LEAD CUSTOMER INTERACTION DURING THE COMMERCIALIZATION PROCESS OF RADICAL TECHNOLOGIES

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Abstract: The radical innovation process initiated by a technology push differs remarkably from the orderly incremental innovation process. The role and form of customer interaction for one vary significantly according to innovation type. It is clear that incremental innovations tend to be customer driven, but customer involvement in the commercialization of breakthroughs is much more contested (Christensen 1997). Nevertheless, several case studies and previous research show the potential value of lead customer input for the commercialization of radical technologies (Jolly 1997).

The paper analyzes collaboration of innovating companies with industrial lead customers during the different phases of technology commercialization. Access, transfer and creation of knowledge are key processes in the interorganizational collaboration. Lead customers benefit by acquiring a superior product. The supplier manages to reduce lead times and improve new product performance by accessing customer expertise (Brown and Eisenhardt 1995). The dynamics of uncertainty, opportunism, power and suspicion can severely harm interorganizational learning. In contrast high stakes, trust, commitment and a long-term orientation motivate both partners to see the unpredictable technology commercialization process through.

We take the knowledge-based theory of inter-firm collaboration (Grant and Baden-Fuller 1995) as the predominant paradigm of our research. The conceptual framework comprises concepts such as technology commercialization (Jolly 1997) and lead customer interaction (Leifer et al. 2000).

These concepts provide a relatively clear description of the context for a study of lead customer interaction for technology commercialization. We investigate what exactly to learn collectively, when and with whom. An exploratory study consisting of five cases in large firms provides preliminary insights. We anlayse customer interaction in these cases and delineate topics for further research.

Keywords: knowledge, technology commercialization, lead customer interaction.

Introduction

In innovation-driven competition numerous promising technologies originate in R&D departments all over the world. However, few of these new technologies find their way to the market, let alone become commercial successes (Korac-Kakabadse 2001). Soon marketing management is indicated as the weak link in the technology commercialization process (Millier 1997, Clugston 1995). Various research tracks look for a solution.

First, in the marketing literature the R&D/marketing interface and its role in the new product development (NPD) process has been a subject of extensive study. Griffin and Hauser (1996) summarize the scientific evidence for the proposition that cooperation between the two functional areas increases development success.
In the technology management literature we find a plea for the conceptual separation of the research function from the development function. Wood and Brown (1998) motivate their finding by showing how different these functions really are. Research projects and development projects differ in approach, objectives and predictability. Maintaining consistency of research with development functions and efficiently transferring research results to development are key managerial challenges when commercializing new technologies.
Second, there is a growing awareness of the need to combine technology commercialization with a market orientation throughout the entire process (Jolly 1997, Souder et al. 1997). Dutta et al. (1999) study the influence of marketing on success in high-technology markets specifically. R&D based firms appear to be the ones with the most to gain from a strong market orientation. It is important to distinguish breakthrough technologies from incremental technological improvements. Awareness exists that according to innovation type different practices are needed to manage the NPD process (Ettlie et al. 1984, McDermott and Handfield 2000, Dewar and Dutton 1986). Customer interaction is also very likely to occur in different forms and serve different purposes when it takes place in a context of radical rather than incremental innovation (Desza et al. 1999, Kanter 1997, Mascitelli 2000, von Hippel et al. 1999).

We are not studying the market-driven incremental innovation process. We focus on innovation that emerges from a technology push. Hence the initiative for interaction with a lead customer comes from the supplier, who is looking for a market for his technological breakthrough. Even though some authors contest the benefits of customer interaction for radical innovation (Christensen 1997), we also identify a growing body of researchers, that advocate interaction with potential users of the products under development during and preferably early in the commercialization process of radical technologies to increase the likelihood of success (Jolly 1997, Leifer et al. 2000, Athaide and Stump 1999, Gupta and Wilemon 1990). Potential customers, usually users of substitute or complementary products and processes, appear to be interesting partners for various goals ranging from product development and prototype testing to business development.

This paper creates a framework for the study of lead customer interaction for the commercialization of radical technologies. We integrate results of an exploratory study consisting of in-depth interviews with managers involved in this type of technology commercialization.

A knowledge-based view

Before we discuss the specific constructs in the conceptual framework, we elaborate on the knowledge-based view of both the firm and of inter-firm collaboration.

The firm

The firm can be considered as a social community specializing in knowledge integration, combination, creation, transfer and application (Kogut and Zander 1996, Grant 1996, Kogut and Zander 1992, Spender 1996). While knowledge is essentially individual, firms provide the structure, routines and procedures, vision and context for shaping knowledge into competencies that can be commercially exploited in the marketplace (Teece 1998, von Krogh, Ichijo and Nonaka 2000). Knowledge is seen as a most strategically important resource.

In successful technology commercialization knowledge plays a key role (Teece 1998). The process starts off with the appropriation, access or creation of the needed technological and market knowledge. This knowledge is then integrated, combined and applied to lead to commercially viable technological applications that answer to the real needs and preferences of industrial customers.

Inter-firm collaboration

Earlier work documents how the sources of innovation often lie outside the firm (von Hippel 1988). Also when the innovation originates from within the firm it is wise to scan the external environment for complementary knowledge during commercialization of the innovative idea (Chesbrough 2003). Cohen and Levinthal (1990) confirm how external information can contribute to effective commercialization of innovations. Grant and Badenfuller (1995) identify the integration of specialized knowledge as one of the motives for inter-firm collaboration. They describe the incongruence between knowledge and product domains that exists within every firm. The knowledge domain is the scope of the knowledge available within one firm. The product domain lists the firm's product offering. Since individual products require a broad range of knowledge and not all knowledge is product specific, the firm experiences a mismatch between its knowledge and product domains. We are particularly interested in cases where a firm envisions a product for which it does not possess the full range of required knowledge. When the most promising application of a radical technology lies outside the firm's current businesses, a collaborative arrangement with another firm, in our case a potential customer, might be a way to access and integrate customer knowledge, which can be more efficiently provided by the user than it can be developed internally. Not only because internal knowledge development is likely to be more costly in terms of time and expenses but also because once appropriated the knowledge will probably be under exploited by the existing product ranges. In radical innovation projects there is a tendency to engage in collaboration agreements to overcome these competency gaps (McDermott 1999). Working closely with a lead customer provides an occasion to gain valuable feedback on early prototypes in a relatively safe environment.

It is important to note that we focus our research to business-to-business markets. Consequently, a customer is a company and collaboration takes place in the form of inter-firm interaction.

Conceptual framework

The process of technology commercialization

In what follows we go from a definition of the concept technology commercialization to the actual description of the technology commercialization process.

Technology commercialization (TC). In pursuit of Zahra and Nielsen (2002) we adopt Mitchell and Singh's (1996, p. 170) definition of commercialization as "the process of acquiring ideas, augmenting them with complementary knowledge, developing and manufacturing saleable goods, and selling the goods in a market." Hence the process of technology commercialization entails all activities from idea generation to product design, prototype testing, manufacturing and marketing. A business model is developed to transform technological capabilities into economic value (Chesbrough 2003). The extent to which the innovating firm succeeds in capturing this economic value depends highly on the characteristics of its business model. Often the appropriate business model for a new technology is not immediately obvious. The development of a business model may require breaking away from current practices both within the firm as within the market. Consequently technology commercialization can be a long process with numerous milestones to be reached before value realization is even in sight (Leifer et al. 2000). Therefore it is essential to align research with development, to focus efforts toward clear objectives and to dedicate enough attention to diffusion, utilization and acceptance of the technology-based outcomes in the market.

The process of technology commercialization. Jolly (1997) comes up with an interesting conceptualization of the technology commercialization (TC) process. He describes a wide range of TC processes, covering a broad spectrum of technologies and formulates a process description that fits them all. The five key sub processes of the TC process are depicted in figure 1. Each of the sub processes involves solving problems of a technological and/or market nature. Equally important as these sub processes are the four bridging activities between them. They all involve mobilizing support and resources to enable the transition to the next sub process. According to the specific process phase value has to be demonstrated to varying stakeholders with evolving interests in the technology. It is interesting to note that potential users and customers are viewed as main stakeholders in every phase from phase two onward in the five-phased process of figure 1. Value creation and stakeholder management characterize the process as a whole.

Figure 1 shows how the commercialization process starts off with imagining an application for the new technology that can be linked to an interesting market opportunity. This process entails elements of serendipity and individual talent but "drivers such as stretch goals, scientific discovery and interest and strategic context seem to have the most impact when it comes to the visioning process as it pertains to discontinuous new product development (O'Connor and Veryzer 2001, p. 244).
The first bridging activity in the intersection of the first two circles in figure 1 entails thinking the base technology well through and sharing scientific findings with peers in and outside the firm. For external communication a balance needs to be found between arousing sufficient interest in the technology without enabling imitation (Easingwood and Koustelos 2000).

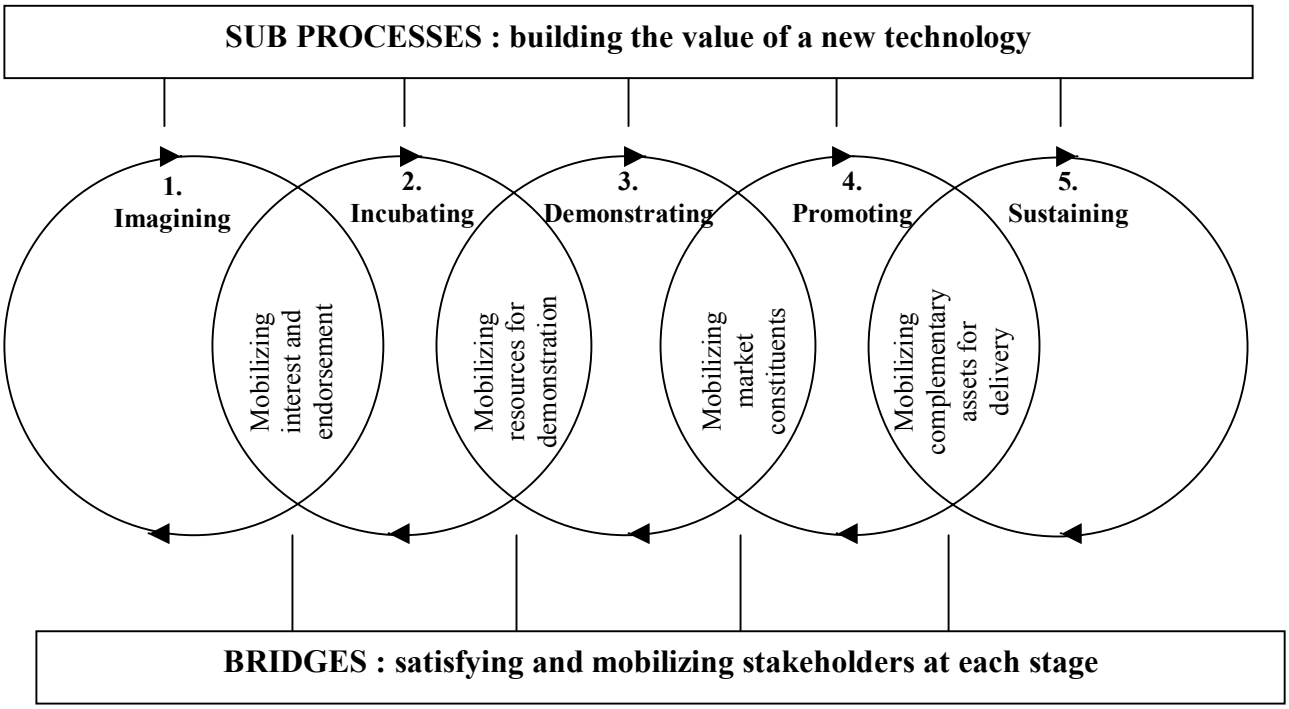

Fig. 1: The process of technology commercialization (source: Jolly 1997, p. 4)

The next step is incubating the technology by defining its commercializability. Early and frequent prototyping help reaching technical milestones and the market experience helps identify an attractive set of applications (Lynn et al. 1996). Intellectual property rights are put in place (Teece 1998).
Perceived technological risks are reduced considerably to arouse interest and gather resources. An alliance with a key customer can signal to internal management that there is indeed market interest for the new technology and persuade them to invest in the innovation project (McDermott 1999).
Demonstrating the technology contextually in products and processes is about actual product development tailored to customer needs and wants. Potential customers must be able to perceive the value of the radically innovative technology. Techniques used are prototyping with customers, trial sampling and direct observation of usage patterns with current technologies in the customer's natural environment (O'Connor 1998).
Various market constituents need to be convinced of the value of the new technology. Opinion leaders and government institutions might play important roles. For delivering the new technology a business model is built and important sourcing decisions are made (Zahra and Nielsen 2002).
For radically new technologies promoting adoption might have to take place inside as well as outside the innovating firm. When the technology differs from current activities it might not be obvious to relate it to an existing business unit (Bond and Houston 2003). In the market educational efforts are aimed at clarifying the technology's advantage and usage (Stump et al. 2002).
Finally, the business model is in place to allow value appropriation by the innovating firm (Chesbrough 2003).
While sustaining commercialization market development activities enable realization of long-term value (O'Connor et al. 2002) and the market is monitored for changing customer needs and emerging new technologies.

On the next pages table 1 gives a summary of our literature review structured according to the five-phased model of technology commercialization. The table contains the five sub processes of figure 1, the bridging activities are not explicitly mentioned to allow for a clear overview. The included articles are scanned for appropriateness by using radical innovation, in large firms and in a business-to-business context as criteria. We attempt to mention only one idea per row in the findings column, this sometimes results in mentioning some authors more than once. We also hope that this will aid clarity of our literature review.

Jolly (1997) stresses the need to see innovation as a segmented process, where each of the five segments requires a multifunctional approach and generates a commercial outcome. This line of thinking contrasts with the traditional sequential approach to the various functional activities. We oppose the two visions in figure 2. Figure 2a is the sequential approach and 2b shows how multiple functions play a role in each of Jolly's (1997) five sub processes.

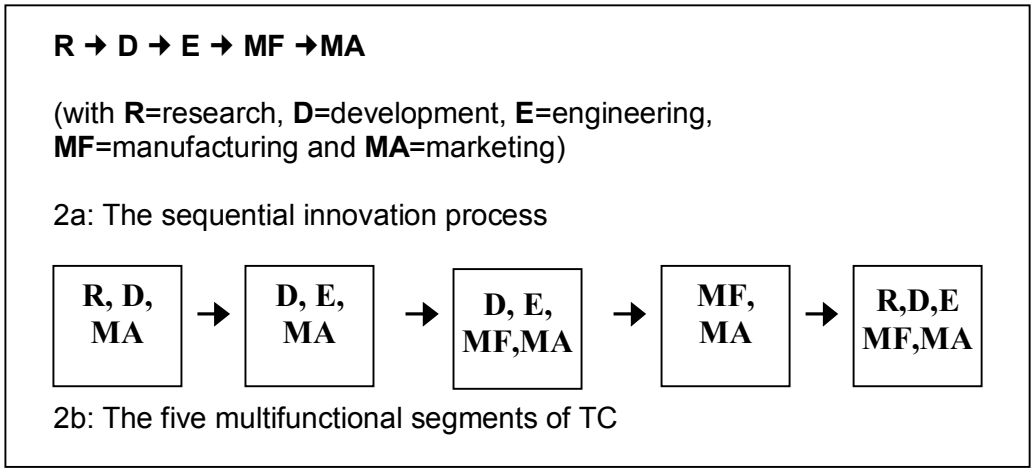

Figure 2: Innovation as a multifunctional segmented process
(source: adapted from Jolly 1997, p. 15)

Note that in figure 2b the marketing function is the only function that is present in every segment. It represents the need to imagine applications from a user standpoint, to create a design from a deep understanding of customer problems and to maintain a commercial focus throughout the entire process.

Author(s)	Research topic	Conceptual (C) Empirical (E)	Findings
1. Imagining the techno-market insight			
Bond and Houston (2003)	Barriers to matching technologies and market opportunities	C	External barriers: technology availability, technology/market capabilities of competitors. Internal barriers: competition for limited resources, technological capabilities, general technology portfolio goals.
Easingwood and Koustelos (2000)	Marketing high technology	C	Provide pre launch information "to arouse sufficient interest in the new product without losing a competitive edge in a market where imitation can materialize…"(p.28)
Mascitelli (2000)	Tacit knowledge and breakthrough innovation	C	"… breakthrough innovations are often an outgrowth of a deeply held and highly personal form of knowledge, derived from a lifetime of experience and learning." (p. 181)
O'Connor (1998)	Market learning and radical innovation	E (8 innovation projects in large firms)	The early stage of radical innovation that involves technological forecasting coupled with imagining is an introspective process without customer contact[1].
O'Connor and Rice (2001)	Opportunity recognition and breakthrough innovation	E (12 innovation projects in large firms)	Low- to mid-level research managers are most often the initial opportunity recognizers. The 'opportunity' lies not in a market promise, but in a conceptualization of what the delivered benefits of the technology might be.
O'Connor and Veryzer (2001)	Market visioning for radical innovation	E (11 innovation projects in large firms)	"Contrary to the findings of some researchers (von Hippel 1988) customers or lead users seem to play little if any role in the visioning process" of radical innovations[1] (p 244). A case in which customers did play a role is described as when an innovating firm publicized its technology's specifications in the market. Then the firm worked with inquiring firms to develop applications.
Veryzer (1998)	Evaluation of discontinuous new products	E (7 innovation projects in large firms)	In this study "product ideas originated within the firms rather than coming from customer input." (p. 149)
2. Incubating to define commercializability			
Leonard and Rayport (1997)	Innovation through empathic design	C (anecdotal evidence)	"Empathic design techniques [such as customer observation and prototyping]… exploit a company's existing technological capabilities in the widest sense of the term. When a company's representatives explore their customer's worlds with the eyes of a fresh observer while simultaneously carrying the knowledge of what is possible for the company to do, they can redirect existing organizational capabilities toward new markets." (p. 108)
Lynn, Morone and Paulson (1996)	Discontinuous innovation: the probe and learn process	E (4 cases in large firms)	During definition of commercializability potential markets are probed with early prototypes with the aim of learning, reducing technological risks and increasing the likelihood of success of the next probe.
McDermott (1999)	Managing radical product development in large firms	E (7 projects in large firms)	All of the projects studied created alliances of some form to fill competency gaps. A lack of market knowledge was the major incentive for alliances. Alliances with key customers not only provided valuable feedback, they also served as internal justification for the project. "While the income generated from these relationships was clearly not enough to recoup sunk costs, it provided upper management with encouragement that there was indeed a potential market for a project that had thus far been a money pit." (p. 637)
McDermott and O'Connor (2002)	Managing radical innovation	E (12 projects in large firms)	Projects can be directed at markets that are familiar territory to the firm or they may be aimed at new markets. The authors list the challenges of both. Challenges of familiar markets: (1) ensuring delivery of perceptible benefit, (2) managing the threat of cannibalization and (3) overcoming market resistance to the technology. Challenges of new markets: (1) where to locate the business within the firm, (2) how to build an effective business model.

[1] There seems to be a contradiction concerning the customer role in imagining when comparing O'Connor (1998) and O'Connor and Veryzer (2001). However the last authors themselves explain how their expectation that a single individual would create a vision was rejected by the discovery that numerous parties contribute to the formulation of a vision. One of which in some cases are customers, be it that they contribute mainly indirectly to the visioning process.

Moriarty and Kosnik (1989)	Market and technological uncertainty in high-tech markets	C	The example is given of how Digital Equipment Corporation met with their leading customer organizations to exchange ideas on how to use Digital's new technology.
O'Connor (1998)	Market learning and radical innovation	E (8 innovation projects in large firms)	The authors expect divergent thinking during application generation for radical innovation.
Teece (1998)	Capturing value from knowledge assets	C	In advanced industrial economies management of intellectual property is a major challenge.
Thomke (2001)	Experimentation for innovation	C	New technologies allow cheap and quick experimentation. Experiment early and frequent to shape ideas and to increase the likelihood of breakthrough discoveries.
3. Demonstrating contextually in products and processes			
Day (2002)	Market learning	C	For breakthrough products: do not ask customers what they need, but identify their problems and outperform current alternatives with your offer.
Mascetelli (2000)	Harnessing tacit knowledge to achieve breakthrough innovation	C	"By accelerating the fabrication of early prototypes and encouraging the continuous updating and manipulation of these prototypes throughout the design process, managers can create a visible focus for team interaction, customer involvement, … and creative insight." (p. 191)
O'Connor (1998)	Market learning and radical innovation	E (8 innovation projects in large firms	There is a need to work closely with customers to test and to understand the design requirements that allow value to be perceived. Techniques used are early prototyping or trial sampling with lead customers and direct observation of usage patterns of current technologies.
O'Connor and Rice (2001)	Opportunity recognition and breakthrough innovation	E (12 innovation projects in large firms)	Investment in the projects is typically staged along multiple instances of opportunity recognition in a context where critical sponsors come and go and corporate strategies change.
Stump, Athaide and Joshi (2002)	Seller-buyer NPD for customized products	E (questionnaire data from 296 firms)	Particularly in the case of customization of technology-based innovations the customer can attempt to negotiate exclusivity or joint patent ownership, which may delay or even prevent the seller from offering the product to the larger marketplace. Nevertheless, the authors stress the need to involve buyers in the product development process as soon as the product innovation, as well as its underlying technology, has reached an acceptable level of development. This allows product knowledge generation in the form of obtaining reactions to product design and prototype as well as generating feedback on desirable product modifications and alternative applications.
Veryzer (1998)	Evaluation of discontinuous new products	E (7 innovation projects in large firms)	The author lists factors influencing customer evaluation of prototypes and discontinuous new products (p.143-146): First, lack of familiarity with the new products in most cases took the form of resistance to the product. Unfamiliarity with new products appears to promote seemingly irrational thinking or prompt customers to focus on, in the minds of members of the development team, irrelevant attributes. Second, the ability of the product to be understood in terms of how it is to be operated and the benefits that it offers has a considerable impact on customer evaluations. Third, the degree of compatibility that a new product has with a costumer's business situation influences evaluation. Products that are highly discontinuous with respect to their usage pattern are subject to the most customer scrutiny. Finally, aesthetic aspects of the product seem to affect customers' sense of the product's safety. Managers note that it can be detrimental to ignore the aesthetic aspects of a product during customer testing of early prototypes because this can affect customer responses to the products.
Veryzer (1998)	Evaluation of discontinuous new products	E (7 innovation projects in large firms)	"… inclusion of marketing research personnel to help with customer testing as early on in the development process as possible is likely to improve the quality of the information obtained during testing. … quality and utility of customer research inputs were [also] greatly improved when engineers on the development team participated in conducting customer research (e.g. focus groups)." (p. 148)
Veryzer (1998)	Evaluation of discontinuous new products	E (7 innovation projects in large firms)	"… alliances with key customers did sometimes play an important role in the development process." (p. 149)
4. Promoting adoption			

Bond and Houston (2003)	Barriers to matching technologies and market opportunities	C	External barriers: business model-market feasibility. Internal barriers: connecting the new technology to a business unit.
Dewar and Dutton (1986)	Adoption of radical and incremental innovations	E (data from 40 firms)	For adoption of radical innovations it is more important than for incremental innovations that the customer firm has considerable depth in its knowledge resources. Organizational size is important only for radical innovation adoption.
Dunn, Friar and Thomas (1991)	Selling high-tech solutions	E (12 cases)	"Unmet promises and repetitive obsolescence of technology add to buyer apathy." (p. 154)
Dunn, Friar and Thomas (1991)	Selling high-tech solutions	E (12 cases)	"… buyers reflect a derived demand orientation. Companies are buying technology not to benefit internal employees or cost center managers, but for its impact on the buyer's buyers, an external audience." (p.157)
Easingwood and Koustelos (2000)	Marketing high technology	C	"Targeting existing customers is a strategy particularly appropriate to rapidly changing, advanced technologies. It can be particularly relevant for complex technologies when the decision to adopt often relies on a high degree of technical expertise and mutual trust between buyer and supplier." (p. 30)
O'Connor, Hendricks and Rice (2002)	Assessing transition readiness for radical innovation	E (12 innovation projects in large firms)	"… new products based on discontinuous innovation are sufficiently different from current products that potential customers need to be educated" (p.52)
Stump, Athaide and Joshi (2002)	Seller-buyer NPD for customized products	E (questionnaire data from 296 firms)	"Conducting extensive educational efforts is particularly appropriate in technology-based industries because the rapid pace of technological change renders buyers' knowledge structures obsolete. … Educational activities often evolve around explaining the underlying technology, clarifying the innovation's relative advantages, delineating appropriate product usage, as well as specifying performance criteria to be used in evaluating the innovation." (p.443)
5. Sustaining commercialization and realizing long-term value			
Chandy, Prabhu and Antia (2003)	Dominance, technology expectation and radical innovation	E (primary data and lab studies)	"…current research is overly pessimistic in portraying dominant firms as laggards in pursuing radically new technologies. …[Among dominant firms] the fear of obsolescence appears to be a much stronger motivator of investments in radical innovation … than is the lure of gains from enhancement." (p. 14)
O'Connor, Hendricks and Rice (2002)	Assessing transition readiness for radical innovation	E (12 innovation projects in large firms)	For market development purposes the authors recommend the innovating firm to have a plan in place for exploring alternative applications for the technology.

Table 1: Literature review of the technology commercialization process

Radical

We focus our study on radically innovative technologies. By radical we mean that the technology is viewed within the firm to have the potential to offer unprecedented performance features or embody familiar features that offer the potential for five- to tenfold improvements in performance or at least a 30% reduction in cost (O'Connor and Veryzer 2001).

Lead customer interaction

Lead customer. Our lead customer concept is inspired by von Hippel's (1986) lead users characteristics. Applied to our research focus lead customers are:

- industrial customers that are among the first to adopt a technological innovation
- users that benefit significantly from the technological innovation meaning that adoption results in a significant reduction of their costs or a significant improvement of performance, both natural inferences of the radicalness of the technology involved.

Lead customers usually are users of to the new technology substitute or complementary products or technologies and they are potential customers for the technological application under development. The two characteristics above seem highly interrelated. Lead customers not only benefit significantly because of the radicalness of the technological breakthrough. Being among the first to adopt the new technology also means a better chance of being able to fully enjoy the offered benefit before its value erodes in the marketplace.

Lead customer interaction. Because of the technology push involved we only regard instances of lead customer interaction, that are initiated by the supplier. From our literature review (see table 1) we learn that user interaction mainly occurs during the phases of incubating and demonstrating the technology. Lead customer interaction can serve early idea testing, observation of the user in his natural environment as a means for tapping into customer's experiences and tacit knowledge (Leonard and Rayport 1997, O'Connor and Veryzer 2001 and Kanter 1997), technological and market learning during prototype testing (Lynn et al. 1996) and joint product development. For further details we recommend lecture of sections 2. and 3. of table 1.

The dynamics of learning with lead customers

Because of the high stakes in a buyer/supplier collaboration and the value of the exchanged information, mutual trust and commitment are essential determinants of the outcome of the joint learning process. In this section we illustrate the dynamics of learning with lead customers.

Understanding and managing strategic relationships with customers is of capital importance in industrial markets (More 1986). The most important sub process in this kind of relationship "is conceptualized as negotiation involving two central 'flows': information flows and resource flows. These two flows characterize a mutual relationship in which both organizations try to effectively manage their continuously evolving risks and payoffs in the situation" (More 1986, p. 508). Customers compete for value (Prahalad and Ramaswamy 2000) on multiple fronts. The supplier can find himself confronted with a customer requesting 'dream' features (von Hippel 1988)

impossible to implement or successfully commercialize. Furthermore, “radical innovation development will almost certainly produce new intellectual property. Therefore determining issues of ownership and control is an important part of the partnership negotiation process” (Leifer et al. 2000, p. 128). Particularly in the case of technology-based customized innovations the customer can demand “contractual stipulations like exclusivity clauses or joint patent ownership by the seller and the buyer, which may delay or even prevent the seller from offering the innovative product to the larger marketplace” (Stump et al. 2002, p. 440).

Exploratory study

Our exploratory study is an exploration of the market for case material. We plan a multiple case study research focused on lead customer interaction for technology commercialization. We identified five cases within two large firms. Because of the exploratory character of our study we usually interviewed one or two persons per case. Interviews took at least 1,5 hour each and for each case relevant secondary material was studied in addition. Table 2 summarizes some of the case characteristics. It gives a general idea of the technologies involved and their application industries.

	Base technology	Application industry	Current TC phase
A	Electronics	Consumer electronics	3. Demonstrating
B	Chemicals	Laser marking	4. Promoting
C	Chemicals	Food testing	2. Incubating – 3. Demonstrating
D	Chemicals	Bulk chemicals	2. Incubating – 3. Demonstrating
E	Advanced materials	Shipping, fishing, ballistics, medical, leisure, ...	5. Sustaining

Table 2 : Cases of technology commercialization

Case descriptions

In what follows we provide a short description of each case. Names of projects and firms are disguised, the information remains unaltered.

Case A. At the beginning of 2001 a large Dutch electronics company partners with an American start-up company to commercialize the new display technology of the start-up. The large company gains access to the new technology, while the start-up hopes that the reputation of the large company will facilitate commercialization of the technology. The role of the start-up is limited to delivery of materials to the large company. The latter is responsible for commercialization of the technology. Currently efforts are focused at an application aimed at the consumer market. Main characteristics of the new display are its resemblance to paper, its low energy use and the feature that displayed images are insensitive to the angle under which they are viewed. A drawback is the inability to display colour. The innovating firm regards it as a promising substitute for paper e.g. for journals, magazines, the so called e-book. Hence the end market for the application is the consumer electronics market. The project is now in its demonstrating phase. Since end of 2001 a joint development agreement exists with a Japanese lead customer, an OEM company. Development is progressing, even though it is behind on the original schedule. According to adjusted projections development activities should be finalized by the summer of 2004.

Case B. The customer base of the laser centre at a large chemicals company is decreasing. In February 2002 a business development manager is appointed to work out a new future for the group. In May 2002 two of the group's R&D members discover a chemical that enables high quality laser marking independent of the characteristics of the polymer in which it is used. The inventors team up with the business development manager to commercialize this new technology. By the end of the year a patent application is written and filed and the first business plan is completed. Beginning of 2003 the technology is recognized as a breakthrough by leading market constituents. Application possibilities are identified and first trials take place. At this moment the team has everything in place to start production and at least 25 customers have put in their first orders. Promotion of adoption of the innovation can begin.

Case C. In 1999 a chemical is discovered in a large chemicals company that allows a fast, reliable and easy detection of antibiotic residues in food products. Initially diary products are considered to be the interesting segment, but when the test does not take off the meat product market is targeted. The development team has prepared documentation material to educate the market, has contacts with governmental agancies in various European countries and experimented with the product form of its application. Until now commercial value has failed to materialize. The project goes back and forth between incubating and demonstrating the technology but fails to proceed further.

Case D. Since 1996 a large chemicals company has been doing research on high performance rubber. In 1998 a production technology is discovered that allows production of the rubber at much lower capital and variable costs. Furthermore the process delivers a by product that can be sold in the market. Unfortunately, by this time the company exited production of the base material needed for production of the high performance rubber. As a consequence the development team does not only lose easy access to raw material but even more importantly the necessary production facility is no longer available in house. The development manager is confronted with the difficult task of capturing the technology's value while the potential production partner and potential end users are each competing for their piece of the cost advantage. Negotiations are going on with competing firms, production partner and end user to build the business model. Hence the project is stuck right before phase four of the technology commercialization model.

Case E. In 1978 an innovative production process is discovered that enables production of a very strong fiber. It takes the company until 1986 to fine tune the process and acquire the necessary competences for fiber handling, which is not a core competence of the company. Subsequently the company invests about another 10 years to getting to know the unfamiliar industrial markets and their end markets. In 1992 the choice is made to focus on applications for ropes, nets and ballistic protection. The development team succeeds in translating the fiber's benefits into parameters relevant for the customer. Production capacity is expanded but the focus continuous to be on small, very lucrative segments. By now the company is sustaining commercialization of its technology by serving various market segments with a range of applications. The latest development is a high purity version of the fiber aimed at the medical market.

Discussion

After a short description of the cases, we elaborate on customer interaction during the projects. Once again we use the five-phased conceptual model of technology commercialization to structure our analysis. Table 3 indicates when companies engaged in customer interaction and for which activities. The phases that the projects have not yet reached are marked grey to indicate that they are not included in the analysis.

	1. Imagining	2. Incubating	3. Demonstrating	4. Promoting	5. Sustaining
A		Idea testing	Joint development		
B			Trial sampling	Customer problem solving	
C			Trial sampling		
D			Trial sampling		
E		Idea testing Iterative probing and learning	Joint development	Customer problem solving	

Table 3: Customer interaction during technology commercialization

In the following paragraphs we discuss customer interaction for our five cases. We mention with whom interaction is sought at which moment in the TC process and during which activity. We dedicate one paragraph to each of the five steps in the technology commercialization process.

1. Imagining a techno-market insight. In all the cases linking the technological benefits to an interesting application was an internal exercise without customer contact. The respondents all found the application area for the new technology to be quite obvious.

2. Incubating to define commercializability. In two out of the five cases initial ideas were tested in the market by discussing them with potential customers and users.
In case A the display technology was shown to industrial customers to gain feedback on the technology and possible applications and to check how interested industrial customers were to integrate the technology into their own products. Finding these potential customers is reported as easy since the display market is a relatively concentrated market of about 30 players. Furthermore most of these companies were already customers of the innovating firm, be it for other products than displays. Hence it was relatively easy to convince them to take a look at the new display technology and obtain their feedback. Convincing them to integrate the new display into their products was a far more difficult task because of the relatively high cost of the technology. Companies were satisfied with their current solutions. This is why the development manager started looking for an application that was not possible with current display technologies. He hoped that if there was no current solution to a problem, customers would be willing to take the technology's high cost for granted. For the e-book application he did in fact find an OEM company who had been playing with the idea of e-books but until then had not found an appropriate display technology. So for case A interactions with industrial customers helped identify a possible commercial application.
For the super strong fiber of case E a similar situation occurred. The link with ropes and nets was made quite easily but it was not before interacting with rope and net manufacturers that the firm started to be able to define attractiveness of the strong

fiber in terms of parameters that were actually valued by the customer. Since the company had no competencies in the field of rope or net manufacturing manufacturers were persuaded to do trials for them. These trials flopped frequently. Essential was that the innovating firm kept on learning from these incidents and acquired knowledge to help increase the likelihood of success of the next trial.
In case A the feedback from industrial customers was supplemented with market research with end users. End users were asked to evaluate a prototype of the e-book. This enabled the development team to look beyond the industrial customer to define commercializability. For the laser additive in case B communication of the technology's benefits to the market prompted the reaction of a competitor who stated that if the innovation could really do what the firm promised it could do, they had a breakthrough. The internal market research department conducted a market study to estimate the market for laser marking. Initial application possibilities were still generated internally. The development manager of the super strong fiber, case E, also mentions trying to define commercializabilitiy by doing desk research on markets where he thought the fiber might prove to be useful.

3. Demonstrating contextually in products and processes. In all five cases some form of customer interaction occurred during the phase of demonstrating the technology in products and processes.
In cases B, C and D trial samples were delivered at request of potential customers. In all three cases the potential customer could find out for himself that the product actually delivered upon its promise, but only in case B, the case of the laser additive, could the customer also agree on the suggested price level. The situation for case C in the food industry poses the very specific problem that everyone in the food chain is aware of the growing concern for antibiotics in food products, but at this moment, nobody is willing to pay for doing tests themselves. The new test is integrated in the official tests used by government agencies in the UK, Germany and Belgium but the development team would like to penetrate the market beyond these official agencies. Apparently, the food industry prefers running the risk of getting caught with food that contains antibiotic residues, rather than incurring expenses to be able to test their products themselves. In case D of the rubber production technology, both the potential production partner and potential customers compete for value. Potential customers have been sent lab samples of the high performance rubber to confirm that its quality is equal to that of performance rubbers manufactured by the current production process. However it does not outperform current alternatives, so both the end customer as well as the potential production partner refuse to let the innovating firm capture all of the value of the process technology.
Development teams in cases A and E engaged in joint development programs with lead customers. In case A the innovating firm engages in a joint development agreement with a Japanese OEM company. For each development stage a fixed financial contribution is requested from the OEM company, which is mainly symbolic to show commitment. At the start of each development stage technical specifications are negotiated for the next prototype. The development manager mentions the tough balance between on the one hand gaining useful information on technological features that are wanted in the market from its development partner but on the other hand not letting the development partner take over control of the direction the development activities take. For example, at the start of the joint development partners agreed on restricting the technology to displaying black and white. This way the innovating firm tried to avoid getting into the difficult and risky research for displaying the different shades of grey. However during the course of development the OEM insisted shades of grey would be included. The innovating firm gave in. As a consequence development is about one year behind on schedule. Joint

development in case E, the rope applications for the strong fiber, was not formalized at all. Because the innovating firm lacked expertise and the necessary installations for rope production rope manufacturers were simply requested to try certain methods of rope manufacturing for them with the super strong fiber. The company had no problem switching from one rope manufacturer to another either. In some cases the rope manufacturer ended the cooperation after one too many failures. Luckily other manufacturers remained interested until the innovating firm acquired the necessary knowledge.
It is interesting to note that managers in cases D and E mention that market leaders are usually not the parties most interested in working on new technologies with innovating firms. The development manager in case E describes market leaders as almost being to lazy to bother, occupying in an interesting position in the market anyway. Second best players in the industry might attach higher potential gains to switching to an innovative technology and hence they might be more willing to cooperate in the development process with an innovating firm.

4. Promoting adoption. In cases B and E customer interaction took place at this stage of technology commercialization in the form of solving customer problems or requests related to implementing the new technology. In the case of laser marking, case B, the innovating firm even has a consulting agreement with a laser supplier mainly to keep a foothold in the colour laser marking market. The innovating firm restricts itself mainly to dark on light marking, but shares his expertise with laser suppliers and customers mainly for the purpose of relationship management. The company in case E is also thinking with customers to solve problems that might inhibit switching to the new fiber.

5. Sustaining commercialization and realizing long-term value. To sustain commercialization the company in case E has a policy of sharing its expertise with whom ever shows interest in the strong fiber. The company is confident that production of the fiber requires investments that are so high that they prevent imitation and that parties who are not interesting to work with will loose interest as soon as they are informed of the high cost of the fiber. Up until now this has proven to be a successful approach.

Conclusion

Customer interaction only seems to be relatively unimportant for the fuzzy front end of technology commercialization where a vision for applications of the new technology is created. From that moment onwards during the different phases of technology commercialization different types of customer interaction can contribute to the commercialization process. For definition of the technology's commercializability early prototyping with customers enables the innovating firm to learn not only about the technology but also about markets for its applications. Joint product development may occur with a lead customer. Observations seem to indicate that market leaders are not necessarily the most interested parties for such a joint agreement. In industrial markets customers invest time and efforts into testing the offered innovation. It is important that the innovating firm delivers free trial samples and thinks the testing process through with the customer. Sharing of expertise can also help promoting the new technology with customers. Solving problems together with customers can persuade customers to switch to the new technology. Finally, a market development plan with a set of additional applications for the new technology can enable long-term value realization.

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