international players respectively. For 2023, 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, IHI, Digital Europe and the Europe's Beating Cancer Plan;
D. Promote thematic discussions and sensitize 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.

4.6.3 Action plan

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

Table 4.6.1 – 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	T4

4.7 TEC4INDUSTRY

Coordinator: Américo Azevedo
Business Developer: António Almeida

4.7.1 Scope and strategy overview

TEC4Industry presents a double role, 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. TEC4Industry wants to take advantage of a unique combination of knowledge, competences, resources, and infrastructures 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 is anchored in a history of successes, materialised in effective technology and knowledge transfer to companies, based on different formats: a) Important long-term partnerships with companies from different sectors from the manufacturing industry; b) R&D partnerships with consultancy, technology and engineering services companies; c) Distinct consultancy projects targeted to support small, medium and large companies along with their digital transformation; d) Cooperation with national industry associations to foster the digital transformation; f) Promotion of iiLab as a unique TestBed for industry, offering different type of services, such as advanced training, new technology prototyping and demonstration, and support to start-ups; g) Promotion and execution of innovative European projects, where INESC TEC has been involving Portuguese companies from the different; h) Follow PRR projects execution to promote the interaction between academia, industry and technology providers to drive the development, demonstration and promotion of new Portuguese products, technology and services (PPS).

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 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; an autonomous industry, driven by information and knowledge towards self-awareness and self-learning processes and machines, capable to adjust and optimize its performance; a human-centred industry capable of leveraging human capabilities, increasing human-machine collaboration, reducing risky and non-value operations performed by humans and promoting people's well-being, reinforcing attractiveness to young professionals; 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 sustainable Industry where industrial companies are active agents of Circular Economy, minimizing 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; and 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.

4.7.2 Main objectives for 2023

The strategic lines that will drive TEC4INDUSTRY along 2023 will focus on the twofold mission of better understanding the market to influence INESC TEC technology, knowledge, and services evolution. In 2023, TEC4INDUSTRY will take advantage of the INESC TEC participation in the different PRR agendas to promote and demonstrate the innovative products, processes, and services (PPS) that will be developed. Furthermore, we intend to leverage the potential of INESC TEC competencies and services, geared by the new iiLab infrastructure as a TestBed. 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; and 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 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.

4.7.3 Action plan

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

Table 4.7.1 – 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	All year
Participate in Summits and events promoted by European Commission, EU programs/initiatives or others EU organisations.	2.g	See the future of manufacturing from global experts and have visibility on EU initiatives and programs	All year
Visits to European and International institutes facilities	2.e; 2.g	Benchmarking	All year
Participation in National and International fairs	2.a; 2.c, 2.f	Disseminate and demonstrate the technologies and case studies developed in INESC TEC	All year
Participation in International Conferences for education and manufacturing	2.e	Collect new ideas and technologies as well as challenge TEC4INDUSTRY innovation (IEEE EDUCON 2023, ICMR 2023 or FAIM 2023)	All year
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	All year
To consolidate iiLab's value proposition and thus characterize and specify its service offering.	1.a; 1.b; 2.a; 2.d	Structured service offer	1S
Promote INESC TEC and Industry collaboration within the PRR Agendas	2.b; 2.f	Facilitate collaboration between INESC TEC, Technology companies and Industrial companies towards the dissemination of new product and services (PPS).	All year
Advanced Training Courses and Master Classes for target domains	1.b; 2.d	Build flexible, multidisciplinary, and customized courses in the digital transformation domain	All year
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)	Each T
TEC4INDUSTRY Summit	2.a; 2.e; 2.f	Bring together national/international companies and INESC TEC experts in industry 4.0 domain to address important topics for this industrial revolution	T3
INESC TEC meets Industry	2.c; 2.e	Promote workshops and events between research centres and new industry	All year

4.8 TEC4SEA

Coordinator: Eduardo Silva
Business Developer: Carlos Pinho
Industry Liaison Officer: Paula Lima

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 these sectors. Towards these objectives, 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.

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 Horizon Europe and Mission's objectives, the new European vision targeting 2050, up to global challenges. TEC4SEA in organising this outlook in three vectors:

a) Sensing.

b) Digitalisation.

c) Energy.

d) Robotisation and autonomy.

These vectors are aligned with INESC TEC 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, aquaculture, and deep sea biology), Marine Renewable Energies (including green hydrogen), Shipbuilding and repair, Deep Sea Mining, Ports, Maritime Defence and environmental Climate Change.

4.8.2 Main objectives for 2023

The main objectives of TEC4SEA for 2023 are the following:

INTERNAL

1. Continue the internal consolidation with different centres, adapting to the continuous changes, pursuing relevant impact in the Blue Economy sectors as well as in society;
2. Promote internal awareness of INESC TEC resources and capacities available for centres to leverage the Blue Economy R&D+I;
3. 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, tasks, and projects. Develop a continuous work of synchronisation, strategy, and priority alignment.;
4. Promote internal awareness and alignment with the medium-term strategy and action-plan (2030), fostering current and future strategic opportunities (e.g., H.E., EITs, national programs, etc.);
5. Initiate the strategic awareness for data gathering and specific model's development towards the future Digital Twin of the Ocean.

EXTERNAL

1. Promote and disseminate the resources and capacities of the TEC4SEA Infrastructure, fostering R&D+i and subcontracting opportunities;
2. Develop and pursue national and international mechanisms to establish INESC TEC Sea domain as a Centre of Excellence;
3. Consolidate INESC TEC position in the Ocean Renewable Energies test site of Aguçadoura;

4. Continue to strengthen the collaboration with entities in the entrepreneurial ecosystem to help revitalise a competitive and innovative Blue Economy in Portugal;
5. Request "*Títulos de Utilização Privativa do Espaço Marítimo* (TUPEM)" to support INESC TEC R&D+i;
6. Identify and establish close collaboration mechanisms/protocols with international leading organisations (e.g., Sintef Norway and GCE Ocean, DMEC, EMSA, ISA);
7. Foster the successful accomplishment of all Sea related initiatives within the "*Plano de Recuperação e Resiliência*", leveraging these projects and corresponding impact with complementary initiatives (e.g., H.E., PT2030, Mar2030) and strategic partners in the domain (e.g., IPMA, Portuguese Navy);
8. Continue the consolidation of international relations (Europe, Latin America, India, South Korea);
9. Contribute for the 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 4.8.1 – TEC4SEA – Main actions planned

Action	#Objective	Expected Outcomes	Calendar
National Businesses visits	I1, I3, I4, I5, E1, E2, E3, E4, E5, E7.	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	all year
International Businesses visits	I1, I3, I4, I5, E1, E2, E3, E6, E8.	• Project proposals • Identify future opportunities • Make the brand INESC TEC/TEC4SEA known • Develop SEA intelligence	all year
Participation on European Maritime day (Brest)	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	24-25 May
Participation with stand at Oceans 2023 in Limerick (Ireland)	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	5-8 June
Participation with stand at Business2Sea	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	4T
Conferences inscription (Marine Minerals + ICOE)	All objectives (scouting & intelligence)	• Scientific/market orientation • Develop SEA intelligence • Make the brand INESC TEC/TEC4SEA known	all year
Sponsoring ESG Handbook Marine Minerals	All objectives (scouting & intelligence)	• New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	all year
Participation with stand at Aquaculture Europe 2023 (Austria)	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	18-21 September
International event organisation - promoting INESC TEC Sea Domain	All objectives	• Project proposals • New partners • Future opportunities • Make the brand INESC TEC/TEC4SEA known	2T
Fisheries business awareness	I1, I2, I3, I4, I5, E2, E3, E7, E9.	• Develop SEA intelligence • Identify future opportunities • New partners	3T

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.

For Financial, Construction and Internet Market sectors, the actions foreseen in their strategic planning documents will be implemented in order to consolidate INESC TEC as a technologic partner. We will organise the offer based in INESC TEC research lines and will prepare supporting documentation. We will promote participation in networking events and fairs and identify funding opportunities in Horizon Europe and other public funding sources that include companies. We will also organise initiatives to promote the link between the internal community of researchers with R&D entity/groups with complementary skills and technology companies.

Regarding the Defense 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:

- Defence & Security – Consolidate activities with the creation of a community of practice (CoP), organise an internal workshop and a create a presentation with INESC TEC's D&S public profile. Continue to identify opportunities and business partnerships under European Defence Fund, Horizon Europe Cluster 3, NATO, EDA, PT Government (MoD and Internal Affairs), EARTO's Security and Defence WG and AED Cluster.
- Space – Develop activities with CoP under PRR, Horizon Europe Cluster 4 and ESA, establishing new partnerships nationally and internationally, particularly taking advantage of New Space opportunities, under EARTO's Space WG (and in the new EASTRO association, which will replace it) and AED Cluster.
- Mobility – Consolidate activities with a community of practice (CoP), organise an internal workshop and create a presentation with INESC TEC's Mobility Profile. Explore synergies among Rail, Road, Shipping as well as emerging trends, such as cable or soft schemes. Develop participation in Rail Cluster (PFP) and Rail CoLAB. Explore new aeronautical collaborations, after recent investments by AERNNOVA and AIRBUS Atlantic, with TEC4INDUSTRY. Take advantage of specific funding programs, to develop business partnerships, such as Shift2Rail, CEF, Clean Aviation, SESAR, Horizon Europe and P2030.
- Public Administration – Continue to support the Digital Transition of Portuguese Public Administration, developing new collaborations with technology providers as well as end users. Explore synergies with other areas, particularly Mobility.

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

Table 4.9.1 – TECPARTNERSHIPS– Main areas/sectors under consideration

Sector	Core Centres	Phase	Existing Network
Construction	Computer Science, CESE, CRAS, CRIIS, CITE	Startup	PCTP, BuiltColab, REBuilt
Defense and Security	CRAS, CTM	Study	AEDCP, EARTO (Security and Defence WG)
Space	CAP, CRAS, CTM	Startup	AEDCP, EARTO (Space WG)
Internet Market	Computer Science, CTM, CESE, CEGI	Startup	NEM, TICE.PT
Finance	Computer Science, CTM	Startup	
Mobility	CEGI, CESE, HumanISE, CTM	Study	AEDCP, ITS Portugal, PFP, Rail CoLAB
Public Administration	Computer Science	Study	

4.9.2 Main objectives for 2023

The main objectives of TECPARTNERSHIPS for 2023 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 4.9.2 – 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 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	all 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	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: Filipe Ribeiro and Rui Campos

5.1.1 Scope, vision and activities

The Centre for Telecommunications and Multimedia (CTM) consists of about 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 areas: Optical and Electronic Technologies (OET, led by Luís Pessoa); Wireless Networks (WiN, led by Hélder Fontes); 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 the 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, computing, and sensing systems of the future, building on competences in microwave engineering, fibre optics, integrated photonics, digital and analogue integrated electronics, and signal processing, while targeting applications in optical/radio communication systems, human sensing and embedded computing. Research activities include: 1) reconfigurable antennas and intelligent surfaces using novel materials up to sub-THz, and signal processing techniques with a focus on localisation and beamforming; 2) transmission of light waves in optical fibres and unconventional media (e.g. water and biological tissues) and photonic integrated circuit design enabling the processing of microwave signals; 3) circuit design and modelling, addressing the integration of memristors and transistors using thin-film substrates, exploring applications in neuromorphic computing and reconfigurable antennas; 4) reconfigurable devices and application-specific computing striving for improved power-performance trade-offs, providing hardware acceleration at the edge combined with transparent and adaptive mechanisms. This research line contributes to the vision of the “Context-aware communications systems” and “Novel Perception tools” INESC TEC Research Challenges.

RL2. Wireless Networking

The main goal of this research line is to investigate networking solutions towards autonomous and robotic-borne communications systems. The focus is on wireless networks and mobile communications, extending infrastructure networks and enabling the Internet of Everything in terrestrial and non-terrestrial environments. This includes the design of algorithms and mechanisms and requires theoretical and simulation modelling (including Network Digital Twins), implementation, and experimental evaluation of wireless networks. Research topics include positioning, routing, radio resource management, energy-efficiency, and context-aware optimization using cross-layer techniques. Relevant scientific contributions are: 1) algorithms and mechanisms for obstacle-aware optimal node positioning and radio resource management in robotic-borne networks; 2) novel reinforcement learning based algorithms addressing smart link adaptation and dynamic positioning of flying nodes; 3) mechanisms and algorithms enabling wireless communications solutions for underwater environments; 4) Network Digital Twins for accurate, cost-effective validation of wireless networking systems; 5) algorithms and mechanisms for energy-efficient communications. This research line contributes to the vision of the “Context-aware communications systems” INESC TEC Research Challenge.

RL3. Media platforms and audio-visual content management

This research line investigates strategies and develops solutions for capturing and accessing real-world audio-visual and other sensory data and for extracting meaning from it, targeting the creation of applications with enhanced and adapted content that provide added value to diverse remote audiences in varied situations and purposes. Among other aspects, it tackles the use and manipulation of immersive media content such as 3D, 360°, panoramic, and multi-view content, the exploration of enhanced data navigation and visualisation paradigms and Human-Media interaction mechanisms to improve the quality of experience, enabling the personalised access to content and the construction of different narratives. The RL strives to develop a comprehensive set of methodologies and algorithms to foster the creation of enhanced and adaptable multimedia applications with realistic and dynamic immersion, scene recreation, interaction, and participatory capabilities. Targeted scenarios include media and creative industries, culture and cultural heritage, sports, video surveillance, robotics and industrial systems, well-being, and societal challenges. This research line contributes to the vision of the "Beyond human vision" and "Context-aware communications systems" INESC TEC Research Challenges.

RL4. Machine perception

This research line carries out research in an interdisciplinary field that aims at gaining a high-level of understanding from digital images, videos, sound, and music. It combines engineering aspects of sensing hardware (signal formation), signal filtering and signal processing with pattern recognition for high-level understanding and decision-making. The focus is on the development of intelligent systems, which combine audio-visual content-understanding capabilities with any available additional information to enable sophisticated recognition, targeting application areas such as autonomous vehicles, medical image analysis, biometrics, forensics, security, space, multimedia content understanding, human-media interaction, agriculture, zootechny, sports, entertainment, culture and arts. The main activities are focused on developing computer vision architectures achieving functionalities and performances beyond human capabilities, centring on never-ending learning capabilities, multi-objective perception, generic artificial vision, and causal and explainable models. This research line contributes to the vision of the "Beyond human vision" INESC TEC Research Challenge.

RL5. Medical Image Analysis

Medical imaging plays an important role throughout the clinical process, from diagnosis and treatment planning to surgery and follow-up research. Learning methodologies can be a way to help physicians in their daily tasks, for example, when dealing with multiple data sources, data sparsity or providing information about visual findings using explainable methods. This research challenge is present in different use cases: cancer management, biological image analysis, biomedical imaging, and computational anatomy. In this RL we aim to continue contributing with 1) approaches on computational pathology to assist the radiologist in the diagnosis, 2) methodologies to facilitate surgery planning, 3) computer-aided systems to perform aesthetic evaluation after treatment, 4) colposcopic and histopathological image analysis by developing methods for image quality analysis and support of diagnosis, and 5) radiogenomics, pathomics and omics analysis. This will be accomplished through 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 vision of the "Beyond human vision" INESC TEC Research Challenge.

INNOVATION ACTIVITIES

INOV1 Design of planar antennas and microwave components addressing specific industrial requirements; characterisation of radio systems in anechoic chamber; and design of radio-based localisation systems. (Aligned with TEC4AGRO-FOOD, TEC4HEALTH, TEC4INDUSTRY, and TEC4SEA initiatives)

INOV2.A 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 non-terrestrial environments. (Aligned with TEC4AGRO-FOOD, TEC4ENERGY, TEC4INDUSTRY, and TEC4SEA initiatives)

INOV2.B Design and development of novel on-demand and self-adaptable networking solutions for network infrastructure extension in terrestrial and maritime environments. (Aligned with TEC4AGRO-FOOD, TEC4ENERGY, TEC4INDUSTRY, and TEC4SEA initiatives).

INOV3.A Algorithms for visual attention prediction to reduce response times during view switching in multi-view streaming. (Aligned with TEC4INDUSTRY initiatives)

INOV3.B Visual scene analysis approaches and models for scene description and information synthesis. (Aligned with TEC4INDUSTRY initiatives)

INOV 4.A Development of solutions to demonstrate, test and validate AI models with respect to their utility, in the context of biometrics, forensics, security, space, media industries and autonomous vehicles areas of application. (Aligned with TEC4INDUSTRY initiative)

INOV 4.B Development of algorithms for the automatic generation of content based on arbitrary. (Aligned with TEC4INDUSTRY initiative)

INOV 5. Development of solutions to demonstrate, test and clinically validate AI models with respect to their utility, aiming at improving the standard-of-care, by developing health-related digital twins. (Aligned with TEC4HEALTH initiative)

5.1.2 Main objectives for 2023

Organisation, human and material resources: Increase number of core PhDs by 15% and number of core researchers by 20%. Establish new lab infrastructures for validating 5G/6G solutions and characterising biological tissues. Increase capacity of the computational resources (GPUs) and improve internal SLURM platform.

Research: Increase number of papers published in Q1 journals to 70% and papers published in CORE A*, A, and B (or equivalent h5-index) conferences to 60%. Publish two open access datasets: 37K MIDI music samples with perceived continuous emotion annotations; 6 omnidirectional multiview videos with visual attention annotations.

Innovation: Increase to 2 the number of IP protection results/FTE. Have at least 1 technology transfer contract.

Advanced training: Organise 3 advanced training Programs.

Dissemination: Co-organise 8 scientific events (as organising committee or chairing technical committees). Submit at least 2 proposals for organizing workshops in high-ranked conferences.

Internationalisation: Submit at least 4 international project proposals. Publish 10+ papers within international collaborations. Organise at least 4 scientific events in international cooperation. Set up new international collaborations through student/staff exchanges.

5.1.3 Main actions planned for 2023

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

Table 5.1.1 - CTM – Main actions planned

Action	Expected Outcomes
Organise CTM Open Day and Summer Internships	Higher national and international visibility and recognition. Attraction of MSc and PhD students.
Organise monthly CTMeet Up meetings, bimonthly meetings between full-time PhDs, and Scientific Council meetings (RCU)	Increased internal articulation and debate. Creation of new joint research and advanced training opportunities. Periodic monitoring of the main objectives accomplishment.
Organise two centre-wide team-building events (summer and end of the year)	Increased centre cohesion, articulation, and debate. Creation of new joint research opportunities.
Promote internally high-quality journals and conferences for the publication of key research results	Increased impact of the centre in the scientific community. Higher international recognition.

Action	Expected Outcomes
Take advantage of the INESC TEC International Visiting Researcher Programme	Improved networking with international peers. Increased chances of attracting high-quality international researchers.
Participate in national and international fora (6G-IA, AIOTI, One 6G, and NEM associations, COST actions, ANACOM Working Groups and Stakeholder Group Mission Cancer)	Higher visibility and recognition. Influence national and EU funding programmes and research priorities.
Intensify cooperation with INESC TEC's TTO by means of periodic meetings for identifying at earlier stage IP protection and technology transfer opportunities	Increased IP protection and technology transfer results.

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, and quantum optical engineering. The overall objective is to work towards the incorporation of our sensors as novel perception tools, such as: 1) imaging technologies enhancing the capabilities of autonomous underwater vehicles, 2) analytical laser induced breakdown spectroscopy (LIBS) and ultraviolet/visible spectroscopy systems providing real time analysis tools for robots in hazardous environments, and 3) 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 three 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. Development of photonic based platforms for environmental monitoring, medical diagnostic, and industrial applications

This research challenge foresees the medium-term development of photonic based devices that allow monitoring and analysis of specific targets, using label free and reagent free sensing technologies, aiming for miniaturization, handling simplicity, speed of operation and long-term stability. To advance with these objectives, next year work will focus on the following activities:

- Processing optical materials through advanced fabrication techniques, as femtosecond laser writing, to develop integrated optics, gratings, optical waveguides and optofluidic systems.
- Development of plasmonic based sensors with thin metallic coatings and specially designed nanoparticles for biochemical detection.
- Development of dielectric photonic crystals on top of optical waveguides mixed with plasmonics for high efficiency sensing devices.
- Development of solutions for water and air quality monitoring, combining chemical processes and high performance optical transducers through a set of mechanisms (evanescent wave, scattering analysis, absorption and emission spectroscopy).
- Explore sensor fusion strategies to enhance LIBS systems performance for industrial purposes, by seeking the implementation of an experimental system and of the necessary algorithms for a multimodal LIBS-hyperspectral solution.
- Develop accessible and high-performance computing solutions for data processing and analysis of LIBS data in the context of the lithium value chain.
- Explore the use of optical tweezers systems for the detection of nanovesicles supported by molecularly imprinted polymers.
- Adapt, automate and enhance the optical tweezers setup, adding new capabilities such as Raman and wavefront shaping.
- Light-activated cap for catheters sterilization based on- graphene oxide.

RL2. Photonic sensing for extreme environments

This challenge addresses the development of modular sensor systems for permanent deployment in extreme environments using optoelectronic systems as measurement tools. The objectives for the next year are:

- Development of interrogation systems for demanding space applications that require ?K resolution and relying in temperature references based on integrated optics;
- Monitoring the behaviour of the Atlantic Ocean with Distributed Acoustic Sensing technology and by means of its implementation in intercontinental submarine cables;
- Explore methodologies to real time monitoring of metal corrosion and the degradation of concrete structures using optical fibre sensors combined with nano structures;
- Study and development of optical sensors for gas leak detection and quantification, as hydrogen and methane, aiming the implementation in industrial natural gas distribution systems following the energy transition strategy.

RL3. Optical systems and devices for analogue quantum simulations

This research challenge envisions the medium-term deployment of accessible and versatile analog quantum simulators and all-optical processing systems using tabletop optical experiments. Paving for this final goal, the work for the next year focus on two operational objectives:

- Deploy an experimental system working as an all-optical extreme learning machine, operating the matrix multiplications in the optical domain, adding a nonlinear optical material as an all-optical activation layer, and possibly exploring robust designs with integrated optics devices.
- Upgrade the existing experimental system for analogue quantum simulations by increasing the effective simulation time using wavefront shaping techniques.

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 2023

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.

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, PRR, will be an important instrument to fund and develop such projects.

Dissemination (including events organisation). CAP will organise the EMSLIBS2023 event, Euro-Mediterranean Symposium on Laser-Induced Breakdown Spectroscopy, that will take place in September with a foreseen participation of around 220 researchers.

The Centre talks and other dissemination activities will continue to be included in 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. Also, cooperation with the DFA-FCUP initiatives like Open Days, "Ciência Viva" and Physics Summer School, providing projects for short internships, will be maintained.

Internationalisation. An increase of internationalization 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.

5.2.3 Main actions planned for 2023

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

Table 5.2.1 - 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
New PRR proposals	Participation in one new PRR proposal

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 localization 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 vehicles docking to other vehicles or systems. Methodologies and algorithms are sought to deal with obstacles (greater accuracy required to manage 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 lie the development of computer vision techniques and algorithms, sensing strategies for single or multiple robotic systems, adaptive sampling techniques, multi sensor data fusion 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. 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 suitable for underwater operation) are also addressed by this research line.

Innovation activities

The CRAS innovation activities are the following:

INOV1. Robotics systems prototyping and upscaling

The Centre will proceed with 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, demonstrations and support of scientific work 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 GNSS 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 structured light system for underwater applications, real time detection of fiducial markers for very close-range navigation, underwater stereo vision systems, and coupled observation/grasping mechanisms.

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 communications. The ability to create innovative solutions in this domain, highly customized and flexible, is a key competence essential for going further on multiple aspects of underwater autonomy.

5.3.2 Main objectives for 2023

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, team building activities and other actions will be promoted to foster cohesion.

The number of human resources associated with CRAS has been growing steadily and reached around 80 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 project delays due to the pandemic being resolved and the outdoors activities returning to support field validation, we estimate a significant growth, returning 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 Mine.IO 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 will take place in Max Planck Institute, Germany, about "Deep Reinforcement learning". Other actions will be sought in relevant areas for robotics, such as underwater computer vision, or navigation and control, for example.

Dissemination (including events organisation). 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 have been returning to conventional formats. The same applies to the participation in technology fairs, or conference-related events, where the Centre will promote the flagship projects and main achievements. On a 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 2023 will be to revive existing MOUs and other interactions with international organisations, that were on hold during the pandemic and have been resuming throughout 2022. In general, the Centre will take the advantage of interchange opportunities to stimulate researchers to visit top-ranked institutions. The exchange of PhD students is an example that has started in 2022 and will proceed in 2023. 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 2023

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

Table 5.3.1 – 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 23 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 Centre for Biomedical Engineering Research (C-BER) vision is to be a "promotor of scientific knowledge excellence through fundamental and applied research, advanced training and innovation in Biomedical Engineering".

SCIENTIFIC ACTIVITIES

To accomplish its mission, C-BER is guided by the following scientific 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.

INNOVATION ACTIVITIES

Furthermore, C-BER complement the scientific goals with the following innovation goals:

- To protect medium TRL results with patents to that they constitute assets to future TRL progression and promote the spin-off of these results to new startups.
- To promote internal synergies and strategic partnerships with other Centres of INESC TEC, clinical partners, research institutes, medtech companies & startups and foster international cooperation.

RL1. Biomedical Imaging Lab

Coordinator: Miguel Coimbra

The focus of the Biomedical Imaging Lab is the development of advanced image analysis and machine leaning methodologies, including generic approaches. These methodologies will be applied to medical and biological images, with the aim of creating computer-aided diagnosis tools to support medical decision making.

The Biomedical Imaging Lab current research activity is focused on four active lines of research:

- Ophthalmology CAD: Analysis of different types of eye images, namely colour retinal photographs and optical coherence tomography (OCT) and OCT-angiography (OCTA) images, aiming at developing 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), 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.
- CAGED – Computer Assisted Gastroenterology Examination: Image & clinical video analysis and characterisation of digestive tract images for diagnosis & follow-up.
- Multiscope – Multimodal digital stethoscope for non-invasive assessment of the cardiac activity: Signal processing research of simultaneous PCG and ECG signals for cardiovascular disease screening in point-of-care scenarios.
- (Emerging) Cardiovascular Imaging: Analysis of various cardiac imaging modalities (CT, US, others) for cardiac disease screening, diagnostic and characterisation.

- (Emerging) Capsule Endoscopy: Analysis of capsule endoscopy video exams for screening, diagnostic and disease characterization.

RL2. BioInstrumentation Lab

Coordinator: Miguel Velhote Correia

The main goal of the BioInstrumentation Lab is to perform high-level interdisciplinary R&D in engineering and computational approaches applied to rehabilitation, occupational health, wellness, and sports performance, crossing knowledge from several scientific areas, such as Physics, Electronics Engineering, Computation, Physiology, Biomechanics, Physiotherapy and Sports science.

By pursuing advances in smarter, more adaptable, and reliable sensing and measurement technologies, with novel embedded biosignal acquisition and processing methods, the lab also aims to innovate and facilitate technology transfer to the high-tech market. The main research activity lines in the lab are:

- Smart sensing technologies and advanced biosignal processing methods;
- Wearable devices and monitoring systems for human physiology and movement analysis.

RL3. NeuroEngineering Lab

Coordinator: João Paulo Cunha

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

- Brain imaging (&signals);
- Man-machine symbiosis with edge-AI (e.g. Brain-Computer Interfaces);
- Quantified Movement multimodal analysis in neurological diseases;
- Neurosurgery Aiding Systems;
- From Macro-to-nano bio-neuro-sensing.

5.4.2 Main objectives for 2023

Organisation, human and material resources

- To mitigate the physical distances between C-BER Labs (INESC TEC, FEUP, FCUP and UTAD), the coordination will organise several events during the year to increase our cooperation and share scientific knowledge;
- Two new members will be contracted to support new national and international projects approved in the end of 2022, allowing to increase our scientific production and impact;
- Some laboratories facilities will be improved, and new workbenches will be enhanced, namely the hardware and biophotonics workbenches and also the high performance computing servers;

Research (including publications, communications, datasets, artefacts)

- Active fund raising for the next R&D cycle and execute the current funded projects (namely new Horizon Europe).
- Maintain the publication and scientific outputs, raising the impact of those results as much as possible.
- Recruit the best students in the area.

Innovation (including knowledge valorisation and technology transfer). After launching iLoF-Intelligent Lab on Fiber (7M€ funding now in Series A) and inSignals Neurotech (100k€ pre-seed funding) start-ups in previous years, we plan to be able to attract funding to our start-up #3- **WeSENSS – Wearable SENsors for Safety.** We plan to license three patents – one on wearable bioinstrumentation (Patent PT109596/WO2018037389) and two other on advanced signal processing methods for biometrics (Patent PT109357/WO2017187422) and stress/fatigue detection (Patent PT110584/ WO PCT/IB2018/056558), aiming at developing a monitoring platform for safety & security of mission-critical professionals such as first responders, air traffic controllers or oil&gas workers involved in potentially hazardous procedures. We plan to support SAL's efforts in transferring the most recent Multiscope patent (Ref), by enabling contacts with relevant industry actors.

Under the scope of the TexBoost project, an utility model was submitted to the national patent office in 2022. The new Texpact project funded by PRR is a follow-up of the previous TexBoost project and it is expected that it may generate new IP to be transferred to the company members of the project consortium.

Dissemination (including events organisation). C-BER researchers are currently serving in the board of the IEEE Engineering in Medicine and Biology Society Portugal Chapter (https://embs.ieee-pt.org) and will lead (Chair & Co-Chair) the Organizing Committee of the ENBENG 2023 - 7th Portuguese Meeting on Bioengineering to be held in Porto, on the June 22nd 2023 at the *Fundação de Serralves*. This is the main national congress in Bioengineering in Portugal.

C-BER members plan to participate in 16 conferences, of which 14 will be international conferences such as the IEEE EMBC 2023 that will be held in Sidney, Australia or the ICASSP 2023 that will be held in Greece.

Internationalisation. A C-BER member serves as scientific director of the Carnegie Mellon Portugal program from the Portuguese Government & Carnegie Mellon University, USA.

C-BER members hold the Chair and Treasurer bord seats of the IEEE Engineering in Medicine and Biology Society at the Portugal Chapter board (https://embs.ieee-pt.org)

C-BER members have Associate Editor roles in several high impact scientific journals (e.g. Nature/Scientific Reports and Frontiers in Signal Processing.

5.4.3 Main actions planned for 2023

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

Table 5.4.1 – C-BER – Main planned actions

Action	Expected Outcomes
Raise the impact factor of our scientific publications	Raise the citations track-record (we have raised 30% in recent years and aim to continue this trend)
Establish R&D program contracts with spin- offs	Contracts and direct funding for early low/medium TRL outcomes aligned with spin-offs objectives
Promote focused efforts to attract funding to the two emerging lines of the Bioimaging Lab (Cardiovascular Imaging, Capsule Endoscopy)	Successful funding contracts (FCT, European, internal, Industry) for the two emerging research lines
Lead the Organizing Committee of the IEEE Portuguese Bioengineering conference	National visibility on the Bioengineering area

5.5 CPES - Centre for Power and Energy Systems

Coordinators: Manuel Matos and Ricardo Bessa

Assistant Centre Coordinator: David Rua

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 2023

Organisation, human and material resources

In 2023, the centre will review its present organisation in research domains and business areas (ongoing process), in order to share management responsibility more efficiently.

Present and future engagements will lead to expansion of the research team in all the scientific areas of CPES, with an emphasis in energy modelling and optimization. CPES will offer 10 grants for PhD students, 4 post-doc grants, and hire at least 20 researchers at MSc and PhD level. Contracting and maintaining specialised human resources is one of the main sources of concern in the present global circumstances. This 2023 plan of CPES assumes that no major deviations will occur, but contingency actions may be necessary.

CPES will extend the lab infrastructure for the management and control of EV vehicles fleet of INESC TEC and renovate the sensing and energy monitoring infrastructure of INESC TEC building for energy management.

Research (including publications, communications, datasets, artefacts)

CPES will continue to develop scientific research in the framework of financed projects and PhD theses and publish the results in international journals and in international conferences (IEEE Power Tech and EEM in 2023). Open datasets regarding indoor air quality indicators, EV chargers and other building performance variables will be created.

In scientific terms, priority will be given to data-driven models, federated learning and edge computing technologies, Monte Carlo tree search, convolutional neural networks and cross-entropy methods, decentralized energy-driven business models and algorithmic solutions for data markets.

This kind of research will be fundamental to address the emergent topics of the area, like renewable energy communities (REC) and distributed flexibility provision, power system resiliency with ageing infrastructure and climate change, uncertainty in planning and operation, green hydrogen, energy use in tertiary buildings, very large off-grid offshore wind farms and hybrid storage systems, and energy common data spaces.

Innovation (including knowledge valorisation and technology transfer)

CPES will continue to address timely challenges from the Society, namely through direct contracts with the industry and Portugal 2030 and Horizon Europe projects, with an adequate IP protection (pre and technical disclosures, patents) and software licensing. We also expect to study a potential strategy for open source (eventually aligned with Linux Foundation for Energy).

Some of the topics follow: define new services for transmission and distribution system operators (based on previous research developments, like preventive network management tools integrating the uncertainty of RES generation and loads), adoption of modular solutions to monitor and control relevant energy assets, based on interoperability frameworks, resilience against extreme events, platform for the operation of energy communities.

Advanced training

Besides new versions of the courses for REN and EPAL, development of materials and organisation of courses for energy efficiency education and energy poverty mitigation with CEVE - Cooperativa Eléctrica do Vale d'Este. Moreover, in the framework of PRR, courses for the decarbonization of the energy system will be organized with other academic partners, like IST and Faculty of Sciences of the University of Lisbon.

Continuation of the Power and Energy open webinar series on relevant scientific topics.

Dissemination (including events organisation)

Participation in relevant fairs (ETSI IoT Week, Enlit2023).

Members of CPES will participate in CIGRE (x2), IEEE (x2), IEA (Task 25 and 51) working groups / task forces.

Members of CPES will organise special sessions in three major conferences of the power systems area (IEEE Power Tech, EEM and IEEE General Meeting), and will also organize a tutorial session in IEEE General Meeting.

Joint participation with REN in the XIX Ibero-American Regional Meeting of CIGRE aiming at promoting the PS-MORA tool.

Internationalisation

CPES joined Iberdrola i-DE Global Smart Grids innovation Hub, having the opportunity to develop new partnerships with the largest Spanish utility.

Leverage on the results of H2020 InterConnect, HE ENERSAHRE and HE GreenDataAI projects to foster the participation in relevant energy dataspaces initiatives such as IDSA and GAIA-X.

Participation in standardization bodies such as ETSI and IEEE to provide contributions towards advances in standards and other normative documentation.

5.5.3 Main actions planned for 2023

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

Table 5.5.1 – CPES – Main planned actions

Action	Expected Outcomes
Demonstration of LV state estimation and voltage control tool and of MV and LV coordinated control strategies	Software prototypes validated in real environment (TRL 7) in H2020 EUniversal project
Development and validation of preventive and self-healing control strategies for improved resilience	Software prototypes validated in real environment (TRL 7) in H2020 EUniversal project

Action	Expected Outcomes
Demonstration of adaptive protection strategies for future smart substations	Laboratorial infrastructure and testing in the framework of P2020 SCALE project (TRL 5)
Reengineering of CEVESA market simulator for the Iberian electricity market with new functionalities	Enhanced software tool for market simulation with application in consultancy projects (TRL 8)
Development and operationalization of a digital platform for the operation of REC under the Portuguese regulation	Software and services for the actual operation of REC at TRL 9 and with licencing agreements with industrial partners
Consultancy on REC developments	Support to real REC design and implementations in different activity sectors
Development of a model based on Monte Carlo Tree Search for generation expansion portfolios under uncertainty	Publication of a Q1 journal paper
Development of advanced models for assessing the influence in the security of supply of the hydrogen-based scheme of seasonal production transfer	Participation in the wide public discussion about green hydrogen deployment and system integration. Support to public policy. Publication of a Q1 journal paper
Implementation of new features in the PS-MORA tool according to the specifications of the phase 2 of the project	New version of the PS-MORA tool (Dec 2023) – TRL 9
Demonstrate an interoperable cloud-based energy management system for domestic buildings	Demonstration in a large group of consumers (TRL 8) in the framework of InterConnect Portuguese pilot
Demonstration of a modular EV charger compatible with ISO 15118	Demonstrate in a real environment in the Portuguese pilot of POCITYF (TRL 7)
Conclusion of the Smart4RES EU project	Federated learning and data markets for renewable energy forecasting; predictive management of flexibility; for predictive inertia dispatch in isolated systems (TRL 4-6)
Conclusion of the AI4PV Eureka project	Digitalization of PV power plants. Machine learning for fault detection in PV inverters. (TRL 5)
Multi-technology optimization tool for offshore hybrid farms	Optimization tool for determining the amount of different offshore technologies to be installed (TRL 5)
Development of an algorithm to optimize the operation of multi-energy infrastructures considering network constraints, flexibility and CO2 emissions	New tool for energy infrastructure integrated management (TRL 5)
Development of an algorithm to optimise hybrid energy storage systems operation in isolated networks	Tool to optimise hybrid storage systems operation and extend its lifespan (TRL 5)
Development of forecasting algorithms for green hydrogen consumption and production in industry and mobility applications	Tool to forecast green hydrogen consumption and production
Improvement of our federated learning algorithms with data privacy for time series modelling and forecasting	Dual license open software code (academic and commercial use) and EPO patent (increase our family of patents in federated learning) – TRL 8
Intelligent edge control for electric vehicles charging	Algorithm and strategies embedded in the EV charger compatible with ISO 15118 (TRL 4)
Improvement of the data market prototype in IOTA and algorithmic solutions	Prototype aligned with the GAIA-X and common data space architecture and use cases
Finalization of the work about developing new alarm data representations (graph-based representation)	New ideas and concepts for smart alarm management in power systems that are aligned with on-going research in graph-based representations for AI

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 is a multidisciplinary research centre that contributes to a sustainable, resilient, and human-centred industry through systems engineering. It plays both roles of research and business partner in creatively co-developing solutions for complex challenges, and in developing the capabilities of industrial organisations for an on-going digital and green transformation. 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 aims at developing and researching innovative methods and tools for designing and managing more sustainable, resilient, and human-centred production systems. In this context, the focus is on the **design of adaptable production systems, decision-making processes for planning and scheduling, and continuous improvement of operations**.

RL2. Supply Chain and Collaborative Networks Management addresses the study of supply chains aiming to create knowledge that contributes to the development of strategies and models for sustainable and resilient supply chains and collaborative networks based on the use of digital technologies. The topics addressed are **circular supply chain models, visibility and supply chain strategies, and the role of public policies.**

RL3. Industrial Information Systems aims to develop new concepts of information systems for industrial management addressing a data-driven, sustainable, and circular industry transformation. The research activities are developed across **digital enterprise architectures, industrial data & information management, design and impact of Industrial Information Systems.**

RL4. Technology Management in Industry. focuses on studying the impact of the adoption and implementation of digital and green technologies on innovation, resilience, and circularity of manufacturing companies and their value chains. The topics addressed are **technology adoption, technology management, value chain strategies for the adoption of emergent technologies, collaboration strategies**.

RL5. Transportation and Logistics. aims at designing and developing innovative and integrated solutions for transportation systems, logistics and mobility services, thus contributing to the uptake of the circular and green growth economy. The two main dimensions of this research are **MaaS (Mobility as a Service) and inter-modal logistics and 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 along three areas: **Design and management of manufacturing systems, Industrial Data Driven Systems and Platforms, and Technology adoption and management.**

5.6.2 Main objectives for 2023

Organisation, human and material resources. In 2022 we achieved the objective of articulating the development teams with the RLs, aiming to implement the scientific strategy while maximising the scientific production of the centre. 2023 will be the year for refining this form of organisation but also to consolidate the scientific competencies by involving more deeply in research projects academics recruited during 2022. The goal of updating the technical knowledge and skills of most researchers in the fields of Data Science and Artificial Intelligence established in 2022 will continue this year. Moreover, we intend to reinforce the team in the sustainability and circularity area. The iiLab is pivotal for CESE in articulating research and innovation. 2023 will be the year of moving to the new iiLab space, fostering important research and development activities to support this evolution.

Research (including publications, communications, datasets, artefacts)

The 2023 objectives for the research lines are the following:

RL1. Manufacturing Systems Design and Management. In terms of production systems design, the aim is to investigate how optimisation and simulation approaches can help to design more adaptable and sustainable production. In the management dimension (planning and scheduling), we will contribute to the design of a reference framework to support decision-making in planning and scheduling for complex operations environments. In the continuous improvement dimension, the goal is to structure methodologies that help organisations to advance their continuous improvement systems, in contexts of uncertainty and high operational dynamics, and considering ever more demanding sustainability.

RL2. Supply Chain and Collaborative Networks Management. In 2023, we will study how the configuration of supply chains needs to change to face the complexity and uncertainty of current environments; in the context of the project ReSChape, RL2 will propose new technology-based strategies for innovative supply chain models and will carry out a cross country analysis of the existing public policies concerning supply chains in Europe in order to assess the regulatory readiness and the limitations of existing legislation. In this RL we will also explore new circular supply chain business models, especially for the textile, plastic, packaging, and food sectors within the scope of the SoTecIn Factory project.

RL3. Industrial Information Systems. In digital enterprise architectures we aim to deploy semantic asset administration shells to ensure semantic interoperability whilst guaranteeing traceability of data transactions. As a result of the TRF4.0 project, a proof of concept of a Digital Twin Enabled Platform Ecosystem will be developed. In industrial data and information management we are designing ontology development patterns, methodologies, and services to support circular product fair data design, enhancing interoperability and reusability of data, and boosting circular innovation. Finally, to research the design and impact of IIS we aim to publish a systematic literature review on digital transformation in industry through the lens of sociotechnical systems.

RL4. Technology Management in Industry. RL4 will continue to research the main drivers and barriers in Technology Management, developing strategies for the adoption of Human-Centred technologies such as digital twins, green technologies, IIOT Platforms and data management within the scope of projects Change2Twin and SoTecIn Factory, contributing to a green and sustainable industry. In addition, RL4 aims to develop frameworks and models to design new schemes for technology adoption and training in emergent technologies, within the scope of project AI-Regio, applied at the iiLab.

RL5. Transportation and Logistics. In terms of MaaS (Mobility as a Service), we expect to contribute for the design of innovative mobility services (both for people mobility and urban logistics), based on the co-creation of solutions and on digital platforms, and addressing the new e-commerce challenges and current environmental concerns, and providing more efficient, shared-connected and low-emission sustainable operations. In terms of inter-modal logistics and transportation systems, we expect to deliver a framework to support decision-making in intermodal freight operations and global supply-chains, through the use of synchro-modality in transportation networks and global supply-chains.

Innovation (including knowledge valorisation and technology transfer)

The 2023 innovation objectives are described below, alongside the innovation areas where the centre is working:

Design and management of manufacturing systems. We will continue exploring Reinforcement Learning algorithms to solve industry problems, for example in the allocation of tasks to resources in an intelligent and dynamic way. In the scope of the European project AI-Regio results are expected to support the decision to adopt these kinds of methodologies in real production environments.

Industrial Data Driven Systems and Platforms. To support the execution of several research projects, a general framework (NeoFramework) is being developed, finishing in 2023, that includes common and generic functions required by CRUD (create, read, update and delete) database-oriented information systems, both at the front-end and back-end elements.

Technology adoption and management. During 2023 we will continue to develop the advanced services aligned with European Digital Innovation Hubs, Technological Centres and other associations. These services include: access to technical expertise and testing, as well as the possibility to 'test before invest', and advanced training and skills development on technological adoption topics. Environmental, economic and social issues are also considered, in particular with regard to the use of digital technologies for sustainability and circularity.

Advanced Training. CESE will continue helping iiLab in consolidating its role as the training hub for most of the advanced training provided by the centre. In this area our 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.

Internationalisation. CESE has a strong and diverse network of international partnerships, particularly European partners, and will continue to focus on 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 substantial number of finished projects, and more approved for 2023. Other international projects reinforced our partnership with MIT in the area of sociotechnical systems development, and the participation in the Global Manufacturing Research Group and SCM4.0 is expanding our network in the area of supply chain management. One area that still need improvement is the internationalisation of the services provided by the centre. In 2022 we achieved one international contract together with CPES, but our goal is to identify (e.g., through EU tenders) EU companies that could benefit from value added services, in the scope of CESE's research and innovation activities.

Participation in the Industry and innovation Lab (iiLab). In 2023, iiLab will have a new physical site with improved conditions. Therefore, CESE will reinforce its activities using iiLab as a vehicle to boost its innovation and R&D project results, more specifically: (i) define roadmaps for the main CESE activities in iiLab, mainly creating synergies among project results, and advanced services and training; (ii) continue the definition and implementation of internal processes for the identification of training and services activities resulting from research project results; (iii) continue to pursue strategic partnerships with industrial companies, associations, and technological clusters, among others, to strengthen relationships.

5.6.3 Main actions planned for 2023

CESE will carry out the actions below, considering the prior objectives and its continued activity towards its vision.

Table 5.6 – CESE – Main actions planned

Action	Expected Outcomes
Develop services, models and methodologies to support companies in the adoption of Digital Twin, IIOT technologies and Industrial Data Management	We expect at least one of these new services provided during 2023
Include sustainability and circularity criteria in the services provided in the area of design and management of manufacturing systems	We expect at least one service provided with these new criteria during 2023
Include strategic data management as a key dimension in the centre's approach to digital maturity assessment of industrial/manufacturing	We expect at least one service provided with this new dimension during 2023

5.7 CRIIS - Centre for Robotics in Industry and Intelligent Systems

Coordinators: António Paulo Moreira and Germano Veiga

Assistant to the Centre Coordination: Luís Rocha

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, 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 main research topics. The challenges are related to the design of autonomous robotic solutions capable of robustly operating in harsh and dynamic environments with great efficiency and effectiveness. Challenges address semantic navigation, Long-Term SLAM, mobile manipulation, distributed and cooperative mapping, coordination of multiple robots considering communication failures and online deep learning for perception and navigation.

RL2. Intelligent Sensors and Control of Dynamical Systems The main research challenge 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, iv) crop yield forecast in the context of digital and precision agriculture. These AF topics are aligned with the Farm-to-Fork Strategy and are a critical step towards sustainability.

RL3.2D/3D Visual Perception, Advanced Sensing and Object Manipulation the flexibility of collaborative robotics is a composition of varied contributions, namely: simplified programming solutions, advanced systems interfaces, and new perception and manipulation capabilities. The ability of robots to recognize, locate and carry out object picking and placement, using trajectories without collisions, is of fundamental importance to sustain their autonomy. 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, and digital twin representations, among others.

RL4. Advanced Human Machine Interfaces the Centre is currently exploring 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 interact with complex production resources easily and intuitively. This system will be empowered with artificial intelligent methodologies to allow it to recognize, adapt and evolve in time with the user experience. Furthermore, with this adaptability and evolution in mind, the integration of such interaction systems with human and/or production line digital-twin representations will be investigated, as the latter could serve as a repository of valuable data about the human and/or production resource status.

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 or IT support systems), close collaboration with humans and continuous process learning. This requires a multidisciplinary work that includes 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 recognize and autonomously adapt its behaviour, not only to changes in the operational environment, but also in accordance with the human operator.

RL6. Advanced Robotics and Automation for Industry 4.0 with the advent of Cyber-Physical Systems and their utilization in an industrial context, it is of paramount importance to the added effectiveness of automatized 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 use of Industrial robotic systems on SMEs is in strong demand 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 digitization are being explored. The accumulated expertise in the different scientific/technological areas and a well-established network of partnerships, give the Centre a large set of tools to answer the most demanding challenges. In this regard, the Centre's goal is to effectively deploy a mobile manipulation solution for intra-logistic activities in the Retail industry soon. Furthermore, the centre will move forward with the integration of agile robotic systems in typical more challenging industrial environments for robotic systems, as is the case of the textile and shoe industries.

INOV2. Inspection, Control and Embedded Systems. The experience of the Centre will support the development of reinforcement learning-based approaches, auto-reconfigurable and self-parameterizable, to address 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. As part of the Centre's active presence within iiLab, a prototype for quality control of aluminium alloy casting parts based on the combination of machine vision and deep learning technologies will be installed.

INOV3. Cloud-based Robotics. This innovation path is materializing 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. To reach the ultimate level of precision and smart agriculture, the Laboratory of Robotics and IoT for Smart Precision Agriculture and Forestry has the mission to develop R&D in robotics, automation, and IoT based solutions, to improve the levels of smart precision (“right time, right amount, right place”) agriculture and forestry, and hence of profitability. The innovation line tackles this mission from two fronts: R&D in advanced and smart IoT solutions considering heterogeneous wireless networks; and R&D in modular, safe and swarm robotics systems for monitoring/phenotyping, spraying/fertilization, harvesting and pruning operations. In this line, R&D is focused on cost effective visual-based sensors, manipulators and small machinery equipped with advanced localization, mapping, control, and perception algorithms, considering the agricultural and forestry sectors constraints and needs.

5.7.2 Main objectives for 2023

Reinforcement of the coordination team to begin its renewal; continue to prioritize contracts for HR in projects (scholarships are not so attractive for those who do not intend to complete a PhD); optimize the use of material resources and equipment of 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, to 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 and making these datasets public to increase our visibility; try to find more fundamental research lines for the future and use these ideas to submit project proposals on all scientific areas; optimize applied research by carefully choosing the type of projects and their partners; trying to have fewer and larger projects and concentrating on CRIIS core knowledge.

Innovation (including knowledge valorisation and technology transfer) Trying to 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, analyzing, 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 (Industry 4.0/5.0, agriculture 4.0, IoT, VR, etc.) that monetize iiLab/CRIIS resources.

Dissemination (including events organisation) Participate in the organisation of some international conferences (ROBOT- Iberian Robotics Conference, IEEE-ICARSC - IEEE International Conference on Autonomous Robot Systems and Competitions, ICRES - International Conference on Robot Ethics and Standards, CLAWAR - International Conference Series on Climbing and Walking Robots and the Support Technologies for Mobile Machines, CONTROLO, ECPA...) 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 we want to cooperate with Wageningen University & Research, Institute of Robotics and Intelligent Systems (IRIS) from ETH Zurich, STEMS-CNR, EURECAT, CMU, MIT, and Lincoln Agri-Robotics; maintaining and promoting greater participation in national (SPR, APCA) and international (ROS-Industrial, euRobotics, CLAWAR Association) working groups/ interest associations.

5.7.3 Main actions planned for 2023

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

Table 5.7.1 – CRIIS – Main actions planned

Action	Expected Outcomes	Deadline
Move the Mobile manipulator technology for logistic operation towards TRL 8	Knowledge valorisation trough software licensing contracts.	October 2023
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 transferable to SME’s. These platforms will also be useful for industrial logistics and surveillance applications.	November 2023

5.8 CEGI – Centre for Industrial Engineering and Management

Coordinator: Lia Patrício

5.8.1 Scope, vision and activities

Centre scope and vision

CEGI is an international reference in systems engineering and management, with a focus on management science (operations research, operations management, business analytics and performance evaluation), and service science (human-centered approaches, and service system design and innovation). Building upon these scientific domains to advance knowledge and address classes of engineering problems in multiple application areas, its research can be characterized in three vectors: scientific domains, classes of problems, and areas of application.

The Centre leverages research competences in systems engineering and management with a vision of innovative technology enabled system solutions, and integrated and flexible value chains across industries. To address related challenges, the combination of the Centre's competences in its core scientific domains is crucial. Such vision will be materialized through a blend of qualitative and quantitative research for systems innovation, adequately handling available data from a systems perspective and providing robust solutions.

Contribution to society through knowledge transfer is also central for the Centre. Building on its experience, CEGI continues to develop advancements in Manufacturing, with a focus on logistics, production and operations. Additionally, it is contributing to the Energy sector with novel strategies for engaging citizens with sustainable energy solutions, asset management expertise and enhanced performance evaluation. Aligned with the EU agenda, it contributes to de-materialize processes and improve insights in the Health sector, and to sustainable operations in Retail and Agro-Food supply chains. The Centre also has contributions in Transportation and Mobility, through advanced decision-support systems for improved urban transport and shared mobility services.

SCIENTIFIC ACTIVITIES

CEGI's scientific domains focus on systems engineering, industrial engineering, and management, particularly on management science and service science. Building upon them, it tackles classes of problems covering the systems development life cycle, from understanding to conceiving, developing, implementing, operating and evaluating.

SERVICE SCIENCE

Service System Design and Innovation: The Centre will continue to research service system design and innovation, in B2C, B2B and B2G environments. Research covers customer experience with technology enabled services, citizen engagement with sustainable technology solutions, the design of technology enabled services in complex service systems, and service system transformation. To this end, the Centre develops conceptual and empirical work, using social science qualitative and quantitative methods, as well as design science research.

MANAGEMENT SCIENCE

Operations Research / Operations Management: The Centre will continue to contribute to several sectors within this domain. The main contributions will focus on advancing quantitative decision-support, namely for classes of problems within logistics, strategy, production and operations, and decision-support systems development. New real-world challenges will be tackled by developing hybrid optimisation methodologies, able to provide managerial insight and solutions robust to scenario changes, or quickly reactive in dynamic environments.

Business Analytics: Research under this topic will include methods and techniques in knowledge acquisition and visualization, and their application in forecasting and recommendation methods. In particular, they will address Marketing and Customer analytics and Artificial Intelligence for areas such as business, education and healthcare.

Performance Evaluation: This topic's main contributions include developing advanced efficiency and productivity measurement techniques, with insights and applications in sectors such as Energy, Health and Education.

EMERGING TOPICS

Systems innovation and transitions for sustainability. Systemic challenges such as climate change and the UN's Sustainable Development Goals (SDGs) require profound changes in sociotechnical systems such as energy transition. CEGI pursues research on understanding citizen engagement and designing smart energy solutions to foster a sustainable energy transition. Building upon these competences, CEGI is addressing more systemic challenges such as understanding and designing for system innovations and transitions toward sustainability, of value for areas such as Energy, Mobility or Healthcare.

Advanced decision-support in dynamic, uncertain and complex environments. New market challenges in an increasingly dynamic and uncertain setting, associated with a significant rise in data availability, require innovative and fundamental advances in quantitative decision-support methods. The key challenges that CEGI is contributing to are real-time and dynamic decision-making, responding to uncertainty with robustness, resilience, and innovative hybrid methodologies (e.g., combining Machine Learning with Optimization) to deal with the increasing complexity of real-world systems across sectors of applications

Sustainability in business models, decision-support and analytics. The UN's SDGs set new challenges for research on systems, with the rise of new business models and the need to further innovate on business analytics tools and decision-support methods to incorporate in a realistic and insightful way the social, environmental, and economic perspectives of decision-making.

INNOVATION ACTIVITIES

CEGI research is applied in multiple sectors, such as industry, energy, retail, agro-food, mobility, and healthcare.

INDUSTRY. CEGI has strong expertise in Industry 4.0 concepts, in particular: (1) advanced production planning and scheduling algorithms, (2) blockchain protocols over the supply chain, (3) asset management, and (4) intelligent algorithms for logistic operations. Through ongoing research, we expect to establish activities to transfer knowledge that has been developed (e.g., dynamic scheduling algorithms for collaborative human-robot production lines). Besides, in the Produtech R3 project, within the Recovery and Resilience Plan, advanced algorithms for logistic operations will be customized for different partners. These activities are tightly related to TEC4Industry.

ENERGY. Energy is a core area for CEGI knowledge transfer. Asset management, decision support and prescriptive analytics have improved industry processes, particularly predictive and prescriptive maintenance, and system planning. EU projects XFLEX_HIDRO and EURO_SCORES have provided exposure for international collaboration. CEGI has advanced the understanding of citizen engagement with sustainable energy solutions and developed novel strategies tailored to different contexts and citizen value cocreation styles, with the participation in EU project POCITYF contributing to its positioning in the area. These activities closely relate to TEC4Energy.

RETAIL & AGROFOOD. Over the last years, a set of PhDs at CEGI developed empirical and analytical methods for decision making in offline and online retail. This innovation line can now benefit from transferring such results to industry. In 2023, with project BeFresh, we expect to influence large retailers sustainability indicators. In the food industry, CEGI is also starting project InsectERA, targeting the creation of insect-based products, to promote the circular economy and leverage new solutions for sustainable transitions. These activities are closely linked to TEC4AgroFood.

HEALTHCARE. This area has evolved through close collaborations with public entities, namely hospitals and regulatory agencies. Service Design and Operations Research/Operations Management have contributed best practices to the sector. CEGI has researched patient experience and the design of technology enabled services for people-centered care. Collaborations are also targeting medical report digitalization, to develop Clinical Decision Support Systems, based on data treatment, extraction and inference. These activities are closely linked to TEC4Health.

5.8.2 Main objectives for 2023

Organisation, human and material resources. Academic staff, grant holders and trainees are expected to remain stable, while employees are expected to increase due to the new PRR projects. We will continue to foster the involvement of academic staff in the different scientific areas, and to assist hired researchers in improve their

R&D skills, motivating the teams to collaboratively search for national and international funding. The aim is to strengthen the teams and to help younger researchers develop scientific autonomy and proactively contribute to the Centre's objectives.

Research (including publications, communications, datasets, artefacts). The Centre will continue to publish high-impact papers, targeting quality over quantity, and further consolidate its international position across its research areas. This brings added external visibility to the internal work. From 2016 to 2023, the Centre moved from a negligible impact of EU Projects to 40% of its budget. These projects bring extra visibility and enhance our research. We will continue to target projects that are mainly geared towards research (e.g., FET calls), or other EU projects that can support the development of high-quality research.

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.

Advanced training. CEGI has traditionally hosted students from FEUP's Industrial Engineering and Management PhD Program. We expect to keep that strategy and expand it to other programs such as 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 Program Committees of international conferences. We will also continue organizing invited sessions in conferences, and foster regular meetings of the European Working Groups that we lead.

Internationalisation. CEGI will leverage opportunities brought by EU projects to improve its international dimension and get closer to strategic companies. The Centre will also pursue the development and consolidation of its international research network, and explore collaboration opportunities with strategic international partnerships such as CMU Portugal.

5.8.3 Main actions planned for 2023

CEGI will carry out the actions below, considering the prior objectives and its continued activity towards its vision.

Table 5.8.1 – CEGI – Main actions planned

Action	Expected Outcomes
Improve communication and teamwork among researchers.	Further explore synergies and cross collaborations among research areas.
Promote sessions to present and discuss research papers prior to submission.	Increase the chances of publishing in highly ranked journals. Increase peer-pressure for publication.
Leverage multi-annual budget allocation to support activities strategically relevant for the Centre, especially regarding the emerging research areas.	Increase submissions of projects in core and emerging areas, and establishment of new partnerships.
Promote internal workshops to transfer built-in expertise on EU project proposal and participation.	Increase overall participation in EU Projects with high research potential.

5.9 CITE – Centre for Innovation, Technology and Entrepreneurship

Coordinator: Alexandra Xavier

5.9.1 Scope, vision and activities

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

Scope:

- Research and develop theories, methods, and models to support sustainable innovation, with a particular focus on:
  - Innovation Management and Front End of Innovation;
  - Technology Management and Policy;
  - Technology Entrepreneurship with a focus on Business Model Innovation and Co-creation.
- Apply state of the art conceptual models and tools to Consulting Activities and Executive Training.
- Act as a transversal Centre for all Domains and TEC4s, contributing to 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 its main research challenge "Responsible and Sustainable Innovation", CITE develops the following research lines to support strategic innovation management, technology adoption and entrepreneurship.

RL1. Innovation Management & Fuzzy Front-End of Innovation (FEI). Strengthening the conceptual and methodological foundations of Innovation Management and the Front-End of Innovation, towards a responsible, ethical, and sustainable industry and society. Emphasis is placed on state-of-the-art innovation management frameworks, practices, tools, and metrics, building on an active participation in ISO TC 279 – Innovation Management.

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

RL3. Business model innovation. The strategic alignment between emerging technologies and business model innovation is becoming more relevant to the competitive environment. A cross-disciplinary approach to design business model innovation and new value chain strategies, as well as the exploration of new challenges of the circular and the sharing economies, 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 (RL4), that promotes Innovation labs, accelerator programs, executive training activities and offers mentoring, coaching, and business consultancy, having as main goals: 1) to develop entrepreneurial skills; 2) to facilitate the development of new technological enabled early stage entrepreneurial projects; and 3) to strengthen 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 providing advanced support in the assessment, implementation, and improvement of Innovation Management Systems and Technology Management, towards strategic management of responsible and sustainable innovations.

INOV3. EEN Portugal 2022-2025. Continuing the work carried out since 2015 by CITE, of running the international project EEN Portugal which aims to provide free advisory services to companies, and promote R&D and innovation capabilities and partnerships to support growth and expansion in international markets.

5.9.2 Main objectives for 2023

Organisation, human and material resources

Reinforce internal and external collaborations:

- Continuing the development of collaborations with SAL to identify opportunities for working together on the field of Technology Exploitation and Entrepreneurship and organise the support process for INESC TEC spin-offs.
- Continue the collaboration with ForestWISE in the European project FIRE RES to foster the development and adoption of innovative solutions in the forestry sector (RL3, RL4).
- As an active participant in project SmartHealth4All, continue to cooperate to explore all the opportunities to develop projects and explore new business models in health domains.
- Continue to develop new projects with positive net value to ensure financial sustainability and reinforce the team.

The centre aims at strengthening its team by attracting at least 3 master students and 2 new PhD students.

Research (including publications, communications, datasets, artefacts)

For 2023, the research highlights are:

- Effort will be put into working on a proposal to lead the scientific committee of the IAMOT Annual conference for 2024, one of the worldwide leading conferences in Management of Technology (RL2).
- Participate in four international conferences (with papers published in the conference proceedings).
- Submit six papers to international peer-reviewed journals, exploring RL1, RL2, and RL3.
- Submit one paper targeting practitioner audiences, transferring knowledge developed in the Turing project.
- Five PRR projects in cooperation with several centres will start, in which CITE will participate in research activities in the scientific areas of Business Model Innovation (RL3), and Value Creation, and Technology Exploitation (RL1, RL2), developing and applying several methodologies from RL4.
- Participation in two EIT Manufacturing projects, leveraging synergies with European organisations, to foster technology exploitation and entrepreneurship (RL2, RL3, RL4).

Innovation (including knowledge valorisation and technology transfer)

- Develop a Sustainable Business Model for offering Integral Executive Training on the topics of Strategic Innovation and Roadmapping, as exploitation of the activities developed in 2022, under the projects FIRE RES and Turing; prepare one training program for test and validation.

Advanced training

- Implementation of technological innovations, through advanced consulting services and tailored executive training, with a special focus on Innovation Management Practices, Co-creation methodologies for innovation, and Technology Management and Adoption.

Dissemination (including events organisation)

- Possible organisation of TMP (Technology, Management and Policy) Consortium annual meeting (postponed since 2020 due to COVID-19 pandemic).

Internationalization

- Organizing an International Open Innovation campaign to be launched in May 2023 under the FIRE RES project.
- Organizing an International Hackathon, targeting the Consortium and Stockholders of the FIRE RES project to develop innovative solutions for Fire Management.
- Participate in a European sector group under the project EEN.

5.9.3 Main actions planned for 2023

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

Table 5.9.1 – CITE – Main actions planned

Action	Expected Outcomes
TURING II	Develop and implement a training program on the topic of Technology Adoption (INOV2).
Every1	Technology Adoption; one paper in an international peer reviewed journal.
FIRE RES	Design and launch an Open innovation campaign for responsible innovations applied to the forest sector (RL4, INOV1); develop an innovation impact assessment tool, to be applied in the scope of R&D & innovation projects (RL1).
SoTecIn Factory	Monitoring industrial circularity challenges definitions in four value chains (RL4).
Vr2Care	Exploitation plan and business models definition for Smart Living Solutions (RL3).
SmartHealth4ALL	Exploitation plan and business models for health technologies; development of a public procurement and health technology assessment (RL1, RL3).
HfPT - PRR	Innovation management in healthcare – training sessions; technological evaluation advising; business model development support (RL1, RL3, RL4, INOV1).
EIT Jumpstarter	Organise and implement a local accelerator training for European projects (INOV1).
Advisory services to clients, especially on Innovation. under EEN-PORTUGAL 2022-2025	20 Companies supported (INOV3).
Nexus (PRR)	Development of a business model for monetization of private 5G networks (RL3).
InsectERA (PRR)	Creation of Insect Boot Camps to support entrepreneurs and an “Insectpreneur Centre”, mentoring entrepreneurial actors in creating new businesses (RL4, INOV1, INOV2).
ATE (PRR)	Developing an Open Innovation methodology for fostering new innovative solutions (RL4, INOV1).
Transform (PRR)	Exploitation plan for forest biomass (RL2).
Transpath	A capacity-building programme for SMEs on the topic of technology adoption regarding the transition path towards CO_2-neutrality (RL4, INOV2).

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 and 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, Large Scale and Special Purpose Computing Systems, Languages and Tools, and Computing for Embedded and Cyber-Physical Systems. In addition, 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 doctoral 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 personalizing their user experience and adapting the interaction to the context and the user profiles. This contextual availability of information triggers user motivation and highlights the benefits of the use of technology in daily life. Moreover, endeavours contextualized 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), Visualization, Digital Games, and Interactive Multimedia applications. The high-performance hardware and new algorithms push global illumination rendering to real-time, particularly in the digital games area and 3D movies production. Virtual and Augmented Reality applications can also take advantage of high performance and affordable hardware for distinct applications, particularly with the Industry 4.0 paradigm, providing new tools for planning, supervision, and operation. A significant trend is the integration of 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 Visualization is also a definite necessity to explore and provide knowledge on Big Data.

Information Management and Information Systems. Information systems have evolved from specialized systems operating on curated data managed at the institutional level to pervasive structures, incorporating different technologies and data from multiple sources. This evolution brings new technical and social challenges to information management 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 (LaSPeCS). The research addressed by the **LaSPeCS** area is focused on methods, algorithms, techniques, software tools, and compilers to map computations to the new and emerging computing systems. **LaSPeCS** also focuses on researching algorithms, data structures, and programming languages to cope with the heterogeneous, parallel, and distributed hardware support by those systems. The research findings can enable computations in devices with strict restrictions (such as the mobile and handheld devices) but also can contribute to more efficient embedded, cloud, and high-performance computing (e.g., in terms of energy consumption, scalability, and other performance requirements), empowering the competitiveness of companies and the innovation and research findings in many areas. This research track will also explore the opportunities for the development of custom or domain-specific languages and code transformation tools to help port applications across platforms or recover existing code basis.

Computing for Embedded and Cyber-Physical Systems. The development of embedded systems went from the small-scale development of isolated embedded monitoring and control devices to the development of complex, connected, system of systems, integrating hardware, software, control and the physical processes, in what is referred as Cyber-Physical Systems (CPS). Embedded and Cyber-Physical Systems are omnipresent in our environment, with applications as diverse as automotive autonomous systems, air quality systems, renewable generation control, being the enabler of the smart society. The CECPS research area focuses on research and development in (1) middleware for CPS, Internet-of-Things (IoT) and edge computing; (2) management of computation in parallel and distributed IoT/edge ecosystems; and (3) methods, tools and languages for the development, deployment and maintenance of embedded and cyber-physical systems software.

INNOVATION ACTITIVIES

[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, big data analysis and Digital Twins 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 systems.

[Platforms and Methods for] Personalised Health Research. This area focuses on empowering researchers in the health domain achieving evidence-driven science towards personalized treatments. It splits into two sub-areas: a) personalized Internet-based treatments; and b) human data storage, harmonization, and controlled sharing. Important trends and challenges include collaborative tools and methods for health research, leveraging on the FAIR principles, security, and privacy preservation. 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 visualization 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 specialized 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 Engineering; Enterprise Computing; Data Management Systems and Applications; Digital Business.

5.10.2 Main objectives for 2023

After a two-years period of refinement and consolidation of a new vision and objectives for the research and innovation activities of the centre, the main goals nowadays are on improving our scientific knowledge, competences, and research results.

Organisation, human and material resources. i) Establish the centre's vision and identity, internally in the centre and INESC TEC, and to all our research and industrial partners. ii) Select and explore new ways to improve the attractivity, motivation, and performance of our researchers, while shaping the culture of collaboration and knowledge sharing to enable medium to long-term excellence in research and innovation activities.

Research (including publications, communications, datasets, artefacts). i) Capitalize planned research projects' achievements and deliverables as publications, datasets, software prototypes, specifications, licences, and other kinds of artefacts (e.g., in projects Inno4Vac, VR2Care, INFRAVINI and ILIAD). ii) Pursue research in both established and new scientific topics, when relevant in partnership with other INESC TEC centres and research institutes. iii) Explore novel source-to-source compilation techniques related to performance engineering; novel customizations of Agile processes for safety-critical systems development; novel tools for code refactoring. We expect to be involved in the edition and writing of books and chapters, and to publish in relevant 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+, INFRAVINI, WalkingPAD project, Health and Space Recovery and Resilience Plan approved agendas), resulting in licensing of inventions and software copyright registrations.

Advanced training. Specialized 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 or involvement in organizing committees and chairing technical committees; iii) Participation in program committees of international events; Participation in events such as fairs, exhibitions or similar.

Internationalisation. Consolidation of participation in core scientific research networks (e.g. AIRR, EPOS, OGC, HiPEAC).

5.10.3 Main actions planned for 2023

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

Table 5.10.1 – HumanISE – Main actions planned

Action	Expected Outcomes
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.
HumanISE Dashboard	Increased internal awareness over key centre's activities, results and achievements
Disseminate and promote open positions of centre projects among Postdoc and PhD candidates	1 new Postdoc and 4 new PhD students
Mentor and support researchers to favour high-quality venues for publication of research results	Increase the 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 dimension and impact
Track 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, optimization 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; 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 through a human-centred approach.

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 digitalization and growing importance of AI systems by developing algorithms, methods and models that will help shorten the gap between collected data and knowledge, offer diverse modelling solutions and promote a high level and 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 while pursuing fundamental research goals.

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 2023 challenges:

- Improve causal inference from data using machine learning and Bayesian reasoning and use causal models for explainability and enable the transparency 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.

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 and consumer modelling. In **NLP** we pursue the semantic and adaptive extraction of narrative structures from news, clinical records, business reports and tweets, their understanding and visualization. Some important challenges:

- Improving online recommender systems with smart incremental ensemble models while 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
- Enhance narrative extraction and understanding from text in Portuguese (news and tweets)
- Enhance consumer behaviour by integrating distinct data sources describing the consumer journey

Modelling and Optimisation: Heuristic and exact methods are developed and applied to combinatorial optimization 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.

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

Genomic Data Science and Biomedical Data Mining: we develop the full data analysis pipeline for large scale genomic dataset obtained from high-throughput sequencing technologies. The overall goal is to obtain insights into the biology of health and disease by identifying patterns of variation across different tissues, conditions (i.e. Tumor vs Normal) and individuals in the population.

- Gene differential expression and functional enrichment between conditions.
- Analysis of gene network differential topology. Identify sub-networks specific of a given condition.
- Predictive models of gene expression for different traits, phenotypes or time from death.
- Integration of multi-omics datasets to obtain disease insights.
- Predictive models based on histological images (e.g. CNNs) for phenotype prediction. Link between image features and genes.

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.

Document summarization and management

- Document summarisation, extraction of keywords, mentions of participants and of relevant events in the following domains: medical, publicity and product complaints.

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.
- Development of systems for distributed privacy preserving Machine Learning (ML) that leverages Trusted Execution Environments (e.g. Intel SGX).

5.11.2 Main objectives for 2023

Organisation, human and material resources

LIAAD hired new researchers in 2022. At the same time, we have lost two of our key PhD researchers. Our HR aims for 2023 are the following:

- Consolidate the contracts with the current hired researchers.
- Hire new researchers under the Recovery and Resilience Plan (RPP).
- Increase the number of funded PhD students, who are ready for collaborating in projects and proposals.
- Increase project readiness by promoting a PhD forum.

Research (including publications, communications, datasets, artefacts). We plan to the number of indexed publications by FTE, 1.5 publications in indexed journals and 1.5 in weighted indexed publications. We have a good activity of publishing software tools and data. In 2023 we plan to contribute with new datasets and resources in NLP for Portuguese within the internal seed project PT.Pump-up. We also plan to publish 1 book authored by LIAAD researchers (Imbalanced Learning - Nuno Moniz and Rita P. Ribeiro, CRC Press).

Innovation (including knowledge valorisation and technology transfer). NLP, fraud detection and predictive quality are promising areas for knowledge transfer in 2023. The domains of application will be health, industry, publicity and finance.

Advanced training. We foresee concluding 7 PhD theses: Maria Pedroto, Shamsuddeen Muhammad, Thiago Andrade Silva, Pedro Teixeira Moreira, João Fernandes, Marta Moreno and Evelina Pereira. We organise a Summer School in NLP.

Dissemination (including events organisation). LIAAD is strongly involved in the organisation of the following conferences: **Discovery Science 2023** in Porto, EPIA 2023 in Faial, ECIR 2023 in Dublin, JOCLAD 2023 in Viana do Castelo. We continue the usual collection of international scientific workshops at main conferences: **Text2Story**@ECIR, **SoGood**@ECML/PKDD and **ORSUM**@RecSys. We are also involved in the **Datastreams** track at ACM SAC.

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.

5.11.3 Main actions planned for 2023

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

Table 5.11.1 – LIAAD – Main actions planned

Action	Expected Outcomes
NLP advanced school and associated events	Attracting students, companies and scientific partners
PhD Forum	Increase project readiness
Fintech event	Attracting projects
Internal scientific performance analysis	Increase scientific impact

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

ERC Starting Grant: Bruno Loff applied for and won an ERC Starting Grant for a project entitled "The hardness of finding good algorithms" where he is interested in answering the following meta-complexity question: “Fix some computational model (e.g., decision trees, communication protocols, data structure problems, etc.) and suppose we are given a full description of a computational problem and wish to find an efficient algorithm for solving it, or at least to estimate its computational complexity, how hard is this algorithm-finding/complexity-estimation task?”. Bruno became interested in this question when trying to prove computational complexity lower-bounds, and believes that it is a good angle with which to approach the most important problems in the field, on one way because it explains why attacking such problems is difficult, and on the other hand because it may help guide the way towards an eventual solution.

Logic Programming: participation in a survey reviewing the research in parallel logic programming covering the period since 2001. The survey is a reference for developers of logic programming systems and an engaging reading for anyone interested in logic and for researchers in parallel systems outside logic programming.

Quantitative Types for Programming Languages: usage of non-idempotent intersection types, also known as quantitative types, to build resource aware semantics for different extensions of the lambda-calculus formalizing different concepts of programming languages and proof assistants. So far, we focused on pattern-matching and global state. Work in collaboration with IRIF at Université de Paris.

Tight Types and Linearisation: usage of tight types to address open problems that relate the set of terms for which there is a possible linearisation with strong normalisation. Current work has led to type-based characterisation of the class of weak-linear lambda terms, given an answer to an open conjecture that related terminating terms and weak-linear lambda terms. Work in collaboration with *Universidade Federal de Goiás*.

Quantum Algorithms: in the classical RAM, if an algorithm uses M memory and, at any point in time, only m out of M cells will be non-zero, then we may recompile it into a compressed version by simulating the memory using either a hash table or a self-balancing tree. We showed an analogous result for quantum algorithms equipped with quantum random-access gates, i.e., for a Quantum Random-Access Machine (QRAM). We also showed that known quantum algorithms for many different problems are optimal, meaning that they cannot be made any faster. For example, for various problems in computational geometry, it follows that quantum algorithms cannot be more than quadratically faster than their classical counterparts. The argument can be made, then, that people who work on such problems should not concern themselves with quantum computing.

Hierarchical Higher-Order Graphs for Proofs: develop a graph-based tool for the representation, analysis and management of proofs using rewriting techniques over hierarchical higher-order graphs. The tool can facilitate the understanding of proofs and help to increase the interoperability and usability of proof systems, which is the key goal of an ongoing COST Action (EuroProofNet). Work in collaboration with King’s College London.

Semantic Graphs: development of a linked data crawler to collect interrelated semantic information; summarization of massive semantic graphs using namespaces; supervised extraction of narratives from semantic graphs.

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.

Tampered Photos and Videos Detection: exploration of innovative ways to detect manipulated images by presenting a confidence score, which may bridge the gap between lab models and real-life applications like social media images or smartphone filters. Creation of a new dataset with media content with filters, obtained from social networks and based on an existing dataset.

Automated Assessment of Programming Languages: improvement of teacher's user experience in managing pedagogical content with automatic assessment; assessment of simple web applications; development of a multi-language transpiler for educational purposes; authoring of collections of gamified exercises. Exploitation of new approaches to extract information from semantic graphs.

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). The source code is available for download at Github (https://github.com/jqmmes/jay).

Deep Learning Applications: development of deep learning models with applications to Biology (automatic species identification), astrophysics (automatic determination of stellar parameters from spectra) and indoor-location (determining the location within a building based on models trained on Bluetooth RSSI measures or on video frames grabbed in loco).

Privacy Management for Mobile Devices: following the crowd-sourcing campaigns performed on the COP-MODE project, a joint project with University of Cambridge and University of Coimbra, we have presented: (i) results of the field-study and characterization of the impact of user expectation of mobile app privacy; (ii) methods for prediction of privacy preferences that can act on behalf of users for added privacy protection; and (iii) federated-learning methods for prediction of privacy preferences in a secure and private manner (best paper award in ACM CODASPY 2022).

INNOVATION ACTIVITIES

Tampered Photos and Videos Detection: Google Chrome plug-in to detect the fakeness level of multimedia content in a webpage. A labelled dataset of 20808 multimedia files, which contains several state-of-the-art datasets of non-manipulated images and other subject to manipulation.

Fake News Detection: new dashboard for the Fake News identification system.

BioLens: web portal that includes several deep learning models to automatically identify animals and plants. Collaboration with the *Sociedade Portuguesa de Botânica, Parque Biológico de Gaia* and the *Museu de História Natural e Ciência da Universidade do Porto*. Software available at https://rubisco.dcc.fc.up.pt/biolens.

Indoor Location Systems: developing low energy, non-intrusive and low-cost indoor location solutions. Development of a testbed based on Ultra-wide band (UWB) devices for testing indoor location algorithms in physical or simulated environments and the use of WiFi-RTT as an indoor location technology through a data sampling app and offline evaluation of indoor location algorithms. Work in collaboration with the *Museu de História Natural e Ciência da Universidade do Porto*, where we have a pilot installation at *Galeria da Biodiversidade*, and developed in the context of project Safe Cities with Bosch *Ovar* and in the context of project Augmanity with Bosch *Aveiro* and other partners.

Applications to astrophysics: developing models that automatically deduce a star's physical parameters from a sample spectrum and the presence of exoplanets from stellar radial velocities time-series. We use deep learning techniques and tools such as regression algorithms and convolutional neural networks. Work in collaboration with Centro de Astrofísica da Universidade do Porto.

Cyber Threat Intelligence (CTI): development of a CTI search and sharing service using searchable encryption together with the imposition of data exchange policies, fostering the sharing of cyber security information and thus promoting greater resilience against cyber-attacks. Work developed in the context of project PANDORA EDIDP and in collaboration with the armed forces of several Member States of the European Union.

5.12.2 Main objectives for 2023

Dissemination & Internationalisation

A key objective for 2023 is to maintain CRACS's international visibility, notoriety and publication output. In particular, we aim to maintain the track record of publications by CRACS's members around a total of 50 publications in indexed journals and conferences. We also aim to maintain the numbers of international events organised by CRACS members, participations as editor in international journals and participations in program committees (we estimate the organisation of 2 events and the participation in 11 journals as editor and in more than 35 program committees). In 2023, we will start our participation in the Horizon Europe project PRIVATEER, which we hope will be a driving force for other successful projects, both at national and European level.

SCIENTIFIC ACTIVITIES

Continue the development of a generic high-level interface implementing synchronization procedures for memory reclamation in lock-free data structures. This is an essential step to enable a wider usage of lock-free data structures in modern multi-core programming environments where garbage collection is not available.

Continue the development of Autopsy modules to automatically detect artifacts in forensic images**.** Improve the work already developed on tampered digital photos detection.

Extend the Jay workbench for setting up, monitoring, and logging experiments with hybrid cloud topologies and the Jay framework for simulating the performance of task offloading strategies in hybrid cloud topologies.

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.

Continue work on privacy protection for location data, namely on the privacy risks beyond location traces – what can be inferred about user location from other sources of data – and on adaptively adjust privacy protection according to user velocity and report frequency.

Develop mechanisms for blockchain-based authentication in distributed and multi-cloud environments.

In the context of project PRIVATEER, starting in January 2023, we plan to (i) develop a Symmetric Searchable Encryption (SSE) mechanism based on a distributed reverse index that will enable Cyber Threat Intelligence (CTI) exchange between authorized entities when the CTI is stored in a Malware Information Sharing Platform (MISP) instance; and (ii) develop a toolbox of anonymization mechanisms for heterogeneous data types to cover the lifecycle of the 6G service chain and corresponding data types being used, such as traffic profiles, usage patterns, location, etc.

INNOVATION ACTIVITIES

Continue the development of the BioLens project by adding new deep learning generated models for new taxa, and by exploring different learning techniques to handle problems such as the scarcity of images for certain species.

Continue the development of low energy, non-intrusive and low-cost indoor location solutions. New software for managing a Bluetooth beacon infrastructure and for communication with smartphones within a venue.

Continue the development of artificial intelligence models applied to the detection of exoplanets from time-series of stellar radial velocities.

Public release of the first version of the data privacy framework, focused on location data and including privacy methods for other data types according to security and privacy requirements of ongoing and future initiatives.

Consolidate the Angi code playground as a learning tool with support for different forms of automated assessment, both on the client and server side, providing a good user experience to both students and teachers. Explore the creation of a gamification design framework in the educational domain.

Advanced training

Create a university-level Data Visualization course funded by PRR.

5.12.3 Main actions planned for 2023

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

Table 5.12.1 – CRACS – Main actions planned

Action	Expected Outcomes
Submit project proposals to national and European calls	Development of new projects and increased funding
Participation in project Theia with Bosch Braga and in the Horizon Europe project PRIVATEER	Reinforce expertise in the area and promote networking
Organisation of international scientific events (we estimate the organisation of 2 events)	Reinforce organisation experience and promote networking
As part of the JuezLTI and FGPE+ European projects, exploit the creation of a gamification design framework in the educational domain	Reinforce links with European groups working on automated assessment towards a new European Project proposal
Provide a labelled dataset composed of synthetic fake news samples. Develop a framework for assessing the utility of the generated data.	Consolidate and reinforce visibility on synthetic data creation and evaluation
Continue and reinforce collaboration with institutions related to Nature conservation	Growth of the BioLens initiative and its use by both the amateur and scientific communities
Continue and reinforce the collaboration with CAUP to tackle astrophysics problems with artificial intelligence techniques	Extend expertise in machine learning applications to other scientific domains

5.13 HASLAB – High-Assurance Software Laboratory

Coordinators: Alcino Cunha and António Luís Sousa

Assistant to the Centre Coordination: Catarina Leones Fernandes

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 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, Mathematics of Computing, or Quantum Computing. 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.

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 focuses on:

- **Software Engineering** – methods, techniques, and tools for rigorous software development, which 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** – minimize 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

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 2023

Organisation, human and material resources. To better cope with the increasing load of research and development contracts, in 2023 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). Concerning the number of publications, HASLab continues to experience some stagnation, even with a slight increase in the number of collaborators. In 2022, this issue was discussed in the aforementioned staff meetings, but no clear definitive reasons where identified that could explain this stagnation. In 2023, we will keep monitoring the current publication patterns, identify under- and over-performers, and keep trying to identify reasons that can explain such low or high productivity, respectively. As in 2022, this analysis will mainly be conducted in the monthly staff meetings.

Apart from the long-term goal of increasing the overall scientific productivity, we specifically intend to increase the number of publications in top international conferences (CORE A* and A) and top journals, as the publication in these venues continues to be sporadic. In 2022 we informally asked all senior researchers to define a publication plan that identifies research topics with potential to be published in such top venues, but in 2023 we will intend to be more strict about this plan, and ask researchers to disclose their ongoing submissions, including rejection/acceptance notifications.

Innovation (including knowledge valorisation and technology transfer). Technology transfer and industry contracts in HASLab has been decreasing, and is focused in a few specific competences (namely, privacy and cloud). This decrease jeopardizes the financial sustainability of the centre and a crucial activity in 2023 is to raise awareness for this problem and try to engage all senior researchers to actively seek new opportunities for cooperation with industry. We specifically aim to have 4 new industry contracts in 2023, ideally covering the three main areas of the centre. We also intend to keep raising awareness for the knowledge valorisation in HASLab, and in particular aim to have more invention disclosures. The service of the Technology Licensing Office (SAL) will be disseminated through all the HASLab's researchers, in order to promote direct contacts in this area.

Advanced training. In 2023 we foresee the conclusion of 5 PhD theses. During the upcoming year, we will also keep the mentoring program for PhD students, where they meet with the centre coordination, and focusing on keeping the research plan on track and defining a high-quality publication plan. Concerning MSc students, the HASLab internship program, which started in 2021, offers BII grants to students doing their theses in the centre. Since in the past years this program was quite successful, with some of these students opting to pursue a PhD in the centre, we intend to continue with this program in 2023.

Related to MACC, which involves the direct collaboration of some of the HASLab's researchers, during the next year some training sessions focused on the HPC fields will be promoted for different audiences.

Dissemination (including events organisation). Concerning the events organisation, some of the HASLab members will be involved in the organisation of at least the following conferences: INForum 2023 – *Simpósio de Informática* – which is the main national symposium in computer science; 35th Symposium on Implementation and Application of Functional Languages (IFL) - which aims to bring together researchers actively engaged in the implementation and application of functional and function-based programming languages.

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 intend to define a medium-term plan to submit proposals for organising more top-level international conferences or workshops, an action already planned for 2022, but which was not concluded.

It is important to highlight that the centre intends to keep presence on the media with the dissemination of some press releases (in a national and international level) related to the activities in the scope of the R&D projects, but also through the production of some opinion articles. We intend also to keep promoting the production of some scientific blog posts related to the main applications areas of HASLab, for example at BLOG@CACM. In 2023 we also intend to resume our internal regular scientific seminar, promoting the organisation of internal talks done by our researchers, but also by some invited speakers in the areas of the centre. The challenge here is identifying a format that is appealing to most researchers, to avoid the low attendance we experience in past seminars. The participation of our researchers in external events as speakers and experts will also be promoted. We will also organise an open day for students and potential junior researchers, to attract some attention to our activity and R&D job opportunities available in the centre.

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, chats and mailing lists; increase the presence of HASLab members in international professional societies, namely IEEE and ACM, namely promote the application to higher membership ranksMain actions planned for 2022

5.13.3 Main actions planned for 2023

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

Table 5.13.1 – HASLab – Main actions planned

Action	Expected Outcomes
Organisation, human and material resources: Continue with the monthly meetings with the senior researchers Attract new employees and new students	11 meetings 6 new R&D contracts 5 new scholarships for PhD students 15 new scholarships for MSc students
Research: Publish in top international conferences and journals Submission log Release datasets to the public domain	6 CORE A* and A papers Detailed analysis of scientific productivity 2 new public domain datasets
Innovation: Industry contracts Raise awareness for the knowledge valorisation	4 new industry contracts 2 new invention disclosures
Advanced Training: HASLab internship program to attract MSc students, Mentoring program for PhD students	15 MSc students Decrease mean time for PhD completion and increase the average number and quality of scientific publications per PhD thesis
Dissemination: Conference organisation Scientific seminar Open day for prospective students	2 organised conferences 1 conference organisation plan 11 scientific talks 1 open day
Internationalisation Attract foreign researchers	1 new foreign researcher

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 2023 of a selection of those research and technology infrastructures are presented below in this Section.

6.1 CLOUDinha Laboratory

The laboratory provides computational support to research and development activities of INESC TEC and University of Minho, providing bare metal, virtualization 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 one hundred 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 heterogenous 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).

As in previous years, 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, databases and AI frameworks
- Privacy and security
- Blockchain and Internet of Things
- Software engineering

The laboratory will continue to provide access to bare metal servers, where virtualized 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.

6.2 EMSO-PT Research Infrastructure

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 2023 are the following:

- **Deployment of a Turtle node with an EGIM system** – The EGIM system assembled at INESC TEC 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, ended in December 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.

6.3 iiLab - Industry and Innovation Laboratory

Unfortunately, for several reasons, the adaptation works of the installations for the iiLab have suffered delays, so it has not yet been possible to put them into operation. Thus, several of the objectives set for 2022 for the iiLab had to slide forward to 2023, so they are listed again here.

In 2023, in addition to concluding the new iiLab (PORTIC) facilities and equipping them, the intention is to carry out, in conjunction with various Centres, several actions already planned.

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 offer innovative and advanced training courses and educational programs, that have already been identified, mainly for companies.

For the year 2023, the main actions planned are:

- Monitor the final phase of the construction and adaptation works of the new spaces in the PORTIC building, as well as install and commission 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;
- Explore and develop innovative activities under the new iiLab infrastructure, including new research project proposals, services, advanced training and technology transfer activities based on the completed research projects results of the centres represented in the iilab;
- Complete the definition of a roadmap for technologies and technological concepts and put it into action;
- In accordance with the roadmap and taking into account the required material and equipment, develop and implement training actions that have already been identified (CESE, CRIIS and other INESC TEC Centres);
- Implement the communication and dissemination plan developed for the iilab;
- Promote new partnerships with companies, such as technology providers, in order to make more efficient technology transfer activities;
- Participate in educational research projects, at a national and European level, to develop new approaches to training and education initiatives (e.g. Confacts 2, Turing 2, TransPathCO2).

6.4 Laboratory of Communications

The Communications Laboratory (ComLab) was established in 2006 at INESC TEC's main building following a successful proposal to the Foundation for Science and Technology (FCT) under the National Program for Scientific Hardware Renewal (PNRC) with the aim of renewing the national scientific infrastructure, by financing the acquisition, updating and expansion of scientific equipment.

The ComLab, originally named "Optical Communications and Microwave Laboratory," has been constantly evolving over the years. In 2021, benefiting from funding from the National Roadmap for Scientific Infrastructures from FCT, the laboratory underwent a refurbishment having now not only excellent conditions for researchers (high quality illumination and air renovation) but also better conditions for carrying out experiments such as water supply, improved communications network infrastructure and uninterrupted power supply.

ComLab is composed of optical and electronic test equipment for R&D in electronics, optical and RF communications, including modulation/demodulation of RF signals using custom digital vector/analogue modulations as well as low frequency characterisation equipment and a 3D printing machine. An electrically large anechoic chamber (1.2 m x 0.6 m x 0.6 m) designed for evaluating different source antennas at mmWave bands from 67 GHz to 115 GHz is also available.

The laboratory is also equipped with Software Defined Radio (SDR) hardware, companion computing nodes and robotic platforms (e.g. drones, balloons, and robot dog), supporting networking research activities related to radio and acoustic communications targeting mobile air, land and waterborne scenarios. A small sized water tank gives support for the characterization and validation of optical, acoustic and RF underwater communications solutions.

The main objective of the ComLab is to support the experimental evaluation and testing of next generation communications solutions in a controlled environment, after they are evaluated in simulation and before they are tested in real-world scenarios. Toward this objective, the following actions are planned for 2023:

- Deploy initial versions of the vision-aided large intelligent surface and mobile base station, including the assembly of a multi-camera testbench suitable to test computer vision algorithms;
- Integrate a Low Earth Orbit (LEO) Satellite communications gateway in the laboratory giving support for new Wi-Fi and 5G-based backup communications solutions for emergency/disaster management scenarios;
- Extend the laboratory facilities to a complementary room enabling research on beyond 5G and 6G solutions in cooperation with a mobile operator;
- Contribute to a training session related to tools and instruments associated to vision-aided communications;
- Establish and build within the laboratory a test assembly suitable for the characterisation of biological tissues using optical signals.

6.5 Laboratory of Computer Graphics and Virtual Environments

The Laboratory of Computer Graphics and Virtual Environments in focus on the intersection of Computer Graphics and Human-Computer Interaction with a particular focus on Virtual Environments.

This research scope will be continued in 2023, by developing fundamental research on multisensory virtual reality and on ways of interacting with these virtual environments and digital content, and in close connection to the Immersive Learning Research Network (iLRN). But also, the lab will be developing projects for transferring this scientific knowledge to the industry, with close connections to the EIT Manufacturing and specific industries and other institutions.

There is a special line of technology transfer to be adopted in collaboration with CPES on the use of gamified applications towards reducing energy consumption in corporative buildings, on the scope of the current global context and of the UN sustainable development goals.

The MASSIVE VR laboratory will focus on both consolidating the fundamental research activities on multisensory virtual reality and on transferring knowledge to the industry. Regarding the fundamental research activities, several experimental studies are planned, allowing to output of 10 scientific publications in international indexed journals and conferences.

Knowledge transfer to the industry will be achieved by executing different projects with different partners. In addition, it will allow putting forward at least 3 immersive virtual reality prototypes that take advantage of virtual reality technologies for improving the training of specialised technicians.

The GIG lab will focus our work on researching novel ways of interacting with virtual environments and digital content. Namely, we intend to continue our research agenda regarding: (1) haptic and tangible feedback for increased presence in virtual reality; (2) ergonomic interaction techniques for prolonged usage of immersive technologies; (3) immersive analytics as an alternative to traditional 2D desktop visualization; and (4) approaches for authoring innovative multimedia content, such as 360 videos and spatial audio. We are aiming to obtain one publication in a Q1 journal (Elsevier Computers & Graphics), one publication in an A* conference (ACM CHI), 3 publications in other and international conferences and to start a new funded project.

6.6 Laboratory of Microfabrication

This microfabrication laboratory explores non-traditional microfabrication techniques based on femtosecond laser direct writing processes, ranging from high resolution tridimensional localized refractive index modification in transparent substrates to silica micromachining.

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); improve the currently fabrication set-up;
- Explore the creation of nitrogen vacancies centres on diamond.

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 INESC TEC which made its micro/nanofabrication equipment available on this infrastructure for widespread use.

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

The Laboratory of Robotics and Internet-of-Things (IoT) for Smart Precision Agriculture and Forestry was established in 2013. This laboratory has the mission to research and develop 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 2023 it was established the next objectives:

- Further research and develop the AgRob and AgIoT technology (TRL6) till TRL 8;
- Promote more technology transference (1 Start-up and/or licensing);
- Increase the in 20% the number of publications and patents;
- Organise two open days with our AgRob and AgIoT technology;
- Increase the international cooperation with relevant institutions in EU, Israel, UK, Brasil, USA and Australia;
- Promote the creation of three experimental pilots with lab technology (Vineyard, Orchards and Urban Greenhouses);
- Expand the laboratory to other INESC TEC centres members and increase the alignment with TEC4AgroFood Initiative;
- Increase the number of European Funded Projects;
- Explore new R&D lines with lower TRLs, such micro-robotics, agro-robotics-photovoltaic systems, and robotic algorithms in systems on chips.

6.8 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) and we are divided in 5 main research lines: Brain imaging (&signals); Man-machine symbiosis with edge-AI (e.g. Brain-Computer Interfaces); Quantified Movement multimodal analysis in neurological diseases; Neurosurgery Aiding Systems; and from Macro-to-nano bio-neuro-sensing.

BRAIN Lab also has a Stim-BRAIN Lab which has an f-MRI simulator fully equipped with 64ch video-EEG medical systems from Micromed, wearable EEG devices, video cameras, 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.

BRAINLab research group in the last academic year of 2021/2022 counted with 3 interns, 7 MSc Thesis and 4 undergoing PhD thesis and 1 concluded PhD.

BRAIN Lab strategy defined for 2022 was a success with scientific and internationalization achievements, mainly concerning high impact publication that increased our visibility and partnership with several European research groups and organisations that will endorse our international Network.

For the next year of 2023, we aim to continue this effort with 5 main goals:

- Leverage the high-impact computer vision technology that is being develop for epilepsy seizure quantification and classification monitoring. In 2022 new deep learning and 3D human pose estimation approaches were researched and publish in high-impact journals and conferences, being of high interest to further explore these methods within this research line;
- Jointly with our start-up InSignals Neurotech implemented clinical trials in 3 international clinical centres for Parkinson Disease patient's data collection. These trials aim to improve and validate at an international level the algorithms that are under development for the evaluation of Parkinson Disease motor symptoms;
- Attract more national and international student for internship programs and MSc and PhD Thesis;
- Pursuit the research and development of new personalized brain med-tech, making use of our multidisciplinary team (biomedical, electrotechnical and informatic engineers, psychologists, physics and clinicians) to create new knowledge in both engineering and clinicians' scientific communities;
- Integrate EBRAINS European infrastructure to increase our international visibility and possibly provide distinctive services to support this research community. During 2022 a huge effort was made to reach EBRAINS administration and to understand how BRAINLab could position itself in this recent European Infrastructure that is part of the ESFRI. With a closer relationship with EBRAINS in 2023, BRAINLab will pursuit new funding opportunities and will try to create a national node in the area of neuroengineering to support new research projects and clinical trials, bringing researchers from different fields and country closer to clinicians.

6.9 Robotics and Autonomous Systems Laboratory

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 Centre for Robotics and Autonomous Systems is also managing the TEC4SEA infrastructure in *Leixões*, an area dedicated to support sea operations and logistics. In the case of larger R&D projects, the Centre is also renting temporary laboratory space to support local development at supervision.

The main objectives of the Robotics and Autonomous Systems Laboratory for 2023 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 2023 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 2023 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.

6.10 Smart Grids and Electric Vehicles Laboratory (SGEVL)

TRANSVERSAL GOALS

Consolidate SGEVL capabilities regarding human resources and testing infrastructures considering the areas of energy storage, hydrogen, EV charging and real-time simulation.

Reinforce SGEVL infrastructure to improve its capabilities in supporting research activities in INESC TEC, provide services to industry and harbour training and educational activities in accordance with CPES guidelines.

Promote the exploitation of CPES research results, with creation of new added-value services for industry and production of relevant publications and patents. Make efforts to increase the dissemination activities and international collaboration with other scientific partners aiming to attract new clients and strategic partners based on the list of developed services. Dissemination of SEGVL website and production of support material.

SPECIFIC GOALS

Development of EV smart charging laboratory scale testbed, integrating an EVSE (Electric Vehicle Supply Equipment) with V2G capabilities (POCITYF and GreenDataAI projects). The testbed to be developed will enable the development of pre-certification services of EV smart charging appliances and also the development of new solutions ensuring interoperability between EVSE and other household/building appliances (Horizon InterConnect project). Besides the physical part, this test bed will also consist of a virtual part suited to test edge AI algorithms ("Green AI") for electrical mobility integrated in low voltage grids and Energy Data Spaces.

Implementation of a laboratorial-scale green hydrogen test-bed, allowing testing a PEM electrolyser and the control of its power electronic interface (under the GREENH2ATLANTIC project).

Implementation of a laboratory scale hybrid AC/DC microgrid (in the scope of SmartGlow project) with the objective of testing local control strategies for the interlink converter and energy dispatch of the microgrid.

Expand Power-Hardware-In-the-Loop (PHIL) testing capabilities to support real-time simulation of grid dominated inverters and of distribution network protection and automation systems. A PHIL based test system for smart substations and MV network automation will be developed (SCALE project).

Implementation of a testbed for low inertia power grids with grid forming converters, aiming to support the realistic emulation of static and dynamic behaviour of electricity grids with synchronous generator emulator targeting. The work will be mainly developed through MsC and PhD students.

Support the development of digital-twins namely for PV plants and power electronic inverters, aiming to develop new O&M tools for future and existing PV pants (Portugal 2020/Eureka AI4PV).

The laboratorial infrastructure will be reinforced next year with funding from the Portuguese recovery and resilience plan (PRR), namely with a test bed for battery storage systems and additional equipment to test and validate hybrid microgrid concepts.

6.11 Tec4sea Research Infrastructure

The TEChnologies for the Sea (TEC4SEA – www.tec4sea.com) infrastructure, finished the first implementation phase in December 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 2023 are the following:

- **Validation of services** – the definition of services was finalised at the end of the implementation phase. Validation tests were already conducted, but others are still needed, as new services are offered to the community.
- **Present itself to the world** – the end of the first implementation phase will be commemorated with a special event in the beginning of 2023. 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.

7 SUPPORT SERVICES

7.1 Legal Support Service

Manager: Rita Barros

The Legal Support, ensures the conformity of the activity carried out by INESC TEC with the National, European and International Law, seeking to prevent or limit the risk of the various actions carried out in the most diverse domains, always trying to follow the best practices in human resources, institutional relations, contracts, public procurement and personal data protection, working together with the other services in the pursuit of the most appropriate solution for the Institution.

In this sense, it will have the following objectives in 2023:

- Contracts: continue to ensure that the highest standards of quality are met in the drafting of legal acts. safeguarding internal interests, but open to external contributions that ensure the guarantee of INESC TEC's strategic position;
- Public Procurement: raising awareness of the importance of the figure of the contract manager in public procurement and of the different frameworks to which the institution is subject;
- Promotion of Internal Partnerships: promote greater synergy with the Services with which it most directly interacts, in order to optimize the joint response, ensuring presence in the various stages of project construction (applications) or proposals;
- Labour Law: continue to assist the review of labour contracts 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;
- Create Awareness for the EU Directive as well as for the respective national Whistleblowing legislation and the protections that whistleblowers are entitled to under it;
- Awareness-raising on the subject of Dual Use, promoting the respective and appropriate training with the AT;
- Support for the implementation of the Compliance Programme for the Prevention of Corruption.

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.

The main objectives and actions planned for 2023 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.

7.3 Management Control Service

Manager: Vanda Ferreira
Assistant Manager: Bárbara Maia

Considering the main areas of activity, such as internal control, control of Contract Research projects, and control of funded projects (National and European), the service has the following main actions planned for 2023:

- Continue the development and implementation of management guidelines and internal procedure manuals;
- Regarding the projects, we intend to improve the project's digital dossier and we will schedule regular meetings with the IR and/or centre coordinators;
- We also propose to define and review workflows related with our catalogue of services, such as, for example, submission of payment reports, or requests for issuing invoices;
- Collaboration in the search, selection, and implementation of a new management information system (ERP);
- Implementation of tools for improving the automation of the consolidation of information for payment requests, among others;
- Implementation of new and appropriate internal management tools, based on Power BI or others;
- Concerning internal control, we plan to simplify and automate quarterly processes and improve the HR budget control.

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.

Activities in the Strategic Development Area

In detail, during the year 2023 the following activities will take place:

- **Approve and implement the role and competences policy**: validate and implement the role and competencies policy, as well as the job descriptions for all the positions and the respective competency catalogue;
- **Elaborate and implement the career policy**: integrate EC (Executive Commission) feedback on strategic guidelines; elaborate (in accordance with the role and competences policy) and validate the career policy;
- **Elaborate and implement the new performance appraisal policy**: incorporate EC feedback on the strategic guidelines and develop the performance appraisal policy; assess and incorporate appraisal components, described on the strategic guidelines already delivered on the current performance appraisal process;
- **Remodel and implement the new welcoming and onboarding policy**: conduct a new and revised onboarding process based on the novel developed contents and materials;
- **Approve, design, and implement the training policy:** present to the EC the results of the expert working group (GTE); elaborate, validate and implement the training policy;
- **Design, elaborate and implement 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;
- **HR Excellence in Research Award (HR4R) –** definition of the strategic plan that conforms to the European Charter and Code for Researchers.

Activities in the Operational Area

In detail, during the year 2023 the following activities will take place:

- **Improvement of HR processes** on internal platforms;
- **Increase information sessions about new internal rules, procedures, and labour legislation /** scientific employment to reduce workload, time of processing and error occurrences;
- **Process internal reorganisation;**
- **Continuous update of HR documents available on the intranet and website**, including the creation of the HR Guide and FAQs;
- **Improve the response time** of the service;
- **Review of benefits attributed to employees and their dissemination** on the intranet;
- **Work on a more attractive welcoming template / video regarding the duties and rights of employees**;
- **Providing personal documents on IRIS** so that employees can consult it (contracts, addenda, edicts, receipts, training certificates...);
- **Availability of a training registration module for employees.**

7.5 Management Support

Manager: Isabel Macedo

The Management Support Service will focus its activity for 2023 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 endeavour to achieve the following objectives:

- In collaboration with SIG, development of new visual tools in order to enhance the use and interpretation of the institutional strategic performance indicators;
- Completion of INESC TEC's Document Management Policy with the integration of a record conversion procedure;
- Conclusion of the reorganisation process of the institutional archives in collaboration with the respective support services;
- Deployment of an INESC TEC Open Access Policy, for both scientific publications and research data;
- Restructuring of the INESC TEC´s Documental Repository mainly to facilitate document browsing, improve overall quality of the metadata, and to comply with open access policies for publications;
- Boost of the area of continuous improvement towards business processes' analysis and improvement, fostering cross-Services actions and collaboration;
- Ongoing participation in research data management related initiatives, both nationally and internationally, such as the EOSC Future User Group.

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 17 employees, develops their work directly under the responsibility of a coordinator within a structure, centre or 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 14 Assistants that support the Research Centres and Services.

Each manager supervises its 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.

Main objectives and actions planned for 2023

1.	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;
2.	Implement updated and accurate activity indicators to be applied to the team;
3.	Training of the team regarding the use of CRM as an institutional contacts database;
4.	Organise training sessions of MS Office updating and Event Management;
5.	Organise networking initiatives such as “Assistant Day@INESCTEC” Workshop and “Strategic Thinking - a Joint Vision”;
6.	Monitor the execution of the new Travel Agency contract.

7.7 Funding Opportunities Office

Manager: Marta Barbas

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. To accomplish these objectives, the service will implement the following actions:

- Recruitment of a new element for the team, to reinforce the capacity to explore new funding opportunities and to respond to increasing researchers' demands;
- 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;
- Organisation of tailormade workshops to present funding opportunities to specific groups of less proficient researchers (particularly junior researchers) or to specific calls or programmes (p.e. ECTenders);
- Improvement of "proposals workflow" in articulation with SIG;
- Development and implementation of a new area in the internal website for funding opportunities in order to guarantee an effective dissemination among all INESC TEC community, segmenting information and providing researchers the best practices in the proposal stage.

7.8 Technology Licensing Office

Manager: Daniel Marques de Vasconcelos

The INESC TEC Technology Licensing Office (TLO) will continue its transformation into a Knowledge Transfer Office in 2023. With the aim of consolidate its strategic role at INESC TEC, the office will pursue the following objectives:

- **Fine-tune the systematic follow-up of strategic INESC TEC projects** by developing new rules and tools to ease the identification of new R&D results, the organisation of these R&D results in a database, and their valorisation in future projects and business opportunities;
- **Continue the implementation of the new market-driven IP portfolio management including a Tech Review Day with external advisors and look for synergies with TEC4s** to increase the number of commercialized R&D results and the IP revenue;
- **Co-develop a Spin-off Committee** with the Board and CITE to follow-up INESC TEC spin-offs and assess new entrepreneurial projects based on the INESC TEC's IP;
- **Strengthen the network** with national and international key players and **promote INESC TEC as a European reference in knowledge transfer** implementing international KPIs to benchmark evaluation;
- **Offer hands-on training in tech transfer** to INESC TEC researchers and to students who would like to have a first experience in the field that could team-up with the present tech managers to boost the outreach of scouting and pre-commercialization activities.

7.9 International Relations Service

Manager: Andreia Passos

As a young service, the SRI must consolidate its role in the organisational chart. This means streamlining its operations and processes while continuing to look out for innovative ways to help INESC TEC improve its international standing. However, the walk towards this consolidation has been made somehow challenging by staff turnover, with efforts to create a permanent core team failing short of expectations. Overall, the service's objectives remain the same as last year: to carry on supporting INESC TEC's international standing as a Science & Technology player, 2) keep track and disseminate information about the global setting in matters of interest to the institution's stakeholders; 3) enhance high-impact international collaboration through targeted support; 4) help foreign staff settle in, and 5) contribute to raising the institution's international profile.

For 2023, the SRI is set on the following actions and goals:

- **Lay down the Board of Directors' vision for internationalisation.** In the past, right after the service creation, small steps have been taken to enable the organisation to articulate and communicate its international commitments. The SRI intends to draw on past efforts and help the BoD put forward a document with the principles INESC TEC adheres to in order to deepen its global engagement while allowing for room for bottom-up internationalisation initiatives.
- **Carry on assisting in bilateral and multilateral cooperation**, taking advantage of individual initiatives that may leverage international agreements in areas deemed strategic for the institution and strengthening existing international institutional partnerships. This action breaks down into:
    - Organising tailored training for our community on topics such as "trusted research" or "intercultural competencies in international research collaboration";
    - Working closely with INESC Brussels Hub to ensure that our international aspirations converge as much as possible with EU agendas and programmes;
    - Putting in place a monitoring procedure to track the progress and outcomes of signed MoUs.

  At the same time, the service will continue to support FCT in coordinating and implementing the long-standing global partnership with the University of Texas at Austin, particularly in preparing for the next funding cycle.
- **Carry on supporting inbound and outbound research mobility processes**. This entails:
    - Continuing to work closely with HR to help the institution expand its talent recruitment base abroad, considering the Centres' recruitment needs and requirements; INESC TEC's commitment to a working environment supportive of diversity and inclusive of difference; and critical external factors affecting global recruitment and talent retention;
    - Improving support to foreign newcomers by using feedback reports from Welcome Appointments and Mobility Reports to align our assistance with newcomers' expectations and needs;
    - Launching a new edition of INESC TEC International Visiting Researcher Programme, bracing for an upgrade of the first pilot based on previous results and lessons learned while incentivising the participation of our staff in international mobility schemes.
- **Contribute to enhancing the institution's standing as an institution of choice for talented researchers from all over the world.** This action intertwines with action no. 3 but is also very much contingent on compelling communication of INESC TEC's success stories in the international arena. We expect to work with SCOM to spot and give visibility to these stories and improve how our website communicates the institution's global engagement.

7.10 Communication Service

Manager: Joana Coelho

The Service's strategy for 2023 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 2023 are divided in two main axes:

- External communication, through two main actions:
    - A reformulation of INESC TEC's website, to properly answer to the current needs of the institution's community and to better target the institution's stakeholders;
    - A reinforcement in terms of Science Communication contents to disseminate the INESC TEC research and innovation activities and outcomes among different audiences. Besides the Science & Society Magazine and other types of contents available at INESC TEC's Magazine (BIP), new science contents, such as illustrations, long articles and multimedia items will be one of the main focuses of the service.
- Internal communication, through:
    - A diagnosis of the actual internal communication procedures in order to later set up a strategic communication plan capable of: 1) providing internal tools that allows collaborators to easily access information about the institution (ex: scientific and innovation activities, achievements, etc.); 2) informing in a most effective way the collaborators about what happens at INESC TEC; 3) involving the different communities; 4) retaining INESC TEC's 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.

Besides daily support in the utilization of resources (e.g. network access, telephony, hybrid events, printing, etc.), permanent activities of the service include the continuous monitoring of the infrastructure, namely to allow for preventive and corrective measures. Strategic modernization and improvements (concerning e.g. performance, scale, security) is also conducted, for example in the provisioning of datacentre resources, network equipment, videoconferencing facilities, printing park, etc.

Besides the aforementioned activities related to INESC TEC's communication infrastructures, its associated services and connections to external entities, the Networks and Communications Service will particularly focus during 2023 in:

- Modernizing the WiFi infrastructure, namely by:
    - Starting a replacement procedure in order to evolve to new standards like IEEE 802.11ax (WIFI 6 / 6E) or WPA3, for enhanced performance and privacy;
    - Implementing the RadSec protocol, which substantially improves the security and reliability of the authentication process across institutions (e.g. eduroam);
    - Adopt and Implement the OpenRoaming framework, which aims for an open mechanism for guest access using federated authentication (e.g. Apple, Google, Microsoft, etc.).
- Enhancing the cybersecurity maturity, namely by:
    - Further tune and streamline cybersecurity processes like detection, tracking and event response;
    - Enhance the off-site disaster recovery infrastructure;
    - Elaborate contingency plans and define resiliency tests with failure simulations;
    - Review the various lab and IoT (sub-)networks, assessing them under a cybersecurity point of view, in order to suggest, plan and implement changes towards a safer environment;
    - Other punctual measures that contribute to lower the overall cyberthreat exposure.

7.12 Management Information Systems Service

Manager: José Carlos Sousa

The service strategy for 2023 is to improve the development and maintenance of INESC TEC's management information system. To cope with the currently increasing workload, the service has been planning to hire one new collaborator.

Besides the maintenance and continuous improvements of the website, processes and INESC TEC Information System (IRIS), next are highlighted the five main objectives and actions planned for 2023:

- Prepare the current ERP system renewal and bulk data migration;
- Complete the integration of timecards management with the INESC TEC information system;
- Replace the current network management application (NetDB) by a new and extended implementation;
- Develop multilingual support of intranet system;
- 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

The System Administration Service is responsible for managing servers, computers systems and common applications, and for providing support to end-users, administrative staff as well as research and development teams. SAS is a member of the multidisciplinary Data Protection Team, appointed to support and monitor the implementation and compliance with the GDPR.

The SAS strategy for 2023 is to continue improving the computing infrastructures, the collaborative applications, evaluate MLOps platforms, and continue to increase the overall security at both servers and users' computers.

Besides the maintenance and continuous improvements of the infrastructures and services provided by SAS, and assisting the Data Protection Officer to enforce the deployment of the GDPR, next are highlighted the five main objectives and actions planned for 2023:

- Computing infrastructures: SAS will continue expanding and improving the computing infrastructures to deal with the growing demand of resources and technologies. New GPGPU computing nodes will be installed and the CCloud computing infrastructure will be extended to offer Virtual machines with GPU support. Storage capacity will be extended to meet the growing demand for research data storage;
- MLOps: as part of INESC TEC's strategy to improve the DevOps culture, SAS will closely evaluate new Machine Learning Operations (MLOps) platforms with researchers to increase Machine Learning resources and overall GPU utilization efficiency;
- DevOps. SAS will hire a collaborator to promote and improve DevOps ecosystems;
- Security. SAS will continue extending the Disaster Recovery site with new application services in collaboration with SRC;
- SAS will look for a solution that can guarantee the availability of the SAPE server in the medium term.

7.14 Infrastructure Management Service

Manager: Jorge Couto

The Infrastructure Management Service guarantees the support services necessary for adequate management and maintenance of INESC TEC's building and infrastructures.

Overall, for 2023 a set of measures to improve the conditions for co-workers is the priority of the service, with a set of actions in the headquarters buildings, the conclusion of the iiLab building and the creation of a new room in the Vila Real pole in UTAD.

Additionally, we will support the R&D Centres in the management of the outsourcing car rental, an innovative service that will reduce operational costs and provide a significant gain in time and comfort to users.

In detail, during the year 2023 the following activities will take place:

- Replacing the heat-reflecting films on the windows of building A;
- Install inverter panels in the distribution transformers to facilitate their power supply by generator, during annual maintenance and during breakdowns;
- Increase the number of solar panels to increase electricity production capacity, and continue to replace lighting with LEDs;
- Carry out a fire drill to test the self-protection measures and respective teams;
- Reduce the heating costs of headquarters buildings by installing a heat pump in the circuit;
- Renewal of the cafeteria spaces (in A and B buildings) to increase comfort and efficiency at lunch time;
- Installation of EV charging points in the parking lot in front of headquarters, to allow the implementation of a cross benefit system that provides electricity for co-workers as exchange of sustainable behaviour;
- Overall refurbishment of B building interior, namely with repairment of walls, painting and lighting of open spaces and offices.