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The contribution of collective action to the commercialisation of high technology

Microsystem technology in the Netherlands

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Abstract

In the development of new technologies, actors will pursue their private interests, but they may also try to improve the conditions for the new technology in general. This we call 'collective action'. In this thesis, the contribution of collective action in the commercialisation process of high technology is investigated, following indications that this occurs and is intended to benefit industries as a whole. By means of conducting interviews with involved actors, performing document analysis, six cases of innovation in the microsystem technology industry in the Netherlands are reconstructed, in which the contribution of collective action is investigated. Aspects under observation are: the coordination within networks, the mobilisation of resources and attention in networks, and the representation of networks to the outside world. Finding partners to cooperate with was found to be important for the success of commercialising microsystem technology, but no clarity on the role of collective action was found. The mobilisation of resources was very important for acquiring public funding, collective action positively influences this. The mobilisation of attention and the representation also profited from collective action, but innovators regard the involvement of users as very important. Current collective action leaves room for improving this. Future research should focus on the macro scale effects of collective action as well as incorporate quantitative analysis.

1 Introduction

Together with nanotechnology, microsystem technology represents a promising wave of new technology in the 21st century (Kassicieh, Kirchhoff, Walsh, & McWhorter, 2002; Walsh, 2004), but microsystem technology is currently further developed and closer to the market. Microsystem technology is characterised by the efficiency, flexibility, and safety gains of miniaturisation. Processes in which microsystem technology proves its added value are in particular chemical or biological (Kassicieh et al., 2002). The microsystem technology industry, which is known as a high tech sector (Walsh, 2004), has an enabling character, which means it is "...no industry per se but a set of technologies with the potential to transform various fields" (Powell, Koput, & Smith-Doerr, 1996: p123). Microsystem technology, therefore, has a knowledge intensive nature, a complex and rapidly expanding knowledge base and is developed in networks rather than in individual firms (Powell et al., 1996).

In high tech industries like microsystem technology there is a relatively large share of New Technology Based Firms (NTBFs) with a good knowledge base (Powell et al., 1996). New technology based firms can be spin-offs from universities or larger firms, intended to commercialise new technology. Due to their small size, they face a lack of resources to acquire all necessary knowledge themselves (Rothwell, 1989; Spencer & Kirchhoff, 2006), making networking necessary. Networking also helps established firms. By means of getting engaged in networks, these established firms can keep up with the rapidly expanding knowledge base despite their lower level of flexibility (Hoang & Antoncic, 2003). In addition, both NTBFs and established firms seem to benefit from organisations and activities that seek to improve the general conditions in which innovation takes place. These activities are called *collective action*.

Collective action can be defined as actions that intend to improve the conditions at collective level that may benefit not only individual firms and organisations, but also the industry as a whole (Breshnahan, Gambardella, & Saxenian, 2001). Examples of conditions at collective level that seem important are the availability of funding (Colombo, Grilli, & Verga, 2007; Oakey, 2003), knowledge exchange between different firms and between firms and universities (Lee, Lee, & Pennings, 2001), favourable innovation policies (Breshnahan et al., 2001), and visibility and legitimacy of actions (Zimmerman & Zeitz, 2002). Because of the importance of these conditions, collective action is expected to contribute the commercialisation of microsystem technology. Yet it is unclear which and how collective action is most helpful. Therefore, the research question is:

How does collective action in innovation networks contribute to the successful commercialisation of innovations in microsystem technology in the Netherlands?

This thesis provides more insight into the role of collective action within an emerging high tech sector. It provides more insight into the contribution of collective action to successful commercialisation within such a sector, and it provides some recommendations for its actors. This is done in three steps. The first step is investigating which collective action is applied in microsystem technology commercialisation. Second, the question who performs the actions on behalf of who is answered. Thirdly, the degree of importance of collective actions is investigated. The thesis is built up as follows. The next section contains a literature review providing the relevant concepts and their characteristics. Thereafter, the operationalisation of the concepts is described. Then, the cases that are investigated are introduced, as well as the methods applied. The results section contains reconstructions of the cases in which microsystem technology is commercialised in innovation projects in the Netherlands. The data are collected by means of interviews and document analysis. In the discussion, the results are compared and linked to the theory on each aspect of collective action. Finally, a provisional answer to the question how collective action contributes to successful commercialisation of microsystem technology in the Netherlands is given.

2 Theories of collective action

2.1 Clusters and networks

This section discusses the literature that involves collective action within networks of innovation. Scholars have studied innovation in networks, especially within complex high tech sectors. Technology clusters of firms are defined as "... geographically proximate groups of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 2000: p16). They are inter alia described in terms of triple helices, in which firms, universities, and governments jointly shape innovation systems that continuously change (Etzkowitz, 2000; Lee et al., 2001). They are also described in terms of interlinked entrepreneurial entities, in which the building of knowledge infrastructure and provision of education helps knowledge spillovers from academic research to flourish within NTBFs (Kirchhoff & Phillips, 1988; Kirchhoff et al., 2007). In order to map the actors present within a network, cluster theory can be applied. It teaches us that entrepreneurial activities are important, but also that universities and governments are important factors behind success.

Due to the high tech and enabling character of microsystem technology, it is expected that innovation takes place in networks (Powell et al., 1996; Leana & Van Buuren, 1999). Networks are able to lead to more innovative output, because the linkages between firms and between firms and universities in such a network lead to knowledge spillovers (Ahuja, 2000), combination of knowledge and skills, and access to new markets (Pittaway, Robertson, Munir, Denyer, & Neely, 2004), all of which facilitate innovation. Scientific literature describes networks as forms of cooperation in between firms and markets, being legally independent, but economically dependent (Musiolik & Markard, 2011). More than cluster theory, network theory is able to describe the presence of some form of coordination or common purpose of interconnected companies and associated institutes. In order to describe this, it is necessary to involve literature on collective action.

Currently, there is limited insight in formalised collective initiatives from a theoretical point of view (Pittaway et al., 2004). Cooke and Willis (1999) relate the presence of an innovative climate to the presence of social capital, which is the presence of trust within interactions, but they do not elaborate on what actions to take in order to promote innovation in high tech networks. However, the importance of collective action for innovation networks in order to benefit from knowledge spillovers and the combination of knowledge and skills is recognised. Also, the importance for the access of new markets is recognised (Leana & Van Buuren, 1999).

2.2 Coordination within networks

Because it is not possible in the real world to observe collective action in total directly, one has to identify some aspects of collective action that can be observed. Networks that are built around a technology or a region exist because of a common purpose of interconnected firms. This can be the development of technology or increase and improve existing workforce in a region. Literature distinguishes between explicit top-down institutions and implicit bottom-up institutions, in which the first are initiated from government (local, national or regional) initiative. The latter are generally initiated by those who profit (Fromholt-Eisebith & Eisebith, 2005; Breshnahan et al., 2001), being firms, institutes, or university research groups. In a study on a high tech sector in Germany, Musiolik and Markard (2011) contribute the existence of so-called supportive institutional structures to the interplay of different actors, with the help of formal networks. The results are beneficial institutions, for example standardisation or vocational training. Moreover, it seems difficult to find partners to cooperate with when innovating, both in horizontal (cultural terms), and vertical (buyer-supplier) sense. Consequently, markets are difficult to be established. Following Musiolik and Markard (2011), creation and diffusion of knowledge within networks, and bringing together organisations that had not known each other is expected to help establishing markets. This is called coordination within networks.

2.3 Mobilisation of resources and attention for networks

From literature, it appears that emerging technologies face difficulties in the desirability, propriety, and appropriateness of the actions of firms involved, mostly but not necessarily NTBFs (Zimmerman & Zeitz, 2002). A possible explanation is that potential users or sources of capital are averse to ambiguity, because of the fear of negative evaluations of actions by peers (Trautmann, Vieider, & Wakker, 2008; Cao, Han, Hirshleifer, & Zhang, 2011), caused by the uncertainty surrounding emerging technologies (Gerard Sanders & Boivie, 2004). Legitimacy is regarded as a prerequisite for the formation of new industries (Bergek, Jacobsson, & Sandén, 2008), since being unknown creates an important economic and competitive disadvantage. This results in difficulties in establishing markets for emerging technologies like microsystem technology, but also in difficulties in acquiring resources (Zimmerman & Zeitz, 2002; Oakey, 2003)

Due to the risks involved in innovation, private funding is hard to acquire. This affects established firm innovation projects, but this especially affects NTBFs. Instead of tapping out of an innovation portfolio, they rely on one single technology for their survival, the development of which needs to be funded. This funding can be either private investments or public funding (Oakey, 2003). Whereas being known is expected to affect private funding positively, collectively mobilising resources and attention is expected to promote public funding, which can be easier allocated to a collective of organisations rather than individual organisations (Cooke & Wills, 1999; Oakey, 2003). Furthermore, favourable innovation policies support high tech sectors (Breshnahan et al., 2001). If firms collectively mobilise attention for networks, this is expected to include obtaining legitimacy (Elfrink & Hulsink, 2003; Zimmerman & Zeitz, 2002) and mobilising and securing resources. Lobby activities where networks are represented are included. Technology policy has experienced the influence of political lobby activities from out of industries for decades. For example, the development of nuclear power in Sweden has been affected by a "green" lobby, while favouring forest energy (Björheden, 2006). A certain influence of collective lobby activities on microsystem technology in the Netherlands is expected.

2.4 Representation of networks to the outside world

Apart from funding, legitimacy of actions affects innovation in other areas as well. Especially, intermediate and end users. New technologies are often aiming for markets that do not yet exist (Kuratko & Brown, 2010), and potential users often are ambiguity averse (Trautmann et al., 2008; Cao et al., 2011). It can be beneficial for actors within a high-tech sector to represent the industry and building an image. In this case, collective action takes the shape of representation of networks to the outside world. This includes collective marketing and communication. Rinallo and Golfetto (2006) describe trade fairs and exhibitions as an important collective way of representation, defining them as "... staged events whose purpose is to represent markets" (p865). Trade fair exhibitors have the purpose to represent their organisation, whereas the purpose of the trade fair, as a collective activity, is to present an industry. Since the goal is to position the technology, and especially in a market, doing this collectively can result in more impact generated at lower cost.

In addition to trade fairs and exhibitions, other forms of collective marketing activities include digital communications (Felzensztein & Gimmon, 2009; Gabrielli & Balboni, 2010), "regional brand development" (Tu, 2011), or cooperative generic advertising (Neves, 2007). In line with the mobilisation of attention and resources, however, representation also includes lobbying activities, where stakeholders are seen as the "outside world" (Elfrink & Hulsink, 2003). Together these three basic characteristics of collective action may support commercialisation of high technologies, as illustrated in figure 1.

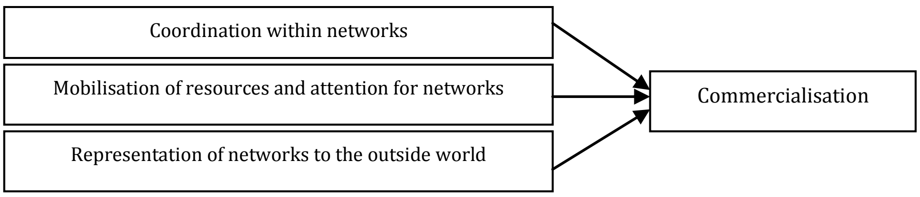

Figure 1: Conceptual Model

2.5 Commercialisation

Scientific literature helps understanding the concept of commercialisation and its possible success. Based on ample experience and case studies, Vijay Jolly (1997) developed a stage model in which the distance from mind to market rather than from laboratory to production is used as a way to describe commercialisation. Jolly's (1997) model of commercialisation is particularly useful for the cases in this research, because it not only provides starting points for investigating the activities carried out in commercialising innovations, but can also be used to distinguish between successful and unsuccessful innovations. Jolly's (1997) stages combine different research and development stages with market building and manufacturing stages. The stages are: imagining, incubating, demonstrating, promoting and sustaining.

In the *imagining* stage an imaginary coupling of the technology with its potential market is created. Out of the competition for ideas rises the interest of resource providers, who only want to be involved in commercially interesting technology development. In the *incubating* stage, the commercialisability is defined. This implies reasoning why and how the technology will be feasible and whether the foreseen needs within the foreseen markets can be fulfilled by means of technology. The incubating stage is related to the collection and security of resources. *Demonstrating* means the actual (physical, at least in a prototype or small batch in the case of new products) coupling with its application. The actual product or process is thus developed in this stage. *Promoting* includes all activities that are related to the introduction and the commercial exploitation of the innovation. *Sustaining* means all efforts after market introduction involved with sales and after sales support in the case of products or services, but also improvement in processes (Jolly, 1997).

Just as important are the bridges between stages. Bridges between stages are related to mobilisation of resources and new stakeholders, being key factors in successful technology commercialisation. Jolly (1997) states that, as the innovation moves from one stage to another, the composition of the stakeholder map changes as well. In other words, the group of stakeholders differs along the commercialisation trajectory from mind to market. The early stages show more need for public funding, whereas in the later stages, venture capitalists become more important. This is called the "cast of stakeholders" (Jolly, 1997:p24). Moreover, the early stages require predominantly research partners, later stages require launching customers, or early adopters whereas the stages closest to the market call for end users, or the early and late majority (Rogers, 2003) and suppliers (Santamaria & Surroca, 2011; Luo & Deng, 2009). Jolly's (1997) model seems to provide a framework for the description of commercialisation trajectories and the distinction between successful and unsuccessful commercialisation. Most important here is the distinction between innovations in their final, sustaining stage, or innovations in another stage.

The conceptualisation of "collective action" and "commercialisation" make it possible to study how collective action influences commercialisation in terms of actions that actors take, and in terms of the role that involved organisations play. By examining six cases of microsystem technology commercialisation, successful as well as unsuccessful, the influence of coordination, mobilisation, and representation on the commercialisation of specific developments can be understood.

3 Operationalisation and data

3.1 Operationalisation

First of all, it is important to distinguish between successfully commercialised innovations and unsuccessful ones. By applying Jolly's (1997) commercialisation model, an indicator of the success of commercialisation can be constructed. One can determine the stage of an innovation at a certain point in time. However, there is no guarantee that this stage will be followed by a stage closer to market, because it can still either fail or succeed. Put differently, being close to market does not necessarily guarantee success on that market for an innovation. When an innovation is sold, improved, and users are supported, it is sustained. Only then its commercialisation can be regarded as successful with certainty, at least for the time being. Except in retrospect, there is no definitive way to decide whether an innovation is successful, but being in the sustaining stage does provide a useful indication.

Consequently, an innovation in any other stage at a certain point in time still may fail or may succeed. There is no decisive answer to the questions whether it is or will become a success. In such cases, the level of activity is important. If there are many activities focused on moving the innovation to a stage closer to market, there is a greater possibility that the innovation succeeds. It can therefore be regarded being in a promising situation. When there are not many activities anymore related to the commercialisation of an innovation, it does not matter in which stage the innovation is or was. It can be regarded as depleted rather than sustained. If the last stage in which the innovation found itself was not sustaining, its commercialisation can be regarded as failed.

Numerous ideas occur in the imagining stage, of which only a few are commercialised (Jolly, 1997). Most of these cannot be observed, since no hardware, software, or orgware has been developed. Hardware, software, and orgware are not created before the demonstrating stage. An innovation therefore "exists," in the sense that it can be observed, starting from the demonstrating stage. Failure, that is the depletion of the project, or success, that is reaching the sustaining stage, therefore depends on the stages demonstrating, promoting, and sustaining. This does not mean that imagining and incubating are not important, but rather that innovations that do not pass these stages are invisible in markets. Table 1 represents an overview of Jolly's (1997) stages and the effect of the level of activity.

Jolly Stage	**Imagining**	**Incubating**	**Demonstrating**	**Promoting**	**Sustaining**
High level of activity	N/a	N/a	N/a	Promising	Success
Low level of activity	N/a	N/a	Fail	Likely to fail	Success

Table 1: Level of activity and Jolly stage providing an indication for the degree of success.

Assuming, with the literature review in mind, stating that collective action does incorporate the three aspects shown in figure 1, makes it possible to investigate the role of collective action in the cases. First, in order to operationalise the coordination within networks, the creation and diffusion of knowledge and the matching of partners should be taken into account. Specific features of knowledge creation and diffusion are their effect on firms innovating within such a network. The diffusion of knowledge furthermore involves the presumed presence of a knowledge pool out of which the innovating firm can tap, or the bilateral knowledge exchange between individual partners within a network. A third indicator is the combination of knowledge of different parts of a network within a single innovation. In relation to partners, it is possible to discover whether the partners with which collaboration takes place are found in the network providing for the collective action. This applies to customers, suppliers, and competitors that become partners in an innovation.

Second, to understand if, and how the mobilisation of resources and attention for networks contributes to commercialisation in the cases studied in this research, one can look at the degree of being known within the network and outside the network. Being known relates to obtaining legitimacy. This influences the ease with which resources can be mobilised, contrary to direct resource mobilisation by means of, for instance, acquiring public funding. By examining how the provision of resources came about and the role that networks have played in securing such will provide insight in the security of resources. Also, the mobilisation of attention for networks can be done collectively. Finally, questions about lobby activities help covering collective actions that regard either the acquisition of public resources or favourable innovation policy.

Third, representation to the outside world of networks includes collective marketing as well as communication activities and lobbying activities. The first are easy to trace, and can include digitally or printed joint communication, participation to trade fairs and exhibitions as well as shows and seminars that include technical lectures. The degree to which single organisations within a network participate can differ. They can assist in the organisation, think about concepts and shows, or just participate with a presentation either technological or commercial. The participation of organisations in formal collective arrangements like industry associations, or innovation programmes which include SME are a step further. The latter can be examined by the questions about lobby activities that regard the mobilisation of resources and attention for networks. The operationalisation is listed in table 2.

Concept	Dimension	Indicator	Scale
Commercialisation (DV)	Distance to market	Jolly Stage (imagining, incubating, demonstrating, promoting, sustaining)	Nominal
	Level of activity	Activities (low-high level)	Ordinal
Coordination within networks	Knowledge creation and diffusion	Knowledge creation and diffusion	Nominal
		Knowledge pool	
		Knowledge combination	
	Partnering	Finding partners in coordinated networks	Nominal
Mobilisation of resources and attention for networks	Public debate participation	Physical debate participation	Ordinal
		Online debate participation	
	Direct resource mobilisation	Public funding	Ordinal
	Lobby activities	Lobby activity input delivery	Nominal
Representation of networks to the outside world		Formal collective agreement participation (e.g. MinacNed)	Nominal
	Collective marketing and communication activities	Digital or printed material	
		Trade fair and exhibition	

Table 2: Operationalisation

3.2 Data

The cases studied in this research were found within the networks surrounding the association MinacNed. MinacNed (MIcrosysteem- en NAnotechnologie Cluster NEDerland), is an association with sixty member organisations, mostly NTBFs but also established firms, universities and research institutes. The association seeks to reinforce the economic activity in the Netherlands based on microsystem technology and nanotechnology. Hereto, the association activities along three routes are focused on collective marketing activities and market development, interest protection, and the development of the organisation of the association (MinacNed, 2011). This can be technology specific clusters, subsidy programmes, or other activities that benefit its members.

Despite the fact that nanotechnology has a lot of promises for the future and the association keeps track of all developments, microsystem technology currently is the most important concern of the association, since most economic activity involves microsystem technology. Also, more members are involved in microsystem technology. Members that have activities regarding nanotechnology are often either university research groups or equipment manufacturers and suppliers. Table 3 gives an overview of the innovations that are investigated. The table provides for each case the key firm and other organisations involved. All cases involve an innovation that is at least partly based on microsystem technology. They are all developed in the Netherlands, and by joint development. They differ, however, in the degree of success. It is expected that forms of collective action have influenced the degree of success in the cases.

	Innovation	Key firm	Other involved
1	C2V-200 Micro Gas Chromatograph	C2V-Thermo Fisher	University of Twente
2	Microcryogenic Cooler	Kryoz Technologies	University of Twente, Micronit, ASTRON
3	IQ+Flow Mass Flow Sensor	Bronkhorst High-Tech	LioniX
4	Medimate Multireader	Medimate	University of Twente
5	MST Windmeter	Mierij Meteo	LioniX
6	Microflown for consumer	Microflown	Sennheiser

Table 3: Cases

4 Method

In order to collect data about the cases semi-structured interviews are conducted. Semi-structured interviews can provide more insight than a survey, which either requires substantial information about the concepts in advance, or follow-up interviews. Free attitude interviews, on the other hand, provide a lot of in depth information about the cases, but this type of interview does not inshore that relevant topics will be discussed, whereas a semi-structured interview guarantees this by using a topic list. The topics that were used during the interviews are listed in appendix A.

The interviewees were selected by the snowball method. Starting with the representative of the organisation that commercialises the innovation, additional interviewees are found by including interview questions that regard partners. This can be either horizontally (technology partners), or vertically (mostly suppliers, also customers). The snowball method has the advantage that the interviewees are actively involved in the cases that are under observation. It will not happen that a group is investigated in which the units are not related.

In order to increase validity of the data generated, interviews with more representatives were held where possible, but also document analysis was performed. By cooperating with the association for microsystem and nanotechnology in the Netherlands, MinacNed, a lot of networks were accessible for the sake of this research. This association covers a significant part of the cluster and the networks in the Netherlands. Furthermore, some lobby activities that are organised in a more or less coordinated way are expected to take place in name of the association and its adherents. Where possible, documents that are present within the association MinacNed were included to increase the validity of the data. This can include meeting reports, but also for example cooperation statements.

The acquired data have resulted in believable reconstructions of the cases; subsequently the role of collective action was investigated via the three aspects described above. The roles of coordination, mobilisation and representation within the single cases were analysed. Furthermore, the successful cases were compared with the unsuccessful cases. By including both successful and unsuccessful cases, it is possible to identify when and why success occurs and what the role of collective action has been.

5 Results

In this section, the results are discussed. In each subsection a case is described in a uniform way. First, the innovation is shortly described in terms of product, process or service, the market in which it is commercialised, or was intended to be, and the technology, a so-called product (or process) market technology combination (PMTC). Secondly, the commercialisation trajectory is reconstructed, following the model of Jolly (1997). Thirdly, the network in which the innovation was developed is described. Finally, the role of the three identified aspects of collective action is discussed. The cases are put in alphabetical order. All information that has no reference is based on the interviews held. All other information has a reference. Table 4 lists all conducted interviews

Case	Organisation	Interviewee	Date
C2V-200 Micro GC	C2V	Vincent Spiering	16 June 2011
	enablingMNT	Henne van Heeren	16 July 2011
IQ+ Mass Flow Sensor	Bronkhorst High-Tech	Wybren Jouwsma	17 June 2011
	Bronkhorst High-Tech	Joost Lötters	17 June 2011
	LioniX	Henk Leeuwis	1 August 2011
Medimate Multireader	Medimate	Steven Staal	29 June 2011
	enablingMNT	Henne van Heeren	17 July 2011
Microcryogenic Cooler	Kryoz Technologies	Pieter-Paul Lerou	22 June 2011
	Kryoz Technologies	Erik-Jan de Hoon	22 June 2011
Microflown	Microflown Technologies	Alex Koers	22 June 2011
MST Windmeter	Veluws Centrum voor Technologie	Rijk Verheul (former Mierij Meteo director)	20 June 2011

Table 4: Interviews

5.1 C2V-200 Micro Gas Chromatograph

5.1.1 Product market technology combination

The C2V-200 Micro Gas Chromatograph is a small system by which the composition of a gas mixture can be analysed. For that purpose, the gas is led into a gas chromatography instrument containing a microchip. Claimed advantages over competing GCs are ease of use, reduced maintenance, and low gas consumption (C2V, 2009). It is commercialised by C2V, a company recently acquired by Thermo Fisher Scientific. C2V was a university spin-off, based on microsystem technology developed by the University of Twente. Therefore it was then regarded a NTBF.

The product has been developed for the laboratory market, and the professional market in the process industry. It is sold either as a stand-alone or as an integrated system. Its purpose in the process industry is to check processes. The device performs gas chromatography using smaller samples, and it works faster and more accurate.

The core technology of the C2V gas chromatographic instrument is a microchip developed at the University of Twente. The initial idea was to use it as a flow sensor. As such, one of its weaknesses was its dependence on the gas properties. One must know the exact specific conductivity of the gas in order to be able to calculate the gas flow. It was realised that is could also be used differently: if the gas flow is known, the device can measure the conductivity. The market for analytical devices offers much more space for entrepreneurial companies than the flow sensor market and the added value of such a device is much higher than of a sensor in this market. On top of the microchip, the C2V device consists of a number of components to control the gas flow and electronics.

5.1.2 Commercialisation

5.1.2.1 Imagining

In the 1990's, Total Micro Products (TMP) was founded as a firm to commercialise university technology. It was involved in the development of microsystem technology, as a service for commercial partners. In 2000, TMP was acquired by Kymata (Lewotsky, 2000). Kymata on its own turn was acquired by Alcatel, to form the Dutch division of Alcatel Optronics. This followed from an increased interest in optical telecom technologies. In 2002 C2V was established, the founders having bought back the firm from Alcatel after the telecom hype was over. The new firm was based on three core activities. The first was to commercialise knowledge about software that was present inside the firm. Secondly, development services were delivered to third parties, like TMP used to do. Finally, an OEM product development trajectory was started. Herein, the knowledge developed by the University of Twente was to be applied in a commercial product.

5.1.2.2 Incubating

The decision to develop a product meant that the market should be explored. The C2V-200 was developed by a technology push process. C2V first involved only engineers that developed technology. The technology included micro chip technology. A channel system for a flow is added. By applying more chips on top of each other, a complex system can be created. During the development of the lab on chip (LOC) system, the developers did not have an idea about any application for the technology. However, the advising role of large process industry companies was very important.

5.1.2.3 Demonstrating

Only in the demonstrating stage, a working prototype was built, after which aggressive marketing by means of trade fairs was applied. The Pittsburgh Conference (Pittcon) is a good example of a trendsetting international exhibition, where a whole industry is meeting. Pittcon is a very renowned conference and exhibition, organised by the Spectroscopy Society Pittsburgh (SSP), and the Society for Analytical Chemists of Pittsburgh (SACP). The target group is the worldwide laboratory market, and it is often used as a place to present the latest developments before other trade fairs and exhibitions (Pittcon, 2011). HET Instrument is a good example of a Dutch exhibition. HET Instrument is organised by FHI, Federation of Technology Branches, a federation that consists of industry associations for industrial electronics, industrial automation, laboratory technology, and medical technology in the Netherlands. 800 Technology companies are member of one of the four FHI industry associations. HET Instument is the largest technology fair in The Netherlands, Belgium and Luxembourg (HET Instrument, 2011) in terms of surface, number of exhibitors, and visitors. There is a discrepancy between HET Instrument and FHI, because the FHI industry association for medical technology is not represented at HET Instrument. Although it has less impact, partners were found that could help improve the C2V-200, by means of technology input and testing of prototypes.

5.1.2.4 Promoting

The promoting stage furthermore included trade fair and exhibition participation, like Analytica 2010 (Analytica, 2011). Moreover, the involvement with users rather than micro system technology shows, was important. In order to promote the C2V-200 even more, clients were offered to use the C2V-200 for free, as long as they were willing to feedback testing results.

5.1.2.5 Sustaining

The C2V-200 has been introduced on the market. In 2010 Thermo Fisher Scientific acquired the firm. Thermo Fisher is a large multinational firm that develops and sells laboratory equipment. With this acquisition, the sustaining stage started. Distribution and after sales support are now the main tasks. Still, the development of an improved version of the C2V-200 is planned. Under Thermo Fisher, acquisitions are not fully integrated into the firm, but maintain a certain degree of freedom to further develop the niche market. It has an autonomous position.

5.1.3 Network

The network includes competitors on a global scale, customers, technology suppliers (especially electronic components) and the universities of Twente and Amsterdam. Less important, for the development of the C2V-200, are Dutch networks involving collective action on a regional or a national scale, MinacNed or Kennispark Twente, for example. The interviewees state that the providers of venture capital would not be amused if they were to find out that their money was used to pay for activities that would benefit an entire region rather than the interest of the resource providers. However, programmes in which funding could be acquired were interesting and important for C2V, the mobilisation section will reflect further on this.

5.1.4 Coordination

The network described by the interviewee did not involve coordinated action, except for projects with small groups of firms, R&D consortia. In these cases, C2V preferred a leading role. No pool of knowledge was present within the projects. All knowledge transfer was done in bilateral relations between partners, this did not facilitate knowledge diffusion. One of the directors, Job Elders, used to be active as a board member of the association Point-One, which is an association involved in collective action supported by public resources. Point-One will be discussed in the mobilisation section. When C2V was acquired by Thermo Fisher, he had to give up his position as member of the board, because he was selected to represent SMEs which C2V was, but as a part of Thermo Fisher, not anymore.

5.1.5 Mobilisation

The mobilisation of resources was very important, since the availability of public funding was crucial for the firm, and thus the product C2V-200, to survive. Already in the 1990's, a cooperation between TMP and Philips resulted in the mobilisation of public funding. Later, C2V participated in Point-One. Point-One followed from the public support that Philips received in the past. In order to make this support more fair, SMEs were invited to join Philips in a programme focused on technology development support. Point-One is an association of high tech companies and institutes occupied with research and development in nanoelectronics, embedded systems, and mechatronics for health, ICT, leisure, transport and security. Its activities are related to the Phase 2 Innovation programme, including university-industry cooperation, national and international R&D programmes, and support of a knowledge infrastructure (Point-One, 2011). Through the Point-One programme MEMS Land, C2V found Boschman as a partner (Bullema, 2009). C2V realised that being active in innovation programmes would make public funding more accessible, it would also make it possible to deliver input for programme setup. Job Elders was a member of the Point-One board as SME representative.

5.1.6 Representation

In the demonstrating stage, trade fairs and exhibitions where the process industry and the laboratory industry were present were utilised to find partners and to explore the market. The participation in exhibitions and trade fairs was very important for the commercialisation, because in this way, a lot of awareness was created. In the demonstrating and promoting stage, trade fairs and exhibitions were utilised to find partners and to explore the market. The Pittcon is the most important fair for C2V worldwide. In the Netherlands, HET Instrument was the most important one. Later on, when the product was developed, the trade fairs are found to generate publicity for the Micro Gas Chromatograph. C2V participates in the Instrument Guide (Instrumentengids). This is a booklet and website that contains the contact details and a short description of all participating companies (Instrumentengids.NL, 2011). Ten thousand copies of the booklet are printed. No data about the visitors of the website are available. Just like HET Instrument, the Instrument Guide is set up by FHI, Federation of Technology Branches.

Due to the technology push character of the development of the Micro Gas Chromatograph, no cultural terms were involved in the imagining stage, because the risk of unwanted knowledge spillovers overshadowed precompetitive synergy effects. The firm is active in lobbying as well, but more on a personal title than representing the collective, or actively making sure they include the collective that is being represented.

Furthermore, the firm was included in the international organisation MANCEF. This all had the aim to acquire renownedness and increasing the chance of public funding more. C2V currently is active in NanoNextNL, the follow up programme of both MicroNed and NanoNed, both to be discussed below, but this relatively new programme has not yet shown any observable results.

5.2 IQ+ Mass Flow Sensor

5.2.1 Product market technology combination

The IQ+ Mass Flow Sensor is designed for equipment manufacturers. The sensor is able to determine very precisely the magnitude of the flow of a gas. Furthermore, coupled with the appropriate software, it is able to determine the composition of this gas. The advantages of using microfluidics, so claims proprietor Bronkhorst High-Tech from Ruurlo, are the small amount of reagent needed, the downscaling cost savings, and the faster generated results. Bronkhorst High-Tech started as a NTBF, but already exists a number of decades.

The IQ+ Mass Flow Sensor was introduced during the Pittcon 2005. Customers can choose a number of sensor types, a liquid sensor, a pressure sensor, or a mass flow sensor. Also, a version that can be integrated into a processing system is included. The sensors include a measurement and control system. It furthermore includes software and a system to connect it into a flow system. However, most customers are OEMs or system integrators. Therefore, the IQ+ Mass Flow Sensor can be regarded as a component within a (closed) gas or liquid system rather than a product or system.

The main concern in developing the IQ+ Mass Flow Sensor was miniaturisation. Miniaturisation is necessary for doing (mostly) gas analysis in the field, since such a system consists of a lot of components. Making all components smaller results in a smaller and more manageable system. The sensors are applied in the analysis industry, for example in mass spectrometers and gas chromatographs, automotive, equipment manufacturers, and solar cell factories. For the future, applications are expected in semiconductor markets. The chip inside the IQ+ Mass Flow Sensor was specially developed for the IQ+ Mass Flow Sensor. Technically, the challenge was to integrate the pyrometer into a chip. This knowledge was brought into the project by TNO.

5.2.2 Commercialisation

5.2.2.1 Imagining

The whole process of developing the IQ+ Mass Flow Sensor started back in 1975, when Professor Simon Middelhoek stated that if one could make chips with integrated circuits, one could also make chips with sensors. A university research project was initiated in which PhD students at Delft University of Technology (Technische Universiteit Delft, TU Delft) performed research in developing a flow sensor. The target of these activities was to develop a chip that contained a sensor. This had no application, but Bronkhorst High-Tech technical director Wybren Jouwsma nevertheless was involved, seeing the commercial potential for the analysis market.

5.2.2.2 Incubating

In 1983, Professor Fluitman of the University of Twente actually developed a flow sensor, that was able to measure flow, but this was not usable for integrating it into marketable products. In the 1990's, the focus shifted from the technology to the market. The intended market was the analysis market, which is currently still of interest. The reactions from the market were negative at first, because the potential customers expected several problems, and they had a point. In the end of the 1990's, however the Swiss firm Sensirion was established, starting as a supplier of Bronkhorst High-Tech, but moving to the same concept as Bronkhorst High-Tech. Sensirion aggressively approached potential users (the analysts) by stating that they had solutions without any additional costs. In this way, the analysts' interest was created, but they also reached other potential customers of Bronkhorst High-Tech products. Bronkhorst High-Tech was therefore approached with the question why they did not deliver such a system and they started to realise that there was a need for such a system in the analyst market existed. Therefore, the existence of a serious competitor forced Bronkhorst High-Tech to give the development an impulse.

5.2.2.3 Demonstrating

In order to fulfil the market demand, Bronkhorst High-Tech started the actual development, and the demonstrating stage was reached soon. In 1999, Bronkhorst High-Tech participated in the subsidy project BTS together with the Netherlands Organisation for Applied Scientific Research (Nederlandse Organisatie voor toegepast-natuurwetenschappelijk onderzoek, TNO), 3T (current LioniX), and the University of Twente. A consortium was formed that transformed the principle into a usable technology and product. The team was composed with care to create a complementary group of organisations, with Bronkhorst High-Tech taking the lead. Bronkhorst High-Tech knew the targeted market, the specifications of the clients, and how to integrate chip technology into a product. TNO was included for their modelling skills and fluidic knowledge. The University of Twente, a technical university, was selected because of their state of the art knowledge about sensor technology and to get access to their clean room. LioniX was included for its expertise in small scale production of microsystems. LioniX still had to develop a chip specifically for the IQ+ Mass Flow Sensor. The small volumes that come with a high-end market are favourable for the development of technology by SME, since they do not have the resources to invest in cheap products with large volumes.

The cooperation resulted into a usable analytic instrument. A marketable project, however, would require a lot more research and development, and the focus in this project was still in research. In 2001, Applied Instruments, a firm that produces analytical instruments, joined the consortium. As a producer and known player in the analytical market, Applied Instruments provided the perfect link with the users of the technology. On the supply side, Elect joined the consortium, not so much in developing the technology but as a component supplier. Eventually, the IQ+ Mass Flow Sensor was introduced at the Pittcon in 2005.

5.2.2.4 Promoting

At the Pittcon, a demonstrator kit containing three versions of the IQ+ Mass Flow Sensor and the software was sold on the spot to booth visitors. This differs from the traditional way of promotion at technology fairs where only contacts are obtained, which might turn out as potential buyers. This early sales resulted in fast feedback about the performance and needed improvements of the product.

Trade fairs and exhibitions proved to be an important way of promoting the IQ+ Flow Mass Flow Sensor. In the Netherlands, HET Instrument was the most important trade fair, because the main actors on the Dutch market are present at this fair. Furthermore, the Electronics & Automation fair was used for promotional activities. This fair is smaller, yet more specialised compared to HET Instrument. Finally, advertisement in specialist literature and other magazines was used for promotion.

5.2.2.5 Sustaining

Sustaining the innovation in this case is done by replacing conventional components and original equipment manufacturers (OEMs). It took 5 years from the development trajectory and another five years to develop the market.

5.2.3 Network

Bronkhorst High-Tech strictly distinguishes between the network of customers and the network of suppliers. On the side of the suppliers were amongst others their aforementioned partners the University of Twente, TNO, and LioniX each with their own specific added value. In a quite natural way, the consortium grew out of the existing network surrounding Bronkhorst High-Tech, and later on Elect and Applied Instruments joined. TNO was already involved in flow sensor technology projects, LioniX was involved in electronics projects.

Bronkhorst High-Tech has experienced a difficult relation with competitors. Sensirion is regarded as a competitor, because they applied the same technology in the same market, while they initially acted as a supplier for Bronkhorst High-Tech. Customers, especially launching customers, were initially found at the Pittcon. The new product was also offered to customers in the existing network of Bronkhorst High-Tech. Knowing the market and already having a good reputation means that the barriers for commercialisation were much lower than in the other cases studied.

5.2.4 Coordination

Knowledge exchange within the network is actively promoted, because the partners applied to the advantages of open innovation. The deeper technical knowledge diffusion, however, is limited to the partners directly involved in the development of the IQ+ Mass Flow Sensor. Strict agreements regarding intellectual property and scientific publications from TNO or the University of Twente were made in advance of developing such knowledge. Scientific publication was only allowed with the permission of Bronkhorst High-Tech, and only after patentable knowledge was secured.

Within the project, Bronkhorst High-Tech played a coordinating role. During regular six-weekly plenary meetings, the project and its advancements were discussed, and additional tasks were allocated. In between meetings, however, all necessary communication was bilateral. Due to the fact that partners were chosen to form a complementary team, the combination of knowledge in the innovation can be recognised in the resulting composition of components. The project was performed in an informal atmosphere, which is necessary to work smoothly together. Innovation is regarded as steered coincidence, therefore, strict procedures to maintain the network are not regarded effective by the interviewees. The role of the University of Twente was limited, because the focus of the University is to do research rather than to commercialise technology. However, it triggered the university to think of follow-up projects and products. LioniX introduced a new supplier to the network, Elect, a company that was able to do some specialist assembly work, mounting the chip on a silicon house.

5.2.5 Mobilisation

The BTS project was a subsidy programme in which Bronkhorst High-Tech participated with its partners LioniX, TNO, and the University of Twente. There were two projects in which the technology was developed, of which the second was more focused on commercialisation rather than technology development. Bronkhorst High-Tech found their partners through their existing network, in which also other projects were carried out. Furthermore, the MicroNed programme played a role as well, Bronkhorst High-Tech, LioniX, Micronit and Demcon were involved in SMACT, a part of MicroNed.

The programme MicroNed, in which the natural gas benefits were invested in the reinforcement of the economic infrastructure through the so-called FES (Fonds Economische Structuurversterking), was divided into technological themes in which different research projects were initiated. This involved first and foremost universities, including the three technology universities in the Netherlands. Within MicroNed, however, also industry, mostly SMEs, was included. The theme Smart Microchannel Technology (SMACT) was part of the MicroNed programme. One of the applications of microchannels was flow sensors, a variant of the IQ+ Mass Flow Sensor. MicroNed is described in terms of collective action: it is publicly funded, but a large network of not only firms, but also (technical) universities has made this public funding available for the development of this technology.

Lobbying collectively is actively performed by Bronkhorst High-Tech. Bronkhorst High-Tech's activities are focused on education, development (including university activities), entrepreneurs and the government, including politics. The Confederation of Netherlands Industry and Employers (Verbond Nederlandse Ondernemingen - Nederlands Christelijk Werkgevers-verbond; VNO-NCW) and play an important role in which united entrepreneurs lobby for, amongst others, subsidies for technology development. But the most important is the representation of "microsystem technology" in the Netherlands in general. Minac was the ancestor of MinacNed, as well as the Sensor Technology Club, but this did not evolve into a microsystem technology club. Both LioniX and Bronkhorst High-Tech were involved in Minac. MinacNed had a role in the realisation of MicroNed and NanoNed. Transforming Minac into MinacNed would provide one representative organisation of the technology and the firms involved in the Netherlands. One of the interviews said about the role of lobbying in the development of the IQ+ Mass Flow Sensor

"You cannot say that lobby activities have not played any role? (...) You cannot say that it was caused by (the lobby activites), but is must have had some contribution. What would have happened if we held our course?"

5.2.6 Representation

Brand awareness is very important in high tech sectors. The reason is that suppliers for very innovative products do not exist and are sometimes very hard to identify. Being known makes the right suppliers of knowledge, technology, or components, more accessible, although this cannot be predicted. Maintaining the network therefore is very important. An example thereof is participating in trade fairs like the Precisiebeurs (precision exhibition).

Trade fairs and exhibitions are important. In some of them, Bronkhorst High-Tech takes a leading role, like in the Netherlands MicroNanoConference, where the most important developer of the IQ+ Mass Flow Sensor, Joost Lötters, participates in the programme committee. The Netherlands MicroNanoConference is the largest microsystem and nanotechnology event in the Benelux region. The conference has a scientific and a commercial part. Within the scientific part, lectures of academics and industry intend to cover knowledge distribution within networks, hence coordination within networks. The commercial part consists of an exhibition, intended to facilitate representation. The Netherlands MicroNanoConference is organised together with MicroNed and NanoNed. In others, like HET Instrument, Bronkhorst High-Tech just participates for image building, and to meet new potential partners. The Pittcon is an exhibition in the

United States of America, where the laboratory industry is present. The Sense of Contact is an exhibition focused on sensor technology, an important component of Bronkhorst High-Tech's IQ+ Mass Flow Sensor.

Wybren Jouwsma, Bronkhorst High-Tech's shareholding director, was the first chairman of MinacNed, the association for microsystem and nanotechnology (Micronanocluster Nederland, vereniging voor microsysteem- en nanotechnologie). Henk Leeuwis from LioniX, one of Bronhorst's partners in developing the IQ+ Mass Flow Sensor, was also one of the founders of MinacNed. The importance of the network in finding the right partners to cooperate with in the development in new technology in general, and the IQ+ Mass Flow Sensor specifically, and the possibilities to build and maintain a network through the association were the main reasons to get involved in this. Since innovation is never finished, an association is being regarded as the way to keep being inspired. Another reason was that in order for the natural gas benefits to get invested into microsystem and nanotechnology, governments required a single organisation to represent the sector. The company Bronkhorst High-Tech was also a member of FHI, and it was suggested by Wybren Jouwsma that FHI would be the ideal partner for MinacNed to assist in the running of the association.

Joost Lötters furthermore is member of the steering committee of the recently established industry cluster MicrofluidicsNL. It was established on 1 October 2010. Its purpose is to jointly build up the market in the Netherlands for microfluidics. This is done by interest protection, collective marketing, and individual service provision, thereby touching all three collective action aspects identified in the literature. Members of MicrofluidicsNL are affiliated with FHI or MinacNed (MinacNed, 2010). Although the IQ+Mass Flow Sensor was already introduced on the market before the cluster was established, they intend to meet new contacts through the cluster that can lead to improvements and new versions of flow meters. Microfluidics is a specialism that still is in development, both for Bronkhorst High-Tech and for the technology in general. By participating in the cluster, they intend to walk in front of developments. The cluster intends to build up the market in the Netherlands, by means of collective marketing, the promotion of interests of the members, and individual services. Networking as well as knowledge diffusion in the cluster is done by means of interactive workshops.

Collective marketing activities that are printed or digitally available are the profile guide "Microfluidics: Holland's high tech Entrepreneurship in Microtechnologies" and the Instrument Guide. The profile guide "Microfluidics: Holland's High-Tech Entrepreneurship in Microtechnologies" is a booklet presenting fifteen companies or institutes active in microfluidics; technology development or applications. Participants pay for the production of the booklet and are represented by their company profile. Two thousand copies are printed, half of it is distributed by the participants, the other half is distributed by the association agency. This activity provides the opportunity to represent networks to the outside world. Both the profile guide and the Instrument Guide are non-profit marketing activities organised respectively by MinacNed and FHI. Bronkhorst High-Tech participates because of the brand imaging, despite the fact that competitors participate as well. In fact, not participating because of competitors cannot be justified since interested parties that consult these media would only find the competitors.

5.3 Medimate Multireader

5.3.1 Product market technology combination

Medimate is a typical NTBF. It was founded to commercialise lab-on-chip technology developed in the MESA+ laboratory of the University of Twente. The Medimate Multireader is their first product to be introduced on the market and provides bipolar patients the opportunity to measure lithium rates in their blood by a simple home test. This is intended to reduce healthcare cost and increase patient comfort.

In 2005 the research results of a lab-on-chip group on the University of Twente were published. It was found that measurement of lithium in a blood sample of one droplet was possible by means of a lab-on-chip system. Two students, Arjan Floris and Steven Staal, came up with the idea to commercialise this technology into a product for self tests of bipolar patients.

Lithium salts are used as a therapeutic drug, but can be dangerous in high doses. Current measurement techniques are lab based and therefore not suited for regular control. They are however very reliable and cost effective. The Medimate Multireader aims to improve this situation by offering a Point of Care device for patients to use in a domestic situation. They work hard for the last two years to improve yield and also the reliability, which is a critical item in medical products.

The product consists of a disposable consisting of two bonded thin glass chips in a plastic carrier and a entrance point for the blood sample. In this device, capillary electrophoresis is performed. By means of an electrical field, the ions are drawn out of the blood sample. As each type of ion has its own diffusion speed, they are separated from each other. By measuring the conductivity, one can identify the individual components, Na+, Li+, K+ etc. On a display, coupled to the chip, information about the composition of the blood sample, in this case the lithium, is presented.

5.3.2 Commercialisation

5.3.2.1 Imagining

The innovation followed the research work of Elwin Vrouwe, at the University of Twente. Professor Albert van den Berg of the University of Twente was the first to advocate the development of a commercial product out of the technology in 2005. From the start, bipolar patients were seen as the target market. But at the same time, it was also evident that the platform of the Medimate Multireader has potential for other analyses, like measuring sodium (Na^+) or potassium (K^+). The device is developed with disposable sensors, so that cheap and simple tests can be performed. In order to build trust, try out systems are made available for professional markets, like clinical chemistry or psychiatry. The regulation for the medical market differs between nations. This makes it very complicated to commercialise the Medimate Multireader in an international context. Furthermore, the medical market has very strict demands on quality.

5.3.2.2 Incubating

The greatest challenge was to finance innovation. Feasibility studies and patent applications were important means of convincing financiers to finance Medimate, the new firm that was founded especially to commercialise the multireader. The early stage of the process also included time to create business plans. The most important source of finance was a subsidy from the technology foundation STW, the first phase valorisation grant.

The technology foundation STW is responsible for allocating public funding for university research projects and facilitating industrial participation in the initiated process. The valorisation grant is utilised in order to fill the finance gap that has been encountered in the past between research and commercialisation (Technologiestichting STW, 2010). Attracting external private investors requires a more than just a proof of principle. Valorisation grants are meant to facilitate the process of commercialisation. More feasibility studies were performed, but an attempt to receive the second phase valorisation grant failed at first. Only in the end of 2006 this second phase valorisation grant was received. An experienced industrialist, Huub Maas, joined the organisation by means of a management buy in. He was charged with product development as well as attracting new financial sources.

5.3.2.3 Demonstrating

The development of a market ready system started. Some setbacks were encountered. Partly because of the experience that Huub Maas brought into the organisation, it was possible to overcome these problems. From 2007 onwards, a reliable point-of-care (POC) measurement system was developed. At the end of 2008, the first prototype was ready, but this did not confirm to the required specifications. A larger model was developed, producing less heat. The correct working of this product was proven in the end of 2009, which resulted in CE certification, necessary to sell a product. This was followed by market tests that demonstrated that the reliability was still not high enough. Thanks to some fundamental changes currently being developed, the reliability should increase substantially to reach a level needed for commercial sales.

Another difficulty of the medical market is the validation of the production process. The medical market requires a production process, that guarantees that the product can be produced reliable and reproducible in the future. Robustness is also a very important characteristic, while the Medimate Multireader is to be used in a domestic setting; it should be suited for non-professional users.

5.3.2.4 Promoting

At this moment, about twelve persons work on the first commercial release, although several demonstrators are already sold and in use. The new versions are expected to be even more reliable. Achmea, a health insurance company, is involved in projects introducing the product in different markets to test it with medical professionals as well as patients. In a research project sponsored by Achmea, Trimbos Institute in involved, patient experience is protracted. Furthermore, in another research project the suitability to measure sodium in urine was demonstrated. This was sponsored by the kidney foundation. This measurement has less stringent reliability demands, its suitability was quickly demonstrated. The opportunities to run those projects were created by actively searching the right parties to cooperate with, partners far outside the normal scope of a technology project like insurance companies (Achmea), relevant patient or medical professional organisations and individuals. Financing for such projects is always specific compared to more general funding programmes like MicroNed.

Despite of the different applications and markets that the technology can apply to, Medimate only focuses on the medical market. Other applications will be consistently spun out, like Blue4Green that uses the technology for the veterinary market.

5.3.2.5 Sustaining

Not much information about the sustaining stage is available, since strictly taken, this stage is not yet accomplished. It is, however, very likely that this stage is soon to be reached, because the development of the product is far advanced, and there are established relations with the user community. However, this stage is expected to become a complex one. In every nation, regulation about medical devices differ, and all are complex.

5.3.3 Network

Medimate's network starts at the University of Twente, especially the BIOS Lab-on-chip group led by professor Albert van den Berg. Throughout the development of the Medimate Multireader, the University provided a lot of knowledge of the technology and access to research facilities. But furthermore, the network consists of non micro-nanotechnology actors mainly. These include Achmea, a Dutch health insurance provider, and organisations active in the health care sector, like the kidney foundation and the Hans Mak Institute, or the Association for Manic Depressives and Involved ones (Vereniging voor Manisch Depressieven en Betrokkenen; VMDB). In this network, Medimate can be regarded as a supplier. They need the user network because of the specific characteristics of the medical sector, which is a very complex sector. Most partners of Medimate were found through the network of the University of Twente.

Micronit is an important partner on the supply side. Micronit is a spin-off from the University of Twente, that is specialised in fabricating glass chips with microchannels. Their location and specific technological knowledge is an advantage, but the fact that they are one of only a few suppliers worldwide provides a risk. Within this cooperation, knowledge of both companies is combined. enablingMNT is a partner that provides advice on the production process. This is also in the supply side.

5.3.4 Coordination

The most important knowledge transfer regarding the Medimate Multireader is between the university group and the firm Medimate. Not only are ideas generated jointly, also students have joined Medimate on a temporary base to perform research activities. The key role that Medimate plays in the development of the Medimate Multireader implies a coordinating role. Micronit is a technological firm as well, knowledge exchange involves the design and production of the chips, but also ramping up of the production. Because of their involvement in the promotional research that preceded the foundation of Medimate, they remained involved in the development and preproduction of the Medimate Multireader. Achmea is involved in the development of the Medimate Multireader, but not in a technological sense. A workshop initiated by the University of Twente, which actually is organised periodically, provided the contacts with this insurance companies, which resulted in a sponsorship.

The region of Twente provides infrastructure for high tech development, with a key role for the University of Twente. A very important collective artefact thereof, the MESA+ laboratory of the University of Twente, is used by high tech companies from that region. Within the laboratory, cleanroom facilities can be used. The University of Twente intends to present the Twente region as a high tech "ecosystem", to which purpose a developed infrastructure has been built up. Thereto, the university actively lobbies for public funding for technology development in the area of microsystem technology.

Without the explicit intention probably, HET Instrument played a role since Huub Maas and Medimate found each other at that exhibition. This was during the lecture programme, where Huub Maas was present and Medimate was nominated for an award.

5.3.5 Mobilisation

One of Huub Maas's roles in the development of the Medimate Multireader is resource mobilisation. These are bank loans, Achmea and kidney foundation sponsorship, but also the province and the region of Twente. The funding from Achmea followed from consulting together after having met on a workshop of the University of Twente. Specifically, the regional government is to be mentioned. Knowledge Park Twente (Kennispark Twente) is a regional foundation and an initiative of the province Overijssel, the municipality of Enschede, the University of Twente and the Saxion University of Applied Science. Its mission is to provide for an attractive climate for high tech firms to establish. Hereto, real estate, joint research facilities and incubating facilities are set up. This is the High-Tech Factory, which is partly publicly funded. Furthermore, financing, coaching and events are organised (Kennispark Twente, 2011).

Mobilisation of attention goes through the same channels. The university provides entrepreneurs the opportunity to get into contact with politicians like prime minister Mark Rutte, or former minister Maria van der Hoeven. Medimate also participates in regional activities like university view days. Within the region of Twente, local government is very keen on supporting high tech companies. This is because, as opposed to the conurbation "Randstad" or the Eindhoven region in the Netherlands, the Twente region has yet much less economic activity. Being aware of this, public resources were made available to correct this situation. The entrepreneurial attitude of the University of Twente perfectly fits to this local construction. High Tech Factory is the shared research and production facility of NTBFs from the region that share a cleanroom, financed with public funding of 11.7 million Euro's from national and regional governments.

5.3.6 Representation

Trade fairs and exhibitions play no role in the development of the Medimate Multireader or any activity of Medimate, because, according to the interviewees, such participation has no added value without a commercial product. Only meetings that can provide either funding or technological progress are regarded as useful. When the product is finished, only meetings where potential customers can be found are thought to be useful. This need not be trade fairs and exhibitions.

HET Instrument provided added value during the development, especially in the incubation stage. This has resulted in the assignment of Huub Maas. Medimate participated in the technology congress, a number of poster presentations in psychiatry, but now only focuses on product development and deadlines. They participated in the profile guide because this was made possible financially. This was because of the microfluidics activities of the region, sharing it with the lab-on-chip group of the University of Twente, and the colleagues from Blue4Green.

"In the region of Enschede, we have a microfluidics cluster, and what we do is very interesting. If it is not too much trouble, we are glad to contribute (...) on the other hand, it is not where our clients come from (...) you can invest time in it, but it will not result in revenues."

Furthermore, the participation in associations or innovation programmes has no added value, according to Medimate. The target group cannot be found in associations of technology companies, because these are patients and medical professionals. Medimate was involved in NanoNed, however, because NanoNed could provide funding. NanoNed was, just as MicroNed, a research programme of universities (and to a lesser degree companies, of which the main role was reserved for Philips), in which the natural gas benefits were utilised to reinforce the economic structure.

5.4 Microcryogenic Cooler

5.4.1 Product market technology combination

The Microcryogenic Cooler is a cooling device that can be used in systems where low temperature leads to better performance. It is based on microfluidic technology, developed by the University of Twente. Its added value is its small size, and its ease of use. Both make it applicable in systems where small size and low energy consumption are crucial. It is commercialised by Kryoz Technologies, an Enschede based NTBF just like C2V. The Microcryogenic Cooler is a product that cools down chips and other components to cryogenic temperatures, ranging from 4K (-269 ºC) to 70K (-203 ºC), in order to reduce the noise in incoming and outgoing signals in antennas and sensors. The system is intended to become a plug-and play system, but also a laboratory application is in development.

The first application, the plug and play system, is intended to become integrated into infrared sensors in night vision equipment, space electronics, process technology, X-ray sensors for the inspection or defence of equipment, low noise amplifiers of mobile networks in telecom, radio astronomy for space research, and super conduction applications. The advantages over conventional cooling systems are the reduced size, the reduced energy consumption, the better performance, and the improved reliability due to the absence of moving parts.

Cooling of such devices will contribute to noise reduction. In telecom base stations, the Microcryogenic Cooler will increase the range of the base stations with a factor two. For super conducting applications, the low temperature is necessary to reach the desired conductivity. Current coolers are sterling machines, with pumps and moving parts that keep the temperature low, but create vibrations that increase the noise. The advantage of the Microcryogenic Cooler is that the system operates without moving parts and is fully integrated making it much smaller. Furthermore, having no moving parts, the reliability is expected to be higher, saving on maintenance for its users.

The second application is a type of cooler in which the cooling chip is built in a laboratory device. The microcryogenic cooling performance makes it possible to perform cryogenic tests within (R&D) laboratories very fast, cooling in 8 minutes instead of hours, but is less suitable for field applications, because of the large additional systems needed. The development of this product is intended to reach commercial sales earlier than the integrated system.

The technology involves both cryogenic cooling as well as sorption technology. Microcryogenic cooling works according to the principle of the refrigerator. Nitrogen is compressed. When it passes a heat exchanger, it is expanded, resulting in a cooling effect. The sorption technology is based on active coal. Cooled down coal takes the gas on, when it is heated, the gas is repulsed again. In this way, a cycle exists.

5.4.2 Commercialisation

5.4.2.1 Imagining

The development started in 1997, when the Low Temperature research group of the University of Twente, led by Marcel ter Brake facilitated the promotion of Johannes Burger, developing a chip that had a cooling mechanism based on MEMS technology. The PhD work resulted in a proof of principle. A new research project, in which Pieter Lerou participated until 2006, led to the development of a cooling chip that was smaller and made out of one material. Technology foundation STW financed the research and coupled the university group with a user committee in which a number of interested (commercial) parties participated.

After his promotion, Lerou started working at an Australia based large provider of telecom antenna's, Lerou integrated chips into the telecom base stations. At this point the idea to use the technology in telecom base stations came up. In 2008, Kryoz Technologies was founded, with the intention to develop a marketable product, a plug-and-play system. Furthermore, a medical application was identified later.

5.4.2.2 Incubating

A valorisation grant facilitated the first step towards financing the development of the Microcryogenic Cooler. In order to generate cash flows on a short term, the laboratory application was pursued. The cooling system had already been developed in university settings, but the sorption technology was not far enough developed yet. Therefore, a new application was developed, that did not require the sorption technology to function. Despite the fact that most effort was put into the development of the laboratory application, all experience and learning involved will also be used in the development of the plug-and-play system whenever appropriate.

5.4.2.3 Demonstrating

Currently, the laboratory application is fully engineered, all integrated parts are developed. The prototype is currently delivered to a number of launching customers, universities institutes, and even R&D companies. These customers are asked for feedback. The knowledge that is generated will, whenever appropriate, also be applied to improve the plug-and-play system (MicroNed, 2010)

5.4.2.4 Promoting
Although the Microcryogenic Cooler is still in a prototype state, promotional activities are already started. Kryoz Technologies presents itself at a number of exhibitions. Furthermore, since a number of launching customers have found Kryoz Technologies through their website, this website is regarded as an important promotion tool, on which a lot of time is spent. They also actively promote the Mirocryogenic Cooler, at least the technology and its promises, through their network. Finally, a number of non-advertorial publications were made in regional newspapers.

5.4.2.5 Sustaining
The Microcryogenic Cooler unfortunately has not yet reached the sustaining stage. This makes it difficult to tell something about the success of commercialisation. It is however regarded promising, because of the high level of activity currently in the development of the plug-and-play system of the Microcryogenic Cooler.

5.4.3 Network
Kryoz Technologies distinguishes between suppliers and technology partners (knowledge suppliers). The suppliers are found in the region, which is expected by regional public funding suppliers. In technology development, the partners can be found on a national scale. Users, like ESA or Astron are involved in the development, in terms of user needs and required specifications. Furthermore, the University of Twente is involved in the development of the Microcryogenic Cooler.

Their network relies on formal member networks, of which MinacNed is a national scale association, and the others, Knowledge Park Twente (Kennispark Twente), Venture Lab Twente, Technology Circle Twente (Technologiekring Twente) are all regional activities in which the University of Twente, Saxion University of Applied Science (Saxion hogeschool), and the province of Overijssel play a leading role. Technology circle Twente is a business support initiative of the University of Twente, for technological entrepreneurs in the region of Twente. The regular member meetings, in which current issues are treated, serve the diffusion of knowledge and provide attendees with the opportunity to work on their networks. In addition, all sorts of match making events are organised. One hundred eighty firms are member of technology circle Twente. It is region based, but diverse in technology (Technologiekring Twente, 2011).

Within mostly international consortia, but also national initiatives like the MicroNed programme (MicroNed, 2010) joint developments regarding the Microcryogenic Cooler result in contact with potential customers. Because of the specificity of the developments, involvement in Kryoz Technologies leads to a position as the only supplier of the outcome of the consorted projects. One example is FEI, with which Kryoz Technologies is involved in a project. Engineering firms are involved to assist with the coupling of their technology with the specifications of their customers. Other examples are ESA, Astron and the University of Twente. The glass chips are developed and produced by Micronit, because of their expertise in glass production. Criteria are reliability and the possibility to jointly develop chips. These are considered more important than aspects like costs.

5.4.4 Coordination
Since the network of Kryoz Technologies mostly involves MinacNed and the regional initiatives, coordination often takes place outside Kryoz Technologies. Venture Lab is an entrepreneurial support office initiated by NIKOS, which is part of the university of Twente. Venture Lab provides business development support (Venturelab Twente, 2011) Venture Lab Twente is focused on start-up companies, but can also assist established companies. Thereto, they organise business development training on a regular base. Venture Lab Twente, however, is not a member organisation. Kennispark Twente, also provides financial aid. Technology Circle Twente was initiated by the university but now is a member association. As one of the interviewees stated about how Venture Lab operates:

"There is always a coordinator, or organiser that dictates what will be done, it is just called Venture Lab with a whole scala of employees, secretaries, managers..."

MinacNed, however, is a member organisation on a national scale. Its sixty members are SMEs, research institutes, universities, and some large firms, more or less involved in the same, but foremost complementary technology. MinacNed has a board, and regular member meetings. Kryoz Technologies joined the association to meet both suppliers as well as potential customers. A firm like PANalytical, found through the network meetings of MinacNed, could profit from the technology Kryoz Technologies offers.

Furthermore, MinacNed has a coordinating role in a number of collective marketing activities, like trade fairs and exhibitions, or collective digital or printed media advertisement, to be discussed in the representation section. The general member meetings are intended to discuss with the members the association affairs, but also have a lecture programme which is about an actual topic, and long breaks to network with all present. One of the interviewees is quoted:

"The idea is to shape a cluster with people with more or less the (application of) the same technology, each can profit from that. It is funny that for us, there are also potential customers and suppliers involved. (...) For instance Lars' presentation on laser composition, where we are looking at laser methods..."

Here, the interviewee referred to a presentation of Lars Pennings from Next Scan Technology, about scanning in laser technology. The sharing of knowledge remains to the level that is necessary for the development of the project, without running the risk of unwanted spillovers. Furthermore, non-disclosure agreements are coupled to the projects. The projects, however, do not involve pools of knowledge.

5.4.5 Mobilisation

Kryoz Technologies has relied on subsidy from the beginning. The innovativeness of the technology cannot attract bank finance or other forms of private funding, according to the interviewees. Not only because of the risk, but also the amount of money. For high tech activities, therefore, it is important that public funding is available. Before Kryoz Technologies was founded, STW funded the university research which led to the development of the small chip based cooling concept. After that, a STW Valorisation Grant provided Kryoz Technologies with the means to develop the research results of the University of Twente from a laboratory result into a marketable technology (Mechatronics Valley Twente, 2011). Kryoz Technologies participates in a "Pieken in de Delta" project together with FEI, a potential customer.

Kryoz Technologies does not expect the Microcryogenic Cooler to benefit from Point-One. Projects are already defined, which makes it difficult for outsiders to join. A Point-One meeting does not facilitate business networking for small firms, whereas MinacNed has an open character. Kryoz Technologies, and the Microcryogenic Cooler, have profited from participating in MicroNed.

Lobby activities are not carried out deliberately. SMEs often lack resources to deliver much input for lobby, despite the necessity. However, through the network, Kryoz Technologies is represented in lobby activities. Especially, the region of Twente has a strong lobby in which Kryoz Technologies is involved. On a national scale, only the representation of MinacNed and their links with government can be regarded as a lobby in which Kryoz Technologies, and thus the Microcryogenic Cooler is represented. An example is the funding for the realisation of MicrofluidicsNL, in which Kryoz Technologies participates (MinacNed, 2011). Applicationwise, NSO, the Netherlands Space Office represents the interests of the space industry, Kryoz Technologies is a stakeholder here.

5.4.6 Representation

Like Bronkhorst High-Tech did with the IQ+ Mass Flow Sensor, Kryoz Technologies promoted the Microcryogenic Cooler in the profile guide "Microfluidics: Holland's high-tech Entrepreneurship in Microtechnologies". This is their way to promote the Microcryogenic Cooler outside the network of Kryoz Technologies. Collective advertisement means profiting from the network of other, more renowned companies. This is especially beneficial for NTBFs. Furthermore, the network provides a stage for lectures, exhibitions play a role as well, to be discussed in the representation section. A quote:

"Together we are strong, it shows again, and we have until now (...) a less known name, so in that sense, you can profit if you are in a guide with Philips and Bronkhorst..."

MinacNed furthermore has made the participation in HET Instrument possible, by means of a collective stand, the MicroNanoPavilion (MicroNanoPaviljoen). More than MinacNed's own conference the Netherlands MicroNanoConference, according to Kryoz Technologies, HET Instrument provides a platform in which the applications of the technology can be presented to potential users. Finally, the Sense of Contact provided a platform for Kryoz Technologies to promote (FHI, federatie van technologiebranches, 2009), MinacNed's network includes the organisation of this event.

"From HET Instrument, the effects were directly measurable, the interest and the contact details that people left are used to enlarge your dataset of people that you call when the product is ready"

The result of regional lobby activities, Pieken in de Delta, also supports Kryoz Technologies, especially in its cooperation with FEI. Nothing can be published about the contents about this project, due to confidentiality issues, the value of the subsidy is about € 600,000. Also, a project with the University of Twente and some hospitals just has started. The value of this subsidy is about € 150,000

5.5 Microflown

5.5.1 Product market technology combination

The Microflown was intended to become a very small microphone that used microsystem technology to transform sound waves into signals. It was developed together with Senheiser. The intended market was consumer electronics. Unfortunately, the project was stopped. Nowadays, the technology is applied in the automotive sector, in noise vibration reduction. It measured interior sound. A recent new application is found in the defence industry, in which the situational awareness is mapped by means of measuring sound in three dimensions. However, this technology is sourced out in AVISA.

5.5.2 Commercialisation

5.5.2.1 Imagining

Hans-Elias de Bree, a researcher at the Transducer Science and Technology (TST) group of the University of Twente, currently the MESA+ Institute for Nanotechnology, invented a sensor that did not measure the sound pressure, the commonly used technology for sound registration, but instead, measures the speed of air particles. The sensor is based on two small wires, that pulsate. From the air speed, the sound intensity can be determined. The technology was a new enabler for new product, but no market was available yet for commercialising this technology. However, a mechanical engineer with commercial experience, Alex Koers was interested in De Bree's sensor technology, because the technology showed potential for consumer electronics. Together, they established the company Microflown Technologies in 1998, with the intention to commercialise the technology in the consumer electronics market.

5.5.2.2 Incubating

Microflown Technologies started a technology push development and commercialisation trajectory, based on the idea to create acoustic instruments for consumer markets. Ericsson and Nokia were approached with the proposition to integrate the Microflown into mobile phones. They expected the new technology to compete with the established technology, the utilisation of air pressure, in price. This is about € 0.50 per device, not a realistic price target for this technology at that time. Microflown Technologies then stopped the development of consumer acoustic instruments. In what followed, the professional market was the new target. It was not easy to reach this market. Automotive applications came in the picture. There were not only difficulties relating to the lack of knowledge about the market, but also relating to the role that the technology could play in that market. Typical problems that come along with technology push trajectories. Furthermore, this technology push trajectory made it difficult to include users or other stakeholders in the development of products, processes or services.

5.5.2.3 Demonstrating

This resulted in a difficult process in which each demonstrated step resulted in scepticism from the potential users. Questions about the relative advantage, compatibility, and other innovation characteristics described by diffusion theory forced Microflown Technologies to produce new concepts and prototypes over and over. Furthermore, standardisation sometimes provided a hurdle for the development of the technology. Gradually, the focus of Microflown Technologies shifted from sensor development to application development. In order to further develop the technology and assure Microflown Technologies that a proper market was available, system integrators were necessary. This was not easy and there were a lot of activities related to promotion. Ultimately, the interest of the automotive industry grew.

5.5.2.4 Promoting

One of the most important aspects of Microflown Technologies' promoting activities was to sell the technology as early as possible. This was done in order to receive feedback from the market in an early point in time in the development process. Especially for a technology that had not been coupled with a specific or even generic application or applications in the imagining stage, feedback from the market is important. Microflown Technologies did so by selling products, or prototypes, that still needed development. To overcome the reluctance of the potential buyers, Microflown Technologies offered free updates in the upcoming two years for the launching customers.

5.5.2.5 Sustaining

In order to sustain the firm and its technology, a lot of R&D efforts are focused on application development rather than sensor technology development in sensor technology. Microflown technology has not yet been accepted as a standard. However, they are lagging behind in technology and business development.

5.5.3 Network

Microflown Technologies is characterised by developing technology under direct management rather than in cooperation with cultural terms. The University of Twente, however, is an important technology partner. This is shown by the fact that two PhD's graduated in research projects that involved sensor technology with Microflown Technologies. The National Aerospace Laboratory (Nationaal Lucht- en Ruimtevaart-laboratorium, NLR) and TNO were two other technology partners with which cooperation was set up. These cooperations did not become successful.

There was however, feedback from launching customers. In this way, users were involved in the developing process. However, the lack of a target market in the imagining stage made it very difficult to find launching customers in the right and potentially interesting application areas, like for example automotive interior measurements.

5.5.4 Coordination

The main reason that cooperation with NLR and TNO failed, according to the interviewee, is that knowledge institutions are behaving like competitors of NTBFs rather than facilitators and knowledge suppliers. Because of acoustic expertise based on air pressure sensors, the introduction of particle speed sensors gets blocked. A comparison with e-mail technology can be made, fax experts were not motivated to support the development of e-mail. In the end, all technology was developed in-house, based on university generated sensor technology knowledge. Furthermore, the lack of cooperation and communication between the institutes and NTBFs appear to lead to overinvestment. Both Microflown Technologies and TNO presented the Dutch solution for submarine detection systems, completely separate (De Jongh, 2010). Microflown Technologies found it curious that a government subsidised institute competed with commercial companies.

"Subsidies from The Hague are diminishing (...) knowledge institutes now collect money in Brussels, and that is exactly the problem SMEs encounter..."

Microflown Technologies director, Alex Koers, was one of the founders of Minac, MinacNed's ancestor, (Metalektro, 2001). Together with Wybren Jouwsma and LioniX's Henk Leeuwis, a Twente based technology platform was established. One of Alex Koers objectives within Minac was to perform a nationwide scan, in cooperation with Syntens, a government initiated consultant network, in which companies were to be surveyed by with questions about their needs and interests with regard to microsystem- and nanotechnology. However, this survey was never carried out.

Despite the fact that the development of the Microflown was included in a STW project, the relation with STW was not smooth. The scientists that judged projects and the applicants are using the same funding source, due to which their objectivity is disputable. Microflown Technologies has experienced this as having a negative influence on the innovativeness in microsystem technology in general and towards the Microflown in particular.

The acoustic measuring market is quality controlled by the ISO norm. The technology that Microflown Technologies applies, measuring sound with ultra thin wires based on the speed of air particles, is not supported by the ISO norm, because it explicitly states that sound ought to be measured by measuring air pressure. This is an indication that standardisation is an important aspect. Collective action could possibly can play an important role (coordination).

5.5.5 Mobilisation

When Delft University of Technology (Technische Universiteit Delft, TU Delft) got involved in Minac, Alex Koers moved over in favour of TU Delft professor Fred van Keulen. With Fred van Keulen, Wybren

Jouwsma and Henk Leeuwis, Minac was transformed into MinacNed, a nationwide member association for microsystem and nanotechnology (FHI, federatie van technologiebranches, 2004). The association had to function as the central communication partner for the microsystem and nanotechnology industry in the Netherlands, whereas the natural gas benefits were allocated to MicroNed, a public private partnership involving the technical universities, and also a number of companies, which was responsible for the microsystem and nanotechnology science (MicroNed, 2010). According to the interviewee, colliding interests between involved individuals and the collective, led to the exclusion of Microflown Technologies, a firm with a promising technology. His quote:

"That (MicroNed) professor was really street smart, so he quickly found his way in The Hague and managed to tap from the natural gas benefits, money."

The mobilisation of attention is done by Microflown Technologies director Alex Koers personally. In a publication in the a daily newspaper, the Financieele Dagblad (FD) in which the governmental policy in general, but specifically the role of TNO competing for funding with NTBFs was criticised (De Jongh, 2010). The MicroNed programme was criticised as well, since Microflown Technologies was excluded from the programme. On personal title, Alex Koers wrote a letter to the then minister of economic affairs (Economische Zaken, EZ) Laurens-Jan Brinkhorst.

Instead of public resources, private resources could be made available via a metal firm one of the directors owned besides Microflown Technologies, and additional income Hans-Elias de Bree had. Another source of resources are European funds, that are allocated to the 7th Framework Programme. Microflown Technologies is actively involved in Point-One. Three projects: Reconserve, a project with 3 SMEs, detecting ships at sea. APRA, with two SMEs from Gelderland, improving the security of air traffic, and VAUDEO, situational awareness, by combining sound with video recordings with another SME, are led by Microflown Technologies director Alex Koers. No large companies are involved in these projects, the subsidy value is € 1,000,000 per project. Universities are involved, and the projects are focused on defence and security applications.

5.5.6 Representation

Trade fairs and exhibitions form an important part of Microflown Technologies' representation activities. However, Microflown Technologies does not participate in collective fairs of cultural terms like the Netherlands MicroNanoConference, or even HET Instrument, but instead, participates in users fairs. Furthermore, Microflown Technologies aspires for providing a lecture within trade fairs and exhibitions that incorporate lecture programmes.

Lobby activities are carried out through a number of collectives, but as opposed to most of the other cases, Microflown Technologies is represented by application oriented associations, like Automotive Netherlands. The interviewee also points to negative outcomes of lobby activities. Knowledge about competing proposals can arrive at competitors. In this way competition of funds is not fair anymore. Another example is the limited added value that knowledge institutes provide to the Dutch society. Director Alex Koers is in contact with secretary general Chris Buijink from the ministry of Economic Affairs, Agriculture and Innovation (Economische Zaken, Landbouw en Innovatie, ELI), and Willem Zwalve, director of NL Agency (Agentschap NL).

5.6 MST Windmeter

5.6.1 Product market technology combination

The MST Windmeter was an attempt to integrate microsystem technology into a windmeter device by Mierij Meteo. Unfortunately, the project was abandoned and the MST Windmeter never reached the market. The MST Windmeter was intended to serve the professional measuring market. The basic idea originated from a market demand for more accurate and less maintenance intensive systems, while at that time in the meteorological world, most systems dated from the 1950's and required very intensive maintenance. The MST Windmeter was therefore particularly suited for locations that not easy accessible. The presumed relative advantage over conventional wind measuring systems are the decrease in maintenance activities, which is an especially important asset in those difficult to reach locations. Examples are found in marine and petrochemical applications.

Within the MST Windmeter, the chip was used in a different way than was usual at that time. This led to other requirements, which caused several problems. Instead of applying the chip in an electronic circuit, the chip was integrated into the measuring unit, which physically aggravated the chip. In order to solve these physical problems, knowledge of fluid dynamics was necessary in addition to knowledge of chip technology.

5.6.2 Commercialisation

5.6.2.1 Imagining

The commercialisation trajectory was expected to be ten years. In the imagining stage, the coupling with the professional measuring market was made. The technology was developed in university surroundings. According to the interviewee, university inventions are often not suitable for straightforward commercialisation. Mierij Meteo also accounted for the relative advantage of less maintenance intensity, since the MST Windmeter did not have any moving parts as opposed to conventional windmeters working with a vane. One quote from the industry perspective is:

"When the professor states that an invention is ready, we still need ten years. Even if you invest three times the human resources or five times the financial resources, it remains ten years."

5.6.2.2 Incubating

In the incubating stage, the development activities of the MST Windmeter included designing the housing, the processing unit, and the microchip. However, the development work was not without surprises and setbacks. Technical problems with the chip, which was now tested in real life conditions, resulted in an increasing need of resources and specific expertise. In a period of six years, various prototypes were developed. However, none of the prototypes came near the requirements of the professional measuring market.

5.6.2.3 Demonstrating

Finally, the development of the MST Windmeter for the professional market was stopped, because investors did not want to invest anymore in a project with a bad track record. In order to convince the investors of the potential of the technology, Mierij Meteo searched for an alternative and less demanding market. The development of a volume model with lower performance requirements was started. Windmeters that are used within the consumer market for water sports do not require calibration and certification, as opposed to windmeters for the professional market. The development of a model for this application with its lower performance requirements was started The development of the MST Windmeter, the innovation that is investigated in this research, was abandoned.

Every technical aspect of the chip required another specialist suppliers. Mierij Meteo, the system integrator, therefore spent a lot of effort in finding partners. Except SMEs from the Netherlands, also firms from Germany and the United Kingdom were approached. At some point, even the TU Delft got involved. Problems were also encountered in the packaging technology.

Promoting and sustaining

After the abandonment during the demonstrating stage, a new and different project was started. Therefore, the promoting and sustaining stage of the MST Windmeter cannot be discussed in this thesis. The coupling with a new application, the development of new, less demanding technology, and the involvement of new clients accounted for the classification as a different project, starting from imagining again. Furthermore, the firm was sold to new owners. Nowadays, the MST Windmeter has only commercial value within the consumer market

5.6.3 Network

Mierij Meteo was a member of the User Committee (Gebruikerscommissie) within two STW projects in which the chip sensor was developed (Technologiestichting STW, 2003). STW projects are university research projects that are funded by the Technology foundation. Within such projects, the existence of a user committee is obliged in order for the funding to be applied. In this setup, a number of companies are involved within the research project. Two times per year, consultations in which R&D progress is discussed are organised. In such a way, university knowledge is expected to be distributed to the industry, and firms might have the opportunity to implement the latest scientific knowledge into commercial products (Technologiestichting STW, 2009).

Partners involved in the development of the MST Windmeter were selected from those having an interest in the technology involved. The flex foil and ceramic bonding both required different partners. With Mierij Meteo taking the initiative, a quest for the right partners was set up worldwide. In order to integrate the packaging into the system, Xensor Integration was found. Following the example of Xensor Integration, a total of six additional partners were found by a search induced by Mierij Meteo. Sources in which the partners are to be found, and if not, at least the right directions in which to search, can be provided by both the university departments involved in the sort of technology at stake as well as through scientific symposia.

5.6.4 Coordination

Knowledge traffic was present in the STW project. The university developed knowledge within the STW project. Mierij Meteo was actively involved in the project. As opposed to other user committee members, Mierij Meteo monitored university research progress on a regular base. Also, entrepreneurial expertise was introduced in the research, due to which the commercialisability was intended to be improved. However, the partners that were involved were specialised suppliers.

Mierij Meteo was involved in the Sensor Technology Club of FHI. This club has a coordinating role in activities that lead to mobilisation of resources and attention, and the representation to the outside world. Furthermore, to facilitate the cooperation between its members and to broach research consortia are two of the aims (FHI Sensor Technologie Club, 2009). However, Mierij Meteo's partners were no consortium broached by the Sensor Technology Club.

5.6.5 Mobilisation

The mobilisation of resources was very important. STW was a very important resource provider, not only within the STW project, but also the Simon Stevin price that was awarded to professor Huizing. This price was used for the research work for chip technology development that was to be applied in the development of the MST Windmeter. Within the network that was built up around the partners that were involved in the development of the MST Windmeter, also partners of partners were linked to partners of other partners that could be of interest.

With regard to lobby activities, one incident proved to be important. The development of a new wafer required additional resources, but investors were unwilling to provide such. Therefore, the university contacted a subsidy provider to persuade them of the need for resources for this development. The lobby activities out of which Mierij Meteo benefited were thus carried out by the university.

5.6.6 Representation

The Sense of Contact, organised by the Sensor Technology Club of FHI, was an important way of representing the technology to the outside world. Mierij Meteo has given various presentations at this event. Furthermore, publications in scientific journals as well as presentations and publications through STW created scientific awareness. Drawing the attention from consumers, however, was not successfully done by means of participating in the Sense of Contact.

6 Discussion

6.1 Actions and organising entities

This research intends to shed light on the contribution of collective action to successful commercialisation of microsystem technology based products. This section will discuss the results from the six cases of collective action in the commercialisation of microsystem technology in the Netherlands and links these results with the literature section, and finally, the research question. The emphasis of this section is on three important facets. The first is what collective actions are performed in the development of microsystem technology. Out of the six cases, a number of actions and organising entities are identified. The second related to the organising entity behind the observed collective actions. The third is the degree to which collective actions are important, both in a positive and a negative sense, for the development of microsystem technology. To determine this, a link with Jolly's (1997) commercialisation model is made again.

First, the degree of success of the innovations that are investigated in the cases is discussed. When the cases were selected, an attempt was made to include both successful and unsuccessful cases. The research evidenced that the distinction between successful and unsuccessful cases as a dichotomous variable is very difficult to make, due to which a comparison between those types of cases is very difficult as well. The MST Windmeter and Microflown were regarded as cases that could serve as an example for unsuccessful cases, but during the research, this proved not to be the case. It turned out that an MST Windmeter has found its way to the market as a device for the leisure marine market instead of a professional measuring device for the meteorological market, and a Microflown device found its way to the professional market in predominantly automotive and defence applications. In both cases, it was a totally different PMTC, for which the commercialisation had to start from an imagining stage again.

Two cases were in the sustaining stage, the IQ+ Mass Flow Sensor, and the C2V-200 Micro Gas Chromatograph. The IQ+ Mass Flow Sensor is exploited by the firm that was leading the consortium in which it was developed, Bronkhorst High-Tech from Ruurlo. The C2V-200 is also exploited by its proprietor, but in a different way. C2V was acquired by a large (established) multinational, Thermo Fisher Scientific. Within Thermo Fisher, C2V has an autonomous position. However, the second dimension that was identified for describing the degree of success was the level of activity. Two were in the promoting stage with a high level of activity and a realistic chance of reaching the sustaining stage. They can therefore not be regarded successful with certainty. Following table 1, we regard these innovations as promising. The Medimate Multireader and Microcryogenic Cooler are both spin-offs that are established to commercialise university based technology.

The difficulty to distinguish unsuccessful cases from successful cases limits the results in the sense that no direct comparison between the factors of success or failure can follow from the research results. What rests is the possibility to identify collective action which is present within microsystem technology in the Netherlands, and to determine the degree of importance within the cases. The research is still able to provide insight in the contribution of collective action to the commercialisation of high technology. The process that led to moving from imagining to the stage where progress eventually ended up, which is always necessary when striving for sustaining, can be mapped

In all cases, technology from different partners is combined within the innovation. There are different ways in which such comes about, as identified in the six cases that are investigated. In order to give a clarifying overview of collective action in the development of microsystem technology in the Netherlands, the actions that are identified in the cases are transformed in an overview with the organisation or institute that carries out collective action. This section will provide this transformation. Also, there is a certain degree of overlap between entrepreneurs on one hand, and performers of collective action (acting on behalf of the represented group) on the other hand.

MinacNed is an association of sixty organisations that are active in microsystem and nanotechnology. Most of them are SMEs (including NTBFs), but also larger firms and university research groups are member. The activities identified in the cases are periodical member meetings, the profile guide Microfluidics: Holland's High-Tech Entrepreneurship in Microtechnologies, industry cluster MicrofluidicsNL, and the Netherlands MicroNanoConference. The general member meetings are coupled with lecture sessions with long breaks that the participants can use to build or maintain their networks. This contributes to the aspect coordination within networks. The profile guide "Microfluidics: Holland's High-Tech Entrepreneurship in Microtechnologies" combines fifteen company profiles guide of paying participants in a booklet of which two thousand copies are distributed. This activity provides an excellent opportunity to represent networks to the outside world.

The establishment of industry cluster MicrofluidicsNL, intended to build up the market in the Netherlands by interest protection, collective marketing, and individual service, was identified within the cases. The Netherlands MicroNanoConference is the largest microsystem and nanotechnology event in the Benelux region, with a scientific part consisting of lectures serving knowledge distribution, and a commercial part serving representation. The Netherlands MicroNanoConference is organised together with MicroNed and NanoNed. MicroNed and NanoNed are public private partnerships. Supported by public funding, research projects are carried out by consortia with university research groups, SMEs, and larger firms. This facilitates the mobilisation of resources and attention for networks. The development of those research consortia requires knowledge about the activities (technology and application domains) of all involved or to involve companies, which requires the coordination within networks. In the context of this research the role of NanoNed, contrary to the role of MicroNed, is limited. The reason being that NanoNed, as the name indicates, is about nanotechnology rather than microsystem technology. Also, NanoNed is less valorisation oriented compared to MicroNed.

Within the region of Twente, three activities are identified. Technology circle Twente is a business support initiative of the University of Twente with one hundred eighty firms being member. They have regular member meetings and match making events are organised. Venture Lab foresees in business development trainings, but is not a member organisation. Knowledge park Twente is a foundation and an initiative of the province Overijssel, the municipality of Enschede, the University of Twente and the Saxion University of Applied Science. Its mission is to provide for an attractive climate for high tech firms, in order to increase their number and promote their growth. Hereto, real estate, joint research facilities and incubating facilities are set up. It also runs the High-Tech Factory, which is partly publicly funded. The initiative for Knowledge park does not stem from NTBFs or established firms, but rather from politics and universities.

Point-One, the programme that originated from the public support that Philips traditionally received was oriented to developing microsystem technology. MANCEF, the Micro and Nanotechnology Commercialization Education Foundation is an international organisation focused on the commercialisation of both microsystem and nanotechnology. In order to achieve this, the association publishes roadmaps and foresights, and also organises conferences. The Dutch MESA+ Institute of the University of Twente and enablingMNT are very active in this association.

FHI, Federation of Technology Branches is the federation of technology industries in the Netherlands. Four industry associations belong to the federation. In total, eight hundred technology companies are part of the federation. FHI runs the MinacNed secretariat and some overlap between FHI and MinacNed members exists. Activities of FHI that were identified in the six cases are the trade fair HET Instrument, Electronics & Automation, the Sense of Contact and the Instrument Guide. HET Instrument is a traditional technology exhibition, with seventeen thousand visitors and five hundred exhibitors the largest in the Benelux region. The target groups are industrial automation, industrial electronics, and laboratory technology. Special about this exhibition is the presence of a special MicroNano pavilion. This pavilion, populated by microsystem and nanotechnology companies was, being an enabling technology, fittingly situated in between the different industry areas.

Electronics & Automation is a smaller fair, representing only the industrial electronics industry. No special activities regarding microsystem technology were identified. The Sense of Contact is an activity of the Sensor Technology Club, a subgroup within the federation of technology industries with a focus on sensor technology. This event has both an exhibition as well as a lecture programme. The Instrument Guide is a classic catalogue in which firms, participating in HET Instrument, suppliers and manufacturers are presented. Listing in this guide is complementary to participating in HET Instrument. Additional firms willing to be listed have to pay, it is a not for profit initiative. VNO NCW is the Confederation of Netherlands Industry and Employers. On behalf of employers a lot of lobby work is done. The focus is on a national scale and not limited to any sector or technology.

Table 5 provides an overview of the identified collective actions. The first column represents the organising entity. The second column lists the actions. The third column provides a short description. In the fourth column, a first attempt is made to state which aspect of collective action is covered by the identified action at stake. A lot of activities cover more than one aspect. In addition to the collective actions that are listed in table 5, some factors of influence were identified in the cases. These are the funding that is provided by STW, the subsidy programme BTS, which later on developed into WBSO, and the programme Pieken in de Delta. However, the funding handled by STW comes from the ministries of economic affairs (current ministry of economic affairs, agriculture, and innovation), and the ministry of education, culture, and science. This research was not able to put a link between these activities and a joint effort of parties interested in improving general conditions. It can therefore not be regarded as effects of collective action with certainty. In the next section, the importance of the collective actions will be discussed. In order to give a more clarifying overview of the relation with the dependent variable, commercialisation, a link with the Jolly model will be made.

Organising Entity	Activity	Description	Aspect
MinacNed	Member meetings	Periodical meetings of the association members and designated guests designed for networking and running the association	Coordination
	Microfluidics: Holland's High-Tech Entrepreneurship in Microtechnologies	Profile guide for companies with microfluidics based technology and/or application, 15 companies, 2000 copies.	Representation
	MicrofluidicsNL	Technology cluster for microfluidics companies for networking and collective marketing puposes, as well as knowledge diffusion workshops	Coordination, representation
	Netherlands MicroNanoConference	Scientific conference and exhibition, designed for networking, knowledge exchange and marketing purposes	Coordination, representation
MicroNed / NanoNextNL	Research projects	Publicly funded research projects with university and industry combining consortia	Mobilisation, coordination
Point-One	Research projects	Public funded research projects for large firm and SME integration	Mobilisation, coordination
MANCEF	COMS	International networking club focusing on commercialisation and networking	Coordination, representation
FHI, Federation of Technology Branches	HET Instrument	Trade fair for industrial automation, industrial electronics, and laboratory technology	Representation, coordination
	Electronics & Automation	Trade fair for industrial electronics	Representation
	Sense of Contact	Scientific conference and exhibition designed for networking, knowledge exchange and marketing purposes	Coordination, representation
	Instrument Guide	Catalogue collection suppliers, products, and manufacturers of FHI members and participants	Representation
VNO-NCW	Lobby Activities	Serving the interests of represented organisations	Mobilisation, representation
Technology circle Twente	Member meetings	Periodical meetings of the association members designed for networking	Coordination
	Matchmaking Events	Meetings intended to match potential business partners	Coordination
Venture Lab Twente	Business Training	Providing business courses for entrepreneurs	Coordination
	Funding	Providing funding for entrepreneurs	Mobilisation
Knowledge Park Twente	High Tech Factory	Providing research facilities for entrepreneurs	Mobilisation

Table 5: Overview of collective actions

6.2 Importance

Within a high-tech sector, not only the cooperation with cultural terms, clients, and launching customers is important. Involving government and universities is crucial as well. Table 6 represents an overview of the partners that were involved in the six cases. Also, how this evolved over the Jolly (1997) stages is shown. The different rows distinguish between the cases whereas the different columns distinguish between the different stages.

Within the imagining and the incubating stage, it is shown that all cases apply university based technology in the initial stages, whereas launching customers and users become co-developing organisations in stages closer to market, demonstrating and promoting. For the IQ+ Mass Flow Sensor, and the MST Windmeter, the STW User Commissions were the main mechanisms to facilitate the transfer of technology from out of the university into NTBFs. C2V, Medimate and Kryoz Technologies, however, were spin-offs. Table 6 gives an overview of co-developing organisations in each case in each stage.

Within the development of the C2V-200, collective action played a minor role in the early stages. There was knowledge traffic between the partners, but limited to specification level. The IQ+ Mass Flow Sensor was developed within a consortium, but this was composed out of the existing network of the proprietor Bronkhorst High-Tech. Although partners Bronkhorst High-Tech and LioniX state that their organisations profit from coordination activities that are done collectively, in the development of the IQ+ Mass Flow Sensor specifically, this was not observed. The Medimate Multireader was developed by Medimate. This is a university spin-off. Coordination activities were not important in the early stages imagining and incubating, despite the fact that Micronit and some other local companies were found as a supplier. STW played an important role, but is not regarded as an entity performing collective action, because it is not a joint initiative of players in the field.

Innovation	Co-developing organisations Imagining	Co-developing organisations Incubating	Co-developing organisations Demonstrating	Co-developing organisations Promoting
C2V-200	Alcatel, University of Twente, University of Amsterdam	N/a	Point-One partners	N/a
IQ+ Mass Flow Sensor	Delft University of Technology	University of Twente	TNO, 3T (LioniX), University of Twente	N/a
Medimate Multireader	University of Twente	University of Twente, Micronit	Achmea, VMDB, Micronit, enablingMNT	Achmea, Trimbos Institute, Kidney Foundation
Microcryogenic Cooler	University of Twente	Micronit	Micronit, FEI, Hospitals, TNO, NLR	Astron, , ESA
Microflown	TNO, NLR, University of Twente	Automotive	N/a	N/a
MST Windmeter	Delft University of Technology	Specialised suppliers (e.g. Xensor)	N/a	N/a

Table 6: Co-developing organisations

The development of the Microcryogenic Cooler started at the university as well as the early development of the Microflown. The role of coordination was also limited in the beginning, when Microflown Technologies attempted to cooperate with NLR and TNO, which unfortunately failed. The development of the MST Windmeter started as an effort to comply to the market demand for innovative wind speed measuring techniques. Activities from the sensor technology club were applied in finding partners, especially suppliers. The Sense of Contact event provided in coordination.

In the later stages, coordination within networks increased in importance, in the demonstrating stage partners were often needed to help transforming the technology into a usable device, product or system. For the C2V-200, partners were found at the trade fairs and exhibitions C2V participated in. These were launching customers. Furthermore, the Point-One partners were found in the demonstrating stage. The developers of the IQ+ Mass Flow sensor found each other in the demonstrating stage. Despite the fact that this consortium grew out of existing networks, the interviewees underpin the importance of coordination within networks. Knowledge traffic was present in an open setting within the consortium. The Medimate Multireader has found support from VMDB and Achmea in the demonstrating stage. They were found through the network of the University of Twente. The Microcryogenic Cooler developers were actively looking for partners, and are now active in two partially publicly funded Pieken in de Delta projects with FEI, and with a number of health companies and hospitals. They participate in projects with NLR and Astron, both found in the demonstrating stage. For the Microflown and the MST Windmeter, finding partners did not profit from coordination. But also HET Instrument played a role in coordination since Huub Maas and Medimate found each other at that exhibition in the lecture programme, although unintended.

With regard to mobilisation of resources and attention for networks, especially the research projects with public private participation were important. These were the MicroNed and Point-One projects. Bronkhorst High-Tech and Kryoz Technologies have participated in a MicroNed project. Furthermore, the Pieken in de Delta projects are important for amongst others Bronkhorst High-Tech and Kryoz Technologies, but these are the result of lobby activities of entities not specified in the cases, other than efforts of Wybren Jouwsma from Bronkhorst High-Tech. Furthermore, public funding has proven to be important, as shown in the cases. It takes a very long time to go from mind to market, and as a rule, revenues are scarce within the whole trajectory. This scares off private investors. The STW Valorisation grant has proven to be an important success factor for both the Medimate Multireader, and the Microcryogenic Cooler. More important, the funding of (applied) university research formed the basis of all technology applied in all cases.

It was difficult to map the effort and effect of lobby activities within the cases. Wybren Jouwsma, for example, has performed lobby activities which has resulted in Pieken in de Delta projects. But Wybren Jouwsma represents different entities, like MinacNed, then in the role as chairman, MicroNed, the region of Gelderland, but also SMEs in general, as a member of the innovation platform (IP). His lobby activities were carried out in difficult compositions. Alex Koers of Microflown Technologies carries out lobby activities on his own initiative. Mierij Meteo of the MST Windmeter was represented by a university when they lobbied for additional funding for the development.

The interviews and a number of quotes indicate that lobby activities have played a role, at least in the development of the IQ+ Mass Flow Sensor and the establishment of the MicroNed programme, but no motives or relations of representations follow. Therefore, it is not possible to give a representation of lobby activities collectively, although lobby activities in general seem to have contributed to the positive climate in the Netherlands as a whole and particularly in Twente, resulting in programmes like MicroNed and programmes like Pieken in de Delta for start-up companies. The table below gives an overview of the mobilisation of resources and attention in the cases, seen through the different Jolly (1997) stages, vertically and horizontally respectively.

Innovation	Mobilisation of Resources and Attention Imagining	Mobilisation of Resources and Attention Incubating	Mobilisation of Resources and Attention Demonstrating	Mobilisation of Resources and Attention Promoting
C2V-200	Private Capital		Point-One	
IQ+ Mass Flow Sensor	Research Funding		BTS (WBSO)	MicroNed
Medimate Multireader	STW	STW, Private Capital (Huub Maas)	Achmea	Achmea, Kidney Foundation
Microcryogenic Cooler	STW	STW, MicroNed	MicroNed, Pieken in de Delta, European ESA subsidy	Pieken in de Delta, ESA
Microflown	STW	Private Capital	Private Capital, but different PMTC	7th EU Framework Programme, but different PMTC
MST Windmeter	STW	Private Capital	None	None

Table 7: Mobilisation of resources in each case in each stage

With regard to the representation of networks to the outside world, various collective actions were identified. The Microfluidics Profile Guide Microfluidics: Holland's High Tech Entrepreneurship in Microtechnologies played a role for the awareness about the Microcyogenic Cooler, and the IQ+ Mass Flow Sensor. Also, the Medimate Multireader is mentioned in the profile guide. Owner Medimate, however, does not expect to profit from this initiative, because they think their specific target market will not be reached with this profile guide. The cluster MicrofluidicsNL is only recently established, therefore no effects of the activities were observed yet in the cases. The Netherlands MicroNanoConference has an exhibition that is used for representation purposes. The IQ+ Mass Flow Sensor and the Microcryogenic Cooler were represented at this exhibition. Furthermore, the COMS was identified as playing a role in the case of the C2V-200, but it is not clear what the role is that the COMS played in representing the C2V-200.

Within all of the cases, representation is done during so-called third party exhibitions. These are called third party exhibitions, because they are not focused on microsystem technology (or microsystems and nanotechnology), which strictly also applies to the Instrument Guide, VNO-NCW, and Point-One. The cases are characterised by the importance of finding and connecting to the users of the innovations. The Netherlands MicroNanoConference is not enough focused on the wide array of users, but is renowned for the knowledge diffusion, and networking role.

The Microcryogenic Cooler has been represented at HET Instrument on the MicroNanoPavilion. This is a part of the exhibition especially for microsystem and nanotechnology, organised by MinacNed. The C2V-200 and IQ+ Mass Flow Sensor have been represented at HET Instrument, although not at the MicroNanoPavilion. Therefore, it seems that collective action in representation is not only important when the network presents itself, but also in the communication to the users of the innovations. At the MicroNanoConference, a lot of equipment manufacturers are represented, who can act as suppliers for other microsystem (and nanotechnology) companies. The MicroNanoPavilion provides a good example of collectively representation towards technology users.

With regard to the role that collective action fulfils within the development of microsystem technology in the Netherlands, three observations can made that show up in different cases and seem to provide an indication. First of all, the role of collective action differs between the different Jolly (1997) stages within the cases. Whereas in the early stages imagining and incubating, the role of mobilisation of resources and attention for networks has a prominent role, the latter stages demonstrating and sustaining give more room for representation of networks to the outside world. The role of coordination within networks, especially the role of collective action, was to a limited degree observed in the cases. Especially remarkable in the cases is the limited role of precompetitive cooperation within collective action.

Innovation	Representat-ion Imagining	Representat-ion Incubating	Representation Demonstrating	Representation Promoting	Representation Sustaining
C2V-200	N/a	N/a	HET Instrument, third party exhibitions	HET Instrument, third party exhibitions	Third party exhibitions, Instrument Guide
IQ+ Mass Flow Sensor	N/a	N/a	N/a	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies, HET Instrument, third party exhibitions, Electronics & Automation, MicroNanoConference	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies, HET Instrument, third party exhibitions, Instrument Guide, Electronics & Automation, MicroNanoConference
Medimate Multireader	N/a	N/a	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies	N/a
Microcryogenic Cooler	N/a	N/a	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies	Microfluidics: Holland's High-Tech Entepreneurship in Microtechnologies; HET Instrument	N/a
Microflown	N/a	N/a	Different PMTC	Different PMTC	Different PMTC
MST Windmeter	N/a	N/a	Different PMTC	Different PMTC	Different PMTC

Table 8: Representation in each case in each stage

Figure 2 provides an illustration of all involved actions, organisations, and relation from the cases. Double bold arrows represent mutual relations, single arrows represent one way traffic. The colour of the arrows represents the innovations in which they are applied. The background colours behind the collective actions represent the organising entity. Dark yellow stands for MinacNed, Dark blue stands for MicroNed, Red stands for Point-One, light yellow stands for MANCEF, white stands for FHI, Federation of Technology Branches, light blue stands for VNO NCW.

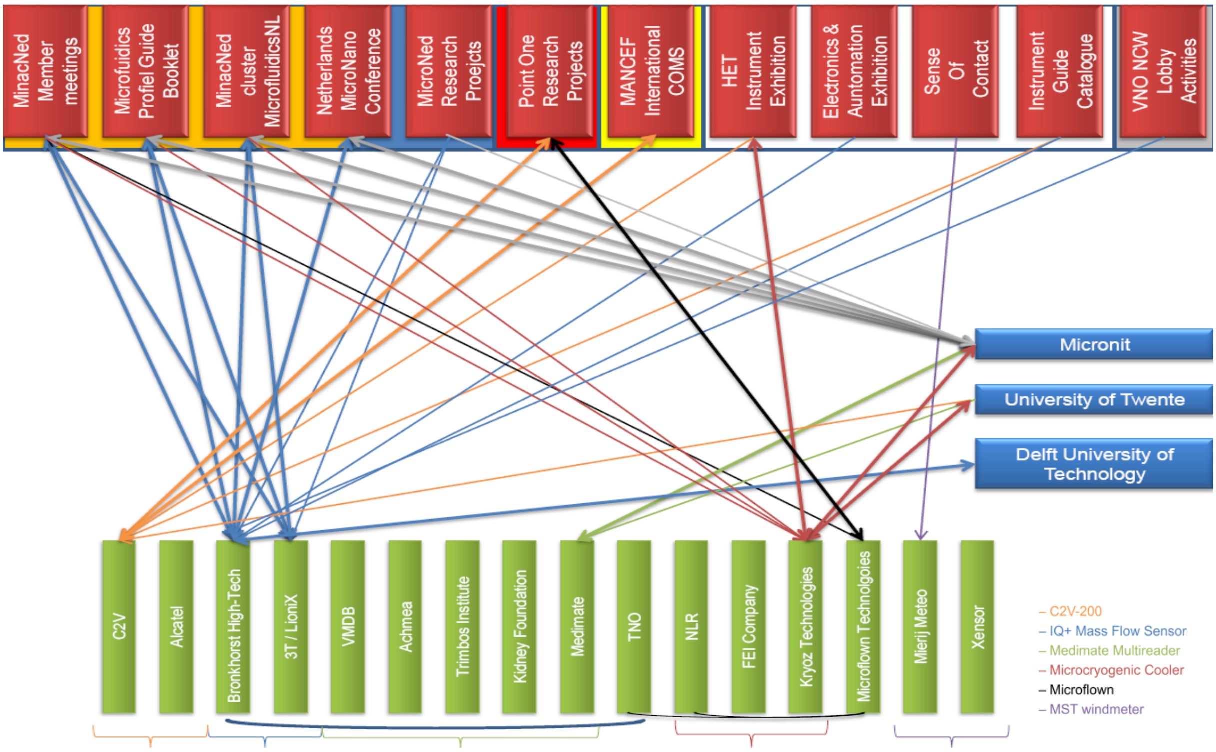

Figure 2: Schematic view of the role of actions and their organising entities in the cases

6.3 Implications

The scientific literature describes clusters and networks as forms of cooperation, either serving some common purpose (Musiolik & Markard, 2011) or not (Powell et al., 1996), in which a very important role for governments and universities is dictated (Etzkowitz, 2000; Lee et al., 2001). In all investigated cases, the technology that is applied originated from (technical) university laboratories. Scientific literature had no direct answers to the question how knowledge spillovers (Ahuja, 2000), the combination of knowledge and skills, and access to new markets (Pittaway et al., 2004) was accomplished, but this research found how actors in high technology networks managed this by the mobilisation of resources and attention for networks, coordination within networks and representation of networks to the outside world.

The actions that were labelled to serve "coordination" in table 5 were foremost applied in finding partners, either upstream or downstream the value chain. It appears that sometimes the fear of unwanted knowledge spillovers is greater than the expectations of synergy by precompetitive cooperation. This leaves room for organisations like MinacNed, that act on behalf of companies to reinforce economic activity, to serve in the organisation of activities that intercept this, separated from stakeholders like universities or governments,. This is also the responsibility of NTBFs and other firms involved. Building trust and increasing social capital (Cooke & Wills, 1999) is crucial.

This research has attempted to investigate lobby activities within collective action. Following scientific literature (Björheden, 2006), this was expected to help the mobilisation of resources and attention for networks. Advantages of doing this collectively were also expected (Cooke & Wills, 1999). Some indications were found that the role of lobby activities within the development of high technology had some importance, but this research has not been able to provide more clarity on this topic. However, innovation programmes and other subsidies or favourable policies, but also unfavourable policies that were identified played a significant role in the mobilisation of resources and attention. It therefore seems beneficial for entrepreneurs to build social capital and to tie up to a network that is involved in this whenever possible.

Regarding the role of trade fairs (Rinallo & Golfetto, 2006), finding users in application areas seemed more important than the representation of industries. The enabling character and broad array of applications, which especially applies to microsystem technology makes it difficult to attract target groups directly. Doing this on a smaller scale by means of a pavilion adjacent to application markets appears to be a good start in improving this. Digital or printed media (Felzensztein & Gimmon, 2009; Gabrielli & Balboni, 2010) were applied for reasons of brand imaging, not wanting to miss any prospects by not participating because these prospects would only find competitors that do participate, and profiting from being linked with more renowned companies. The latter applies to start-up companies.

6.4 Reflection

The used method proved to be sufficient to get enough data to examine the cases. The snowball method resulted in finding interviewees that were truly involved in the cases. In this way, the internal validity is reinforced. Furthermore, replenishing the cases with document analysis makes the data even more reliable. However, not in all cases did this result in the same amount of interviews. This makes it more difficult to compare the cases. Especially the less successful cases provided limited insight.

Taking MinacNed as a starting point provided a lot of insight in the market for microsystem technology in the Netherlands. The association has relations with its members, most involved in microsystem technology, as well as in related industries. These include the FHI branches industrial automation, industrial electronics, laboratory technology and medical technology. All these branches are potential markets for microsystem technology (OECD, 1998; Walsh, 2004), which attracts micro system technology companies to the association. A disadvantage of this starting point, however, is that all cases are in some way related, which limits the generalisability of the results. Also, cases with no or very limited relations with MinacNed, or indirectly in a limited number of links, cannot be identified.

Including both successful and unsuccessful cases helped comparing the effects of different actions. It turned out that there were differences in collective action between successful and unsuccessful cases. Through collective action, it is easier to acquire public funding than by single action, as the Microflown and the MST Windmeter have shown. However, during the research, it appeared to be very difficult to distinguish between successes and failures. A number of successes proved to be in the promoting stage at the time of the interviews, which meant that no certainty on commercial success was present. On the other hand, the unsuccessful cases were still sustained or promoted innovations, but in a very different context. This makes it difficult to draw conclusions about factors that lead to failure. It is possible to observe that it becomes more difficult to accomplish success.

The role of legitimacy could not properly be investigated by the cases. The fax e-mail metaphor found in the Microflown case provided an indication, but this might as well be strategic behaviour from incumbents rather than legitimacy issues for NTBFs. Perhaps a better method would be to investigate legitimacy from the demand side instead of from the supply side.

The reason that the regional initiatives from Twente are not regarded as collective actions is that they are not initiated by those who profit. However, the provinces, municipalities and institutes can profit indirectly, because they are important stakeholders in a region and profit from their economic and employment development. This underlines the difficulty of distinguishing collective action from other actions of which groups profit, and questions the necessity of such.

Furthermore, the complexity of the microsystem technology industry and the diversity in cases following do not allow a ceteris paribus investigation of single variables like the identified actions. All actions must be placed in perspective. The “failure” of MST Windmeter and Microflown, and the promises of the Medimate Multireader and the Microcryogenic Cooler, cannot be solely put down to the differences in how the involved actors are influenced by collective action, but also in terms of technology, angel investors, interests of stakeholders, market characteristics, timing, and luck.

The use of semi-structured interviews is very useful to combine in-depth knowledge with the guarantee that all necessary aspects are included. Only one interviewer and a limited number of interviewees in the less successful cases limit the reliability of the results. Also, not asking further on crucial points during the interviews made it necessary to perform a more extended document analysis, in order to fill the gaps. Finally, in the process of sending and receiving information, some nuance may get lost, leading to less reliable results.

7 Conclusion

This thesis attempts to provide more insight into the contribution of collective action to the successful commercialisation of microsystem technology in the Netherlands. Within the six cases, three aspects were important. These are the collective actions that were performed, the organising entity that executes them, and the importance of them within the cases. Three important observations follow from the cases.

1. The importance of collective mobilisation of resources and attention is the greatest in the initial stages imagining and incubating, because high-tech start-ups are in need of public funding due to the uncertainties that are inherently present in the development of high technology. Collective mobilisation of resources has taken shape through MicroNed research programmes, and Point-One funding. STW grants, although important, are not regarded collective, because the initiative does not come from (collective) companies.

2. The importance of collective representation is the greatest in those close-to-market stages demonstrating and promoting. From the cases follows an image where the existence of a product or at least a prototype is important before promotional activities are carried out.

3. The importance of coordination within networks is the greatest in stages in which feedback from (potential) users, launching customers, is sought and technology partners are required. Despite the fact that coordination was expected to be important in all stages in order to find partners, evidence to support this was only found in the later stages.

With regard to the representation of networks to the outside world, the cases illustrate the difficulty of reaching the potential (end) users within activities that are collectively organised for microsystem technology specifically. The collective participation in HET Instrument with micro- and nanotechnology provides an indication that this perceived limitation can be resolved.

Not always were the identified actions that intended to improve general conditions originally initiated by those actors with an interest. Examples are the regional activities in Twente, but also the STW funding, which is a shared facility. These are not regarded as collective action, despite their positive contribution on the development of microsystem technology.

The methodology is very useful for the purpose of this research. Future research can incorporate quantitative analysis, although there are not many cases of microsystem technology in the Netherlands specifically. Also, to investigate the role of lobbying requires more research, the cases investigated provide an indication of the importance of lobbying activities, but relations between representation in lobby circuits and commercial success could not be established here. Finally, the effect of public funding on a macro-economic scale is not discussed in this thesis, but is certainly worth further investigation.

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Appendix A: Topic List Interview

- Innovation/development
    - Market/target group
    - Application
    - Technology
    - Product/process/service

- Commercialisation trajectory
    - Imagining?
    - Incubating?
    - Demonstrating?
    - Promoting?
    - Sustaining?

- Partners
    - Technology suppliers
    - (Launching) customers
    - Precompetitive

- Coordination
    - Knowledge creation and diffusion in interaction
        - Knowledge in- and out flow
        - Knowledge pool
        - Knowledge combination in innovation
        - Who coordinates? How?
    - Finding partners
        - Customers (firms, universities)
            - Who?
            - How?
        - Suppliers (firms, universities)
            - Who?
            - How?
        - Cultural terms
            - Who?
            - How?
        - Who coordinates? How?

- Mobilisation of Resources and attention
    - Fame within network
        - Elevator pitch
        - Other
        - Who? How?
    - Fame outside the network
        - Own efforts
            - Education / Public debate (on/offline)
        - Collective efforts
            - Lobby(under representation)
        - Who? How?
    - Mobilisation of resources
        - Direct mobilisation of resources
            - Public funding
- Representation to the outside world
    - Participation trade fairs / exhibitions
        - Think
        - Co-organise
        - Lecture/stand
    - Participation collective marketing activities digital/printed media
    - Participation association /branch cluster/ innovation programme
        - Think
        - Active member
        - Image and reputation purposes
    - Input delivery for lobby municipality/province/nation
        - Collective
        - Active
        - Result?
            - Policy
            - Resources