DT LAUNCH PAD

Enabling Deep Tech Entrepreneurship

European Deep Tech Commercialisation Trajectory Report

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Abstract

This report examines the current state of Deep Tech commercialisation in Europe, highlighting the unique challenges faced by ventures that are deeply rooted in scientific and engineering innovations. Despite the progress in building a strong startup ecosystem, Europe lags behind the United Sates and Asia in scaling up Deep Tech due to fragmented markets, limited funding, and a lack of commercial expertise. The report identifies three critical stages—pre-incubation, incubation, and acceleration—each requiring specific support such as mentorship, legal guidance and targeted funding. Europe's strengths lie in its robust research institutions and increasing public support for innovation through initiatives like Horizon Europe and the European Innovation Council.

To drive Deep Tech forward, the report emphasises the importance of fostering technical, entrepreneurial, and transversal skills for founding teams and support staff. It calls for stronger collaboration between academia, industry and government, and recommends improving commercialisation services by structuring more tailored support systems, enhancing funding access and developing programs that address the specific needs of Deep Tech ventures. These actions are crucial for unlocking Deep Tech's potential to address the most complex and pressing societal challenges.

1. Introduction

The *European Deep Tech Commercialisation Trajectory Report*[1] explores the state of the art of Deep Tech commercialisation, the essential requirements for researchers to successfully bring their innovations to market, and the support universities provide to Deep Tech startups during the (pre-) incubation and acceleration stages. More specifically, it focuses on the current state of Deep Tech research commercialisation in Europe and the necessary adjustments that need to be made to the pathway that non-deep-tech (e.g., traditional tech startups, software as a service provider, etc.) innovations follow from lab to market in order to better support Deep Tech ventures. Additionally, this review addresses gaps in the literature on Deep Tech research commercialisation in relation to skills and training needs for researchers to commercialise their innovations. This document also delves into the key success factors, drivers and barriers concerning the process of Deep Tech research commercialisation, paying particular attention to the support that incubators and accelerators offer to Deep Tech innovators and their ideas born within the university. Lastly, this review strives to increase our understanding of the Deep Tech commercialisation process, highlighting the specific training- and incubation-/acceleration-related needs of universities and helping us create structures and support mechanisms to address them, ultimately building capacity at universities to better support their researchers and unlock the full potential of Deep Tech to tackle some of the most pressing challenges in our world.

Definition of Deep Tech

Coined in 2015 by Swati Chaturvedi[2], the term Deep Tech was originally defined as "companies founded on a scientific discovery or meaningful life sciences, energy, clean technology, computer sciences, materials, and chemicals innovation". Since then, as Deep Tech has become more popular in media and literature, new attempts have been made to define it.

As of 2024, definitions of Deep Tech in the literature are vague and varying, which reflects the fact the concept is still being developed. Furthermore, there is a lack of profound understanding of how Deep Tech differs from what has been called traditional tech and shallow-tech (Tekic, Z., et al, 2023).

Some of these definition attempts have focused on the meaning of the word "deep" in "Deep Tech". We find definitions that understand "deep" as fundamental, describing Deep Tech as "disruptive solutions built around unique, protected or hard-to-reproduce technological or scientific advances" (Hello Tomorrow & BCG, 2017, as seen in Romasanta et al., 2022); or definitions that understand "deep" as profound and define Deep Tech as ventures built on "cutting-edge technologies that can have a profound effect on the overall human society" (Dataquest, 2019, as seen in Romasanta et al. 2022). However, under this expansive definition, Deep Tech innovations and ventures become commingled with other adjacent concepts such as high-tech, hard-tech, disruptive technologies, and technology-based and knowledge-intensive ventures.

The European Commission (SWD (2023) 205 final), building on the Deep Tech definition by Hello Tomorrow & BCG (2017), has referred to Deep Tech as "an institution, an organisation or a startup company, with the expressed objective of providing disruptive solutions built around unique, protected or hard-to-reproduce technological or scientific advances". These solutions are distinguished by their complexity, both in terms of the science that underpins them and the IP they generate, often having long development cycles, significant capital requirements and challenging regulatory barriers to overcome (SWD (2023) 205 final).

We have reviewed grey literature, white papers and policy documents on Deep Tech, and analysed different European initiatives to combine the different visions of Deep Tech into a comprehensive definition: *Deep Technology or "Deep Tech" refers to organisations, institutions or startups that seek developing advanced technological solutions to address larger-scale societal challenges. Deep Tech entities engage in extensive research and long development cycles to apply emergent scientific or engineering breakthroughs by translating them into*

[1] A research output of the DTLaunchpad initiative, co-founded by the European Commission.
[2] The term "deep-tech" was first coined in 2015 by Swati Chaturvedi, founder of Propel(x), the world's first platform dedicated to angel investing in deep-tech startups. (https://www.linkedin.com/pulse/so-what-exactly-deep-technologyswati-chaturvedi/)

innovative products or services. The uncertainty surrounding Deep Tech is an essential element of what makes it unique."

Definition of commercialisation stages

Three main stages of commercialisation are identified in literature (Goldsmith, 1999; as cited in Максименко, 2020; Yildirim, 2022; Dealroom et al., 2023a), showing the path for innovation to progress from its first conceptualisation (pre-incubation) to prototyping and development (incubation) to its scaling in the market (acceleration). This refers to a general roadmap for technology to be commercialised, thus differences between Deep Tech and standard tech are presented in a subsequent section. 8

The **pre-incubation stage** refers to the ideation or concept phase, where the innovative idea is still at an embryonic stage and requires rigorous definition by testing critical assumptions and determining its potential entrepreneurial potential. As Kirby (2006) notes, pre-incubation targets startups that have not yet developed a business plan, prototype or set up an entrepreneurial team. This highlights the importance of understanding the available entrepreneurial options, which in turn influences decisions about which technology applications to commercialise (OECD & The World Bank, 2014).

This is a crucial step for Deep Tech ventures, as it sets the foundation for commercialisation by transforming early-stage research into marketable innovations. Researchers must conduct a market needs assessment during this stage, providing an overview of market trends, barriers, and risks. This feeds into the initial drafting of a business plan, estimating financial forecasts (Максименко, 2020; Yildirim, 2022) to avoid ideas that will not be profitable as early as possible. Often, this phase begins within universities, where researchers identify problems and embark on the development of technological solutions, typically requiring interdisciplinary expertise. The transition from lab research to exploring market potential is challenging, with researchers needing significant support from technology transfer offices (TTOs) and incubators to navigate commercialisation pathways. Together with the incubation phase's product development phase, pre-incubation is one of the most research-intensive periods. Programs offering mentoring and business concept validation are essential during this phase. These initiatives help scientists refine their technologies while also fostering a deeper understanding of entrepreneurship and market dynamics. Such support is critical in preparing ventures for future market entry and securing early funding.

The **incubation stage** provides the environment and resources necessary to transition from research to market readiness (Максименко, 2020; Yildirim, 2022). During this stage, the technical feasibility of the idea becomes a focal point, as a working model or prototype is developed to test the product's features for potential markets. This is supported by market studies aimed at identifying market size, potential customer volume, pricing, and distribution strategies. Incubators, often affiliated with universities, play a pivotal role by offering essential support such as entrepreneurial mentorship, funding opportunities, and business development guidance through their TTOs. Researchers, who are typically unfamiliar with business strategies, gain vital skills in areas such as business model development, acquisition of initial funding, and connecting with industry players. Prototyping a minimum viable product (MVP) becomes essential in this stage, as it provides a tangible demonstration of the technology's potential, often in collaboration with industry partners. Successful prototyping helps validate the product's market fit and attract investors, despite the challenges Deep Tech ventures face in securing funding due to their long development cycles. Nonetheless, "the traditional approach of developing an MVP to test market waters must be recalibrated for Deep Tech" (Dahlander & Véricourt, 2024).

The **acceleration stage** of commercialisation involves setting up the first production facilities and scaling operations and achieving (international) market entry, which may lead to the scale-up of both the technology and the company. During this post-incubation phase, the production of the technology for commercial use is initiated, and distribution is expanded, while the product is refined based on customer input (Максименко, 2020; Yildirim, 2022). However, this phase presents significant challenges due to high costs and limited access to specialised scale-up programs. Structured and strong follow-up support, as well as ongoing investment are crucial in ensuring that promising projects do not stagnate after the prototype phase.

In terms of the commercialisation of Deep Tech, in Table 1 we present an overview of the main types of support needed for each phase to be used as a reference:

Table 1
Description of the commercialisation stages

Stage	Description
Pre-incubation	This stage involves researchers working alone or in a small group to **establish the entrepreneurial potential of a Deep Tech that will bring the (deep) tech business idea to life**. Researchers and entrepreneurs in the pre-incubation stage need special training, mentoring and consultancy services to understand whether their ideas are feasible, marketable and scalable.
Incubation	Researchers and entrepreneurs in the incubation stage **establish their companies (which can also happen during pre-incubation)** and demonstrate proof of concept or (potentially) produce their prototypes/minimum viable products. They require physical space, training, consultancy and mentoring services (as in the pre-incubation period), assessment of their innovation, further business plan elaboration, and support in accessing financing
Acceleration	Entrepreneurs in the acceleration stage would have **created their products and started commercialisation** but have difficulties gaining market share and reaching internationalisation. The product for commercial use is produced and distributed, as well as updated based on customers' feedback. These typical difficulties can be addressed with the help of acceleration programs. At this stage, startups especially need access to funding for scaling, legal and regulatory support, mentorship, a business plan that covers internationalisation strategy and development of solid networks.

Note. Adapted from Paroje (n.d.) & Yildirim (2022).

Methodology

The Deep Tech Innovation Launch Pad (DTLaunchPad) initiative aims to enable and empower a European Deep Tech community through **building capacity among Deep Tech talent** within participating universities and encouraging the international exchange of knowledge on the topic of Deep Tech commercialisation.

Project partners (i) reviewed scientific and grey literature, as well as completed asset mapping of the regional assets used to support Deep Tech commercialisation, (ii) conducted 78+ semi-structured qualitative interviews. These interviews were conducted with representatives from universities (private, and public research universities, as well as universities of applied sciences), governmental agencies, private companies and NGOs across 12 countries (Austria, Canada, Finland, France, Ireland, Italy, Malaysia, Slovenia, Spain, Switzerland, The Netherlands and United States (U.S.). - for the full list of interviewees refer to Appendix). Lastly, (iii) partners hosted a series of 8 roundtable discussions with international experts in Deep Tech commercialisation processes educators of Deep Tech, and incubation professionals to validate the results of their research, incorporating new perspectives and deriving recommendations for the subsequent stages of project implementation.

The interviews aimed at collecting insights on (i) the opportunities, challenges and success factors of the Deep Tech commercialisation process on a European and partners' regional level, and (ii) the current status of Deep Tech pre-incubation, incubation and acceleration services and gaps within the partner HEIs. To achieve this, partners interviewed individuals across three profiles. This resulted in a total of:

- **38 interviews with Deep Tech experts** sharing their expertise on the uniqueness of Deep Tech commercialisation and differences between the Deep Tech and non-deep-tech commercialisation process
- **16 interviews with Deep Tech educators,** with expertise in the competencies that Deep Tech talent should acquire to successfully pursue Deep Tech commercialisation

- **26 interviews with incubator staff members** experienced in the provision of training and support to Deep Tech ventures receiving pre-incubation, incubation and acceleration services.

Interviews were anonymised to reduce identifiability and coded according to their profile and theme (see Appendix, Table 4).

The European Deep Tech Commercialisation Trajectory Report is complemented by (i) seven reports on the trajectory of Deep Tech commercialisation across the countries of the consortium partners diving in depth into different national opportunities, challenges and needed support in Deep Tech ventures' incubation, (ii) a dedicated report on relevant competencies required by both the founding teams of Deep Tech ventures and as well as for by educators and incubation specialists to support the commercialisation process for Deep Tech commercialisation,[3] and (iii) an interactive Digital Regional Asset Map to showcase the Deep Tech ecosystem in partner countries, all available at the DTLaunchpad initiative's website.

2. Commercialisation of Deep Tech Innovations in Europe

Evolution of Deep Tech on the European Policy Landscape

The origins of Deep Tech in Europe go back to the early 2000s when the European Union (EU) began directing investments towards R&D to foster innovation. In 2000, the Lisbon Strategy was released to make the EU the "most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth […] and greater social cohesion" (Presidency conclusions, Lisbon European Council, 2000), laying the groundwork for technological innovation.

Building on this, the Seventh Framework Programme (FP7), launched in 2007, increased R&D funding and focused on critical technologies like nanotechnology, Information and Communications Technology (ICT), and biotechnology, paving the way for Deep Tech (European Commission, 2007).

In 2014, Horizon 2020 was introduced, explicitly funding Deep Tech areas and establishing the European Innovation Council (EIC) to support the development and commercialisation of game-changing innovations. Additionally, the Digital Europe Programme (DIGITAL) was launched in 2021 to promote digital technology in businesses, civil society, and public administration, focusing on supercomputing, AI, cybersecurity, advanced digital skills and society-wide use of digital technologies.

The New European Innovation Agenda was adopted in 2022 with a view to positioning Europe at the forefront of the new wave of Deep Tech innovation and startups, ensuring the best talent is working at the best companies and that Deep Tech innovation creates new breakthroughs to solve the most pressing societal challenges (European Commission, n.d.). It focuses on five key areas: funding for Deep Tech scale-ups, enabling innovation through experimentation, strengthening innovation ecosystems, fostering talent, and improving Deep Tech policymaking.

The Status-quo of Deep Tech Commercialisation in Europe

Over the past decade, Europe has made significant progress in terms of strengthening its technological startup ecosystem. According to BCG (2022), the European landscape has seen the number of technological startups rise from about 1,850 to almost 6,600 between 2015 and 2020. This systemic improvement has also been echoed in the literature (Dealroom, 2023 a-b; European Innovation Council and SMEs Executive Agency, 2024).

There are comparisons aplenty between the European Union and the United States in terms of (deep) tech performance (Sifted, 2024; Financial Times, 2024; DigitalEurope, 2024; McKinsey, 2022) and the majority of them point out that Europe lags behind the U.S... McKinsey (2022) identifies several reasons why Europe has, so far, been unable to catch up with the U.S. when it comes to Deep Tech, some of them include: (i) corporate underperformance and the fact that European companies grow more slowly than their American counterparts; (ii)

[3] The Deep Tech Entrepreneurs Needs Analysis can be found online at dtlaunchpad.eu.

the aftermath of missing the last technological revolution, particularly in ICT, which has led to a competitive disadvantage for the European-based companies; (iii) the U.S. outpaces Europe in venture capital funding and R&D investment, especially in tech sectors; (iv) higher market fragmentation in Europe, that causes the scaling possibilities and speed of adoption to drop below that of the U.S.; (v) the inability of Europe to attract and retain top global talent, aggravated by a lower degree of entrepreneurial activity compared to the U.S.. One additional factor at play in comparing Europe and the U.S., as mentioned by BCG (2022) refers to cultural differences and consequent alternative approaches to funding. European investors in venture capital seem to be more prone to minimise present and potential future risks. On the contrary, U.S. investors are used to and actively look for, riskier opportunities as those are the ones capable of providing greater returns on investment. Moreover, there is a difference also in the average size of investments, where the U.S. also outperforms European investors (BCG, 2022).

On a more positive note, for the European Deep Tech scene, literature seems to agree that Europe has the necessary tools to improve its position when compared to the U.S.. McKinsey (2022) highlights the quality of the European education systems, which produce leading science, technology, engineering, and math (STEM) talent, as well as the openness and connectedness of the European economy. Similarly, Dealroom et al. (2023b) emphasises Europe's strong fundamental research, its STEM talent, and the increasing public support that the Deep Tech ecosystem has received in recent years through initiatives such as the European Innovation Council (EIC), the Joint European Disruptive Initiative (JEDI), and Germany's SPRIND, the Federal Agency for Disruptive Innovation. This foundation contributes to Europe having the largest share of highly-cited research publications in the world, amounting to 43%, as well as having more Deep Tech startups with a patent than the U.S. (Dealroom, 2023a), demonstrating the region's potential.

BCG (2022), in its article "Can Europe Create Its Own Deep Tech Giants?", mentions some challenges that align very much with the ones we have already discussed, but points out to the certain signs of progress made tangible through the Scale-Up Europe and the European Tech Champions Initiatives, which tackle two of the most prominent challenges that Deep Tech faces in Europe: (i) need for investment, and (ii) structural and institutional issues. In terms of investment in Deep Tech, Europe's efforts have increased over the last years, showing a growth rate of about 50% per year (BCG, 2022). Moreover, Deep Tech is the category that receives the largest amount of venture capital in Europe, with figures close to 15 billion USD (Dealroom, 2023b).

Thus, literature seems to agree that Europe is taking steps towards strengthening its (deep) tech global position, showing commitment by establishing the aforementioned initiatives, launching deep-tech-focused calls under its funding schemes (e.g., Horizon Europe, Erasmus+, European Institute for Innovation and Technology (EIT) opportunities and EIC programmes) and emphasising the strategic importance of the digital and green transitions for the EU at a systemic level (European Commission, 2024). In this revitalised approach towards a stronger tech position for Europe, the European Commission has identified ten key areas crucial for Europe to stay competitive against other global powers, with the ultimate aim to develop those technologies and reduce reliance on foreign supply. These include: energy, quantum computing, robotics, advanced manufacturing, space tech, sensing tech, biotech, AI, advanced connectivity and advanced semiconductor tech.

Horizon Europe

Horizon Europe is the EU's current flagship research and innovation programme. With an activity between 2021 and 2027 and a budget that exceeds €95 billion, Horizon Europe fosters scientific excellence and boosts the EU's innovation capacity and competitiveness, ultimately strengthening the EU's technological output. Within Horizon Europe, Pillar 2 – Global Challenges and European Industrial Competitiveness – and Pillar 3 – Innovative Europe (Horizon Europe Investing to Shape our Future, 2021) specifically aim to support Deep Tech.

Pillar 2 supports areas such as digital health solutions, climate science, clean energy, AI and robotics, emerging technologies, and quantum computing through funding opportunities and capacity-building programmes. This pillar is designed to address global challenges and enhance the competitiveness of European industries by fostering innovation and technological advancements in these critical areas. Pillar 3 includes the European Innovation Council (EIC), the European Innovation Ecosystems, and the European Institute for Innovation and Technology (EIT), which support Deep Tech as part of their operations and funding initiatives2. This pillar aims to create a more innovative Europe by supporting breakthrough innovations and scaling up high-potential technologies. The EIC, in particular, plays a crucial role in identifying, developing, and scaling up game-changing innovations and technological breakthroughs.

The European Institute for Innovation and Technology (EIT)

The EIT builds innovation capacity in Europe by fostering the integration of industry, education and research. It operates through independent sub-entities called Knowledge and Innovation Communities (KICs), each of them with a specific topical focus aimed at tackling global challenges. EIT is currently implementing two of their flagship initiatives that support Deep Tech directly: The Cross-KIC HEI Initiative and the EIT Deep Tech Talent Initiative (EIT DTTI), established in 2023.

The HEI Initiative aims to boost innovation and entrepreneurship capacity in the higher education sector. This is done through frequent calls for applications for universities to build multi-stakeholder projects within the scope of the initiative. Overall, however, the role of the EIT in supporting Deep Tech in Europe mainly manifests itself in the Deep Tech Talent Initiative.

EIT DTTI aims to skill one million people in Deep Tech fields to address the most pressing global challenges by capitalising on the new technologies driving the green and digital transition. The initiative focuses on learners across different educational levels (from secondary education to higher education and adult learners who need up- or re-skilling) and aims to substantially support the new wave of Deep Tech innovation throughout the majority of Deep Tech fields. It contains 120+ available courses on capacity building across different Deep Tech fields (see figure 1). The majority of courses in EIT DTTI embed transversal skills into the curriculum to help researchers and scientists take their innovations forward to achieve impact (EIT DTTI website, accessed September 2024), showing a tendency to prioritise such skills over traditional hard-skills.

Those transversal skills can be clustered into the following groups:

- **Non-scientific skills linked to the Deep Tech field**, including skills such as commercialisation of Deep Tech, intellectual property management, digitalisation, regulation and market analysis.
- **Entrepreneurial skills**, including the development of an entrepreneurial mindset, business model development, funding and investment, prototyping, product development, market research, validation of ideas and product market fit.
- **Pure transversal skills**, such as project management, communication and pitching of ideas, innovative and critical thinking, leadership, teamwork and creativity.

The initiative has already trained over 70,000 individuals and is one of the flagship initiatives in Europe for the development of Deep Tech talent, aiming not only to foster talent, but also to retain it and make Europe an attractive ecosystem for Deep Tech scientists and entrepreneurs.

The European Innovation Council (EIC)

The European Innovation Council supports the identification, development and scale-up of game-changing innovations and technological breakthroughs. It provides a structure for the development of a training programme to support Deep Tech entrepreneurs in Europe and provide them with skills and competencies for the commercialisation of their innovations (EIC, 2022). The structure proposed by the EIC starts by addressing the specific features of Deep Tech, helping Deep Tech entrepreneurs create a plan towards creating an impact with their invention. The programme then moves to the development of soft skills that are essential to the Deep Tech innovators (e.g., empathic leadership, science communication, market analysis, etc.), especially for those with a strong scientific profile.

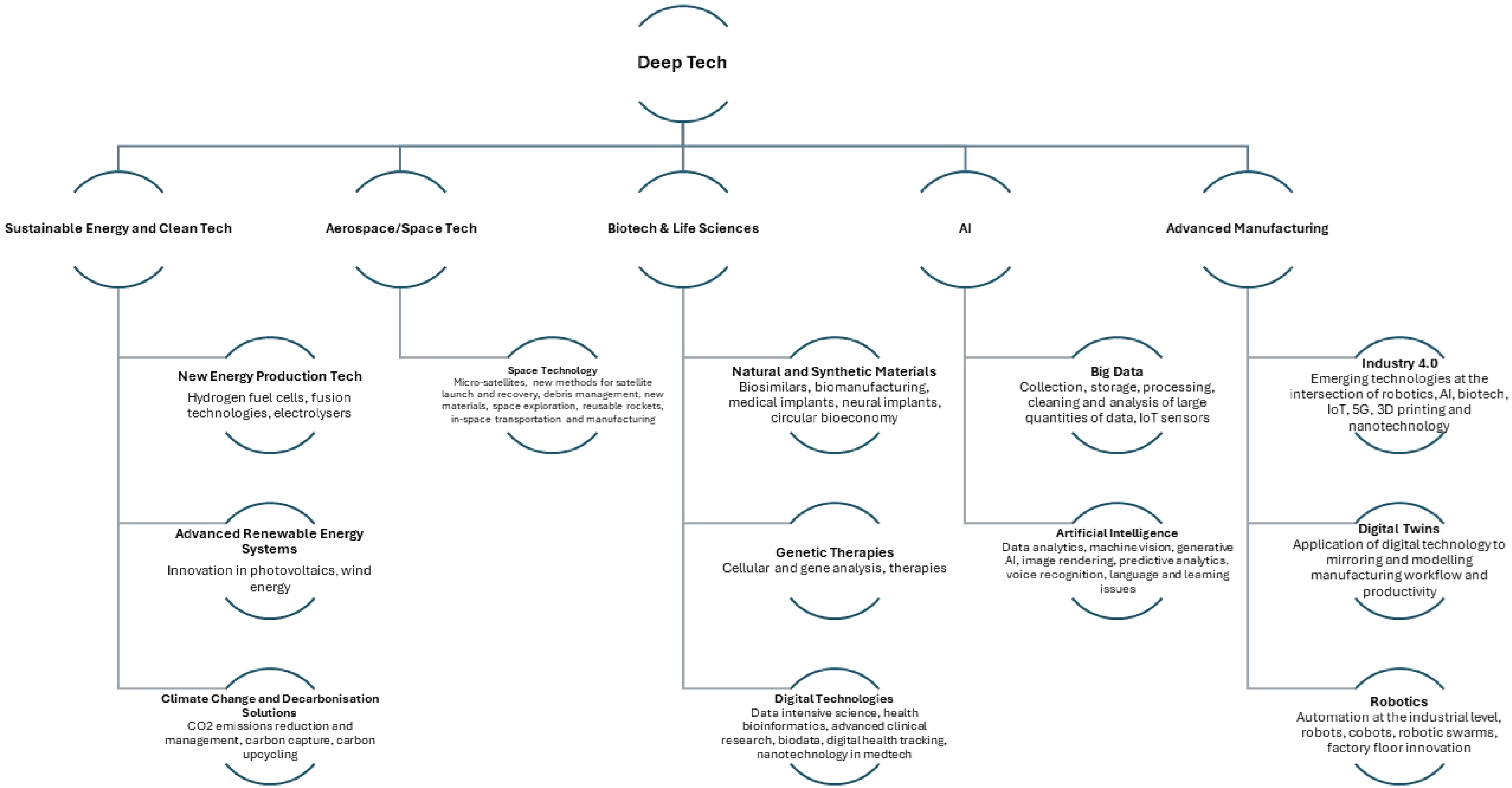
The next stage of the training focuses on the development of market skills among the entrepreneurs, who learn to define addressable markets, value propositions, target groups and market opportunities, establish tangible goals and engage in prototyping, testing and validation. Additionally, at this point, entrepreneurs receive support to build partnerships that will help them in every step of the development process. In subsequent phases, entrepreneurs receive training on how to build a company around their invention, moving from founders to growth companies, defining their business models and learning how to lead teams and work with investors to secure growth.

While the training structure proposed by the EIC emphasises the development of entrepreneurial and commercialisation skills among the Deep Tech innovators (often academic scientists and researchers) there is also room for deep-tech-specific modules such as modelling of specific components and industrial design. Similarly, legal and IP-related topics are covered to offer the entrepreneurs a 360º perspective when it comes to commercialising their invention. A review of the business acceleration services provided by the EIC to their different target groups shows three main support streams, namely a coaching programme, the EIC Tech to Market Entrepreneurship programme and the EIC Women Leadership Programme (EIC website, accessed September 2024).

The EIC offers three funding schemes: EIC Pathfinder, EIC Transition and EIC Accelerator; these are aimed at supporting from the early-stage research to the scale-up of startups and SMEs. The EIC Pathfinder programme supports research and scientific Deep Tech projects, the EIC Transition programme supports validation of novel ideas from lab to business, and the EIC Accelerator programme supports startups and SMEs in scaling up to new markets or disrupting the markets they are already in. Between 2018 and 2023, the EIC achieved a combined portfolio valuation of nearly €70 billion, including 8 Unicorns and 150 Centaurs, 15 of which have a valuation above €500 million, as well as demonstrating, on average, 35% employment growth and 68% revenue growth in the 2 years after receiving support (EIC, 2023). Thus, the EIC merits recognition for boosting the European Deep Tech ecosystem and contributing to Europe’s efforts to catch up with the U.S. and Asia in terms of ventures created, revenue generated and funding provided.

Figure 1

Deep Tech fields. Own author's elaboration based on data from European Institute of Innovation & Technology, EIT Deep Tech Definitions (2023)



3. Deep Tech Commercialisation: Risks

Overview of Uniqueness of Deep Tech vs. Traditional Tech Startups

"Comparing traditional startups to Deep Tech is like comparing two different sports. In traditional startups it's about traction, speed, and winning markets quickly; the goal is to score as many points as possible. But with Deep Tech, you only score a few goals. You can't apply the same rules of traction and speed to Deep Tech as you do with generalist SaaS startups".[4]

Deep Tech commercialisation is fundamentally the novel application of physical sciences, mathematics and engineering into products, services and ventures, and therefore its risk profile is overall different than that of non-Deep Tech ventures (Dealroom et al. 2023b). Adapted from Dealroom's 2023 European Deep Tech Report, in this report we identify five major risks, which are often greater compared to non-Deep Tech ventures: (i) the **initial, longer development of novel technology risk** during the research and development phase, (ii) the **team risk**, which entails lack of commercial expertise in the academic and scientific founding members' backgrounds, (iii) the **capital intensity risk**, ahead of the Deep Tech ventures market entry, (iv) the **market risk**, based on the developed Deep Tech's application in solving complex problems, and (v) the **competition risk** which is often lower compared to the non-Deep Tech ventures. Due to those differentiating characteristics concerning time, capital intensity and uncertainty, Deep Tech ventures require new approaches to their founding, growth and support (Bobier et al., 2022, as seen in Ruiz de Apodaca et al., 2023). As per Dealroom (2023b), Deep Tech startups are supported by multiple stakeholders involved in de-risking, from the research and development phase to entering the market. Each of the risks and its influential factors is presented below in Table 2 below and further elaborated on in the subsequent section.

Table 2

Overview of identified risk for traditional VS Deep Tech ventures.

	Non-Deep Tech venture	Deep Tech venture
Development times	(Low) Often marketed within months of starting, due to the usage of existing, proven technology	(High) Long initial development phase, due to the development of breakthrough/novel technology
Team risk	(Low) Teams are usually more balanced	(High) Teams have a strong research focus
Capex intensity	(Low) Quick go-to-market with basic MVP	(High) Often times heavy capex ahead of revenues and PMF (not a simple MVP process)
Market risk	(High) Existing market demand, but also existing alternatives	(Low) Often no comparable product in market. In general, substantially lower market risk due to the clear potential value of solutions [5]
Competition risk	(High) Network effect and market dominance as main edge	(Low) Strong tech edge

Note. Authors' own elaboration based on data from Dealroom (2023b) and EIT (2023).

[4] CT_Ed1

[5] European Institute of Innovation & Technology, EIT Deep Tech Definitions (2023)

Risk #1: Deep Tech's longer initial R&D cycles

"In Deep Tech, it is critical to know the problem before the solution".[6]

In Deep Tech, the process begins with a problem statement rooted in scientific research, and the subsequent technology aims to address this issue. These innovations typically come from the university labs, require substantial effort to transition from concept to commercialisation and have a low technology readiness level (TRL; De la Tour et al., 2023). Hence, unlike standard tech ventures that often focus on commercial applications from the outset, Deep Tech ventures are grounded in scientific discoveries or engineering innovations, and characterised by "solutions built around unique, protected or hard-to-reproduce technological or scientific advantages" (Hello Tomorrow, 2017).

Due to their scientific foundation, Deep Tech ventures require long and uncertain initial R&D phases (Dealroom et al., 2023b), subsequently demonstrating greater R&D risks compared to non-Deep Tech ventures, often spanning multiple years or even decades. The lengthiness of these processes is considered a feature in its own right. These processes are deemed inherent to Deep Tech as fundamental innovations require more R&D because of the groundbreaking potential they hold and the higher impact potential they have (Myers & Albats, 2024; Chaturvedi, 2015). Moreover, accentuating the differences with non-deep-tech, Deep Tech ventures are considered to be a specific subset of technology-based and innovation-driven enterprises that: (i) operate at the forefront of scientific knowledge, leveraging technological competitive advantages and distinctive technological capabilities (Storey & Tether, 1998; Trenado & Huergo, 2007); (ii) are based on the commercialisation of inventions or innovations that involve significant technological risks (Little, 1978); and (iii) focus heavily on R&D activities, often requiring long and costly R&D cycles to mitigate technological risks (Conforto & Amaral, 2016).

According to McKinsey's (2021) report, Deep Tech startups prioritise R&D early on to commercialise scientific breakthroughs, investing in R&D before scaling sales teams to launch new products and services. These high-investment needs make Deep Tech companies face high levels of uncertainty, technological and commercial risks, and complexity especially when it comes to future applications and market fit, making commercialisation more challenging (Conforto & Amaral, 2016; Mewes & Broekel, 2022).

This length and level of uncertainty surrounding the development of Deep Tech was also emphasised among interviewees. A researcher and expert on tech transfer from Slovenia[7] mentions that the development process is extremely lengthy for Deep Tech and can sometimes be complicated. An advisor from Austria[8] with expertise on biotech and medtech points out that the main challenge is the lengthy development period that comes with Deep Tech, which triggers a series of negative consequences for the startups. This message is clear and common among the interviewees, who explain the longer development periods are an inherent feature of Deep Tech.[9] [10] [11]

Hindering Factors for Risk #1

Deep Tech ventures often face increased difficulty in the initial stages of research and development, as they require extensive research, sophisticated equipment and a high level of subject-matter expertise. The journey from low technology readiness level (TRL) innovations to marketable products is both lengthy and costly, deterring many investors from engaging in early-stage Deep Tech solutions. Two educators from Finland highlighted this radically different time perspective in comparison to more traditional business-to-business software as a service

[6] MTU_Ex1
[7] UL_Ex4
[8] Ac_Ed3
[9] MTU_Ex4
[10] UIIN_Ed4
[11] TUD_Ex1

startup, whereby Deep Tech innovations can take 10 to 15 years to scale or even to take off [12].

These longer development cycles require ventures to secure funding streams that can sustain them throughout the process. Moreover, in Deep Tech, the problems are often not well-defined, and the solutions unclear, making early-stage funding challenging as many investors lack the expertise to properly assess the technology's potential. Furthermore, due to their longer development cycles, there is a risk that the solutions become disconnected from the problem, in that the problem can evolve while the solution is still being developed[5]. Consequently, the challenge of aligning the solution with an evolving problem and maintaining the technology's market fit, adds to Deep Tech's complexity; this is a further significant departure from the faster, more iterative cycles found in standard tech.

One such challenge is the availability of equipment and facilities, which often are expensive and inaccessible. While access varies across countries, startups have very limited access to specialised laboratories and equipment to develop and refine their innovations. On a more positive note, regions in countries such as Poland and Slovenia[13] have reconditioned old semi-industrial facilities to support the commercialisation of Deep Tech, showing how collaborative ecosystems and co-sharing can bridge the gap between universities and industry to provide solutions. In general, these partnerships remain underdeveloped throughout the researched regions.

Risk #2: Deep Tech founding teams' lack of commercial skills

"Deep Tech solutions are often not immediately understood by non-experts, requiring more effort to communicate their value effectively. Entrepreneurs need to be adept at explaining complex technologies in simple terms to attract investment and customer interest".[14]

Another issue common to Deep Tech ventures is talent, as its attraction and retention is deemed to be problematic for all stages of development, (BCG, 2022; EU Tech Venture, 2023). This is crucial especially, considering the case of Europe, as Europe lags behind in terms of securing and retaining talent to harness new technologies for the digital and green transition (European Institute of Technology and Innovation, n.d.). Furthermore, global competition for talent may result in talent migration from Europe to other Deep Tech hubs, such as the U.S. and Asia, creating talent shortages and hindering innovation efforts. A slightly different view on the topic is proposed by Dealroom et al. (2023b), who states that Europe has enough talent, but it is too dispersed.

The unique nature of Deep Tech often requires interdisciplinary collaboration and a combination of different expertise to address the complex, research problems at hand, both involving "setting up a team with technology experts as well as domain experts to gain a broader understanding of how the developed innovation will solve a real-life problem" as it was pointed out by an interviewee. [2]

Hence, in the context of Deep Tech ventures, the risk associated with the founding team is a significant challenge, particularly due to the lack of commercial expertise among academic and scientific founding members. As Deep Tech ventures are rooted in fundamentally new physics, mathematics and engineering fields, the founding teams are primarily composed of individuals with strong technical and scientific backgrounds, but limited experience in business development, marketing, and operations. Still, conveying commercial, on top of technical, credibility and viability is important (Dias & Condessa, 2022).

However, the lack of business acumen in ventures' founding teams is not endemic to Deep Tech. It has been found that founding teams operating in non-Deep Tech industries need a diverse set of competencies, such as entrepreneurial and managerial on top of their technical expertise to craft their strategy (Blank and Carmeli, 2021). For Deep Tech ventures to stay connected to real-life problems and succeed in finding solutions for them, collaborative efforts, particularly between academia and industry, are essential to ensure that Deep Tech

[12] CT_Ed2
[13] UL_Ex4
[14] TUD_Ex2

innovations remain viable and can be scaled effectively[15], not only in terms of developing the technologies but also when it comes to talent and strengthening the founding teams.

Hindering Factors for Risk #2

"Many engineers view these fields [business and humanities] as less valuable, often considering them as lacking in meaning or rigour compared to technical subjects like mathematics. This mindset stems from the belief that business is simply about basic skills, like selling or quick learning, which undermines the depth and complexity of business knowledge".[16]

One of the biggest challenges Deep Tech startups face is assembling a multidisciplinary team that balances technical and business expertise. At first it may not constitute a barrier and as an educator from Finland puts it "in Deep Tech you don't need a CMO right at the beginning"[17], however, including commercial skills early on in the process may allow the R&D to flow smoothly by pre-identifying potential commercial applications and market opportunities (BCG 2022; Dealroom 2023a). Additionally, the lacking business acumen in the Deep Tech ventures' founding teams may hinder the venture's navigation in the commercial landscape. This gap can lead to difficulties in defining market strategies, managing day-to-day operations, and scaling the business effectively. As Deep Tech ventures often require long and complex R&D cycles, this lack of experience can lead to missed opportunities or inefficient use of resources (Kask and Linton, 2023).

Furthermore, literature underscores that an entrepreneurial culture within research organisations focussing on Deep Tech is important to ensure research gets to be commercialised (Pacher & Glinik, 2023). As Dealroom et al. (2023a) mention, entrepreneurship is oftentimes not encouraged at universities, preferring to focus on academic publications rather than research commercialisation. An entrepreneurial mindset in Deep Tech raises the possibility that a startup will enter the market (Myers & Albats, 2024). A professor and startup coach from the United States[18] indicates that "Deep Tech teams should include both technical experts and individuals skilled in marketing and business development".

When it comes to team dynamics and establishing leadership, cohesion among the team members becomes a critical factor for the success of the startups. Founders must ensure the flow of information and alignment between the technical and business team members. As an expert from Slovenia points out "core team staying the same (complementary in competences, energy, motivation and personality traits) is crucial to avoid bottlenecks down the road"[4]. Concerning leadership, challenges may arise as startups evolve and founders are often required to wear many hats, sometimes realizing that they are not fit for a leadership role and stepping out for the sake of the venture. The importance of the leadership element, as well as the challenges that Deep Tech startup leaders need to face, is emphasised by experts and educators in the United States[19], Switzerland[20], France[7] and other corners of the world.

If we pay attention to markets that are inherently smaller than others, we observe that talent acquisition and retention becomes a struggle for many Deep Tech ventures. As mentioned, the unique nature of Deep Tech requires a combination of scientific expertise and business acumen but larger, more stable companies present themselves as more attractive to talent, making it more difficult for startup founders to assemble their teams. According to an incubator director in France[16], it is not easy for Deep Tech researchers to find co-founders and even assembling a team of people with the right skills can be an immense challenge. This is echoed by experts and educators in those smaller countries such as Ireland or Austria, who express that in some instances the process of

[15] IMT_Ed3
[16] UIIN_Ed2
[17] CT_Ed1
[18] AC_Ex2
[19] UIIN_Ex2
[20] UIIN_Ed2

assembling the right team can take three to seven years for the founders.[21, 22]

Lastly, it has been mentioned that the need for commercial profiles is not a must right at the start of the venture, but as the company grows and the product approaches final development stages, the emphasis is placed on commercial roles as the startup faces its entrance into the market. Failure in assembling the right team for the venture or being late in doing so, will inevitably lead to a stretched research and development process and more difficulties in creating a business model and market entry strategies.

Risk #3: Capital expenditure intensity risk and the lack of accessible funding

"Getting the money in the first place is hard, but getting a product to market before running out of cash is the hardest. The graveyard is littered with amazing technology that couldn't get out the gap because of a lack of funding at crunch points".[23]

Deep Tech ventures require significantly higher capital investments than standard tech startups, especially during the research and prototyping phases. These ventures typically demand advanced equipment, specialised laboratories, and extensive validation processes, which make the journey to commercialisation both resource-intensive and prolonged, as discussed in Risk #1. On this risk, the European Investment Bank (2018) states that Deep Tech solutions associated with key enabling technologies (i.e., micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics and advanced manufacturing; EC, 2018) are inherently capital-intensive, which necessitates substantial funding before a product can be fully developed and brought to market compared to standard, nonDeep Tech startups (Kruachottikul et al., 2023).

Elements such as infrastructure, skills and talent, as well as the research process itself, are resource-intensive in Deep Tech. Dealroom & Sifted (2021) mention that "early experimentation and prototyping often rely on "specific and costly equipment" that outside of Deep Tech would not be necessarily needed. Specifically, according to Dealroom et al., (2023b) Deep Tech startups take at least 48% more capital than traditional startups to obtain revenue levels superior to U.S.D 5 million, which means they need more capital to reach product-market fit (PMF). Literature findings are corroborated by interview findings, with experts pointing out that in the European Deep Tech sectors, "there is a lack of significant investment in infrastructure and development before products can be sold" on top of "a lack of money to form a team to spin out. For instance, a team would need a CTO nearly straight away. Universities and research institutes provide money for R&D, bust this funding can't be fully utilised unless there is follow up funding to form the team for commercialisation". [4, 24]

However, capital expenditure is not spread evenly throughout Europe, mirrored by the fact that institutions on both national and international levels are not well coordinated (BCG, 2022). In the words of an expert on the development and adoption of AI innovations from Finland, "market validation and proofs of concept are important, but they also require funding, creating a chicken-and-egg problem. Some concepts, like health tech, have obvious potential if funding is secured". [25] Indeed, demonstrating a "proof of concept" through customer interaction could be a relevant source of trust in the Deep Tech innovations' potential. This trust can, in turn, translate into valuable partnerships, such as having one or more customers ready to purchase the innovation, or letters of intent for partnerships, which can serve as indicators of potential market interest and collaborations, even in the absence of finalised sales agreements (Granath, 2021).

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[21] AC_Ex4
[22] MTU_Ex4
[23] MMS_Ex2
[24] MTU_Ex3
[25] CT_Ex3

Hindering Factors for Risk #3

"There is also no funding available specifically for high-risk projects that allow you to fail fast. The funding providers are not thinking far enough ahead and funding seems to only become available when something becomes popular".[1010]

High initial costs are the most immediate barrier. Deep Tech ventures face high capital expenditure needs and funding risks due to the significant financial commitment they require for their development, discouraging potential investors from engaging with them. These startups require high initial investments in order to cover the substantial costs for research facilities, equipment and talent (BCG, 2021a), and they often exhaust resources before reaching market readiness.

Moreover, Deep Tech relies on demonstrating tangible progress to stakeholders and hard data backing up the activities in order to secure funding, as traditional metrics are unable to capture the value of innovation (Romasanta et al., 2022). Thus, the reluctance of investors, and venture capitalists in particular, is further fuelled by the nature of Deep Tech minimum viable products, which are complex and costly to develop, making it more difficult to prove to investors that the concept works[26]. As pointed out by an expert in Ireland[27], "when startups are looking to move on to the next stage of development they find investors who are inherently averse to hardware, as they see risk". This aversion of investors who are used to the faster results of software-based solutions or don't want to deal with longer return-on-investment timelines hinders Deep Tech ventures and pushes them to alternative sources of funding and financial support.

Our research shows that public funding for Deep Tech ventures is, in general, lacking. An incubation and acceleration expert from the Netherlands[28] states that different funding strategies are required and public funding needs to be intensified, and followed by the introduction of commercial types of funding. In alignment to that, experts from Turkey[29] and France[30] indicate that public funding for startups is very low and is only accessible for startups seeking seed funding, respectively. Later-stage funding remains largely inaccessible compared to markets like the United States.

In addition, linked to funding, every Deep Tech field has different necessities and access to funding opportunities. For instance, data provided by Hello Tomorrow shows that the costs for developing a first prototype in blockchain amount to about U.S.D 200.000, whereas in biotech the costs are drastically different, amounting to circa U.S.D 1.3 million (BCG & Hello Tomorrow, 2019). This is summed up as part of a paradox in BCG (2021b) which portrays two contrasting trends in Deep Tech commercialisation. On one hand, barriers fall down in terms of costs: initial costs for research and development in Deep Tech are steep, but with time the curve flattens with the use of new platform technologies; and on the other hand, barriers rise for the entry of new investors: much of the large-capital investment "is bound up in the kind of sizeable legacy funds with solid reputations that are preferred by limited partners (LPs). It is therefore unavailable to Deep Tech ventures in their later rounds" (BCG; 2021b, p. 11). Having only a few different funds raising support for Deep Tech ventures may not be sufficient to provide tailored support to specific needs of specific Deep Technologies. Furthermore, among investors, risk aversion towards revolutionary technologies surrounded by uncertainty, and the associated high-risk investments is quite widespread, subsequently resulting in higher likelihood of under-investment, especially during later stages of funding (Raff et al., 2024; BCG, 2022).

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[26] UL_Ed8
[27] MMS_Ex3
[28] UIIN_Ed4
[29] Ege_Inc1-4
[30] IMT_Ex3

Risk #4: Navigating market-entry and product-market fit

"Despite efforts to foresee future developments, accurately predicting the trajectory of Deep Tech innovations remains challenging. The unique nature of these technologies means they often materialize in unexpected ways, making the commercialisation process distinctively complex".[31]

This next risk on market entry refers to the dynamics between demand and supply, and whether the Deep Tech innovation meets the market appetite and finds its place in it. In principle, the market entry and product-market fit of Deep Tech ventures increases significantly when it has been thoroughly tested and validated, and especially in the case of in the case of groundbreaking and complex technologies, where near-perfect functionality is needed upon market introduction (Kruachottikul et al., 2023). Since Deep Tech ventures work with highly innovative solutions, and as pointed out by Deep Tech entrepreneurs "solutions are often developed in response to specific customer problems, rather than starting with a technology and then trying to find a market for it"[32;33], there tends to be a lack of comparable products in the market. This means that once Deep Tech solutions have been validated, they have the potential to occupy a large part of the market or even create a brand-new market for themselves (Dealroom et al., 2023b).

As a consequence, the market risk of Deep Tech ventures shares elements of all other types of risk (e.g., will the technology succeed and make it to the market, will venture capital support the development of product-market fit will competition get to market before, etc.). In theory, market entrance risk is lower for Deep Tech ventures, due to the absence of copycats. However, in reality, "the deeper the technology, the more uncertainty it carries regarding its future applications and market-fit"[31], which often leads to Deep Tech products not being market-fit, so they need some further adjustment, which is rarely the case for standard tech products. Moreover, this high level of capital intensity poses a barrier to market entry for Deep Tech ventures (Kolev et al., 2022, as seen in MIT, 2023), which is not often the case for traditional tech startups trying to take their products to the market. For instance, drawing from an interviewee's experience with licencing a Deep Tech innovation in the field of space technology, "the traditional academic model of licensing for future royalties was not feasible due to the high risk and long development time frame involved. Instead, their team opted to sell the technology upfront for an immediate and discounted return, an approach necessary given the uncertainty of the tech's market fit"[5]. This issue worsens in the case of certain Deep Tech fields such as health or raw materials, where regulation tends to be more restrictive, as demonstrating a certified, functional and complying prototype is crucial to secure funding[4].

Hindering Factors for Risk #4

A significant number of startups fail to successfully enter the market, due to insufficient market research, which is crucial for understanding customer needs, validating business concepts, and developing effective strategies. More specifically, a number of reasons can hinder a Deep Tech venture's ability to create a product-market fit, including directly engaging with potential customers, understand their needs and use communication and marketing strategies to best highlight the way in which their product addresses these needs (Sharma and Luhar, 2023).

One of the first challenges that Deep Tech startups face when entering the market is due to the novel nature of their technologies, as many markets are not yet prepared for such innovations. As an expert from Slovenia explains, "the market is not (yet) developed; it must be prepared for new solutions, and companies do not like to change their core processes"[4], this also holds true from a customer perspective in many instances. To make things more difficult for Deep Tech ventures, timing is a critical success factor. As we have discussed in previous lines, the commercialisation process is typically slow, with long development cycles delaying the time to market.

[31] CT_Ex4
[32] IMT_Ex4
[33] MMS_Ex4

Startups need to be careful when choosing to enter the market to avoid going in too early, before the market is ready, or too late, when their technology becomes outdated or mainstream.

When it comes to developing a proof of concept or a minimum viable product, Deep Tech presents its own set of challenges. While in other sectors, or more specifically in standard software as a service companies, a minimum viable product can be quickly developed and tested, Deep Tech prototypes, heavily based on hardware, often take years to build. Our conversations with experts and educators that, for Deep Tech ventures, has shown a discrepancy in the perception of the concept of minimum viable product for Deep Tech. On one hand, it provides tangible evidence for potential investors and increases the likelihood of securing greater funding. Testing the product early on also allows for valuable customer feedback, which not only enhances the technology but also helps build trust with the target market [31, 39, 42, 62, 73]. On the other hand, however, the actual development of a minimum viable product is much harder or, in some cases, even impossible [27, 34, 35, 36], calling for greater focus on proof of concept (showing that the technology works) rather than focusing on customer interaction (Dahlander & Véricourt, 2024). This shows how knowledge around Deep Tech is still under development due to its novelty, not allowing for one-size-fits-all approach and ideas.

Lastly, another challenge that Deep Tech ventures face when entering the market is building trust with customers, as the technologies developed are often unfamiliar and complex to them. A startup CEO from France states that "building trust with customers is crucial for Deep Tech companies, as the technologies may be perceived as 'black boxes".[33] Linking to the previous point about heavily regulated sectors, obtaining certification is a way to gain trust and, although expensive and hard to get, it is the only way to succeed in those sectors. [37] In other sectors, engaging trusted advisors and industry experts can help validate the technology and increase credibility, according to a Deep Tech commercialisation expert from the United States. [20]

Risk #5: Deep Tech ventures have a strong competitive technological edge

"90% of Deep Tech projects never advance and potentially only 10% actually make it an acceleration stage. To support Deep Tech projects, you need to invest in a lot, to get a limited number that can go to market".[16]

In general, the literature points out a lower competition risk for Deep Tech ventures compared to traditional startups (EIT, 2023; Dealroom et al., 2023b). This is due to the strong technological edge that Deep Tech ventures have, which puts them in an easily defensible position against competitors. More specifically, when examining the effects of competition levels for highly technological startups, in highly competitive markets, it's hard for ventures to sustain market shares and profit margins, which are typically small. Such markets are typically characterised by a large number of rival firms and a low degree of differentiation. On the other hand, in markets where competition is low, startups have access to large market shares and a high-profit margin, making inter-market competition more challenging (Hashai and Markovich, 2017).

In comparison, non-Deep Tech and non-technology-based startups do not usually rely on the complexity and innovativeness of their products, but on network effects and slowly acquiring market share, including a panoply of complementary assets, brand recognition, and high reputation (Singh and Mitchell 2005). Therefore, to compete with established non-Deep Tech ventures, deep-tech startups can adopt two strategies for market-entry: (i) directly competing with established companies, or (2) collaborating with them by licensing their technological innovations or forming strategic alliances, to leverage the complementary assets of established firms (Hashai and Markovich, 2017).

[34] MMS_Ex1
[35] UL_Ed2
[36] UL_Ed4
[37] UL_Ex5

Hindering Factors for Risk #5

Competition risk in Deep Tech entails different challenges depending on the Deep Tech field. Thus, extremely popular topics such as artificial intelligence present different topics than other areas such as aerospace, for example. An expert on AI ecosystem development points out that "the technological risk is especially high in AI, where faster development by competitors can make years-long projects obsolete". [26]

On one hand, the fast pace of technological advancements in certain Deep Tech sectors presents a difficult challenge for Deep Tech startups, which, due to their long development cycles, risk being outpaced by competitors who can bring their solutions to market faster. This is especially true in ecosystems such as the United States, where "competitors can be very aggressive with their legal strategies to slow down rivals in the race to market"[18]. Litigation is a tool that startups have at their disposal and ventures in the United States seem to be aware of that and capitalise on it to safeguard their work and their positions. It is for that reason that a lack of IP management knowledge and skills can put a Deep Tech venture in a dire situation. However, as an innovation officer[38] from the Netherlands points out, the process of acquiring patents and navigating licensing requirements is complex and often overlooked by founders, leaving an opening for more prepared ventures to exploit those vulnerabilities.

The other side of the coin is that startups often have to deal with regulatory complexity, particularly at the intersection of multiple industries within Deep Tech. This can create barriers to market entry and increase compliance costs, as well as redirect resources that would have gone in R&D processes. This is valid especially when startups have to navigate various different national regulations for each field, which makes it more difficult for Europe to reach the scale of U.S. unified markets (BCG, 2022; EU tech Venture, 2023). Understanding industry-specific regulations is critical for Deep Tech ventures, particularly in those sectors that are heavily regulated such as biotech, medtech and AI. Founders need to become acquainted with regulatory pathways for clinical trials[10], product approvals, certifications and meeting international standards. Failure to navigate these complex environments can delay market entry and increase risk of venture failure.

Lastly, on the topic of competition, the size and characteristics of the ecosystem of origin of the Deep Tech venture plays a role in its ability to scale. In small countries like the Netherlands, the small physical space available for large production facilities makes it very challenging to scale up operations[39], which has an impact on making digital or software-based startups much more attractive than hardware-based ones. This holds true as well for countries like Finland and the Nordics, as due to their different societal and educational models struggle to internationalize their ventures, limiting their ability to scale in the global market. A different interpretation of this phenomenon could be that commercialisation models are not easily applicable to all countries and contexts, as has been pointed out by a founder and tech transfer specialist from Finland.[40]

4. Deep Tech Commercialisation: Drivers

"It's essential to approach Deep Tech on a European level to create impactful synergies. Accelerating IP transfer processes and embedding Deep Tech companies into a supportive ecosystem with corporates and investors can significantly enhance commercialization success". [22]

Deep Tech ecosystem

Collaboration networks between startups, academia, industry, and public institutions are significant when it comes to lowering the risk associated with prolonged R&D processes in Deep Tech (i.e., Risk #1). Similar ecosystems enable a successful commercialisation of Deep Technologies and without this web of actors, Deep

[38] TUD_Ex3
[39] TUD_Ex4
[40] CT_Ex2

Tech cannot thrive (McKinsey, 2024; BCG & Hello Tomorrow, 2021). As mentioned by Gachet (2024) and Nedayvoda et al. (n.d.), knowledge sharing and cross-sectoral collaboration help support Deep Tech ventures in their commercialisation efforts. Companies looking to commercialise their product would greatly benefit from a network of allies helping them in navigating regulatory landscapes and develop an effective strategy to reach customers (Gachet, 2024). However, BCG and Hello Tomorrow (2019) point out that such ecosystems are not fully established yet due to Deep Tech being an emerging and evolving topic. For instance, as it was repeatedly brought up by technologists and researchers through interviews, the start-up ecosystem of smaller European countries, "such as Slovenia, […] are not in a position to support groundbreaking Deep Tech solutions because there is no capital and no strong industry"[41] and hence "to overcome these market entrance barriers and to create conditions for customer acquisition, Deep Tech ventures need to join forces and operate through ecosystems."[42]

For Deep Tech ecosystems and networks of collaboration to be strengthened, European institutions can valorise their strong research ecosystem, providing fertile ground from which startups can flourish. Such robust academic foundations in Deep Tech foster collaborative research efforts, knowledge sharing and, ultimately, the development of breakthrough technologies (EU Tech Venture, 2023; Dealroom, 2023 a-b). Success stories illustrate how ecosystems significantly impact commercialisation efforts; one notable example is the Technical University of Munich (TUM) and its spinoff platform, UnternehmerTUM, which demonstrates successful technology commercialisation. UnternehmerTUM's network includes over 20,000 active members from companies, industry experts, scientists, and investors, providing comprehensive support for startups (UnternehmerTUM, n.d.b). This ecosystem is further enhanced by TUM Venture Labs and the TUM Entrepreneurship Research Institute, which focuses on Deep Tech and life sciences. The centralised knowledge and networking opportunities help Deep Tech founders secure funding, collaborations, and talent (UnternehmerTUM, n.d.a). However, the current ecosystem at TUM is only partially focused on Deep Tech, suggesting that developing similar ecosystems with aligned incentives among key players could enhance commercialisation success (European Innovation Council and SMEs Executive Agency, 2024).

For Deep Tech researchers and venture founders looking to connect and strengthen their Deep Tech network, an attorney expert in IP/IT management for Deep Tech ventures shared that it's important to understand that there is "no standard process":

"On the contrary, it is an iterative process, that requires a multidisciplinary approach, involving continuous learning and adaptation and it heavily depends on the level of expertise the ventures manage to hook into, whether from universities, professors, networks, professional advisors, or commercial parties".[43]

On the same topic, a professor of deep entrepreneurship had a similar reflection:

"Generally, the process begins with realising that the initial idea is just the starting point. Entrepreneurs need to involve people who can handle development, market fit, customer fit, financing, and legal aspects. Many academics quickly realise that starting a business is more challenging than anticipated, leading to founder problems within the first year. To tackle these issues, exposure to experienced professionals, such as mentors with market knowledge and IP lawyers who guide on intellectual property strategies is vital. Additionally, events where scientists can connect with others facing similar challenges are highly valued".[44]

[41] UL_Ex7
[42] CT_Ex1
[43] TUD_Ex2
[44] UIIN_Ex1

Governmental policies & funding schemes supporting Deep Tech commercialisation

"European startups need to shift from a reliance on government support to a more proactive approach in seeking funding and partnerships. Building a larger, more connected ecosystem and fostering a culture of proactive engagement can help bridge the gap in commercialisation success".[19]

The current state of funding for Deep Tech ventures in Europe faces several challenges, but there are potential factors that can enable its improvement. Deep Tech startups often struggle to transition from grant funding to equity capital, despite increasing overall investments. To address this funding gap, collaboration between governments and private investors can facilitate the flow of both public and private investments, enabling the creation and scaling of deep-tech ventures (Romme et al., 2023).

Public funding

A major institutional and structural support mechanism that can be crucial in the development of a Deep Tech startup ecosystem is the alleviation of Deep Tech ventures' funding needs (i.e., Risk #4), particularly regarding incentivising the provision of funding and investment. University teams primarily receive their funding from the government to the degree that "if government funding priorities change, and [a specific Deep Tech technology] is no longer a priority, funding could end completely", as reflected by board members in a university's entrepreneurship society.[3] "While there are strategic funding avenues ostensibly addressing this," as remarked by a tech transfer manager in Finland, the real impact is often diluted because "those in charge lack a comprehensive understanding of research commercialisation, tech transfer, IP, startups, and venture capital".[34] Similarly, a CEO of a deep venture shared that "the available subsidies for salaries, while helpful, come with many strings attached adding to the complexity of submitting applications, and can also distract from the primary goal of commercialisation".[16] Reevaluating existing funding policies can help address this disconnect between policy and support for Deep Tech funding. To foster an ecosystem where Deep Tech can thrive, large-scale funding programs for scaling up are essential, as this type of funding is often challenging to secure within different national venture capital ecosystems. [5, 19]

VC funding

When it comes to VC funding, there is a financial gap in Europe between series B+ startups and above (Dealroom et al., 2023b; EU Tech Venture, 2023), and investments in Deep Tech venture capital are lacking in the post-seed stage of a startup. Looking at other global powers, we observe that almost 50% of investment in the U.S. and Asia goes to ventures in the late stages of development. Overall, investments in Deep Tech startups in Europe amount to one third of the total amount in the U.S. (Dealroom et al., 2023b). Addressing this issue in Europe would allow for a stronger Deep Tech ecosystem, with increased access to capital that supports not only venture creation but scaling and sustainability. For example, interviewees highlighted a few instances of VC funding across Europe. When it comes to the French context, VC funding happens in pre-seed, seed and series A, but not in series B, which is dominated by U.S. companies. This pattern of capital acquisition should be critically examined, as French-funded ventures are often acquired by U.S. firms, leading to a reduction in the shares held by French individuals and organisations, with the financial benefits largely flowing to the U.S.. Moreover, France lacks corporate venturing models, such as the 'venture client' approach employed by BMW's Startup Garage, which could offer more sustainable pathways for startup growth within the country".[45] In Turkey, for example, interviewees reflected that "government grants are very low for Deep Tech startups and currently VCs are not willing to invest in high-risk projects"[26], while in Slovenia VC funding opportunities are "on the rise (Angel, VC capital), and there is also the

[45] IMT_Ed1

newly established Vesna Fund, supporting also low TRL technologies from public research organisations".[46]

Knowledge transfer policies & IP management of Deep Tech innovations

"IP is crucial for capturing the value of innovations. It gives startups a seat at the table and helps protect their creative and intellectual work, ensuring they can capitalise on their inventions". [12, 84]

Intellectual property (IP) management in Deep Tech sectors in Europe involves various strategies and challenges. Current IP management of publicly developed Deep Tech innovations is conducted by the European Patent Office (EPO), which assesses the technological novelty and inventiveness of Deep Tech projects, reducing costs and streamlining procedures for patent owners, especially benefiting European Deep Tech ventures (European Innovation Council and SMEs Executive Agency, 2024).

There are many examples in recent literature of how regulation can simultaneously act as a facilitating or a hindering factor to the commercialisation of Deep Tech (Dealroom et al., 2023b; EU Tech Venture, 2023; BCG, 2021a). On one hand, regulations can support and favour a policy environment that fosters innovation and protects IP. This is especially valid considering legal and market frameworks to encourage innovation that avoids imposing burdensome requirements on startups and businesses (Dealroom et al., 2023b). In that respect, EU Tech Venture (2023) highlights France as a country where favourable regulations that encourage innovation and R&D spending around Deep Tech are present. Hearing from Deep Tech specialist interviewees from universities and NGOs in France, "even though a lot has been done over the last few years [in terms of Deep Tech-supporting policies] an entrepreneurial friendly legal framework is still pending, for cutting-edge Deep Tech technologies to overcome slow and bureaucratic regulatory tech transfer processes".[47]

As highlighted by various tech transfer experts in our interviews, universities play a crucial role in Deep Tech commercialisation by managing and implementing effective knowledge transfer policies resulting from publicly-funded research, while being explicit on the commercial use of such research outputs. Forming dedicated committees with representatives from research, legal, and business departments to draft comprehensive IP policies is essential to align with evolving Deep Tech landscapes and market needs [4, 12].

Interviewees with expertise in pitch coaching, venture capital raising, and Deep Tech research emphasised that Deep Tech founders and researchers should "talk to patent attorneys and litigators early on. They need to know how to protect their IP and fight their battles. It's not just about getting a patent; it's about making sure that a patent can stand up to challenges. We give them the tools to defend their IP because competitors will try to slow them down in any way they can".[8] Our analysis detected that, a correct IP management ensures the survival of a Deep Tech startup against the, sometimes, unfair competition; "you can't expose your technology before you've patented it. Shady team members can also be a problem. You really need to know who you're working with. We check backgrounds, criminal records, everything. The core team is crucial; you need to know who you can trust".[2] As "the amount of resources needed for good IP protection at the global level is underestimated, universities with fewer resources face significant challenges, as their constrained budgets leave them in precarious positions. Without support from initiatives such as ERC PoC and EIT Raw Materials funding, the pursuit of patents would, in many cases, be unfeasible".[42] There is a shared feeling that "it's essential to approach Deep Tech on a European level to create impactful synergies"[22], to facilitate international cooperation inside the European continent.

[46] UL_Ex8
[47] IMT_Ex2

5. Knowledge, Skills and Attitudes for Deep Tech Commercialisation

Competencies for founding teams of Deep Tech ventures

"Encouraging researchers to engage in commercialisation, despite the high likelihood of failure, is essential. This involves cultivating a culture where failure is seen as a learning opportunity rather than a setback".[32]

We interviewed a variety of professionals with expertise in Deep Tech ventures and start-up coaching to understand the challenges of commercialising Deep Tech innovations. From these interviews, three main categories of skills and competencies emerged as essential for founding teams to have in balance: (i) technical, (ii) entrepreneurial, and (iii) transversal competencies.

Firstly, teams should possess **technical knowledge, skills, and attitudes** (hereafter referred to as "competencies"), which encompass a deep understanding of science and technology. These competencies typically come naturally to the founding teams of Deep Tech ventures, as they are often deeply rooted in scientific research (De la Tour et al., 2017). Nonetheless, as start-ups grow, new hires should have a solid technical foundation, to best innovate and bring the startup's ideas to market. Technical competencies encompass a deep understanding of domain-specific expertise, advanced technologies, and the ability to work across various disciplines to drive innovation. In sectors such as artificial intelligence, data analytics, and neural networks, business-focused startups need to stay ahead of technological advancements to develop competitive and scalable solutions. As for the team members heavily involved in R&D, interdisciplinary awareness enables the integration of knowledge from different fields to create more comprehensive and impactful solutions [4, 12, 19, 20, 21, 28, 36, 31, 48, 49, 50, 51, 52].

Entrepreneurial competencies are also critical to the success of commercialisation processes. In the initial phases of venturing, the Deep Tech founding teams should go beyond technical expertise and embrace a comprehensive understanding of business dynamics, market demands, and financial management to achieve sustained growth. In regions in countries like Slovenia and Finland, technical founders often face challenges in bridging the gap between their technological knowledge and business acumen. Developing these entrepreneurial skills or hiring new talent specialised in the business development is crucial for navigating market entry, scaling the business, and ensuring long-term success. A strong entrepreneurial mindset, characterised by adaptability, resilience, and a willingness to embrace risk, is equally important; this mindset empowers entrepreneurs to handle the uncertainties of commercialisation, learn from failures, and push their ventures forward. Additionally, competency in regulatory matters and IP management is vital, particularly in highly regulated sectors such as artificial intelligence, biotech and medtech. [2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 15, 18, 19, 20, 21, 23, 24, 28, 25, 26, 27, 30, 31, 33, 34, 35, 36, 38, 41, 42, 44, 45, 47, 48, 49, 50, 51, 52, 54, 55, 56, 57, 58, 59, 60, 61, 63, 64]

Lastly, **transversal competencies** transcend specific industries or technical expertise and equip individuals with the ability to navigate complex and multidisciplinary environments. For founding teams, these skills are vital in translating technical innovations into commercially viable products by ensuring seamless cooperation. Effective communication, teamwork, emotional intelligence and networking are a few of the most essential transversal skills required in this process. By mastering these areas, innovators can more effectively present their ideas, collaborate across disciplines, and build meaningful relationships that foster long-term success. [3, 4, 13, 15, 16, 18, 19, 20,

[48] UL_Ex3
[49] IMT_Ex3
[50] AC_Ed1
[51] AC_Ed2
[52] AC_Ex3

21, 22, 24, 25, 27, 29, 30, 31, 32, 43, 18, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65

To successfully commercialise Deep Tech innovations, the founding teams need a balanced combination of technical expertise, transversal skills, and an entrepreneurial mindset. These key competency categories, including domain-specific knowledge, market understanding, networking, and regulatory knowledge, form the foundation of the competencies required to bring Deep Tech innovations to market.

Competencies for Deep Tech educators and incubation specialists

"While events can be organised, direct support is challenging without qualified personnel. Without a strong funnel from pre-incubation and incubation stages, effective acceleration becomes difficult or not viable".[37]

To effectively support Deep Tech innovations through each stage of commercialisation, educators and incubation specialists must possess a diverse set of competencies to be able to support and guide the founding teams. Based on our analysis, these competencies can be summarised as: (i) technical, (ii) entrepreneurial and (iii) transversal competencies.

Experiential knowledge of commercialisation's challenges

Firstly, it's important for teams supporting Deep Tech commercialisation to include specialists with **experiential knowledge**, as opposed to a priori knowledge, and understanding of the advanced technological and scientific principles behind the innovations. These professionals, who have successfully launched their own Deep Tech ventures bring valuable insights into the challenges of commercialisation spurring from direct experience. Many incubation centres collaborate with external mentors, such as entrepreneurs, former startup founders, and investors, who bring real-world experience and help instil an entrepreneurial mindset in the founding teams through hands-on guidance. Tech incubators typically have people with singular viewpoints without an entrepreneurial background, therefore experienced mentors provide a **plurality of perspectives** to the founding teams, who can implement the insights that are most beneficial to them. Moreover, several of our interviewees point out that founders tend to show higher interest and respect for the lessons and support when they come from experienced professionals[8, 16, 44]. Finally, the supporting specialists who know the science inside-out help the founding teams, ensuring staff stays up to date with the latest trends and technical developments [8, 30, 66, 67, 68, 69,

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[53] UL_Ex2
[54] UL_Ed7
[55] IMT_Ed2
[56] IMT_Ed4
[57] UIN_Ed2
[58] UIN_Ex2
[59] AC_Ex1
[60] AC_Ex2
[61] MMS_Ed1
[62] MMS_Ex2
[63] MTU_Ed1
[64] MTU_Ex1
[65] TUD_Ed3
[66] UL_Ed5
[67] CT_Ed1
[68] CT_Ed3
[69] EGE_Ed1-4

[70, 71, 72, 73].

Ecosystem engagement competencies

It is important for Deep Tech commercialisation support teams to employ staff who are closely connected to, but most importantly who can leverage the Deep Tech ecosystem. It became apparent through interviews that a key aspect of supporting these founding teams is being able to **connect the founders with the right experts** based on their needs at each stage of the process. Such experts include financial coaches to help ventures with negotiations and the financial turnover of Deep Tech products; legal coaches to guide through IP management and regulation, and business development coaches to help with pitching their ideas and playing the startup game, among others. For support staff to fully understand the startup game and to connect the ventures with the experts they need, they must possess strong market assessment abilities, as well as a deep understanding of the unique challenges that lie in each stage of the Deep Tech commercialisation cycle. Moreover, it is also important for support staff to have **industry-specific knowledge** (though not as deep as the aforementioned domain-specialised mentors) related to the type of tech they are supporting. Vertical specialization within the staff makes sense, as it allows them to provide more targeted and effective support [30, 31, 32, 33, 34, 74, 75, 76, 77, 78].

Thus, staff must have firsthand entrepreneurial experience, or know where to find the necessary knowledge, and a strong understanding of business strategies, financial management, and legal issues. Their experience in navigating the challenges of running or supporting a startup enables them to guide Deep Tech entrepreneurs through complex market conditions and strategic decisions, as well as through the ecosystem itself. Naturally, entrepreneurial experience in a specific Deep Tech startup's field is difficult to source, given the emerging nature of the topic [30, 31, 32, 33, 34, 79, 80, 81, 82, 83].

Interpersonal and mentorship competencies

Lastly, successful commercialisation requires a combination of strategic thinking, a deep understanding of the technological landscape and a keen awareness of market dynamics. Equally important is the role of educators and mentors, who need to be empathetic and bring emotional intelligence, as well as a genuine understanding of the experience of the founding teams. The teams that support commercialisation efforts must excel at interpersonal competencies, ensuring there is open communication, asking the right questions and being ready to offer help. This entails an ongoing engagement between the support staff and the founding teams, and it allows staff to not only provide support, but also to ensure that the startups are aligning with market needs, validating product-market fit and planning for sustainable growth in the long term.

"Mentors need to understand the startup game, not just the corporate or scientific side. We need global players, people who understand how to scale startups internationally. You can't just offer

[70] UL_Ed5
[71] CT_Ed1
[72] CT_Ed3
[73] EGE_Ed1-4
[74] MMS_Ed4
[75] MTU_Ed2
[76] TUD_Ed2
[82] TUD_Ex3
[78] TUD_Ed4
[79] MMS_Ed4
[80] MTU_Ed2
[81] TUD_Ed2
[82] TUD_Ex3
[83] TUD_Ed4

corporate advice—you need to understand the unique challenges of scaling a Deep Tech startup".[5]

Given the fast-evolving nature of Deep Tech, adaptability and commitment to continuous learning are crucial, enabling support staff to stay at the forefront of emerging technologies and changing market trends. Moreover, personalised 1-to-1 mentorship is essential, as each startup faces its own unique set of challenges and requires tailored guidance. By offering clear communication and empathetic support, support staff can empower founders to make informed decisions, manage obstacles and navigate the complex landscape ahead [30, 31, 84, 32, 33, 34, 36, 37, 39].

6. Implications For and Improvements Of Commercialisation Services

"Improving Deep Tech incubation services requires stronger industry ties for mentorship, market insights, and customer access, along with enhanced business training and funding opportunities. Additionally, fostering a robust support network, integrating advanced technological resources, and maintaining a feedback loop with alumni and industry experts will ensure the program's ongoing relevance and effectiveness".[32]

There is a strong need for the improvement of the current commercialisation services in order to address the aforementioned challenges and competency gaps. Support services provided to researchers and entrepreneurs, at any stage of the commercialisation process, are diverse - from offering broad-based mentoring, to accessing funding, and making infrastructures for research and development available.

On a European level there is widespread consensus that commercialisation services need to be more structured, comprehensive, and connected across universities, industries, public research organisations, as well as incubators and accelerators. A recurring theme is the disconnect between academic programs and the specific needs of commercialisation. Courses offered by universities, although available, often go unutilised due to institutional politics, lack of collaboration across departments, or show an absence of alignment with industry needs. For example, faculties may prioritise local courses, with the risk of disincentivising an international mindset and missing out on wider opportunities. Naturally, each country has specific challenges they face, for instance, Slovenia struggles with limited resources and competition from foreign markets; Ireland faces regional disparities in support; and Finland needs to combine the strengths of research universities and universities of applied sciences to create a more holistic support system for startups.

Areas of improvement at each commercialisation stage are detailed in the section and table 3 below:

[84] AC_Ed3

Table 3

Areas of improvement at each commercialisation stage

Stage	Area of improvement	Description
Pre-incubation	Early-stage validation of technologies	Startups at this stage tend to lack adequate commercial awareness. Improvements in pre-incubation should focus on financial viability and market orientation
	Training in entrepreneurship	There is a significant need for training programs that emphasise market understanding and entrepreneurial mindset and skills development for researchers
	Triple helix collaboration	Collaboration between academic institutions, industry and government is essential to bridge the gap between research and commercialisation
	Financial frameworks	There is a need for more robust financial frameworks to help startups bridge the gap between ideation and commercialisation to reach an early idea validation
	Team diversity	Ensuring the creation of diverse core team that combine scientific expertise with business acumen is essential
Incubation	Advanced, targeted training	Training in technology, business scaling, cash flow management and customer acquisition for researchers and founders is critical
	Mentorship programs	Startups transitioning from research-focused ventures to market-ready businesses require structured mentorship and strategic business development with mentors who have the appropriate experience in Deep Tech commercialisation and are fairly compensated for their mentoring
	Legal support	Facilitate navigating the bureaucracy and ecosystem linked to funding opportunities, tailored to the specific needs of ventures in different fields.
Acceleration	Enhanced internationalisation support	Startups can struggle to access the resources and connections needed for global market entry and need support such as better access to international talent and market-entry resources
	Specialised coaching	There is a growing demand for specialised coaching in areas such as financial management, intellectual property, business development, as well as for CEOs.
	Tailored acceleration support	Startups in highly specialised sectors like Deep Tech face unique regulatory and market-specific demands that are not met by generalised accelerator models and require more customised acceleration support

Note. Authors' own elaboration

Pre-Incubation Services

Ensuring that enough opportunities for networking and better understanding of (i) the technology, (ii) the industry and (iii) the commercialisation rollercoaster are crucial. From our research, we have seen examples such as networking events and university initiatives like the "Rector's Award" in Slovenia that can help researchers pitch ideas and gain confidence during this initial stage of the commercialisation process. Interviewees from countries such as Turkey and Finland report challenges in finding experienced business developers to support these early-stage ventures. Countries like Turkey, as well as Austria and the Netherlands appear to be struggling with a lack of access to necessary research facilities and technical staff during this stage. Financial backing for early-stage startups remains insufficient, particularly in regions like Slovenia, where government programs limit the resources available. Moreover, also needed at this stage is the development of strategies to assess the viability of a specific technology before its development, as both research and market have to influence each other to a certain degree for Deep Tech to be successfully commercialised.

Incubation Services

Respondents from Slovenia, Finland and Austria highlighted the importance of incubation programs being tailored to specific industries, such as biotech and medtech, and providing continuous support through product development, ensuring the avoidance of the valley of death (Romme et al., 2023). Moreover, "incubators should emphasise objective-driven activities such as workshops on securing funding or creating product requirements"[39], as at this stage it is believed that more action-oriented approaches are required.

Startups also face broader ecosystem hurdles, particularly in securing VC funding and navigating regulatory environments. This is visible in the French venture capital ecosystem, where startups often encounter difficulties at later funding stages, which pushes successful ventures towards acquisition by U.S.. firms. These obstacles complicate the journey from incubation to market readiness, underscoring the importance of comprehensive business support alongside technological innovation.

Limited institutional capacity is another highlighted challenge, as insufficient available resources, including limited staffing and access to infrastructures, constrain the ability of incubators to effectively support the growing number of Deep Tech startups.

Acceleration Services

Several countries, including Slovenia and Ireland, recognise the need for stronger acceleration programs that provide structured support for startups entering international markets. In some cases, acceleration programs are limited by a lack of industry-specific knowledge, while programs like the DeepTech Alliance and YES!Delft's Acceleration Program offer tailored support for startups to refine product-market fit and secure funding.

The acceleration stage of Deep Tech startups presents distinct challenges, including a lack of advanced financial support, scaling expertise, and access to international markets. Turkey and France face similar challenges due to the limited venture capital available in their ecosystems, depicting the general European current status quo, which makes international expansion more difficult.

Cultural change for Deep Tech Training Curricula

For the competencies our analysis has identified to be taught at institutions and achieve impact, a paradigm shift in institutions need to be fostered. To ensure that the development of entrepreneurial skills is possible among researchers and academics, a systemic change is needed that allows for, and incentivises researchers to commercialise their innovations, academics to engage externally and does so at an institutional level. Many researchers remain hesitant to engage in entrepreneurial activities, often opting for traditional academic paths due to the deeply ingrained traditional career advancement metrics for researchers and fear of failure. Although policies supporting entrepreneurship exist, particularly in regions like Slovenia and Finland, a general cultural ambition is lacking.

This cultural shift is crucial to integrate entrepreneurship into academic career frameworks. Currently, commercialisation is undervalued at many institutions, seen as a side activity rather than a core academic pursuit. Academics who venture into entrepreneurship often struggle to re-enter traditional academic circles, discouraging further engagement with externals or in commercialisation activities. Modifying career advancement metrics and rules to recognise entrepreneurial outputs, alongside traditional academic achievements, is essential to encourage more researchers and academics to pursue innovation. More specifically, academic systems still prioritise publications over commercialisation, actively disincentivising researchers and deterring them from engaging in entrepreneurship.

"There will always be a high percentage of researchers sitting on wonderful technologies and innovations that will never want to pursue an entrepreneurial path. Building those capabilities and that mindset is important, but at the same time we make other efforts e.g., in capacity-building initiatives, or pairing students with our researchers and perhaps they will take this research to market, but this is a difficult marriage to make work". [85]

One way to contribute to the cultural shift needed to foster this mindset is by offering targeted training opportunities. Institutions should design their training programs to address the unique challenges and demands of this emerging field, or turn to private institutes that could provide it for them (see Tecnet R2V in Austria). Training offerings should be able to encompass and respond to academics and entrepreneurs as well as students who are early in the educational process. They need to be able to cater to long-term needs of researchers who have already embarked in the research journey, as well as allow for fostering interest and awareness in younger students, who still have different career pathways ahead. In all cases, hands-on, practical learning is essential for all participants.

Considerations for the enhancement and tailoring of training are therefore twofold: process specific and field specific. On the one hand, offerings aimed at training researchers for the commercialisation process should address the uniqueness of Deep Tech; on the other hand, training should also factor in the differences linked to the specific Deep Tech field, as a startup in biotech may have different requirements than one in quantum computing.

Addressing the uniqueness of Deep Tech commercialisation processes would entail providing training opportunities on commercialisation strategies that focus on scaling, IP management, and navigating complex business environments, among other. Moreover, courses should provide guidance on accessing industry networks, which are crucial for building partnerships with stakeholders, securing testing environments, and engaging with regulatory bodies. Simultaneously, training consideration addressing the specific field of a Deep Tech venture are just as relevant as customised support services, such as specialised incubators for biotech and medtech, as they provide essential resources, including expert advice and access to industry-specific equipment. Programs should thus emphasise ecosystem engagement, encouraging startups to collaborate with industry partners and utilise networks for customer access, regulatory consultation and testing purposes in their respective fields.

Deep Tech process-specific considerations

"The curriculum must address the unique challenges and complexities associated with Deep Tech ventures, such as advanced technology development, IP management (especially regarding patents), and regulatory compliance. These topics require specialised knowledge that goes beyond traditional entrepreneurship education".[30]

Ecosystem engagement and real-world applications

[85] RT_Ex6

For Deep Tech startups, practical experience is essential. Curricula must focus on real-world applications, where participants can engage with practical case studies, hands-on workshops, and simulations of commercialisation-related challenges. Additionally, engaging with the broader ecosystem is vital, and programs should integrate opportunities for participants to collaborate with industry stakeholders, regulatory experts, as well as potential customers. By fostering direct engagement with the commercialisation ecosystem, participants are helped in understanding the potential real-world application of their technologies, giving them the tools to navigate commercialisation processes effectively. Through active participation in industry networks, startups are better positioned to commercialise their innovations.

Market-specificity

Given that many Deep Tech startups operate in highly regulated industries, it is essential for training programs to integrate regulatory and market-specific content to enable startups to gain the specialised knowledge required to bring their technologies to market. Founders must understand the underlying differences and requirements that commercialising Deep Tech has in respect to standard tech. Training programmes must ensure that starting entrepreneurs have the instruments to face upcoming challenges such as longer research and development cycles, the greater importance of IP management from the get-go, navigating fundraising schemes and early market orientation. Standardised programs fail to meet these needs, necessitating the creation of Deep Tech topic-specific curricula.

Customer orientation

One of the most difficult aspects of Deep Tech entrepreneurship is teaching market analysis and customer discovery as startups often struggle to identify and validate customer needs. Programs must focus on equipping entrepreneurs with the skills to independently assess market demand and customer requirements. This ensures that startups can make data-driven decisions about product development and market entry, avoiding costly assumptions.

Field specific considerations

"Programs must be tailored to be highly specific to each industry, such as biotech and quantum physics, ensuring startups receive relevant support".[51]

Industry specificity

Deep Tech training programs must be highly customised to address the distinct needs of various industries, including quantum physics, biotech, medtech and space tech. General Deep Tech training, crucial at early stages, may lack enough depth of field-specificity, thus risking not providing entrepreneurs with apt instruments in fields with very stringent requirements. requiring the creation of topic-specific curricula. Modules focusing on areas like regulatory processes for obtaining trials, product approvals and certifications, intellectual property, and market dynamics of specific fields are crucial for helping startups navigate complex commercialisation challenges.

Mentorship

Specialised mentorship is an essential element for successful Deep Tech commercialisation. Mentors with experience in both the technical and business aspects of Deep Tech can guide startups through commercialisation challenges and become even more relevant when they have direct experience in the field trainees are working in. These mentors help entrepreneurs avoid common mistakes by providing sector-specific advice on issues such as scaling, fundraising and market validation, among others. Moreover, mentorship programs should also focus on networking, connecting startups with industry leaders, investors, and potential customers, which is vital for their growth.

Engagement of external stakeholders in curricula design

Our analysis has highlighted that collaboration with external stakeholders—such as companies, industry mentors, and other ecosystem players—ensures that educational programs remain relevant and meet real-world needs. By incorporating regular input from industry steering committees and mentors, curricula can be updated to reflect evolving technologies, industry demands and market trends. This approach replaces generic topics with Deep Tech-specific modules, ensuring the content remains relevant to startups. These collaborations may also offer hands-on opportunities such as internships, joint research initiatives and practical projects. Additionally, as previously mentioned, industry experts contribute to networking opportunities, helping students and startups connect with mentors, investors and other key players in the Deep Tech ecosystem.

Conclusion

As this report has highlighted it is critical that the current European status quo around Deep Tech is enhanced. The traditional approaches to commercialising technology has to factor in the specific characteristics, and meet the consequent specific needs, that Deep Tech carries. From structural problems weakening the ecosystem of stakeholders and their interconnectedness, to a cultural shift boosting the entrepreneurship spirits of institutions, investors and researchers, more efforts can be made. A number of actions can be undertaken to fortify the commitment towards the strengthening of Deep Tech commercialisation. Training can be an effective to forge an entrepreneurial mindset both in individual researchers as in broader institutions. The European Union seems to be on the right path, efforts from the early 2000s show an increase in the willingness and support towards technological innovation and Deep Tech. Europe is well-positioned with all the key elements to craft a winning formula, it’s a matter of enhancing momentum and strive to ensure that elements come together and function in unison/work in synchrony on a cross-national scale.

Appendix

Table 4
Anonymised interviewees list

	Identifier	Role	Type of organisation	Country
Deep Tech experts	UL_Ex1	Technology Manager	Research institute	Slovenia
	UL_Ex2	Head of Knowledge transfer office	HEI	Slovenia
	UL_Ex3	Entrepreneurship coach	Secondary education institution	Slovenia
	UL_Ex4	Project manager	Research institute	Slovenia
	UL_Ex5	Professor on entrepreneurship & investor	HEI	Slovenia
	UL_Ex6	Head of the technology transfer office	HEI	Slovenia
	UL_Ex7	Technologist and researcher	Company	Slovenia
	UL_Ex8	Head of the technology transfer office	Research institute	Slovenia
	IMT_Ex1	Deep Tech project manager	Company	France
	IMT_Ex2	General manager on Deep Tech	NGO	France
	IMT_Ex3	Deep Tech industry expert	Governmental agency	France
	IMT_Ex4	Chief executive officer & entrepreneur on software development	Company	France
	UIN_Ex1	Assistant professor of Deep Tech commercialisation	HEI	Spain
	UIN_Ex2	Chief executive officer & entrepreneur in robotics	Company	U.S.
	UIN_Ex3	Head of research and product development	Company	Malaysia
	UIN_Ex4	Director of industry & partnership services	HEI	Canada
	AC_Ex1	Life science advisor	Company	Austria
	AC_Ex2	Professor & startup coach	HEI	U.S.
	AC_Ex3	Investment manager	Company	Austria
	AC_Ex4	Venturing partner	Governmental agency	Austria
	AC_Ex5	Investment manager	Company	Austria
	CT_Ex1	Chief Business Officer	Company	Finland
	CT_Ex2	Founder and researcher on tech transfer	Company	Finland
	CT_Ex3	AI Ecosystem Advisor	HEI	Finland
	CT_Ex4	Professor of AI and software engineering	HEI	Finland
	MMS_Ex1	Chief executive officer & entrepreneur in health technologies	Company	Ireland
	MMS_Ex2	Chief executive officer & entrepreneur in telecommunications	Company	Ireland
	MMS_Ex3	Co-founders of a space technology innovation	Company	Ireland
	MMS_Ex4	Startup co-founder and entrepreneur in robotics and AI	HEI	Ireland
	MTU_Ex1	Commercialisation specialist	HEI	Ireland

	MTU_Ex2	Commercialisation specialist	HEI	Ireland
	MTU_Ex3	Commercialisation specialist	Research institute	Ireland
	MTU_Ex4	Chief executive officer	Company	Ireland
	TUD_Ex1	Director of technology transfer of biophysics and pharmaceuticals	Research institute	The Netherlands
	TUD_Ex2	Lawyer on IP/IT & Lecturer	Company and HEI	The Netherlands
	TUD_Ex3	Innovation Officer	Governmental agency	The Netherlands
	TUD_Ex4	Director managing investments	Incubation centre	The Netherlands
	UIN_Ed2	Doctoral student on construction engineering	HEI	Switzerland
Educators	UL_Ed1	Professor of engineering	HEI	Slovenia
	UL_Ed2	Chief technologist	Company	Slovenia
	UL_Ed3	Program manager	Company	Slovenia
	UL_Ed6	Professor of biomedicine	HEI	Slovenia
	UL_Ed7	Professor of data science	HEI	Slovenia
	UL_Ed8	Consultant and startup coach	Company	Slovenia
	IMT_Ed4	Professor of entrepreneurship	HEI	France
	MTU_Ed3	Manager of student entrepreneurship and tech transfer	HEI	Ireland
	TUD_Ed3	Professor of entrepreneurship	HEI	The Netherlands
	MMS_Ed2	Head of Enterprise & Innovation	HEI	Ireland
	CT_Ed1	Pitch coach & venture partner	Company	Finland
	CT_Ed2	Board member in entrepreneurship societies	HEI	Finland
	EGE_Ed1-4	Consultant and startup coach	Company	Turkey
		Commercialisation specialist and service provider	Company	Turkey
		Program manager on entrepreneurship and incubator manager	HEI	Turkey
		Angel investor, coach and business developer	Company + Governmental organisation	Turkey
Incubation specialists	UL_Ed4	Innovation consultant	HEI	Slovenia
	UL_Ed5	Partner at a venture fund	Company	Slovenia
	IMT_Ed1	Incubation specialist	Incubation centre	France
	IMT_Ed2	Innovation ecosystem coordinator	Company	France
	IMT_Ed3	Director	Incubation centre	France
	UIN_Ed1	Deep Tech startup coach	Governmental agency & U.S.	U.S.
	UIN_Ed3	Chief executive officer	Incubation centre	Italy
	UIN_Ed4	Co-founder and director of a Deep Tech company	Company	The Netherlands
	AC_Ed1	Head of Innovation	Austria	Austria
	AC_Ed2	Founding advisor on IP management	HEI	Austria
	AC_Ed3	Project Manager on Deep Tech incubation	Company	Austria

	MTU_Ed1	Enterprise Programmes Manager	Company	Ireland
	MTU_Ed2	Incubation Centre Manager & Start-Up Mentor	Incubation centre	Ireland
	TUD_Ed1	Professor at strategic management and entrepreneurship	HEI	The Netherlands
	TUD_Ed2	Incubation lead at a manufacturing plant	HEI	The Netherlands
	TUD_Ed4	Director managing incubation	Incubation centre	The Netherlands
	MMS_Ed1	Chief executive officer & entrepreneur in marketing communications	Company	Ireland
	MMS_Ed3	Head of Ventures at a Deep Tech	Research institute	Ireland
	MMS_Ed4	Incubation staff for manufacturing and pharmaceuticals	Research institute	Ireland
	CT_Ed3	Head of Incubation and acceleration	Research institute	Finland
	MTU_Ed1	Enterprise Programmes Manager	Company	Ireland
	MTU_Ed2	Incubation Centre Manager & Start-Up Mentor	Incubation centre	Ireland
	EGE_Inc1-4	Vice director of a Technopark	HEI	Turkey
		Incubator staff	HEI	Turkey
		Incubation Center Manager	HEI	Turkey
		General Manager of a Technopark	Company	Turkey

Note. Authors' own elaboration. *It includes a differentiation per role, type of organisation and country of origin, including 38 interviews with Deep Tech experts, 16 interviews with Deep Tech educators and 26 interviews with incubator staff experienced in the provision of training and support to Deep Tech ventures undergoing through pre-incubation, incubation and acceleration services.*

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