Title

From Research to Market:What the EU can learn from the USA?

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Annex 1 List of Actors Interviewed for the Study
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Executive Summary

The research project “From Research to Market: What the EU can learn from the USA” addresses the gap between laboratory research and market. I examine how government, universities and private companies facilitate the transition of research results to market in the USA. I present various programs that are available to the researchers and entrepreneurs in the US and invite to consider them for implementation in Europe.

Specifically, I address the following questions:

- When the research is ready to be commercialized and by whom;
- What are the mechanisms that government, university and industry put in place to facilitate a transition of the research results to market (the role of technology transfer office, collaboration between university and industry, support for creation of startups)
- What is the role of finance in bringing the technology to market.

I argue that different stages of lab-to-market transfer require different mechanisms that should not be limited to funding but include technology transfer assistance and advice on intellectual property, mentoring by peers and industry mentors and access to the laboratory space and incubators. I conclude that the Bay Area answer to closing the lab-to-market gap is by a **combination of support mechanisms** that **reinforce and complement** each other, when **implemented simultaneously**. I invite to discuss which of the US initiatives and programs described in this report shall be promoted in Europe and at which level.

“Learn all you can from the entrepreneurs of Silicon Valley
but don’t become like them. “
Vivek Wadhwa

Introduction

The present study addresses the crucial area where Europe, despite its efforts, does not have the leading position in the world: the effective transition of the research results to market, leading to creation of new companies, jobs and economic growth. My interest in the subject was provoked by the report of Pascal Lamy, the chair of the independent High Level Group on maximizing the impact of EU Research & Innovation Program who noted that Europe is good at growing science, “but not good enough at getting growth out of science."[1] This report was one of building blocks of the new Horizon EU program 2021-2027 that commits to investing in excellent science in Europe and strengthening the EU's industrial innovation by means of investments in key technologies, greater access to capital, and support for small businesses. The program also intends to promote breakthrough innovations through the establishment of the European Innovation Council.

The importance of transition of the research results to market was recognized in the US decades ago. The “Lab-to-Market” initiative by Barack Obama was announced in 2011. Its goal was set to accelerate and improve the transfer of new technologies from lab to market. The initiative included optimization of federal patent management , increase in use of federally funded research by innovators, enhancing entrepreneurial education, maximizing the impact of SBIR and STTR programs.[2] The proposed measures included creation of business incubators and technology transfer centers in the universities, creation of federal agency/industry partnerships assisting the startup companies and provision of entrepreneurship training to the scientists and engineers. These objectives were carried forward in Trump management agenda of 2018.[3]

A number of the US Federal and private initiatives were successfully put in place aiming to close the “valley of death”[4]. In this report I explore some of them. I group them into government, universities and industry initiatives designed to facilitate the transition of research results to the market. I aim to answer the following questions:

- When is it the right time to commercialize the research and by whom;
- What are the mechanisms that government, university and industry put in place to facilitate a transition of research results to market (the role of technology transfer office, collaboration between university and industry, support for creation of startups)
- What is the role of finance in bringing the technology to market.

Methodology

The starting point of the study was the moment when the innovation had been created as a result of the research done within a research center of the university, institute or a private company. The end point of the study was the commercialization of the product. The place of study was California, the United States.

I focus is on a deep tech, defined broadly as cutting-edge technologies that are built on tangible scientific discoveries or meaningful engineering innovations that are intended to solve complex problems that affect the real world. These technologies are the riskiest, the most investment intensive and need considerable time and money to be shaped into a commercial product. At the same time, such breakthrough innovations can drastically change the course of the human’s history.

I carried out a qualitative research including a review of the literature on the subject, a review of publicly available information, complemented with over 40 semi-structured eye-to-eye interviews with researchers, faculty, venture capitalists, angel investors, startups and entrepreneurs (I met with several interviewees more than once). Interviewees were chosen based on the interviewees current or past positions within organizations and their previous expertise in technology transfer and commercialization of technology. The goals of the interviews were: to understand the role that the actors play in lab to market transition; to gather examples of current initiatives in place that function well but also those in need of the improvements; to discuss the pilots those efficiency remains to be assessed; to validate the information from the research literature and other sources. The interviews were complemented with the visits to the laboratories and technology centers of Autodesk, Lawrence Berkeley National Laboratory, Neuroscape (laboratory of the Neurosciences institute of UCSF) and Virtual Human Interaction Lab (Stanford University). For logistical reasons the face to face interviews were conducted in the Bay area – Berkeley, San Francisco and Silicon Valley. The interviews in other areas of California were carried out by phone. The detailed list of actors that were interviewed is enclosed in Annex 1.

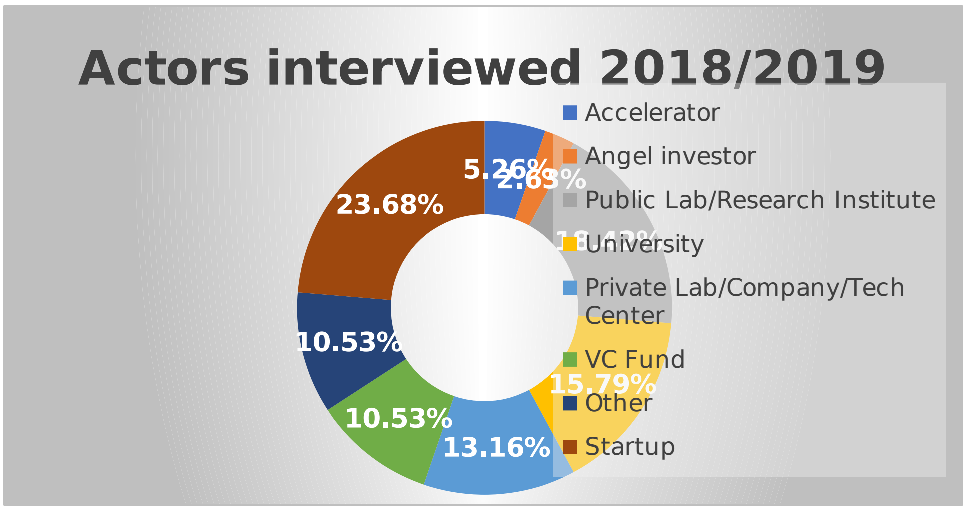

Figure 1. Actors interviewed for the study

My participation in three innovation courses at Haas Business School, Berkeley Law School and Sutardja Center for Technology and Entrepreneurship at UC Berkeley complemented my knowledge of the technology transfer process from the laboratory to market.

1. From University Lab to Market

Imagine a scenario when a new technology has been created in the laboratory.[5] This process most probably included numerous experiments and failed attempts. The innovation could have been created by mistake or error, the situation that is not uncommon[6] and that underlines the importance of experimentation. Not always the positive results are the only valuable results in science.[7] So the technology is there, however in its very early stage. More tests and data collection should be carried out to prove the technology is working as intended, perhaps a working prototype needs to be built. It still may not be clear how exactly the technology can be used and who would buy it. But this is the start of the story.

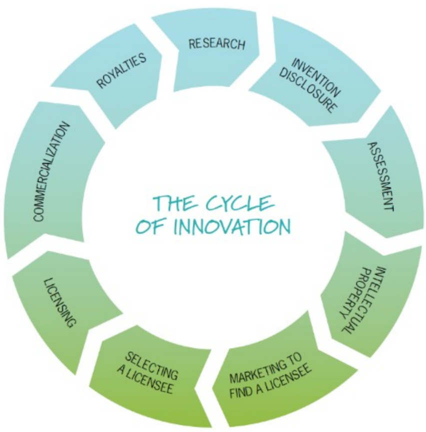

Figure 2: The standard process of technology transfer[8]

1.1. From Idea to Invention Disclosure

During the process of lab to market transfer, there are a few critical decisions, that need to be taken by a researcher (being a principal investigator (PI), the head of laboratory, a postdoc or a PhD student.) The first one is when (and if at all) to take the research out of the university laboratory to market. The first step in the process is an invention's disclosure to the technology transfer office (TTO). It is a starting point for consideration of the patentability. At the moment of the invention disclosure it might not be clear if the technology in question has a potential to be commercialized. It normally would be very early stage technology but the researcher shall contact the licensing officers very early, still at the pre-disclosure stage, so the correct procedure is followed since the beginning.

Can the technology be transferred to market without the invention disclosure? It is unlikely and irregular. All intellectual property (IP) on inventions produced in the US university laboratories belong to the university and thus shall be licensed. Bringing technology to the world without taking legal arrangements infringes the rights of the university and can result in penal proceedings.

Next decision is when it is the right moment for a scientific publication. The reputation and promotion opportunities for the researcher are linked to the number of publications, name of the journals where articles are published and number of citations they trigger. The wish to publish the discovery as quickly as possible is quite understandable: the desire to share the invention with the peer researchers, to receive a feedback and open a discussion on the further steps of the research, a wish for recognition, all these considerations can push the scientist to publish the discovery as quickly as possible. However, if one intends to commercialize the technology, other considerations would come into play. Protection of intellectual property is one of them. In the US, inventors have one year from the date of publication to file a patent. However, in other countries (also the EU), the patent rights are lost at the moment of publication and thus alignment between the filing for the patent and the publication is of paramount importance. The delayed publication may also postpone the imitation of the technology by rivals, a valid argument in the business world.

Following the invention disclosure, the TTO carries out the preliminary assessment aimed to estimate if there is a market interest for the invention. The possibility of patent application is considered, keeping in mind that the technology should meet certain criteria to be patentable: to be new, useful, patent eligible and non-obvious.[9] As patent costs are quite high (about USD 50,000) the TTO can decide against the patenting if no demand for licensing technology is foreseen. In the US it is possible to file for provisional patent, that gives the founder 12-18 months grace period to determine the possibilities of licensing of the technology and to decide on whether to pursue final patent application.[10]

1.2. To Patent or Not to Patent

US Department of Energy (DoE) takes a broad view on the technology transfer stating that "Technology transfer can mean many things – technical assistance to solve a specific problem, use of unique facilities, licensing of patents and software, exchange of personnel, and cooperative research agreements while ensuring fairness of opportunity, protecting the national security, promoting the economic interests of the nation, and preventing inappropriate competition with the private sector."[11] Often, the term "technology transfer" relates to the legal transfer of innovative solutions of problems that are protected by intellectual property rights from one party to another. When the technology is created in the university or research laboratory and is being prepared to enter the market, the formalized legal agreement "releasing" the technology from the laboratory must be concluded.

The critical legislative act for understanding industry-university relationship in the US is the Bayh-Dole Act or Patent and Trademark Law Amendments Act of 1980. It deals with intellectual property arising from federal government-funded research. The key change introduced by Bayh–Dole Act is in ownership of inventions made with federal funding. Before the Bayh–Dole Act, federal research funding contracts and grants obligated inventors (wherever they worked) to assign inventions they made using federal funding to the federal government. Bayh–Dole permitted a university, small business, or non-profit institution to pursue ownership of an invention in preference to the government.[12]

In the US, the intellectual property (IP) produced in the university's laboratory is the propriety of the university.[13] The universities secure intellectual property rights and then license those rights to companies who develop the commercially available products and services. A company may already exist or be created for the purposes of commercialization of the technology. Universities cannot directly commercialize the research discoveries.[14]

Risky R&D process including the manufacturing and regulatory approvals to bring early stage discoveries to the point of practical application cost money. Without the protection afforded by the patent license, the industry would not risk their funds and resources on lengthy R&D programs that are necessary to commercialize products.[15] The IP licensing gives industry an incentive to invest. It is particularly true in case of deep technologies, like life sciences for example.[16] The timeline to successfully develop a commercial product from an academic discovery can vary widely, but it most often takes 3-10 years. Importantly, in case of a breakthrough technology, like gene editing for example, the commercialization process can take well over 10 years and can cost several billion dollars. In contrast in software development, where the technological advancements are extremely quick and versatile, it is often viewed that time and money spent on filing the patent could be better spent on development of the technology.

The US had first-to-invent system until 2013, when it turned to the first-to-file system to be in alignment with the rest of the world.[17] In a first-to-file system, the right to grant a patent for a given invention lies with the first person to file a patent application regardless of the date of invention.

Having a patent does not guarantee a care-free ride. According to the startup CellFe[18], that has developed novel cell delivery technology, that is patented but which principle is quite simple to imitate, there are many ways to "go around" the patent that competitors may use. In case of infringement of the patent, the cost of proving this infringement is so high that it may not be feasible for a small company to engage in the lengthy and costly legal proceedings. (Patenting may still be wise to protect oneself against others claiming property of their own developments.)

If the inventor does not intend to generate IP in the university, she needs to clearly distinguish her invention from the university work that s/he is doing. This is what happened to the biotech startup Visolis[19], who from the beginning worked on the technology outside the university, in the privately rented wet laboratory.

1.3. Who and When is Bringing the Technology to Market?

At the different stages of the technological development two types of risks have to be addressed. One is the invention risk, answering the question whether technology can actually work and if it is sufficiently mature and robust. Another one is the customer/market risk, establishing if the technology would have the customers and the market.[20] The decision to take the technology out of the university laboratory should be done with consideration of both risks.

From one side, the longer the technology stays in the university, the costlier licensing would be. From another side, gathering more data and working on the technology by using the resources of the university allows bringing the technology to market in a more mature stage. It is up to the inventor to decide when to commercialize (license) the technology.[21] So who would bring the technology from the university laboratory to the market?

Would it be a **principal investigator**? Being an expert in technology, he is deeply rooted in the academic system and is unlikely to exchange the security of his position for an unstable and risky startup business. But she could be an adviser to the company, letting others "to do the hard work" of launching the new company. The PI, through her connections in academia and industry may promote the technology during conferences and networking events. She could raise interest of a large company who would be ready to license the technology or cooperate via a joint research project to develop it further in the university setting. The interesting approach to engage the PI in the commercialization of the technology is taken by the i-CORPS program of the National Science Foundation (NSF) (more in section 2.3).

Would it be a **postdoc/junior researcher**? In the US, the big hopes are put on the young scientists to bring the technology to market. Their jobs in laboratories are temporary and according to the statistics, only 5% of them will be able to continue their careers in academia. One of the opportunities that is open to them is to found a startup. Universities increasingly support researchers in this role by providing courses, seminars and mentoring on what it takes to become an entrepreneur, so everyone could assess whether this path would suit them. (more in section 3.6.)

In order to achieve the highest benefits for the society and also to ensure the flow of revenue to the university, it is in the interest of the university to license the technology to the party that is best suited to create the product on the basis of the technology and bring it to the market in a quick and efficient way. In some cases, the TTO shall make a choice between licensing to an existing company (well established industry) or to a newly created start-up, formed by the researcher/inventor of the technology. The TTO shall remain impartial and think of the best possible return from the commercialization of the technology. However, naturally, it gives a consideration to the inventor of the technology that may have the in-depth knowledge and unparallel motivation to bring the technology to the market.

Licensing to the inventor is not unproblematic.[22] The inventor must incorporate the company, and then have an initial funding to be able to pay for the licensing fee.[23] Statistics showing that 90% of startups fail increases the risks of licensing to a newly founded startup. The TTO of UC Berkeley attempts to address this risk by granting non-exclusive licensing rights, which means that the technology can be licensed to a few parties at the same time. According to Mike Cohen, Director of TTO of UC

Berkeley, startups are more efficient (and quick) to develop and put a product to the market.[24]

Sometimes an experienced industry partner can commercialize the technology better and turn it more efficiently into a new product, leaving the inventor with the royalties from the licensing and freedom to pursue the next research. An established company may have readily available financial and human resources, as well as technical equipment, in advantage over the newly founded company. On a flip side, licensing to an existing company could mean losing the control of the technology and potential delay in bringing it forward to the market. An existing company may put the licensed technology "on hold" due to other priorities. If technology would create a competition to their already launched products, it could even prevent its launch to the market.

Often existing companies are not willing to take over very early stage technologies and invest into technology development. They wait that the technology "de-risks" itself, perhaps following the creation and development of a startup and, at a later stage, consider its acquisition.

While UC Berkeley tends to grant a non-exclusive licensing[25], as not to forgo the opportunity if the technology would create significant returns, LBL approach is different. By engaging in the cooperative research agreements (industry financially contributes in return to research on specifically defined problem), LBL grants exclusive license to the industry willing to commercialize the technology. These decisions are done by the Technology Transfer Office (TTO) that play an important role in bringing technologies to market. The TTOs have different missions, governance structures and sources of financing at different universities:[26]

- Facilitate the technology transfer from university to market.
- Support and foster entrepreneurial efforts of the inventors to enhance their capacity to bring their invention to market.
- Seek to maximize the financial returns on intellectual properties to help fund the university.

- Raise money and support new inventors by bringing in successful entrepreneurs back to the University's community.[27]

One of the roles is to advertise the technology available for licensing. The TTOs of UCSF, UC Berkeley, Lawrence Berkeley National Laboratory (LBL), Caltech and Federal Laboratories have the databases of the technologies ready to be licensed that are open for consultation. However, such passive offering of the technology does not help much technology commercialization. The industry is not interested to absorb technologies in early stage and with no clear application to a product. According to the Chief TTO of LBL, Dr. Elsie Quaite-Randall, "push marketing does not work – creation of patent databases, "advertising" of the research by the TTO is not effective".[28] According to her, there are two approaches that have proven to be successful: one is the focused programmes, conferences and symposia where people meet each other and establish personal connections that can result in collaborative research. And another approach tested by LBL in collaboration with other US national laboratories - **a multipatent portfolio approach** adopted by the National Laboratories in the US. The reason to create a multipatent portfolio was driven by the fact that the industry is not interested to approach the national laboratories for just one or two patents. In order to maximize the interest from the existing companies, six national US laboratories funded by the Department of Energy (DOE) screened and constructed multipatent portfolios that are tailored for the industry needs. The common database of patents was created, analyzed and patents were clustered by subject by the technology experts, in order to build the critical mass. The interinstitutional agreement between the laboratories was concluded (as the fact that patents were owned by different laboratories had to be addressed). Then, the portfolios were presented to the industry at show case events.

Lessons learned: Following the successful adoption of the multipatent portfolio by the National Laboratories, this new approach considered to be a success in bringing laboratories

research to industry (it even won an institutional award). Similar practice is also taken on board by the University of California, that has recently launched an initiative to map, bundle, evaluate and revive all of university's IP and patents, in order to better commercialize them and to better serve industry interest and needs.(each of University of California campuses has its own Technology Transfer Office).[29]

1.4. The Assessment of Technological Potential and Company Viability

Having a promising technology and excellent team is important, but money is essential in bringing technology to market. An ideal investment approach would be the gradual one-source support that links solutions at the earliest stages of development to more mature solutions. However, in the real world, technology commercialization has to be supported by various independent investors and partners, each contributing at a different stage of technology life cycle.

Investors typically look into the idea, the team, the product and its fit to the market, the growing rate of customer adoption, and potential of revenues. Depending on the team and founder's reputation, it is possible to raise money without the customer/revenue traction, but it is unlikely. Two main factors: the team and the market are cited as the critical factors in evaluation of the startups' potential and investment decision.

In analogy with the Technology Readiness level (TRL) developed by NASA, Steve Blank introduced the Investment Readiness Level (IRL), demonstrating what it takes for a company to get financing. The tool helps to assess the chances of raising a round of financing of a startup at its current stage of development.

While the TRLs and IRLs are necessary for testing demand for a certain technology solution they lacks the integration of a social dimension that is often the case with shared infrastructure.[30] The market readiness is an important indicator in order to establish whether the markets are ready to accept the technology. The community readiness level (CRL) scale addresses the readiness of the markets.

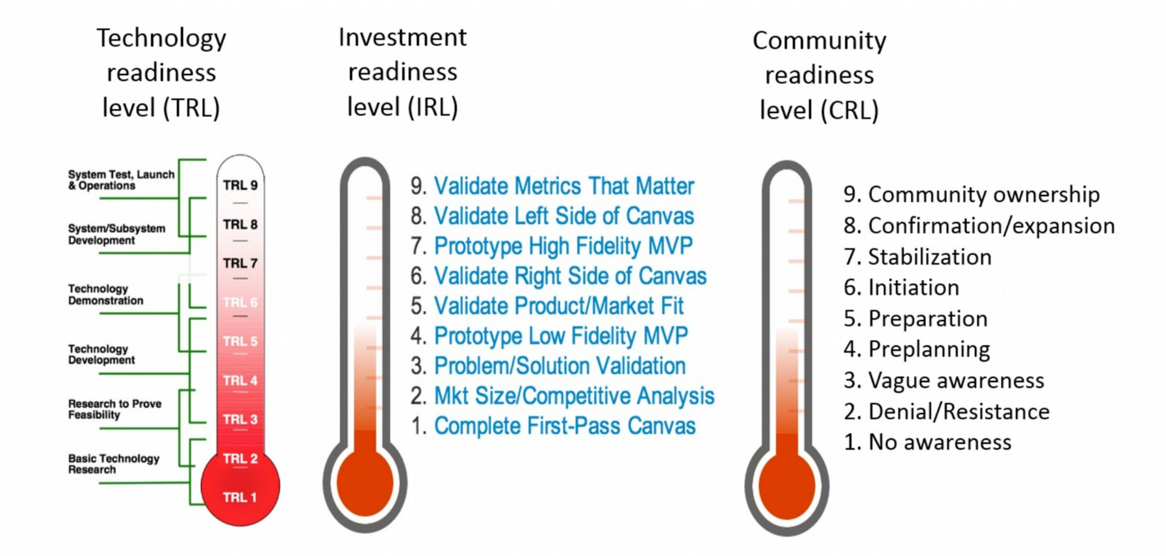

Figure 3. Technology, Investment and Community readiness levels combined serve as a canvas for assessing the chances of the technology to be adopted by the market

There is a quasi-unified approach on evaluating the promising technology and assessment of company's viability in the Silicon Valley. Internal Google Accelerator Area 120 boils it down to three key components: the team, with the focus on team diversity, the problem or need the technology tries to solve, and the impact it would make if the problem is solved. (for more details, see item 5.2).

ARPA-E project teams are asked to prepare a Tech-to-Market Plan, which serves to guide planned activities to assess and advance the commercial viability of their technology. The successful projects needs to demonstrate a transformational technical concept or prototype. Two areas that are considered in assessing the viability of a technology and potential for impact are:

- **Market:** Will a product based on the technology create enough economic value to drive adoption by the market?

- **Manufacturing:** Can a product based on the technology be manufactured cost effectively and at reasonable scale?

Three additional factors are taken into account in evaluating a project's long-term success:

- **Team:** Does the team have the right skills and capabilities?
- **Intellectual Property:** What is the plan for securing intellectual property related to the technology?
- **Funding:** If the project is a success, how will the effort be funded after ARPA-E's involvement? [31]

Typical startup evaluation by a Venture Capital firm focuses on the five components: a clear high value **market** with advantageous positioning, **product** that meets customer needs and a clear indication that customers are willing to pay for it, a competitive advantage that **customers value** and the team can execute on, a highly skilled **team** in the areas that are critical to success, a company structure that allows VC funding and **exit** in a 10-year timeline"[32]

Team is at the core of the funding decision. Other three questions are asked when assessing a deep tech company: Why now? Is this feasible in a venture time frame? How do you build a business in that time? [33] More developed evaluation matrix shows other questions that the VCs consider when evaluating the company's potential to scale:

Criteria	Questions
Value Proposition	What is the addressed problem? How does the solution satisfy the unmet need? Who values that? Cost/benefit ratio?
Product	What does product offer? How does it affect clinical decision making? How does it fit into clinician workflow? Does it replace any product?
Technology	What is the underlying science and engineering?

	Alternatives? What does the proof of principle study shows? Publications? Validation? Development plan?
Competition	Current and emergent players profiles
Market	Target market segments? Market size model with unit volume, penetration curve, pricing
Regulatory path	FDA or EMA routes? Data submission requirement? Pre-IND FDA feedback?
Business model	Revenue source? Product economics? Pricing strategy? Out licensing? Partnering?
IP	Barrier to competition. Patent filings? Breadth and strength of claims? Prosecution status? Patent analysis? Freedom to operate? License terms?
Management	Team background? Advisory board? Staffing plan? Organization structure?
Financing	Cash requirements VC key milestones? Sources of capital? Use of funds? Future capital requirements?
Reimbursement	How do you get paid?
Exit	Exit path? At what stage? Potential acquirers? ROI? Comparables?

Figure 4. Sample Checklist of a VC company evaluating life science/biotech startup

1.5. Lab-to-market Example: Neuroracer’s Video Game

Neuroscape center, a translational neoroscience laboratory, is a part of UC San Francisco (medical graduate school). It houses about 100 principal investigators and more than 500 researchers and staff. The Neuroscape center emerged from Dr. Adam Gazzaley’s lab, founded at UCSF campus in July 2005. Dr. Gazzaley’s research aims to deliver a therapy for people struggling with memory problems, for example, or ADHD. Gazzaley believes games he's developing could become "the world's first FDA-approved prescribed video game”.

The laboratory deals with the research until the proof of concept stage[34]. All of the computer games developed at Neuroscape are research tools, not commercially available products. Neuroscape builds prototypes that are tested through scientific experiments to determine their effect on cognitive abilities. This is only the first step to creating a validated product for general use. There are several running projects, at the moment, at different stages of development.

Building a product based on a prototype is an expensive and time-consuming endeavor. Neuroscape, as an academic center, has neither the resources nor the objective to build and support commercial games. If the results of the studies show that the game may improve patients’ cognitive abilities, then it may be licensed through UCSF to a company that is able to develop it into a viable product.

In early 2009, Dr. Gazzaley, the head of Neuroscape center, saw such an opportunity to move beyond the lab’s focus on basic science by applying the gaming technique to the aging brain to improve functioning in individuals and developed a therapeutic video game (*Neuroracer*) designed to improve cognition in older adults. This technology development project and the series of research studies that followed it, over the next 4 years, resulted in a 2013 publication in the journal Nature, a UCSF patent filing of the methodology behind the game training approach, and the founding of a novel healthcare company — Akili Interactive Labs — to transform this breakthrough into commercial product and advance the game as a clinical therapeutic device.

So far, only one game from the center has been licenced under exclusive licence and is evolving into a commercial product and it is Neuroracer. All the other games are still being tested in ongoing studies. Akili Interactive Labs is developing a clinical product in the form of a mobile video game (“Project: EVO”) that is based on the technology behind Neuroracer. In 2018, Akili added an extra $13 million to a prior $55 million Series C round, bringing the company’s total funding to just over $140 million. The FDA is currently reviewing Akili Interactive Labs' first experimental product—a mobile video game designed to assess and treat attention deficit hyperactivity disorder (ADHD)—after Boston-based Akili reported a successful 348-patient clinical trial last December. After the FDA approval, the game may become available to the general public.

2. Governmental Measures Facilitating the Transition of Research Results to Market

In the Silicon Valley, on the wake of computers industry, federal government has acted in three capacities: "as setter of the rules by which firms operate", "as buyer of their products" and "as financier of research and early system development".[35] Now, government initiatives are particularly important in supporting the very early commercialization attempts when technology is not of interest to any private investor. It is still immature, prototype not yet created and tested, let alone the absence of potential traction in the form of revenue or customers. The support at this stage is available through the "traditional" federal grant program of SBIR (The Small Business Innovation Research). This is a highly competitive program that encourages domestic small businesses to engage in federal research that has the potential for commercialization. Another program is STTR (Small Business Technology Transfer), whose goal is to facilitate the transfer of technology developed by a research institution through entrepreneurship. The above programs are highly regarded by the researchers, although the success rate for first phase grant is about 12-15%. This award rate increases for the second phase grants up to 20% (see chapter 6.1.).

The Advanced Research Projects Agency (ARPA-E) within the U.S. Department of Energy (DOE) was modeled after the successful Defense Advanced Research Projects Agency (DARPA) and created to address the lab to market gap.[36] Preparing technologies for an eventual transfer from lab to market is a key element of ARPA-E's mission. It focuses on "high risk, high reward" technologies that isn't being pursued anywhere else. The top talents are recruited on a temporary contract basis that ensures fluidity between industry and Agency. The hands-on and autonomous approach means program directors are involved in developing budgets, timelines and milestones that projects must meet to receive continued funding. This metric-driven process also means that when projects are underperforming and need to be terminated, these decisions can be made swiftly.

Other government funded programs in the US that support transition of research results to the market are the following:

- Fellowships to the scientists that bring technology closer to the market;
- Shared User Facility - use (rent) of facilities, specialized equipment or testing centers;
- I-Corps™ program to help the customer discovery process for new entrepreneurs;
- Researchers exchange and Entrepreneur-in-Residence programs.

2.1. Fellowship to Support Entrepreneurial Scientists (example of Cyclotron Road)

Cyclotron Road program was created in 2014 at the Lawrence Berkeley National Lab and is funded by the Department of Energy Advanced Manufacturing Office. It aims to "create a new institutional home for application-driven research"[37] in the sectors of energy, water, food, and health and to provide support to mature ideas into commercially viable products.

The former DARPA director Arati Prabhakar commented: "The Cyclotron Road model recognizes that there are really smart people with a lot of passion to deeply understand research advances. But in the way they've been trained, there is no reason to expect they have the moves to go commercialize that technology, or know what the best commercialization path might be. So, bringing them in and giving them access to laboratory facilities they need to do their work, and also immersing them in thinking about business—this is very different from just thinking about the research or the science.”[38]

The program focuses solely on hard technology. It provides two years funding that includes salary, health insurance, travel and research expenses, provides laboratories for use. It is a grant in its essence. According to Brenna Tiegler, a Head of Program Operations at Cyclotron Road, the unique feature of Cyclotron road is that the researcher keeps the IP rights (despite working in the federally funded lab). The program accepts projects at the very early stage. It is worth to mention that Cyclotron Road enjoys exceptional access to the expertise and knowledge both of UC Berkeley and Lawrence Berkeley National Laboratory.

Since 2014, four cohorts of fellows had graduated. The teams have crossed the science-to-product bridge, having either developed their first prototype or acquired sufficient funding to do so. By advancing their research to the stage of the prototype, allowed the teams the access to a variety of private sources – angel investors, venture capitalists, philanthropists, and industry-backed strategic investors.

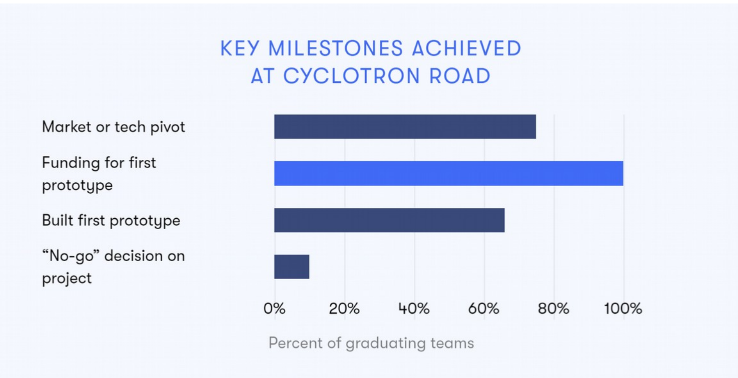

Figure 5. Extract from Cyclotron Road impact report[39]

Lesson learned: ***The value added of this program is the collaborative environment with the very clear mission to advance a technology into the commercial product, so all efforts during the two years programme are devoted to achieving this goal.***

2.2. Shared User Facility and Small Vouchers Program (example of Molecular Foundry)

Shared user facility, funded by the Department of Energy, provides users with access to cutting-edge expertise and instrumentation in nanosciences. The access is open to researchers from the universities and companies (small businesses are particularly encouraged) providing materials and facilities that are not available everywhere. In 2018, 45 researchers were working in this facility on their research while helping the external users of the foundry with advice and assistance.

Brandon Brough, Deputy Director, notes that 95% of all users are small businesses. Besides regular bi-annual admissions, a rapid access program also exists. Access is based only on a two-page proposal and is completely free for one year, both for the use of laboratories and scientist's assistance and support.

There are two important points that characterizes the program. Firstly, it is the fact that IP is owned by the inventor. (If one makes a discovery in cooperation with scientists from Molecular Foundry then the IP should be shared).

Secondly, the Foundry's primary focus is the facilitation of the non-proprietary research whose purpose is the publication and not scaling up the business. Thus, the companies shall present their ideas as a research concepts. It does not prevent them, however, from using the developed technology for their business purposes.

The described two programs: Cyclotron Road and Molecular Foundry are focused on the development of the technology at the very early stage, before prototype creation. Both allow the researcher to keep the IP rights.

Another program of the Department of Energy that is at its pilot stage: **"Small Business Vouchers (SBV)** program**"** aims to provide small businesses access to selected national labs—making the contracting process simple, lab practices transparent, and access to the labs' unique facilities practical. Through SBV, selected small businesses in the field of clean energy, receive access to the state-of-the-art facilities and experts at participating DOE national labs, while the labs expand their knowledge of, and involvement with, the private sector, helping small businesses with advanced technologies to contribute to the US competitiveness and economic growth.[40]

The above programmes focus on the development and fine tune of the technology for commercialization, helping to address and mitigate the invention risk.

Lesson learned: ***Provide access to the facilities to experiment and test new technologies, not only to university students and federal researchers, but also to startups and anyone interested to test and experiment with the new technology.***

2.3. National Science Foundation (NSF) Innovation Corps (I-Corps™)

The I-Corps™ program was created by the National Science Foundation (NSF) in 2011 to help bringing the academic research it previously funded to the market. Its objective is to prepare scientists and engineers to extend their focus beyond the university laboratory, and to accelerate the economic and societal benefits of NSF-funded, basic-research projects that are ready to move toward commercialization. The program aims to reach a large number of the faculty and scientists via the seven regional Hubs across the US. The ambition is to setup an innovation ecosystem within universities that will train the next generation of entrepreneurs, encourage partnerships between academia and industry, and boost commercialization of science and technology. It is based on a special, accelerated version of Stanford University's Lean LaunchPad course. Lean Launchpad methodology, based on the work of Steve Blank, is the reference methodology in the Bay area for commercialization of technology.[41] The approach engages the researcher to get out from the laboratory to the market space and to push her to understand the market needs and potential for a new product by interviewing a large number of potential customers.

The University of California, Berkeley, UC San Francisco and Stanford University are forming the “NSF Bay Area Regional I-Corps Node”. The best graduates of regional nodes enter the national competition where the cohort of 24 teams work on their project and present their results to the panel, who decides on the winning team. The team receives about 55,000 USD to cover travel and related expenses. The teams are composed of three members: the technical lead, the entrepreneurial lead and the mentor. By adding the mentor from the industry to the team, the connection to the industry is ensured. The technology which potential the team explores is typically (very) early stage.

According to Todd Morill, Director of NSF i-CORPS Bay Area Node, the “hidden agenda” of NSF is that it wants all US professors to go through the program so later they can pass the knowledge to their students (creation of spill off knowledge transfer). The main incentive for the professors to participate (and to allow their postdocs to participate) in the program is the following message: “How many of your students will become professors? The answer is “probably zero”. Do you want your students to find their place in the industry? The answer is “Yes”. So i-CORPS will teach you how to help them.”[1] In evaluating the results of the program, Todd Morill mentions the importance of the “negative statistics”. According to his experience, half of the teams result in deciding on not forming a company. Is it a failure? Not really. It only means that they managed to do a weighted decision based on tangible data that they gathered and analyzed to **“succeed in not proceeding”** that saves them the time and the resources. “If you are destined to fail, then it is better to fail quicker”.[2]

The success of NSF program led to its adoption by other federal agencies: the Department of Energy, the Department of Defense, the

[1]
[2]

National Institute of Health (NIH). The NIH made it mandatory for the SBIR holders to participate in the program.

Lessons learned: ***The objective of the program is "to cultivate a pipeline of university-based researchers who can turn ideas into successful commercial products". Multiple federal agencies have successfully adopted a curriculum and one of them made the attendance the prerequisite for receiving a federal grant (SBIR).***

2.4. Science/Industry Exchange programs

Another mechanism of knowledge transfer between federal laboratories, universities and industry are through exchange programs:

- **Cooperative Research & Development Agreements** (CRADAs): Joint research between federal laboratories and the private sector. The non-Federal party could be an individual from a state or local government, public or private foundation, university, company, or non-profit organization, any of which could also be the licensee of a government-owned invention.
- **Entrepreneurial Leave Programs**: allowing staff to take "entrepreneurial leave," spending time focused on commercializing a technology developed in the laboratory. With current examples at the Department of Energy (DOE) and the Department of Defense (DOD), this type of personnel exchange is also called an "Entrepreneurial Separation to Transfer Technology".
- **Entrepreneur-in-Residence (EIR) Programs**: Entrepreneurs from outside of government who wish to apply their skills for the benefit of the public good can do so through EIR programs. EIRs are typically mid- to senior-level professionals and may be academics, technology entrepreneurs, software designers, policymakers, business experts, or non-profit leaders who have demonstrated a significant record of innovative achievement in their field.

Lessons learned: ***The exchange between academia, industry and government allows for a circulation of best practices and the ideas. It unlocks staff potential by forcing them to adapt to different cultures and environments that enhance the vision and perspective on the processes, preventing people from being "locked" in their roles and helps extend the borders of science and enrich experiences of both the participants and host organization.***

3. University-Funded Programs and Initiatives Supporting Transition of the Research Results to Market

Universities play a crucial role in research to market transfer. Firstly, researchers ensure the production of the critical mass of basic and applied research leading to the development of prospective technologies and products. Secondly, universities concentrate the young talents that in a few years' time will enter the national work force.

The programs on campus help students with the scientific background to understand the basic business concepts as well as learn about the career opportunities outside academia. They range from information seminars explaining what it takes to bring the technology to market to more concrete programs like i-Corps that helps to identify the market/customers fit for the given technology. The programs in the accelerators strengthen the business model with the help of the industry mentors. The overall objective is to:

- Develop instinct in the scientists to identify the technology that has potential to go to the market;
- Develop the ability to perform market fit analysis to see whether the markets exist;
- Have a network to get in touch with a group of similar minded individuals who would help with the advice/direction and guidance – mentors.

(A discussion takes place in the US on the role of the professors in promoting entrepreneurship. It is argued that there should be distinctive careers for the professors who conduct research, who teach, and who promote entrepreneurship and technology to market. Currently, academia's award system put more emphasis on the research work of the faculty, leaving teaching, entrepreneurship and mentoring less rewarded).

In the recent years major universities in the Bay Area have created the "innovation centers" or "innovation hubs" to concentrate and disseminate the know-how of research to market process (TTO may be a part of these centers). Besides these centralized efforts, coming from the top of the hierarchy, there are many decentralized and independent initiatives and programs created by the faculties of engineering, business, law and also other faculties, aimed to support the innovation.

UC Berkeley is an excellent example of how the innovation ecosystem has flourished in the last 5 years. With the coordinated efforts coming from the University of California headquarters and the specific initiatives launched by the different departments, institutes and centers, UC Berkeley is making a conscious and targeted effort in helping the faculty, postdocs and young entrepreneurs to bring their research to market.

Along with UC Berkeley also UCSF and UC Davis have transformed their innovation ecosystems and adopted entrepreneurial and venture programs in order to boost the technology transfer. The latest initiative of UC Berkeley is to nominate a Chief Innovation Officer whose role would be to streamline and promote the innovation and entrepreneurship efforts on campus. However, many initiatives at these public universities are at an early stage, comparing to Stanford, whose innovation ecosystem has been established decades ago. That explains a number of overlapping initiatives and a somewhat confusing structure that may act as a barrier for the scientist entering this ecosystem with the intention to commercialize a technology s/he has generated.

There is a multitude of ways how the university supports the research transition to the market. I will present a few examples in some detail.

Some novel formations are still in a pilot phase, but they show the direction and trends in the development of the innovation ecosystem.

3.1. Advancing from Basic to Applied Research – example of QB3 Pop Up Institute[42]

Quantitative Biosciences Institute (QB3) was created by the California state legislature in 2000. It is an innovation center made up of over 200 quantitative biologists at three northern California campuses (UC Berkeley, UC San Francisco, and UC Santa Cruz) working at the interface of the physical and biological sciences.

Initially supported by a governmental grant of USD 4 million a year, the funding today decreased to annual 800K, matched by the private partners – donor funds and industry contributions. Private companies bring USD 50-200K each in funding, some companies sponsor events and conferences. One part of QB3 hosts the core facilities and carry out the (basic) academic research. Another one, InnoLABs, created to promote applied science, also provides assistance to the startups.

The QB3 launched its pop-up institute 5 years ago as an attempt to bring researchers together to work on a multidisciplinary problem. According to Ioana Aardei, Entrepreneurship Program Manager at QB3, the concept arised from the fact that it is very expensive to set a “proper” institute. The pop-up institute allows principal investigators to work part time on a specific problem while staying in their laboratories.

Calico (an Alphabet company) funded the first symposium on aging.[43] That presented the projects in the field of basic research. Five years later, the second symposium advanced to the area of applied research. Part of was already devoted to technologies taken over by startups that pitched their projects to the investors. It demonstrated that in the five given years, the technology field had matured. In the next 5 years, another symposium may take place, but already involving the FDA (Drug

Development and Approval Agency) discussing drug profiling, bringing reimbursement experts etc. in the field of aging.[44]

Following success of the initiative, QB3 has recently started a new pop-up institute on fibrosis, thanks to a donor donation. Next considered projects are "what is an inflammation" and "blood vessels exploration".

Lessons learned: *In order to foster the innovation and technology advancements there is no need to create fixed costly structures. Fluid organizations with a clear objective and limited time frame (max 5 years) can offer an inexpensive and dynamic solution.*

3.2. Deployment of a Mix of Complementary Support Mechanisms – example of CITRIS

The Center for Information Technology Research in the Interest of Society (CITRIS) is another center created in 2000 by former California governor Gray Davis. The mission of the Centre and the associated Banatao Institute is to create the information technology solutions for society's most pressing challenges and to shorten the pipeline between world-class laboratory research and the development of applications, platforms and companies. From concept to prototype, the CITRIS innovation ecosystem includes:

- competitive seed funding,
- specialized testbeds,
- Marvell Nanofabrication Laboratory,
- CITRIS Invention Lab, and the
- CITRIS Foundry startup accelerator.

CITRIS unites four University of California campuses: David, Merced, Berkeley and Santa Cruz. The fact that there are four campuses each having their own center of excellence and specialization is helpful when discussing the cooperation with big companies/corporations – it is a strength that distinguishes the center from the private universities. In its vision for 2025, Costas Spanos, the Director of CITRIS, focused on interdisciplinary technologies. The center already operates at the intersection of disciplines and in 2018 has extended its activities to the policy field.[45]

The CITRIS Foundry is an accelerator for deep technology startup companies—those founded on the basis of scientific discovery and/or meaningful, hard-to-reproduce technological innovations with the potential to transform society. The Foundry's accelerator program offers startup teams a variety of valuable resources that include flexible maker space, access to the Marvel Nanofabrication Laboratory, wet lab space in the QB3 Stanley Hall Garage and MBC Biolabs in San Francisco. The Foundry pays for the startup teams' use of space for the 12-month program. Over the last five years, the Foundry has expanded its portfolio from predominantly IT-focused startups to teams working at the frontiers of gene editing, artificial intelligence, biomedical technologies, programmable hardware and energy systems. Thus far, the Foundry has supported 42 teams, the vast majority of which (79%) were driven by graduate students.

The institute (foundry) takes a small amount of equity from the participating companies. Intentionally, the amount of equity retained has been kept small, as the objective is not to stifle innovation, but to give back to the campus in the event of success.

Lessons learned: *In order to maximize the effect of innovation and technology transfer, the mix of tools and mechanisms brings added value. CITRIS combines seed funding with accelerator facilities and access to laboratories as many other successful accelerators in the Bay Area (for example, IndieBio).*

3.3. University Supported Accelerator - example of Skydeck[46]

Skydeck is the largest startup accelerator at UC Berkeley campus. Skydeck was founded six years ago but has grown significantly in the last 3 years. Since 2018, Skydeck is fully industry funded. Its aim is to invest in breakthrough technologies. While for certain verticals like software

Skydeck would request some traction from the companies in the form of revenues and customers, biotech companies come to Skydeck at a very early stage.

Many companies participating in Skydeck have a connection with UC Berkeley. But recently Skydeck started to accept global participants, although they are not eligible to receive the funding. By the end of program, the companies develop connections with UC Berkeley and industry advisors, may employ the UC Berkeley postdocs to their company and can benefit from the use of UC Berkeley laboratories under certain conditions (SSUFIE agreement discussed later in the text).

Selection of the participating startups is very tough, only 3,5% of applicants are selected. All projects are arranged by verticals (software, biotech, etc.) and each vertical is evaluated by about 5 people. If the project receives a good score, the team is invited to a first interview. Even if one person from the panel is very excited about the project, it may result in the project passing the preselection. 15-20% of the companies that apply are admitted to the first interview stage that may be conducted remotely. During the interview, 25 minutes are devoted to the team composition and 10 minutes to the project presentation. Very much focus is on the team: how committed and invested in the project members are. The interviews are done by the committee comprised of VC, industry partners and Skydeck staff.

About 30% of the companies will make it to the second interview, where they have to be present at Skydeck in person. During the second interview the focus is on technology: for more indepth discussion the faculty member, specialist in the technology or member of a company working in this field may be invited. The potential funding sources and existing competition are also evaluated. If necessary due diligence is performed and/or additional questions are mailed to the CEO. About half of the second round participants will make it to the finals (around 100). The best 20 will be funded. The selection takes place twice a year.

Recently Skydeck started to invest in the top startup companies at their accelerator via the created fund. Core cohort is funded in the amount of 100,000 USD for the equivalent of 5% equity at a $2 million cap (SAFE note)[47]. Fund is legally separated from Skydeck and the money from the fund is distributed via the board of directors. Any profits, when the startups are sold or go public, will be split 50-50 with UC Berkeley.

The success is measured whether the company managed to raise money. After graduation from Skydeck about 60-70% of companies receive additional financing and this is a very high percentage.[48] The high success rate of Skydeck is explained by three factors: proximity to the university and the possibility to use its resources; proximity of Silicon Valley; focus on the cutting-edge technology.

Lessons learned: ***There is a general trend that with time the (successful) accelerators grow in size (number of startups accepted) and also create the venture capital funds to secure the early stage investments for the most promising companies. An interesting feature of Skydeck VC fund is that half of its proceeds will go back to the University of California.***

3.4. Shared Special User Facility (SSUFIE)- example of UC Berkeley

SSUFIE is a new structure introduced by UC Berkeley for the new technologies to be tested in the laboratory in return to a fair market value fee, while ensuring environmental, health and safety compliance, and managing the conflict of interest.

SSUFIE closes the gap between the research done in laboratory and start of the product development in the startup. It was destined for the early stage (pre-product sales) startups affiliated to one of the university's accelerators. It satisfies the need of the students, especially those who already have been working at UC Berkeley laboratories, to continue using the laboratory for their product development. Prior to the pilot, it was not allowed due to concerns over conflict of interest, non-profit rule, environmental and health control considerations, even if laboratory had spare capacity and was willing to accommodate such work. The participating startups are required to pay market rates for the (tightly defined and time-limited) use of faculty lab facilities. Proceeds from this program support research and education in the SSUFIE faculty labs and corresponding departments.[49] It is a win-win project, as the laboratory receives extra funding but the startup's founder can continue working in the known conditions (often it is the laboratory where the founder did research previously, as a PhD or a postdoc), but pursuing research with a commercial intent.

The SSUFIE agreement fall under novel intellectual property (IP) provisions called *joint ownership with university commercial forbearance*. To account for this exceptional use, IP solely invented or authored by startup employees under the SSUFIE agreement is jointly owned by the startup and the university. However, the university agrees to forbear from commercially licensing the IP, and can only use the IP for research, education and non-profit purposes. In summary, the startup has exclusive commercial rights without the need of an university license. These IP provisions are unique and approved by the University of California Office of President as an exception to University's IP policy.

Mike Cohen, head of Technology Transfer Office of UC Berkeley explains[50] that the program has faced initial concerns similar to the ones that newly created accelerator Skydeck faced back in 2012: that it can't be done and shouldn't be done. In both cases decisive argument was that these types of initiatives are a part of an educational process.

Mike Cohen makes it clear that it is not the intention to overrun the university IP rights and the mission of basic research with SUFFIE agreements. It is an exceptional opportunity and will remain as such. In numbers, since the launch in 2017 there were 35 enquiries about such an agreement and 8 SSUFIE agreements were signed. So, the size is very small comparing to the size of the University. The pilot is considered successful and there is an interest at other campuses to implement the SUFFIE idea, too.

Lessons learned: *Pilot of the UC Berkeley, SSUFIE agreement gives an opportunity to a startup to "rent" the place in laboratory of its choice, keeping the IP rights. The laboratory benefits from the additional funding while startups have the lab space where they can develop the technology for commercial use.*

3.5. Entrepreneurs in Residence Program

The program "Entrepreneurs in Residence" is a new program at the Institute of Innovative Genomics (IGI), academic research organization in partnership with UC Berkeley and UC San Francisco. Susan Jenkins, Managing Director of Institute of Innovative Genomics shared her experience and lessons learned managing the program.[51]

The funding of Entrepreneurial Fellows Program came from a donor. The concept of the program was to provide up to 250,000 USD for two years to researchers who thought that their idea could be brought to the market. The postdocs could use the laboratory and hire a technician under this funding. It was meant to be a postdoc program where more applied research/proof of concept studies were conducted.

The program was advertised worldwide but the response rate was much lower than expected. IGI received only 10 applications, one from India, one elsewhere from the US and 8 from UC Berkeley. With the hindsight IGI understood their mistake: as the program was focused on the commercialization of the technology, researchers from outside did not want to apply to the institute as complicated issues of IP transfer were involved (need to split the pre-IP with the IP created during the program).

What IGI did not anticipate was that both selected candidates would incorporate their company already after 3 months in the program (in contrast to the expectations that they would do it at the end of the program). After 6 months in the program they started the talks about licensing the technology. They wanted to use fellowship money to do it. That was of course not an option. Next, the researchers came up with the idea of leasing laboratory space and work on their company in the “free time”. As they would lease laboratory on commercial terms, it would allow them to own their IP. This idea was again declined by the due to difficulties to split IP created during the fellowship and the one created for the company. One of the researchers finally raised external money and also got SBIR funds and after graduation from the program devoted himself fully to the company. Other one managed to split two components of his study and worked on one component under fellowship in the IGI laboratory, and the other one in the leased laboratory of IGI, creating his own IP. Researchers also had tensions with Intellectual Property Office (IPIRA), as they were hoping to get exclusive license on their technology, which IPIRA was not willing to provide (licensing of a breakthrough technology, can bring millions to the university if non-exclusive rights are provided. As small companies founded by researchers are very likely to fail, the university hesitates to grant them exclusive right for the use of technology).

Based on this experience, Susan suggests that a one year program would be sufficient and more milestones about what researchers should achieve in 6, 9 and 12 months should be defined. Also the timing of incorporating a company needs to be discussed upfront.

The example clearly shows mismatch of expectations for the program: while funding partners wanted that the research was done, and envisaged licensing only at the end of the program, the researchers saw a program as the help to start their private business and tried to find a way to create IP that were not locked by the university.

Lessons learned: ***The attempt to bring technology towards the market with the entrepreneur in residence program had yielded mixed results. With the hindsight one year residency would be sufficient and more specific milestones determined in the beginning of the program. The potential conflict between***

research and business interests are clearly highlighted in this case, raising the question about a "traditional" research institution being the right place to bring technology to the market.

3.6. University Education and Support Programs

In each university various educational programs are offered to scientists and students considering entrepreneurship. The few programs that I had a chance to audit were FORM and FUND offered by Berkeley Law; Startup 101, offered by UCSF Medical School; Management of Technological Innovation course, offered by Sutardja Center for Entrepreneurship and Technology; and Berkeley Post Doctoral Entrepreneurship Program (BPEP).

At BerkeleyLaw, FORM and FUND series teaches the core legal, financial, and organizational aspects of starting and scaling a new business by leading Silicon Valley attorneys, entrepreneurs, and/or venture capitalists. The course mixes people from engineering, technical, law and business backgrounds and provides free incorporation services and office hours with the advisers and venture capitalists for the startups.

Startup 101 offered by UCSF Medical School is an experimental, team-based class that covers the topics important to starting a scalable for profit venture, teaching how to recognize a business opportunity, to do market research, develop business plans and business models, clinical development, regulation, how to get reimbursement from insurance companies, intellectual property, building the team, financing strategy, budgeting, sources of capital and more.

Management of Technological Innovation is a course offered by Sutardja Center for Entrepreneurship and Technology, which prepares graduate students and post-doctoral students across all disciplines to be able to translate technical work into value as a new venture or in industry settings.

Berkeley Postdoctoral Entrepreneur Program (BPEP) aims to foster entrepreneurship in the UC Berkeley postdoctoral and graduate community by providing tools, mentoring, and a platform for science-business communication to enable research innovations to move into the marketplace.

Besides, some UC Berkeley centers (like, for example, Berkeley Sensor and Actuator Center BSAC founded by National Science Foundation, UC Berkeley and UC Davis) have the Visiting Industrial Fellows programs, where industry representatives join the lab and carry out their research. The Fellows are free either to join an ongoing research project or launch a new one.[52]

Lessons learned: ***The programs on campus help students with the scientific background to understand the basic business concepts and present them with career opportunities beyond academia.***

3.7. Program that Matches the Technology and MBA students - Cleantech to Market

The program was launched 10 years ago at the Haas Business School at UC Berkeley. It is privately funded by donations from corporations, non-profit organizations, and former alumni. It greatly benefits from the location in Berkeley and the proximity of Lawrence Berkeley National Laboratory, Hass Business School, other Berkeley faculties and the Silicon Valley where solar and battery companies are concentrated.

According to the Director Brian Steel[53], the program is unique. The only place where a somewhat similar program exists is the MIT. But in the MIT students work on the preselected technologies and do not actively participate in their selection.

The main stages of the program are technology application selection, building a team, updating the syllabus (adjusted on the basis of the technology selected for the current year), followed by 15 weeks of class, for which a credit is awarded, and a public symposium. The selection of projects is national wide, including several partner organizations like ARPA-E, Lawrence Berkeley National Lab, and top-tier universities.

The selection is focused on the technology that is currently between TRL[54] stages 3-6 (between the first tests of the proof of concept and tested prototype). Cleantech to Market (C2M) cannot accept the technology in too early a stage, as it needs data to do technoeconomic modelling. C2M searches for core technologies that are already risk-free, sufficiently robust and proven with respect to function.

There are three phases of evaluation of the technology. The first one is internal, when C2M talks to people who know about the specific technology (both at university and industry) to validate the idea. Then, an external advisory board consisting of executives (VC, investors) and prior year students evaluates the technological potential.

Next, the team leaders are selected and they choose the technology they want to work with. Other students join and, normally, at least one of the team members has a technical background. Based on 4-6 technologies selected, the syllabus gets adapted and specific guest speakers are invited based on the needs of teams.

During their assessment, students will have to provide 40-80 possible scenarios of use of technology that later will be cut down to 12 and then to 3, understand the competitors and interview the players in the market, potential users and investors, conduct technoeconomic modelling and prepare a pitch.

The program provides a win-win situation both to the startups and the students. The startup gets out of the program about 1000 hours of free work on developing viable business models, market reports, interviews and analysis of the markets and competitors. The student gets out of program the real business case to work and practice on, sometimes subsequent employment by startup, particularly if the startup managed to raise funds.

Lessons learned: ***C2M is a win-win program. Startups receive up to 1000 hours free marketing research and students get hands on experience of the market.***

4. University-industry collaboration and its role in bringing the research results to the market

The university-industry ties are historically strong in the Bay Area. In contrast to Europe and Japan, the faculty in the US are not civil servants and thus are allowed to engage in private sector activities. In exchange of their involvement in the industry, they may receive a compensation for consulting services or a small part of equity for being at the advisory board for a startup. [55]

If we look at the historical examples of collaboration between university and industry, already in the 60s, "Terman (provost of Stanford university since 1955) encouraged Stanford faculty to serve as paid consultants to corporations, a shrewd directive that bridged the gap between academia and industry. He believed that it would not only be beneficial for professors to keep up-to-date on industry interests and future directions, but it would be an effective vehicle to provide research funding and fellowships for Stanford's most promising students. Terman's policy is so valued among faculty that, to this day, they credit it as the single most important contribution of the academic-entrepreneurial environment".[56] However, while industry played a significant role in the private universities, in public ones involvement with the industry was taken with a degree of caution. The concerns of diverting the basic research and resources from the "core" research and education mission were the reason for that.

With the decrease of federal funding for the public universities over the recent years (the funding of University of California had dropped almost by one third since 2000), the role and participation of industry in public universities increased. A set of tailored collaborative models emerged.

Besides traditional sponsored research collaboration, other forms coexist: industry membership scheme, single lab contract research, joint research centers, entrepreneurs-in-residence, competitions and hackathons for students, sponsored conferences and workshops. [57]

4.1. The Sponsored Research Agreement

The core university/industry agreements are sponsored research agreements and facility use agreements. The sponsored research agreement is prepared with the help of the Intellectual Property Office or similar organization of the university. Contribution from the industry is normally higher under the sponsored research agreement, comparing to the gift funding (see item 4.3), but in contrast with the gift or donation, contractual obligations are clearly outlined and it is expected that the University (through the work carried out by University faculty and students) helps the sponsors accomplish their goals.

Depending on the needs of laboratories and industry the concluded agreement could be a master agreement (covering broad scope of cooperation, including one or more laboratories and institutes) or a tight scope agreement, limited to specific research and/or specific laboratory. For IP developed under sponsored research agreements, ownership follows inventorship and authorship. If the sole inventors or authors are university employees, then the university owns any associated IP. Typically, sponsored research agreements stipulate that the university will give the corporate sponsor the first right of offer to exclusively license the associated IP rights.

The initiative of collaborative sponsored research comes from both parties: on the one hand, industry may seek collaboration with the laboratory after attending a conference or reading a publication. On the other side, laboratory or rather principal investigator (PI) or students may reach to the industry with the intention of having access to funds for the research.

“A typical sponsored project for research begins with a faculty member becoming interested in the study of a particular phenomenon, for example, the genome of crop plants. The faculty member realizes that she needs to buy materials and equipment and hire graduate assistants to engage in this research project. Since the faculty member’s department does not have enough funds to support this research internally, the faculty member looks for an external sponsor, also interested in studying the genome of crop plants”.[58] The faculty members generate leads and develop a network through conferences, publications and presentation of their work.

A few interviewees have noted that the corporations have recognized that they are not able to innovate in house. The big companies with the hierarchical structure and their business/profit-oriented approach are not able to ensure (radical) innovation inhouse. The structure and setting of the internal organizational processes stifle innovation. It needs external, free and creative space to make the innovation happen. And they can find this place in the university, hence the increased interest for the collaborative sponsored research.

Industry provides the funds to do the research and University provides the laboratory, PI and students to do the work. To have an agreement, both industry and laboratory need to have “a match”, the research should be of interest to the PI and also she has to have a capacity (space) to do it. If research could result in a product, the IP rights licensing agreement is made. The university is doing research and only research work. Once the research is entering the stage of the product development the research is handed over to the company.[59]

“Increased corporate sponsored research results in more mature inventions that companies are likely to want to license, compared to early-stage inventions that are far from being a commercial product”[60,] state Director of IPIRA, Dr. Mimura in the Report on Entrepreneurship at Berkeley. The industry sponsored research has grown 8-fold at UC Berkeley since IPIRA was established in 2004. On average, about 15-20% of new invention disclosures are sponsored by companies that want a license to the IP and, therefore, are on board to pay the costs associated with IP protections.[61] At UC Berkeley sponsored projects are short term activities typically lasting from one to five years. Sponsored projects may be renewed and continued for a longer period, but there is always an end date. The funds provided by the sponsor are also limited to a certain amount. The sponsor may choose to give additional funds over time, but typically there is a finite amount of funding provided for a sponsored project.

Facility use agreements aren't collaboration agreements; instead, they are designed for the commercial use of university resources that are set-up to be regularly used by companies (and companies pay user fees for the commercial use). Therefore, any IP developed under a facility use agreement is presumed to be solely invented or authored by the company's employees, and accordingly, the company solely owns the associated IP rights. SSUFIE agreements are a specific form of facility use agreement that is at pilot phase at UC Berkeley (described in chapter 3.4.)

4.2. Individual faculty funding – example of Energy Biosciences Institute

Another type of university/industry relationship is the individual faculty funding. One example of it is the British Petroleum (BP) funding of Energy Biosciences Institute (EBI)[62]. Craig B. Vaughn, a process technology advisor for the Vice President in the BP, was responsible for the IP strategy at the Energy Biosciences Institute (EBI) and was directly involved in the setup of the institute.[63] He explained that back in 2007, BP decided to get into the biofuel and the renewables fields but did not have the required know-how inside the company. BP specifically looked for the academic environment as they felt that in their business oriented company (aiming to meet quarterly goals etc.) and considering their limited expertise in the field, they could not create the environment that stimulates research. BP put together a proposal and sent it to a number of universities (including MIT and UC Berkeley). By assessing the universities by the different criteria: specific expertise in the field, analytical capabilities and IP terms, UC Berkeley was chosen. Energy Biosciences Institute (EBI) was created under an agreement with British Petrolium (BP), which contributed 50 million yearly (35 million for basic research and 15 million for BP core research) over 10 years.[64]

BP hoped that the cohort of researchers would achieve the breakthroughs in the renewable energy field in the “open section” of the institute and then the technology that would be moved to the “closed section” for further development and commercialization. In addition, BP Venture Group was created with the purpose to fund the promising ideas that could be commercialized in the core areas of BP interest. However, according to Susan Jenkins, former managing director of EBI, not a single project was funded by this VC group. There were few spin-offs from the institute but not in the core fields of interest to BP and therefore they were not funded by them.

The important aspect of collaboration between BP and the university was that there was a lot of interaction between BP and researchers. It was not a situation in which a PI, after winning the grant, would spend two years at the laboratory without interacting with the company. Vice President, process technology advisor, and few staff at BP regularly kept the research on track. Monthly seminars were organized, BP regularly attended the research group meeting to see where the research was going. Unfortunately, BP started to back up from collaboration after 8 years due to Golf Coast oil spill and decrease in oil prices. They renegotiated the contract keeping the same (beneficial) conditions, as regards to patenting and licensing, but significantly decreased their contribution to 2,5-5 million USD per year.

This cooperation was beneficial for University of California. The contributions of BP were more than 300 million USD to the EBI since 2007, an amount that the EBI would never get from Federal funds. BP funded 100 million USD purchase of materials and instruments, basic research, hundreds of graduates and all patents. EBI funded more than 75 research programs or projects in areas such as biofuels, biomass and renewable chemicals. The cooperation with EBI resulted in 80 patents in 8 years, paid by BP, but BP did not directly commercialize any of them and the research was never passed on to the “closed” part of BP.

The terms of agreement were also favorable to the BP. The contract gave the opportunity for BP to opt for exclusive license at a pre-negotiated rate. (However, the contract still contained a clause that, in the case of technology that would bring significant royalties, the pre-negotiated rate could be renegotiated). Looking in retrospect, Craig B. Vaughn thinks that if BP were only be interested in the commercialization, it would be more beneficial to acquire a company than pursuing collaboration with the university. But the reason of collaboration was that BP wanted to address a broader issue and make an impact in the biofuel field. It wanted to participate in the food and fuel debate and other social economics work as it was not clear, at that moment, where the US policy in this field was heading. EBI provided a perspective on the above issues that was a value added for the BP.

4.3. Industry Membership Programs and Gift Funding

Industry Membership Programs link academy and industry. The contribution from the industry in the amount between 50,000 and 300,000 USD, with 100,000 USD on average goes to the centers or institutes. In return, the sponsoring company gets direct access to different faculty members, the opportunity to attend exclusive events, have a firsthand non contractual access to the research findings and also access to recruitment of graduates. Let’s take the Center for Long-Term Cybersecurity at UC Berkeley as an example. It is a translational hub created between research and industry funded by a private foundation. The cybersecurity issues are spread across the UC Berkeley campus as they are present in many disciplines (sociology, school of information, etc). The Center helps to bring all these competencies together and provides an entry point to the industry. After having established relationship with multiple faculties, in one or two years, the industry partner may decide to focus on sponsoring one specific faculty.

The most generous form of funding, gift funding, means that no requirement can be imposed by the industry, there are no deliverables and no contract. This is of course the preferable collaboration for the faculty. It should be said that, informally, the faculty still provides the feedback to the company and may share research results. The relationships established allows the company to be “the first to know” about research developments. It has been noted by the faculty, that “gift funding”, or donations, became increasingly rare, as more and more contributors are looking for part of the equity or some return to their investment.

4.4. Institute as a Mediator Between Industry and Startups

For the strategic alliances, networks and collaboration are crucial. They are formed via internal referrals, industry networking, conferences, publications, proactive contacts, VCs, investment bankers, and unsolicited inquiries. One of the missions of the Institute of Qualitative Biosciences, QB3 (already presented in chapter 3.1), is to bring industry and startups together, to introduce them to one another. If industry expresses interest in the startup, the dialogue may start even at the incorporation stage of a startup and, later on, based on the company’s development, it could lead to a deal. If a corporation has interest in a startup, the Business Development team from the corporationside may pay for the pilot or licensing of the technology.

A strategic alliance or partnership with the founder, who stays either in the university and continues the research work (this is described in more detail in the chapter on university-industry relationship) or creates the startup, may bring access to new innovations and products without a major internal investment. It allows to utilize her expertise instead of building an internal innovation capacity. Academical environment and newly created startups are more open and their culture is more supportive to cultivating breakthrough ideas that entail higher risk. The strategic alliance may help the large company to reach new markets, enter related businesses or expand the internal portfolio and this is the reason why corporations collaborate with research institutes at the leading universities.

The startups benefit from strategic alliances financially, by attracting the technical expertise to develop a product, as well as industry knowledge on how to develop and commercialize products. [65] By collaborating it may also benefit from the corporation's existing clients portfolio.

Institute of Qualitative Biosciences, QB3, assists startups from the incorporation stage (startup in the box) that resulted in incorporation of 650 companies. It helps with sorting out their IP issues and give other advise. Some companies come for consultation only once and never again. Others have continuous collaboration with QB3. Participation is voluntary and startups are free to participate in other accelerators, or programs.

QB3 looks for the win-win approach and consent and interest from both sides in the industry-university relationship. Some industry partners just want to be "in the know". The collaboration goes throughout the year as they want to be informed about the interesting subject/research that is going on. QB3 makes introductions to the new teams and startups once they see the technology that is of interest to its industry partners. By means of partnerships, industry is looking for the new innovative solutions and advantage of QB3. Through the institute, they can access very early stage research that is not published or listed anywhere. One example is the collaboration with Procter and Gamble (P&G). QB3 introduced ten teams to P&G that presented their research projects and P&G followed about half of them, which is quite a good indicator.

5. Lab to Market Transfer in Large Companies and Corporations

The industry (by that I mean large established companies and corporations) traditionally has been nurturing new technologies in their R&D labs. The iconic example is the Bell Laboratories - an industrial research and scientific development company owned by Finnish company Nokia, origin of radio astronomy, the transistor, the laser, the photovoltaic cell, the charge-coupled device, the Unix operating system, and the programming languages C, C++, and S. Nine Nobel Prizes have been awarded for work completed at Bell Labs along with three Turing awards.

Many companies tried to replicate the success of Bell Labs. But it has proven not that easy. By exploring the capacity of innovation in the industry, it has been noted that big corporations may still be good in incremental innovation, but extremely poor in radical innovation. By examining the reasons for this to happen, inflexibility, organizational culture, and misaligned objectives were noted.

The organizational cultures are very different in a startup and a large company. As Steve Blank[66] explains, the startup company is focused 100% on innovation and entrepreneurship. By its definition, the startup is a temporary organization established to experiment and innovate until finding the right business model that would allow it to scale and become the large organization. Once becoming a large organization that already found its business model it sets the goals of profitability and longevity. (It is especially true if the founder is removed from the CEO position and replaced by the "professional" CEO that is often the case of the venture capital funded company).

If the large company tries to innovate, it may run out of business. It does not mean it cannot innovate but innovation processes should be done in parallel with the traditional operations. How? The answer ranges from the innovative team within the organization to external innovation hubs and companies' acquisition. Below, I give examples of:

- Innovation inside the company – 5.1., 5.2. and 5.3.
- Innovation outside (or in the margins) of the company – 5.4., 5.5., 5.6.

- Attracting external innovation – 5.7.

5.1. Internal Innovation Team - example of Telefonica

Telefonica[67], a large communication company, is an example of the application of the Lean Startup methodology. Telefonica created a small innovative team of intrapreneurs inside the organisation. The team benefited from the access to high value assets of Telefonica: platforms, infrastructures, global communication facilities, 350 million customers and sales channels. Besides, access to relevant stakeholders was a lot easier as the name of Telefonica itself opened many doors.

Telefonica faced challenges when applying Lean Startup, such as cultural challenges, finding intrapraneurs, corporate politics and processes, branding issues, and project/product transfer. “External startups are our competition. It’s very hard to do things better than startups. The reason why the innovation and development department exists, however, is that we have many advantages that startups don’t have—our network capability, customer data, and our distribution channel. We develop innovations that leverage these three capabilities.”[68]

The study of Henry Chesbrough revealed several trends that should be taken into account when considering innovation in the large organization:

- Innovation through a small group of people, employees of the company who are able to apply the Lean Startup approach to the project in question;
- Importance of autonomy without looking for permission to spend the budget and excessive reporting. As a team leader put it: “I try to create the illusion that we are a startup.”
- Processes at large companies like Telefonica could affect negatively innovation projects: “If someone in a startup needs to build a prototype and needs three SIMs, they would just go to buy them at any store. When we started at Telefonica, we had to use our purchasing process and it would take three weeks to get them. Corporate processes can be a huge challenge and you have to work

within those processes.” That finding is also supported by the Seco Tools team (see chapter 5.3) who noted how they mentally struggled at first to make the first orders without the approval of the hierarchy. Only being placed in the US cocreation spate allowed the team to take initiative and start takin initiatives without waiting for approval from the headquarters.

5.2. Internal accelerator - example of Area 120 in Google

There are few structures created by Google that address innovation and help ideas to go out to the market. One of them is X or “the moonshot factory”, tackling radical innovation projects that are independent from Google. Another one is Advanced Technology and Products Group within Google. And lately, the Area 120, where an internal Google incubator was created.

Area 120 originated from the idea of Google that employees shall devote 20% of their time to personal projects that might have value to the company. With the growth of the company though, the 20% of “free creative” time slowly disappeared, replaced by the 120% working hours.

Despite the high workload, Google wanted to stimulate bottom-up innovation and that was the reason for the creation of Area 120. Through the creation of physical space (that exists now in three US cities and abroad) and by having access to Google experts and tools, it gives the opportunities to Google employees to transfer their ideas into a product. Anyone can apply, being the engineer, marketing, sales or business development person at Google. If the idea is accepted, the person gets a team of 4-6 people, 6 months and some budget to work on the idea.

“There have been many, many kinds of corporate incubators over the years…We wanted to do something with a very specific Google approach to it.” Employees “can actually leave their jobs and come to us to spend 100% of their time pursuing something that they are particularly passionate about,” explains managing director Alex Gawley”[69].

The type of people that Google 120 is looking for are those who are "in love with the user centric products, have some vertical skills but mostly horizontal skills, and have people centered approach" as Shelly Glennon, partner in Google says[70]. On the question of selection of ideas, she emphasizes that "we really want you to identify the need, there are too many solutions without a problem". Selection comes down to three key components: the team, with the focus on team diversity, the problem or need they try to solve and the impact if the solution is provided.

It is expected that many ideas will fail, but a handful will succeed. One successful example is a Grasshopper - a smartphone app that teaches users JavaScript coding via games. The timeframe for the projects is 3-5 years (In comparison, Google X, the Google spin-off that tackles radical innovation projects, has 10-20 years project lifespan).

Lessons learned: ***The idea of Area 120 resonates with the claim of Steve Blank, who says that out of 1000 people in the organization there are 50 innovators hiding somewhere, so one needs to identify them and create a parallel structure to give employees freedom to innovate.***

5.3. Sending a Team Overseas – example of Seco Tools

The below example illustrates how the big company enhanced its innovative capacity by sending small teams of engineers overseas and giving them a loosely defined task with a direction to come up with the product in a six month time.

Seco Tools[71] is a Swedish industrial company. This traditional manufacturing company wanted to modernize and explore digital direction. The question was "how?". The solution that the company came up with was to send a team of engineers to the Bay Area for 6 months, giving them budget and a task. The task was defined broadly: to create a new product in the digital area by employing sensors. The team was selected in Sweden and “shipped” to Flex premises where they had to work. They had online progress meetings with managers every 3 weeks.

Flex is the SF Invention Lab and Micro-Factory, a prototyping, design, and small batch manufacturing facility in downtown San Francisco. Specifically serving early-stage product teams, hardware startups, and high-touch product designs, the Invention Lab allows a team to work on products together on-site with Flex designers and engineers. Teams can also experiment with materials, technologies and processes that disrupt conventional thinking or business models. The space was ideal for early proof-of-concepts and design exploration.

Flex is not a unique space in the Bay area. Other similar spaces are located across the Bay area to help teams to test and experiment with their technologies. The Seco team was assisted by the Enterpreneur in Residence of Flex in their task.

Very early the team realized that they had to come up with a roadmap and do something realistic, “basic” (“Minimal Viable Product” in the Lean Startup terms) to cope with of the six month deadline target. They came up with the idea of a sensor pen that is able to identify products in the factory. The pen (light, plastic, unbreakable and waterproof) allows to scan products with a small chip attached to them. The application gives specification of the part and also shows if it is compatible with other parts. There is a high interest from customers in this product and the pen gets ready for production.

Lessons learned: ***To create an innovative product, it is easier if the team is externalized and put in a different environment or, at the very least, operates on the margins of the big organization. Flex premises was an ideal place in this situation, providing a creative collaborative space equipped with the machines and entrepreneurs in residence, having knowledge and expertise.***

5.4. The Separate Research Facility – example of British Petroleum Biosciences Center

Oil and gas industry is particularly inflexible in adopting the radical innovations and it is particularly difficult and rare to witness the move from research to market[72]. In the previous chapter 4.2. I described how British Petroleum collaborated with the University of California, Berkeley in setting out the Energy Bioscineces Institute. After severely reducing the funding of the Energy Bioscineces Institute, in 2015, BP established its own independent research facility in San Diego, San Diego Biosciences Center (BSC) that conducts research aimed at accelerating the world's transition to a lower-carbon future. The Biosciences center functionally is a division of BP consisting of about 30 scientists.

The BSC conducts research and development programs that can help the biosciences make larger contributions to various aspects of BP's operations, including the production of renewable energy, oil and natural gas, along with the development of innovative and efficient fuels and lubricants. It also identifies academic programs that can complement business needs. Among other capabilities, the BSC performs research on microbiology, metabolic engineering, microbial physiology, metabolic modeling, biochemistry, enzymology, fermentation and biogeochemistry.

In 2017, BP Biofuels formed a joint venture with Copersucar — the world's leading sugar and ethanol trader — to own and operate a major ethanol storage terminal in Brazil. The joint venture has helped BP better connect its ethanol production with the main Brazilian fuels' markets.

In the years ahead, the BSC plans to expand its research in areas such as wastewater, remediation and enhanced oil recovery. For example, it plans to help BP make further progress on converting waste streams into biogas, cleaning legacy industrial sites and producing oil more efficiently from existing resources.

Another model that BP is using in getting new technologies onboard is the venture capital model that attracts new companies. The BSC advises BP Ventures on low-carbon and other investments. To date, BP Ventures has invested more than 190 million USD in California-based companies, partnering to bring clean technologies and other leading-edge energy solutions to market. BP invests money in early companies, puts a person on board and helps the company grow. It might take a share of 20-25% of the company, and if the company grows and the product interests BP, BP could purchase its product at a discounted rate. If the company really succeeds, BP may eventually decide to internalize it, by acquiring all its shares (but this has not happen yet). A similar model is used by Chevron to fund startup companies.

5.5. Innovation Hub - example of Autodesk

Companies create external innovation hubs open to new startups and researchers in order to complement their knowledge, attract new workforce or get new ideas for the products. Autodesk, Inc. is an American multinational software corporation that makes software for the architecture, engineering, construction, manufacturing, media, and entertainment industries. Autodesk became best known for AutoCAD software, but now develops a broad range of software for design, engineering, and entertainment—and a line of software for consumers, including Sketchbook.

Autodesk has created three research/innovation hubs to develop research that may (or may not) result in a product. One hub oriented to design and digital manufacturing is in San Francisco, another one is in Boston (architecture, engineering and construction) and a third one is in Toronto (oriented toward emerging technologies, AI, robotics, VR, IoT). Another Autodesk office, in Birmingham, UK, works on inventive manufacturing solutions for the customers. They are all part of ARCO, a special Autodesk division oriented toward innovation.

These research/innovation hubs are the spaces where Autodesk and their partners can explore and test new technologies.

Through the Autodesk program residence in place, external companies have access to the tech space for a period of time ranging from a few months to a year. They can use it at no cost, and keep their IP. In return, Autodesk has the opportunity to follow the frontline research, to show their consumers that they take research seriously and want to continuously improve, in addition to establishing potential ties with the customers. The residents in the program are accepted on a rolling basis by evaluating the relevance of their technology to Autodesk's core business.

According to Alyra Merchert[73], the objective of this program is neither to acquire the company nor its technology. Autodesk benefits from the spill-over effects that the research produces and possible partnerships and collaborations that could result in working together. As this is purely a research facility, not all research results find their way into production. Only a few ideas continue to be developed, maturing in scale and resulting in a product. The facilities provided by Autodesk are excellent to test the technology out of the factory environment.

The result of residency program is that the companies leave with their IP after having tested their product. Autodesk does not acquire technologies developed in the hub, it is rather a service to connect with potential customers and create an image of a research/innovation oriented company.

Lessons learned: *Autodesk is yet another example of created collaborative working space where one can explore and experiment with building new forms of tools and mechanisms without disrupting large companies' operating cycles.*

5.6. JLABS - Johnson and Johnson Innovation (J&J) labs

JLABS San Francisco[74] innovation center works as an external center – independent innovation hub of Johnson and Johnson, medical devices and consumer goods corporation. It hosts 29 independent companies (in 2018). JLABS are life sciences incubators – the companies use the lab during 6-9 months, and can keep their own IP. No equity is required for participation, so “no strings are attached”, according to James Viola, head of JLABS SF. Besides the use of the “wet lab”, JLABS helps new companies to navigate in the vast universe of Johnson and Johnson and foster long term relationships with innovators in healthcare.. JLABS serve as an entry point.

JLABS are reinforced with the JJDC that is a corporate VC branch investing in bio companies that is involved into all stages of investment from seed to series A, B and beyond[75]. The corporate VCs understand the market and may be open to invest in the technology when sufficiently mature (that of course is good if it matches the objective of the founder). JJDC works closely with the innovation center colleagues, covering each therapeutical area in R&D, evaluating the process and deciding if the technology is ready for investment. The JJDC aims to form a strategic partnership with the new companies that go beyond the venture investor-company relationship. JJDC always takes a seat at the board of the newly invested company. In Vijay Murthy’s (head of JJDC experience[76]) view, companies tend to do better with corporate investors than traditional ones, as JJDC provides expertise, know-how and introductions specific to the industry.

Another department, Johnson Business Development, deals at the late stages of development. They focus on mature companies that potentially could merge with or be acquired by J&J and also takes care of the licensing deals.

Lessons learned: ***By providing the lab space for innovation and experimentation, JLABS not only supports new companies but also scouts them for potential VC investment, making sure that***

they detect the potentially interesting companies ahead of the market.

And lastly, one can consider merger and acquisition (M&A) strategy and strategic partnerships in creating innovative products and bringing them to the market.

5.7. Acquisitions as a Way to Move Forward

The acquisition of new technologies versus developing the innovation in-house is a popular strategy. It is believed that startups are better placed in “de-risking” innovative technology. However, the acquisitions are not unproblematic. The internal innovation department may have a hard time to accept the startup’s technology and team and that could create an internal conflict. By buying outside, the companies are trying to buy reduced risk and to buy time. But divisional managers sometimes are not incentivized to implement the innovation proposed by external innovative teams. As a result, when acquiring a startup, the best way may be not to integrate the startup, but let it act independently and continue doing what they were doing before, with the condition that the startup should be mature enough not to be fully absorbed by the big company[77]. Sometimes a startup is acquired solely for the team competences in the acqui-hiring acquisition (acquisition, which primary objectives is to acquire the talent not the product itself).

6. The Role of Funding in Closing Lab-to-Market Gap

The early funding for the technological development can be provided in terms of grants, loans, angel and VC capital. While the very early technology is mainly supported by federal grants and philanthropical donations, scaling up requires angels’ and venture capitalists’ investments. The evolution in graphically presented in Figure 6 that illustrates the sources of capital for the cleantech, but which equally can apply to other deep technologies.

The "bootstrapping" means that the company tries to survive on its own, without depending on external funding. Typically, it can use the founders' savings, or money from the "family, friends and fools". Sometimes, money can come from the "liquidity event" – if a founder sells previous company or receives a large payout from a stock holding.[78] "Bootstrapping" could be feasible for the company that does not require laboratory experiments and expensive raw materials to pursue the research and develop the product. In case of deep tech, while in principle it is possible to find a "rent-free" laboratory for a limited period of time (place in the wet-labs incubators), the costs of raw materials, on their own, may be difficult to cover by the bootstrapping.

In recent years, venture capital funds have grown and so have their investments. Seed and pre-seed rounds took place in situations that would previously involve round A funding. Accelerators and angels stepped in to fund seed startups. A new class of micro-VCs appeared, who make 25-500 K investments.[79] The typical investment round in seed stage is from 10,000 — 500,000 USD from angel investors and around $1M from venture fund, but usually no more than 3 million USD.[80]

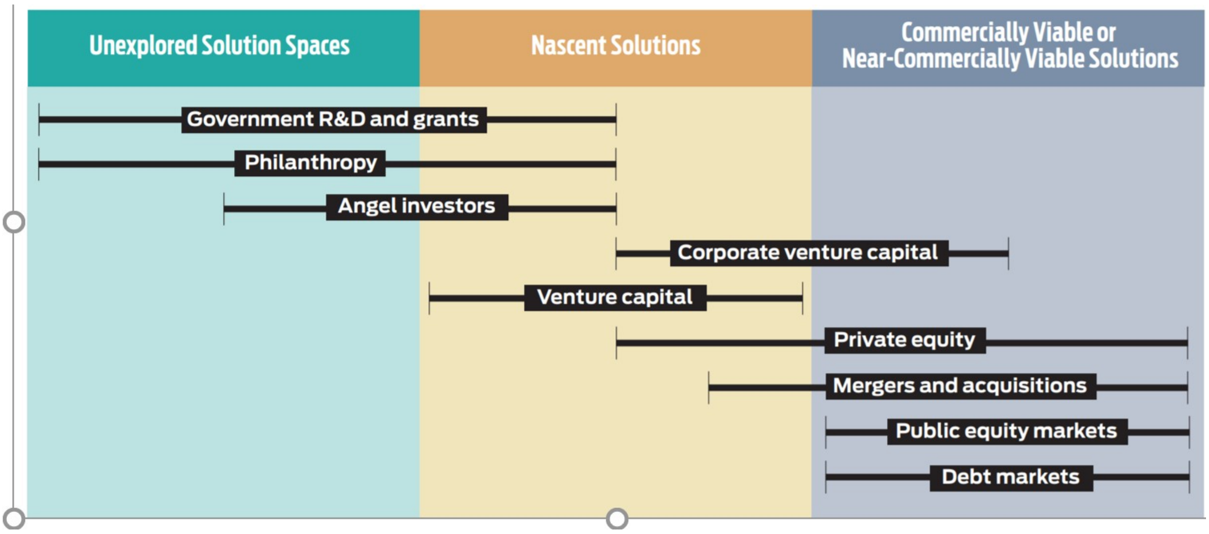

Figure 6. "The Investment Gap That Threatens the Planet by Burger, Murray, Kearney and Liquian, Stanford Social Innovation Review, Winter 2018

Venture Capitalists, and also angel investors, have strong customer/market considerations in weighting whether a technology is ready to enter the market. From the VC perspective, the technological potential is not the only key feature. The focus is on the startup potential to scale and attract customers and revenue. The product/market fit is the key concept for the Lean Startup method of Steve Blank that measures the potential of the company to succeed in the market. Technology must come not too early and not too late to the market and, most importantly, the market should be ready to adopt it. If technology comes too early, it is not able to attract customers and, if too late, the market may be already saturated with developed (same type or alternative) technologies.

The evolution in the sources of funding can be further presented assigning the sources of funding to technical and business milestones in the commercialization readiness level.

CRL	Technical Milestones	Business Milestones	Funding Milestones
0	Research validated	Opportunity validated: corp. license if applicable	Public research grants
1	Startup and technology development plan	Startup created, management team. IP licenses, legal issues settled	Public/Private
2	Market and technical feasibility established	Business plan validated at accelerator level	Public; Ph1 SBIR/STTR *, other public sources
3	"Works-Like" laboratory proof of concept	Key corporate advisors in hand; pharma target validated	Public; Ph2 SBIR/STTR*, other
4	"Work-Like" operational prototype	Commercialization plan updated incl. competitive update; tech landscape; preclinical validation and safety profile	Public; Ph2 SBIR/STTR, other
5	Operational product development and launch	Funding for manufacturing/organizational development; human clinical validation	Public; Ph2 SBIR/STTR, other; Angel. Pharma: corp/VC/Angel
6	Sales/service/support/scaling	$ 0-1 million revenues	Angel/VC/Corp
7	Sales/service/support/scaling	$ 1-5 million revenues	Angel/VC/Corp
8	Sales/service/support/scaling	$ 5-10 million revenues	VC/Corp
9	Sales/service/support/scaling	$ 10-25 million revenues	VC/Corp
10	Sales/service/support/scaling	More $ 25 million revenues	Exit/IPO

Figure 7. Sources of Funding at different CRL levels[81]

* SBIR/STTR federal grants will be dealt with in the next section.

6.1. Federal Grants

The two Federal programs: The Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) help small businesses to develop inhouse research and development that has the potential for commercialization by providing them funding. Their ultimate goal is to stimulate technological innovation that is in line with federal R&D needs, increase the commercialization of private-sector innovation and support women and socially and economically disadvantaged persons.

Funds for the SBIR program come from eleven Federal agencies with extramural research and development (R&D) budgets that exceed 100 million USD and which are required to allocate 3.2% (FY 2017) of their R&D budget to these programs. Each agency administers its own individual program.

STTR's most important role is to bridge the gap between the performance of basic science and the commercialization of resulting innovations. Central to the program is the expansion of the public/private sector partnership to include the joint venture opportunities for small businesses and nonprofit research institutions. The Small Business Technology Transfer (STTR) requires participation of the research institution.

Funds for STTR program come from the five[82] Federal agencies with extramural research and development (R&D) budgets that exceed 1 billion USD and are required to reserve 0.45% of the extramural research budget for STTR awards to small businesses. These agencies designate R&D topics and accept proposals.

Both programs are structured in three phases:

Phase I. The objective of Phase I is to establish the technical merit, feasibility, and commercial potential of the proposed R/R&D efforts. Phase I awards normally do not exceed 150,000 USD total costs for 6 months.

Phase II. Is a continuation phase of Phase I. Funding is based on the results achieved in Phase I and the scientific and technical merit and the success rate normally increase from 12-13% to 25-30%. Phase II awards normally do not exceed 1 million USD total costs for 2 years.

Phase III. The objective of Phase III is for the small business to pursue commercialization objectives resulting from the Phase I/II R/R&D activities but the SBIR/STTR program does not provide funding for that. At this point companies must be able to raise funds from angels and venture capitalists.

Both programs are very competitive and the first funding is awarded only to 12-13% of applicants. I have met a few deep tech companies that received SBIR/STTR grants. These programs are highly valued, as they provide funding in forms of grants. So, unlike the venture capital, they do not require the company's founder to give up part of the equity in the company. The agencies do not get involved in the management of the company. Normally, these grants are not only one type of support that companies receive. Other types of support involve admission to Cyclotron Road program, use of Shared User Facilities, participation in QB3 or FAST[83] programs.

However, the grant may also become an obstacle for the successful development of the company as it happened with Correlia Biosystems, a bioengineering company[84]. Having received 600,000 USD SBIR grant from NIH in 2014, the company quickly discovered that, in order to enter the market, they needed to pivot significantly from their original idea. However, for the next two year, the company remained "locked" to the grant it had received and the type of research it had committed to conduct and were not being able to pivot until the end of the grant.

6.2. Accelerators' micro funds

In the past few years, accelerators started to form small investment funds to help their own startups in exchange of equity. Typically, the accelerators provide about 100,000-120,000 USD investment in the form of a standard SAFE note, in exchange for an equivalent of 5-7% of company's equity.

The UC Berkeley largest accelerator, Skydeck, has formed its Fund about a year ago. The Fund is created in the way that 50% of proceeds (profit) will be given to UC Berkeley. The founders claim that even by very pessimistic scenarios, the fund will bring profit to the university.

The micro funds help to fill the gap in funding that a startup faces, especially in life sciences, between federal grants at the earliest stages and Series A venture investment. QB3 created a micro seed fund to address the lack of funding for the medical research at the "gathering of data" stage. Launched in 2009, Mission Bay Capital raised 11.3 million USD for their first fund and it is closing now the fourth fund in the amount of about 13 million USD. The last fund focuses on medical devices and does not require traction of customers and revenues. Part of proceeds from the fund goes to UCSF. The Indie Bio, "the worlds' leading life sciences accelerator", unlocks the technology in just four months through a very intense program, by providing the wet lab and partnering with leading universities and companies. The accelerator focuses on the proof of principle, sets milestones and lets the company carry out the parallel experiments to maximize success.

6.3. Angel investors and Angel Investor groups

An angel investor is an individual, who has an accreditation as an investor, and who provides his/her own capital for a business startup, usually in exchange for convertible debt or ownership equity. "Angel investments bear extremely high risks and are usually subject to dilution from future investment rounds. As such, they require a very high return on the investment. Because a large percentage of angel investments are completely lost, when early stage companies fail, professional angel investors seek investments that have the potential to return at least ten or more times their original investment, within 5 years, through a defined exit strategy, such as plans for an initial public offering or an acquisition. "[85] Current investment climate dictates that angels might do better setting their sights even higher, looking for companies that will have at least the potential to provide a 20x-30x return over a five- to seven-year holding period.[86] While the investor's need for high rates of return on any given investment can make angel financing an expensive source of funds, cheaper sources of capital, such as bank financing, are usually not available for most early-stage ventures. With this high return expectations, no wonder that it is not easy to gain access to "angel's" money. Standard angel investment is 25,000 USD.[87] In case of angel networks, the founder may raise up to 100,000 USD in one go.

Besides individual angel investors there are angel investor groups in the Bay Area, like Sand Hill Angels of Stanford and The Berkeley Angel Network (BAN) that share research and pool their investment capital. These networks are the ideal starting point for the unexperienced angel investor to start investment practices, by observing peers in order to get the necessary experience that will allow him/her to continue independently if s/he so wishes[88]. Networks also allow to diversify the portfolio without the necessity to invest big amounts in a single venture.

Networks do have different rules of operations. For example Sand Hill Angels do the collective investments and also bear the collective risks. The BAN, created in 2011, allows individual investors to make a choice and commit without a need of collective consent. Compared to some of the other 16 angel investing groups in the Bay Area, the BAN is on the informal side, with all members being volunteers. The only criteria to be a the BAN angel is that one meets the SEC requirements for becoming an accredited investor, and that one has a UC Berkeley affiliation of some kind.

The groups not only provide startups with seed funding to pursue their ventures, but also serve as a mentoring and coaching space for the first-time entrepreneurs. Again, the level of involvement depends on each participating investor and the group. Fred Drinkwater, an angel investor with the BAN, said that although angel investing takes a significant amount of time and has a very high risk factor — 1 in 10 deals turn out successful — there is a culture in the Silicon Valley of giving back to the next generation of entrepreneurs through mentoring and coaching. For angel investors, it's not so much about the money as it is about sharing a lifetime's worth of experience with up and coming companies.[89]

There are no strict criteria that define whether or not the angel investment will be granted to the founders. However, one of the top criteria mentioned by angels is the potential of the founder. This criterion goes before the technology, prototype, finished product and even before evaluation of the market profile and size. "They want to know, is there something sustainable about the solution, the team, and the proposition, so that as the market and competitive landscape evolve, is the company the one that is left standing?" says Catherine Chiu, co-president of the BAN.[90]

As it was mentioned above, angels are not always risk takers. According to David Onek, the BAN tends not to be the lead investor. It rather prefers companies in which someone has already invested (meaning that the due diligence has been already done and trust conferred by another party). In return to the investment, investors ask for equity that may come in the form of SAFE notes. The BAN equally is looking for some traction, for the company to have already either revenue or users that are, in fact, the main challenges of the early stage company.

6.4. Venture Capital Firms

One would expect that VC firms would close the gap between research and the market. However, the deep tech has a relatively unappealing risk-return profile compared with software investments. Moreover, the financial interests of investors who participate in the innovation process are often not in alignment with the social goals of scientist-entrepreneurs. The venture capital financing is the exception, not the norm, among deep tech startups. And historically, only a tiny percentage (fewer than 1%) of U.S. companies have raised capital from the VCs.

The VCs, despite their name, are quite conservative. They invest primarily into a handful of familiar sectors. They tend to invest locally, they tend to invest only in large markets that are, at least, $1B in size and they are susceptible to group thinking. “Because VCs are inherently risk averse, despite the fact that they invest in risky new businesses, they feel more comfortable in a group where the majority invest in the same sector, in companies implementing familiar, proven business models.”[91]

The critics of the VCs say that “The venture capital firms increasingly look for investment that is not too long-term, not too expensive, and does not involve too much technology or market risk. “Venture investing shifted away from funding transformational companies and toward companies that solved incremental problems or even fake problems.... VCs have ceased to be the funder of the future, and instead became funders of features, widgets, irrelevances.”[92]

Today, according to the National Venture Capital Association, the largest venture capital investors are pension funds (37% of investors), corporations (23%), foundations and endowments (16%), families and institutions (12%) and others (12%).[93] These are the general numbers of the typical VC firm: 4,000 proposals are reviewed yearly, 400 startups get a 30 minutes phone call to discuss a project, 100 are invited for a one-hour meeting, 20 get funded and about 15 Silicon Valley startups provide 95% of all returns in the Silicon Valley.[94] The VCs expect high return in the short time span. In early 2000, it was not uncommon for a company to reach an IPO in a year and a half.[95] Now, the exit is expected in between 5-7 years, but not more than 10.

“The reason there aren't more Googles is not that investors encourage innovative startups to sell out, but that they won't even fund them”, says

Paul Graham, cofounder of Y Combinator, the leading SV accelerator. “The most surprising thing I've learned is how conservative they (VCs) are. VC firms present an image of boldly encouraging innovation. Only a handful actually do, and even they are more conservative in reality than you'd guess from visiting their web sites. He continues: “I used to think of VCs as practical: bold but unscrupulous. On closer acquaintance they turn out to be more like bureaucrats. They're more upstanding than I used to think (the good ones, at least), but less bold. Maybe the VC industry has changed. Maybe they used to be bolder. “[96]

In effect, venture capitalists focus on the middle part of the classic industry S-curve. They avoid both the early stages, when technologies are uncertain and market needs are unknown, and the later stages, when competitive shakeouts and consolidations are inevitable and growth rates slow dramatically. “Picking the wrong industry or betting on a technology risk in an unproven market segment is something VCs avoid.” Exceptions to this rule tend to involve “concept” stocks, those that hold great promise but that take an extremely long time to succeed. Genetic engineering companies illustrate this point. In that industry, the venture capitalist’s challenge is to identify entrepreneurs who can advance a key technology to a certain stage—FDA approval, for example—at which point the company can be taken public or sold to a major corporation.”

Final Remarks

A collaboration between university, government and industry (a “triple helix” model) [97] creates the unique innovation ecosystem (or entrepreneurial ecosystem as referred in some literature) that leads to the positive impacts on innovation and results in economic growth and regional development.[98] In this model, university is “generating new institutional and social formats for the production, transfer and application of knowledge”[99]. In the US, the universities and industry, up to recently relatively separate and distinct institutional spheres, are starting to assume tasks that were formerly largely the province of the other.[100] Their collaboration and interdependence form a foundation of current US model that facilitates the transfer of research to market.[101]

How can one stimulate the recognition of the potential of the technology and make a push forward to the commercialization? The Bay Area answer to it is by a **combination of support mechanisms**[102] that **reinforce and complement** each other, when **implemented simultaneously**. The research by industry and university-related institutes working on joint research projects, centers for science-industry collaboration, incubators and accelerators, new programs to support startups, including awareness building, networking and mentoring events. All of that is complemented by assistance of the technology transfer offices of the universities, clear IP transfer rules and the mobility schemes for researchers between universities, government and industry. Finally, funding provided in forms of grants, small business vouchers, angels and VC money.

1. Commercialization of Already Available Technologies

So many new technologies are already created in the laboratories but remain unexploited. To create a database of the patents, publish it and wait for the industry to express the interest has proved to be insufficient. “Push marketing does not work – creation of patent databases, by the TTO is not effective”.[103] Targeted work on analysis, clustering of patents and offer preparation is needed. An example is a **multipatent portfolio** approach adopted by the National Laboratories in the US, where patents from the several laboratories are analyzed and clustered by the tech experts, in order to build critical mass before being presented to the market as a package. University of California recently launched similar initiative to map, bundle, evaluate and revive all of university’s IP and patents, in order to better commercialize them and better serve industry interest and needs.[104]

Besides, clear intellectual property transfer rules, information and hands on assistance in disclosure and filing the patent and its subsequent licensing help to identify, record, patent and license technologies created in the universities. The support to the scientist willing to become the entrepreneur could help technology transfer to market. Assistance in incorporation of a new company, advice on legal and financial aspects of running the company could help the creation of small businesses that constitute the backbone of the US and EU economies.

2. **Grants and fellowships support the advancement of deep tech technology into a product**

An access to targeted Lab-to-Market fellowship programs is necessary to advance the research in the early stage deep tech technologies. What makes such programs different from the traditional grant schemes is that the possibility of technology transfer to the market is the key objective and not the research results per se. The example of the Cyclotron Road program, funded by the DOE Advanced Manufacturing Office and the California Energy Commission demonsrates advantages in bringing the researchers from their laboratories to the specifically created **collaborative environment** with the very clear mission to advance a technology into the commercial product, so all efforts during the two years program are devoted in achieving this goal. Besides access to the scientific facilities, fellows receive one-to-one mentorship, access to the network and training in business strategy, product development, personnel management, and many other skills that are essential to entrepreneurship. Giving the researchers the opportunity to keep their IP provide additional incentive to participate in such a program.

3. **Access to Shared User Facilities**

In the US, the national **shared user facilities** are **open** not only to university students and federal researchers but also **to startups** and anyone interested in testing and experimenting with the new technology. Access is provided free of charge to experiment and test new technologies and the advice of the residing researchers is offered. Even that the primary focus is the facilitation of the non-proprietary research, that purpose is the publication and not scaling up the businesses. Still, small companies can benefit from the facilities and later use the developed technology for their business purposes. Joint ownership with university commercial forbearance contract that is at the pilot stage at the UC Berkeley allows startups to "rent" place in a university laboratory of choice while keeping the IP rights. The laboratory benefits from the additional funding, while startups have the lab where to develop the technology they need.

4. Defining the Market for the New Technology

Following success of NSF program, multiple federal agencies have successfully adopted a curriculum and one of them (National Institute of Health) made the attendance of the i-CORPS program a prerequisite for receiving a federal grant (SBIR). The program's objective is "to cultivate a pipeline of university-based researchers who can turn ideas into successful commercial products". This program helps teams to define and test the product/market fit of their technology by conducting interviews with their customers. It pushes the scientists and entrepreneurs to leave the laboratories and face "the real world" to see if there is a market for their products. Besides, the program **reaches the professors** and train them in the lean launchpad approach. The professors in turn **disseminate this information to their future students**, thus increasing the outreach of the program.[105]

Bringing startups and MBA students together benefit both of them shows the Cleantech2Market program developed by Haas Business School. Startup receive up to 1000 hours of free marketing research and the students get hands-on experience of the market. The key of this program is a connection between startup, in the possession of the new technology, and MBA students, willing to apply their business skills to a real case scenario. That is a win-win for both parties involved. Students get the experience and credits for the course (and some are employed by the startup they were working with) and startup receives analysis of the future markets where technology can be applied.

5. Interdisciplinary Research and Dual Degrees

It is more and more common that the technological advances are happening on the edge of the disciplines. The breakthrough gene editing technology, CRISPR, was discovered by a biochemist and a microbiologist. Nanotechnology is being applied both in physics and medicine. Thus, bringing scientists from different fields closer, facilitating the exchange of scientific challenges and ideas on how to overcome them, could foster innovation and research. Interdisciplinarity becomes a key word to describe the emerging innovation model and universities and research centers play a crucial role in it.

In order to foster the innovation and technology advancements, there is no need to create fixed costly structures. Fluid organizations with the clear objective and limited time frame (max. 5 years) can offer an inexpensive and dynamic solutions. The pop-up institutes, with a set date of termination, allow researchers to be brought together for working on a problem, without removing them from their laboratories. The created synergies allow to advance the selected field of research from the basic to applied science that can be further advanced in the next stages of technology development.

Equally, the dual university degrees that combine chemistry, engineering or life sciences with entrepreneurship allow the emergence of the scientists with entrepreneurial skills. These scientists, with the expertise in “science” or “engineering but also having business, leadership and communication skills are better equipped to identify the commercialization opportunity and to pursue the path to the commercialization.

6. The Importance of University-Industry Relations

Industry is looking for the first hand access to the new technologies and new talents. The university-industry collaboration helps industry to carry out research outside the fixed operational constrains of the running business. University in turn receives industry’s funding and, more importantly, is able to orient their research in the direction of the real needs of the industry and markets. Different levels of engagement from the funding of the whole institute to the limited task specific collaboration, allow to match the expectation of both parties.

7. Industry Internal Innovative Practices

Besides traditional R&D departments in the big companies, industry is searching for alternative ways to innovate. The big companies experiment with the application of startup methodology to innovation inside the companies. By placing innovation teams outside the organization, the companies try to create burden free fluid cells, where ideas can be quickly transformed to the prototype products and tested outside the companies' traditional business processes. The creation of incubation or manufacturing experimentation spaces on the margins of the big companies and inviting the external companies to join these labs, allows industry to follow the latest research trends and invest in the most promising technologies at the early stage. By creating innovation spaces or incubators inside the company, the corporations try to keep the talented people within the company and also profit from their creations.

8. Research/Industry Exchange programs

Exchange between industry, academia and government may take many forms – exchanges between scientists and entrepreneurs working on a common project in the labs, flexible short-term projects, coaching and mentoring. It allows for a circulation of best practices and ideas. It unlocks staff potential by forcing them to adopt different cultures and environments that enhance the vision and perspective on the process. The industry members come to the University to explore technological challenge outside their organization. Faculty members engage in the entrepreneurial activities either as mentors, consultants, or, in some cases, even as co-founders of startups.

9. The Dense Innovation Ecosystem With a Mix of Support Mechanisms

Bay area has dense and strongly interlinked innovation ecosystem where industry and researchers work hand in hand in driving the technologies to market. The examples of Stanford with technological companies spread in proximity to the campus and a Sand Hill Road with the venture capital firms; UC Berkeley, with the Skydeck accelerator outside campus and National Lawrence Berkeley Laboratory up the hill, UCSF in Mission Bay with the biotech cluster in South San Francisco, ensure that industry, finance, and science participate in constant interaction. The **mix of support mechanisms** is available to the researcher, founder and entrepreneur from which he/she could pick the best suited ones. These support mechanisms are not limited to funding. Network, mentoring, access to the laboratories, advice on IP, are all crucial for facilitation of research to market transfer. The tendency observed in the Bay Area is that with time the (successful) accelerators grow in size (number of startups accepted) and also create their venture funds to secure the early stage investments for the most promising companies. As no one yet unlocked the "secret source" of Silicon Valley and there is no single "recipe for success" for the few unicorns originated in the Valley, the tendency is to diversify the investments and not limit the access to the support programs to a specific country and institution or technological vertical. In the selection of projects, the emphasize is made on the **diversity** of the project selection committee: having different backgrounds and skills represented provides different perspectives on the future of the technology and the company. "If everyone agrees on the project, it is most likely not worth pursuing"[106].

I describe in my report some initiatives that I observed in the US, California during 2018-2019, during my stay at the University of California, in Berkeley, as an EU fellow. Some of them are in the pilot stage so their impact still needs to be assessed. **To sum up, what measures can facilitate a transfer of research results to the market? First,**

clear technology transfer rules and assistance to the patenting and the licensing process both to the university and Federal laboratories and the industry. Second, the enhancement of technology innovation networks by fostering (Federal and university) laboratory engagement with the industry. Third, exchange of talented people with complementary skills between government, academia, and industry. And the last but not the least, the access to finance.

Many initiatives, similar to those described, are already implemented in different parts of Europe. Ireland cooperates with the US on sending teams to participate in the I-Corps program. SchoolLab, a French accelerator, applies Lean Startup methodology of Stanford to advise their startups. European Universities offer entrepreneurial courses, incubator's space and mentoring for those who wants to launch their company. Is the knowledge diffusion and quality and density of the lab-to-market program the same across the EU countries and regions? Probably not. Are the current initiatives enough? What more can be done in order to boost the European innovation ecosystem? What US initiatives and programs described in this report shall be promoted in Europe and if any, at which level? Is it up to the EU, national or regional authorities or individual universities and businesses to promote and administer such initiatives? I hope with this report to open the discussion on these topics.

[1] https://ec.europa.eu/research/evaluations/index_en.cfm?pg=hlg

[2] The White House briefing of 2014 stated that "Federal Government spends more than $130 billion on research and development (R&D) each year, conducted primarily at universities and Federal laboratories....some research discoveries show immediate potential for commercial products and services, and the President is committed to accelerating these promising technologies from the laboratory to the marketplace, based on closer collaboration with industry." https://obamawhitehouse.archives.gov/blog/2014/03/14/lab-market-accelerating-research-breakthroughs-and-economic-growth

[3] In his management agenda of 2018, Donald Trump pointed out five strategies for the Federal agencies:

- To identify regulatory impediments and administrative improvements in Federal technology transfer policies and practices;
- To increase engagement with private sector technology development experts and investors;
- To build a more entrepreneurial R&D workforce;
- To support innovative tools and services for technology transfer; and
- To improve understanding of global science and technology trends and benchmarks. https://www.whitehouse.gov/wp-content/uploads/2018/04/ThePresidentsManagementAgenda.pdf

[4] The valley of death –is a common term in the startup world, referring to the difficulty of covering the negative cash flow in the early stages of a startup, before their new product or service is bringing in revenue from real customers.

[5] The new technology, the invention can be born both during the so called basic or applied research process, while the latter is by definition closer to the market. In biotech and life sciences the term used is translational research, the process of applying knowledge from basic biology and clinical trials to techniques and tools that address critical medical needs. Unlike applied sciences, translational research is specifically designed to improve health outcomes. It uses an integrated team of experts who are focused on translating useful information from laboratories to doctors' offices and hospitals, so called "bench to bedside" bridge.

[6] The company CELLFE developed the cell delivery technology that had been discovered by error in the laboratory of the Georgia University. Interview with CEO Alla Zamarayeva, 18 October 2018

[7] Garry Duffy, PI of Duffy Lab at the School of Medicine at the National University of Ireland Galway (NUIG) mentions that several unexpected incremental innovations had been created during his Horizon 2020 project implementation. Interview 7 February, 2019.

[8] Prepared by Stanford Technology Transfer Office

[9] For detailed criteria of patentability, one may consult: https://en.m.wikipedia.org/wiki/Patentability

[10] In Europe there are no provisional patents. However, the cost of filing European patent is significantly lower than in the US, and the cost is the main consideration for filing the provisional patent in the US.

[11] https://science.energy.gov/lp/technology-transfer/

[12] https://en.wikipedia.org/wiki/Bayh%E2%80%93Dole_Act

[13] In Europe, each country has its own rules regarding ownership of the invention. For example, in Sweden, it is an inventor who owns the IP rights, while in Denmark it is the university (interesting topic for the future research: how different ownership models affect the countries' invention capacity).

[14] www.ipira.berkeley.edu/sites/default/files/shared/docs/Startup_Guide.pdf

[15] www.ipira.berkeley.edu/sites/default/files/shared/docs/Startup_Guide.pdf

[16] Industries most impacted by Deep Tech breakthroughs include: life sciences, aerospace, clean energy, robotics, agtech, and computing. https://www.quora.com/How-would-you-define-deep-tech

[17] The America Invents Act of 2011 switched U.S. right to the patent from the previous "first-to-invent" system to a "first-inventor-to-file" system for patent applications filed on or after 16 March 2013.

[18] The interview with CellFe CEO Alla Zamarayeva on 11 December

[19] Interview with Deepak Dugar, Founder, Director , Visolis, 15 January 2019

[20] HorizonEU programme makes a distinction between two types of funding: one a "pathfounder" focus on technology development and another one is "accelerator" focus on the growth and scale up of the company.

[21] Interview with Ioana Aardei, Entrepreneurship Program Manager at the California Institute for Quantitative Biosciences

[22] There are several forms of licensing arrangements that can be used by a start-up company especially the one that does not yet have the financing. Letter agreement, the simplest form of the licensing arrangement allows "to delay" the entering into force of the licensing agreement providing 3-12 months for negotiations and legalization of the deal. It helps the company to incorporate and seek the financing if it has not been already done. Option agreement, is another type of arrangement giving the opportunity to take an option on the obtaining the license during the period between 1-3 years in return to fixed annual fee. This arrangement gives the opportunity for a start to advance further its business model, and to confirm that the selected technology would ultimately fit within the product line. License agreement is the final option, giving the rights to the company to sell commercial products. The duration of the agreement is normally the same as the life of the patent. For this type of agreement, the startup has to funds to be able to conclude it. In certain cases, University accepts "equity' in a company as a partial consideration for technology transfer.

[23] At the University of California according to the current policy, 35% of royalties go to inventor.

[24] Interview with Mike Cohen, Director of TTO UC Berkeley, 20 September 2018 "IPIRA (Intellectual Property and Research Alliance) is very open to the possibility of licensing technology to campus startups, and educating faculty about Bayh-Dole regulations could foster a deeper understanding of IPIRA's role. We also note that faculty should, and often do, designate a startup company representative to negotiate a license, in order to avoid a financial conflict of interest."

[25] This assertion is based on the interviews. The formal communication from the TTO of UCBerkeley states that "nearly all IP licenses to startup companies are exclusive to provide an inventive to invest in high-risk research and development and to reward entrepreneurs for their commitment to the commercialization process" (from Entrepreneurs' startup guide of IPIRA)

[26] Entrepreneurship at Berkeley, report of 20 July 2018 of the VC for research

[27] Depending on the staffing, workload and governance, some TTOs limit themselves to the legal technology transfer assistance (as the office of the MIT, for example, that due to the high number of invention disclosures does not have the capacity to go beyond its traditional role). Others extend their role to support the faculty in startups' creation (in the case of UCSF).

As for the governance structure, some TTOs are part of a university and report to campus leadership while others (UCLA) are created in a form of a non-profit entity (the UCLA Technology Development Corporation) and are independent from the university.

At MIT, TTO is allowed to take 15% off the top of the royalty revenue to help pay for its operations. At UCSF, funding comes primarily through the Dean of the School of Medicine, and unlike Stanford or MIT, there is no connection (e.g., percentage) between revenue generated by Innovation Ventures and the operating budget. As an independent entity, the UCLA Technology Development Corporation endeavors to adopt a business mindset and operate on the cycle of business as opposed to an academic one.

The review process is also different. For the review process at MIT, UC Berkeley and UCSF, the staff meets regularly (weekly at MIT) to decide "go" or "no go" on the files for provisional applications for all invention disclosures received that week. At Stanford, the licensing agents enjoy complete autonomy in the evaluation process and have the authority to veto the patent application. (Entrepreneurship at Berkeley, report of 20 July 2018 of the VC for research)

[28] Interview with Elsie Quaite-Randall, Lab's Chief Technology Transfer Officer Lawrence Berkeley National Laboratory, 1 November 2018

[29] Article "The Changing Relationship Between Academia and Entrepreneurship", Published on April 21, 2019, Chief Innovation Officer, Christine Gulbranson, https://www.linkedin.com/pulse/changing-relationship-between-academia-christine-gulbranson-phd-mba/

[30] https://research.csiro.au/oznome/tools/readiness-level-metrics/

[31]

https://arpa-e.energy.gov/?q=site-page/tech-market-t2m

[32] https://500.co/blockchain-company-vc-fundable/

[33] http://fortune.com/2018/06/20/renata-quintini-lux-capital/

[34] Visit to Sandler Neurosciences Center 6 December, Neuroscape laboratory, meeting and lab visit with Peter Wais, Faculty, Assistant Professor - Neurology

[35] The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship (Stanford Business Books) , Stanford university press, 2000, 424 p, P.189

[36] https://arpa-e.energy.gov/?q=arpa-e-site-page/arpa-e-history

[37] https://vcresearch.berkeley.edu/sites/default/files/2018-08/Entrepreneurship_at_Berkeley.pdf

[38] http://www.cyclotronroad.org/journal/2018/8/5/qa-with-former-darpa-director-arati-prabhakar

[39] http://impact.cyclotronroad.org/

[40] https://www.sbv.org/about.html

[41] The key books advised for the program are: Blank, Steven. The Four Steps to the Epiphany. 2005. Steve Blank's book provides step-by-step strategy for any new company or product, including organizing sales, marketing, and product development., Blank, Steven and Bob Dorf. The Startup Owner's Manual. 2012.
[39] Interview with Tod Morill, Director of NSF i-CORPS Bay Area Node and Whitney Hischier, 13 November 2018
[40] The data pulled in November 2018 by Venture Well and consisting of all the cohorts as well as teams that have completed the NSF i-Corps program between 2012-2018 shows that: out of 63 cohort trainings, 1,315 teams, 3,745 individuals trained - including entrepreneurial lead, principal investigators, and industrial mentors in 271 universities, institutes, and colleges represented from 47 States, 644 startup companies were formed, $301M follow-on funding raised, and 6 startups acquired

[42] Based on the Interview with Ioana Aardei, Entrepreneurship Program Manager at QB3, the California Institute for Quantitative Biosciences (QB3),

[43] QB3 has a partnership with Calico that spans 2 agreements. First, there is an annual grant program, the Longevity Fellows program, that provides funding for 3 projects each year, at $120K/year. These projects are selected after a spring request for proposals. Calico also has a sponsored research master agreement with QB3 to facilitate collaborations between faculty at UCSF, UC Berkeley and UCSC and Calico.

[44] Interview with Ioana Aardei, 17 October 2018

[45] Presentation of Costas Spanos, Director of CITRIS on 4 December 2018 presenting the vision of CITRIS 2025.

[46] Based on the Interview with Bree Cahill, Director of Partnerships, On 26 September 2018

[47] SAFE (simple agreement for future equity) notes are a simpler alternative to convertible notes. They were created in 2013 by Y Combinator, a Silicon Valley accelerator, and allow startups to structure seed investments without interest rates or maturity dates. SAFEs are short five-page documents. The valuation caps are the only negotiable detail.

[48] Interview with Bree Cahill of Skydeck, Director of Partnerships, 26 September

[49] https://vcresearch.berkeley.edu/sites/default/files/2018-08/Entrepreneurship_at_Berkeley.pdf

[50] Interview with Mike Cohen, Director of the Office of Technology Licencing, UCBerkeley, 20 September 2018

[51] Interview with Susan Jenkins, 31 October 2018

[52] http://www-bsac.eecs.berkeley.edu/about/BSACVIF.pdf

[53] Interview with Brian Steel, Director, Cleantech to Market, 27 September 2018

[54] TRL = Technological Readiness Level

[55] The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship (Stanford Business Books) , Stanford university press, 2000, 424 p, P.187

[56] The silicon valley edge: a habitat for innovation and entrepreneurship., by William F. Miller (Author), Marguerite Gong Hancock (Author), Henry S. Rowen (Author), Chong-Moon Lee (Editor), William Miller (Editor), Marguerite Hancock (Editor), Henry Rowen (Editor) p.55

[57] The MIT Lab for Innovation Science and Policy finds “that the business goals that drive university interactions can often be grouped into five distinctive categories:

- Short term, incremental problem-solving within an existing product line, sometimes referred to as “extended workbench” and probably most closely associated with the Fraunhofer-model.
- Talent identification and hiring.
- Long-term development of new technologies/solutions to broad-based customer needs which may lead to new product lines or new businesses
- Systematic exposure to new start-ups (either research-driven or student-driven) while still part of the university has become an emerging imperative need.
- Publicity and political influence.”

Engaging in Regional Innovation Ecosystems: Six Questions to Get Your University Partnerships Right! Lars Frølund , Fiona Murray , Max Riedel, July 2017 https://innovation.mit.edu/assets/Engaging-in-Regional-Innovation-Ecosystems.pdf

[58] https://spo.berkeley.edu/guide/new2grantscontracts.html

[59] Interview with Mike Cohen, Director of the Office of Technology Licencing, UCBerkeley, 20 September 201

[60] https://vcresearch.berkeley.edu/sites/default/files/2018-08/Entrepreneurship_at_Berkeley.pdf

[61] https://vcresearch.berkeley.edu/sites/default/files/2018-08/Entrepreneurship_at_Berkeley.pdf

[62] Interview with Craig B. Vaughn, Intellectual Property and External Relationships Manager, BP San Diego Biosciences Center, 17 January

[63] Interview with Craig B. Vaughn, Intellectual Property and External Relationships Manager, BP San Diego Biosciences Center, 17 January

[64] Interview with Susan Jenkins, former Managing Director of Energy Biosciences Institute explained how the industry funding led to creation of the whole institute.

[65] Startup 101 Series, Andrew Dickinson, JD, SVP Corporate Development, Gilead

[66] http://innovationanswered.libsyn.com/startup-culture-in-big-companies

[67] Berkeley Haas Case Studies, H. Chesbrough et al “Telefonica: A Lean Elephant”, 2016

[68] Berkeley Haas Case Studies, H. Chesbrough et al “Telefonica: A Lean Elephant”, 2016

[69] https://www.fastcompany.com/90262791/an-exclusive-look-inside-googles-in-house-incubator-area-120

[70] Meeting with Google 120 during Newton series

[71] The case was presented at EIT breakfast by Anders Ericsson VP Strategy and Innovation, VP Seco Consultancy services, Quentin Hardoin, Solution Owner

[72] Interview with Craig B. Vaughn, Intellectual Property and External Relationships Manager, BP San Diego Biosciences Center, 17 January

[73] Visit to Autodesk technology center on 7 November 2018, interview with Alyra Merchert, Communications Liaison

[74] There are four regional Innovation Centers—located in Boston, California, London and Asia Pacific—to catalyze, support and invest in highly differentiated early-stage innovations that extend and improve lives everywhere. The new JLab was opened in Beerse, Belgium in March 2018.

[75] Series A, B, C etc rounds of financing are the round dof financing that a startup receives from a venture capital firm.

[76] Visit to JLABS – James Viola, Vijay Murthy, 6 November 2018

[77] At EIT Hub opening at SF on 27 March

[78] Mastering the VC game, Jeffrey Bussgang, Portfolio, 2010, 245 p , p 44

[79] Startup second edition, 2019, Andreas Ramos, p.93

[80] http://www.anagard.com/blog/2015/02/02/is-your-startup-a-high-growth-venture-capital-type/

[81] https://www.youtube.com/watch?v=zNAQmBBQ3VA&feature=youtu.be

[82] Department of Defense, Department of Energy, Department of Health and Human Services, National Aeronautics and Space Administration, National Science Foundation

[83] FAST advisory program of California Life Sciences Institute

[84] Presentation of Akwasi Apori, CEO, Correlia Biosciences, 11 December 2018

[85] https://en.wikipedia.org/wiki/Angel_investor

[86] https://www.equitynet.com/crowdfunding-terminology/what-is-angel-investor-definition

[87] Interview with David Onek, Berkeley Angel Network 10 October 2018

[88] Interview with David Onek, Berkeley Angel Network 10 October 2018

[89] https://scet.berkeley.edu/berkeley-angel-network-a-shark-tank-for-startups/

[90] https://scet.berkeley.edu/berkeley-angel-network-a-shark-tank-for-startups/

[91] http://www.anagard.com/blog/2015/02/02/is-your-startup-a-high-growth-venture-capital-type/

[92] https://genius.com/Founders-fund-what-happened-to-the-future-annotated

[93] Startup second edition, 2019, Andreas Ramos, p.133.

[94] Startup second edition, 2019, Andreas Ramos, p.91

[95] The Silicon Valley Edge, 2000, Stanford University Press, p.307

[96] http://www.paulgraham.com/googles.html?viewfullsite=1

[97] https://triplehelix.stanford.edu/3helix_concept

[98] https://jipi.cat/en/posters/from-triple-to-quadruple-helix-the-role-of-society-citizens-customers-in-innovation/

[99] https://triplehelix.stanford.edu/3helix_concept

[100] Etzkowitz, Henry and Leydesdorff, Loet, The Triple Helix -- University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development (January 1, 1995). EASST Review, Vol. 14, No. 1, pp. 14-19, 1995. Available at SSRN: https://ssrn.com/abstract=2480085

[101] Over time, society and the societal needs were added to the model, acknowledging the importance of market-driven bottom-up process of knowledge creation. In this interlinked model the technology can thrive and grow creating the markets, jobs and growth or, to the contrary, stagnate. In this quadruple helix model four key actors cooperate with the objective of pushing the innovative technology to the market.

[102] Mechanism: a process, technique, or system for achieving a result. A mechanism is more about 'how' a particular task (possibly a policy) is done where as a policy is more about 'what' needs to be done.

[103] Interview with Elsie Quaite-Randall, Lab's Chief Technology Transfer Officer Lawrence Berkeley National Laboratory, 1 November 2018

[104] Article “The Changing Relationship Between Academia and Entrepreneurship”, Published on April 21, 2019, Chief Innovation Officer, Christine Gulbranson, https://www.linkedin.com/pulse/changing-relationship-between-academia-christine-gulbranson-phd-mba/

[105] The data shows that between 2012-2018: out of 63 cohort trainings, 1,315 teams, 3,745 individuals were trained - including entrepreneurial lead, principal investigators, and industrial mentors in 271 universities, institutes, and colleges represented from 47 States. 644 startup companies were formed, 301 million USD follow-on funding raised, and 6 startups acquired.

[106] Paul Graham, Y combinator founder, http://www.paulgraham.com