PRODUCT AND SERVICE INNOVATION

Final Report

NIST

Manufacturing Extension Partnership

SRI International

P16877

Georgia Institute of Technology

June 2006

Task Ordering Contract:

SB 1341-03-Z-0014

Designed by Danielle Hinkley-Abba, SRI International

PRODUCT AND SERVICE INNOVATION FINAL REPORT

Sushanta Mohapatra and David Cheney

SRI International, Prime Contractor
Center for Science Technology and Economic Development
Arlington, VA 22209-3915, USA

Philip Shapira, Jan Youtie, Erin Lamos, and Ajay Bhaskarabhatla

Georgia Tech Program in Science, Technology, and Innovation Policy
School of Public Policy and the Georgia Tech Enterprise Innovation Institute
Georgia Institute of Technology
Atlanta, GA 30332-0345, USA

June 2006

CONTENTS

EXECUTIVE SUMMARY

This report examines innovation in product and service offerings relative to established small and medium-sized manufacturing enterprises (SMEs) Information sources for this report include: a synoptic literature review, analysis of case studies of innovation in SMEs, and presentation of international knowledge bases on product and service innovation.

Product and service innovation is defined here as technologically new or significantly improved goods or services introduced into the marketplace. The paper discusses how product and service innovation have evolved over time. The biggest change has been in the view that product and service innovation can be developed through a process rather than occurring in an ad hoc fashion. In addition, product and service innovation has become faster, more interactive and networked rather than linear, more global and more local, more knowledge intensive, and places more emphasis on organizational innovation/collaboration as well as harder technological changes. It is common to speak of the distinction between incremental (involving existing technologies and market positions) and radical (or disruptive) product innovation. In addition, examinations have been made of the linkages between the product as a whole, its parts and components, and the extent to which the two are integrated (i.e., architectural innovation) or modularized.

Service and product innovation have been found to differ from one another in that service innovation more closely joins the end result and the process. Customers tend to be more involved in service innovation. Services also tend to be less R&D intensive but more knowledge intensive based on the expertise of the service provider. Despite these differences, there can be profitable relationships between product and service innovation. Products have traditionally created an after market for services. However, services can create a market for products as in the case of iTunes and the iPod.

The report identifies seven models of product and service innovation.

- Linear innovation models
- Knowledge production and content models
- Staged processes
- Open innovation systems
- Institutionalized networks
- Venture management approaches
- Hybrid firms

Against this backdrop of product and service innovation, existing SMEs face constraints relating to scale, unstable finances, lack of or simple product offerings, and strategic direction. This report presents eight examples of SMEs with innovation orientations based on existing published case studies.

- Gage Products Co., which produces paints and chemicals, has engaged in value-added services and process innovation which changed its business model.

- DeFeet International, a manufacturer of high performance socks, has drawn on professional athlete lead users for product design information, and exemplifies process innovations and strong leadership.

- Capstone Turbine, which offers microturbine technology solutions, illustrates ways to conduct R&D with reduced costs (through the use of government grants), intellectual property management, firm culture restructuring, and the ability to capitalize on interest in alternative energy sources.

- Asheboro Elastics, a maker of apparel elastic ware, demonstrates ways to stimulate customer involvement, packaging and innovations, equipment investments.

- Arizant Inc., a manufacturer of medical devices, shows how organizational innovation, firm leadership, and customer involvement can encourage employees to generate actionable ideas.

- Williams Pyro, which offers products in engineering and fire prevention areas, undertook organizational innovation and firm transformation with the ascension of new leadership and utilized external R&D databases as a source for development of new materials.

- Palomar Medical Technologies, Inc. shows how leveraging external R&D resources through contract research or joint R&D projects and short time-to-market cycles for new products can help small manufacturers stay innovative and ahead of competition.

- Miken Sports, a manufacturer of composite bats for baseball and softball from petroleum resins, innovates fast through its “small company” approach to learning and knowledge sharing, and cross-training of employees leading to flexible production lines and cross-fertilization of new ideas.

An international perspective on innovation is presented through the Community of Innovation Surveys (CIS) used in 51 countries in Europe, Southeast Asia, Australia, Africa, and the Americas outside the United States. CIS-based econometric studies have explored the link between innovation and productivity.

The following guiding principles are recommended for encouragement of product and service innovation by MEP specialists:

- Every firm should have an innovation orientation.
- Companies can set up basic planned processes to ensure that innovation is an ongoing activity.
- Innovation is not just about manufacturing a product anymore. Attention must be paid to the service element as well.
- Look to various sources of information for ideas—inside and outside the company, locally and across the globe—including customers and suppliers.
- Consideration should go toward how the capability or part can be moved up the value chain and become more complex or more integrated into the core technology of the end product.
- Innovation in product and service requires "soft" changes to organization in addition to hard technological changes.
- Because innovation can involve the need for resources not directly devoted to production to finance development, cost sharing and risk mitigation through industry partnerships, government finance programs, and other sources are critical levers for small and medium manufacturers.
- Formal and/or informal knowledge sharing among employees and between SMEs and other organizations are important in the generation and nurturing of new ideas and in the development of those ideas into products.

Service and policy recommendations include extending MEP to advance the appetite for innovation at all levels:

- Assistance with initiation of basic planning of innovation processes.
- Assistance with intellectual property issues through mechanisms such as preliminary searching of patent databases and matching with legal resources.
- Assistance with linking to university and other innovation sources.
- Organizational capability to develop, broker, and support multi-firm product development networks.
- Facilitation of customer and supplier innovation sessions.
- Matching services linking company R&D efforts with grants or other financial resources.
- Financial modeling capability to support company product and service innovation decisions.

In addition to a refocusing of MEP services, complementary policies need to be encouraged beyond R&D tax credits, including training and human capital development, cluster policies, and programs to foster innovation opportunities in context-dependent areas (energy, health care, transportation, etc.). It is also recommended that more research on innovation in the firm be undertaken. MEP can stimulate this through discussions with the National Science Foundation, creation of consortium of state level innovation surveys, and incorporation into evaluation and study tools on a periodic basis.

I. INTRODUCTION

The competitiveness of U.S. manufacturing is increasingly grounded in its ability to be innovative. The importance of innovation to manufacturing has come into sharp focus today as US manufacturers face challenges from technologically capable nations such as China and India with an enormous pool of low-cost talent.

This report examines innovation in product and service offerings relative to *established* small and medium-sized manufacturing enterprises (SMEs). This is a domain that is relatively under-studied and less recognized: much of the available research on innovation and its stimulation and management focuses on new high-technology start-up ventures or large corporations. Innovation by new high-technology ventures and by large companies is critically important to US competitiveness. At the same time, the vast majority of manufacturing enterprises in the US are neither new high-tech startups nor large firms: they are mature manufacturing enterprises, generally with fewer than 500 employees, that have existing products, processes, employees, and customers. They operate in diverse manufacturing fields, as intermediate suppliers or final product manufacturers; they are not candidates for venture capital funding (but may need access to other forms of financing); and their survival and growth is fundamental to the maintenance of the US manufacturing base. Yet, if such firms are to survive and grow, they will need to pursue customized strategies of innovation, to ensure they have distinctive, high-quality offerings in the marketplace – or risk being driven out of business by competitors located elsewhere. A survey of Georgia manufacturers conducted in 2005 found that fewer than 10 percent of Georgia manufacturers compete for customers through innovation or new technology compared with more than twice that amount competing through offering low prices. Yet innovative companies are much more profitable and pay on average $10,000 more in average wages (Youtie, et al., 2005).

In exploring the field of product and service innovation, the report begins with a synoptic overview of the literature in this area that includes how these concepts are characterized and how our understanding of them has evolved. Emerging from the literature review are seven models of product and service innovation, which are profiled in this report. Also presented based on secondary information and existing case studies are examples of product and service innovation in eight SMEs, some of which operate in relatively traditional industries such as apparel. A presentation of international knowledge bases on product and service innovation is portrayed and conclusions that focus on guiding principles for practitioners and MEP policy are developed.

II. PRODUCT AND SERVICE INNOVATION

A. Components of Innovation

There is much more to innovation than the development of new high technology products (undeniably important as this is). According to the National Innovation Initiative (NII), innovation encompasses inventions and insight that generate economic and social value.[1] This definition in essence contrasts innovation (a new application) with invention, which is a new creation not tested in the market. The Organisation for Economic Cooperation and Development (OECD) highlights product innovation and process innovation as drivers for technological progress, while also considering a class of non-technological innovations which include organizational, management, and marketing advances.[2] Abernathy and Clark (1985) distinguish between innovation in the technical capabilities of a firm and innovation in the firm's understanding of its market and customer needs. Innovations may be associated with both goods and services. And innovation also frequently has important "spillover" effects, leading to additional benefits for users, suppliers, and industrial clusters as well as the innovating firm (Griliches, 1992).

While innovation has always been considered as important to industrial development, it is particularly important in the context of today's increasingly information and knowledge-intensive economy. Moreover, as the economy becomes more knowledge-intensive, the nature of innovation changes, with growing importance given to a range of material and non-material ways in which innovative outcomes are developed and valued in the marketplace. Thus, innovation is often viewed as being based on research and development (R&D), but much

Box 1
Basic Definitions

Information: Data that has been organized, processed, and communicated in a logical and meaningful way (Shapira et al, 2004).

Knowledge: The cumulative stock of information, skills, and intelligence (Shapira et al, 2004).

Research and development (R&D) "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." (OECD, 2002a, p.30.).

Innovation: Technologically new or significantly improved goods, services, processes, and organizational and marketing approaches in the marketplace. (OECD, 1997).

[1] Innovate America, Council on Competitiveness, Washington, DC, December 2004, p. 6.
[2] OECD, Proposed Guidelines for Collecting and Interpreting Technological Innovation Data, Manual Oslo, Eurostat, 1997.

innovation is not R&D based, and much involves soft as well as hard technologies. Similarly, while the production of information and knowledge is often associated with new innovation, that information or knowledge has to be organized and applied in tangible ways in order for innovation to be successful. (See Box 1 for definitions of innovation and similar concepts.)

This paper builds on the OECD's definition of innovation, which is the introduction of technologically new or significantly improved goods or services. This definition allows for innovations to be new to the firm as well as new to the market or to the industry. Excluded here is the resale of goods purchased elsewhere or simple modifications or extensions to existing products or product lines through changes to color or look. Copies of competitors' products would be considered product innovations that are new to the firm but not new to the industry.

Innovations can be incremental but new to the firm. Incremental innovations typically involve improvement of existing technologies and maintenance of existing competitor positions. Radical innovations are those that disrupt industries or markets with new designs or new engineering or scientific principles. There is often great experimentation and evolution in the creation of templates or design standards (Leifer, 2000). Henderson and Clark (1990) envisaged a four-cell matrix that added a dimension capturing the difference between the product as a whole and its parts or components. (See Table 1) They added the notion of architectural innovation, in which the linkages between components are reconfigured, but the basic design concept remains the same. In contrast, modular innovation is a change in the core design that leaves the linkages between the components unchanged. Ulrich (1995) further explicated that modular innovation, unlike integral architecture that involves complex interrelationships among components, can be decoupled and provided through a supply chain.

Table 1
Framework for Innovation

		Core Concepts Reinforced	Core Concepts Overturned
Linkages Between Core Concepts and Components	Reinforced	Incremental Innovation	Modular Innovation
	Overturned	Architectural Innovation	Radical Innovation

Source: Taken from R. Henderson and K. Clark, "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. Administrative Sciences Quarterly 35 (1990), p. 12.

It has been argued that innovation dynamics are changing. Previously, traditional product development was characterized as a linear model that moved from discovery to prototyping to product launch. However, today's perspective on product development views it as much more of a complex, multifaceted innovation process that involves ongoing interaction between the firm, its suppliers and business partners, business consortia, the marketplace, and society at large. Decentralization of production, the need to leverage technological capabilities outside as well as inside the firm, and the ability to operate in product development models that cross company, industry, and geographic boundaries characterize contemporary manufacturing product development environments. Time to market is increasingly critical in product innovation.

At the same time that product development has become more global (through partnerships with firms, consultants, research institutions in other countries) it has also become more local in the sense that it increasingly capitalizes on unique niches, design attributes, and capabilities that are found within its geographic region. Examples include processed food products with artistic container design and local histories that add value to the packaging and marketing of an item, or Scandinavian design elements of furniture products. In addition to creativity, product development increasingly embeds or otherwise uses knowledge into its offerings. Data mining of customer and competitor information and knowledge bases has become more central to product development, which has led to greater involvement of customer input in the design state and greater customization to user needs in the final product.

There are also increasingly linkages made between product innovation and softer organizational attributes. Whereas formerly product development was a separate functional implementation of management decisions, product innovation often calls for a change at the core of the firm itself in terms of its competitive strategy and business model. Product innovations also may call for organizational, service, logistical, knowledge management, and other forms of "soft" innovation across business in general (Tushman and Moore, 1988; Stewart, 1997; Wengel and Shapira 2004). Figure 1 illustrates this interrelationship between product, process, organizational, and service innovations, and illustrates the shift of focus of product innovation from a focus on physical products to also incorporating process, organizational, and service innovations.

Figure 1
Product Innovations in the Innovation Spectrum

INNOVATION FOCUS ↓	INNOVATION FORM: **Physical** (material, hard)	**Immaterial** (organizational, soft)
Process	**Process innovations** • Improved technologies in manufacturing process, use of informatic	**Organizational** • New production concepts, teamwor • Networking, chain - managemen
Product	**Product innovations** • R&D based innovations in new or improved	**Service** • Valu -added services to support

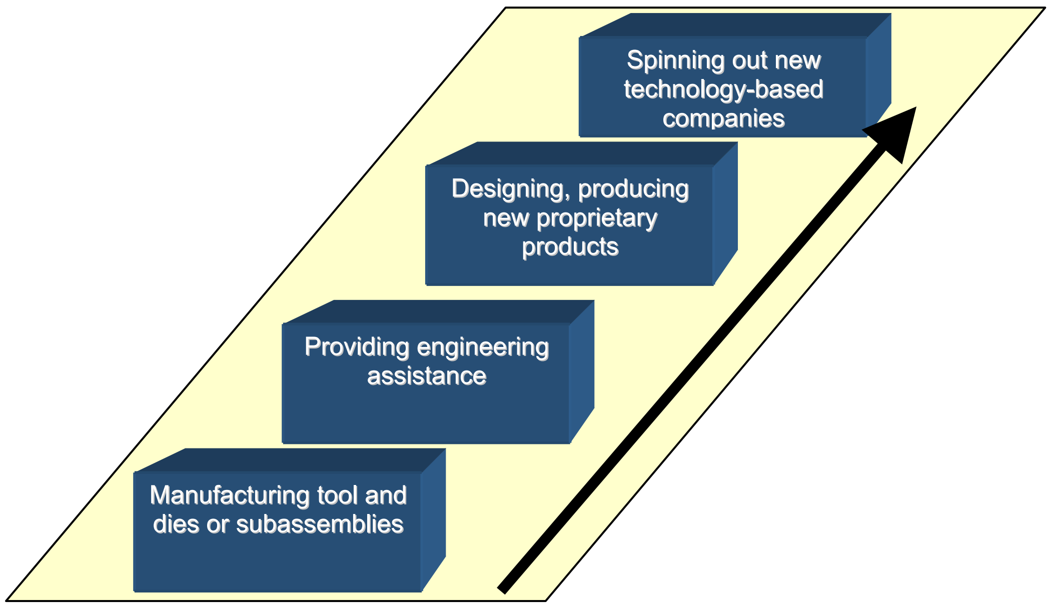
Source: Based on Wengel and Shapira (2004), "Machine Tools: The Remaking of a Traditional Sectoral System; and Wengel, et. al. (2000), Surveying Organisational Innovation on a European Level - Challenges and Options

Another trend in product innovation is to make the innovation process more systematic. Conventional innovation has followed an ad hoc route which may not be reproducible. The growing desire for more systematic product innovation processes has led to more codification and formalization of the experience to encourage learning and competence development in product innovation.

Several typologies have been developed for classification of product innovations. Pavitt (1984) originally distinguished among four general industrial sectors based on the technological and innovation trajectories they adopted. Supplier dominated firms, in traditional agricultural and textiles industries, were reckoned to be most influenced by suppliers of machinery, equipment, and other inputs. Scale intensive firms, found in bulk materials and automotive industries, used product and process innovations in tandem through incremental changes informed by, for example, internal engineering departments. Specialized suppliers were in high tech instruments, and machinery industries that focus on product innovation for use by other sectors. Science-based firms in chemical and pharmaceutical industries utilized internal R&D and relationships with academic researchers to develop product innovations and the new processes to make these products.

Oldsman and Heye (1998) identified a classification of increasing complexity through which a segment of machinery manufacturers might undertake innovation: (1) developing capacity to manufacture tooling and dies or produce subassemblies and final products, (2) employing new materials in existing products, (3) providing engineering assistance in product development efforts (which may also be considered value-added services), (4) designing and producing new proprietary products, and (5) spinning out new technology-based companies. (See Figure 2)

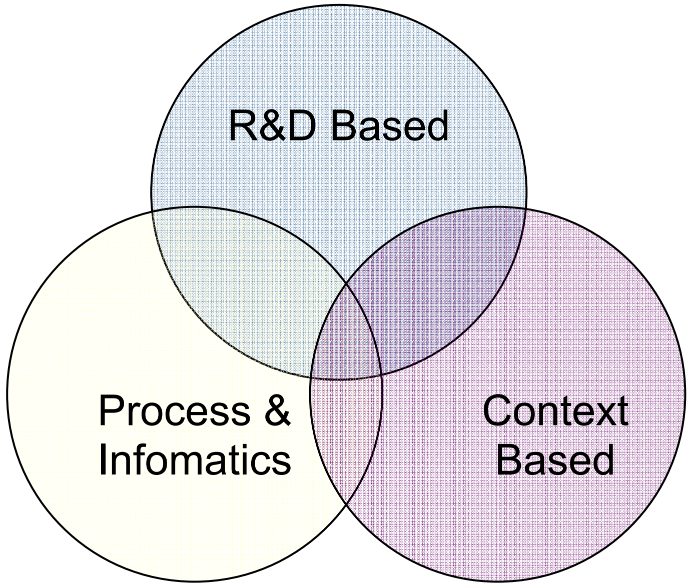
Figure 2
Product Innovation Staircase



Source: Oldsman and Heye (1998).

A further classification based on “drivers” was proposed by Shapira and Youtie (2005). Product innovation may be R&D-driven, such as new pharmaceuticals and devices formed as a result of experiments and testing in biotechnology and eventually nanotechnology. It may be oriented around supply chains and new information technologies for mass customization. And it may be context-based to leverage high value niches in areas such as specialized manufacturing parts, recreation and life style. Context based innovation may also capitalize on opportunities emerging from society as a “frontier” in the energy, sustainability and transportation areas. (See Figure 3)

Figure 3
Manufacturing Innovation Orientations



Source: Shapira and Youtie (2005).

B. Service Innovation

Conventionally, manufacturing and services have been perceived in opposition to one another. For example, the growth in service sector employment typically coincides with manufacturing employment declines. In actuality, the two have become intertwined through the offering of services that add value to manufacturing goods. Firms such as Xerox, General Electric, and General Motors have been engaged in leasing and financing services that compete with conventional service-sector lending institutions.[3] These are examples of how a new product can create an after market for services such as monitoring, training, finance. The goods are primary and the services are in a subordinate position (De Brentani 1989, Edvardsson 1990). The addition of the service makes the good innovative.

However, there are other instances in which an innovative service actually creates a market for a manufactured product. The classic example is iTunes. The rise of iTunes for music downloading resulted in demand for a manufactured good – Apple's iPod (Salkever, 2003; Economist 2004).

[3] M. Gallagher, et al., Measuring Service Sector R&D, U.S. National Institute of Standards and Technology, Gaithersburg, MD, March 2005, p. 2-9.

Value-added services from a manufacturing perspective are activities that support a manufactured product or component, such as training, software development, maintenance, manufacturing process consulting, or arrangement of financing. Innovation in value-added services can be conceived of, based on the OECD definition of service innovation, as new or significantly improved services. Again these services may be new to the company, market, or industry. For example, manufacturers sell equipment and provide training in how to use that equipment may be furnishing service innovation that is new-to-the company but not new-to-the-market. However, if the manufacturer improves curriculum or offers distance teaching through new technological avenues, these developments could be conceived of as being new or significantly improved services in the context of a wider market or industry.

Teleservice is one way that new-to-the-industry service innovation may be introduced. Under this model, Company A sells to Company B a machine which contains an embedded system that tracks performance and automatically indicates when the machine needs maintenance for example. There has also been an emergence of manufacturing firms that offer innovative services to reduce waste and environmental byproducts through consulting assistance (e.g., six sigma, material ordering, inventory tracking, maintenance, regulatory compliance) and the introduction of systems based on new non-chlorinated cleaning materials that have fewer negative impacts (Rothenberg 2005).

Innovation in services has been found to differ from innovation in products in several ways (Berry 2006; Djellal and Gallouj 2001; Gallouj and Weinstein 1997; Drejer 2004; Gadrey et al 1995). Innovation in services tends to be more collaborative and interactive. There is less distinction between product and process innovation in services than in manufacturing. Customers are often more involved in production in services than in manufacturing. Service innovation tends to be more ad hoc and less R&D intensive than in manufacturing. However, services often are more knowledge intensive, based on the expertise of the producer.

The biggest challenge in service innovation is to craft an appropriate business model that offers something of sufficient revenue-generating value and allows for customer choice. Manufacturers with distinctive expertise in offering innovative services linked to their production goods and appropriate marketing strategies can develop a new revenue stream from these offerings. One study compared the use of value-added service among manufacturers in the state of Georgia with those in Germany. Less than 40 percent of firms in Georgia offered value-added services to their customers, and of those offering such services, 63 percent did not charge for them. Value-added services accounted for 8 percent of total sales among those firms charging for them. Capital goods industries (metalworking, industrial machinery, transportation, electronics, electrical equipment, and instruments) were less likely to have sales coming from value-added services in Georgia than in Germany (Youtie et al., 2002). In addition, sometimes the packaging of services with goods causes negative customer reactions among those segments that want the option of purchasing the product without the service contract.

III. INNOVATION ATTRIBUTES OF SMES

Many of the innovation frameworks or models that have been developed fit the organizational structures and processes of large corporations. But established SMEs have distinctive innovation attributes that substantially color product and service offerings. First, SMEs are simply smaller. Large corporations typically have R&D, engineering, marketing, sales, finance, manufacturing, legal, and other departments engaged in the creation of new products and services. In the case of SMEs, it may be one or two individuals (e.g., the owner, a family member of the owner, or someone in engineering or sales) who are responsible for all product development functions. This co-occurrence of functions within a single person or small number of employees can make SMEs more flexible in responding quickly to product innovation than large corporations (which often have to deal with barriers between these functions). Still, the SME cannot specialize in the range of expertise areas that a large corporation can. The very size of the SME can limit the ability to absorb multiple sources of information and participate in cooperative arrangements with external public and private organizations.

In addition, many SMEs have unstable finances. Small firms typically have a high risk of going out of business, which can make it difficult for them to acquire financial support for new product innovation. Insecure financial circumstances compel more attention to short term cash flow considerations rather than long term innovation. One wrong move could put such a small firm out of business. Financial risk is often the most prominent barrier to innovation, according to surveys of manufacturers.

In addition, the typical SME often lacks diversity in products or markets (or both), and this can be a constraint on innovation. Many SMEs produce simple subcomponents or parts for less complex products. Others offer capabilities rather than parts of products. SMEs may work within a narrow geographic market (i.e., within their local region). They often are closely tied to a single sector or supply chain of a single big corporation. So their fortunes are dependent on these narrow markets and customers.

Finally, there can be low levels of demand for product and service innovation among SMEs because of strategic orientation. Some SMEs are simply not growth or improvement oriented. They are “lifestyle” companies that support personal needs and desires even as they fulfill an owners work life. Or, they can be SMEs where the owners are aging, and there is no succession plan, hence no willingness to take risks for a future generation.

Certainly these generalized capabilities attributed to the typical SME must be modified depending on firm size and industry. SMEs with a strong technological orientation offer important exceptions with respect to R&D absorptive capacity (Arnold, 1998). Mid-sized firms have been suggested to have relatively specialized internal capabilities. Important role models are offered elsewhere, for example the numerous “mittelstand” or medium-sized companies in Germany that succeed through world-class technology and quality in specifically-defined market niches and extensive exporting.

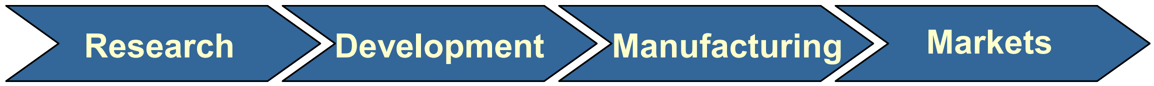
IV. INNOVATION MODELS

This section will present some of the main innovation models which have become known in the last several decades. The models will be presented in light of some of the major benefits and critiques that have been addressed to them, particularly those from the perspectives of SMEs.

A. Linear Innovation Model

The linear innovation model posits that discovery moves through various categories from research to development to production to sales in a sequential manner (see Figure 4). This model has been criticized for ignoring feedback loops throughout the process and for over-narrowly equating research and development with innovation. Public and private sector policies based around this model tend to fund research and hope that innovation will emerge at the other end. In addition, to the extent it still has value, this model is oriented toward the innovation activities of technology-based SMEs in scientific industries and does not take into account innovation in mature industries, particularly “soft” process and organizational innovation.

Figure 4
Linear Innovation Model



B. Staged Product Development

Staged product development is designed to move new products from conceptualization to introduction through a sequential process. The most well known of these staged product development models is Dr. Robert Cooper's Stage-Gate Process (and its reduced version for smaller manufacturers, ATOM-SME) (Cooper, 2001). Stage-Gate takes product ideas through a progression of steps that include discovery, scoping, building a business case, development, testing and validation, launch, and post-launch review (see Figure 5). Within these stages, systems and advances have been developed. For example:

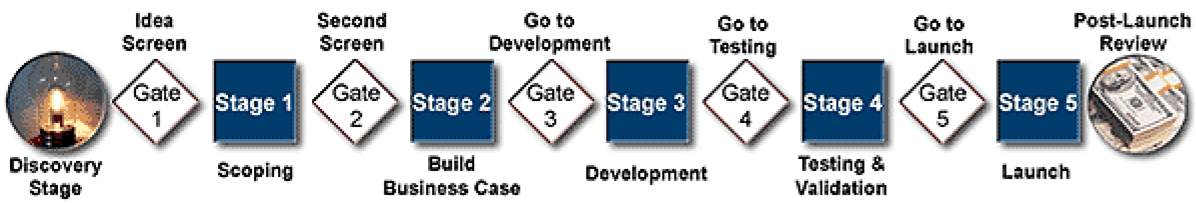
- Ideation: Various brainstorming and creativity techniques have emerged throughout the twentieth century. One process that has attracted attention is TRIZ (Theory of Solving Inventive Problems). The idea behind TRIZ is to dispel contradictions in ideas that solve a problem. Software packages have been developed to automate algorithms that bypass negative impacts of good ideas. A related process is systematic inventive thinking (SIT), which employs a 5-template method for the extension of existing products and services into new areas. The methods include subtraction of features, multiplication and alteration of components, division of products into component parts, task unification or bundling, attribute dependency change or the relationship between the product and its environment (Goldenberg et al., 2003).

- Business case: Many of the steps required to develop a business case require a substantial amount of information. Traditional approaches include net present value which assesses investments by discounting future cash flows into their present worth. Uses of "real option" methods have attained recent notice. Real options attach a value to investment decisions such that the benefits and risks can be gauged in a systematic way in the face of uncertainty.

A variation on the staged product development model is sequential product development where companies try to build new products based on their existing offerings which have complementarities in the manufacturing process. For example, a manufacturer may design another higher-value product using the same materials and machinery as in its existing mature product. This substitutability of a higher-value product for an existing mature one is subject to market demand and often requires some process-related changes.

The benefits of the staged product development process include a more standardized process for making decisions about new product ideas, increased customer input throughout product design and development, and minimization of the cost of failed introductions. The latter can be substantial in light of the high proportion of new products that fail. However many judge the process to be somewhat lengthy and overly complicated for SMEs, in that too much overhead and administration is required to proceed through the stages. In addition, the process has been criticized for its sequential nature. Staged processes are a better fit for firms that offer products rather than for branch facilities or process manufacturers.

Figure 5
Stage-Gate Process



Source: R. Cooper, 2001, Winning at New Products, http://www.prod-dev.com/stage-gate.shtml.

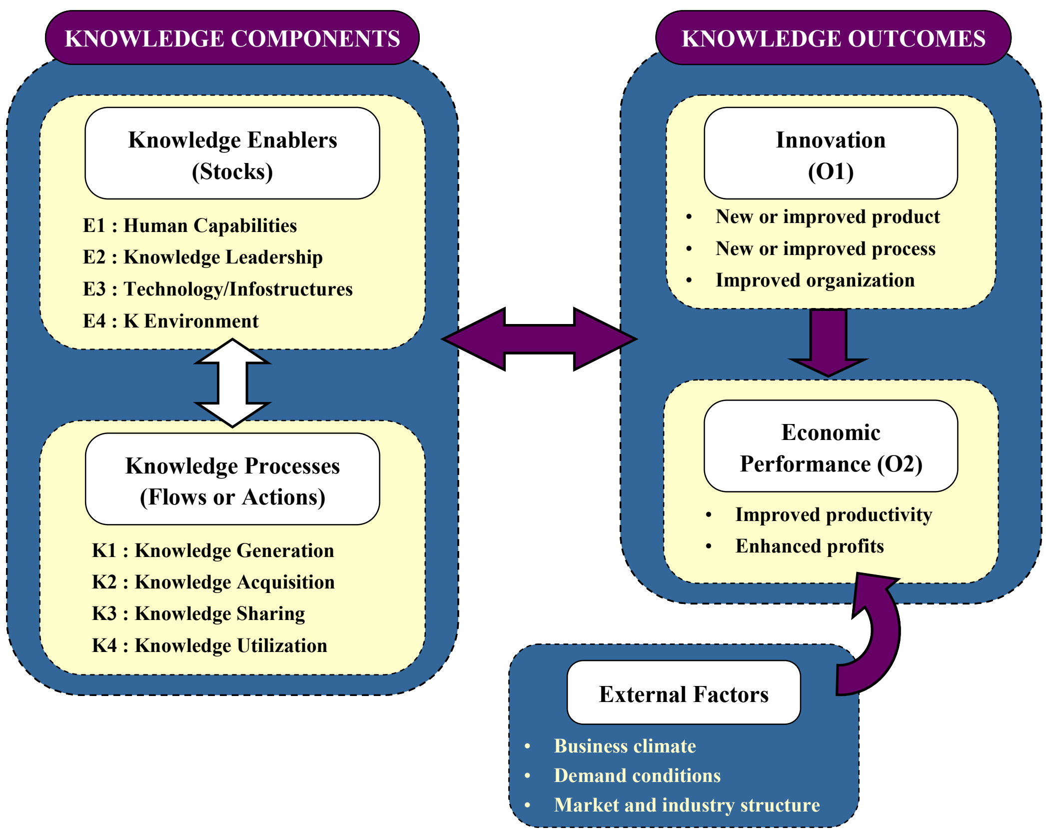
C. Knowledge Production and Content Models

The "knowledge production function" proposes that new knowledge outputs are dependent on R&D capital, labor and other inputs (Griliches, 1990, 1992). Various measures of "new knowledge" include citation weighted patents and new product announcements (see Griliches, 1990, 1992, for discussions of related efforts). This model is actually part of a system of econometric models that represent: (1) the relationship between new knowledge/innovation and productivity (the productivity equation), (2) the relationship between R&D capital and labor and new knowledge/innovation (the knowledge production function), and (3) the determinants of investment in R&D (the research investment function) (Crepon, Duguet, and Mairesse, 1998).

Shapira et al. (forthcoming) depict a knowledge content model which begins with knowledge enablers or stocks in human capabilities (e.g., training and education levels), leadership (e.g, top management's commitment to knowledge-driven efforts), technology/infostructures (e.g., information and communications technology), and external environment. Knowledge processes (flows) involve the generation of new knowledge through R&D or learning, the acquisition of internal and external information, the sharing of this information within and outside of the firm through organizational systems, and the utilization of this information in decision making. Outcomes include the application of new knowledge toward new or improved products, processes, services, and organizational approaches, which in turn is proposed to impact productivity (see Figure 6).

Existing levels of knowledge have been observed to be important in the ability of SMEs to be able retain absorptive capacity to adopt innovation (Cohen and Levinthal, 1990). In other words, a firm may need to invest internally and develop experience engaging in knowledge building and utilization activity to be able to create new products or services. The challenge of knowledge content models is that they imply the need for resources not directly devoted to production to ensure that there is sufficient internal capabilities.

Figure 6
Knowledge Content Model



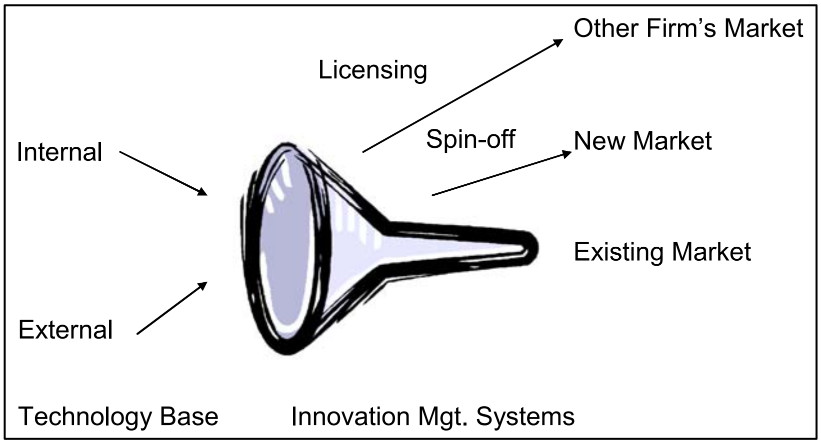
Source: Shapira et al (forthcoming).

D. Open Innovation

The lead idea behind open innovation is that strategies to keep all good ideas and innovations inside a single firm (even a large multinational corporation) will produce limited returns. No given company has a monopoly on good ideas. And any one company's own market will be too small to produce returns for all the innovations that are generated or acquired by the company. An open innovation system demands that firms look to a variety of external sources (e.g., private firms in complementary or competitive markets, trade associations, and university and government laboratories) for new ideas that can hasten their internal innovation. In addition, these firms should be willing to yield innovations they cannot fully exploit—e.g., orphan patents—to external firms and markets (Chesbrough, 2003). Procter & Gamble's *Connect + Develop* initiative has been cited as an example. This initiative fixed a quantitative goal of increasing the use of external sources (to account for 50 percent of the company's innovations), established a Director of External Innovation, and set up portals to address R&D and customer challenges by accessing the external capabilities of scientists, existing companies, and entrepreneurs across the globe (Huston and Sakkab, 2006). Another perspective on open innovation is that of von Hippel (2005), who highlights the role of developing and organizing lead users of existing or related products into a user-centered innovation system. Lead users may be developing significant innovation in the pursuit of customizing a manufacturer's products. users also tend to be closer to the market than their suppliers, giving users access to key information assets to call for innovations. Von Hippel proposes organizing lead user communities and providing platforms and resources to enable these users to have the tools they need to engage in innovation. Kelley (2000) discusses the importance of observing customers as they use the product to identifying innovations that can solve problems with it. On the side of expanding markets for internally developed innovations, the focus is on crafting of a business model that provides sufficient value for the innovator through licensing and spin-offs. The open innovation model also argues that different types of firms hold different positions in the value chain. Some will create new ideas, others will put them together, and still others will use them in novel ways.

The benefit of this model is that it takes into account limits in an SME's ability to generate and capitalize on its own innovations. Its encouragement of establishing connections with external product and service developers is an important precept for SMEs that tend to operate in isolation. However, most of the models of open innovation—such as those aspects that are dependent on intellectual property management—are oriented towards large corporations or small specialized technology-based firms. Although many of the principals of the model are applicable, the model may need to be modified to ensure value creation for the average SME. In addition, Chesborough and Teece (2002) note that open innovation based on virtual networks and alliance formation is not always appropriate for every effort and can cause late entry and loss of market position. Finally, it is important for firms to recognize that knowledge from customers or suppliers is available to a number of firms and hence may not create much of a competitive advantage.

Figure 7
Open Innovation Model



Source: J. West, (2005). Open Innovation in an R&D Environment. TechnoBusiness 2005 Proceedings, Atlanta, Georgia.

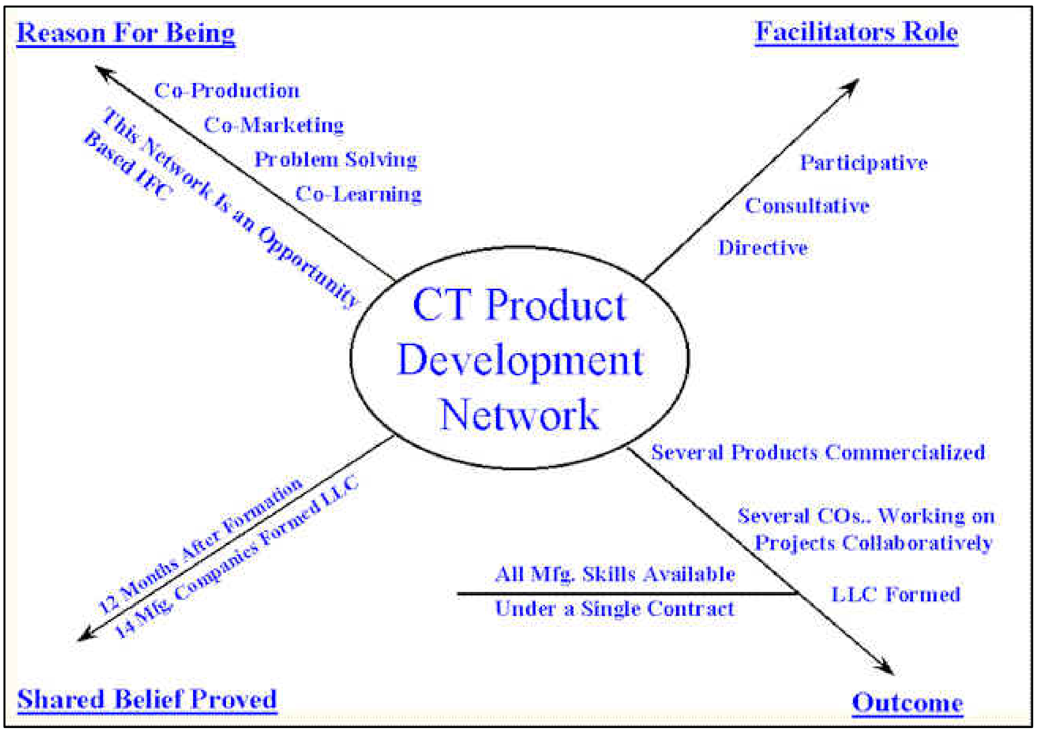
E. Institutionalized Network Innovation

Taking the inter-firm concept of open innovation to the next level is the inter-firm network organization for promotion of product and service innovation. Networks draw on cluster and agglomeration theories, which highlight the internal and external economies of scale and scope that can occur when firms locate in regional concentration with other firms. Researchers rediscovered clustering as they examined the allied and flexibly specialized textile industries in northern Italy (Piore and Sabel, 1984), broker-facilitated formal networks of Denmark (Indergaard, 1996), and the information technology industry in Silicon Valley (Saxenian, 1994). Similar is Michael Porter's Diamond of Competitive Advantage which identifies clusters based on four drivers of competitiveness: context for firm rivalry, input factor conditions, demand conditions (such as level of sophistication), and related and supporting industries (Porter, 1990).

Networks formalize the concept of clusters into membership-based organizations with common business goals. They can be particularly beneficial in development of non-incremental products because SMEs typically do not have all the resources necessary for the creation, production, and marketing of complex products. One example of product development networks is the Connecticut

Product Development Network of job shops seeking to develop their own proprietary products (see Figure 8). Another is the Center for Advanced FiberOptic Applications (CAFA) developed in the mid 1990s in Central Massachusetts to promote joint development of commercial photonics and fiber optics products through sharing of a laboratory facility and procurement of grants from NASA. A third is the Technology Coast Manufacturing & Engineering Network (TeCMEN) in Florida. TeCMEN started in 1988 as a network of several dozen machine shops that had good capabilities but no product. The idea behind TeCMEN was to exploit the combined manufacturing and engineering capabilities of TeCMEN members in the development of commercial products.

Figure 8
The Connecticut Product Development Network



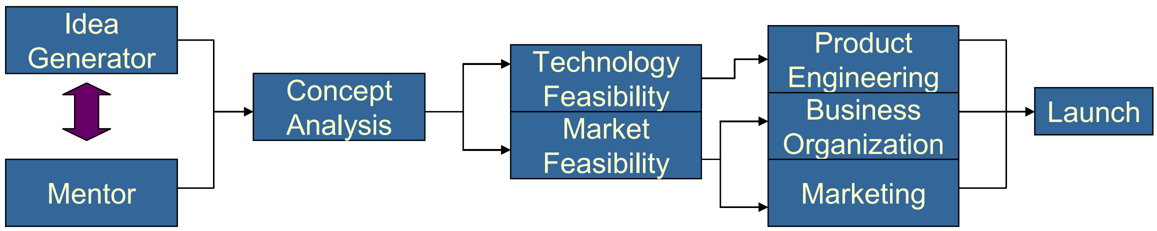
Source: A. Kendrix, 1997, May, Strategies for Promoting Inter-firm Collaboration, Seminar on Industrial Modernization: Policy, Practice, and Evaluation. Atlanta, Georgia: Georgia Institute of Technology.

Networks have been used throughout the Manufacturing Extension Partnership (MEP) system mostly to promote implementation of ISO principles and other process improvements. From 1994 to 1997, the MEP piloted a project called USNet to build capacity to promote inter-firm collaboration. Although the program was judged to be successful (Shapira, 1998) it is unclear that substantial follow on activities have occurred since that time. Administrative challenges in maintaining the network, ability to achieve measurable outcomes, timeliness in effecting actions and decisions, and issues in generating contractual agreements with network members are among the reasons that inter-firm networks have not become more widespread among US SMEs. In the product development area in particular, trust issues regarding competitive factors among the members can inhibit network formation and continuation; however, there are standard approaches to addressing such concerns.

F. Venture Management Model

The venture management model draws on the practices of venture capital firms, entrepreneurship programs, and technology incubators. Other terms for this approach are corporate entrepreneurship and intrapreneurship (see for example, Antoncic and Hisrich, 2003). The notion behind this model is that of entrepreneurship within an existing organization. Although its narrow definition refers to the creation of startup companies within a large corporation, the venture management model has been extended to any activity that represents a departure from existing processes, such as developing of new business strategies, products, processes, technologies, and the like. One example of the venture management model involves the linking of idea generators and experienced venture managers within the firm. Idea generators—be they scientists and engineers, or business process and marketing specialists — are paired with experienced mentors who help further develop the concept. These mentors draw on their mentors' "serial" experience, connections with knowledgeable sources about markets, and simulation capabilities to estimate value relative to risk and uncertainty. Mentors and idea generators may jointly develop product/service plans, address scalability issues, deal with intellectual property, develop preliminary budgets of resources requirements, and lay out time lines. One example: Whirlpool invested in a system of 600 internal I-mentors throughout the organization who have had particular training in how to assist innovation projects (Arndt, 2006). This method could be applied in SMEs, with the mentors being outside of the firm, much as is practiced in entrepreneurship programs. This approach overcomes the loss of good ideas that are not brought to fruition through its matching of experienced mentors with inventors. The challenge is to identify and encourage this capability within the local geographic region such that there is a sufficient pool with appropriate expertise bases.

Figure 9
Venture Management Model



Source: Taken from VentureLab Process, Atlanta, GA: Georgia Institute of Technology. May 15, 2004.

G. Hybrid Firm

The hybrid firm is a business model in which both products and services are offered. This model leverages the capabilities from the core manufactured offering as a platform for providing services. This model is prevalent among software firms that make proprietary packages and also offer information technology consulting services. While this model generates additional revenue streams, which can help the firm even out its financial cycles, it can be challenging if there is not a sufficient base of customers of the product. Bundling of products and services can cause negative as well as positive customer reactions for segments that prefer to purchase only the product. In addition, unbiased delivery of consulting services may actually call for fewer purchases of the core product, so new business and financial models have to be developed to compensate for this decline (Rothenberg, 2005).

H. Synthesis of Selected Models

This section has reviewed selected models of innovation. There is diversity in the models, particularly in level of application, for example, at the level of a product, a company, an industry, or a regional cluster. Each model has strengths and weaknesses, which are summarized in Table 2.

Table 2
Models of Product and Service Innovation

Model	Overview	Strengths	Weaknesses
Linear innovation models	Research leads to development, manufacturing, and product launch	Identifies general elements in engaging in research-based innovation	Ignores networked, interactive nature of innovation
Staged processes	Ideas are generated and screened for likelihood of business success	Introduces a planned process for innovation	Requires administrative overhead and appears too sequential
Knowledge production and content models	Knowledge is stimulated by human capital, leadership, technological investments, which in turn leads to innovation	Introduces the importance of knowledge to innovation	Requires a high degree of resources not directly devoted to production
Open innovation systems	Customers, suppliers, and other external organizations are important sources of information	Takes into account firm-level limitations for innovation	Everyone has access to open knowledge
Institutionalized networks	Firms organize in new organizational arrangements to develop new products	Diverse capabilities of individual firms can be leveraged	Difficult to implement because of trust, other issues
Venture management approaches	Idea generators are matched with experienced innovation managers	Addresses potential inability to implement ideas	Challenge is to identify mentor expertise
Hybrid firms	Product and service innovations are bundled	Generates diverse revenue streams from offering	Requires different business model from typical manufacturing approaches

V. CROSS CASE ANALYSIS OF US SMES

This document has defined product and service innovation, explored the special innovative aspects of SMEs, and depicted several existing innovation related models. We have undertaken an analysis of available case studies of established SME product and service innovators based on the framework summarized in Table 3. The framework includes an emphasis on firm characteristics and draws on the differences highlighted in the work of Pavitt and Arnold regarding innovation types and attributes and barriers to innovation faced by SMEs. We examine the types and intensity of product and service innovation (drawing on the hybrid firm model where appropriate) to capture the extent to which some of the trends and distinctions (e.g., radical vs. incremental) are being played out in the SME. As in the staged product development and venture management literature, we have depicted the processes these firms used to undertake innovation inasmuch as product and service innovation have implications for process, organizational, and marketing changes. The open innovation and network models guide us to include intellectual property, ties to competitors, lead users and customers, and ties to external sources of R&D. And the knowledge product function guides us to examine the existence of various types of outputs that can be expected from product and service innovation.

Table 3
Product and Service Case Analysis Framework

Firm, Industry, and Regional Characteristics	Primary products or services sold
	Industry the firm belongs to
	Year of establishment
	Ownership
	Number of employees
	Location and regional type (including if part of cluster or network)
	Access to capital, financial position (resources not directly devoted to production)
Type of Innovation	Product or Service
	New or significantly improved
	Product or service new to the firm
	Product or service new to market
	Service innovation in training/ consulting/ installation/ maintenance/ testing/ finance
Intensity of Innovation	Product lines/ division-level/ firm-level
	Isolated within plants/ across plants
Innovation Triggers	Change in leadership/ management
	Break-through idea/ Knowledge
	Competitive pressures
Innovation Processes	Any new or significantly improved manufacturing process or technology
	Integration of IT with manufacturing process
	Any new or significantly improved logistics, delivery, or distribution method
	Intellectual property strategy
	In-house R&D vs. purchased R&D
	Market research
Organizational Change	Change in management systems to better use information, knowledge and skills
	Change in organization of work/ structure
	Change in reward system

	Change in culture/ management focus
	Change in relations with other firms, such as alliances, partnerships etc
	Relationship with universities/ R&D centers
Innovation in Marketing	Significant change in design or packaging
	Significant change in sales methods or distribution channels
	Market segmentation/ niche products
	Entry into risky markets
	Entry into export markets
Impact of Innovation	Revenue growth
	Profit growth
	Exports
	Market share
	Productivity

This framework is applied to a set of cases of product and service innovators among SMEs in the United States. The criteria for inclusion of these cases are that the subject manufacturer is an SME, there is existing documentation of the innovation in the SME, and that we have distribution across mature as well as high technology sectors. In our cross-case analysis, we summarize the case based on the presence or absence of the variables in our framework. In addition, we will provide a two-page narrative summary of the case. It should be kept in mind that these cases are based on secondary information rather than new primary research. Much of the information comes from case studies that have been written by other researchers for other contexts, so the summaries may not capture the full range of innovation practices in these manufacturers.

A. Gage Products Company[4]

Gage Products is a manufacturer of specialty paints and chemical blends. Started in 1936 as a distributor of specialty chemicals for Shell, the Ferndale, Michigan-based, family-owned company evolved into a maker of combination chemical blends for automotive plant applications. However, when stringent environmental regulations threatened the survival of the chemicals products business, the innovative small manufacturer adapted quickly to the emerging market needs, added remanufacturing and refining operation and transitioned into a full-service paint system cleaning and management service provider. The firm's transformation began in 1987, although its newest innovation and service-oriented strategies have really paid off in the last six years.

[4] This case is based on information compiled from the following sources: *Selling Small and Smart: The Future of the Sustainable Enterprise*, By Sandra Rothenberg, A joint project of The Printing Industry Center at RIT and The International Motor Vehicle Program at MIT, Downloaded from http://print.rit.edu/pubs/picrm200401.pdf; and Company Website: http://www.gageproducts.com/

Gage currently has over 70 employees located in the U.S., Germany, the Netherlands, Mexico, and Brazil. The company now offers the following products and services:

- Purge-solvent remanufacturing – solvents used to clean paint systems between paint color changes are refined to remove paint solids so that the purified solvent can be recycled.
- Chemical supplies
- Calibration-test fuel formulation
- Paint system management and cleaning services – complete paint system management services for the client automotive plants leading to reduction in solvent use, reduction in cost and improvement in sustainable, environment-friendly application of chemicals.

Innovation at Gage

Innovations at Gage have been multi-pronged. First, in the early part of its life, the firm introduced many chemical blends for automotive paint applications. As the automobile paint system - the most important business segment for Gage – grew in complexity, the firm became increasingly engaged in consulting color changes, adoption of new paint technologies and equipment to its clients such as Chrysler, Ford etc.

However, introduction of Cobra – a new product for cleaning paint circulation systems in auto assembly lines truly accelerated innovation at Gage. Cobra was an innovation in the product space. However, the unique nature of this product innovation catalyzed major transformation in the firm's business model. Prior to the introduction of Cobra, most plants used methylene chloride to clean paint lines. But, for environmental reasons, plants needed to adopt a replacement for this heavily regulated material. Gage introduced Cobra as a non-chlorinated material that started mechanical cleaning of the lines as an industry practice. The product was new to the market, and needed certain technical expertise at the plants. Seizing the opportunity created by stringent environmental regulations and Chrysler's urgent need to improve the use of solvents, Gage changed its business model from purely selling solvents to providing consulting and technical assistance in implementing new solvents and cleaning systems. Gradually Gage moved up the value chain to provide complete paint system maintenance for plants resulting in cost savings, better paint selection and lower solvent use leading to reduced environmental footprints of their clients.

Apart from onsite consulting on paint maintenance systems, Gage developed a refining process to recycle millions of gallons of purge solvents which would otherwise end up in landfills. Today, Gage collects the purge solvents from clients, purifies in a large distillation system, and returns almost 70 percent of the purge solvent as clean reusable solvent to the plant. The byproduct is used as fuel for making cement. This process innovation in the form of recycling solvents has led to environmentally sustainable new products and applications, reduced cost and improved productivity at automobile plants.

In order to fully embrace these innovations, the firm had to fight resistance from inside and from the clients. Gage employees and plant employees had to be educated to relinquish age-old paint practices and adopt new techniques and products. Gage redefined basis for pricing and profits in contractual agreements. The company also changed the sales incentive system to focus away from volume of solvents sold to emphasize cost savings for the client in the paint shop.

Impacts of Innovation

Innovations in the form of new products and process have led to a complete transformation of the firm's business model. Gage is not looked at a chemical supplier, rather in the automobile and other client industries, the firm is perceived as a paint solutions provider. In some cases, the entire paint process is managed by Gage, including providing paints and solvents, onsite paint system cleaning and management, supply invoicing, environmental compliance in the paint shop etc. The new business model allowed gage to change its pricing structure from price-per-gallon to price-per-unit (for example the number of cars painted in the paint shop) basis. The overall impact for the firm has been that Gage has turned around its business, survival of which was threatened by stringent environmental regulations. The firm's 2004 revenues from products and services amounted to $35 million.

Insights from this Case

- External factors such as government regulations sometimes create the need for radical change in products and services and trigger innovations at small manufacturers who can adapt quickly to the changes.
- Introduction of a new product provides an opportunity to change the firm's business model.
- Process innovations not only enhance productivity, but can lead to new products. For example, refining of solvents by Gage not only allowed the retrieval of original solvents to the extent of 70 percent, but also led to the use of byproducts as a fuel for cement industry.
- Service innovations (new services such as consulting, technical assistance in product selection etc.) can lead to a growth and higher profits.

B. DeFeet International[5]

DeFeet is a specialized athletic apparel manufacturer with a focus on high-performance socks. The company was established in 1992 by Shane Cooper, a semipro racer and the son of a hosiery knitter and distributor, who imagined knitting socks in a radically different way. Based in Hildebran, NC in the foothills of the Blue Ridge Mountains, DeFeet supplies socks to some of the world's top athletes. While the textile industry in North Carolina has declined in the past decade owing to competitive pressures from low-cost textile producing countries, DeFeet has succeeded in identifying and exploiting a niche market that has contributed to high profitability and growth for the company.

DeFeet currently has over 80 employees designing and knitting a wide range of high performance and aesthetically attractive socks. While socks comprise the core of DeFeet's product portfolio, the company has recently extended its offerings to other athletic wear. The DeFeet brand now offers the following product lines:

- Socks – Industry leading products including LeviTAtor, AirEAtor, SpeeDe, Blaze and SkiD etc. providing higher endurance, better comfort through extra cushion and moisture management and longer life through high-quality fabric.
- Other athletic wear – Patented products including Arm and Knee Warmers, Gloves, Jerseys and Shorts, Bib shorts, and Shoe Covers.

Innovation at DeFeet

DeFeet was founded on the innovative idea of knitting socks differently from the traditional way. Yet, the change in manufacturing process was not the only factor behind the company's success. Innovation has been an integral part of all activities in the firm, starting from design, to sourcing and manufacturing to marketing.

First, by knitting socks inside out, i.e. putting cotton on the inside and nylon for strength on the outside, Shane provided a breakthrough in comfort for athletes that was unavailable in the market. Second, Shane added some features for cyclists, such as an airy mesh weave on the top and a super-tough fiber known as Cordura, typically used in backpacks, in the heel and toe. Addition of this new material increased the performance of the socks. In addition, DeFeet

[5] This case is based on information compiled from the following sources: *Still made in the U.S.A: As textile jobs bolt overseas, creative N.C. firms survive,* By Patti Bond, The Atlanta Journal-Constitution, 9/21/03. Downloaded from http://www.ajc.com/business/content/business/0903/21textiles.html; Economic Development Strategy, Vance County, North Carolina, Downloaded from http://www.gvdhd.org/download/Vance%20AppG%20Team%20Vance.pdf?477b38687198e386788c0b072618e51f=14d64eaa3ffb7f45f113e5ab6addc2b0; and Company Website: http://defeet.com/

orchestrated a series of marketing innovations to break the white-sock barrier. Through the use of flashy colors, and attention-grabbing graphics coupled with design names like "Kickin' Arse," "Beer" and "Godzilla," DeFeet caught the attention of the cycling circuit. Instead of reaching out to the mass market, DeFeet targeted the lead cyclists with custom made products. Once DeFeet was able to land on the feet of lead cyclists, it was able to change the perception of a wider base of customers. Started with the biking segment, the company has extended its sock line into other sports such as skiing with additional features such as winter protection or extra padding for cushion. Entirely new product lines such as gloves, shorts, jerseys and arm warmers have been added. To retain market leadership DeFeet has patented its innovations and has at least 4 U.S. patents assigned to its socks and arm warmers.

DeFeet has continuously sought inputs from lead users to further innovations. For example, the company enlisted the help of world champion Bode Miller to add design input and enhance the DeFeet line of ski socks. Bode continually uses DeFeet ski socks to the limit and provides decisive feedback. As the company expanded its market and evolved to be more creative, it established a mechanism to seek, compile and use end-users' inputs into the design process. The company's web site allows users to provide design inputs while ordering custom-made socks. As the DeFeet brand began to gain popularity, the company broke out of exclusive sales agreements with its retailers. Sales through retailers had been the traditional way of selling socks, but DeFeet started selling directly to its customers through its website. This innovation increased its profitability and combined with the custom-ordering provision, took the Defeet brand closer to the end users.

DeFeet serves the high-end of the sock market in the United States and abroad. To stay close to the market and its customers, DeFeet took a strategic decision not to relocate to China or Mexico or any other low-cost production region. Proximity to the cluster of yarn spinners that feeds the North Carolina hosiery industry helped DeFeet procure its input material quickly. Local sourcing in a specific niche segment has helped DeFeet reduce its response time and maintain high-quality of its end products.

Impacts of Innovation

Focusing on a small, specialized segment of the apparel market has not only insulated DeFeet from import pressures, but has allowed it to carve out a leadership position among its competitors. Starting with semi-pro racers in North Carolina, DeFeet's innovations have led its products to be widely adopted by lead athletes such as Lance Armstrong and Bode Miller. Focus on innovation has also resulted in higher profitability as the company is able to price its products significantly higher than competition ($10 - $30 per unit of socks and upto $120 per unit of warmers and bib shorts).

Insights from this Case

- Lead users inspire creativity and influence a firm's innovation behavior. The ability to seek inputs from lead users and quickly adapt products and services to meet their needs greatly affects innovation outcomes and market acceptance of those outcomes.
- Process innovations – e.g. a new way of knitting socks from the inside out – can lead to products that are completely new to the market.
- Innovative ways to let users participate in the design process (e.g. DeFeet's integration of end user inputs into the design of socks through the company's website) can expand and improve product ideas and accelerate innovation.
- Firm's leadership, particularly the CEO, can single-handedly shape organization's orientation toward innovation.

C. Capstone Turbine Corporation[6]

Capstone Turbine Corporation develops, manufactures, markets and services microturbine technology solutions for use in stationary distributed power generation applications. Established as a technology developer in Chatsworth, CA, Capstone added manufacturing to its functions in 1998 and became the first company to offer commercial power products utilizing microturbine technology. Capstone MicroTurbine™ systems generate electricity and heat from natural gas, methane, propane, diesel and kerosene as well as from unprocessed oilfield flare gas, landfill gas, 7-percent sour gas and other waste gases. In 2000 Capstone won a $10 million grant from the U.S. Department of Energy to develop higher-efficiency, next generation turbines. In the same year, the company won the prestigious Most Innovative Commercial Technology Development Award at the second annual Financial Times Energy Global Awards for its line of microturbine power systems. Capstone has also been profiled as a market leader in low-emissions power systems in INC Magazine's *Innovative 50.*

[6] This case is based on information compiled from the following sources: *Capstone Turbine Corporation Annual Report 2005*, Downloaded from http://media.corporate-ir.net/media_files/NSD/CPST/reports/AR2005.pdf; *Innovative Technology Inventory (ITI): Capstone Turbine Corporation*, EPA New England's Center for Environmental Industry and Technology (CEIT). Downloaded from http://www.epa.gov/NE/assistance/ceit_iti/tech_cos/capstone.html; *Capstone Turbine Wins "Most Innovative" Award at Financial Times Energy Global Energy Awards*, Downloaded from www.businesswire.com/webbox/bw.120100/203360340.htm; DOE Awards Capstone Turbine $3M to Develop Microturbine-Powered Cooling/Heating/Power Systems, July 12, 2001. Downloaded from http://www.businesswire.com/webbox/bw.071201/ 211930373.htm; and Company Website: http://www.microturbine.com/index.cfm

Operating out of its facilities in the Los Angeles area, the 225-employee company has marketing and service centers in New York, Mexico City, Milan, Shanghai and Tokyo. Capstone has shipped more than 3,200 Capstone MicroTurbine systems to customers worldwide and those systems have logged more than 11 million documented runtime operating hours in the following primary application areas:

- Hybrid electric vehicles (HEVs) with onboard generation
- Resource recovery applications including converting oilfield, landfill and sewage waste gases into electricity
- Micro-cogeneration including combined heat/power/chilling solutions (CHP/CCHP)
- Power reliability and remote power applications

Innovation at Capstone

Capstone's business model hinges on its impeccable record in generating intellectual property in microturbine technology. The fact that the company was established as an R&D center and added manufacturing to its core corporate functions later enables the company to retain a strong culture of research innovation eight years after stepping into manufacturing.

A key aspect of Capstone's approach to innovation is research and development in related technology for federal initiatives and agencies. For example, Capstone won a $10 million grant in 2000 from the U.S. Department of Energy to develop higher-efficiency, next generation turbines. A year later, the Department of Energy awarded a $3-million award to Capstone for the research, development and testing of packaged cooling, heating and power systems for buildings. Capstone has also collaborated with with FuelCell Energy for several years as part of a DOE grant program to support the design of an ultra-high efficiency, fuel cell/turbine hybrid power plant based on FuelCell Energy's DFC product. Earlier this year the company unveiled a newly operational fuel cell/microturbine hybrid energy system. The integrated system, a patented Direct FuelCell/Turbine® (DFC/T®) power plant has yielded a combined total electrical efficiency of 56% for 800 continuous hours during initial testing - nearly twice the fuel efficiency of the average fossil-fueled utility power plant.

Capstone's microturbines incorporate three major design features: advanced combustion technology; patented air-bearing technology; and digital power electronics. The company currently holds 86 domestic patents and 26 international patents in these and related technologies reflecting Capstone's innovation-centric organizational culture and structure. To accelerate technology development and commercialization, Capstone splits the engineers who are working on its products into four groups: a) Maintenance and reliability - to focus on the cost-reducing tasks relating to the existing-products group; b) Functionality – to create significant new versions of Capstone's primary technology platforms -- generators that burn various fuels; c) Product management - to concentrate on market research on which new-product designs might be feasible; and d) New-product development – to create wholly new technology platforms.

Emphasis on research and development has led to innovations in multiple aspects of the company's product offerings. For example, in current applications, exhaust heat from Capstone MicroTurbines has been used to supplement boilers, maintain proper greenhouse temperatures, and to heat water or air, mitigating the natural gas or other fuel otherwise needed to perform these heating tasks. The company has also extended its business model from only microturbine producer to installation, repair, engine overhauls and other services. In fiscal 2004 Capstone began its direct sales efforts in addition to selling through distributors and dealers.

Impacts of Innovation

Capstone is an example of a business based on radical innovation. Continuous R&D and generation of intellectual property has not only helped Capstone to be the market leader in a specific technology, but has also helped create a whole new industry (commercial microturbines). In 2005 the company's total revenues amounted to nearly $17 million, an increase of over 35 percent over 2004, although excessive sunk cost associated with research and development have limited the firm's ability to be profitable.

Insights from this Case

- Focus on R&D can lead to creation of a new market and establishment leadership position even by small manufacturers. R&D costs can be mitigated through government grant programs.
- Protection of intellectual property is an effective means to protecting one's market leadership, especially for small companies.
- Product innovation is successful when the organization's culture and structure are aligned with the firm's research and commercialization goals.
- Certain industries like alternative energy are evolving, and although small at this time, hold enormous growth potential for innovative manufacturers.

D. Asheboro Elastics Corporation[7]

Asheboro Elastics Corp. is a manufacturer of knitted and woven narrow fabrics for the apparel, home furnishings, healthcare and other industries. Established in 1986 by Keith Crisco with a small loan from the Small Business Administration and four working investors, Asheboro today is a global leader in narrow-band knitted elastics. Based in Asheboro, NC, AEC has warehouses in Mexico, Central America and the Caribbean but manufactures all its products in three plants within a 10-mile radius of its hometown. The company has grown steadily over the last 20 years and has been profitable every single year from inception. In 2003 AEC purchased the assets of the elastic division of Sommers Inc., and integrated the division's West Coast, Northeast and Miami, FL, operations under its umbrella. In 1992 Asheboro Elastics was named by the Inc magazine as one of the fastest growing privately-owned firm in the United States. In 2003 the company received the US Department of Commerce Export Achievement Award.

Asheboro Elastics currently has over 230 employees engaged in various activities in fabric production and packaging in three manufacturing facilities. The company produces narrow-band elastics for branded products. Asheboro has designed and manufactured over 4,000 types of elastic bands for name brand apparel producers such as Hanes, Fruit of the Loom, Oshkosh, Liz Claiborne, Lee Jeans, Healthtex etc. A major share of its sales is in the private labels.

Innovation at Asheboro Elastics

At AEC, there is a research department charged with product design and development activities. Headed by a Vice President, this department has led innovations both in product and process relating to elastic knitting. AEC has at least five patents to its credit in elastics technology. The company has invented a new product called the EZ Cord™, an elastic waistband with the drawstring built in so it doesn't disappear in the washer. Recently, AEC announced Ravlok™, a patented process designed to re-create the benefits of woven elastics in knitted elastics at less cost. With Ravlok™, knitted elastics can be created without top-edge raveling. AEC innovations have extended product life and matched the bulk and hand (feel) of knitted elastics to that of woven elastics.

Apart from its focus on research and development, AEC has invested continuously in modern equipment. "One reason that we're able to compete so

---

[7] This case is based on information compiled from the following sources: Statement for U.S. Senate Finance Committee by J. Keith Crisco, President of Asheboro Elastics on the benefits of the proposed DR-CAFTA Free Trade Agreement - April 13, 2005;
Quite a Stretch: Keith Crisco proves farm boys can become successful city slickers and stay true to their roots, By Kevin Brafford. Downloaded from http://www.nccbi.org/NCMagazine/2001/mag-08-01execprofile.htm; *Asheboro Elastics recognized for export success*. By J.D. Walker, Staff Writer, The Courier-Tribune, www.courier-tribune.com, 8/16/03; and Company Website: http://www.asheboroelastics.com/

well is that we've never bought a piece of old equipment," Crisco, AEC's Founder and President says. "When we started, we had machines that ran 900 RPMs. The ones we have now run 2,300 or 2,400 RPMs.

Asheboro Elastics has deployed both EDI- and Internet- based ordering systems. It also provides its customers a menu of options to customize their products. Custom products cover a wide range of thermal and mechanical specifications, strength, sewability, comfort and looks. A market innovation created by AEC is its ability to offer its customers a variety of packaging options. Depending on the customers manufacturing process needs, AEC provides its products as festooned, rolled or spooled so that the customer's sewing operation is optimized for efficiency. Another innovation that has given AEC a competitive edge is the launderability of its products. AEC elastic performs extremely well in home laundering and retains original appearance after repeated washings. It dries faster and eliminates the problem of dry garments with still-wet elastic bands.

In addition to the product features, AEC has been creative in minimizing cost of operation. Although not related to product or service innovation, AEC's direct involvement in healthcare provision to its employees to control healthcare costs is considered a major operational innovation directly affecting its profitability and growth.

Impacts of Innovation

In 2004, AEC shipped about half a billion yards of elastic fabric. The company now sells products in 20 countries, with international sales accounting for more than 30 percent of total sales. Fueled by strong export sales to apparel customers in Mexico, Dominican Republic and throughout the Caribbean Basin, AEC's sales have increased five-fold since 1990 when the company produced a little over 100 million yards of narrow band elastics. In 2000, it produced over 430 million yards of knitted elastic for textile, furniture and other industries generating sales exceeding $20 million. Sales increased by a further 15 percent in 2001.

Insights from this Case

- Service innovations – participatory design to assist customers in their product design – can lead to improved performance.
- Service innovations – changing the packaging of products to suit and optimize customers' manufacturing process - can lead to increased customer satisfaction and increased sales, especially for small manufacturers producing intermediate products.
- Process innovation is as important as quality of input material to generate high quality and performance of products.

- Investment technologies and modern equipment is critical for small firms to stay at the frontier of design and manufacturing trends.
- Firm's leadership can decisively steer the firm's culture toward innovation and efficiency.

E. Arizant Inc.[8]

Arizant is a medical devices manufacturer specializing in forced-air patient warming products such as warm-up blankets and gowns. Based in Eden Prairie, MN, Arizant was founded in 1987 as Augustine Medical by a practicing anesthesiologist Dr. Scott Augustine. The company underwent reorganization in 2003, following which it was renamed as Arizant and its ownership was transferred to Citigroup Venture Capital Equity Partners (CVC). Arizant's innovative technologies and path-breaking products have positioned the company as a market leader in patient care. Arizant has been profiled as a leading healthcare company in INC Magazine's *Innovative 50* and MIT Technology Review *Patent Scorecard*.

Arizant currently has over 300 employees and $70 million in annual revenue. It serves more than 80 percent of U.S. hospitals. The holding company Arizant Inc. has been organized into five companies including Arizant Healthcare Inc. – the main healthcare product division – and four marketing companies targeting export markets in Europe and other regions. Arizant Healthcare Arizant Healthcare develops and manufactures a complete line of temperature management products:

- Bair Hugger® Temperature Management including blankets, temperature management units and accessories. This range of products was the first in the forced-air products market.
- Ranger® Blood/Fluid Warming System that warms up fluid while instantaneously adapting to blood flow.
- Bair Paws® Patient Adjustable Warming System recognized as the world's first temperature-adjustable gown.

Innovation at Arizant

Arizant was founded on an innovative idea of forcing hot air around the patient's body in post-operative care. Since then innovation has been the hallmark of this company. The company invests approximately 8-10 percent of its revenue in

[8] This case is based on information compiled from the following sources: *The Innovation Factor: Inside the Idea Mill*, Inc. Magazine, Aug 2002, Leigh Buchanan; and *Arizant Healthcare: Corporate Story*, Downloaded from http://www.augustinemedical.com/arizant/pdf/corporate_story.pdf

research and development. Arizant holds over 110 patents and patent applications have risen sharply in recent years. For example, in the eight years before 1995, the company filed 27 U.S. patent applications whereas in the seven years from 1995 through 2001, the number of applications had increased to 129. The patent portfolio has become increasingly complex as researchers strive to maintain Arizant's leadership in forced-air products and related technologies. Apart from the formal process of invention disclosure and patenting, the company claims many breakthroughs in manufacturing processes. All product lines of Arizant are certified with ISO 9000 and ISO 13485.

The most important factor behind Arizant's success as an innovative company stems from the organizational culture set forth by the leadership. As the founder and former CEO Scott Augustine says, "innovation has been institutionalized" at Arizant. Innovation is not looked upon as a separate activity, but as a part of routine in all activities. The leadership puts high priority on creativity, not only in product development, but in all aspects of the corporation including sales, marketing and information technology. Employees are given ample flexibility to structure their work schedules, venues and styles. The senior management requires that employees "experiment" with ideas and discuss their ideas with the leadership at any time. Most of Arizant's innovations have been the products of in-house R&D. In the past few years, the firm has started seeking intellectual property from outside the company. However, the innovation partnerships are not substantial when it comes to the company's patent portfolio.

The company has a dedicated staff member who serves as the Director of Intellectual Property Management and is responsible for directing Arizant researchers to successfully patent their inventions. The firm hires researchers from a diverse set of fields. For example, the senior designer of the company is a former theatrical-prop builder. While computers are used for all tasks, designers are encouraged to use any machining tool they are comfortable with to produce innovative test products quickly. The company leadership believes that product experiments are less expensive in the research and development stage than in the marketing and selling phase. For example the Bair Paws gowns cost $10 million for development over three years, but the selling and marketing costs have exceeded $40 million in the three years after product launch. That is the rational supporting the company's encouragement of its employees to experiment and innovate until top quality products are ready for the market.

The company uses its corporate website, which is structured around its products to disseminate information to its customers. However, it relies on a sales force to sell its products to hospitals and healthcare service providers around the country and overseas.

Impacts of Innovation

With the introduction of its Bair Hugger range of products, Arizant can be credited for having started a completely new market within the patient care products industry. While information on revenues and profits by product line is not available, the $70 million company is believed to be profitable since its fourth year of existence. The company has continually expanded its market share within the United States through a range of products and accessories relating to three lines of products. Over 40 million patients have benefited from Arizant's products and Bair Hugger has remained the market leader in this field. The subsequent additions such as the Bair Paws gowns have proved not only new to the company but also new to the market. The company has now steered its attention to the European market and has started three subsidiary companies to sell its products in France, Germany, UK and other countries.

Insights From This Case

- Organizational culture is a key driver of innovation.
- Firm's leadership, particularly the CEO, can single-handedly shape organization's orientation toward innovation and inspire employees to be creative.
- Freedom to experiment with ideas leads to continuous innovation by employees.
- Close interaction with users shapes innovation early on.

F. Williams Pyro Inc.[9]

Williams-Pyro Inc. is a woman-owned small business that develops, manufactures and sells solutions to test weapons systems, monitor machinery and equipment and suppress stove top fires. Established in 1963 in the Fort Worth, Texas area, the company is an outcome of a 1998 merger of Williams Instruments and Pyro Control – both founded and run by Robert Williams and Della Williams. Founded on an innovative product idea to test weapons systems, today the firm's over 200 products cater to a variety of clients in the military, oil and gas exploration, energy, transportation and residential fire extinguishers industry. Apart from many competitive research grants and awards, the company has won many accolades from the private and the public sector, including the SBA Administrator's Award for Excellence, DSCR Automated Best Value System Gold Medal etc.

[9] This case is based on information compiled from the following sources: *Williams Pyro Inc.: Diversity Drives Success*, The University of Texas at Arlington. Downloaded from http://arri.uta.edu/marketing/companysuccesses/Williams.pdf; and Company Website: http://www.williams-pyro.com/

Williams-Pyro employed nearly 53 people in 2003, experiencing double digit growth since 1997 when the firm had 22 employees. Most of the firm's products fit into one of three categories:

- Weapon systems testing equipment including customized adaptors and sensors for military aircrafts.
- Geophysical products including *Measurement While Drilling* adapters, cabling systems, connectors and an igniter that allows 24 core samples to be taken at once.
- Fire safety devices including the *StoveTop FIRESTOP* device that is installed in millions of residential units.

Innovation at Williams Pyro

Innovation has remained at the core of the company's business proposition starting from inception. Both of the predecessors of the current company, Williams Instruments (1963) and Pyro Control (1972) were founded on two innovative product ideas – first a weapons test device and then the stove-top fire suppression device. Since the merger, the company has reorganized internally, further elevating the role of research and development and placing increased emphasis on technology commercialization. Today, almost one third of its employees are engaged in design, development and prototyping of new products. The R&D department has 16 engineers with advanced degrees organized into three teams: (1) Intelligent Sensing, (2) Wireless Communication, and (3) Condition- Based Monitoring and Maintenance. These teams integrate various technologies including wireless communication, ad-hoc networks, artificial intelligence, digital signal processing, field programmable gate arrays etc. to develop products in the areas of the firm's core competencies.

A key factor in the company's success in developing new products is its ability to leverage federal research dollars. Williams-Pyro has been very successful in getting research grants from various federal agencies, including the US Navy, NASA, the Department of Transportation, NSF and NIST through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. It first began submitting SBIR proposals in 1997 and won its first Phase I award at the end of 1999. Since then, the company has won 34 Phase I awards and converted 9 of them into Phase II awards. Federally funded and internally supported research has generated over 47 patents for Williams-Pyro. Based on this impressive suite of intellectual property, the company has rolled out many new products year after year. Currently, the firm has increased its attention to the commercialization of R&D through its partnerships with universities and big companies. Williams-Pyro researchers are collaborating with academic researchers from reputed universities including Georgia Tech, Texas Christian University, and University of Texas at Arlington, as well as with corporate partners including Texas Instruments, Boeing, Northrop Grumman, and Lockheed Martin.

Although R&D is key to the firm's innovation success, it is not the only factor behind its commercial success. The company has continuously invested in machining tools and design simulation software, leading to a full-scale, modern, machine shop and electrical assembly operation. The company is ISO 9001 certified and its business operation is run on an integrated ERP platform leading to efficient, on-time delivery of products and solutions. The company has adopted many marketing innovations and explored multiple distribution channels to establish brand identity to each product line. Williams-Pyro has also creatively leveraged Texas Department of Economic Development funds to retrain its workers.

Impacts of Innovation

Innovation-based strategy has clearly secured market leadership for this woman-owned small business in some specific product segments. By leveraging federal funds through research grants and by strategically commercializing intellectual property resulting from such research engagements, the firm has been able to have continuous cash flow even during adverse market conditions. While many small manufacturers in Texas were struggling to survive in the later half of 90s, Williams-Pyro doubled its revenue and more than doubled its profits between 1997 and 2002. The company has steadily added employees and strengthened its R&D department.

Insights from This Case

- Research and development-based business strategies yield product niche and market leadership in specific segments.
- Firms that can creatively leverage R&D funds from federal and state agencies as well as big private sector partners, succeed in maintaining continuous cash flows and being profitable even during adverse market conditions.
- Creative small firms leverage state funds (from economic development agencies) to improve their human resource capabilities through education and training critical for business transformation.
- Continuous investment in technological infrastructure that supports innovations is key to small firms' prosperity.
- Executive leadership (CEO/President) can influence the firm's culture of innovation.

G. Palomar Medical Technologies, Inc.[10]

Palomar Medical Technologies, Inc. is a researcher, developer and manufacturer of laser-based systems for hair removal and other cosmetic procedures. Based in Burlington, Massachusetts, Palomar started operation in 1991 to design, manufacture, market and sell light-based products and related disposable items and accessories for use in medical procedures. The company grew through acquisitions following its initial public offering in 1992. In 1997 the company, under a new management, exited from all non-core businesses and retained its focus on the use of laser systems in dermatology and cosmetic procedures. Palomar was the first company to obtain FDA clearance for high power diode laser system in 1997 and received FDA clearance for permanent hair reduction in 1998. Business Week ranked Palomar third in its 2006 100 Hot Technology Companies.

As of the end of 2005, Palomar had 188 employees and earned $65.8 million in total revenues. Currently, the company develops and manufactures a wide range of products based on proprietary technologies to cater to the following medical and cosmetic treatments:

- Hair removal
- Non-invasive treatment of facial and leg veins and other benign vascular lesions, such as rosacea, spider veins, port wine stains and hemangiomas and removal of benign pigmented lesions such as age and sun spots
- Tattoo removal
- Acne treatment
- Wrinkle removal
- Pseudofolliculitis Barbae or PFB treatment
- Treatment of red pigmentation in hypertrophic and keloid scars
- Treatment of verrucae, skin tags, seborrheic keratosis
- Deep tissue heating for relief of muscle and joint pain

Innovation at Palomar

Innovation is at the core of Palomar's leadership in its market and its great financial performance of recent years. Palomar pursues a three-pronged strategy to stay innovative – acquisition of smaller companies in related markets; contract research and development for both private and public sector clients in the U.S. and substantial investment in intellectual property creation and protection in

[10] This case is based on information compiled from the following sources: *Palomar Medical: Zapping away the signs of aging*, June 06, 2005, Downloaded from http://www.businessweek.com/magazine/content/05_23/b3936417.htm; Company Website http://www.palomarmedical.com/palomar.aspx?pgID=913; and Annual Report Downloaded from http://phx.corporate-ir.net/phoenix.zhtml?c=96490&p=irol-sec

critical markets. The first phase of the company's focus on innovation and growth centered on its ability to acquire smaller companies engaged in related fields. In more recent years, the company has focused on research and development of new technologies, including contract R&D for Massachusetts General Hospital, Gillette, Johnson and Johnson and the United States Department of Army. In 2004, Palomar was awarded a $2.5 million research contract by the United States Department of the Army to develop a light based self-treatment device for Pseudofolliculitis Barbae or PFB, commonly known as Razor Bumps. In the same year, it signed a license agreement with Johnson & Johnson Consumer Companies, Inc. to develop, clinically test and potentially commercialize home-use, light based devices for (i) reducing or reshaping body fat including cellulite; (ii) reducing appearance of skin aging; and (iii) reducing or preventing acne.

Palomar spent 17 percent of its 2005 revenues on research and development. It uses a variety of protection measures to safeguard its inventions including patents, trademarks, copyrights, and contractual restrictions. Palomar owns 14 U.S. and related foreign patents. The company is also a joint owner of three other U.S. patents and is the exclusive licensee of two U.S. patents and non-exclusive licensee of three other U.S. and related foreign patents.

In addition to its investment in IP creation and protection, Palomar succeeds in creating cost-effective, upgradeable product lines for consumers. These product lines are introduced to the market at regular and short intervals to outpace competition. For example, the first product with the Lux Platform - the EsteLux Pulsed Light System was introduced in 2001. In March 2003, Palomar introduced the higher priced MediLux Pulsed Light System with the same six hand pieces, but also with higher power, faster repetition rate and a new snap-on connector for faster changes between hand pieces. In October 2003, the lower cost NeoLux Pulsed Light System was introduced specifically targeting the beauty industry. In February 2004, the introduction of the StarLux Pulsed Light and Laser System was introduced with many technological advances such as increased power, a computer controlled touch screen, instant hand piece recognition, active contact cooling etc. Such rapid release of new product versions has expanded customer choices and expanded Palomar's market share.

Impacts of Innovation

A strong portfolio of patents and the rapid release of new product lines based on those patents have helped Palomar gain market share in the hair removal market. Palomar pioneered the laser-based hair removal system and successfully expanded its product portfolio into other dermatological procedures. The results of Palomar's product innovations are visible in its financial performance in the last few years. Between 2001 and 2005, this publicly held company's total revenues have increased from $16.6 million to $76.1 million. During the same period, its profits have increased substantially, rising from a net loss of over $5 million in 2001 to a net profit of $17.4 million. Exports generated nearly 30 percent of Palomar's total sales in 2005.

Insights from This Case

- Leveraging private and public R&D funds through contract R&D and joint R&D projects can lead to substantial pay-off for small companies.
- Rapid release of product variants and shorter research-to-market cycles can establish and help retain market position.
- Technological innovations can not only expand markets, but also create completely new markets in which competition is minimal or absent.

H. Miken Sports[11]

Miken Sports is a Caledonia, MN based manufacturer of composite bats made from petroleum-based resins. Founded in 1997, Miken was one of the first companies to introduce a significant improvement over traditional aluminum bats for baseball and softball. Competing against some of the big brand names in its market, this small and innovative company has carved out a strong and fast-growing niche for itself at the top end of the markets for composite bats used in little league, high school, and college baseball and in all levels of slow-pitch and fast-pitch softball.

Miken, was founded by Jeb Griffith, a serial innovator, and grew from a just a few employees to over 60 employees in 2004. It became part of the Carlsbad, CA-based sporting goods company K2 Inc. in 2004 when its sales reached around $12 million. In the following years, the company saw increased demand for its products and has expanded its workforce to over 100 employees. Last year, Miken produced 20 different bat models for various markets, with each model available in between three and five various sizes. The bats, which are sold in Dick's Sporting Goods, other chains and independent dealer outlets across the country, are typically priced near the top of the range for any given market.

Innovation at Miken

Miken's core product suite is based on an innovation that has been preserved by the company as a trade secret. In its 15,000-square-foot facility, bats are made

[11] This case is based on information compiled from the following sources: *Hitting the Sweet Spot: Manufacturing in Action*, Feb 08, 2006. Downloaded from http://www.themanufacturer.com/us/detail.html?contents_id=4039; *Miken Sports sold*, By David Heiller, Argus News Editor. Downloaded from http://www.hometownargus.com/2004/november/16miken.html; and Company Website: http://www.mikensports.com/

through a resin-transfer molding and pressing process that uses heat and pressure to combine a carbon fiber material with a two-part injected resin. The raw bats then undergo a number of finishing processes, including inspections, sanding to smooth the exterior, trimming to meet the right weight and the addition of painting and decals. Each bat is carefully inspected and tested to ensure the highest quality. Inside the production process, Miken tries to leverage its small-firm approach to allow for maximum efficiency and growth. It also eschews many standard metrics for judging manufacturing efficiency and progress in favor of its own “common sense” approach.

According to the senior management of the company, the firm’s primary sources of manufacturing innovation are its employees. The company relies on continuous improvement and small, incremental innovations to streamline its manufacturing process and to come up with new product ideas. The management has instilled a culture that encourages both formal and informal communications and cross-training of employees. Cross-training helps each employee see where his or her job fits in the entire production process and identify potential process improvements that may affect the entire production value chain. An interesting result of this people-based innovation approach is that although Miken is known for the highest quality composite bats in the market, it has no quality department to impose quality standards. Each production employee is a quality inspector on his or her own.

The “small company” culture and approach to learning, experimenting and knowledge sharing has kept the stream of innovation flowing for this small manufacturer. As the workforce learns from the manufacturing operation, it has been able to design a set of proprietary engineering and production processes that is expected to drive its operations in the future.

Impacts of Innovation

Continuous innovation has been the hallmark of this small sporting goods manufacturer from the beginning. Its original market-shaping product – composite bats – established a specialty market in the early days even though other firms had attempted and failed at similar efforts earlier. Since then, innovations have led to 20 different models that cater to a wide range of baseball and softball players. Demand for its products has grown substantially in recent years. Miken experienced 37% growth in sales between 2004 and 2005. Its products sell at the top end of the price range of bats in any market segment, making it a highly profitable venture. Higher profits and sales growth has enabled the company to expand its workforce rapidly.

Insights from This Case

- Small company approach to learning and knowledge sharing can generate a continuous stream of improvements which unltimately leads to product and process innovations.
- Cross-training of employees not only offers production-line flexibility, but also helps each employee see how his or her job fits into the entire production cycle. This makes participation of each employee in the innovation process smooth and easy.
- Trade secrets are powerful ways to safeguard intellectual property for small companies and can lead to rapid business growth if applied to production appropriately.

I. Cross case analysis

The cases selected for this analysis represent a wide range of manufacturing sub-sectors. It must be noted that this analysis is a secondary analysis of published cases and no significant new research has been done on these companies. Therefore, application of the aforementioned cross-case analysis framework to these cases was limited by the inconsistency of reported qualitative and quantitative indicators of practices and performances of these companies. Nonetheless, the cross-case analysis revealed a set of striking trends in the innovation orientation and practices of small and medium manufacturers.

All of the companies included in this study reported innovations leading to products that were new to the company. Two of the cases reported having introduced service innovation in the form of participatory design or new packaging to speed up customers' manufacturing activities. In the case of Gage Products, service innovations included value-added consulting and technical assistance to its customers.

A majority of the small companies studied reported innovations that were not only new to the firm, but also new to the market. Innovations reported by most of the companies were cross-cutting and at the firm-level. These innovations cut across all production facilities and product lines. As can be seen from the following table, most of the innovations reported in these cases were triggered by a breakthrough idea, often arising out of the deep technical knowledge and understanding of the product and the markets. In the case of Williams Pyro, a change in senior management led to the unleashing of a strong innovation appetite for the employees.

These cases show that small and medium manufacturers have a reasonable success in orchestrating innovation through the integration of information technology into production and strong market research. With regard to their innovation processes, small manufacturers studied here reported having a firm-level strategy to create, nurture and protect intellectual property. Most small firms conducted R&D in-house, sometimes leading to patents on which future products or product lines were based.

Table 4a
Cross-case analysis by Innovation Type, Intensity, Triggers, and Processes

Type of Innovation	
Variables	**# of Cases Reporting**
Product or Service	Product - 8; Service - 2
New or significantly improved	New - 7; Improved - 1
Product or service new to the firm	8
Product or service new to market	6
Service innovation in training/ consulting/ installation/ maintenance/ testing/ finance	2
Intensity of Innovation	
Variables	**# of cases reporting**
Product lines/ division-level/ firm-level Isolated within plants/ across plants	Firm-level - 8 Across plants - 8
Innovation Triggers	
Variables	**# of cases reporting**
Change in leadership/ management	1
Breakthrough idea/ knowledge	6
Competitive pressures	2

Innovation Processes	
Variables	**# of cases reporting**
Any new or significantly improved manufacturing process or technology	4
Integration of IT with manufacturing process	6
Any new or significantly improved logistics, delivery, or distribution method	4
Intellectual property strategy	6
In-house R&D vs. purchased R&D	In-house – 7
Market research	6

The cross-case analysis framework emphasized two dimensions of the innovation process: organizational change initiating and sustaining innovations in those firms. With respect to organizational change, four out of the eight companies studies reported change in culture/ management focus and change in relations with other firms, such as alliances, partnerships etc were critical to innovation. Change in management systems to better use information, knowledge and skills, change in organization of work/ structure, and change in the reward system also affect the innovation orientations and outcomes of SMEs.

Almost all the small firms had niche products that helped them develop market leadership in a specific segment of the market. Product and/or service innovations also helped small manufacturers penetrate export markets. Given the level of investments required to create the reported innovations, some small companies stepped into risky markets and succeeded.

Table 4b
Cross-case analysis by Organizational and Marketing Changes

Organizational Change	
Variables	**# of cases reporting**
Change in management systems to better use information, knowledge and skills	2
Change in organization of work/ structure	2
Change in reward system	2
Change in culture/ management focus	4

Organizational Change	
Variables	**# of cases reporting**
Change in relations with other firms, such as alliances, partnerships etc	4
Relationship with universities/ R&D centers	1
Innovation in Marketing	
Variables	**# of cases reporting**
Significant change in design or packaging	2
Significant change in sales methods or distribution channels	2
Market segmentation/ niche products	7
Entry into risky markets	3
Entry into export markets	4

Innovations reported by the companies led to significant revenue growth for most of the small and medium manufacturers. Although quantitative indicators were not always available, there is qualitative evidence that most of these firms had significant growth in profits due to the reported innovations. Innovations also led to increase in market share for these companies.

Table 4c
Cross-case analysis by Innovation Impacts

Impact of Innovation	
Variables	**# of cases reporting**
Revenue growth	7
Profit growth	6
Exports	4
Market share	6
Productivity	n/a

VI. INTERNATIONAL PERSPECTIVES ON INNOVATION THROUGH THE COMMUNITY OF INNOVATION SURVEYS

Widespread international attention has been given to creating new information sources about firm-level innovation practices. Although such a knowledge source does not exist across the United States, more than 50 countries do collect this information through the Community of Innovation surveys (CIS)[12].

The CIS has a two-fold purpose: (1) to monitor the level of innovation within private sector firms and (2) to provide a statistical basis for innovation policy. The methodological basis for the CIS surveys is the Oslo Manual, which was developed by the OECD in 1992. The first round of CIS (CIS1) was reported in 1993 based on data from the 1990-1992 time period. CIS1 was conducted by 13 European countries (*Belgium*, *Denmark*, *France*, *Germany*, *Greece*, *Ireland*, *Italy*, *Luxembourg*, *Norway*, *Portugal*, *Spain*, *Netherlands* and the *United Kingdom*). The second round of CIS (CIS2) was reported in 1997 on information gathered in the 1994 to 1996 time period, and included four additional European countries (*Austria*, *Iceland*, *Finland* and *Sweden*). The third round of CIS (CIS3) was conducted between 2001 and 2002. CIS4 is currently in process.

CIS surveys are administered by the statistical offices or competent research institutes in the Member States. Some countries make the survey compulsory; others allow firms to complete it voluntarily. This results in a wide range of survey response rates between countries. The results of the surveys are analyzed at the national level using a common methodology and country level comparisons are assessed by Eurostat. Data gathering and analysis has been funded primarily by the European Commission (executive branch of the European Union), with the Member States contributing to at least 10 percent of the total cost.

The earliest CIS surveys focused on questions about *science and technology activities* (R&D, design engineering, tooling and engineering, manufacturing, marketing). In addition, there was a strong focus on manufacturers in these surveys. Later surveys have moved towards questions about *innovation-systems* and include service as well as manufacturing establishments. These more recent CIS surveys are meant to contribute to a better understanding of non-technical aspects of innovation, such as management techniques, organizational change, and design and marketing issues. For example, CIS3 includes questions about collaboration and cooperation. Hence CIS3 is a longer questionnaire than

[12] For more information or more studies see "Empirical Studies and the Community Innovation Survey (CIS)" at http://cordis.europa.eu/eims/src/stud-3.htm.

previous versions. CIS3 also includes a larger range of small firms with 10 or more employees, whereas the size limitation in the previous surveys was 20 employees.

CIS collects data at the establishment level. CIS1 represented responses from 40,817 firms in 13 countries. CIS2 surveyed 11,667 service firms and 27,102 manufacturing firms in 17 countries. CIS 3 surveyed 64,000 firms in 17 countries. It can be difficult to make comparisons between countries. Even though the same survey questions are used, different sampling and statistical methodologies are used by each country (compulsory vs. voluntary response, for example). Despite these limitations, comparisons are performed by The European Union Commission, in its publication “European Innovation Scorecard.”

Innovation surveys have provided valuable information, though they have also been subject to critiques. First the early innovation surveys did not differentiate between innovations that are new to the firm, the country, and the globe. In analysis, they have been lumped together as just “innovation”, regardless of the potential impact. In addition, innovation surveys typically make a distinction between product and process innovation, which may be appropriate for technological innovation, but not for the increasing blurring of product and process found in the bundling of value-added services around manufactured products. Second, innovation surveys have placed too much emphasis on high-technology practices and capital investments that may not be as readily adapted by mature industries. This emphasis on “hard” practices sometimes overlooks important soft organizational processes dynamics, relationships and interactions (although later versions of CIS aim to incorporate more soft topics into the survey). On the other hand, capital investments are not always an indicator of innovation, but rather of business-as-usual. Third, the establishment is the unit of analysis so some innovative activities between firms are not captured. In addition, it can be helpful to look at non-innovative behaviors and failures, not just innovators and winners, the latter of which are emphasized in innovation surveys. Innovation surveys may not reflect the practices of the full facility because only one person (usually the senior manager) completes the questionnaire. A further issue related to the emphasis on the establishment is that establishments operate in the context of a regional innovation system, but insufficient regional information is captured to examine this context. (Salazar and Holbrook, 2003)

Numerous statistics analyses of the factors that lead to innovation and the role of innovation in generating business performance have been published. Appendix 1 summarizes these studies. Some of the findings of these studies are:

- Many of the studies focus on the percentage of sales from new to the market goods and services, which assumes a relationship between the share of sales from innovation and competitiveness (Loof and Heshmati, 2002; Roper et al, 2002)
- Product and process innovation are associated with different factors (Arundel and Kabla, 1998). Product innovation is more likely to be associated with a set of non-capital intensive factors than process innovation, which is more likely to be associated with a set of capital-intensive factors. (Rouvinen, 2002; Blind and Hipp, 2003)
- Organizational innovations are as important as adoption of technologies. In particular innovation is not achieved in isolation.

    - Internal R&D is positively associated with innovation (Mairesse and Mohnen, 2001)
    - External and internal information sources are important in stimulating innovation Belderbos, Carree and Lokshin, 2004)
    - Collaborative relationships such as on R&D is important in stimulating innovation (Amara, Landry, and Ouimet 2003; Tether 2002)

- Business strategy is an important determinant of the introduction of product, process, organizational, and marketing innovations. (Youtie and Shapira 2006)
- Size sometimes has non-linear inverted “U” relationships with innovation. (Kaiser, 2001)
- It is mixed whether innovation is related to industry sector (some studies find that to be the case; others do not) (Bartoloni and Baussola 2001; Evangelista 1997)
- Although firm characteristics have a greater impact on firm-level innovation than regional ones, a region’s R&D levels are an important determinant of firm-level innovation (Sternberg and Arndt, 2001)

To the best of our knowledge, the only innovation survey that has been conducted with some consistency in the United States is the Georgia Manufacturing Survey. Since 1999, Georgia Tech in partnership with the Georgia MEP has conducted an innovation survey every two-to-three years as part of its Georgia Manufacturing Survey. Surveys of manufacturers are not new to the United States, but most of them at the state level are focused on economic development concerns such as whether the manufacturer plans to expand its facility, which often does not coincide with the actual practice of a manufacturer. National surveys done through the Census Bureau and NSF may incorporate one element of innovation (such as R&D expenditures) but they do not include benchmark questions from CIS that measure the full innovation enterprise, which is important since it has been found that innovation often has much to do with non-R&D "soft" practices. The aim of the Georgia Manufacturing Survey has been to understand business and technological conditions of the state's manufacturing base. The survey goes to all identifiable manufacturers with 10 or more employees. Respondents receive a customized benchmark report that compares their answers to those of the top manufacturers in their industry and size classification on selected metrics (they also receive a summary of the survey results). The survey Web site is www.cherry.gatech.edu/survey.

Many of the questions in the Georgia Manufacturing Survey are designed and worded to enable benchmarking of results with the CIS. In some cases, special collaborations were developed to enable direct comparisons with survey results. For example, a benchmarking effort conducted with an innovation survey administered in Germany in 1999 found that Georgia firms in capital goods industries held an early lead over German firms concerning the adoption of teamwork in production, but by the end of the 1990s, German firms had completely closed the gap. (Youtie, Shapira, and Oh, 2001)

Several insights about innovation have emerged from this survey. For example, only 8 percent of Georgia manufacturers compete primarily through innovation, compared to 20 percent that compete through offering low prices. However, profit rates (which declined between 2002 and 2005) dropped much more sharply for manufacturers that prioritized low price strategies compared to those that compete primarily through innovation. Moreover, manufacturers that competed primarily through innovation were much less apt to be impacted by outsourcing than are those competing primarily through low price. Innovation strategies were also found to be associated with the introduction of new-to-the-market products, significant organizational changes, widespread use of technologies in the workforce, and highly skilled and educated employees.

These results have been used as a basis for changes within the Georgia MEP. The parent organization for the Georgia MEP has switched its name to reflect a greater orientation toward innovation (the new name is the Enterprise Innovation Institute). Additional resources have been reallocated to creating a market and product development skill base. Efforts are being explored to link lean manufacturing to the firm's innovation capability. And the Georgia MEP is in the process of developing a one-day training offering in innovation.

VII. CONCLUSIONS AND RECOMMENDATIONS

Based on the interrelationships between product and service innovation discussed in this report, we conclude that innovation is not just about manufacturing a product anymore. Attention must be paid to the service element as well. In addition, it is noted that the nature of product and service innovation is evolving to reflect greater speed, interactivity throughout the process, and increasingly involves softer organizational and knowledge-based capabilities as well as hard technological issues. Consideration should be given to these changes in assistance service design and offering.

Based on the literature and case studies profiled in this report, we suggest that there are guiding principles for the MEP manufacturing specialist working with companies on product and service innovation.

- Every firm should have a strategic orientation toward innovation to ensure long-term survival in the global economy.

- Innovation does not need to occur in an ad hoc manner. SMEs may move toward planned processes that encourage innovation.

- Look to various sources of information for ideas—inside and outside the company, locally and across the globe. One source of innovation is direct observation of how current, potential, or “expert” customers use or could use the product. Particular notice should be made of solutions to problems that customers may have with the product or with components, parts, or processes linked to the product. Similarly with suppliers. Manufacturers have reported success with hosting groups of customers or suppliers to provide input for future product and service innovations.

- For SMEs that do not offer products or manufacture relatively low-cost goods, consideration should go toward how the capability or part can be moved up the value chain and become more complex or more integrated into the core technology of the end product. Creating a network of firms with different capabilities can help with the development of new products as a single enterprise may not possess all the necessary resources and expertise.

- Innovation in product and service will inevitably require “soft” changes to organization. For example, attention should be paid to the role of human resources in the encouragement and fostering of innovation. New ideas often come from new hires with expertise in other industries. In addition, it can be important to pair the internal innovator with a process manager that has a track record of successful new idea introductions to move the innovation forward; the venture world has found that inventors do not always make the best business managers.

- New sources of innovation can be found in developments in informatics, in R&D-intensive areas such as nanotechnology, and in high value niches in recreation, lifestyle, societal issues such as energy.

- Innovation can involve the need for resources not directly devoted to production to finance it and the development or acquisition of new administrative capabilities such as intellectual property management or risk analysis. Emphasis should be placed on mitigation of these costs through government grants and programs (e.g., SBIR awards), university partnerships, state R&D programs, ventures with suppliers or customers, and industry consortia.

Policy considerations suggest that not enough manufacturers innovate. Moreover, the various systems involved in innovation (such as training, finance, research, intellectual property management, business processes) are not well connected. MEP is crucial to helping existing SMEs deal with these challenges. However, its traditional focus on working with firms individually and delivering services that produce short-term cost savings is useful but not strategic enough to change the appetite for product and service innovation in SMEs. A case in point is found in statistics from the Georgia MEP in the 2001 to 2003 time period, which showed that product development and marketing were most apt to generate sales and jobs impacts, yet most of the center's services were in lean process and quality. (See Table 5).

Table 5
Surveyed Manufacturing Customers in Georgia Reporting Sales Increases or New Jobs Created Relative to All Customers by Type of MEP Service Provided Group

Type of Service*	(a) % of surveyed customers receiving this type of service who reported sales increases or new jobs created*	(b) % of all customers receiving this service	Ratio of (a) to (b)
Product development/marketing	18.8%	9.0%	**2.09**
IT	18.8%	13.3%	1.41
Quality	39.6%	35.3%	1.12
Lean/process	31.3%	37.6%	0.83
Energy	8.3%	17.9%	0.46

*Type of service refers to MEP substance area. These percentages do not add to 100% down the columns because there can be multiple activities and substance areas per project.
Source: NIST MEP Company Surveys, 2001 and the first quarter of 2002, and Georgia MEP Activity Data Logs, 2001, 2002, first six months of 2003

MEP should be extended to be effective in encouraging an appetite for innovation at all levels. One important question is the extent to which MEP offers the right portfolio of services. Several centers are seeking to better understand the needs for and expand services in innovation-related areas. The 2006 MEP National Conference with its theme of "Innovation: Seize Tomorrow's Potential Today" and series of sessions examining various aspects of innovation and technology development is a good start and should be continued and extended. This report has highlighted findings with various implications for service offerings such as:

- Assistance with initiation of basic planning of innovation processes
- Assistance with intellectual property issues through mechanisms such as preliminary searching of patent databases and matching with legal resources
- Assistance linking SME with universities and other innovation resources.
- Organizational capability to develop, broker, and support multi-firm product development networks
- Facilitation of customer and supplier innovation sessions
- Matching services linking company R&D efforts with grants or other financial resources
- Financial modeling capability to support company product and service innovation decisions.

In thinking about innovation, MEP serves two important roles. The paragraphs above highlight MEP's critical role at the firm level. A second role for the MEP involves participation in the strengthening of frameworks and complementary policies for innovation at the regional/state and national levels. At the regional/state level, the MEP center is a critical organization. MEPs have a great deal of knowledge about problems and opportunities facing manufacturing, and they need to feed back this knowledge into the formulation of local and state policies that impact manufacturing's ability to engage in innovation. MEP centers should be engaged initiatives around the formation of industry clusters and networks, which will take some time to develop. Centers can work with higher education on enhancing university-industry relationships—traditionally focused on large companies—to make them friendlier to SMEs. Many centers have collaborations with community colleges, but this relationship could to be extended across the network where applicable to take up initiatives such improving the design of curriculum to be more relevant to manufacturing innovation efforts. Stuart Rosenfeld's work with community colleges in his "Learning and Innovation Networks of Community/Technical Colleges" is one example of such an initiative.[13] In some cases, the MEP can serve as an integrator of various national and state level innovation policies such as SBIR,

[13] See http://www.rtsinc.org/ for more information.

government procurement, and tax incentives from the perspective of the local manufacturing community. With its capabilities and knowledge of manufacturing, MEP can furnish a long-term view in helping states and communities to deal with innovation – bottlenecks and blockages.

At the national level in policies and futures groups, MEP can provide an important perspective on the SME. One particular initiative could focus on the need for more research on innovation in to provide a knowledge base for moving forward with US innovation policy. This research base is under-developed in the United States. There are few instances of state-level innovation surveys, with the Georgia Manufacturing Survey serving as a notable exception. The state of California is currently entertaining a proposal to fund an innovation survey in its manufacturing base.

There are several options that MEP can consider to stimulate the creation of an innovation knowledge base. NIST can work with the National Science Foundation to develop a new survey-based information source on innovation in private sector firms with parallel questions to those in CIS. This option would provide national coverage, but could require some negotiation and administrative difficulties. A second approach NIST could take is to stimulate a consortium of states to come together and pioneer an innovation survey. This activity could be cost shared by NIST or some other funding source and the states. This option allows for more flexibility and possibly a faster startup, but it would not have the coverage of a national survey.

NIST can also utilize its regular evaluation and study tools to create a more service-oriented innovation knowledge base. For example, the MEP client survey asks about various outcome measures such as job creation and cost savings, but changes in behavior and strategy are not addressed. The latter need not be measured on a regular basis but could be assessed during a quarter's worth of surveys from a sample of clients on a two to three year time table.

APPENDIX

Appendix
Summary of Selected Studies Based on CIS and Similar Surveys

Study	Region	Dependent Variable	Key Independent Variables	Innovation Findings
Amara, Landry, Ouimet (2003)	Canada	Indicators of interactions (weak/strong) and learning (weak/strong), differentiate four categories of milieux innovateurs	Firm size; sector; R&D intensity	Firm size predicts the evolution from less to more innovative environments; collaborative arrangements with other firms or organizations are significant
Arundel, Kabla (1998)	EU	Propensity to patent product and process innovations	Firm size, sector, R&D intensity, location in Germany, importance of patents, secrecy	Patent propensity rates increase with firm size; R&D intensity of the firm has no effect; sector of activity has a strong influence on product but little on process
Bartoloni, Baussola (2001)	Italy	Dummy variable for product and process innovation introduction	Firm size, ownership, sectoral R&D, industry sector, employee skills, customization strategy, internal and external information sources, growth	Innovation is affected by firm size and information sources. Sectoral R&D is not significant.
Belderbos et al (2004)	Netherlands	Firm R&D cooperation decisions with 4 partner types: competitors, suppliers, customers, universities/ research institutes	Information about partner types, R&D intensity, firm size, innovation constraints, enterprise affiliation, others	Determinants of R&D cooperation vary by type of partner; firm size is consistent predictor; incoming source-specific information is important; R&D intensity is significant for all but competitor cooperation
Belderbos, Carree, Lokshin (2004)	Netherlands	R&D cooperation: Four dummy variables equal to one if	Firm-specific measures of the importance of incoming spillovers	Incoming source-specific spillovers are an important determinant of R&D cooperation, especially

Study	Region	Dependent Variable	Key Independent Variables	Innovation Findings
		the firm was engaged in 1998 in an active R&D partnership	(information sources used by the firm), R&D intensity, firm size	those directly related to the firm's innovation process.
Blind, Hipp (2003)	Germany	Probability of introducing process innovation – ISO 9000 – in service firms	Firm size; sector; use of risky technology	Sector- and size-specific differences significant; use of 'risky' technologies positively influences the probability of introducing ISO 9000
Evangelista et al. (1997)	Italy	Dummy variable for introduction of product and process innovations; R&D; % of sales from new-to-market products	Industrial sector, size	Introduction of innovation and R&D increases with sector and size; percentage of sales from new-to-the-market products is small
Kaiser (2001)	Germany	Propensity to cooperate on research	Vertical (customer-supplier) vs. horizontal cooperation, research productivity, market demand, heterogenous information sources, spillovers (based on education level and constraints)	Research cooperation is positively related to vertically-related arrangements, research productivity, heterogeneity of information sources, and market demand; spillovers reduce research cooperation; the relationship between cooperation and size is an inverted "U"
Loof, Heshmati (2002)	Sweden	Labor productivity	% of sales from innovation; knowledge sources; domestic and foreign cooperation on innovation; factors hampering	Productivity growth is positively related to % of sales from innovation and lack of constraints; % of sales from innovation is positively associated with use of knowledge sources within the firm and from competitors,

Study	Region	Dependent Variable	Key Independent Variables	Innovation Findings
			innovation	cooperation on innovation
Mairesse, Mohnen (2001)	France, 7 EU countries	Propensity to innovate and innovativeness (measured by % sales from innovation)	Size, industry, enterprise group, R&D measures, strength of competition	Share of sales from innovation is related to R&D effort, size, closeness to basic research or competition
Roper at al (2002)	UK, Ireland, Germany	Sales and employment growth; profit margin	Managerial and organizational capabilities, knowledge sourcing (supply chain, internal R&D, other)	Knowledge sourcing through in-house R&D and other collaborations are positively related to innovation; innovation is positively related to sales and employment but not profits
Rouvinen (2002)	Finland	Dummy variable for product and process innovation introduction	Cooperation (academic, nonacademic); inward spillovers (inflows of technical knowledge); firm size; employee education; internal and external R&D; sector-level characteristics	Process innovations benefit stocks of capital embodied technology; product innovations require the disembodied forms of technology; ability to benefit from inward spillovers is the only variable with a symmetric effect on both types of innovation.
Sternberg, Arndt (2001)	EU	Dummy variable for introduction of product and process innovations	Firm-level variables (number of employees, R&D expenditure); region-level variables (population with university degree, manufacturing employment, patent applications)	Firm-level determinants have a greater overall influence on innovation activity than most region-level determinants; a region's capacity for research is the most significant of innovation behavior
Tether (2002)	UK	Engagement in cooperative	R&D, R&D intensity	Engagement in cooperative

Study	Region	Dependent Variable	Key Independent Variables	Innovation Findings
		arrangements for innovation	(expenditures, frequency), expenditure on technologies/ services; introduction of new-to-the-market innovations; finance limitations, others	arrangements for innovation is positively related to R&D, R&D intensity, expenditure on technologies/services; new-to-the-market innovations, finance limitations
Youtie and Shapira (2006)	Georgia, USA	Dummy variable for introduction of product, process, organizational, marketing innovations	Innovation strategy, quality strategy, industry sector, other firm-level characteristics	Innovation strategy is positively associated with introduction of innovations; quality-based strategies are not.

References

Abernathy W. and Clark K. 1985. Innovation Mapping and the Winds of Creative Destruction. Research Policy 14: 13-22.

Amara, N., Landry, R. and Ouimet, M. 2003 Milieux Innovateaurs: Determinants and Policy Implications. Paper to be presented at the DRUID Summer Conference 2003 on Creating, Sharing, and Transferring Knowledge, Copenhagen, Denmark.

Antoncic, B. and Hisrich, R. 2003. Clarifying the intrapreneurship concept. Journal of Small Business and Enterprise Development. 10 (1): 7-25.

Arndt, M., 2006, March 6. How Whirlpool Defines Innovation. BusinessWeek Online. http://www.businessweek.com/innovate/content/mar2006/id20060306_287425.htm?chan=innovation_innovation+%2B+design_innovation+and+design+lead.

Arnold, E. 1998. Developing Company Techno logical Capability: A Learning Perspective. In Manufacturing Modernization: Implications of Evaluation Results for Program Improvement and Policy Development, P. Shapira and J. Youtie, editors. Atlanta, Georgia: Georgia Institute of Technology, 199-134.

Arundel, A. and Kabla, I. 1998. What percentage of innovations are patented? empirical estimates for European firms. Research Policy, 27, pp. 127-141.

Bartoloni, E. and Baussola, M. 2001 Determinants of Technology Adoption in Italian Manufacturing Industries. Review of Industrial Organizations. 19, pp. 305-328.

Belderbos, Carree, Lokshin 2004. Cooperative R&D and Firm Performance. Research Policy. 33, pp. 1477-1492.

Belderbos et al 2004. Heterogeneity in R&D cooperation strategies. International Journal of Industrial Organization 22, pp. 1237– 1263.

Berry, L. et al. 2006 Creating new markets through service innovation. MIT Sloan Management Review. 47 (2): 56-63.

Blind, K. and Hipp, C. 2003 The role of quality standards in innovative service companies: An empirical analysis for Germany. Technological Forecasting & Social Change 70 653-669.

Cohen, W. and Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Sciencd Quarterly, 35: 128-152.

Chesborough, H. (2003). Open Innovation. Cambridge, MA: Harvard Business School Press.

Chesbrough H and Teece D (2002, August). Organizing for innovation: When is virtual virtuous? Harvard Business Review 80 (8): 127.

Cooper, R. 2001. Winning at New Products. Ancaster, ON, Canada: Product Development Institute.

Crépon B., Duguet, E. and Mairesse, J. 1998, Research, Innovation, and Productivity: An Econometric Analysis at the Firm Level, NBER Working Paper No. 6696.

Djellal, F., Gallouj, F., 2001. Patterns of innovation organization in service firms: portal survey results and theoretical models. Science and Public Policy 28, 57–67.

Drejer, I 2004. Identifying innovation in surveys of services: a Schumpeterian Perspective. Research Policy 33: 551-562.

Economist (2004, June 12). The meaning of iPod. 371 (8379).

Evangelista, R. et al. 1997 Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey. Research Policy 26, pp. 521-536.

Gadrey, J Gallouj, F. and Weinstein O. 1995. New modes of innovation: How services benefit industry. International Journal of Service Industry Management 6 (3): 4-16.

Gallouj, F., Weinstein, O., 1997. Innovation in services. Research Policy 26, 537–556.

Goldenberg, J., et al. 2003, March. Finding Your Innovation Sweet Spot. Harvard Business Review, 120-129.

Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 284, 1661–1707.

Griliches, Z., 1992. The search for R&D spillovers. Scandinavian Journal of Economics 94, 29–47.

Henderson, R. and Clark, K., 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly 35, 9–30.

Huston, L. and Sakkab, N. 2006, March. Connect And Develop: Inside Procter & Gamble’s New Model for Innovation. Harvard Business Review. 58-66.

Indergaard, M., 1996. Making networks, remaking the city. Economic Development Quarterly, 10 (2): 172-187.

Kaiser, U. 2001 An empirical test of models explaining research expenditures and research cooperation: evidence for the German service sector. International Journal of Industrial Organization, 20, pp. 747–774.

Kelley, T. 2000. The Art of Innovation. New York: Currency/Doubleday.

Leifer et al, 2000. Radical Innovation. Cambridge, MA: Harvard Business School Press.

Loof, H. and Heshmati, A. 2002. Knowledge capital and performance heterogeneity: A firm-level innovation study. Int. J. Production Economics 76. pp. 61–85.

Mairesse, J. and Mohnen, P. 2001 To Be or Not to Be Innovative: An Exercise in Measurement. Cambridge, MA: NBER Working Paper 8644.

Oldsman E. and Heye C. 1998, Spring. Waste not, want not—A look at the impact of Manufacturing Extension Centers. Journal of Technology Transfer 23 (1) p. 37-41.

Pavitt, K. 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy 13 (1984), pp. 343–373

Piore, M., and Sabel, C. 1984. The Second Industrial Divide. New York: Basic Books.

Porter, M. 1990. The Competitive Advantage of Nations. New York: Free Press.

Roper at al 2002. Innovation and Business Performance: A Provisional Multi-Regional Analysis. Belfast: Northern Ireland Economic Research Centre.

Rothenberg, S. 2005, December. Selling Small and Smart: The Future of the Sustainable Enterprise.

Rouvinen, P. 2002 Characteristics of product and process innovators: some evidence from the Finnish innovation survey, Applied Economic Letters, 9, pp. 575-580.

Salazar, M. and Holbrook A, 2003, October. A Debate on Innovation Surveys. Paper presented at the conference in honour of Keith Pavitt “What do we know about innovation?”, SPRU, University of Sussex, 12-15 November 2003.

Salkever, A. (2003, May 7) A Talk with iTunes' Conductor, Business Week Online.

Saxenian, A. 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Boston: Harvard University Press.

Shapira, P. and Youtie, J. 2005, December. The Future of Manufacturing: Policy and Research Implications. Prepared for Innovation and the Future of Manufacturing Roundtable, Arlington, Virginia USA.

Shapira, P. Youtie, J., Yogeesvaran, K, and Jaafar, Z. forthcoming. Knowledge Economy Measurement: Methods, Results and Insights from the Malaysian Knowledge Content Study. Research Policy.

Shapira, P. 1998, August. The Evaluation of USNet: Overview of Methods, Results, and Implications. Atlanta, GA: Georgia Institute of Technology.

Shapira, P. et al., 2004, November. The Value of Information and Productivity. Prepared for NIST MEP, Gaithersburg, MD.

Sternberg, R. and Arndt, O. 2001 The Firm or the Region: What Determines the Innovation Behaviour of European Firms. Economic Geography. 77 4, pp. 364-382.

Stewart, T. 1997. Intellectual Capital, New York: Doubleday/Currency.

Tether, B. 2002 Who co-operates for innovation, and why: An empirical analysis. Research Policy 31, pp. 947-967.

Tushman, ML, and Moore WL. 1998. (Eds.) Readings in the Management of Technological Innovation, New York: Harper Collins.

Ulrich, K. 1995. The role of product architecture in the manufacturing firm. Research Policy 24: 419-440.

von Hippel, E. 2005. Democratizing Innovation. Cambridge, MA: MIT Press.

Wengel, J., and Shapira, P. 2004. Machine Tools: The Remaking of a Traditional Sectoral Innovation System, in Sectoral Systems, Innovation and Growth in Europe (F. Malerba, Ed.), Cambridge University Press, pp. 243-286.

Youtie, J., et al., 2005, August. Innovation in Manufacturing: The 2005 Georgia Manufacturing Survey. Atlanta Georgia: Georgia Institute of Technology.

Youtie, J., Oh, E., Shapira, P., 2002, January. Focus on Manufacturing, Atlanta, Georgia: Georgia Institute of Technology, p. 2.

Youtie, J., Shapira, P., Oh, E., 2001, October. Focus on Manufacturing, Atlanta, Georgia: Georgia Institute of Technology, p. 2.

Youtie, J. and Shapira P, 2006 (forthcoming). Innovation Strategies and Manufacturing Practices: Insights from the 2005 Georgia Manufacturing Survey.