Journal of Organization Design (2023) 12:217–237
https://doi.org/10.1007/s41469-023-00144-y

RESEARCH

# Designing a deep-tech venture builder to address grand challenges and overcome the valley of death

A. Georges L. Romme[1] · John Bell[2] · Guus Frericks[3]

Received: 16 February 2022 / Accepted: 2 May 2023 / Published online: 10 May 2023


## Abstract

A vital problem of the European economy has long been its limited capacity to transform technological inventions and breakthroughs into successful new companies that help solve grand challenges in, for example, climate change, energy production, and poverty. Various measures and initiatives addressing this problem have not yet resulted in increasing numbers of successful ventures overcoming the so-called valley of death, especially in the case of deep-tech innovations arising from technological breakthroughs in, for example, new materials, mechatronics, high-precision engineering, and photonics. In this paper, we adopt a design perspective on crafting a Deep-Tech Venture (DTV) builder that creates, supports, and develops new ventures arising from deep-tech breakthroughs accomplished in leading research institutes in Europe. This approach to building DTVs incorporates key elements of extant theories and tools in the field of entrepreneurship but also moves beyond the contemporary body of knowledge. As such, the DTV approach provides a comprehensive system for creating and scaling deep-tech ventures—the most complex and risky, yet most impactful breed of ventures. The DTV blueprint was implemented and further developed in a venture builder that sources technologies from leading research institutes, such as CERN and European Space Agency. The initial results are highly promising. The main contribution of this study involves a comprehensive system design for building deep-tech ventures that help solve the SDGs, one that is (a) grounded in the literature on technology sourcing, entrepreneurship, ecosystems, entrepreneurial finance, and talent acquisition and (b) tested in a major European venture builder.

**Keywords** Venture creation · Deep-tech · Technological breakthroughs · Grand challenges · SDGs · System design · Startups · Entrepreneurship

## Abbreviations

| | |
|---|---|
| DS | Design science |
| CERN | Conseil Européen pour la Recherche Nucléaire (European Organization for Nuclear Research) |
| DTV | Deep-Tech Venture |
| ESA | European Space Agency |
| IP(R) | Intellectual Property (Rights) |
| SDG | Sustainable Development Goal |
| TNO | Nederlandse organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research) |
| TRL | Technology Readiness Level |

✉ A. Georges L. Romme
a.g.l.romme@tue.nl

John Bell
john@hightechxl.com

Guus Frericks
guus@deeptechxl.com

1 Eindhoven University of Technology, Eindhoven, Netherlands

2 HighTechXL, Eindhoven, Netherlands

3 DeepTechXL, Eindhoven, Netherlands

## Introduction

One of the greatest challenges in Europe has long been its (comparatively) limited capacity to transform scientific breakthroughs and technological achievements into successful ventures and companies (European Commission 2008; Klofsten and Jones-Evans 2000). There is an abundance of scientific breakthroughs and innovations developed by European universities and research institutes, but many of them never get applied to societal solutions (Dealroom 2023; EARTO 2015). This limited capacity implies that Europe continues to lag behind in developing technological solutions for sustainable development goals (SDGs) in the area of climate change, energy production, poverty, health, hunger, and so forth (e.g., Brattberg et al. 2020), but also in terms of labor productivity and employment growth (Atkinson 2018). The main policies and strategies to enhance Europe's capacity in this area include programs for improving entrepreneurship education (Ndou et al. 2018) and various incentive schemes for entrepreneurship (Román et al. 2013); and the creation of technology transfer offices (Baglieri et al. 2018), startup studios (Baumann et al. 2018) and innovation intermediaries (De Silva et al. 2018). To date, the results of these various attempts have been limited.

Various efforts to increase Europe's capacity in transforming technological breakthroughs have also been biased by adopting Silicon Valley as a key benchmark (e.g., Baumann et al. 2018; Ester 2017; Palego and Pierce 2020). This benchmark is problematic, because Europe does not have a (strong) internet platform economy largely based on software innovations, but a manufacturing economy with many universities and other knowledge institutions excelling in, for example, new materials and other hardware innovations (Romme 2022). As such, Europe is facing a very complex and unique problem that calls for actions and interventions with long time horizons, involving a broad range of actors (Ferraro et al. 2015; Howard-Grenville et al. 2019) and hybrid arrangements, such as private–public partnerships and social enterprises (Luo and Kaul 2019).

In this paper, we, therefore, argue that European universities and companies should seek to become leading in so-called *deep-tech* innovations, that is, disruptive solutions arising from major technological or scientific advances that are unique, well-protected, and often hard to reproduce (De la Tour et al. 2017). These disruptive solutions emerge from pioneering work in, for example, high precision engineering, mechatronics, electronics, photonics, new synthetic materials, and embedded software. A deep-tech venture typically combines multiple technological inventions in a disruptive solution in the area of, for example, healthcare, advanced robotics, clean-tech, or energy storage. The term "deep-tech" was also introduced, because popular terms such as "big-tech" and "high-tech" increasingly refer to technologies that are mostly or entirely software-driven and thereby less complex than deep-tech innovations that combine extremely complex software with novel forms of complex hardware (De la Tour et al. 2017; Perelmuter 2021). The sheer complexity of deep-tech innovations implies that the so-called *valley of death* (Barr et al. 2009; Ellwood et al. 2022) in commercializing these innovations is extremely deep and large, which calls for new ways and strategies for overcoming this valley of death. More specifically, this huge valley of death implies that the failure risk is substantially higher for deep-tech ventures than for other ventures. Moreover, one cannot assume novel deep-tech inventions are readily available for venture founders, which means they have to be deliberately sourced from leading research institutes.

This raises the following research question: how can Deep-Tech Ventures (DTVs) that address the SDGs be effectively created from scientific and technological breakthroughs accomplished in leading European research institutes? In addressing this question, we develop an integrated approach to building DTVs, one that incorporates key elements of extant theories and tools in the field of entrepreneurship (e.g., Aulet 2013; Ries 2011), but also moves beyond the contemporary body of knowledge. In this respect, the contemporary literature takes a lead founder and her/his team as the main starting point for building a new venture; and this literature also tends to underestimate the critical role of technology sourcing in venture creation, assuming a (technological) invention is simply available for the lead founder(s) to exploit (e.g., Pauwels et al. 2016; Roach and Sauermann 2015; Shepherd et al. 2021; Song et al. 2008). Therefore, creating and growing *deep-tech* ventures is much more complex and challenging than creating and growing other types of ventures, implying that a distinct approach is required.

As such, the DTV building approach described in this paper incorporates tools for sourcing technologies (e.g., from research institutes), whereas existing methods for new business incubation typically start from a given venture team that has already developed an initial proposition (e.g., Cohen 2013; Feld and Cohen 2010; Miller and Bound 2011). It, therefore, also includes a deliberate strategy for attracting (both junior and senior) talent as well as a systematic process for creating venture teams. Overall, the DTV building approach arises from designing a comprehensive system for creating and scaling up DTVs.

A deep-tech venture builder in The Netherlands implemented and further developed this approach as of 2015, in a highly iterative manner. In doing so, this DTV builder created a local ecosystem with multinational companies, tech institutes, consulting companies and public institutions while sourcing breakthrough technologies from all over Europe (e.g., CERN, European Space Agency, Polish Organization for Research and Technology, and University of Copenhagen). The initial results obtained by this venture builder are promising. The main contribution arising from this paper involves a blueprint for deep-tech venture building which is (a) grounded in the literature on venture creation, entrepreneurial finance, talent acquisition, and innovation ecosystems as well as (b) alpha tested in a major European venture builder.

## Background: the valley of death in deep-tech entrepreneurship

The *valley of death* notion (Barr et al. 2009; Savaneviciene et al. 2015) serves to understand the main challenges arising from deep-tech innovation and entrepreneurship. More specifically, the 'valley of death' perspective serves to understand the main risks that deep-tech ventures are exposed to. In this respect, deep-tech ventures are characterized by extremely 'high risks' and (potentially) 'high benefits': they constitute a huge risk for the entrepreneurs and investors involved, but they can result in immense benefits for society at large (Perelmuter 2021; Romme 2022).

Figure 1 provides a visual overview of the valley of death, based on Romme (2022). The horizontal axis of the graph in this figure represents the time-to-market, operationalized in terms of the well-known Technology Readiness Level (TRL) scale. The vertical axis involves the resources needed to develop the initial technology (e.g., in research institutes or universities) and, at a later stage, the resources that a venture team needs to apply and commercialize this technology. Many DTVs do not survive the lowest point of the "valley" in Fig. 1 when the initial resources in the form of academic and/or pre-seed funding are no longer (or hardly) available, while the investment capital required for commercializing the technology is not available yet (Barr et al. 2009; Ellwood et al. 2022; Savaneviciene et al. 2015). In terms of TRL, the valley of death typically starts at TRL 2 or 3 (e.g., a scientific proof of concept is available and/or a small-scale prototype of the technology is validated in the lab) and ends around TRL 7 or 8, when a prototype of the new technology operates successfully in the industrial setting of a lead customer (EARTO 2015).

For deep-tech ventures, the valley of death is rather deep (on the vertical axis of Fig. 1) and long (on the horizontal axis). That is, investors often perceive a deep-tech venture to be both nascent and complex, and it often lacks "an articulated narrative and, as a result, suffers from a void of understanding or inaccurate reputation" from the perspective of these investors (Portincaso et al. 2021, p. 13). The high risks of deep-tech ventures are evident from their high failure rates. Whereas specific data for deep-tech ventures are not available, previous studies have collected data on the broader population of technology-driven ventures. For example, Marmer et al. (2011) observed a failure rate above 90% of technology-driven ventures and Song et al. (2008) reported a failure rate around 80%. Because deep-tech ventures are likely to be the riskiest ones in this population, we can readily assume they have failure rates well above 90%. More specifically, deep-tech venturing is extremely challenging and risky because of three reasons (cf. Romme 2022):

- First, a DTV develops products or systems with an extremely high technological complexity, arising from the combination of extremely complex hardware and software (De la Tour et al. 2017; Perelmuter 2021). We call this the *technological risk* of failure, arising from the very high complexity of the product or system being developed and the associated difficulties in getting the new technology effectively applied and scaled up in an industrial setting.
- Second, a DTV typically has a rather long time-to-market of, at least, 5–7 years—but often much longer—and thus require major investments, in terms of both financial and human resources. In terms of financial resources, a deep-tech venture often needs 10 to 20 M€ in the first (series A) investment round and up to hundreds of millions in subsequent investment rounds (Degeler 2021). This is the so-called *financial risk* of not being able to acquire the investment volume needed.
- Finally, a DTV often requires an extensive innovation ecosystem that "encompasses a set of actors that contribute to the focal offer's user value proposition" (Kapoor

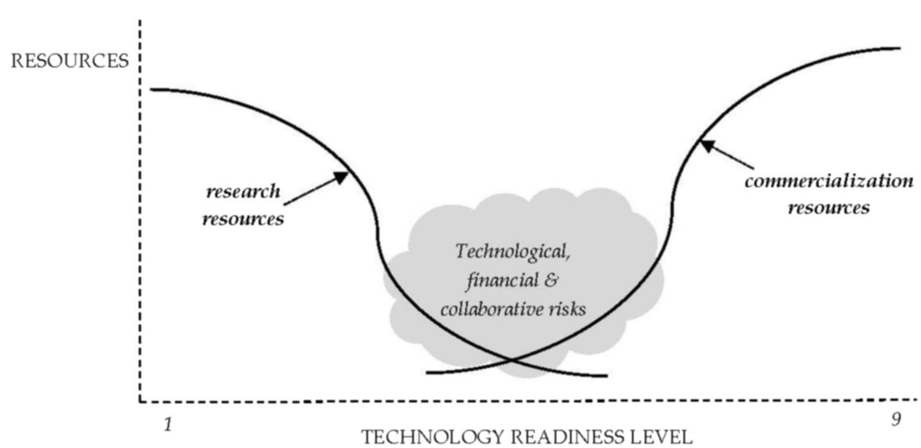


**Fig. 1** Valley of death in deep-tech venturing. Source: Romme 2022, p. 3

2018). In this innovation ecosystem, various suppliers, distributors or other complementors collaborate with the focal venture, typically also by proactively investing in the design and development of new components and services (Adner and Kapoor 2010; Talmar et al. 2020; Walrave et al. 2018). The *collaborative risk,* therefore, arises from not being able to obtain the commitment of all suppliers and other co-creating stakeholders needed to realize the value proposition of the focal venture.

These major technological, financial and collaborative risks also imply that venture capital firms typically do not invest in early stage deep-tech ventures with TRLs between 2 and 7). Venture capital firms avoid the early stages of technology-driven ventures, when technologies are uncertain and market needs largely unknown (Dimov et al. 2007), that is, they primarily invest in technology-driven ventures that have already reached a TRL of 8 or higher.

Notably, the three risks previously outlined may not cover all risks arising from deep-tech venturing. For example, an additional factor is the team-building risk of not being able to attract people with specific kinds of expertise and/or experience which the venture team strongly needs; or not being able to build sufficient chemistry within the venture team (Roach and Sauermann 2015; Sauermann 2018). However, this team-building risk also applies to all other types of ventures, and we can readily assume that in DTVs this risk is modest compared to the three risk factors previously outlined.

Each of these three risks constitutes a potential cause for failure of a deep-tech venture. Moreover, the three risks are evidently somewhat interdependent. For example, if a key supplier cannot supply a critical component and there are no other suppliers with the same capabilities available (i.e., constituting a major collaborative risk), this obviously also enhances the risk of technological failure, in the sense that without this component the envisioned product cannot be made to work. Another example is the interdependence between technological and financial risks: if the prototyped technology cannot be demonstrated to perform at the expected level, the existing investors will withdraw from the venture and new investors are not likely to come on board. In any case, deep-tech venturing is characterized by rather high levels of risk on all three dimensions.

## Methodology

We first describe the research methodology adopted as well as the data collected and analyzed, and then outline the empirical setting of this study, a deep-tech venture builder located in The Netherlands.

### Design science

This paper draws on a design science approach (Dimov 2016; Romme and Endenburg 2006; Romme and Reymen 2018). As a generic research methodology, design science (DS) arose from Simon's (1969) *The Sciences of the Artificial,* in which he argued that human intentionality and environmental contingency, as key properties of human systems, make an exclusively 'scientific' approach inadequate for studying and improving them. In this respect, human intentionality and environmental contingency are at the heart of entrepreneurship practice and scholarship (Romme and Reymen 2018). Research informed by DS can effectively address entrepreneurial systems and practices, by engaging in both creative design and scientific validation as complementary and equivalent research activities (Dimov et al. 2022). Moreover, DS is strongly oriented on problem solving (Romme and Holmström 2023), which makes it a highly suitable approach to address the research question raised earlier. Informed by previous DS applications (e.g., Pascal et al. 2013; Van Burg et al. 2008), we adopted the following solution-oriented design cycle:

1. Review the extant body of knowledge to develop design propositions/guidelines regarding a particular problem (solution);
2. Formulate functional requirements for the solution;
3. Create a solution, informed by the outcomes of the previous two steps;
4. Alpha-test and (possibly) beta-test the solution and implement it.

Notably, the first step (i.e., reviewing the literature) serves to develop tools and practices that are well-grounded in the state-of-the-art of the field, whereas the second step (i.e., functional requirements) allows the key agent to formulate additional requirements (e.g., specific to deep-tech venturing and the agent's local ecosystem). While the first two steps in the DS cycle typically provide a clear direction (for designing a solution), the third step may be highly creative and abductive in nature, in the sense that a novel solution is designed which goes beyond the extant body of knowledge.

The fourth step involves alpha- and beta-testing. In line with DS conventions in adjacent disciplines (e.g., March and Smith 1995), design scientists use the 'testing' notion in a more eclectic and flexible manner than social scientists. That is, they talk about testing when assessing the practical feasibility and usefulness of a solution (Pascal et al. 2013; Romme and Endenburg 2006) as well as when more rigorously evaluating this solution, for example, by comparing the improved version of a solution against the existing version in terms of key metrics (Kohavi et al. 2020; Koning et al. 2022; Osterwalder et al. 2015). The main distinction between alpha and beta tests is that the designers of the solution actively participate in the former, whereas they do not in the latter.

The four stages outlined above are highly iterative, that is, any DS project tends to go back and forth via this cycle many times (e.g., Romme and Dimov 2021). Especially the third creative step and the alpha/beta testing step are highly iterative, that is, the most recent test outcomes inform the redesign and adaptation of the solution, which is then tested again, and so forth. In the next section, this DS cycle serves to describe how the DTV building approach was designed and validated. This DTV building approach is the overall artifact created, which involves many components (as artifacts in themselves) that were also designed, tested and implemented by HighTechXL.

This study draws on extensive engagements by two of the authors of this paper, who have been key agents in setting up and developing the DTV builder studied (see next subsection). These practitioners joined forces with the first author of this paper to form a so-called insider–outsider research team (Bartunek and Louis 1996). This type of collaborative work has the unique quality of *marginality*, that is, being neither altogether inside or altogether outside the system. That is, in an insider–outsider research team "the outsider's assumptions, language, and cognitive frames are made explicit in the insider's questions and vice versa. The parties, in a colloquial sense, keep each other honest—or at least more conscious than a single party working alone may easily achieve" (Bartunek and Louis 1996, p. 62).

In applying DS methodology, this insider–outsider team also invited 12 graduate students, from the adjacent University of Technology, to conduct their final thesis projects on various tools and practices for building DTVs. These MSc thesis projects were part of the Innovation Management MSc program of this university and were all jointly supervised by the authors of this paper. The most relevant graduation projects for this paper are those by Bunt (2019), Biert (2020), Mittelmeijer (2020), Mulder (2020), Van Scheijndel (2020), Jansens (2022), and Schutselaars (2022). These thesis projects were all informed by DS, drawing on data collected via interviews, participant observations, surveys, prototyping, and alpha/beta testing to create new tools and practices and/or improve extant practices in deep-tech venturing. Appendix A provides a detailed overview of the data collected and analyzed in these studies.

## Empirical setting

In 2011–2012 Guus Frericks, an industrial engineer who had previously led various new ventures within Royal Philips Electronics and NXP Semiconductors, started exploring the unique deep-tech ecosystem emerging in the Dutch region around Eindhoven. He wondered what would happen if this ecosystem would be deliberately mobilized to support young technology-driven ventures. A major source of inspiration was the story of ASML, a small venture that Philips spun out in 1984. As a new company, ASML sought to commercialize the breakthrough lithographic technology developed in Philips but was up against many giants in the semiconductor industry such as Nikon and Canon that long dominated the wafer lithography equipment business. ASML's founding team was, however, convinced they had superior technology to become a leading player, despite the fact it needed at least 100 million (Dutch guilders) to develop the first tool that could be commercially applied. Facing huge technological, financial and commercial hurdles, the ASML team managed to fight themselves into the industry. Around the start of the twenty-first century, ASML had become the dominant company in the semiconductor industry, one that determined the speed of each next generation of microchips, thereby keeping Moore's law alive. (The company today employs more than 32,000 employees worldwide and was valued at around 240 billion € in March 2023.) Thus, Guus Frericks believed ASML provides an excellent example of how entrepreneurship can exploit advanced deep-tech technology to change the world. It was also obvious for him that ASML's evolution, especially in its early stages, was enabled by an elaborate ecosystem; he thus wondered:

> "What if we could replicate the story of ASML, by mobilizing the power and unique strength of the local ecosystem? What if we could create the next BSML, CSML, DSML, and so forth?"

A second source of inspiration was Frericks' experience in building a deep-tech venture based on breakthrough Ultrawide Band Technology developed at research institute IMEC. This technology enabled real time, highly accurate indoor localization and the company set up by Frericks and several partners was successfully sold to one of the biggest companies in the world, which subsequently incorporated the technology in millions of devices produced by this company. One key learning from this venture's journey was that it (in hindsight) would have benefited substantially from a structured DTV building program, one that taps into the unique strengths and knowledge base available in the deep-tech ecosystem in and around Eindhoven.

Another relevant observation was the non-existence of structured programs for developing hardware-based startups. At the time, many incubators and accelerators had already been launched; two prominent American examples were Y Combinator (launched in 2005) and Techstars (founded in 2006). Many incubators and accelerators subsequently set up in Europe were inspired by these two examples. Guus Frericks recalled:

"Studying them, I discovered that most of these initiatives were looking for the next Facebook, Airbnb, Uber or Dropbox, focusing on digital platform-based 'web and app' propositions. At that time, there were only few initiatives specifically geared to support 'high-tech hardware' propositions. This has probably to do with the fact that hardware venturing is challenging, very challenging. Unlike 'web and app' propositions, high-tech hardware ventures have to think about building a scalable supply-chain, creating IPR, and building global distribution channels for tangible products. In addition, these ventures typically have relatively long R&D and time-to-money cycles: at least 2–3 years, but sometimes longer. Furthermore, high-tech ventures are considerably more capital intensive in the pre-revenue stage when compared to web/app ventures. Finally, having built high-tech ventures myself, I witnessed many times that incredibly bright engineers and scientists tend to fall in love with technology development; they often lack the skills to transform technology into business."

Several studies underline the last observation: the number one reason that startups fail is that they offer a product or service that does not address a real market need; in other words, there is no product-market fit (CBI Insights 2019; Griffith 2014). Fréricks thus started thinking about the creation of an incubator program specifically focused on high-tech hardware ventures, because no such program existed (around 2012) in the USA, Europe or elsewhere. These insights led Frericks to explore whether he could build such a structured program. A handful investors, including Philips and ASML, provided the initial funds to set up HighTechXL and the managing director of the High Tech Campus Eindhoven offered office space to get going.

## Main findings

In this section, we describe how HighTechXL developed its DTV building approach. The initial *design proposition* formulated around 2013, also informed by the literature reviewed in the Background section (e.g., Adner and Kapoor 2010; Barr et al. 2009; Song et al. 2008), was as follows:

> An integrated system for building DTVs that provides the best possible conditions, resources and processes for creating and developing these ventures serves to effectively bridge the (major risks arising from) the broad and deep 'valley of death' for DTVs.

The *functional requirements* formulated by HighTechXL's management team were as follows:

> In addition to mitigating and/or overcoming the major risks arising from the 'valley of death' in deep-tech venturing, the DTV building approach to be developed has to capitalize on the key strengths of the regional (deep-tech) ecosystem in and around Eindhoven.

The initial design of HighTechXL's deep-tech venture building approach was similar to the design of various accelerator programs (e.g., for software-driven startups), by globally recruiting and selecting promising venture teams with attractive ideas and technologies. After a few years (in 2018), the HighTechXL team decided to adapt its venture-building strategy toward sourcing breakthrough technologies from leading research institutes (such as CERN and ESA) as well as recruiting talent globally to form venture teams that could build successful ventures from these technologies. The main reasons for this strategic shift were that, first, many venture teams (applying for participation in HighTechXL's program) apparently had no access to the most advanced technologies relevant for their value proposition; and second, there was a large pool of scientific breakthroughs and innovations developed at European universities and research institutes, which hardly or not found its way toward societal application (EARTO 2015). The DTV building approach was thus extended with two key activities: sourcing breakthrough technologies from leading institutes and recruiting talent globally. Figure 2 provides a visual overview of the *final solution* designed to meet the functional requirements, based on the extant body of knowledge on stage-gates, entrepreneurial finance, and many other aspects of venture building.

In the remainder of this section, we first outline HighTechXL's blueprint for building DTVs and describe how various components were designed and tested. Subsequently, the preliminary results obtained are described. As such, we focus in this section on (the design and results of) HighTechXL's approach toward addressing the risks arising from the valley of death. At the component level, we especially zoom into the interdependencies between the various components, rather than providing all details of how each component was designed and tested (see Appendix A for an overview of various more specific studies conducted).

### A system design for building DTVs

The body of knowledge on how to create technology-driven ventures from technologies developed at universities and other research institutes (e.g., Clayton et al. 2018; Nair et al. 2022; Siegel et al. 2023; Van Burg et al. 2008) is underdeveloped, especially when one moves beyond the standard "university spinoff" creation approach. Moreover, almost all previous work in this area focuses on one specific dimension of new business creation (e.g., Hu and Zhang 2012;

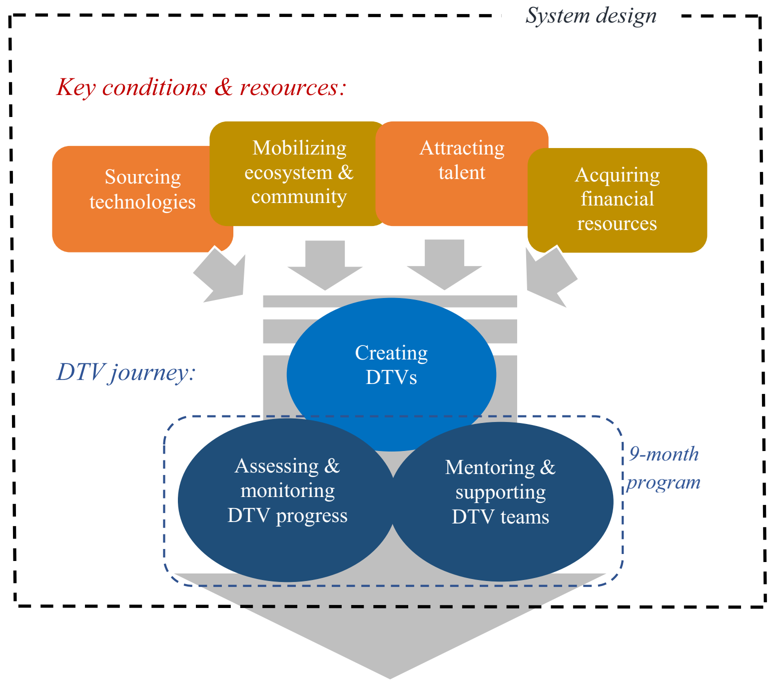


**Fig. 2** System design of the DTV building approach

Mansoori et al. 2019). As a result, a comprehensive model or recipe for creating and building DTVs is not available in the literature. We, therefore, set out to develop such a comprehensive system. First, the system for creating and building DTVs, arising from our study conducted in the period 2017–2023, is outlined. Subsequently, we outline the various components and how these were developed.

Figure 2 provides an overview of the DTV building blueprint, involving several complementary components that are categorized in two major subsystems: (a) key conditions and resources and (b) the DTV journey. The subsystem of key conditions and resources is the most distinctive element of the DTV building approach, given that almost all existing incubators and accelerators focus on the venturing process and do not deliberately invest in creating optimal conditions and resources. For example, most incubators and accelerators focus on selecting and supporting entrepreneurial teams that have already committed to a particular idea or value proposition (e.g., Pauwels et al. 2016; Mansoori et al. 2019; Roberts and Lall 2019). The two subsystems and their components operate simultaneously and iteratively in creating and accelerating DTVs:

a. Key conditions and resources

- Technology sourcing, that is, identifying and assessing new technologies with commercialization potential developed in leading research institutions;
- Mobilizing the local ecosystem and community;
- Attracting new talent that will help create and grow ventures; and
- Acquiring the financial resources for venture building.

b. DTV journey

- Creating deep-tech ventures;
- Assessing and monitoring venture progress;
- Mentoring and supporting venture teams.

In the remainder of this section, we describe and illustrate how HighTechXL developed the two subsystems and their components.

## Key conditions and resources

This subsection serves to outline the key conditions and resources for DTV building: technology sourcing, mobilizing the local ecosystem and community, attracting talent, and acquiring financial resources.

### Technology sourcing

As outlined earlier, a key component of the DTV building approach of HighTechXL is to source novel deep-tech technologies directly from leading European research institutes. In doing so, it focuses on patented technologies which provide a form of protection and thereby a substantial period of time to (try to) build deep-tech companies from these technologies. Technologies sourced from prominent research institutes also provide additional credibility when recruiting new talent, setting up new collaborations, and attracting investors (discussed later). The search for these novel technologies requires close ties and alliances with research institutes and R&D units of high-tech companies, because the most promising technologies cannot be taken "from the shelve" but need to be evaluated with active input from (the inventors in) these institutes and companies.

The extant literature in this area (e.g., Rohrbeck 2010; Tsai and Wang 2008) focuses on technology sourcing by big companies, rather than by venture builders. HighTechXL, therefore, set out to develop a codified framework (including a process as well as tool) for assessing and sourcing technology from leading institutes and companies, with the help of a graduate student conducting his thesis project on this topic (Biert 2020). The development of the technology sourcing approach involved a systematic review of the literature, the development of a prototyped tool and procedure, and various alpha tests before the final approach was implemented. The resulting technology sourcing framework has four phases: collecting, screening, assessing, and selecting technologies. In case a technology is selected, it enters the venture building program of HighTechXL (discussed later), in which a venture team is formed to commercialize this technology. Throughout the entire sourcing cycle, the HighTechXL scouts evaluate the potential societal impact, deep-tech characteristics, intellectual property (IP), fit with key competences available in Eindhoven's ecosystem, various skills required, maturity level, and market potential of a specific technology. A key insight arising from applying the sourcing framework (for more than 3 years) is that while it may be tempting to apply the above criteria in a very strict manner, it appears to be more effective and realistic to source an ongoing stream of promising technologies from prominent research institutes and then use the other steps in HighTechXL's venture building program to filter out the technologies that present too many (insurmountable) difficulties and prioritize those with the best overall profile. Another key finding is that this technology sourcing approach is most effective in the context of long-term collaborative ties with a limited number of prominent research institutes, given the reciprocal nature of these ties and the organizational routines needed (at both sides) in the area of IP disclosure and licensing. As a result, in the period 2019–2022 HighTechXL sourced four breakthrough technologies from CERN, four other technologies from TNO, and another four technologies from ESA (see Appendix B). For example, high-capacity free-space optical technology was sourced from CERN, fast-swing process technology was sourced from TNO, and additive manufacturing technology based on wire feeding was licensed from ESA.

### Mobilizing the local ecosystem and community

The business ecosystem and local community are critical resources for any venture builder. Especially the capabilities and assets of large corporations can help DTVs in, for example, developing prototypes and identifying market opportunities (Weiblen and Chesbrough 2015; De la Tour et al. 2017). Moreover, although professional expertise, entrepreneurial talent and investors can possibly be mobilized across large distances, these various resources can most easily be mobilized from the local and regional community (Bell et al. 2006, 2014). HighTechXL, therefore, created a dedicated and formalized alliance network with ASML, Philips, NTS, Brabant Development Agency, TNO, Brainport Development, High Tech Campus Eindhoven, and the City of Eindhoven. This network, called the *Eindhoven Startup Alliance*, serves to create strong bonds between the DTV building efforts of HighTechXL and several multinational corporations, financial institutions, public agencies, and other key entities in the Eindhoven region. This alliance operates as a platform providing support in all stages of the DTV journey. For the large companies and other stakeholders, the alliance offers ample opportunities to tap into a fast-moving entrepreneurial ecosystem, providing access to promising new ideas, technologies, and talent. The CEOs of the companies in the alliance—such as Philips, ASML and NTS—also believe that they have a collective responsibility to invest in the region, to diversify this region and sustain its leading position in deep-tech venturing. For example, ASML's CEO Peter Wennink observed:

> "In its turbulent early years, ASML experienced first-hand how important a support system is for a young company. Supporting HighTechXL is our way of giving back to the community. In addition, we have the experience that these young companies can also be of value to us: startups are a great source of ideas."

Similarly, the CEO of Philips Benelux observed that:

> "125 years ago, Philips was itself a startup. We stand for innovation and entrepreneurship, and we believe that the future of successful innovation and growth lies in the collaboration between corporations and startups. There are many ways in which young and established companies can complement each other, and HighTechXL offers a great platform to do just that. Along with the other members of the Eindhoven Startup Alliance, we can give a push to innovation, and thus invest in the future growth of the region."

Most importantly, the commitment of key actors in the local ecosystem of HighTechXL provide its venture teams easy access to the (e.g., market and technical) expertise available within this ecosystem. Many venture teams created by HighTechXL also use various (e.g., lab) facilities of partners, such as TNO and Philips to test their prototypes. The partners in the Eindhoven Startup Alliance also helped position HighTechXL as the preferred venture-builder for leading research institutes, such as CERN, TNO and European Space Agency.

### Attracting talent

A critical asset to any deep-tech venture (builder) is the human talent needed for each venture team. That is, the formation of an effective team is decisive in building the venture (Roach and Sauermann 2015; Sauermann 2018; Shah et al. 2019). HighTechXL, therefore, developed an evidence-based framework for talent acquisition by a deep-tech venture builder (Van Scheijndel 2020), involving four key elements: the (a) business environment, (b) career development, (c) jobs and tasks and (d) social and ethical issues connected to deep-tech venturing. This framework also uses measures of innovativeness, risk-taking and proactiveness to determine a (young) talent's interest in joining a new venture. The graduate student developing this framework also created and tested several survey instruments that operationalize this framework (Van Scheijndel 2020). A short survey was developed to provide immediate feedback to anyone visiting HighTechXL's website (see https://www.hightechxl.com/co-founders). In addition, a more extensive questionnaire was developed for a later stage in the recruitment and selection process.

The recruitment and selection process at HighTechXL thus involves four phases. In phase one, a dedicated recruiter continuously scouts, approaches and attracts potential entrepreneurial talents in deep-tech around the globe, by appealing explicitly to their specific ambitions and wishes. In the second phase, anyone visiting the venture builder's website can conduct a quick self-assessment of his/her interest in joining a deep-tech venture, to allow candidates to self-select in or out of the recruitment process. In phase three, a more detailed self-assessment is performed to get a complete overview of the applicant's interest in joining a venture. In the last phase, face-to-face interviews serve to make a final decision as well as assess which (team) roles in new venture building would fit the candidate.

Via this structured approach in attracting and assessing candidates, HighTechXL seeks to increase each venture's success chances, as the assessment also draws on the key performance indicators in the DTV Journey (described later). By ensuring the venture team has the capabilities to meet all these KPIs, the success chance of this venture may increase substantially.

### Acquiring financial resources

Whereas the conditions and resources described thus far are all critical in addressing the various risks arising from the valley of death (visualized in Fig. 1), the lack of financial resources may be the most challenging one (Barr et al. 2009; Savaneviciene et al. 2015). In this respect, developing commercial applications of deep-tech innovations is a truly "high risk, high benefit" exercise. As a result, DTVs provide a huge risk for the entrepreneurs and investors involved but can also result in immense benefits for society-at-large as well as the entrepreneurs and investors in the venture. HighTechXL, therefore, also needed to address the key challenge of attracting sufficient volumes of financial resources for its ventures.

HighTechXL thus set out to develop a systemic solution in this area, after it had already built the alliance of committed (e.g., corporate) partners which was described earlier—again with the support of a dedicated graduate student (Mittelmeijer 2020). Based on a detailed analysis of the entrepreneurial finance literature (Bellavitis et al. 2017; Cosh et al. 2009; Fisher et al. 2016) and the funding landscape for DTVs, two funding instruments were designed and tested. The first instrument was in the form of listing a cluster of 30 shell companies on an alternative Exchange that uses blockchain technology to tokenize shares. This clustering approach would provide each venture with more easy access to substantial funding volumes via the initial public offering (IPO) on this exchange, while it might significantly reduce the risk level for investors (Mittelmeijer 2020). This funding instrument was alpha-tested via interviews with various types of investors; while some investors were highly interested, most perceived it to be too novel and risky and appeared to be uncomfortable with the blockchain nature of the instrument.

The second instrument designed and tested was a somewhat more conventional investment fund, dedicated to deep-tech ventures (Mittelmeijer 2020). The alpha-testing of this solution among various institutional and corporate investors resulted in a more positive outcome, in terms of the interest raised among various representatives of these investors. One key requirement raised by institutional investors (e.g., Dutch pension funds) was that the ticket size (i.e., minimum investment volume required per participant) would have to be substantial. As a result, the so-called DeepTechXL investment fund of 100 million € was created early 2022, with a large Dutch pension fund, ASML, Philips, Brabant Development Company, Dutch government, and several family offices investing in this fund (Dutch government 2022).

## The DTV journey

We now turn to the three key components of the DTV journey (see Fig. 2): creating deep-tech ventures, assessing and monitoring progress, and mentoring and supporting venture teams.

### Creating deep-tech ventures

A key step for any deep-tech builder is, of course, the actual creation of ventures by matching novel technology with entrepreneurial talent and allocating initial funds and other resources. Thus, the creation of deep-tech ventures in HighTechXL is an incubation process that also serves to connect the key conditions and resources created in the orange area of Fig. 2. The most promising technologies arising from technology sourcing are assessed and scrutinized in a so-called *FasTrackathon* (a reverse hackathon, so to speak), a session in which the technologies and their potential applications are discussed by engineers, physicists, business developers, financial experts and seasoned entrepreneurs. These participants typically come from the local ecosystem in and around Eindhoven, selected from a larger pool of professionals committed to the mission of HighTechXL. A FasTrackathon usually takes half a day, and ends with teams pitching their business cases. For example, in a FasTrackathon session that explored the photonic gyroscope, a novel technology sourced from ESA, various applications in the medical, transport, energy and other sectors were discussed. The group dialogue in this FasTrackathon served to rank the application of this technology in monitoring wind turbines as the most promising one. One of the participants, who later also joined this venture team, commented on this opportunity as follows:

> "Photonic gyroscope-based sensors can remotely monitor wind turbines to predict mechanical failures. Energy companies spend big bucks for visual inspection of multi-million euro turbines that often misses problems. Visual inspection is expensive and labor-intensive. Preventive maintenance can't be done under normal circumstances, because shutting down turbines is an expensive proposition for energy providers. The industry needs sensors directly monitoring the wind turbines that can predict when maintenance and repairs are needed … sensors that are accurate, inexpensive and simple to install. Maintenance can't be done randomly, because it costs companies millions to shut down the turbines. Visual inspection is only done while turbines are stopped by trained techs and it's only a snapshot. (...) This is a large and rapidly growing market, with 300,000 wind turbines worldwide and no feasible solution. Can you imagine?"

A FasTrackathon session typically results in an initial value proposition that is explicitly connected to one of the SDGs (Schutselaars et al. 2023) as well as some people already committed to joining one of the venture teams. HighTechXL subsequently explicitly seeks to optimize each venture team by adding members that have skills complementing those of the initial members. These so-called pre-program sessions are conducted to further strengthen the venture teams. These preliminary teams subsequently enter a selection process for HighTechXL's 9-month venture building program (see Fig. 2), in which they benefit from the facilities and resources offered by the next two components of the DTV journey. Once selected for entering this program, each venture is typically also incorporated in a legal entity. The initial equity in this new company is distributed between the venture's CEO and CTO (as lead founders) as well as HighTechXL.

### Assessing and monitoring DTV progress

A key challenge for any venture-builder is to monitor the (lack of) progress that the venture is making. For assessing and monitoring the level of maturity and economic viability of a deep-tech venture, HighTechXL, therefore, developed an evidence-based model of the DTV journey, which serves to assess and rate the venture regarding its business model, market, financial support, product, supply chain, technology and sustainability. This journey model and its milestones was designed with help of another graduate student (Bunt 2019), drawing on the extant literature about stage-gate processes and startup development (e.g., Cooper 2008; Marmer et al. 2011; Miller and Friesen 1984; Salamzadeh and Kawamorita Kesim 2015; Song et al. 2008).

This model of the venture journey consists of nine *maturity levels*, distributed across three key phases: phase A involves the (1) dream, (2) stand, and (3) step levels; phase B contains the (4) walk, (5) bound, and (6) run levels; and phase C involves the (7) leap, (8) fly, and (9) cruise levels. These nine maturity levels are highly similar to the TRL scale described in the Background session; the main difference is that the maturity scale is tailored to deep-tech venturing only, whereas the TRL scale has a much broader scope. During HighTechXL's 9-month program the ventures are expected to reach (at least) the fifth level. Each phase is structured in terms of the deliverables of the venture team: for example, in technology application research, product development, market research, and team development. To conclude a phase, the highest maturity level in that phase needs to be reached. The DTV journey continues after the program (i.e., as of level 5), when the newly formed companies are part of HighTechXL's portfolio of companies in which it has a minority equity position.

The three phases operate as a funnel, with only those ventures that deliver the required results going to the next phase; if a venture repeatedly fails to deliver the required results, the decision to stop this venture's development is taken and it exits from the program. In addition, each venture team is assessed and receives regular feedback regarding its team composition (e.g., experience, diversity, credibility), execution skills, and its high performance team culture (e.g., result orientation, learning, psychological safety). These assessments are incorporated in a venture journey team report, which is continually updated. This assessment approach helps each team obtain a realistic view of their progress as well as a detailed understanding of what needs to be done to move the venture forward. An example is Aircision, a venture focusing on bringing broadband internet to those areas in the world, where fiber cable cannot be embedded in the ground. This team started with promising laser-based technology from CERN to develop high-speed connections for transferring data through the air. The team formed by HighTechXL consisted of (highly complementary) technological, business and financial experts from around the globe. However, the initial prototype did not deliver the expected performance when it was tested at a facility in France. The team then pivoted rapidly and identified a novel free-space optics technology at TNO. With the help of TNO, Aircision is currently conducting elaborate tests of their product with several of the largest telco operators in the world, and has also been able to attract external investors based on their progress. The Aircision case illustrates how the milestones and metrics in HighTechXL's venture journey drive the venture team to adapt and learn.

### Mentoring and supporting venture teams

The existing body of knowledge on venture creation and growth suggests that mentors can be a great help to venture teams. A mentor draws on extensive knowledge of venture-building to coach (individual members of) the venture team and provide various kinds of support (St-Jean and Audet 2012; Pauwels et al. 2016). Rather than merely giving advice on business topics or resolving a specific problem, DTV mentoring involves various ways of providing support to the venture team, especially in areas, where the team lacks knowledge, skills or expertise (Mansoori et al. 2019). With help of a graduate student (Mulder 2020), HighTechXL, therefore, developed an elaborate process of attracting, selecting, and supporting mentors, including a self-evaluation tool and a systemic approach toward matching mentors with venture teams.

HighTechXL also provides support by means of weekly workshops, mentoring, pitch training, video production services, and so forth. A related asset is the access to a network of experts, including (potential) lead customers, suppliers, IP lawyers and financial experts (mainly arising from the Eindhoven Startup Alliance, described earlier). A highly complementary activity is HighTechXL's corporate talent mentoring program. This program provides the corporate partners of HighTechXL the opportunity to directly engage in DTV work, by immersing talented professionals (e.g., employed by ASML or Philips) in entrepreneurial venture-building. This talent mentoring program also gives venture teams additional access to specific kinds of expertise (e.g., on system architecture, photonics, embedded software).

The jargon and tools used by venture teams, their mentors and external experts draws to a large extent on the state-of-the-start of startup methodologies, including lean startup (Ries 2011), disciplined entrepreneurship (Aulet 2013), and other methods and insights (Shepherd et al. 2021). Thus, some key constructs widely used within HighTechXL include: minimum viable product, hypothesis-driven experimentation, lead customer feedback, pivoting, and the build–measure–learn cycle.

### Key interdependencies between subsystems and their components

Obviously, the two subsystems and their components outlined in Fig. 2 are highly complementary in nature, with the various components feeding on and reinforcing each other. For example, the venture creation attempts in FasTrackathon sessions capitalize on the technologies sourced from other institutes, the young as well as senior talents attracted to join HighTechXL's DTV program, the various experts from companies, such as ASML and Philips joining the FasTrackathon, and so forth.

Moreover, the various components within a single subsystem also create substantial synergies. For instance, the funding strategy developed by HighTechXL benefits from several other resources in Fig. 2. In this respect, the access to advanced deep-tech inventions developed at institutes such as CERN and ESA serves to enhance HighTechXL's reputation and legitimacy in the eyes of institutional and other investors. A similar positive effect on funding efforts arises from HighTechXL being explicitly supported by a strong industrial ecosystem in Eindhoven, including global players, such as ASML and Philips. An example is Carbyon, a venture created in 2019, based on technology to capture $CO_2$ directly from the air (developed at TNO). This venture recently attracted substantial investments as well as won a major grant in Elon Musk's X-Prize initiative for $CO_2$ capturing.

A more operational type of synergy exists between technology sourcing and the local ecosystem around HighTechXL. Here, HighTechXL's scouts that explore and assess which technologies developed in institutes such as TNO and CERN are the most promising ones, often consult experts from (members of) the Eindhoven Startup Alliance network to help evaluate these technologies. Another example is the synergy between mentoring activities and the venture journey's milestones and metrics developed for assessing a venture's progress, as in the Aircision case described earlier. In this respect, the mentor's frequent interactions with the team help to enrich the assessment of what the venture has (not yet) accomplished, whereas the milestones and metrics support the mentor in giving more specific feedback and guidance to the team.

### Preliminary results

As observed in the Background section, DTVs typically have a time-to-market of at least 5–7 years, which implies that it is too early to conduct a final assessment of the outcomes of HighTechXL's deep-tech venture building approach. This subsection thus serves to describe the preliminary results obtained.

As described earlier, HighTechXL initially adopted a (more conventional) accelerator approach in the period 2014–18. This episode in HighTechXL's history has produced several viable deep-tech ventures: a total of 64 ventures was selected and supported by HighTechXL in this period; for 6 ventures, HighTechXL has thus far made a successful exit and 13 other ventures are still in HighTechXL's portfolio (all in phase 3 in terms of the venture journey). All other venture teams were stopped, due to various reasons. The current success rate for this episode of HighTechXL, therefore, is around 10%, which may increase somewhat, dependent on the results that will be obtained with the 13 companies still in HighTechXL's portfolio.

We will focus here on the period as of 2019, when HighTechXL's started to apply its DTV building approach, as outlined earlier. Appendix B provides an overview of the 26 ventures built in 2019–2022: it outlines the (current) value proposition, technology sourced, SDG addressed, and current maturity level (in terms of the nine levels of maturity described earlier in this section). This overview demonstrates that eight ventures were stopped, due to various reasons. For example, Imagin Motion, the venture arising from photonic gyroscope technology sourced from ESA (mentioned earlier in this paper) reached out to many companies in various industries, because the technology had a wide range of potential applications. After receiving valuable feedback during these market validation efforts, the team pivoted toward applying this novel technology to MRI scanners, also by collaborating with Philips in this area. This value proposition could also not be developed in a convincing manner. In addition, there were several major changes in the venture team, which also undermined progress in this venture journey. HighTechXL thus decided to stop its efforts to further develop this venture. The Imagin Motion venture and the other seven unsuccessful ventures share the fact that they all were unable to specify a convincing value proposition linked to at least one SDG of the United Nations.

It is too early to assess the current (high) survival rate of the DTVs listed in Appendix B (i.e., 18 out of 26 ventures in April 2023). In the Background section, we referred to the deep-tech 'valley of death' typically being 5–7 years long; thus, a more final evaluation of the success rates of the DTVs started in 2019–2022 can only be done in a valid manner as of 2028. In this respect, the 18 ongoing ventures in Appendix B are at maturity levels 3 to 7, which also implies they still have a substantial path to go until they operate and thrive as independent companies. As such, at least some of these ventures are also likely to be stopped in the next few years. In any case, HighTechXL will continue to build new DTVs every year and is, therefore, likely to learn and improve its operations over time.

## Conclusions and discussion

The main contribution of our paper is a practical one, in the form of a blueprint for creating deep-tech ventures that address various SDGs. This blueprint, outlined in Fig. 2, is grounded in the literatures on technology sourcing, entrepreneurship and new venture creation, entrepreneurial finance, alliance management and entrepreneurial ecosystems, team building and talent acquisition, and mentoring entrepreneurs. Moreover, it is alpha-tested in a major European deep-tech venture builder.

This blueprint for building DTVs is a novel solution for the limited capacity of European industry and knowledge institutions to transform scientific and technological breakthroughs into successful ventures and companies and thereby address major challenges in the area of climate change, energy production and other SDGs. This blueprint and its instantiation in HighTechXL may constitute a significant addition to other programs and measures developed to enhance Europe's innovation capacity (e.g., Baglieri et al. 2018; Baumann et al. 2018; De Silva et al. 2018; Ndou et al. 2018; Román et al. 2013). Moreover, this blueprint for building DTVs exploits Europe's enormous reservoir of deep-tech innovations, which are essential in addressing various grand challenges. The focus on deep-tech innovations is also promising, because it deliberately goes beyond attempts to imitate the 'Silicon Valley' benchmark (e.g., Baumann et al. 2018; Palego and Pierce 2020) and instead capitalizes on Europe's tradition and excellence in new materials and other hardware innovations (Romme 2022).

We started this paper by arguing that the extant literature assumes a lead founder (team) is the main starting point for building a new venture and tends to underestimate the critical role of technology sourcing in venture creation, thereby assuming a (technological) invention is simply available for the lead founders to exploit (e.g., Shepherd et al. 2021). Our study implies that DTV building requires a co-creation perspective on entrepreneurship, in which a (to be formed) venture team is part of a broader collaborative constellation of stakeholders enacting the entrepreneurial process, and all stakeholders contribute resources and derive benefits from this co-creative process (Karami and Read 2021). Accordingly, the model for building DTVs developed in this study appears to provide a more complex perspective on creating and growing ventures than available in the extant literature.

More specifically, the DTV blueprint is unique in its focus on ventures that are created from deep-tech inventions directly sourced from leading knowledge institutes. As such, prominent startup accelerators such as Y Combinator, Techstars and Angelpad in the United States (Cohen et al. 2019; Feld and Cohen 2010) and startup studios such as Rocket Internet in Europe (Baumann et al. 2018) largely focus on sofware-driven ventures, which are much more attractive for investors because they generate profits more quickly. Consequently, these organizations do not externally source deep-tech inventions to build ventures that exploit these inventions (Baumann et al. 2018; Cohen et al. 2019). While this strategy has been very successfully in generating thousands of new software-driven companies, it is not suitable for growing Europe's capacity to create more successful deep-tech companies, such as ASML (Economist 2020).

Moreover, in contrast to various highly popular practical tools (e.g.,Osterwalder et al. 2015; Ries 2011), the scholarly body of literature on venture building appears to be highly descriptive-explanatory in nature (e.g.,Baumann et al. 2018; Pauwels et al. 2016; Roach and Sauermann 2015; Roberts and Lall 2019). Here, the DTV building approach is instrumental in practically guiding and supporting any organization that seeks to create and grow DTVs addressing SDGs, in ways that significantly reduce their high failure rates. As argued in the Methodology section, we used a DS approach to develop an instrumental model that draws on the extant body of knowledge, but also goes beyond it.

The need for an instrumental body of knowledge also informed our choice to adopt a system design perspective on building DTVs. System design is the interdisciplinary field that focuses on how to design, integrate and manage a complex system over its life cycle. In our study, this is a system that creates and grows DTVs on a regular basis. The DTV blueprint described earlier incorporates key elements of extant theories and tools in the field of entrepreneurship, but also extends the literature by providing a set of tools and processes for enhancing the operational excellence of efforts to co-create and grow DTVs.

The initial results obtained with this DTV approach are highly promising, also in the sense that it appears to significantly alleviate the three risks outlined in the Background section. The *technological risk* of failure, arising from the extremely high complexity of deep-tech systems or products, is reduced especially by obtaining access to the most advanced technological breakthroughs patented by leading institutes such as CERN as well as capitalizing on the DTV expertise available in HighTechXL's regional ecosystem (Romme 2022). While the technological risk of failure can never be completely eliminated, the blueprint for DTV building may constitute the best shot at substantially reducing this risk. In this respect, many venture teams developing their business cases elsewhere (e.g., Baumann et al. 2018; Pauwels et al. 2016) may not have access to the most advanced hardware technology developed at and owned by leading research institutes, such as ESA, TNO and CERN, which severely constrains their ability to create a substantial and sustained competitive edge.

Second, the *financial risk* of not being able to acquire the required investment volumes for any specific DTV is especially addressed by setting up a deep-tech seed-investment fund, one that also helps reduce the risk of other investors coming on board. While seed-investment funds have existed for a long time (e.g.,Baldock and Mason 2015; Wilson and Silva 2013), this is the first time that such a fund is dedicated to financing DTVs.

Finally, the *collaborative risk* arising from a venture not being able to obtain the commitment of all suppliers and other co-creating stakeholders is especially addressed by mobilizing (the expertise available in) HighTechXL's ecosystem, including several multinational companies that have committed to it. This provides any specific DTV with additional resources to develop its own innovation ecosystem (Walrave et al. 2018), but also enhances its credibility toward potential investors (Ellwood et al. 2022). As is evident from the previous section, the various components of the DTV building model outlined in Fig. 2 are highly interdependent. This interdependence underlines the synergetic impact of the various components operating together to facilitate the creation and growth of DTVs.

A boundary condition of the DTV blueprint is that it may only work in European and similar settings with a long history in deep-tech. That is, North-American investors and public policy makers are more focused on platform-based ventures that tend to generate a return on investment within a shorter time horizon (Barwise 2018; Ester 2017), and they are, therefore, less likely to re-allocate investments to deep-tech ventures and companies. Another boundary condition is that the blueprint for creating and building DTVs, developed in the Eindhoven region, very likely requires a sustained culture of collaboration and trust between local investors, deep-tech entrepreneurs, local government and other key agents (Romme 2022), one that may not (yet) be present in other European regions seeking to adopt this blueprint.

From an organization design perspective, this study is also one of the first to apply Simon's (1969) 'science of the artificial' perspective to designing real-life organizational systems, as advocated by Puranam (2012) and Burton and Obel (2018). In this respect, the vast majority of publications in the Journal of Organization Design and related outlets adopt a descriptive-explanatory approach rather than a forward-looking design approach. Our study demonstrates the potential of DS methodology for practitioners and researchers teaming up to bridge the rigor-relevance gap and create artifacts that are science-based as well as practically useful (Dimov et al. 2022).

A major limitation of this study is that the blueprint designed has been implemented and (alpha) tested in a single DTV builder, located in the Netherlands. Moreover, the valley of death for deep-tech ventures typically involves a period of 5–7 years, which implies that a substantially longer data period (i.e., > 10 years) is required to assess HighTechXL's effectiveness in a more rigorous manner. The results outlined previously are, therefore, preliminary in nature. The intermediate nature of the analysis also means we have to be cautious in claiming any progress regarding the SDGs. While each venture entering HighTechXL's program is required to formulate a value proposition that is explicitly linked to at least one SDG (Schutselaars et al. 2023), the real impact in terms of SDG metrics is still to be made.

Overall, the DTV approach described in this paper provides the first comprehensive framework for creating and scaling up deep-tech ventures that each address at least one of the SDGs. This framework is implemented in a major European venture builder as well as grounded in the literature on entrepreneurship, technology sourcing, ecosystems, entrepreneurial finance, and talent acquisition.

## Appendix A

### Overview of data sources and data analysis

In designing and further developing the various components of the blueprint for building DTVs at HighTechXL, a group of 12 graduate students helped in collecting and analyzing data. All these final MSc projects were all jointly supervised by the authors of this paper. This appendix provides an overview of the most relevant graduation projects, which are those by Bunt (2019), Biert (2020), Mittelmeijer (2020), Mulder (2020), Van Scheijndel (2020), Jansens (2022), and Schutselaars (2022). These thesis projects were all informed by DS, drawing on data collected via interviews, participant-observations, surveys, prototyping, and alpha/beta testing to create new tools and practices or improve extant tools and practices. We outline the goals, research questions (RQs), and data collected and analyzed in these thesis projects below. Notably, the various tools and protocols developed in these projects were subsequently fully integrated and thus more extensively beta-tested in HighTechXL's DTV building program and related processes.

#### Bunt (2019)

Goal: design a stage-gate process (i.e., HighTechXL's venture journey model) by means of a systematic review of the literature and alpha-testing this process.

RQ: how can high-tech startups be assessed on their maturity and economic viability?

Methods/data: systematic literature review of high-tech startup accelerators; venture journey model was created, based on design propositions (inferred from literature) and additional design requirements; data collected via 4 focus groups, 25 interviews, and 21 pages of participant-observation field notes; these qualitative data were fully transcribed and coded.

#### Biert (2020)

Goal: this study aimed to find out how a deep-tech venture builder can best assess technologies regarding their potential for commercial application.

RQ: how can technology be assessed regarding its potential for a deep tech venture building program?

Methods/data: literature review of technology sourcing and assessment practices; protocol/checklist for sourcing technologies was designed, based on design propositions synthesized from the literature and additional design requirements formulated by HighTechXL; data collected by means of a focus group session, 2 interviews, and 5 pages of participant-observation notes, and around 50 patent documents, venture presentations and related documents; the qualitative data from the focus group and interviews were fully transcribed and coded.

#### Mittelmeijer (2020)

Goal: create a sustainable investment framework that bridges the Valley of Death for deep-tech start-ups until they have a minimum viable product.

RQ: how can a deep-tech venture builder (like HighTechXL) structurally obtain and manage early stage investments in its newly created ventures?

Methods/data: systematic literature review of research on funding early stage ventures; based on design propositions inferred from the literature, two optional design solutions were created, of which one was tested via interviews with potential investors; the data collected involves 27 semi-structured interviews and 2 focus groups, 11 pages of participant-observation field notes, and a large number of archival documents, such as Investor Relation documents, financial forecasts, portfolio documents, business models, and venture presentations. These mostly qualitative data were coded for key constructs and patterns.

### Mulder (2020)

Goal: develop a framework that brings knowledge, expertise and support from mentors to new ventures.

RQ: how can a deep-tech venture builder structurally facilitate and manage knowledge and expertise from its partners and mentors to support new ventures?

Methods/data: systematic literature review of new venturing and mentor support; data collected via 2 focus groups and 10 interviews, which were fully transcribed and coded for key patterns; protocol for match-making between mentors and venture teams was designed and alpha-tested (with 16 mentors and 7 venture teams).

### Van Scheijndel (2020)

Goal: develop a framework for attracting talent that can join new ventures.

RQ: how should deep-tech venture builders recruit and select young talent to join new ventures?

Methods/data: systematic literature review of entrepreneurial talent (recruitment and selection); 11 interviews that were recorded and fully transcribed, and subsequently coded for key constructs and causal patterns; various documents and participant-observation field notes; two survey tools were designed (for recruitment, respectively, selection purposes) and alpha-tested with 8 people.

### Jansens (2022)

Goal: help HighTechXL as a venture builder get more grip on the development of the internal dynamics of their teams, including ways to safeguard a psychologically safe environment.

RQ: how can HighTechXL in its 9-month program monitor and stimulate the creation of psychological safety within new deep-tech venture teams to improve their performance?

Methods/data: systematic literature review of new venture team development, psychological safety and team performance; 7 focus groups and several additional interviews; and participant-observation notes of informal discussions, program-related meetings, KPI-feedback sessions, and other events.

### Schutselaars (2022)

Goal: enhance the effectiveness of the communication of deep-tech value propositions to early stage investors (long before the first customer comes on board).

RQ: how can deep-tech ventures communicate their value propositions more effectively to investors?

Methods/data: literature review of methods and tools to communicate value propositions to potential customers and investors; inferring design propositions from this literature; formulating design requirements together with HighTechXL's CEO and other team members; participant-observation field notes of 14 workshops, feedback sessions and related events; reports of 12 tests of prototypes of the tool.

## Appendix B

### Overview of ventures in HighTechXL's DTV building program (since 2019)

| Name (start year) | Value proposition | Technology | Sourced from | SDG addressed | Maturity level (April 2023) | Reason for stopping |
|---|---|---|---|---|---|---|
| Aircision (2019) | Powering the high-speed connected world | High-capacity free space optics systems | CERN and TNO | 9. Industry, innovation and infrastructure | Run (6) | |
| AlphaBeats (2019) | Play your music, pause the mind | Neurofeedback technology arising from EEG research | Philips | 3. Health and well-being | Leap (7) | |

| Name (start year) | Value proposition | Technology | Sourced from | SDG addressed | Maturity level (April 2023) | Reason for stopping |
|---|---|---|---|---|---|---|
| Avoxt (2021) | Using pulse-based technology to produce energy efficient hydrogen | Electrochemical process for splitting water into hydrogen and oxygen | CERN | 7. Affordable and clean energy | Walk (4) | |
| Carbyon (2019) | Closing the CO2 cycle by capturing CO2 from ambient air | Fast-swing process technology based on a rotating drum that contains material that is modified to efficiently capture CO2 out of air | TNO | 13. Climate action | Run (6) | |
| Dynaxion (2019) | New-generation scanning system that greatly improves accuracy, efficiency and safety of security and PFAS screening processes worldwide | Scanning system with a novel Radio Frequency Quadrupole (RFQ) particle accelerator to create a beam of neutrons to be used for scanning objects | None | 3. Health and well-being | Bound (5) | |
| Hica Solutions (2020) | Revolutionizing the rehab industry through force feedback technology | Force feedback technology | ESA | 3. Health and well-being | Walk (4) | |
| Imagin Motion (2020) | This team explored multiple applications and then made a pivot toward developing photonic sensors to stabilize images in MRI scanners | Photonic gyroscope technology | ESA + University of Bari | Unspecified | Stopped | Lack of progress in several areas |
| Incooling (2019) | Cooling down the planet one server at a time | High Performance Computing custom-built server that achieves the fastest clock speeds available on the market | CERN | 9. Industry, innovation and infrastructure | Run (6) | |
| Infitiv (2020) | Reduce food loss and protect the environment: offering innovative solutions to reduce food loss in the post-harvest stage for a sustainable and responsible food supply chain | Terahertz camera technology for measuring ethylene gas | ESA | 12. Responsible consumption and production | Walk (4) | |
| Inner (2022) | CMOS-based detectors for low-cost X-ray applications in developing countries | Novel X-ray technology | Two inventors based on Israel | 3. Health and well-being | Bound (5) | |

| Name (start year) | Value proposition | Technology | Sourced from | SDG addressed | Maturity level (April 2023) | Reason for stopping |
|---|---|---|---|---|---|---|
| InnoFlex (2019) | Deep-tech solution for air pollution: a highly efficient mass-produced foil capable of reducing pollutants from the air when illuminated by sunlight | Foil that uses nanotechnology to break down articles in the air | Inventor/co-founder | 3. Health and well-being | Bound (5) | |
| Innsentec (successor of optify) (2021) | Unspecified | Confidential | Confidential | Unspecified | Stopped | Lack of progress in various areas |
| InPhocal (2019) | Become the new standard technology in the laser processing industry by 2025, by offering a non-invasive solution that replace inkjet and other established solutions | Novel laser focus technology | CERN | 12. Responsible consumption and production | Leap (7) | |
| Keiron (2019) | Additive micro-fabrication equipment that allows high volume manufacturing for micro-scale components | By focusing a laser on the top layer of the solder paste, a gas pocket is created | TNO | 9. Industry, innovation and infrastructure | Run (6) | |
| Meltify (2021) | 3D metal printing with LED | Additive manufacturing technology with wire feeding | ESA | Unspecified | Stopped | The team formed does not have the capabilities required |
| Mikron.X (2022) | Anti-icing coating to be used on blades of wind turbines | Anti-icing chemical coating technology | PORT | 7. Affordable and clean energy | Stopped | Technology did not deliver what was expected |
| Nestegg (2021) | Automation of laboratory processes | Confidential | Confidential | 3. Health and well-being | Stopped | Went bankrupt |
| Optiflux (2020) | Advancing the field of radiotherapy with radiation optics, introducing a new era of highly focused cancer treatments | Confidential | Confidential | 3. Health and well-being | Stopped | Lack of progress in several areas |
| Optify (2019) | Precise and cheap radiation measurement | Confidential | Confidential | Unspecified | Stopped | Lack of progress in several areas |
| Senergetics (2022) | Optical fiber sensors for measuring corrosion under insulation (COI) in process industry | Optical fibers with Fiber-Bragg grating | PhotonFirst | 9. Industry, innovation and infrastructure | Bound (5) | |

| Name (start year) | Value proposition | Technology | Sourced from | SDG addressed | Maturity level (April 2023) | Reason for stopping |
|---|---|---|---|---|---|---|
| SLE Enterprises (2021.) | Creating a scalable liquid encapsulation solution for the food, pharmaceutical and cosmetic industries | Novel ultrafast and scalable encapsulation technology that is highly flexible in using a large variety of cargo-shell combinations, but avoids the use of microplastics | Waterloo Institute | 12. Responsible consumption and production | Walk (4) | |
| Tarucca (2020) | Structural health monitoring of wind turbine blades to advance clean energy | Photonics-based sensor technology and AI software | ESA + University of Bari | 7. Affordable and clean energy | Step (3) | |
| Udentity (2021) | Next generation device biometrics | Authentication technology based on unique vein structure | TNO | 16. Peace, justice and strong institutions | Walk (4) | |
| Veridis (2020) | Creating a better future for humanity and planet using science and technology by delivering key recycling technologies to advance the transition to a circular economy | Differential Scanning Calorimetry (DSC) technology that is made scale-free and has several additional functionalities | Developed in-house | 12. Responsible consumption and production | Run (6) | |
| Viffera (2021) | End-to-end authentication solution that leverages advanced sensor and biometric algorithm technology to protect access to a company's data | Confidential | Confidential | Unspecified | Stopped | Lack of progress in several areas |
| VitalWear (2022) | Optical fiber sensors for measuring vital body signs via textiles | Optical fibers with Fiber Bragg grating | PhotonFirst | 3. Health and well-being | Step (3) | |

**Data availability** See Appendix A for an overview of data availability.



## References

Adner R, Kapoor R (2010) Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. Strat Manag J 31:306–333

Atkinson RD (2018) How ICT can restore lagging European productivity growth. Working paper. https://ssrn.com/abstract=3324656

Aulet B (2013) Disciplined entrepreneurship: 24 steps to a successful startup. Wiley, Hoboken

Baglieri D, Baldi F, Tucci CL (2018) University technology transfer office business models: one size does not fit all. Technovation 76:51–63

Baldock R, Mason C (2015) Establishing a new UK finance escalator for innovative SMEs: the roles of the enterprise capital funds and angel co-investment fund. Ventur Cap 17:59–86
Barr SH, Baker T, Markham SK, Kingon AI (2009) Bridging the valley of death: lessons learned from 14 years of commercialization of technology education. Acad Manag Learn Edu 8:370–388
Bartunek JM, Louis MR (1996) Insider/outsider team research. Sage, Thousand Oaks
Barwise P (2018) Nine reasons why tech markets are winner-take-all. Lond Bus Sch Rev 29:54–57
Baumann O, Bergenholtz C, Frederiksen L, Grant RM, Köhler R, Preston DL, Shane S (2018) Rocket Internet: organizing a startup factory. J Organ Des 7:13
Bell J, Den Ouden B, Ziggers GW (2006) Dynamics of cooperation: at the brink of irrelevance. J Manage Stud 43:1607–1619
Bell J, Kaats E, Opheij W (2014) Bridging disciplines in alliances and networks: in search for solutions for the managerial relevance gap. Int J Strateg Bus Alliances 3:50–68
Bellavitis C, Filatotchev I, Kamuriwo DS, Vanacker T (2017) Entrepreneurial finance: new frontiers of research and practice—editorial for special issue "embracing entrepreneurial funding innovations." Ventur Cap 19(1–2):1–16
Biert JD (2020) Assessing technology for a deep tech venture builder. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/admin/files/160105737/Master_Thesis_Jan_Biert.pdf
Brattberg E, Csernatoni R, Rugova V (2020) Europe and AI: leading, lagging behind, or carving its own way? Working paper, Carnegie endowment for international peace, Washington. https://carnegieendowment.org/2020/07/09/europe-and-ai-leading-lagging-behind-or-carving-its-own-way-pub-82236
Bunt S (2019) High-tech startup maturity: design of an evidence-based decision-support tool to assess the maturity and economic viability of high-tech ventures. MSc thesis, Eindhoven university of technology. https://pure.tue.nl/admin/files/131839212/Final_report_Thesis_Sabine_Bunt_digital.pdf
Burton RM, Obel B (2018) The science of organizational design: fit between structure and coordination. J Organ Des 7:5
CBI insights (2019) The top 20 reasons startups fail: Research brief. https://www.cbinsights.com/research/startup-failure-reasons-top/. Accessed 25 Apr 2022
Clayton P, Feldman M, Lowe N (2018) Behind the scenes: intermediary organizations that facilitate science commercialization through entrepreneurship. Acad Manage Perspect 32:104–124
Cohen S (2013) What do accelerators do? Insights from incubators and angels. Innovations 8(3–4):19–25
Cohen SL, Bingham CB, Hallen BL (2019) The role of accelerator designs in mitigating bounded rationality in new ventures. Admin Sci Quart 64:810–854
Cooper RG (2008) Perspective: the stage-gate idea-to-launch process—update what's new and NexGen systems. J Prod Innov Manag 25:213–232
Cosh A, Cumming D, Hughes A (2009) Outside entrepreneurial capital. Econ J 119:1494–1533
De la Tour A, Soussan P, Harlé N, Chevalier R, Duportet X (2017) From tech to deep tech: Fostering collaboration between corporates and startups. Report by BCG and Hello Tomorrow. http://media-publications.bcg.com/from-tech-to-deep-tech.pdf
De Silva M, Howells J, Meyer M (2018) Innovation intermediaries and collaboration: knowledge–based practices and internal value creation. Res Policy 47(1):70–87
Dealroom (2023) The European deep tech report 2023. https://dealroom.co/reports/the-european-deep-tech-report-2023. Accessed 27 Mar 2023
Degeler A (2021) European deeptech in 2021: these were the 10 biggest funding rounds. Tech.eu platform. https://tech.eu/2021/12/30/european-deeptech-in-2021-these-were-the-10-biggest-funding-rounds/. Accessed on 7 April 2022
Dimov D (2016) Toward a design science of entrepreneurship. In: Corbett AC, Katz JA (eds) Models of start-up thinking and action: theoretical, empirical, and pedagogical approaches. Advances in entrepreneurship, firm emergence and growth, vol 18. Bingley, Emerald, pp 1–31
Dimov DP, Shepherd DA, Sutcliffe KM (2007) Requisite expertise, firm reputation, and status in venture capital investment allocation decisions. J Bus Ventur 22(4):481–502
Dimov D, Maula M, Romme AGL (2022) Crafting and assessing design science research for entrepreneurship. Entrep Theory Pract: Forthcom. https://doi.org/10.1177/10422587221128271
Dutch government (2022) Deep-tech fund for knowledge-intensive start- and scale-ups launched. Announcement. https://www.rijksoverheid.nl/actueel/nieuws/2022/03/10/deep-tech-fonds-voor-kennisintensieve-start--en-scale-ups-gelanceerd. Accessed 10 Mar 2022
EARTO (2015) The European innovation council—a new framework for EU innovation policy. Brussels, European association of research and technology organisations (EARTO). https://www.earto.eu/wp-content/uploads/EARTO_Paper_-_European_Innovation_Council.pdf. Accessed 17 Dec 2022
Economist (2020). How ASML became chipmaking's biggest monopoly. https://www.economist.com/business/2020/02/29/how-asml-became-chipmakings-biggest-monopoly. Accessed 15 Mar 2021
Ellwood P, Williams C, Egan J (2022) Crossing the valley of death: five underlying innovation processes. Technovation 109:102162
Ester P (2017) Accelerators in Silicon valley: building successful startups. Amsterdam University Press, Amsterdam
European Commission (2008) Survey of entrepreneurship in higher education in Europe. http://ec.europa.eu/enterprise/policies/sme/files/support_measures/training_education/highedsurvey_en.pdf
Feld B, Cohen D (2010) Do more faster: techstars lessons to accelerate your startup. Wiley, New York
Ferraro F, Etzion D, Gehman J (2015) Tackling grand challenges pragmatically: robust action revisited. Organ Stud 36:363–390
Fisher G, Lahiri A, Kotha S (2016) Changing with the times: an integrated view of legitimacy, logics and new venture lifecycles. Acad Manag Best Paper Proc 41(3):383–409
Griffith E (2014) Why startups fail according to their founders. Fortune. https://fortune.com/2014/09/25/why-startups-fail-according-to-their-founders/. Accessed 25 Sept 2014
Howard-Grenville J, Davis GF, Dyllick T, Miller CC, Thau S, Tsui A (2019) Sustainable development for a better world: contributions of leadership, management, and organizations. Acad Manag Discov 5:355–366
Hu W, Zhang Y (2012) New venture capability of the transformation from entrepreneurial orientation to new venture's performance: theory model and empirical study in China. Nankai Bus Rev Int 3:302–325
Jansens J (2022) Measurement and stimulation of psychological safety in high-performing teams within a venture builder. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/admin/files/195282170/Master_Thesis_Joris_Jansens.pdf
Kapoor R (2018) Ecosystems: broadening the locus of value creation. J Organ Des 7:12

Karami M, Read S (2021) Co-creative entrepreneurship. J Bus Venturing 36:106125

Klofsten M, Jones-Evans D (2000) Comparing academic entrepreneurship in Europe—the case of Sweden and Ireland. Small Bus Econ 14:299–309

Kohavi R, Tang D, Xu Y (2020) Trustworthy online controlled experiments: a practical guide to a/b testing. Cambridge University Press, Cambridge

Koning R, Hasan S, Chatterji A (2022) Experimentation and start-up performance: evidence from A/B testing. Manag Sci 68:6434–6453

Luo J, Kaul A (2019) Private action in public interest: the comparative governance of social issues. Strat Manag J 39:2591–2617

Mansoori Y, Karlsson T, Lundqvist M (2019) The influence of the lean startup methodology on entrepreneur-coach relationships in the context of a startup accelerator. Technovation 84:37–47

March ST, Smith GF (1995) Design and natural science research on information technology. Decis Support Syst 15:251–266

Marmer M, Herrmann BL, Dogrultan E, Berman R, Eesley C, Blank S (2011) Startup genome report extra: premature scaling. Startup Genome 10:1–56

Miller P, Bound K (2011) The startup factories: the rise of accelerator programmes to support new technology ventures. NESTA, London

Miller D, Friesen PH (1984) A longitudinal study of the corporate life cycle. Manag Sci 30:1161–1183

Mittelmeijer HG (2020) Vertical: an innovative financial mechanism to bridge the Valley of Death. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/admin/files/163429722/Master_Thesis_Hessel_Mittelmeijer.pdf

Mulder P (2020) Managing knowledge and expertise support in deep-tech venture building. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/admin/files/164232961/Master_Thesis_Patrick_Mulder.pdf

Nair S, Gaim M, Dimov D (2022) Toward the emergence of entrepreneurial opportunities: organizing early-phase new-venture creation support systems. Acad Manage Rev 47:162–183

Ndou V, Secundo G, Schiuma G, Passiante G (2018) Insights for shaping entrepreneurship education: evidence from the European entrepreneurship centers. Sustainability 10(11):4323

Osterwalder A, Pigneur Y, Bernarda G, Smith A (2015) Value proposition design: how to create products and services customers want. Wiley, Hoboken

Palego C, Pierce I (2020) Inspiring a self-reliant learning culture while brewing the next Silicon valley in North Wales. Educ Sci 10(3):64

Pascal A, Thomas C, Romme AGL (2013) Developing a human-centred and science-based approach to design: the knowledge management platform project. Brit J Manage 24:264–280

Pauwels C, Clarysse B, Wright M, Van Hove J (2016) Understanding a new generation incubation model: the accelerator. Technovation 50–51:13–24

Perelmuter G (2021) Present future: business, science, and the deep tech revolution. Fast Company, New York

Portincaso M, Gourévitch A, De la Tour A, Legris A, Salzgeber T, Hammoud T (2021) The deep tech investment paradox: a call to redesign the investor model. Report by BCG and Hello tomorrow. https://hello-tomorrow.org/wp-content/uploads/2021/05/Deep-Tech-Investment-Paradox-BCG.pdf. Accessed 19 Sept 2022

Puranam P (2012) A future for the science of organization design. J Organ Des 1:1

Ries E (2011) The lean startup: how today's entrepreneurs use continuous innovation to create radically successful businesses. Crown, New York

Roach M, Sauermann H (2015) Founder of joiner? The role of preferences and context in shaping different entrepreneurial interests. Manag Sci 61:2160–2184

Roberts P, Lall S (2019) Observing acceleration: Uncovering the effects of accelerators on impact-oriented entrepreneurs. Palgrave Macmillan, London

Rohrbeck R (2010) Harnessing a network of experts for competitive advantage: technology scouting in the ICT industry. R & D Manage 40:169–180

Román C, Congregado E, Millán JM (2013) Start-up incentives: entrepreneurship policy or active labour market programme? J Bus Venturing 28:151–175

Romme AGL (2022) Against all odds: how Eindhoven emerged as a deeptech ecosystem. Systems 10:119

Romme AGL, Dimov D (2021) Mixing oil with water: framing and theorizing in management research informed by design science. Designs 5:13

Romme AGL, Endenburg G (2006) Construction principles and design rules in the case of circular design. Organ Sci 17:287–297

Romme AGL, Holmström J (2023) From theories to tools: calling for research on technological innovation informed by design science (editorial). Technovation 121:102692

Romme AGL, Reymen IMMJ (2018) Entrepreneurship at the interface of design and science: toward an inclusive framework. J Bus Ventur Insights 10:e00094

Salamzadeh A, Kawamorita Kesim H (2015) Startup Companies: Life Cycle and Challenges. In: Proceedings of the 4th International Conference on Employment, Education and Entrepreneurship (EEE). Belgrade. https://doi.org/10.13140/RG.2.1.3624.8167

Sauermann H (2018) Fire in the belly? Employee motives and innovative performance in startups versus established firms. Strat Entrep J 12:423–454

Savaneviciene A, Venckuviene V, Girdauskiene L (2015) Venture capital as catalyst for start-ups to overcome the "valley of death": Lithuanian case. Proc Econ Financ 26:1052–1059

Schutselaars J, Romme AGL, Bell J, Bobelyn ASA, Van Scheijndel R (2023) Designing and testing a tool that connects the value proposition of deep-tech ventures to SDGs. Designs 7:50

Schutselaars J (2022). Communicating the value proposition of new deep-tech ventures to investors. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/ws/portalfiles/portal/271733451/Master_Thesis_Joppe_Schutselaars.pdf

Shah SK, Agarwal R, Echambadi R (2019) Jewels in the crown: Exploring the motivations and team building processes of employee entrepreneurs. Strat Manag J 40:1417–1452

Shepherd DA, Souitaris V, Gruber M (2021) Creating new ventures: a review and research agenda. J Manage 47:11–42

Siegel D, Bogers MLAM, Jennings PD, Xue L (2023) Technology transfer from national/federal labs and public research institutes: Managerial and policy implications. Res Policy 52:104646

Simon HA (1969) *The sciences of the artificial* (first edition published in 1969; third edition in 1996). MIT Press, Cambridge

Song M, Podoynitsyna K, Van Der Bij H, Halman JIM (2008) Success factors in new ventures: a meta-analysis. J Prod Innov Manag 25:7–27

St-Jean E, Audet J (2012) The role of mentoring in the learning development of the novice entrepreneur. Int Entrep Manag J 8:119–140

Talmar M, Walrave B, Podoynitsyna KS, Holmstrom J, Romme AGL (2020) Mapping, analyzing and designing innovation ecosystems: the ecosystem pie model. Long Range Plann 53:101850

Tsai KH, Wang JC (2008) External technology acquisition and firm performance: a longitudinal study. J Bus Venturing 23:91–112

Van Burg E, Romme AGL, Gilsing VA, Reymen IMMJ (2008) Creating university spin-offs: a science-based design perspective. J Prod Innov Manag 25:114–128

Van Scheijndel R (2020) Recruiting young talent in deep-tech venture building. MSc thesis, Eindhoven University of Technology. https://pure.tue.nl/admin/files/148942281/Master_Thesis_Robin_van_Scheijndel.pdf

Walrave B, Talmar M, Podoynitsyna KS, Romme AGL, Verbong G (2018) A multi-level perspective on innovation ecosystems for path-breaking innovation. Technol Forecast Soc 136:103–113

Weiblen T, Chesbrough HW (2015) Engaging with startups to enhance corporate innovation. Calif Manage Rev 57(2):66–90

Wilson KE, Silva F (2013) Policies for seed and early stage finance. OECD Sci Technol Ind Policy Pap. https://doi.org/10.1787/5k3xqsf00j33-en