Policies and Structures for Spinning Off New Companies from Research and Development Organizations

by

Edward B. Roberts* and Denis E. Malone+

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This paper develops five alternative structural "models" for formal efforts aimed at spinning off new companies from universities, government laboratories, and other research and development organizations. In various ways the models combine the roles of the technology originator, the entrepreneur, the R&D organization itself, and the venture investor. The paper also presents the policies and structures of technology commercialization operations from investigations at eight R&D organizations in the United States and the United Kingdom. The data indicate that a R&D organization operating in an environment where venture capital and entrepreneurs are readily available (e.g., MIT and Stanford) can appropriately: (1) exercise a low degree of selectivity in choosing technologies for spin-off creation, and (2) provide a low level of support during the spin-off process. The spin-off process is more difficult in environments where venture capital and entrepreneurs are scarce (e.g., ARCH) and mechanisms for high-selectivity and a high level of support must be in place by the R&D organization to compensate for this scarcity.

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Introduction

Governments worldwide are seeking ways to generate economic impact from the research and development (R&D) carried out by their own laboratories and universities. Military R&D enterprises in particular are in search of means to commercialize their technologies. Universities are trying to derive financial benefits from the creativity of their academic research centers. To all of these "clientele", the technology-based spin-off company appears potentially to be a powerful and useful approach for transferring technology from a research and development organization into a commercial organization. In the case of such a spin-off, the new venture can, in theory, be designed to suit the technology, the needs of the owners of the technology, the needs of its customers, and the constraints of the environment in which it will operate. The new organization can presumably be freed from the constraints of the existing organization's culture and operating framework.

The excellent track records of organizations such as the Massachusetts Institute of Technology (MIT) and Stanford University in interacting with the local community to create new business ventures are well known. MIT and its major laboratories were important starting points for many start-up companies in the Greater Boston area, producing what is often referred to as the "Route 128 phenomenon". These companies have made a considerable contribution to economic growth in Massachusetts. The Bank of Boston (1989) estimated that MIT spin-offs (both spin-offs via formal channels and informal spin-offs) contributed $10 billion annually and 300,000 jobs to the Massachusetts economy. An average of 25 companies spun off from MIT each year in the 1980s. Technology originating from research at Stanford University has fueled the growth of many companies in California's Silicon Valley. University spin-offs occur from many other U.S. institutions (Brett et al., 1991; Smilor, et al., 1990). Well-known examples of research and development organization spin-offs are not restricted to the U.S. (Olofsson, et al., 1987) In Sweden Chalmers University produces 10 to 15 spin-offs each year, many of them small consulting and computer companies. Chalmers spin-off companies contribute $100 million to the local economy each year (McQueen and Wallmark, 1991). In the United Kingdom Cambridge University has generated a large number of spin-offs (Wickstead, 1985). Many of the 450 high-technology companies in its region derive from Cambridge University spin-offs, which provide more than half the manufacturing jobs in the region.

Employment growth is often very high in the early days of spin-off companies and the spin-offs are likely to produce further spin-offs from themselves. The second and subsequent generations of spin-off companies provide substantial amplification of the benefits derived from the first generation of spin-offs. R&D organizations involved in creating new ventures can expect the spin-offs to generate the following advantages: positive influences on research and teaching, a more exciting atmosphere in the organization, and an enhanced reputation and role in the region. The possible disadvantages relate mostly to the traditional freedoms and impartiality that might exist within a university research organization (Allen and Norling, 1991). Some academicians perceive a threat to intellectual freedom and worry that value systems may change through increased exposure to commercial practices. Some researchers are concerned that commercial considerations may prevent the publication of scientific papers, thus removing a source of recognition for researchers, and that career advancement will depend on the production of commercially useful technology rather than scientific excellence. While there may be some truth to these arguments, many organizations such as MIT's Lincoln Laboratory have for many years predominantly carried out applied research on a contract basis while still developing reputations for scientific excellence. Nor has the existence of Lincoln Laboratory detracted from MIT's teaching and research excellence.

A notable aspect of the spin-off phenomenon is that in the communities mentioned above, entrepreneurship and the creation of new business are activities that are not only understood, but also admired and supported. Close interaction is expected in these communities between industry and especially university R&D organizations. The benefits of such synergy to the economies of these communities have clearly been substantial. Yet even globally the regions are rare where such entrepreneurship and spin-off activities are common. In most regions, even those with R&D organizations producing good and useful technology, the new company spin-off phenomenon is virtually absent. It is desirable to gain a greater understanding of how the phenomenon functions and how it might be created in those regions where it is absent. Extensive analyses of the literature on corporate venturing, new enterprise formation, and R&D technology transfer and spin-offs have served as the background for this paper. These provided a basis for carrying out an investigation of eight R&D organizations in the U.S. and the UK that have been engaged in various formal approaches to spinning off new companies. The purpose of this paper is to share these experiences in new company spin-off and the alternative models derived from observing them, and to develop conclusions for policies and structures to guide others in facilitating new company spin-offs from R&D.

Structures for Technology Transfer

Many structures are available for technology transfer (Dorf and Worthington, 1989). Some of these are aimed purely at transferring information about the technology to either select audiences or to as wide an audience as possible, generally without cost to the user. Information dissemination techniques generally fall within this category. Other structures are aimed at transferring the technology to selected companies or organizations with the specific aim of commercialization by only a few of those organizations. Licensing and starting new business ventures are the main techniques for satisfying these objectives. We focus in this paper only on those mechanisms through which new companies are formed from a R&D organization's knowledge and/or human resources base. Relevant to this focus is the study of Gregory and Sheahen (1990) that compared the returns from licensing with those from spin-off companies. 149 principal investigators (sampled from SRI International data on 4,077 National Science Foundation funded principal investigators over a period of nine years) experienced the probability of producing significant patent income through licensing of only 1.5 parts in 10,000 per person-year of research effort and 7 parts in 10,000 for any income. In more intense study of 50 researchers, from which seven spin-off companies had resulted over a period of 15 years, Gregory and Sheahen found that the probability of producing a significant spin-off company income was considerably greater at 5 parts in 1,000 per person-year of research effort for significant income and 13 parts in 1,000 for any income. Earlier data by Morgenthaler (1970) found similarly low income benefits from patent licensing.

Technologies that might be transferred to the commercial sector can originate in university research programs, government R&D laboratories, or corporate scientific and engineering efforts. The choice to the organization between licensing and spinning off is not always available as different technologies or innovations and different circumstances may favor one method over the other. For example, a spin-off company can produce an income from a modest invention or technology and provide the nurturing required in many cases. However, the investment required for spin-offs is usually far greater than that for license agreements.

A spin-off company is a separate business entity that is formed using investment funding. The parent organization provides the technological base, supplemented on occasion by some risk capital, in return for equity. Some R&D organizations have their own venture capital whereas others depend on outside sources of venture capital. In the corporate setting spin-offs appear to be most pursued when the parent organization is not very familiar with either the new technology or the new market. Years ago, for example, the General Electric (GE) Research Center in the United States established its Technical Ventures Operation to spin-out as new companies some R&D projects that deviated from GE's mainstream strategies. (Ben Daniel, 1975; Sabin, 1973) Eastman Kodak similarly established an Office of Innovation to move technical innovations forward for internal applications preferably or into spin-off companies when necessary. (Tuite, 1991) And more recently Xerox began to pursue the setting up of spin-off companies from internal R&D ideas as an alternative means for moving ideas to the market entrepreneurially (Armstrong, 1993). The corporate spin-off seems to provide a good way to establish a new technology or get into a new market and for this reason holds some attraction for R&D-based organizations. Roberts and Berry (1985) state that spin-offs are unlikely by themselves to be a major stimulus for a large corporation's growth. However, they may well meet the needs of the R&D organization or its parent while providing wider benefits to the community. To be assured of good management of the new venture the parent organization may, in some cases, provide managerial assistance to the spin-off.

Spin-off ventures are one way for a R&D organization to retain contact with and limited access to experienced managers, scientists and engineers. These people may have a career or personal need for experiences and rewards that the parent cannot provide and may receive significant financial rewards through the realization of capital gains if the venture succeeds. Making provision for such rewards can be an important strategy in some cases (Mitton, 1987). The risk for the investing organization is that it will not usually have control of the spin-off or the ability to sell off at will. The investor's lack of control and the associated inflexibility may prove to be unacceptable to some organizations. "Patient money" is needed as well, as the investment period is typically in the order of four to eight years. Even so, the returns can be very good. Sykes (1986) documents an example of benefits that can be derived from investing in new ventures. Under his direction Exxon Enterprises provided risk capital to outside entrepreneurs to start 18 new ventures. A total investment of $12 million over a period of 10 years provided the extraordinary total returns of $218 million in the 12 years from the start. But Exxon later withdrew from this corporate venturing to concentrate on its core petroleum and oil business. The General Electric and Kodak examples mentioned above, however, did not even provide meaningful financial benefits, while also not contributing to corporate goals.

The two basic alternative processes that underlay the formation of a spin-off company are technology push and business pull. Technology push is a more costly method of forming a spin-off from the point of view of a R&D organization. More must be spent to promote the benefits of the technology to would-be entrepreneurs and venture capital funds. Business pull may also cause problems. If the pull is too great, then traditional academic freedoms of research direction and impartiality may appear to be threatened. The two motivations represent the two extremes of R&D organization policy and procedures. In most R&D organizations differing degrees of both technology push and business pull exist side by side. Not all innovations arising from a R&D organization are suitable as a basis for a spin-off company. Nelsen (1991) states that only 3 per cent of inventions disclosed at MIT have the characteristics that make them suitable for spin-off ventures. Most other MIT invention disclosures are deemed more appropriate for licensing (Roberts and Peters, 1981). Klofsten et al. (1988) note significant differences in marketing knowledge, marketing personnel, and external capital between university and non-university spin-offs in Sweden. Lower levels of these factors put research organization spin-offs at a disadvantage. If these difficulties can be overcome, then spin-off companies represent an attractive means of commercializing technology for R&D organizations.

A Model of the Spin-off Process

The creation of a spin-off venture must be carried out with care and deliberation in order for the spin-off company to succeed in the general sense and to meet also the goals and objectives of the parent R&D organization. A wide variety of choice can be exercised by an R&D organization in setting policy and procedures for the spin-off process. The organization must identify the technology that it has created, select the technologies appropriate for licensing and spinning off, and determine the level of support to be given to a spin-off venture.

Key Roles in the Spin-off Process. The spin-off process is one of different groups of people interacting to transfer a technology from the R&D organization where it was developed to industry where it will be incorporated into usable products and services. Four principal groups are involved in the spin-off process: the technology originator, the entrepreneur, the R&D organization itself, and the venture investor.

The technology originator is an individual engineer or scientist or a group working in the R&D organization. In many R&D organizations, whether in universities, government or industry, technical people devote considerable time to carrying out the initial stages of "Ideas Generation" and "Concept Investigation". From these concepts this group works through the stages of the innovation process to the point where transfer of technology is possible. An important aspect of an organization's technology policy and strategy is whether it attempts to guide this process, either passively or actively, with the aim of having technology that is suitable for commercialization by licensing or spin-off. The main motivation of a technology originator, especially if an academic researcher, is likely to be to achieve peer recognition through producing new insights into technical phenomena and publishing papers on these scientific advances. Some difficulty or conflict may result if the organization pushes any concept of "potential for commercialization" too hard. However, in many cases these originating persons are very entrepreneurial or discover their entrepreneurial talents when presented with a suitable opportunity. This is particularly true in a more developmentally-oriented organization. To accomodate these alternatives, it is important for any spin-off model to incorporate the facility for combining the roles of entrepreneur and technology originator into one role.

The second key figure in both the innovation and company spin-off processes is the entrepreneur. The entrepreneur, or the entrepreneurial team, takes the technology generated by the originator and attempts to create a new venture from it. Maidique (1980) states that the entrepreneur (or entrepreneurial team in many cases) is important as a champion for the new technology as vigorous promotion is needed to overcome resistance to the new idea and the creation of the new venture. Among other features the successful technological entrepreneur has been found to have a high need for achievement and the drive to succeed. The existence of role models (such as a self-employed father) has been found to be common for entrepreneurs (Roberts, 1991a) as has a belief in self-determination. Various psychological profiles of entrepreneurs have been identified but, as Vesper (1990) points out, "differences that are found to be significant statistically may not be different practically." These profiles may find some application when assessing the potential of an organization to become involved in the process of spinning off companies but not when choosing between individuals. Bird (1989) has suggested two levers to increase entrepreneurship: cultural and political contexts that create an environment suitable for entrepreneurship and contexts that create motivations for individuals to be entrepreneurial. The entrepreneurial individual or team plays an essential and valuable role in creating the new venture but is often considered unsuited to providing the stable base needed for long term growth (Burgelman 1984). Abernathy and Utterback (1988) describe how a team involved in the process of innovation matures with time from an initial fluid stage with little organizational formality to a more developed unit. At its initial stage the organization is informal and entrepreneurial. It then moves to one with groups that are project and task oriented with relatively informal relationships, to one with an emphasis on structure, goals and rules. As this occurs the company moves from being product development oriented to being production and customer oriented.

The R&D organization is usually represented in its formal spin-off process by its technology licensing office. The technology licensing office has the responsibility of ensuring that the intellectual property (for example the inventions relating to the technology) that is generated by the scientists and engineers in the organization is captured by the organization, legally protected if necessary, and then utilized in a manner that maximizes the achievement of the organization's goals. This generally means licensing the technology to an existing firm, facilitating the creation of a spin-off venture, or releasing the technology into the public domain.

The venture investor is generally a venture capital (VC) organization that provides funding for the new venture in return for equity in the resulting new company. A VC organization may be active in seeking new technology and entrepreneurs to fund, or it may be more passive and generally respond to technology entrepreneurs who approach it with proposals. Most VC organizations combine both modes of operation. Relationships between a venture capital organization and a R&D organization also vary widely. In many cases the relationship is passive and the two organizations have only a normal arms-length business relationship. In some cases the R&D organization may be an investor in the venture capital organization but takes no active role in the management of the venture capital organization. In other situations the R&D organization takes some active role in establishing and setting the objectives for the venture capital organization in order to achieve its own objectives of technology commercialization. As with the combination of the entrepreneur and technology originator roles, a model of the spin-off process must be capable of representing this important and often controversial alliance or combination of roles.

Stages of the Spin-off Process. A "stages model" can be used to describe the evolution of new ventures, emphasizing the sequential nature of venture development. For example, Galbraith proposed a model of new venture development with five stages: proof of principle, model shop, start-up production, natural growth, and strategic maneuvering (reported by Burgelman, 1984). Factors for these stages are tasks, rewards, processes, structures and leadership. This model does not take account of the corporate context of the new venture, particularly strategic activities that take place at various management levels. Roberts (1990) presents a partial model of the evolution of a technology-based company. The model is partial in that some important resources, such as capital, are intentionally omitted. It shows three stages to this evolutionary process: Founding, growth and success. The main properties that contribute to progress through these stages are entrepreneurial drive, technical capabilities, market orientation and a product idea. Entrepreneurial drive and technical capabilities are regarded as essential. The additional paths created by the existence of products or market perspectives strongly contribute to the success of a new venture. These properties are important even at the founding stage.

Burgelman (1984) depicts a model with simultaneous as well as sequential strategic management activities for an intrapreneurial venture, i.e. one that seeks to develop a "new business" but within the confines of an already existing corporation. The process of intrapreneurial venturing is analogous to the formation of a R&D organization spin-off particularly if the new venture starts due to technology push and the R&D organization wishes to maintain strong linkages with the spin-off. The model describes management activities at various levels (corporate, new venture department, and venture leader) with respect to core processes (defining the new venture, providing impetus) and the corporate context (strategic- the change in the company strategy to accommodate the new venture; and structural- the change in corporate administrative procedures to accommodate the new business). Burgelman makes the following points that illustrate the dynamic nature of the new venture development process.

- New venture initiators encounter resistance and find it difficult to demonstrate project technical and commercial feasibility due to the difficulty in obtaining resources. The problems of venture formation are outside the decision-making experience range of many managers.
- Once the new venture starts a dilemma often arises for the venture management. Should they maximize growth by pouring available resources into producing growth or should they put resources into building a more stable base? Generally management unrealistically expects that the venture will very quickly produce results.
- The perception of the importance of a new venture is very dependent on the performance of the

main activities of the parent company. If these are going well then the new venture is treated as a background task. If the main activities are performing poorly then the new venture is needed urgently. This fluctuation from low interest to unrealistic expectations does not provide a stable environment for the new venture to develop products, structures and skills.

• Parent organizations often lack strategic structures that include the generation of new ventures in realistic terms. Resistance to the new venture also arises from managers of existing departments where some overlap (and therefore challenge) is possible. Without an adequate strategic context, politicking replaces long-term coordination and optimization.

These indicate that in some cases the active involvement and support of the parent R&D organization in the creation of a new venture may well have some adverse effects on both the spin-off and the parent. These adverse effects arise in the areas of management interaction and experience, organization structure, and differences in objectives.

Spin-off Stages Model. Figure 1 presents a model showing the stages of formation of a spin-off venture based on technology from a R&D organization. The model follows the flow of funding, resources and intellectual property through these stages. The earliest stages include the use of funding to provide the resources (both human and material) for research and development. R&D efforts lead to the generation of technological intellectual property ("Invention" in the model) which is in turn either lost by the R&D organization via "Leakage" or captured via "Disclosure" to its technology licensing office. Leakage may occur deliberately and openly, as in the case of scientific publication; inadvertently; or surreptitiously, as in the case of the creation of a new venture using undisclosed technology that has been removed from the organization (Knight, 1988). Disclosed technology is put through a process of "Evaluation" by the R&D organization's technology licensing office. The outcome of Evaluation is a decision on whether or not to pursue and complete a process of "Protection" of the intellectual property. Protection takes the form of patents, industrial copyright, trademarks, registered designs and trade secrets. On some occasions unprotected intellectual property is commercially exploited. It is important to note that if the intellectual property is exploited, typically it occurs via Licensing to an existing commercial concern such as a manufacturer. However, some intellectual property follows the route that is the central interest of this paper, "New Venture Creation". The technology may then go through the optional stages of "Product Development" and "Incubation" (for which "Seed Funding" will generally be necessary) but often goes straight through to the stage of "Business Development". In reality, Business Development is a complex series of steps or stages but these are not the focus of this paper. Roberts (1991), Block and MacMillan (1993) and Vesper (1990) provide comprehensive descriptions of the business development process. The Business Development stage requires considerable funding from investors. The investor usually takes equity in the spin-off company in return for the investment funds. Usually several rounds of funding are needed by the young company ("First et seq. Round Funding" in the figure) on its path toward self-sustaining growth. At some stage the original investors will sell their equity in order to reap the benefits of the gain in value of the company. Generally the new venture will be "harvested" through a direct "Sale to a Third Party" larger company, but frequently the venture goes public and an "Initial Public Offering" is made to the stock market. Funds derived from the sale of the venture may be reinvested in further ventures. Of course some new ventures do not make it that far and cease operating without sale ("Failure").

Alternative Spin-off Processes

As property moves from stage to stage, various interactions must occur between the technology originator, the entrepreneur, the R&D organization's technology licensing office, and the venture investor or venture capital fund. As indicated above these four parties have the primary roles in the formation of the new spin-off venture. The interactions of these parties can vary considerably within the framework described by the stages model. Observations made at several universities and R&D organizations that have attempted to spin-off new companies indicate several different models of these interactions. Three models with two additional derivatives are proposed here. Others are possible, but will be either derivatives of these five models or probably unrealistic in the context of rational business. Derivative models generally arise from the combination of two roles into one person or group or alliances between groups. For example, in some environments it is common for the technology originator to be the same as the entrepreneur. All models address the basic objectives of the interactions that occur between the parties:

• To transfer the technology from the R&D organization in a controlled manner, usually through a licensing agreement. The technology that is provided establishes the initial core competencies of the new company.

• To identify a business opportunity and create a business based upon this opportunity. This complements the technology and establishes the other functions required by the business to interact

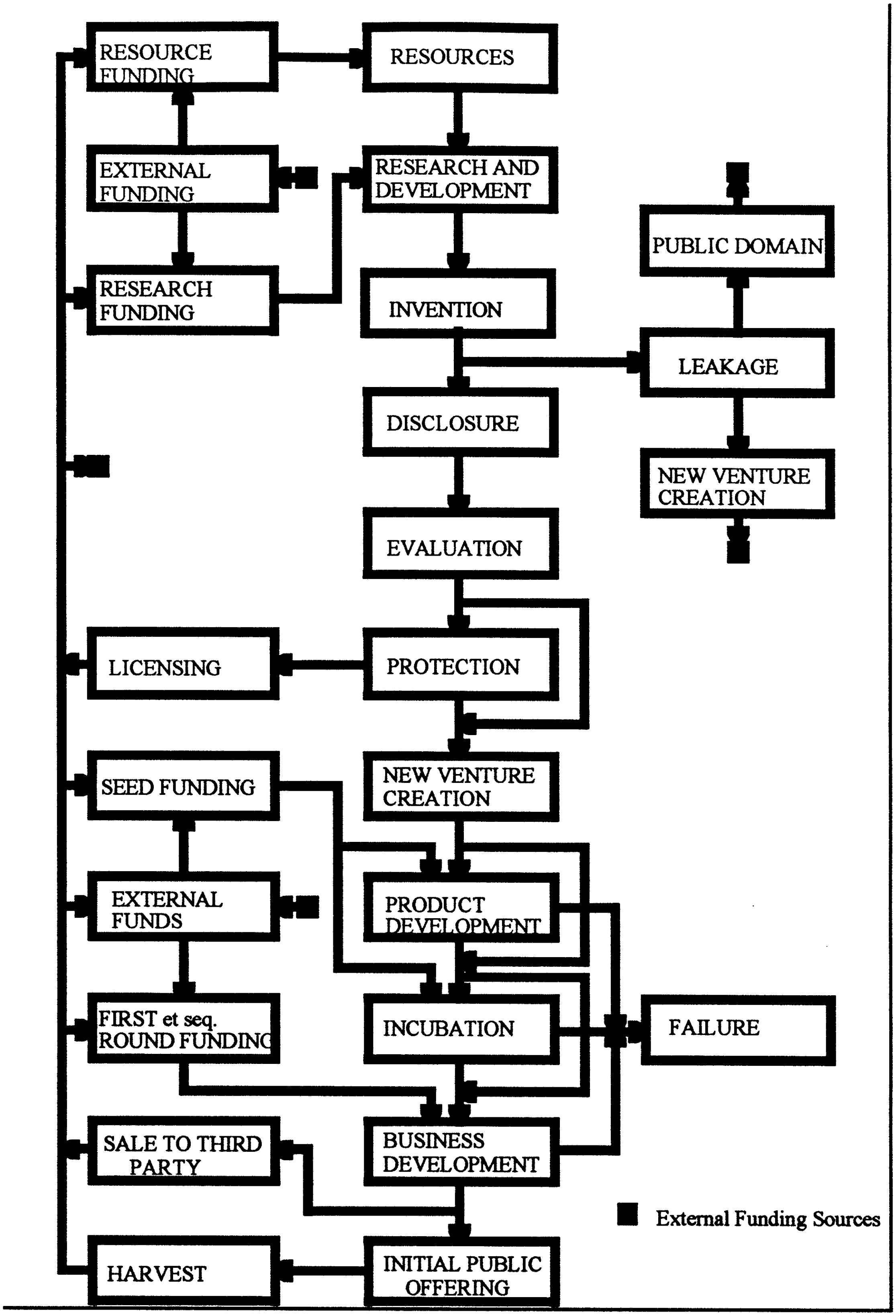


Figure 1. Spin-off stages model.

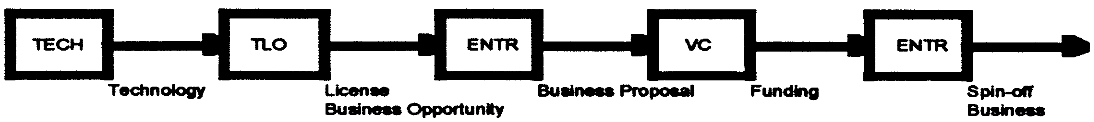
with customers, such as a product and channels of distribution.

• To provide the management resources for the company that give it the direction and control necessary for it to succeed.

• To invest funds in the business to provide it with the resources necessary to grow. This growth can potentially satisfy the needs of the principal parties (and perhaps others) through financial and other less tangible means.

The five process models describe the sequence of interactions between the parties and the objectives of these interactions. The role of each party in the interactions that occur at each stage, if any, is also described below.

Process Model 1. This model is the most basic of the five. The role of each of the four principal parties is clearly separate and the process follows the sequence of the stages model in an obvious manner. In this model the technology originator has the role of providing technology to the technology



Model 1: Technology push with independent principal groups. (TECH = technology originator, TLO = technology licensing office, ENTR = entrepreneur, and VC = venture capital fund)

licensing office that then seeks and finds an entrepreneur, from within or more usually from outside of the organization. For this reason the process is regarded as one of technology push. Business pull is exerted in this model when the R&D tasks of the technology originator are influenced by the external environment (perhaps indirectly through the internal organizational environment) to carry out research in areas where there are potential business opportunities. The recruited entrepreneur constructs a business proposal around the technology and the business opportunity in order to seek funding for the nascent venture. When funding is provided by the venture investor the entrepreneur creates the spin-off business and proceeds to develop that business. This Model 1 process is followed by the MIT Technology Licensing Office for some of its cases. Table 1 describes the processes and interactions of each of the four principal parties at each stage of the spin-off process beginning with the "invention".

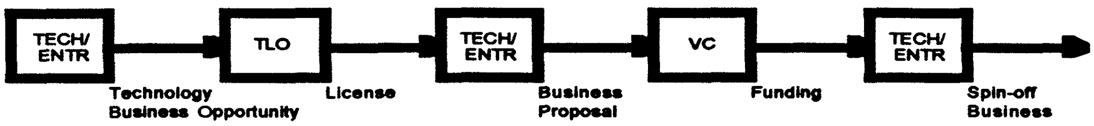
Table 1. Model 1: Technology push with independent principal groups; interparty processes occurring at each spin-off stage.

Invention	Technologist	Makes invention as a result of research & development work.
	Entrepreneur	No involvement.
	Licensing Office	No involvement.
	Venture Investor	No involvement.
Disclosure	Technologist	Reports technology discovery to the TLO.
	Entrepreneur	No involvement.
	Licensing Office	Receives disclosure.
	Venture Investor	No involvement.
Evaluation	Technologist	Often participates in evaluation due to knowledge in technical area.
	Entrepreneur	May be involved to comment on commercial possibilities.
	Licensing Office	Principal decision maker.
	Venture Investor	Approaches may be made to the venture capitalist by TLO.

Protection	Technologist	Required to assign ownership of technology to parent R&D organization.
	Entrepreneur	No involvement.
	Licensing Office	Makes arrangements for the legal protection of the technology.
	Venture Investor	No direct involvement but prefers protected technology.
New Venture Creation	Technologist	No direct involvement.
	Entrepreneur	Principal instigator of new venture creation. Seeks seed funding.
	Licensing Office	May direct entrepreneur to VCs. Takes equity in return for license.
	Venture Investor	May provide seed funding and business advice.
Product Development	Technologist	Transfers technology. Often continues development work.
	Entrepreneur	Focuses on market and product characteristics and in team development.
	Licensing Office	No direct involvement. License may include prototype milestone.
	Venture Investor	May provide seed funding. Monitors progress.
Incubation	Technologist	Continues to transfer technology.
	Entrepreneur	Closes gap between new venture and fully functional business.
	Licensing Office	May provide and manage incubation facilities. Sometimes represented on board.
	Venture Investor	May provide seed funding.
Business Development	Technologist	May continue to transfer technology.
	Entrepreneur	Very active in building business. Equity diluted by VC equity. May be replaced as CEO as business requires more formal organizational structure. Marketing development is important.
	Licensing Office	Sometimes represented on the board. Equity usually diluted.
	Venture Investor	Will invest first and perhaps second round venture capital. Usually on the board. Forces any changes in management.
Sale/IPO	Technologist	No involvement.

	Entrepreneur	Management will arrange sale/IPO. No direct involvement in decision.
	Licensing Office	Will generally harvest at same time as VC.
	Venture Investor	May strongly influence sale/IPO timing and direction. If IPO, sells equity then or in later secondary offering.

Process Model 2. This model is a derivative of Model 1 but differs in that the technology originator is the same person or group as the entrepreneur. The existence of an entrepreneurial technology



Model 2: Technology push/business pull with an entrepreneurial technology originator.

originator markedly increases the degree of business pull in this model compared with Model 1, even at the earliest stage, without particularly dissipating the degree of technology push. One would expect that if this model exists in an organization, i.e. entrepreneurial technology originators, then there would be a relatively high number of spin-offs and that the success rate would be relatively high as well. The fact that the technology originator stays with the venture increases the effectiveness of technology transfer (Roberts and Hauptman, 1986). In addition the technology is more likely to be attuned to use by a spin-off as this was at least part of the intention of the technology originator when the research and development work was being carried out. This model applies to about one-third of the MIT spin-offs and most of the Stanford spin-offs. The difference is due to Stanford's reluctance to become involved with company spin-offs except in those cases where the technology originator is also entrepreneurially involved. The processes and interactions of each of the three principal parties are shown in Table 2.

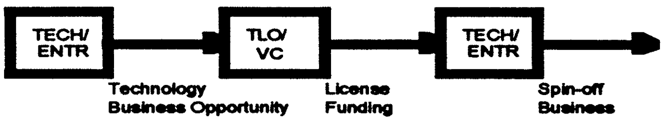
Table 2. Model 2: Technology push/business pull with an entrepreneurial technology originator; interparty processes occurring at each spin-off stage.

Invention	Technologist/Entrepreneur	Makes invention as a result of R&D work. Often has spin-off in mind when doing the R&D.
	Licensing Office	No involvement.
	Venture Investor	Generally no involvement. On rare occasions may sponsor some R&D.
Disclosure	Technologist/Entrepreneur	Reports technology discovery to the TLO. Indicates interest in forming spin-off.
	Licensing Office	Receives disclosure.
	Venture Investor	No involvement.
Evaluation	Technologist/Entrepreneur	Often participates in evaluation due to knowledge of technical area and commercial possibilities.
	Licensing Office	Principal decision maker concerning intellectual property protection.

	Venture Investor	Approaches may be made to venture capitalists.
Protection	Technologist/Entrepreneur	Required to assign ownership of technology to parent R&D organization.
	Licensing Office	Makes arrangements for the legal protection of the technology.
	Venture Investor	No direct involvement but prefers protected technology.
New Venture Creation	Technologist/Entrepreneur	Principal instigator of new venture creation. Finds seed funding.
	Licensing Office	Often directs entrepreneur to venture capitalists and other sources of funding. Takes equity in return for license.
	Venture Investor	May provide seed funding and business advice.
Product Development	Technologist/Entrepreneur	Product development to close gap between technology and market needs. Technology development may continue. Develops team.
	Licensing Office	No direct involvement. License may include a prototype as a milestone.
	Venture Investor	May provide seed funding. Monitors progress.
Incubation	Technologist/Entrepreneur	Gap between the new venture and a fully featured business closed. Establishment of marketing function is particularly important.
	Licensing Office	May provide and manage incubation facilities for spin-off. Sometimes represented on the board.
	Venture Investor	May provide seed funding.
Business Development	Technologist/Entrepreneur	Very active in building business. May be replaced in CEO role as business requires a more formal organizational structure. Valuation a critical issue during VC negotiations. Equity diluted by VC equity.
	Licensing Office	Sometimes represented on board. Equity usually diluted.
	Venture Investor	Will invest first and perhaps second round venture capital. Represented on the board. Might force changes in management.

Sale/IPO	Technologist/Entrepreneur	Will help arrange sale/IPO. No direct involvement in the harvesting decision.
	Licensing Office	Will generally harvest at same time as VC.
	Venture Investor	May influence sale/IPO. If IPO, sells equity then or in secondary offering.

Process Model 3. This model is a further derivative of Model 1. The roles of the technology licensing office and the venture capital fund are combined, i.e., the technology licensing office has a venture capital fund at its disposal. As with Model 2 the technology originator and the entrepreneur are also



Model 3: Technology push/business pull with an entrepreneurial technology originator and an internal venture capital fund.

combined. This model is likely to have levels of technology push/business pull similar to Model 2. It is tempting to think of this model as an ideal starting point in an environment in which spin-off ventures are not common and the R&D organization has the goal of generating spin-offs to: (1) transfer technology, (2) provide investment opportunities and returns, and (3) over time create an environment where spin-offs are more common. However, it is unlikely that a sufficient supply of entrepreneurial technology originators will exist under the circumstances where spin-offs are uncommon, and rather more business pull will have to be exerted by the venture capital part of the R&D organization. Boston University with its Community Technology Fund tends to follow Model 3. The GE, Kodak and Xerox approaches mentioned previously are variants of Model 3, with their own internal financing generally restricted to seed stage and initial product development financing. They typically sought more substantial funding from independent VCs.

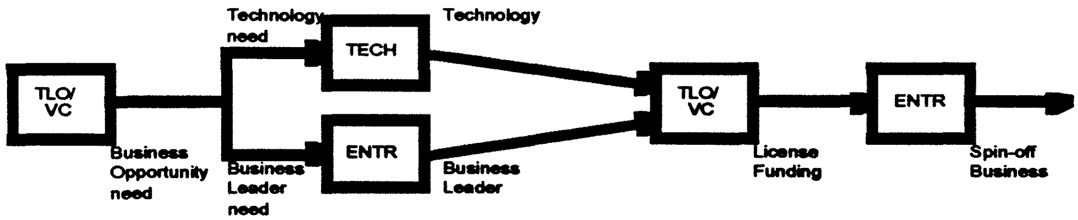
Table 3. Model 3: Technology push/business pull with an entrepreneurial technology originator and an internal venture capital fund; interparty processes occurring at each spin-off stage.

Invention	Technologist/Entrepreneur	Makes invention as a result of R&D work. Often has spin-off in mind when doing R&D.
	Licensing Office/Venture Investor	Generally no involvement. May occasionally sponsor some R&D.
Disclosure	Technologist/Entrepreneur	Reports technology discovery to the TLO. Indicates interest in forming spin-off.
	Licensing Office/Venture Investor	Receives disclosure.
Evaluation	Technologist/Entrepreneur	Often participates in evaluation due to knowledge of technical area and commercial possibilities.
	Licensing Office/Venture Investor	Principal decision maker concerning intellectual property protection.

Protection	Technologist/Entrepreneur	Required to assign ownership of technology to parent R&D organization.
	Licensing Office/Venture Investor	Makes arrangements for the legal protection of the technology.
New Venture Creation	Technologist/Entrepreneur	Principal instigator of new venture creation. Finds seed funding.
	Licensing Office/Venture Investor	May provide seed funding and business advice. Takes equity in return for license and funding.
Product Development	Technologist/Entrepreneur	Product development proceeds to close gap between technology and market needs. Often continues development. Continues team development.
	Licensing Office/Venture Investor	May provide seed funding. Monitors progress. License may include a prototype as a milestone.
Incubation	Technologist/Entrepreneur	Gap between the new venture and a fully featured business closed. Establishment of marketing function is particularly important.
	Licensing Office/Venture Investor	May provide seed funding and incubation facilities for the spin-off. Sometimes represented on the board.
Business Development	Technologist/Entrepreneur	Very active in building business. May be replaced in CEO role as business requires a more formal organizational structure. Valuation a critical issue during VC negotiations.
	Licensing Office/Venture Investor	Will invest first and perhaps second round venture capital. Usually represented on board. Generally forces any changes in management.
Sale/IPO	Technologist/Entrepreneur	Will arrange sale/IPO. No direct involvement in harvesting decision.
	Licensing Office/Venture Investor	May strongly influence sale/ IPO timing and direction. If IPO, sells equity then or in later secondary offering.

Model 3 is more likely to be successful in the case where a R&D organization is itself inactive so far as spin-off activity is concerned but the community in which the organization exists is one where spin-offs, entrepreneurs and venture capital funds are common. The organization may have been inactive for reasons of policy but has now adopted the strategy of using an internal venture fund to stimulate activity and achieve a more rapid "penetration" of the spin-off "market" than would have been possible with a more passive approach. Once a satisfactory penetration has been achieved the need for an internal fund may be reduced or eliminated.

Process Model 4. Model 4 is a more likely outcome than Model 3 when a R&D organization chooses to develop a venture capital fund to increase spin-off activity in an environment that is not rich in venture capital and where spin-offs are uncommon. Sometimes an outside venture capitalist develops an exclusive or preferred relationship with the R&D organization and fulfills the role of the organization's venture capital fund. The situation that this model describes is one where the R&D organization has a



Model 4: Business pull with internal venture capital funds.

strong need to use technology to generate new spin-off ventures. R&D organizations are under increasing pressures to commercialize their technology and the new company spin-off route has been shown to be an effective way of satisfying commercial objectives in some environments. R&D organizations that are not in an environment where spin-offs are frequent and accepted face the task of changing the environment to one that is more amenable to spin-off ventures. One approach is for the organization to put in place some of the principal missing elements to make the spin-off process possible initially, in the hope that in the long term the success of new ventures will initiate growth of these missing elements on a more permanent basis in the business community. The elements that are typically seen to be missing are the venture capital fund and the entrepreneur. Typically the proactive R&D organization will set up a venture capital fund on the assumption that "dormant" entrepreneurs are in the R&D organization or at least in the community. Such an assumption is debatable; a simple free market philosophy argues that if suitable market opportunities were available for the technologies then the entrepreneurs and the funding would come forward. However, such an argument ignores the fact that synergies do seem to exist in some regions and that R&D organizations producing technologies of plausibly comparable value in different regions have vastly different results in terms of producing spin-offs. Successful use of this model depends on: (1) generating sufficient returns to the fund, thus ensuring that it is worthwhile for the R&D organization to continue with the fund, and (2) making visible progress towards the achievement of the objective of changing the external environment. Satisfaction of the latter objective is difficult to measure, particularly as it is likely to be a long term exercise. The model shows the need for the organization to act as a business and take an active role in first defining business needs, then finding the technology and the entrepreneurs, as well as providing the venture capital to overcome the inertia existing both inside and outside of the organization. ARCH tends toward this model on behalf of its combined constituency of the Argonne National Laboratory and the University of Chicago. Harvard Medical School created its Medical Science Partners fund consistent with the Model 4 approach.

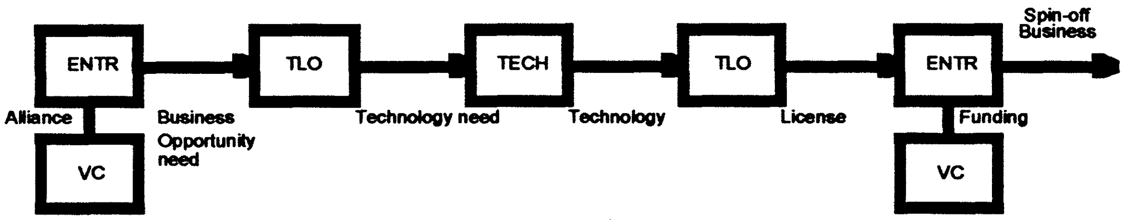
Table 4. Model 4: Business pull with internal venture capital funds; interparty processes occurring at each spin-off stage.

Invention	Technologist	Makes invention as a result of R&D work.
	Entrepreneur	No involvement.
	Licensing Office/Venture Investor	Business needs are established then searches R&D organization for technology with commercial potential. Searches for entrepreneur.

Disclosure	Technologist	Shows technology to the TLO.
	Entrepreneur	No involvement.
	Licensing Office/Venture Investor	Receives technology.
Evaluation	Technologist	Often participates in evaluation due to knowledge in technical area.
	Entrepreneur	Matched to possible commercial opportunity.
	Licensing Office/Venture Investor	Principal decision maker regarding suitability of technology and entrepreneur for spin-off.
Protection	Technologist	Required to assign technology to parent R&D organization.
	Entrepreneur	No involvement.
	Licensing Office/Venture Investor	Makes arrangements for the legal protection of the technology.
New Venture Creation	Technologist	No direct involvement.
	Entrepreneur	Agreement with TLO/VC over new venture structure. Works closely with TLO/VC to create new venture.
	Licensing Office/Venture Investor	Agreement with entrepreneur. May provide seed funding and business advice. Takes equity in return for license and funding.
Product Development	Technologist	Transfers technology. Often continues development work.
	Entrepreneur	Focuses on market and product characteristics and in team development.
	Licensing Office/Venture Investor	May provide seed funding. Monitors progress. License may include prototype milestone.
Incubation	Technologist	Continues to transfer technology.
	Entrepreneur	Closes gap between new venture and fully functional business.
	Licensing Office/Venture Investor	May provide seed funding and incubation facilities for spin-off. Sometimes represented on board.
Business Development	Technologist	May continue to transfer technology.
	Entrepreneur	Very active in building business. Equity diluted by VC equity. May be replaced as CEO as business requires more formal organizational structure.

	Licensing Office/Venture Investor	Will invest first and perhaps second round of venture capital. Represented on board. Forces any changes in management.
Sale/IPO	Technologist	No involvement
	Entrepreneur	Management will arrange sale/IPO. No direct involvement in decision.
	Licensing Office/Venture Investor	May strongly influence sale/IPO timing and direction. If IPO, sells equity then or in later secondary offering.

Process Model 5. On some occasions, in the well-developed spin-off environments, alliances are formed between experienced entrepreneurs and venture capital funds to discover and use technology-based business opportunities that exist in R&D organizations. The alliance is based on the venture fund's belief



Model 5: Business pull with an entrepreneur/venture capital fund alliance.

in the capabilities of the entrepreneur to succeed with a spin-off opportunity that is, at that stage, unidentified. In turn the entrepreneur trusts that the venture fund will provide the funding if a suitable opportunity is discovered. Generally the technology licensing office of the R&D organization takes an active role in finding suitable technologies to satisfy the entrepreneur's need. The entrepreneur will not have any involvement in the invention process. By taking an active role the technology licensing office can maintain some control over the exercise and can take appropriate steps to ensure that the interests of the R&D organization are looked after. Other than the interactions described above the interactions that occur between the parties at each stage of this model are similar to those described in the other models. On occasion this model is used at Harvard and MIT.

Selecting and Supporting Spin-off Projects

Assessment of all five process models demonstrates that selectivity and support are the two main dimensions of a technology commercialization policy directed at facilitating the formation of spin-off ventures from a R&D organization. A R&D organization must decide how severe to make its selection criteria for spin-off ventures. One possible measure of selectivity is the proportion of invention disclosures that are selected for spinning off. However the quality of disclosures as well as the spin-off policy will influence that selection rate. For example, a higher rate of selection might be expected from an organization that consistently produces high quality technology suitable for the basis of a spin-off. Spin-offs as a proportion of R&D expenditures also does not give a particularly helpful figure as this measure combines selectivity with R&D efficiency and direction (although these issues are of concern with respect to the broader policy issues). Merely dividing selectivity into two qualitatively ranked groups of "high" and "low" has some practical appeal for examining and determining R&D organization policy.

Support is the level of managerial and financial assistance given to a spin-off venture by the R&D organization. In the broadest sense this should include all assistance given from the time of first disclosure through to the time when the R&D organization relinquishes all interest in the new venture. As with selectivity, broad qualitative measures of the level of support given to spin-offs are sufficient for the examination and determination of R&D organization policy. The implications and results of different levels of selectivity and support are:

- Role in project discovery. A highly selective R&D organization will take an active role in seeking out potential spin-offs and the technologies upon which they are based. In contrast, an organization with a policy of low selectivity is likely to take a passive role and rely on disclosure by the researchers.

• Effort put into spin-off opportunities. A highly supportive organization will put a greater effort into each spin-off than a low support organization.

• Final selection decision about the launch of a spin-off. With a low support organization this decision will generally be in the hands of an external venture capital fund. A high support organization is likely to have its own venture capital fund and will therefore play a more significant role in the decision to go ahead with the venture.

• Source of venture capital funds. As described above, the low support organization will not provide venture funds other than taking equity in return for the technology transferred. A high support organization will provide a significant proportion of at least the seed capital for the new venture from its own venture capital funds. Low selectivity will require the use of external funding sources to supplement funds in the case of high support organizations

• Management involvement. An organization offering high support levels will provide considerably more formal management support to the new venture than an organization providing low support levels. Such support may extend to the utilization of incubator facilities but is frequently administrative only. Significant support may be provided through informal channels in all cases. Management assistance from highly supportive organizations will be diluted where high selectivity is not exercised.

• Spin-off rate. High support will tend to increase the spin-off rate.

• Cost per spin-off. A high support level will tend to increase the cost per spin-off.

• Return on input. High support levels will require more funding. A high degree of selectivity (i.e., a low selection rate) will be necessary to avoid investment in spin-off ventures with a low potential return. Low support level organizations need not be so selective and should act to broaden their "portfolio" of potential spin-offs.

Figure 2 shows a matrix of high and low levels of support and high and low levels of selectivity. The matrix shows the likely implications and results of the support and selectivity policies in terms of the technology licensing office's role in the spin-off process. It is evident that only two of the four quadrants of

SUPPORT		LOW SELECTIVITY	HIGH SELECTIVITY
	HIGH	Passive role in project discovery High spin-off effort Internal selection decision Mixed source of venture funds Moderate management involvement Moderate spin-off rate High cost per spin-off Low return on input	Active role in project discovery High spin-off effort Internal selection decision Internal source of venture funds High management involvement High spin-off rate High cost per spin-off High success rate
	LOW	Passive role in project discovery Low effort per spin-off External selection decision External source of venture funds Low management involvement Low spin-off rate Low cost per spin-off High return on input	Active role in project discovery Low effort per spin-off External selection decision External source of venture funds Low management involvement Low spin-off rate Moderate cost per spin-off Low return on input

Figure 2. Support and selectivity policy matrix: Likely results and implications for technology licensing office.

the matrix appear to be rational and viable courses of action for a R&D organization. These are the Low support/low selectivity and High support/high selectivity quadrants.

Low support/low selectivity (many ventures but with little support for the ventures) reduces the cost of the spin-off operation but seeks safety in numbers. Choice is left to external agencies (such as venture capital funds) who are generally felt to have greater experience and expertise in "picking winners" and less potential for conflicting objectives than the R&D organization.

High support/high selectivity (a few well-supported ventures) relies on picking potential winners and supporting them so that they have every chance of success. As discussed earlier this strategy is more likely in environments where spin-offs are not usual and venture capital is scarce.

Low support/high selectivity has the risk of under-investment in an unreasonably narrow portfolio. Costs per spin-off will be moderate as a considerable selection effort is required.

High support/low selectivity is the most risky strategy in that much of the investment will be made in the more risky, low potential return spin-offs.

Data Gathering: Examinations of R&D Organization Spin-off Experiences

The technology licensing operations of eight R&D organizations in the United States and the United Kingdom were studied to determine their spin-off policies, structures and achievements. All the U.S. organizations are universities although some incorporate operations that extend beyond the core activities of a university. MIT, as an example, has various contract research laboratories such as Lincoln Laboratory. Four of the U.S. universities are private institutions located in the new venture-rich areas of greater Boston and greater San Francisco. These organizations are Boston University and its venture capital investment organization Community Technology Fund, Harvard University including the activities of Harvard Medical School and the associated venture capital organization Medical Science Partners, MIT, and Stanford University. Other U.S. R&D organizations studied are the University of Connecticut and ARCH Development Corporation. The latter organization was formed to commercialize the technology of The University of Chicago and the U.S. Department of Energy's Argonne National Laboratory. Two British organizations were studied: British Technology Group Ltd. and the technology transfer unit of King's College London, KCL Enterprises Ltd. Data were collected by interviewing senior staff in these organizations and by examining organizational documents provided by them. We provide here a brief synopsis of each of the eight organizations, ordered alphabetically.

ARCH Development Corporation. The Argonne National Laboratory/The University of Chicago Development Corporation (ARCH) was founded in October 1986 with the objective of commercializing technology arising from publicly funded R&D carried out at the two organizations. It is a not-for-profit affiliate corporation of The University of Chicago (UoC) governed by a board of directors drawn from UoC and Argonne. ARCH functions very independently but receives considerable support from its two parent organizations and the board. To achieve its objective ARCH primarily employs a strategy of creating new venture companies. Its premise is that creating a new venture is a more effective method of commercialization than traditional licensing. However joint ventures and traditional licensing are also used if appropriate. ARCH focuses on identifying technologies at UoC and Argonne that provide suitable spin-off opportunities. It has the right of "first look" at technology from these organizations. ARCH management often assumes operating responsibility for a new venture and upon being satisfied as to its growth potential after this period of "incubation", arranges additional venture capital and recruits management. Management is recruited by using an executive search agency or through network contacts. This is a difficult and crucial part of the spin-off process. Researchers are never appointed to this position as ARCH feels that experienced managers with a knowledge of the relevant interests and markets are what is needed. ARCH also takes an active role in assisting these spin-off companies to raise grants and contract R&D funding.

To facilitate the starting of new ventures a venture capital fund of $9 million was raised, principally from institutional and private investors in Illinois. This fund, ARCH Venture Fund (AVF I), is a limited partnership in which ARCH is the general partner. The fund began investing in April 1989 and by May 1993 had invested $5.9 million in eleven of the thirteen spin-off companies started by ARCH. To date, no ventures have failed and two have gone public. The parent organizations have also been assisted to secure over $5 million in research grants. Although UoC has a much smaller research budget ($110 million) and number of researchers (1000) than Argonne ($500 million, 4500 researchers), it has generated as many spin-offs. This is because Argonne is more focused on government-oriented research (for example, nuclear fuels processing) that does not often produce technology suitable for founding a spin-off company. A second fund (AVF II) was started in late 1993 with the objective of raising $30 million by July 1994 and being lead investor in two new ventures per year for four years.

ARCH has two additional objectives: to contribute to the education process at UoC, and to contribute to the economic development of the Midwestern region of the United States. One way in which the first of these goals is being achieved is by using 20 students from The University of Chicago Graduate Business School (where ARCH is located) as volunteer ARCH associates. Four students work as ARCH interns over the summer vacation. These students typically have a technical background and are keen to work in the new business development area. Several former associates have become employees of the ARCH-created spin-offs. The latter objective is one of environmental change as it is hoped that by demonstrating that the early identification and transfer of technology can be profitable in the region, others will take up the challenge as well. It is felt that none of the spin-offs would have started (even outside of the Chicago area) if ARCH had not been active. This is part of a wider effort in Illinois to develop new entrepreneurial industry in the region. The Illinois Coalition and the Governor's Science Advisory Committee helped guide almost $40 million of technology investment programs through the Illinois State Legislature in 1989 and 1990.

Boston University. Boston University (BU) has a strong focus on spin-offs as a means of transferring technology to the public arena. From research activities with an annual funding base of approximately $100 million, 90 disclosures of inventions were made and 23 patents issued in 1992. Four license agreements were executed including two to spin-off companies based on Boston University-owned technology. Technology transfer is the responsibility of BU's Community Technology Fund (CTF). CTF has two aspects to its operation: (1) Patent and Technology Administration (PTA), which receives, evaluates and administers technology disclosures with a staff of two professionals; and (2) a venture capital unit with six professional staff. CTF was started in 1974 as a venture capital fund primarily aimed at transferring and commercializing BU technology with BU investment funds. Since 1974 CTF has invested in more than 120 early stage companies. Of the 69 for which details were available, 20 had gone public and 12 had been acquired. The proportion of the firms that originated from BU is unclear.

BU focuses on spin-offs because it believes they offer a better combination of technology transfer and financial return than traditional licensing for the amount of effort put in by PTA and other university staff. It is also regarded as being a more robust investment. If a company changes its technology, the royalty stream from the license would die but equity in the company would remain. Should a company fail, the technology ownership remains with the university. Another drawback that BU sees with traditional licensing is that success generally requires a champion in the licensee company and if this champion changes his or her position or job then the risk of the technology not being used is high. The main disadvantage of creating spin-offs is that they are time consuming, particularly those where the technology originator is starting the spin-off. Other difficulties with the spin-off process are: Valuing the spin-off is much more difficult than setting the royalty for a license; raising venture capital can be difficult although having the CTF venture capital unit helps; the opportunities are less frequent; and the portfolio of transferred technology is narrower and therefore more risky.

BU's emphasis on and approach to spin-offs has occasionally attracted some controversy. Seragen Inc., a medical technology spin-off launched in 1985, was such a case. BU, through CTF, had a 45 per cent share of Seragen after dilution. At the time of the launch this large holding of equity, and the close rather than arms-length relationship between the university and the company, highlighted the potential conflict of interest that many felt existed. This issue became a matter of public debate several years later, heightened by BU's president becoming a candidate for governor of Massachusetts.

Over time the primary aim of the CTF venture capital unit has shifted from transferring and commercializing BU technology to satisfying university investment objectives by investing in start-ups from a wide range of sources. Several years ago all BU spin-offs were funded by CTF's venture capital unit, today approximately only half are. Since its start, the venture capital unit, which has a $6 million rolling fund, has invested $50 million in new ventures in which it was lead investor. The CTF venture capital unit does not fund pre-startup research as BU has its own internal fund to help develop promising technologies closer to the commercialization or application stage. This small $100,000 fund typically makes grants to eleven projects each year and pays for materials, supplies, equipment and graduate student stipends.

When funding a venture the CTF venture capital unit looks for the following in the venture proposal: (1) technology that replaces an existing product with no changes in existing customer behavior or distribution channels being necessary; (2) management expertise; (3) marketing experience; and (4) a minimum market size of $100 million. Researchers are regarded as generally having low market familiarity, low product development skills, and low entrepreneurial skills, and are not generally preferred by CTF as managers for the new ventures in which it invests.

British Technology Group PLC. British Technology Group (BTG) was formed in 1981 as a result of the merger of two public sector corporations, with technology transfer activities dating back to 1949. BTG was privatized in 1992, being acquired by a consortium led by BTG's management and staff. Its present investors are financial institutions (58.31%), BTG employees (30.78%), eleven UK universities (4.03%), and other institutions (6.88%). The objective of BTG is the profitable commercialization of technology by: Identifying and protecting commercially viable technology resulting from research performed by individuals and research organizations; licensing the resulting intellectual property to companies throughout the world; and facilitating intercorporate licensing of technology. After recovering costs, BTG shares license income on a 50:50 basis with the source organization. All eleven of the investing universities use BTG's services. In recent years many other UK universities (for example, King's College London) have become active in commercializing their technology themselves rather than just using BTG's services. BTG has offices in London, the U.S. and India.

Before privatization BTG was active in providing finance for technology development and for academic researchers or institutions who wanted to set up spin-off companies. Following privatization this policy was changed and BTG has discontinued all equity investment activity. This change has been implemented for three reasons: (1) to enable its resources to be focused entirely on its core business of technology transfer; (2) because there are now adequate sources of venture capital available in the UK (in 1992 the 117 members of the British Venture Capital Association invested £1.4 billion in 1297 companies compared with an investment of £20 million in 1979); and (3) the government has withdrawn funding that facilitated this type of investment. Pre-privatization investments continue to be held for disposal at a commercially appropriate time. Future investment opportunities will be referred to BTG's institutional shareholders.

In 1993 BTG received 511 disclosures and executed 75 licenses. Approximately 40 per cent of disclosures are patented and in turn, approximately 40 per cent of these are licensed. In 1993 revenues were £26.8 million of which around 80 per cent is derived from outside of the UK. Profit was £1.69 million before exceptional items and taxes. The number of inventions and licenses in BTG's portfolio are 1,525 and 499 respectively.

Harvard University. The Office for Technology and Trademark Licensing (TTL) is the central office responsible for the administration of intellectual property at Harvard University. The Office for Technology Licensing and Industry Sponsored Research (OTL) has similar responsibilities for the Harvard Medical School and its affiliates in coordination with TTL. The principal objectives of TTL (including OTL) are: (1) to ensure that intellectual property produced at Harvard is used for the greatest public benefit; (2) to protect the traditional rights and freedoms of scholars; and (3) to distribute income resulting from developments made at the University in a manner that reflects the University's contribution. All discoveries and inventions at Harvard University are expected to be reported to TTL by the researcher. Harvard owns all discoveries and inventions where required by a research sponsorship agreement or contract, or where individuals elect university involvement in the management of the intellectual property. Individuals may elect to make their own arrangements for the protection and commercialization of intellectual property. If this route is chosen then the individual is entitled to all financial returns from the commercialization unless Harvard's involvement is substantial in which case returns will be divided. Should the discovery not be made available for public use by the individual then Harvard may elect to take over this role. Should TTL's involvement be requested by the individual, then TTL will, after disclosure, evaluate the protectability of the technology and ensure that it has sufficient potential for commercialization. After protection the technology will be commercialized, either by means of traditional licensing (often exclusive) or through a spin-off company. Cumulative income from commercialization, after expenses, is distributed as follows: (a) first $50,000 of income: Inventor, 35%; Inventor's academic department, 30%; Inventor's academic school, 20%; and the University, 15%; (b) subsequent income is divided 25:40:20:15%. Procedures and policies for the Medical School and its affiliates are similar in all respects except that the Medical School and affiliates own all inventions of a medical nature.

Taking equity shares in spin-off companies by faculty and directly by the university (as opposed to indirectly by means of investments in financial institutions) has been a contentious issue at Harvard for 15 years. This has its roots in the late 1970s, when some faculty proposed that Harvard should participate in forming a genetic engineering company on the campus and that Harvard should take equity in that company. In internal discussions many university faculty felt that there was great potential for conflict of interest. The proposal was also widely discussed in the public arena. The 1979-80 President's Report (Bok, 1980) discussed the issues of conflict of interest and concluded, among other things: "The same [that the risks could be acceptably controlled and that the same public benefit cannot achieved by other mechanisms] cannot be said of efforts to join the university with its professors to launch new entrepreneurial ventures." This statement was widely interpreted (for example by Wilson and Szygenda, 1991) as meaning that Harvard should not take equity in spin-offs. However President Bok also said, "The point is not to discourage faculty members from becoming entrepreneurs." He concluded that the problem was one of how to assure that conflict of interest was avoided. Today Harvard's conflict of interest policies primarily require that individuals accord Harvard their primary professional loyalty and that they should not seek to influence the technology research process in ways that could lead to personal gain. If faculty or university equity represents the best licensing possibility, then the situation must be approved by the Harvard University Committee on Patents and Copyrights.

This debate and discussion within Harvard seems to have had the effect of reducing and further delaying the development of spin-off activities at Harvard, which had never had a history of many spin-offs. With the exception of Harvard Medical School activities there have been only two spin-offs observed in the last three years. One was done jointly with MIT (the Harvard staff member had already left so the conflict of interest issues did not arise) and the other was based on technology that was at the edge of the researcher's normal area. Harvard's total research funds were in the order of $275 million ($750 million including the affiliates of the Medical School) in 1992. Not including the affiliates, royalties of $3.2 million were received from 90 licenses, and 73 patents were filed on the 87 disclosures that were received (AUTM, 1993).

Harvard Medical School (HMS) has led Harvard's advance into the use of spin-off companies and in 1988 it established the Medical Science Partners (MSP) venture capital unit. The purpose of establishing MSP was to create a "friendly" early stage venture fund to speed the transfer of HMS technology and to profit from that transfer. Harvard is represented at MSP by its wholly owned subsidiary, ION Inc., which is a limited partner with a ten per cent share in the general partnership of MSP. To separate Harvard's academic interests from the business interests of MSP and avoid the possibility of conflicts of interest, MSP operates autonomously and Harvard is not an investor in MSP's fund. Harvard's input to the governance of the company is via ION. MSP does not have first rights to HMS technology nor is it restricted to HMS technology. However at least one HMS researcher acts as an advisor or technology contributor to each MSP venture. MSP's first fund (MSP I) of $36 million had sixteen investing partners from the U.S., Europe and Singapore. A second fund of $30 million has been raised to be invested or committed over the next three years. Ten of the thirteen ventures funded since March 1989 by MSP I are HMS spin-offs. MSP typically takes equity of 20 to 25 per cent in each portfolio company after the first round. MSP generally arranges for experienced business managers to head the new ventures. As with ARCH MSP is reluctant to use medical researchers as CEOs and the technology originators are generally utilized as technical leaders or consultants.

KCL Enterprises. King's College London, a college of the University of London, formed KCL Enterprises Ltd. (KCL) in 1993 with two objectives in mind: (1) to secure more research funding and to assure that funding is adequate for the research to be done; and (2) to identify and commercialize the intellectual property generated by Kings College London. King's College London has 8000 students and in 1993 research funding was £27 million. The use of BTG had not proven successful for the College and it was felt that BTG had put insufficient marketing effort into the College's technologies. By having KCL develop strong contacts with both industry and funding bodies and actively managing the transfer of technology process exclusively for the College, it is hoped that the level of technology transfer and the returns from that transfer will be greatly improved. KCL leadership anticipates taking equity in spin-offs on only rare occasions during the first few years of its operations and that traditional royalty-based technology licensing will be its mainstay. The reasons given for this are: (1) resources of KCL are very limited at this stage and focusing on only a few new ventures is a strategy that is too risky; and (2) it is rare for British academics to be entrepreneurial. KCL's leadership estimates that once KCL is fully operational, it will receive approximately 120 disclosures per year from the science and medical faculties of the College, that 10 to 20 of these will be patented after evaluation, and that 5 to 10 licenses will be executed each year. The low proportion of disclosures to patenting is primarily due to funding limitations at this stage. Of the 5 to 10 licenses expected per year it is anticipated that two may provide a significant return and that one spin-off company might be formed every one or two years. KCL plans to actively assist potential spin-offs to secure venture capital. It is the policy of the College that one third of the royalties from technology licenses after expenses will be given to the technology originator with the university retaining the remaining two thirds.

Massachusetts Institute of Technology. MIT, in common with other universities, regards technology transfer as subordinate to its education and research goals and the rapid dissemination of information that those goals imply. Although few at MIT remember the organization, in the 1970s MIT established the MIT Development Foundation, with linkage to a number of major corporations interested in emerging technologies, to encourage and nurture spin-off companies from MIT, including the possible provision of seed funds. After a disappointing five year period, during which only two companies were created via this route, MIT abandoned the approach. Today MIT's Technology Licensing Office (TLO) is responsible for the transfer of the technology generated by the research and development activities at MIT (including the Lincoln Laboratory and the Whitehead Institute) for public use or benefit. TLO has two principal objectives: (1) to manage the transfer of technology as a means of maximizing the benefit of the technology to the public, in a manner that avoids conflicts of interest; and (2) to provide an additional financial return to MIT for the purposes of supporting education and research at MIT. Technology may be licensed to existing companies in the traditional manner or used as the basis for a new venture.

MIT will usually own the rights to an invention by MIT faculty. If the invention is developed in the course of unsponsored research and without the significant use of MIT funds or facilities, then the inventor will be owner. In the case of sponsored research, ownership is determined by the sponsorship agreement. Salaries, offices, machine shops and desktop computers are not regarded as being significant funds or facilities. Technology owned by MIT must be disclosed to the TLO by the inventor for evaluation. Technology not owned by MIT need not be disclosed unless the owner wants TLO to help commercialize it. Generally TLO will only take steps to protect disclosed technology if it is commercially attractive. Commercial attractiveness is usually assessed by approaching potential licensees or investors. To avoid conflict of interest situations MIT will not allow the inventor's MIT research group to accept research funding from a company in which the inventor has equity. License royalties after expenses are divided among the inventor, the inventor's department, and the MIT General Fund in a method that gives approximately equal parts to each party. Conflict of interest situations must be avoided.

R&D funding for the MIT campus was $286 million in 1992. Including laboratories such as Lincoln Laboratory total R&D funding was approximately $750 million. MIT has a portfolio of over 1000 patents. In 1992 income totalled $11.7 million from 174 licenses (excluding Lincoln Laboratory) (AUTM, 1993). An estimated 40 per cent of license agreements made by TLO are with large corporations, fifty per cent with companies with fewer than 100 employees, and ten per cent with new companies. In recent years TLO has received an average of approximately 350 disclosures per year from all sources, of which 50 per cent were patented. Of those patented, two-thirds will eventually be licensed, generally on an exclusive basis. Sixty per cent of attempted spin-offs succeed in obtaining more than $0.5 million of investment funding. In the past ten years there have been 64 spin-offs from MIT through TLO (Preston 1993). MIT graduate students, faculty and staff also start many other new companies without TLO involvement. TLO puts a relatively low (compared with ARCH, for example) effort into the process of selecting and supporting spin-offs, instead allowing the venture capital market to do this. A third of the spin-offs that involve TLO are suggested by a technology originator wanting to start a company (the technology originator/entrepreneur "model"), another third by TLO which recognizes the technology and business situation as having the characteristics for a successful spin-off, one sixth by a venture capital fund/entrepreneur alliance that sees that technology as fitting their need for a business opportunity, with a remaining sixth being various combinations of the preceding three alternatives.

Stanford University. Stanford University has a long history of successful technology transfer by means of licensing and spin-off companies. The Office of Technology Licensing (OTL) was established in 1970 to commercialize technology owned by Stanford and by Stanford faculty, staff and students. Today the policies pioneered by Stanford are reflected in the policies of many other R&D organizations. The objectives of OTL are: (1) to provide a mechanism for bringing inventions developed as a result of Stanford research forward to public use and benefit; and (2) to provide an additional source of income to the university for research and education. The goodwill generated by transferring technology to the public is also considered to be of value to Stanford.

Unlike many other research organizations, Stanford's inventions rights policy allows all rights to the invention to remain with the inventor or technology originator unless otherwise specified by an external contract for sponsored research. OTL receives disclosures of both technology owned by Stanford and Stanford-created technology owned by faculty, staff or students. Disclosures are evaluated for commercial potential. Generally patenting is pursued only if an expression of commercial interest in a license has been received. By policy Stanford prefers non-exclusive licenses but commercial considerations will cause it to negotiate exclusive licenses. Stanford regards non-exclusive licenses as the best way of making the technology available to the public and producing income. Two thirds of Stanford's major income earners are non-exclusive licenses, but most of these relate to basic biotechnology processes. This policy does make license agreements difficult to negotiate at times. However, once executed a multiple license does offer some safety, or reduction in risk, through numbers. Royalties after expenses are divided equally among the inventor, the inventor's department, and the inventor's school. OTL negotiates for equity to supplement royalties where possible. Stanford takes a proactive approach to the problem of conflict of interest. Some situations must be avoided (for example, a faculty member's participation in negotiations between Stanford and a company with which the faculty member has significant involvement) and other situations must be disclosed (for example, recommending university purchases from a company in which an individual has an interest).

Stanford has established guidelines for technology licensing to spin-off companies in which faculty are involved. They state that the involvement by faculty in the transfer of technology to a start-up company should fall within the time constraints imposed on consulting activities (13 days per quarter). Before OTL will proceed with licensing arrangements to such a spin-off, a faculty member must inform the department chair of the proposed arrangement and its purpose, and state how conflict of interest issues are to be managed. It is regarded as "important to avoid the appearance that the university laboratory is being used ... for product development or other business purposes" (Stanford, 1994). Incubation is clearly not regarded as being Stanford's role. Equity may be held in such spin-offs by the faculty member and the university. Spin-offs are not a preferred means of technology transfer at Stanford. They are felt to be somewhat incompatible with Stanford's non-exclusive license culture. OTL puts no effort into seeking out potential spin-offs and will only become involved if requested to do so. When venture capital investors approach OTL for possible spin-off opportunities they are referred to researchers with whom they talk directly. OTL typically processes three spin-offs each year.

In 1992 Stanford's total research funding was $280 million excluding the Stanford Linear Accelerator that produces insignificant amounts of commercially applicable intellectual property. Income from 165 licenses totalled $25.5 million, of which $14.7 million was from the Cohen/Boyer DNA patents. In that year OTL received 177 disclosures from all sources and filed 70 patents. Of those patented 10 to 15 per cent are licensed. 128 licenses and options were executed in 1992 (AUTM, 1993)

University of Connecticut. The University of Connecticut (UConn), chartered by the State of Connecticut, illustrates some of the difficulties that may be experienced by a research organization when attempting to establish a licensing and spin-off activity. UConn first established permanent mechanisms for the specific purpose of technology transfer in the early 1980s. In the following decade several approaches to technology transfer were tried. The first mechanism established, and the only one remaining today, was the Technology Transfer Office (TTO). The TTO was established to review invention disclosures and to determine the commercial potential of university owned inventions on behalf of the University of Connecticut Research Foundation. By state law the owner of all inventions conceived at the university is the University of Connecticut and all such inventions are assigned to the Foundation. By state law faculty may not have more than 5% of the stock of any company. Royalties are split 33:17:50 among the inventor, the inventor's department and the university.

In 1984 UConn established the University of Connecticut Research and Development Corporation, commonly known as R&D Corp. R&D Corp was an "arms length" organization that was a wholly owned subsidiary of the University of Connecticut Foundation which in turn was a non-profit private corporation and separate from the University of Connecticut Research Foundation. Its specific purposes were to evaluate technologies owned by UConn, evaluate their potential for commercialization by creating spin-off companies, arrange financial assistance for completing the research and development, and secure venture capital for those companies. R&D Corp had first rights to any university technology. R&D Corp was funded by retaining the first $250,000 of its net income per annum. Above this level it retained 15 per cent with the remainder going to the Research Foundation (Krisst, 1991). This arrangement proved to be controversial as it meant that the university would receive no royalty income from R&D Corp in the early years when the spin-off portfolio was small. As it was R&D Corp produced only two spin-offs before ceasing operations in 1990. It appears that a one man operation that had to find venture capital on a case by case basis was an insufficient level of resources to grow or even sustain the operation. One of the spin-off companies, TargeTec, was sold to a California company in late 1992, and is now doing well; the other, Genex Corporation, initially did well but had the misfortune to be dependent upon Kuwaiti investors at the time of the Iraqi invasion of Kuwait. Sufficient alternative sources of funding were not found and the company dissolved. The biopolymer patents on which Genex was based have been sold by UConn to defray the debts of R&D Corp. In both cases the inventors remained with the university but took equity in the spin-off. UConn faculty may receive research funds from their own company subject to satisfactory provisions to avoid conflict of interest problems. However, faculty may not serve as a director of a company if the company's activity is the same as their research activity.

The university's other approach to technology commercialization was initiated in 1985 when it entered into a contract with the University Technology Corporation (UTC) to license the university's technology. This arrangement did not prove to be a success and was curtailed in January 1990. Other than a non-exclusive invention management contract with Research Corporation Technologies, UConn now has a more focused approach to technology transfer with all activity handled by the TTO which is now trying to build up the operation. One crucial goal is to increase faculty awareness of the value of intellectual property. In 1993 research funding for the university totalled approximately $100 million and licensing income was approximately $400,000. Current spin-off activity is not great with only one spin-off formed since 1990. With limited resources and the need to build up awareness of the value of technology transfer, UConn feels it would be unwise to risk repeating the past. A stable base of traditional licensing activity needs to be built up before attempting a substantial spin-off activity.

Discussion: The Policies and the Models

Interaction of policy and environment on spin-off results. The eight organizations studied: a) exist in a variety of internal and external environments relative to spin-offs; b) utilize different policies towards spin-offs for operating within these environments; and c) achieve different results. The results-policy-environment perspectives provide a framework for examining the interaction of R&D organization policy and environment upon new company spin-off results. Figure 3 illustrates this with some of the organizations studied.

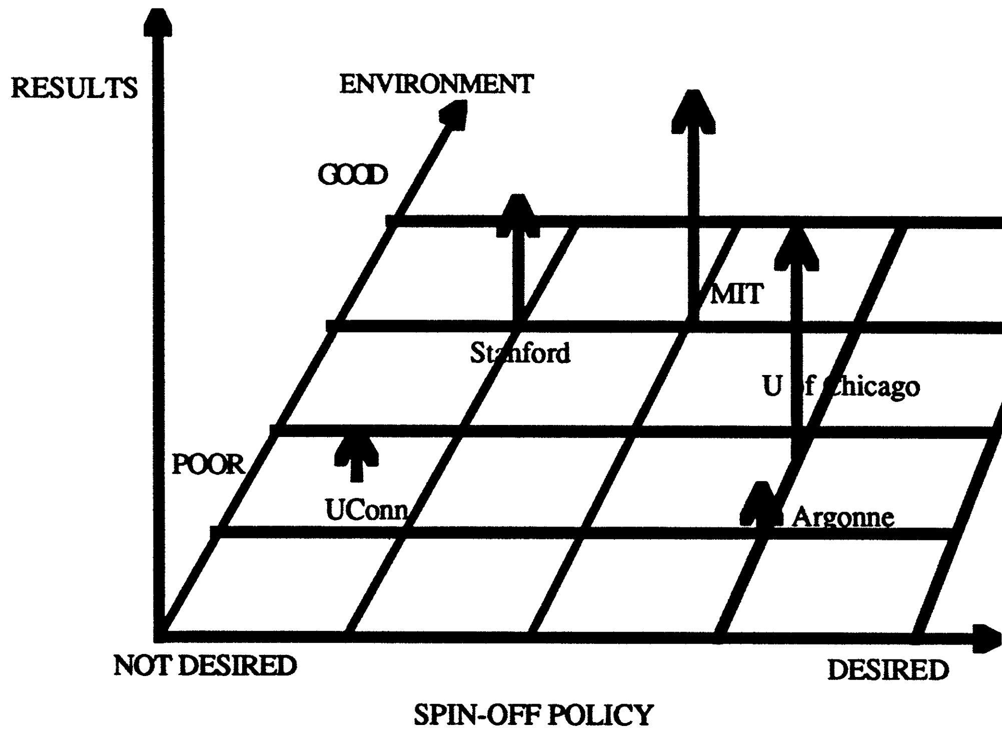


Figure 3. Results of interaction between policy and environment for a selection of R&D organizations.

The figure shows how the same spin-off policy applied to both Argonne and UoC through ARCH leads to greatly differing results (in terms of spin-off rate per $100 million research funding). While their external environments are the same, the internal environments for the two organizations are quite different. In this case it may not be appropriate to change the policies of ARCH and Argonne regarding spin-offs.

Although some fine tuning of the interaction might be appropriate and might lead to some improvement in spin-off rate it is unlikely that a major change in the spin-off policies and procedures would have much positive effect. However, these policies clearly work for UoC. Maintaining this policy and putting in place other policies within Argonne that change its internal environment through altering its culture, organization and research directions are likely to be more successful, though requiring a long time period. The University of Connecticut is portrayed as operating in an environment that is not too different from that of the ARCH organizations. It has a policy that does not prefer spin-offs as a means of technology transfer. A sudden change in policy would still leave it in a poor environment for spin-off.

A process of gradual policy and environmental shift would appear necessary for other R&D organizations to attain the policy and environment situation occupied by MIT. MIT and Stanford operate in very similar environments. Internally they are both entrepreneurial and attract top level academics and students. Both have high levels of achievement with traditional technology licensing. The difference between the two is in their spin-off policy and this is reflected in their spin-off results. As a matter of policy Stanford has chosen to not actively seek spin-off opportunities; following this policy reduces the number of new ventures that formally spin-off from Stanford. MIT's policy regards spin-offs as the best option for technology transfer in a wider range of cases than Stanford and application of this policy leads to greater number of spin-offs.

Selectivity and support. Selectivity and support are two crucial dimensions of R&D organization spin-off policy that were described previously. An organization must decide how severe its selection criteria should be. Venture capital funds, such as those of ARCH, must be highly selective as they are committing considerable resources to each venture. They are both highly selective and highly supportive of new ventures. Other organizations such as MIT exercise a much less severe set of selection criteria, and instead let outside venture capital organizations choose the "winners". In constructing Figure 4

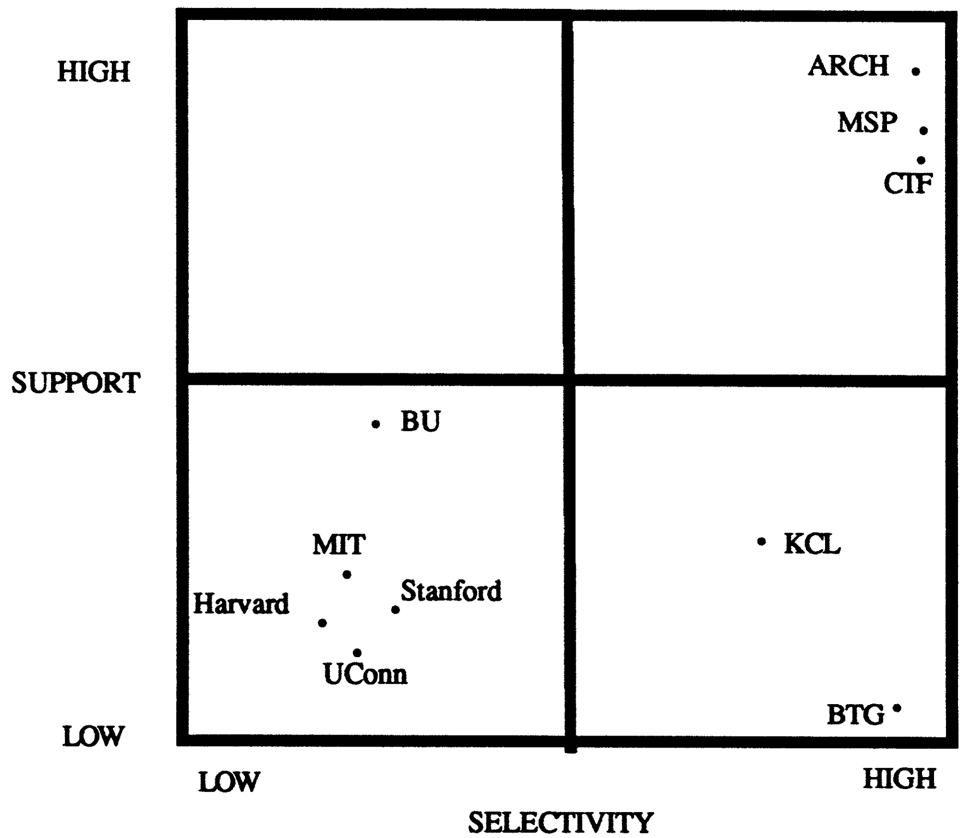


Figure 4. Selectivity and support of spin-off companies in various R&D organizations.

two benchmark organizations were chosen: ARCH is defined as the benchmark against which other organizations that are clearly of the high selectivity/high support type are measured; MIT is defined as the benchmark against which organizations that are clearly of the low selectivity/low support type are measured, although MIT itself is seen as low-medium selectivity/low-medium support. From these definitions the relative positions of the others were determined as follows: Harvard's MSP and BU's CTF are as highly selective as ARCH, but both offer less support to the spin-off; Stanford is more selective than MIT in assessing disclosures and requests for spin-offs but also is less willing to support such a proposal; The University of Connecticut is as critical as MIT in its selection but less able to provide support due to having a smaller resource base; Harvard (not including MSP) is less supportive than MIT at present (although it does wish to increase spin-off activity in the future) and less selective in assessing disclosures; KCL anticipates being more selective of disclosures but is hoping to provide the sort of assistance that MIT provides; BTG is highly selective of the technology it manages but does not support spin-offs; BU (not including CTF) differs in that it puts more effort (support) into each spin-off than MIT does.

Most of these organizations are clustered in the upper right quadrant or the lower left quadrant and fall around the diagonal from bottom left to top right corner, indicating a sustainable spin-off policy of support that is comparable to its selectivity. BTG clearly does not want to sustain any rate of spin-off creation at all so its position is to be expected. KCL may well not reach its predicted spin-off rate due to under-resourcing the few that it does intend to select, and BU may be reducing its potential income by devoting too much effort to too many spin-offs.

Overall policies, activities and results. All the organizations studied conform to the stages model proposed in Figure 1. In all cases except ARCH, the incubation phase is absent as a formal mechanism for spin-off. The incubation provided by ARCH is only in the form of management assistance to the spin-off. However, with many of the organizations the parent R&D organization often provides a considerable amount of informal nurturing to get the spin-off started. This may take many forms, for example a leave of absence for the faculty inventor, or a protracted departure from the R&D organization as the transition from R&D team to spin-off team occurs. The policies and activities of the eight organizations studied also represent a wide range of what is conceptually possible in terms of our five "process models", with a wide range of results produced. For example, some of the organizations have venture capital units but the policies defining the relationships between each of these R&D organizations and their venture capital units differ in many respects. In some cases the venture capital unit may be part of the R&D organization albeit with mechanisms to keep it at arms length in order to avoid conflict of interest issues and to allow it to make decisions using only investment criteria. In the cases where the R&D organization has no venture capital unit the organization's technology licensing office sometimes has good contacts within the venture capital community as well as with the other professional groups that are essential to the spin-off process. The policies and activities of the eight organizations are summarized in Table 5.

The spin-off policies of the R&D organizations studied (including the British Technology Group, which is basically a contract technology licensing office for other R&D organizations) vary widely. BTG is at one extreme with a policy that reflects a reversal of its earlier policies and now rejects equity involvement in spin-offs entirely. BTG's motivation is to concentrate on the business from which it has profited most, licensing, and to avoid the longer term uncertainties of a narrower portfolio of spin-offs with long term payoffs. The University of Connecticut is an organization that has drawn back dramatically, but not entirely, from the promotion of company spin-offs as a means of technology transfer. Having been down the route of promoting spin-offs without success has driven UConn now to concentrate on traditional licensing as a better way of building an environment for commercial technology transfer. KCL Enterprises finds itself looking into the future with a similar vision. Stanford University is somewhat reluctant to take the spin-off route, for it does not want to, or see the point in running the risk of altering the internal environment that has contributed to it achieving financially the best track record for licensing for an individual U.S. university. However, Stanford has also generated an impressive number of spin-offs through informal channels. At the other extreme are ARCH, Boston University, and MIT. BU achieves a high spin-off rate through partial use of an internal venture fund and at the expense of traditional licensing. ARCH has been specially formed to tap into the resource of technology that exists in the University of

Table 5. Spin-off related policies and activities of eight R&D organizations.

	ARCH	BU	BTG	Harvard	KCL	MIT	Stanford	UConn
Research Funding ($m)	610 total 110 UoC	100	NA	750 total 275 excl affil.	40	750 total 292 excl Linc.	280	100
Spin-offs (p.a.)	3.25 total 1.75 UoC	2	None	2.66 total .65 excl HMS	0.5 predicted	6.4 total 5.1 excl Linc.	3	0.25
Spin-offs /yr./ $100 million	0.55 total 1.6 UoC	2	None	0.35 total	1.25 predicted	0.85 total 1.75 excl Linc	1.1	0.25
Licenses (p.a.)	NA	4	75	55 excluding affiliates	5-10 predicted	95 total 78 excl Linc	128	5
Patents filed (p.a.)	NA	23	NA	73 excluding affiliates	10-20 prdicted	170 total 143 excl Linc	70	14
Disclosures (p.a.)	NA	90	511	87 excluding affiliates	120 predicted	350 total 291 excl Linc	177	29
Spinoffs/100 Disclosures	NA	2.2	NA	NA	0.4 predicted	1.8 total 1.75 excl Linc	1.7	0.9
V C Fund ($m, yrs)	9, 4 (I) 30, 4 (II)	6, rolling	None	36, 5 (I) 30, 3 (II)	None	None	None	None
ConflictIssues Exclusivity	Weak High	Moderate High	Weak High	Strong Medium	Weak High	Moderate High	Moderate Low	Moderate High
Policy on spin-offs	Spin-offs are an objective	Spin-offs preferred	No spin-offs	Desire more spin-offs	Spin-offs not important	Spin-offs important	Spin-offs not preferred	Spin-offs not important
Internal Environment	High VC Low entreprnr	High VC High entreprnr	NA	High VC High entreprnr	No VC Low entreprnr	No VC High entreprnr	No VC High entreprnr	No VC Low entreprnr
External Environment	Low VC Low entreprnr	High VC High entreprnr	Mod. VC Mod entreprnr	High VC High entreprnr	Mod. VC Mod entreprnr	High VC High entreprnr	High VC High entreprnr	Mod VC Mod entreprnr
Process Mod#	4	2/3, 4, 5	NA	4, 5	2 expected	1, 2, 5	2	2
Selectivity	High	Low-Medium	High	Low overall High at MSP	Medium-High	Low-Medium	Low-Medium	Low-Medium
Support	High	Medium	None	Low-Medium Med-Hi, MSP	Low-Medium	Low-Medium	Low	Low

Chicago and Argonne National Laboratories. Through using the approach of having a solid resource base of venture capital funds and close project management it appears to be avoiding the terminal troubles that Connecticut's R&D Corporation and Purdue's INventure (Thompson, 1991 and Willey, 1994) encountered. This has been achieved in an external environment in which capital for new technology-based ventures is scarce. MIT has added high proactivity to its long tradition of informal technology-based spin-off entrepreneurship to achieve a high rate of company spin-offs as well as a high financial return from its traditional licensing activities. Consideration of conflict of interest issues has slowed the occurrence of spin-offs from Harvard University. However, Harvard is eager to increase the amount of technology transferred and commercialized by means of spin-offs. In order to move more rapidly in this direction the Harvard Medical School and its affiliates have established a venture capital unit, Medical Science Partners, that is attuned to its needs.

BU, Harvard, MIT and Stanford clearly benefit from existing in an entrepreneurial and venture capital rich environment. Even with its distinct lack of preference for participating in spin-offs, Stanford still generates a significant number each year. When compared with its level of research funding or its disclosures BU achieves a slightly higher rate of formal spin-offs than MIT and ARCH (Figures 5 and 6), but this is at considerable expense to traditional licensing in

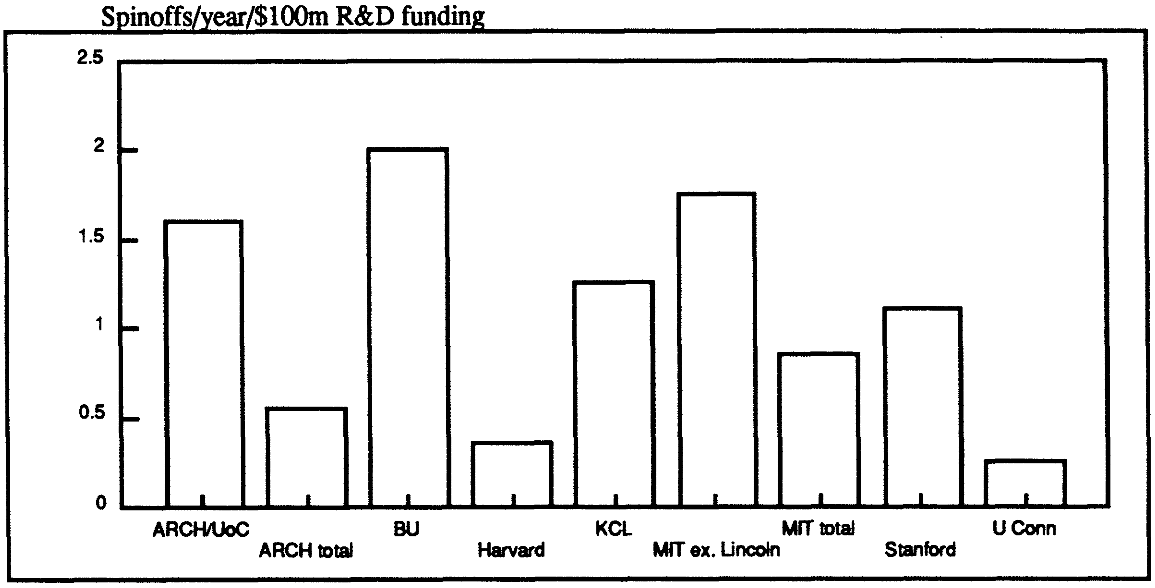


Figure 5. Spin-offs per year per $100 million R&D funding for various organizations.

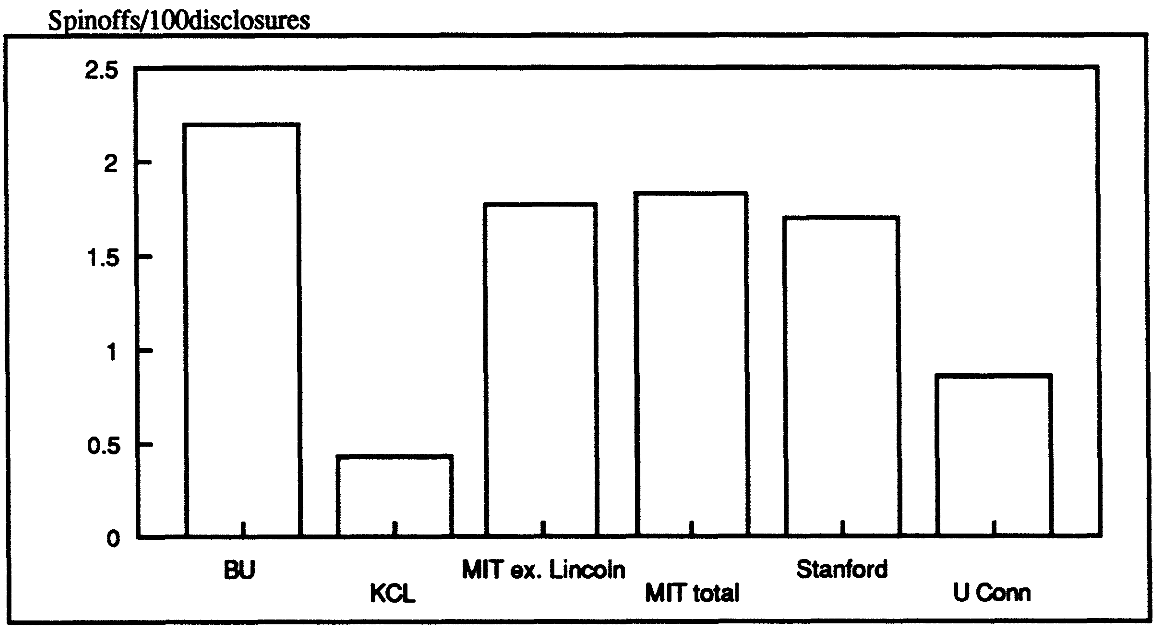


Figure 6. Spin-offs per 100 disclosures for various organizations.

comparison with MIT and others. In the past it has also been at the expense of some conflict of interest considerations for BU. Of course, the absolute rate of spin-offs from BU is much smaller than from Stanford or especially from MIT. It is unlikely that BU's approach will yield a greater return in the long term than MIT's broader approach. From a government policy point-of-view it is vital to note in Figure 5 that even in these best situations, the number of "by-product" company spin-offs generated per $100 million of research funding is tiny. The research that is being funded at these R&D organizations had better be justifiable in its own right, and not just motivated by the likelihood of spin-off companies.

Of the operations in regions less endowed with venture capital and experienced entrepreneurs the performance of ARCH is significant (even allowing for the fact that it is based in one of the major commercial centers of the U.S.). It has, in a relatively short time built up a significant activity of technology transfer with spin-offs. Argonne shows that if the technology focus of the R&D organization is towards large specialized projects that are somewhat removed from the needs of commercial markets, then the amount of technology that can be transferred is somewhat limited. Therefore the number of spin-off companies that can be generated is also limited. KCL and the University of Connecticut illustrate the magnitude of the task and the lack of options that face many technology licensing organizations. They not only need to build up a base of successful license agreements but must also achieve some internal cultural change to achieve greater internal recognition of the value of intellectual property and the advantages that licensing and company spin-offs have as means of technology transfer as compared with mere information dissemination.

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