Management & Engineering

A.a. 2024/2025

Graduation Session November 2025

# Translational Deep-Tech

## How Translational Medicine approach can be adopted by Deep Tech innovation in University Spinoffs to overcome some of its main challenges

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# INTRODUCTION

The aim of this master thesis is to investigate whether the concepts used in Translational Medicine can be applied to solve some of the most common criticalities faced by Deep Tech innovations developed in Europe.

To achieve this goal, the first chapter discusses what the term "deep tech" really means, what are the commonalities of these types of technologies that all experts agree on, how they can be classified, what is the landscape of deep tech startups in Europe and the main challenges faced by deep tech startup innovation, with a specific deep dive over University Spinoffs in this sector.

The second chapter analyses the Translational Medicine approach in depth, starting with the historical development of this methodology to understand the needs it addresses. The common principles that govern this approach are then abstracted and some examples of application are presented.

In the following chapter, the similarities and differences between Translational Medicine and deep tech startup development will be considered, with a discussion of how some of the principles of TM can be applied to deep tech innovation. Based on these considerations, it theorises 'Translational Deep Technology', a new approach to addressing some of the key challenges in deep tech startup development. The chapter then discusses how this idea differs from the methods already published in the current literature to address these problems.

The final chapter aims to establish whether the theory presented in the first three chapters has any practical relevance. To this end, interviews with experts have been conducted. This chapter therefore explains the methodology adopted and discusses the outcomes of the interviews and their implications for Translational Deep Tech theory, defining how the theoretical principles can be transferred into real practice. Finally, the possible validation process of the TDT theory is discussed.

# Chapter I: Deep-Tech Innovation

This first chapter tries to explain what the buzzword "deep tech" refers to, as different articles in the literature can give different definitions of it. It shows how a comprehensive definition of "deep tech" should be based on the main characteristics of this type of innovation, which are essentially based on the development of an early-stage technology to address a major societal challenge.

The second part of this chapter presents a possible classification of current deep-tech innovations, although the list will evolve over time and it is impossible to make a comprehensive and exclusive classification of them, given their interdisciplinary nature in research and their wide range of applications in different sectors. In order to delve deeper into the subject, an example of a European deep tech start-up is presented for each cluster, giving an insight into the wide range of these technologies and showing companies at different stages of maturity.

Then, the European landscape of deep technology startups in Europe is presented, explaining the increase in interest and investment in the field in recent years. On the other hand, this landscape will also show how Europe is lagging behind other continents in many areas despite its potentialities and is failing to retain its deep tech companies when they grow up.

In the following part, the main challenges faced by deep tech startup innovation are presented, showing how the differences between them and traditional tech startups may create many problems if not recognized by all the actors involved in the innovation process.

Finally, the European landscape of Deep Tech university spin-offs is examined, showing how university spin-offs in this sector represent the most untapped potential for EU Deep Tech.

# Deep-Tech innovation definition

Innovation has long been recognised as a key driver of economic growth, technological progress and competitive advantage. In recent years, the term "deep tech" innovation has become a buzzword, mainly referring to the development of new breakthrough technological innovations that would change the current paradigm. However, the various literatures fail to provide a common, universal definition of deep tech innovation that everyone can agree on. Therefore, in order to explain what this category of innovation refers to, it is necessary to base a definition on what are the key characteristics that can be found in any deep tech innovation.

To explain them, these commonalities have been grouped into 5 main themes:

- **Timing**:
  Deep-tech innovations have longer development cycles than normal ones (Romasanta, Ahmadova, Wareham, & Priego, 2022).

  The causes of this are four: first, these types of innovations are R&D intensive as they are usually based on low TRL technologies (Technology Readiness Level) (Manning, s.d.) as the technology has yet to be developed, the research process will therefore take longer than for innovations based on ready-made technologies. The difference in pace of deep tech startups compared to traditional ones is reflected by the comparison of funding cycle (McKinsey, 2024) where deep tech ventures take on average 12 months longer than traditional tech to progress from seed to Series A, while the funding pace accelerates rapidly from Series B to Series D.

  Second, these innovations are complex because the innovative nature of deep tech requires a high level of interdisciplinary knowledge. Unlike digital start-ups, deep tech is typically based on advanced integration of hardware and software, covering fundamental functions such as sensing, imaging, detection, connectivity, computation, inference, actuation and control. (J.Siegel & S.Krishnan, 2020). The need for interdisciplinarity tends to lead to longer development times compared to an innovation based on a single field of study, as the latter one would require less and easier communication between the researchers involved who would also have similar backgrounds.

  Then, deep tech innovations are usually at a low Market Readiness Level (MRL) (Mealling, s.d.). The potentially disruptive nature of them and the aim of addressing a potential grand challenge means that most of the time the market is not ready to embrace that innovation. In fact, it would usually require changing an established paradigm, which takes time.

Finally, in the case of deep-tech innovations based on physical products, even the industrialisation process may take longer, as it may require some specific features to be designed from scratch, as this has never been done before.

- **Investments**:
  Strictly linked to the longer development times, deep-tech innovations are associated with high investment intensity, especially upfront, due to their R&D intensity. In addition, communication between innovators and investors is usually more difficult than for normal start-ups; indeed, the deep technological level required to understand the technology itself, and the complex development process make it very difficult for investors to evaluate it economically.

  This results in either a very small pool of possible investors who have the knowledge and skills to have a deep understanding of what is going on in the innovation development process, or to a certain misevaluation by investors who do not have the tool to assess the R&D performance of the company, leading to a possible early exit strategy. In fact, the usual KPIs used by venture capitalists to evaluate normal start-ups can be misleading in the case of deep techs.

  It is worth to notice that, even if deep tech ventures typically demand up to 40 percent more funding to reach the revenue stage than conventional tech ventures (McKinsey, 2024), they demonstrate superior capital efficiency. The enhanced efficiency can be attributed to a significant share of funding from sources that do not dilute ownership, such as government grants and hybrid debt instruments.

- **Strategy**:
  A common aspect of all deep-tech innovations is that they address a major challenge by developing a new complex technology. This perspective suggests that this type of innovation usually aims to create a whole new market for its final product or service rather than compete in existing markets, resulting in a blue ocean strategy for the company.

  Moreover, deep technologies usually do not aim to sell products to end customers, but prefer a B2B strategy to act as a platform on which several products for end customers are created. This is also suggested by the fact that deep technologies tend to focus more on research in product innovation and less on customer needs, as the final products are developed only after the technology has been proven to work.

- **Risk**:

  Deep tech innovations face two main types of risk: market risk and technological risk. The first, similar to that of ordinary start-ups, is based on the uncertainty that end customers will be willing to adopt the new product or service.

  On the one hand, the general purpose of a deep-tech innovation to address a societal challenge should reduce this risk, but on the other hand, the use of a technology with a low MRL increases the uncertainty of final adoption and makes it difficult to estimate the time of market maturity.

  In terms of technological risk, this is something that a typical start-up rarely has to face. Focusing on low TRL means that the technology still needs a proof of concept to be considered feasible and estimating when this will happen (if ever) is very difficult.

  Therefore, we can say that startups based on deep tech innovations can be considered as slightly riskier than normal ones. This is reflected in the comparison of failure rates between traditional tech and deep tech (figure 1) (McKinsey, 2024): the latter one seems to have higher failure rates in the early stages due to high research and technology-development costs, while in the commercialization phases this rate diminish mainly due to their competitive advantage and blue ocean strategy.

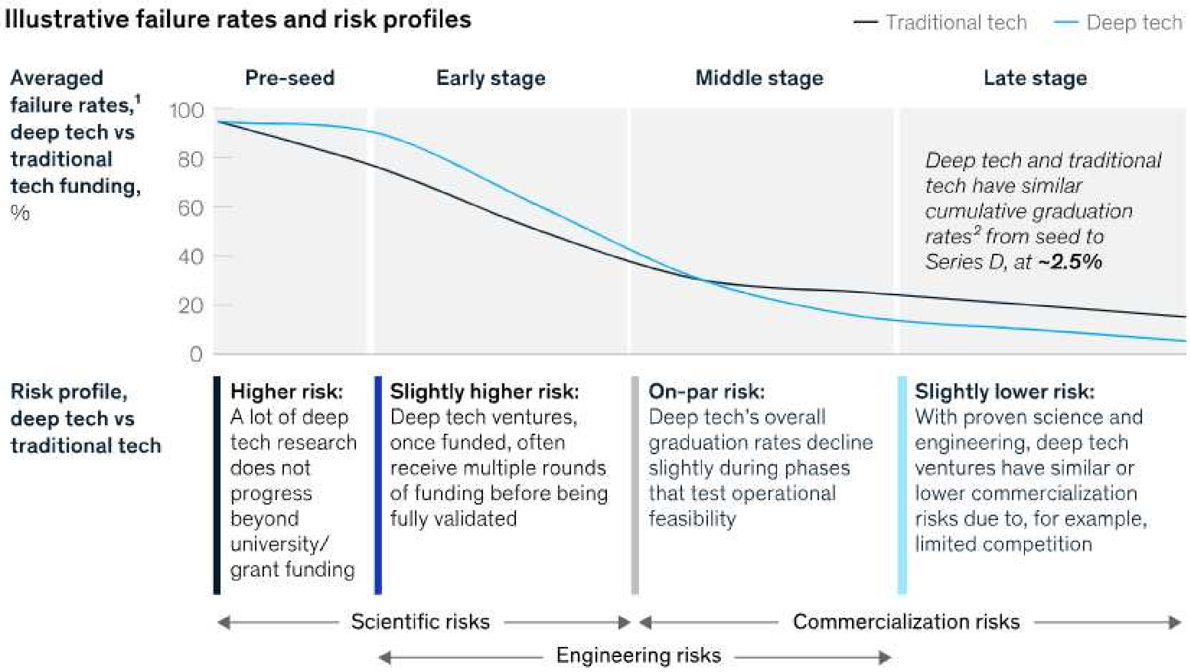


*Figure 1: failure rates and risk profiles*

- **Competitive advantage**:

Because deep-tech innovations are inherently complex and require a lot of resources and specific knowledge, they are not easily replicable. While this is a competitive advantage in the business plan of a deep-tech startup, it does not affect the sustainability of their business model. In fact, while this means that deep tech companies aim to offer highly novel solutions, it also means that it may be difficult to find compatibility with existing technology architectures, so the right effort must be made to shape the new paradigm. Moreover, even if the innovation generates valuable intellectual property and is difficult to replicate, it may have a limited life span, as what is considered deep tech today may become a common technology in the future, and risks being replaced by new deep tech innovations if it does not keep pace with them or raise the right barriers.

Thanks to these characteristics, it is possible to give the main definition of deep tech innovation that enclose all of them as the following:

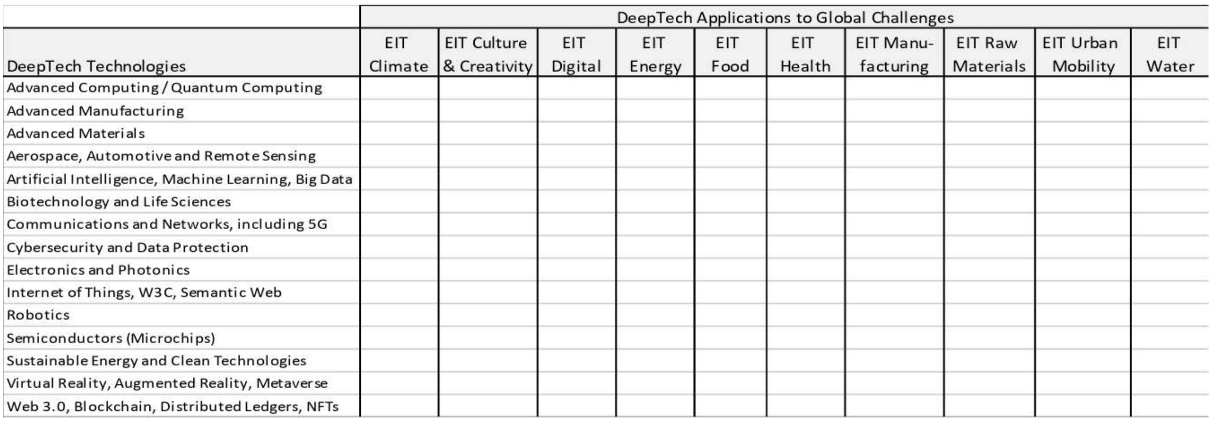
*"Early-stage technologies based on scientific or engineering advances, requiring long development times, systemic integration, and sophisticated knowledge to create downstream offerings with the potential to address grand societal challenges"* (Romasanta, Ahmadova, Wareham, & Priego, 2022).

## Deep-Tech classification

In order to better understand which technologies are currently considered 'deep', a classification of the main application areas in which they are being developed should be presented. As one of the main characteristics of these types of technologies is that they are interdisciplinary and address major challenges, it is impossible to find a clear categorisation of technologies that is mutually exclusive.

However, a general classification of them has been made by the European Institute of Technology and Innovation for its Deep Tech Talents for Europe (DTTI) initiative in 2023.. Aiming to train people in deep tech fields in the coming years, the initiative defines deep tech innovations as 'cutting-edge technological solutions that combine science and engineering in the physical, biological, and digital spheres'.

The classification is based on the technology on which the main innovation is built and encompasses the 15 main deep tech fields. These clusters are therefore  based on the main underlying technology, and the choice of these specific categories reflects alignment with existing EU innovation priorities and recognisable knowledge bases and industrial domains. There is also a balance between emerging fields and strategic areas for Europe that address major societal challenges. In the programme, the fifteen categories are then correlated with Application to Global Challenges to create the 'deep tech matrix' (Figure 2).



| | DeepTech Applications to Global Challenges | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DeepTech Technologies | EIT Climate | EIT Culture & Creativity | EIT Digital | EIT Energy | EIT Food | EIT Health | EIT Manu-facturing | EIT Raw Materials | EIT Urban Mobility | EIT Water |
| Advanced Computing / Quantum Computing | | | | | | | | | | |
| Advanced Manufacturing | | | | | | | | | | |
| Advanced Materials | | | | | | | | | | |
| Aerospace, Automotive and Remote Sensing | | | | | | | | | | |
| Artificial Intelligence, Machine Learning, Big Data | | | | | | | | | | |
| Biotechnology and Life Sciences | | | | | | | | | | |
| Communications and Networks, including 5G | | | | | | | | | | |
| Cybersecurity and Data Protection | | | | | | | | | | |
| Electronics and Photonics | | | | | | | | | | |
| Internet of Things, W3C, Semantic Web | | | | | | | | | | |
| Robotics | | | | | | | | | | |
| Semiconductors (Microchips) | | | | | | | | | | |
| Sustainable Energy and Clean Technologies | | | | | | | | | | |
| Virtual Reality, Augmented Reality, Metaverse | | | | | | | | | | |
| Web 3.0, Blockchain, Distributed Ledgers, NFTs | | | | | | | | | | |

*Figure 2: EIT Deeptech Matrix*

The main idea behind this matrix is to demonstrate that the same deep tech technology can address different global challenges, and that the same challenge can be addressed by different technologies either in parallel or jointly. However, the EIT itself explained that their list of categories should not be considered exhaustive or fixed, given that deep technologies change over time in response to evolving challenges.

Another key element that distinguishes deep tech innovation from traditional innovation is the existence of the matrix itself, which demonstrates one of the main characteristics of DT: addressing different market needs with the same technology. As will be explained later in this chapter, one of the main challenges faced by DT innovation is deciding which market needs to address with the new breakthrough technology, as this is not always obvious.

## EIT DeepTech Categories

The following part of this section it will be presented in detail an overview of each of the 15 deep tech innovation (European Institute of Technology and Innovation, 2023), along with some of the main issues currently faced in this specific category, from technological, market, industrial and linking perspectives,  followed by an example of a company (start-up or more established) innovating in Europe in the field.

This approach is intended to show how this theoretical list is applicable in the real European innovation landscape, while at the same time providing a better understanding of the Deep Tech definition by looking at real examples:

### 1. Advanced Computing / Quantum Computing

Technologies that deal with the speed and scale of data processing and operations. It includes quantum computing, edge computing, cloud computing and other technologies.

This field is facing major scientific challenges, such as quantum decoherence and error correction, as well as the development of stable qubits. It also requires substantial infrastructure in cryogenics, photonics and advanced semiconductors. While the market is still uncertain, with few clear killer applications, there is enormous long-term potential in finance, energy, and materials. However, industrialisation is hindered by supply chain dependence and extremely high costs. Collaborating with major companies such as IBM, Google, and corporations in the aerospace and pharmaceutical industries is crucial for establishing early use cases and credibility.

Figure 3: Pasqal logo

An example of successful innovation in this field is Pasqal, a French start-up that builds programmable quantum simulators and quantum computers from 2D and 3D atomic arrays. The platform is highly scalable and benefits from tens of years of development and discovery. They are developing the lasers, vacuum technology, electronic controls and software stack to make the individual atoms accessible to quantum programmers around the world. This technology has enabled them to offer solutions in many different industries, such as aerospace and defence (partnership with Thales), banking and finance (Crédit Agricole CIB), energy and utilities (Aramco and Eni), manufacturing and product design (Dassault Systems) and even transport and mobility logistics (CMA CGM Group).

## 2. Advanced Manufacturing

Includes Industry 4.0 technologies (McKinsey & Co, s.d.), robotics, rapid prototyping, circular manufacturing, digital twins, IoT and Sensoring.

This category is addressing issues of scalability, precision and standardisation. Market adoption is driven by the demand for efficiency and sustainability, but is slowed by fragmented industries and conservative customers. The industrial impact is significant, as it has the potential to reconfigure global supply chains and enable reshoring. While connections with established manufacturers and OEMs are essential, integration is slow due to the need for significant capital expenditure and upskilling of the workforce.

Figure 4: Caracol logo

Caracol AM is an Italian company that provides 3D printing services for large, complex and critical industrial components. Its integrated hardware and software platform is designed for the production and development of the most demanding manufacturing needs.

## 3. Advanced Materials

Materials with engineered properties such as polymers, advanced nanostructured materials, synthetic fabrics, wearable technology, high value-added metals and materials, biomaterials.

The mian scientific challenge lies in engineering new properties into nanomaterials, polymers, biomaterials and high-value metals. While the market rewards successful breakthroughs with high margins, commercialization is a long and uncertain process involving complex regulatory approval, particularly for health-related applications. Industrially, advanced materials enable progress across sectors, from aerospace to energy storage. Collaboration with large firms is essential, since they control supply chains, standards and testing infrastructure, making start-ups highly dependent on partnerships.

*Figure 5: Skeleton Technologies logo*

Skeleton Technologies is an Estonian company that has used its patented curved graphene technology to drive advances across industries and support the transition to a net-zero future. Founded in 2009, the company is now the world's leading manufacturer of supercapacitors for industrial applications and is at the forefront of innovation in energy storage. A leader in deep technology, its solutions power critical sectors such as data centres, grid infrastructure, E-STATCOM, automotive and heavy-duty transportation, in each of which Skeleton supplies some of the market leaders.

4. **Aerospace, Automotive and Remote Sensing**

Focus on new methods of transport, mobility and space technology, or sensor, data and telecommunications processing systems.

The core challenges here involve propulsion systems, autonomy, energy storage and sensing technologies for space and mobility. While the market is promising due to the expansion of urban air mobility, drones and satellite applications, regulatory barriers are significant. Industrialization requires substantial investment and integration with existing mobility and space infrastructures. Collaboration with well-established players in the aerospace and automotive industries is essential, since they control certification, standards, and access to markets.

*Figure 6: Lilium logo*

Lilium N.V. is a German aerospace company founded in 2025 to develop electric vertical take-off and landing (eVTOL) aircraft. They now have the opportunity to reshape the regional mobility paradigm with their high speed aircraft.

5. **Artificial Intelligence and Machine Learning**

Focus on the interaction between data science, big data and data mining, and the methods used to process data through algorithms.

The main technological challenges lie in improving the efficiency of algorithms, reducing bias, meeting data requirements and ensuring explainability. While the market is expanding rapidly, with demand in every sector, competition is fierce and there is a risk of commoditization. Although industrial adoption is strong, particularly in sectors such as healthcare, retail and finance, it requires adaptation to specific workflows and data availability. Start-ups often require partnerships with established companies to gain access to data, build credibility, and integrate into existing platforms.

*Figure 7: V7 logo*

V7 is a UK startup based in London, which has developed a platform that enables data to be transformed into trusted AI models and GenAI-powered automated workflows.

Their platform is being used in very diverse industries such as healthcare, with a collaboration with Mauna Kea Technologies to develop an AI-driven decision support tool in oncology and immunology, retail, with a partnership with TaskUs to enable the delivery of enterprise AI products, and even in the agriculture sector, with a collaboration with Aya Data to accelerate the development of visual AI for training in the sector.

## 6. Biotechnology and Life Sciences

Represent cutting-edge Deep Tech technology in natural and synthetic materials and research, including genetic therapies and digital technologies.

Scientific challenges include gene editing, biomaterials, precision medicine, and advanced bioinformatics, all requiring strict ethical and regulatory oversight. The market is huge and resilient, but time to market is long due to clinical trials and approvals. Industrialization depends on biomanufacturing capacity and stringent quality standards. Connections with pharma, healthcare providers, and regulators are essential, as startups cannot operate in isolation in this heavily regulated sector.

*Figure 8_ Arctoris logo*

Arctoris is a technology-enabled Partnership Research Organisation (PRO) based in Oxford. It is a drug discovery services company that advances drug discovery experimentation by combining its Ulysses automation platform with world-class laboratory scientists to manage and rapidly advance its partners' drug discovery programmes. Ulysses is an automation platform that ensures accuracy in every element of the laboratory process to significantly improve precision, consistency, scalability and data quality, resulting in the delivery of thousands of successful experiments with superior results. This automation platform can support diverse experiments in biochemistry, cell biology, protein science, structural biology, biophysics and biologics.

## 7. Communications and Networks

Includes areas of innovation such as 5G / 6G networks, advances in high-bandwidth communications, navigation systems, telematics, and material and communications security.

Technically, the challenges lie in reducing latency, managing bandwidth, and developing new antenna and frequency technologies. Market demand is clear and is driven by the Internet of Things (IoT), mobility and the cloud, but the market is dominated by large telecom operators. Industrialisation is tied to infrastructure deployment and standards, which evolve slowly and require significant investment. Partnerships with telecoms and network equipment providers are essential for scaling up.

*Figure 9: Accelercomm logo*

AccelerComm provides high-performance physical layer solutions for 4G and 5G radio access networks. Its platform-independent algorithms can maximise the value of RANs, enable optimal performance of 5G Radio Access Networks and solve the challenges that would otherwise limit the speed, latency and spectral efficiency of 5G. The company is active in a number of industry associations, including membership of the O-RAN ALLIANCE, founded by some of the world's leading players in the sector, including T&T, China Mobile, Deutsche Telekom, NTT DOCOMO and Orange.

## 8. Cybersecurity and Data Protection

Covers the security and proper functioning of the Internet of Things (IoT) and 5G, encryption systems and methods, including those using machine learning and artificial intelligence, intrusion detection systems and methods, and privacy-enhancing technologies.

Technological advances are being made in encryption, intrusion detection and quantum-proof security, as well as AI-based defences. While the market is huge and growing alongside digitalisation, it is also highly competitive due to the rapid evolution of threats. Industrial adoption is crucial across all sectors, as security is now as much a compliance requirement as a business necessity. Start-ups often collaborate with corporations through pilot projects or integration, but credibility and certifications are crucial for acceptance.

*Figure 10: Darktrace logo*

Darktrace is a UK company founded in Cambridge in 2013, which in less than 10 years has become the global leader in cybersecurity AI, providing the essential cybersecurity platform to secure organisations today and for an ever-changing future. Darktrace AI learns from each organisation's unique data in real time, detecting threats and intervening against attacks. Its services now include real-time learning cybersecurity for networks, email, cloud, OT, identity security and endpoints. This company is an example of how quickly a deep-tech startup can become a market leader, disrupting previous incumbents.

## 9. Electronics and Photonics

Includes quantum computing applications, microelectronics / printed circuit board engineering, photonics engineering for various applications, haptics, AI and VR/AR engineering, power management required by electronics, photonics and associated hardware.

Scientific challenges include miniaturization, advanced semiconductors, new photonic devices and integration with AI and VR/AR systems. There are market opportunities in healthcare, energy and ICT, but development costs are high. Industrialization is limited by complex manufacturing processes and globalized supply chains. Forming partnerships with major industrial and semiconductor companies is essential for scaling up, as this requires foundries, fabrication facilities, and specialized infrastructure.

Figure 11: Amazec Photonics logo

Founded in 2021 in the Netherlands, Amazec Photonics focuses on the development of ultrasensitive temperature sensing using photonics in the medical field. It is envisaged that this integrated photonics technology will enable new modalities of monitoring, diagnosis and treatment with a major impact on healthcare.

## 10. Internet of Things, W3C, semantic web

Focus on physical and networking systems for IoT such as communication protocols, mesh computing / distributed computing / embedded systems, automation and sensing.

Technologically, the Internet of Things (IoT) faces challenges in terms of interoperability, communication protocols and distributed computing. While the market is large and growing, it is fragmented across sectors such as logistics, manufacturing and smart homes. Industrialization requires secure, scalable platforms and the integration of diverse devices. Start-ups often need to collaborate with established companies to integrate their solutions into existing infrastructures and gain adoption.

Figure 12: EVRYTHING logo

EVRYTHNG is a UK company founded in 2011 whose flagship product is the EVRYTHNG Product Cloud, a fully managed, scalable IoT software-as-a-service platform for businesses to issue and manage digital identities for physical products and manage data from and about physical products to power applications. Application use cases include authenticating and tracking products through the product lifecycle from manufacturing to the hands of the end customer, as well as providing direct services to the end customer associated with product items.

This company was acquired by Digimark in 2022 to leverage the synergies of its product identification engine with the acquired company's product intelligence cloud platform.

## 11. Robotics

Develops hardware and software solutions for process and machine automation, including robotic process automation (RPA), factory robots/cobots, humanoid/artificial intelligence robots/cobots, drones and transportation solutions.

The scientific challenges range from autonomy and vision to dexterity and human-machine collaboration. Although market demand is rising in logistics, healthcare, and industry, adoption is limited by costs and integration issues. In industry, robotics is transforming manufacturing and services, but it requires additional systems, such as sensors, AI and connectivity. Collaborating with established companies is essential, as they provide test environments, distribution channels, and industry credibility.

Nanoflex Robotics is an ETHZ spin-out company based in Switzerland. It is developing endoluminal soft robotic systems that can be remotely manipulated inside the body. This would enable interventional neuro-radiology procedures to access and treat ischaemic and haemorrhagic stroke.

*Figure 13: nanoflex logo*

## 12. Semiconductors

Includes advanced microchip manufacturing methods, non-conventional computing systems and semiconductors, haptics, AI and VR/AR engineering, - power management required by semiconductors and associated hardware.

The challenges here lie at the forefront of physics, including nanometer scaling, new architecture and advanced materials. While the market is strategic, with demand for AI, mobility and HPC exploding, it is dominated by global giants. Industrialization is one of the most capital-intensive processes on Earth, requiring fabrication plants and highly specialized supply chains. Start-ups must collaborate with existing industry leaders as independent growth is almost impossible.

SiPearl is a company that aims to develop European high-performance, energy-efficient processors for High Performance Computing (HPC) and Artificial Intelligence, designed to work with any third-party accelerator (GPU, AI, Quantum). This new generation of microprocessors will initially target the ecosystem of the EuroHPC Joint Undertaking, which is deploying world-class supercomputing infrastructures in Europe to solve strategic public

*Figure 14: SiPearl logo*

challenges in medical research, security, energy management and climate with a reduced environmental footprint.

## 13. Sustainable Energy and Clean Technologies

Including new energy generation technologies, advanced renewable energy systems, energy storage system innovation, advanced energy efficiency, systems, sustainability and cleantech solutions, climate change and decarbonization solutions, energy supply/demand/distribution forecasting and optimization.

Scientific frontiers include hydrogen technology, fusion power, new battery chemistries and carbon capture. While the market is driven by the energy transition and strong policy support, scaling is slow and dependent on regulation. Industrialisation faces challenges relating to infrastructure lock-in, grid integration and cost reduction. Collaborations with utilities, major oil and gas companies, and governments are essential for adoption and deployment.

*Figure 15: Paebbl logo*

Paebbl is a Dutch company that seeks to accelerate the mineralisation process of CO2, turning it into rock to make building materials. This approach would disrupt the current concept of construction, transforming it from one of the most CO2-intensive industries to a tool for cleaning the atmosphere. Their technology has been noticed by Amazon's Impact Fund, which invested $25 million in Series A in 2024.

## 14. Virtual Reality, Augmented Reality, Metaverse

Focuses on the creation and application of digital information and content in either partially or fully immersive environments.

Technological hurdles include the miniaturization of hardware, the reduction of latency, and the creation of realistic multimodal interaction. While the market is still uncertain, with hype cycles and unclear consumer adoption, there is strong potential in training, design, and entertainment. Industrialization is currently limited by hardware costs and content ecosystems. Start-ups must collaborate with major technology and industrial companies to develop scalable applications and platforms.

*Figure 16: Varjo logo*

Founded in Finland in 2016, Varjo is now one of the most advanced virtual and mixed reality producers in the world. Developing both hardware and software, their solutions have a wide range of applications: they are already being used to train astronauts, pilots and nuclear power plant operators, to design cars and to conduct groundbreaking research.

### 15. Web 3.0, including Blockchain, Distributed Ledgers, NFTs

Focus on Web 3.0 applications that address a major societal challenge.

The scientific challenges lie in the scalability, interoperability and security of these decentralised systems. While the market has strong potential in finance, supply chains and digital identity, it faces volatility and regulatory uncertainty. Industrial adoption remains limited, with only a few pilots having been scaled beyond crypto. Building connections with corporations is essential for gaining credibility and moving beyond speculation to enterprise-grade applications.

*Figure 17: Briccken logo*

Briccken is a Barcelona-based startup that is transforming tokenisation and asset management with its comprehensive token suite. Its platform simplifies the creation, sale and management of tokenised digital assets, enabling companies to tokenise their assets and enable effortless self-tokenisation and management.

Although the list of examples of deep tech companies just given may seem long and general, it is essential to provide an overview of the main theme of this thesis. In fact, deep tech innovation often take place in well-established tech companies that are not the focus of this project. The scope of this thesis is to look for a possible way to solve the main difficulties that a Deep Tech funded startup may face in its development. Therefore, a comparison between very recently founded companies (seeds) and well-established players who happened to be startups a few years ago is fundamental to understanding the development of these innovative deep-tech companies. On the other hand, it would be misleading for the purpose of the project to look at big tech companies (namely Google, Microsoft, Apple...).

Another exclusion from our panel of deep-tech startups is biotech based on drug discovery. This is because, although they are also capital intensive and take longer to bring to market, this type of innovation is a well-established asset class where the longer timeframe is mostly due to testing and regulatory approval rather than the initial discovery phase (figure 18). Biotechnology and life science start-ups (6th on the list) are still considered deep tech.

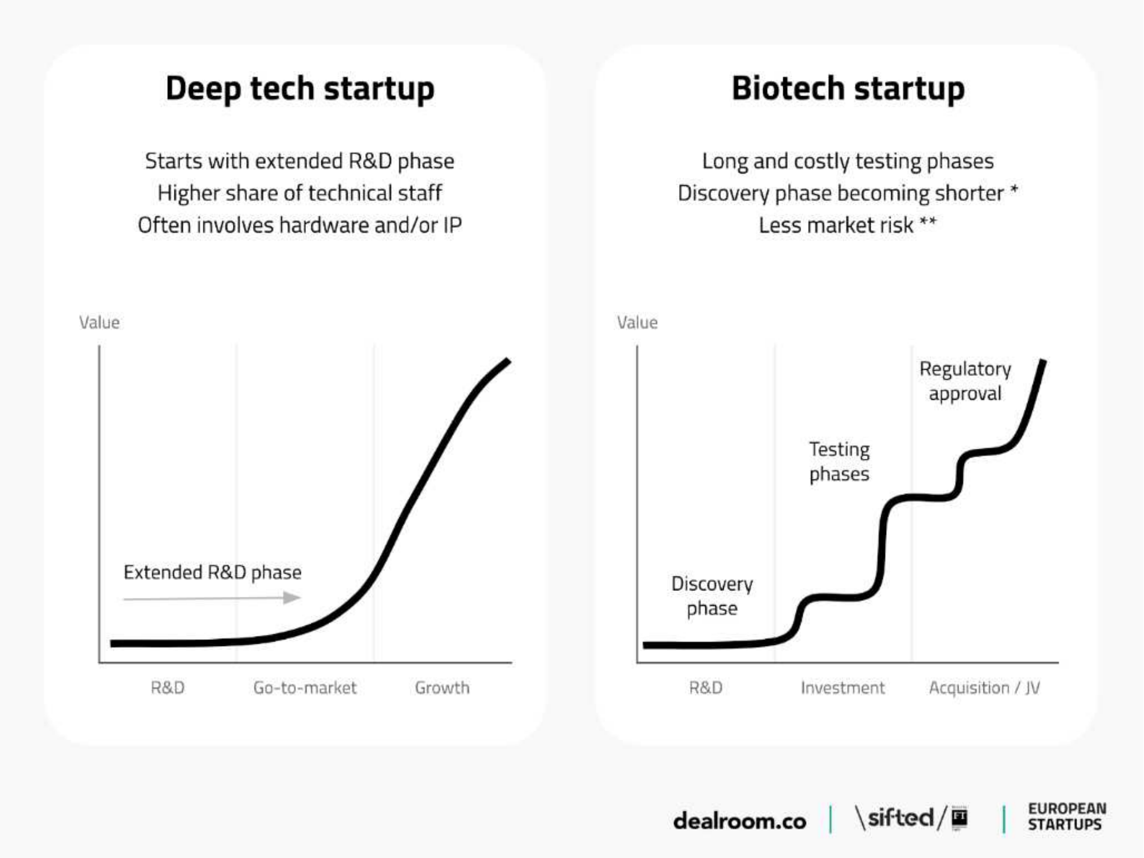


*Figure 18: Deep tech VS Biotech drug discovery*

## DeepTech categories comparison

A comparison of the analysis conducted on the 15 deep tech categories revealed that they all exhibit certain key similarities. In fact, they all share long development times, capital intensity and technical risk, as opposed to market risk. Furthermore, most of them depend on IP and require strong links with established corporations for scaling up.

Conversely, some clusters can be formed from the 15 categories based on the main challenges they face and their strict development links:

- Deep computing stack: Quantum computing, semiconductors, electronics/photonics and AI/ML come together to form a coherent cluster. These technologies build on each other: semiconductors enable new computing hardware; photonics contribute to faster data transmission; quantum technology adds new architectures; and AI exploits the computational power. The challenges they face are complementary, and progress in one area often accelerates progress in the others.

- Industrial production: Advanced manufacturing, robotics, the Internet of Things (IoT) and advanced materials cluster around physical production. Manufacturing integrates robotics and the IoT into digital factories, with robotics depending on advanced materials for lighter, more efficient machines and the IoT providing sensing and connectivity. Together, they underpin Industry 4.0.
- Life & sustainability: Biotechnology and clean technologies converge in the bioeconomy (e.g. biofuels and circular bio-materials) and in the healthcare sector's connection to environmental sustainability. Both face high regulatory demands and long testing cycles, but their societal impact is immense.
- Digital experience: VR, AR and the Metaverse, as well as Web3 and blockchain, all focus on how humans interact with digital environments. They both create new forms of digital presence, ownership and interaction. However, they rely on network effects and have uncertain adoption rates and volatile business models.

However, some categories may have peculiarities that are not advisable in others. For instance, the Biotechnology & Life Sciences category carries the heaviest regulatory burden, involving clinical trials, ethical constraints (e.g. gene editing and embryo research) and approval processes that can take up to ten years. No other category has such a stringent combination of scientific and legal hurdles.

Conversely, the Semiconductors and Aerospace categories are considered the most capital-intensive. Semiconductor fabrication plants require billions of pounds of investment, and aerospace projects demand large facilities, certification procedures and state or corporate backing. Both sectors are strategic for sovereignty and defence, adding a geopolitical dimension.

AI & Machine Learning is the most transversal technology. It has applications in nearly every other category, including biotech, data, robotics, the Internet of Things (IoT), clean tech optimisation and cybersecurity. Its flexibility makes it a unifying layer for deep tech innovation.

Finally, Web 3.0 and blockchain may be considered the most uncertain category. Unlike the others, the societal value proposition is still being debated, the regulatory framework is uncertain, and speculative volatility undermines credibility. Although it has the potential to transform trust, identity and ownership online, its adoption remains inconsistent compared to fields such as clean energy or biotech.

## The European Landscape of Deep Tech Startups

Deep tech in Europe is one of the most important VC investment categories, with rapid growth over the last decade. From 2019 to 2023, the share of investments in deep tech increased from 26 to 44 percent of all tech investments in Europe (McKinsey, 2024). Figure 19 shows the evolution of total investment in Deep Tech startups over the last 10 years.

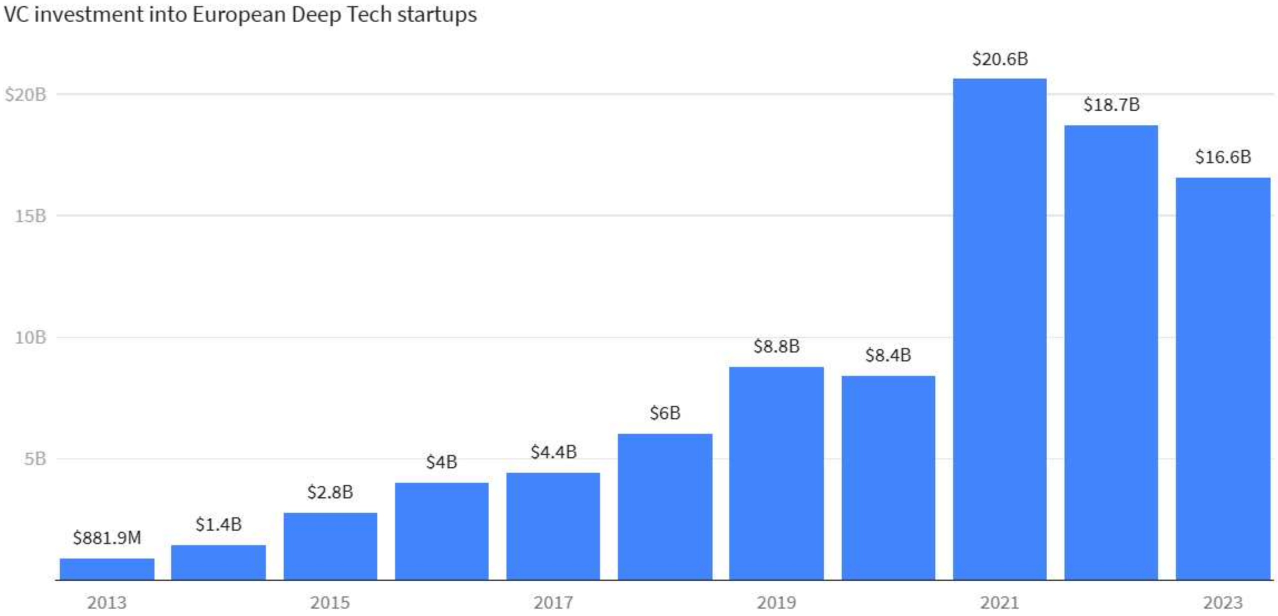
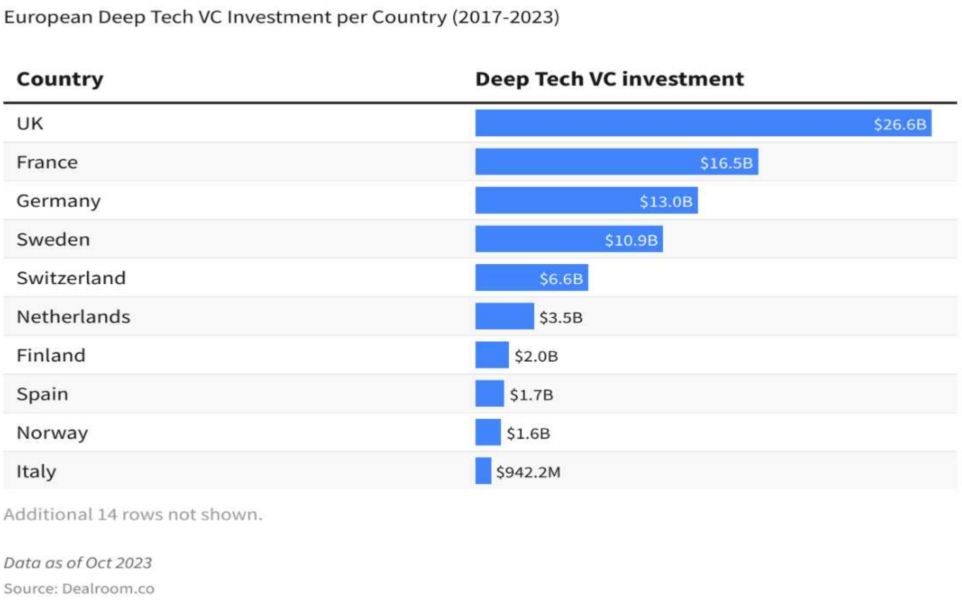


*Figure 19:European investments in Deep Tech startups. Source DealRoom*

In 2021, there was a spike in investment due to several factors: the most important was that the Covid pandemic showed how this type of innovation could be vital for crisis management, with BioNTech being a key example with its early success in developing mRNA-based vaccines. In addition, the geopolitical tensions of the time highlighted Europe's total dependence on other countries for both technology development and energy supply.

These reasons, combined with the fact that deep-tech investments have been shown to outperform traditional tech investments, with an average IRR of 17 per cent compared to 10 per cent for the latter. (McKinsey, 2024), have led to the emergence of many initiative around deep-tech sector in Europe. The most important is Horizon Europe, the EU's main funding programme for research and innovation, with a budget of 95.5 billion euros for European innovators in 2021-2027. Then the European Investment Fund (EIF) is the main LP in most European deep tech funds, providing almost 40% of the capital allocation. Then, by country (Figure 20), the main investments in Deep Tech are made in the UK (also thanks to its UK

Innovation Agency), followed by France and Germany, while Italy is lagging behind these countries.



European Deep Tech VC Investment per Country (2017-2023)

| **Country** | **Deep Tech VC investment** |
|---|---|
| UK | $26.6B |
| France | $16.5B |
| Germany | $13.0B |
| Sweden | $10.9B |
| Switzerland | $6.6B |
| Netherlands | $3.5B |
| Finland | $2.0B |
| Spain | $1.7B |
| Norway | $1.6B |
| Italy | $942.2M |

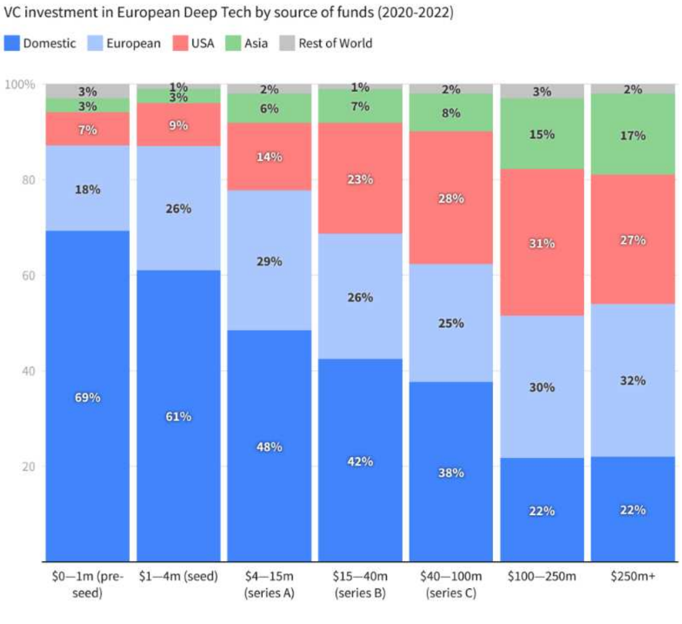
Additional 14 rows not shown.

*Data as of Oct 2023*

Source: Dealroom.co

*Figure 20;European Deep tech investments by country. Source dealroom*

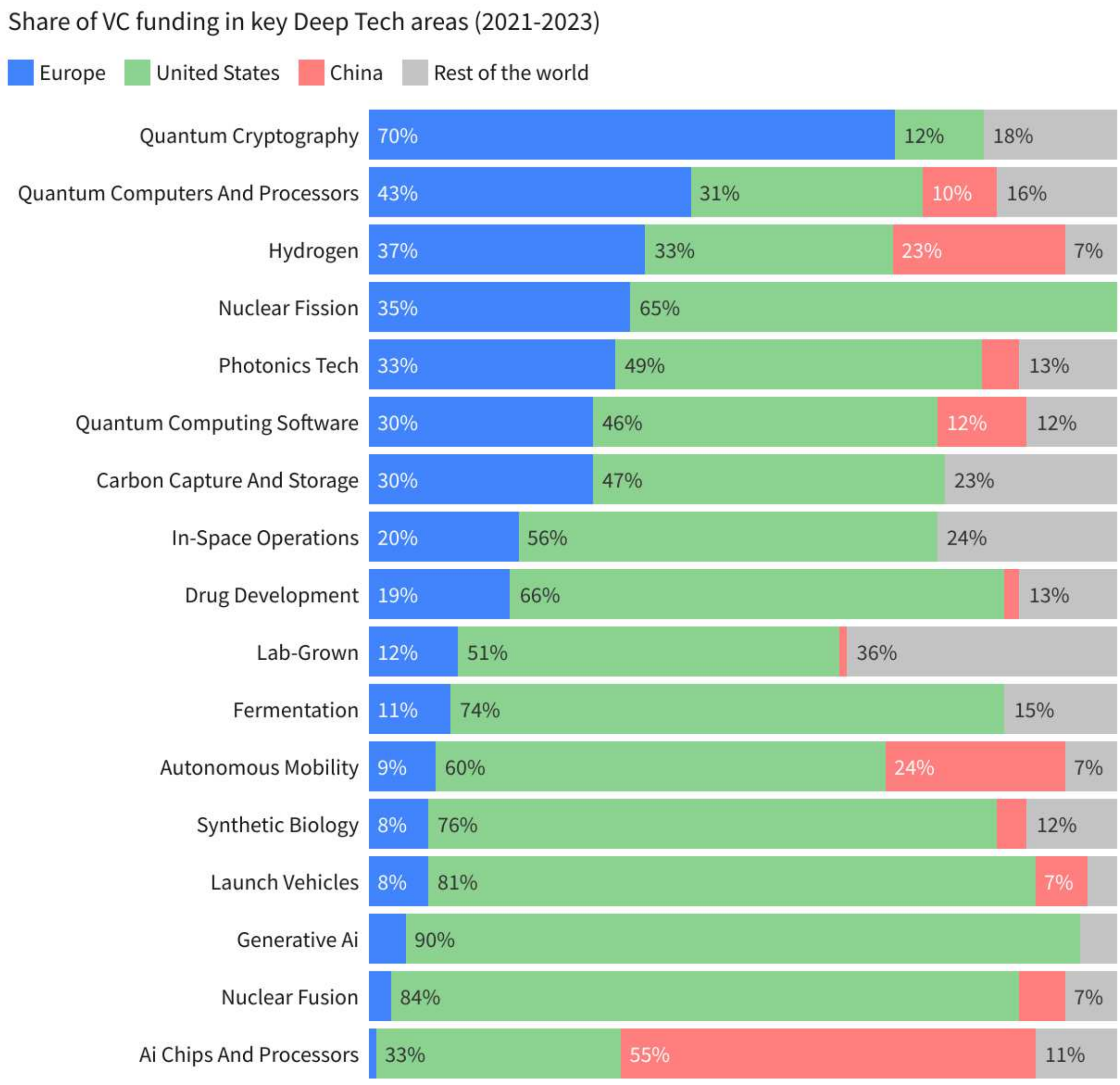
However, not all the wealth generated is captured by European companies, as many investments, especially in the later rounds, come from abroad (Figure 21). In fact, European deep-tech start-ups are the target of mergers and acquisitions by large American or Chinese groups, such as Apple, Meta or Microsoft.



Source: Dealroom.co

*Figure 21: European Deep tech investment source by round. Source: Dealroom*

As shown in Figure 22, the main Deep Tech fields in which European start-ups are created are quantum computing and green technologies. However, as the graph only considers VC fund investments, it cannot be used as a proxy for technological development in these fields. China, for example, is a leader in quantum cryptography in terms of patents and research.



Source: Dealroom.co

*Figure 22: VC funding by key deeo tech area. Source dealroom*

Even Mario Draghi’s report of 2024 (Draghi, 2024) pointed to innovation as one of the key challenges for Europe's future. He pointed out that although Europe is now producing a significant number of start-ups, comparable to the US, European companies often fail to make it through the growth phase. As a result, the EU has a lower number of unicorns (i.e. start-ups valued at more than USD 1 billion), a third of which move their headquarters abroad. To address these issues, Draghi's report recommends several solutions based on creating a better financing environment for disruptive innovation and investing in world-leading research and technology infrastructure.

## Deep Tech challenges

Due to the specific characteristics that distinguish deep-tech startups from traditional ones, many challenges may arise during the development process that could prevent the company from successfully innovating and growing.

The first obstacle comes from the fact that all the actors involved in the investment phases may not recognize the startup involved as a deep tech startup with the appropriate characteristics. As explained in the first part of the chapter, deep tech investing involves backing technologies that are still developing their underlying science, considering potential markets and creating business plans, so investments take longer to mature than other tech investments - on average 25% to 40% more time between funding each stage from seed to Series D. (BCG, 2023). The venture capitalists involved should be aware that their investments may take longer and should not push for unmotivated early exit strategies.

The uncertain commercial application and regulatory framework around a deep-tech innovation is another challenge, as it makes it very difficult for investors to assess the potential of the start-up. Add to this the fact that these types of innovations tend to be more capital intensive than traditional ones, and many investors may prefer to redirect their money.

One of the main challenges faced by deep tech innovators is identifying the best application field and market need for their breakthrough innovation. This problem is particularly prevalent among innovations originating from university research, where TTOs struggle to assist researchers in identifying the most impactful and lucrative market applications for their innovations.

Uncertainty also relates to go-to-market strategy and timing, as half of all deep-tech startup founders, who thought they would reach the market in less than three years later, admitted that they had underestimated the time required. (BCG & hello tomorrow, 2021)

On the other hand, even start-ups themselves may not find the support they need in their partners. In addition to funding, they may need help with market access, technical expertise and business know-how. They may lack basic things such as a distribution network, database access, customer base or business expertise to drive their efforts.

Venture capitalists can provide some solutions to these needs, but the best providers would be corporates. However, even collaboration between startups and large companies has many obstacles, such as the lack of clear value proposition, application and proof of concept from the startups, or the timing and process misalignment between the two parties (fast decision making for startups, slow bureaucracy for corporations).

Some literature has already tried to provide recommendations on how to solve these and many other problems that can hinder the healthy development of Deep Tech start-ups. However, as the challenges have not been solved yet, this thesis will try to find a new perspective by investigating the principles of Translational Medicine and trying to see if they can be applied to face some of those development problems.

As the main purpose of this Master Thesis is to model a new theory to support the development of Deep Tech startups in Europe, the next section will explain why university spin-offs in Deep Tech represent the most unexpressed potentiality in this sector in Eu due to many obstacles faced in their development process.

## Deep Tech University Spinoffs in Europe

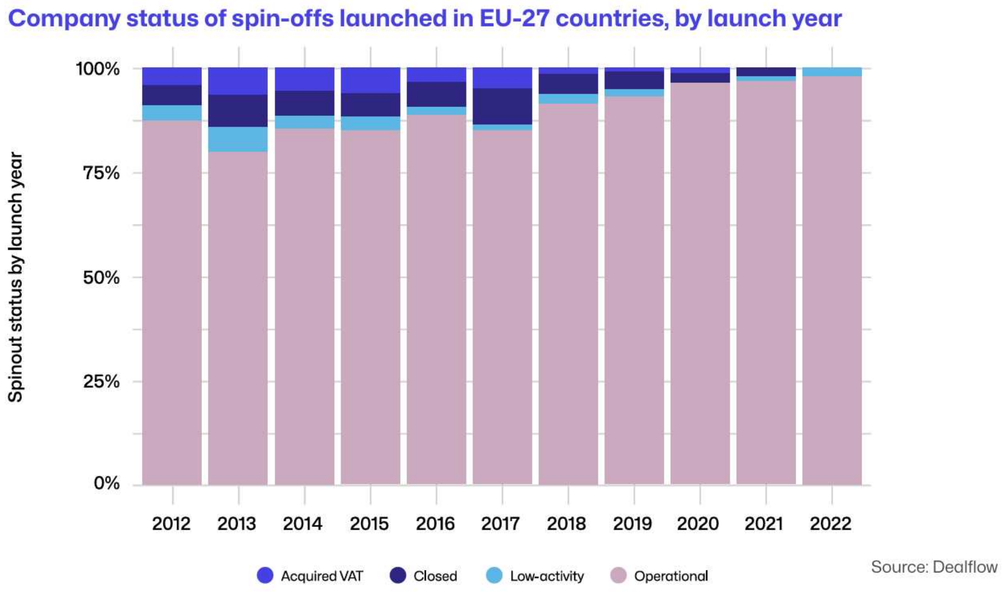
University Spinoffs (or Spinouts) are startup companies created based on technological inventions and intellectual property (IP) that have emerged from university research. University spin-offs facilitate knowledge transfer between universities and industry, fostering an innovation ecosystem that drives regional economic growth. They create highly skilled jobs, attract investment, and contribute to the formation of technology clusters.

The EU boasts world-class research institutions and a high number of STEM graduates per capita, counting on 10 institutions among the top 25 of the world's 100 most innovative universities and research institutes by Reuters.

Despite the potentiality of EU Universities and the fundamental role for economy and innovation of Spinouts, according to the report “Spin-offs: reinforcing a vector of value creation for EU-27” (European Commission, 2025), European Spin-offs face significant challenges in scaling, securing funding, and navigating regulatory frameworks.

Many deep-tech spin-offs fail to attract the funding needed to scale. Complex intellectual property (IP) rules, high university equity stakes that discourage private investors, and a lack of targeted financial instruments for later-stage growth all contribute to this challenge.

Compared to other start-ups, European spin-offs have a lower failure rate, but also relatively few exits. The majority of spin-offs created after 2012 remain in operation (Figure 23). The closure rate is relatively low, with less than 10 percent of spin-offs launched in any given year closing within a few years. However, acquisitions, the most typical exit route for start-ups, are also rare for spin-offs, while IPOs are even rarer.



Source: Dealflow

*Figure 23: Company status of EU spinoffs*

Moreover, while Eu based spinoffs can quite quickly secure the first funding rounds compared to other regions, they face difficulties shifting towards seed rounds and later stages financing (figure 24).

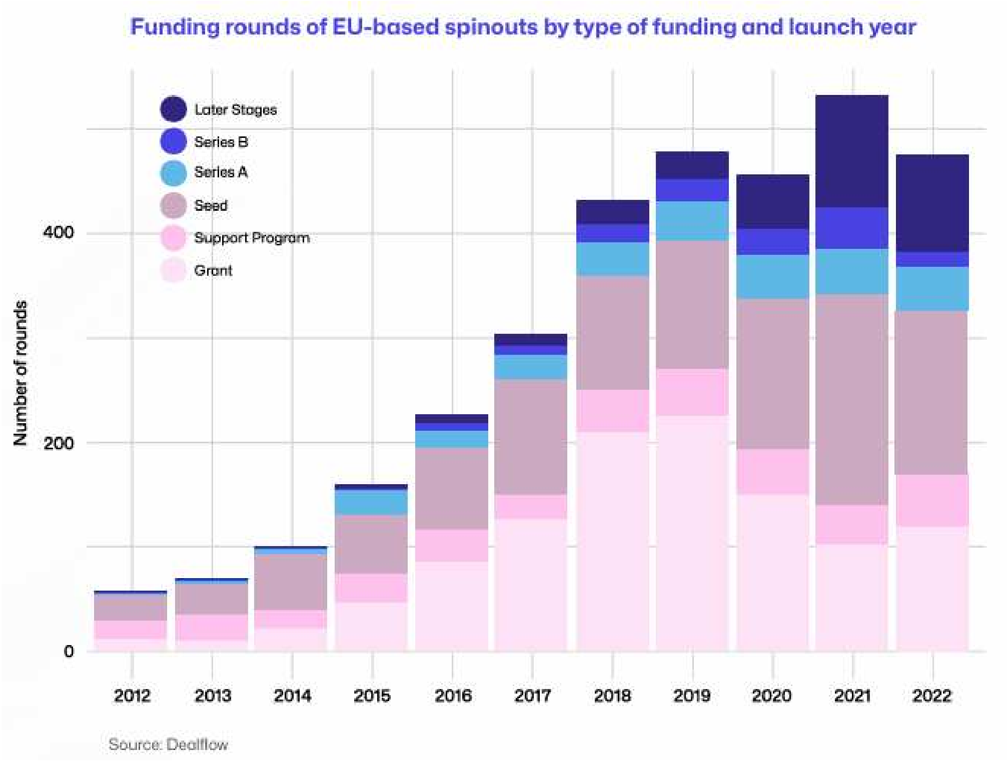


*Figure 24: Funding rounds of EU- spinouts*

In EU approximately 23% of Deep Tech startups are Spin-offs and they reach only 11% of the total valuation of all Deep Tech startups. As showed in figure 25, the decreasing trend of creation of Deep Tech spinoffs comes in the same period of an increasing trend of investment in those type of startups, signaling how universities are failing in leveraging their potentialities.

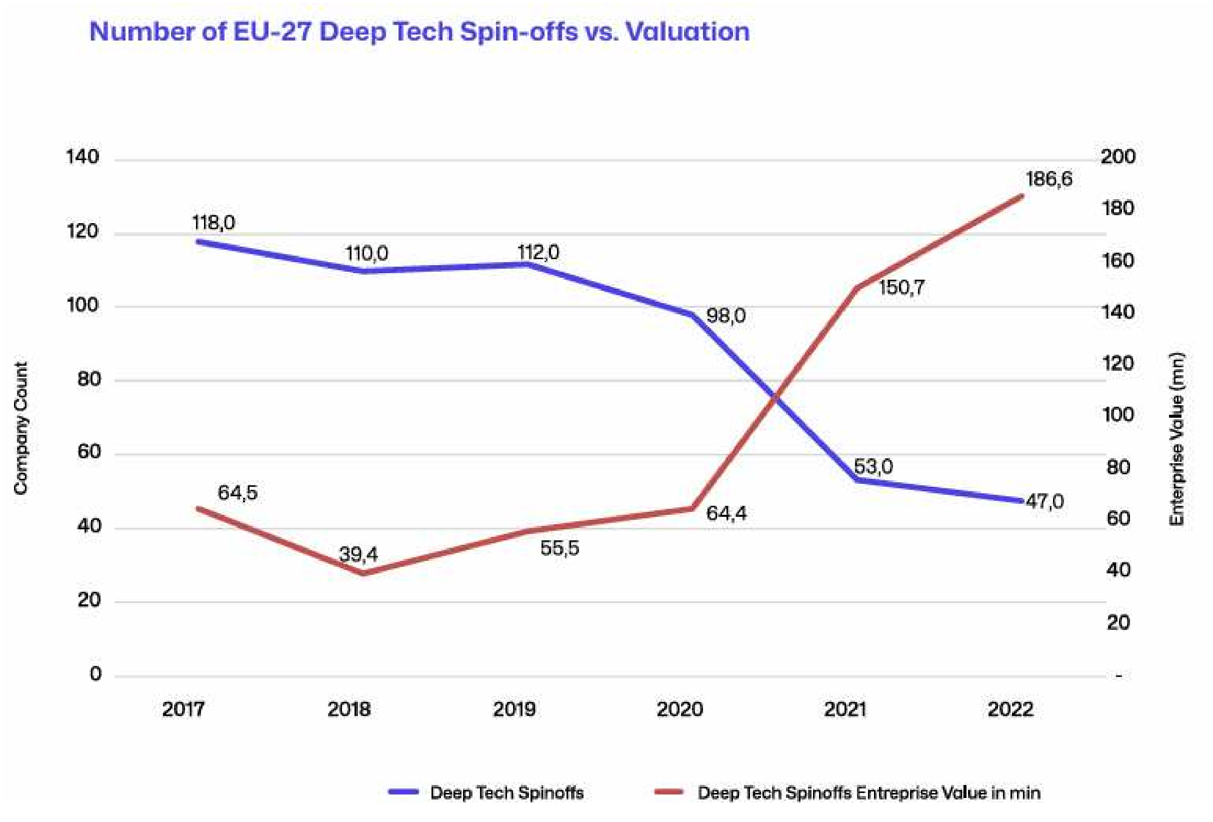


*Figure 25: Eu Deep Tech Spinoffs VS Valuation*

An independent report of the Department of Science, Innovation and Technology of the UK Government (Tracey & Williamson, 2023) highlighted what are the main needs necessary to create a world-class centre of spin-out creation:

1. A diverse and experienced pool of academic founders, creating foundational intellectual property (IP) and working closely with experienced start-up operators.
2. Anchor institutions, particularly universities, enabling researchers to create world-leading IP in science and technology, nurturing technical talent, and connecting and convening stakeholders in the local ecosystem.
3. A range of service providers, from accelerators to professional services firms, competing to provide business and entrepreneurship support to spin-out founders.
4. Accessible investment capital, ranging from pre-incorporation translational funding to pre-seed/angel investment to other forms of capital, including venture capital investment, particularly from investors with experience in building high-tech startups.
5. A mix of large science and technology companies that provide spinouts with partnerships, access to global markets, and experienced technology leaders as co-founders or advisors.
6. A supply of talented early employees to do the necessary work.

7. Infrastructure (lab space, equipment, computing, housing, transportation) to support growing spin-outs and their employees, ideally in close proximity to their anchor institutions to allow for porosity among all elements of the ecosystem.

Of this “recipe” to create a Spinout encouraging environment, EU seems to be very strong in the points that look at the pure research and academic assets, while it is lacking in points 3, 4 and 5, that need the involvement of third parties like companies and investors. To improve these aspects, some inspiration may come from Translational Medicine approach explained in the next chapter.

# Chapter II: Translational Medicine

This second chapter explains what Translational Medicine is about.

The first part gives a definition of TM, shows how the practice has boomed in recent years and how it has evolved over time from a unidirectional to a bidirectional and finally to the 3-pillar approach now promoted by many organisations worldwide.

The second part of the chapter shows how Translational Medicine can be modelled, from the "4Ts" model to a spectrum of continuous feedback forward and backward in the chain. An alternative model is then presented that highlights the 2 most difficult steps in TM.

The third section looks at the basic principles of Translational Medicine, while the last part of the chapter aims to show how these principles have led to real applications in medicine to support healthcare development.

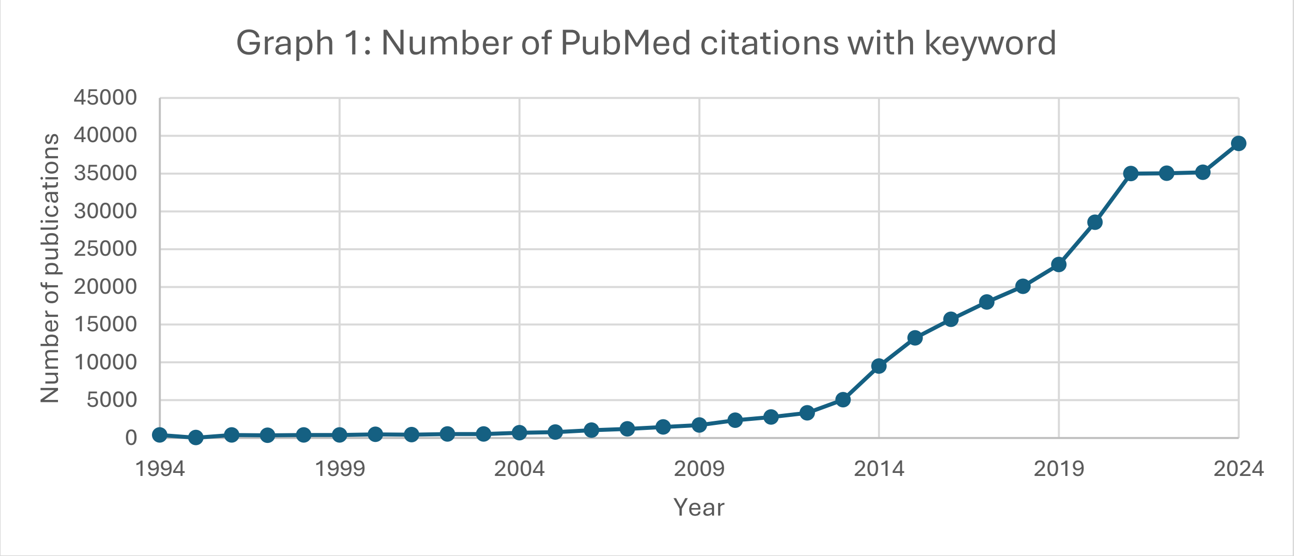
The approach used in all these analyses is from an organisational and procedural point of view of Translational Medicine, as it is not within the scope of this thesis to go into the medical and biotechnological details of this discipline.

## Definition and history

Translational Medicine is defined by the European Society for Translational Medicine as “an interdisciplinary branch of the biomedical field supported by three main pillars: benchside, bedside and community. The goal of TM is to combine disciplines, resources, expertise, and techniques within these pillars to promote enhancements in prevention, diagnosis, and therapies” (Randall J. Cohrs, 2015).

As explained in the definition, Translational Medicine (also known as translational science, experimental medicine, discovery medicine or clinical discovery) is a highly interdisciplinary field that aims to exploit the synergies of different approaches to improve patient outcomes and the prevention, screening and treatment of disease. The need to develop this discipline comes from the division created by the separation of medical education and pharmaceutical research into preclinical and clinical categories. (Wehling, 2021). Another reason for this cleft appears to be the enormous proliferation and breadth of techniques, platforms, models and clinical approaches, leading to separate "silos" of expertise.

Bridging the gaps by mastering cross-cutting processes is becoming critical to success in curing human disease. As shown in Graph 1, the number of citations of the keyword "Translational Medicine" in literature searches has increased significantly over the last 20 years, demonstrating how this method has become a reference in the field.



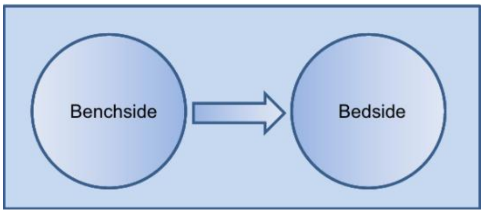


*Figure 26:Traditional translational model: unilateral benchside (lab) to bedside (clinical)*

Historically, Translational Medicine began with a "bench to bedside" (Figure 26) approach that emphasised the translation of laboratory discoveries into clinical applications to benefit patients. This first ides began to break down the barriers between laboratory and clinical research, but failed to value the feedback from the bench to the laboratory.

Translational Medicine at this stage was described as a two-stage research process (Institute of Medicine, 2003):

1. Basic science to clinical science
2. Clinical science to public health impact

From 1999 onwards, emerging technologies provided the opportunity to create multidisciplinary focus groups with biomedical, clinical, basic scientists and engineers all together. The aim of this new approach was to shorten the pathway for translating scientific discoveries into the clinic, creating a "benchside to bedside to benchside" concept (Figure 27) to bring clinical findings back into the research laboratories to redefine hypothesis-driven research efforts that could lead to innovative discoveries.

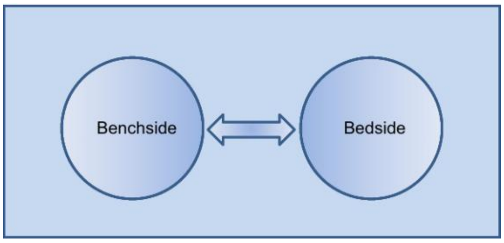


*Figure 27:Updated translational model: bi-lateral "two-way" iteration between bench side and bedside*

This bi-directional approach includes:

- Bench-to-bedside factors, to increase the efficiency of clinical testing of new therapeutic strategies developed through research
- Bedside-to-bench factors, providing feedback on the application of new treatments, diagnostics and preventive measures, where clinical observations can inform research to generate new hypotheses. Using real-world evidence or real-world data, these applications can be improved and new solutions generated.

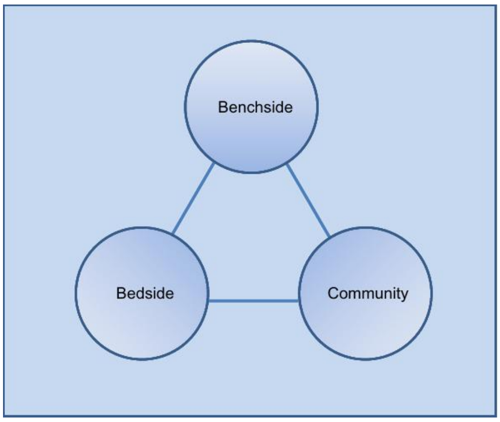


*Figure 28:EUSTM Translational Medicine model: the "community" as another key pillar.*

The latest theory of Translational Medicine completes the healthcare cycle by adding the community (Figure 28) as a fundamental pillar of Translational Medicine. (Randall J. Cohrs, 2015). The community includes healthy people as well as patients, healthcare professionals, public health systems, industry partners and NPOs from different geographical regions of the world. It can support Translational Medicine by providing valuable input to improve existing tools and treatments, involving patient groups or healthy volunteers in clinical trials, shaping public policy with public bodies, or raising funds through grants or general fundraising.

The Translational Medicine model is mainly promoted by many not-for-profit or governmental organisations, which may be regional or global, and whose main purpose is to promote the use of TM in as many institutions as possible in order to increase the community around it.

One of the main promoters of TM today is the European Society for Translational Medicine (EUSTM), whose main objective is to improve healthcare worldwide through the use of Translational Medicine approaches, resources and expertise. To this end, they have created both the Global Translational Medicine Consortium (GTMC), which aims to bring together international TM resources and expertise under a single umbrella to promote collaboration and support multi-site or multi-national clinical trials, and the Academy of Translational Medicine Professionals (ATMP), a certification agency to ensure that all TM professionals have the resources and training to undertake the tasks involved.

In the US, the National Canter for Advancing Translational Sciences (NCATS) was established in 2011 to support the creation of innovative methods and technologies to accelerate the development, testing and implementation of diagnostics and therapeutics for a wide range of human diseases and conditions (National Center for Advancing Translational Sciences, s.d.).

To this end, the organisation promotes a so called "3Ds" program:

- Develop new approaches, technologies, resources and models
- Demonstrate their usefulness
- Disseminate data, analysis and methods to the community

From a global perspective, the Translational Medicine Academy (TMA) is a not-for-profit foundation dedicated to bridging the gap between medical research and patient care by providing continuing medical education (CME) and continuing professional development (CPD) programmes for healthcare providers, organising expert forums and supporting translational science through funding opportunities. In addition, the Society for Translational Medicine (STM) is a Hong Kong-based not-for-profit organisation whose main aim is to improve patient survival and quality of life through the use of Translational Medicine approaches, resources and expertise, and to promote collaborative research, evidence-based medicine, medical innovation and continuing medical education.

## Translational Medicine Model

The translational model involves many stakeholders, such as academia, industry, patients, regulators and the public, to cover both research disciplines and operational and regulatory aspects to address systematic bottlenecks that could slow down the process of bringing innovation to patients. The main objective is therefore to optimise the efficiency of each step of the translational process, building on advances in basic research that are integrated with clinical observations to develop new therapies or medical procedures.

From a procedural point of view, Translational Medicine has been modelled into the so called “4 T’s” model (Muin J. Khoury, 2007):

- **T1: From gene discovery to candidate health applications**

  T1 research in genomics begins after gene discovery and aims to develop a candidate application for use in clinical and public health practice. In general, such applications are used either to support clinical evaluation (e.g. predictive testing, screening, diagnostic testing, prognostic testing) or to select the most effective therapeutic options.

- **T2: From health application to evidence-based guidelines**

  The translation of a genetic test from research to practice begins with the identification of the disorder (or pharmacogenetic effect) being tested for, the specific test to be used, and the clinical scenario in which the test will be used (e.g., diagnostic versus predictive, population to be tested). Evaluation often begins with the determination of analytical performance characteristics; once a test is in use, additional data can sometimes be collected through proficiency testing programmes. Clinical validity is usually established in observational studies of genotype-phenotype association; if properly designed and conducted, such studies can be used to estimate the clinical sensitivity and specificity of a genetic test and, if the study is population-based, its positive and negative predictive values. In general, T2 research for genetic tests begins once analytical validity has been established and early results of clinical validity look promising to the test developers. T2 research also includes the evaluation of benefits and risks on a larger scale, which is necessary to assess the clinical utility of tests in the context of a wide range of ethical, legal and social issues. The end result of such research is a systematic review and synthesis that will support the development of evidence-based practice guidelines.

- **T3: From evidence-based guidelines to health practice**

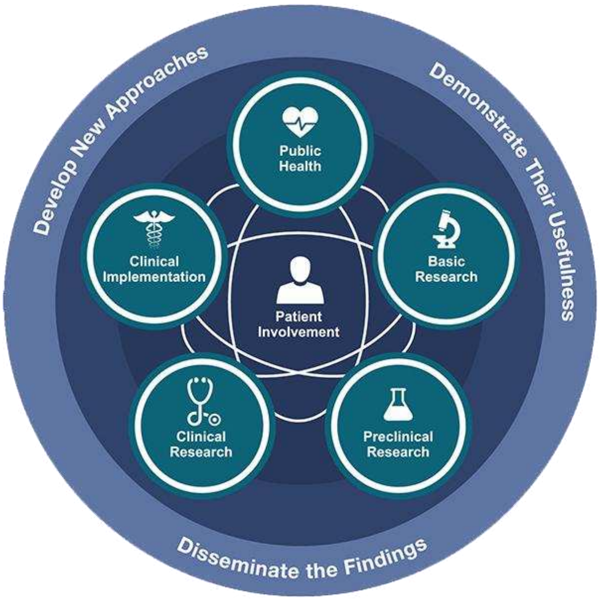
  Translating evidence-based guidelines into practice is one of the most challenging problems in health care and disease prevention. T3 research addresses issues such as increasing knowledge of evidence-based interventions (dissemination research), integrating these interventions into existing programmes and structures (implementation research), and ensuring widespread adoption of these interventions by stakeholders. T3 research highlights the complexities of compliance and education that may ultimately affect the clinical utility of a genetic test in the 'real' world, as opposed to the inherent clinical utility of the test in the ideal scenarios of controlled clinical trials.

- **T4: From practice to population health impact**

  The final stage of translation research assesses how the adoption of evidence-based recommendations and guidelines can make an impact on real-world health outcomes.

After a few years, a systematic literature review in 2017 re-proposed the model, with the additional phase T0 as the start of the process, in order to increase the importance of genome-wide association studies, which return to basic research (T1). (European Patient's Academy on Therapeutic Innovation).

This model must not be seen as 5 isolated progressive phases as it was in the past, but the main scope of Translational Medicine from an operational perspective is to see them as a spectrum or continuum. This spectrum (Figure 29) is neither linear nor unidirectional, as each step builds on and informs the others by demonstrating its usefulness or sharing its findings.



Credit: National Center for Advancing Translational Sciences

*Figure 29: Translational Medicine spectrum*

The first step (National Center for Advancing Translational Sciences, s.d.) focuses on basic research aimed at uncovering fundamental mechanisms of biology, disease or behaviour. Preclinical research then seeks to translate the fundamental discoveries of basic research into human medicine by developing model interventions to further understand the basis of a disease or disorder and find ways to treat it. This may involve tests in cell or animal models of disease, samples of human or animal tissue, or computer-based simulations of drug, device or diagnostic interactions in living systems.

The third part of the spectrum is clinical research, the main aim of which is to generate data to support regulatory approval of an intervention. This includes studies to better understand a disease in humans, testing and refining new technologies in humans, testing interventions for safety and efficacy in people with or without disease, and behavioural and observational studies.

If the intervention has been shown to be useful in a research setting, it can be transferred to clinical care for the general population. This stage also includes implementation research to evaluate the results of clinical trials and to identify new clinical questions and gaps in care.

Finally, the public health stage studies health outcomes at the population level to see the results of the new treatment. The results help guide scientists working to evaluate the effects of current interventions and develop new ones.

However, other literatures (Wehling, 2021) prefer to explain the process of Translational Medicine in terms of a two-stage model, highlighting the obstacles to be overcome at each stage.

The first is translation in development pathways from preclinical to clinical stages, particularly as applied to the development of new drugs. These developments would bring innovation to the patients who receive the new drug, test or device.

The second gap that needs to be addressed is the translation of innovation into 'real life', even when innovative medicines have changed clinical guidelines and regulations and thus have undoubtedly proven to be beneficial options for appropriate patients. Under-treatment may be due to ignorance, budget constraints or patient or physician non-compliance, and often has serious socio-economic implications. This means that innovations that have successfully passed all the translational hurdles in the bench-to-bedside development process may still not reach patients at large, as there is a second barrier between guideline recommendations and real-life medicine (Figure 30). This translational aspect of innovation is sometimes referred to as secondary translation (as opposed to developmental primary translation).

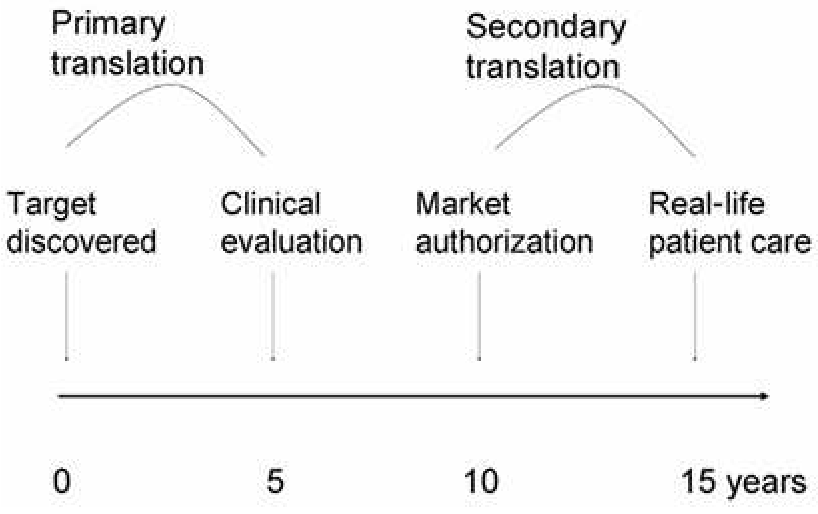


*Figure 30: two principal transition phases for drug discovery*

## Translational Medicine Principles

As Translational Science seeks to overcome common challenges across the translational research pipeline, it relies on scientific, operational, financial and administrative innovations to make research faster, more efficient and more impactful.

According to NCATS, to achieve this goal, Translational Medicine has evolved around 7 key scientific and operational principles that enable successful implementation of Translational Medicine. These are (National Center for Advancing Translational Science, s.d.):

1. **Prioritize initiatives that address unmet needs**.

The focus is on the pursuit of scientific objectives that address unmet scientific, patient or population health needs. These needs may be scientific needs to contribute to research advances in under-researched areas of science or scientific questions that present unique research challenges or disincentives. They may also be patient and population health needs to advance research to develop solutions for unmet patient and population health needs.

2. **Produce Generalizable Solutions for Common and Persistent Challenges.**

Developing innovations that address persistent challenges to the advancement of translational progress that are common to a number of research initiatives or projects, or that cut across research into a number of diseases or conditions. Three main approaches are possible. First, it can be applied across multiple projects or initiatives to advance research through the identification, development and/or testing of solutions to common constraints or barriers that are holding back multiple projects. These may be scientific, operational or administrative.

Secondly, it can be applied across diseases or conditions. This would mean that research challenges are approached and solutions are developed by looking for common ground between research projects on a range of diseases or conditions.

Finally, organisational settings may allow generalisable solutions to be developed and tested through organisational strategies, structures and shared resources.

3. **Emphasize Creativity and Innovation.**

To increase the impact of research, use creativity and innovation in research design, implementation and enabling factors. This may include designing and conducting research, research processes and structures, or the organisational environment.

The first is to formulate innovative research questions and develop and implement innovations in research methodologies, technologies and approaches that increase the impact of research, e.g. paradigm-shifting aims or innovations that can be generalised to advance research across multiple initiatives, diseases and conditions.

The second would develop and implement innovations in how research teams interact, lead and manage, partner and operate that facilitate and support the quality and impact of research.

The third would be the enabling of creativity and innovation through policies that are supportive of innovation and do not penalise failure.

### 4. Leverage Cross-Disciplinary Team Science.

To produce research that advances translation along the translational research continuum, engage team members with expertise across disciplines, fields and professions. Several approaches can be used to achieve this.

First, engage colleagues from across disciplines, fields and professions to advance research along the translational continuum to leverage broad expertise. This may be in the form of scientific, administrative, financial and operational expertise.

Second, to integrate concepts, theories, methods, technologies and approaches from across the range of disciplines, fields and professions that can contribute to the advancement of the research objectives. This would enable knowledge to be integrated to produce more holistic research designs and outcomes that become more relevant to practical applications.

Finally, organisational policies, team leadership and management, shared instrumentation and space, and recognition and reward systems should enable team science.

### 5. Enhance the Efficiency and Speed of Translational Research

Implement evidence-based practices and scientific and operational innovations to accelerate the pace of translational research.

Exemplary approaches include:

- Scientific efficiency: Accelerating the pace of translational research by developing and implementing innovations in scientific approaches, methods and technologies.
- Collaborative efficiency: The implementation of evidence-based practices to increase the speed with which collaborations and teams are formed, to develop a shared vision and goals, to communicate effectively and to co-ordinate work tasks.
- Project management efficiencies: Introduce milestone decision making to quickly agree go/no-go decisions for the most effective use of resources.
- Organisational Environment: Rewarding efficiency, allowing rapid failure and encouraging the redirection of resources to subsequent trials.

### 6. Utilize Boundary-Crossing Partnerships

To accelerate translational progress, cross-agency and cross-sectoral collaboration should be used and patients and communities should be involved in research.

To leverage diverse expertise and resources to accelerate translational progress, cross-sector partnerships can be implemented with partnerships across government, academia and industry.

Patient and community engagement can involve affected patients and communities as research collaborators to enable research advances across the translational continuum (e.g., through disease registries, participating in clinical trials, designing interventions).

Organisational environment: Leadership, policies, and recognition and reward systems that enable and incentivise cross-boundary partnerships.

Evidence-based practices should be implemented to make all these partnerships and collaborations effective.

### 7. Use Bold and Rigorous Research Approaches

Develop ambitious research questions and address them using rigorous and robust methods. This will produce reproducible results that will help advance translation.

For example, a bold scientific approach that explores ambitious research aims has the potential to make major advances and/or shift paradigms. This may be in areas that have been historically difficult to address or where there is a high risk of failing.

In these instances, rigorous and robust approaches are essential to generate reproducible results and high FAIR (Findable, Accessible, Interoperable, Reusable) data, enabling the research to advance translational advances regardless of whether the original research goal was met (for example, learning from failure).

To the extent possible, dissemination of all parameters used to conduct the study, study methods and conditions, authentication of reagents/biological materials, datasets, metadata, analytical approaches and statistical tools used for experiments and data interpretation, results and conclusions, to enable replication and/or to inform future study design.

Finally, an organisational environment should be created that enables the rigorous testing of bold, paradigm-changing ideas, including opportunities with high risk and high reward.

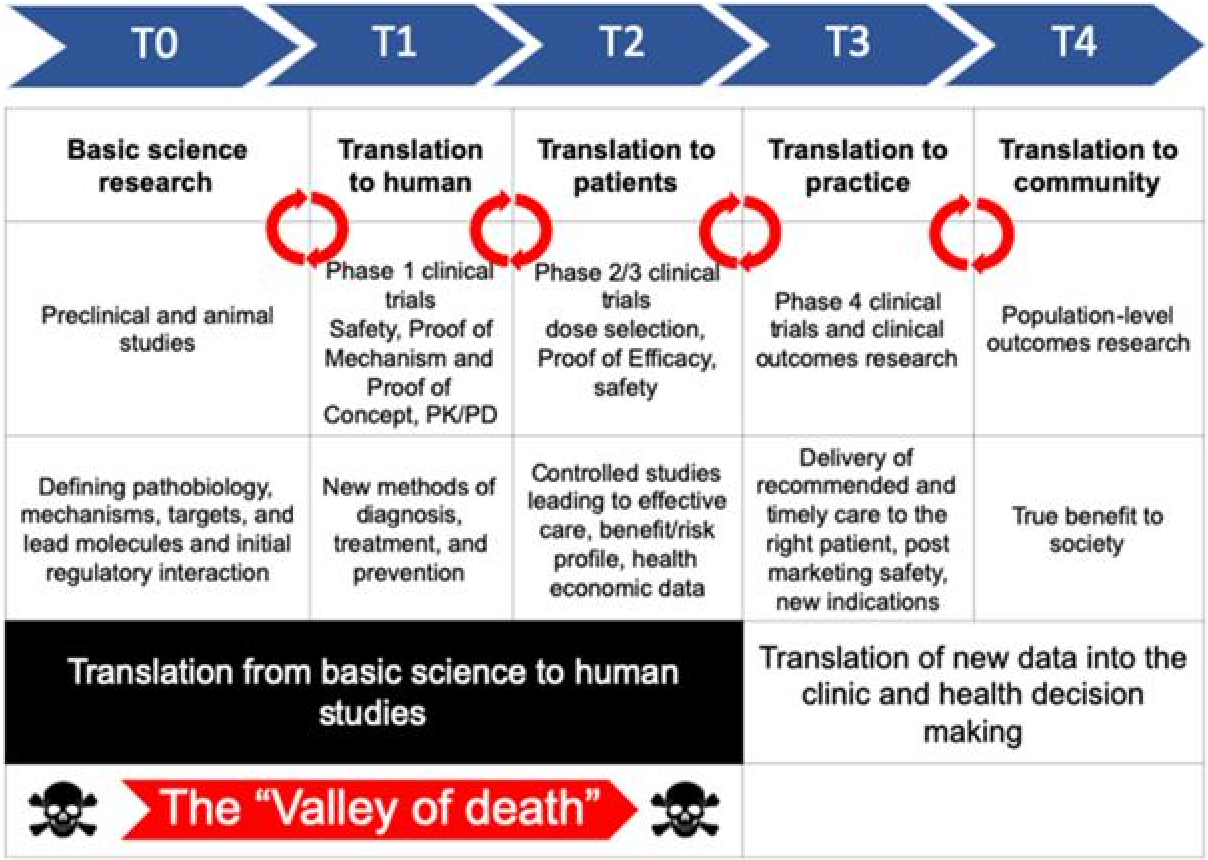
## Application of TM principles

The principles of Translational Medicine just outlined have been interpreted by scientists to create or adopt practices and instruments to solve some of the most common problems. In this part of the chapter some of them will be showed, to explain what Translational Medicine principles led to.

### The early testing

The main example of Translational Medicine principles in action is on the attrition problem in the pharmaceutical industry (Wehling, 2021), where shrinkage correlates with high late-stage attrition rates, meaning that many drug projects die after billions of dollars and 5/10 years of investment.

In terms of the T's model of Translational Medicine, this attrition can be explained by the so-called "valley of death" (Figure 31) in the pharmaceutical industry, which encompasses the T0-T2 phases of research. (Seyhan, 2019). The traditional method of identifying genes in vitro and then generating experimental animal models of human disease in vivo has been a challenging process because targets and drugs developed in animals often fail in human trials; the "valley of death" refers to the gap between bench research and clinical application.

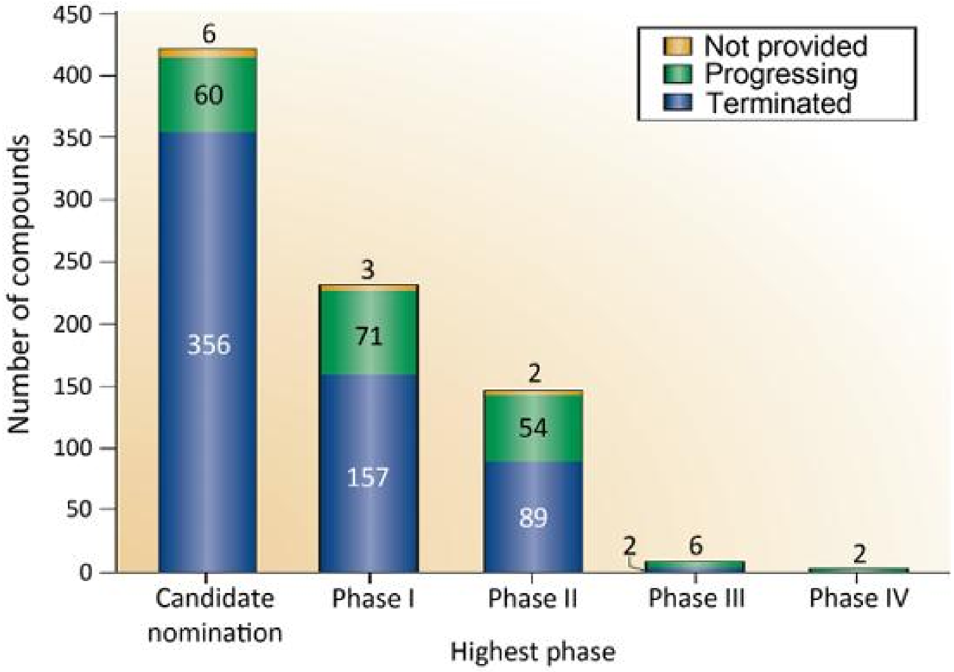


| T0 | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| **Basic science research** | **Translation to human** | **Translation to patients** | **Translation to practice** | **Translation to community** |
| Preclinical and animal studies | Phase 1 clinical trials<br>Safety, Proof of Mechanism and Proof of Concept, PK/PD | Phase 2/3 clinical trials<br>dose selection, Proof of Efficacy, safety | Phase 4 clinical trials and clinical outcomes research | Population-level outcomes research |
| Defining pathobiology, mechanisms, targets, and lead molecules and initial regulatory interaction | New methods of diagnosis, treatment, and prevention | Controlled studies leading to effective care, benefit/risk profile, health economic data | Delivery of recommended and timely care to the right patient, post marketing safety, new indications | True benefit to society |
| Translation from basic science to human studies | | | Translation of new data into the clinic and health decision making | |
| The "Valley of death" | | | | |

*Figure 31: T's model of Translational Medicine*

Late-stage attrition is a problem for all large companies, and lack of innovation is a major reason for the recent stagnation of progress in the treatment of some, but not all, major diseases. Thus, addressing the translational challenges in the R&D process may become essential to the pharmaceutical industry's struggle for success in an increasingly challenging environment. Translational Medicine, if successfully applied, appears to be an important means of improving the ethical (i.e. patient-centred) and financial success of the R&D process.

The process of bringing a new drug from initial testing to final FDA approval and ultimately to market is long (more than 13 years from discovery to approval of a new drug), costly and risky, and nearly 95% of drugs that enter human trials fail. According to the National Institutes of Health (Duxin Sun, 2022), 80 to 90% of research projects fail before they are ever tested in humans and for every drug that receives FDA approval (Figure 32). The main reasons for failure are lack of efficacy and poor safety profiles that were not predicted in preclinical and animal studies.



**Total**

| | | | | |
|---|---|---|---|---|
| 422 | 231 | 145 | 8 | 2 |

**Ratio of progressing:terminated**

| | | | | |
|---|---|---|---|---|
| 0.17 | 0.45 | 0.61 | 3.00 | – |

*Figure 32: Success rates from candidate nomination to*

In 2012, concerns about declining pharmaceutical R&D efficiency led to 'Eroom's Law' (Jack W. Scannell, 2012), the reverse of Moore's Law for microprocessors. Eroom's law states that the inflation-adjusted cost of developing a new drug roughly doubles every nine years. The causes of this have been identified in 4 main areas:

- The 'better than Beatles' problem, or the progressive raising of the bar for improvements over existing therapies;
- The 'cautious regulator' problem, or the progressive lowering of risk tolerance by regulators, making R&D more costly and difficult;
- The 'throw money at it' tendency, or the tendency to add other resources to R&D that could lead to project overruns;

- The 'basic research-brute force' bias, or the tendency to overestimate the power of advances in basic research and brute force screening methods.

The proponents of Translational Medicine believe that the high attrition rate can be improved through the main tasks of Translational Medicine. By achieving 3 different goals (Wehling, 2021):

- **Target identification and validation in humans.**

  The basic principle is the early testing of human evidence at a preclinical stage of the drug development process. This goal can be achieved through many possible approaches to target validation or identification. The first may be the Human Genome Project, which has successfully identified all the genes in the human body, with validation of known genes being the next task. Another approach uses test or probe molecules.

  On the other hand, the reverse approach could also help to reduce attrition: knowledge of the side effects of drugs can be used to discover new drugs by revealing this side effect as the main effect.

- **Early evaluation of efficacy and safety using biomarkers in humans.**

  Biomarkers describe physiological, pathophysiological and biological systems and the effects of interventions in these systems, including drugs. This is the most important translational work, and 80% of translational effort is devoted to finding or developing the right biomarker to predict subsequent success across species, including humans.

  Biomarker work includes the intelligent design of early clinical trials that make best use of these experimental biomarkers. This work may also include the validation work necessary to establish the predictive value of novel biomarkers; thus, it may include a development programme (for the biomarker) embedded in the drug development programme. In addition, successful biomarker development work could enable personalised medicine, using profiling to achieve a better match between success rates and thus increase cost-effectiveness.

- **Use the intact living human as ultimate screening test system.**

These human studies are called exploratory studies, and they may involve experimental investigational new drugs, which are compounds that are known to have shortcomings but may be ideal test compounds. They may prove the basic hypothesis of efficacy in the ultimate test system: humans.

The ultimate goal of this translational approach is to create forward and backward signalling loops along the artificially linear drug development line (Figure 33). This would speed up the process, allow parallel processing and generate knowledge for other projects. This approach would reduce the attrition problem in drug development by using innovation to test drugs and cures early, before a lot of money is spent on development, and by allowing the early elimination of unsuccessful ones.

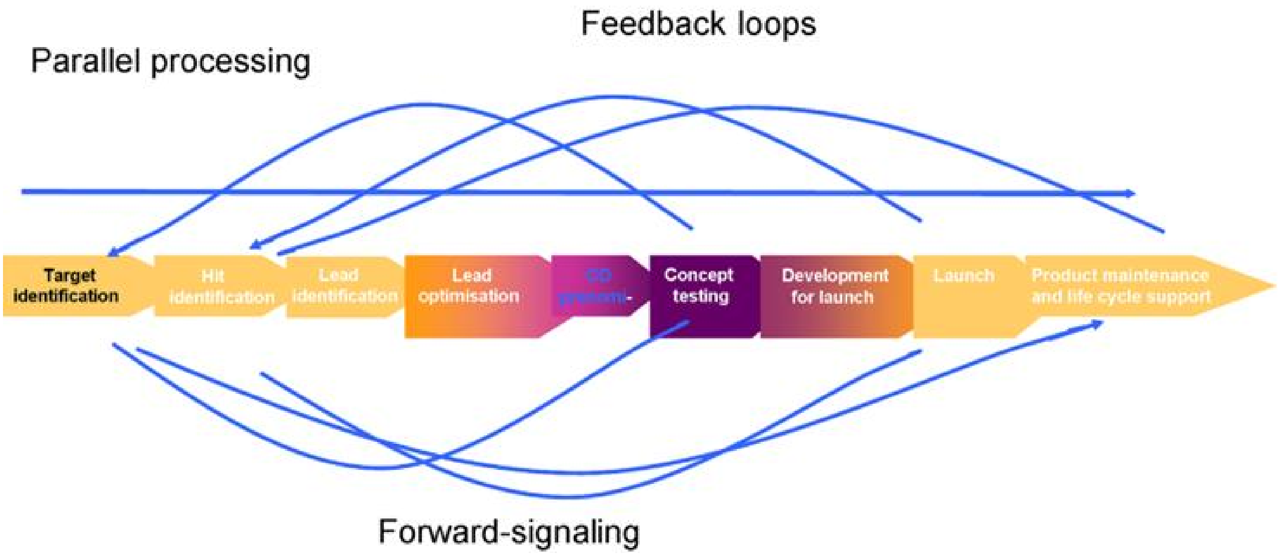


*Figure 33: The pseudo-linear model of drug development in Translational Medicine*

## The accurate selection

Critical selection of the few discoveries suitable for translation is the first step in early-stage idea selection. If the selection strategy is poor, this step can be extremely costly and wasteful on the long run. Technological feasibility, probability of success, intellectual property value, reasonable development costs and timelines to PoM and PoC, importance of the unmet medical need, end-user (physician) requirements and clear regulatory requirements must all be carefully considered in this selection process. Early feasibility studies assessing these factors for any new technology are essential, as is a full analysis of the manufacturing and regulatory hurdles that will be faced later in the translational process.

The main assessments to perform for an early-check are (Hans-Dieter Volk, 2015):

- An opportunity review: assessment of technological and financial feasibility, analysis of targeted unmet medical need, cost/benefit ratio of end product, advice on therapy category for regulatory guidance and potential industrial partners.
- Risk assessment procedures: routine review of project progress, new opportunities and challenges that arise over time, requiring a willingness to fail/exploring multiple ideas in parallel.
- Pre-regulatory support: identification of appropriate disease models and endpoints, study design and validation, and appropriate documentation of pre-clinical work.
- Core facilities: biomarker laboratories, good laboratory practice (GLP) animal facilities and good manufacturing practice (GMP) manufacturing.
- Intellectual property support: prior art searches (including patent and product database searches), patenting strategies, freedom to operate analysis and strategic patent advice/support.
- Early Health Technology Assessment (HTA): payer reimbursement potential and cost-benefit analysis.
- Partnering opportunities: academic and industry partners, including licensing models, return on investment (ROI) assessments and reward based on risk assumption.
- Funding support for bridging mechanisms between basic and translational R&D.
- Recognition of the value of translational research that does not result in technical publications, and the ability to reward individuals who play a significant role in translational teams and products.

## Drug Repurpusing

Drug repurposing is another strategy for accelerating drug development and bypassing early-stage hurdles. In drug repurposing, drugs already approved to treat one indication or condition are evaluated to see if they are safe and effective to treat other indications. To do this, drug repurposing analyses different types of large-scale data, using a variety of computational, experimental and clinical data synergistically.

By repurposing existing drugs for different indications or targets, drugs can be developed in 4-5 years with little risk of failure. This is achieved by reverse engineering and licensing intellectual property (IP) rights. This is because many repurposed drugs have already passed the early stages of development, clinical safety and bioavailability testing. They can therefore potentially gain FDA approval in less than half the time and at a quarter of the cost. However, side effects acceptable for a life-threatening disease may not be acceptable for chronic conditions.

## AI to improve decision making

Machine learning algorithms can identify features and then use those features to make predictions or classify new data faster, more systematically and sometimes better than human to answer questions and gain insight into how to analyse the ever-increasing amount of large data sets. AI has the ability to handle the complexity of the rules that must be applied for the understanding of these large data sets.

The US federal government's Tox21 program, a collaboration between the Environmental Protection Agency, the National Institutes of Health and the Food and Drug Administration, maintains a large dataset of molecules and their toxicity against key human proteins. This provides an opportunity to apply this large data to AI to search for features that relate structure, properties, function and possible toxic effects.

Machine learning algorithms could predict how a candidate compound might respond to different physical and chemical environments, in addition to identifying potential toxicities. In this way, scientists can have a better understanding of how the compound or molecule might behave in different tissues of the human body.

AI could also be the starting point for the design of a new therapeutic molecule. For example, some companies are using machine learning to discover drugs by mimicking the decision-making of a medicinal chemist, while also learning from the input of real human medicinal chemists. These developments suggest that in the near future, drug targets and molecules designed to bind them will be influenced by their AI platform's output.

Moreover, AI could be used to find new therapies or identify patients who are more likely to respond to specific therapies for difficult-to-treat diseases.

# Chapter III: Translational Deep Tech

Based on the analysis carried out in the previous sections, this chapter aims to theorise a new methodology called "Translational Deep Technology" (TDT), which wants to be a list of principles inspired by Translational Medicine that can be applied to improve the Deep Tech innovation process.

The first part of the chapter will look at what are the main parallels between TM and Deep Tech innovation, in order to justify the potential improvements that the solutions adopted by the former can have on the latter.

On the other hand, the second section will discuss what are the key differences that differentiate the innovation of Deep Tech startups from Translational Medicine, highlighting which aspects prevent to directly apply TM methodology into TDT principles.

The third section of the chapter will encapsulate what has emerged from all the analysis done in this thesis, listing what may be some good practices or methodologies derived from TM that can be applied in Deep Tech startups to overcome some of the main challenges faced by this type of innovation. This new methodology will be called "Translational Deep Technology" and the main areas of application of it will be discussed.

Finally, the last part will be a comparison of this newly born methodology with some of the ideas already theorised or applied that aim to solve the same problems. As it will be shown, the concern about this issue in Europe has led to many different theories and recommendations, even by the European Commission, but none of them seems to be based on the same theoretical foundation of TDT, even if the final recommendation founded by them may have some commonalities with this new theory.

## TM and DT parallelisms

Translational Medicine and deep technology innovation in start-ups have many characteristics that make them similar.

First of all, they both address unmet needs of the population, which reduces the ultimate adoption risk if they are successful in their research. TM aims to provide new solutions for the health of the population, so a new medicine, treatment or therapy that proves to be beneficial for people and less dangerous than the previous one would be adopted without hesitation. On the other hand, by its own definition (see Chapter 1, paragraph 1), Deep Technology has the potential to address major societal challenges. Therefore, similar to what happens in TM, if a Deep Tech start-up succeeds in developing a technology that can contribute to one of these challenges that affects the whole of humanity and does not create conflict with other challenges, the adoption risk will be very low.

Another important similarity between the two is their cross-disciplinary nature. A Translational Medicine project may involve many professionals from different backgrounds, such as basic or biomedical researchers, clinical researchers, data scientists and bioinformaticians, experts from the pharmaceutical industry, patient advocacy groups, lawyers specialising in regulatory affairs, and some translational scientists acting as project coordinators.

Similarly, a deep-tech start-up may involve several different actors in its development; the founders are usually the basic researchers who act as scientific innovators in their field, but they usually need engineers and developers in other specialisations to take their innovation forward, some entrepreneurs and market analysts to deal with the business aspects of the idea, incubators and investors for the financing part, and academic and IP experts to ensure compliance and protect the intellectual property of their innovation.

Even from an evolutionary point of view, TM projects and DT start-ups have many similarities. For instance, the two step translation model of Translational Medicine (Wehling, 2021) which highlights the two main challenges to be overcome for a successful TM project, can be compared with the two main risks for a DT start-up innovation. In fact, the first translation from preclinical to clinical stage in the former is similar to the technology risk in the latter, since both are about the correct functioning of the innovation, going from a theoretical point of view to a practical one; a clinical success of the therapy is the respective parallel of a proof of concept of a technological innovation.

Then, the second challenge in TM, to disseminate the new therapy to make it a common treatment for the majority of addressable patients, is very similar to the market risk faced by DT innovations. Even if both should have a limited adoption risk, in the first methodology some budget constraints, non-compliance of patients or physicians or other socio-economic implications may lead to undertreatment, just as strategic moves of incumbents, market conditions or difficulties in changing the current paradigm may limit the adoption of a startup's innovative deep technology.

Moreover, both TM and DT startups have the concept of the "valley of death" to express a period in which the death rate of projects is very high. While in the former this refers to the difficulties in translating basic science into human studies (T0-T2), in the startup environment it expresses the period when the technology is not yet fully validated or market-ready, and at the same time it is too early for many investors to jump in, leading to an early end of the startup.

Another relevant similarity between the two themes analysed is the attrition rate and the selection process for Translational Medicine projects and the ones of investors looking at deep tech startups. In both cases, the selection starts with many projects/start-ups funded with a small amount of money, while as the idea develops through the translational phases in TM and the business phases in DT start-ups, the attrition rate becomes higher due to the increase in the budget required, resulting in the selection of those that have been able to demonstrate better potential in each funding series.

A further similarity between the two lies in the multiple application possibilities for a single innovation or discovery. As explained in Chapter 1, a real breakthrough in Deep Tech may open up many potential market applications, making it challenging to identify the most promising and profitable one. Similarly, Translational Medicine projects often originate from a specific medical discovery (such as a new genetic pathway or treatment) that could be directed towards several conditions or diseases. Applying TM principles to this process is therefore fundamental in order to prioritize the application with the highest likelihood of success and impact, as it would be for DT innovations.

A final relevant parallel can be drawn between the concept of 'secondary translation' in translational medicine and the slow adoption that often characterises deep tech innovations. In medicine, secondary translation refers to the challenges involved in transitioning from evidence-based guidelines to widespread clinical practice. Systemic inertia, compliance issues, and budget constraints can all delay the adoption of effective treatments. A similar dynamic occurs in deep tech, particularly in B2B contexts, where potential adopters are often reluctant to integrate new technologies into existing processes. This reluctance is not necessarily linked to doubts about technological validity, but rather to the lengthy product development cycles and regulatory or certification requirements that constrain many industrial sectors. Therefore, as in TM, the challenge lies not only in proving the innovation's effectiveness, but also in overcoming the systemic barriers that impede its adoption and impact.

## TM and Deeptech divergences

Despite the many similarities between the Translational Medicine approach and the deep tech innovation process, there are many significant differences that make the principles of the former method not directly applicable to the latter.

The most important of these divergences is the level of competition faced. In Translational Medicine, the level of competition is lower because these types of projects rely on a larger community working together towards the same ultimate goal of discovering new treatments to improve human health. Of course, this is a "naive" perspective that does not take into account the specific interests of the private actors involved, but in general, as long as all participants in the process benefit from it, the project does not have to struggle to achieve results in the short term or to compete with the market. This is also due to the mentality of continuous improvement through feedback loops in the process, where any action taken is never considered a failure, as long as the final result is useful to build on and improve the idea.

On the other hand, in Deep Tech innovations, there is a much greater urgency to complete the project due to market competition. This comes both from the founders and the investors who want a return on their investment as quickly as possible, and from the possible competitors who are developing technologies to address the same needs, or the strategic moves that incumbents may make to limit the impact of the start-up. This sense of urgency is exacerbated by the lack of a reliable global community that freely shares information about deep-tech innovations, which tend to be a competitive advantage in the marketplace. In fact, full disclosure of research results to a large community can reduce the competitive advantage gained. However, the absence of an open community to support innovation not only increases the effort for each actor involved, who cannot build on the latest discoveries of the others, but also increases the risk of losing accessible resources for startups.

Another important difference between TM and Deep Tech start-ups is the personal involvement of the key players in the project. From a basic researcher's point of view, clinicians and biomedical scientists working on Translational Medicine projects often have a fixed job position that is not directly dependent on the success of the project, while in deep tech startups it is more common for researchers to be mostly dependent on the funding of the startup to have a financial return on it.

Moreover, even the funding actors have a different perspective on the issue; Translational Medicine projects may be funded by governmental health departments, big pharmaceutical companies or non-profit organisations, which consider a project a success even if it fails in its first objective, but generates important information for other projects, thus creating benefits for the whole community. In this scenario, a high mortality rate of projects might be acceptable (but not desirable), as the effort and resources invested in each of them would be considered a sunk cost, necessary to develop the knowledge for future successful projects that will build on the failed ones.

On the other hand, incubators, venture capitalists and business angels seek to get the most out of each and every investment they make, so if the technology being developed does not achieve this or does not lead to an economic exit (i.e. a clear value added for someone), the investors will consider it a complete failure. This difference results in a less flexible environment for developers, who cannot rely on a trial and error and feedback loop processes as happens in Translational Medicine, as this approach would likely be seen as a lack of strategic view by investors, adding both technological and market risks to their investments.

A final major difference between the TM approach and the development of DT start-ups is the necessity for a business strategy; whereas the former may only require a total addressable market evaluation or an estimate of the expected benefits to be funded, the latter requires a well-structured business plan to access the various rounds of investment. This implies a clear strategic vision of the future of the research and usually requires entrepreneurial skills that are far from those of DT startup funders, who tend to be experts in their technical research fields. A very good innovation in deep technologies that lacks a strategic vision and a clear development plan is less likely to be financed than a poorer project that can give investors a good vision of its end goal and the steps to get there.

Figure 34 summarises the main similarities and differences that have just been discussed.

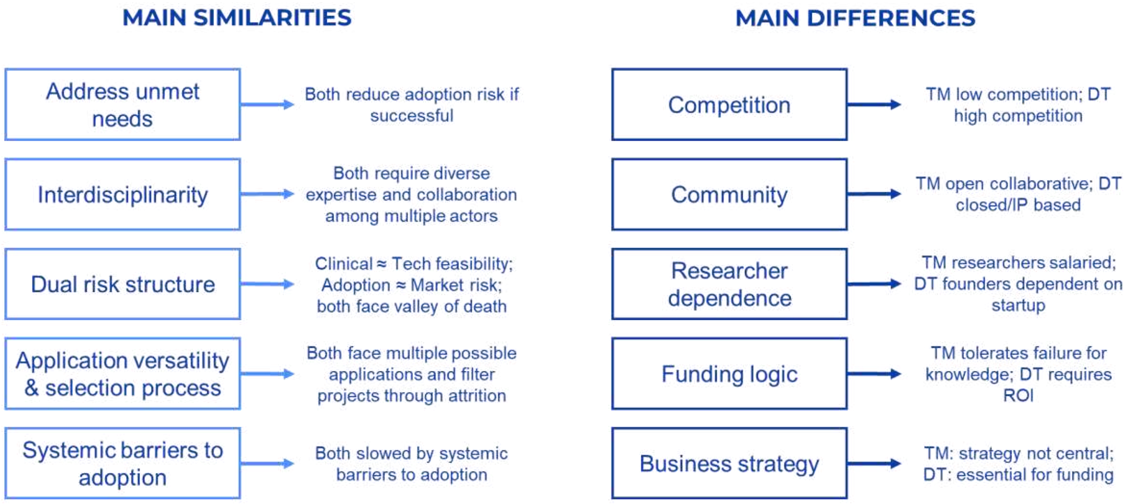


*Figure 34: similarities and differences between TM and DT*

## Translational Deep Technology Theorization

As shown in the last paragraphs, the principles of Translational Medicine cannot be directly applied to the development process of deep tech startups because of the many differences between the two. However, if the analysis focuses only on Deep Tech start-ups emerging from university research (spin-offs), these differences between the two become fewer and less profound, allowing for a much more accurate parallelism.

In fact, university researchers can be compared to the "bench-side" researchers of TM projects, who have their own job on campus, which could allow them the flexibility in deep tech innovation that is missing for other types of startup founders. This flexibility is reflected both in the innovation itself, which can change several times in objective following an iteration process based on data without the constraints of early commitment, and in the time in which the result is achieved, since university research is less competitive than markets.

Moreover, as shown in Chapter 1, university spin-offs in Deep Tech represent one of the most important untapped potentials in the EU, which has some of the best researchers in the world in many fields, but lags behind other regions in terms of successful translation into Deep Tech spin-offs. Therefore, focusing the analysis only on Deep Tech start-ups based on university research not only allows a stronger parallelism with Translational Medicine, but also targets the part of Deep Tech innovation that faces the most development obstacles in the EU and that could lead this sector if the problems are solved. The table 1 below sum up what are the main similarities and differences between Translational Medicine, Deep Tech innovations in common startups and Deep Tech innovations in University Spin-offs, explaining why the latter one is the most comparable to Translational Medicine of the two. Green boxes represent main similarities, yellow ones represent some sort of similarities, and Red ones represent big divergencies between the focused type of innovation and Translational Medicine.

*Table 1: Comparison between Translational Medicine and Common Deep-Tech startups VS University Spinoffs.*

| **Aspect** | **Translational Medicine** | **General Deep Tech** | **Deep Tech Spin-offs** |
|---|---|---|---|
| **Goal** | Improve health via new therapies | Solve major challenges with radical technologies | Same as DT, but anchored in **academic research missions** |
| **Interdisciplinarity** | Multidisciplinary teams from medicine, biology, engineering | Requires diverse technical and business skills | Same need, but often **supported by university structures** enabling cross-discipline collaboration |
| **Main Risks** | Clinical failure & under-treatment | Tech feasibility & market risk | Similar risks, but **can iterate more flexibly** thanks to academic setting and less commercial pressure |
| **Valley of Death** | T0–T2 (preclinical to clinical transition) | Gap between lab prototype and market readiness | Exists here too, but **universities can provide early-stage funding, labs, and credibility** |
| **Selection Process** | Scientific merit & impact | Business case, traction, funding | Can combine both; **academic review + market input** leads to more structured project selection |
| **Knowledge Sharing** | Open science, collaborative culture | Closed IP strategies, secrecy | In between: often **encouraged to publish**, but must balance with patent/IP protection |
| **Stakeholder Incentives** | Knowledge generation helps community even if project fails | ROI-driven: failure = loss | More aligned with TM: **grants, public funds, and prestige** matter as much as ROI |

| | | | |
|---|---|---|---|
| **Job Security of Founders** | Usually salaried researchers | Founders depend financially on startup success | Researchers can often **stay employed in academia**, reducing personal risk of failure |
| **Business Strategy Requirement** | Not central | Essential | Still essential, but **can be developed gradually** with support from tech transfer offices (TTOs) |

Given this new point of view, which reduces the differences between the development of deep-tech university spin-offs and Translational Medicine projects, a new theory can be expressed that tries to apply the principles used in the latter to solve some of the key problems faced by the former.

This new theory will be called "**Translational Deep Technology**" (or TDT). As with the Translational Medicine approach, the basis of this theory is the individuation of the deep tech spin-off development into three main pillars: university researchers, market experts and the community.

University researchers are the equivalent of basic researchers in TM. They are the experts in their deep-tech field, doing a lot of research in it, constantly monitoring the evolution of the technology, and doing their own theories and experiments to further develop innovation in their area of expertise.

The second pillar, the market experts, could be compared to clinical researchers in TM. They are all those actors who have both the business and the technical background to understand an innovation in their area of expertise, to consider different business models for it and to assess its possible impact on the markets. They may be representatives of large, consolidated companies in the sector, venture capitalists with specific expertise in the market dynamics of the technology being analysed, or even successful entrepreneurs who have been through the same process several times.

As for the TM theories, the community is the third pillar; it represents all the many entities that could be involved in the development of a successful Deep Tech spin-off. This category includes all the other researchers needed for the development, even if they are not experts in the specific technological field; university administrations and inter-university communities; regulators and IP experts; private, public or corporate investors; and even communities of ordinary people willing to help, representing public opinion. Even if not all of them are the main developers of a technological innovation, they represent actors that can have a great impact on the success of a deep tech spin-off by reducing the many obstacles faced by this type of innovation. Figure 35 figures the parallelism of TM and TDT actors.

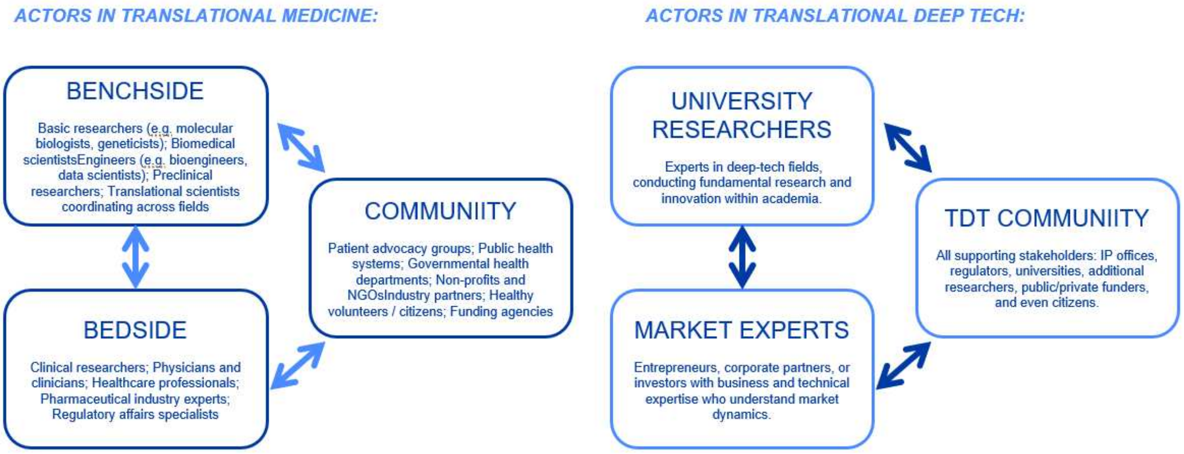


*Figure 35: actors involved in TM and TDT*

Based on the parallelism between these three pillars in TM and university spin-offs in Deep Tech, the current evolution of the latter seems to follow the first concept of "bench side to bedside". Applied from a very high level in terms of DT, the innovation process usually starts with university researchers developing a technological innovation in their laboratories, followed by the creation of a spin-off based on the idea. Then, with growth, the startup will be managed by a market expert who will tailor it based on his own knowledge to get the best valuation out of it.

The theory of Translational Deep Technology aims to apply to the development of Deep Tech spin-offs the two "evolutionary" methods used in Translational Medicine. Firstly, the bidirectional approach adopted in the "bench-side to bedside to bench-side" model could be implemented in DT terms, with the creation of feedback loops between university researchers and market experts, who can both benefit from constant interaction by reducing unnecessary efforts and obtaining inputs to better develop the innovation from the beginning.

However, the third and current "evolution" of the TM approach can only be achieved through the creation of a supportive "community" around deep technology spin-offs that is aware of its importance in the development process. All parties involved should focus their efforts on creating the best environment for the creation and development of university spin-offs, recognising the benefits that both the individual actors and the community as a whole would gain from the success of these innovations.

This '3 actors' theory of TDT may seem too theoretical, but it allows some practical principles successfully developed in Translational Medicine projects to be applied to deep tech spin-offs, with the aim of reducing some of the key barriers they face.

These theoretical principles of Translational Deep Technology and their key benefits are:

- **Constant communication channels between University Researchers and Market Experts**.
  The creation of partnerships between these two actors with regular roundtables would be beneficial at any stage of the start-up development process; for example, when no start-up has been created yet, the discussion between the parties could be inspiring for both thanks to the exchange of information, with the technical researchers gaining insights into the market dynamics and the market experts being informed about the technological innovations coming from the research world. In this scenario, knowledge sharing and discussion from different areas of expertise could bring fresh perspectives and possibly trigger ideas for deep-tech innovations.
  Then, during the first development phases of a spin-off, when the technology is still being developed, market experts could influence some technical specifications of the technology to match market dynamics or identified opportunities, limiting the effort that would be made in the next phases for commercialization.
  Even after a proof of concept and the first marketing phases, communication between the parties remains fundamental, as the university researchers who developed the innovation are the ones who know best the technical potential, the possible implementations and the effort involved of the technology
  Above all, however, the continuous feedback loop established between these two main actors of TDT allows the application in university spin-offs of one of the main objectives of Translational Medicine: the prioritization of initiatives that address unmet needs.

- **Raise awareness in the TDT Community**.

  All entities involved in the successful development of a deep technology spin-off should be made aware of their role in the innovation process and make every effort to reduce the obstacles they may create. This should be underpinned by some training programs on the subject, showing what the dynamics of Deep-Tech innovation in universities are, how the very different actors need to interact with each other, and what the key benefits are when an innovation-friendly environment is created.

  Since deep-tech innovation is so interdisciplinary, the training programs should also provide some basic knowledge in each of the fields involved in order to improve successful communication between the different actors, who could hopefully see the process from each other's perspective.

- **Creation of some European and Global TDT agencies.**

  As is the case in Translational Medicine, TDT success would be enhanced by the creation of cross-national agencies dedicated to the dissemination and application of the theories of translational deep technology. These agencies should have as their main program the same 3Ds as NCATS; develop new approaches, technologies, resources and models; demonstrate their usefulness; and disseminate data, analyses and methods to the community.

  Through these agencies, some boundary-crossing partnerships to accelerate translational progress, inter-agency and cross-sectoral collaborations could be implemented.

- **Find early testing strategies to diminish the attrition rate**

  As TM has found some possible methods in new scientific discoveries to test the future success of projects at an early stage, thus reducing the failure rate of them in the "valley of death", the same could possibly be done in TDT. For example, some early discussions between technological researchers and market experts to predict the possible evolution of different business models could help to find the best one from the beginning. In fact, thanks to the application of industry-specific AI and the data that market experts could provide, a "scenario analysis", performed when university researchers are not sure about the future possible applications of the innovation they are working on, could allow them to focus their efforts on the most promising business model analyzed.

Moreover, such an approach would facilitate access to investment, as investors would be able to review early-stage business models, assess their risks and potential for success, and reduce the undefined future developments that often lead to poorer projects with a clearer business strategy being preferred to those with great potential but no defined scope.

- **The accurate selection**

  In view of the specific characteristics of a university spin-off in the field of deep technology compared to normal start-ups, it is important to create a set of tailor-made KPIs in order to identify and select at an early stage which are the projects that can benefit most from a translational deep technology approach. These indicators should be taken into account by all actors involved in order to correctly assess which are the most promising projects in which to invest the most effort.

  Again, these indicators can be derived from those that have been recognized as key selection drivers for TM projects. Firstly, an opportunity assessment should express the technological and financial feasibility of the innovation, analyzing the real impact that the idea could have on the targeted grand challenge in terms of cost/benefit.

  Then, risk related KPIs should be routinely assessed for TDT projects, reviewing project progress, new opportunities and challenges that arise over time. The need for continuous assessment of risk arises from the new "willingness to fail and explore multiple ideas in parallel" approach of TDT projects, where the continuous feedback loops between actors involved may change the project characteristics more often than in traditional start-ups, especially in the early stages. Consequently, a project that is considered too risky for investment today should not be abandoned forever, as it may completely change its business model in a few months to make it very attractive.

  The set of characteristics to be assessed should also include assessments of the competence and commitment of all third parties involved. A strong commitment of intellectual property offices, industrial partners and the whole TDT community would bring a strong added value to the success of the spin-off.

- **Effort Repurposing**

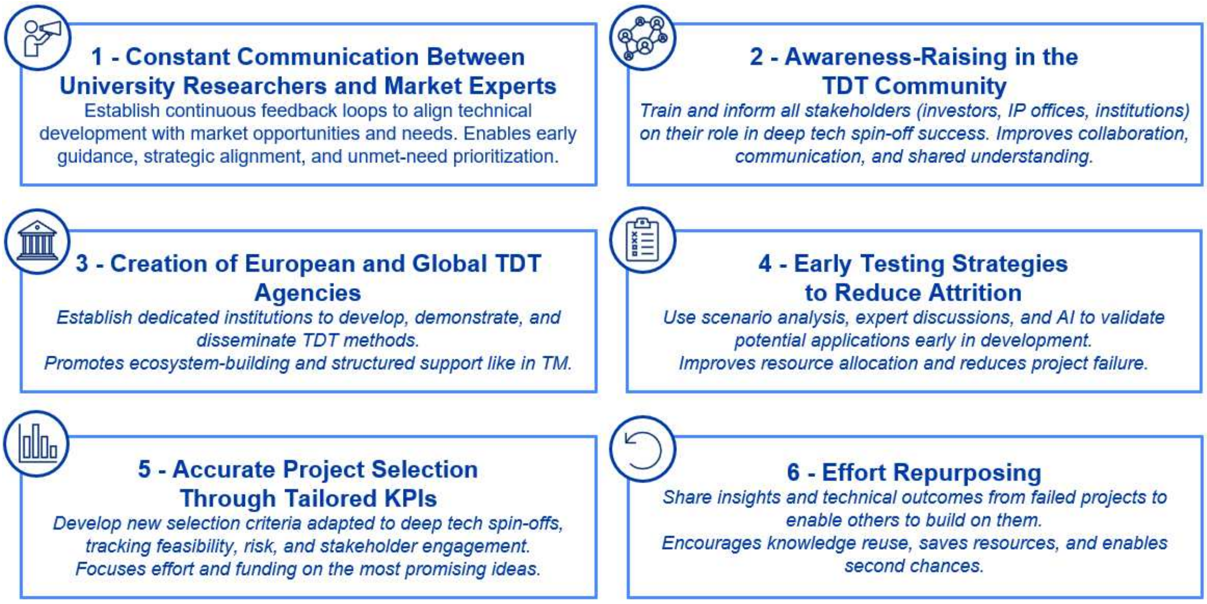
  In addition to the concept of "never wasted effort", another concept that can be derived from Translational Medicine is to share the information from TDT projects that have failed in their primary objective with the community so that it can be used for new ideas.

Sharing information would bring many benefits; for example, if a technology has been successfully developed but failed in the go-to-market phase, it can be re-used by an actor who has come up with a better business model based on the same deep-tech innovation. On the other hand, if a TDT project failed because the technology was technically impossible to develop, some actors in the community may have another technical solution to address the same strong market need it targeted.

However, in order to make this approach of repurposing efforts work, at the basis of any TDT project should be the idea of using bold and rigorous research approaches that can be analyzed by third parties, and of having an open and dynamic mentality about information sharing in the community.

Of course, this idea implies some legal and rights protection issues, as a world in which some actors can freely access the information of others creates some "arbitrage opportunities", but a regulated ecosystem in this direction would allow huge benefits in terms of time, investment and effort savings for projects that could skip some development steps by using those made by others.

These six theoretical TDT principles are sum up in figure 36.



**1 - Constant Communication Between University Researchers and Market Experts**
Establish continuous feedback loops to align technical development with market opportunities and needs. Enables early guidance, strategic alignment, and unmet-need prioritization.

**2 - Awareness-Raising in the TDT Community**
*Train and inform all stakeholders (investors, IP offices, institutions) on their role in deep tech spin-off success. Improves collaboration, communication, and shared understanding.*

**3 - Creation of European and Global TDT Agencies**
*Establish dedicated institutions to develop, demonstrate, and disseminate TDT methods.*
*Promotes ecosystem-building and structured support like in TM.*

**4 - Early Testing Strategies to Reduce Attrition**
*Use scenario analysis, expert discussions, and AI to validate potential applications early in development.*
*Improves resource allocation and reduces project failure.*

**5 - Accurate Project Selection Through Tailored KPIs**
*Develop new selection criteria adapted to deep tech spin-offs, tracking feasibility, risk, and stakeholder engagement.*
*Focuses effort and funding on the most promising ideas.*

**6 - Effort Repurposing**
*Share insights and technical outcomes from failed projects to enable others to build on them.*
*Encourages knowledge reuse, saves resources, and enables second chances.*

*Figure 36: TDT principles*

The application of all these TDT principles would create many benefits for both the community as a whole and the individual actors involved.

The basic researchers and market experts running the spin-off would benefit from this dynamic environment in which each actor involved would do their best to support the development of the idea. As a result of the TDT principles, the failure rate of Deep Tech spin-offs is likely to increase in favour of a consequent increase in investments in later stages, which are most lacking in the EU today.

Investors would see both their technological risk reduced, thanks to some possible effort repurposing projects and more competent communication with developers, and their market risk reduced, thanks to the development assessment of the right KPIs, a business model that is constantly updated, and some quantitative analysis done by some early testing strategies.

Universities would then gain prestige and economic benefits from the successful development of deep tech spin-offs, apart from an increase in enriching inter-campus interactions. Finally, regulators would see an increase in technological progress coming from the EU, finally exploiting and keeping in the region the great potentialities of this under-utilised asset.

## Comparison of TDT to existing literature

Despite the innovative idea of comparing the development of deep-tech spin-offs with Translational Medicine projects, the need that the TDT theory seeks to address has already inspired many actors to develop alternative conceptual frameworks that aim to reduce the barriers to the development of deep-tech spin-offs.

The most recent of these is the report published by the European Commission on 25 February 2025, entitled "**Spin-offs: reinforcing a vector of value creation for EU 27**". This report highlights how university spin-offs face significant challenges in scaling up, securing funding and navigating the regulatory framework, despite being considered as "a crucial driver of innovation and economic growth in Europe".

The main challenges identified by the report include bureaucracy and IP complexity that slow down commercialization efforts, scaling constraints, too high equity stakes for universities that can discourage private investment and reduce incentives for founders, and a fragmented and uneven support system across regions, despite the Horizon Europe program.

To address these issues, the report highlights 3 key funding areas and makes recommendations to improve the success rate and scalability of spin-offs:

1. ***“Universities and TTOs (Technology Transfer Office) can drive spin-off success by focusing on entrepreneurial teams.”*** The resulting recommended actions are for the European Commission to create standardized frameworks to measure the performance of TTOs, for universities to allocate more resources to TTOs to make them dynamic centres of entrepreneurship that foster collaboration between academia and industry, and to design reward systems to support academic staff for their entrepreneurial activities.
2. ***“Clear IP guidelines, streamlined spin-off processes, and reduced bureaucracy should be a policy focus”.*** Building on this funding, the EU Commission should create a more supportive environment for innovation across the EU-27 that is adaptable to IP ownership and spin-offs, while universities should reduce their bureaucratic barriers to spin-off creation.
3. ***“To boost EU research commercialization, diverse investors and alignment with venture capital market realities are essential.”*** This finding led to the recommendation to create many investors between regional governments, SMEs and corporations to capitalise on EU research results, and to ensure the alignment of EU regulators and investment programmes with global venture capital standards to attract international investors.

This report, produced by StepUp Startups, an EU-funded project that aims to deliver 12 data-driven in-depth policy reports on key issues and challenges facing the EU startup ecosystem, has indeed many similarities with the TDT principles. Without considering the same theoretical underpinnings, both methodologies emphasise the importance of communication between researchers and market experts, make recommendations on how to reduce the barriers to developing a university spin-off, and aim to create some cross-border agencies that would standardise and regulate the process.

However, the scope and objective of the two are different, as the nature TDT theory is based on the best practices developed in TM to provide some "practical principles" for university researchers, market experts and the community around university deep tech spin-offs, while the European report has the specific objective of suggesting regulatory actions to be taken mainly by universities and regulators to create the most supportive environment for this type of innovation.

Another report on the subject requested by governments is the one published in November 2023 by the UK government's Department for Science, Innovation and Technology, entitled "**Independent review of university spin-off companies**". Even if it does not focus only on deep tech start-ups (but more generally on science and technology), the report looked at the most successful university spin-off ecosystems around the world to identify the best practices that distinguish them, identifying the 7 aspects already explained at the end of Chapter 1.

The funding of this review led the authors to make 11 main recommendations to create this spin-out friendly university environment and to keep the benefits within the country. Although some of the recommendations are similar to those of the European Commission report, some aspects are worth mentioning.

For example, the UK report emphasizes the importance of the involvement of future investors in the design of policies regulating the spin-out process; the easy access of founders to support from individuals and organizations with experience of running successful high-tech start-ups, regardless of the region in which the founders are based or the sector in which they operate; and the high exposure of university researchers to high quality entrepreneurship training, with movement or porosity between academia and industry.

As in the TDT principles, this report expresses the importance of constant and strong relationships between universities and market experts, and seeks a strong involvement of industrial partners and investors in all phases of spin-off development. However, the lack of specificity on deep tech spin-offs and its scope makes this report again more targeted to universities and regulators than to all the actors involved in the process.

On the other hand, in the light of existing recommendations for investors or companies, a number of reputable consultancies have published reports suggesting how to improve the current situation.

The Boston Consulting Group, in partnership with Hello Tomorrow in 2021, has published the report "From Tech to Deep Tech: fostering collaboration between corporates and startups". In this report, the firm identified the unique challenges faced by deep-tech innovations in terms of long time-to-market, high capital intensity, technology risk and complexity, and yet-to-be-developed commercial applications. To overcome these challenges and access the resources they need, start-ups rely on many different stakeholders, making development very fragmented and delayed; while universities, the public sector, business angels and venture capitalists can play a crucial role in the development of deep-tech start-ups, the report found that corporates are the only potential partners that can meet all the needs of a start-up, combining technical, industrial and commercial vision and skills.

According to BCG's recommendations, companies should define a clear mandate for the startup collaboration and create a favourable environment that brings agility, ensures top management buy-in and involves entire business units. From the outset, both sides should be transparent about their objectives and involve R&D and relevant teams in commercial and operational efforts at an early stage. This will encourage partners to check the project's alignment with strategy, avoiding disappointment and wasted time on both sides.

While such a report emphasises the importance of tailored support from companies to improve the development of deep tech start-ups, it does not define a standard process that can drive all collaborations and does not take into account the specificities of a spin-out from a university.

Finally, McKinsey & Company published an article in 2024 entitled "European deep tech: What investors and companies need to know". The article states that Europe could lead in deep tech if an ecosystem approach and a well-managed investment strategy are applied. According to the article, the main barrier to this successful ecosystem is the region's traditionally risk-averse investment culture and fragmented market, with investments resulting in weaker growth financing and limited exit strategies compared to its global competitors.

To improve the situation, McKinsey highlighted three main recommendations:

1. ***Engaging with the broad deep tech ecosystems:***
   In deep tech, traditional VC-founder partnerships are often insufficient due to high capital intensity and technical complexity. McKinsey recommends engaging with two key ecosystems (figure 37): funding, which blends public-private capital, often involving universities, governments, and infrastructure investors; and enabling, which includes universities holding IP, expert researchers, accelerators, and corporate partners. Strong stakeholder collaboration within these networks is essential to access specialized knowledge, navigate regulation, and secure funding. This ecosystem-based approach is critical to unlocking deep tech’s full potential, particularly in regions like Europe where public institutions and industry can play complementary roles in startup development

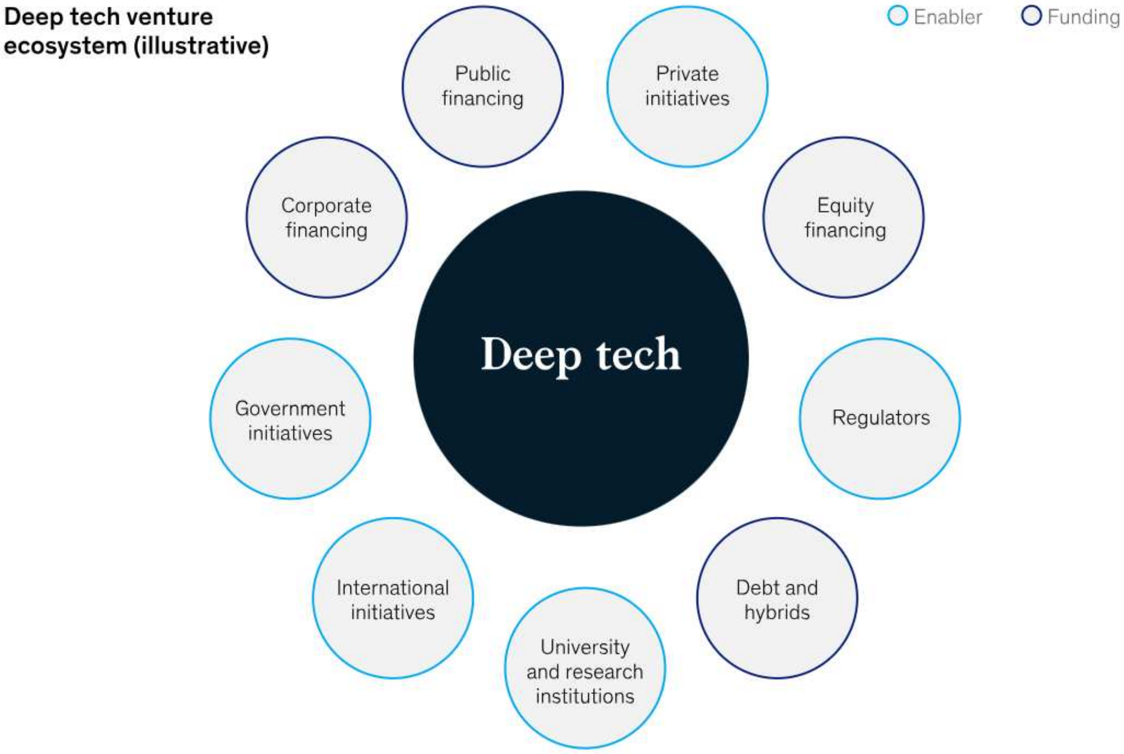


*Figure 37:Deep tech ecosystem by McKinsey*

2. ***Adapting VC strategies to the deep tech sector:***

   VCs must adapt their traditional startup investment skills to the unique demands of deep tech. According to McKinsey the three key actions necessary are to Clarify strategy and constraints before investing, avoiding reactive decisions driven by hype; Develop deep domain expertise by building specialized teams or partnering with experts to improve trust and decision-making; and Build orchestration capabilities, coordinating a network of partners—such as universities, specialized funds, and co-investors—to support complex scaling and innovation. Success in deep tech requires VCs to move beyond generalist approaches and actively engage with the broader innovation ecosystem.

3. ***Building stronger partnerships with deep tech start-ups:***

   As deep tech grows in importance, corporations should move beyond tech adoption and pursue holistic engagement—through partnerships, acquisitions, and investment in deep tech VCs—to stay competitive and drive innovation.

Again, the final recommendations in this article are very similar to some of the TDT principles, highlighting the importance of strong communication channels between stakeholders and the creation of a supportive community engagement in the deep tech development process. However, the McKinsey report is mainly concerned with what companies and investors can do to improve the current situation in the development of deep tech start-ups, while TDT aims to provide some recommendations based on TM best practices for all parties involved, with a particular focus on university spin-offs.

Table 2 illustrates how the four papers on the recently discussed topic are linked to the TDT principles and their fundamental basis of recognising similar patterns in deep tech innovation and translational medicine. A tick means that the paper identified the pillar as fundamental; a tilde (~) means that the article cited the pillar from a different perspective; and an X shows that there is no evidence of the pillar in the paper.

*Table 2 : Comparison between 4 papers and TDT principles*

| | **TDT** | **European Commission (2025)** | **UK Government (2023)** | **BCG (2021)** | **McKinsey & Co. (2024)** |
|---|---|---|---|---|---|
| 1 - Constant Communication Between University Researchers and Market Experts | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2 - Awareness-Raising in the TDT Community | ✓ | ✓ | ✓ | ~ | ✓ |
| 3 - Creation of European and Global TDT Agencies | ✓ | ~ | ~ | × | ~ |
| 4 - Early Testing Strategies to Reduce Attrition | ✓ | × | ~ | ~ | × |
| 5 - Accurate Project Selection Through Tailored KPIs | ✓ | ~ | × | ✓ | ✓ |
| 6 - Effort Repurposing | ✓ | × | × | × | × |
| Recognize similarities with Translational Medicine | ✓ | × | × | × | × |

As shown in the table, the first two principles of TDT seem to be widely accepted in similar papers, the fifth is promoted by consulting firms, and the remaining three seem quite innovative in the literature on deep tech innovation. Furthermore, none of the analysed articles recognised any similarities between Translational Medicine and deep tech innovation, demonstrating that this thesis offers a novel perspective that has not yet been explored.

To better understand whether any of the theoretical principles expressed so far may have practical relevance, the next chapter will focus on interviews with experts in the European deep tech landscape.

# Chapter IV: Expert Interviews

This final chapter uses expert interviews to test the theoretical foundations of this master's thesis, aiming to validate the findings and gather initial reactions from people familiar with the practical aspects of this field.

The first part of the chapter therefore explains the methodology used for the interviews and the main aim of them.

In the second part, each interview is analysed in detail, explaining the background information on each of the interviewed experts, which aspects were analysed and reporting the most relevant extracts. Given the different backgrounds and job positions of the interviewed experts, different aspects were considered during the interviews.

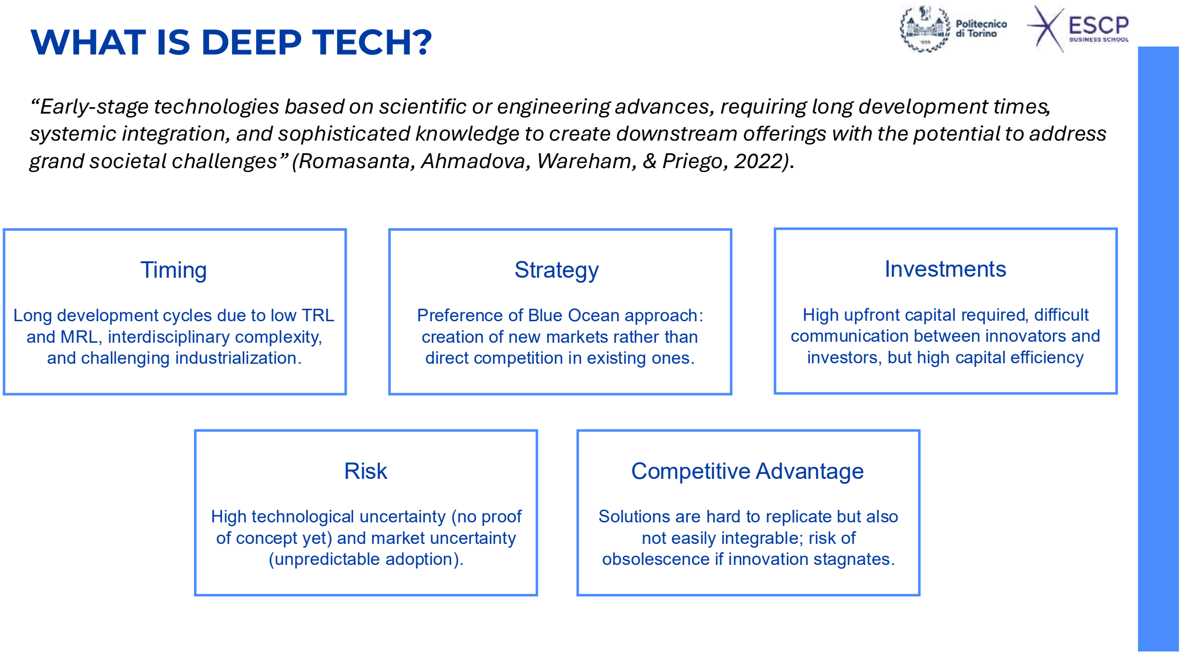
The final part of the chapter summarises the most important findings from the interviews and discusses whether these can be used to validate or refute the Translational Deep Tech thesis.

## Interviews methodology

The expert interviews were conducted after the first three chapters of this Master's thesis had been completed, to validate some of the main concepts that would otherwise be considered purely theoretical.

The interviews were structured as discussions of approximately half an hour conducted in person and based on a set of slides that aimed to show the highlights of this thesis.

The first slide (figure 38) presented the main characteristics of deep tech start-ups identified in chapter one. The aim of this slide was to ascertain whether the experts agreed on all the characteristics and whether they could identify any additional aspects.



**WHAT IS DEEP TECH?**

*"Early-stage technologies based on scientific or engineering advances, requiring long development times, systemic integration, and sophisticated knowledge to create downstream offerings with the potential to address grand societal challenges"* (Romasanta, Ahmadova, Wareham, & Priego, 2022).

Timing

Long development cycles due to low TRL and MRL, interdisciplinary complexity, and challenging industrialization.

Strategy

Preference of Blue Ocean approach: creation of new markets rather than direct competition in existing ones.

Investments

High upfront capital required, difficult communication between innovators and investors, but high capital efficiency

Risk

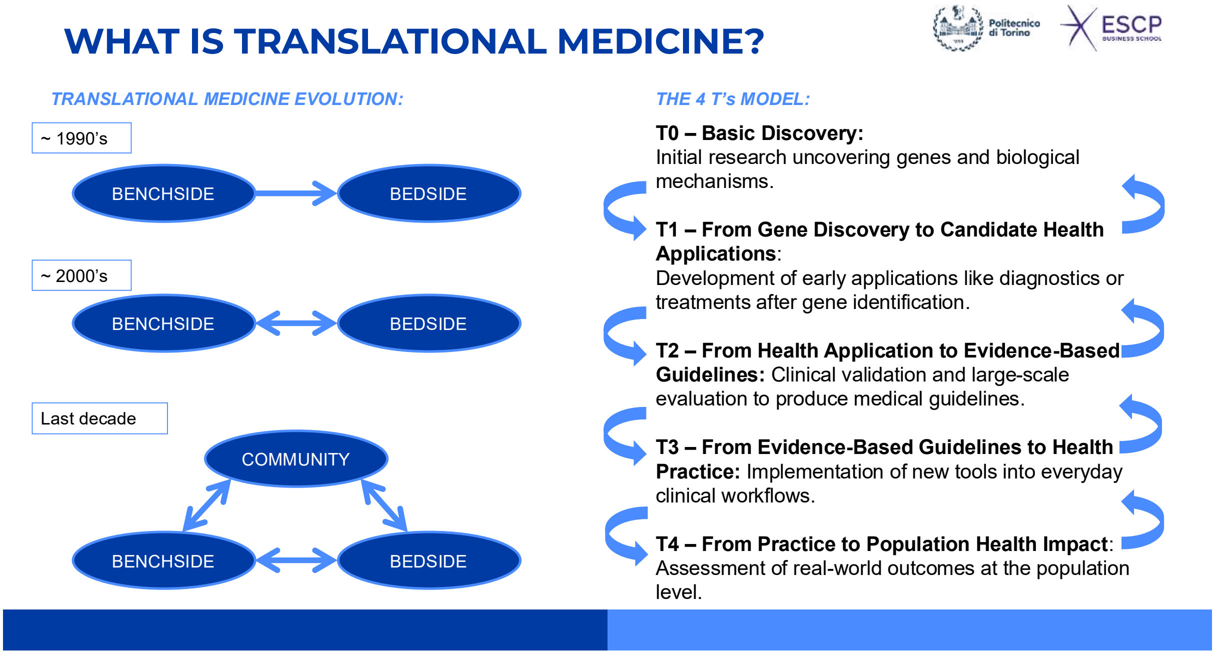
High technological uncertainty (no proof of concept yet) and market uncertainty (unpredictable adoption).

Competitive Advantage

Solutions are hard to replicate but also not easily integrable; risk of obsolescence if innovation stagnates.

*Figure 38: slide 1 of interview deck*

Slides two and three (figures 39 and 40), based on chapter two, were presented to explain what Translational Medicine is from historical and organisational points of view. The key principles and practices were explained to provide a logical basis for extrapolation and application in TDT theory.



## WHAT IS TRANSLATIONAL MEDICINE?

*TRANSLATIONAL MEDICINE EVOLUTION:*

~ 1990's

BENCHSIDE → BEDSIDE

~ 2000's

BENCHSIDE ↔ BEDSIDE

Last decade

COMMUNITY

BENCHSIDE ↔ BEDSIDE

*THE 4 T's MODEL:*

**T0 – Basic Discovery:**
Initial research uncovering genes and biological mechanisms.

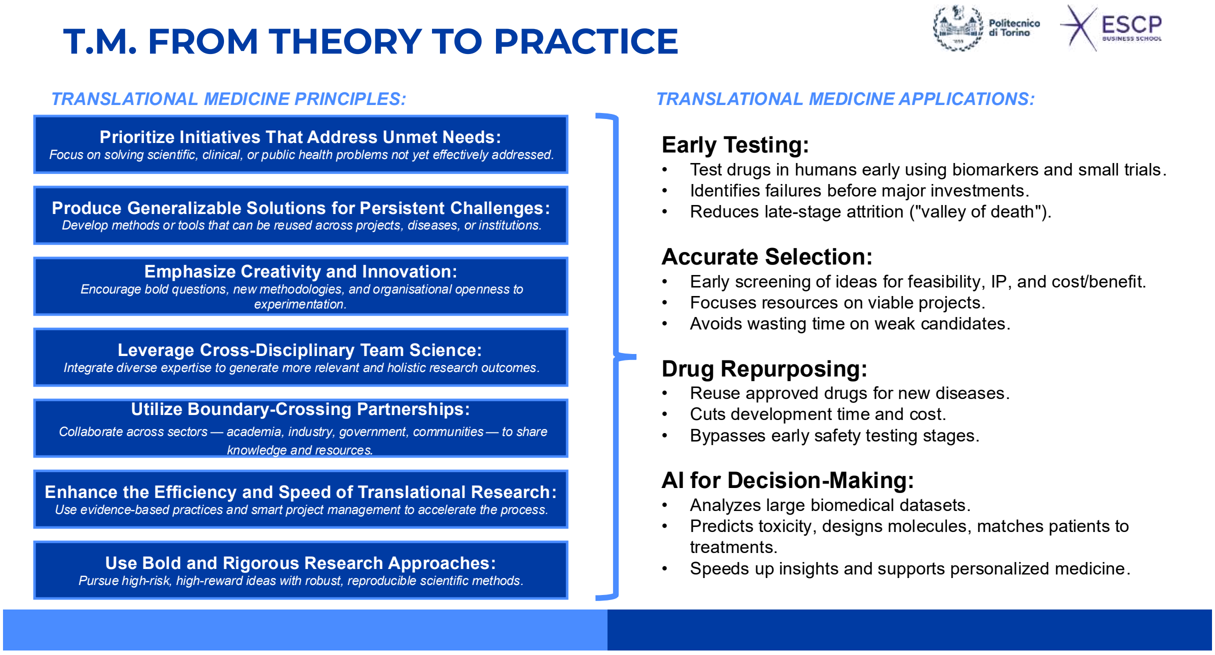
**T1 – From Gene Discovery to Candidate Health Applications**:
Development of early applications like diagnostics or treatments after gene identification.

**T2 – From Health Application to Evidence-Based Guidelines:** Clinical validation and large-scale evaluation to produce medical guidelines.

**T3 – From Evidence-Based Guidelines to Health Practice:** Implementation of new tools into everyday clinical workflows.

**T4 – From Practice to Population Health Impact**: Assessment of real-world outcomes at the population level.

*Figure 39: slide 2 of interview deck*



## T.M. FROM THEORY TO PRACTICE

*TRANSLATIONAL MEDICINE PRINCIPLES:*

**Prioritize Initiatives That Address Unmet Needs:**
*Focus on solving scientific, clinical, or public health problems not yet effectively addressed.*

**Produce Generalizable Solutions for Persistent Challenges:**
*Develop methods or tools that can be reused across projects, diseases, or institutions.*

**Emphasize Creativity and Innovation:**
*Encourage bold questions, new methodologies, and organisational openness to experimentation.*

**Leverage Cross-Disciplinary Team Science:**
*Integrate diverse expertise to generate more relevant and holistic research outcomes.*

**Utilize Boundary-Crossing Partnerships:**
*Collaborate across sectors — academia, industry, government, communities — to share knowledge and resources.*

**Enhance the Efficiency and Speed of Translational Research:**
*Use evidence-based practices and smart project management to accelerate the process.*

**Use Bold and Rigorous Research Approaches:**
*Pursue high-risk, high-reward ideas with robust, reproducible scientific methods.*

*TRANSLATIONAL MEDICINE APPLICATIONS:*

**Early Testing:**
- Test drugs in humans early using biomarkers and small trials.
- Identifies failures before major investments.
- Reduces late-stage attrition ("valley of death").

**Accurate Selection:**
- Early screening of ideas for feasibility, IP, and cost/benefit.
- Focuses resources on viable projects.
- Avoids wasting time on weak candidates.

**Drug Repurposing:**
- Reuse approved drugs for new diseases.
- Cuts development time and cost.
- Bypasses early safety testing stages.

**AI for Decision-Making:**
- Analyzes large biomedical datasets.
- Predicts toxicity, designs molecules, matches patients to treatments.
- Speeds up insights and supports personalized medicine.

*Figure 40: slide 3 of interview deck*

Slide 4 showed Table 1 (*see Chapter 3*), which compared Translational Medicine with common Deep Tech start-ups and university spinoffs. The main reason for this was to demonstrate why a comparison between Translational Medicine and Deep Tech spinoffs was more appropriate than comparing TM to general Deep Tech startups. The aim was to generate discussion about the main differences between the three areas.

With a similar scope, slide 5 showed a comparison of the main actors involved in TM and TDT, as shown in Figure 35 (*see Chapter 3*).

The final slide showed the six main TDT principles, as shown in figure 36 (*see Chapter 3*). The aim of this slide was to stimulate critical analysis of each of the pillars by the interviewee, to understand their opinion on each of them: whether they are already applied in common practice, whether they are considered useful or too theoretical, their applicability in practice, the reasons why they may not be used, and any other considerations.

## Interviews highlights

As explained in the previous section, the three interviews were based on the same set of slides. Given their different backgrounds, knowledge and job positions, however, different aspects were analysed to obtain as much value as possible.

All the three experts currently work at LIFTT (LIFTT S.p.A., 2025) a venture capital fund specialising in deep tech and quickly gaining relevance in the European VC landscape. By the first half of 2025, they had invested in over 60 start-ups from around the world, with a particular focus on Europe. In 2024, they signed a deal with the European Investment Bank (EIB press, 2024), whereby the EIB could double the amount invested by LIFTT in European deep tech start-ups.

LIFTT's business model already incorporates some of the principles discussed in this thesis as best practices dealing with Deep Tech startups. For instance, the company invests in deep tech companies from the seed round up to Series B using an evergreen approach, meaning there is no time limit on investments and the exit strategy is more flexible. Furthermore, they have a dedicated PM department aimed at supporting the sustainable growth of startups in their portfolio, providing assistance and advice as required. Finally, the fund is creating a network of valuable contacts in many deep tech sectors, allowing them and the startups in their portfolio to easily access different sets of knowledge when needed.

Therefore, interviewing LIFTT experts from different departments and with different backgrounds has been a good starting point for assessing the possible validity of this thesis. The next section will first present the background of each interviewee, followed by the main highlights of each interview, along with summaries of the most important concepts and points of view expressed.

## Interview with Alessandra Scotti

After graduating in law, Alessandra started her career at Unioncamere Piemonte, providing support to Start ups and SMEs on European regulations and funding. She then moved to London where she lived for over 12 years, managing CPD courses, inhouse training and events at the IoPPN (Institute of Psychiatry, Psichology & Neuroscience).

Today, Alessandra is the "Institutional Relations & Scouting Manager" in LIFTT, a strategic role in the company that allows Alessandra, among the others, to maintain the relationship with all the Technology Transfer Office of many universities in Europe.

During the interview, many interesting points were raised. One point that Alessandra wanted to make on the first slide was that when a deep tech innovation is truly revolutionary, it does not have just one clear market application; it can be implemented to meet many different market needs. This characteristic, which may be implicit in terms of timing, strategy and the market, is considered very important, as one of the main difficulties with deep tech innovation is finding the best and most valuable application field.

On this topic, Alessandra also pointed out that British universities such as Cambridge, Oxford and UCL have a strong tradition of technology transfer offices (TTOs) compared to European universities. This allows them to have strong relationships with industry players who may influence the research, aiming from the beginning "to find a solution to an existing problem rather than researching a need".

Alessandra also provided valuable insights into the actors involved in the innovation process as theorized in Translational Deep Tech, which appears to bear significant resemblance to the actors recognized by various specialized consulting firms as essential for creating a startup ecosystem in a given region (Figure 41).

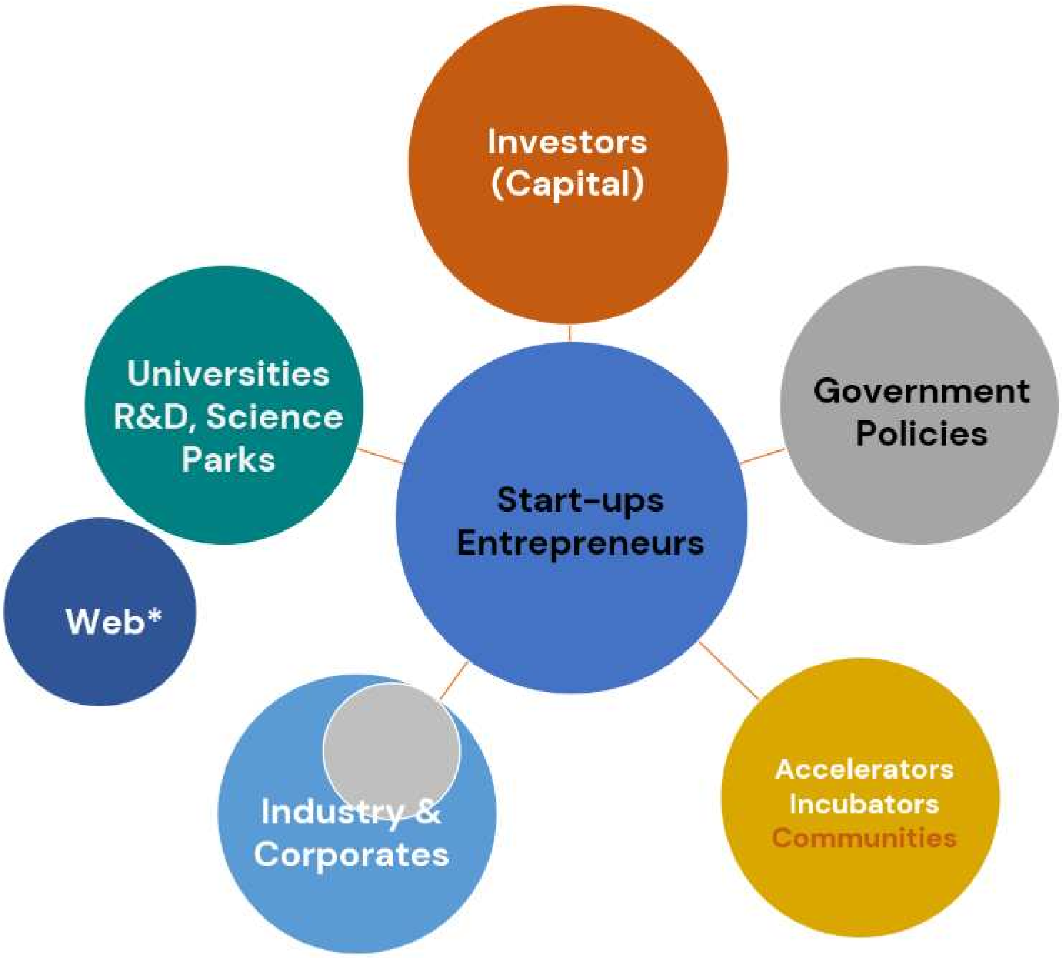


*Figure 41: actors needed to create a successful startup ecosystem*

While the TDT 3-actors model focuses solely on spin-off innovation, this consulting firm cites all the main actors in the model theorised in this thesis.

Looking at the final slide, which outlines the six principles of translational medicine, Alessandra noted that some of these principles were very similar to the main idea behind the creation of the European Innovation Council (EIC, 2025), which had the aim to link investors and the research world. This was intended to be achieved by fostering a mindset that facilitates communication between financial providers and pure researchers, even finding a 'common language'.

European Innovation Council works mainly through four core funding instruments (or schemes) and one nonfinancial one, each targeting a different stage of innovation:

- **EIC Pathfinder** focuses on early-stage, high-risk research into radically new technologies. This instrument supports consortia of researchers, universities, start-ups and SMEs in exploring breakthrough scientific ideas and laying the groundwork for future innovations.

- **EIC Transition** takes promising results from Pathfinder projects (or European Research Council Proof of Concept) closer to the market by supporting activities such as technology validation, prototyping, business modelling and early commercialization steps. The aim of this second instrument is to bridge the gap between research and practical innovation.
- **EIC Accelerator** provides grants for R&D and equity investment through the EIC Fund to help small companies scale up and bring disruptive innovations to global markets.
- **EIC STEP Scale-Up** (Strategic Technologies for Europe Platform), wants to scale up strategic deep tech innovations crucial for Europe providing equity investments between €10M and €30M for startups, SMEs, and small mid-caps. The aim of this instrument is to enable European companies to grow into global tech leaders while strengthening EU sovereignty in critical technologies.
- **EIC Business Acceleration Services (BAS)** provides non-financial support in the form of mentoring, coaching, networking opportunities, and access to investors, corporates and ecosystems to accelerate the growth and internationalization of innovators supported by the EIC.

As Alessandra explained, the EIC may be an organization that addresses principles 2 and 3 of the TDT without explicitly establishing Translational Agencies.

On the other hand, the interviewee explained that point 4 of the TDT, which concerns the accurate selection of projects, would be very important to university technology transfer offices (TTOs), especially when deciding on the market for new technologies.

Regarding point 5, Alessandra confirmed that Deep Tech requires tailored KPIs. She also mentioned that, in recent years, this has been recognized by various stakeholders, who have established dedicated funds or branches of venture capitalists that understand the return potential of deep tech innovations when assessed using the right criteria.

Finally, the expert opinion on the last point regarding effort repurposing is that it may be applicable on a case-by-case basis, depending mainly on the development stage and the people involved. However, she confirmed that such an approach would only work if a university spin-off is led by both a technical research expert and a market expert who can work together to determine the best steps to make the start-up as successful as possible.

## Interview with Camilla Nicolotti

Camilla has an university background in Management at the University of Turin, plus a Master of Science in Innovation Management & Entrepreneurship at Alliance Manchester Business School. Following to an early work experience at KPMG in the Risk & Sustainability Advisory practice, she gained expertise in the areas of Risk Management, Internal Audit and Organization for the management consulting firm Protiviti, specifically serving clients within the manufacturing and services sectors.

She currently holds the position of Business Analyst at LIFTT, where she is responsible for strategically deciding which startups to include in the fund portfolio, performing due diligence on them, and negotiating contract terms. Between 2024 and 2025, she undertook a one-year expedition to the USA to gather information on American Deep Tech dynamics and ecosystems, and to establish strong relationships with local stakeholders to increase LIFTT's presence in the US.

Camilla's background and US experience make her the perfect candidate to be interviewed, with a specific focus on the differences between the EU and US Deep Tech landscapes, which may better explain some of the main criticalities of the former compared to the latter, as discussed in chapter one of this thesis.

In the first part of the interview, the expert pointed out the important difference between software and hardware in terms of deep tech characterization, stating that the latter is far more deep tech than the former. In fact, hardware is more defensible through IP, and real breakthrough innovations in this field come from physical innovations, which are then possibly followed by new software systems.

The importance of IP has also been considered when looking at the difference between normal start-ups and university spin-offs. Camilla explained the importance of university IP policy, as the common European model is that if a researcher makes a breakthrough innovation, the IP becomes the property of the university, which is usually given to the spinoff in the form of an exclusive license after its creation. However, Sweden is considered a best practice in this area, as IP immediately becomes the researcher's property, smoothing a complex step in the investment process that is usually considered very critical by investors. On the other hand, US universities take a similar approach to the one commonly used in Europe. However, they overcome obstacles with the help of strong technology transfer offices (TTOs), which quickly adapt or discuss with investors to find the best solution for innovation.

When discussing the main characteristics that make the US innovation model in deep tech so successful compared to the European model, Camilla explained that an important reason for this is the territorial proximity of all the different actors within each innovation ecosystem. The creation of physical hubs where research institutions and large companies are within walking distance of each other, or even co-working spaces, is a key factor in US innovation. This makes it easier for the parties to communicate constantly, and companies and researchers can even influence each other's culture and habits.

Corporate influence and investment represent a key difference between the US and EU ecosystems, with American companies being far more proactive and investing far more in innovation than their European counterparts, who are much more conservative. In the US, companies are investing in accelerators and incubators, whereas European companies are failing to take risks.

Another important US characteristic is the advisor figure, who is someone with market experience and valuable connection that links to the company through accelerators or investors. They provide market guidance and prestige to the company in front of other investors. These figures are fundamental to the US ecosystem and are very similar to the 'market expert' identified in this thesis. The advisor follows the company from its early stages, cultivating relationships with companies from the outset — something Europe lacks.

Therefore, while Camilla explained that researchers in the US also lack a business perspective and risk missing market opportunities, as in the EU, good advisors can intervene to address this issue without compromising the research itself. However, in the US, this figure usually emerges once the technical innovation has been completed, primarily to lend credibility to the startup in the eyes of companies and investors.

The US innovation landscape has the advantage of greater diversity of cultures and backgrounds within the same project, which can be performed across the country with the same regulations, whereas local differences in policies between countries prevent Europe from having this advantage.

Camilla's final recommendation was about the 'tailored KPIs for project selection' in the fifth TDT principle. She explained that it would be useful to have different KPIs to differentiate Deep Tech from common investments and to distinguish between different Deep Tech sectors. For example, an investment in quantum computing may require very different indicators to an investment in agritech, and failing to recognise this could result in misjudging investments.

## Interview with Pierluigi Freni

Pierluigi is an atypical engineer keen on design and technology, pursuing innovation with an entrepreneurial mindset. Lately, he has focused on how the disruptive potential of blockchain is reshaping the concept of business innovation. Previously, he was the founder and CEO of Sherlock S.r.l., a startup in the IoT sector, and he holds a Ph.D. in Material Science and Technology from Politecnico di Torino.

Pierluigi is currently a Project Manager at LIFTT, meaning he supports startups from the moment they join the portfolio until they exit, providing all the help he can. This role is useful for both the fund, which can monitor the development process of the start-up from the beginning and provide valuable insights, and the start-up itself, which can leverage the expertise and valuable network of a company like LIFTT through figures like Pierluigi.

Pierluigi's position and background put him in a unique position to offer insights from both the entrepreneurial and investor perspectives on this thesis. Having been a startupper himself, he recognizes the difficulties and challenges of that position. In his current role as supervisor and advisor, he can also explain the VC perspective on the development of deep tech start-ups.

One valuable contribution Pierluigi made during the interview was raising the question of who would orchestrate a deep tech project. This doubt arises from the fact that, with many contributions to the same project (as with the TDT aim, for example, from researchers, market experts, TTOs and other community actors), the person with the most important contribution usually has ownership of the project. However, with many actors involved in making the innovation successful, a key ownership must be established.

Therefore, what drives each actor involved must be better studied, along with their interests and expected “remuneration” (be it economical, prestige or else), otherwise the model would not work.

Similarly to what Camilla pointed out, Pierluigi emphasized the importance of IP policy and ownership between universities and researchers. According to him, this aspect represents one of the main critical points that investors consider when deciding whether to invest, as some universities demand excessive royalties, stifling startup development from the outset, whereas a straightforward IP transfer facilitates investment. On the other hand, Pierluigi explained how Professor Privilege — the legal rule that gives university professors ownership of patents for their inventions — led to excessive fragmentation in IP management, which damaged the investor perspective as well.

Looking at the 6 principles of TDT, the expert expressed some contradiction in the fourth principle about the early testing strategy. In the discussion, it came out how this may be in contrast with the “blue ocean” strategy of deep tech startups, as if the companies would influence the research process too early, they may create a bias from the beginning, preventing innovation to be a real break through one.

Therefore, one critical point of discussion has been to determine the optimal time to begin influencing the research process. One possible solution is to use TTOs as a critical actor who looks at research before it is published as a scientific article. Researchers' main aim is to publish their research, but this conflicts with IP rights. When a researcher has something about to be published, this could be the right time for the TTO to examine each case individually, deciding whether to proceed with an academic article or try a spinoff approach, reaching out to corporations and market experts first.

Pierluigi's final recommendation concerns point 6 of the TDT principles. He said that something with this aim already exists: Innovation Radar. However, no one uses it.

The European Innovation Radar (Europe Innovation Radar, 2025) is an initiative of the European Commission that identifies, assesses, and promotes high-potential innovations developed within EU-funded research and innovation projects. The purpose of this initiative is to act as a 'radar' to identify innovations with strong market potential that emerge from EU research programs such as Horizon 2020 and Horizon Europe. Promising innovations are published on the Innovation Radar platform, a public database. The aim is to provide visibility for European start-ups, SMEs, universities and research organizations that could benefit from it.

The initiative should help innovators connect with investors, industry partners and policymakers while encouraging the commercialization of research results. In short, it’s the EU’s tool for turning publicly funded research into real-world innovations and market opportunities — a concept similar to the "effort repurposing" aim of the sixth pillar of TDT.

Pierluigi also explained that, in his opinion, the reason for the failure of this platform is the poor quality of the database, due to poor supervision and the lack of a real owner to represent the platform. In fact, he said that having a dedicated team to act as owners and supervisors of the platform, who could help actors looking for innovation navigate the radar and keep it constantly updated, would make it far more useful and effective.

## Interviews main outcomes

A comparison of the three interviews reveals that the experts generally validate the theory expressed in this master's thesis, providing useful insights to complement the analysis. Thanks to the expert interviews, the six theoretical principles defined for TDT could be further developed in the six “practical principles of TDT” (figure 42).

Of the six TDT theoretical principles, the first, *Constant Communication Between University Researchers and Market Experts*, has been strongly validated and even expanded. The interviewed experts explained the importance of this principle in real practice, saying that they accelerate the process of raising awareness of deep tech. In particular, they highlighted that structured integration of advisors, a figure already common in the US ecosystem, could institutionalize this constant exchange. The presence of such “market experts” from the earliest stages of development was considered one of the reasons why American deep tech start-ups scale more easily than European ones. According to these considerations, the new name has been changed to “Structured Advisory Integration” in the six TDT practical principles.

The second principle, *Awareness-Raising in the TDT Community*, has also been accepted, but the interviews suggested broadening its scope. Beyond training and awareness, experts emphasized the importance of ecosystem-building, pointing to the US model of physical hubs and cultural exchange between companies and researchers. This suggests that raising awareness should be combined with concrete actions to strengthen the innovation ecosystem, where co-location and continuous interaction become as relevant as knowledge dissemination. The practical principle could be named “Ecosystem & Awareness Building”.

Regarding the third principle, *Creation of European and Global TDT Agencies*, it seems that the EIC may be the perfect candidate to fulfil this role, as it already has most of the characteristics that a TDT agency should have in its objectives. Instead of creating new structures, the interviews suggested focusing on strengthening existing institutions such as the EIC or the Innovation Radar, ensuring proper governance and more effective use of these platforms to support deep tech translation. The principle become “Strengthening Existing Translational Agencies”.

The fourth principle, *Early Testing Strategies to Reduce Attrition*, was the most discussed, as it represents a significant innovation in the current paradigm. The main concern raised was how to maintain free research, from which breakthrough technological innovations arise, while finding ways to solve the problem of their market application. Experts stressed that the timing of market influence is crucial: too early intervention could create bias and prevent radical discoveries, while too late intervention risks missing viable opportunities. For this reason, some pointed out that Technology Transfer Offices could act as gatekeepers, reviewing research before publication to decide whether it should remain academic or move toward a spin-off approach. This reframes the principle into a matter of “strategic early alignment”. The TTOs will need to take the initial ownership of the project to allow TDT.

The importance of the fifth principle, *Accurate project selection through tailored KPIs*, has been emphasized, with further specification of the creation of a set of KPIs tailored to each sector, as these may vary considerably between different deep techs. For instance, investments in quantum computing may require completely different evaluation metrics compared to agritech. Therefore, experts suggested developing sector-specific KPI frameworks, adaptable to the different clusters of deep tech innovation. Therefore, the name of the practical principle is “Sector-Specific Translational KPIs”.

Finally, although the sixth principle, *Effort Repurposing*, may seem somewhat unrealistic, it is considered a worthwhile goal for research, and a concrete application of it could be found in improving the existing European Innovation Radar. Experts explained that the platform already contains the seeds of this approach, but suffers from lack of ownership and poor quality control. A stronger supervision, with dedicated teams curating and updating the database, would make this principle more practical and transform effort repurposing into a real instrument to reduce waste and accelerate innovation cycles. The practical principle could be defined “Institutionalized Knowledge Repurposing Platforms”.

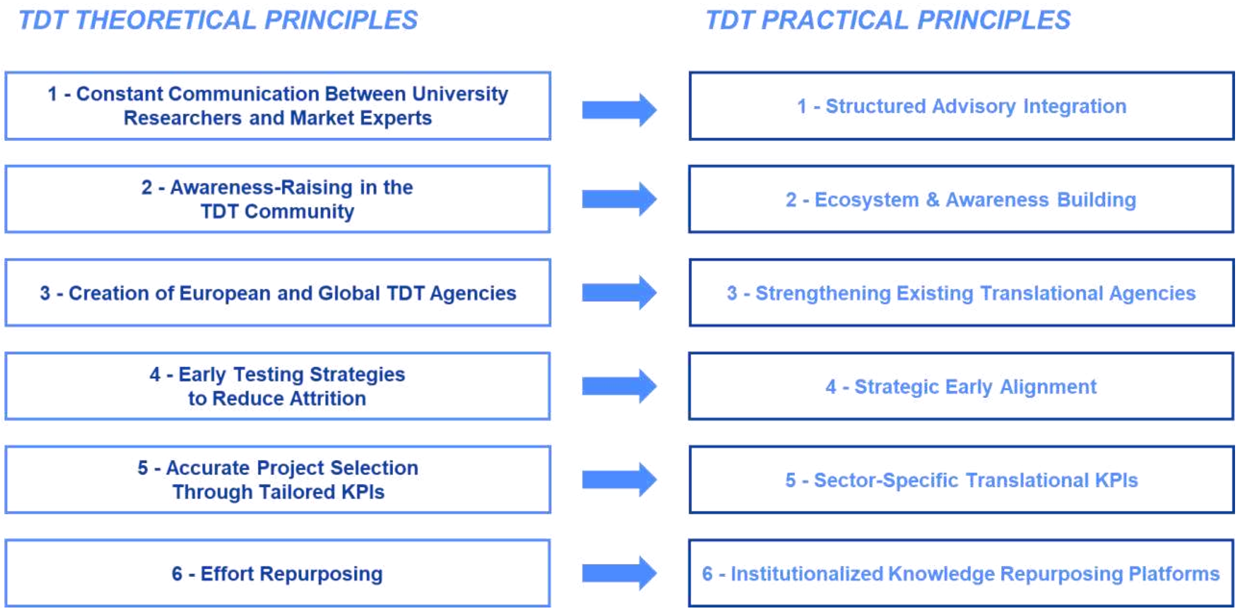


*Figure 42: TDT practical principles*

## Next Steps for Validation

The interviews provided initial qualitative confirmation that the TDT principles are relevant and align with emerging practices in the European deep tech landscape. The next step is to progress from theoretical plausibility to practical validation through a sustainable, progressive process.

One useful way to approach this is via a two-dimensional matrix (figure 43). In terms of territory, pilots could initially focus on a single player (e.g. Politecnico di Torino or LIFTT), where conditions are easier to control and existing processes can be adapted to test some of the TDT principles. If successful, the model could then be scaled up first to a regional ecosystem involving several universities, technology transfer offices (TTOs) and investors within the same area, then to a national level where differences in governance and regulation would become apparent, and eventually to a European scale where the challenge would be to harmonise fragmented systems and coordinate multiple countries.

| | Some Deep Tech Compartments | All Deep Tech |
|---|---|---|
| **Single Player (University, VC)** | Pilot projects (e.g. Politecnico di Torino, LIFTT) | Single player covering all DT areas |
| **Regional** | Regional ecosystem pilots (few DT sectors) | Regional pilots covering all DT sectors |
| **National** | National level pilots (selected DT sectors) | National-level implementation |
| **EU** | EU-wide pilots (selected DT sectors) | Full EU-wide implementation (ultimate goal) |

*Figure 43: TDT Validation Matrix*

In terms of sector, validation could initially involve applying the TDT principles to a few specific areas of deep tech, such as quantum computing or biotech. These are sectors in which ecosystems are already relatively mature, and the impact of advisory integration, tailored KPIs and repurposing platforms can be more clearly measured. Once feasibility has been demonstrated, the model could be expanded progressively to cover other deep tech categories until it encompasses the full range of the 15 areas identified in this thesis.

This approach suggests that validation does not have to be 'all or nothing', but can follow a step-by-step pathway. This would start with small-scale pilots that are both sustainable and meaningful. Then, the model could be scaled both vertically (from single players to the EU) and horizontally (from a few sectors to all deep tech). This allows the theory to be stress-tested gradually, ensuring that early experiments provide robust evidence of feasibility and scalability.

Ultimately, the success of this progressive approach hinges on the initial actors' willingness to serve as 'living labs' of TDT, experimenting with structured advisory boards, sector-specific KPIs and knowledge repurposing platforms. These pilots would provide the evidence needed to convince larger ecosystems and policymakers to adopt the model more widely.

# Conclusions

The aim of this Master's thesis was to determine whether Translational Medicine could provide inspiration for developing a new theory that addresses some of the key issues and challenges that prevent Deep Tech innovation from start-ups in Europe from reaching its full potential.

To achieve this, Chapter One began by providing a clear definition of the term 'Deep Tech', identifying its key characteristics and outlining a potential current classification. It then moved on to explain the European landscape and the main challenges preventing Europe from realizing its potential in this field. The final part of the chapter examined Deep Tech innovation from university spin-offs, demonstrating that university excellence is the key to improving the European situation.

The second chapter introduced Translational Medicine, covering its historical and organizational development, the issues it has addressed, and its achievements. Translational Medicine has been modelled, and its main principles have been extrapolated in order to understand the keys to its success and how these can be transferred to deep tech.

In the third chapter, the main similarities and differences between the dynamics of Translational Medicine and Deep Tech innovation were discussed. Based on this, the scope of the 'ready to born' approach was narrowed to Deep Tech innovation originating from a university spin-off. This eliminated most of the differences with translational medicine, making the transfer of principles more appropriate.

The Translational Deep Tech approach has therefore been conceptualized: a methodology that translates the principles of Translational Medicine into the innovation process of Deep Tech spinoffs. The aim of this idea is to theories principles that may help European spinoffs to overcome the main challenges preventing them from reaching their full potential. These principles have been conceptualized as six main pillars. The new theory has then been compared to existing literature on the topic, demonstrating how innovative the approach is, while also showing that some aspects have been theorized by important firms and organizations.

The final chapter of the thesis aimed to provide practical validation of everything expressed in theory up to that point. This was achieved through expert interviews conducted as discussions around the main topics covered in the previous chapters.

Translational Deep Tech has generally been validated, with some of its six principles having a practical counterpart already existing and others representing a completely new approach. Based on these considerations, a 'practical' version of the six TDT principles has been developed, along with a potential validation pathway. This pathway starts with small but meaningful pilot schemes, which will then be scaled up progressively across sectors and territories. The aim is to demonstrate the ability of the theory to reduce barriers and accelerate the success of deep tech spin-offs.

The main outcome of this Master's thesis was to investigate the parallels between translational medicine and deep tech innovation dynamics. This paper may represent the first in-depth study of the topic, which, given the strong initial feedback received from literature reviews and expert interviews, may be worthy of further investigation.

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