Critical Junctures in the Growth in University High-Tech Spinout Companies

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Abstract

This paper presents an empirical investigation into the development of university spinout companies. Specifically, we focus on the issue of how these ventures develop over time. Employing a case-based research method we investigated how nine different spinout companies developed over their history. We use the capabilities framework in order to analyze the case-data. Our research indicates that each of the ventures can be considered to move through a number of distinct phases of their development. Furthermore, we found that each of the ventures came up against generic problems whilst attempting to move from one phase to another. We term the problem of moving between the different phases as "critical junctures", as ventures cannot develop into the next stage without overcoming each of the junctures. We identify four different critical junctures that spinout companies need to overcome if they are to succeed. Finally, we propose that unless the entrepreneur or the entrepreneurial team possesses the necessary entrepreneurial capabilities to overcome these critical junctures, the venture will stagnate, and eventually fail.
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INTRODUCTION

The spinning-out of university-based scientific inventions into separate companies represents a potentially important but as yet under-developed option to create wealth from the commercialization of research (Bray and Lee, 2000; Siegel, Waldman and Link, 2001; Shane, 2001). Exploitation of these inventions, in what has historically been a non-commercial environment, raises new entrepreneurial challenges beyond those faced by new high tech ventures in general.

The difficulties associated with new high tech ventures are well-documented. In general, the novelty of the venture and inexperience of the entrepreneur, gives rise to a "liability of newness" (Singh, House and Tucker, 1986). This barrier constrains the ability of the new venture during the early stages of growth to become an established firm in a market, capable of earning sustainable profits. Entrepreneurs need to overcome this challenge to achieve a succession of transitions from one stage of growth to the next.

University high-tech spinouts (USOs) can also be characterized as new ventures in transition. The process by which USOs take scientific inventions from the laboratory to the marketplace has not been documented. As with other high-tech start-up ventures, university spinouts face considerable difficulties in achieving sustainable growth and profitability. However, entrepreneurs and USOs face specific obstacles and challenges as they evolve from an initial idea in a non-commercial environment to an established and sustainable new technology base firm (NTBF) (Siegel, et al., 2001; Siegel, Waldman and Link, 2002; Nelson, 2001). Much of the literature related to the growth of new ventures discusses the characteristics of each growth stage, yet fails to address the impact of the entrepreneur on the venture's ability to make the transition from one stage to the next. This may be especially important in a USO where academic entrepreneurs may lack commercial skills but at the same time seek to exert a continuing influence over the venture while maintaining an academic career.

This paper aims to address these issues by providing an empirical investigation into how university high-tech spinout companies develop, from which we build theory concerning the nature of the transition problems they face. Drawing on existing research into the life-cycle/stages of business development, and recent advances in the resource-based view of the firm we specifically address two questions. First, what phases do spinout companies go through in their development? Second, what challenges do such ventures face in their development?

The paper is structured as follows. The next section outlines the different theoretical contributions on which we draw in developing our insights from the case data. The third section presents the methods of data collection and analysis. The fourth section presents an analysis of the empirical evidence in terms of the different phases that spinout companies pass through in their development and the "critical junctures" that USOs must overcome as they seek to move to the next phase of development. We find that these "critical junctures" characterize the transitions between the different phases of development, and are fundamental impediments to USO development. Building on this notion of critical junctures the fifth section presents a discussion of
the underlying forces, which give rise to these critical junctures. Finally, we conclude with a summary of our findings and theory development.

THEORETICAL BACKGROUND

To understand how USOs develop there is a need to consider both the stages in their life-cycle and the challenges they face in their development. In particular, it is necessary both to examine how these challenges arise and to analyze their impact on the transformation of USOs into complex organizations. The development of a firm can be seen as an unfolding process based on endogenous changes in the firm’s resources (Penrose, 1959).

The resource-based view (RBV) considers the firm to be a historically determined collection of assets or resources that are tied semi-permanently to the firm’s management (Barney, 1991; Barney, Wright and Ketchen, 2001; Lockett and Thompson, 2002). A distinction can be drawn between a resource as a stock and a resource as a flow or competence or capability (Teece, Pisano and Shuen, 1997). This distinction emphasizes the importance of the firm’s ability to develop competencies or capabilities since it is these factors that enable firms to learn over time and generate stocks of new resources (Penrose, 1959).

Traditionally, attempts to understand the complexities of the evolution of new ventures have been portrayed in various stage models. These models emphasize that the nature of a business changes as it grows. More specifically, they identify a number of organizational characteristics exhibited at each stage of development and suggest the changes required in the behavior and practices of entrepreneurs if their business is to progress to the next stage. Several different models have been presented identifying three (Smith et al, 1985), four (Flamholtz, 1986) and five stages (Miller and Friesen, 1984; Van de Ven, et al., 1984) in the development of a new venture.

Stage-based models have been criticized on a number of counts. First, while overall firm development may take place in identifiable stages, all firms cannot be presumed by some inevitable logic to pass through all stages or to pass through each stage sequentially (Foss, 1997). Second, most models describe the structure and internal firm characteristics at each stage of development without providing significant understanding of why those characteristics emerge (Kazanjian 1988). Third, many ventures will not be successful and will not move through the different stages (Romanelli and Tushman, 1986). Fourth, stage models typically fail to capture the important early stages in the origin and growth of a business (O’Farrell and Hitchens, 1988). These models typically focus upon the growth of a firm from a small unit to a large corporation rather than attempting a detailed understanding of the process of change and growth of the small, independently owned firm itself. Finally, while movements between stages may be triggered by a crisis, the nature of these problems and the extent to which they may inhibit this transition have been neglected.

However, common patterns of organizational transition that recur frequently in complex established firms can be identified (Miller and Friesen (1984). Kazanjian (1988) describes the growth-stages of NTBFs as configurations of organizational design variables representing how these ventures respond to the sets of dominant problems they face at sequential times. These dominant problems are important not only in defining and measuring discrete stages, but also in understanding the transitions from stage to stage. Foss (1997) argues, therefore, that stage approaches provide a conceptual mechanism for analyzing how the activities at different stages of a firm’s development are supported by different types of resources. Stage approaches also provide a dynamic means of examining firm growth and change through the identification of where firms
are weak in resources and capabilities and how they learn to overcome these weaknesses. This discussion leads to the formulation of our first research question (RQ1): What different phases of growth do USOs go through?

From a resource-based perspective, it is clear that in order to progress through different phases of development, USOs need to develop their resource/capability base over time. Established firms have, and continue to develop, capabilities through their management and management systems/routines. Brush, Green and Hart (2001) categorize resources/capabilities into: physical, organizational, technological, human, financial and social. These capabilities help managers to manipulate resources into new productive combinations in the context of changing markets (Galunic and Eisenhardt, 2001; Eisenhardt and Martin, 2000, Teece et al, 1997). The traditional non-commercial nature of universities indicates a lack of resources to promote USOs.

This problem is exacerbated by the potentially constraining influence that the initial resource of a USO may have on its development (Page-West and De Castro, 2001). Specifically, academic inventors, due to commercial inexperience, may focus too much on the technical aspects of the innovation (Daniels and Hofer, 1993). It is well-recognized that the individual who first identifies an innovative opportunity may not be the best person to champion it (Venkataraman, MacMillan and McGrath, 1992). To alleviate this problem "surrogate" entrepreneurs, as outsiders with commercial experience, may be brought in to work alongside the academic inventor to develop the venture (Franklin, Wright and Lockett, 2001; Lockett, Wright and Franklin, 2002). The surrogate can bring entrepreneurial capabilities to the venture, which are defined by Mosakowski, (1998) as the propensity of an individual to behave creatively, act with foresight, use intuition, and be alert to new opportunities. The presence of these entrepreneurial capabilities introduces the ability to identify and address other resource/capabilities constraints. These constraints will change over time as the development of the ventures will not necessarily be smooth (Miller and Friesen, 1984). As a result, the pressure on the firm to access resources will reach specific junctures, which we consider "critical" if the venture is to develop successfully. At each of these junctures there is a requirement by the firm to access, acquire or develop resources/capabilities in order to overcome the constraint. This discussion leads to the formulation of our second research question (RQ2): What factors give rise to the critical junctures encountered by USOs?

RESEARCH DESIGN

The research design employed an inductive approach in order to obtain a rich understanding of how USOs evolve from research activities in to commercial organizations (Van de Ven, 1992). The multiple case design permits a "replication" logic (Yin, 1984), allowing the case analyses to be treated as a series of independent experiments (Brown and Eisenhardt, 1997). This method allows for close correspondence between theory and data, a process whereby the emergent theory is grounded in the data (Eisenhardt, 1989).

For purposes of this study, a USO is defined as a venture founded by employees of the university around a core technological innovation which had initially been developed at the university (Birley, 2001). The USO is created solely to overcome technical and market uncertainties inherent in the perceived commercial opportunity. This definition deliberately excludes those USOs traditionally regarded as life-style companies that are not established with the objective of pursuing high growth opportunities.

Data were collected using in-depth face to face and telephone interviews with representatives from nine USOs in five universities over the sixth month period from July to December 2001.
These universities were selected on the basis that they are among the top ten research elite universities in the U.K. (as measured by research income earned) and that they are actively pursuing a program of university technology transfer (both through both licensing and USOs). To assist in generalizing the theory building, it was important to include a sample with distinctly different technologies, origins and degrees of development. Each of the selected ventures has a fundamentally different technology platform ranging across biological, chemical physical and computer sciences. Each of the cases is at a different stage of development, allowing greater insights into specific stage-related growth issues. Table 1 summarizes the characteristics of the nine cases.

**INSERT TABLE 1 HERE**

In conducting each case study we followed the approach outlined by Eisenhardt (1989). First, background material was collected for each of the institutions about how they organized their technology transfer activities. From this data a list of interviewees was compiled. For each of the cases, semi-structured interviews were carried out with the head of the university technology transfer office (UTTO) (or equivalent), a range of business development managers (BDMs) and the members of a spinout company who had taken the venture through the process at the university. This included both the academic entrepreneur (inventor) and the "surrogate" entrepreneur where applicable. In addition, we interviewed the head of each department from which the USO originated.

The interviews ranged in duration from one to two hours and were openly recorded and afterwards transcribed. By using a number of key actors from each university we ensured that we elicited views on the universities' role in the spinout process to cross check our interpretation of events.

Responses from the interviews, and other data, were used to develop a case study database, which included table shells to record data (Miles and Huberman, 1984). These table outlines ensured that the data collection was focused on the research questions and verified the same information was being collected for all cases. Once the individual case studies were complete, we used cross-case analysis, relying on methods suggested by Miles and Huberman, (1984) and Eisenhardt (1989) to develop common and differential factors. Conceptual insights were in turn drawn out and refined during an iterative process as the case studies progressed. Triangulation was also aided by the collection of archival data (Deshpande, 1983; Yin, 1984), including university level information, and spinout company information such as business plans, patent filings and published press articles were also collected where available. To avoid confirmatory biases, one of the authors was kept at a distance from the field observations and focused on conceptualization and analysis of the material and interpretations developed by the other researchers (Doz, 1996).

**EMPIRICAL EVIDENCE**

Two key findings emerge from the data. First, spinouts evolve over five distinct phases. Second, by examining the interstices between these five phases our results show that spinouts encounter "critical junctures" that must be overcome in order to make the transition from one phase to the next. Both these findings are examined in turn. Importantly, we recognize that USOs develop not so much through discrete stages of growth but rather through "phases". Furthermore, USO management need to focus on how to overcome the each "critical juncture" in order to move to the next phase of development. We prefer the term "growth phase" as opposed to growth-stage in order to capture the essence of fluidity of USO, which are ventures in transition.
Empirical Evidence I: The Phases of Growth

In the following section we present the case material relating to the different phases which the nine cases encountered in their development. These phases we identify as the: (1) research phase (2) opportunity phase (3) pre-organization phase (4) re-configuration stage and finally (5) sustainable high growth phase. Each phase is intended to characterize a specific group of activities as well as strategic focus that the firm must accomplish before it can move to the next phase of growth. A diagrammatic representation of the different phases is presented in Figure 1.

INSERT FIGURE 1

A summary of the data relating to the distinct phases experienced by each spinout company is presented in Table 2. We draw on this data in expanding our arguments below. The analysis indicates that the different phases are sequential in nature. Each venture must pass through the previous phase in order to progress to the next stage of development.

INSERT TABLE 2 HERE

Research Phase
At the research phase no idea of a venture exists. Analysis of the case-study data demonstrates that for all the academic entrepreneurs (or academic innovators) interviewed, their main focus prior to any commercial opportunity being recognized is on perfecting academic research within the academic community. This point was encapsulated by the academic entrepreneur who formed 3G Wireless Co., who stated that, "… when you’re a young academic, the mentality is publish or perish.” Furthermore, the academic in question was at the forefront of research in his or her chosen field. In the case of Silicon Microchip Co, the surrogate entrepreneur described how:

"The academic was at the forefront of research into the design and potential application of silicon microchip based sensing and monitoring devices. He had played a major part in inventing this whole new industry..."

In the research phase valuable intellectual property (IP) is created, which then creates the potential opportunity for commercialization.

Opportunity Phase
The opportunity phase is characterized by the identification of a potential "market” opportunity to exploit the IP, coupled with what several of our interviewees termed as "pervasive uncertainty” with respect to how best to realize that opportunity. During this phase activity mainly focuses on the academic and the UTTO. In each case, either independently or together, the academic and the UTTO worked towards examining whether the opportunity had sufficient underlying value to warrant further effort in pursuing commercialization. This "screening” process first involves identifying many technical uncertainties such as ensuring there is sufficient evidence that the technology actually exists and works. At the same time, there is a need to flesh out the opportunity and define the market scope to which the technology can be applied.

During this phase there is a need to deal with the intense uncertainty surrounding the technology and the application of that technology in a particular market. The uncertainty arises due to a lack
of information and the lack of an obvious route to a suitable market in which to exploit the technology (Miller and Friesen, 1984). This absence of information creates decision uncertainty and decision complexity (Busenitz and Barney, 1997; Covin and Slevin, 1989; 1991). In turn, this means that market specific applications of the technology that serve existing customer needs are difficult to design. From cross case analysis, the most salient uncertainties that occur during the opportunity stage can be categorized as market, technical, manufacturing, resource, and entrepreneurial. The entrepreneur from Stem Cell Co remarked,

"Commercial partners and industry were not interested. It was so early stage they thought it was a bit wacky. They all had first option to acquire the patents that had been filed from the sponsored research but did not take any of them up which left the university in an interesting position with a huge patent portfolio to exploit commercially."

While universities are capable of providing a fertile source of potentially lucrative opportunities, they typically lack the resources to determine, with some measure of certainty, which ones "will become blockbuster hits", which ones will "achieve a moderate steady rate of return" and which ones "aren't worth wasting time on".

**Pre-Organization Phase**

During the pre-organization phase many fundamental uncertainties about industry, location, size, market, and administrative intensity may be resolved. Furthermore, once a number of fundamental uncertainties have been dealt with the management of the venture can begin to make and implement strategic plans. It was clear from each case that the pre-organization phase represents the steepest learning curve for the academic entrepreneur, particularly if they have little or no commercial experience or knowledge of how the industry operates. In addition, any decisions taken at this stage impact upon the entire future success of the USOs since they direct the path it will follow. The surrogate entrepreneur from Silicon Microchip Co. explained.

"To begin with, we had a real problem in identifying the right application to develop for the right market. Deciding what market to focus on initially was an important first decision as it would impact upon the entire future of the company".

Cross-case analysis indicated that it was imperative that management of the USOs performed a number of specific tasks at this phase of development. First, to clearly, and precisely, define the opportunity in terms of a viable business model and a route to generating revenues from customers in the target market. Second, to develop an explicit strategy that identifies the goals and milestones necessary to realize that opportunity. Third, to identify the necessary resources/capabilities needed in order to implement the business model. Finally, to identify and gain the commitment of key individuals who will form the venture's entrepreneurial team. The academic entrepreneur in Software Co illustrated this clearly.

"I had acquired a university held patent to the software rights of the technology to be exploited initially. I then put together a potential team to support the venture. We developed a marketing plan, based on our industry knowledge and ideas. I defined the role each team member would play."

**Re-Orientation Phase**

The two main challenges during this phase are how to "build and then re-build the business". In
order to build the business it is necessary to perfect the application of the technology to a particular market niche. In addition, and in parallel, it is necessary to acquire, develop and integrate resources/capabilities, identified during the previous phase, into the business. There is an important development here in that rather than just identifying resources, the USO seeks to develop its capabilities/routines/systems that enable it to undertake productive activities. In addition, whereas, the previous phase represents the steepest learning curve for the entrepreneur, we found that this phase represented the steepest learning curve for the "entrepreneurial team". The team now has to learn how to "manage" the business, and develop the necessary capabilities (systems/routines) to do so. Entrepreneurial teams exemplify this imperative across all the cases we studied, as articulated by the academic entrepreneur from Biomedical Co.

"Managing growth over the last eighteen months has been the real challenge because our management systems have had to evolve not monthly, not weekly but sometimes daily to adjust to internal and external changes. We were constantly aware of what deficiencies were constraining the company's growth. The problem was knowing how to acquire the resources and expertise to fulfil that deficit and also how to integrate them into the firm. That's the challenge of growth."

As highlighted above, this phase involves the challenges of building and then re-building the business. Therefore, many iterations of a business model will be necessary to adapt to changes, to learn from mistakes, to correct poor previous decisions, and to apply the knowledge gained from this learning in order to reassemble and build resources and capabilities as well as perfecting the technology. The academic entrepreneur from 3G Wireless Co. impressed upon us how his USO required:

"… constant repackaging to incorporate technological advances within the business model, as well as closely monitoring a constantly changing marketplace to keep ahead of alternative technologies and rival competitors who are going after the same chunk of venture capital funding."

For all nine spinout cases, the business model, the market focus, make-up of the team and the technology all had to evolve in this re-orientation phase. Furthermore, this evolution of different aspects of the business had to occur in parallel. This "constant repackaging" clearly illustrates how USOs can be regarded as experiments to test the size of particular markets or whether particular technologies or ways of competing are promising (Cooper, 2001).

Sustainable High Growth Phase
The final phase is characterized by the USO attaining sustainable high growth. The fundamental objective of the entrepreneur is to put together a transaction set that allows the venture to reach such a stage (Venkataraman and Van de Ven, 1998). In arriving at this phase of development the USO will have resolved many of the early uncertainties via the resolution of its precise business model. For example, Optical Co. had achieved exactly that and emerged from the re-orientation phase as an aggressive, highly focussed business. On behalf of his team, the CEO highlighted what enabled them to become established as a sustainable firm.

"We knew we had moved on from becoming a chrysalis university (high tech) spinout to a proper high tech company when we started to get some traction in the marketplace. We hammered home to the whole team that we're a business which exists by winning orders, shipping products and making money - the science and technology are just part of that equation."
Optical Co, Biomedical Co and Stem Cell Co have reached this sustainable growth phase. Once they have reached the sustainable high growth phase the ventures should no longer be called USOs, but more accurately as high growth NTBFs. As former USOs, these now high growth NTBFs are characterized by four key criteria. First, the presence of a credible management team that has the potential ability to steer the venture through the sustained high growth phase. Second, the venture is profitable or has the express goal of becoming profitable in the near future. This is essential if the equity stakeholders in the venture are to eventually make a successful exit via an IPO or trade sale. This is the current position in which Biomedical Co. finds itself:

"We reached critical mass twelve months ago and we've grown the company by 77 per cent in the last financial year, at a turnover of £6.7 million. We're now on target to do £11.2 million in the current financial year, and have grown to a staff of 140 people. If I walk away now, the business sufficiently established to sustain itself."

Third, the venture will have moved off the university campus, or at the very least from out of the research laboratory, into a commercial environment. This may either be outside the university or within a university affiliated science park or incubator. Fourth, the venture will almost certainly have retained close links with the university. This typically occurs via the academic inventor remaining in academia while acting as a technical advisor to the new venture. This is essential if the venture is to have an innovation pipeline consisting of new technologies coming through from the university that can continue to be exploited via licensing in new patents.

**Empirical Evidence II: The Critical Junctures**

In order to reach its full potential as a sustainable high growth company, the venture must successfully make the transition between the different growth phases, as outlined above, that creates what we term "critical junctures" for the firm. We define critical junctures as a complex problem that occurs at a point along a new high-tech venture's growth path preventing it from achieving the transition from one growth phase to the next. Unless each critical juncture is overcome the venture cannot move to the next phase of development, and hence will stagnate.

From our cases we found that a venture at a critical juncture faces two generic problems. First, the venture faces an impending crisis, which threatens the existence of the venture. Second, the venture faces uncertainty over how to resolve the cause of the crisis. Furthermore, we were able to identify that critical junctures arise due to an absence of one or more key resources/capabilities required by the firm. Although the problem is generic the nature of the required resources differs across the different critical junctures. The resources/capabilities at each of these junctures we term critical (Brush and Lichtenstein, 2001), because if the USO does not either acquire, access or develop the resource/capability it will not be able to progress to the next phase of development.

USOs were found to face four critical junctures, which result from the convergence of a number of events occurring outside the control of the USO entrepreneur, together with the outcomes of previous strategic decisions taken by the venture management. These critical junctures are: (1) Opportunity recognition; (2) entrepreneurial commitment (3) venture credibility; (4) venture sustainability (Figure 1).

The following section presents case-study evidence for each of the different critical junctures. A summary of the evidence is presented in Table 4 and is referred to below in the text.
Critical Juncture A: Opportunity Recognition

The critical juncture of opportunity recognition lies at the interface of the research phase and opportunity phase. Opportunity recognition is the match between an unfulfilled market need and a solution that satisfies the need that most others have overlooked (Shane, 2000; Ucbasaran, Wright, Westhead and Busenitz, 2002). This involves capturing break-through ideas that trigger an evaluation, as a precursor to the formation of commercialization effort (O'Connor and Rice, 2001). Relatively little is known about the process leading from opportunity recognition to the creation of a new business (Delmar and Davidsson, 2000). However, it is clear that the possession of idiosyncratic information allows people to see particular opportunities that others cannot, even if they are not actively searching for such opportunities (Shane, 2000). The importance of idiosyncratic information was illustrated by the co-founding academic entrepreneur of Stem Cell Co.

"The discovery was an accidental discovery based on research we were doing in a different field at the time, and it struck me as amazing. I began a dedicated research program to investigate why this phenomenon occurred. I knew there and then that there were potential commercial products to come out of this because it solved a major medical problem and was infinitely more effective than current treatments that are medieval by medical standards. The potential to deliver benefits to patients was clear."

Simply being in the possession of valuable information is a necessary, but not sufficient, condition for opportunity recognition. This therefore, presents the first critical juncture, which must be overcome. The ability to make the connection between specific knowledge and a commercial opportunity requires a set of skills, aptitudes, insights, and circumstances that are neither uniformly nor widely distributed (Venkataraman, 1997). However, we can define the transition between an initial opportunity and the formative steps to creating a new venture. From our case evidence we are able to identify overcoming the critical juncture of opportunity recognition as the ability to synthesis knowledge and insights from different domains but principally between the domain of scientific knowledge and the domain of the market.

The critical juncture of opportunity recognition is the constraint that must be overcome if an academic entrepreneur is to move from the research phase to the opportunity phase. University academics have little knowledge of how to serve markets and derive profits from the technologies which they invent. This point was made clearly by the academic entrepreneur from 3G Wireless Co, who explained how he found himself publishing numerous ideas in academic journals, which with hindsight could have potentially been patented.

"This highlights my naivety and the dilemma I faced whilst I was doing all this great work for industry, which they were profiting from. I eventually realized that, surely I could do something for my own wealth creation rather than giving away my intellectual property."

The critical juncture arises due to a lack of commercial awareness, not just on the part of the academic, but also within the culture of university. The academic entrepreneur from Software Co. informed us how:

"… unfortunately hundreds of potentially commercializable academic inventions
are gathering dust within someone’s old PhD thesis’s lying on a shelf somewhere. It just needs the right person to pick it up.”

It seems that the traditional environment of the university, with its lack of incentives to think and behave commercially, is not conducive to having an entrepreneurial alertness (Kirzner, 1973) and therefore, individuals lack the ability to recognize opportunities and search for relevant information to evaluate opportunities (Caplan, 1999).

**Critical Juncture B: Entrepreneurial Commitment**

An entrepreneur’s ideas and intentions form the initial strategic template of a new organization and are important underpinnings of new venture development. Since intention precedes venture formation, it plays a critical role in the initial conditions of the new venture (Bird, 1992). However, in practice intentions are no substitute for sustained persistence and committed actions in order to add value to an emerging business venture (Erikson, 2002). In order to move from the opportunity phase to the pre-organization phase the critical juncture of entrepreneurial commitment must be overcome. Entrepreneurial commitment is necessary for a potential venture to be taken forward from a vision that the academic has created mentally, to the formation of a business that is operational and engaged in business transactions.

Whereas entrepreneurial intentions define a state of mind, entrepreneurial commitment can be defined as acts which bind the venture champion to a certain course of events. The co-founding academic entrepreneur from Stem Cell Co illustrates the necessity of entrepreneurial commitment.

"I was naïve to think that a big company would see the potential an early stage to earn billions of dollars and snap the technology up. The reality is that I am an external scientist who would upset the agenda of development plans inside a company, and an internal scientific team would lose resources, which would be allocated to me instead. They were very good at finding reasons that were nothing to do with the science not to take on my technology. It made me realize that if the technology was ever going to get commercialized, then I would have to set up a biotech company as a vehicle through which to do it."

"Early on I had to make a personal choice about what I wanted to do about setting up the company, and whether to remain as an academic and become a consultant to it or to throw myself into it full-time. There are implications that you have to think about early on that affect the model of the venture you eventually create. I am intellectually resolved to the later option."

Entrepreneurial commitment binds the entrepreneur to tenaciously widening their existing portfolio of activities, to learning new skills and acquiring new abilities with the aim of transforming their vision into a successful new venture. Our research indicates that the critical juncture of entrepreneurial commitment arises due to four possible reasons (Table 3). First, the majority of academic inventors we interviewed showed a reluctance to commit to taking the idea forward to actively explore the commercial potential of exploiting their invention, because doing so would mean going against accepted convention. The surrogate entrepreneur from Silicon Microchip Co explained how,

"…the academic would never have taken the technology forward and done anything about commercializing it by himself because he doesn't want to be involved in the commercial world."
Second, a lack of belief in their own ability to cope in an alien commercial environment prevented academics from taking a leap of faith and pursuing their inclinations to form a USO. The academic entrepreneur from Human Genome Co. disclosed,

"I was reluctant to commercialize the invention by myself and found not knowing the risks involved in running a business to be a daunting prospect. It was completely outside my field of expertise."

Third, according to the heads of academic departments, UTTO managers and some of the academics themselves, a common characteristic of academics is a "reluctance to accept and live comfortably with ambiguous situations". What makes some academics great scientists or engineers clearly does not give them a predisposition to naturally behave in an entrepreneurial manner and take risks.

Finally, from all our interviewees we uncovered an insight relating to the lack of self-awareness over personal limitations and sometimes a lack of humility on the part of some academics. According to one UTTO executive:

"The really smart academics are the ones who know that they add value when it comes to the science and know not to get in the way when it comes to designing the marketing plan or negotiating terms with a venture capitalist. They know when to take a back seat and leave it to the experts. The not so smart or really insecure academics want their hands over everything. These prima donnas make a complete mess of things, get nowhere with their companies and end up disappointed professionally and financially."

It is difficult for distinguished academics that are already directors of large research groups not to be involved with projects at a detailed level. The majority of the academics we interviewed found it difficult to delegate or share responsibilities when it came to the commercialization of their intellectual property. This is a natural outcome, given many years of scientific training during which time they have examined their work and the work of others meticulously, often isolated in their research from others outside their own group. Therefore the problem of not having the commercial expertise necessary to the successful exploitation of their intellectual property is compounded by the fact that these academics "do not like being told what to do or how best to do it", according to one UTTO manager. Of course, so long as these issues cannot be tackled, a venture champion who has made a solid commitment to the venture remains elusive.

**Critical Juncture C: The Credibility Threshold**

Once an academic or surrogate entrepreneur has conceived an opportunity, and committed themselves to developing it into a potential USO, a critical juncture arises constraining the entrepreneur's ability to actually start doing business. During this pre-organisation phase a key imperative is raising sufficient finance to acquire the necessary resources with which to formally start the venture. In all cases, finance was the key resource without which the entrepreneur was prevented from carrying out the transition from the venture being a "pre-organization" to a fully operating organization able to engage in repeated resource transactions. The dilemma that the academic and surrogate entrepreneurs consistently faced was that the building blocks of the venture needed to be put "on standby" ready for the formation of the venture, but these essential resources could not be acquired without financial investment.

We term this critical juncture the *credibility threshold*, as a lack of credibility constrains the
entrepreneur's ability to raise seed finance. In the case of Virtual Reality Co (which did not receive seed finance) the UTTO manager told us.

"The technology was undoubtedly novel and world class [but] the venture capitalist questioned the team's commercial and managerial skills [and] expressed doubt about the team's ability to attract new people in order to grow the company."

Traditionally it has been up to the academic entrepreneur to find the means to overcome this critical juncture. This was the case for Optical Co., Biomedical Co, Human Genome Co and Stem Cell Co. However, more recently universities have realized that through their UTTO they may be able to play a vital role in enabling USOs to put forward more credible business models to attract potential financiers or to entice customers to place orders for the USOs market offering.

The critical juncture of credibility does not just relate to potential financiers but also to potential customers. In the case of Biomedical Co., the entrepreneurial team all agreed that in order to attract more clients, and revenues per client, they had to appear credible, and business-like. However, they perceived that this was a problem so long as the venture remained within the university.

"We knew that there was an market opportunity there, it just had to be exploited in the right way. We had great a technology and an excellent management team. However, to appear credible in front of clients, and to charge them more for our service, we needed to get our own facility, with our own name above the door and be able to control our immediate environment."

The process by which customers learn about a new venture and come to perceive it as established will affect its risks, as well as its organizational momentum, legitimacy and organizational trust (Singh et al. 1986; Aldrich and Fiol 1994). Without this initial credibility, new high tech ventures in general, will not be able to overcome skeptical customer perceptions, gain access to markets and successfully achieve the transition from a "concept” to a "business” engaged in transactions in the market.

**Critical Juncture D: The Critical Juncture of Sustainability**

Once the venture has received seed financing and embarks upon the process of commercially exploiting the technology, our research shows that it comes up against a final critical juncture, which we define as the critical juncture of sustainability. In large organizations, elaborate policies, procedures and routines (Nelson and Winter, 1982) simplify decision-making uncertainty and complexity facing managers (Busenitz and Barney, 1997). However, in the new ventures we studied, the entrepreneur needed first to assemble an organizational structure that specified tasks, allocated people those tasks, and provided avenues of authority. The entrepreneur also needed to re-configure these structures and routines on a regular, sometimes daily basis. According to the surrogate entrepreneur from Optical Co., "as a USO our mission was simple: to evolve and to do it quickly”. Informal structures also need to be developed in order to facilitate communication within the organization. This dynamic of constantly reconfiguring the venture's resources in order to overcome the next critical juncture was common across all cases. The CEO of Optical Co. expands.

"Growing a high tech spinout company isn't for the faint hearted, the anxious or the suicidal. Sure, one day you may have a big problem to resolve, but the chances are in three months time it will be replaced by yet another one. The only certainty
is that the pace of change just keeps on and on. You just have to stay ahead and focus on the next crisis."

To overcome these junctures the entrepreneur, and increasingly the team, need to be able to deal with high levels of organizational turbulence. They will also encounter serious difficulties in raising first-stage finance, unless they can demonstrate to investors that they have the capability to achieve sustainable high growth. The academic entrepreneur from Human Genome Co describes the imperatives she faced born out of the critical juncture.

"At this stage we didn't have the resources or the experience to take the technology we had spent years developing onto the next stage. At the same time, speed became the important priority, because unless we could show that we were going to get to market quickest, we'd lose out on both financial investment and market share."

In general, this critical juncture arises because the USO lacks the necessary resources to build the business, perfect the technology and business model, and establish itself in the marketplace simultaneously. All these things have to evolve in parallel for the USO to overcome a threshold of sustainability. The surrogate entrepreneur from Optical Co., confirmed this point:

"We needed to move quickly to shape the technology and apply it to market needs in order to sustain financial and R&D growth and to get beyond a state of just surviving."

"We knew that we would not be able to trade our way to success. To achieve sustainability, we needed to put the infrastructure in place to provide a £20 million turnover, and that takes a lot of resources for a high tech spinout. We had perfected the technology and had managers who were capable of growing the business as we went along. However we needed more finance to acquire that infrastructure."

Unless this parallel development can be achieved, the USO will stagnate as financial and other resources become depleted. This may then further constrain the entrepreneur's and team's ambitions for the success of the venture. Growing a business is an expensive and resource intensive exercise. The importance of finance is emphasized by the entrepreneur who set up Software Co.

"Cash-flow remains to be the key constraint to growing the business. If we did have more money, we'd be able to achieve more, take on more engineers and increase the input of our non-executive directors who we can only afford to bring in part-time. For the moment we find ourselves trying to be more resourceful which in itself takes up more time, so it would be useful to have that extra capacity."

The raising of first round finance is a reflection of the fact that the USO has demonstrated a clear route to market and profitability. Without the necessary cash-flow to sustain the venture, inertia will continue until the venture declines and eventually fails. This failure may be due to the technology, however, in most cases it is the poor exploitation of the technology that leads to failure.
DISCUSSION

This paper has explored the transition phases experienced by USOs. In particular, our study helps develop theory regarding the problems faced by new high tech spinouts from universities in two ways. First, evidence from the case-study analysis indicates that USOs go through a number of different distinct phases in their development and that these phases are sequential in nature. Second, at the interstices between the different phases of development we found that ventures face "critical junctures", which must be overcome to progress to the next phase of development. Furthermore, if the critical junctures remain unresolved for a prolonged period of time, the venture will eventually fail. We summarize the themes raised by each of the junctures in Table 4. These factors clearly signify that critical junctures arise due to an acute constraint or absence in one or more key resources or capabilities. We discuss each of the critical junctures in more detail below.

Opportunity Recognition: The academic's pre-eminence in a research field may be important in providing the basis for an opportunity to be recognized. However, it is clear from our study that academic entrepreneurs involved in creating USOs have little commercial awareness and/or experience in how to go about the process. The lack of commercial experience is particularly acute in respect of marketing. As a result there is an inability to conceptualize how a technological discovery can be best applied to satisfy a real consumer need. The research highlights that typically the initial concept from the academic innovator changed considerable in arriving at the final product or service. The route to market and the target customer initially envisaged also changed dramatically. Furthermore, it was common in each case for the university to provide little incentive for the scientist to think and behave entrepreneurially. This had the effect of reinforcing the non-commercial mindset of academics. All these factors demonstrate the importance of universities developing links with industry if they are to be successful at commercializing technology through USOs. This point is exemplified by the central role surrogate entrepreneurs played in helping to recognize the opportunity in a number of the case-studies we investigated.

Entrepreneurial Commitment: It was found that the imperative during the opportunity stage is largely one of dealing with the intense uncertainty surrounding the technology and the application of that technology in a particular market. As a consequence, there is a need for an individual to be committed to resolving this uncertainty and intense complexity through championing the venture beyond start-up to commercial operation. However, as shown in Table 4, a number of factors prevent this from occurring. The commitment of the academic may be especially important to ensure a continued flow of innovations to enable the venture's product portfolio to develop, but this does not necessarily make the scientist the best candidate for the role of venture champion. The evidence from the cases shows that the venture champion also needs to have capabilities relating to industry and entrepreneurial experience, which the academic scientist may not possess sufficiently. Furthermore, the academic scientist may be unable or reluctant to commit to the venture through either a lack of personal motivation or an institutional culture, which discourages commercial behavior.

Therefore, it appears that the critical juncture of entrepreneurial commitment develops through a combination of individual deficiencies in the academic scientist and institutional barriers, which prevent the academic scientist or anyone else (i.e. a surrogate entrepreneur) from championing the commercialization of research. These factors appear different from those present in a normal start-up in holding back initial progress towards exploiting the value that has been recognized in
an opportunity.

**Credibility:** Credibility was identified as a key issue in obtaining the necessary financial resources to allow the business to operate commercially. In turn, financial resources are essential to obtaining other resources necessary to turn the idea into a sustainable business. Therefore, the issue of credibility becomes more significant for USOs when compared to many other business start-ups. The initial resources of the USO are intangible, comprising mainly technology related know-how, which at best may be may be codified within a patent. In addition, the very nature of the USO means that it is likely that the entrepreneur and team may have little or no track record of working in the particular market, or growing NTBFs. This was the case with Stem Cell Co, Human Genome Co, Virtual Reality Co, Biomedical Co and Materials Co, which all had limited ability to generate credibility in the market. This lack of credibility means that USOs are frequently viewed as high risk by the market, making it difficult to secure finance and other start-up resources.

As the lack of commercial credibility among academic entrepreneurs poses a notable barrier to obtaining finance, surrogates may be particularly important in helping to acquire, access and develop the required resources and capabilities required to gain credibility. However, in order to attract a potential surrogate entrepreneur it may first be necessary for the firm to develop some credibility with the surrogate. USOs can demonstrate credibility to the market in a number of ways such as developing a portfolio of products with clear prospects of profitability for the venture and locating off the university campus in order to signal credibility in terms of commercial intentions.

**Sustainability:** As with other new ventures, the challenge for a USO in entering and becoming established in a market depends greatly on its ability to accessing resources and then employing them to develop requisite organizational routines and capabilities. In achieving this USO entrepreneurs are able to professionalize the venture (Hellmann and Puri, 2001) which in turn enables it to cope with the challenges of growth. However, for a USO, developing the necessary organizational processes, routines and capabilities from scratch is costly and time consuming. The majority of cases endured a highly turbulent growth pattern due to ad hoc routines and procedures having to be constantly reconfigured to cope with changing internal and environmental conditions. This reduced the venture’s speed to market and its ability to compete, generate revenues quickly and seize market share.

Unless the USO entrepreneurs manage to overcome these inadequacies and weaknesses, their ventures will not have the infrastructure or capacity to sustain themselves within the market and hence fail to become established as rent generating business. In short the entrepreneurial team must posses a set of entrepreneurial capabilities in order to succeed in overcoming this and other critical junctures.

Evidence from our study suggests that the transition from one phase of growth to the next presents a different set of constraints and problems to the previous phase. This necessitates the development of a set of skills for the entrepreneur to maintain the USO growth momentum. The factors giving rise to critical junctures suggest the need for two key capabilities on the part of the entrepreneurs involved in USOs. The first is the capability of spotting the problems, i.e. foresight (Mosakowski, 1998). The second concerns the capability to acquire, access or develop the necessary resources/capabilities to overcome the juncture. Our findings suggest that it is the individual entrepreneur in the earlier junctures who needs to develop the requisite capabilities. However, over time, and as the complexity of what needs to be done increases, the capabilities to deal with later junctures become located in the team. Therefore, there is an interesting shift in the
locus of interest in the USO from the initial entrepreneur to that of the team.

This study has a number of limitations. First, in order to obtain the depth of analysis necessary to enable theory building it focuses on a small set of cases and universities. Further research using large representative samples is needed to test the theory developed here. Second, the study has focused exclusively on USOs. There is scope for additional research that directly compares different groups of entrepreneurial high tech ventures. For example, studies might usefully analyze the barriers to development faced by USOs and other new entrepreneurial ventures, including those entrepreneurial ventures that approach universities for assistance (Shane, 2002). There is also scope to examine the barriers to the development of those independent USOs that receive venture capital support with spin-outs that emerge as joint ventures with industrial partners in order to obtain insights into the comparative capabilities of financial and industrial investors to assist technology transfer.

CONCLUSION

This paper has sought to model the development of USOs companies from universities. In doing so we have identified that the growth of the ventures if characterized by a number of distinct stages of development, the interstices between which we term "critical junctures". These junctures are critical because a USO needs to overcome them to progress to the next stage of development. The critical junctures create an imperative for the entrepreneur and entrepreneurial team to act to overcome them.

Our work adds to existing research into the development of USOs and NTBFs in a number of different ways. First, our model contrasts with the literature on growth models of new ventures. The latter focus on specific firm characteristics during different stages of growth, but ignore how firms achieve the transition from one growth phase to the next. It is only by capturing the specific micro-processes involved during these inter-phase transitions that an understanding of how new ventures originate, emerge and evolve into established firms can be achieved.

Second, our work extends studies carried out by Kazanjian, et al. (1989) to address the dominant problems arising along the evolutionary growth path of NTBFs. In particular, we demonstrate why these difficulties emerge and the implications of their emergence. We conclude that during the evolution of NTBFs, a series of critical junctures are encountered which must be overcome to ensure that the venture becomes established within it market as a sustainable rent generating firm.

Third, our work examines the role of capabilities in the context of USOs, and in particular, where the locus of these capabilities lies. It is important to recognize that USOs are by definition resource limited. The task of the entrepreneur and entrepreneurial team is to identify, acquire and integrate resources to form capabilities, which eventually enable the venture to succeed. This is in sharp contrast to the context of established firms where research on capabilities has been developed. In large established firms, capabilities are the organizational and strategic processes by which managers manipulate resources into new productive assets in the context of changing markets (Galunic and Eisenhardt, 2001). In new high tech ventures, no such organizational and strategic processes exist initially. Rather, there is a reliance on the capabilities of the entrepreneur and entrepreneurial team to construct them. The initial venture champion will play the key role in developing the required capabilities. However, as the venture progresses and the complexity of the critical junctures increases so the locus of capability development will increasingly shift to the entrepreneurial team.
Fourth, our study contributes more generally to the debate concerning the dynamic nature of resources and the processes of resource change (Foss, 1997).

Finally, in addition to aiding the development of theory, the identification of these critical junctures highlights implications for practitioners. The analysis provides the actors concerned in this process with structured insights concerning focused intervention at different stages, rather than attempting to implement general actions irrespective of the stage of development.
REFERENCES


<table>
<thead>
<tr>
<th>SPIN OUT COMPANY</th>
<th>TECHNOLOGY</th>
<th>CURRENT GROWTH PHASE</th>
<th>VENTURE CHAMPION</th>
<th>INITIAL FINANCING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Co.</td>
<td>Design and manufacture of telecommunications network equipment</td>
<td>Sustainable Growth Phase</td>
<td>Surrogate Entrepreneur</td>
<td>VC invested £1m for a 20% equity share.</td>
</tr>
<tr>
<td>Silicon Microchip Co.</td>
<td>Design and manufacture of diagnostic monitors and sensors</td>
<td>Re-orientation Phase</td>
<td>Surrogate Entrepreneur</td>
<td>Angel invested £330,000 for a 15% equity share.</td>
</tr>
<tr>
<td>Human Genome Co.</td>
<td>Anti-viral drug discovery and development</td>
<td>Re-orientation Phase</td>
<td>Academic Entrepreneur</td>
<td>Angel invested £650,000 for a 50% equity share.</td>
</tr>
<tr>
<td>Software Co.</td>
<td>Diagnostic software for the automotive industry</td>
<td>Re-orientation Phase</td>
<td>Academic Entrepreneur</td>
<td>Angel invested £200,000 for a 15% equity share.</td>
</tr>
<tr>
<td>Virtual Reality Co.</td>
<td>Virtual reality software for the manufacturing sector</td>
<td>Pre-organization Phase</td>
<td>Academic Entrepreneur</td>
<td>None received</td>
</tr>
<tr>
<td>Biomedical Co.</td>
<td>Drug delivery and patient monitoring equipment</td>
<td>Sustainable Growth Phase</td>
<td>Academic Entrepreneur</td>
<td>Financed through sales</td>
</tr>
<tr>
<td>3G Wireless Co.</td>
<td>Mobile telephone equipment design</td>
<td>Re-orientation Phase</td>
<td>Surrogate Entrepreneur</td>
<td>VC invested £250,000 for a 15% equity share.</td>
</tr>
<tr>
<td>Stem Cell Co.</td>
<td>Drug discovery and treatment development for healing human tissue</td>
<td>Sustainable Growth Phase</td>
<td>Academic Entrepreneur</td>
<td>VC invested £8 million for 55% equity share</td>
</tr>
<tr>
<td>Materials Co.</td>
<td>Technology for analysis of material surface coatings</td>
<td>Re-orientation Phase</td>
<td>Surrogate Entrepreneur</td>
<td>£25,000 loan</td>
</tr>
</tbody>
</table>
Figure 1: The Different Phases of Spinout Company Development and Critical Junctures

A: OPPORTUNITY RECOGNITION
B: ENTREPRENEURIAL COMMITMENT
C: THRESHOLD OF CREDIBILITY
D: THRESHOLD OF SUSTAINABILITY

SPIN-OUT COMPANY GROWTH IN CAPABILITIES

OPPORTUNITY PHASE
PRE-ORGANIZATION PHASE
RE-ORIENTATION PHASE
SUSTAINABLE HIGH GROWTH PHASE

NEW VENTURE MORTALITY RISK

TIME

LOW
HIGH
### Table 2: Characteristics of the Different Growth Phases

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>RESEARCH PHASE</th>
<th>OPPORTUNITY PHASE</th>
<th>PRE-ORGANISATION</th>
<th>RE-ORIENTATION</th>
<th>SUSTAINABLE HIGH GROWTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Co.</td>
<td>maintaining its world-wide publishing the results of its scientific research into the in materials and telecommunications.</td>
<td>who had worked in the telecom industry study into potential market applications of the</td>
<td>Surrogate used his network of contact to gain access to business plan was prepared. An initial investment of £1 million was secured from a venture capitalist.</td>
<td>Early prototypes failed. Team had developed sufficient IP and market intelligence to realign strategy towards new opportunities. Company reorganized with changes in human resources to reflect requirements of the new strategy.</td>
<td>The business is profitable and continues to grow by exploiting new IP created by its engineers and the university. The VC reinvested £6 million.</td>
</tr>
<tr>
<td>Silicon Microchip Co.</td>
<td>Technology emerged from a large, well-regarded team of physicists and chemists dedicated to researching the fundamental science of silicon based nanotechnology.</td>
<td>Results from industry sponsored research showed the lead academic that the new technology significantly increased the speed of obtaining results, enabled improved device performance, cost reduction in comparison to existing technologies.</td>
<td>A prototype device was developed by the academic. Social and industry networks were used to identify possible routes to market. Surrogate developed a business plan, recruited engineers and management, and secured seed finance.</td>
<td>Team searched for premises in a commercial environment, off university campus. A financial director joined the company. The activities of the company were reorganized in order to better position it attract venture capital.</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
<tr>
<td>Human Genome Co.</td>
<td>worked on designing new protein molecules based on research project.</td>
<td>The scientist realized from creating a set of new protein molecules that viral infection in humans.</td>
<td>Patents were filed for and invention. A business plan was public funding for early stage clinical trials.</td>
<td>the technology and discovered new market applications that</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
<tr>
<td>Software Co.</td>
<td>A team of academic scientists and engineers from industry were researching methods to computerized control vehicle systems. The research was sponsored by a large automotive manufacturer.</td>
<td>Whilst working with an industry partner, the academic identified key applications to fulfill the need for intelligent software and diagnostic systems to serve the automotive industry.</td>
<td>Academic brought together a team to support the venture. Team designed a product development plan based on their industry and academic backgrounds. Team networked with contacts to acquire market intelligence. Licenses acquired from university.</td>
<td>Original business plan became irrelevant as the team interacted with potential customers. Better applications for the technology were discovered. The commercialization strategy diversified to target profitable niche markets.</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
<tr>
<td>Virtual Reality Co.</td>
<td>Academics took existing technology from the lab and began to carry out research into novel applications of it across a range of industries.</td>
<td>From interacting with industry research partners, the academic found that the technology had potential commercial applications in a number of manufacturing sectors.</td>
<td>Research was carried out on existing and competitor products. Academic liaised with the university technology transfer office to create a business plan. Prototypes were developed.</td>
<td>The spinout has not yet entered this phase.</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
<tr>
<td>Biomedical Co.</td>
<td>A team of academic scientists carried out industry sponsored research to transfer discoveries in physics into medicine and biochemistry.</td>
<td>The academics discovered a new approach to a drug delivery mechanism in the human body and began running early laboratory trials to develop the mechanism.</td>
<td>Academic team searched for and located commercial premises on a nearby science park. Academic team financed development and testing by themselves. Key personnel identified to direct operations.</td>
<td>The focus turned to attracting profitable customers and developing the technology to serve their needs. A major difficulty was managing rapid growth and learning how to integrate new resources into the venture whilst keeping focused on growth targets.</td>
<td>The business became profitable shortly after formation. Annual revenue growth has averaged 65% over five years. 140 staff employed. The entrepreneurs are now positioning the business for an IPO or trade sale.</td>
</tr>
<tr>
<td>3G Wireless Co.</td>
<td>A leading academic in the field of electronics and telecommunications was sponsored by industry to carry out research to design new telecom systems.</td>
<td>A surrogate entrepreneur with industry experience guided the academic into developing a platform technology that could be applied to several different electronic device markets.</td>
<td>Business plan created around the most lucrative market opportunity. Key human and physical resource identified. Prototype devices developed Venture capital firms contacted.</td>
<td>Seed funding used to develop the technology to a state of market readiness. Teams structures were built around projects. The original target market crashed and customers disappeared. Alternative market opportunities were investigated and product strategy redefined.</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
</tbody>
</table>
## Table 2 (cont): Characteristics of the Different Growth Phases

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>RESEARCH PHASE</th>
<th>OPPORTUNITY PHASE</th>
<th>PRE-ORGANISATION</th>
<th>RE-ORIENTATION</th>
<th>SUSTAINABLE HIGH GROWTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem Cell Co.</td>
<td>Pharmaceutical industry sponsored a research group to study cell and tissue behaviour under certain conditions.</td>
<td>The research provided sufficient evidence to compel the lead scientist to develop a treatment for human skin complaints. Sponsored by industry, the group filled over 100 patents.</td>
<td>Academic used industry and social contacts to learn how the market operated. Research staff and management identified for new venture. IP due diligence carried out.</td>
<td>The academic entrepreneur became the CEO and recruited high quality human resources from industry. Knowledge from experts was integrated to create organizational structures, functions, and routines. An R&amp;D lab was created off campus to generate new IP for commercialization.</td>
<td>There is strong growth in new patents and development of products ready for commercialization. Early products have become successful in the market. The entrepreneurs are positioning the business for second round funding and a future IPO.</td>
</tr>
<tr>
<td>Materials Co.</td>
<td>The research group focused upon determining the fundamental factors governing growth and formation of new synthetic materials.</td>
<td>Tests carried out in partnership with industry confirmed efficiency improvements of 97% over existing methods and hence presented a potential market opportunity.</td>
<td>Networks of contacts used to acquire information, lab equipment, facilities and finance. Market research carried out to benchmark competitors. Business plan created.</td>
<td>The team focused upon identifying new markets for the technology in order to build revenues. It was challenging to grow the company organically, and acquire necessary resources whilst financially constrained.</td>
<td>The spinout has not yet entered this phase.</td>
</tr>
</tbody>
</table>
### Table 3: How Spinouts Encountered the Critical Junctures

<table>
<thead>
<tr>
<th>SPIN OUT FIRM</th>
<th>OPPORTUNITY RECOGNITION</th>
<th>ENTREPRENEURIAL COMMITMENT</th>
<th>THRESHOLD OF CREDIBILITY</th>
<th>THRESHOLD OF SUSTAINABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Co.</td>
<td>The surrogate entrepreneur recognized the opportunity almost by accident whilst engaged with academics in the design of applications of their technology.</td>
<td>The senior academics on the research team did not want to leave their posts. The surrogate entrepreneur was strongly committed to commercializing the technology.</td>
<td>Academic and surrogate entrepreneur realized they needed to form a strong team and put the building blocks into position before approaching a venture capitalist.</td>
<td>The first two development projects failed, due to design mistakes and a shift in the market, making the original opportunity technically unfeasible and unprofitable. The spinout had to adapt and stay on course for profitability despite project failures.</td>
</tr>
<tr>
<td>Silicon Microchip Co.</td>
<td>The technology had been created by the academic but he did not have any wish to pursue profits from his research.</td>
<td>The academic would not leave his research post and only committed to the venture once the surrogate entrepreneur agreed to become the CEO and manage the business.</td>
<td>The surrogate realized that to get investment the entrepreneurial team would need to demonstrate that the technology worked and that the team had the right credentials to exploit it.</td>
<td>Temporary university post-docs were used for development and testing but a dedicated team of engineers would be needed to enable the spinout to achieve sustainability.</td>
</tr>
<tr>
<td>Human Genome Co.</td>
<td>The scientist had developed a technology that created a new market but had no realization of how to exploit it.</td>
<td>The academic lacked confidence in her ability to run a business, by herself. She assembled a team of advisors from industry to provide guidance and offer assistance in making decisions and managing the business.</td>
<td>The team had to learn how to best present the opportunity to potential investors. This involved carrying out market research, attracting potential quality human resources as acquiring a valuable portfolio of patents.</td>
<td>The spin-out has not yet reached this critical juncture.</td>
</tr>
<tr>
<td>Software Co.</td>
<td>While working on collaborative research with industry, the academic spotted a need for an application of the technology.</td>
<td>The academic had no business experience but was unsatisfied with a career in academia, so decided to take the risk following encouragement from colleagues, friends and family.</td>
<td>Without adequate funding, the small team could not penetrate the market and sales growth was very slow during the first year, as products had to be adapted to meet customer requirements more closely.</td>
<td>The spinout has not yet reached this critical juncture.</td>
</tr>
<tr>
<td>Virtual Reality Co.</td>
<td>Existing technology in the university department was not recognized as commercially valuable by the academic until it was applied to an industry sponsored research project and generated interest from the industry partner.</td>
<td>The academic did not want to leave his research post, having built up a career in academia, and having no commercial experience. His knowledge of business was very limited.</td>
<td>On presenting the business plan to venture capitalists the plan was rejected as not being credible. This was due to factors concerning the team’s lack of experience, poor market research and an unviable business model in a very competitive market.</td>
<td>The spinout has not yet reached this critical juncture.</td>
</tr>
<tr>
<td>Biomedical Co.</td>
<td>During studies to investigate how a particular technology could be applied to new areas of science the research team recognized a new application that presented a real commercial opportunity.</td>
<td>Early test results encouraged onemember of the academic team to carry out market research and to develop a business plan in order to assess the potential in commercializing the research. The academic formed a company and initially ran the business in his spare time, in order to test the market.</td>
<td>The team realized it needed to quickly assemble resources to create a professional image for the firm in order to attract customers and generate more revenue.</td>
<td>The team struggled to maintain its high rate of growth and become a market leader, whilst continuing to develop and commercialize new innovations. It became more difficult to co-ordinate and control activities as the venture became more successful.</td>
</tr>
<tr>
<td>3G Wireless Co.</td>
<td>The scientist had been working for nearly 10 years on a technology that did not have an obvious market application. The technology provided a solution to a market need that the surrogate identified.</td>
<td>The scientist did not have the business experience or the managerial expertise to grow a business. He did not want to give up his research post at the university because it provided him with the infrastructure to create new technologies.</td>
<td>The credibility of the entrepreneurial team and the potential of the technology was excellent. The entrepreneurial team were able to package and sell themselves as a business with all the necessary resources ready to be put in place in order to attract venture capital investment.</td>
<td>The entrepreneurial team raised too little seed finance to support their growth plans and the venture has stagnated in a period when the venture capital market for high tech investments had gone flat.</td>
</tr>
<tr>
<td>Stem Cell Co.</td>
<td>The academic and his large research group were working on an extensive research program out of which a discovery had been made by accident. The scientist knew that potential commercial products could result, but is solved a major medical problem.</td>
<td>Commercial partners and industry were not interested in commercializing the technology because it was too early stage. The academic resolved to set up a spin-out and commercialize the intellectual property himself.</td>
<td>The CEO was careful in signalling credibility to investors by hiring head-hunters to independently recruit a management team. He also carried out extensive due diligence and patent protection over the IP and secured lab facilities on the university science park.</td>
<td>Through ensuring a large first round of funding, the team has acquired 48 scientists, over 200 patents, a management team of industry experts and assembled organizational structures and routines to enable the spinout to manage rapid growth.</td>
</tr>
<tr>
<td>Materials Co.</td>
<td>An opportunity was recognized not directly related to the issue being researched but to the way in which the research results were measured and analyzed. Through industry interaction, the value of this technology was realized to be commercially lucrative.</td>
<td>Both the academics were unable to fulfill the role of the venture champion and recruited a surrogate entrepreneur from industry with product development and commercial experience necessary to manage the growth of the company.</td>
<td>The team worked hard to create the perception that they were not linked to a university or that they were academicians. Instead they presented themselves to customers as having industry and commercial experience as well as technical and engineering expertise in order to generate sales revenues.</td>
<td>The CEO sees a major barrier to becoming sustainable being lack of sales and marketing capabilities to generate more revenues and fuel growth into new markets. Unless this capability can be acquired and developed, the spinout will suffer from cash-flow problems.</td>
</tr>
</tbody>
</table>
Table 4: How Critical Junctures Arise

<table>
<thead>
<tr>
<th>GROWTH PHASE:</th>
<th>RESEARCH PHASE</th>
<th>OPPORTUNITY PHASE</th>
<th>PRE-ORGANISATION PHASE</th>
<th>REORIENTATION PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACTORS INITIATING CRITICAL JUNCTURES:</td>
<td>Lack of prior knowledge about how markets and industries operate.</td>
<td>Reluctance or inability to act against convention.</td>
<td>Lack of suitable facilities outside the university department to locate the new venture.</td>
<td>Inability to manage growth through the identification, acquisition and integration of resources and capabilities</td>
</tr>
<tr>
<td></td>
<td>Inability to focus upon how a technical discovery can be applied to serve a residual customer need.</td>
<td>Inability to accept risks, and tolerate uncertainty.</td>
<td>Inability to secure quality human resources to form a well balanced managerial and scientific team.</td>
<td>Inability to employ resources and develop capabilities to acquire speed to market.</td>
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<td></td>
<td>Inability to define a clear route to market for the technology.</td>
<td>Prior business management experience and responsibilities.</td>
<td>Inability to achieve proof of concept and move the technology to a state of market readiness.</td>
<td>Inability to recognize opportunities and threats and make strategic decisions under pervasive uncertainty.</td>
</tr>
<tr>
<td></td>
<td>Lack of incentive to think and behave commercially.</td>
<td>Lack of self awareness over personal limitations.</td>
<td>Inability to generate or show a clear route to revenues and profitability in order to attract financial resources.</td>
<td>Inability to gain traction and build momentum in the market through generating sufficient sales and taking market share.</td>
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<td></td>
<td>Inability to build teams and delegate responsibility.</td>
<td>Lack of depth and breadth in the technology portfolio to provide sufficient long-term options for commercialization.</td>
<td>Inability to integrate knowledge and learning into the venture.</td>
</tr>
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<td>Inability to obtain and leverage social capital through social, academic, commercial and industrial networks</td>
<td>Lack of receptivity for the technology by supply chain distributors and customers in the market.</td>
<td></td>
</tr>
<tr>
<td>RESULTING CRITICAL JUNCTURE:</td>
<td>OPPORTUNITY RECOGNITION</td>
<td>ENTREPRENEURIAL COMMITMENT</td>
<td>VENTURE CREDIBILITY</td>
<td>VENTURE SUSTAINABILITY</td>
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