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NEW PRODUCT STRATEGY IN SMALL HIGH TECHNOLOGY FIRMS

by

Marc H. Meyer

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INTRODUCTION

This paper is an exploratory probe into new product strategy for small high technology firms. The motivation behind it grew from the author's participation in a study of Massachusetts Route 128 high technology companies, performed under the auspices of the Center for Policy Alternatives (M.I.T.) and the Swedish Board for Technical Development. In discussing the products made by these entrepreneurs, and in seeking to evaluate both the similarities and differences between the de facto new product strategies pursued by them, it became evident that although the firms had followed markedly different strategies in deciding "what to make next", there was little available research methodology to get a handle on these differences. The work may provide a start at developing some tools to tackle this problem.

Special thanks go to Professors Edward Roberts, Dorothy Leonard-Barton, and James Utterback of M.I.T., and of course, to the entrepreneurs who participated in this study.

LITERATURE REVIEW

New product strategy guides that dimension of the firm's innovative activities which concerns the products or services it develops for the marketplace. New product strategy should not be confused with project selection criteria or resource allocation, which are subsets of it. In the literature on project selection are a variety of proposed selection criteria, ranging from profit maximization to technical feasibility to the enthusiasm of R&D personnel for the projects under consideration (Kelly and Kranzberg 1975). New product strategy is the set of objectives and underlying orientation of management towards technical risk, market opportunity and corporate growth which determine and set priorities for both the explicit and implicit criteria used by the firm to create its agenda of future products or services. In playing this guiding role, new product strategy emerges as a central aspect of the firm's overall business strategy. There are other important dimensions of corporate strategy, including industry structure (Chandler 1962), management's objectives for the size and functional scope of the organization, and external socio-political considerations such as government regulation (Rosenbloom 1975). Clearly however, without "good" products the firm cannot be expected to survive in the long run. An effective new product strategy will guide the firm into the pursuit of new product opportunities for which it has a competitively distinct ability to achieve, or alternatively, to steer it away from those projects which the firm is not appropriately positioned to successfully undertake.

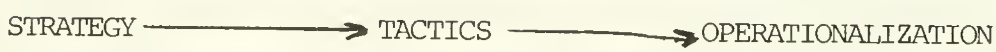
This research will examine the strategic aspect of innovation within organizations. Technological innovation, which is aimed at making new products or services by developing the application of either new or existing sets of technology, should be distinguished from scientific research, whose principal output is not in a physical form but one which disseminates information, either in a written or oral form. (Allen 1977) When the term innovation is used here, it therefore refers to the spectrum of activities which are aimed at achieving a defined product objective which is intended to be to the commercial benefit of the organization, e.g. applied research and development. The results of the innovation may be "embodied" within an actual product or service, or exist in the form of "unembodied" know-how, both of which may be used to the firm's advantage. (Von Hippel 1979)

Various types of innovation are themselves distinguishable. At the most general level, one can view innovation pertaining to the technology embodied within products as separate from that which concerns how products are manufactured. Although product and process innovation may in fact share common goals, such as improving product quality and reliability, each contributes to the objective in a different way. For example, design engineers may build-in modularity and substitute into the product new generations of components, while their counterparts in manufacturing implement new assembly machines and tougher testing requirements within the production environment.

Research into product innovation has encompassed a broad range of disciplines, including technological forecasting, project selection, problem solving and communications, and project management. Process innovation, on the other hand, covers manufacturing techniques and issues such as quality control. Utterback and Abernathy (1975) have provided a linkage between these two types of innovation by hypothesizing that the rate and scale of each one undergoes a predictable evolution over time. Theirs is a dynamic portrait of innovative activities within the firm. When the "productive unit" first begins its activities in a product area, product innovation is frequent and major in scope. The inherent instability in product design during this period precludes effective major activity in the area of process innovation. In a hypothesized "second stage", however, the design of the product begins to stabilize as incremental improvements dominate. These improvements may, for example, serve to tailor the basic product to specific sets of customers, reflecting the overall segmentation of the product's market as the market matures. Greater stability in product design allows the industrial engineers to gear up production. Process innovation in this period is frequent and major. In a third and final stage, the product design reaches a stable state and process changes tend to be a fine-tuning of production techniques to squeeze out extra margins over the cost of manufacturing.

This research focuses on "product" innovation, and does so within the context of the small high technology enterprise, that is, a firm engaged in making products which embody complex technology, and which has annual sales below $50M. Roberts (1968) examined approximately 200 high technology firms which were spin-offs from M.I.T. research laboratories, in other words, started by individuals who had worked in these laboratories. He looked at a broad range of factors, including the characteristics of entrepreneurs, start-up motivations, and organizational patterns. Entrepreneurs were found to have a number of common traits, such as a family heritage of self-employment, a high level of education, and a technical background in product development as opposed to basic research. Roberts also found that the more successful firms were founded by a team of individuals rather than by a single person, and that it was preferable that the founding group display a combination of specific skills rather than be strictly technologists or marketers.

What are the components of new product strategy? The new product decision process may be seen as composed of sequential stages, shown below (Ansoff 1965).



Strategy encompasses the technological and business objectives by which management decides on the types of new products the firm will seek to produce, and those product areas that will be avoided. Once having made that decision, and having selected a new product initiative, the firm must decide how to fulfill its objectives. Should the firm, for example, acquire the new technologies needed in the product from outside vendors, or should these technologies be developed in-house? Similarly, should the product be manufactured by the company, or should assembly work be subcontracted out to other organizations? Tactical constraints which emerge at this point should feed back into a reconsideration of the feasibility and attractiveness of the new product which had been selected. Lastly, management must decide how to operationalize its tactical programs. It must select the individuals who will lead the various aspects of the new product initiative, including outside subcontractors or distributors if they are called for, and coordinate all involved parties (Lawrence and Lorsch 1964, Hayes and Schmenner 1978). All three components of the decision process -- strategy, tactics, and operationalization -- are critical to the ultimate success of the new product effort. A firm may choose excellent product ideas to pursue, and develop a sound gameplan, but select incompetent managers to direct product development, manufacturing, or distribution. Similarly, the firm may have good strategy and have at its disposal a cadre of qualified managers, but choose inappropriate distribution channels. In either case, the success of the overall product effort stands in jeopardy.

Given this description of the goals and components of new product decision-making, how is strategy formulated within organizations ? The two key elements of the organizational context for strategy formulation are the various processes by which products are chosen, defined, and implemented, and the leading individuals with the company who have a critical impact upon the resulting decisions. These individuals may either work within or outside of the formal procedures for identifying new product opportunities and specifying basic product designs. Roberts (1980) and Maidique (1980) both note the importance of sponsors, product champions, and internal entrepreneurs for successful corporate venturing. Lorange and Vancil (1977) concentrate on the other key element of strategy formulation : formal planning systems. They argue that effective strategic planning systems actually serve to reconcile and integrate the inherently diverse objectives which may be found at different tiers in large complex organizations. They propose a "three cycle" system by which corporate executives, business managers, and functional operations managers may coordinate their planning activities with respect to the strategic, tactical, and operational stages of new product decision-making.

New product planning processes are not always formalized within technological organizations, however. Nor is it clear that formal planning is the best way to induce effective innovation within an organization. Speaking primarily about large corporations, Abernathy and Hayes (1980) suggest that such businesses "manage their way to decline" by overemphasizing short-term planning, that is satisfying existing market needs with variations of present technology. The risks and potential rewards of more daring technological innovation which seeks to create a new market and which may take ten or more years to achieve commercial application are thereby avoided. Mansfield (1977) suggests that finding the appropriate balance between high risk, high return projects and those projects which have surer technical and financial outcomes is one of the critical management decisions.

For smaller firms, the overhead associated with a formal planning system may be too costly. Management may instead use periodic meetings of key technical, marketing, and financial officers scheduled "on demand." Or, at a greater extreme, the CEO of the firm may impose his will upon others in the selection of new products, and closely participate in the specification process. Maidique (1980) describes the critical role of the "technological entrepreneur" in small technological firms as both the primary definition agent for the new product and the leading sponsor who insures that sufficient resources are committed to the development effort. However, if the technological entrepreneur consistently "hits the mark" with his new product decrees, the firm will eventually grow too large, and its products perhaps too diverse for him to continue a hands-on domination of new product decision and design processes.

In addition to planning systems and key individuals, research in several specific disciplines can also be a source of useful information for new product strategy-making. First, there is technological forecasting, by which management can estimate the future viability of its current product technology, and that of technologies which it is considering for development. Jantsch (1965), Roberts (1969), Martino (1972), and Utterback (1979) examine the various types of "exploratory" and "normative" forecasting. One well-known method of exploratory forecasting is the Delphi technique, which seeks to gain insight from expert sources. Trend extrapolation, either as a straight line or a "S curve", depending upon the forecasters's assumption of technological saturation in the product area, is another exploratory method. Normative forecasting, on the other hand, tries to provide a deterministic modeling of the goals, resources, and resulting technological outputs which may be involved in a new product decision. Normative techniques typically employ sophisticated computer-based optimization models. Roberts (1969) has criticized existing exploratory forecasting methods as being too naive, and normative techniques, as costly, cumbersome, and often inaccurate. He urges the integration of the two, where expert opinion and trend fitting can lead to a more accurate understanding of the resources-to-technological outputs relationships necessary for effective normative modeling. Utterback (1979) has also suggested that forecasting tools should be coordinated with the firm's competitive strategy, and thus, some are better suited towards certain business situations than are others. This appropriateness is based on the complexity of the firm's business environment and the pace of change occurring within that environment.

Another channel of information for new product strategy comes from the marketing literature, in which there exist methods for pretesting product ideas and mapping the conceptual preferences of intended customers. (Urban and Hauser 1980, Pessemier and Root 1979). Von Hippel (1976, 1978) has taken another tack by suggesting that firms might look towards their customers for future products. He found that a clear majority of major innovations in manufacturing process equipment and scientific instrumentation were first developed by users, and then adopted by manufacturers. The benefits of user-originated innovation strategy are that a certain degree of user feedback and market-testing of the product design is already incorporated within the prototype received by the manufacturer. Furthermore, much of the cost of prototype development is effectively shifted to the user-innovator by the manufacturer, who can then concentrate on aspects of production and reliability engineering once a basic product design is received.

In continuing this probe into new product strategy, this research is directed towards a very basic, and oftimes perplexing question facing managers of high technology firms: what products, or set of products, should the firm make next at a given point in time? In other words, if the firm is presently at Point A in terms of its product technology, what will its portfolio of products look like at Point B? In turn, this question can be narrowed down to two basic alternatives. Should the firm limit its selection to only those products which will embody the firm's existing technology? Or, in light of what may appear to be strong market opportunities and with a group of talented engineers who have performed well in the past at its disposal, should management venture into new product technology fields?

To answer these questions, the first step of this research is to propose a new framework by which to consider new product strategy. This is done in the following chapter. Then, based on this framework, a hypothesis which refutes the commonly used theory of portfolio diversification for new product strategy is presented in Chapter 3. Chapter 4 describes the research design and methods used to gather and process data to test the hypothesis, and in Chapter 5, the results of the analysis are presented. Linking these phases of research is the underlying approach of this study, being to concentrate on two basic parameters -- the embodied technology and market applications of products -- as the key elements of the strategic consequences of new products.

II. STRATEGY: A NEW PRODUCT FRAMEWORK

When management asks itself what products it will make next, it inevitably looks to what it has developed successfully in the past. The relationship between the new product opportunity and past product activities can be expressed as a type of "newness." This newness constitutes, in a broad sense, the consequences or implications of that opportunity for the firm. Product newness has two key elements, which are a) the newness of the technology required in the new product; and b) the newness of market applications for which the product is targeted. The question becomes, how can these two parameters be measured across a range of products?

TECHNOLOGICAL NEWNESS

A new product does not necessarily entail new types of technology. In fact, the majority of product innovations undertaken by firms consist of minor technological improvements, the objective of which are to upgrade existing products for "new releases" or to broaden a particular product line by providing certain new features to users. In such cases, the strategic consequences of the product innovation decision in terms of technology are known to management. In-house engineers are disciplined in how to use the technology, and can handle scheduled improvements given the appropriate manpower, development equipment, and time. However, when the proposed product takes the firm into new technological domains, the implications of that new product decision are not so clear. Various types of new product efforts will entail varying degress of technological newness, and a commensurate level of uncertainty with respect to how and within what time framework the challenge of development can be tackled.

Past research has tried to evaluate the consequences of a new product with respect to the firm's technology. Johnson and Jones (1957), for example, presented a framework which categorizes the technological parameter into three levels: "existing" technology, "improved" technology, and "new" technology. They also developed a similar calibration for newness of the customers for a product. By setting these parameters on a two-dimensional grid, Johnson and Jones thereby provide a mechanism by which to pinpoint the combined technological and market consequences for product innovation under consideration. Their framework is shown in Exhibit 1A.

This approach of evaluating technological and market elements jointly shall be used in this study. However, the problem with the Johnson and Jones framework is that it is not sufficiently exact in its definitions of either new technology or customers. For example, is a "new" technology required by a product in some way related to the firm's existing technological base, or is it largely unrelated? It does not seem appropriate to treat related new technology and unrelated new technology as one and the same for strategic considerations.

Day (1975) has improved the approach described above by being more specific in his categorizations of technology embodied within products. His framework is shown in Exhibit 1B. Note that he incorporates the distinction between related and unrelated new technologies in products. However, the

EXHIBIT I

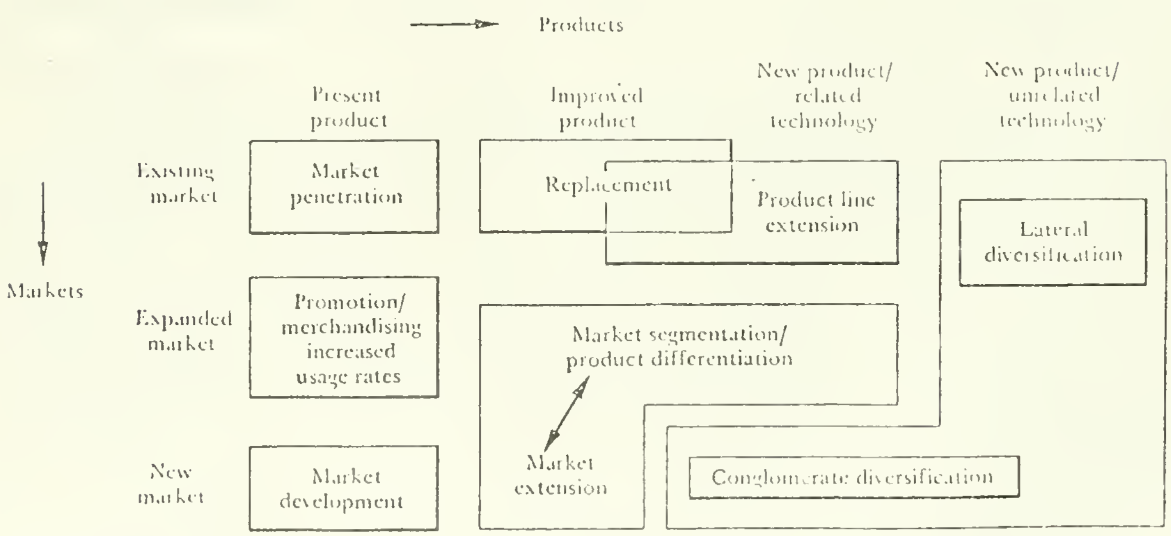
New Product Evaluation Frameworks

A. Johnson and Jones, 1957*

New products classified by product objective

Product objectives		Increasing technological newness → No technological change	Improved technology	New technology
Increasing marketing newness ↓	No market change		*Reformulation* Make minor modifications in product to reduce cost and/or improve quality.	*Replacement* Make major modifications in product to reduce cost and/or improve quality.
	Strengthen market	*Remerchandising* Make present products more attractive to the type of customers presently served.	*Improved product* Make present product more useful to present customers by improving present technology.	*Product-line extension* Widen the line of products offered to present customers by adopting a new technology.
	New market	*New use* Extend sale of present products to types of customers not presently served	*Market extension* Extend sales to types of customers not presently served by offering a modified present product	*Diversification* Extend sales to types of customers not presently served by offering products of a new technology.

B. Day, 1975**

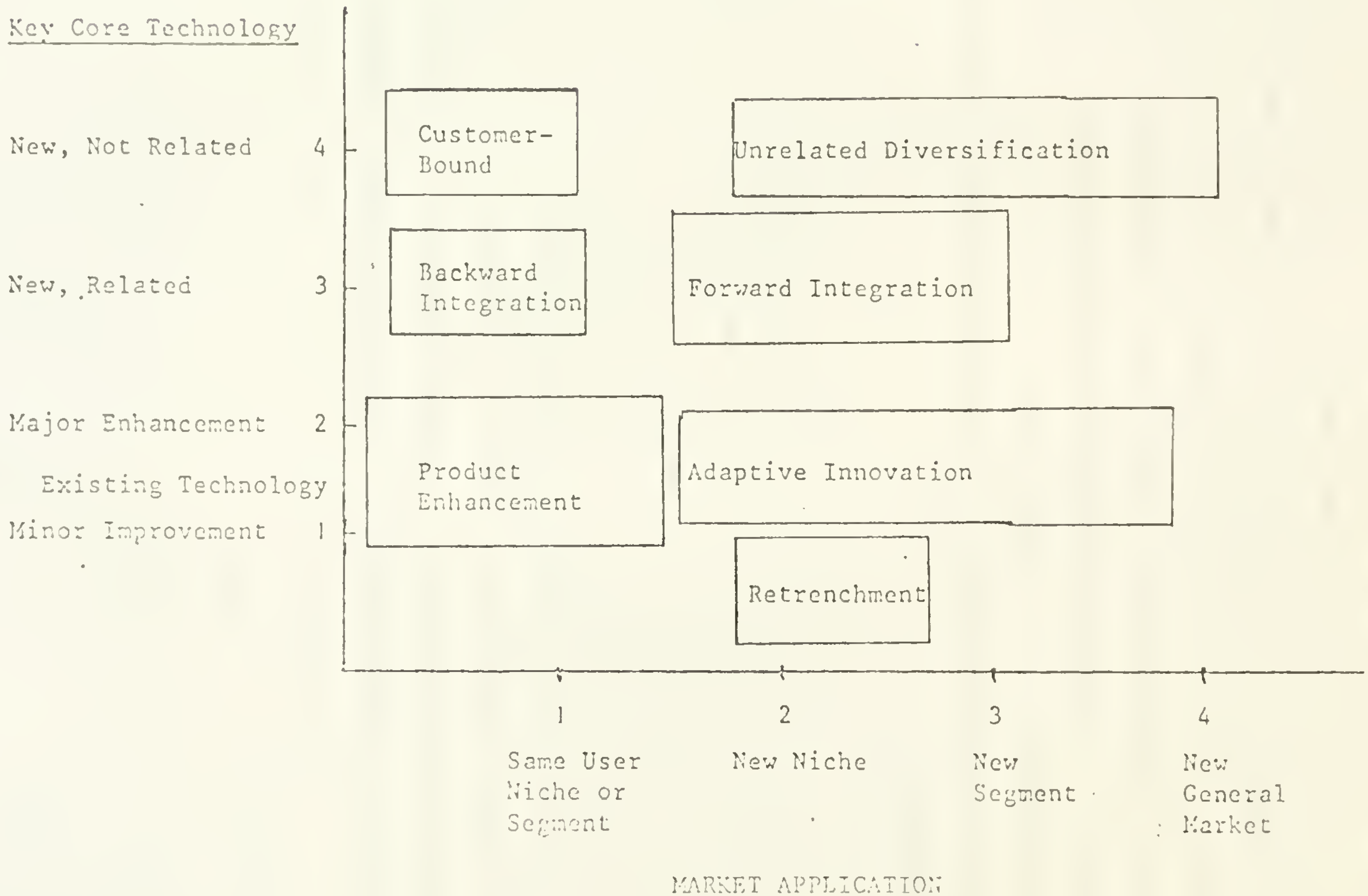


* Samuel C. Johnson and Conrad Jones, "How To Organize For New Products," Harvard Business Review, May-June, 1957, p. 52.

** George S. Day, "A Strategic Perspective on Product Planning," Journal of Contemporary Business, Spring 1975, pp. 1-34.

EXHIBIT IC

A PRODUCT INNOVATION FRAMEWORK



basis for his technological evaluation depends on the newness of the product itself, e.g. whether it is "new." The implicit assumption is that a product must be new to have substantive technological activity. It is often the case however, that firms "improve" their existing products with substantial amounts of new technology, as much perhaps, as that required to develop wholly "new" products. Therefore, as Fusfeld (1978) has noted, it can be misleading to use "products" as the basic unit of analysis for evaluating technology strategy because of the potential for technological functions or skills to cross formal product boundaries. Thus, any framework to be used in this research must be based on the newness of embodied technology, as opposed to the newness of products *per se.*

Accordingly, let us first define a *core technology* as a discrete, unique set of skills and techniques which find application within products or services. A given product will embody at least one identifiable core technology, and it may consist of several or many separate core technologies.+ Secondly, not all core technologies embodied in a product have the same impact upon the firm's competitive advantage. Those particular core technologies which provide the firm with a proprietary, competitive edge and differentiate it from other companies making similar or substitute products are called by

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+ This should not be confused with Thompson's (1967) use of the term "core technology", by which he means a much broader combination of the firm's research, manufacturing, and other organizational resources directed towards a common product area objective. Day (1975) also uses the term "core technology" in his framework, and although he never defines what it means, the intended usage appears to be the same of this study.

Ketteringhan and White (1982) key technologies. These can be distinguished from those other technologies used by the firm which are commonly available in the marketplace as components, which technologies Ketteringham and Whitecall base technologies. In high technology firms, one typically finds that management concentrates on specific key core technologies, and by packaging or integrating them with a variety of component base technologies, makes the final, and hopefully competitive product. The key core technology is the basis for the firm's "value added" to the assembled product.

The example of a typical computer system for small business applications illustrates these concepts. The computer's "hardware" includes technologies such as the central processor, a screen display processor, memory chips, and special devices for communications interface. It will also have peripheral technology, e.g., terminals, a printer, and secondary storage devices. These are all core technologies. The operating system used by the computer is another discrete technology because it is the result of a set of skills referred to as "systems programming." Lastly, applications software for end-users, such as a payroll package, constitutes another distinct core technology. The reason for this is that although applications programmers and systems programmers may share some of the same techniques, their skills and concerns are clearly different, and their outputs are significantly differentiable.

A firm which "makes" computer systems may produce in-house all, some, or none of these core technologies. A frequent case in smaller computer-related companies is that they purchase the hardware components from outsider vendors and then assemble them, build their own operating system, and then either develop applications packages to sell "turnkey" systems to end-users, or place their machines with software companies which will in turn add the applications software. For this type of computer company, the hardware consists of base technologies. Over time, the firm may redesign its computers to take advantage of better components such as processors or memory chips. The operating system, on the other hand, is a key core technology for the firm. It is produced in-house and may give the final end-product a competitive edge in the speed of job and I/O processing, file management, and system's utilities to aid applications program development. If the applications programs are also made in-house, they also constitute a key technology.

Using the concept of a core technology, four levels of technological newness in a new product may be identified. These levels are:

-minor improvements to a key core technology;

-major enhancement to a key core technology by adding new base technologies;

-new key core technology, related to existing key technologies;

-new key core technology, unrelated to existing key technologies.

It is assumed that any "new product" shall, for the purposes of this research, contain some level of technological improvement. From the technologist's perspective, a basic consequence is that the "newer" the core technology is relative to the firm's existing technology skill base, the more difficult it ordinarily will be to implement that technology and to succeed in generating a competitive commercial product.

The first two levels of technological newness listed above involve the release of new products which are based on existing key core technology within the firm. The first level encompasses product improvements which are relatively minor in scope, and in a computer company are the types of developments that are typically achieved within a year's work. Management often has a clear agenda of the improvements it feels are necessary in a given product line, improvements which it knows that it must make in order to stay ahead of, or at least abreast of its competition. This type of incremental product engineering can be tightly scheduled, and have fairly predictable outcomes. Less planned are instances in which the firm's salesmen, existing customers, or prospective ones identify new applications for the firm's product technology which require only minor revisions to achieve. Placing new instructions in Programmable Read Only Memories (PROMs) is an increasingly popular way to implement such changes for microprocessor-based products.

"Major enhancement", which is the second level of technological newness, refers to substantial product redesign. To use a ballpark estimate for a computer company, this type of development generally requires at least a year's development effort to complete. Major enhancement often occurs when a firm wishes to incorporate a new generation of base component technologies into its product line. This addition allows the company to provide additional product features to users, to provide existing features at a lower price, or both.

Major enhancment to an existing key core technology may also encompass bolder new product ventures, wherein the firm combines one of its existing products with a set of new components or subsystems not previously used in that product to make a new product which is substantially different in its uses or purposes than anything that the firm has made in the past. This is how a firm may leverage its existing key technology into new product areas without having to develop entirely new key technologies of its own accord.

The third level of technological newness entails the in-house development of a core technology which is related to the firm's existing key core technologies. The new technology is related to existing technology if either of two general conditions exist, a) the technology shares a product application in which the firm is presently involved, and thus the new product shares a common market application with existing products, or b) the technology can be integrated or combined with the firm's existing technology for a product application which management has planned in the future.

There are three common occurances of this type of technological newness. The first is when management decides to produce in-house certain components which it had previously purchased from outside vendors. Thus, these base technologies become key core technologies. This important strategic repositioning is often referred to as "backward integration." In addition to using the new components for its own products, management may also sell surplus inventory in the marketplace in competition with its former suppliers.

The second common occurance of related new key core technology can be called "forward integration." Many firms make products which are portions of final, complete end-user systems. To integrate forward, management decides to produce in-house some or all of the other technologies which have been assembled with its own products. A simple example of this might be a company which manufactures computer hardware and has licensed a standard operating system to run on its machines. To achieve forward integration, management hires a dozen systems programmers to make its own operating systems. This enables the firm to capture greater margins on final system sales, to end its reliance on an outside vendor for a critical product component, and lastly, to build a basis for future growth opportunities, such as in the area of applications software for "turnkey" systems.

The third common instance of new related key technology development is similar to "forward integration" but pertains specifically to product applications in which the firm is not presently involved. Management sees that it can combine a new key technology with its existing core technology to build a product for a new market opportunity. An example from the field research performed in this study is a manufacturer of electronic funds transfer (EFT) terminals for credit-checking in retail stores. Management saw that by adding cash dispensing software and mechanisms, a safe box, and modifying its EFT terminals somewhat, it could make Automated Teller Machines (ATMs) for the largely untapped supermarket niche. Thus, by making its own cash-dispensing machines, the firm entered into a new key core technology. Note however, that if the firm had made its supermarket ATMs by buying all new required components from outside vendors, and simply assembling them with a redesigned version of its existing EFT terminals, the case would be an instance of "major enhancement" described above.

The fourth and last basic level of technological newness is new key technology unrelated to the firm's existing technology by virtue of any present or future product application. This occurs when management either deliberately seeks risk diversification by constructing a non-homogenous portfilio of products, or, is willing to gamble with technology and tackle new technological fields in response to perceived market needs.

MARKET APPLICATION NEWNESS

No specific project can be evaluated strictly from a technologist's perspective. Just as there are varying degrees of technological newness presented by a new product effort, there are also levels of newness in market applications. Urban, Johnson, and Brudnick (1979) provide a mechanism to construct a scale for this parameter. Their hierarchical market definition methodology views the market applications for a given product-technology as a tree structure: the top level is the "general market", the next level, the "segments" within the general market, and the last level, the "niches" of each segment. This concept is applied to computer printers in Exhibit II.

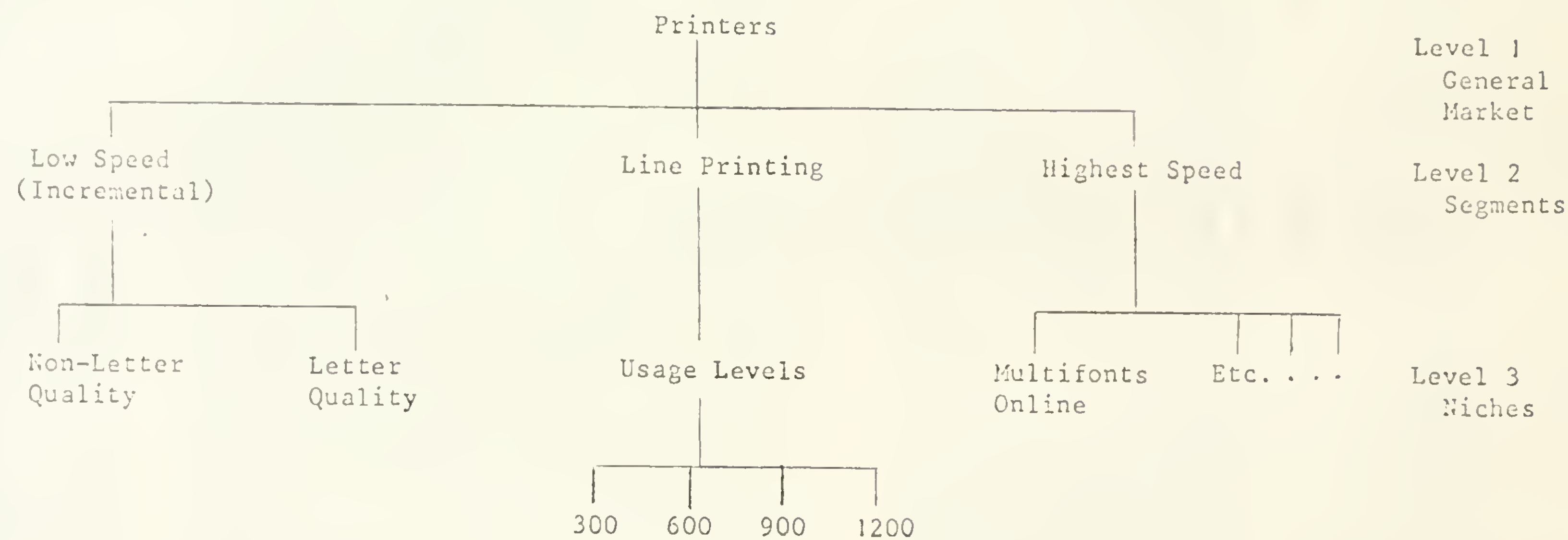
Four levels of market application newness stem directly from the hierarchical definition methodology, being a new product for:

- a new market niche;

- a new market segment;

EXHIBIT II

The Hierarchical Definition Method



- a new general market;

- or no newness, e.g. an existing market niche, or an existing market segment if the market is sufficiently small or young so as to have only "general purpose" type products.

The basic consequences of market application newness is that the more dramatic the change in customers entailed in a new product, the more difficult it will be ordinarily for the firm to both understand users' needs, which must be incorporated into the product's design, and effectively to reach the new users. Implicit within the market application parameter are factors which include distribution, service, and various marketing activities.

Probably the most frequent type of product innovation occurs when the firm implements new techniques or mechanisms to deliver improved functionality in a product area to existing customers. Relating this back to the technological parameter, this involves "minor improvements", and less frequently, "major enhancements" to the firm's key technology. For example, in the printer business, one manufacturer of line printers recently extended its product line by substituting a welded-band font carrying device for its traditional linked-chain printing elements. This enhancement has allowed for a more compact, less expensive product to be sold for the same applications. Instances of "backward integration" would also fall within this category.

The next level of market application newness, which is when a firm makes new products for new market niches, is also common among high technology companies and has been facilitated by the widespread substitution of integrated circuit components for "hardwired" circuitry. Upon identifying a new set of customers closely related to its existing ones, manufacturers can now adapt their products relatively quickly by inserting new microcode instructions into PROM memories and inserting these PROMs into the main product chasais. For example, a producer of access control devices, which open doors based on software algorithms which read the magnetic strip on the backside of plastic cards, has adapted its key technology from innercity banking ATM applications to apartment complexes, industrial computer facilities, and even to a particular university which wants to track individuals attending classes. The technological medium of PROM-programming has allowed this company effectively to leverage its key technology into a series of new market niches.

The third level of market application newness, where the firm makes new products for new market segments, can also occur through "adaptive innovation." For example, a company in the electronic funds transfer market was described which combined its in-house key technology with new base technologies to make ATMs for supermarkets from its original point-of-sales terminals. Segment-jumping can also occur as the result of new key technology development. One entrepreneur in the medical imaging industry has made products for three distinct market segments: a full body scanner using advanced X-ray technology, a cardiovascular imager employing techniques of nuclear medicine, and lastly, a machine for abdominal scanning which employs ultrasound wave-bouncing technology.

The fourth level of market application newness is product innovation for new general markets, and, as above, can be accomplished by either applying the firm's existing key technology to a new product area, which will be referred to as "technological leveraging", or by the development of new key technology. Another example from field research illustrates this. A manufacturer of tape drive calibration devices which it sells to large computer manufacturers decided to produce a small business computer system. While purchasing all necessary hardware components from outside vendors, the firm developed its own operating system and applications software. Similarly, the transfer of military technology to commercial markets is an important instance of technology adapted to new markets. Gee (1971) describes how visual acuity testing technology for fighter pilots in the Second World War was rediscovered years later to become the basis of standard opthamological testing instruments used by eye doctors.

THE PRODUCT INNOVATION GRID

The technological and market application parameters can now be combined into a two-dimensional grid, as shown in Exhibit 1C. It will referred to as the product innovation grid. Within this framework there are three special, and interesting situations of product innovation which deserve additional comment. The first situation reflects a new product strategy of "customer-bound" innovation, wherein the firm makes a series of markedly different products for the same users or industry. A case from the field reseach demonstrates this idea. The firm was founded by a group of electrical engineering professors and one manager from a news courier service. Its first product line was a series of optical character reading (OCR) machines for large-scale input of news copy into text-editing systems. The next product line was based on a sophisticated image processing camera, derived from the professors' university research, and was also specifically made for newspaper applications. Lastly, the firm developed a multi-user text editing system for the newspaper industry. Being short on marketing skills, but confident that they could "fix" anything once the problem was defined, these entrepreneurs have developed three key core technologies for the same user industry.

For the purposes of using the innovation grid, it could be argued that each product described above targets a different type of user, or in other words, that there are three discrete general markets within the newspaper industry. However, a customer-bound new product strategy represents a concentrated, narrow focus on one specific industry. If the new key technology is applied only to that industry, then the new product seems deserving of the categorization "new niche." If however, the firm should manage to escape its customer-boundedness, and bring that key technology into different user industries, then that new product may be said to have initiated a "new general market" for the firm.

A second special case is a type of forward integration, and happens when a firm switches from being a supplier of components to other manufacturers to selling more complete systems or products to end-users. Although the target end-product is still the same, the company's output is sold to a different type of customer. The rule to be used to judge these situations is that a change from OEM buyers to end-users will be considered a shift to a new market segment. If, however, the firm integrates forward to a higher level of component supply in the overall product development chain, and sells its products to merely a more advanced stage of OEM buyer in that chain, then it will not be considered to have shifted to a new market segment, but to a new niche. The end-user/component customer distinction therefore becomes the evaluation criterion for such cases.

The third and last special case occurs under circumstances not so fortunate for the firm. Having tried to make a product which required several or more key technologies but failed over a period of years to achieve a reliable and adequate level of sales, management decides to "retrench", that is, to specialize in just one technology and become a component supplier. This happened to a manufacturer of end-user speech recognition systems. Its first product involved two key core technologies: a) voice sampling and pattern matching algorithms with associated database software, and b) a considerable amount of applications programming required for each applications to, for example, filter out background noise. Several years after startup, the firm also embarked on making its own extremely high-speed map array type hardware. Although some systems were sold over the course of ten years, the firm had not been able to make a standardized product. A shareholder-forced change in management saw a policy of retrenchment initiated, with the cessation of all hardware manufacturing activities. The firm's new strategy is to package its voice recognition algorithms as a type of operating system utility, to be sold to computer manufacturers in the form of a printed circuit board. Retrenchment therefore entails the repackaging of an existing technology, e.g. either minor improvement or major enhancment depending on the scale of that effort, and a significant market reorientation to a new market segment.

In working with the grid framework, the generic labels such as adaptive innovation or retrenchment given to particular types of product innovation are not themselves especially important; rather, it is the degree of technological and market application newness of each associated new product activity which is the critical aspect. This product innovation grid may be used to assess a new product proposal, or, for the purposes of research, to provide an overall portrait of the firm's product strategy by plotting all past product efforts on the grid. Specifically, one could generate a scatterplot diagram of all past product innovation efforts up to a certain point in time, with each point representing the technological content and market application for each respective product. The grouping of points in particular regions of the grid, or a lack of any grouping, will thus provide a caricature of the firm's new product strategy. This basic concept shall be used in the next section to develop certain hypotheses on new product strategy in high technology firms.

III. RESEARCH QUESTIONS

Having developed a conceptual framework for considering new product strategy, we can proceed to construct the main hypothesis and then, to operationalize the framework in order to test the hypothesis.

Rosenbloom and Abernathy (1982) have noted the tendency of American businesses to seek a diversity in their product technologies: "Since the 1950's, a penchant for diversification has led U.S. firms away from their core technologies and markets." (p. 27) On the product innovation grid, this reflects a new product strategy of consistently pursuing new, unrelated key technologies for new market applications. This may be referred to as a "horizontal" diversification strategy. (Hayes and Schmenner 1978). It stands in contrast to the other general types of diversification strategies, which may be identified broadly as a) product diversification within a given market, or product enhancement, b) market diversification using a given product line, or adaptive innovation, c) process innovation for a single product or across a mix of product lines, otherwise known as vertical integration, or d) some combination of these three stratgies.

A horizontal diversification strategy has several theoretical underpinnings. The first is portfolio theory, adopted from the field of finance. It asserts that the risk of technological obsolescence or market decline for any product technology can be hedged by the firm as a whole if the firm has other unrelated product technologies, or businesses, to take up the slack should such misfortune occur.

The second justification for unrelated diversification is in the notion of the product life cycle. This theory holds that technological obsolescence and a decline in sales for a product technology are inevitable, and hence, there is increasingly less reason for management to continue to invest in a particular area after the product technology has reached a "peak" in its life cycle. As Day (1975) states, "Eventually all product categories become saturated or threatened by substitutes and diversification becomes essential to survival...a company should have a mix of products in each stage..." of the product life cycle, e.g. introduction, growth, maturity, and decline.

Lastly, there is learning curve theory, the essence of which is that the doubling of manufacturing output for a product leads to a characteristic decline in the costs of production, usually in the range of 20% to 30% (Henley 1971). This allows the firm to increase its market share, and its total revenues. The resulting goal of management, in terms of the Utterback and Abernathy (1975) model described in the first section of this paper, is to accelerate movement into Stage II process innovation. Thus, if the firm wishes to invest in product research and development, it must find new areas for investment because existing product technologies cannot tolerate substantial innovative changes due to the scaled-up, and inflexible, production.

Taken as a whole, these three principles "have been applied increasingly to the creation and management of corporate portfolios -- that is, a cluster of companies and product lines." (Rosenbloom and Abernathy 1982) This particular brand of new product strategy, which seems so prevalent today, is not without certain distinct flaws, however. In fact, early increases in production volume, which seek to reduce production costs and thereby increase margins, can lead to a premature standardization in product design. Such standardization brings with it an inflexibility which may hurt the firm in its efforts to remain competitive in its product technology. Not only will incremental product improvements be more expensive and difficult to achieve, but more critically, the firm can be restricted severely in its ability to respond to major, radical innovation demanded by the marketplace.

Abernathy and Wayne (1977) describe a classic example of this strategy-induced inflexibility. This was Ford's difficulty in switching from the Model T, America's first mass volume, inexpensive automobile, to the heavier, roof-topped, more luxurious Model A, a change which was necessitated by new consumer preferences. General Motors, on the other hand, did not have such large scale production prior to that point in time and was able to more quickly exploit the new market opportunity. It has even been suggested by Skinner (1974) that the assumed relationship between large scale production and minimized costs can be fallacious. His concept of the "focused factory", which can achieve high quality output with small-scale yet cost-effective manufacturing, is in fact a reality for the typical small high technology firm.

Two studies present some empirical evidence to further challenge the diversified portfolio as a new product strategy. First, Rumelt (1972) examined approximately a hundred Fortune 500 corporation and concluded that the most successful ones showed "related" new business diversification. The less successful firms were either conglomerates with a portfolio of dissimilar businesses or were companies which had sought to become vertically integrated within their major business areas. Rumelt's method was to construct approximately a dozen categories of diversification types, and then to classfy his sample by using annual reports and product literature collected from the firms. The reasoning which supports his findings are that in both the conglomerate and the vertically integrated corporation, the inherent complexity of managing a number of different technological ventures exacts its toll on the effectiveness of any one body of management. The second study was performed by Peters (1980), who looked at ten highly successful large companies and also found that the management of these firms adhered to a policy of closely related diversification. His conclusions were that "these companies have achieved unusual success by sticking to what each knows best."

This vein of thought leads to the main hypothesis of this study:

> Successful small high technology firms tend to leverage their technology, pursuing a strategy of enhancing their existing key key technologies to make new products for either current or new market applications.

As a corrolary to this hypothesis, it may be further hypothesized that successful high technology firms will tend to achieve more radical new product initiatives, such as to start a new product line, by selecting projects in which existing key core technologies may be combined or integrated with new base component technologies. This second hypothesis describes a special, more ambitious instance of technological leveraging.

The justification behind the main hypothesis is that new products which require the development of technologies of which, by definition, the firm has no real working knowledge, will present a degree of difficulty in successful project completion which will tend to be prohibitive. New technical persons must be hired, brought up to speed, and coordinated with other parts of the organization. The complexity which results from new technology development does not necessarily doom the project to failure; however, successful completion will require more time, expense, and prototypes than projects which are enhancements or extentions of key technologies already within the firm. Over time, these consequences will affect the firm's economic performance.

The main hypothesis has been formulated with an emphasis on the technological parameter of new product strategy. It should be noted, however, that in the market application parameter, the targeting of new "general markets", or even "new segments" may also pose a formidable barrier to successful project completion. There are two reasons for this. First, the more different the market application, the more difficult it can be for product engineers effectively to understand user needs and tailor the key technology of the product to these needs. Secondly, the firm may find itself having to work through new distribution channels, such as through dealers instead of its own direct sales force. Indeed, one of the side questions which may be answered by this research is the comparative impact of technological and market application newness upon the firm's performance. Similarly, another research question is whether the actual number of new products made by the firm is reflective of its commercial success. With these research issues established, the next task is to describe the research design and methods to collect data and test the hypothesis.

IV. RESEARCH DESIGN AND METHODS

The research design of this study is to collect data based on the conceptual framework of Chapter 2, and to construct a measure which represents the cumulative newness of technology and market applications for the products of each of a sample of high technology firms. The higher the index or score, the more the firm's new products will have tended to require new key technologies and/or be targeted to new markets.

Once this index is developed, the product newness index can be used to provide an expected ranking of a sample of firms in terms of commercial success. The expected ranking can then be matched against the actual ranking of the cases as determined by another constructed measure which reflects each firm's economic performance. Therefore, the product newness measure shall be the independent variable, and the constructed growth figure, the dependent one. If the main hypothesis is correct, product newness should be a predictor of commercial success. That is, firms with low scores should be more successful than those with high scores.

This chapter will examine how this design is operationalized. The issues covered are, in order:

- the sample of firms used for this study;
- what shall be considered "products", how to identify key core technologies, and how to identify market applications;
- dependent variables;
- data collection tools and the processing of the collected data.

THE SAMPLE

The sample used in this study is not "scientific" per se , but rather one of convenience, used to develop the hypotheses and methodologies of this paper. The sample consists of ten companies. These firms were interviewed as part of a larger research project performed under the auspices of the Swedish Board for Technical Development (Utterback, et al., 1982). This study examined across a broad range of issues a group of approximately 100 Swedish manufacturing companies formed between 1965 and 1975, and 25 Boston/Route 128 firms, started in the same time interval. The American companies are engaged in the manufacture of computer-related hardware such as whole computers, peripheral devices, special purpose printed circuit boards, and other computer-based projects. These Massachusetts firms were themselves compiled from a variety of directories and by snowball sampling, and checked for completeness against a complete listing of Massachusetts incorporations for the years 1965 to 1975 obtained from the state government. Of the approximately 60 firms which were identified in this manner, 25 consented to be interviewed within the project time period, being the first three months of 1982.

The specific Route 128 firms used for the paper were interviewed by the author personally. They cover a broad spectrum of size within the general category of a "small high technology enterprise", ranging from under $100K to over $35M in 1980 sales. In all but one case, the interviewees were the present CEOs of their organizations, and in seven cases, they were also part of the founding group. Exhibit III provides descriptive information about the ten firms.

EXHIBIT III

The Sample

	Main Product	Current Sales (in millions) (1981)	Start Date	Number of Employees
Case 1:	Access Control	$ .89	1968	12
Case 2:	Mainframes	$17.20	1973	237
Case 3:	Printers	$35.65	1968	--
Case 4:	OCR/Process Camers	$15.00	1969	180
Case 5:	EFT Terminals	$3.00	1970	50
Case 6:	Speech Recognition Systems	$ .20	1971	75
Case 7:	Peripheral Processors	$9.60	1976	138
Case 8:	Tape Calibration Devices	$1.35	1971	38
Case 9:	Portable Terminals	$19.94	1969	200
Case 10:	Business Computers	$ .10	1976	2

IDENTIFYING PRODUCTS, TECHNOLOGIES, AND MARKET APPLICATIONS

The interview process was a give-and-take affair wherein the basic research concepts using the product innovation grid were described, and then, working together with interviewees, the analysis of their respective product bases was performed. It was found that the entrepreneurs by and large accepted the notions of key core technology and the various levels of market applications, and understood how the grid could be used to evaluate their own *de facto* new product strategies. It also became clear that the best way to describe a core technology and the hierarchical market definition tree was to use the firm's own products as an example. This could be accomplished by obtaining product literature before the actual interview. Mistakes or misinterpretations about the product-technology made at this point were in fact a good way to get the interviewee's direct input, and to begin the collection of product data. It was useful to have the interviewees sketch out the market trees to which their products apply.

To operationalize the research design, it was necessary to construct certain practices or rules for identifying: a) "products" as units of analysis; b) core technologies; and c) market applications. These are discussed below.

PRODUCTS

As a point of reference, a firm's "product base" is its entire portfolio of products or services for commercial applications. A "product line" or "product family" is a subset of this, and refers to the series of separate products which stem from the same key core technology. One company, for example, makes a family of IBM 4300 plug compatible mainframe computers which are based on its special type of high speed processor architecture. This product family is its product base, because the firm makes nothing else. Another previously mentioned company manufactures a line of optical character reading devices, constituting one product family, but also produces graphics image processing cameras and text editing systems, each the basis of another product line. Within product lines, manufacturers often adopt a product family strategy to allow users to obtain increasingly larger systems commensurate with their growing needs.

"Products" are the individual elements of a product line. Identifying products is not as easy as it may first appear, particularly in high technology firms. This is because not all research and development in a firm necessarily culminates in the release of a new product. Mechanisms for the transfer of R&D from labs to product engineering and marketing groups may be ineffective, for example (Quinn and Mueller 1963, Roberts 1977). Another reason can be a contract R&D business orientation by the firm. Many high technology enterprises start out by landing a good-sized contract from a larger organization desiring the entrepreneurs' particular technical skills. This mode of operation can continue for years, until perhaps management is asked for similar R&D services by a number of clients or otherwise sees that its contract work can be turned into a full-fledged "product" for active marketing on a commercial basis. However, one-time R&D contract prototypes shall not be considered "products" <u>per se</u> for this research.

There is another, more general issue pertaining to the identification of products to be plotted on the innovation grid. It is best illustrated by example. The aforementioned manufacturer of access control devices also has a minor product line of encoding machines which implant characters on the magnetic strips of plastic cards. On the firm's price list, there are several dozen models of encoders, each doing the task in a slightly different way for various situations. When asked to identify his products in this area, however, the entrepreneur said that there were only two, one older version, and a newer one. The twenty-odd different models on the price list were minor variations achieved by PROM-programming, and the inclusion or exclusion of certain mechanical parts. In contrast to this case is the manufacturer of line printers, described before in Chapter 2, which has two separate product lines based on chain printing elements and newer band elements respectively. Each line of printers has four "products", which differ by virtue of their components, which allow printing at various line speeds per minute; and each "product" has contributed in the order of millions of dollars to company revenues.

As researchers, it would be most difficult to discern consistently between these two types of cases for identifying products without establishing fairly arbitrary criteria. Therefore, the data and associated results of this analysis will be based on what the entrepreneurs themselves have stated as their "products." To exclude instances of R&D contracts however, the device or machine must have been sold to at least two independent customers in order to qualify as a product.

A final product identification issue concerns components which are sold as products. In the second chapter, cases were described in which the firm's major products were components marketed to other manufacturers or systems integrators, and in which the firm then decided to integrate forward to produce more complete or end-user systems. In these situations, the original components are bona-fide products for grid tracking. Similarly, a "retrenchment" scenario was also described wherein the firm takes a reverse direction and becomes solely a supplier of components. These components are its new products, and must be counted as such for this analysis. There is also a third type of situation, and here too the components shall also be considered full-fledged products. This occurs when a firm makes a component for its own current products, and because it produces excess inventory or deliberately wishes to match its in-house parts against those of the marketplace, decides to sell that component to other manufacturers. Note that these manufacturers may also be the firm's competitors in the main product line area.

TECHNOLOGIES

The research design tracks changes made in key core technologies during the evolution of the firm's product base. The degree of technological newness in a new product is based on any product technology developed by the firm in the past, that is, which has been incorporated into any product line of the firm's cumulative product base, whether the specific product line is being actively marketed now or not. The concept of both key and component base technologies were explained at the beginning of the interview. The interviewees were asked to state the key technology(ies) in the firm's first product. Then, working through the rest of the products, we noted whether minor improvements or major enhancements were made to the firm's key technologies at that time, or if new key technologies were developed, by definition, in-house. Knowing the various base technologies involved in a product line, and in general, the sources of important technologies introduced into the firm's products, proved critical in labelling the appropriate technological step for each product.

The incorporation of new generations of base components into a set of products often requires substantial redesign efforts, in which case it deserves the label of "major enhancement." Many instances of leveraging an existing key technology into new market application also fit into a similar category. Lastly, differentiating between "related" and "unrelated" new key technologies required further probing, pinpointing how existing key technologies have been used and ascertaining if those uses have a clear relationship with the new technology in terms of a product application.

If a new product required more than one new key technology, all such technologies were noted, but certain precedence rules were employed just for the purposes of marking the grid. Given the research framework, a new product can have only one plot point for its newness of technology and market application respectively. Therefore, a new product which required two new,related key technologies was designated as a single "new,related" plot point. If a product somehow required both a new,related key technology, and another which was new but unrelated, the more extreme degree of technological newness took precedence in marking the grid. Again however, all new key technologies had to be recorded for a thorough evaluation of subsequent new product activities.

MARKET APPLICATIONS

Hierarchical market definition trees of the entrepreneur's products, made during the preliminary stage of the interview, facilitated appropriate product evaluation for the parameter of market newness. Several ground rules had to be established, however. First, to differentiate between "existing users" and "new niches" or "segments", a threshhold level for product sales to a new application may be necessary. Going into the interview, a level of 10% was employed, that is, if 10% of a new product's sales for any given year had been to a new set of users, then the appropriate level of newness in application would be marked. The reason for this is that minor instances of new market applications of a new product should not be allowed to hide the product's predominant usage.

Guidelines for handling certain special cases in this parameter were also noted in the end of the second chapter. The foremost of these was differentiating between OEM and end-user customers for a new product. A shift from the former class of customer to the latter should be recorded as a "new market segment." This would occur, for example, in certain instances of forward integration. The previously mentioned manufacturer of large, IBM plug-compatible computers had sold all of its machines through the salesforce of a major office products company under a private-label agreement. Recently however, management decided to abandon this distribution channel and build its own direct sales and field service force. This was combined with the release of a new model in its computer line, and thus, this new product was recorded as targeting a "new market segment."

Customer-bound innovation is another special case. If a firm makes a new product which required a new key technology but for the same user-industry, and never escapes this single industry orientation, then product is marked as "new niche." However, if at some later point in time, the firm adapts the technology to applications outside that industry, the resulting product may well be the beginning of a "new general market" for the company.

THE DEPENDENT VARIABLE

The selection of the "growth" variable for this study was not an easy decision. The sample is comprised of relatively young firms, the oldest of which is now 14 years old, and the youngest, six years. There is a broad range of "success" in the sample: some of the firms are strong performers, and others on the verge of bankruptcy. The objective in choosing a dependent variable, the objective was to base the measure on sales performance, but at the same time, incorporate the age factor into the final result. Average annual sales, for example, proved unreliable because it is biased towards young, fast-growing firms. For example, a five-year old company which grew from $5M to $10M in 1980, would come out as far more successful that an older firm which grew from $25M to $35M.+

The solution adopted for this problem was to base "growth" on the size of the firm in terms of current sales, divided by the age of the firm. It was not feasible to collect sales figures for every year of each company.

+ Earnings were ruled out as a basis for a dependent variable because of tax manipulation, tax loss carry-forwards, and the sale of certain assets, all of which are not uncommon among small, fast-moving high technology firms, and which can distort the true nature of their performance. Similarly, the number of employees as an estimate of firm size is inappropriate because of the different labor requirements in different business areas. Also, policies regarding the use of subcontractors, joint ventures, and so forth make the use of the number of employees unsuitable.

However, the past two current years of sales were taken, and each was divided by the age of the firm at that time. The average of the two figures was then obtained. Two years were used instead of just 1981 sales, for example, to lessen the risk of having a freak year bias the results.

DATA COLLECTION TOOLS AND PROCESSING

Recording Data

The basic data collection tool is shown in Exhibit IV, and is filled in for one of the companies of the sample, Case 4. In Appendix 1, the data sheets for the other nine cases are enclosed. The categories shown across the top of each sheet are derived directly from the product innovation grid. To expedite the interview process, the practice of grouping products into clusters according to product line was adopted. Within each product line, the products are then listed in the chronological order of their release onto the marketplace. Thus, there may be some overlap between the start date of the first product of a particular product line and that of products within clusters which come before it on the data sheet. New product data could have been recorded in a strictly chronological order across all products, but this might have involved jumping back and forth between product lines and would have therefore been confusing to the interviewees.

The case used for illustrative purposes in the accompanying exhibit was mentioned briefly in the second chapter. It is particularly interesting in that this firm developed three product lines based on distinct key core technologies which span the spectrum of technological newness. Its first set of products were OCR machines, which employed laser scanning technology. The second product line consists of a high resolution image processing "camera", which like the OCR product line, has been targeted for the newspaper industry. To make these image processing machines, the chief engineers of the firm

EXHIBIT IV.

Data Recording Sheet

			TECHNOLOGY						MARKET APPLICATIONS			
			New Key Core (Y/N)	Same: Minor	Same: Major	New: Related	New: Unrelated		Existing Users	New Niche	New Segment	New Market
	OCRs	**Key Core:**										
1970	1. OCR machine Dumb Scanner	Laser Scanning Input	√					Newspapermen				
1973	2. Improved version Model 2 substantially re-engineered				√				√			
1974	3. Model 3	Intelligent scanners			√					√		
1979	4. Model 4			√				90% of sales to one market	√			
1980	5. Model 5			√					√			
1981	6. Model 6 "Dumb Scanner"			√								
	Process Cameras											
1976	7. Model 1 Process Camera	Add Image Processing from Laser input	√			√				√		
	8. Graphics Subsystem Takes mag tape input/output to/from Autoscan Camera	(Type of OCR)		√					√			
	Text Editing System (Developed In-House)											
1977	9. Model 1 Editing System	For newspaper editing appl. Middle range of the market	√				√	Newspaper editing		√		
1977	10. Model 2 Business Software	Bought circulation package		√						√		
1977	11. Model 3 with	Bigger disk drives		√					√			
		Counts		6	2	1	1		6	4	0	0

combined the existing OCR laser scanning technology with newly developed image processing algorithms which adjust hue, resolution, size, and other aspects of a photograph to meet composition specifications. Because of this combination of an existing key technology with a new one for the new product, the process camera has been recorded as having involved a "new, related" key technology. As for the market application, it has been tagged "new niche", going by the established procedure for handling instances of customer-bound innovation. The last product line developed by this company was a family of text editing systems. Once again, this product was geared for the newspaper industry. While the firm used other manufacturers' hardware for the new product line, it hired several dozen programmers to develop the applications software. The technological content of the text editing systems was therefore a "new, unrelated" key technology.

Processing Data

The product newness measure developed and used in this research is designed to capture the relative degree to which an organization has focused its product development activities in one technological and market application area, or alternatively, sought to diversify into new key technologies and markets. As seen in the description of the sample used for this study provided before, the firms to which this measurement methodology is applied here are comparatively small. This does not mean however, that the product neweness measure could not be generated from an examination of larger technological firms.

The product newness measure is the result of a series of steps using the information contained in each firm's data recording sheet. First, each of the two points for each product is multiplied by the appropriate weighting factor used to represent the respective level of technological and market application newness. Four sets of arbitrary weighting factors will be employed to process the data for sensitivity testing. These sets of selected weighting factors are shown in Exhibit V. Note that the increasing degree of newness of each level of technology and market application are reflected in the upward direction of each set of weights. In selecting the sets of weighting factors used in the analysis, it was important to test out various scales. For example, one set is 1,2,3,4, and another 1,3,6,10. Obviously, this last set of weights will score more heavily those products which incorporate higher levels of either technological or market application newness. None of the weights is based on research evidence or theory.

After multiplying the two data points for each product by the assumed weighting factor, the next step is to sum up the resulting product scores. In this way, a total weighted product newness figure is calculated for each company's entire product base.

A third proposed step is to add to this sum the number of key technologies required in the firm's very first product, multiplied by the weight for "new, related" technology for the given set of weights being used in the calculation. The reason for this addition is to take into account that firms whose first products present varying degrees of technological difficulty. The number of initial key technologies is a representative measure of this. An alternative method could be to have a panel of experts

EXHIBIT V

Weightings for Product Newness

	Set 1	Set 2	Set 3	Set 4
Minor Improvement	1	1	2	1
Major Enhancement	2	3	4	3
New, Related Technology	3	5	6	6
New, Unrelated Technology	4	7	8	10
Existing User	1	1	2	1
New Niche	2	3	4	3
New Segment	3	5	6	6
New General Market	4	7	8	10

judge the relative difficulty of initial key technology development for each firm, whether that development was for one or many separate key technolgies. The cost of implementing this method was prohibitive for this study, however. The need to take into account this aspect of a firm's product development efforts is shown by the example of a manufacturer of speech recognition systems, which was described before as a case of "retrenchment", attempted to commercialize an initial product which required the development of two discrete key core technologies. As for weighting these initial technologies as "new, related", this decision was based on a more subtle reasoning. Each firm would ordinarily have at least one key technology embodied in its first product; if additional initial key technologies are attempted in the product effort, they will be "combined" with this first technology for a "future" product, e.g. the firm's first offering. These additional technologies therefore fit into the definition of "new, related" key technology provided in the second chapter. For exploratory purposes, the analysis of the data will also be performed without this third step, so as to see the importance of including it for the overall results.

The fourth and last step of the data processing procedure is to divide the total sum by the number of products in the firm's product base. This yields a product newness measure for the firm's product strategy on a per product basis. It is the "product newness index" to be used for subsequent analysis with the dependent variable.

An illustration of the procedures described in this section is provided in Exhibit VI. These methods will produce the desired result : those companies which have pursued a strategy of product enhancement and/or adaptive

EXHIBIT VI

Processing of Data Using Set 2 Weights for Case 4

	Occurrances	x	Weights	=	Subtotal
Minor Improvements	6		1		6
Major Enhancements	2		3		6
New, Related Technology	1		5		5
New, Unrelated Technology	1		7		7
Same Users	6		1		6
New Niche	4		3		12
New Segment	0		5		0
New Market	0		7		0
				Total	42

Number of Products = 11 Initial Key Technologies = 1

Product Newness[A] $= \frac{42}{11} = 3.81$

Product Newness $= \frac{42 + (1)5}{11} = 4.27$

A = Without initial key technologies added.

B = With initial key technologies added.

innovation will have a comparatively low score, whereas firms which have sought horizontal, unrelated diversification will generate indices which are comparatively high. Other methods not tested here might have similar effects and might also be appropriate indices.

V. RESULTS

The research design and methods presented in the last section were used to analyse the ten firms chosen for this study, and thereby test the main hypothesis on new product strategy and examine the other issues raised in Chapter 3. The results are presented below.

TESTING THE MAIN HYPOTHESIS

The product newness index appears to be a strong predictor of commercial success for the ten high technology firms in the sample. This finding, which holds for all four sets of weighting factors, is tested for significance with Spearman's rho (r_s). The basic procedure is that the cases are ranked according to the product newness index (in order of low to high) and the growth variable (high to low). The sum of the squares of the differences for these two rankings is the basis for calculating r_s. In Exhibit VII, the procedure for generating the measure and testing for significance is shown using Set 2 weightings, with the initial key core technologies included in the calculation. Appendix 2 contains the calculations for all sets of weights. In Exhibit VIII, the results of the analysis are shown for all sets of weightings, both with the initial key technologies included and excluded for the r_s calculation.

EXHIBIT VII

Analysis of Data*

Case	Main Product Line	Product Newness** Index	Product Newness** Rank	Growth Index	Growth Rank	d_1	d_2
3	Line Printers	3.63	1	2.75	1	0	0
2	Large Computers	3.80	2	1.96	2	0	0
4	OCR Machines	4.27	3	1.15	5	2	4
9	Portable Terminals	4.56	4	1.76	4	0	0
7	Peripheral Processors	5.07	5	1.84	3	-2	4
5	EFT Terminals	5.29	6	.235	6	0	0
10	Small Computers	6.17	7	.041	9	2	4
8	Tape Calibration Devices	6.25	8	.123	7	-1	1
1	Access Control Systems	6.88	9	.063	8	-1	1
6	Speech Recognition Systems	8.50	10	.035	10	0	0
							14

$$\text{Spearman's rho}(r_s) = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - N} = 1 - \frac{6(14)}{990} = .92^{***}$$

* The methods used here are taken from Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill, New York, 1956, 202-213, and Table P, 284.

** With initial key technologies added in.

*** For N=10, r = .92 is significant at the .001 for a one-tail test, and therefore we may reject the null hypothesis that there is no association between product newness and growth for the firms in our sample and that r_s of .92 occurred by chance.

EXHIBIT VIII

Results of Analysis

		Significant at .01 level
Set 1	(1,2,3,4)	
	$r_s^A = .87$	Yes
	$r_s^B = .90$	Yes
Set 2	(1,2,5,7)	
	$r_s^A = .84$	Yes
	$r_s^B = .92$	Yes
Set 3	(2,4,6,8)	
	$r_s^A = .81$	Yes
	$r_s^B = .86$	Yes
Set 4	(1,3,6,10)	
	$r_s^A = .84$	Yes
	$r_s^B = .92$	Yes

A measures do not include consideration of critical key technologies; B measures do include them.

In testing for significance, the null hypothesis is that the predictor variable, product newness, has no statistically significant relationship to the ranking of the firms by commercial success. The alternative hypothesis is the main hypothesis of this study, which may be restated that firms with low product newness indices will tend to be strong performers, and those with high product newness scores, poor performers. The results of the analysis show that the alternative hypothesis can be accepted at a high level of significance. For a sample size of ten firms, r_s would have to fall below .746 to not be significant at the .001 level (for a one-tail test). It can be seen from Exhibit VIII that all the generated rank coefficients have a comfortable margin over this threshhold point.

It is also evident that there is not a substantial difference in the results do to the usage of a particular set of weightings. Prior to performing the calculations, it was expected that that Set 4 weights would show an even stronger relationship between product newness and commercial success, given that it scored successively higher levels of newness in both parameters with increasingly greater values and would thus emphacize the thrust of the main hypothesis. Exhibit VIII shows that Set 4 r_s were tied as the strongest predictors for both sets of calculations. However, the difference between all the rank coefficients is marginal, and the small size of the sample limits any concrete conclusions in this regard.

The inclusion or exclusion of the number of initial key core technologies does have a more pronounced effect upon the results. The rationale for including initial technologies, weighted as "new, related", was provided in the last chapter and basically argued that firms which embark on highly ambitious startup projects must, in some way, be accounted for in a study of new product strategy. In the sample used for this study, there was only one firm - Case 6 - where multiple key technologies were developed for a first product, and this did have a slight impact on the bottom half of the ranked lists. Again however, in no case do any of the rank coefficients fall below the .001 level of significance.

As for the companies "behind" these ranked lists, the two most successful firms (in terms of growth and using the ranking shown in Exhibit VII) have both concentrated on one key technology, and have both undertaken major enhancement projects by introducing new base component technologies, being new printing elements and LSI technology respectively. Similarly, the fourth, fifth, and sixth ranked companies have, by and large, focused their energies in one key technology area. In contrast, the seventh, eighth and ninth ranked firms had all tackled "unrelated" new key core technologies in their histories. All three companies have diversified into new product-technology areas. The interviewees of these firms indicated that their initial product lines were not capable of sustaining future growth, being a graphics plotting system, calibration measurement systems for tape drives, and plastic card encoders respectively. The bottom ranked company is the case where the firm tried to tackle three highly complex key technologies in its first generation of products. This case was one of "retrenchment" described in Chapter 2.

From these findings, several basic observations can be made, still keeping in mind the small size of the sample and the exploratory nature of this research. The most successful high technology firms seem to begin their activities by selecting a product-technology area which has strong growth potential and then remain firmly focused in that technological area. This growth potential can be a combination of a) that the product-technology is adaptable to a number of different, but closely related market applications through product enhancement activities, and/or b) that the technology can be leveraged into different, but related market applications by combining that technology with new key technology or by substantially enhancing it with new types of base components available from outside vendors. Although the role of competitors has not been examined in this research, one might suspect further that the presence of a few, competent competitors, as opposed to a highly fragmented industry, may actually benefit the firm by forcing it to bring its technological acumen to a sharp, distinctive edge and may also serve to keep the firm's margins high due to a quasi-oligopolistic price umbrella.

This suggests that a firm's first product should be based on a key technology which has "room" for substantial but sufficiently difficult future enhancement so as to present a barrier to entry for would-be competitors. This provides the firm with the opportunity to bring new generations of superior product-technology to both existing and future types of users. As the cases in the bottom half of the ranked sample show, a company which does not choose a viable product-technology must eventually develop a new key technology or close down business. This radical, but neccessary diversification takes its toll on the firm's already laggard performance. This is not to say that a poor performing company cannot turn itself around by jumping to a new key technology, but it will take considerable time, and of course, patience on the part of both investors and employees.

Therefore, the argument presented here is that major technological achievements are more likely to be achieved by a firm which continually builds upon its knowledge and skills in a particular field, one which has ample growth potential. This accumulated experience is necessary for the firm to discover and implement new applications of its key technology, a process which is facilitated by a close linkage between engineers and those individuals who are the firm's "eyes and ears" in the marketplace.

OTHER RESEARCH QUESTIONS

It was also hypothesized that a firm may best achieve more radical product reorientation by somehow leveraging its existing key technology into that new application. The three unsuccessful firms mentioned above did not do this. For example, the manufacturer of tape calibration devices decided approximately five years ago to get into the business of making small business computers, ostensibly to be sold through retail computer stores. Not only was this a new market but, further, the firm developed its operating system and applications software in-house. The new computer system, which has been available for sale for several years, has not been successful. This is due to a failure by management to develop reliable and effective channels of distribution and because the new computer is an undistinguished, "me-too" type product.

In contrast to this case is the third most successful firm in our sample, a manufacturer of peripheral processors. It also made a decision to make small computers, but implemented this strategic decision by leveraging its existing technology. The basic product idea was to package a powerful combination of components into a single compact unit, including good-sized Winchester disks, tape cartridge for data backup, and considerable main memory. Further, management wanted to license a popular operating system, so that it could sell the new computer to either applications software houses who wrote programs for that operating system environment or to end-users who had compatible software. The "link-pin" between these various components, at least in management's eyes, was the firm's existing peripheral processing technology. The various components mentioned above (and others) were assembled around a specially programmed I/O controller board of the firm's own making. The project required about a year to complete, and now the new computer is beginning to bring revenues back into the company even though management has had to build a new direct sales force to reach the new target market. Technology leveraging has allowed the firm to concentrate its limited resources on the manufacturing and marketing dimensions of the new product effort.

Another issue raised in Chapter 3 concerned the relative impact of technological and market application newness. It is clear that both types of product newness are important; saying which one is more important is impossible, however. The sample contains cases of adaptive innovation, where the firm leverages its technological assets by enhancing an existing key technology to new market applications, but these new applications tend to be new niches, as opposed to new segments or general markets. The activities of Cases 1, 3, 5, 7, and 9 may all be characterized, for the most part, in this way. There was also one instance of the opposite strategy, that is, substantial technological newness for the same set of users. This is Case 4, the firm used to illustrate the data processing techniques in the last chapter. Each type of strategy offers major challenges : developing a new, appropriate distribution channel for adaptive innovation (which may not always be required, however), and mastering a new technological field in a customer-bound strategy. Although the sample is too small to permit any conclusions in this matter, the author's intuition is that extensive technological newness may be more risky than getting products to new types of customers, and that to try to achieve major levels of newness in both areas is foolhardy, particularly for smaller high technology firms. This issue, like that of the tactics involved in major product reorientation, is deserving of further research.

Lastly, there is the issue of the pace of new product innovation. A Spearman's ranking of the companies, in order by the number of products (high to low) and growth (high to low, also) is shown in Appendix 3. The results of the analysis are not significant at the .001 level, nor at the .05 level. Although the size of the sample is once more limiting, it seems that quantity is not representative of quality in terms of the firms' innovative activities. Of course, the analysis here compares apples to oranges : in other words, matching the number of products made by a mainframe computer manufacturer to that of a terminal producter can be highly misleading. To fairly measure this issue, a sample might be constructed of companies consisting of matched pairs of firms involved in the same product areas.

This study should be viewed as a pretest of a more detailed inquiry into the new product strategy of high technology enterprises. The research design and methods developed here can be improved and applied to a larger sample of firms. As suggested just above, a matched-pair structuring of the sample, where the strategies and performance of firms making very similar or the same products across perhaps a dozen specific product areas, would be a desirable foundation for collecting data. Further, the tactics chosen to implement new product ideas is another critical area of concern which has only be touched upon in this study and which is deserving of further research. Tactics could be divided into four areas - prototype development, manufacturing, distribution, and customer service -- and one could track whether the firm implemented each function with in-house personnel or turned to outside organizations. This might show how different tactics induced different results for companies choosing the same new product initiative. Lastly, the impact of the competitive environment is another critical factor which could be studied by observing the nature of the firm's competition over time and comparing it to the firm's evolving strategy. Thus, a more in-depth look into product strategy with an improved sample, and the development of tools to examine both the tactical and competitive dimensions, serve as an agenda for continued research.

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CASE: 1

Access Control Systems	New Key Core	SAME Minor	SAME Major	NEW Related	NEW Unrelated	Existing	Users	NEW Niche	NEW Segment	NEW Market
I) 1968 1. Cable TV system - 1 Core. FCC stops implementation.	✓									
II) 1970 2. Encoders - Model 1 A new Core. Tries its own implant technique	✓				✓	Companies who need to encode plastic id. cards				✓
1973 3. Model 2 Switches to IBM standard			✓				✓			
1974 4. Model 3 for implanting characters → different types of codes allowed various "customized" versions		✓						✓		
1977 III) Card Readers - Access Control New Core Tech - used w/ Encoders						Access Control based on reading plastic cards				
5. Model 1 Hardwired Version - 1 Character bit	✓			✓					✓	
6. Model 2 Implements CPU/Proms 3-6 character bit reading			✓					✓		
7. Model 3 More Memory - Better Prom-code up to 2048 characters per card Cost - about $1500 per door		✓				Banking ATM facilities Computer Rooms, Apartment Complexes		✓		
8. Full Access Control System New Core. Based on Commodore Pet microcomputer and its own applications software - time in/time out combined with access control - some reporting $10k plus $1000/door. Combines its access control devices with new software and OEMed components	✓			✓		Organizations who want access control with time in/out tracking		✓		

CASE: 2

IBM Plug Compatible Medium-Sized Comp's (4300)	New Key Core	SAME Minor	SAME Major	NEW Related	NEW Unrelated		Existing Users	Niche	NEW Segment	NEW Market
1976 1. Model 1 — 1 key core technology: the special CPU architecture; all other components OEM'ed and assembled	✓					Sold through a major OEM in U.S.				
1979 2. Model 2 — Faster M.I.P.S		✓					✓			
1980 3. Model 3 — Emulate More IBM op. sys. features; Upgrade - more memory		✓				Switched to its own direct sales force			✓	
1981 4. Model 4 — Upgrade - more features		✓					✓			
1982 5. Model 5 — Major improvements: LSI components			✓				✓			

Features versus IBM:

Faster

Less expensive: $300,000 to 500,000

Faster Delivery of Systems

An interesting case of about a dozen engineers who have been working together for over 10 yrs, with no new technical personnel in the design Team. (Katz 1979 - Group Longevity)

Recently signed a deal with major Japanese manufacturer, to use that firm's CAD/CAM for LSI design and to do production in Japan.

CASE: 3

Line Printers	New Key Core	SAME Minor	SAME Major	NEW Re-lated	NEW Unre-lated		Existing Users	NEW Niche	NEW Seg-ment	NEW Mar-ket
I) 1970 1. Drum Printer) key core (no longer sold) (Two founders were co-pilots) (origins: Navy consulting WW II - output device for communications intercept/decoding machines)	✓									
1977 II) 2. Chain Printers Model 1 1000 lpm — substituted "chain" elements for drums			✓				✓			
3. Model 2 enhanced by firm programming 1200 lpm		✓				New Niches by virtue of		✓		
1978 4. Model 3 " 600 lpm		✓				different line speeds		✓		
5. Model 4 " " 900 lpm		✓						✓		
(these sell for $7-14k)										
1980 III) 6. Band Printers Model 1 900 lpm			✓			Same lpm as Chain.	✓			
Substituted band fonts for Chain Elements										
1981 7. Model 2 1200 lpm		✓					✓			
8. Model 3 1200 lpm		✓					✓			

Buys printing elements, does control programming, and assembles with other purchased hardware (cabinets, etc.)

Band Elements (Welded fonts) are less expensive, and more compact than Chain elements — not as durable (yet)

	EFT Terminals	New Key Core	SAME Minor	SAME Major	NEW Re-lated	NEW Unre-lated		Existing Users	Niche	NEW Seg-ment	Mar-ket
	I) Timeshare Software Services — 1 key core Telecommunications software										
1971	1. Credit Authorization Service	✓					EFT Services For Supermarkets and				
1973	2. Check Authorization Service (small core service bureau) 50% of revenues			✓			Department Stores		✓		
	II) Hardware Business: Terminals using Telecomm's skills										
1974	3. Model 1 Transactions Terminals	✓			✓		Banks: Sell EFT			✓	
	4. Model 2 Terminal Enhanced: new exterior		✓					✓			
1978	5. Automated Teller Machine: added safebox, and new Prom coding to EFT Terminals			✓					✓		
1980	6. Model 3 improved Model 2: "Swipe reader" "Flat" printer		✓				↓	✓			
1982	7. Model 2 ATM: "Full service" cash dispenser		✓				Supermarkets			✓	

CASE: 6

Speech Recognition Systems	TECHNOLOGY: New Key Core	SAME: Minor	SAME: Major	NEW: Related	NEW: Unrelated	MARKET APPLICATIONS	Existing Users	Niche	NEW: Segment	NEW: Market
1975 1. Keyword Recognition System — for the gov't - turned into a product; used DEC PDP-11 hardware. 2 key core's: algorithms, applications software	✓✓					"Spook" system initially				
1976 2. Independent Word / Speaker independent System — New Core: its own high speed array processor; Enhanced algorithms	✓			✓		Independent word: Pilots: FAA Messages; Pocket Pagers; Telephone Network Access			✓	
1980 3. Continuous Speech System			✓			Continuous Speech: US. Post office - mail sorting by zip code		✓		
1982 4. Printed Circuit Boards contained modified voice recognition algorithms. no hardware production; no applications programming						To be sold to manufacturers, rather than end-users - on an OEM basis.			✓	

A case of retrenchment

CASE: 'I

Peripheral Processors	New Key Core	SAME Minor	SAME Major	NEW Re-lated	NEW Unre-lated		Existing Users	Niche	NEW Seg-ment	Mar-ket
Link Computers to Various Types of Storage Devices										
I) "Intelligent" I/O Controllers (as P.C.B.'s)										
A) For Various Hard Disks and Tapes (1 key core)	√									
1976 1. Model 1 Unibus DEC computers to CDC Ampex Disks										
2. Model 2 Multibus 8080/8086 to CDC			√					√		
"1st Wave" 3. Model 3 LSI 11/23 QBus to DEC RK05's			√					√		
1977-1979 4. Model 4 Unibus DEC computers (new Model 1)		√						√		
5. Model 5 Unibus to Tape Drives		√						√		
6. Model 6 Data General Nova Series to Disks			√					√		
7. Model 7 Q-Bus to Cartridge Tapes		√						√		
B) I/O Controllers for "Winchester" and Larger Hard Disk Drives										
1980 "2nd Wave" 8. Model 8 Q-bus to Winchester Drives			√					√		
9. Model 9 DEC Computers to Honeywell "Cynthia" drives		√						√		
10. Model 10 Q-Bus to Very large Hard disks		√						√		
11. Model 11 Multibus Intel 8086 to Large Disks		√						√		
12. Model 12 Data General to Large Disks and Winchesters		√						√		
II) Subsystem (no new core technology)						"Technology Leveraging"				
1980 13. Controllers since packaged with 2 24Mb (maximum) Winchester Drives (from CDC) Assembled and Q.C. in-house			√			↓	√			
1981 III) Small Computer (no new core technology) LSI 11/23 CPU, RSX-11 Operating System			√			Sold on OEM basis to				
14 own I/O controller, CDC Winchesters (two 20Mb) none of its own applications software (yet)						fewer buyers and large end-user organizations				√

CASE: 8

TAPE CALIBRATION DEVICES AND BUSINESS COMPUTERS	TECHNOLOGY: New Key Core	SAME: Minor	SAME: Major	NEW: Related	NEW: Unrelated		MARKET APPLICATIONS: Existing User	NEW: Niche	NEW: Segment	NEW: Market
I) Calibration Devices — 1 key core										
1. North/South Alignment Check — 300 byte per inch	✓					Sold to Tape Drive Manufacturers				
1972 2. — 600 bpi		✓						✓		
3. — 1600 bpi		✓						✓		
1973 4. Tracking Alignment (using all bpi above)			✓			Brought complete tape calibration checking services to	✓			
1974 5. Output Verification (" ")			✓				✓			
II) New Key Core										
6 Magnetic Heads: High performance R/W heads to be sold to same manufacturers who used calibration devices (discontinued - found out that too much customization was required per client)	✓			✓		Becomes a component supplier of heads			✓	
1977 III) 7 Small Business Computer — New Key Core	✓				✓	Tried retail selling + direct sales				✓
Own operating system: no applications										
8 Adds general ledger package + other applications	✓			✓				✓		

CASE:

Year	PORTABLE TERMINALS	New Key Core	SAME Minor	SAME Major	NEW Related	NEW Unrelated		Existing Users	Niche	NEW Segment	Market
1971	1. Model 1 Dumb Terminal 300 baud (1 key core technology)	✓					"Portability" - used by salesmen in the field, and field service crews				
1974	2. Printer for the Model 1 - had OEM'd a printer; now made in-house - cost savings (based on NCR design)	✓			✓			✓			
1977	3. Model 2 Upgraded Model 1: Cost improvements		✓					✓			
	4. Model 3 "Intelligent" Terminals started			✓					✓		
	5 Model 4 Adds acoustic coupler + comm software		✓				Users who need comm's		✓		
	6 Model 5 Adds more memory (RAM) Assembler with it, floppy diskettes + cassette for off line storage		✓				" " off-line storage		✓		
1978	7. Model 6 Combines Models 4 & 5 Coupler, carry case, Floppy & Cassette		✓					✓			
	8. Model 7 Adds Basic Interpreter			✓			Users who want to program themselves		✓		
1980	9. Model 8 Develops and Sells Applications Software sold as plug-in ROM's	✓			✓			✓			

A classic example of the implementation of successive waves of new component technologies to make "dumb terminals" into full-fledged microcomputers for business applications

CASE: 10

Small Computer

Year		TECHNOLOGY: New Key Core	SAME: Minor	SAME: Major	NEW: Related	NEW: Unrelated		MARKET APPLICATIONS: Existing Users	NEW: Niche	NEW: Segment	NEW: Market
1976	1. Disk operating system for Z-80 computers (CP/M competitor) (most [illegible])	✓									
1977	2. Word Processing Software package	✓			✓		Applications users -			✓	
1978	3. Printer Controller software - to make Diablo printer do graphics (offshoot of op. sys.)			✓			Retail store selling		✓		
1979	4. Complete Small Business Computer	✓			✓		Sold mostly direct.			✓	
	5. Adds 8" Floppy Disk Drives		✓					✓			
	6. Adds Own Communications, CP/M emulator			✓				✓			

A one-man show primarily - tries to do everything - designed computer, keyboard, floppy drives, and software - and "manufactures" units in his basement.

APPENDIX II

Set 1

Case	Product Newness[A*] Index	Rank	Product Newness[B+] Index	Rank	Growth Rank	d_1^{2A}	d_1^{2B}
1	4.00	9	4.38	9	8	1	1
2	1.8	1	2.4	1	2	1	1
3	2.38	2	2.75	2	1	1	1
4	2.82	3	3.09	3	5	4	4
5	3.14	5	3.57	6	6	1	0
6	4.50	10	6.00	10	10	0	0
7	3.29	6	3.50	5	3	9	4
8	3.85	8	4.25	8	7	1	1
9	2.89	4	3.22	4	4	0	0
10	3.50	7	4.00	7	9	4	4

$$r_s^A = 1 - \frac{6(22)}{10^3-10} = .87 \qquad r_s^B = 1 - \frac{6(16)}{990} = .90$$

A = without initial key technologies added.

B = with initial key technologies added.

APPENDIX II

Set 2

Case	Product Newness[A*] Index	Rank	Product Newness[B+] Index	Rank	Growth Rank	d_1^{2A}	d_1^{2B}
1	6.25	10	6.88	9	8	4	1
2	2.8	1	3.80	2	2	1	0
3	3.0	2	3.63	1	1	1	0
4	3.81	3	4.27	3	5	4	4
5	4.57	5	5.29	6	6	1	0
6	6.00	9	8.50	10	10	1	0
7	4.71	6	5.07	5	3	9	4
8	5.63	8	6.25	8	7	1	1
9	4.00	4	4.56	4	4	0	0
10	5.33	7	6.17	7	9	4	4
						26	14

$$r_s^A = 1 - \frac{6(26)}{990} = .84$$

$$r_s^B = 1 - \frac{6(14)}{990} = .92$$

APPENDIX II

Set 3

Case	Product Newness[A] Index	Rank	Product Newness[B] Index	Rank	Growth Rank	d_1^{2A}	d_1^{2B}
1	8.00	10	8.75	9	8	4	1
2	4.40	1	5.40	1	2	1	0
3	4.75	2	5.50	3	1	1	4
4	4.91	3	5.45	2	5	4	9
5	6.29	5	7.14	6	6	1	0
6	7.50	8	9.00	10	10	4	0
7	6.57	6	7.00	5	3	9	4
8	7.75	9	8.50	8	7	4	1
9	5.77	4	6.44	4	4	0	0
10	7.00	7	8.00	7	9	4	4
						32	23

$r_s^A = 1 - \frac{6(32)}{990} = .81$

$r_s^B = 1 - \frac{6(23)}{990} = .86$

APPENDIX II

Set 4

Case	Product Newness[A] Index	Rank	Product Newness[B] Index	Rank	Growth Rank	d_1^{2A}	d_1^{2B}
1	7.38	10	8.13	9	8	4	1
2	3.0	1	4.2	2	2	1	0
3	3.38	2	4.13	1	1	1	0
4	4.18	3	4.73	3	5	4	4
5	5.00	6	5.86	6	6	0	0
6	6.75	8	8.25	10	10	4	0
7	4.93	5	5.36	5	3	4	4
8	7.13	9	7.88	8	7	4	1
9	4.22	4	4.89	4	4	0	0
10	6.00	7	7.00	7	9	4	4
						26	14

$r_s^A = 1 - \frac{6(26)}{990} = .84$

$r_s^B = 1 - \frac{6(14)}{990} = .92$

APPENDIX III

Case	Rank by Products	Growth Rank	d_1^2
4	2	5	9
7	1	2	4
9	3.5	4	.25
2	9	2	49
3	5	1	16
5	6.5	6	.25
10	8	9	1
1	6.5	8	2.25
6	10	10	0
8	3.5	7	12.25
			94

$$\sum x^{2*} = \frac{990}{12} - 3 \frac{2^3-2}{12} = 81$$

$$\sum y^2 = 82.5$$

$$r_s = \frac{81 + 82.5 - 94}{2\sqrt{(81)(81.5)}} = .42$$

Not significant at .05 level of significance.

* Using Siegel's method for tied pairs: Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill, New York, 1956, 202-213.

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