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From Building Block to Application: A Deep Tech Commercialization Framework

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Abstract: Deep Tech has already attracted a considerable amount of attention from the public sector and venture capitalists, with academia also demonstrating a rising interest in the concept. Scholarly literature has widely discussed the general challenges associated with the commercialization of Deep Technologies. However, there is a dearth of new practical solutions and only a few researchers have addressed the difficulties encountered in the technology transfer of Deep Tech. This paper seeks to explore the pertinent issue of innovation management in regards to the persistent difficulties experienced in the technology commercialization process, while drawing on the unique characteristics of Deep Tech. The fundamental premise of our framework is the new perspective on Deep Tech as a core technology respectively a main technology layer - we call it Building Block, which is capable of providing the basis for numerous multidisciplinary applications. With this approach, the commercialization of Deep Tech can be advanced.

Keywords: Deep Tech; technology transfer; technology commercialization; entrepreneurship; startup; conceptual paper

1 Introduction

In recent years, Deep Tech has already attracted a considerable amount of attention from the public sector and venture capitalists (European Innovation Council, 2020), with academia also demonstrating a rising interest in the concept. (Romasanta, Ahmadova, Wareham and Priego, 2022) There are various terms with similar traits to Deep Tech (e.g. emerging technologies) However, several publications have argued that Deep Tech is distinct from these existing terms due to its unique combination of characteristics, which

have a considerable impact on its transfer dynamics (Romasanta et al., 2022; Siegel and Krishnan, 2020; Kask and Linton, 2023)

DeepTech is rooted in novel scientific breakthroughs and resource-intensive (Romasanta et al., 2022; Portincaso and Soussan, 2019). Its complexity and an extended transfer process impedes the efficiency of transfer and necessitates the exploration of novel commercialization strategies. (Kask and Linton, 2023) Deep Tech is not merely an application-technology restricted to one particular purpose, but rather a fundamental enabling-technology Building-Block applicable to a variety of applications. Following this view, a new perspective on the transfer process and the possibilities of commercialization opens up. This paper aims to explain the concept and propose a new framework for commercializing Deep Tech.

Scholarly literature has widely discussed the general challenges associated with the commercialization of technologies. (Kaushik, Kumar, Luthra and Haleem, 2014; Hossinger, Chen and Werner, 2019) Despite this, there is a dearth of new practical solutions and only a few researchers have addressed the difficulties encountered in the commercialization of Deep Tech.

This paper seeks to explore the pertinent issue of innovation management in regards to the persistent difficulties experienced in the technology commercialization process, while drawing on the unique characteristics of Deep Tech. Consequently, the current paper endeavours to create an initial conceptual framework for Deep Tech-oriented commercialization guided by the following research questions:

> *What could a technology commercialization framework look like that takes into account the specifics of Deep Tech?*

In the following section, the underlying research design of this paper is described. Subsequently, the results from the analysis of current related work in the field of Deep Tech as well as technology transfer and commercialization are presented. Based on this, our conceptual framework for Deep Tech commercialization is developed. Subsequently, the framework will be analysed in detail and the results will be discussed and conclusions as well as implications will be presented.

2 Research Design

This conceptual paper is based on the “Model” research design as outlined by Jaakkola (Jaakkola, 2020). The design is used to formulate theoretical propositions which introduce novel constructs. To create these novel constructs, the identification and elucidation of relationships between pre-existing constructs is essential. For that purpose, a review of extant constructs and literature within the realm of Deep Tech and technology transfer as well as commercialization have been chosen.

Additionally, the findings will be supplemented by an analysis of successful technology transfer and commercialisation approaches from practice. To guarantee a high standard of quality, the discussion of this paper will consider Whetten's seven assessment questions for conceptual papers. (Whetten, 1989)

3 Related Work

In order to follow the research design this chapter comprises an analysis and discussion of the pre-existing constructs and literature in the field of Deep Tech and technology commercialization. As a result, this chapter is divided into two sections. Each section comprises definitions as well as discussions of relevant aspects (e.g. models, characteristics, barriers) to the development of our new Deep Tech commercialization framework.

Deep Tech - Definitions, peculiarities, models and current use-case
In academia, parallels between DeepTech and the terms "emerging technologies," "radical innovation," "disruptive innovation," and "HighTech" are discussed. (e.g. Romasanta et al., 2022; Siegel and Krishnan, 2020) However, the same studies highlight DeepTech's unique characteristics and their impact on the technology transfer. (Siegel and Krishnan, 2020) To gain a more comprehensive understanding of the term Deeptech and its characteristics and their impact on the technology commercialization, the origins and the current understanding of Deep Tech as well as further relevant studies are discussed.
The table below offers an extensive overview regarding the prevailing comprehension of DeepTech in the academic and business realms. It displays terms used to characterise or define DeepTech in several publications:

Author:	Romansanta et al.	Siegel & Krishnan	Portincaso & Soussan	De la Tour et al.	Chaturvedi
Year:	2022	2020	2019	2017	2015
Characteristics:	"Based on significant scientific or engineering advance"; "Requires understanding of interdependencies"; "Needs extended development"; "Underpins the applications that serve end users"; "Difficulty in measuring impacts"	"was impossible yesterday"; "barely feasible today"; "will quickly become so pervasive and impactful"; "difficult to remember life without"; "reimaginations of fundamental capabilities that are faithful to real and significant problems or opportunities, rather than to one discipline"	" can have a big impact"; "take a long time to reach market-ready maturity"; "require a significant amount of capital" "offer significant advances over technologies currently in use"; "Many of these technologies address big societal and environmental challenges"; "technologies have the power to create their own markets or disrupt existing industries."; "hard to reproduce or well protected, so they often have a valuable competitive advantage or barrier to entry"	"Strong research base"; "Heavy industrialization process"; "large investments needed"; "Yet-to-be-defined commercial application:"	"founded on a scientific discovery or meaningful engineering innovation";"built on tangible scientific discoveries or engineering innovations"; "trying to solve big issues that really affect the world around them"; "struggle to find initial funding because of their complex nature"

Table 1 Terms used to characterise or define DeepTech in several publications

Romasanta, Chaturvedi and De la Tour concur that the inception of DeepTech innovation is rooted in either the sciences or research. Moreover, the majority of literature indicates that DeepTech is tackling fundamental issues facing humanity, leading to a variety of far-reaching consequences. Such an endeavour necessitates substantial resources and a lengthy development period, as well as a high capital investment. (Romasanta et al.,

2022) (Chaturvedi, 2015) (Siegel and Krishnan, 2020) (Portincaso and Soussan, 2019) (De la Tour et al., 2017)

Despite the groundbreaking nature and potential of Deep Tech, the exact commercial applications of the core technology are usually not immediately evident. (De la Tour et al., 2017) Nevertheless, it is widely accepted that the core technology is capable of providing the basis for numerous multidisciplinary applications (Romansanta et al., 2022; Siegel and Krishnan, 2020) We refer to this core technology as a "Building Block," as it can serve as the foundation and platform for a variety of potential applications. Our findings suggest this Deep Tech specific characteristic being currently neglected in the academic and business realm.

Recent publications have provided several analysis of the commercialization process of Deep Tech, primarily within the context of entrepreneurship and startups (Schuh, Studerus and Hämmerle, 2022; Reisdorfer-Leite, Rudek and Junior, 2023; Dioniso, Junior, Morini and Carvalho, 2023; Kask and Linton, 2023). Furthermore, the importance of financing (Nedayvoda, Delavelle, So, Graf, and Taupin, 2021; Schuh and Hamm, 2022), collaboration with industry (Siota & Prats, 2022; Harlé, Soussan & La Tour, 2017) and the role of government (Schuh and Latz, 2022; Schuh, Latz and Lorenz, 2022) have been highlighted.

DeepTech startups can differ significantly from conventional startups in terms of their R&D focus and related requirements, leading to extended development phases with an unknown application of the technology at the outset. (Schuh, Studerus and Hämmerle, 2022; Reisdorfer-Leite, Rudek and Junior, 2023)

Research has indicated that Deep Tech is primarily distinguished by its strong emphasis on technology. This impedes the technology commercialization, as it necessitates more resources and a longer period of development. Additionally, we highlighted the so far widely neglected perspective on Deep Tech as a building block and its potential impact for the technology commercialization.

Barrieres in the Technology Commercialization

In order to gain an understanding of how to optimise the commercialization of Deep Tech, it is essential to analyse the barriers in the technology commercialization process. Initially, the concept itself as well as the most pertinent transfer medium for Deep Tech (Spinoffs) must be defined. Technology commercialization and technology transfer are frequently used synonymously. (Kirchberger and Pohl, 2016) However, the interpretation of these terms is contingent on the respective discipline and outlook. (Zhao and Reisemann, 1992) In this context, technology commercialization is construed as the process of transferring and developing science-based inventions from fundamental research to end-products on the market. Spinoffs are autonomous entities which transfer promising research results from a parent organisation (e.g. university or research institute) to the market. (Achleitner, 2018) Consequently, these organisations are strongly associated with academic entrepreneurship and play a significant role in the transfer of technology from science to application. (Pomffyová , Rostašová and Krajčík, 2020; Barth and Schlegelmilch, 2013)

A dearth of entrepreneurial competency and attitude has been frequently highlighted as a major barrier (Nsanzumuhire and Groot, 2020; Vohora, Wright and Lockett, 2004; Festel, 2012; Hossinger, Chen and Werner, 2019; Gbadegeshin et al., 2022; Müller-Wieland, Muschner and Schraudner, 2018). This is compounded by systemic barriers such as inadequate and inappropriate incentives for researchers to create spin-offs (Festel, 2012;

Hossinger, Chen and Werner, 2019; Gbadegeshin et al., 2022; Müller-Wieland, Muschner and Schraudner, 2018). Additionally, researchers are typically risk-averse when it comes to spin-offs. (Vohora, Wright and Lockett, 2004; Hossinger, Chen and Werner, 2019). Moreover, entrepreneurship is usually viewed as contradictory to academia and a lack of entrepreneurial culture in science is documented in several publications. (Nsanzumuhire & Groot, 2020; Hossinger, Chen and Werner, 2019) Moreover, the shortage of financial, human and infrastructural resources is a significant impediment to technology transfer (Nsanzumuhire and Groot, 2020; Vohora, Wright and Lockett, 2004; Festel, 2012; Hossinger, Chen and Werner, 2019; Gbadegeshin et al., 2022; Müller-Wieland, Muschner and Schraudner, 2018). The high risk associated with deep tech is a major cause of the lack of financial support (Portincaso, Gourevitch, De la Tour, Salzgeber and Hammoud, 2021), in addition to insufficient networking and conflicting cultures among stakeholders as well as insufficient public funding (Nsanzumuhire and Groot, 2020, Hossinger, Chen and Werner, 2019).

In conclusion, the literature reviews above revealed the following five main obstacles in terms of Deep Tech Commercialization:

When working with bulleted lists, use the following styles:

- Transfer reluctant academic (support) system
- Lack of entrepreneurial capabilities and attitude in academia
- Lack of financial support
- Extended development and resource requirement
- High degree of uncertainty and risk

4 Results

The main objective of this chapter is the derivation of a conceptual DeepTech commercialization framework based on findings of the previous chapter.

Derivation of the two-stage Deep Tech commercialization framework
Despite the potential of Deep Tech, the process of commercialising these technologies still remains a complex challenge especially for academic entrepreneurs. The conducted literature reviews have identified several main barriers, which will be primarily considered in the following development of the new conceptual commercialization framework.

The fundamental premise of our framework is the new perspective on Deep Tech as a core technology respectively a main technology layer - we call it Building Block, which is capable of providing the basis for numerous multidisciplinary applications, as described in section 3. We argue that this technology building block has basically been developed within a research project (e.g., a PhD dissertation), where all the scientific fundamentals were worked out and transferred via a technology-centric spinoff from a university or public research institute. Although technology-based spin-offs possess a high degree of technical proficiency, they often lack the skills necessary for successful technology commercialization, such as entrepreneurial capabilities, familiarity with industrial use-cases, and access to venture capital. However, we believe that this deficiency is not

necessary. The Deep Tech Building Block has the potential to be applied to a wide range of contexts, and industry-specific knowledge across various sectors is indispensable but difficult for technology-based research spin-offs to acquire. As a result, we can infer that the commercialization process for Deep Tech consists of two phases: a technology-focused development stage and an application-oriented stage. Academic entrepreneurs (AEs) are highly skilled in the development stage, but may lack expertise in the application stage. Therefore, we suggest separating the second stage from the AEs' responsibility. This can be done by transferring the final development steps and commercialization paths not only through spinoffs, but primarily through licensing to existing or newly founded companies.

The graph below illustrates our two-stage Deep Tech commercialization framework. The scientific fundamentals take place in a university or research institute environment. The building block would ideally be a separated spin-off entity. Applications are created by either deep tech-enabled companies (e.g. startups) or tools, such as features in existing products or other applications.

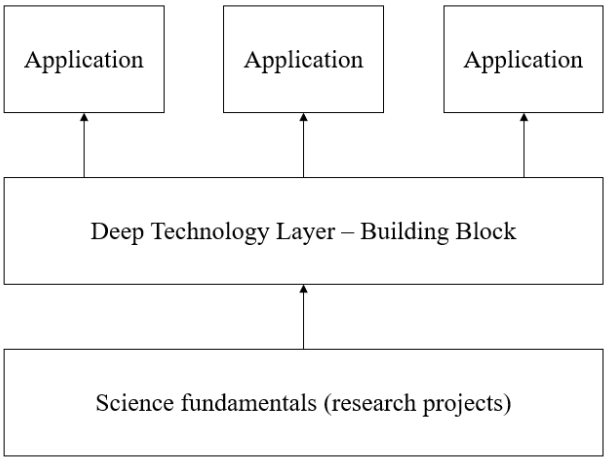

Figure 1 Framework for DeepTech commercialization

We argue that our framework has the potential to address four of the five identified main obstacles in terms of Deep Tech commercialization. Due to the “outsourcing” approach of the final development steps as well as the commercialization, researchers are enabled to focus rather on research than entrepreneurial challenges.

The division of the commercialization process into two stages holds various potentials. For example, it enables the AEs to focus more on their strengths in research and less on the commercialization aspects (product, business model, growth etc.). Also, the later-stage development times can be made much more effective and efficient due to the additional input and resources from a collaboration with those external more market-oriented parties (e.g. business entrepreneurs, venture capital). By considering a broader portfolio of applications, the risk of failure also decreases, since commercialization is not only tied to one stream but to multiple streams. This also increases the possible technology utilisation potential and allows the building block

spin-off entity to act as a kind of platform, which in turn can increase the interest of investors.

5 Discussion

Through analysis and discussion of pre-existing constructs and literature in the field of Deep Tech and technology commercialization, we derived a profound Deep Tech commercialization framework. This framework considers Deep Tech-specific peculiarities, such as the Building Block concept, as well as common barriers to Deep Tech and general technology commercialization.

Our proposed framework opens up the possibility of realising the long-awaited dream of more lab-to-market. It is not about turning scientists into entrepreneurs, but rather encouraging them to create a science-based spin-off (Deep Tech Spin-off). This fits better with their personal characteristics, and the connection to the university and research remains intact. In addition, research projects help to further develop the technology at its core. On the other hand, we see the possibility of allowing more market-to-lab to take place. Entrepreneurial talent from outside the scientific world, who are more focused on business, can build on an already developed technology layer (Building Block), and use it for a specific problem-solution fit in a specific market vertical. This can also be done in parallel in different market segments by different teams. This allows a Deep Tech Building Block to be commercialised in different directions at the same time.

Questions remain open about how exactly the connection and also the exploitation rights between the Building Block and applications can be designed. In addition, according to our investigations, there are investors who can imagine investing in a Building Block as well as only in applications if they include the Building Block or if there is some kind of exclusivity.

It remains to be seen to what extent our framework can be applied across the various categories of Deep Tech. For the more digital Deep Tech categories (e.g. AI, Blockchain), it seems to be viable, as the platform and middleware logic is already established here. Initial investigations show that the logic is also suitable for BioTech and Advanced Material areas. Above all, it can help to take pressure from the academic spin-offs (more scientists becoming entrepreneurs) while enabling diverse commercialization. This is particularly relevant as Deep Tech solutions primarily find application in the B2B sector, where individual markets and market segments differ significantly in their structure and functionality. At the same time, it is important to examine at which stage in the approach the ideal technology readiness level (TRL) should be present to ensure high exploitation and commercialization.

In a follow-up study, we are attempting to apply the model to OpenAI (Building Block) and the numerous AI tools (applications) built upon it. There are already indications that support our concept. For example, the application startup Jasper.ai, as a separate successful VC-backed startup company in the USA. Jasper.ai, however, primarily uses OpenAI or ChatGPT as its technology core, which is proven to represent a Deep Tech Building Block.

6 Conclusion

Deep Tech is increasingly being perceived at all levels (politics, science, economy) and is considered a relevant topic, particularly in Europe. The need to successfully commercialize excellent research is not new. However, existing approaches to technology commercialization are insufficient to meet the increasing pressure of disruptive technologies as a response and solution to urgent global problems. With our framework, we aim to:

1. Expansion of the well-known pipeline-oriented approach to technology transfer (Lab-to-Market) by adding a new component (Market-to-Lab)
2. Alleviate the pressure on scientists and universities to build the next unicorns in series
3. Enable more commercialization of outstanding technology and thereby secure prosperity for countries and regions,
4. Give smart business entrepreneurs a chance to use differentiating technology as a competitive advantage and create impact with their solutions.

If Europe succeeds in solving the knot of deep tech transfer and successfully commercialising more of the technologies that were previously extensively researched, we can respond to the major crises of the world for the next decades and play on par with the USA and China.

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