Master thesis in Entrepreneurship, Innovation and Society

The “super class” of electronics 1991 and 1992 – what was the key? On fostering entrepreneurship beyond organized support system.

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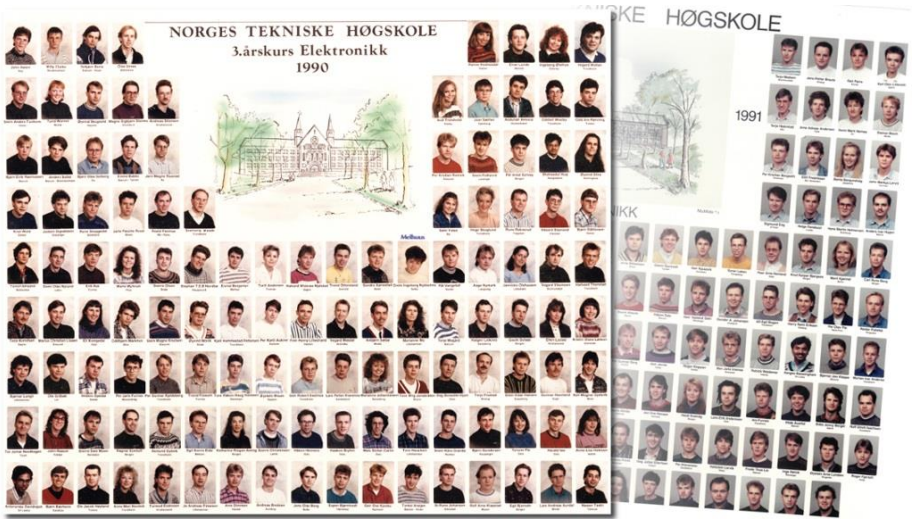

Author: Karolina Lesniak

Academic supervisor: Asbjørn Karlsen

NTNU
Norwegian University of
Science and Technology

Cover figure: The “super class” of electronics of 1991 and 1992. Source: Adresseavisen

Abstract

The university gains constantly greater importance in the local and regional development policies. Apart from two traditional roles of university that is research and education, the third mission was added in recent decades – commercialization of science and technology by new firm formation. Although various institutionalized measures for fostering and supporting entrepreneurship were developed, like technology transfer offices, incubator, science parks, or formalized entrepreneurial education, the perfect formula for encouraging academic entrepreneurship has not yet been devised.

The main aim of this study was to investigate the distinctive case of technology entrepreneurs from classes of 1991 and 1992 of electronics at NTNU. The case combines 9 entrepreneurs who established 6 highly successful technology companies. Among the companies 3 were categorized as corporate spin-offs and 3 as university spin-offs. The case stands out due to the fact that in the period in question the institutionalized support system for entrepreneurship was non-existent, and no forms of encouragement towards firm formation were noted.

First research question asked in this study is concerned in the role that NTNU had in fostering entrepreneurial activities among the students in question. Through the case study it was argued that despite the lack of organized system for fostering commercial activities, NTNU indirectly influenced future entrepreneurs in several ways. Following factors were decisive for creating university environment that built the entrepreneurial base: state-of-the-art research; the close collaboration with industry; presence of entrepreneurial professors and example of entrepreneurial ventures within the faculty; and finally the conducive university culture that fostered innovative thinking.

The second part of the study was devoted to investigation why so many tech entrepreneurs spun off from the two classes at NTNU. It was argued that decisive for future entrepreneurs was job experience in the industry, that enabled individuals in question to acquire necessary skills and resources. For the entrepreneurs who commercialized their PhD research, of crucial importance was the connection with the industry that contributed to recognition of commercial potential. The impact had also the entrepreneurial example form other peers.

Through this case it is therefore argued that universities can foster entrepreneurship beyond organized forms through close cooperation with industry, and startups, and presence of academic entrepreneurs.

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Contents

List of figures

List of tables

1 Introduction

1.1 The background problem

The concept of "entrepreneurship" and "innovation" gained unprecedented attention both in media and research domains. No day can pass by without newspaper headlines concerning another "disruptive innovation" coming to the market, or "the next big company exit". The roots of the exponential growth in interest around entrepreneurship and innovation can be traced to the rapid changes world´s economy underwent in the recent years. Simultaneously, various research fields tried explaining both phenomenon in the light of their respective theoretical advances.

One of the major changes noticed by scholars and policy makers in the last decades is turn to so-called knowledge based economy that is economy which development is rooted in the advancement of science and technology. In addition to that role of small and medium size companies, together with entrepreneurial venture achieved great recognition among scholars as a motor for local and regional development (Pike, 2006). Due to that both entrepreneurship and innovation gained their momentum and substantial place in research policy.

With the recognition of knowledge based economy, also role of universities as "knowledge producing organizations" has changed. Apart from research that is creating progress in science, education that is dissemination of knowledge, also the third part was added to the mission of higher education institutions, namely contribution to the overall economic development by commercialization of technological advancements created within academia (Etzkowitz, 2013).

In response to those advancements universities taken upon the task of not only creating progress in science but also fostering innovation and entrepreneurial mindset within the walls of academia. The encouragement towards starting new companies based on knowledge and technology is directed towards both students and university employees. It frequently takes institutionalized forms of new organizations that are to take care of the business development process on behave of the scientists (technology transfer offices) or offer help to the students with idea development on every step of the way in form of incubators, or science parks (Mitra, 2012).

1.2 The case

The commercialization of technology gained great importance also for the Greater Trondheim Region. One of the main goals for the development of the region is to become a leading region in Norway when it comes to creating new technology-based companies (Trondheimsregionen, 2010). An element of that goal is to create 1000 technology companies in Trondheim Region by 2025 (NiT, 2017). In 2016 there were 618 technology companies in the Greater Trondheim Region (Impello, 2016).

NTNU – Norwegian University of Science and Technology based in Trondheim is not only the biggest university in Norway, but also one of the main technology producers for the region (NTB, 2016). In accordance with the policy developments towards fostering entrepreneurship among scientist and students, the university created extensive ecosystem for entrepreneurship and technology. The ecosystem combines bottom-up student driven organizations, School of Entrepreneurship and formalized institutions that take care of the commercialization process on behave of NTNU (Rasmussen, 2011).

Nevertheless, some of the most notable entrepreneurial successes from the university precede the creation of the ecosystem for entrepreneurship and innovation. There is a certain commercial story stemming from the electronics milieu at NTNU that immediately turns attention, namely, the history of so-called "super class of NTNU" (Leirset, 2006). The story of classes of 1991 and 1992 stands out among other similar classes in the same time, or other classes from the Faculty of Electrical Engineering both prior to 1991/92 and after that. The reason for that is the fact that to this group of students can be traced the origins of career paths of some of the Norwegian most successful technology entrepreneurs. Taking into account the non-existence of a support system for entrepreneurship at NTNU at that time, the case is worth closer investigation.

Therefore, the main aim of this project is to find out:

> *How did university foster tech entrepreneurship before facilitation took organized forms?*
>
> *Why so many entrepreneurs spun off from the two classes of 1991 and 1992 at NTNU?*

This project aims at contributing to growing body of research on entrepreneurial environments by utilizing qualitative research methods to investigating the distinctive case. It

is important to mention that the majority of research concerning both entrepreneurial environment and fostering entrepreneurship and innovation is concentrated around institutionalized measure and created by using quantitative research methods.

The case includes 9 individuals: Alf-Egil Bogen, Vegard Wollan, Geir Førre, Svein Anders Tunheim, Sverre Dale Moen, Egil Eide, John Raaum, John Markus Lervik and Haakon Bryhni. Companies they established were aimed at commercializing the state of the art technology in areas of semiconductors design, radio and signal processing, telecommunications and data, and signal processing. The companies in question are Atmel, Chipcon, 3d-Radar, Arctic Silicon Devices, Fast Search & Transfer and Advanced Communication Technology.

Three of the companies, Atmel, Arctic Silicon Devices and Chipcon can be treated as corporate spin-offs, as they spun off from respectively, two first from an established company – Nordic Semiconductor, and the last one from commercial research center – SI. The remaining companies, that is 3d-Radar, Advanced Communication Technology and Fast Search & Transfer can be treated as university spin-offs, as they were established due to commercialization of results of PhD thesis of Egil Eide, Haakon Bryhni and John Markus Lervik.

Apart from Atmel and 3d-Radar all other companies achieved successful exits by selling the companies and patents to bigger actors in the market. In addition to that none of the original founders is any longer involved in the companies in question. However, it is important to mark, that those tech firms not only achieved huge market success by exiting with tremendous monetary reward, but also created new industries (like Atmel and Chipcon, in semiconductors) or Fast Search & Transfer in Internet search and transfer services, attracted household names, like Microsoft and Yahoo to establish their research and development centers in Trondheim.

The time span of the events in question starts from 1987, that is the year when most of the individuals in question started studying at NTNU, until 2007, that is when the last of the companies in question, Arctic Silicon Devices was established. However, in order to fully describe, and in turn explore the "phenomenon" of entrepreneurs of classes 1991 and 92, sometimes called "the super class" by the media, one needs to delve into even further history, namely 1970s and 80s. The events of the period prior to the period in question have a decisive

significance to describing the environmental and cultural settings the students turned entrepreneurs met during their time of master studies at NTNU.

In terms of geographical range of the case, the main events were set in Trondheim (around NTNU, Nordic Semiconductor, Atmel, 3d-Radar, Fast Search & Transfer and Arctic Silicon Devices were established firstly in Trondheim) and in the lesser degree in Oslo (one of the key individuals took PhD degree in Oslo, and Chipcon, one of the companies in question was established and operated in Oslo).

1.3 Structure of the report

The following thesis consists of 5 chapters: theoretical framework, methodology, case results, discussion and conclusions. In the second chapter the scientific theories connected to the case in question will be presented. The chapter opens with the description of three key concepts used actively in analyzing the case in question that is entrepreneurship, innovation and a person of entrepreneur. The second subsection of that chapter is concerned with the concept of entrepreneurial opportunities, with special attention to the new knowledge as a source of entrepreneurial opportunity, and the process of opportunity recognition. The third subsection of the theoretical framework chapter will present the key elements of entrepreneurial environment with main focus on what influences the decision to exploit opportunity, importance of entrepreneurial capital, and role of culture in research on entrepreneurship. The following section will present the main concepts connected to the dynamics between university and entrepreneurship. Special attention will be placed on the changing role of universities, their role in fostering entrepreneurship and innovation, the relations between academia and industry, and finally on the importance of university culture in creating conducive environment for entrepreneurship. The last section will be concerned with presenting theoretical framework on rationale and characteristics of corporate and university spin-off companies.

The third chapter will present closely the methodological approach utilized to investigate the case in question. In that chapter, the rationale for choice of qualitative methods will be presented. The second subsection of that chapter will be concerned with describing reasons for choosing case study research design as the research strategy for this project. Moreover, semi-structured interviews as the main method utilized in this project will be showcased in following subsection. The attention will be put on the interview preparation, process and presentation of the informants. Next subsection of that chapter will describe the research

process, with the detailed information about various stages of that process. Finally, the ethical considerations of the applied research strategy will be discussed in the last subsection of chapter three.

Chapter four will serve to present case in details. First subsection of that chapter will show the case background information that is the university history and structure, the surrounding research ecosystem, as well as closer look on the entrepreneurs and companies in question. Following part of chapter four will present results of the investigation. The resulting data are divided into subsections concerned with main categories that arouse during data collection process. The categories are focused around the time of master studies of entrepreneurs in question at NTNU with focus on the study characteristics, level of courses, and study environment; the attitude towards entrepreneurship and innovation at NTNU in the period in question; the career path of the entrepreneurs from classes of 1991 and 1992 after graduation from master studies at NTNU; and finally, the rationale and establishment of companies in question.

The chapter five will discuss the findings in light of the theoretical framework presented in chapter two. It will be divided in two main parts. The first part of the fifth chapter will focus on the factors connected to the first research question that is the role of university in the case in question. The special attention will be put on the issues of technology development and knowledge dissemination; the relations between NTNU and relevant industry in the period in question and prior to that; the role of entrepreneurial professors; and finally, the characterization of university culture and environment in the time of the case. The second part of the fifth chapter will present issues connected to analysis of the second research question that is why so many tech entrepreneurs came from those two classes of 1991 and 1992 from NTNU. In this part, the key scrutiny will be placed upon concept of entrepreneurial personality; the importance of obtaining an entrepreneurial capital; the place of external factors like financial crisis of the boarder of 1980s and 1990s; and finally the discussion on the impact of entrepreneurial examples.

The sixth chapter will offer summary of the previous sections in this report. It will be concerned with presenting answers to the research questions, as well as describing certain proposition for the further understanding of the main research problem. In addition to that, this chapter will include the section focused on the implications of this study, and some suggestions for further research.

2 Theoretical Framework

The main aim of this chapter is to present existing body of research within fields that are recognized as crucial for analyzing the phenomenon of entrepreneurs of classes of 1991 and 1992, and respond to the research questions stated in the introduction. Following four main fields were chose from the extensive body of literature: entrepreneurship and innovation, entrepreneurial opportunity, entrepreneurial environment, and university and its place within entrepreneurial creation. The first subsection of this chapter is concerned with presenting main, out of many, critical views on entrepreneurship, the definition and sources of innovation with special attention towards the technological change as the entrepreneurial opportunity. The second subsection is focused on the role of entrepreneurial opportunities, with special attention on the new knowledge as a source of innovation, and the recognition of the opportunity. The third section is concerned with the entrepreneurial environment and its role on the decision to exploit the possibility. And finally, the fourth section is devoted to the dynamics between entrepreneurship and innovation.

2.1 Entrepreneurship and innovation

2.1.1 Entrepreneurship

The phenomenon of entrepreneurship is undeniably a central concept for this project. Although the concept is not new in scientific literature, it gained new momentum since the beginnings of 20th century, and the scholar discussion on the revival of economy in general, and country and regional development in details. The 21st century brought even bigger attention on entrepreneurship, due to the academic and policy recognition of the role of new firm formation for the local economies (Pike, 2006). Despite the fact that the definition of the word entrepreneurship is still actively discussed by the scholars, the most widespread understanding of this phenomenon encompasses a process of identifying an opportunity in the market and exploiting it through the new entrepreneurial venture creation (Mitra, 2012).

This definition touches upon some key points in the phenomenon - the concept of opportunities, and the procedure of recognizing them and utilizing them in a way that creates value. The concept of the entrepreneurial opportunities will be developed below in the following sections. It is important to mention that some scholars still debate the difference between entrepreneurial venture and small company. Both are connected to creating new firm, which start as a small venture and creates some value. However, the key to understanding the differentiation between those two forms of company creation lies in the character of

opportunity exploited in the new venture. The roots of entrepreneurship are set in the opportunity, which is based on innovative solutions and inventions. Entrepreneurship is therefore concerned with exploitation of innovation, in contrast to a traditional small firm, which can be based on the imitation of existing solutions, products and services (Shane, 2003)

2.1.2 Innovation

If innovation is a central phenomenon for entrepreneurship, how it can be defined? Joseph Schumpeter, an Austrian economist, seen by many as the father of today's understanding of entrepreneurship, defines innovation as a "new combination" (Schumpeter, 1934). The new combinations can have several forms:

- Introduction of a new product
- Introduction of a new manner of production
- Introduction of a new market
- Introduction of a new raw-material
- Introduction of a new type of organization (Schumpeter, 1934).

Innovation is therefore concerned with creative process of creating new combinations that change market structure and in turn have implications for the whole economy. Furthermore, according to Schumpeter innovation can have two general forms: it can be radical or incremental. The radical innovation brings so-called "creative destruction", which destroys existing market structure by introducing new products, services, or opening completely new markets. Incremental innovation is a much gentler process, which is concerned with steadily developing existing products or services by adding some innovative features (Schumpeter, 1934).

Innovation is directly concerned with "change", which is a source of the opportunity for entrepreneurs. The success of an entrepreneur lies in two-folded process – recognition and exploitation of the opportunity (Drucker, 1985). The innovation can come from both internal and external sources according to Drucker (1985). Among the internal sources he names the unexpected, incongruities, process need or industry and market structures. External sources of innovation lie in demographics, changes in perception and new knowledge. The last one, new knowledge is especially interesting and most relevant in the case of the entrepreneurs from classes of 1991 and 1992, as it was the source for their entrepreneurial creations.

2.1.3 Entrepreneur

The central factor in entrepreneurship is a person that carries on those new combinations - that is an entrepreneur. According to Schumpeter (1934), entrepreneur is a special individual who

can be characterized by some distinctive features of both character and behavior. First of all, Schumpeterian entrepreneur carries the task of implementing the "new combinations", that is, he is responsible for introducing the innovation. To be able to do that he has to think in not a standardized way, but he must be open for new ideas, both economic and scientific. In other words, he has to think in an innovative and creative ways. He flourishes in the environment characterized by ambiguity and can create a strategy on how to operate in such an environment. The ability to function in ambiguous situations is extremely important, as introduction of new things and innovative solutions is always rooted in uncertain, difficult to foresee conditions. He is therefore characterized by a flexible and open mindset.

Furthermore, in order to be able to introduce the new combinations under the circumstances of ambiguity, entrepreneur has to have strong leadership skills. However, those skills are not merely connected to the ability of managing people, they are concerned with attracting people, attracting followers of the new ideas. What is more leadership is seen as captivating possible investors and engaging the markets (Schumpeter, 1934). Important part of so-called "entrepreneurial leadership" is not only the ability to attract people, but also capacity to organizing available resources into their most productive use (Ireland, Hitt, & Sirmon, 2003).

Very important feature of an entrepreneur is also creativity. That quality is seen by some as decisive for introducing new ideas into the market (Shane, 2003). In addition to that, entrepreneur is a rational individual, whose motivation comes from willingness to "found a private kingdom", ambition, and drive for standing out from the crowd. Not less important is also love for implementing his or her plans and ideas, acting on them and realizing them (Schumpeter, 1934).

On a level of personality entrepreneur can be summarized as risk taking, creative and charismatic individual, who is focused on active implementation of ideas. The important question at this point is, where those qualities come from? There are several contrasting positions in this matter. For Schumpeter (1934) the personal treats of an entrepreneur are "given" to him or her. In other words, those qualities are natural from him or her. On the other hand, Shane (2003) sees the possibility of environmental influences of developing those qualities. The following section will present parallel framework for understanding entrepreneurial activity, based on the knowledge perspective.

2.2 The entrepreneurial opportunity

As mentioned in the previous section entrepreneurship is concerned with introducing the new combinations that is innovation into the market. The innovation can have different sources, however one of the crucial points of connection is that the innovation comes from change, and change is in turn source of opportunity. The opportunity is therefore defined as: "a situation in which a person can create a new means-ends framework for recombining recourses that the entrepreneur believes will yield a profit" (Shane, 2003, p. 18).

The role of opportunity in entrepreneurial venture gains steadily bigger attention in the entrepreneurship research domain. The main concern is focused on answering questions why, when and how individuals that are to become entrepreneurs, recognize the opportunities and take decision on exploiting them (Shane & Venkataraman, 2000). Current research suggests that opportunity recognition is an individual process deeply immersed in one's cognitive abilities. However, the significant role is put on the heuristic ability to assess the available information, evaluate risk and surrounding conditions in order to take entrepreneurial action (Alvarez & Busenitz, 2001). The entrepreneurial action is therefore concerned with utilizing available and person specific resources to exploit the recognized opportunity.

2.2.1 New knowledge and technology as a source of entrepreneurial opportunity

As presented in the previous section, innovation can originate from various sources. For some (Schumpeter, 1934), the occurrence of innovation is conditioned by the personal qualities an entrepreneur. One the other hand, Drucker (1985) puts attention on the external sources that can spur innovation. One of those external sources is new knowledge, and in turn new technology. The innovation based on new technology is difficult, time and resources consuming, characterized by high grade of uncertainty but in the same time gives possibilities of high return on investment (Drucker, 1985).

Moreover, the technological opportunities themselves can have various sources, and vary depending on the field and industry. The sources of technological opportunities can be then threefold: general developments of scientific knowledge, technological developments coming from outside of a certain industry, and finally positive assessments of technological advances from the industry (Klevorick, Levin, Nelson, & Winter, 1995). The authors find positive correlation between advancements in basic and applied research and its influence on the technological opportunities. The developments on basic science enlarge accessible stock of knowledge, that later can be used in an applied manner both in the academia and in the

industry. The application-oriented activities develop problem-solving attitude, which is directly linked to creation of technological opportunities (Klevorick et al., 1995).

Klevorick et al. (1995) also finds that advancements in technology outside of the industry positively influence the amount of available technological opportunities. Those advancements can come from universities, governmental research and development institutes and others, and can be understood as for example new materials or new methods that can be applied in other industries than designed for. The stock of available technological opportunities is however different in various types of industries. It was found that developments in computer science and electrical engineering had very high rates of influencing technological developments in the respective industries (Saxenian, 1994).

According to Shane (2001) the possibility to commercialize the technological opportunity is dependent on three main factors, namely the "importance, radicalness and patent scope". The more important technological developments have greater chances to be successfully commercialized. Similarly, the more radical the invention, the bigger probability that it will find its way to the market. And finally, the patent scope that is the capability to protect intellectual property rights of the invention must be secured in order to deepen the chances for commercialization. Moreover, the existing market structure and segmentation play a role in creating entrepreneurial opportunities (Klepper, 2009).

2.2.2 Opportunity recognition

The process and ability to recognize the entrepreneurial opportunity can be influenced by several factors. Firstly, of great importance is access to information (Shane, 2003), which in turn is influenced by job experience the individuals have, the willingness to search for information, and the social network that one poses. Among those factors interesting is the job experience, which varies depending on the type of the job done in the past. Interestingly the positions within research and development area are thought to give better prerequisites to recognize the opportunity in the new science and research developments (Klepper & Sleeper, 2005). What is more, the closer the function to the tasks connected to the development part, the bigger chance to see the opportunity (Freeman, 1992 in: Shane 2003).

Secondly, the factors influencing opportunity recognition are connected to the cognitive function as mentioned above. Shane (2003) also specifies that the opportunity recognition is dependent on the absorptive capacity that is the ability to gain new and processes existing knowledge (Cohen & Levinthal, 1990). Important here is the knowledge connected to the

markets: what is the structure; how the markets work, and what potentially can find a place within the markets.

Another major factor is the type of thinking process that is different from person to person. According to Gaglio and Katz (2001, in Shane, 2003; 54) *"some people are better than others at understanding casual links, categorizing information, seeing relationships and patterns in information, understanding how processes work, and evaluating assumptions and information accurately, all of which facilitate their ability to discover opportunity".* Those abilities are based on the level of perception, intelligence, creativity and risk assessment.

2.3 Entrepreneurial environment

Research on entrepreneurship usually focuses on one of two axes: the environmental conditions influencing entrepreneurs (like market structure or institutional environment) or the specifics of entrepreneurial personality (like risk-taking attitude). However (Stam, 2009) suggest that entrepreneurship is conditioned by synergy between individual features of an entrepreneur and the environment that surrounds him or her. Recently the big influence gained so-called integrated models of entrepreneurial environments that give a similar weight to both internal and external factors conditioning entrepreneurship (Mitra, 2012).

However, as this case is focused on individual experiences and especially individual paths to the exploitation of entrepreneurial opportunity, the somehow simplified model by Shane (2003) is preferable. The first part of this model concerned with the importance of opportunity recognition was described in the previous section. The second most important part of this model are factors influencing the decision of exploiting the opportunities.

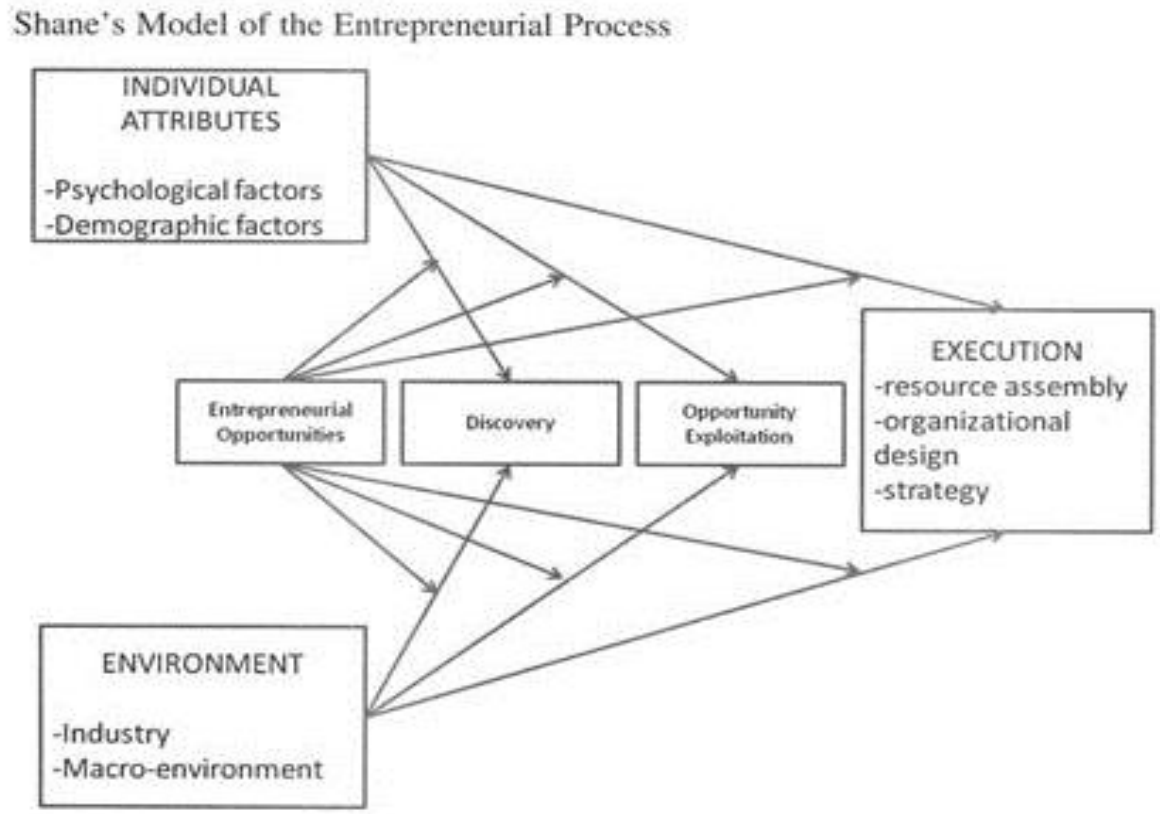

Figure 2.1 Model of entrepreneurial process by Shane (2003)

2.3.1 Opportunity exploitation

As mentioned above the decision to exploit an entrepreneurial opportunity can be influence by the great amount of various factors. In this section only the individual factors will be further described. The aspects connected to the influence of the university will be developed in the subsequent sections.

Among the personal factors that can either foster or hinder the decision on exploitation of the opportunity is the family situation and employment. According to Norn (2011) there is a positive correlation between stable family environment and the decision to start a company. On the other hand, unemployment was also found as a situation that contributes to taking entrepreneurial actions, however, only if the whole economy is not in a recession. Personal traits like positive attitude towards learning and independence also were found as good for entrepreneurship. Important were also the aim at self-realization, creativeness and innovativeness. In addition to that people who have the university degree are more prone to embark on establishing own company (Shane, 2003). Similarly, business or entrepreneurship classes make chances higher for exploitation of the opportunity. Extremely significant role

plays previous work experience, especially if it is an experience from the same industry that an entrepreneur set on (Norn, 2011).

This paragraph serves as a summary of the most important internal factors that can be conducive for entrepreneurship. Some of them will be further touched upon in the later sections, when connected to spin-offs activity or university. Two factors, entrepreneurial capital and the influence of culture were devoted special attention in this section.

2.3.2 Entrepreneurial capital

Entrepreneurial capital is seen as one of the most important factors for entrepreneurs who decided to exploit the recognized opportunity. The entrepreneurial capital can be understood as the entirety of various resources that an individual possess that are necessary to successfully exploit and realize the opportunity (Battisti & McAdam, 2012). Among the different resources the greatest attention is put on the importance of the social capital (Battisti & McAdam, 2012) and businesses skills (Mitra, 2012).

The entrepreneurial capital is obtained through the work experience prior to establishment of a new company. Of crucial importance is experience within the same industry that one plans to enter with a new venture. Reason for that is that this kind of experience gives distinctive knowledge on characteristics of certain fields and markets (Klepper, 2009). Moreover, work for incumbents equips future entrepreneurs with organizational blueprints and management techniques (Aldrich & Martinez, 2007). Those two issues will be further described in the subsequent sections. Interestingly, due to the factors shown above it is suggested that the probability of becoming an entrepreneur is higher with age (Battisti & McAdam, 2012).

2.3.3 Culture and entrepreneurship

Culture can be defined as a specific set of values, ideas, beliefs, and symbols. Hofstede (1991) presents four distinctive measures by which culture can be understood: the attitude towards collectivisms vs. towards individualism, power distance, the level of avoidance of uncertainty, and finally the relation between femininity and masculinity. According to Mitra (2012) two of those factors, ambiguity avoidance and collective vs. individualistic attitude can have great importance for entrepreneurship. The high level of tolerating the ambiguity is said to contribute positively to taking a decision of starting a new company. Furthermore, the individualistic orientation is seen as conducive for entrepreneurship (Mitra, 2012).

What is more, culture affects how people think and operate, and in that sense culture can either hinder entrepreneurship, or foster entrepreneurial activities. According to Ireland et al. (2003, p. 970):

> *"Committed to the simultaneous importance of opportunity-seeking and advantage-seeking behaviors, an effective entrepreneurial culture is one in which new ideas and creativity are expected, risk taking is encouraged, failure is tolerated, learning is promoted, product, process and administrative innovations are championed, and continuous change is viewed as a conveyor of opportunities".*

Similarly, Stam (2009) points that culture may affect the decision on exploiting the opportunity in form of new venture creation, by for example the tolerance for some behaviors like risk taking. What is even more important is that some theories suggest that *"individuals acquire information and skills by observation of (entrepreneurial) activities by others, that might trigger and enable their choice of an entrepreneurial career"* (Stam, 2009, p. 8). That shows the importance of role models in creating conducive environment for entrepreneurship. Interestingly, recent studies showed the importance of entrepreneurial example for fostering entrepreneurial mindset among peers (Kacperczyk, 2012). According to that study, the co-students are more likely to start a new company if they witnessed one of their peers successfully establishing a company. In addition to that, the greater influence has the fact "who" established the company, and not necessarily "when" (Kacperczyk, 2012).

Furthermore, the local and regional differences in culture can contribute to either hindering or fostering entrepreneurship. In a classic work, Saxenian (1994) shows how cultural characteristics influenced the development of two distinctive regions in the US, Silicon Valley and Route 128. She points towards some key characteristics of a conducive culture of Silicon Valley. Among the most important are change, and even more importantly, the high tolerance of rapid and often disruptive change; extensive social network that contribute to quality contact between firms, research and suppliers; collective attitude towards problem solving; and finally, horizontal structure that enable easy and effective contact among the parties involved (Saxenian, 1994).

2.4 University and entrepreneurship

In the previous section of this chapter the correlation between the technological opportunities and advancement in science was shown. Undeniably, the great share of technological

advancement takes place within the universities – knowledge producing organizations. Recent years brought growing attention for the role of universities in economic development of nations and regions (Pike, 2006), what in turn opened the discussion on the mission of higher education institutions.

2.4.1 The role of universities

Up until recently the contribution of universities to the economic development was twofold. First of all, research carried on within the academia contributed to better understanding of surrounding world, devising new rules, laws, and the development of new technology, products and services. Secondly, education, which is the primary mission of the universities contributes to the production of candidates with desirable skills and knowledge that can be used by the industry into solving existing problems, and in that sense creating progress and development of the existing market and industry structures (Bishop, D'Este, & Neely, 2011).

Apart from those traditional two roles of university that is research – creating development in science and available stock of knowledge, and education, that is dissemination of that knowledge into the society, recently the third part has been added. The third role of the higher education institutions is creating development of the economy by knowledge spillovers into the existing industry, as well as by commercializing the new science and technology developments in new entrepreneurial ventures (Etzkowitz & Leydesdorff, 2000).

Some claim that commercial activity of universities is positive not only for the general economic performance of countries and regions, but also universities themselves. The reason for that is the fact that universities capitalize on the commercialization of their knowledge, and can therefore utilize the surplus on their two most important missions, that is research and education (Shane, 2004). Furthermore, the presence of so-called "entrepreneurial scientists" (Etzkowitz, 1998), contributes to entrepreneurial training among students, by giving them business example within academia, as well as access to practical advice. Not less important is the fact that commercial activity also helps in retaining and obtaining good scientists. The reason for that can be twofold. First of all, growing ethos of the ability to create a viable product that brings value not only to the scientific community, but also society as a whole, becomes of growing importance for researchers. Secondly, the possibility to simply capitalize on own invention is of growing value (Shane, 2004).

2.4.2 Universities fostering entrepreneurship and innovation

After recognizing growing role of universities in creating the economic value by commercialization of technology, several initiatives were taken upon by the academia administration in the last two decades. Those initiatives took form of venture funds directly connected to the universities, or internal agencies that were supposed to help students, professors and other scientific employees in the process of commercialization of the science based technology (Shane, 2004). Later years brought even further formalization of the universities action in fostering entrepreneurship and commercialization of technology by developing so-called science parks or official incubators, with main aim of practical business development of the technology based ideas. Undeniably, the most widespread supportive measure utilized by universities in recent years are technology transfer offices, which take upon the whole process of business development of science based commercial ideas (Mitra, 2012).

Although extremely relevant to the topic of the role of universities in fostering entrepreneurship, are those issues of lower importance for the case in question, as they were nonexistent in the period in question. For example, the Technology Transfer Office of NTNU was established inly after 2002 and NTNU Accell that is universities incubator started officially after 2006.

However, apart from purely institutional and administrative measures, universities can foster entrepreneurial behaviors in various other ways. Important is to mention, that promotion of entrepreneurial activities is nowadays directed towards two distinctive groups: university students, and university professors and other scientific employees. Despite heavy reliance on the institutional measures in entrepreneurship promotion among researchers and scientist, some scholars claim that indirect methods of encouraging entrepreneurial activity can bring substantial results (Rasmussen, Moen, & Gulbrandsen, 2006). Promotion of entrepreneurial culture is seen as one of most effective measures in fostering entrepreneurship. Nevertheless, very often the cultural aspects are organized in institutionalized forms like mentioned above science parks and incubators in order to stimulate entrepreneurial activity (Klofsten & Jones-Evans, 2000).

Recent years show also growing attention put on fostering entrepreneurship among students. Two main measures utilized in the quest for developing entrepreneurial mindset is entrepreneurial education and establishment of student driven organizations aimed at promoting the sole idea of starting own entrepreneurial ventures by the students. Those to

roles are realized at NTNU by the School of Entrepreneurship responsible for entrepreneurial education, and student organizations like Start NTNU responsible for entrepreneurship promotion (Rasmussen et al., 2006). The role of entrepreneurial education among students both as a full study program, as well as individual courses have been proved to have a positive impact on fostering entrepreneurial mindset and in turn entrepreneurial activities among students. Also, the bottom-up approach of student driven organizations that encourage development of entrepreneurial mindset have also shown positive impact on the university entrepreneurship (Davey, Hannon, & Penaluna, 2016).

Important is to mention that both measure where non-existent in the period in question of the case of entrepreneurs from classes of 1991 and 1992.

2.4.3 Academic entrepreneur

Important element of university´s role in fostering and creating entrepreneurship are so-called academic entrepreneurs (Rahim, Mohamed, & Amrin, 2015). Although the phenomenon of an academic entrepreneur is not entirely novel, the term itself is relatively new, and connected to the development within university spin-off activity described in previous section. Interestingly, first mentioning of university professors establishing companies are dated back to the 19th century Germany (Etzkowitz, 1998). Previously the term "entrepreneurial professor" was used to describe a professor who sets on commercialization of his research and technological developments. Usually they were on the forefront of scientific developments, and had constant active contacts with existing industries and business in their field. Moreover, this term was also used to describe professors who actively worked towards obtaining external financing for research projects, wishfully from the industry (Etzkowitz, 1998).

Currently the term of an academic entrepreneur is associated with a university employee who not only develops the science and technology, but also actively sets on the process of commercialization of technology (Rahim et al., 2015). The decision of an academic to commercialize the technology developed by him or her is conditioned by several factors. Shane (2004) turns attention the role of institutionalized measures that can contribute to greater rates of university entrepreneurship. Among those measures are the intellectual property rights, support system, and the division of revenues. Interestingly, Rahim et al. (2015) shows a connection between industry – academia collaboration and the scientist´s decision to commercialize. According to them, cooperation with industry "expose academic researchers to real industrial problem and market needs" (Rahim, et al., 2014; 56). That is

contribute to better understanding of market needs, and in turn, to higher chances of recognition of business opportunity.

2.4.4 University culture

The university culture as seen as important environmental factor that can either foster or hinder occurrence of entrepreneurial ventures within academia, both spin-offs and students' companies (Shane, 2004). The scientist, who wishes to set on commercialization of his or her invention is very often confronted with the dilemma of choosing between research career and creating a company. The reason for that is the current academic policy that puts scientific publications as the primary method of evaluating academic development of the scientists. It was however found that the environment that values both the science and product development is seen as conducive for taking the decision on exploitation of new inventions (Rahim, et al., 2014).

Shane (2004) highlights the role of technology licensing offices as the ones that can create a positive attitude and conducive culture for academic entrepreneurship. The office that serves help and advice, but in the same time is willing to actively include the scientist into the business development projects are seen as helpful for fostering entrepreneurship within academia. Not without importance according to Shane (2004) are also the technical arrangements connected to the patent, share and potential income division between university and academics if they embark on establishing a company based on the technology developed at the university. Since the 1980 and so – called Bayh-Dole Act all the intellectual rights of inventions and technologies developed within the universities belong to the universities. Due to that, it is seen as an important to ensure satisfying return for the scientists themselves.

Another important factor within the university culture that stimulates entrepreneurship among both scientist and students is the presence of entrepreneurial example within professors or colleagues. Entrepreneurial role models give practical examples of how the commercialization process can be done, and what is even more important that it can be done (Rahim, et al., 2014). Furthermore, those role models can give examples that are then simply executed in a new venture creation by other scientists (Shane, 2004).

Interestingly, an addition to the role of university culture is a case study carried on at the Chalmers University of Technology in Sweden (Jacob et al., 2003). The case is chosen as relevant for this project due to the similarities in the national culture between Norway and Sweden, as well as the similarities between the role of Chalmers in Sweden and NTNU in

Norway, that is the main producers of technical competence in the respective countries. Jacob et al., find positive correlation between individualistic orientation of the scientists and their willingness to commercialize the technology. In addition to that, they show an ethical issue connected to commercialization – some of the scientist are reluctant towards capitalizing on their inventions when they are an effect of governmentally financed research. It was strongly connected to the individual understanding of the role of research in the society. Furthermore, they also point towards different understanding of the concept of academia and industry as a reason for lack of commercial instinct. Finally, they also find positive relationship between the scientist that have close connections to the industry and their willingness to implement more entrepreneurial orientation (Jacob, et al., 2003).

Similarly, Rasmussen et al. (2006) carried out a case study with both Chalmers and NTNU as the research objects, in order to compare various measures for fostering entrepreneurship primarily among scientists. Their findings point towards an importance of "academic freedom" of the researchers and the voluntarily decision to take commercialization activities. According to the authors, creating entrepreneurial culture within universities took very institutionalized forms, whereas interviewed scientists turn attention to the role of traditional academic ethos.

Those two cases show how little the impact of entrepreneurial culture on the technology commercialization from the university has been understood, especially in terms of the impact of values and behaviors, instead of institutionalized measures.

2.4.5 University – industry connection

University - industry connection traditionally had various forms. First of all, the connection was concerned with educating future industry employees of desirable skills and competences, and creating scientific and technological advancements that aim at development and renewal of industry (Mitra, 2012). The cooperation evolved into more active industry presence within academia by becoming an active part of research community. One of the main examples of industry´s activity within higher education institutions was cooperation in research programs, where on one hand industry directed their "real-life problems" to the academia, and on the other hand financially participating in the research programs (Etzkowitz, 1998). This type of relationship contributed to bigger application orientation within cooperating industries, and gave way for a more problem-solving orientation of academia.

Although, the direct correlation between university – industry cooperation and startup rates has not been sufficiently proved (Mitra, 2012), the positive influence on level of entrepreneurial activity within academia, especially in terms of spin-offs creation, was found in the situation when the research was financed by the industry (Shane, 2004). The reason for that is seen in the fact that industry founded research is more likely to be application oriented, than government financed projects. Due to that the research results are more likely to be market specific, and more easily turned into new products or services. In addition to that industry founded research contributes to building technical skills used in cooperation with business that can be then utilized in the new firm formation. That also creates better understanding of the markets, its structure and functioning, and in the same way bigger chances of realizing the commercial potential of science and technology (Shane, 2004).

Similarly, some researchers claim that industry – university cooperation can be conducive for fostering entrepreneurship among researchers and scientists. The reason for that is the influence cooperation with industry and real-life problems have on the mindset of the scientist. It contributes to development of more problem-solving mindset, and better understanding between the world of business and academia. Interestingly, also the industry commissioned research is seen as a type of academic entrepreneurial activity, due to necessity of applying entrepreneurial measures to solicit industry research programs (Klofsten & Jones-Evans, 2000).

Important factor in the collaboration between academia and existing industry are also professors themselves. The connection between higher education institutions and business organizations are often created based on the personal relations among scientists and businessmen. Those personal linkages contribute to the innovativeness in both university and economy. Those connections enable mutual contributions to science development – basic science development can be successfully implemented within the industry, and on the other hand industry can influence the further specialization of that knowledge customized to the specific industry needs (Bishop et al., 2011).

2.5 Spin-offs

Spin-offs are among the most widespread entrepreneurial ventures. In general spin-off can be defined as a new company started by one or several employees that left the original company to establish new one in the same business (Klepper & Sleeper, 2005). Among spin-off two distinctive types are devised: corporate and university spin-offs. Corporate spin-offs originate

from the private companies or corporations, while university spin-offs have their origins in the higher education institutions. Both categories are of relevance to this project, as among the companies in the investigated case can be found corporate, as well as university spin off.

2.5.1 Corporate spin-offs

Spin off activity is thought to be of value and importance for both industry and economy. It not only creates new businesses and work places but also leads to constant business and technology development. Furthermore, spin off activity is said to contribute to utilization of technologies that otherwise would be left untouched due to lacking resources or interest of existing companies (Klepper, 2009). Shane (2001) points toward interesting relationship: the more radical innovation, the bigger chance that it will be commercialized within new company then within the existing one. The reason for that is usually lack of either sufficient resources or willingness from the management of the incumbent company to take upon the risky new product development.

2.5.1.1 Knowledge conversion capability and prior experience

Important role in spin-off creation plays so-called knowledge conversion capability that is the ability to turn scientific research into successful product. This is an extremely important factor especially in case of high-tech entrepreneurship (Zahra, Van de Velde, & Larrañeta, 2007). The authors also put great attention on the prior experience from the mother company in shaping spin-offs. It was found that entrepreneurs, who decide to spin off from the incumbent company, obtain both skills and knowledge in their parent company. The knowledge and experience are then transferred to their new venture. The resources they bring from their employers can involve market and product understanding, business formation skills, technical knowledge, as well as personal contacts. Interestingly corporate-spin-offs are also prone to replicate the parent company business model (Zahra et al., 2007).

Furthermore, industry experience gives potential entrepreneurs better prerequisites to understand market, its structure and characteristics (Klepper & Sleeper, 2005). It also deepens the possibility to recognize and name potential market niches (Stam, 2009). As mentioned in the previous section, it was found that entrepreneur tends to replicate the structural and organizational forms from parent company in a new venture (Aldrich & Martinez, 2007). In that sense, the experience within an established company contributes to acquiring organizational resources that could have decisive importance for the survival of an entrepreneurial venture (Aldrich & Martinez, 2007).

2.5.1.2 Spin-offs and industry

Differences in occurrence of spin-off activity have been found among industries. There are several factors that are used to explain this situation. As the most important are named inter-industry characteristics, like maturity and composition of the industry, as well as the type of technology utilized in certain sectors. What is more, there was also found a correlation between the success rate of a parent company and spin-off - spin-offs stemming from a successful parent company are more prone to achieve success themselves (Klepper & Sleeper, 2005).

Interestingly, one of the industries that show highest rates of spin-off activity is semiconductors industry. The reasons for that are seen in high speed of technology development and high rate of the innovativeness (Klepper & Thompson, 2007). In addition, Saxenian (1994) turns attention into the role of prior entrepreneurial example in spin-off creation. According to her, the successful spin-off ventures enhance the willingness of other employees to leave parent firm and start own company.

2.5.1.3 Rationale for spin-off activity

Current research recognizes several types of rationale for the spinning off processes within existing industries. Firstly, employees may make a discovery that due to the insufficient channels of communication is not recognized as valuable by the incumbent firm, and that lead to the decision on exploitation by some of the employees. Secondly, the new product or service stemming from an incumbent may be of a bigger value for a new company, then the existing one. Thirdly, employees gain extensive experience, market and competition understanding and are willing to exploit that knowledge by establishing a new company. And fourthly, spin off activity may occur due to disagreements within the company, or between employee and employer (Klepper and Thompson, 2007).

2.5.1.4 Corporate culture and spin-offs

Some researchers also see the correlation between the type and characteristics of a corporate culture of a parent company and spin-off activity. First of all, the culture of cooperation is said to be conducive for innovative mindset of the employees. The culture of cooperation is highly evident in companies that are still in the period of growth and development, that not yet come to the corporate stadium. That environment is characterized by high ambiguity, fast pace of change and sometimes unclear roles (Cordes, Richerson, & Schwesinger, 2014). Those characteristics make it necessary of the employees to contribute to the overall well-being, and sometimes, even survival of the company. That in turn builds up creativeness and

innovative mindset. Apart from "entrepreneurial imprinting", that is directly copying the patterns from the incumbent company, also the entrepreneurial mindset is being developed in that process. All those features are said to have positive influence on the spin-off activity (Cordes et al., 2014).

2.5.2 University spin-offs

University spin-offs defined as *"a new company founded to exploit a piece of intellectual property created in an academic institution"* (Shane, 2004) gain steadily greater momentum in the research in both entrepreneurship itself and the role of universities in fostering entrepreneurship and economic development. Similarly, to the corporate spin-offs they contribute to the overall development and renewal of economy, creating new job places and variety in the market. What is seen as specific for the university spin-offs is their contribution to commercialization of technologies created within the academia, which otherwise could be overseen by the established companies (Shane, 2004). Furthermore, they very often focus on bringing to the market "radically new and disruptive" technological inventions, due to the fact that they are charged with high level of ambiguity and high investment risk (Zahra, et al., 2007; 570). However, if successful, university spin-offs can disrupt existing market structure and competition.

University spin-offs occur most often as a result of long lasting and complex research and development projects (Rasmussen, 2011). However, the frequency of university spin-offs varies across time and space. It was found that apart from the superiority of technology created at the university also other factors influence the level of spin-off activity. Among those factors are the internal university policies, the expertise within technology licensing, and the culture of the university (Shane, 2004). Some also see the connection between the "eminence" of the university and the entrepreneurial activity (Di Gregorio & Shane, 2003). According to that theory, the universities that are associated with higher competence can attract better researchers and students. Thanks to that they create atmosphere of interest around their research activities, what can contribute to attracting industry and investors (Di Gregorio & Shane, 2003).

2.6 Summary

This chapter presented the theoretical framework, which will be applied to analyze results of this study. As a starting point the explanation of the concepts of entrepreneurship and innovation was presented. Both have crucial importance for the case in question, which is

concerned with creating value through new firm formation that introduces new combinations into the market. Certain attention in this chapter was also devoted to the role of personal characteristics of an entrepreneur. An entrepreneur is than a creative, risk-taking, solution oriented individual with leadership skills. Nevertheless, in a comparison to the personal perspective the second approach of understanding entrepreneurship was discussed – the knowledge and technological skills perspective. It was concluded that as progress in science creates new entrepreneurial opportunities, and relevant job experience contributes to opportunity recognition and exploitation.

The relation between opportunity recognition and exploitation was further described in separate section. The environmental elements that influence the decision to exploit an entrepreneurial opportunity were presented. Among the factors that have the strongest impact on the entrepreneurial activity was closely presented entrepreneurial capital and the influence of culture. Entrepreneurial capital is therefore presented as the entirety of tangible and intangible resources that are in the disposal of an entrepreneur. The crucial importance has business and organizational skills obtained during job experience.

Moreover, the role of the university in fostering entrepreneurship was presented. The discussion on mission of the higher education institutions was shown. It was concluded that universities take upon new role in the changing economy - the role of commercialization of technology. In realization of that mission, great importance has academic entrepreneurs, that is scientists who decide to start companies based on technological developments. Apart from the institutionalized forms of supporting entrepreneurship within academia, also the impact of environmental and cultural aspects was described. Moreover, attention was also put on the collaboration between academia and industry. Although the direct connection between university – industry relation has not been proved, it was shown that this collaboration might have positive impact on the rates of university entrepreneurship.

The last part of this chapter was devoted to presentation of characteristics of spin-off companies. Spin-off companies can be analyzed within two frameworks, corporate and academic. The corporate spin-offs are in great degree conditioned by the environmental factors of the industry and parent company. That is especially visible in the resources and organizational forms that spin-off companies acquire from the incumbents. University spin-offs are conditioned by the institutionalized support system of the universities, and in some degree by the level of competences and general progress in science developments.

3 Methodology, research design and process

The purpose of this chapter is to describe the rationale for choice of qualitative methodology for investigating the case in question. In addition to that this part of the report will present the choice of case study as research design, with interviews as main method applied. The research process with the most important stages will be shown. Finally, the ethical issues connected to this study will be touched upon.

3.1 Choice of a methodology

The choice of methodology and subsequently methods used in a research project is undeniably the most important step in the whole research project. The decision should primarily be based on what one wishes to find out. In addition to that the effectiveness of both methods and process in giving the most suitable and relevant data should be taken into account when deciding on the type of methodology chosen for the research project (Tjora, 2010).

Currently the research world is devoted to two specific methodological approaches: quantitative and qualitative. Tjora (2010, p. 19) describes the relation between those two methodologies as "qualitative methods highlight insights while the quantitative highlight overview, or that qualitative methods seek understanding, while quantitative seek explanation. Furthermore, qualitative methods aim primarily at creating greater understanding of social phenomenon, are relevant in the field that has not been thoroughly researched before, seeking deeper understanding and explaining meaning of social phenomenon (Thagaard, 2009). Qualitative approach involves closer connection to the field, and are suitable when the topic calls for more flexibility in research approach.

The following report addresses the broader issue of the role that university plays in technological entrepreneurship. To specify this topic following research questions were devised: *how did university foster tech entrepreneurship before facilitation took organized forms?* And *why so many entrepreneurs spun off from the two classes of 1991 and 1992 at NTNU?* To be able to answer those questions I had to get deeper understanding of both the situation and the phenomenon, using methods that primarily cope with text and unraveling of meanings, not numbers. Taking that into account I decided to employ qualitative research methods in following research project.

3.2 Rationale for case study research

According to Yin (2014, p. 16) *"a case study is an empirical enquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident"*. Furthermore, he claims, *"a case study allows investigators to focus on a case and retain a holistic and real-world perspective"* (Yin, 2014, p. 4).

The story of entrepreneurs stemming from classes of 1991 and 1992 can be treated as a phenomenon in itself. As mentioned above students from those two classes established successful technological companies, but what is even more important is the fact that those companies include different types of entrepreneurial ventures – corporate and university spin-offs. In the period of question (1987-1992) the ecosystem for entrepreneurship and innovation as we know it today was non-existent. In addition to that numerous other students from those two groups devoted their careers to entrepreneurship by working for venture capital companies. Taking all that into account it seems worth investigating closely the history of the tech entrepreneurs of classes of 1991 and 1992 and treating them as a separate phenomenon.

Furthermore, the story is set in a wider context of university, its structure, functioning and values that were present in the 1980s and 1990s. Due to the intricate and multilevel connections between student environment and university environment it can be expected that both are entangled, and one cannot be fully understand without the other. Taking that into account choosing a case study research design seemed a natural choice for this research problem.

Yin (2014) presents certain conditions that should be met when deciding on case study research design. Among the most important are: the degree of influence the researcher has over events in question, the character of research question, and the concentration on current events. In the case of classes of 1991 and 1992, I as a researcher would have very little influence over the events, as they had already happened. My role would be limited to gathering factual information about those events, as well as meanings and opinions from people involved in the story.

Secondly, I chose research questions that employ "how" and "why" structures as they seek to explain the reasons of a certain situation and look at the situation as the whole phenomenon. Thirdly, the story in question had already taken place and on the first sight could call for historical study. However, according to Yin (2014), there are some exceptions that can

classify some studies as case study and not historical study. Namely if the results on the situation in question are still being observed and first hand data are possible to be obtained from people primarily involved in the phenomenon, case study research design can still be employed. Both conditions are met in the case of classes of 1991 and 1992, as the results (some of the companies still exist, their founders are still alive, and in addition they had an influence on existing milieu for innovation and entrepreneurship) are still visible and primary informants are still available.

It is important to mention the ongoing discussion on the reliability of case study research. The most visible concern is connected to the rigidity of the design, use of multiple sources and connection between theory and the case (Baxter, 2010, Robson, 2002, Yin, 2014). Rigidity of design on one hand helps maintain order and reliability in the project, but it has to be treated with a certain dose of flexibility (Baxter, 2010). In qualitative research, one cannot be always sure what data will be found in the field, and as such the adaptability to the conditions and findings needs to be met.

Connected to that is issue of theoretical propositions. Yin (2014, p. 30) states very clearly the need for building theoretical propositions before researcher sets on to the field of study, as *"each proposition directs attention to something that should be examined within the scope of study"*. However, in my case, I found it extremely hard to create reliable theoretical propositions at the beginning of the research process. Reason for that was the very little knowledge available about my research field, and at some point, uncertainties of "researchability" of the case. All in all, I decided to set on without clear theoretical propositions, however employing the Baxter´s idea (2010) of cyclical approach to the field – exploring the field and building theoretical propositions based on the case, and then applying them to the scrutiny of existing body of literature. Due to the numerous uncertainties connected to my field, the flexible-cyclical approach gave satisfactory results.

What is more, use of multiple sources of evidence strengthens the reliability of the case (Yin, 2014). It seems to be of vital importance in my case, as a major part of the project is devoted to unraveling factual information and recreating a certain environment and history behind the case. As such, whenever it was possible I tried to examine data from articles and documents, by checking their accuracy with the informants, and the other way round. Among the main documents employed for data triangulation in the case background part I used especially three books: the collection of essays about the Department of Physical Electronics (Fysikalsk Elektronikk ved NTH/NTNU i 50 år. Undervisning, forskning og innovasjon by various

authors); the collection of essays prepared for the occasion of the establishment of NTNU (Teknologi for samfunnet. NTH i en brytningstid 1985 – 1995), and the book about history of NTNU by Brandt and Nordal, 2010.

Among documents employed to clarify issues connected to the tech entrepreneurs and companies they established, I used in great degree newspaper articles, which came mainly from national media like Aftenposten, Dagens Næringsliv, as well as local newspapers, especially Adersseavise. In addition to that helpful proved to be articles published in Teknisk Ukeblad, especially those concerning technological inventions. In addition to that databases like Bloomberg and Crunchbase were extensively used to check professional information about entrepreneur in question. Important source of secondary data was also EE magazine, the brunch magazine of electrical engineering. Nevertheless, in numerous instances, there were no secondary data I could apply. Therefore, I checked the same factual information with many of the informants to gain clarity in the issues in question.

3.3 Interview as the main research method

Qualitative research design involves a wide variety of methods, observations or surveys (Thagaard, 2009). They are all suitable and of equal value in qualitative research, however the issue in question calls for a method that can give insight into detailed factual information, as well as experiences and opinions of individuals involved in the story. As qualitative interviews are used to *"investigate complex behaviors and motivations, and to collect a diversity of meaning, opinion and experiences"* (Dunn, 2010, p. 102), they were chosen as the main method used in data collection.

There are several types of qualitative interviews: structured, semi-structured, unstructured (Robson, 2002), and focused (Tjora, 2010). For purpose of this project I chose semi-structured interviews, as they offer combination of following the topics that are of interest to researcher and flexibility in the sequence of questions answered (Robson, 2002).

All of the 16 interviews were carried out during the data collection process 7 interviews were face-to-face interviews, 5 were carried out via Skype and 4 were telephone interviews. Independent from the means of execution, the interviews took from 40 minutes to 1,5 hour with average duration of one hour. Informants represented all four informants' categories: students from classes 1991-92 turned entrepreneurs, other students form classes 1991-92, professors who thought the students in question, and other researchers involved in the

department and creation of the ecosystem of entrepreneurship and innovation as we know it today.

Face-to-face interviews were executed in the places chosen by the informants, in order to give them "comfort" in the situation of being extensively questioned by an unknown person (McCracken, 1988). It was mostly offices of the informants, in one case it was a university café, and once I was invited to home of an interviewee. As Weiss (1994) suggests, face-to-face interview is the most effective form of interviewing, as it builds trust and gives a ground for mutual understanding. Due to the fact that part of the potential informants live out of Trondheim, and being active businessmen, have very hectic schedules, interviewing via Skype or telephone seemed to be most reasonable choices. Interestingly, I did not notice the difference in duration of interviews between face-to-face and Skype or telephone interviews. Furthermore, the longest interview, 1,5 hours was carried out via Skype. The short duration of some interviews, were dictated rather by the time constraints of the informants, than by the means of communication.

Interviews were pre-arranged first by establishing contacts with the key informants. Due to the fact that telephone numbers and e-mail address not always were accessible, the main way of contacting the potential informants was LinkedIn´s messages, so called In-mails. However, the untraditional the method was, it had some advantages. First of all, the LinkedIn sends multiple notification and reminders about In-mails received, what can potentially make chances for getting an answer bigger. Second (of all), by sending an in-mail to a potential informant, my own credibility as a sender is justified by my LinkedIn profile.

In some cases, the informants were hardly accessible by in-mails, or other means of contacts that I was able to find. In order to connect to people I wished to interview I used the existing contacts, mostly by asking about any possible way of connecting to informant "x". The interviewed informants were extremely helpful in that matter, and very often I was able to get a private e-mail or telephone number. In some cases, also being able to refer to the person from whom I got the contact details helped in gaining a positive response to my request for the interview.

I was able to execute an interview with 8 out of 9 students turned entrepreneurs. The only person from this category that I was not able to connect to, even though multiple trials, was Alf-Egil Bogen, student of class of 1992 and co-founder of Atmel Norway. In order to compensate the lack of first-hand information from that informant, I carried out a thorough

search for existing articles about him and establishment of Atmel, as well as profile stories about him, existing interviews with him, or even podcast and recorded speeches of him. In addition to that some extra questions about him were added to the interviews with other students turned entrepreneurs who were closely connected to Alf-Egil Bogen either during the time of master studies at NTHTNU or the period of working for Nordic Semiconductor and establishment of Atmel Norway.

From the second category that is other students form classes of 1991 and 1992, 3 interviews were carried out with two and one respective representatives informants from those classes. The choice of interviewees in this group was not random. The selection was fueled by two factors: the class they were a part of, and the second of all what kind of professional experience they have. As such, there were two representatives with business/corporate and venture capital background, and one informant with an academic background.

The third category, (that is) the professors of the students in questions, proved to be the most difficult one. All in all, I was able to carry out three interviews with only two professors. Both of them were not only the active researchers and lecturers at NTNU, but they were also successful entrepreneurs who were able to commercialize their research and technology created during the period at NTNU and/or Sintef. The biggest obstacle in this category was the fact that some key figures, like Einar J. Aas passed away. Remaining professors who could shed some light on this case were unfortunately either not interested in participation in an interview or were not able to take part in an interview due to hectic schedules.

Two interviewees represented the fourth group of informants embracing the researchers and professors, who were involved in the department and are also responsible for creation of current milieu for innovation at the NTNU. The full list of informants, their position and purpose of the interview are described in the table below:

Table 3.1 List of informants

No.	**Name**	**Company/Organization**	**Role**
1.	John Raaum	Arctic Silicon Devices	Entrepreneur, class of 91.
2.	Vegard Wollan	Atmel	Entrepreneur, class of 91.
3.	Svein Anders Tunheim	Chipcon	Entrepreneur, class of 91.
4.	Sverre Dale Moen	Chipcon	Entrepreneur, class of 91.

5.	Geir Førre	Chipcon / Energy Micro	Entrepreneur, class of 92.
6.	Egil Eide	3d-Radar	Entrepreneur, class of 91.
7.	John M. Lervik	Fast Search & Transfer	Entrepreneur, class of 92.
8.	Haakon Bryhni	Advanced Communications Technology / Elliptic Labs	Entrepreneur, class of 91.
9.	Eivind Bergsmyr	Nacre; Viking Venture	Class of 91. Background information on the study environment and contextual conditions of the case.
10.	Per Gunnar Kjeldsberg	NTNU Professor	Class of 91. Background information on the class and study environment, and professors.
11.	Geir Ove Kjesbu	Ex CEO of Q-Free and Investinor	Class of 91. Background information on class and study environment, plus investor perspective.
12.	Patrick Waldemar	Fast Search & Transfer, Telenor	Class of 92. Background information on class and study environment. Perspective on establishment of Fast.
13.	Karl Klingsheim	NTNU Prof, Founder of Clustra, NTNU TTO and Accel	"Professor perspective". Background information on the NTNU-Sintef-Industry cooperation and conditions for commercialization of technology at NTNU in the 1990s and at the beginning of 2000.
14.	Arne Halaas	NTNU Prof. Computer Science. Fast Search & Transfer	Professor perspective on conditions for commercialization of technology at NTNU in the 1990s.

15.	Oddvar Aaserud	Co-founder of Nordic Semiconductor, NTNU Prof. Entrepreneur	Background information on NTNU-Sintef-Industry cooperation. Establishment of Nordic and connection between Nordic and NTNU in the 1990s. Perspective on other professors.
16.	Kjell Arne Ingebrigtsen	NTNU Prof, GE Ultrasound	Background information on the institute and relation to the industry. Conditions for commercialization of technology.

For every informant´s category, separate interview guide was prepared accordingly to the type of information I was looking for and the type of insight certain group could possibly give me due to their background and place in the case. However, all of the interview guides, were prepared with the same rule, suggested by Cook (2007). The interview started with easy questions concerned with factual information, then gradually going deeper in more detailed information, to finally arrived on questions about their experiences, memories and opinions. All of the informants were offered to get interview guides beforehand. Only around half of all the interviewees preferred to have it before the interview in order to be able to prepare themselves.

All in all, the interviews were rather clear and focused on the topic. My informants were very open about the events in question and willingly added information even without specific questions. In some cases, the informants took long time to give an answer, setting detailed background first. Nevertheless, the interviews were easy to direct. The interviewees showed "business like attitude" and were rather letting me to focus the conversation.

13 out of 16 interviews were recorded. In 3 instances the informants did not wish to be recorded. In those cases, extensive notes were taken during the interviews. Out of 13, recorded interviews 10 were transcribed. The remaining three were not transcribed due to time constraints. Transcription was a very time consuming process, mostly due to the long duration of interviews. In addition to that, the process had to be done very carefully, as in some cases informants were very clear about going to "off the record" mode. In the case of the 3 untranscribed interviews, extensive notes were taken under the interviews. To ensure

that my notes were correct, I listened to the recording several times and market the most important parts. When writing the case results section, I also went back the recordings to check all the information.

3.4 Research process/strategy

The data collection process was carried out in five separate stages. The first stage was so-called preparation stage. The second stage was focused on choosing informants and preparation to the interviews. The third stage was devoted to clarification of aroused issues, while the fourth was concentrated on the research interviews. Finally, the fifth stage was focused on data analysis.

3.4.1 Stage one

The first stage, which I called a preparation stage, was focused on gathering initial information about the case. The main aim of this stage was to set background for the case and identify main categories of informants. Decisive method applied at that stage was extensive Internet, as well as library search for article, documents and other scholarly works about the NTNU and especially Department of Electronics and Institute of Physical Electronics within it. Invaluable source of information proved to be, mentioned above anniversary book "50 Years of Physical Electronics" (various authors, 2013), as well as archives of Gamle Universitetsavisa.

The second part of the "preparation stage" was concerned with identifying key persons involved in the story, the main categories / groups of informants and finally the informants themselves. As the key characters involved in the story were primarily named students from the classes of 1991 and 1992, who established technology companies in following years, as well as professors working in the department at that time. Here the first major "obstacle" came to my attention. As the case is set in the historical events, that happened over 15 years ago, it turned out that some key people in the story passed away. That was mainly the case of professor Einar J. Aas, who in many sources was named as not only the key researcher within the institute, but also as the "father of entrepreneurship" in the institute.

However, at that stage main categories of informants I perceived as suitable for achieving objectivity in the project were as follows: students of the classes of 1991 and 1992 that established technology companies; other students from those two classes, who could possibly shed some light on both the story and class environment; professors who taught the students turned entrepreneurs; and researchers of Institute of Physical Electronics, who were also

involved in entrepreneurial ventures and creation of the ecosystem for entrepreneurship and innovation at NTNU as we know it today.

As Yin (2014) suggests, the key for the successfully executed case study research is a case database. The case database was established and divided into categories at that point. Every article, document, scholarly article or, later on, interview and notes from respective interviews that was connected to the case was then set into the database. The main categories in the database included the background information about the university, and within it the department, the institute and the professors; informants with informant's categories, and within them every informant got a separate folder; and finally, companies established by the former students of classes of 1991-92, with every company in a separate sub-category.

3.4.2 Stage two

The second stage focused on identifying initial informants, as well as preparing initial interview guide. Names of key informants were obtained through thorough search and analysis of accessible data mainly in newspaper articles that tried to describe and unravel the case. Some input to the individuals involved in the story came also from the Chamber of Commerce in Trondheim. During that stage the key 9 informants, that is tech entrepreneurs from classes of 1991 and 1992 were named. The reason for starting data collection from entrepreneurs came naturally, as they are at the core of the story. As one of my tasks was to find out how the university environment within the Department of Electronics influenced students to establish high-tech companies in later stages of their career path., and therefore the students turned entrepreneurs, their life stories, memories and experiences seemed crucial starting point of the case study.

The second step in that phase was search for personal data, documents and articles about the initial group of informants – students turned entrepreneurs. The first source of information was LinkedIn, the Internet portal creating social network of professionals. All of the entrepreneurs have extensive profiles on LinkedIn, presenting their career paths starting form the time of master studies at NTNU until the current occupation. The information from the profiles was used to create a matrix that combined, summarized and cross-connected the background of those informants.

The matrix presented key milestones in the lives of entrepreneurs: master studies, graduation date, first professional job experience after graduation, subsequent experience and education, and finally firm formation and further development, and recent years in career´s development.

The matrix was employed in preparation of categories and questions for initial interview guide. The categories built upon the combined LinkedIn profiles include: studies and university environment, with subcategories of the practical information about master studies at NTNU, social network, and study environment; work experience, and technology creation and firm formation.

Creation of the matrix was extremely useful in establishing points of connection and differentiation between the entrepreneurs in question. However, it also gave rise to some technical questions. Even though accessible newspaper articles, for example Leirset (2006), about this particular case described the entrepreneurs as students of one and the same class in one and the same institute, the look at information they themselves present on their LinkedIn profiles gave rise to some doubts. Some of the entrepreneurs in question states in their profiles that they graduated in 1990, some in 1991, and others in 1992. In addition to that they also present names of different institutes.

I tried to clarify this issue by contacting administration office at NTNU, but unfortunately, due to the internal policy, the university does not share personal information about current and previous students. Similar issue was connected to the university structure at the time in question, as since the beginning of the 1990s, the university underwent numerous organizational and structural changes, which involved restructuring existing departments and institutes into new ones. Those concerns gave way to questioning the story as a researchable case.

3.4.3 Stage three

That gave rise to the third stage in the research process, which was primarily concerned with clarifying the concerns that arouse in the earlier stages, and confirmation on suitability of the categories and directions in the interview guide. In order to clarify the issues concerning the field of studies, I used some elements of exploratory research at that stage. According to Stebbins (2001, p. 6): *"researchers explore when they have little or no scientific knowledge about the group, process, activity, or situation they want to examine but nevertheless have reason to believe it contains elements worth discovering "*.

The technical questions that came from the second stage of the research process, showed how little is known about the widely discussed in the media story and gave the assumptions to approach the topic an as a not fully known field. In order to explore the field a researcher has to show *"flexibility in looking for data and open-mindedness about where to find them"*

(Stebbins, 2001, p. 6). In addition to that, all ethically approved methods that can help with gaining new knowledge and understanding can be used in exploration.

Taking that into account I decided to treat three first interviews with students turned entrepreneurs as the explorative interviews, in order to obtain first-hand information about the field and clarify the issues that came into light in previous stages. The first three interviews were therefore a bit longer and more detail oriented then the following ones. Great pressure was also put on gaining technical information concerning the structure of the department and the class structure.

Those three first interviews were recorded, and immediately transcribed. Rigorous coding and analysis followed. Invaluable at that stage was the method of memo writing suggested by (Straus A. L., 1987), which involves noting categories, hints towards evolving theory and arising categories during and immediately after interviews. Thanks to that process, I gained detailed information about (issues in question that is) structure of the department and institutes, class and group structure and confirmation on the field. The interview guide categories derived based on LinkedIn profiles information, and other accessible data sources, like articles and documents where confirmed. Furthermore, this stage corroborate the chosen direction of the research problem, and what is even more important the rationale for treating the story of classes 1991 and 1992 as a single case. The interview process itself will be described in following sections.

3.4.4 Stage four

The fourth stage of the research process was mainly focused on execution of research interviews with initial informants, identifying following informants form the remaining categories of the informants, and carrying on the interviews and finishing (up) on the search for other articles and documents concerning the case.

3.4.5 Stage five

The fifth stage was concerned with data analysis. As mentioned above 10 out of 16 interviews were transcribed, in three instances I worked with recordings during the process of analysis, and in 3 last examples the notes taken under the interview where subjected the same analytical activities as the rest of the data. The most important part of the analytical process was coding and categorizing. As suggested by Miles (2014), coding helps with finding crucial elements and datasets, that are later on subjected to the process of finding patterns. Codes and patterns were later on used to building the analytical categories upon them.

In the instances of the 3 untranscribed interviews mentioned in the previous section, the extensive notes were made from the recordings and subjected to the same process as transcriptions, with the change that every analytical category was checked multiple times with the recordings in order to ensure the reliability of the data. Not recorded interviews proved the most difficult to analyze. In order to ensure the quality of the data, I remained in the e-mail contact with those informants and ensured my understanding and data stated with them.

As a vital part of this project was to recreate the historical events two strategies were very helpful. First was to create separate documents containing scraps of information from various sources concerning the same topic (as suggested in Weiss, 1994). Among main topic applied to organize data were "study environment", "study culture", "peers", "professors" and "job experience". Those thematic documents created an order and allowed for sequential data analysis. Secondly different topic matrices were created based on the information from various sources (as suggested by (Miles, 2014). The matrices were used to derive meaning and opinions, and in some cases cross check facts and establish certain understandings.

Valuable source of data were also the field notes. The notes were created before, under and after interviews. The notes made before interviews were concerned mostly with preparatory and factual information, while those taken under interviews were mostly focused on observations (some specific expressions, meanings that immediately turn one´s attention, and my ideas and understandings). The third part of notes was taken shortly after the interview, when the information had time to settle, but impressions were still present in my mind. The field diary helped in categorizing data and building theoretical propositions underway.

Due to the fact that the case deals with the past events, the data gathered are in major parts based on people´s memories. When working with such a material a researcher has to take into account certain issues. First of all, the men´s memory is not a perfect tool, very often involuntarily people may give the wrong information being completely sure of its accuracy. Second of all, after certain period of time, in this case over 16 years, people "want to remember" some events, and willingly omit others, in the same way creating their own life stories (Denzin, 1989). In both cases to ensure data accuracy, multiple informants were asked about the same facts. When possible, the data triangulation method was applied by using also other sources, like article or documents to corroborate the story.

3.5 Trustworthiness of this study

The trustworthiness of the studies that apply qualitative research method is widely discussed among scholars. However, certain criteria are suggested to ensure the trustworthiness of research projects: credibility, transferability, dependability, and confirmability (Guba, 1981). Credibility is concerned with presenting the credible picture of researched events. Various tactics for ensuring credibility are suggested by Shenton (2004). In this project, I concentrated on using widely recognized methods, that is case study design and qualitative interview. Those methods have established procedures that can be used to validate the credibility of the research process. In addition, data triangulation was applied to corroborate data from the interviews when possible.

Transferability is concerned with the possibility of applying the results in areas of research (Shenton, 2004). The case in question is rather a distinctive example on its own, nevertheless the results can be transferred and generalized to other case studies of the influence of the university environment on entrepreneurship.

Third point that is dependability, is concerned with the extent to which replication of the study with its research design, methods and participant will give similar results (Shenton, 2004). In order to ensure dependability, the detailed research design and process is being presented in this chapter. The list of informants involves names and the interview guides were created with direct question, what deepens the possibilities of reapplication the design on the same sample.

The last point, confirmability, focuses on ensuring that the results are grounded in data, not personal biases (Shenton, 2004). First of all, to ensure that, data triangulation was used in this study. Apart from corroborating findings from interviews with secondary sources, the same issues were discussed more than couple of informants in order to check all the data. Moreover, application of the analytical matrixes during the data analysis stage enabled the full concentration on the data material.

3.6 Ethical considerations and lack of anonymity

When working with people and real life issues, researcher must act upon some general ethical rules and keeping them constantly in mind. Among those rules the most important are always informing informants about the aim and nature of the project; avoiding situation that could create risk and harm for the participant, and being tactful when touching upon sensitive issues (Robson, 2002). To avoid any potential breaches of ethical limits, all informants were

informed about the scope and aim of the project already in the first e-mail or message aimed establishing contact. The same information was also repeated during the interview. At the beginning of every interview I asked a participant´s consent to record the interview. If the participant did not agree, I only took notes. In the same manner, I agreed upon with every informant, that whenever I would like to use a direct quote or use them as a direct source of information, I will have their acceptance before publishing.

None informant was put in a potential risky situation in the interview. The interviews were carried on in the places chosen by the informants, or by mutually agreeing on using the certain form of communication. In addition to that, no sensitive issues were taken upon during or after interviews. Important factor to consider was the language used during data collection. As the project report is being written in English and I am not native Norwegian speaker, I wished to execute interviews in English. Every informant was asked in the e-mails about that issue, and again the issue was once more clarified at the very beginning of the interview. All the participants had also a chance to choose to speak Norwegian, if they decided that it is more suitable or simply easier for them. However, none of the interviewees expressed any concern with speaking English.

In a similar manner, I discussed the issue of anonymity with every participant. As the story of entrepreneurs from classes of 1991 and 1992 is a well-known and widely discussed in the media story, not to anonymize the sources seemed an obvious choice. Firstly, using the names of the informants gives more credibility to the factual information. Secondly, the case deals with the personal memories and experiences, and is at its core about certain individuals. The idea of not using the names in the final report seemed counterproductive, as the people in the case are recognizable anyway. However, the issue was raised with every informant individually, and they all agreed upon using their names in the story, with the condition of checking the final quotes with them before publishing, as described above.

The last issue I would like to take up in this section is the question of positionality in qualitative research. As in the real-life people have different positions due to their material status or origins, similarly this difference of position can be also visible in the relations between the interviewer and the informants. In my case I could expect the asymmetrical relationship with the informants (Dowling, 2010), as I am a master student, and a woman, who is not Norwegian, while my informants are males in their fifties with high status (successful businessmen and professors). As such, one could expect that it would be the informants who will direct the conversation and present superior attitude towards me.

However, that was not the case. I felt treated equally and seriously. My informants presented "business like attitude" being rather focused on questions and main issues in question, and in the same time open for discussion and follow up questions. As for me not being Norwegian, I felt it was an advantage, rather than an obstacle. That made the informants more factual in presenting the story, and more willing to go into technical details, due to my lack of knowledge of Norwegian school system for example.

3.7 Summary

The qualitative methodology was chosen to investigate the case of tech entrepreneurs of classes of 1991 and 1992. Case study research design was applied in order to study the phenomenon in question. This design was favorable due to the fact that is allows for involving background information into the analysis, what proved to be necessary. As a main method, semi-structured interviews were utilized. All in all, 16 interviews were carried on, most of which as face-to-face interviews. In some instances, also Skype and phone interviews were used due to the geographical disposition of informants. Apart from interviews, also other documents were used to corroborate the critical and factual information. Data analysis was carried on by active use of the techniques of categorizing and matrix creation.

4 Case

4.1 Case background

This chapter will present the results of the study. However, firstly the background for the case in question will be set. The information concerning the university and its ecosystem are seen as crucial for the later analysis. In addition, the figures of the tech entrepreneurs of classes of 1991 and 1992 will be closely presented, together with the description of the companies they established. Secondly, the result of the investigation will be described. They will be showcased thematically in this section, concerning university time of the entrepreneurs in question, the environment for entrepreneurship, job experience after graduation form master studies, and finally the establishment of tech companies. The order of presenting the findings is not connected to the research questions at this point.

4.1.1 NTNU - Norwegian University of Science and Technology. History and objective for establishment.

The university was established in 1910 in Trondheim and initially called NTH, Norwegian Institute of Technology (Norges Teknologiske Høyskole). The new primary politechnical college was created to become "lever of the society" and Norwegian industry, with the purpose of educating new wave of engineers who could take care of building up the nation. From the very beginning NTH was based on the German ideals and structure of polytechnic. The general rule stated that two first years of education were to be devoted to mastering basic subject demanded for all engineering specializations, that is physic and mathematics. Only starting from the 3rd year students were to gain insight into specialized subjects. In addition to that professionally relevant practical experience was required to obtain diploma (Brandt, 2010).

Since the very beginning clear ideals of the future engineer were set. Namely, a person who graduated from NTH should command both theoretical and practical knowledge and skills, enriched by creativity and understanding of a surrounding world. Furthermore, also special expectations were set for the professors. In the spirit of building up the country, the NTH´s professors were supposed not only to take care of making existing industry interested in newest research and technological development, but also create new industries based on those developments. Important is also to mention the ongoing discussion between NTH and existing industry on the profile of the graduates, where industry was more focused on a very

specialized alumnus, and NTH rather favored multidimensional education that could be applied in various areas of the economy (Brandt and Nordal, 2010).

Important is to mention that in the post Second World War period some organizational changes were introduced at NTH, mainly visible in the introduction of research groups by the British example. Each and every group was led by a strong professor figure, and involved number of both doctoral and later also postdoctoral candidates, as well as, very often, master students and other associated researchers. Technically, the groups were financed with the respective institute´s money, and to some extent with the money from the commercial assignments carried out by Sintef (more detailed information about NTH – Sintef cooperation in the following sections). However, the groups and the professors had a great level of flexibility when choosing the research areas and focus. Moreover, NTH professors used to have an extensive network of contacts within other research institutions, as well as industry, which was often the conditional for attracting applied or commissioned research and development assignments. Interestingly, up until 1980s research activities were directed mostly to the cooperation with Norwegian industry, while the scientific collaboration was targeted towards United States (Gjeitnes, 1997)

In 1968, NTH together with other existing colleges in Trondheim were associated together in a loose administrative structure called UNiT (University in Trondheim). Due to the loose technical connections, the initial culture and character of NTH remained unchanged (Moe, 1997). NTNU – Norwegian University of Science and Technology was established in 1995 with an aim of unifying existing colleges in one university. The new structure encompassed NTH, AVH (Norwegian College of General Science), VM (Museum of Natural Science and Archeology), DMF (Faculty of Medicine, MiT (Trondheim Conservatory of Music) and Trondheim Academy of Fine Arts. The creation of a new university entity also brought challenges in the unification of all of the scientific milieus and traditions under one cultural umbrella. Especially the former NTH environment faced the difficulty of retaining of its strictly technological identity (Moe, 1997).

4.1.2 The ecosystem for industrial and commercial oriented research

After the Second World War both state and the university faced challenge of rebuilding the nation. The challenge turned into the further discussion on the role and character of applied and, what is even more important, commissioned research. In order to enhance the response of the research institutions to the industrial and societal challenges, new research regime was issued in 1945, which involved putting greater responsibility in enabling and fostering applied

research on the state. In response to that, in 1946 the NTNF – The Royal Norwegian Council of Scientific and Industrial Research (in 1992 became a part of The Research Council of Norway with four other research councils). It´s objective was to coordinate all technology and industry oriented research in the country (Brandt and Nordal, 2010).

In the same year, also FFI – The Norwegian Defense Research Establishment was created. It´s rationale was to take charge of all research activities that could be potentially used by the Norwegian army and contribute to the country´s defense system (Brandt and Nordal, 2010). The institution had a headquarter in Kjeller in the South of Norway, and was supposed to cooperate with all Norwegian universities and research institutions in order to retain the best possible quality of activities and access to the newest research. From FFI came such an invention like a first Norwegian computer (what later gave rise to Norsk Data). They were also pioneers in the research on the transistors (the initial technology, predecessor to microchips) and in turn gave impulse to research and development activities within integrated circuits design (FFI website).

FFI have an important place in this case, as it was not only a driving force for most innovative research, but also a place where quite a substantial group of researchers within the later microelectronics milieu at NTH worked and some of the future entrepreneurs in this case either worked or had internships. Moreover, a substantial role had also Televerkets Forskningsintitutet that was collocated with the FFI. The main aim of Televerket was to take responsibility for all research activities connected to telecommunications activities, and be a linkage between research institutions, especially the ELAB at NTH and the industry (Collett, 1993). In 2001 Televerket became a research and development center of Telenor.

As a tool for more industry and commission oriented research, in 1949 the SI – Central Institute for Industrial Research was brought to life by the NTNF. The main aim of the new institution was to bear the weight of the research and development projects of an immediate importance for both industry and society. The institute was based in the capital, and cooperated primarily with the University in Oslo. The situation brought certain concern to NTH in Trondheim, that because of the localization of the new industrial research center in the capital, NTH will lose its leading position as a technology institute. In response to that, in 1950 Sintef – The Company for Industrial and Technological Research at Norwegian Institute of Technology was established. The main aim of Sintef was to take care of the commercial research assignment on behalf of NTH, and in the same time be a bridge between the institute and the industry (Brandt and Nordal, 2010).

All of the mentioned above institutions, since their beginnings up until present day, create a certain Norwegian ecosystem for the industry oriented and commissioned research. The triangle between NTH – Sintef – FFI, with the overall function of the NTNF had also great importance for shaping the research activities, and in turn education plans within microelectronics milieu at NTH (check: Fysikalsk elektronikk ved NTH/NTNU i 50 år).

4.1.3 NTH – Sintef cooperation

As mentioned in the section above, Sintef was created with the idea of close cooperation with NTH. The cooperation was mirrored in common use of labs and personal resources of both institutions in the research projects, what led to creation of so-called "connected research groups" where the boarders between NTH and Sintef were blurred. Important is to mention that the research carried out within those groups was characterized by mixed financing: state founding, and private – industry founding (Gjeitnes, 1997). One of the so-called "connected group" was ELAB, Electronic Laboratory, which was the center of all the research activities within microelectronics.

After 1950, Sintef quickly became important actor within the commissioned research in Norway. Especially since the 1970s, with the boom in the oil industry the demand for commissioned research within oil and gas field grew exponentially. Interestingly neither NTH, nor Sintef had a "research coordinator", as mentioned above it were the professors who had the responsibility for creating and controlling research activities. Only in 1986 first research coordination plan was prepared at NTH. Since the mid-1980s also the growing separation between Sintef and NTH could be observed. The reason for that was the financial division – Sintef acquired the greatest control over the incomes from the commercial assignments. The final separation took place after 1993 when Sintef merged with SI in Oslo, what led to spreading research and development activities to both Trondheim and Oslo, and in the same time NTH and University in Oslo (Gjeitnes, 1997).

The NTH – Sintef cooperation takes an important place in the story of the entrepreneurs from classes of 1991 and 1992. The microelectronics milieu at NTH was still inseparable from the twin milieu at Sintef, at the period of the master studies of future entrepreneurs (1987-1991/92), what gave the additional boost for state of the art research and development activities. As recalled by Karl Klingsheim, Director of Research of ELAB group at Sintef,

there was no visible distinction between people who were officially "hired" by NTH, and those who were Sintef´s employees. People were working together:

> *"(…) there was sort of invisible divisions between Sintef and NTH at that time. So people were going back and forth, and there was really very homogenous atmosphere, which really caused the culture to be very industry friendly and closely linked to that." (Karl Klingsheim)*

NTH employees contributing to the research and development assignments carried out by Sintef, while Sintef´s researchers took part in the lectures and student´s education. (interview with Karl Klingsheim).

4.1.4 ELAB and electronics milieu at NTH

The microelectronics milieu at NTH was organized within the faculty for Electrical Engineering and Computer Science. In the period in question students could choose one of three so-called lines that were created on the borders of different departments. The lines were: electronics, power supply and distribution and computer science and cybernetics (Balchen, 1997). The future entrepreneurs that are the core of this case study were part of electronics department, which has its origins in the 1960s and establishment of ELAB, that is Electronics Laboratory at Sintef, and connected institute at the NTH.

The Electronics Department had a wide range of scientific interests, spanning from telecommunications, with acoustics, signal processing and radio communications, to physical electronics with optics and semiconductors. From the very beginning both the department and ELAB were on the forefront of research and development within its areas, from the transistors in the 1950s, through the micro acoustics, optical fibers and radio communication, to the microprocessors and microchips (Bløtekjær, 2013). The latter is of the great importance for this project, as the majority of the companies established by the former students of the classes of 1991 and 1992 were commercializing developments within semiconductor design.

Physical electronics encompass both elements of physics and electronics that are connected to the production of physical, electronic components. The environment was characterized by up to date lectures that attracted clever and ambitious students (Bløtekjær, 2013). The most important part of physical electronics for this case is design of so-called integrated circuits for microchips. Important is to mention that professors within electronics had a wide network of international contacts, with a decisive part in the US, and were themselves either studying,

doing research or lecturing on the best American universities, for example Kjell Arne Ingebrigtsen had a sabbatical year at MIT (Johannessen, 2013).

The development within design of integrated circuits was first caught by researchers at mentioned above FFI, and later at ELAB/NTH. The end of 1970s brought important progress with methodology for designing of so-called ASIC - "application specific integrated circuits". In the 1979, NTH/ELAB was assigned big research program from NTNF within ASIC design. Another important development within that sector was so-called VLSI design method, "very large integrated circuits", that is designing the system of interconnected transistors on the one chip. The program brought Einar J. Aas as a professor within Integrated Circuits design to the NTH in 1981. He will later play an important role in the university environment which attracted the future entrepreneurs in question. This professorate was a crucial step towards creating new base of students specialized within this innovative method, and in the same time the visible proof of the fact that lectures were based on the newest research development. Important is to mention that those developments contributed to obtaining the extensive amount of industry assignments for ELAB (Aaserud, 2013).

Simultaneously, the decisive developments took place in the parallel part of the Faculty, Computer Science and Cybernetics Department Starting from the 1950s, where the extensive research and development activities directed to building a computer were carried out (Balchen, 1997). The fist experimental machine called "Konrad" was built already in 1962 in the group led by Jens Balchen, one of the most important figure within cybernetics at NTH (Brandt and Nordal, 2010). Also in the 1960s., first operational system, SINTRAN, was created at that group. What is more important, the system became basis for the further development of the operative systems within Norsk Data (Balchen, 1997). Norsk Data, mentioned in the sections above, was a Norwegian company established in 1967 in Oslo, spinning out from FFI and devoted to creation and building Norwegian computer machines (interview with Arne Halaas). Importantly, in the milieu of Norsk Data started his career Arne Halaas, later named "technology father of Fast Search & Transfer", before he came to a professorate at NTH in 1972.

4.1.5 Commercial activity within electronics at NTH/ELAB and establishment of Nordic Semiconductor

The milieu within the Faculty of Electrical Engineering and Computer Science could showcase state of the art, inventions within research and science development. In addition to that, it had also substantial experience within commercialization of both technology and

research done within the university walls. One of the first commercial achievements spun out from the cybernetics department – the marine vessels positioning system created by the group of Jens Balchen. In addition to that, probably one of the most substantial successes within commercialization of technology from NTH, the ultrasound equipment spanned from the electronics milieu. The ultrasound technology had its roots within research on the surface acoustic waves carried out by the group of Kjell Arne Ingebrigtsen (Brandt and Nordal, 2010). At that time, the ecosystem for fostering commercialization of technology as we know it today was nonexistent. The reasons for those business successes are seen in close collaboration between the university and Sintef groups, what provided not only the scientific development but also close connection to the industry (Johannessen, 2013).

Probably the most important part of this background description is the establishment of Nordic VLSI, late Nordic Semiconductor. The company was started by four ELAB researchers, Oddvar Aaserud, Frank Berntsen, Jan Meyer and Trond Sæther in 1983. The rationale for creation of Nordic VLSI was growing demand for custom specified designs for the so-called very large integrated circuits (namely VLSI). At some point, the interest from the industry exceeded the ELAB´s development capacities, what led to the initial idea of leaving Sintef and setting up a separate company that could take upon those assignments. The initiative had a great support from Aasmund Gjeitnes, who was the general manager of Sintef ELAB (Aaserud, 2013). Oddvar Aaserud came back to the NTH in 1989 in professor capacity but still kept part time position at Nordic VLSI (interview with Oddvar Aaserud).

4.1.6 Tech entrepreneurs from the class of 1991 (in alphabetical order)

The biographical notes are based on the information from LinkedIn profiles, publicly accessible databases (Bloomberg, Crunchbase) and in some detail from research interviews.

4.1.6.1 Haakon Bryhni

He received master diploma in 1991 from NTNU within signal processing and telecommunications, and PhD diploma in 1998 from University in Oslo within computer communications. In 1998, he established a company called Advanced Communication Technologies. After the company was acquired by Birdstep Technology ASA in 2000, he served there as CTO. In 2001, he co-founded a venture capital investment company called Nunatak AS. He has served as CEO of numerous companies, including Advanced Communication Technology, Mobyson Technology AS, Media Network Services AS, Faster Imaging AS, VoiceRoaming Technology, and recently as COO of Elliptic Laboratories As. In addition to that he also served as a Board Member of numerous companies he invested in

through Nunatak AS. He holds 10 patents, and in 2003 was awarded with Telenor Research Award, in 2010 Norwegian Gazelle Award for 3d-Radar, and in 2014 Vebjørn Tandberg Electronics Award for Elliptic Labs. Simultaneously he works as an assotiated professor at University in Oslo.

4.1.6.2 Sverre Dale Moen

He received a master diploma in Electrical Engineering in 1991, with specialization in physical electronics. After graduation, he worked as a research scientist in SI in Oslo (later Sintef in Oslo) for three years. In 1996, he became a co-founder of Chipcon, where he served as Board Member, VP Sales and Marketing, and from 2002 as a VP Business Development. After the company was sold to Texas Instruments in 2006, he stayed with a company as an Integration Manager. Since 2007 he did business consultancy work. In 2009, he became a CEO of New Index, a tech startup company founded by a NTNU professor from the Institute of Physical Electronics, Tormod Njølstad. After the company was acquired by Japanese EPSON in 2011, he remained in the CEO position. He also served as a board member of several technology companies, among other Crosshairs Embedded AS and Conoptica As. He also holds 2 patents.

4.1.6.3 Egil Eide

He received a master diploma from Electrical Engineering from NTNU in 1991 with specialization in radio communication. He then worked in a company in Oslo called Susar. He later on came back to NTNU, where he obtained a PhD degree in 2000 with dissertation "Radar Imaging of Small Objects Closely Below the Earth Surface". Between 2001-2012 he served as a CEO and a founder of company 3d-Radar. He stayed with the company until the beginning of 2016. He is currently employed at NTNU as Adjunct Professor II in the Department of Electronics and Telecommunications. He holds 2 patents.

4.1.6.4 John Raaum

He received a master diploma in Electrical Engineering in 1991 from NTNU with specialization within physical electronics. After graduation, he worked two years as a research scientist for Norwegian Defense Research Establishment (FFI). Between 1994 and 2007 he worked for Nordic Semiconductor, where he held various positions (project manager, ASIC designer and Senior Technical Manager). In 2007, he worked for short period of time for Q-Free as a Manager Industrialization Group. After that he became a co-founder of Arctic Silicon Devices, where he served as a CEO until 2011 when the company was sold to Hittite Microwave. He stayed on with Hittite Microwave until 2014 as a General Manager. Currently

he serves a CEO of an investment company Greenway Technology AS. He holds several diplomas of Management and Leadership form MIT Sloan School of Management.

4.1.6.5 Svein Anders Tunheim

He holds a master diploma within Electrical Engineering with specialization in physical electronics from NTNU. After graduation, he worked as a research scientist in SI in Oslo (later Sintef in Oslo). In 1996, he co-founded a technology company called Chipcon, where he served as CTO until 2005. After the company was sold to Texas Instruments, he stayed on with the company until 2008, and served as Technical Director in the Low Power Wireless division. In 2008, he established an investment company, Vallenus AS that invests in IT companies of early stage development. Since then he has served as Board Member of several technology companies, Miitors ApS, Numascale AS, Com4 AS and CUPP Computing AS.

4.1.6.6 Vegard Wollan

He holds a master diploma in Electrical Engineering from NTNU with specialization in physical electronics. After graduation, he worked for Nordic Semiconductor for 5 years, first as a development engineer and later as Marketing Director. In 1995, co-founded Atmel Norway together with Alf-Egil Bogen and served there as CEO until 2016. He now serves as an Executive Director of an investment company, Calypso Invest AS. In addition to that in 2016 he became a co-founder of technology startup MyWo. He holds several patents.

4.1.7 Tech entrepreneurs from the class of 1992 (in alphabetical order)

4.1.7.1 Alf-Egil Bogen

He holds a master degree from NTNU within Electrical Engineering, with specialization in physical electronics. After graduation, he worked for over 4 years for Nordic Semicondutor, where his responsibilities encompassed analog design and software development, as well as project management and marketing. In 1995, together with Vegard Wollan he became a co-founder of Atmel Norway, where he served as CMO until 2013. Between 1996 and 2002 he served firstly as Board member and then a Chairman of Chipcon AS, the company founded by Geir Førre, Sverre Dale Moen and Svein Anders Tunheim. Subsequently, in 2013 he served as CMO of Ebergy Micro AS, a company started by Geir Førre. After the company was bought by American company Silicon Labs, he stayed there as Member of the Board of Directors. Since 2013 he is involved as a CEO and Chairman of the Board of a technology company called Novelda AS. Alf-Egil Bogen is also an active part of current entrepreneurship and

innovation ecosystem in Trondheim, being among other initiatives one of the initiators of Trondheim Maker´s Fair. He also holds several patents.

4.1.7.2 Geir Førre

He holds a master diploma from NTNU within Electrical Engineering with specialization in physical electronics. After graduation, he worked for 4 years as a research scientist in SI in Oslo. In 1996, together with Svein Anders Tunheim and Sverre Dale Moen he established Chipcon AS, where he served as CEO until the company was sold to Texas Instruments in 2006. After the acquisition, he stayed on with the company as a Managing Director of Texas Instruments Norway. In 2007, he co-founded technology company called Energy Micro. He served as a CEO of the company until it was sold to the American Silicon Labs in 2013. He has been holding various positions within Silicon Labs since then. In 2008, he established investment company Firda AS. Since then he invested in various technology companies, among others in: Disruptive Technologies (spin off from Energy Micro), Airthings, Adoq, Zivid Labs, Novelda. Firda AS, he is also involved in two other investment funds that focus on early phase startup: Alliance Venture Spring As and Founders Found I AS.

4.1.7.3 John Markus Lervik

He holds a Master and PhD degree from NTNU within Electrical Engineering, with specialization in digital signal processing. In 1997, he became a co-founder of a company called Fast Search & Transfer (Fast), where he served as CTO until 2001, and subsequently as CEO until 2008. After the company was acquired by Microsoft in 2008 he stayed on and served as Corporate Vice President until 2009. In 2010, he founded the technology company Cxense, which was listed on the Oslo Stock Exchange in 2014.

4.1.8 The timeframe

The case involves events spread from 1987 that is the point in time when the future entrepreneurs were accepted to the NTNU (then NTH) until 2007 that is the point in time when the last company of the entrepreneurs in question was established. Nevertheless, the timeframe goes further back in time in the instance of the case background. The figure below shows the time spam of the events that are further investigated in this case study. The events that are placed over the time line are the main events within the case itself, whereas the events placed under the line belong to the case background.

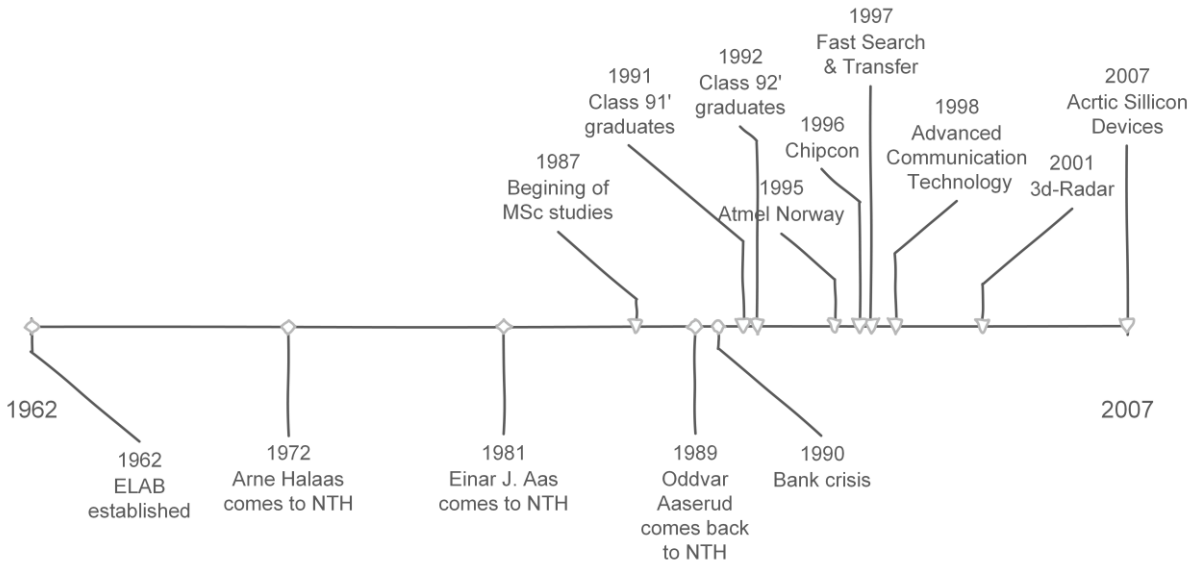

Figure 4.1 The timeframe of the case. Author´s own figure

4.1.9 The geographical disposition

The events encompassed by this case study took place in two crucial locations: Trondheim and Oslo. Trondheim is the home of NTNU that is the university where all of the entrepreneurs in question took master education, as well as where Egil Eide and John Markus Lervik took PhD education. In addition to that, Trondheim became headquarter of following companies established by the entrepreneurs in question: Atmel Norway, Fast Search & Transfer, 3d-Radar, and Arctic Silicon Devices. Oslo on the other hand is the place where one of the future entrepreneurs, Haakon Bryhni took PhD education, as well as where Chipcon and Advanced Communication Technology were established.

4.1.10 The companies (in chronological order)

4.1.10.1 Atmel Norway

Nordic Semiconductor spin-off. Atmel Norway was a branch of the American corporation Atmel, devoted to commercialization of so-called AVR architecture developed by Alf-Egil Bogen and Vegard Wollan. The company was established in 1995 with headquarter in Trondheim. The technology was acquired by Atmel Corporation by the undisclosed sum. Since then Atmel Norway became main design entity of the whole Atmel Corporation. Although both co-founders are not involved with the company any longer (Alf-Egil Bogen left the company in 2013, and Vegard Wollan in 2016), the design center in Trondheim still exists under the brand of Microchimp.

4.1.10.2 Chipcon

Spin-off of SI in Oslo. The company was established in 1996 in Oslo by Geir Førre, Sverre Dale Moen and Svein Anders Tunheim. Firstly developed as a consulting firm within semiconductor design, soon developed standardized products within the low-power radio frequency microchips. The company was acquired by American Texas Instruments in 2006 for $200 million. The company spanned off several technology companies, among others Energy Micro established by Geir Førre.

4.1.10.3 Fast Search & Transfer

The company is a NTNU spin-off established in 1997. Its purpose was commercialization of long time research of the two university groups within search tools (prof. Arne Halaas) and transfer methods (Tor Ramstad). First CTO and then CEO became John Markus Lervik. The company offered new tools within Internet search and transfer services. Acquired by Microsoft in 2008 for $1.2 billion. Fast Search & Transfer attracted companies like Google, Yahoo and Microsoft to establish their development centers in both Oslo and Trondheim.

4.1.10.4 Advanced Communication Technology

The company was established in 1998 by Haakon Bryhni and his two collegues from the PhD studies in Oslo as a consulting company within communication system design. In 2000, the company was acquired by Birdstep Technologies for 90 Million NOK.

4.1.10.5 3d-Radar

NTNU spin-off. The company was established in 2001 in Trondheim with an aim of commercializing the results of the PhD dissertation of Egil Eide. The company developed 3-dimensional radar system that could be used in various applications, from the military use to the road construction. In 2008 the company was acquired by Curtiss-Wright.

4.1.10.6 Arctic Silicon Devices

Nordic Semiconductor spin-off. The company was established in 2007 by John Raaum, together with Øyvind Moldsvor and Olav Lindquist in Trondheim. Arctic Silicon Devices was a fabless semiconductor company, that initially offered standarized products for applications within ultrasound and medical devices. The company was acquired by Hittite Microwave in 2011 for $12million.

4.2 Case results

4.2.1 Rationale for choice of microelectronics

The majority of students in question took full master program in the Department of Microelectronics, 4,5 years at that time. However, some like Vegard Wollan started with physics, and only after the second year switched to microelectronics, or like Alf-Egil Bogen and Geir Førre transferred to NTNU after taking bachelor degree in other places, in electrical and computing engineering at College University in Trondheim and in engineering electronics at Bergen University College (HiB) respectively.

Independent from a family background or a place of origins, the choice of obtaining higher education on master level was an obvious one for the students later turned entrepreneurs. Some of them coming from small places, "somewhere in the mountains in Norway" or "place that no one knows exists" had an ambition of achieving something in their lives. Others had great role models in their families, like academic parents or siblings who studied engineering, which was the trigger for the university studies. It was not the question of "should I go to the university", but rather "what should I study".

Electronics was a clear hobby for the majority of the future entrepreneurs from a very early age. Their childhood was full of experimenting, taking apart various electronic devices, trying to build new ones, sometimes even almost nearly setting their homes to fire. As recalled by Egil Eide, founder of 3d-Radar and now NTNU professor:

> *"I was experimenting since I was a kid (...) as a radio amateur, doing the experiments with radio communication, building antennas, transmitters and receivers. That was an interesting area to focus on. I also found that there was a lot of challenge, a lot of things to learn in a way from science, physics and nature, and also that you can make a lot of products in that area."*

For other students, later turned entrepreneurs, the high admission requirements were important factor to apply for microelectronics. Taking into account the interest and high competence in math and physics, in many cases the choice of course of studies lied between microelectronics and medicine. Medicine was traditionally seen as demanding direction, only for the best and most hard working and ambitious students. However, the allure of creating new things, inventing new appliances, and doing "meaningful engineering" was bigger than the esteem connected to studying medicine.

Not without the importance was the general condition of research and industry. 1980s were a period of exponential growth of new, emerging technologies. On the one hand Silicon Valley was booming, spinning constantly and uninterruptedly new companies, inventions and integrated circuits design methods since the 1960s. On the other hand, extensive research activities in areas of telecommunication, and radio and signal processing were taking place, which later achieved its peek with the invention and spread of the GSM technology. All that created an atmosphere of interest and possibility - the interest of learning more about ingenious devices and methods that take shape and spun off from research laboratories in constantly faster pace, and the possibility of being a part of and contributing to creation of progress in science and technology.

The rationale for choosing microelectronics by John Raaum, the founder of Arctic Silicon Devices, summarizes the overall attitude of the former students:

> *"I am an engineer at heart, so I want to create stuff. Combining the interest in tinkering and creating, with physics and math skills, it was natural to go in that direction when I ended my school years. I considered - either select technology or get into a medical education - and I selected electronics. At that time the semiconductor industry was still quite, at least here in Europe, new, interesting and growing. (...) it was really interesting to learn about electronics and new things, and it was an area where you could contribute by creating something. At that time there was no Maker Fair or similar, so you had to create whatever by your own."*

Former students recall that microelectronics attracted a certain kind of people, not only due to high requirements, but also some special characteristics of the field and demanding scope. On the other hand, as one of the informants recalls "it was fashionable to study electronics". Important attraction factor for some of the students in question was the general development of the industry, the fact that exciting things were happening in the Silicon Valley.

All of the reasons future entrepreneurs name as the decisive for choosing microelectronics as the direction of master studies, suggest that those individuals were from early on characterized by ambition, willingness to push boundaries, and wish of being a part of progressing fields. They wanted to do something creative with their lives, but also be "needed" in the society – they considered occupations such as doctor or teacher, both associated with great societal relevance and benefits. In the same time the inner drive to build,

create, and invent new things had been visible from an early age. The idea of finding something that lets one apply one's knowledge in a meaningful way was also a part of motivation, as recalled by Vegard Wollan, the co-founder of Atmel Norway. In other words, application orientation and having a meaningful role within society were also an influencing factor for future entrepreneurs.

4.2.2 The requirements

The admission requirements to get accepted to microelectronics were very high in both 1987 and 1988, around 5,6-5,8 in the grade scale. It was one of the study directions that was the most difficult to be admitted to. Within microelectronics, students could choose among certain specializations, like physical electronics, acoustics, radio and signal processing and telecommunications, and others. From those specializations, the physical electronics was the one that was most difficult to be accepted to, with the highest requirements level. As some of the former students recall, due to that only the cleverest people were accepted to that line. Informants also compare the level of acceptance requirements to today's requirements for medicine or industrial economy, the two most demanding courses in terms of both admission requirements and studies themselves. Only after some years the level of studies in microelectronics fell slightly, as one of the informants suggests due to other disciplines, like computer science and robotics, gaining their academic momentum.

In similar manner, almost all of the former students of classes of 1991 and 1992 I interviewed (with the exception of one individual) recall the study level of being very high, and studies being challenging and demanding a lot of hard work. For some students, the transition from high school system and being "best in everything, without doing much" was a difficult task. For others, the heavy basic courses in math or physics during the first years at NTNU proved challenging due to the great workload, high demands from professors and distinctive level of abstraction. In addition to that, they point out that it was simply impossible to "just learn one week before the exam", because the courses were extremely extensive, detailed and with high level of both competency and material. That made it difficult to comprehend all just in the last moment. Students also turn attention to the lab works, and other mid-semester tasks that also contributed to honest and meticulous work during the whole semester.

4.2.3 Study characteristics

First two years out of full 4.5 years master program, where general in scope. Subjects taught in that period encompassed fundamental courses in fields like math and physics. All of the students from all of the specializations were attending the same classes during the first two

years of studies. The class of microelectronics was around 140 students, however in addition to all specializations within the microelectronics, also students form other study directions, like physics or math were attending the same general classes. During the last two years students were divided into smaller classes, accordingly to the specialization they chose and were accepted to. Remaining half a year was devoted to so-called "main project", that is master thesis, which was written individually by the students.

First of all, all former students that I was able to interview almost unanimously depict subjects taught at university in that period as being definitely more theoretical than practical. As mentioned above, first two years were mostly focused on "general" subjects, like math, physics and electronics. The main focus was on gaining deep understanding of theoretical aspects that lie at the heart of electronics. As Vegard Wollan puts it: *"(...) you build more of a background theory and analytical side for a longer time, up until you apply it".* All of my informants were in agreement that without having thorough foundations it would be simply impossible to comprehend the complexity of following, more specialized subjects, as well as to create new, application oriented solutions. John Raaum points out: *"in work I´ve done for the companies I´ve been in, I had to have a good background in analytics and mathematics to be able to brake new grounds and be in the forefront".*

During later years, practical elements, like laboratory works and application-oriented assignments were introduced. Those exercises gave a type of hands on experience and opportunity to use the theory that was built up along the way. The last two years of master studies were devoted to more specialized subjects. Every student got an opportunity to choose courses respectively to their field of interest and specialization. Among the most demanding were courses from physical electronics, radio communications and signal processing, and telecommunications. However, still the subjects taught were characterized by high degree of theory orientation. As recalled by Eivind Bergsmyr, later CEO of Nacre, Sintef spin-off:

> *"these were the most demanding studies when it comes to intellectual capacities, capacity to abstraction. If you took mechanical engineering, it was much more practical, much more tangible, here it´s more intangible stuff. (...) wave theory for example, that´s really complex theory to understand, it´s very abstract".*

4.2.4 Summer jobs and master theses

One of the aspects showing the practical orientation in the department of microelectronics was the requirement of obtaining relevant practical experience during studies. The majority of

former students that I interviewed gained the compulsory industry experience in the form of summer jobs. Some of the students obtained required experience while doing their compulsory military service within the Norwegian Defense Research Institute (FFI), Nordic Semiconductor, Alcatel, Televerket (later research branch of Telenor), or Dolphin Server Technologies, spin off from Norsk Data. Interestingly the internships took place at either highly specialized research institutions that presented high level of competence and worked on state-of-the-art research projects, or innovative companies of an entrepreneurial character.

Both Norwegian Defense Research Institute, FFI (described closely in the background section) and research institute of Telenor were on the forefront of technology development. While Norwegian Defense Research Institute, was fueled by the military needs and financed in decisive degree from governmental founds, Telenor worked on progressing in technologies that already achieved societal status, as well introducing new solutions in telecommunications. On the other hand, companies such as Nordic Semiconductor or Dolphin Server Technologies were companies of "start-up" ethos and character. Both spin-offs, tried to carry on technology development, basically by creating innovative solutions, and commercializing them within a new company. The role of Nordic Semiconductor will be further presented in subsequent sections.

Master thesis was an individual project in that time. Students recall it as rather theoretical task, although, most of the students in question wrote their theses for the industry, where the theory they were investigating had to be applied to some real-life case or problem. There were various industry partners for the master theses. However, undeniably the most popular industry partner for students from semiconductors line was mentioned above Nordic Semiconductor, the Sintef´s spin off company established in 1983. At that point in time the company kept close connection to the NTNU, primarily through personal connections. One of the founding fathers of Nordic Semiconductor, Oddvar Aaserud, came back to the university for purpose of teaching and research in 1989, while keeping a part time position in his company.

In some cases, it was professors who "had interesting topics or research problems" developed in connection with the industry that involved application of newest theories to existing practical issues. In other cases, ideas for master topics came in the junction of students ideas and real life industry problems. In addition to that, some were able to continue on working on topics developed under summer jobs. The latter was for example the case of Vegard Wollan and so-called AVR architecture, which later became the founding stone of technology of

Atmel Norway. The project was being developed at a time under summer job for Nordic Semiconductor, where Vegard Wollan and Alf-Egil Bogen worked on new design for integrated circuit architecture. Later on, Vegard Wollan continued the topic in his master thesis.

Also Svein Anders Tunheim and Sverre Dale Moen, later co-founders of Chipcon, wrote their theses for Nordic. Interesting fact is that in all of the examples, one of the "founding fathers of Nordic" was involved in the master project, either as an academic supervisor (Oddvar Aaserud) or industry supervisor (Trond Sæther and Frank Berntsen). However, the contact with Nordic Semiconductor was somehow limited during the work on master projects. Mostly it involved just consultations with industry partners, while the main load of supervision lied on the university professor side. The former students emphasize the flexibility in cooperation with Nordic Semiconductor on developing the research problems for their master theses. As mentioned above the general rule was to find an existing area where some theory could be applied, nevertheless, students also proposed ideas for example investigating some innovative technologies on the practical cases from the company.

Other future entrepreneurs from classes of 1991 and 1992, found some other interesting companies they could wrote their theses for and initiated contact themselves. In a similar manner, they recall the theses as theoretical, the theory they were investigating had in their theses practical application. What is important is that the companies that students cooperated with in their master projects were companies of still visible entrepreneurial character. As one of the informants recall, Nordic at that time employed only some 12-15 people, and was still fighting for projects and customers. Another company, Dolphin Server Technologies, was a spin-off from Norsk Data, a Norwegian computing company, which was characterized by the high encouragement level for entrepreneurial and spinning-off activities.

4.2.5 The students and their social environment

As mentioned above, there were around 140 students of microelectronics in each class. In general students were functioning rather in small groups of around 10-20 people, but due to having a lot of subjects together they were "aware" of other students as well. The divide into small, social groups happened already in the first days of school. In some degree it was dictated by the simple fact of whom they sat next to on the first day of school, in other instances who they lived with, or who they shared their reading room with. Similarly, to any other class there were also internal groups or social networks based on common hobbies, religion, or any other extra activities.

However, there was no explicit social network of people interested in entrepreneurship and innovation at that point in time. The majority of students in question were "aware" at that time of other students that later became entrepreneurs, although mostly within classes. They are very clear that, in that point in time they were "just" students. Students of the class of 1991 who later established companies in question, that is Vegard Wollan, Sverre Dale Moen, Svein Anders Tunheim, John Raaum, Egil Eide and Haakon Bryhni, describe themselves as "classmates". Somewhat closer connection was established between Egil Eide and Haakon Bryhni, due to the fact that they shared religious belief and were active in a Christian student organization. Remaining students shared the reading room in various point in time, although not everyone used it in the same extent.

In the instance of students from the class of 1992, that is Alf-Egil Bogen, Geir Førre and John Markus Lervik, Alf-Egil Bogen and Geir Førre new each other, as they used to seat next to each other during classes. John Markus Lervik was not involved in social life, being devoted to skiing during his time at NTNU, for that reason he was not acquainted with other students. The familiarity between those two classes was not big. Most of the former students form the class of 1991 did not know students from the younger class. The exception was Alf-Egil Bogen, who shared reading room with the older class for some time, although it was not a strong familiarity.

Currently, all of the students turned entrepreneurs know each other, very often closely and personally, or do business together. But during their time at NTNU, apart from mentioned above Egil Eide and Haakon Bryhni, as well as John Raaum and Sverre Dale Moen, who were best friends at university, remaining entrepreneurs were just in collegial relations. The fact is very interesting taking into account the "configurations" in which they later on established new companies. Atmel was established by Vegard Wollan (1991 class) and Alf-Egil Bogen (1992 class). They first met in Nordic Semiconductor during their summer job – after 4th year for Vegard, and after 3rd year for Alf-Egil. Similarly, Chipcon was established by Geir Førre (1992 class), Sverre Dale Moen (1991 class) and Svein Anders Tunheim (1991 class). Sverre Dale Moen and Svein Anders Tunheim knew each other during their master studies at NTNU, but they met Geir Førre only in Oslo. Their paths crossed only at SI (later Sintef in Oslo), where they worked for the same research group after graduation.

On a level of personality, former students describe other students in very different ways. Some are remembered as introverts, while others as typical extroverts. Some loved taking risk, others were very shy, "not the entrepreneurial type" as put by one of the informants.

Some were described as charismatic individuals with leadership skills, while others as mild and nice people. Despite the perceived differences in characters and personalities, all of the students turned entrepreneurs are being described as brilliant, smart, clever, interested in their subject and hardworking people. Interestingly, similar description comes from both peers and professors.

4.2.6 University environment. Culture and values

The overall atmosphere among the students in question was described unanimously as friendly and helpful, despite the fact that studies were rather individualistic oriented with very little group work or tasks. People were helping each other to study, to achieve better results. Quite often study groups were created to master difficult subjects or to prepare for the exams. However, the collective approach to learning or exam preparation was not common for all of the future technology entrepreneurs. Some of them were very clear that they had their own routines that not always involved being at school from 8 a.m to 4 p.m. Others were pure individualists that shared their time between learning and skiing without leaving much time for the social, school life.

What was seen as rather special about the overall attitude among students or connected to prevailing "atmosphere" was something that previous students describe as "being allowed to learn". Having good grades, and being constantly a better student, achieving better results were commonly accepted in the classes of 1991 and 1992. According to Sverre Dale Moen, co-founder of Chipcon:

> *"I just felt that it was an atmosphere that allowed to study and work hard, and then people were friendly and helped each other, that I remember. We were sitting together and doing studying and helping each other. But, it wasn´t like a competition when it comes to exams, it was not like, ok, what did you get, what is your grade, it was not like that. I would say no, it was not like a competition, you were competing mostly against yourself".*

The governing attitude was deprived of "rat race" type of pressure, rather a positive influence of ambitious people prevailed. Ambition and hard work are also the qualities that are used by almost all of the informants in relation to the future entrepreneurs, but also the class attitude as well. What is more, ambitious attitude was somehow infecting other people. Majority of the former students, both future entrepreneurs and others, that I interviewed were very explicit about the positive impact of being surrounded by competent people. Important is to mention,

that ambition was visible not only in the race for good grade and perfect diploma, it was in a comparable degree about learning new things, and being constantly better at what you do. As recalled by Egil Eide: *"(...) maybe the common thing was that people had some other aspirations beyond learning electronics? That could be something that is typical for this class, they didn´t want to study just to be electronic nerds, they wanted to do something with it"*.

Infectious was also the hard-working attitude. The ambition and hard work nicely present the story told by Vegard Wollan about the atmosphere in their reading room during writing of master theses:

> *" (...) in the last year, Sverre (Dale Moen), Svein (Anders Tunheim) and John (Raaum) and me we had 10 people reading room together, so we became relatively close, and we were there together on the daily basis. I recall we had a poster on the wall, which was an add from Statoil, which was completely nonsense, and non-meaningful, but it says that if you want to be the best, you have to get up first in the morning, or something like that, which we had on the door, and we were competing to be there at 7.50 or 8, whenever (...) and doing out thesis and in the last year"*.

In addition to that, John Raaum remembers: *"(...) at least in this smaller group that I was a part of socially, it was definitely a drive to do your best and try to be really on top of everything".*

4.2.7 Professors

Significant, if not decisive part of a university´s landscape in that time, were professors lecturing within the Department of Microelectronics. Both on the turn of 1980s and 1990s, and in the period prior to that, the department enjoyed good reputation and attracted numerous scholars who presented high academic competence, strong international orientation and good interpersonal competence. Among the names that former students remember best are: Einar Aas, Oddvar Aaserud, Nils Håheim, Gunnar Støtte, Tor Ramstad, Arne Halaas, Jens Balchen, Kjell Ømo, Asbjørn Krogstad and Tor Schaug-Pettersen.

Overall, the lecturers were praised by the former students for presenting high academic and scientific standard. They were up to date with the newest research developments within their respective areas. However, they were not only outstanding scholars, but also skilled lecturers who could present difficult topics in an engaging and comprehensive manner. Professors are

also being remembered as very demanding towards students, but in the same time inspiring to work harder and "do more". Apart from high professional and academic level, lecturers in this story are being described as friendly, "down to earth" people.

Even though, as mentioned in previous sections, former students recall master studies as being rather theoretical, they also praise professors for being up to date with recent industry developments. Established practice was to invite guest lecturers from industry who presented condition of the industry, and how the technology and newest research were applied there. Those activities contributed to building positive attitude among the students that what they were learning was useful and had a practical application. As John Raaum puts it: "(…) *to have a person from industry lecturing was very interesting for us. At the university side they did a lot to enable a platform of learning with different people with real life experience. It was a good combination".* Students remember professors as being good in creating contacts with interesting industry, having exciting industry oriented topics for projects or master theses.

In addition to that the professors had an extensive net of international contacts, both within business and academia. They were active in academic community on international level, with exchanges, teaching periods at other universities abroad. In addition to that they were also actively publishing in academic journals on the international level. However, what might have been specific for the Department of Microelectronics, was close connection to the industry, based mostly on private relations of the professors. On one hand, there were very strong theoretical professors, and on the other hand those with strong focus on applying the scientific developments in the industry. Oddvar Aaserud, one of the founding fathers of Nordic Semiconductor recalls how focused on industry application he was himself. As the greatest value for him was to use his research to answer existing business issues, he was very active in talking to the industry and trying to show them how they can profit on application of technological progress.

According to Karl Klingsheim, former NTNU professor, co-founder of technology company Clustra and long term CEO of NTNU´s Technology Transfer Office:

> "(…) *the education, culture is a better word, was application oriented and not very sort of academic – scientifically focused, although people did great publications and scored high on the academic side as well, but the overall environment was really looking for physical electronics and the design methodology to solve real life problems".*

Among the distinctive professors from the Department of Microelectronics, some call for closer presentation.

4.2.7.1 Einar Johan Aas (died in 2012)

Einar J. Aas, as mentioned in the background sections, was a professor in the Department of Physical Electronics. He taught circuit and system design. Numerous sources describe him as a central figure in the Department and a key person in the entrepreneurship and innovation promotion. However, the former students are very explicit that there was no direct encouragement towards firm formation from his side. This issue will be further elaborated in subsequent section.

Einar J. Aas is being remembered as a very skilled, knowledgeable professor, whose lectures where always up to date with the latest research in his domain. They were also presented in a very clear way, what made easy for students to understand even the toughest subjects. He was extremely skilled in presenting new design methods in a clear manner. In addition to that, he was also praised for giving good and constructive feedback on assignments. His comments and guidance were not only intended to achieve better results, but also to look into completely new directions and trying innovative angles.

Many former students describe him as being more on the technical and theoretical side of things, in the same time being close to the industry. He was able to transmit the excitement and newest science developments on his students. Future entrepreneurs remember him as an inspirational person, who always encouraged students to make new things and improve the technology. What is more *"he also encouraged people to be active in disseminating the knowledge and telling about the opportunities these new technologies would have"* (Karl Klingsheim). He was in addition very active in forming both research and education programs in the institute, trying to adapt both to the newest developments in the research domain and the industry needs. It is also important to mention that he was actively engaged in promoting both field of electronics, the institute and engineering education in general.

On a personal level, Einar J. Aas was memorized as very social, niece, friendly and approachable professor. Moreover, he was very supportive towards students, engaging and inspiring them to do more and to want more. According to Kjell Arne Ingebrigtsen, NTNU professor and founder of Vingemed Ultrasound AS, now GE Ultrasound, *"he (Einar Aas) encouraged people to be entrepreneurial in the mind".* During the period in question, he was a strong supporter of an idea of so-called Micro Forum presented by Vegard Wolland. The

purpose of Micro Forum was to present relevant industry to the students within the department, and give them better understanding of surrounding business environment. Einar J. Aas was also a supervisor of his master thesis. On the other hand, he was also supportive towards people who left university in order to create companies, in this case especially four founders of Nordic Semiconductor.

4.2.7.2 Oddvar Aaserud

Oddvar Aaserud was one of the key professors in the Department of Physical Electronics. He was also one of four Sintef´s researchers who left organization in order to establish Nordic Semiconductor (previously Nordic VLSI). He came back to NTNU in 1989 to the position established by Einar J. Aas (interestingly, Einar J. Aas was hired by Oddavar Aaserud some 20 years earlier). He was an active connector between Nordic and NTNU. In addition, Oddvar Aaserud was also a supervisor of master theses of John Raaum and Svein Anders Tunheim.

Former students remember him as a very good professor of high-class competency, and a front figure within the institute. They also point out that he was good at giving feedback, and always helping students to find interesting topics or angles for their projects. He was seen as a very friendly, open and social person, who was very "approachable" for his students. His lecturing style was very inspiring and engaging.

Undeniably his application orientation in research was very visible. As he himself say, the true value of research is achieved when the science and technology can be applied for the real-life industry issues. Important fact is that he was "the first commercial professor" (Geir Over Kjesbu) at the department. He is being remembered as an active professor, who always tried to show the industry and possibilities of how the knowledge created within university walls can be utilized in business. During his lectures, he used to present anecdotes about Nordic and management style they practiced there, even inviting people from management team of Nordic to come to classes. *"They explained how did they make money. And it was awakening for some of us, that you can make money on that",* as recalled by Geir Ove Kjesbu. However, former students do not feel that Nordic was anyhow "overselling" at that point in time. Oddvar Aaserud was able to present the potential that lied in the knowledge and technology they were learning to create, without open call for entrepreneurship.

Interestingly, none of the former students I was able to interview remember any direct encouragement towards entrepreneurship or innovation from neither Einar J. Aas, nor Oddvar Aaserud. Similarly, to Einar J. Aas, he is being memorized to inspire people to do more, to

develop new things and to think in a new way. However, all of the future entrepreneurs were definitely "aware" of his presence and role within Nordic. It was of a great importance to them to see and witness the commercialization in practice, without explicit push towards "going out there and creating new companies".

4.2.7.3 Gunnar Støtte

Gunnar Støtte was a leading professor within the field of telecommunications. He is being remembered by former students as one of the most distinctive figures in the department, in a huge part thanks to his extensive international connections: *"THE professor of satellite communication in Norway and spokesperson of telecommunication industry"* (Egil Eide). He was engaged in research projects with NATO and European Space Agency. He was well connected both nationally and internationally, however interestingly he did not present the commercial orientation. He was very open and supportive, but what is even more important he was able to attract smart students and direct them to new, exciting areas of technology. Simultaneously, he was encouraging them to go into new and innovative fields. Later on, he became a shareholder in 3d-Radar.

4.2.7.4 Tor Ramstad and Arne Halaas

Tor Ramstad was a professor within digital signal processing and Arne Halaas was a professor within computer science. Although Arne Halaas was officially part of a parallel department, he is an important part of this case, as he is known as one of the "technology fathers" of Fast Search & Transfer. Tor Ramstad was a supervisor of both master and subsequently doctoral theses of John Markus Lervik. They were both actively involved in the establishment of Fast, where Tor Ramstad was responsible for transfer part, and Arne Halaas for the search part.

Former students describe them both as demanding professors that presented high academic standard, and were able to challenge their students. What is more, they are both described as academic leaders. Both Tor Ramstad and Arne Halaas were able to attract the best and smartest students. They not only worked on state-of-the-art technology and research, but they were in addition to that capable of engaging students in those new research domains, spreading the excitement about the development in science, compelling the students to go into new directions. *"They were quite good from a technology perspective, and, in addition, they were from a human perspective able to inspire and lead students in directions that they found interesting" (John Markus Lervik).* The ability to attract and engage students came from the mix of high academic competences and great interpersonal skills.

Interestingly, as remembered by the former students, those professors showed little commercial orientation, but at the same time they were very well connected and close to the industry. As John Markus Lervik recalls:

> *"(…) both Ramstad and Halaas had good relationships with people outside academia, also in business. They both had relatively little business experience and interest in terms of commercialization. That was not something they really worked on. But again, they were good at establishing relationships, and creating excitement around what we were doing with people in the commercial area. So through those relations, that is really how I got into business and what later became Fast*".

4.2.8 Financial crisis, job market in time of graduation and spirit of the times

Financial crisis that occurred in Norway together with so-called crash of "the time of the yuppies" are being seen by some of my informants as one of the underlying reasons for the phenomenon and the success of former students of classes of 1991 and 1992. In 1987, when students in question started studying, the economic situation was positive in Norway. What is more important the job market was booming, and as informants recall "everyone got a job". However, the situation changed drastically during the 4,5 years of master studies. The financial crisis that occurred at the turn of the 1980s and 1990s shifted people´s mindset to more results oriented. As future entrepreneurs recall, they were soon aware of the tough situation in the economy, but first of all in the job market. That awareness was an additional impulse that made them work hard and be focused on achieving good results in order to be able to get a job after graduation. Nonetheless, the main attention was put on improving one´s prospect on the job market.

Interestingly, all of the students turned technology entrepreneurs found relevant jobs shortly after graduation, while usually graduates in 1991 and 1992 used over 6 months to find a job. What is even more remarkable is that "first jobs" were in the companies, either within industry or within research institutions. As such, Vegard Wolland and Alf-Egil Bogen got job at Nordic Semiconductor; Svein Anders Tunheim, Sverre Dale Moen and Geir Førre at SI; John Raaum at Norwegian Defense Research Establishment; Egil Eide at Susar; and finally, Haakon Bryhni and John Markus Lervik started postgraduate studies almost immediately after finishing master studies.

The first company from the tech firms in question was established in 1995. Some of the informants suggest that the period between graduation and mid-1990s was even more formative in a way for future entrepreneurs. Not only the job market for fresh graduates was problematic, but also the situation in the industry was challenging. Existing companies had to deal with scarce financial and human resources (lack of financial capacity lead to lower employment rates), what put existing employees in a demanding position where they had to be creative and effective in making new products and solutions, as well as finding new clients in short period of time. Those realities were in a certain way conducive for entrepreneurship and innovation.

In addition to that, not without significance was overall atmosphere, or spirit of the 1990s in general. Geir Ove Kjesbu, graduate of class of 1991, and former CEO of Q-Free and Investinor, recalls:

> "*In the 90s in Norway, as a nation we were coming up again, we had Olympics in 1994, prime minister said it was good to be Norwegian, it was unusual, you should be proud, the oil price grew, we started getting surplus in the economy, and we started getting strong economic nation without knowing it (…). You know, it is a joke, but back then, even national football team was good. (…) We have been through a financial crisis in the 80s, and I think that being young then make you maybe work hard, be more creative, but not taking risk, because you didn´t know you were taking risk".*

All in all, the future entrepreneurs from classes of 1991 and 1992 do not perceive the financial crisis and problematic job market as a direct catalyst to establishment of their companies, rather as a catalyst to be a better student, and achieve the best results as possible. They are all in agreement that after graduating from NTNU, finding a good job was the main focus.

4.2.9 Entrepreneurship and innovation

Interestingly none of the former students I talked to can recall any kind of direct encouragement towards entrepreneurship or innovation as such coming from professors, or being anyhow presented by the institute or university environment. Governing attitude among students was being focused on obtaining good grades and finding steady jobs after graduation. As Svein Anders Tunheim puts it:

> *"It was not much focus (on entrepreneurship). I think it was extremely different then compared to now. Now, startup activity is highly encouraged, you have those*

incubators all around. And universities, there is much more focus. Sometimes companies visited NTNU and the last year students, but emphasis was on presenting themselves as potential employers. I think that most people in my class focused on getting a job after finishing their studies."

To be even more explicit, former students do not recall concepts like "entrepreneurship" or "innovation" being spelled out that way. Word "entrepreneur" was being associated with small contractors who did construction or renovation works. In addition to that the notion of capitalizing on one's knowledge was seen as new, uncommon and even capitalistic, in rather negative meaning of that word. Similarly, neither "innovation" nor "innovative thinking" was used within the university walls or was an official part of study curriculum. Nevertheless, what was encouraged was to constantly develop existing technology, create progress in science, and find new ways and solutions. *"We were encouraged to make new things, improve technology, but without it being spelled out like, make patent"* as recalled by Per Gunnar Kjeldsberg, former student of class of 1991, and now NTNU professor.

The main focus was put on high quality of education and competence. Future tech entrepreneurs turn attention to the overwhelming importance of technological competence in setting on establishing a new venture focused on commercialization of technology. According to Sverre Dale Moen, co-founder of Chipcon:

"Startups from classes of 1991 and 1992 – it is not because NTNU supported entrepreneurship, but because they supported high tech education. (…) To learn the basic it´s very important, because if you are to make a high tech company with a national potential, you need to know tech very well, and you have to have very good ideas. So I think you need to be a good engineer, not like an average, you need to have high competence, if not, there will be others after that knows the theory and that are better then you, so it´s basic".

Only single students from the group of future entrepreneurs had a direct interest towards entrepreneurship during time of master studies. The explicit idea of commercializing knowledge and technology in form of a separate company was rather distant for the former students of classes of 1991 and 1992. Although, discussions on how to solve some analytical challenges were not rare, they were deprived of the commercial aspect. Some students looked with an interest towards development in Silicon Valley, but the events there were rather distant and primary focus was on finding a job after studies. Others were looking towards

small and new companies as a potential good working place in order to be a part of challenging milieu and not disappear in big consulting corporation.

Furthermore, none of the future businessmen recall having technology entrepreneurs in their families. As mentioned in the previous section, they have various family backgrounds, however very little of industrial example. In some cases, former students recall having some entrepreneurial examples in their families, in form of small family driven companies or one-person consulting firms. Nevertheless, even in those instances, entrepreneurship, or more precisely the notion or idea of starting an own company after graduation was not seen as a primary focus or opportunity. It was rather seen as "maybe a possibility" somewhere in the future, but as described in previous sections, future tech entrepreneurs were more focused on finding a steady job at that time.

All of the students I interviewed very vividly remember Oddavar Aaserud, as *"a professor who made it with Nordic"* (Vegard Wollan). Although, as mentioned above, none of the professors, not even Oddvar Aaserud explicitly encouraged students to "go out there" and establish new companies, the notion of someone who "made it" was vivid and had an importance among future entrepreneurs. Vegard Wollan recalls:

> *" (...) with Oddvar as founder of Nordic, he was, if you think of it, a seed for everything in the bigger picture, a seed for a lot of things. Of course, that was by itself important and interesting and encouraging having them (meaning Aaserud and Trond Sæther) as lecturers and in the corridors, because we were looking at them, as front figures, that´s clear".*

Nordic Semiconductor and Oddvar Aaserud were "entrepreneurial ambassadors" as recalled by Egil Eide.

Some of the former students, however not unanimously, remember clear "entrepreneurial example" among students – one of the future tech entrepreneurs, Haakon Bryhni, together with two other students of the class of 1991 run successful IT company during the time of master studies at NTNU. The company was offering both consulting services and products within industry optimization systems. Interestingly, it was not the first commercial venture for Haakon Bryhni. At the age of 7 he started working on his first product, electronic timer, which was then produced and sold in over 100 pieces when he was 9. He himself recalls having been interested in both creating new products and commercializing them since very early age. He describes it as "personal moment of joy that drives him" when presenting

something he made and being able to attract customers interested in his invention. In addition to that, his motivation comes from inner drive, rather than something learned at the university.

In a similar manner, also another student, Alf-Egil Bogen, co-founder of Atmel Norway is being remembered as very active and creative individual who had built a successful product, weather station, in the period of master studies at NTNU. In addition to that, another former student of the class of 1992 and co-founder of Chipcon, Geir Førre, recalls the passion for building and creating new things as the inner drive and motivation for both him and Alf-Egil Bogen. According to him, it was neither money, nor electronics that was his primary drive. It is rather the joy of building a company, a culture, a business, something that would sooner or later, result in establishing a firm. Also in this instance, the passion for creating and building things was natural, and comes rather form personality then learned skills at the university.

4.2.10 Role models

University environment played important role for the future entrepreneurs, although not directly influencing them on taking the step to create a company at that time. However, they are all in agreement that up to some degree the milieu at the Department of Microelectronics played a role in the future. Interestingly, important role models in that period of time were coming from this particular environment. For some of the future entrepreneurs that I interviewed, other students were role models that looked up to for inspiration - the inspiration to work harder, to look into new directions, and finally, after some years to start your own company. This aspect will be further elaborated in subsequent section “Inspiration”.

Undeniably, the most important role models at that time were the professors within the department. Both Einar Aas and Oddvar Aaserud are the ones that are named frequently as sources of inspiration and role models for the future entrepreneurs. Their ability to engage, inspire and make people be more creative, choose new ways, develop themselves, was something that students looked up to. In addition to that, the figure of Oddvar Aaserud, as the first commercial professor had an importance for former students. He was an interesting example, of what can be done with knowledge and skills acquired in the field of electronics.

Inseparably connected to Oddvar Aaserud was also Nordic Semiconductor and the person of another founder, Trond Sæther, who in that period was also present in the Department of Physical Electronics having some lectures and co-supervising some of the master theses of the future entrepreneurs. As John Raaum recalls:

"*I was really looking at Nordic Semiconductor as sort of, the model, it was important. When I learned about Nordic VLSI (former name of Nordic Semiconductor), I realized that it was an environment where I could focus on work that interested me. I was deep into semiconductor electronics at the time. During the 4th year, we had a course where one person from Nordic came. This person was Trond Sæther, he´s still at Nordic and worked as professor at NTNU for some time (…) Trond was like a role model to me at that time - you know, the one of the founders, he did a PhD on semiconductor design and for me it was like he ticked all the boxes. Later, when I started to work at Nordic he was my mentor in some of the design work I did there".*

4.2.11 Job experience after graduation

As mentioned in the previous sections, all former students of classes 1991 and 1992 remember job market being tough in time of their graduation. However, in the instance of all of the future tech entrepreneurs, they all found relevant positions shortly after finishing master studies at NTNU – either in industry, small company, research centers or taking a PhD degree at universities. Interestingly, none of the entrepreneurs in question established a company immediately after graduation, but only some years after working in the industry or within research. Undeniably, the most desirable working places were Nordic Semiconductor and SI for those specializing in physical electronics, and Telenor and Alcatel for those specializing in telecommunications technologies.

Two of the graduates in question found job at Nordic Semiconductor right after graduation: Vegard Wollan and Alf-Egil Bogen. Interestingly, Oddvar Aaserud recalls Vegard Wollan being very outspoken during the period of master studies that his dream and the reason why he wanted to transfer to microelectronics was to work for Nordic Semiconductor. Overall, it was seen as very attractive place to work, characterized by interesting type of tasks and projects. Interestingly, students who decided to move to Oslo and found job at SI, were either offered a job by Nordic Semiconductor (Sverre Dale Moen), or would surely apply if it was not for the willingness to move to the capital (Svein Anders Tunheim and Geir Førre).

Vegard Wollan worked in Nordic Semiconductor for 5 years after graduation, first 2 years as a development engineer. He was later promoted to Marketing Director, where he was responsible for commercialization of strategic process and customer pipeline. Alf-Egil Bogen worked in the company for over 4 years, also starting right after studies. According to his LinkeIn profile his responsibilities encompassed analog design, processor design, software

development, as well as project management and marketing. During their time in Nordic Semiconductor they developed further the AVR architecture, that was later the founding technology for Atmel branch in Norway.

After two years at Norwegian Defense Research Establishment also John Raaum got a position at Nordic Semiconductor. He worked there for 13 years before starting his company, Arctic Silicon Devices. He remembers Nordic Semiconductor as a great place to work, which gave a lot of freedom and responsibility in the same time:

> "(…) *it was a fantastic company to me, fantastic company for a clever guy to come into. At Nordic, you were given a lot of freedom to solve challenging problems, you got your responsibility in the development projects and you had to deliver according to the milestones. At that time, we were about 20 people, and the company was transforming from a small company to become a structural system prepared for growth that added value every day. It was a great experience and people there were really, really good. I would say I learned there a lot during that phase in my career, and I stayed on there for many years".*

Svein Anders Tunheim, Sverre Dale Moen and Geir Førre worked for around 4 years in SI in Oslo after graduation. During that time, they were cooperating closely by working for the same group of circuitry design. Their department worked actively with research projects of a definite applied character and in close cooperation with the industry. Importantly, very often research projects had clear developmental character, oriented towards creating new appliances and new products.

Egil Eide worked three years for a small company in Oslo called Susar. The firm worked with research and consulting technology projects. Interestingly Egil Eide recalls this company of having an entrepreneurial character, with employees involved in variety of tasks – from connected to technology development to business oriented. In addition to that, the time at Susar gave him an experience in building motivated teams. After the three years' period in Oslo, Egil Eide came back to Trondheim and took up a PhD education at NTNU.

Two remaining future entrepreneurs, Haakon Bryhni and John Markus Lervik, started PhD projects almost immediately after graduation from NTNU. Haakom Bryhni moved to Oslo, and after obligatory military service done within FFI started a PhD project within computer communication at the University of Oslo financed by the individual grant from the Norwegian Research Council. During his PhD, he cooperated closely with Telenor Research Center and

Norwegian Computing Center. In addition to that he also spent two years in Apple Advanced Technology Group in USA. John Markus Lervik did his PhD at NTNU within digital signal processing. As mentioned earlier supervisor of his thesis was Tor Ramstad. In 1998, he was honored with a prize for the best doctoral dissertation at the NTNU.

4.2.12 Entrepreneurial capital

As mentioned in previous sections, all of the tech entrepreneurs in questions started their companies only some years after graduation from NTNU. They all are very explicit about the fact that they were not thinking about starting a separate company or that entrepreneurship was a viable option in time of graduation from the university. The idea started growing during their time in the industry or during further research at the universities. All the future entrepreneurs I interviewed emphasize the significance of skills gained in the work life and during the time between graduation and establishment of a firm.

First and foremost, independently of the place the future entrepreneurs worked at after graduation, or what were the specific tasks they executed, that period was devoted to further development of their technical competences within their respective areas. Both Nordic Semiconductor and SI worked on the forefront of the newest science and research. The main scope of the activities at those companies was based on consulting business model for other firms and industry actors, where people had to create constantly new solutions for individual customers and their specific needs. To meet customer requirements both research and individual products were being developed on the international level of available competencies and with rapid tempo of research and development process.

For both Alf-Egil Bogen and Vegard Wollan the “real life business school” started very early on. Since the early teenage years, they had various sorts of small and big summer jobs, and later on part time jobs during studies. On the one hand, they learned strong work ethics with great respect for time and money. On the other hand, thanks to those small jobs they also acquired practical skills especially within sales and marketing. Alf-Egil Bogen for example used to sell house alarms, while Vegard Wollan worked part time in a clothing store. Their skills within sales and marketing were further developed in Nordic Semiconductor, where after two years of engineering oriented tasks, they were assigned to more specialized role within project management with focus on finding new clients and selling both services and existing solutions.

Similarly, John Raaum appreciates his time at Nordic Semiconductor, as period of strong personal and professional development. As mentioned in the previous section, the company gave a lot of freedom and in the same time responsibility to their employees. In the same time, Nordic Semiconductor still preserved an entrepreneurial character, what enabled more variations in the tasks and responsibilities. In addition to that, John Raaum gained competencies in business management during his time at Nordic Semiconductor, which were later decisive when establishing Arctic Silicon Devices. He recalls:

> "*The model was to do a consultancy work for other companies. By doing this you learn the application and its solutions and you learn to understand the market, and then you can decide if you should make our own products in this and that direction. I was actually on board of directors, as an employee elected board member, when Nordic decided to focus on RF standard products. This was a great experience, (…) a good school. When we started Arctic Silicon Devices, (…) we made about three different business cases and then deciding one, yes, we go for it. So, for Arctic did it much the same way as we did it at Nordic few years before".*

In a similar manner, future founders of Chipcon, Sverre Dale Moen, Svein Anders Tunheim and Geir Førre remember SI as being a business school for them. Apart from further developing their technical skills, they were also able to gain more of a business and project management competences. The group they worked for not only was responsible for advanced design projects, but they also had a great focus on earnings. Due to that, researchers had to closely follow both the development plan and the budget, without extending it by adding more working hours then the plan provided. Furthermore, future entrepreneurs rapidly obtained more responsibilities within management of the projects: closely cooperating with existing customers, attracting new clients together with managing sales meetings and writing contracts. As summarized by Sverre Dale Moen: *"I learned to run business, (…) it was important to earn money, hunt for customers, and also I would say that my tech skills were further developed because it was such a high level of the research that was done".*

In the instances of Egil Eide, Haakon Bryhni and John Markus Lervik, the road to acquiring entrepreneurial capital was rather different. For them the first focus was science and technology development. As mentioned before, Haakon Bryhni had very strongly visible commercial orientation from an early age, with active entrepreneurial venture during his time as master student at NTNU. Those experiences created a solid entrepreneurial base for the

future ventures. Egil Eide also obtained some business orientation and project management skills during his time at Susar, where he worked closely with management of the company.

Interestingly, John Markus Lervik obtained entrepreneurial capital by "learning by doing". As mentioned above he had very little industry experience when he set on starting Fast. As he recalls, the great learning school was attending business meetings with interested parties. He was very often in the US, where he met, among others, the founders of both Google and Yahoo. In addition to that, the company quickly gained interest from the industry, and people with background from business and entrepreneurship were involved in the process of company formation.

4.2.13 Inspiration

Important factor mentioned by all of the tech entrepreneurs I interviewed is inspiration. It played indirect role during their time of master studies at NTNU, as a positive influence of professors of entrepreneurial mind, like Einar J. Aas or Oddvar Aaserud to work hard, create new things and develop existing technologies. Inspiration took also form of choosing entirely new areas of research and technology under the influence of the skilled professors, and academic leaders like Arne Halaas and Tor Ramstad. Moreover, the clever students themselves were inspiration and encouragement to be constantly better and better in what you do, as recalled by Geir Ove Kjesbu.

However, even more significant was a direct inspiration to establish new entrepreneurial ventures. Although immediate motivation and rationale for starting a tech company, varied among the firms in question, all of the future entrepreneurs identify some level of inspiration for establishing their company from the ones that "made it" prior to them. As such, Vegar Wollan for example admits to the importance of being in Nordic Semiconductor. Not only due the fact that the experience gave both him and Alf-Egil Bogen necessary entrepreneurial capital to start Atmel. For him watching Nordic Semiconductor was an important example of the fact that one can succeed in spinning off from a mother company.

Similarly, for founders of Chipcon being witness to Nordic Semiconductor growing and having one of the Nordic founders as a professor during master studies started a belief that founding a company may be a viable option. However, even more significant example and influence came from their study peers, who established Atmel one year prior. As Geir Førre put it during the talk under the Technoport conference in 2015 (Transistor Podcast):

"I think that if it wasn´t for the fact that Nordic Semiconductor had started, and the fact that you (Alf-Egil Bogen) and Vegar (Wollan) had started, I don´t think that Chipcon would have started, and if Chipcon didn´t start, there wouldn´t have been Energy Micro. So, there is a chain of reactions happening, so to some extent it´s coincidences, to some extent it´s the inspiration, to some extent it´s mutual realization, and some people go forward and saw the possibilities and open people´s minds on what can be done".

In a similar manner, the inspiration from Nordic Semiconductor, Atmel and Chipcon was a source of inspiration for John Raaum, and what is even more important for Egil Eide, even though he was not directly connected to the field of semiconductor design represented by those companies. The idea of peers succeeding in entrepreneurial venture gave him additional motivation to try to start a company by himself. Interestingly John Markus Lervik and Haakon Bryhni points towards the importance of influence from the professors` side then the entrepreneurial peers, although they of course watched and cheered the establishment of Atmel and Chipcon.

4.2.14 The firm formation: rationale and process

As briefly mentioned in the previous sections none of the companies in questions was established during the period of master studies at NTNU of the entrepreneurs in question. The establishment process took place only same years after graduation – after years of research or industry experience. Previous section described the importance of competences acquired during that time for future entrepreneurial activities. Among the companies in questions three can be treated as corporate spin-offs (Atmel, Chipcon and Arctic Silicon Devices), while three are university spin-offs (Fast Search & Transfer, Advanced Communication Technologies and 3d-Radar). The variety of reasons to set on establishing a new company and the processes applied vary from company to company, which calls for closer look at each and every company.

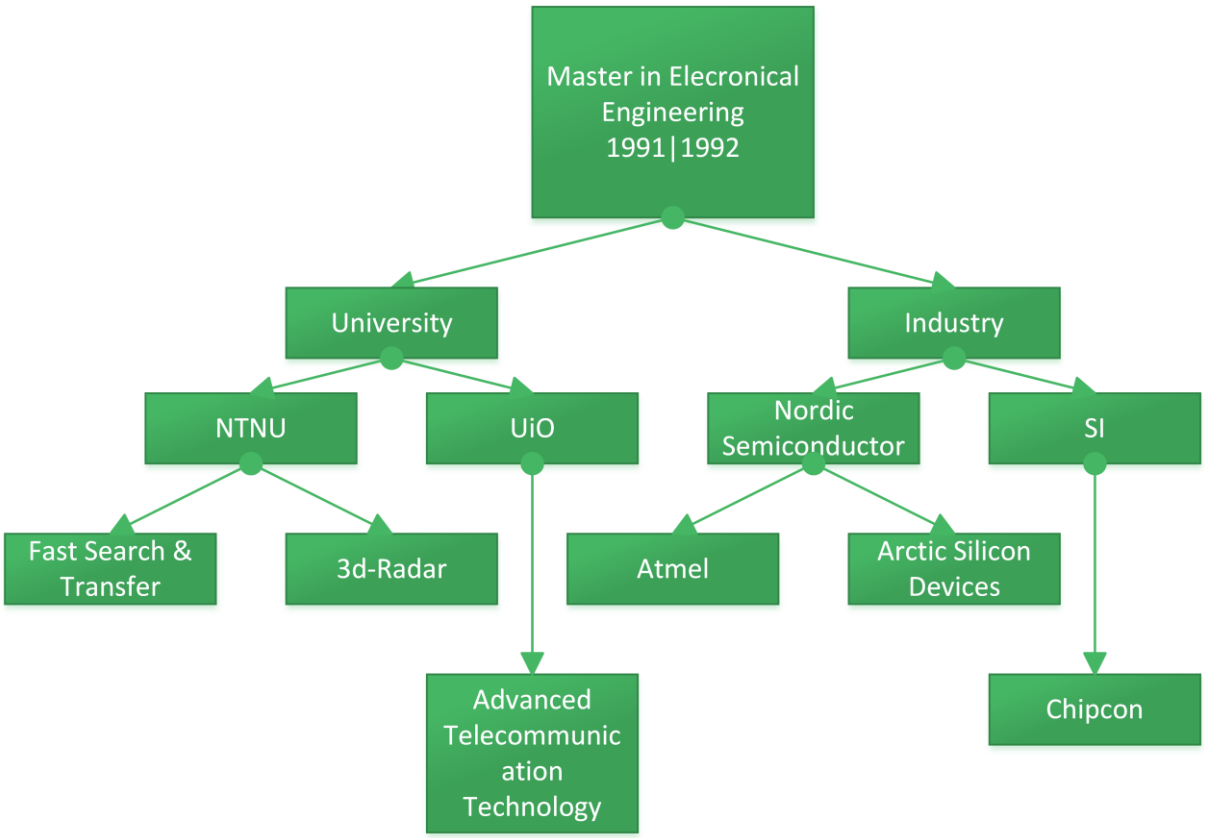

Figure 4.2 Companies in question divided into corporate and university spin-offs. Author´s own figure

4.2.14.1 Atmel (Norway branch)

Atmel Norway was established in 1995 by Vegard Wollan and Alf-Egil Bogen. The rationale for establishing the company was to commercialize the technology that was first developed during the summer job both Vegard Wolland and Alf-Egil Bogen had in Nordic Semiconductor, further developed in the master thesis of Vegard Wollan and during the time at Nordic Semiconductor. The base technology for creation of Atmel was so-called AVR architecture for new microcontrollers. In their duo, Vegard Wollan was responsible for the hardware part, while Alf-Egil Bogen took responsibility for the software part. They first started thinking about commercialization of the architecture while working at Nordic Semiconductor.

The idea for the architecture design was influenced by both the developments in the market for similar products, that is turn into miniaturization, and the forecast of future trends, that is turn to battery powered devices. The new AVR Architecture was created in order to achieve "a simple, clean, clear, structured, elegant and easy design", by taking the inspiration from the large computing systems and redesigning them to miniaturize them. In the end, they created a miniaturized, simple and clean product that in addition consumed less energy. The mix of

design qualities together with the low energy consumption proved to be the convincing enough to attract constantly new customers.

In other words, what Vegard Wollan and Alf-Egil Bogen created was soon to be a standard product that could be used by many various customers. Simultaneously, at that point in time Nordic Semiconductor was operating on a basis of a consulting model that is developing tailor-made products and programs for specific customer needs. The firm did not want to go into direction of standard product creation, which influenced the decision to take the step of commercializing the product out of Nordic Semiconductor. Although the management was split about the idea of standard product, the Atmel co-founders had been strongly supported by the CEO. Alf-Egil Bogen recalls (in the Transistor Podcast from the talk at Technoport 2015 conference):

> *"(...) When we left Nordic Semiconductor, the CEO, Oddbjørn Troøien, was a great man, who really blessed what we were trying to do, and were supporting us instead of fighting us and suing us (...). So, he was a great supporter of what we were trying to do, and I think that's also important".*

Important part of the motivation to take the step to leave Nordic Semiconductor was also the personal situation and risk perception. In the period prior to establishment of Atmel, Nordic Semiconductor underwent a series of downsizing, which almost reduced by half the amount of employees. As recalled by Vegard Wollan, it made both him and Alf-Egil Bogen feel insecure about the future of their employment, even though they were not the part of the stuff reduction process. In addition to that, they both had started families, what also influenced the importance of supporting the future. Interestingly the step to take the AVR design out of Nordic and set out on establishing new venture seemed less risky solution in the long run. The motivation was to create something viable and long lasting, that could ultimately assure the job in the future, although the money, as in getting rich through the new company, were never part of the original motivation, as emphasized by Vegard Wollan:

> "*I think in our motivation we had this need to have security, need to have secure and good job, to make sure we were taken care ourselves, and families we created. So money never has been part of motivation, we really wanted to create something, but really by creating something - that was ultimately the best assurance for us having good jobs".*

Subsequently, the two entrepreneurs were able to present the idea and business potential of their product and design to the Atmel corporation in the US. The presentation was undeniably convincing, as it made the Atmel management to invest in Wollan and Bogen´s design, and what is even more significant, to establish new design center as an Atmel branch in Trondheim, Norway.

4.2.14.2 Chipcon

Chipcon was established in 1996 by Geir Førre, Sverre Dale Moen and Svein Anders Tunheim. In the beginning the company was operating on the "Nordic Semiconductor model", that is consultancy work on integrated circuits design. Only couple of years after establishing Chipcon, the company switched to selling a standardized product. Chipcon founders do not recall having any specified thoughts about establishing own company while studying at NTNU. For them the time at SI, and both further technical and business skills developed there, were decisive when making a decision of starting Chipcon. As Sverre Dale Moen recalls:

> *"I could not have started Chipcon when I finished NTNU. (…) For me it was more like Sintef. I was working for Sintef for 3.5 years after I finished, and then I was more influenced to be entrepreneur there, because there I learned how to run a business and so on".*

In addition to that the awareness of the fact that their university peers established Atmel some time before had also strong influence on taking the step to start Chipcon, as it showed that it was possible to start an own company, that it was an option. This factor will be further discussed in the subsequent section.

Some of the reasons for establishment of Chipcon lie also in the overall situation at SI. In 1993 SI in Oslo merged with Sintef in Trondheim. The merger and subsequent reorganization of the company created tensions within the microelectronics group, due to the ongoing discussion on the divide of tasks and responsibilities. It was especially severe for the future co-founders, as both Oslo and Trondheim divisions wanted to take charge of the IC design unit. Together with awareness of own tech and business skills, favorable personal situations and good understandings with colleagues, it was felt as a natural step for the Chipcon founders to leave SINTEF and start their own company. As recalled by Svein Anders Tunheim:

" (...) we (Geir Førre, Sverre Dale Moen and Svein Anders Tunheim) felt we had a chemistry, it was good. We liked the same kind of projects, working with customers closely, energy, similar energy. We felt we were competent, did good work, and we were aware of risks - there was a risk that we wouldn't get any projects. However, we were early in our lives, so maybe it was easier for us to take risks (...)".

The Chipcon founders wanted to have so-called clean cut from Sintef before creating own business model, and especially own specific product. However, the transition process was met with great understanding from Sintef. The founders recall that in that period although officially the spinning off process was not technically supported, it was seen as a success for Sintef that also attracted additional "reward" from the Norwegian Research Council. Interestingly in the first couple of months, Chipcon operated from Sintef´s offices, in order to give entrepreneurs some time to find suitable location.

Interestingly, Chipcon founders emphasize the overall climate and low market entry barriers for companies within circuitry design. On the one hand, in that period of time there was a great need for the consultancy within integrated circuits design. On the other hand, the new computer based design tools became more popular and accessible, what made the financial needs in startup phase decisively lower. The biggest concern was access to potential customers and consultancy projects. However, during their period at SINTEF, the Chipcon founders created not only a strong know-how base, but also built strong business networks of contacts, which, as recalled by Svein Anders Tunheim:

"(...) became open for new projects with Chipcon. In research institutes like SI or SINTEF, a lot is personal related, so if they had worked with something in SINTEF and then spun off a company, it was a good chance that customers would continue working with them".

4.2.14.3 Arctic Silicon Devices (ASD)

Arctic Silicon Devices was established by John Raaum, and two of his previous colleagues from Nordic Semiconductor, Øystein Moldsvor and Olav Lindquist, in 2007. The idea to start a company first occurred and was discussed some years prior to establishment, however, none of the future founders took action then. John Raaum recalls that shortly before the time of establishment of ASD, Nordic Semiconductor underwent some structural changes, where the department that Øystein Moldsvor worked for was sold to another company. John Raaum

himself wanted a change in his career and took up a position at Q-Free, however, was not fully satisfied with it either. The third founder, Olav Lindquist, worked for an US company Fairchild Semiconductors and was considering moving back to Europe. The private and professional situation of the founders was conducive for taking a step to create their own company.

The initial idea was to: "*develop a semiconductor company and sell it to US company. That was the main idea. Regular: start something, develop, make it attractive, and sell it, because we wanted to learn that cycle"*, as put by John Raaum. As mentioned in the previous sections, the primary business management model was created based on the experiences from Nordic Semiconductor and from observing the US semiconductor business. After evaluating a few business cases, the founders settled on a specific market niche – standalone Analog to Digital Converters. Nordic Semiconductor was in a way keeping encouraging attitude towards spinning off by handing over some clients to the newly started Arctic Silicon Devices. In 2011, the company was sold to the American company called Hittite Microwave Corporation.

4.2.14.4 Fast Search & Transfer

Fast Search & Transfer (Fast) was established in June 1997. Initially, the name was Fast Internet Transfer, with focus on commercializing the results and developments related to the image and video compression group at NTNU (lead by Professor Tor A. Ramstad), including John Markus Lervik´s PhD work. Soon thereafter, work related to search technology at a parallel NTNU research group, led by Professor Arne Halaas, was also included. The research in search tools had been attracting business attention for a long time, due to growing interest and market momentum for new search tools. Important is to mention that Internet search engines as we know them today did not exist at that time (e.g., Google was established in 1998).

John Markus Lervik, student of class of 1992, who took his PhD at NTNU under supervision of Tor Ramstad, looked into methods for image and video transfer and compression. As recalled by Arne Halaas, John Markus Lervik was an energetic person with leadership skills, who approached him with an idea to combine the research results from their respective areas to build a new company with the aim of commercializing the technology developed at NTNU. As such, John Markus Lervik was initially the CTO of the new company, Fast, and employed students from Professor Ramstads group into the "transfer part", while Arne Halaas and students from his group focused on the search part. Important is to mention Tor Egge, who during his PhD (under supervision of Arne Halaas) developed the so-called FTP Search

service. FTP Search was one of the key building blocks for the future Fast search technology. A significant part of the first employees came to the company from the NTNU groups associated with the two professors, Halaas and Ramstad. For John Markus Lervik the rationale for creating a company was the opportunity to have a challenging work, and being unsatisfied with a corporate job he got after finishing PhD.

Fast also attracted interest from the industry and and the technology company Opticom ASA, led by investors Robert Keith and Thomas Fussell, and listed on the Oslo Stock Exchange. Fast was established as a daughter company of Opticom, and listed on the OTC (Over the Counter) market in 1999, before going public on the Oslo Stock Exchange in 2001. Interestingly, at that point in time, the Technology Transfer Office, nor any similar organization, existed at the NTNU. Due to that the founders themselves were responsible for the entire business part. Fast quickly gained a strong market position. The search engine, AllTheWeb was in direct competition to Google. Due to the lack of sufficient investment in developing the search engine into a standalone search service, the search engine was in 2003 acquired for USD 100 million by an American company Overture, soon thereafter taken over by Yahoo!. In 2008, Fast was bought by Microsoft for USD 1,3 billion. Interestingly, both Yahoo and Microsoft established development centers in Norway due to the specialized competences they found there in the milieu around computer science at NTNU.

4.2.14.5 Advanced Communication Technologies

Advanced Communication Technology was by Haakon Bryhni in 1998, after he finished a PhD at University in Oslo in "high speed communication and multiprocessor server system" (Haakon Bryhni´s LinkedIn profile). The company was established in Oslo, where Haakon Bryhni moved due to personal reasons. Advanced Communication Technology was started as a consulting company using knowledge and competence acquired during the PhD studies within communication system design. During the two years of operations, before the company was acquired by Birdstep, Haakon Bryhni took active part in development of three products for Advanced Communication Technology.

The rationale for establishing the company was the willingness to leave academia due to rather unsubstantial rewards that staying at the university offered and the passion for creating new products and services that find interest and application in the market. Interestingly, after Advanced Communication Technology was sold, Haakon Bryhni established his first investment company, Nunatak AS, which made its first investment in 3d-Radar. Since then,

he was an active part of few venture capital companies, and participated in establishment of over dozen technology companies.

4.2.14.6 3d-Radar

3d-Radar was established in 2001 by Egil Eide based on his PhD dissertation, which looked into detection of antipersonnel mines in the ground. During this project Egil Eide created a specific radar that had a potential to not only detect antipersonnel mines, but could also be used in the industry for mapping in for example road construction. His main intention was mostly concerned with humanitarian and academic purposes. However, the result by being very promising and showing commercial potential, attracted interest from the industry.

Interestingly, motivation, investment and support in the business area came from Haakon Bryhni, the founder of Advanced Communication Technologies and former student of class of 1991. As Egil Eide recalls:

> "(…) *we presented it during conferences and it attracted interest from the industry, so then mister Haakon motivated me and also brought some capital, said you should start. So, it was sort of a process of suddenly discovering that your PhD probably had an industry potential, that there was a market pull. It was definitely a technology push, but there were also some elements of market pull, that was something that maybe have the chance of starting".*

In addition to Haakon Bryhni, also Gunnar Støtte, the NTNU professor mentioned in previous sections, invested in the company.

3d-Radar gained traction in the market, quickly gaining customers both in the industry and military applications. The company was acquired in 2008 by an American corporation Curtiss-Wright. In 2010, the company won the Norwegian Gazelle Award for fastest growing company and NHO Trøndelag Innovation Award. In addition to that, in 2011 3d-Radar achieved Technoport Applied Technology Award. The company is still operating, however, Egil Eide left 3d-Radar in 2016.

5 Discussion

Hitherto in the report the purpose of the project, with a general research problem and specified research questions, the theoretical framework that enlightens the research problem, the methods used to investigate the topic and results of the investigation were presented. The purpose of this chapter is to analytically discuss the findings in order to answer the proposed research questions. This chapter is divided into two main subsections. First subsection will present discussion with the results in light of the first research question that is *how did university foster tech entrepreneurship before facilitation took organized forms?* The second subsection will concern the analysis devoted to answering the second research question that is *why so many entrepreneurs spun off from the two classes of 1991 and 1992 at NTNU?* Both of the research questions will be discussed in light of the theoretical framework presented in chapter 2.

5.1 The influence of university environment on technology entrepreneurship

Recent years brought on the debate on the role of universities in the economic development and wealth creation. Next to the two traditional functions, education and research, the third role, commercialization of created science and technology was added to the current strategies of the higher education institutions. The commercialization can have various faces, from the business-oriented activities of university employees in form of university spin-offs, to startups created by students. Both are regarded as highly positive and encouraged by different means.

The standard means in the disposition of the higher education institutions involve technology transfer offices, that offer business support for the commercial activities of university employees; science parks and incubators, that help both scientists and students who set on technology commercialization by giving support on every stage of business development process, from business model generation to seed financing; entrepreneurial education mostly directed towards students, that builds up entrepreneurial and business skills; and other bottom-up, student driven organizations that promote entrepreneurship among students as a viable career option. All those methods are highly discussed also in the scholarly literature on university entrepreneurship. They are seen as crucial elements of university environment that would like to be conducive for entrepreneurship for both researchers and students (Mitra, 2012).

However, all those institutionalized measures directed towards fostering entrepreneurial mindset and activities within academia are rather new, and are phenomenon of last 10-15

years in case of NTNU. It would be reasonable to expect some type of measures towards fostering entrepreneurship from the university side, like for example presentations about starting own tech company, or at least direct encouragement from the professors in the period of question.

The data collected showed something different. My informants, both future entrepreneurs and other students of those two classes, were very clear and unanimous in stating that there was no clear incentive towards entrepreneurship neither from university, nor from the professors themselves. In the period of question that is between 1987 and 1991-1992, the term "entrepreneur" had utterly different meaning for my informants. The word was connected to a person doing commissioned construction work, not a creative individual, who, as put by Schumpeter (1934) introduces new combinations into the market. Similarly, innovation was not a term used at NTNU at that time, or to be more precise, "it was not put like that". Students were not given any tasks specifically oriented towards developing new products or new services. In addition to that, professors did not encourage their students directly to establishing new companies, and commercializing what they had learned. How, then, did the university environment of the Department of Electronics influence future entrepreneurs from two distinctive classes, of 1991 and 1992?

5.1.1 Knowledge-based innovation

> *"Startups from classes of 1991 and 1992 – it is not because NTNU supported entrepreneurship, but because they supported high tech education." (Sverre Dale Moen, co-founder of Chipcon)*

As shown in the theory chapter, innovation, understood, as a change that leads to entrepreneurial opportunity is a decisive starting point for every entrepreneurial venture created (Drucker, 1985). Among various sources of innovation, the knowledge-based innovation is of crucial importance for the entrepreneurs from classes of 1991 and 1992. This type of innovation is based on a long-term research and development process, that involves strong progress in science and available stock of knowledge (Mitra, 2012).

All of my informants (apart form one informant), that is students turned tech entrepreneurs, other students of the classes of 1991 and 1992, professors who thought the two classes and researcher from the Department of Electronics strongly recall high level of courses thought at NTNU at that time. The idea behind the study program was to give strong, general base in basic subjects like math and physics, what was seen as invaluable by the future entrepreneurs.

They see very strong correlation between level of their competence, also, if not especially, the high degree of knowledge within the basic subjects. The so-called basic knowledge was actively used during their career path, and was a founding stone for all of the future developments - starting from being able to move to advanced subjects within electronics that require thorough understanding of the law of physics and mathematical calculation, to real application oriented projects within product development.

The second level, that is specialized knowledge within electronics, telecommunication, signal processing, semiconductor design, was the next stepping-stone for the future success of tech entrepreneurs from classes of 1991 and 1992. The science areas mentioned here were not only new and exciting at that period in time. They were the areas where NTNU had strong and state-of-the-art competences. The sources of the competitive advantage within those areas were twofold. First of all the Faculty of Electrical Engineering and Computer Science was since its very beginnings, working in close cooperation with the military driven research institute – the Norwegian Defense Research Establishment (FFI); Televerket, the research institute responsible for all the science and technology development activities connected to the area of telecommunication; and Sintef, the NTNU affiliated research institute that was involved in commercial and industry oriented research tasks.

Both FFI and Televerket were research establishments funded by the government, while Sintef was co-financed by the government (grants from the Norwegian Research Council) and incomes from commissioned research. The main aim of the cooperation was to create nation-wide net of cooperative research activities that were seen as crucial in light of newest technological developments. In that sense, it is important to note that it was FFI and Televerket that took a role of an initiator of research activities within semiconductor design and mobile telecommunication respectively.

Secondly, responsible for the high level of scientific competences were professors themselves. They were active in disseminating their scientific developments, establishing contacts with other research milieus in Norway and internationally. In addition to that, thanks to the rather substantial degree of freedom in developing their own research programs and devoting their time and efforts to the fields and areas they found worth investigating, they created strong base of specialized knowledge that was then spread among the students.

Thanks to those close collaborations electronics milieu at the NTNU was leading in its domain in the period of question. Furthermore, the progress in science achieved through those

connected efforts was not kept within the research groups, it was also actively disseminated with the international research community through scientific journal papers, and most importantly with the students through academic courses oriented towards the newest science developments. The latter was obtained thanks to the engagement of both professors and Sintef researchers not only in the same research groups, but also in lecturing activities.

I would argue that the high level of scientific expertise at the university and good, demanding lectures had a strong influence on the future tech entrepreneurs from classes of 1991 and 1992. It gave them strong scientific competences in their field, what was later used in the development of their methods and products that were to be successfully commercialized by the new firm formation. It is important to remember that in this case we deal with two distinctive types of companies: corporate and university spin-offs. Due to that, the influence of the university in the firm formation will be slightly different. However, the education they obtained is the point of connection for all of the entrepreneurs in question.

According to Shane (2001) the decision to exploit technological opportunity is grounded in three factors: "importance, radicalness, and patent scope". To put it simply, the bigger technological achievement embodied in the invention, the more radical technology applied, and the higher patent scope, the bigger are the prerequisites for utilization of the new invention by creation of a new company. Development of a new technology depends on the skills and expertise the inventors have, and in this particular case the founding stone of those skills was gained at NTNU. The skills were later (of course), developed through job experience or further doctoral studies, but it would not be possible if people in question did not obtain high quality education on a master level.

In other words, the high-quality education, with both basic and specialized subjects following latest developments in the respective science domains was a first prerequisite to creating technological opportunities that lied in the roots of the future tech companies. In that manner, it can be claimed that one of the ways in which NTNU, however, indirectly influenced entrepreneurship, was by realizing the traditional university missions of education and research. That in turn equipped future tech entrepreneurs with the first stepping-stone of entrepreneurial capital – that is knowledge and technological skills.

Interestingly, in the example of university spin-offs, that is companies established by the researchers or other scientific employees to commercialize technological inventions created within the university, the correlation between the level of academic competencies and the rate

of spin-off activity was not proved without the doubt (Shane, 2004). The research on university spin-offs is centered within few distinctive areas: individual characteristics of academic entrepreneur, institutional framework of commercialization of technology within academia, environmental and cultural factors, and the role of venture capital (O'Shea, Chugh, & Allen, 2008), as the commercial activity usually happens on the crossroads of all those factors.

Di Gregorio and Shane (2003) suggest however, that the "eminence" of university correlates positively with the startup activity. Among various reasons, two are strongly pointed by the authors, namely the fact that the better the reputation of the university, the bigger chances of attracting best researchers and venture capital. The presence of scientists of high competence can contribute to development of better technologies, while the attraction of venture capital can be decisive when financing the new venture. It is therefore claimed that the both the level of competency, and state-of-the-art research activities influenced positively the overall reputation of the university. That in turn attracted the most talented and skilled students and researchers, what had a great importance for the future technology based entrepreneurship.

5.1.2 University – industry connection

The university – industry connection is one of the most important issues when discussing the role of university in fostering entrepreneurship. Traditionally university served as a producer of skilled workforce for the existing industry, as well as knowledge and technology producer for both incumbent and new industries (Etzkowitz, 1998). The connection has also another important face that is cooperation on research and development projects. Industry oriented research is said to contribute to developing problem-solving attitude in academia by working on real life business problems (Bishop et al., 2011). Nevertheless, a direct link between startup rates and university – industry cooperation has not been definitely proved (Mitra, 2012).

Both in the period in question in the case of entrepreneurs from classes of 1991 and 1992, and prior to that, strong linkages with industry characterized the Department of Electronics. The linkages had various forms, however, there were two most important ways of connecting to the industry that call for special attention. First of all, existing industry was commissioning research projects. Second of all, Department of Electronics kept close cooperation with Nordic Semiconductor (previously Nordic VLSI), Sintef spin-off established in 1983.

The industry commissioned research was officially done through Sintef, that is the affiliated with NTNU applied and commercial research institute established in Trondheim to carry on the weight of industry oriented projects. As mentioned in the case background section, the cooperation between NTNU and Sintef was very close, so that even the scientist took part in both university and Sintef projects. The professors I spoke to during the data collection process were very explicit in stating that exactly that connection, or type of cooperation was the crucial factor for the microelectronics milieu at NTNU. On the one hand, university researchers kept focus on academic work, and publishing in academic journals. On the other hand, through Sintef´s commissioned research, the Department of Electronics had continued access to the existing business challenges, what gave the possibility of applying the newest developments.

The combination of basic and applied research strengthened the level of science competences through new possibilities of applying, and in turn testing and developing new solutions. At the same time, constant contact with the industry specific technical issues, contributed to the innovative thinking, even though, as explicitly remembered by both former students and professors, it was never named "innovation". But innovation it was. The aim at constant development of existing technologies, and in turn products, applying them to the market needs, or even creating new markets and industries is in fact another formulation of the classical definition of innovation devised by Joseph Schumpeter in the first decades of the 20th century (Schumpeter, 1934).

The second characteristic aspect of cooperation between university and industry in the example of the Department of Electronics was strong relationship with Nordic Semiconductor. Since the company spun off from Sintef, all of the founding fathers kept close connection to NTNU. Nordic Semiconductor was active in suggesting topics for project work and master theses to the university. This connection was an epitome of using basic, theoretical knowledge and applying it into the technological problems within the real industry. Apart from obvious profits for the company, in terms of gaining access to the newest science developments and fresh sight from the university part, the students got insight in how their knowledge can be applied.

Moreover, in the period of question, Nordic Semiconductor still had strong characteristics of a young company. Even though they were established 5 years prior to the main events in question, they were still undergoing strong development, characterized by great flexibility and ambiguity. The staff was working on many angles to acquire new projects and assignments.

For many of the future entrepreneurs, contact with this company was first real connection to the world of tech entrepreneurship. For some of them this firm was a part of motivation to choose microelectronics, for others it served as clear role model of interesting, exciting and challenging work place.

In addition to that, the cooperation became even more strengthen after Oddvar Aaserud, one of the co-founders of the company returned to the university and took professorial position, while keeping part time engagement with the company. His role will be further discussed in the following section. It is nevertheless important to mention that, apart from the research projects organized by Sintef, the great majority of the contacts with existing industry was obtained and maintained by the professors.

The strong linkages between NTNU and relevant industry contributed in several ways to fostering entrepreneurial mindset among students, even though the process was not explicit and not intended. For the first, it gave the insight to the practical application of technological knowledge. The orientation towards practical application, and solving so-called real life problems is seen by many as a factor conducive for recognizing entrepreneurial opportunity (Shane, 2003).

For the second, the industry connection contributed to overall development of the microelectronics milieu at NTNU and building its reputation as a constructive, and valuable partner for existing businesses. As shown in the previous section, the so-called "eminence" of the university has indirect connection with the rate of entrepreneurial ventures stemming from the university (Di Gregorio & Shane, 2003). I would argue that the reputation of being "business friendly university department" contributed to the positive attitude of business world to that part of academia, in the same time attracting new contacts and creating positive atmosphere of interest around research carried out in that department. The most direct result of that situation was the interest created by Tor Ramstad and Arne Halaas around Fast Search & Transfer, what was decisive for bringing key investors on board.

Finally, of decisive importance for fostering entrepreneurial mindset, but again indirectly, was connection with the business of entrepreneurial character, and companies stemming from the same environment that the future tech entrepreneurs were parts of. According to Shane (2004) role models within academia have crucial importance for other people within university when taking a decision of exploitation of entrepreneurial opportunity. Although the connection between university – industry relation was not proved to have direct impact on the university

startups rate (Mitra, 2012), it is claimed that the close cooperation with industry of an entrepreneurial character, that had roots in the same university environment, might have a role in encouraging students to entrepreneurship. Taking into account the role of entrepreneurial examples, the contact with entrepreneurial companies that gained success is a viable instance of how one can capitalize on one's knowledge, and contribute to one's ability of recognizing an opportunity.

5.1.3 Entrepreneurial professors

> *"Oddvar (Aaserud) as founder of Nordic, he was, if you think of it, a seed for everything in the bigger picture". Vegard Wollan (co-founder of Atmel Norway).*

The Faculty of Electrical Engineering and Computer Science grouped talented professors, that are being remembered as competent, encouraging, inspiring, friendly, helpful and "academic leaders". Most of the professors were remembered as distinctive individuals who could attract the cleverest students, and what is more, direct them to new, developing fields. They were role models for most of the students, future tech entrepreneurs in question included.

What transpires from the interviews is the open-mindedness and risk-taking attitude of the professors in question. Firstly, they are being remembered as inclusive for new students, open for their ideas and impulses coming from them. Both future tech entrepreneurs and other students recall them as being "down-to-earth" and friendly, what contributed to building mutual respect and understanding between professors and students. Secondly, the professors from the microelectronics milieu were open towards the world outside of the academia - towards other research institutions and industry. They are remembered as very good in creating contacts and interest around research of their groups.

The majority of the professors involved in this case had no explicit commercial orientation, like Arne Halaas and Tor Ramstad mentioned also in the previous section. Nevertheless, thanks to their good cooperation with the outside world, they were able to attract people, projects and resources to the university. Others, like Einar J. Aas, in addition to working with close relationship to the existing industry, were focused on disseminating research and technology developments. That contributed positively to the overall industry development, enhancing their level of innovativeness, and in the same time, made the department open for new scientific impluses.

The literature recognizes the figure of so-called "academic entrepreneur" (Rahim et al., 2015) and "entrepreneurial professor" (Etzkowitz, 1998). The first one is connected to the person of

a scientist who sets on the process of commercialization of technology of his or hers invention, while the other one is not only connected to the professor owning a company, but also the one that perform in an entrepreneurial way in order to for example get projects funded by the industry.

If we take into account that:

> *"entrepreneurship is directly concerned with the flows of intellectual, human and social capital to their most productive use, especially in the form of new venture creation. (...) entrepreneurship goes beyond routine forms of industry-academia collaboration; it engages both parties, and indeed government, to derive competitive economic value from innovation and a cultural shift in the process of learning that results from innovation" (Mitra, 2012, p. 192)*

and bear in mind the personal characteristics of entrepreneur derived by Schumpeter (1934), that is charisma, risk-taking, individualism, sense of opportunity recognition, creativeness and passion for putting ideas into real life, the professors involved in the case in question can be treated as entrepreneurial professors.

They were showing creativeness and risk-taking attitude in choosing new lines of research, and lobbying for new fields to be introduced to the university. By being able to attract talent and industry they put in motion the process of network building and utilization that is directly connected to the entrepreneurial behavior (Anderson, Dodd, & Jack, 2010). They were able to direct human capital, students to their best by recognizing talent, and showing them the innovative fields where they could further develop their skills. Moreover, they used entrepreneurial measures of obtaining funding for research projects – in the same way that entrepreneurs gain customers for their products or services, the professors were able to attract financing from different sources to support constant development of science and technology.

Nevertheless, probably the biggest importance for the case of tech entrepreneurs from classes of 1991 and 1992 the co-founder of, Oddvar Aaserud. As mentioned before, he returned to the university to take a position as a professor within semiconductors design, and worked in close cooperation with Einar Aas. Interestingly he came back to the NTNU in 1989 - the year when students in question started their chosen specialization. Oddvar Aaserud was highly recognized as a professor with commercial orientation, the one who "had done it with Nordic". For numerous students, first and foremost, for the future tech entrepreneurs he was a definite role model.

Previous section showed the importance of role models for prospective entrepreneurs (Shane, 2003). Moreover, people within university environment can be characterized by a distinctive model, or "ethos" may be a better word. Their main aim as scientists is knowledge development and dissemination for the better of the societies. Certain hesitation, or even reluctance towards commercialization of one's technology, or sometimes even establishing cooperation with the industry has been found among some research communities (Etzkowitz, 2013). The importance of a role model of academic entrepreneur becomes even more clear and decisive if we also take into account cohort characteristics of the classes of 1991 and 1992 - strong attitude toward creating value not only for themselves, for the society and economy as a whole; the fact that the concept of capitalizing on one's knowledge was new, and unprecedented in the period of question,

Oddvar Aaserud was a professor who was a product of the same milieu they were in, and established a company commercializing what the future entrepreneurs themselves were learning. He, together with his co-founders and support from the mother organization, Sintef, created something that brought value to the local economy and community. Being able to watch a professor who was in the same time a successful entrepreneur, is therefore seen as decisive for formation of future technology entrepreneurs from classes of 1991 and 1992. It gave them an idea, a possibility that being a company owner may be a viable option. In addition to that, they had seen the real "market value" of their knowledge and skills.

5.1.4 University environment and culture

> *"Culture is not a power, something with social events, behaviors, institutions, or processes can casually attributed; it is a context, something within which they can be intelligibly – that is, thickly – described" (Geertz, 1973, p. 14).*

The role of cultural and environmental factors is one of the most discussed topics within the entrepreneurship research domain. The link between the characteristics of national (Senor, 2011) or regional culture (Saxenian, 1994) and entrepreneurial activity and entrepreneurial success has been established. Similarly, some links between organizational culture of mother company and spin-off rates has been shown (Saxenian, 1994) and (Klepper, 2009). Nevertheless, the research domain connected to the influence of cultural characteristics of the university environment has not yet been comprehensively explained. Interestingly the big part of scholarly works concerning this topic concentrates on institutionalized culture, that is the organizational and institutional framework for fostering and enabling entrepreneurship within academia (Shane, 2004).

The classical definitions of culture are focused around values, beliefs and symbols (Hofstede, 1991). However, others (Geertz, 1973) put attention on the importance of context. They claim that the background characteristics, with special attention put to the system of thoughts and values condition people´s behaviors and action. Although those to concepts of culture are very often discussed in opposition to each other, both contribute strongly to understanding the phenomenon in question. The university culture in the case of technology entrepreneurs of classes of 1991 and 1992 can be understood in two parallel dimensions. Firstly, the importance of the culture of the university can be analyzed through the environment created by students themselves, their set of special features, values and unspoken rules. Secondly, the impact of the cultural environment on the entrepreneurial activity of former students in question, can be seen through the lens of the characteristically environment of the electronics milieu at NTNU.

The student´s environment was being remembered as individualistic, but in the same time helpful and creative. People were focused on own projects, but simultaneously willing to help other students with learning. The main feature vividly pointed out by both the future tech entrepreneurs and other students of the classes of 1991 and 1992, was ambition. The students in question were hard-working and ambitious, always looking for the opportunity to develop their skills and knowledge. What is even more important, the study environment was described as one that “allowed to learn" by one of the informants. Being able to put enough effort in ones learning and self-development, and in the same time being encouraged by the environment to do so, is seen here as crucial for future entrepreneurs. On the one hand, it contributed to the fostering of technical skills, which importance to future entrepreneurial actions was described in the previous section. On the other hand, it was a decisive period for building up some personal qualities, like hard-working attitude, which will be crucial for following career development.

Simultaneously, the cultural characteristics of the electronics milieu at NTNU in that period in time, and also prior to that had a great importance for building the context in which future entrepreneurs were educated. In the previous sections, certain characteristics were described. It was the innovativeness and high competence of the Faculty in question; strong figures of entrepreneurial professors and role models combining both business and academic ethos; and finally, the close connection to the industry, that contributed to the certain openness and specific orientation of this environment. All those elements are seen here as the founding elements of the overall culture of the electronics milieu. They built framework conditions for

values and attitudes that were successively spread to the students. It is however, important to point out again, that none of those actions and influences was deliberately directed towards encouraging entrepreneurial activities among the students.

Bearing in mind the characteristics of corporate environment conducive for entrepreneurship described by Ireland et al. (2003) and presented in the theoretical framework chapter, which is centered around qualities like risk-taking, creativity, encouraging innovation and opportunity seeking, it is therefore claimed that the cultural environment of electronics milieu at NTNU in that period of time can be seen as an entrepreneurial environment. That is an environment that contributes directly or indirectly to fostering entrepreneurial mindset, mindset that was later developed thanks to other conditions, to reach it´s peek in the new technology firm creation.

5.1.5 Concluding remarks

This section sought to enlighten the role of university in the fostering entrepreneurship. It is important to point out that the period of master studies was in many ways formative for future entrepreneurs, nevertheless the decisive events took place after they graduated from NTNU. The role of university is therefore seen as base building and stepping stone in obtaining entrepreneurial capital and mindset. The four elements of the academia presented above, that is the knowledge and competence development, university – industry relations, presence of entrepreneurial professors and university culture, are closely entangled with each other. It is important to emphasize that these elements influenced each other, and together created certain environment to which future entrepreneurs were exposed. The figure below serves to summarize the interconnected influence of the factors presented above on fostering entrepreneurial attitudes, however indirectly. The model therefore shows the elements that positively contributed to encouraging entrepreneurial mindsets before the organizational measure took form.

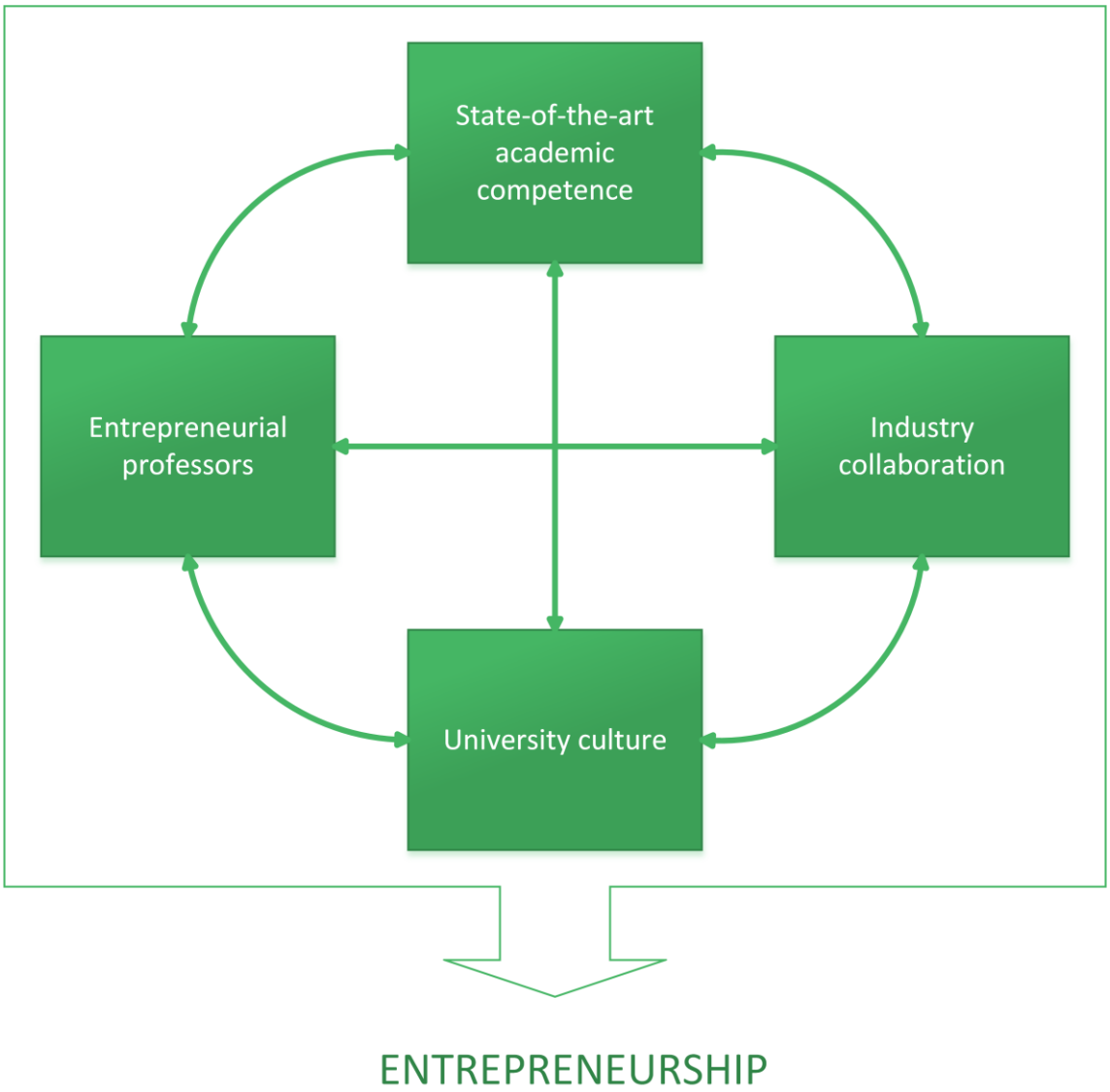

Figure 5.1 Interconnected influence of the university environment. Authors own figure.

5.2 Tech entrepreneurs from the classes of 1991 and 1992 – attempt of explanation

The story of technological entrepreneurs originating in two distinctive classes of electronics at NTNU is widely discussed in local and industry media – both Adressavisen, the regional newspaper in Trondheim and surrounding region of Trøndelag, and Teknisk Ukeblad, Norwegian magazine focusing on technology, attempted to explain the unprecedented success of entrepreneurs in question. Nevertheless, various myths arose around the story of so-called "super class". Some believe it was the hidden encouragement from the professors that stands behind the occurrence of so many companies from the same classes. Others claim that the former students that established high tech companies were always entrepreneurs at heart and created kind of social network of people dreaming about entrepreneurship when taking master

studies at NTNU. Moreover, ideas about the importance of financial crisis at the border of 1980s and 1990s are understood as explanatory for this case.

The purpose of this section is therefore to undertake an analysis of the gathered empirical data in light of the existing theories on technology entrepreneurship in order to shed some light on the reasons for establishment of tech companies by previous students of the classes of 1991 and 1992.

Previous section described how university environment influenced the individuals in question. As the key part of university´s impact were named superiority of technological education and high scientific competences within the Faculty of Electrical Engineering and Computer Science at NTNU in the period in question and prior to that; the presence of entrepreneurial professors who served as role models for the future entrepreneurs; the academia – industry collaboration that characterized that environment and contributed to cultivation of certain features, that were named as crucial for creating environment indirectly conducive for entrepreneurship; and finally the cultural framework that unified the named above factors into group of characteristics that had a positive, though indirect impact on developing entrepreneurial attitudes. It is therefore claimed that university environment in the case in question had indirect influence on fostering entrepreneurial attitudes in the future tech entrepreneurs – indirect by decisive for later career choices and opportunities.

How then the establishment of technology companies from peers from the two classes from NTNU can be explained?

5.2.1 Entrepreneurial personality?

Great attention in the research on entrepreneurship is put on special personal characteristics that are supposed to in some part be responsible for, firstly, becoming entrepreneur, and secondly achieving success in an entrepreneurial venture (Shane, 2003). Among most widely discussed characteristics are risk-taking attitude, problem-solving orientation, creativeness, devotion to actively implementing ideas, leadership abilities and charisma (Schumpeter, 1934). Some of those points were already mentioned in this chapter in relation to the university professors, who were described as entrepreneurial professors.

Taking into account the model devised by (Shane, 2003), where personal qualities are seen as one of the decisive factors for the process of opportunity recognition and then exploitation, it would be obvious to assume, that tech entrepreneurs from classes of 1991 and 1992 were all epitome of the Schumpeterian entrepreneurial personality. That it turn would lead to their

ability to spot the technological opportunity and then successfully exploiting it in form of new firm formation.

The tech entrepreneurs questioned in this case showed extremely various personalities, from rather shy and introverted persons, to typical charismatic extroverts. Both tech entrepreneurs and other former students of classes of 1991 and 1992 cannot see many points of connection when discussing personal traits of the entrepreneurs. Some of the people in question were rather more technically oriented, while others were described as "born managers". Interestingly, the entrepreneurs in question were not focusing very much on the risk-taking attitude during the interviews. For the decisive majority of the entrepreneurs in question, the choice of starting own company was seen as natural step, sometimes even the less risky step then remaining in the company they worked for.

Of course, among the group in question, are persons who could be taken for typical Schumpeterian entrepreneurs – charismatic, creative and risk-taking leaders. Nevertheless, the empirical data only partially corroborate the importance of personality presented by for example Shane (2003), as the future entrepreneurs share only some qualities named by Schumpeter or Shane. What they all have in common is that they are very creative people, who present high level of intelligence and technological skills. It is therefore claimed that those qualities can be seen as influential in the case of entrepreneurs of classes of 1991 and 1992. What is more, it is suggested that some those characteristics may have positive impact on the decision on exploiting an opportunity, but they don´t necessarily condition the opportunity recognition. The process of opportunity recognition was conditioned by their superior technical abilities and entrepreneurial examples in their university and professional environment that is more influenced by their environment then personal qualities. This issue will be further discussed in subsequent section.

5.2.2 Entrepreneurial capital

Entrepreneurial capital involves various resources that are at entrepreneur's disposal, and which are successively exploited to establish new company (Bishop et al., 2011). Among the resources that are seen as decisive for the success of an entrepreneurial company are business knowledge and business skills, in addition to the technological competence when the company has a tech profile (Mitra, 2012). The business skills, understood as business development with strategy building, and sales and marketing, are usually obtained through courses or organized education. In addition to that last years brought the development in professionalized entrepreneurship education on the university level (Rasmussen, 2011).

As described in previous section, the university education on the master level at NTNU contributed to the development of technological competences and skills among the future entrepreneurs from classes of 1991 and 1992. It provided a good "point of departure" for the further building of the technological knowledge, enabling them to get jobs in leading industry and research organizations, or continue studies on the PhD level. However, the master studies within microelectronics at NTNU gave no business education, or sales and marketing skills that are typically understood as important for potential entrepreneurs.

Within the case in question the two distinctive groups of entrepreneurial companies were distinguished – corporate and university spin-offs. The corporate spin-offs were Atmel Norway, Chipcon and Arctic Silicon Devices, while university spin-offs were Fast Search & Transfer, Advanced Communication Technology and 3d-Radar. Those two types of spin-offs have different origins, and therefore the way to obtain entrepreneurial capital was slightly different for all of the tech entrepreneurs in question. Nevertheless, what is alike for the whole group in question is that the decisive part of their entrepreneurial capital was acquired during their work experience or further education after graduating from master studies at NTNU.

5.2.2.1 Corporate spin-offs

The tech entrepreneurs from classes of 1991 and 1992 who established companies categorized as corporate spin-offs, got jobs after studies at Nordic Semiconductor and SI (later Sintef). They all described their respective work environments, which they became part of after master studies, as challenging and offering strong learning opportunities. Both environments were companies working with high, state-of-the-art technology developments. All of the future entrepreneurs working there were unanimous in stating that both Nordic Semiconductor and SI enabled them to further deepen their technological skills. Thanks to active cooperation on the advanced research and development projects, they achieved high competences in their respective fields.

In addition to that, both environments were characterized as oriented towards application side of their knowledge – all the progress in science and technology they were creating there was then to be applied within real life business cases. In addition to that the projects they carried on for industry customers were strongly development oriented, and very often were to end with a specification oriented product. My informants felt very strongly about the role of this kind of work process for creation of their business skills. The research and development process in those two companies was characterized by strong client orientation. For this reason, the future entrepreneurs learned very fast how to cooperate with clients, how to respond to

their needs and create solutions that respond perfectly to their requirements. All those qualities were later seen by the entrepreneurs in question as decisive when setting on establishing their own companies.

What is more, the research and development process in both SI and Nordic Semiconductor was very fast and conditioned by specified budgets and strategies. The future entrepreneurs had to adjust to both fast pace of the process and the rigidity of both budget and strategy. Similarly, to the customer orientation, they see their time at SI and Nordic Semiconductor as formative for their skills to work under pressure of time and scarce financial resources. What is even more important, all of the future entrepreneurs who worked for those two companies, were rather quickly moved to more business or management oriented positions.

Among their responsibilities were also tasks connected to project management, customer and project acquisition, and sales and marketing. Thanks to those roles, and in the same time great degree of responsibility given by their supervisor, the future entrepreneurs developed strong business skills. In addition to that, they also build their professional networks. Those networks were later actively used when struggling to get first clients and finance opportunities. Those qualities are interchangeable with the elements of entrepreneurial capital that spin-off companies obtain from the parent companies as described by Zahra et al. (2007).

Another important factor that future tech entrepreneurs obtained through work experience was market understanding and ability to recognize market structures and potential niches. Those are the two features strongly emphasized by Stam (2009) as important for deciding to leave parent company and finding suitable market position for a new company. It was also found that spin-off companies utilize “blueprints” from their parent companies when establishing new one (Cordes et al., 2014). The “blueprints” may consider type of tasks, client contacts, or network building. Aldrich and Martinez (2007, p. 7) go even further and claim that the majority of entrepreneurs copy the “structures, competencies, and routines of pre-existing organizations”. Taking into account that Atmel Norway used existing contacts of parent company to get access to possible investment opportunities, and Chipcon and Arctic Silicon Devices started with twin business models of their respective parent companies, it is claimed that they gained certain “blueprints” and skills of organizing resources from their parent companies. These in turn, strengthen the importance of job experience for exploitation of entrepreneurial opportunity, as it gave the intangible resources crucial for creating a company.

Taking all those factors into account it is therefore claimed that work experience after graduation determined the development of crucial business, technological, and social skills that is entrepreneurial capital. What is more during the time at the respective companies, the entrepreneurial qualities described in a previous section, such as creativity and innovativeness, were developed. The entrepreneurial capital was essential for both opportunity recognition and exploitation by the founders of Atmel Norway, Chipcon and Arctic Silicon Devices.

Interestingly the motivation behind those three companies varied. For Atmel Norway, the motivation lied in the wish of commercializing completely new technology, what was not seen as possible within Nordic Semiconductor. For Arctic Silicon Devices, also Nordic Semiconductor spin-off, the decisive were structural changes within parent company that led to dissatisfaction, what in a way forced spinning-off process. In the instance of Chipcon, the motivation was grounded in the satisfaction with working environment of SI after it merged with Sintef in 1993. All those reasons are recognized in literature as motivation for spin-off activity within corporations (Klepper & Thompson, 2007). However, what was similar for the founders of those three companies was the willingness to create something new.

5.2.2.2 University spin-offs

The founders of three university spin-offs, Fast Search & Transfer, Advanced Communication Technology and 3d-Radar, had very little industry experience neither after graduation from master studies, nor after their PhD studies. Egil Eide (3d-Radar) gained some entrepreneurial capital while working for a small company after graduating from master studies. He remembered that time as challenging, but valuable in terms of learning about group processes and management. Haakon Bryhni (Advanced Communication Technology), as we remember, had undergone successful product commercialization in the past, and run a company during his time at NTNU. John Markus Lervik had a few months industry experience after graduating from the PhD program at NTNU.

According to Shane (2004) the occurrence of university spin-offs is conditioned by various factors, among which the most important are the level of innovativeness of technology developed at the university and prior work experience. All of the products and services those companies commercialized were on the forefront of their respective research domains. As mentioned above, apart from Haakon Bryhni, the tech entrepreneurs had in fact very little commercial experience. The question then remains: what was decisive for them to recognize an entrepreneurial opportunity and decide to exploit it in the form of new firm formation?

As described in the previous sections the electronics milieu at the NTNU had very strong ties to the relevant industry, visible in major research projects carried out in cooperation with the business organizations, and extensive professional networks of contacts between professors and businessmen in relevant areas. In both cases, of 3d-Radar and Fast Search & Transfer, the opportunity recognition phase was influenced by the industry. The industry partners were very well informed about the technological developments within the department and kept close contact with the inventors. In both cases the impulse for recognizing the market opportunity of the technology created at the academia came from the industry.

Based on that fact, it is claimed that the connection between NTNU and relevant industry actors in the period of question was decisive for both opportunity recognition and decision to exploit it for the academic entrepreneurs. As they remember, they obtained entrepreneurial capital by cooperating with industry and investors on the commercialization of their inventions.

5.2.3 Financial crisis?

Nevertheless, neither industry connection nor business experience do not explain fully why so many entrepreneurs came from the classes of 1991 and 1992. One of the popular explanations was the impact of financial crisis on the boarders of 1980s and 1990s, which contributed to a tougher job market. Unemployment and demanding job market were previously recognized as factors stimulating entrepreneurial activity (Norn, 2011). However, the data collected showed that in the eyes of the entrepreneurs in question the economic downturn did not have that big of an impact on their decision to start their own company. It had an indirect impact on their willingness to work hard during their time of master studies, in order to obtain good grades and in turn find good and relevant job afterwards.

In other words, the harsh external connection connected to the situation on the job market, and then strained conditions in the respective companies, influence further changes on the personal level. The previous section discussed the role of so-called “entrepreneurial personality”, and then the road to acquiring the “entrepreneurial capital”. Taking into account that future entrepreneurs remember that period in time as demanding on the level of employment and overall amount possibilities in the economy, it therefore claimed that harsh economic situation and job market had an impact on further development of entrepreneurial qualities, which were later contributing to taking upon the decision to exploit an opportunity.

As such, the demanding overall economic situation, together with downsizing at Nordic Semiconductor created an environment of uncertainty for future co-founders of Atmel Norway that in turn pushed them to taking a step out of company. The situation can seem paradoxical – one of the founders of Atmel Norway recalls that establishing own firm was less of a risk then staying in parent company. Nevertheless, by leaving Nordic Semiconductor, Atmel co-founder created a precedent that was a source of inspiration for other entrepreneurs from classes of 1991 and 1992.

5.2.4 Entrepreneurial inspiration

According to Stam (2009) observing entrepreneurial actions by people in one´s surrounding might be a trigger for becoming an entrepreneur. The reason for that is obtaining examples about the activities, needs and possible outcomes of entrepreneurial ventures. In addition to that two recent studies by Kacperczyk (2012) and Falck, Heblich, and Luedemann (2012) show clear correlation between the rates of entrepreneurial entry and entrepreneurial example of peers. Interestingly, it was found that having a peer who started own company, even several years after graduation, have very strong effect on the peers and is an important part of motivation to establish a new company (Kacperczyk, 2012). Furthermore, Shane (2004) and Rahim et al. (2015) points towards the importance of a presence of an entrepreneurial academic on fostering entrepreneurial mindset within academia.

The topic of "role models" and "inspiration" to start a company was the one that came back most often during the interviews, with both professors and the tech entrepreneurs in question. As mentioned in the section on entrepreneurial professors, Oddvar Aaserud, one of the co-founder of Nordic Semiconductor and then professor at NTNU, was a visible role model for many of future entrepreneurs of classes of 1991 and 1992. It had an unprecedented importance to witness and be taught by someone who "did it" – who successfully left research in favor of establishing tech company. Even though Oddvar Aaserud did not openly and explicitly encourage his students to entrepreneurship, his example made his mark on some of the individuals in question.

Nevertheless, important is the fact that the entrepreneurial inspirations within the electronics milieu at NTNU did not start with Oddvar Aasrud. It had its origins even earlier in the person of Kjell Arne Ingebrigtsen, who was one of the scientists behind the ultrasound technology. He also left university in order to concentrate on commercialization of the device based on the technology. Interestingly, he was the role model and inspiration both for Oddvar Aaserud and

Karl Klingsheim, who co-founded tech company Clustra in 1995. It points towards visible commercial and entrepreneurial inclinations within this milieu.

Not least important was the inspiration coming from tech entrepreneurs in question. The first company in the line of tech firm from classes of 1991 and 1992 was Atmel Norway established in 1995. Vegard Wollan, the co-founder, was very clear during the interview what an inspiration and role model Oddvar Aaserud was for him. In turn, Geir Førre, co-founder of Chipcon, sees the great part of his motivation to leave Sintef (former SI) to establish Chipcon. For him the fact that his peers had the courage to step out of the company to start their own firm and succeed, had decisive importance. What is even more important, he was encouraged to do so by Alf-Egil Bogen (co-founder of Atmel Norway). Similarly, Oddvar Aaserud, Trond Sæther and Nordic Semiconductor were great role models for John Raaum.

Similarly, Oddvar Aaserud was an indirect inspiration for Haakon Bryhni and John Markus Lervik. Due to the fact that they did not have many courses with him, they did not know him so well as the people who chose the semiconductor specialization. Nevertheless, they were "aware" of both him and Nordic. Interestingly, even though he came from different specialization, Nordic Semiconductor, Atmel Norway and Chipcon, were all inspiration for Egil Eide. What is even more interesting, his direct inspiration and encouragement was Haakon Bryhni, who had a positive impact on his decision to commercialize his PhD results, and even invested in 3d-Radar. The graph below shows the "flow" of inspiration from the various actros in this story.

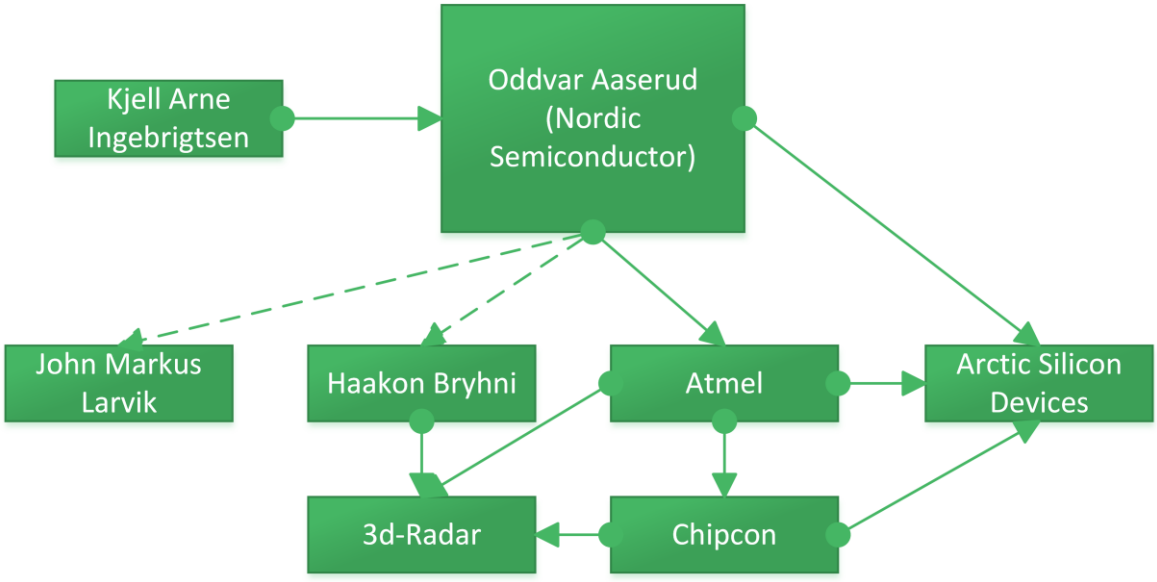

Figure 5.2 The flows of inspiration. Author´s own figure

The mutual inspiration is therefore seen as crucial for explaining the occurrence of the tech startups from classes of 1991 and 1992. I would argue that in the period in time when the concept of entrepreneurship, and the support system was practically inexistent, being able to witness successful entrepreneurial ventures of one's professors and peers was an important factor for developing entrepreneurial mindset and in turn deepened the ability to recognize an opportunity, and made the decision to exploit this opportunity easier to take.

5.2.5 Concluding remarks

The section above discussed several factors that were seen as important to understanding the rationale for establishment of the companies by former students of classes of 1991 and 1992. The main categories examined were the impact of entrepreneurial personality, the decisive importance of gaining entrepreneurial capital during job experience, the influence of the academia – industry connection in fostering university spin-offs, and finally the role of entrepreneurial inspiration and role models. By examining those factors, the following model of framework conditions influencing the entrepreneurs in question was devised:

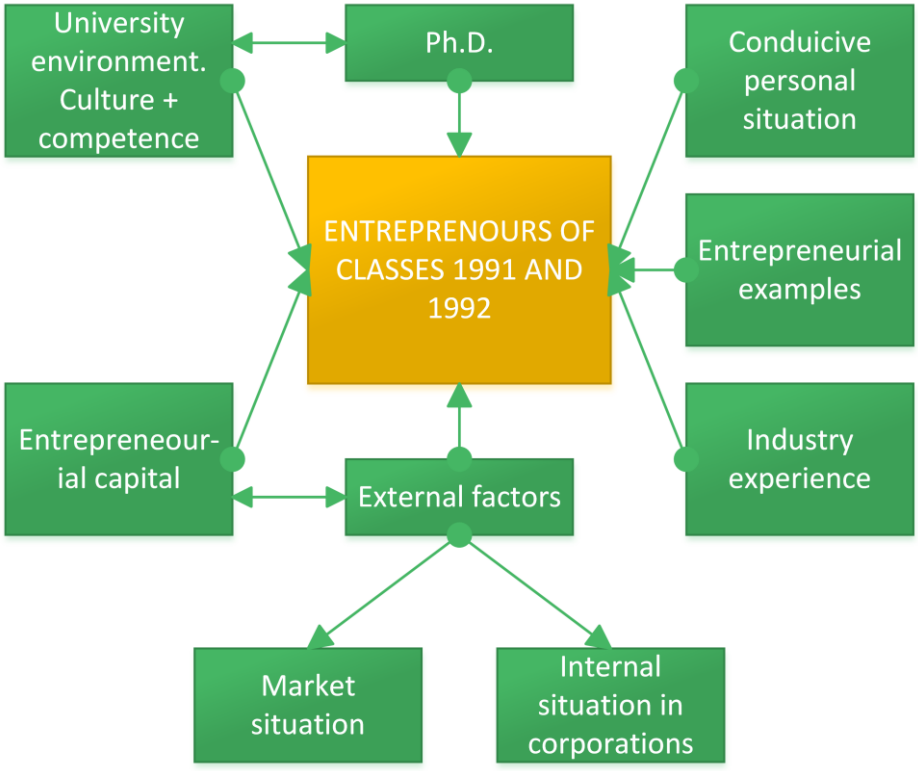

Figure 5.3 Framework conditions for the case. Author's own figure

Apart from discussed above conditional factors, several were added into the figure: conducive personal situation and market situation. Scholars have argued that the stable and supportive family situation has a positive influence on the decision to exploit entrepreneurial opportunity

(Norn, 2011). All of the informants in question were very direct in stating that their individual personal situation contributed to the decision on starting new company. The topic then did not need further elaboration in the discussion. When it comes to the market situation, which is also seen as important factor influencing entrepreneurship (Klepper & Sleeper, 2005), it was assumed, based on the information gained during the interviews with future entrepreneurs, former students, and professors, that in all of the examples the market situation was conducive for deciding to exploit the entrepreneurial opportunity.

By combining and analyzing all the framework conditions, the key conditions were named. I would therefore argue that behind the establishment of the tech companies by former students of classes of 1991 and 1992 lies a chain of events that started during their time at master studies at NTNU. The chain composes of interconnected factors, and it is therefore claimed that the mutual influence of the external factors was responsible for the occurrence of the companies in question. Even though time of master studies at NTNU did not directly encouraged future entrepreneurs to setting on commercialization path, it nevertheless gave them seeds of entrepreneurial mindset and decisive technical competences.

The technical competences in turn enabled them to continue learning on an extremely advanced level in the industry and within the academia. Both environments presented state-of-the-art competences and were on the forefront of technology development. That was responsible for creation of entrepreneurial mindset and acquiring crucial resources for formation of a new tech company. In addition to that demanding economic situation contributed positively to further development of entrepreneurial qualities, that than were decisive for taking up decision on starting new company. The trigger point for the company creation was establishment of Atmel Norway, which gave direct example for other students in the classes of 1991 and 1992.

6 Conclusions

This study was fueled by two-folded motivation. Firstly, it was intended to closely investigate how universities can foster entrepreneurship and innovation among both students and researchers. The topic gains scientific momentum due to the recognition of the role of academia in economic development. Secondly, the history of tech entrepreneurs of classes of 1991 and 1992 has not been scientifically investigated before. This is a distinctive case that can potentially offer insights into the intricate phenomenon of technology and academic entrepreneurship. The investigation was based on two research questions: *how did university foster tech entrepreneurship before facilitation took organized forms?* And *why so many entrepreneurs spun off from the two classes of 1991 and 1992 at NTNU?*

The study applied case study research design in attempt to fully describe and understand the events and relations in this story. Case study was chosen as it allows for looking at the phenomenon in a holistic manner. It also recognizes the context as an element of analysis. That was crucial for exploring the story, as it is deeply rooted in its context that is university environment. Data collection encompassed qualitative interviews with the technology entrepreneurs in question, other students of classes of 1991 and 1992, professors who taught the classes in question, as well as other scientific employees of the Department of Electronics. When possible the information was corroborated by secondary sources, like newspaper articles, essays and other documents concerning the events in question.

The importance of environmental factors on fostering entrepreneurship was argued in the theoretical framework chapter. Through Shane´s (2003) model of conditions influencing opportunity recognition and decision to exploit the opportunity, the correlation between personal and environmental qualities was presented. Moreover, the importance of knowledge development as a source of entrepreneurial opportunity was argued through Drucker (1985). It was also shown how crucial is the entrepreneurial capital, understood as the skills and resources that entrepreneur utilizes in the new firm formation (Battisti & McAdam, 2012). Nevertheless, the greatest implications for the case had the Aldrich and Martinez (2007) theory concerning the replication of the organizational structures of the incumbents by entrepreneurs, the utilization of “blueprints” from parent company (Klepper, 2009), and the role of entrepreneurial role models (Kacperczyk, 2012).

Through the discussion with the case results it was argued that university environment of electronics at NTNU had an indirect influence on the future tech entrepreneurs in question.

The electronics milieu in that period of time was characterized by high academic competence, and research on innovative technologies. What is more, the close collaboration with the industry had an impact on the overall attitudes and cultures within academia. The contact with business contributed to fostering problem-solving approach, as well as appreciation of applied science. In some instances, the close relation to the industry brought investments to one of the companies in question spinning from NTNU. Unprecedented importance for the whole environment had presence of an entrepreneurial professor, who became a role model for some of the future entrepreneurs. All those elements constituted a certain cultural conditions of electronics milieu – openness towards industry, inclusive attitude towards students, risk-taking, and innovativeness.

How than the appearance of so many technology companies stemming from those two classes at NTNU can be explained? It was argued that the understanding of this situation lied in a chain of events started during master studies at NTNU. At that time, future entrepreneurs gained a technological and knowledge base that enabled them to continue careers in the advanced research and industry organizations. In that period, they were also exposed to the first commercial example of successful technology firm formation, namely Nordic Semiconductor. Through further careers, tech entrepreneur acquired necessary entrepreneurial capital – advanced technological competence, business skills and organizational resources. The central point was establishment of Atmel Norway, the first company in the case. It was argued that entrepreneurial example had a crucial importance for explanation of the establishment of the companies in question. Atmel Norway was direct inspiration and source of motivation for the next company, Chipcon.

Taking into account those findings it is argued that entrepreneurship can be fostered by the universities beyond organizational forms like incubators, science parks or technology transfer offices. The case shows the importance of contextual and cultural environment. It is therefore suggested that keeping close relation with relevant industry can contribute positively to creation of conducive environment for entrepreneurship. In addition to that even greater importance have retaining connection to the companies that spun from the university.

6.1 Implications of the study

This study investigated the role of the university in fostering entrepreneurship beyond organizational forms. As the entrepreneurship gains constantly greater importance in the development of policy making on many levels, it can be of interest for several types of actors. First of all, the results may be of interest for universities that seek to develop or strengthen the internal systems for support and fostering entrepreneurship and innovation among both students and scientists. Secondly, the existing industry that aims at deepening its innovativeness and development can find this study interesting. Moreover, also local and regional governing organs can take some insights for the entrepreneurial policies. And finally, the institutions that work for facilitating entrepreneurship and innovation can find some issues of interest in this report.

Probably the most important element to take out from this study is that entrepreneurship and innovation are highly conditioned by the external environment. The environment in turn is built of various interconnected factors that influence and condition each other. The study shows the importance of presence of existing industry in the entrepreneurial framework. Fostering entrepreneurship and creating local and regional development is a two-way street. Not only can universities contribute to the further economic well-being and progress in industries through technology creation and knowledge spillovers. Also, the existing industrial actors can strongly contribute to creating new companies and technologies, by dialogue and impulses sent to the academia. The study also presents the importance of cultural conditions for creating conducive environment for entrepreneurship. It is therefore crucial to build up a culture, understood as set of values and norms set in a specific context, not only organizing resources and ideas into new institutionalized forms.

6.2 Suggestions for further research

The study touched upon several interesting issues that due to time and project size constrains could not be further investigated.

Firstly, the institutionalized support system for entrepreneurship within universities is therefore seen as worth visiting. Special consideration should be put on the connection and contrast between organizational support system and cultural values and trait of universities.

Secondly, the case showed strong importance of the industry experience for future entrepreneurs. Some indication of industry actors as informal incubators for the

entrepreneurial ideas were noticed. Nevertheless, closer investigation the industrial actors as incubators could shed more light on the processes that contribute to spin-off activity.

Thirdly, closer investigation on the influence of connection between academia and university spin-offs stemming from the same university is seen as worth investigating. It was indicated by this case that connection with the companies that come from a certain milieu can have a positive impact on the spin-off rates from this specific university.

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Appendices

Appendix 1 Interview guide for tech entrepreneurs from classes of 1991 and 1992

INTERVIEW GUIDE FOR ENTREPRENEURS

The interview starts with detailed information about the purpose and character of the study. Informant is asked for permission to record the interview, as well the permission to use direct quotes. The details concerning possible authorization are discussed.

First part of the interview serves gaining general and background information about technical issues. The second part is focused on social environment, while the third on the study environment. First questions are to be general and non-invasive. More detailed questions, and questions concerning follows later. The informant is to have freedom in answering questions. After discussing the time at NTNU, the interview will follow the career path, and finally the company creation.

Purpose of the interview is to gain detailed knowledge about the group environment, study environment, professors, time characteristics, job experience and rationale for establishing a company as the main point.

The informant is free to omit some questions if he does not feel comfortable with them. Additional reasoning for asking some question is given when asked by the informants, or when informants do not know where the interview is going.

1) STUDIES / UNIVERSITY ENVIRONMENT

a) Period of studying at NTH:
- i) When did you start studying?
- ii) Bachelor and master or 5-years master?
- iii) What bachelor degree?
- iv) Why physical electronics?
- v) How hard was it to get in?
- vi) What was the level at the NTH at that time?
- vii) Were courses more practical or theoretical?

b) ”Social network”:
- i) One big class or smaller groups?
- ii) Did you know all of the other students?
- iii) Were you close with other students?
- iv) Did you know personally Alf-Egil Bogen, Vegard Wollan, Geir Førre, Sverre Dale Moen, Svein Andres Tunheim, Eiving Bergsmyr, John Raaum, Haakon Bryhni, John M. Lervik and Egil Eide?

v) Supervisor of your master thesis?
vi) Master thesis in cooperation with the industry or theoretical?
vii) Did you know/did you have lectures with Einar J. Aas, Oddvar Aaserud, Arne Halaas and Trond Sæther?
viii) Can you tell me more about your professors?

c) Study environment:

i) "Atmosphere" at the NTH at the beginning of 1990s?
ii) Culture, values and behaviors were represented and encouraged?
iii) Interested in entrepreneurship and innovation before you started studying at NTH?
iv) Entrepreneurship, innovation and creative thinking (as creating new technology) promoted and encouraged in the institute?
v) Working conditions for developing new ideas and entrepreneurial activities?
vi) Any previous knowledge/experience with entrepreneurship and commercialization of technology at that time?
vii) Any roll models within the institute/outside of the institute?

2) WORK EXPERIENCE

a) What was the job market in time of your graduation?
b) Where and how long did you work after graduation?
c) Was it the job you wished to get?
d) What kind of experience did you get?
e) Any experience relevant for further entrepreneurship?
f) Did you have any contact with entrepreneurship and innovation at that time?
g) Was the spinning-off process encouraged by the mother company/institution?

3) TECHNOLOGY CREATION AND FIRM FORMATION

a) How and when did you develop/discover your new technology?
b) Did you have any influences from your work place towards creating new technologies?
c) Opportunity recognition – **when** and **why** did you decide to commercialize your idea as a separate company and not within the company you worked for?
d) What was the market in your field in time of establishing the company?
e) What kind of help and support did you get in commercializing your idea?
f) Was the physical electronics institute involved somehow in creation of the new technology and its commercialization?
g) How did you choose your business partners?

Appendix 2 Interview guide for other students from classes of 1991 and 1992

INTERVIEW GUIDE FOR OTHER STUDENTS

The interview starts with detailed information about the purpose and character of the study. Informant is asked for permission to record the interview, as well the permission to use direct quotes. The details concerning possible authorization are discussed.

First part of the interview serves gaining general and background information about technical issues. The second part is focused on social environment, while the third on the study environment. First questions are to be general and non-invasive. More detailed questions, and questions concerning follows later. The informant is to have freedom in answering questions. After discussing the time at NTNU, the interview will follow the career path.

Purpose of the interview is to gain detailed knowledge about the group environment, study environment, professors, and time characteristics. Informant specific questions will be added depending on the informant´s position in relation to entrepreneurs in question.

The informant is free to omit some questions if he does not feel comfortable with them. Additional reasoning for asking some question is given when asked by the informants, or when informants do not know where the interview is going.

4) STUDIES / UNIVERSITY ENVIRONMENT

a) Period of studying at NTH:

i) Was it hard to get accepted to NTH?
ii) What was the level at NTH at that time?
iii) Were courses more practical or theoretical?
iv) What was your specialization?

b) ”Social network”:

i) Were you organized in one big class or smaller groups?
ii) During your time at NTH did you know personally Alf-Egil Bogen, Geir Førre, John M. Lervik, Vegard Wollan, Sverre Dale Moen, Svein Andres Tunheim, Eivind Bergsmyr, John Raaum and Haakon Bryhni? If yes, can you tell something more about your relation to them?
iii) Who was a supervisor of your master thesis?
iv) Did you write your master thesis in cooperation with the industry?

v) Did you know/did you have lectures with Einar J. Aas, Arne Halaas, Tor Ramstad, Oddvar Aaserud or Trond Sæther? If yes, can you tell something more about your relation to them?

c) Study environment:

i) What was the "atmosphere" at the NTH at the beginning of 1990s?
ii) What type of culture, values and behaviors were represented and encouraged?
iii) Were you interested in entrepreneurship and innovation before you started studying at NTH?
iv) Were entrepreneurship, innovation and creative thinking (as creating new technology) promoted and encouraged in the institute?
v) How were working conditions for developing new ideas and entrepreneurial activities?
vi) What did you know about entrepreneurship and commercialization of technology at that time?
vii) Any role models in the institute/NTH?

5) WORK EXPERIENCE

a) What was the job market in time of your graduation?
b) Where and how long did you work after graduation?
c) Did you have any contact with entrepreneurship and innovation at that time?
d) Where did the interest in investing in startups come from?
e) It looks like a lot of people from your class showed interest towards entrepreneurship and innovation later on in their careers, do you have any idea why?

Appendix 3 Interview guide for professors from the Department of Electronics

INTERVIEW GUIDE FOR RESEARCHERS AND PROFESSORS

The interview starts with detailed information about the purpose and character of the study. Informant is asked for permission to record the interview, as well the permission to use direct quotes. The details concerning possible authorization are discussed.

The informant is free to omit some questions if he does not feel comfortable with them. Additional reasoning for asking some question is given when asked by the informants, or when informants do not know where the interview is going.

The focus in the interview is put on acquiring factual information about the department in question, role of Sintef connection, place of Nordic Semiconductor, and finally the on the social connections within the department.

1. How was ELAB established?
2. What was the scope and purpose of the institute?
3. What kind of research was done there?
4. What was the attitude towards entrepreneurship and commercialization of technology within the institute in the beginning of 1990s? *Attitude towards commercial utilization of research and tech?*
5. What kind of students was there at that time? Was there anything characteristic about them?
6. What was the level of both students and education at that time?
7. What kind of culture, values and behaviors were encouraged at that time?
8. Did you know any of the following students personally? Alf-Egil Bogen, Vegard Wollan, Geir Førre, Sverre Dale Moen, Svein Andres Tunheim, Eivind Bergsmyr, John Raaum, Haakon Bryhni, John M. Lervik, and Egil Eide?
9. Any other students with entrepreneurial background or interest?
10. Any network of alumni? Network for former students?
11. Did you know Einar J. Aas? Can you tell me more about him? He is said to have encouraged innovativeness and entrepreneurial spirit among students, what do you think about that?
12. What was the environment (conditions and possibilities) for entrepreneurial activities within the ELAB and Institute of physical electronics?
13. How and why was Nordic VLSI established?
14. How was the cooperation between the institute and the industry at that time?
15. Did researchers at ELAB have any experience within commercialization of technology?
16. Were there any role models of entrepreneurship for the students?
17. Did any of the researchers within both ELAB and Nordic helped the former students to establish their companies?