



Research Infrastructure

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Executive Summary

This document outlines the Research Infrastructure (RI) for the BIG project, the current state of development, the plans and the weaknesses, challenges and opportunities that exist to successful execution of the plan.

1. Introduction

“Research infrastructure” means facilities, resources and related services that are used by DCentral to conduct top-level research in Computer Science, Design Innovation, Human Computer Interaction, Economics and Architecture in relation to Blockchain technologies. It covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communications Technology-based infrastructures such as grid, computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research. Such infrastructures are either “single-sited” at Técnico or “distributed” (an organised network of distributed resources) across the network of stakeholders involved in the project.

The aims of the research infrastructures are:

- 1) **Interdisciplinarity:** the combination of multiple academic disciplines into Blockchain technology. It draws knowledge from several other fields like computer science, design anthropology, psychology, economics, etc. and achieve academic excellence by thinking across boundaries, strengthened by the technological and knowledge experience of INESC-ID and LARSyS.
- 2) **Interoperability across the network of stakeholders involved in the project:** an information technology or systems engineering services to allow for open information exchange across labs, researchers, and academic department with the use of an academic committee devoted at allowing this cross-disciplinary cooperation. Open access data of the project across the DCentral, European Commission and Portuguese Government.
- 3) **Experimentation with Blockchain technology to advance cross-cutting research practices in multiple areas of Engineering, Computer Science, Economics and Design Innovation.**
- 4) **Adoption of novel methodologies to achieve excellence in research.** The adoption of novel methodologies depends on the facilities and labs infrastructure present at Técnico and its affiliated labs.

Research infrastructures can include:

- major equipment or sets of instruments
- knowledge-related facilities such as collections,
- archives or scientific data infrastructures

- computing systems
- communication networks

Such RI are aimed at creating world-class *sustainable* research infrastructures that are open and accessible to the best researchers from Europe and beyond. RI are designed to support scientific advance and innovation, and to enable open and excellent science in accordance with FAIR principles, alongside activities to create research communities across Europe and beyond. RI should also assist in achieving the Horizon Europe strategic plan, which sets out four strategic orientations for research and innovation investments under Horizon Europe for the next four years:

- Promote open strategic autonomy.
- Restore ecosystems.
- Make Europe climate neutral & digitally enabled.
- Create a more resilient & democratic European Society.

Within Horizon Europe, there are specific areas of intervention:

- Consolidating and developing the landscape of European research infrastructures.
- Opening, integrating and interconnecting research infrastructures.
- Reinforcing European research infrastructure policy and international cooperation.
- Consolidating and developing the innovation potential of European research infrastructures and activities for innovation and training.

2. BIG Infrastructure

The research infrastructure is composed of facilities, labs, resources, and related services at the disposal of the Big Project and the ERA Chair Research Team. They provide different set of skills and expertise in relation to interdisciplinarity, interoperability, experimentation and adoption of new research methods in the area of Blockchain technology and Design Innovation. LARSyS and INESC-ID are responsible in managing the daily-operation of the research infrastructure, ensuring the processes and actors/organizations needed for the collection of data, storage, maintenance, distribution and (re)use of data by the different end users in the BIG Project. The ERA Chair team is responsible in overseeing the research agenda of each lab and promote Blockchain and Design Innovation knowledge to achieve excellence in research.

2.1. Implementation of Research Infrastructure

Implementation of the research infrastructure depends on the cooperation between LARSyS, INESC-ID with the ERA Chair team. This develops competency and ensures the success of the project. Internal administrative practices or operations are necessary to implement this program. Up to date, support can be acknowledged. Marta Candeias Pre-award officer of EU Horizon Funding at Instituto Superior Técnico, has organised three training programs:

- i) EU Funding Session-Networking: Topics discussed include: EU funding programmes such as Hop-on, the European networks & initiatives, and Horizon Europe, Networking among Research organisation, Political Landscape of EU funding streams.
- ii) Implementation of the research infrastructure was aimed at securing sustainable funding streams for the implementation of the research project of DCentral rather than creating the digital or physical research infrastructure of the project.
- iii) Moreover, former officer of DCentral Andreia Cavaco identified the following companies EMDESK, EUROPA MEDIA, ENSPIRE SCIENCE, offering free training regarding EU finding.

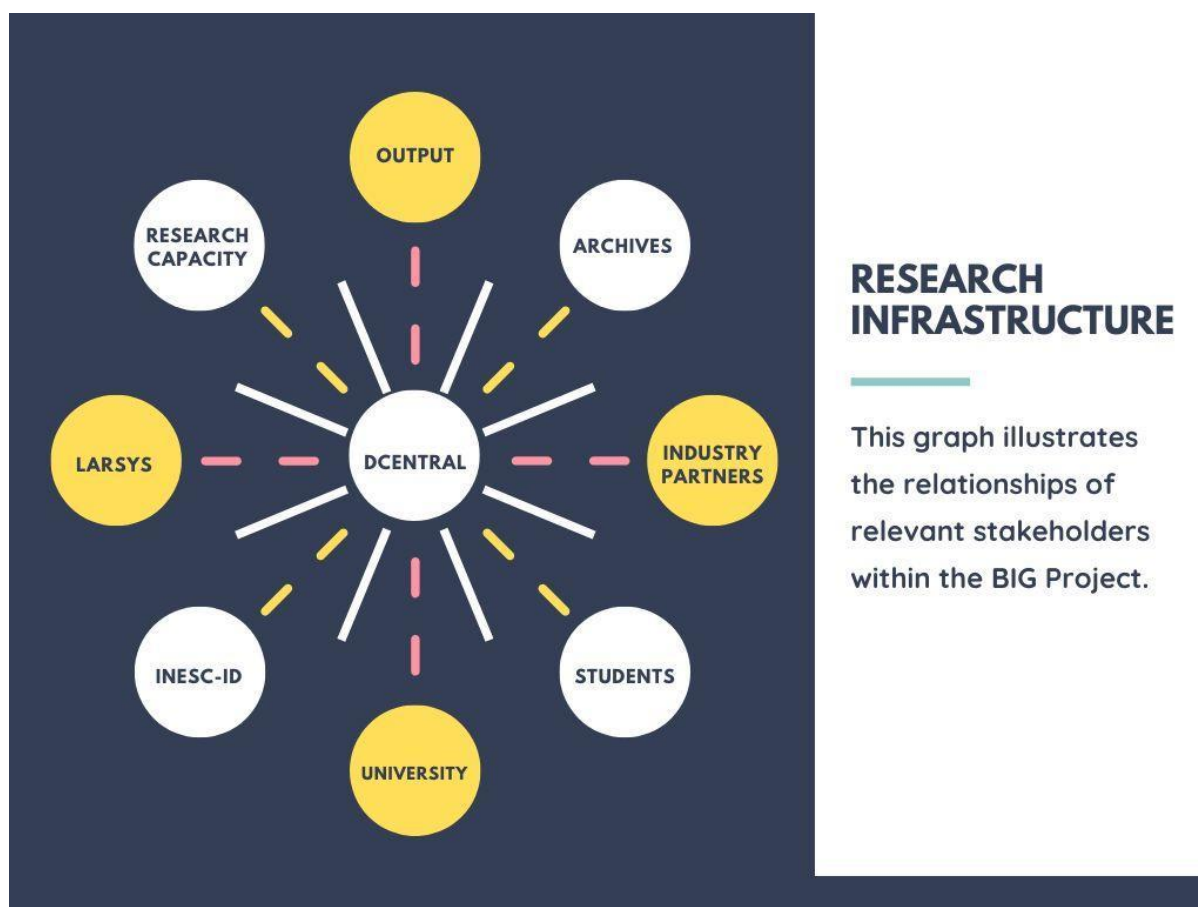


Figure 1 – Research Infrastructure

2.2. Facilities

Since 1996 Portugal adopted a flexible layer of R&D Units of the researchers' initiative, with boundaries crossing the rigid structures of universities, their schools and departments. This model leads to a direct relationship of the R&D Units leaders with funding agents, strengthening their responsibilities, involvement and accountability, and enhancing the role of R&D Units and higher education institutions. While INESC-ID and ITI, and LARSyS are research units and laboratories of IST they are independent structures driven by the collective of researchers that compose them, and they purchase and manage

equipment and space which is provided by IST or by the not-for-profit institutions that host research projects (in the case of INESC-ID).

The group from INESC-ID affiliated with BIG is the Distributed, Parallel and Secure Systems which broadly addresses Systems, ranging from the underlying architectural support for high-performance systems, networks and applications, scalable and secure distributed platforms for cloud computing, big-data storage and processing, to autonomic computing and peer-to-peer systems of Internet scale. INESC-ID also maintains a high-performance data center which hosts several servers (many of them used by different EU and nationally funded research projects), including those initially purchased for the BIG ERAChair and additional equipment already requested.

ITI from LARSyS is the institute with a longstanding tradition of research in human-computer interaction and design innovation. HCI with the focus on user needs, tasks, experiences and social and political contexts is well suited to address a new breed of socio-technical systems that combines emerging technologies (such as blockchain) with the underlying cultural and social fabric. ITI has a established experience in human-centred design and testing of technology for social good, aimed at identifying fresh approaches to the design of new technologies, platforms and socio-technical systems that are better suited to the global challenges of this century. Therefore, ITI is well placed to host the design innovation facilities of BIG which include “in-house” testing of prototypes but also “in the wild” deployment and testing of prototypes in different application domains such as the ones identified in BIG. ITI/LARSyS with the integration of the ERAChair team members is also enhancing the capability to explore design fictions a design practice aiming at exploring and criticising possible futures by creating speculative, and often provocative, scenarios narrated through designed artifacts. This approach was already used by the EU policy lab (e.g. #Blockchain4EU) designed to foster creativity and engagement, and to develop interactions, processes and tools able to bring innovation into European policy-making.

The RI of BIG is designed to combine the computational facilities and experience of INESC-ID in high-performance, scalable and distributed platforms with the design innovation expertise of ITI/LARSyS. The ERAChair team composed of two integrated members of INESC-ID DPSS group (Kevin Gallagher and David Matos) and two integrated members of ITI/LARSyS (Teresa Almeida and Mariana Pestana) is perfectly positioned to bridge both areas and respond to the weaknesses identified in BIG in increasing the research performance of INESC-ID and LARSyS and to galvanise a campus wide initiative in blockchain technologies for social good.

Weaknesses

- **W1. Low critical mass and lack of synergies across key areas like machine learning, blockchain and engineering design** - Although existing skills and competencies at INESC-ID are strong in many scientific fields, in particular in high-performance systems, networks and

applications, scalable and secure distributed platforms for cloud computing, big-data storage and processing, and at ITI/LARSyS in many application domains such as cultural heritage, food, energy, urban systems and sustainability, **both laboratories still lack synergies promoting critical mass across key areas of application of blockchain technology. These are frontier areas; whose development is vital for a successful research strategy and success in the Horizon Europe programmes.**

- **W4. Lack of in-house and large-scale deployment equipment** – INESC-ID and LARSyS have limited laboratory equipment for development and evaluation of large high-performance data storage facilities and in-house research prototypes in particular for robotics and physical computing. **They are also lacking the equipment necessary for the effective deployment of a living lab research infrastructure, which hampers the development of large-scale research efforts. In-house examples include the need for a shared data and computing infrastructure.**

Opportunities

The research infrastructure is designed as the missing link between the weaknesses identified and the opportunities to ensure Técnico can capture benefits from blockchain and associated technologies through:

- Driving increased adoption of blockchain and associated technologies in different areas of the economy and the society for sustainability and social good. This aligns with the opportunity identified in the grant agreement around the ***Increased importance of DLT and blockchain for business corporations and end-user organizations*** – Blockchain technologies have the potential to transform the way that transactions are conducted in many different areas, from financial services to energy. There are several potential benefits of this technology, such as increased transparency, trustworthiness, and efficiency, or the ability to remove intermediaries from the value chain.
- Aligning to the **ERA societal challenges** through ensuring new forms of organizational structures can be developed and implemented to achieve them. These include but are not limited to fair trade, increased transparency, democratic decision making, collaborative economy, innovative financing models for sustainability and social good.
- Enhancing the generation of advanced knowledge (+15% of research outputs in top venues in computer science and engineering) and increasing the use of scientific research / knowledge through an effective strategy for managing intellectual property, creation of start-up and spin-outs and the creation of a flourishing crypto community both internally and externally to Técnico.

- Boosting the generation of **innovative ideas that can be turned into new marketable and usable data intensive systems and services** (+10% of industry transfer contracts) through the increased collaboration with industry and the generation of startups and spin-offs in the Lisbon digital ecosystem.
- Creating a sustainably employed set of critical human capital (**+5% of tenure track researchers and +10% of contracted researchers**) in blockchain and distributed ledger technologies and design thinking, by overcoming the fragmentation of competences (typically driven by focusing on the academic and not the research requirements), which is currently straining the existing human resources of LARSyS and INESC-ID.
- **Creating a unique research infrastructure (Blockchain Design Studio)** that acts as a **platform for collaborative impact**, based on an open innovation model. This platform will leverage Lisbon as an international living lab for testing innovative applications and services based on blockchain and DLTs, and impact EU societal challenges and S3.

Our RI is designed to be one of the main interfaces for the project to interact with the rest of the world and support research development capacity within and outside Técnico. The BIG RI is also designed to assist the BIG project to manage the interactions between the outside world, the researchers, and the students. The Research Capacity development of the RI focused on initiating and fostering programmes that develop new and emerging researchers and providing training, support, and development opportunities for postgraduate students. So far, the DCentral Lab has supervised many master thesis in various topics: Decentralised Autonomous Organisations, Blockchain Financial Data, Food Innovation, Healthcare, etc. Staff has offered to master students training in the following areas: thesis and dissertation writing, writing for journal publication; research design and methodology Quantitative methodologies, including use of Nvivo Qualitative methodologies and Integrated methodology/mixed methods.

As outlined in the GA, we have based this on an open innovation approach - we follow Chesborough's well-known approach to open innovation. The open innovation approach is normally built from an innovation funnel (Wheelright, 1992). The model describes a process of innovation product creation as a sequence of stages from idea development to commercialization. The model involves searching for and selecting ideas. A lot of ideas are introduced in the funnel. They are processed and assessed. Only the most promising ideas are selected. It can be presented as a convergent funnel. While this approach to an innovation funnel works well for closed systems, there are certain aspects of a modern university that require us to adapt the innovation funnel and the approach towards open innovation. This often ends up looking more like a swiss cheese funnel - as illustrated in Figure 2.

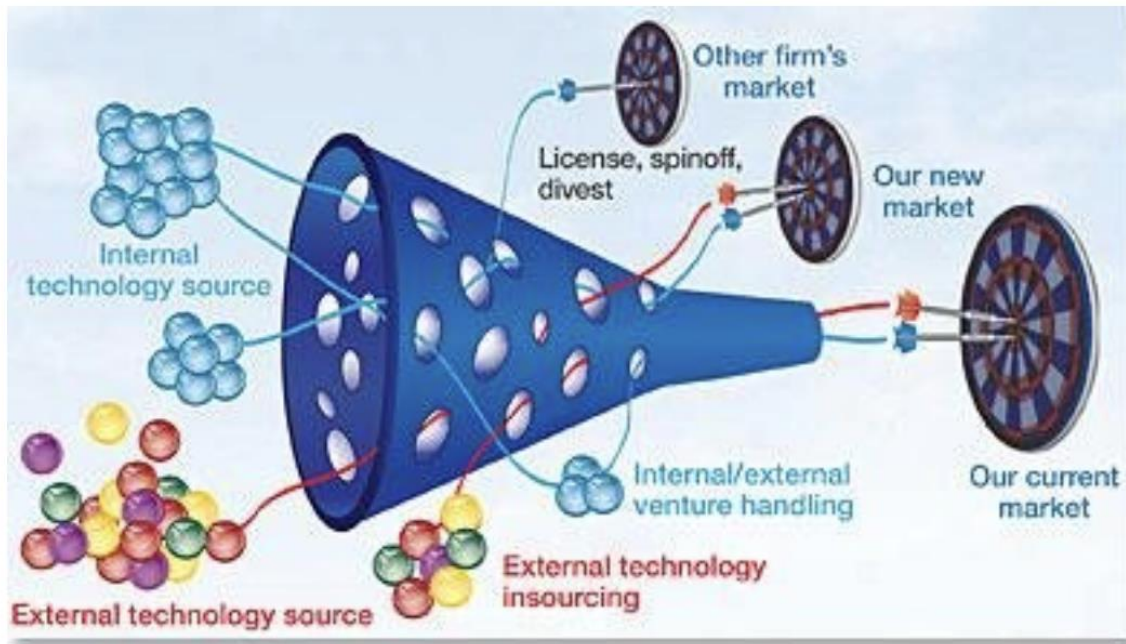


Figure 2 – Research Infrastructure

The model has been used to great effect to assist universities to become engines of innovation and catalyzing scientific research into the real world through:

1. Traditional technology transfer.
2. Student projects together with companies and spinouts.
3. Creation of Open-Source Software done through research projects.
4. Delivery of academic papers.
5. Creating an open approach to academic engagement that enables the more fruitful flow of ideas between the market, the university and broader society.
6. Enable the interchange of conceptual ideas between disciplines in a structured manner that is fruitful for all disciplines, not just one dominant discipline (e.g. HCI or Design normally think of themselves as the “interdisciplinary” organiser - but often leave out the role of deep technology enablement, economics or other disciplines). The open innovation approach enables a structured process to be developed that can be applied to ensure all disciplines get the data and outputs they need to publish top rated scientific research in their disciplines.

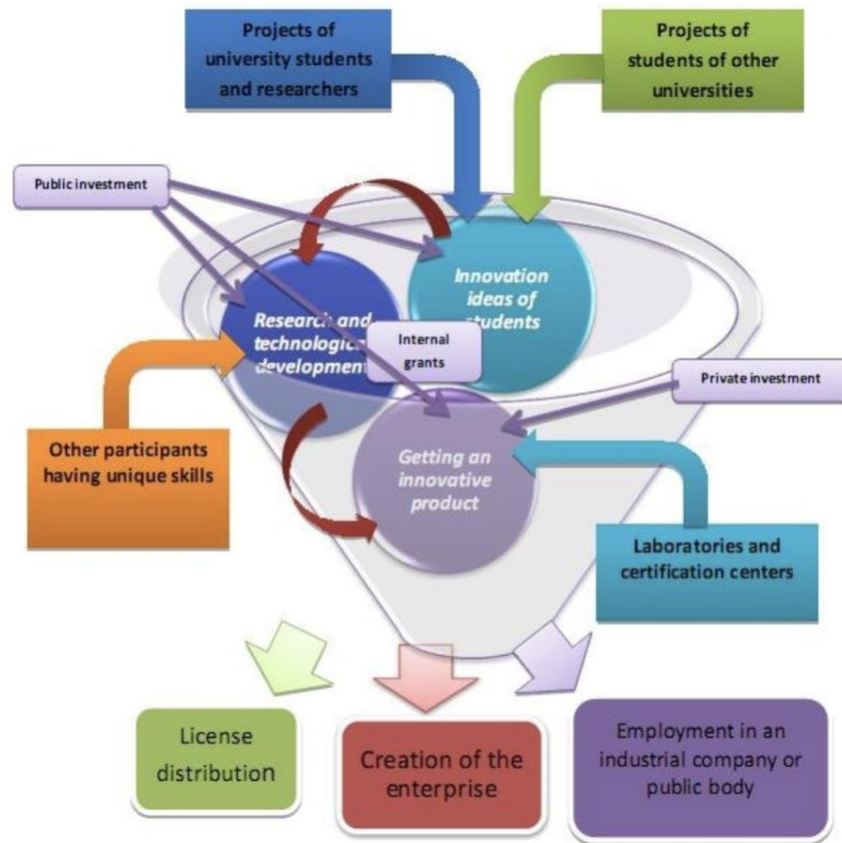


Figure 3 – Research Infrastructure

The BIG project has an ambitious agenda to change through blockchain technologies and design innovation the way Técnico approaches open innovation in the domains identified in the GA. By taking an Open Innovation approach, with some angles expanded to more appropriately reflect the role of a research in modern society - namely that it needs to manage a unique set of interacting stakeholders:

- Students
- Companies
- University Leadership and other internal academics
- Government Agencies
- Tax-payers
- Broader society
- The “Academy”

2.3. Components of BIG Research Infrastructure

In order to manage this effectively, the BIG RI integrates three components: a design studio - i.e. a process by which we can engage with the broader society, a server infrastructure to perform experimentation and build proofs of concept on and research talent that transforms these from ideas into reality. We have established a strong process as illustrated in the following diagram:

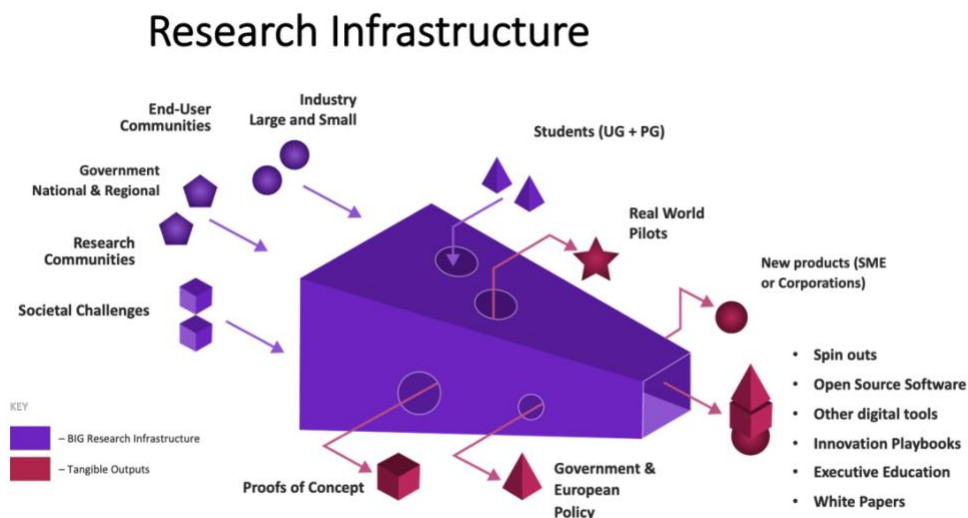


Figure 4 – BIG Research Infrastructure

Design studio

That enables us to connect with the broader community connecting with a broad range of possible end-user communities - including but not limited to companies, NGOs, government and others who may be interested in learning about blockchain and associated technologies. The design studio aims to equip students of all levels, researchers and others with futureproof leadership and problem-solving skills, and to assist with the needs of organisations looking to build capabilities in blockchain and decentralisation, with an emphasis on design driven digital transformation. The design studio allows us to work with end-user communities using a variety of methods to identify issues of interest to them in the space of blockchain applied to achieve sustainability and social good outcomes. The most important part of the design studio will be the process that is put in place to manage the movement of people, companies and communities from the start of the innovation process and through the funnel assisting them in the process of streamlining their ideas towards a set of manageable and usable outputs. Some end-user communities may have specific issues associated with design - e.g. service design. Other end-user communities may also have open issues with technology itself - for these communities, we have a server infrastructure where they can work closely with our technical teams to test and develop their concepts.

Server Infrastructure that enables us to work on technical issues

Our server infrastructure contains an initial set of three servers for the start of our initial test bed. Together with companies and other end-user communities, we will focus on some specific areas of testing that will ensure that Lisbon and Portugal are able to become focal points of the emerging area

of blockchain. A critical issue that is currently unsolved within the space is testing of smart contracts. Through providing static and dynamic testing capabilities for smart contracts, we will ensure that the solutions developed in Portugal are robustly tested. Furthermore, over time, we will develop the server research infrastructure to provide a world leading test bed for economics, innovation and regulation of this space. This will include the development of indices, taxonomies of the space that can be used to understand how to best regulate the space in the European Union. These datasets will be managed live and provided publicly both via our website (DCentral-lab.org) and through other requests. Both the Server infrastructure and the Design Studio build on the other core part of our research infrastructure - the research talent and research pipeline that the BIG project is building.

To address the issues regarding a lack of infrastructure for the BIG ERA Chair Team, we are looking to expand the set of servers to include one more server capable of storage and computation independent from the INESC-ID High Performance Cluster. This server would ideally have similar specifications of the 3XS SER 2U27NE2, which contains up to 64 cores, and up to 4 TB of RAM. Perhaps more importantly, the 3XS SER U27NE2 contains 27 drive bays, which allows for the storage of large amounts of data from different Blockchains, as well as storage of generated data sets and other research artifacts. This will allow the execution of research that is related to the BIG project - in particular the assessment of the flows of different blockchains, the security testing of different types of smart contracts, etc., and overcome the significant issues faced by the Masters students of the BIG lab during the 2021 / 2022 Master's thesis period.

Archives or structures for scientific information

Archives include data in financial information stored on Blockchain platforms, sensitive human data related to health stored on the Blockchain, cyber-security attacks statistics of DAOs among others. Data produced and/or used in the project will be discoverable with metadata, identifiable and locatable by means of a standard identification mechanism. In the case of certain datasets that cannot be shared (or need to be shared under restrictions), because sensitive information, especially in the area female technology-based data solutions may make the participants vulnerable. Data produced in the project is interoperable and agreements between the relevant stakeholders will be signed in line with national and international data protection legal requirements in due course. Objectives of the archives are:

- To create evidence to inform investment in and lay foundations for a sustainable mainstream research resource, complementing other Técnico infrastructures (i.e. projects in the area of Sustainable and Smart Mobility Strategy and Action Plan EV4EU,);
- To allow research users across all sectors and localities can discover and access data and data-driven research to deliver societal benefits.
- To build Technological change at Técnico in order to facilitate cross-labs and cross-disciplinary research.

Research Talent

The most important aspect of our research infrastructure is the research talent itself; namely the researchers and students who are being trained in blockchain and its application in the delivery of sustainability and social good.

Our research talent is the group of people who bring our research infrastructure to life. Starting with the ERA Chair team it will be built out over the course of the project to include a broader range of skill sets from across IST. Each member of the ERA Chair team will be expected to actively participate in the RI, develop research concepts using this approach and bring user communities into the Design studio. Each ERA Chair team member will be responsible for assisting the BIG project achieve its research KPIs through this infrastructure.

2.4. Embedding in Técnico

Through our research infrastructure, we therefore aim to create a flourishing community of researchers across Técnico in the context of the BIG project, delivered via “DCentral”, starting with the four departments illustrated in dark green below (DEG - Management, DEI - Engineering and Informatics, DECivil - Civil Engineering and DEM - Maths):

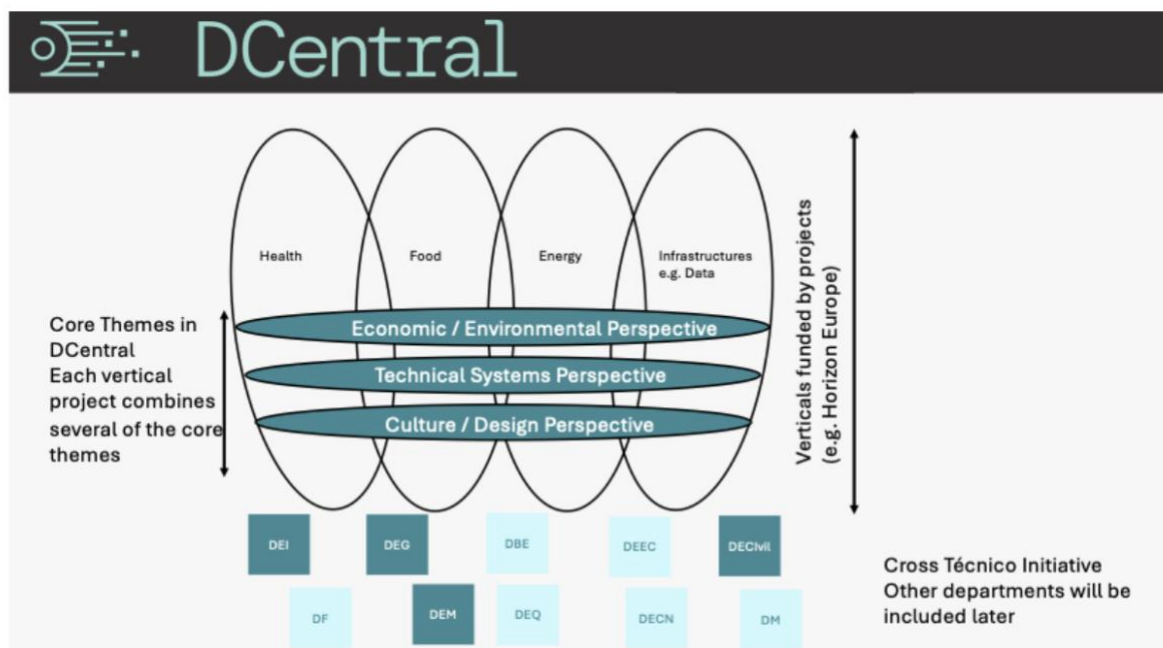


Figure 5 – BIG Research Infrastructure embedded in Técnico: Themes and Application areas

Themes

Generally the themes of health, food, energy and infrastructure and data should revolve around the themes identified by the ERAChair holder and presented in the review meeting (see Figure 6). These are highly interdisciplinary themes which match some Horizon Europe societal challenges and

constitute a basis for collaboration and funding applications. For instance, Future Cities and Resilient Infrastructures are themes which align with the New European Bauhaus and the Bauhaus of the Seas proposals submitted by co-PIs and members of the ERAChair team. Future of Privacy and Cybersecurity is a theme where the group of INESC-ID has a longstanding experience in attracting Horizon funds. While Future of Money is a new theme brought by the research interests of the ERAChair holder. These themes should evolve in collaboration among the ERAChair team, co-PIs and other research groups of Técnico and eventually translate into successful Horizon Europe submissions with external consortia.



Figure 6 – Research Themes for BIG

Expected Outputs

We are still in the development phase of the lab infrastructure, but we envisage making the following data sets available to the European community to deliver our part of the Horizon strategy around open and connected research communities: 1) Innovation Data Sets around Crypto Assets usable by government agencies and the EU Commission 2) State of play of DeFi & CeFi assets 3) Security data sets of the types of attacks against different parts of the cryptocurrency system.

Challenges

The original equipment described in the GA, purchased and available at the INESC-ID datacentre is considered insufficient for the requirements of the ERAChair team. In particular, several experiments require a configuration that is not compatible with the security and usage requirements defined by INESC-ID. Therefore, a proposal to mobilize budget for purchasing additional equipment that could be installed and made available in a less constrained environment therefore enabling for instance access

by Técnico students that are not affiliated with INESC-ID and/or external partners (e.g. industry affiliated or NGOs).

With the new set of equipment hopefully being purchased, the ERA Chair team aims to continue the development of the living lab as outlined in the GA. Work has begun through the interviewing of a variety of start-up and corporate players within the Lisbon area to solicit the types of activities that they will pay for and use in a research environment.

3. Conclusion

The creation and management of an interdisciplinary research infrastructure that spans two different laboratories and requires a combination of computation and design innovation which should support both highly technical computational experiments, but also experimental design prototypes conducted by students and real-world test beds from industry and other stakeholders is a challenge for this project.

The current infrastructure serves the minimal requirements of computational design and testing of blockchain technologies, but a more flexible setup is planned which requires additional equipment budget which was already proposed. The current proposal to expand the servers with additional machines (with the same configuration) but expanded capacity would highly benefit the project and the research team. In addition the design innovation component will also benefit from the new facilities in the Hub Criativo do Beato which Técnico secured and should start to become operational in October.