# Entrepreneurship and Translation in the University Landscape

by

**Jake Drutchas**

Bachelors in Business Administration
University of Michigan, Stephen M. Ross School of Business (2014)

Submitted to the Integrated Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

***Master of Science in Engineering and Management***

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 2023



Authored by: Jake Drutchas
Integrated Design and Management Program
January 24, 2023

Certified by: Giovanni Traverso MD, PhD
Karl Van Tassel (1925) Career Development Professor
Department of Mechanical Engineering
Thesis Supervisor

Accepted by: Tony Hu
Executive Director, System Design & Management Program

# Entrepreneurship and Translation in the University Landscape

**By Jake Drutchas**

Submitted to the Integrated Design and Management Program on January 24, 2023, in Partial Fulfillment of the Requirements for the Degree of

***Master of Science in Engineering and Management***

## ABSTRACT

University research has become a core driver of innovation. Every year, governments around the globe invest in new and potentially groundbreaking discoveries. For this novel research to drive impact, it must be translated from the research setting into the market. This translation process is complex and challenging, and many hurdles and roadblocks stand in the way of success. This paper explores the process of translation, focusing on the process in which academic participants such as students, researchers, principal investigators, and professors must make a decision to invest their time and effort to bring a product to market and the steps involved in spinning research out of the lab and into the market. By examining the variables leading into translation and the early steps of the process, this research provides a playbook that can be utilized by these students, researchers, and staff to reduce the friction to entrepreneurship. This research aims to increase the quantity and success rates of startups out of the university setting.

Thesis Supervisor: Giovanni Traverso MD, PhD
Title: Karl Van Tassel (1925) Career Development Professor
Department of Mechanical Engineering

## ACKNOWLEDGMENTS

Firstly, I want to thank Gio Traverso, my thesis supervisor, for taking me on and helping me work through this process. His role as both my advisor and as one of the most engaging professors on campus meaningfully changed the progression of my Master's studies, and without his guidance my thesis would not have been possible. Thank you for working with me and for helping me learn and build the confidence to explore this space. Due in no small part to the teachings in your class and mentorship I leave school with a passion and energy to dive into entrepreneurial endeavors. I hope to someday drive even a fraction of the impact that you and your work has brought to the world.

Secondly, I would like to thank my friends and family for their constant support throughout my journey. Graduate school was not always easy, and covid only compounded the ups and downs. Without the support of those around me I don't think I would be leaving this program and school with the depth of learning or the passion for new adventures that I have today. Most importantly, the specific support of Mikaela Strech has made this whole experience possible. Your consistent support and encouragement mean the world to me.

Lastly, I would like to thank the IDM faculty for taking me on as a student and helping me ignite so much passion and energy for building new things and wanting to be a part of finding new solutions to big problems. I owe so much to you believing in me and allowing me to be a part of the IDM family.

# CONTENTS

# Chapter 1

## INTRODUCTION

### Overview

Research out of academia is working to push humanity into the future with breakthroughs in fields such as environmental science, energy creation and storage, healthcare, and more. These advancements are set to define what the future of humanity looks like, and impacts lives today. The topic of translating research from the academic setting into a company is not trivial for me. My father and sister are alive because of technological advances over the last century, which have made life-saving treatments and therapies. With this lens, I gained the motivation to pursue this research topic - how can we increase the rate and quality of academic spinouts? Which insights and structure are needed to navigate the translation process in the hopes of improving the pace, quality, and impact?

This paper defines translation as the process of transferring research and findings into application and impact. Generally, this is a new business entity, but it may take other forms, such as non-profits or open-source solutions. These, however, require alternative approaches to bring to market, so for this paper, I will focus on translation into businesses. Academic entrepreneurship is creating a business by utilizing a protected invention from the academic setting and the deep expertise of individuals involved in the research (Perkmann et al., 2013). Within the lifecycle of entrepreneurship, this research will focus on the period around the full maturation of research in the academic setting and the decision to launch into a business entity.

Focusing on this translation process, this research proposes a playbook and roadmap to improve this process by supporting founders and founding teams on the entrepreneurial path. It provides insight into the process with a focused lens around innovation at MIT. While the concept can be globally applied, local resources and characteristics may change the entrepreneurial process elsewhere.

The entrepreneurship path is ambiguous and depends on many circumstances surrounding a new product or service. While there is not a definitive path to entrepreneurial success, commonalities and examples may provide direction. The pace and quality of fundamental science have increased over time (Goldstein & Brown, 1997). This improvement has perhaps been aided by the maturing of the research process, where research goes from question to outcomes, such as publishing with rigorous expectations and an endpoint. For entrepreneurship, general steps and guidelines exist on how to bring a new product or service to market. However, the translation process, which describes the interstitial process between the academic and business/entrepreneurial steps remains elusive.

### Problem Definition

Students, researchers, and faculty are a pool of experts in their field and could be essential members of founding companies. However, these parties experience a lot of friction taking a concept from the lab and trying to bring it to market as a new product or service. What does a win look like for this paper? My earnest hope is that by providing some context around the entrepreneurial journey focusing on this process of translation from lab to market, we can

reduce the friction to taking this path and that more companies will come out of the university setting and go further and faster than before.

MIT faculty published an average of 5,300 articles annually from 2009 to 2017 (OA Task Force & Dunn, 2018). Meanwhile in 2022 MIT was issued 354 patents (Massachusetts Institute of Technology, Technology Licensing Office, 2022). With the amount of pure and applied research occurring on campus, there is a gap between what is being discovered and what is being structured to potentially be brought to market. The problem this paper addresses is how we might increase the volume and success rate of startups coming from academic institutions. This naturally involves a study of the barriers to entrepreneurship that exist and mitigating factors. If we can be successful in this effort, we will work to drive increased societal impact from research. Helping to provide structure so that future solutions tackling intractable global challenges has the best opportunity to drive impact.

## Methods

This research used a series of twelve semi-structured interviews conducted with current and former entrepreneurs who have developed businesses out of the research setting and by stakeholders who support these businesses across various parts of their lifecycle. This includes MIT professors, entrepreneurial organizations that support translation, venture capitalists, and the Technology Licensing Office (TLO).

Interviews were semi-structured to provide a framework for the conversation while allowing for flexibility in the conversation. Conversations were run using a series of predefined topical areas and questions but provided the flexibility to explore topics and conversation points driven by the conversation. Notes were reviewed and documented into an affinity map to group critical thoughts and learnings.

Furthermore, the literature review was completed to share what research has learned about the entrepreneurial process. Research from across fields of study looking at entrepreneurship and academic entrepreneurship was reviewed to ascertain any further strategies and data points that would be helpful for future founders considering this path.

## What is Translation

Understanding the type of innovation you are pursuing is helpful in that there are nuances in the process needed to develop a business around them. One of the approaches to categorizing innovation is to break it into two types: market pull and technology push.

In market pull innovation, the source of innovation's source is from the market and a specific market need (Cotter, 2018). This is a focus on the end-user and their need. The market exists and is well-defined, and the solution is developed to fit that need. This type of innovation is also called demand-pull or need-pull innovation (Cotter, 2018). Many well-known digital solutions come from this philosophy, for example, at one point, consumers needed help to quickly request a taxi or driver to get them to their intended destination, which was a large unmet need from which Uber and Lyft then came. Starting with an understanding of the need in the market the teams were able to create a technological solution to solve this problem.

On the other side of the spectrum is technology push innovation. In technology push innovation, the catalyst for the new product or process comes from research or a novel invention (Technology Push & Market Pull, 2019). The research may be pure or applied, but the outcome of the research must be new knowledge that has a real-world application. It is the commercialization of novel learning. This new technical capability is then brought to the market to solve a need. In this approach, a technology or solution is defined from the research, and then a market or user need must be identified, and the technology adapted and applied to fit that user need. The now well-known biotech company Moderna is a result of a technology push: a breakthrough on modified RNA technology at a lab at a leading university led to the realization that there is a large potential impact of bringing this technology to market, which is why the company was founded.

It can be understood then that university spinouts that come from the setting where novel research is occurring, solution are being discovered, and then brought to the market to find a user need, and adapted to solve for that need is push innovation. This is important to understand because it shapes the path and process that you will follow in trying to develop a business from this research. You may have a novel solution or breakthrough that you think has potential, and your job is to figure out how and where it applies and who will pay for it.

# Chapter 2

## BACKGROUND

### History of Translation

The expansion of effort around the process of translation has been attributed to a series of federal laws that came about starting in the 80s in the United States. Specifically, the 1980 Bayh–Dole Act, the 1980 Stevenson–Wydler Act, and the 1985 Federal Technology Transfer Act are seen as transformative to the process of translation. These pieces of legislation have led to a shift in how scientific discovery in universities and in Federal laboratory settings are commercially used. Since these pieces of legislation passed, the number of American universities that engage in technology transfer and licensing has increased eight times to more than 200 (Markman et al., 2005).

The Bayh-Dole Act is a federal law that permits universities, non-profit research institutions, and small businesses to own, patent, and commercialize inventions developed under federally funded research programs within their organizations (Bayh-Dole Act, 2022). The Stevenson–Wydler Technology Innovation Act required federal laboratories to actively participate in and budget for technology transfer activities (S.1250 - 96th Congress (1979-1980): Stevenson Wydler Technology Innovation Act of 1980, 1980). Lastly, the Federal Technology Transfer Act builds on the Stevenson-Wydler Act. The act established the Federal Laboratory Consortium which empowered federal laboratories to enter into Cooperative Research and Development Agreements (CRADAs) and to negotiate licenses for patented inventions made at the laboratory (H.R.3773 - 99th Congress (1985-1986): Federal Technology Transfer Act of 1986., 1986). This also includes the structure to allow for royalties to be paid to the lab and inventors (US EPA, 2014).

From 1980 to 2017, the number of patents issued to U.S. universities and their faculty has quadrupled. The number of companies emerging from the university setting has also greatly increased from virtually zero to roughly 1,000 per year from the 1970’s to the 2013 to 2017 time period (Cullum Clark et al., 2020). It is the maturing of the body of law around university research and innovation which has empowered the explosion of research and entrepreneurship from this setting over the last nearly half century. And from the public's perspective, that is how it should be. Taxpayer support for research is justified by the return-to-society on the investment. There exists a natural pressure for universities to show tangible returns for the grants they receive for their research. There is an increasing viewpoint from universities that their role is to be the catalyst of new ventures formation (Markman et al., 2005).

### The Importance and Magnitude of Translation

MIT's ambitious entrepreneurship educational program has three core principles: Mens et Manus; teams, not individuals; and cross-disciplinary collaboration. Mens et Manus means "Mind and Hand," which stems from William Barton Rogers' founding conception of linking theory and practice. A large and continually growing curriculum focuses on moving ideas to impact (Roberts et al., 2015).

Academic entrepreneurship and launching spinouts commercializing university research is an impactful mechanism for the economy, creating new jobs and fueling future innovation. MIT is

part of this impact on the global economy. Its dual emphasis on creating innovative ideas and using them to solve real problems is at the core of its ability to boost economic activity (Cohan, 2017). There have been 3,300 companies, including 50 unicorns, founded by alumni of MIT. These companies have attracted over 6,000 investors raising over $112 Billion (Tracxn, 2022). A 2014 report estimated that MIT alumni-founded startups employ over 4.6 million people and generate roughly $1.9 Trillion in annual revenues (Matheson, 2015).

The success of entrepreneurship is mirrored in Intellectual Property (IP) statistics. Between 1991 and 2015, there were approximately 11,000 total patent applications from MIT. 4,000 of these issued patents have value to licensees, and 437 companies licensed MIT owned IP (Cohan, 2017). In 2022 MIT was awarded over 354 US patents and 474 International patents. This makes for a combined 3,718 active patents in the US across sectors with 14% Medical Device, Diagnostics, and Research tools; 26% software; 21% Therapeutics; 36% physical science and hardware; and three percent other. MIT completed 99 new licensing agreements on top of the 3,202 completed between 1960 and 2021 (Massachusetts Institute of Technology, Technology Licensing Office, 2022).

The entrepreneurial environment encourages students to pursue this path. This is shown in the engagement in entrepreneurship over time. Eleven percent of alumni from the 2010s have founded companies, compared with eight percent who founded companies within five years of graduating in the 1990s and four percent in the 1960s (Matheson, 2015). This rate will only increase as entrepreneurship grows in interest and prestige for students coming out of the ecosystem. Moreover, if students and alumni are not actively founding companies, they are joining startups. From 2006 to 2014, the rate of students choosing employment at venture capital-backed startups grew from 2% to 15% (Roberts et al., 2015).

Student interest is driving more classroom content on the topic. A 2014-2015 academic year audit showed that entrepreneurial offerings included 63 courses from departments across the institute and attracted thousands of registrants (Roberts et al., 2015). As students become more engaged, technology licensing matures, and the impact of university-based startups grows, the university's role in the process also matures. Historically universities passively licensed their technologies which have changed to today, where they actively search for ways to channel IP into entities to maximize royalties and launch new companies (Thursby et al., 2001). The office of technology transfer at these schools has become ever more integral to this process as universities have expanded their role, becoming an integral partner to the larger business community which connects scientists to the market (Markman et al., 2005).

The success of startups from the university ecosystem is essential because they begin to fulfill the social contract that Universities have with society. Universities are a principal recipient of public investment for research and have a perceived obligation to support the translation of this research into societal benefit. Whereas it is easy to think that discovery is the best metric to gauge academic success, great discovery is measured by its impact (Stamler et al., 2003).

Founders and their startups exert a ripple effect across economies both locally and globally with the impact of their technology and the expansion of their team as they scale. This is especially true of push-based innovation, which often defines new markets. Economic data from the US shows that startups offer a disproportionate effect on job creation and are a primary driver of job growth, with new and high-growth young firms accounting for approximately 70% of gross job creation (Roberts et al., 2015). There are further secondary benefits that provide multiples on return. There is value in bringing together highly talented individuals and engaging them in new design and development. Also, each startup's success from an academic setting provides a

further proof point and reduces the friction to future founders in acquiring the capital needed to fuel future success. Bringing together interdisciplinary teams with the resources and knowledge to mature research and their focal technology sets the foundation for future research and work. Furthermore, while it is difficult to quantify the notion, you can see how the innovation from the institute drives a much broader impact in lives saved, environmental improvement, and the evolution of humanity.

The growth of interest in entrepreneurship from the academic setting is particularly important. If we look at, for example, where academics out of MIT are going to work post-graduation, we see that they are being employed by some of the largest companies in the world (Graduate Education Statistics, n.d.). This makes sense, given that their knowledge and experience at the cutting edge of their research fields make them valuable employees. However, could they perhaps be even more valuable if they brought their novel solutions to market, addressing some of the biggest problems our society faces by developing their research and work or that of their colleagues and classmates? When you see the impact that institute startups have had and then realize how little of the student body and faculty body goes into private companies, you begin to see how the impact could potentially scale by improving the adoption rates of entrepreneurship by the students and staff.

Spin-offs can provide a valuable and viable career option for students and researchers, particularly in the current job market where there is an excess of PhD graduates in the United States and limited academic employment opportunities. It has been noted recently that in markets including the United States, highly trained and educated researchers face a shortage of academic positions (Boh et al., 2015; Cyranoski et al., 2011). Entrepreneurial efforts to commercialize technologies generated from their research labs would allow students who do not have the interest or ability to obtain an academic position to pursue a different but viable career path that builds on their graduate training (Boh et al., 2015). Imagine the impact of entrepreneurship becoming a preferred choice for those coming from the research setting.

## Challenges with translation

Understanding common reasons startups fail, and the challenges they face allows for remediation and proactive steps to be taken. You can not avoid challenges but knowing that they are there and what might cause them may help de-risk this process and improve how you navigate the creation of a new venture. Before we get into the strategies for success, let us review points of failure and challenges commonly faced. When looking at hardships faced by translational entrepreneurs, there are two main groups. There are challenges faced by all entrepreneurs and then challenges specific to translation.

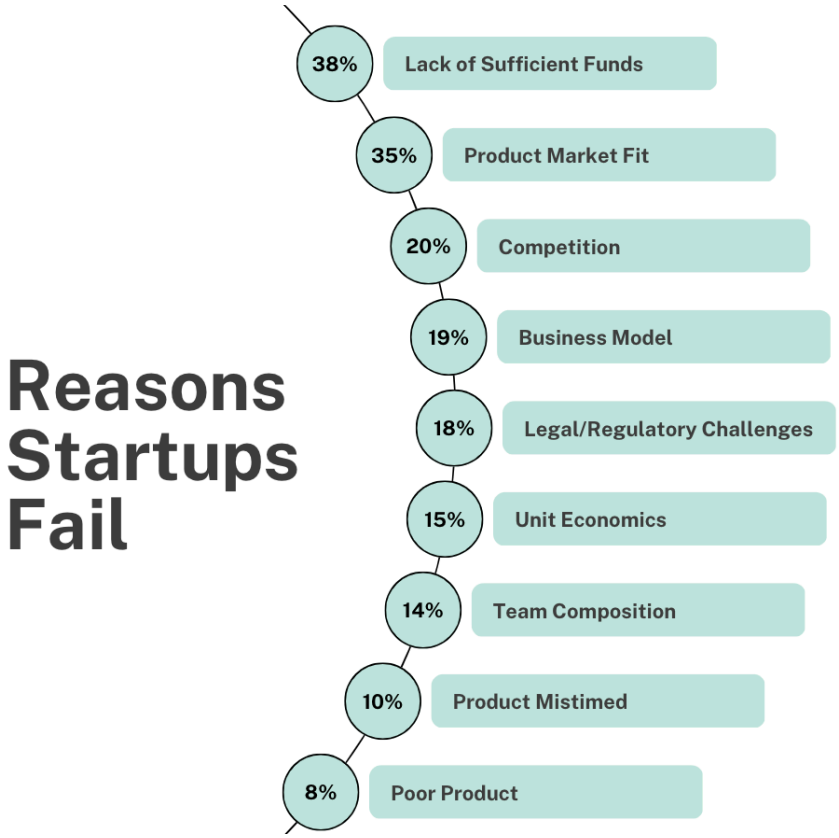


*Figure 1. Top reasons startups fail (Why Startups Fail: Top 12 Reasons L CB Insights, 2021)*

Figure 1 shows a list of reasons startups fail from a post-mortem analysis of over 110 startups (Why Startups Fail: Top 12 Reasons L CB Insights, 2021). Multiple reasons could be listed for each closure which is why the total percentages sum to over 100%. These points of failure may have many or a single cause. For instance, the number one cause is "Ran out of cash/failed to raise new capital". That is usually a symptom of some other failures - if the data is not there if the milestones are not being hit for reasons that are in the control of the team or not (V. Beranek, personal communication, October 5, 2022). The inability to raise money is the big death - the standard advice that venture capitalists and advisors tell founders is that your job is to not run out of money (V. Beranek, personal communication, October 5, 2022).

It is recognized that Academic spin-offs that utilize technology developed at the university frequently encounter a range of obstacles that can hinder their ability to achieve their economic goals. These obstacles often include a lack of resources, technological development uncertainty, market acceptance, and limited entrepreneurial knowledge and skills (Soetanto & Jack, 2016; Gredel et al., 2012; van Geenhuizen & Soetanto, 2009). This is a blend of challenges that arise from the nature of market push innovation. When a business starts with technology and searches for a market, these challenges present themselves. It makes sense that funding can be difficult for these startups because of the additional complexity. Not only are there the conventional risks that venture financers have to grapple with, such as market size and potential product market fit, among others. There are also technological risks with questions such as will this work outside the lab, can we manufacture this at scale, or is this a heavily regulated industry (Knockaert et al., 2010).

Separately, a significant challenge in both the literature and the interviews is the role of the team and team dynamics in the failure (V. Beranek, personal communication, October 5, 2022). The point of failure may be team members who cannot get along, teams who do not trust each other, individuals or multiple people leaving, or team members unable to execute the plan. The status and characteristics of the team can be a significant component of the fundraising process. While a VC analyzes the business holistically, looking at the opportunity and risks present in the status and perception of the founding team is often critical. This point can be pretty extreme, with this perspective from Harvard Business Review "...if forced to choose, most VCs would favor an able founder over an attractive opportunity."(Eisenmann, 2021). The following sections will discuss more what makes for a good team.

Part of the journey that you, your team, and technology will face is the "valley of death." The valley of death is part of the beginning of the startup lifecycle at the transition between scientific research and the commercialization of output technology. This can be a critical point in a startup's lifecycle, as it requires a significant investment of time, resources, and capital to bring a product or service to market. During this phase, startups may struggle to secure funding, build a team, and establish partnerships and customers. The risks and challenges associated with this phase can be significant, and many startups fail to make it through the valley of death. To overcome these challenges, startups may need additional funding, which can be challenging in this phase. As academic entrepreneurs in the early phase, you could be more appropriately re-labeled translational entrepreneurs due to this large and early hurdle, crossing this chasm from research to application.

## Risk and Failure

The valley of death is just the first chasm you need to cross. There are many others, including going from science to technology, tech to product, product to a business, and small business to large business (R. Dhanda, personal communication, December 15, 2022). It is important to note that failure should not be feared. The world of startups is precarious, and success may be found even in failure.

Consider the healthcare innovation industry. There have been numerous instances in the history of medical technology where innovations initially considered unimportant were highly successful. The track record of scientific journals in predicting the future benefits of innovations in human health could be better. Many technologies abandoned by research teams and companies have later been revisited and succeeded. This highlights the unpredictable nature of technological innovation and the importance of persistence and perseverance in pursuing transformative ideas (Coller & Califf, 2009).

Translational entrepreneurship is fraught with failure, but there is value in going through the process. Perhaps beyond all else, what is needed are more shepherds of future academic research. The amount of research coming from research centers is large. Where there exists a bottleneck is the human capital which can take the basic research and expand upon it (Goldstein & Brown, 1997; Contopoulos-Ioannidis et al., 2003). Without sufficient translational resources, we cannot keep up with the pace of research. As a result, the scientific advancements and discoveries made by previous and current generations may not be effectively translated into tangible benefits for humanity (Sung, 2003).

As one tries to launch a company, one acquires a mindset and skill set that can be applied to future companies. Students should view the commercialization of their lab's technology as a

valuable learning opportunity, even if the effort ultimately fails. These entrepreneurial experiences can benefit students at the beginning of their careers and may help them develop valuable skills and insights that will benefit them in the future. Moreover, if the spin-off succeeds, the students may pursue entrepreneurship as a career, either by continuing to manage the growing company or by taking on a new or different role. No matter the case, the value of these experiences should not be underestimated (Boh et al., 2015).

We need to increase the pace of translation while maintaining the standards of quality that we expect for new technology. This is a challenging process, and even the most promising findings of basic science and research can take a long time to reach the market. It is still being determined what an optimal translation rate from basic research to practical applications would be, but current rates appear relatively slow. It is crucial to accelerate the process of evaluating and adopting new research findings to address this issue. In order to be effective and valuable contributors to future research and innovation, we must work to improve the speed and efficiency of this process (Contopoulos-Ioannidis et al., 2003).

# Chapter 3

## PROCESS OF TRANSLATION

It is the founder's job to navigate the process of spinning your research out of the lab and into the market. The notion of the market may mean different things to different teams or technologies. Not every technology necessitates starting a for-profit company, nor does it mean venture capital is the required funding type. There are many paths, including for-profit, not-for-profit, venture capital funding, angel investment, government grants, and more.

The following sections will provide some context on just some of the dynamics you will need to consider as you bring your work from the research setting to the market that works for you. There is a high degree of variability in this process, so while you are reading, please note that there are many ways to accomplish the goal of bringing a novel solution to market.

Steps of spinning out

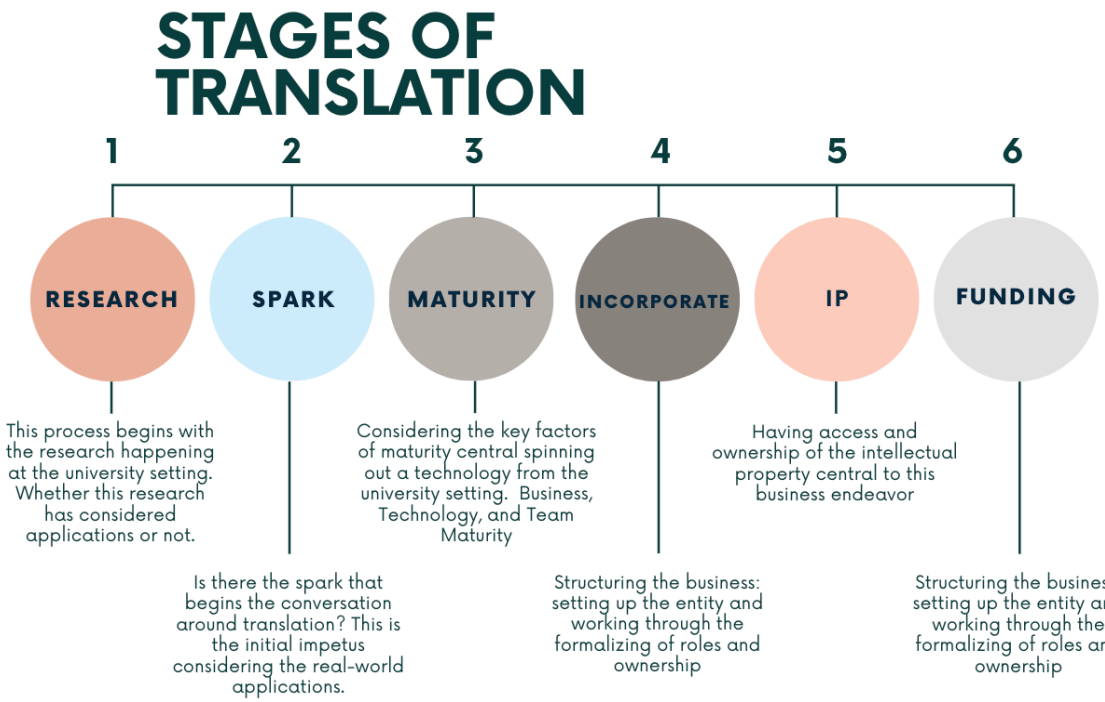


*Figure 2. Stages of Translation*

These first two sections research and spark are the basis of the translation process. Push innovation, as was reviewed, is taking a technology from the lab and finding a market for it. This process is heavily self-motivated and requires a person or persons to recognize its potential and decide to take on the effort of translation. There are many paths to commercialization, but among these paths, there are commonalities. These milestones can be helpful in thinking through what roughly needs to be accomplished as you move forward. These are helpful guideposts or milestones to remember as you consider your commercialization strategy. The order presented is only a recommendation and success can be found approaching these

milestones in a different cadence. Details on these topics will be further covered throughout the following section.

As you work through the progression bringing novel research to market research shows value in using your time in the university setting as an informal incubator. Universities often serve as informal incubators for businesses, providing a space for students and faculty to come together, form teams, and explore the possibility of commercializing technology developed in research labs. Using their time at university as an informal incubation period, students and faculty have the opportunity to refine the technology and develop strategic plans, which can help to reduce the market and technological risks associated with the venture. In this way, universities can play a crucial role in the success of academic spin-offs (Boh et al., 2015).

While not a formal incubator, attending university, students have the unique opportunity to work in the early stages of an academic spin-off without having to forgo a paid job. This allows them to explore their entrepreneurial interests and gain valuable experience without incurring the opportunity cost of leaving the job market. Using time while still affiliated with the school, students will have gained sufficient knowledge and information about the venture to make an informed decision about whether to pursue it full-time. This incubation period allows students to evaluate the potential risks and rewards of working on the spin-off and make a well-informed choice about their future career path. Overall, the university environment can provide a supportive and low-risk environment for students to explore their entrepreneurial ambitions and make informed decisions about their future careers and the technology they are working on (Boh et al., 2015). This time in the university setting offers a crucial period not only to mature and develop a concept but also for a founder to develop the necessary skills and understanding to undertake this effort.

One of the major uncertainties in launching a business based on university research is determining the right time to leave the lab and school and start the company. No definitive rule or clear signal indicates when it is time to make this transition. However, some general guidelines and considerations can inform this decision and explain the moment of readiness.

The head of MIT Deshpande Center for Technological Innovation explained the challenges of correctly timing the spinout. The goal is to bring the technology out of the lab as soon as it is ready, but not before. Finding the right balance and timing is important, as taking it out too early or leaving it too long can pose problems. If the technology is brought to market too early, it may not be ready for commercialization and struggle to secure funding or attract the right investors. On the other hand, if it is left in the lab for too long, it may miss out on growth opportunities and may be held back by the resources and support available at the university. Ultimately, the goal is to get the technology to a point where it is ready for funding and can take off on its own, but this process requires careful planning and evaluation to ensure success (L. Sandler, personal communication, October 19, 2022).

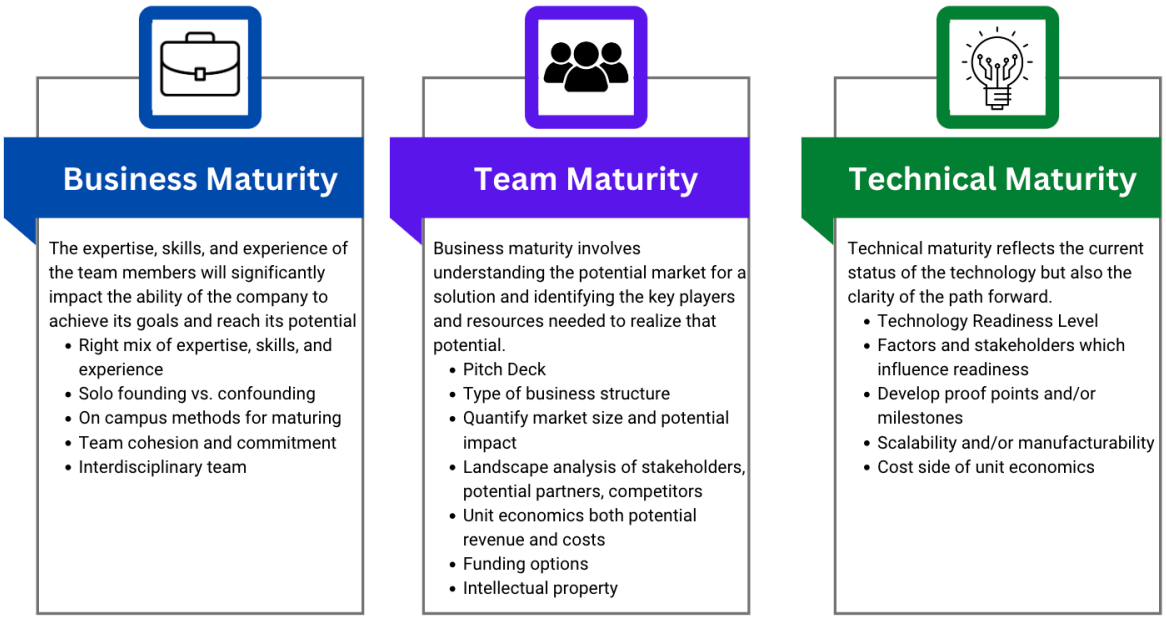


*Figure 3. Three Pillars of Maturity*

According to research and interviews, there are three main areas that founders should focus on to ensure their venture's success. These areas are technical maturity, team maturity, and business maturity. The level of maturity in each of these areas will significantly impact a founder's ability to secure funding, meet milestones, and achieve other key objectives. It is important to note that maturity does not necessarily mean that these areas must be fully developed from the outset but rather that they should evolve and improve over time. Maintaining focus on these three areas is crucial for a startup's long-term success.

No one-size-fits-all level of maturity is required across the technical, team, and business areas. Instead, a company's overall level of maturity should be viewed as an aggregate of its progress and capabilities in each area. As such, companies can spin out and achieve success with different levels of maturity in each of these areas. The examples provided in the case studies in section five demonstrate this point, showing that companies can succeed at various development stages in these areas.

Technical Maturity

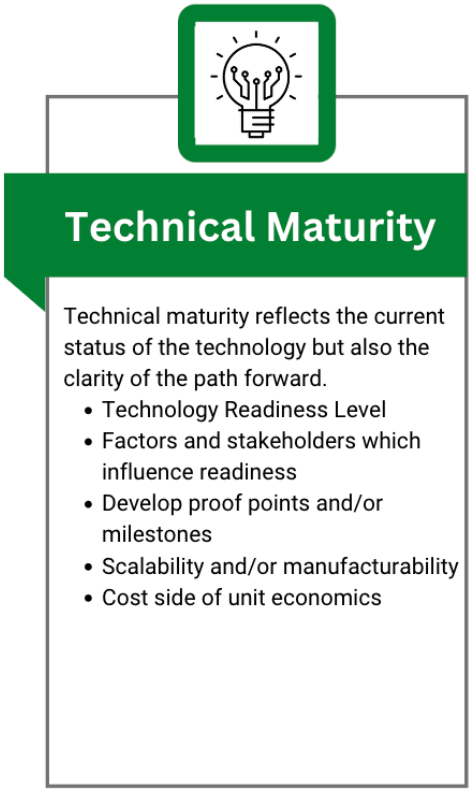


*Figure 4. Factors of Technical Maturity*

Technical maturity or technical readiness can be highly variable, especially as a business spins out of the lab setting. This is not surprising, given the long-time horizon that academic entrepreneurship tends to be on. It also requires partnership and collaboration with many stakeholders across a broad network. Technical maturity reflects the current status of the technology, but also the clarity of the path forward. To be successful, you do not need to work alone through this process. There are many resources to help. A considerable body of work highlights the relevance of collaborative research, contract research, consulting, and informal relationships for university-to-industry knowledge transfer (Perkmann et al., 2013). Ultimately, you need to figure out what the path is - what will it take to get to users (R. Langer, personal communication, November 30, 2022).

Basic research and science are crucial for establishing the technical maturity of a novel solution, but they are not the only factors to consider. A founding team must also gain confidence in the solution's technical maturity by achieving milestones and meeting objectives over time. In order to gain confidence in the technical maturity of a solution, it is essential for a founding team to consistently progress and demonstrate their progress through specific benchmarks and achievements. A model that was first developed by NASA, the Technology Readiness Levels (TRL), offers nine levels which represent the maturity of a technology going from Level 1 having to do with the basic principles such as the fundamental research observed and reported to a Level 9 which is having a user ready technology (Tzinis, 2012). Many companies have adopted and evolved the TRLs to better represent their industry or company, and this can be a great methodology for thinking about your path to user.

As you consider technology readiness there are many factors that go into what it means for a technology to mature. Innovation in the healthcare industry is a good example of the importance of considering these multiple factors beyond just the scientific rationale of a solution. For a technology to be successfully translated and commercialized, it is necessary to evaluate a range of criteria that includes the consistency of data from multiple disciplines, the use of biologically and medically plausible conditions in assay development, and the potential for off-target effects based on known mechanisms. Consider these factors early, as they may inform the need to redesign the technology to achieve greater specificity and effectiveness. Overall, it is crucial to consider a range of factors beyond just the underlying scientific rationale when evaluating the translational potential of a technology (Coller & Califf, 2009).

Another aspect of technical maturity is the ability to define key proof points that demonstrate the progress and potential of the technology. At the early stages of the entrepreneurial journey, the technology may not fully reflect the final vision. However, it is important to be able to communicate the path that will be taken to bring the technology to its full potential and how progress is being measured along the way. This is also important for estimating how much money it will take to reach those milestones (R. Langer, personal communication, November 30, 2022). This is important for convincing potential investors, stakeholders, partners, and customers to believe in the vision and invest in the technology. Defining key proof points can help show the path to technical maturity and may also be used by potential funders to release additional rounds of investment (a topic discussed further in the next section on Business Maturity; C. Elkins, personal communication, October 6, 2022). In short, clearly communicating the path to technical maturity and demonstrating progress along the way is an important aspect of technical maturity for any startup.

When evaluating the technical maturity of a product, it is important to consider its underlying scientific basis, scalability, and manufacturability. Can the technology be produced easily and at a reasonable cost? What will be the costs of bringing the product to end users? These are important questions as academic investigators may not have the knowledge or expertise to understand industrial-scale production's scientific and regulatory complexities. Additionally, some compounds and devices may be more expensive to manufacture than others, which can significantly impact the project's economic viability. Therefore, it is crucial to consider these factors from the beginning of the project to ensure the technology's success in the long run (Coller & Califf, 2009).

Business Maturity

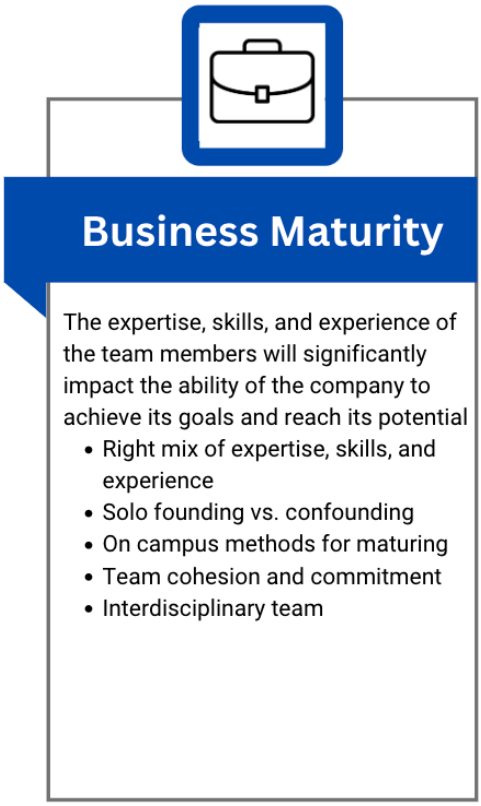


*Figure 5. Factors of Business Maturity*

Business maturity involves understanding the potential market for a solution and identifying the key players and resources needed to realize that potential. An essential part of communicating the details of a solution and outlining a plan for its operation is the "pitch deck," a presentation that showcases the business plan for a new venture. A strong pitch deck should include a clear description of the problem being addressed, a unique solution, a viable business model, and a strategy for bringing the product or service to market (Krukowska, n.d.). Whether presenting to investors, partners, customers, or potential team members, effectively communicating these key elements is crucial for the business's success.

Before you are able to develop valuable business insights you need to understand who your end user is and who will pay for this. A key limitations of push innovation is the concept of a solution in search of a problem to solve. As you begin to search for your market you will need to develop a deep understanding of the stakeholders and their needs. An invaluable resource in building this understanding is getting out and talking to potential stakeholders. This is a fundamental component no matter if you are doing push or pull innovation. There are structured formats that are recommended for this process and resources available to help support teams such as the NSF iCorps program which a link is provided to in the resource section. Talking to users and stakeholders allows the team to develop empathy for the role this potential solution might play in the user journey. It helps the team begin to understand the variables that are crucial and valuable to the various stakeholders, and how a solution might begin to support their needs. Doing user interviews should start at the very beginning of the translation process and

should continue as a consistent part of your business process. The insights you gather will be key factors in putting together your pitch deck.

A pitch deck will help demonstrate the team's business acumen and completing the pitch deck will help you understand expectations and requirements if you do not have a business background. We will not be going into depth on what a pitch deck should consist of because there are copious amounts of online information to this end; links can be found in the resources section. We recommend the resources available at the Martin Trust Center or the content on Y Combinator or Techstars online toolkits. It is important to note that you do not need to have all of the answers; instead, use your time in the University setting to begin filling your gaps in knowledge and build a network that can support your endeavors.

One of the critical early business factors is the potential size of this market and what you are trying to achieve. Knowing your goals for the entity and your work there will help you make decisions that impact development and growth. Part of this is what type of business or entity you are trying to create. You may be trying to build the next fortune 500 company, or you may be building a non-profit driven by factors other than money. This decision will impact how you raise funds, by whom, and how you structure your path to market. For the sake of this paper, we will focus on for-profit entities and businesses aiming to generate revenue as a primary goal, perhaps in concert with other goals such as impact.

In order to develop your business skills and understanding of the market opportunity for your product or service, it can be helpful to consider the "total addressable market" (TAM), "serviceable available market" (SAM), and "serviceable obtainable market" (SOM) as reflected in your pitch deck. By asking yourself questions about the market's size and potential, you can better understand your startup concept's economic viability (Chi, 2021). These figures help you determine whether the size and type of market indicate a high likelihood of economic success for your venture. Overall, understanding the market potential of your solution is an essential factor in developing a successful business plan and achieving long-term success (Coller & Califf, 2009).

It is vital to understand not only the potential market size for your product or service but also to personally assess whether this represents an ample enough opportunity to justify the time and energy required to bring it to fruition. You can use a top-down or bottom-up approach to calculate the TAM, SAM, and SOM figures reflected in your pitch deck. Both approaches have their advantages and can be appropriate in different circumstances. A wealth of information is available online to help you understand these approaches and determine the most appropriate one for your situation. Ultimately, the goal is to ensure that the potential outcome of your venture is worth the effort required to bring it to life.

The potential market size is also important as it impacts your ability to fundraise from venture capital if that is your intended path. There are many avenues of fundraising, and venture capital is just one of them. There are certain types of investors who work at different phases of maturity or with varying focal industries. Many variables go into what potential investors may engage with your entity. This topic will be important for you to understand as you launch your business out of the university.

Along with understanding the potential size of the business, it is vital to understand the landscape around the potential business. Who are the stakeholders, competitors, and potential partners? A potential partner who will work with you has been shown to impact the odds of success of university spinouts (Contopoulos-Ioannidis et al., 2003; Crowley, 2003; Coller &

Califf, 2009). Having an author affiliated with the pharmaceutical or biotechnology industry was associated with an eight-fold to ten-fold accelerated process (Contopoulos-Ioannidis et al., 2003).

A business variable that will be important to develop and improve your understanding of over time is the unit economics. Unit economics refers to the economics of a single unit of a product or service. It is a measure of the efficiency and profitability of the production and sale of each unit of goods or services. In the context of a business, unit economics can be used to evaluate the financial performance of a company, identify areas for improvement, and make informed decisions about pricing, production, and other aspects of the business. Unit economics consists of the potential revenue and the potential costs. Understanding who the end user is, who is the stakeholder who will pay for this, and how much you may be able to make from them is key to developing your business maturity. The other side of unity economics is the cost structure of this product or service. This focuses on items like the manufacturability of what you are producing and whether you can do so at a reasonable cost (Coller & Califf, 2009) which will flow out of the technical maturity. Understanding the costs is essential to understanding what you will be able to make per unit of your product or service. It is understood that this number will change over time. As the business grows you may get economies of scale, which improve your unit economics. You may lose money on each item sold, but you need to understand that and have a possibility and, if possible, a first hypothesis path to profitability. You can demonstrate this early thinking in your financial model, which captures the assumptions and market dynamics and paints a holistic financial picture showing how this business might function over the next 3-5 years.

While your business is not self-sustaining, you will need to acquire capital from outside sources to fill the losses you will incur to get this to market. Understanding how much you need and what sources this money may come from will be a critical factor in your success in spinning out the company from the lab—more information on venture capital and fundraising is in the venture capital section below. Beyond venture capital, funding options include but are not limited to angel investors, strategic partners, impact investors, government funding sources, and foundations. However, they are a common option for higher-risk early-stage companies. Impact investors often have a thesis and impact area they are focused on, and part of their key consideration is the type or scale of impact you potentially offer. There are government grants for startups or within specific industries. As discussed previously, there are also the strategic partners who are stakeholders, who may impact your business as it grows, and who may invest due to the value they see in the business's future.

The final topic for this section is the defensibility of your solution. This most commonly takes the form of intellectual property or IP. This is a crucial component of building a technology-based business. Not having IP or some barrier to entry may limit options for fundraising. Intellectual property is critical to pursue when and where possible due to the monopolistic nature of what it provides for your business as you work to grow and develop. The US patent system, protected by the Constitution and established by the founders of the United States, was designed to promote the public good and advance technological progress by encouraging the dissemination of knowledge. Its purpose is to incentivize innovation and encourage sharing of new ideas and technologies. However, some academic investigators may oppose patenting inventions as they believe it conflicts with the free exchange of knowledge (Coller & Califf, 2009). Coming from the research setting, if you are interested in building a business from the research you are working on, you should be protecting your invention and publishing it (R. Langer, personal communication, November 30, 2022). At MIT, the Technology Licensing Office is the critical stakeholder in the IP process. More about the TLO in additional considerations.

Team Maturity

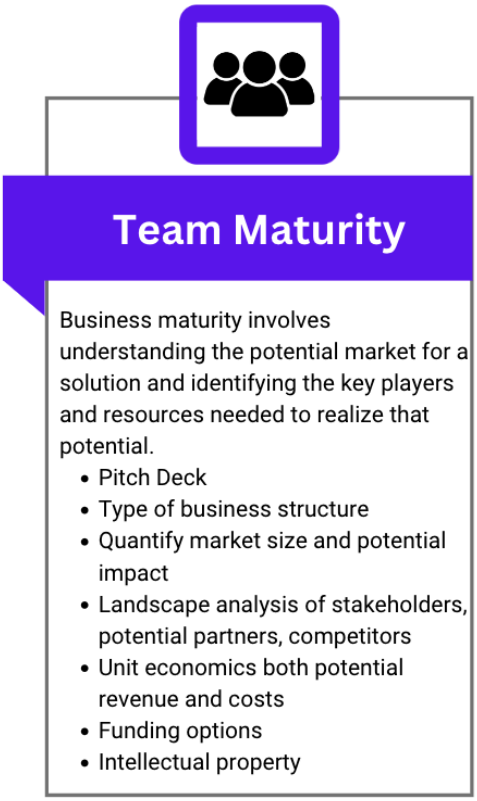


*Figure 6. Factors of Team Maturity*

The organization's human capital, including the founding team and any additional members brought on as the company grows, is a crucial factor in the success of the startup. The expertise, skills, and experience of the team members will significantly impact the ability of the company to achieve its goals and reach its potential. As such, it is important for startups to carefully consider their team composition and continuously strive to build a solid and capable team. This section explores team maturity and factors of import as teams look to build companies out of the university setting.

The team is a central item of note for potential investors in early-phase companies. From the investor's point of view, when evaluating the founding team, it is important to consider whether the team has the right expertise, skills, and experience to achieve the company's goals. Assessing these factors is both an art and a science, as it involves evaluating the team's ability to persuade and inspire others and their practical skills and experience. There is a lot of interfacing and support for many early investors, so they are also asking if they want to work with this team. Ultimately, it is crucial to carefully evaluate the human capital of an organization in order to ensure that it has the right people in place to drive success (V. Beranek, personal communication, October 5, 2022).

Some prospective founders may consider going the solo founder path. This is doable but not advisable for someone starting a company on their own. MIT researchers found that solo entrepreneurs are "considerably less likely to build successful companies than were team". This

factor is so important that it has become a mainstay in curriculum design for entrepreneurship, a team-based approach, in many classes (Roberts et al., 2015). This message is repeated in many forums, such as Y Combinator, one of the leading accelerators. "Our advice remains that one-person startups are tough, and you are more likely to succeed with a co-founder." (Frequently Asked Questions, n.d.).

While finding a partner or partners to work with on your startup can be beneficial, it is important to ensure that you find the right partner or partners. According to research, science-based entrepreneurs should know that their involvement and commitment will be essential for successfully commercializing their technology (Knockaert et al., 2010). It is also important to consider adding team members with a commercial background to the founding team, as they can bring valuable knowledge and experience to the table. However, science-based entrepreneurs may be hesitant to bring on team members with a commercial background. They may worry that these individuals will not fully understand the technology and will try to rush the product to market too quickly. One way to alleviate these concerns is to consider adding team members with both a technical background and commercial expertise. However, it is important to note that simply having commercial experience on paper does not guarantee that an individual has a commercial mindset (Knockaert et al., 2010).

Many options are available for filling the positions on the founding team and beyond. Teams may include faculty principal investigators (PIs), experienced entrepreneurs, PhDs, post-doctoral students, and business school graduates (Boh et al., 2015). That said, graduate students play a critical role in the spinning out of businesses. The students involved in these academic spin-offs are often knowledgeable about the technology and highly motivated to bring it to market. They have access to expertise within and outside the university, and their opportunity costs are relatively low as students. While they may need more formal business expertise and experience, our research suggests that with the appropriate support from the university and broader networks, they can effectively navigate the transition to private funding (Boh et al., 2015).

Team maturity examines the readiness to launch and run a company. Only some people straight from their studies are ready to commit or capable of fundraising. Again, this is where academia is valuable as a proving ground and space to learn and grow. For instance, fellowships exist to help the team learn what it takes and how to climb the learning curve. It provides the space to see if they can build a team around their cause (V. Beranek, personal communication, October 5, 2022). It comes back to this idea of the university as a form of incubation, where you and your team learn and develop the necessary skills or find others to support your mission. To that end, there is no replacement for doing the work and getting the experience. This may mean getting yourself out there to develop your network in the relevant space or getting internships and jobs that provide an interface with areas of professional work that may benefit your entrepreneurial process (R. Langer, personal communication, November 30, 2022).

Team cohesion is a function of independent team members' ability to work together and is a key factor in successful teams (Martens & Peterson, 1971). You want to build and develop a cohesive, committed, multidisciplinary team. Team cohesion allows the team to grow and develop, often through uncertainty, and for team members to build trust in each other (T. Knight, personal communication, October 11, 2022). Getting a new team to a point where there is mutual trust and engagement is challenging and comes down to the role of management in creating a culture and facilitating communication. You must create a space where it is okay to make mistakes and to say, "I don't know." Teams have to be accountable, and they need to be

open with each other. You do not single people out, and you share mistakes (C. Elkins, personal communication, October 6, 2022).

Perhaps the most difficult for team members at this phase is commitment. Commitment is the question that each team member needs to ask: are you here for the long journey ahead? A leader might ask: who is willing to spend the next five to ten years in this startup? If people are anything but committed, it will likely not happen (L. Sandler, personal communication, October 19, 2022). This is because starting a business requires a significant investment of time, energy, and resources, including financial, intellectual, relational, and emotional resources (Brodack & Sinell, 2017; Parente & Feola, 2013). Entrepreneurial commitment is crucial "for a potential venture to be taken forward from a vision that the researcher has created in his mind, to the formation of a running business" (Parente & Feola, 2013). In the field of organizational behavior, commitment is typically defined as a strong emotional and psychological attachment to an organization and its goals. It can be demonstrated through identification with and involvement in the organization's projects (affective commitment), a sense of willingness to put in the significant effort (normative commitment), and a desire to remain a part of the organization in the long term (continuance commitment). Commitment is important because it can impact an individual's motivation, effort, and engagement in their work and their likelihood of staying with the organization (Brodack & Sinell, 2017; Meyer & Herscovitch, 2001; Mowday et al., 1979)] Building and developing a team with all three types of commitment is important.

The last factor is the importance of an interdisciplinary team. According to research from MIT, startups with co-founders from diverse or complementary disciplines, such as engineering and management, tend to perform better and have stronger foundations for future success. The most successful startups are often co-founded by individuals with technical expertise and those with experience in marketing or sales (Roberts et al., 2015). Interdisciplinary teams, made up of individuals with diverse skills and knowledge, have been shown to be effective in engaging with their ideas, maintaining productive interaction, and successfully implementing those ideas. This is because they can bring a range of perspectives and approaches to problem-solving, which can be beneficial in helping to overcome challenges and develop innovative solutions. Additionally, interdisciplinary teams can foster a culture of collaboration and open-mindedness, which can be crucial in driving success in the highly dynamic and constantly changing world of startups and innovation (Brodack & Sinell, 2017). Diverse teams have even been shown to reduce the time to the outcome compared to other firms (Beckman et al., 2007).

# Chapter 4

## ADDITIONAL CONSIDERATIONS FOR TRANSLATION

### Incorporation and Equity Split

Incorporating your business is when you have selected which type of legal entity you plan to be and file the paperwork to be legally recognized as an entity. This can be done on your own, but it is recommended that you utilize legal support services to ensure that you are optimally setup. There are many law firms that specialize in early phase startups. When you are looking for counsel, it is a good idea to have multiple conversations to find a person or team that you work well with. It is generally understood that a very early-stage startup does not have the resources to support paying the fees of a law firm, but it is possible to find a partner who will allow you to defer expenses for a period of time or until a financial milestone is reached. This can and should be a part of your conversations as you are trying to find your legal partner as they can be a valuable resource as your entity grows.

Part of the formalization of the legal entity is ownership equity and establishing the capitalization table. The capitalization table is a record of the equity ownership in a company. It shows the number of shares of stock owned by each shareholder, along with the percentage of ownership each shareholder has in the company. The process of incorporation is an important period where the founding team can and should sit down and sort through the formalization of the previous conversations around commitment, roles and responsibilities and much more. The equity split is only a portion of this greater, ongoing, conversation but it represents a good opportunity to ensure that you as a founding team are on the same page.

Determining the equity split between the founders of a startup can be challenging and complex. There are many factors to consider, including:

- The roles and responsibilities of each founder
- The amount of time and effort each founder is committing to the company
- Outside investments or contributions being made to the company

It is crucial for founders to have open and honest communication about their expectations and to seek legal advice to ensure that the equity split is fair and aligns with the company's long-term goals. Ultimately, the equity split should reflect each founder's value and be flexible enough to account for changes in roles and responsibilities as the company grows and evolves.

This process is further compounded coming out of the academic setting due to potential PI or professor involvement as well as the school. There are some general guidelines to consider when approaching these difficult conversations. First off, an even split between founders is rarely the best choice. Building in a structure that allows for flexibility and a changing environment is crucial to manage from the start (Buchanan, 2014). Also, academic founders, who may or may not include professors or PIs, take a historical perspective looking at the equity split through the lens of the work that has been done so far. This is not the recommended approach. Leon, the head of one of the entrepreneurial centers on MIT's campus, the Deshpande Center, which has worked with countless startups out of the academic setting, recommends that equity should split based on the contribution going forward. Leon’s questions are: *what value do you bring and what risk are you taking* (L. Sandler, personal communication, October 19, 2022). More resources to review and consider will be provided in the resource section.

## Intellectual Property and Technology Licensing Offices (TLO)

Intellectual property is often a central component to a university spinout. Having a defensible technology means that you are able to block others from moving into this space by copying your technology. It is said that intellectual property and having a patent confers a legal monopoly (Blair & Wang, 2017). Having a patent or patent portfolio along with an intellectual property strategy can be central to building a successful business. These patents hold value in and of themselves and it is possible to buy and sell patents or the right to use patents. Furthermore, having this patent in place gives you a time bound period within which you will be able to work to develop that technology without competition. A defendable idea can mean patenting, but it can also utilize a trade secret, copyright, or trademark. Having a defendable idea is very important for a new company to reduce pressure of competition and to help in the fundraising process. Central to this process at the university setting is the technology licensing office.

University technology licensing offices play a crucial role in facilitating the formation and success of startups based on technology developed at the university. These offices protect and commercialize the intellectual property developed at the university, and they help connect entrepreneurs with the resources and support they need to turn their ideas into successful businesses. This includes assisting with the licensing of technology, identifying potential partners and investors, and providing guidance on legal and business matters. By working with technology licensing offices, startups can access the expertise and resources they need to navigate the complex process of bringing new technology to market and scaling their business.

At MIT, the TLO is a partner in entrepreneurship. "Our mission is to move innovations and discoveries from the lab to the marketplace for the benefit of the public and to amplify MIT's global impact. We cultivate an inclusive environment of scientific and entrepreneurial excellence, and bridge connections from MIT's research community to industry and startups, by strategically evaluating, protecting, and licensing technology." (About the TLO | MIT Technology Licensing Office, n.d.). As you complete your research and are ready to publish, the TLO should be engaged to help with the disclosure process (About the TLO | MIT Technology Licensing Office, n.d.; B. Rockney, personal communication, October 20, 2022)]. Protecting your asset often starts with a provisional patent application which provides you protection for 12 months with the option to file for a patent at any time during that period (Provisional Application for Patent, n.d.).

As stated in the mission, the TLO is motivated to get MIT's research to market. There are dual factors within that: first, there is the money-making potential of these inventions, which benefits the university with licensing agreements from the use of the technology. Second, there is also a motivation to benefit society with the research conducted at the school. The TLO is a central catalyst for achieving that societal outcome.

After your novel invention has been protected with a provisional or complete patent, consider: *when and how should you engage with the TLO in your entrepreneurial path?* Engagement is recommended when your entrepreneurial plans are maturing, and you are considering spinning out of the lab. The option is the most common agreement between a startup and the MIT TLO. This is a low-cost method of obtaining the rights to use the technology in a business. It works as a promissory note to license and can be constructed and approved relatively quickly (B. Rockney, personal communication, October 20, 2022). This allows you to go to potential funders and have a document guaranteeing the right to use the technology. Also, part of this

discussion with the TLO can involve exclusive rights to the technology. This option functions as an option to license the technology at a future date if the option is executed by the receiving organization (B. Rockney, personal communication, October 20, 2022).

The TLO does have to balance between its stakeholders. In a case where multiple named participants are on the IP; it comes down to a discussion between the parties to sort out who is taking what rights to the intellectual property between the professors and researchers. Another factor that they must consider is the odds of success. Their goal is to see MIT technology in the market. To that end, when you contact them about licensing technology, they will want to engage you around your ability and capacity to bring this to market. This can be complicated if a prominent player in the market is also interested in the technology. However, special consideration is generally given to the MIT academic entrepreneurs (B. Rockney, personal communication, October 20, 2022).

Lastly, what does this agreement look like? The TLO has a body of prior options and usually starts with a template. From that starting point, the options construction is a conversation, and much of the language is customizable. The agreement may consist of one or many "cases" which are inventions (B. Rockney, personal communication, October 20, 2022). Packaging multiple cases into a single agreement is not linear in terms of costs or outcomes. The number of cases, as well as the importance of the IP to the endeavor, does impact the agreement. If the IP is broad and foundational, then MIT can ask for more (B. Rockney, personal communication, October 20, 2022).

## Raising Funds

### *Angel Investment*

Angel investors are individuals who provide capital for a startup in exchange for ownership equity. They are typically high-net-worth individuals who invest their own money in early-stage or startup companies. The amount of money that an angel investor invests can vary greatly. Some angel investors may invest as little as a few thousand dollars, while others may invest hundreds of thousands or even millions of dollars. It is common for angel investors to invest between $15,000 and $250,000 in a startup.

In addition to providing capital, angel investors often bring valuable expertise, networks, and mentorship to the table. They can provide valuable advice and guidance to the entrepreneurial team, helping them to navigate the early stages of starting a business. They may also have extensive networks that they can tap into to help the startup find customers, partners, and other resources. Angel investors may also have a personal interest in the success of the business or industry. They may be willing to go above and beyond in supporting the team to see the business succeed. Overall, angel investors can be a valuable asset to an entrepreneurial team, providing financial resources and their expertise and connections.

### *Venture Capital*

For many fledgling companies, venture capital is the goal. So, the question becomes, what is venture capital thinking about in terms of early investments? While venture capitalists are looking at many factors, central to their ability to invest is a ratio between the total potential of an opportunity and the total risk. You can motivate the total top-line potential and prove that the risks are manageable and that there is a path to retiring risk. In that case, there is a theoretical

sweet spot for each VC where they become interested in investing. Your goal as a founding team is to prove these components out (O. Kozlowski, personal communication, December 8, 2022).

This is where the previous discussion on TAM, SAM, SOM, competitor landscape, partner landscape, the path to the customer, and many other factors from the maturity section comes into play. A word of caution on taking on investment. An investor is a long-term partner. Once on your capitalization table, these people or entities will have a say in your business, often for years. This can be fantastic when an investor is aligned with your mission and vision, understands your space, and has a track record of working well with founders. However, it is not always a great relationship. So, when considering taking on investment, you should consider carefully who they are and how they work. Choosing your investors is not always a luxury you have, but when the choice is available, you should proceed with careful deliberation.

***Government Funding***

US government funding for startups commonly comes through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. These are competitive, merit-based grants offered by the US government to encourage small businesses to engage in research and development that has the potential to lead to technological innovation and commercialization. These programs fund small businesses to conduct research and development work in partnership with a research institution, such as a university, to bring innovative ideas to the market (SBIR.gov, 2019).

The SBIR program provides funding for small businesses to explore the feasibility of their innovative ideas, while the STTR program requires a small business to form a partnership with a research institution to conduct research and development work. Both programs have three phases: Phase I provides funding for small businesses to conduct feasibility studies and assess the potential of their ideas; Phase II provides funding for businesses to continue the development and testing of their technology; and Phase III provides funding for businesses to commercialize their technology and bring it to market (SBIR.gov, 2019).

To be eligible for SBIR and STTR grants, businesses must meet specific criteria, such as being a small business as defined by the Small Business Administration, being at least 51% owned and controlled by US citizens or permanent residents and being for-profit. The programs are open to a wide range of industries (SBIR.gov, 2019).

Some examples of government funding resources for American university-based startups such as MIT include:

1. Small Business Innovation Research (SBIR) program: This program provides grants to small businesses to conduct research and development (R&D) in order to bring new technologies to the market (SBIR.gov, 2019).
2. Small Business Technology Transfer (STTR) program: This program provides grants to small businesses to collaborate with research institutions on R&D projects.
3. National Science Foundation (NSF): The NSF provides grants to support research and education in science and engineering (SBIR.gov, 2019).
4. Department of Energy (DOE): The DOE provides grants and funding to support energy-related research and development (Funding Opportunity Announcements and Grants, n.d.).
5. National Institutes of Health (NIH): The NIH provides grants to support research in biomedicine and health (SEED - Helping Innovators Turn Discovery into Health, n.d.).

6. National Aeronautics and Space Administration (NASA): NASA provides grants and funding to support research in aeronautics and space (NASA SBIR & STTR Program Homepage, n.d.).

# Chapter 5

## CASE STUDIES

This section will view current companies that successfully navigated the translation process out of the MIT ecosystem. These are companies across industries with diverse sets of teams and experiences. By viewing the factors that led to their success, you may better contextualize the factors discussed throughout this research.

### Commonwealth Fusion Systems

***Background***

Commonwealth Fusion Systems (CFS) is a company working on developing fusion energy. CFS uses a specific type of fusion called magnetic confinement fusion, in which a plasma (a gas of ionized atoms) is contained and heated to very high temperatures using magnetic fields. The company is working on developing a fusion reactor called SPARC, which aims to produce electricity from fusion on a commercial scale. CFS was founded in 2018.

The founding team had all worked together for years at MIT in a lab working on fusion. The government had been the primary funding source for this research, but in the early 2010s, congress moved forward to end its support. The founding team had little experience in business or fundraising, but they knew that to continue their work, they would need to find a new source of funding. They began by looking for philanthropic funders interested in funding this vital next-generation energy source. They used their network and outreach to engage multiple foundations. However, because of the size and scope of the potential impact and the size of this potential market, these funding sources recommended that the team start a business, and they would be more inclined to invest.

***Technical maturity***

Their technology maturity revolved around the age and maturity of their space and their unique value proposition of magnet innovation. Tokamak reactors have been around for over 50 years, and there have been multiple manufactured. For CFS, their magnet is the essential technology they are bringing to this process. So, the complexity came down to the magnet itself.

***Business Maturity***

In looking at their preliminary funding round, they realized they could either do a small desktop proof of concept or go straight to a large-scale milestone. In talking with their mentors and potential funders, they chose to go for the large proof point and raised a $100M+ series A as their initial fundraise. This decision was important because the tools and lab required for their work were a large investment, so fundraising a small pre-seed round would enable them to move effectively into the space.

The team spent a lot of time leading up to their fundraising efforts developing an 800-slide pitch deck. This deck began with the conventional slides and was supported by an appendix that they worked extensively on to answer all the potential questions they could foresee. This effort showed their deep understanding of the industry and market dynamics and demonstrated their knowledge of the effort that lay ahead working to develop this technology.

***Team Maturity***

At the point the CFS team was considering translation, six people had been involved through academia. This group became the core team, and they had many conversations working through who would take on what role. There were team members who were professors who would likely stay in academia and others who were ready to engage full-time in the company. They ultimately decided to have three team members launch the corporate entity, and the three in academic roles stayed at the university. Their shared history of years of working together enabled them to work through these conversations and figure out roles and ownership. They still had to convince the investors that they were the team that was fully capable of bringing this from the research lab to a viable energy source.

***Post Launch***

With this initial investment, they were able to go to MIT and negotiate a three-year sponsored research agreement with their team members who were remaining at the university. This agreement was a win-win because the university had lost the government funding to support the fusion research and their team required the infrastructure, lab space, and equipment to work effectively.

The CFS team has recently hit major milestones demonstrating the potential of their novel magnet technology. Along with this they have raised through a series B and have onboarded $2 Billion in capital to support their continued endeavors (Commonwealth Fusion - Crunchbase Company Profile & Funding, n.d.).

## Ginkgo Bioworks

***Background***

Ginkgo Bioworks is a biotech company that uses engineering principles to design and produce biological solutions. Ginkgo Bioworks uses a combination of software, robotics, and biotechnology to design and create new biological systems for various applications, including producing ingredients for fragrances and flavors, developing new protein-based drugs and therapies, and creating sustainable and environmentally friendly products. The company's core technology is its platform for designing and building custom organisms using synthetic biology.

***Technical maturity***

The team had spent years working on the genetic engineering to produce purpose-built bacteria. These engineered organisms can be customized to fit a customers or markets specific needs. The team was on the forefront of synthetic biology and were actively building a new industry. By the time the team was preparing to graduate they had a deep understanding of the technology and high confidence in their ability to utilize this technology for the market. They did not however have a single use case matured or ready for market as they began the company.

***Business Maturity***

The team did not deeply understand how their solution fits into the market. They had a novel technology, but the industry it would work in still needed to be created. So, they began by bootstrapping their business with limited research funds and money from their faculty team member. They knew the target, but they needed a product. They were a solution looking for a problem. They had to explore all industries to determine who had problems they could help with. They had this bio-engineering solution and, because of their work, knew how and where it could help.

They did know from day zero that they wanted to set up a general-purpose laboratory. They knew they did not want to be deep into a single market early on. With a vast set of potential application areas, they felt it was important not to focus on just one. They wanted to be creating the technology that would let them address many market needs.

***Team Maturity***

Ginkgo was started by a group of graduate students, undergraduate students, and faculty. They met and worked together through the International Genetically Engineered Machine (iGEM) competition, which was started at MIT. As graduation began to near for team members, they looked at their post-graduation options and decided to explore the idea of starting a company. The concept they were considering was the basis of Ginkgo bioworks. Their core team had a mutual understanding of strengths and weaknesses and had worked together through school and iGEM, developing team cohesion. They knew that one of their team members would be their CEO, and the rest of the team has grown and developed their skills and experience in their current roles.

***Post Launch***

Launch for the Ginkgo team was not an immediate leap into outside investment and hyper growth. They started the company by bootstrapping, working to keep costs down as they worked to develop the business. They were able to find grants and team members partially worked in the university as they developed the technology and primarily self-funded in the early years. Their goal, in this early time was to figure out where and how they would make their impact.

During this time, they explored quite broadly. They were able to find industry partners and generate revenue by exploring solutions for various industries. So, while they were founded in 2008, they did not fundraise until 2014, when they were the first biotechnology company to go through Y Combinator. They have since found success developing their industry and most recently raised a series B which brought their total funding to over $800 Million (Ginkgo Bioworks - Crunchbase Company Profile & Funding, n.d.).

## Mantel

***Background***

Mantel has developed a novel solution in the carbon capture space. Using molten salts Mantel's technology is able to absorb and regenerate a pure stream of CO2 that can be stored or utilized (Mantel Launches Carbon Capture Technology to Reduce the World's Atmospheric CO2 and Help Achieve Net-Zero, 2022). Their team is developing a platform of solutions to reduce emissions in industries such as industrial heat, cement, steel, and hydrogen. It can also be used in conventional energy production facilities using coal and natural gas. Mantel was founded in 2022.

***Technical maturity***

This enterprise came out of the doctoral research of the founder Cameron Halliday. During his PhD studies, Cameron came across this research on molten salts and their interesting effects on carbon capture. He was able to dig into this field of research, and it took a few months to go from scientifically interesting to realize that this could be game-changing. It took four to five

years to develop the research and write the papers that showed that this was a viable technology. He used his Ph.D. pursuit to mature the technology: optimizing and understanding the materials, developing bench scale systems, looking at corrosion, and more. At the same time, he understood that the carbon capture market was well-established and proven. There was also a generally established path of technology readiness that was needed to establish a solution in the space.

***Business Maturity***

Upon completing his thesis and PhD work, he moved to business studies and pursued his MBA. He was not focused on the entrepreneurial path at this time but instead was learning more broadly about business. He was ultimately convinced to apply to a class 15.366 Climate and Energy Ventures, which draws some important players from the clean energy field. You apply for the class, which he did, and the goal is to build a team with or without an idea and try and develop a solution.

They were tasked with understanding the industry, customer discovery, business model development, maturing the narrative, and more. Cameron found this very helpful because he had come from this world of research. As he explained, PhDs tend to get bogged down in experiments, engineering, and dealing with limitations. He had lost sight of the big picture, but you need to realize that if you can solve these problems, you can solve a major global problem. While he was studying for his MBA, the market need, and ecosystem were also maturing.

***Team Maturity***

The MIT class 15.366 brought together a multidisciplinary group. The class interest in his project led to the development of a seven-person team. Due to the nature of the class being about real-world applications they were able to work together and begin to build the team dynamics that would carry the concept forward.

Meanwhile, through his MBA studies Cameron had begun to de-risk himself. He did this through getting internship work experience and an offer from a prestigious consulting company. He was coming into the final year of his study, which ended up being his runway. It took 12 months to develop the narrative and to realize this was something that he could build a business.

He used this final year to build a team using his classroom partners and the broader school. He also began working with the TLO to build the licensing agreement. He also had to navigate the conversation with the faculty he had worked with on his research. Ultimately, his team was able to begin fundraising and finalize their term during the summer after graduation.

***Post Launch***

Through the network they developed out of MIT and the surrounding community the team was able to spin out and fundraise. They have since worked closely with this network they have developed, even having The Engine (The MIT built VC fund) participate in their fundraising. They recently closed their Seed round and have raised a total of $2 Million in funding (Mantel - Crunchbase Company Profile & Funding, n.d.). The team is continuing to grow and develop working to bring their technology to market.

# Chapter 6

## SYSTEM LEVEL MODELS OF SUPPORT

The process of translation is ambiguous and challenging but the results can not only enrich the team, but also the university, and society as a whole. This paper explores variables for the team to consider and attempts to provide supporting material which the founder/s could use to consider their path through translation. A topic for future research should include what institution resources may be leveraged to further improve this process. With all of the potential benefit hinging on the ultimate success of the fledgling company there have been some interesting advancements in systemic approaches to supporting translation. This is a movement toward the university increasing its role as a partner in the founding process. This can take many forms from providing space and resources for student entrepreneurs to work or taking a more direct role by injecting entrepreneurial resources into the research process.

An example of universities creating more space and providing resources for students to pursue entrepreneurship is the MIT entrepreneurship ecosystem which includes the Sandbox fund and the Martin Trust Delta V incubator. The Sandbox fund provides up to $25,000 for student teams and provides direct mentorship from industry experts. This creates a collaborative environment that pushes students to improve their entrepreneurial endeavor over time before hopefully launching out on their own. The Delta V is a university supper incubator program which accepts a set of teams and provides them with an exhaustive and engaging program to focus on their startup for a summer. This includes financial resources, mentorship, and camaraderie as the student teams work throughout the summer to bring their startups to life.

The more involved form is what is being done at Harvard's Wyss program or HAI at Stanford. In these setting the setting the school is taking specific steps to intercede in the research process to explore the potential for entrepreneurship. Looking at Wyss specifically, "We employ a unique model of technology translation within academia. Technologies conceived in our research laboratories are refined and de-risked technically and commercially by our Advanced Technology and Business Development teams. Our technologies are licensed to newly-founded startup companies or industry partners to bring about positive, near-term impact in the world." (How We Work, n.d.). Using these technical, business development, and strategic intellectual property teams they are able to study research even as its still under development to understand its potential implications. They have a technology innovation funnel that works to refine, validate, optimize, and commercialize a novel innovation from the lab. Bringing in resources to support the technology working to ensure that technologies that may provide impact if spun out are given the consideration and supported needed to attempt it. The goal is to refine the technology, de-risk the effort, prove out the potential impact and provide a structure with timelines to move project forward. Ultimately, they prescribe to a natural selection methodology where technologies that prove themselves given the criteria for the phase of the funnel it is in continue and those which can't, don't move on (How We Work, n.d.).

Beyond the academic setting there are models of venture capital which are working to de-risk the pursuit of new ideas which may be very beneficial for an academic audience. A venture studio is one of these models. In this approach the studio works to create and launch multiple startups within a short period of time, often through the use of a team of in-house entrepreneurs. This model de-risks being a founder by providing the necessary resources and support for these startups, including funding, mentorship, and access to a network of industry experts. This model allows the venture studio to rapidly test and validate ideas, as well as scale successful startups

more quickly. It also allows startups to benefit from the resources and expertise of the venture studio, helping them to overcome some of the challenges associated with starting a new business. An example of this is Flagship Pioneer, out of Cambridge, which develops ideas in-house as well as using cutting edge technology as the basis of companies out of the university setting.

These new mechanisms in and around the university setting facilitate the translation of technology into the market, either through improving the process of spinning out or by creating a structure for technology to be developed outside of the university setting. With the ultimate goal of increasing the level of impact from research at the university level, these represent viable options which might greatly increase the level of success.

# Chapter 7

## DISCUSSION

As research institutions continue to define the technology of the future it is essential that the system for bringing societal value from this work continues to mature. By creating a holistic system of support around the research and the research teams, we may work to close the gap between the volume of potentially meaningful research and innovations that make it to market.

Efforts need to be taken to improve our understanding of the intricacies of translation and what factors might necessitate new or different approaches. To better understand the impacts of efforts in this space there needs to be an improvement in measuring outcomes. Potential metrics might include the rate of technology licensing and the mix of who is licensing that technology be it university affiliated resources or established companies. The volume of startups being founded by resources out of the university setting and an improved accounting of their growth and impact over time perhaps measured in financing raised, the number of rounds of financing secured, customers served, and more.

By improving the measurement of outcomes, a more scientific approach to creating new support mechanisms can be measured and analyzed. For instance, with the onset of new university approaches such as the work being done at Wyss, future researchers would benefit from this data in an effort to understand which models have the most impact. This intern may improve adoption by institutions across geographies.

Beyond the measurement of new entities being created better understanding the impacts to human capital in this space would be invaluable in increasing the adoption of entrepreneurial paths by students, researchers, professors, and more. Better measuring the funnel of talent in the space and understanding how these entrepreneurs and potential entrepreneurs are approaching this career choice may help shape future efforts to further expand this funnel. Further research should be conducted in how to continue to reduce friction to entrepreneurship to not only spur future success of startups but to create the best possible alternative to the many PhDs coming out of academia every year who will be essential to future startup success.

# Chapter 8

## RESOURCES

This section provides a series of resources for various topics to support individuals or teams in their efforts of translating technology to industry. This list is not exhaustive but represents the start of useful resources worthy of considering as you and your team move forward.

### General Entrepreneurship Resources:

- A founders agreement is a template for a conversation and structure for discussing difficult topics like roles and equity. Working through this process as you build your team may help navigate difficult team conversations. A template is available online through The University of Pennsylvania.
    - https://www.law.upenn.edu/clinic/entrepreneurship/startupkit/founders-agreement.pdf
- The NSF iCorps program is a structured approach to develop your market understanding. They provide mentorship for groups trying to build deeper stakeholder understanding.
    - https://beta.nsf.gov/funding/initiatives/i-corps
- The Y Combinator startup library can answer many questions from how to build a pitch deck to how to navigate challenges.
    - https://www.ycombinator.com/library
- Techstars startup toolkit:
    - https://toolkit.techstars.com/

### MIT Entrepreneurship Resources:

- Martin Trust, Center for MIT Entrepreneurship is an excellent resource for entrepreneurship on campus including courses available on various topics of entrepreneurship, student organizations, advisors, and more.
    - https://entrepreneurship.mit.edu/
- The MIT TLO as discussed, is the organization that works to ensure protection for novel discoveries.
    - https://tlo.mit.edu/engage-tlo/contact-us
- The BU law clinical is a free legal resource for startup teams from MIT who need limited support or advice.
    - https://sites.bu.edu/startuplaw/
- The Venture Mentor Service is an organization that can provide mentors from related fields who may be able to support fledgling startups from MIT.
    - https://vms.mit.edu/
- The MIT Alumni directory provides a list of former MIT students who may be helpful resources.
    - https://alum.mit.edu/online-alumni-directory-virtual-tour-video
- MIT Industrial Liaison Program has resources who work with industry partners who can assist in finding useful connections with potential industry partners and more.
    - https://ilp.mit.edu/

## References


About the TLO | MIT Technology Licensing Office. (n.d.). Tlo.mit.edu. Retrieved January 5, 2023, from https://tlo.mit.edu/engage-tlo/about-tlo

Bayh-Dole Act. (2022, March 24). Office of Research & Innovation. https://drexel.edu/research/innovation/technology-commercialization/bayh-dole-act/#:~:text=The%20Bayh%2DDole%20Act%2C%20formerly

Beckman, C. M., Burton, M. D., & O'Reilly, C. (2007). Early teams: The impact of team demography on VC financing and going public. Journal of Business Venturing, 22(2), 147–173. https://doi.org/10.1016/j.jbusvent.2006.02.001

Beranek, V. (2022, October 5). Thesis Interview (J. Drutchas, Interviewer) [Personal communication].

Blair, R. D., & Wang, W. (2017). Monopoly Power and Intellectual Property (D. D. Sokol & R. D. Blair, Eds.). Cambridge University Press; Cambridge University Press. https://www.cambridge.org/core/books/abs/cambridge-handbook-of-antitrust-intellectual-property-and-high-tech/monopoly-power-and-intellectual-property/3C8E1E63626C511F9F483511A8599BB0

Boh, W. F., De-Haan, U., & Strom, R. (2015). University technology transfer through entrepreneurship: faculty and students in spinoffs. The Journal of Technology Transfer, 41(4), 661–669. https://doi.org/10.1007/s10961-015-9399-6

Brodack, F., & Sinell, A. (2017). Promoting Entrepreneurial Commitment: The Benefits of Interdisciplinarity. Technology Innovation Management Review, 7(12). https://www.timreview.ca/article/1123

Buchanan, L. (2014, October). Getting Your Fair Share of Founder Equity. Inc. https://www.inc.com/magazine/201406/leigh-buchanan/how-to-split-founder-equity.html

Chi, C. (2021, February 4). TAM SAM SOM: What Do They Mean & How Do You Calculate Them? Blog.hubspot.com. https://blog.hubspot.com/marketing/tam-sam-som

Commonwealth Fusion - Crunchbase Company Profile & Funding. (n.d.). Crunchbase. Retrieved January 5, 2023, from https://www.crunchbase.com/organization/commonwealth-fusion-systems

Contopoulos-Ioannidis, D. G., Ntzani, E. E., & Ioannidis, J. P. A. (2003). Translation of highly promising basic science research into clinical applications. The American Journal of Medicine, 114(6), 477–484. https://doi.org/10.1016/s0002-9343(03)00013-5

Cohan, P. (2017, September 7). MIT's $1.9 Trillion Money Machine. Inc.; Inc.com. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjhk_fpn678AhXrRjABHXy9A4gQFnoECA4QAQ&url=https%3A%2F%2Fwww.inc.com%2Fpeter-cohan%2Fmits-19-trillion-money-machine.html&usg=AOvVaw2NMaYDMrr-UdKSvl0ltHti

Coller, B. S., & Califf, R. M. (2009). Traversing the Valley of Death: A Guide to Assessing Prospects for Translational Success. Science Translational Medicine, 1(10), 10cm9–10cm9. https://doi.org/10.1126/scitranslmed.3000265

Cotter, T. (2018, November 26). Necessity Vs. Innovation-Based Entrepreneurs. The Martin Trust Center for MIT Entrepreneurship.

Crowley, W. F. (2003). Translation of basic research into useful treatments: how often does it occur? The American Journal of Medicine, 114(6), 503–505. https://doi.org/10.1016/s0002-9343(03)00119-0

Cullum Clark, J. H., Murri, K., Nijhawan, V., Blackwell, C., Overton, D., & Ingram, S. (2020). THE INNOVATION IMPACT OF U.S. UNIVERSITIES Rankings and Policy Conclusions. https://gwbcenter.imgix.net/Publications/Resources/gwbi-university-impact-report-ranks-exec-summary.pdf

Dhanda, R. (2022, December 15). Thesis Interview (J. Drutchas, Interviewer) [Personal communication]

Education: The PhD factory. Cyranoski, David; Gilbert, Natasha; Ledford, Heidi; Nayar, Anjali; Yahia, Mohammed ISSN: 0028-0836 , 1476-4687; DOI: 10.1038/472276a; PMID: 21512548 Nature. , 2011, Vol.472(7343), p.276-279

Eisenmann, T. (2021, April 12). Why Start-ups Fail. Harvard Business Review. https://hbr.org/2021/05/why-start-ups-fail

Elkins, C. (2022, October 6). Thesis Interview (J. Drutchas, Interviewer) [Personal communication]

Funding Opportunity Announcements and Grants. (n.d.). Energy.gov. Retrieved January 5, 2023, from https://www.energy.gov/osdbu/funding-opportunity-announcements-and-grants#:~:text=The%20U.S.%20Department%20of%20Energy

Frequently Asked Questions. (n.d.). Y Combinator. Retrieved January 4, 2023, from https://www.ycombinator.com/faq
Gamo, N. J., Birknow, M. R., Sullivan, D., Kondo, M. A., Horiuchi, Y., Sakurai, T., Slusher, B. S., & Sawa, A. (2017). Valley of death: A proposal to build a “translational bridge” for the next generation. Neuroscience Research, 115, 1–4. https://doi.org/10.1016/j.neures.2016.11.003
Ginkgo Bioworks - Crunchbase Company Profile & Funding. (n.d.). Crunchbase. Retrieved January 5, 2023, from https://www.crunchbase.com/organization/ginkgo-bioworks
Goldstein, J. L., & Brown, M. S. (1997). The clinical investigator: bewitched, bothered, and bewildered--but still beloved. Journal of Clinical Investigation, 99(12), 2803–2812. https://doi.org/10.1172/jci119470
Graduate Education Statistics. (n.d.). MIT Institutional Research. https://ir.mit.edu/graduate-education-statistics
Gredel, D., Kramer, M., & Bend, B. (2012). Patent-based investment funds as innovation intermediaries for SMEs: In-depth analysis of reciprocal interactions, motives and fallacies. Technovation, 32(9-10), 536–549. https://doi.org/10.1016/j.technovation.2011.09.008
How Much Do Angel Investors Usually Invest? (n.d.). UpCounsel. https://www.upcounsel.com/how-much-do-angel-investors-usually-invest
How We Work. (n.d.). Wyss Institute. Retrieved January 5, 2023, from https://wyss.harvard.edu/how-we-work/(How We Work, n.d.)
H.R.3773 - 99th Congress (1985-1986): Federal Technology Transfer Act of 1986. (1986, October 20).
Kozlowski, O. (2022, December 8). Thesis Interview (J. Drutchas, Interviewer) [Personal communication].
Knight, T. (2022, October 11). Thesis Interview (J. Drutchas, Interviewer) [Personal communication].
Knockaert, M., Ucbasaran, D., Wright, M., & Clarysse, B. (2010). The Relationship Between Knowledge Transfer, Top Management Team Composition, and Performance: The Case of Science-Based Entrepreneurial Firms. Entrepreneurship Theory and Practice, 35(4), 777–803. https://doi.org/10.1111/j.1540-6520.2010.00405.x
Krukowska, D. (n.d.). What Is a Pitch Deck? A Beginner’s Guide to Greatness. What Is a Pitch Deck? A Beginner’s Guide to Greatness. Retrieved January 5, 2023, from https://www.storydoc.com/blog/what-is-a-pitch-deck
Langer, R. (2022, November 30). Thesis Interview (J. Drutchas, Interviewer) [Personal communication]
Mantel - Crunchbase Company Profile & Funding. (n.d.). Crunchbase. Retrieved January 5, 2023, from https://www.crunchbase.com/organization/mantel
Mantel Launches Carbon Capture Technology to Reduce the World’s Atmospheric CO2 and Help Achieve Net-Zero. (2022, August 24). Www.businesswire.com. https://www.businesswire.com/news/home/20220823005248/en/Mantel-Launches-Carbon-Capture-Technology-to-Reduce-the-World%E2%80%99s-Atmospheric-CO2-and-Help-Achieve-Net-Zero
Markman, G. D., Phan, P. H., Balkin, D. B., & Gianiodis, P. T. (2005). Entrepreneurship and university-based technology transfer. Journal of Business Venturing, 20(2), 241–263. https://doi.org/10.1016/j.jbusvent.2003.12.003
Martens, R., & Peterson, J. A. (1971). Group Cohesiveness as a Determinant of Success and Member Satisfaction in Team Performance. International Review of Sport Sociology, 6(1), 49–61. https://doi.org/10.1177/101269027100600103
Massachusetts Institute of Technology, Technology Licensing Office. (2022, August). FY 2022 Fact Sheet. http://web.mit.edu/tlo/documents/TLO-FY2022-FactSheet.pdf
Matheson, R. (2015, December 9). New report outlines MIT’s global entrepreneurial impact. MIT News | Massachusetts Institute of Technology. https://news.mit.edu/2015/report-entrepreneurial-impact-1209#:~:text=Alumni%2Dfounded%20companies%20have%20created
Meyer, J. P., & Herscovitch, L. (2001). Commitment in the workplace: toward a general model. Human Resource Management Review, 11(3), 299–326. https://doi.org/10.1016/s1053-4822(00)00053-x
Mowday, R. T., Steers, R. M., & Porter, L. W. (1979). The measurement of organizational commitment. Journal of Vocational Behavior, 14(2), 224–247. https://doi.org/10.1016/0001-8791(79)90072-1
NASA SBIR & STTR Program Homepage. (n.d.). Sbir.nasa.gov. Retrieved January 5, 2023, from https://sbir.nasa.gov/
OA Task Force, M., & Dunn, K. (2018). Open Access at MIT and Beyond. MIT Open Access Task Force. https://doi.org/10.21428/4090026e.ee80493a

Parente, R., & Feola, R. (2013). Entrepreneurial intent and entrepreneurial commitment of young researchers. International Journal of Technology Management & Sustainable Development, 12(2), 155–166. https://doi.org/10.1386/tmsd.12.2.155_1
Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research Policy, 42(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007
Provisional Application for Patent. (n.d.). Www.uspto.gov. Retrieved January 5, 2023, from https://www.uspto.gov/patents/basics/types-patent-applications/provisional-application-patent#:~:text=A%20provisional%20application%20for%20patent%20has%20a%20pendency%20lasting%2012
Roberts, E. B., Murray, F., & J Daniel Kim. (2015). Entrepreneurship and Innovation at MIT: Continuing Global Growth and Impact. http://web.mit.edu/innovate/entrepreneurship2015.pdf
Rockney, B. (2022, October 20). Thesis Interview (J. Drutchas, Interviewer) [Personal communication].
Sandler, L. (2022, October 19). Thesis Interview (J. Drutchas, Interviewer) [Personal communication]
SBIR.gov. (2019). Sbir.gov. https://www.sbir.gov/
SEED - Helping Innovators turn discovery into health. (n.d.). Seed.nih.gov. Retrieved January 5, 2023, from https://seed.nih.gov/
Soetanto, D., & Jack, S. (2016). The impact of university-based incubation support on the innovation strategy of academic spin-offs. Technovation, 50-51, 25–40. https://doi.org/10.1016/j.technovation.2015.11.001
Stamler, J. S., Taber, R. L., & Califf, R. M. (2003). Translation of academic discovery into societal benefit: proposal for a balanced approach—part 1. The American Journal of Medicine, 115(7), 596–599. https://doi.org/10.1016/j.amjmed.2003.09.006
Sung, N. S. (2003). Central Challenges Facing the National Clinical Research Enterprise. JAMA, 289(10), 1278. https://doi.org/10.1001/jama.289.10.1278
S.1250 - 96th Congress (1979-1980): Stevenson Wydler Technology Innovation Act of 1980. (1980, October 21). Www.congress.gov. https://www.congress.gov/bill/96th-congress/senate-bill/1250
Technology Push & Market Pull. (2019). Design Technology. http://designkmg.weebly.com/technology-push--market-pull.html
Thursby, J. G., Jensen, R., & Thursby, M. C. (2001). Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities. The Journal of Technology Transfer, 26(1/2), 59–72. https://doi.org/10.1023/a:1007884111883
Tracxn. (2022, December 24). Startups by Massachusetts Institute of Technology (MIT) Alumni. Tracxn.com; Tracxn. https://tracxn.com/d/startups-by-alumni/massachusetts-institute-of-technology-(mit)-alumni#:~:text=There%20are%203300%20companies%2C%20including
Tzinis, I. (2012, October 28). Technology Readiness Level. NASA. https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level
US EPA, O. (2014, May 12). Federal Technology Transfer Act and Related Legislation. Www.epa.gov. https://www.epa.gov/ftta/federal-technology-transfer-act-and-related-legislation#:~:text=The%20Federal%20Technology%20Transfer%20Act
van Geenhuizen, M., & Soetanto, D. P. (2009). Academic spin-offs at different ages: A case study in search of key obstacles to growth. Technovation, 29(10), 671–681. https://doi.org/10.1016/j.technovation.2009.05.009
Why Startups Fail: Top 12 Reasons I CB Insights. (2021, August 3). CB Insights Research