

## Chapter 4

### ***MANAGING THE DESIGN PROCESS***

We have seen that simply producing a product that functions well is not enough to ensure success in the market. Something more is required, and we have expressed that something as “elegance,” “customer delight,” and “simplicity.” By thoroughly examining the sales and product lives of an entire genre of competing products we discovered that only a tiny fraction can be judged truly successful. These exemplars exhibit much longer product lives as well as greater sales, and capture the lion’s share of the market and profits.

The one or two firms that create the “classic” designs seem to have done so not by producing a plethora of variations and rushing them to market as many voices advise. Rather, they have carefully devised the architecture and user interfaces of their products, always keeping the users’ experiences and values in mind. A classic product may often be based on technologies and components identical to those used by its designer’s competitors, but through the design concept and design integration the product is given vastly greater salience and meaning in the eyes of the customer.

We have also seen provocative evidence from surveys conducted in the United States and the United Kingdom that firms are depending — to

an ever greater extent — on designers, engineers and others outside their traditional boundaries for a large part of their vital and strategic innovation and product development. Further, firms are relying on suppliers as sources of technology and components. This trend might well be thought of as evolving toward greater degrees of so-called “open-source” innovation in an increasing number of products, services, and markets; indeed, there is tantalizing evidence that leads to this conclusion.<sup>1</sup> These circumstances demand that to succeed one must create a superior product or service idea, and must be prepared to invest in whatever effort is required to “stay in this business forever.”<sup>2</sup> Alternatively, one might reach defensively for such empty strategies as “scale” or “critical mass” or engage in a whirl of usually fruitless and disappointing acquisitions.<sup>3</sup>

We contend that the only way to escape the winds of “creative destruction” is to provide superior products and services consistently to customers and to increase the degree to which products and services are integrated. This is a hugely demanding goal and one that even superior firms often fail to meet. That Sony, which outdistanced the competition with its personal music players, failed when confronted with digital music in the form of the Apple iPod is not the exception, but the norm. Three of four firms that lead in one product generation seem to fail to lead in the next, despite that they routinely pioneer new technologies — as Sony did in digital technology. Something more is required. The vulnerability of established firms is acute when the new product concepts stimulate rapid market broadening and expansion, as have digital media of all forms.<sup>4</sup>

In this chapter we begin a series of investigations into the *how* of design-inspired innovation. How might ideal designs — design *classics* — be conceived and created? Given many possible concepts, combinations, and prototypes, how might synthesis and integration of ideas be successfully achieved? What tools are necessary for the experiment and variation involved? What are the existing and emerging tools for synthesis?

With these questions in mind, the authors visited leaders of design firms in Boston, Sweden, Lombardy, and in the extended community of designers focused on mobility, wheelchairs, and wheelchair sports. This and subsequent chapters present the ideas and answers from our investigations.

### **An ideal design**

A design may be thought of as being defined by its subsystems and by their interfaces or connections. Subsystems in turn may be collections of components having their own defined interfaces or simply single components. Focus on the ensemble of subsystems — that is, on the synthesis and integration of the whole — is what in our mind constitutes the process of design. Pursuing the improvement or ultimate performance of one or a few components at a time may be important in the course of progress, but rarely results in a timeless product design or design classic. Conversely, a new and original synthesis may not incorporate new technology, but it may provide for a whole new regime of performance and progress. In the world of engineering, this is also referred to as

defining a product architecture in the abstract, or perhaps a product platform when referring to a specific product and its variants or models.

One need not search far from the most immediate needs for energy conservation to find examples. Combined electric generation systems are the synthesis of a gas turbine generator and a steam turbine generator to take advantage of the high outlet temperature of the former to generate steam for the latter. This seemingly simple idea has more than doubled the efficiencies of the two units used separately. Another example of design synthesis is provided by the hybrid car. A hybrid combines a standard internal combustion engine and generator with equally well-tested batteries and electric motors to improve the joint efficiencies of both. When the car does not need the entire power of the engine, the surplus is used to charge the batteries. When a surge of energy is required, both the engine and generator and the batteries join in to turn the electric motors. The overall efficiency of the whole is substantially improved.

A critical problem in the synthesis of designs and products is that of sub-optimization — that is, the problem of losing track of the whole by focusing too assiduously on the parts. A law in this field holds that when each part is optimized it is impossible for the design as a whole to be ideal. For the design as a whole to be ideal, compromises must be made in the selection or design of components to allow them to connect and work together. To illustrate the point, Iansiti mentions downhill skier Franz Klammer, who triumphed in every World Cup race for a season without winning a single partial event. He did so by posting the best *overall* combination of times in the “system” of races.<sup>7</sup>

### The Power of Synthesis in Design

The Douglas DC-3 aircraft offers a dramatic example of the potency of synthesis of disparate elements. The DC-3 was actually the first modern airplane and one of the most successful product designs of all time.

While perhaps not familiar to readers who have grown up in the jet age, this aircraft was a culmination of previous innovations and set the standard for commercial aircraft for two decades. Never the largest, fastest, or longest-range aircraft, it was nevertheless large enough and fast enough, and was the most economical plane capable of flying long distances. This aircraft satisfied market needs so well, in fact, that no major innovations were introduced into commercial aircraft design from 1936 until jet-powered aircraft appeared in the 1950s.<sup>5</sup>

This remarkable aircraft, which ruled the skies for nearly 30 years, was based on few original innovations. Rather, it was a brilliant synthesis of 33 ideas, each of which had been tested singly or with one or two of the others in earlier aircraft. These ideas included many now taken for granted: retractable landing gear, shrouded engines, all metal construction, and slotted wings.<sup>6</sup>

Ackoff illustrates this point with the example of designing a car. Suppose, he suggests, that we lined up all of the cars currently in production and then selected the best of each sort of part, fuel injectors, pistons, and so on from the set. We would have a complete set of the

best-designed and best-performing parts, but with no possibility of assembling them to construct a functioning car. In fact, it would probably be impossible even to put them together. The only feasible way to design a working car is to start from a concept of the whole, or at minimum of its major functioning sub-systems, and then proceed to design or select appropriate parts. The essence of design is *wholeness* and *integration*. Understanding each component and making the best component is not a winning strategy, but it is often the implicit path that we take.<sup>8</sup>

A compelling example of the power of synthesis in design, as we will see in the section below, is provided by Alvin Lehnerd from his design work at the Black & Decker Company. Starting with a set of consumer power tools that had been designed and expanded over a number of years, Lehnerd decided to redesign the company's entire product offering at once. Each product had been designed to be best for its time and market circumstances, but that did not make Black & Decker's offerings as a whole appropriate for the future, another sort of sub-optimization. Lehnerd and his group began with a "clean sheet of paper" to determine what set of offerings — designed together — would work best as an integrated whole.

Both Lehnerd and Ackoff speak of making an "ideal design." In other words, if the product or product line could be anything we wanted it to be *here and now*, what would it be? Both then suggest that we should imagine ourselves as being the product or imagine being in those circumstances as if they currently existed. Standing in that place in our imagination, is there a set of feasible steps back to current resources and

knowledge that would allow us to create a feasible migration path working back to our starting point in the other direction? If not, might we slightly modify the goal to create a feasible path?

We are typically taught to define a goal (or, formally, a criterion function) and then to list constraints of resources, time, distance, and so on. The primary optimization problem we deal with every day is to ask how much of our goal we can achieve given the constraints to which we are subject. We often frame this by asking three questions: Where are we today? Where would we like to be? What is the next logical step to take toward our goal?

Ackoff claims that such an approach will normally achieve at best about one-fifth of our personal potential, or of a design's true potential. In analytical terms, he is asking us to focus on the *dual* or mirror image of the optimization problem. To do so, we must begin by ignoring constraints and asking what would we like to be doing or what should our ideal design be if it could be anything we wanted. The answer must meet two tests. If we were that person and in that ideal place, or if we had that ideal design in hand, it must be possible for us, or it, to exist in the world as it is. In other words, we still cannot have perpetual motion or break the laws of thermodynamics. And the goal must be legal and ethical. Having set the goal, we must now ask which constraints we must relax or change and by how much to meet that goal or create that wonderful design. Not accepting the constraints as given creates an entirely different approach, one that is less readily conceived. That may well be the essence of a design process.

One can seldom relax all of the constraints necessary to achieve a stated ideal. When this happens, Ackoff urges us to step a short distance away from our ideal design to see whether something close to it can be achieved. In this manner, we are much more likely to set and to achieve an ambitious goal. Experience suggests that working to relax constraints, rather than optimizing within constraints, results in our reaching about four-fifths of our greatest potential in any pursuit including design.

As an example, let us further examine the Black & Decker case. In Lehnerd's terms, an ideal or conceptual design will examine the connections between each member of a product family. What elements do all members of the family share in common? Analysis of the Black & Decker power tool family showed that the key element was the electric motor, followed by housings, gearing, switches, and so on. A major project was launched to design a modular motor, coil, and armature with plug-in connections. The design was highly suited to automatic manufacturing and motor balancing and, by employing a hexagonal shape, greatly reduced materials waste. The resulting motor could be extended to serve in tools requiring from 60 to 750 watts of power with no changes in materials, manufacturing, or connections between components.<sup>9</sup> The same motor design is now in use worldwide for a range of voltages and frequencies of current.

At the beginning of the project, Black & Decker produced thirty different motors, 60 motor housings, and 140 armatures, each requiring its own set of machining tools. With such variety, the company was required to keep thousands of types of parts in inventory, which increased

the cost and complexity of manufacture and multiplied possible sources of error. By redesigning its entire product line at once and simultaneously streamlining manufacture, Black & Decker was able to reduce labor costs by 85 percent and reduce materials cost by 40 to 85 percent. Similar simplification of other sub-systems such as gears, motor housings, switches, and cord sets was carried out as well, resulting in a massive reduction in variety and cost of all parts used by the company. As a result, the customer experiences benefits such as cost savings and increased reliability among a wider range of available products.

Let us look in more detail at some of the specific aspects of product design.

### **Architecture and modularity**

The first aspects we will explore are *architecture and modularity*. We defined product architecture above as a map in the abstract of sub-systems and their interfaces or connections. One might think of a product design as a specific instance of a given architecture. Thus, the Sony Walkman products all share the same basic architecture of reading head, tape drive, controls, and ear-phones. The many variations of this architecture can therefore be created and produced relatively inexpensively to address different tastes and price levels in the market. To achieve this capability, Sony worked first for a number of years to perfect both the architecture and its basic elements and interfaces.

Black & Decker's modular motor and housing design also allowed rapid extension of their product family to new groups of tools such as

rotary shears. At the height of its project, the company was launching a new tool model every three weeks, and was able to develop completely new tools using combinations of well-tested modules in less than six months. As a consequence of the rising quality and variety of its tools combined with dramatically lower pricing, Black & Decker grew tenfold in a decade from annual sales of \$200 million at the start of the project to more than \$2 billion a decade later.<sup>10</sup>

A key point is that to achieve exceptional success the entire market must be considered and addressed in a dynamic manner. Constantly migrating toward the corner of the market that accepts higher prices and affords higher margins for products offering maximum performance should be seen as a dangerous trap. Such a high-end strategy opens the firm to competition from rivals that offer simpler and less expensive models. With the advance of technology, simpler products may quickly progress to offer performance acceptable to more demanding customers as well, and quickly invade the high-price, high-margin space. Today, one can buy a Toyota Lexus that is at least as good as the once unchallenged luxury cars, but for about half the price. A robust strategy for growth and competition virtually requires any competitor to address the entire market, as did Sony and Black & Decker in the examples above, and to be the lowest-cost producer of the basic version of the product. Design firms may well be more aware of the segments and price points that exist in the market than are their clients, as they integrate across a broad range of client commissions.

Exhibit 4.1 illustrates some of the many types of modularity that a designer can use to create a broad and varied range of models of a given

product architecture. For example, Propeller Design’s saddle illustrated in Chapter 1 employs a combination of component swapping and cut-to-fit modularity to fit each saddle to the measurements of a particular horse and rider and provide types for different competitive events. The Dyson case discussed in Chapter 3 and the Metamorfosi case to be described in Chapter 6 both employ the sharing of a central component to create a range of variety in vacuum cleaners and lighting, respectively.

Exhibit 4.1 illustrates some of the ways one might think of creating variation through modularity. A re-chargeable battery shared among

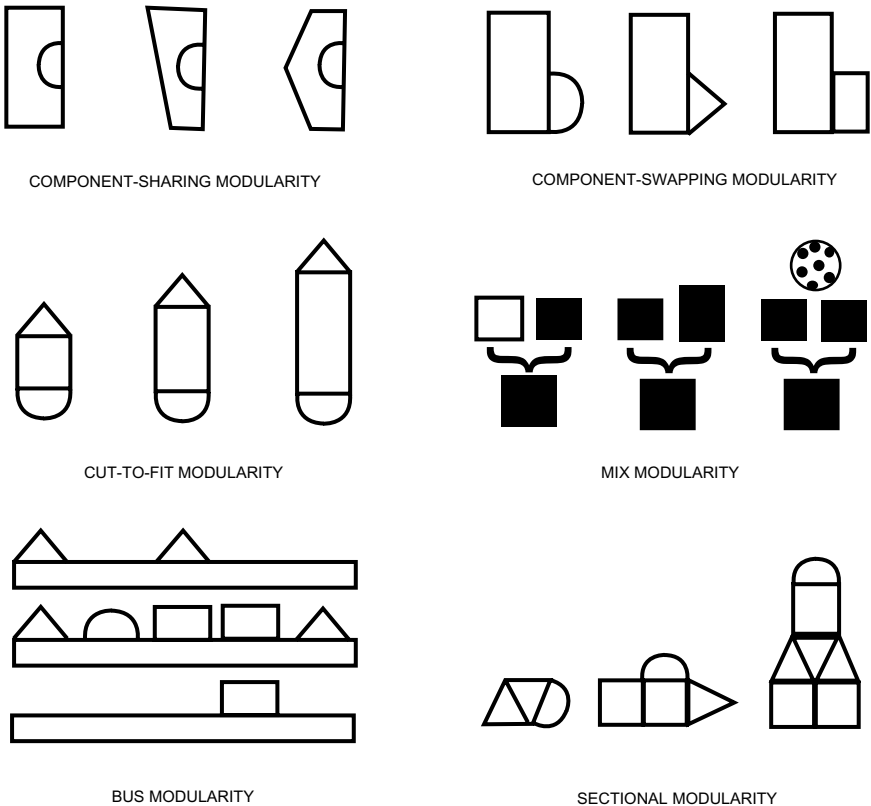


Exhibit 4.1. Various modes of modular design.<sup>11</sup>

various tools such as a drill, jigsaw, and sander is an illustration of component sharing. Sharing the battery reduces expense but, more importantly, it allows one battery to be constantly charging or ready while the second is in use. Component swapping might be illustrated by the example of a drill that can also be used with a sanding disc or a grinding head. Cut-to-fit modularity is the classic case of tailored suits. Levis has extended this theme recently to mass-customized blue jeans. A range of sizes of each piece of a pair of jeans is kept in inventory. After a customer is measured, a computer program makes a selection of components, which are then sewn together into a pair of jeans “tailored just for you.” Not only is a customer better satisfied, the retailer also obtains extra revenue from the service.

Mix modularity is experienced each time we walk into a paint store or a Chinese restaurant, where a wide variety of colors or meals can be compiled from a small stock of pigments or ingredients. Bus modularity is encountered in our daily use of a computer or a telephone system in which all the various components are coordinated by means of a standard communication path, which makes it simple to install added parts. Most pre-fabricated building systems exemplify sectional or snap-together modularity; a classic example is the LEGO® block described in Chapter 2.

The point is not, of course, that Exhibit 4.1 exhausts all the possibilities — there may be many more. Rather, it is to show that a huge array of combinations, variety, and experimentation can be achieved by taking a modular approach. More readily developed and more robust designs are the result.

Pavitt<sup>12</sup> finds that modular product architectures in which components and interfaces are standardized and interdependencies among

components are de-coupled is of increasing importance in dealing with product and technological complexity. He notes that this further enables the contracting of design and production of components and sub-systems to suppliers. Pavitt highlights the growth of “modular production networks” defined by points in the value chain where information can be made formal and highly specific. However, he states that this trend may not extend to “a neatly specified system for the production of innovations, with product and system designers, their sub-contractors for components and sub-systems, and their manufacturers working together through arms length relations.”<sup>13</sup> The reason for this is, of course, the need to convey much tacit knowledge, as Pavitt emphasizes.<sup>14</sup>

The key to success, in Pavitt’s view, is the central task of integrating different technologies that are progressing at widely varying rates. Design challenges in the auto industry provide a vivid current example. In cars, mechanical components that change slowly, over decades, must work with electronics, sensors, and communications technologies that change much more rapidly. Systems integration and perhaps provision for module updating and replacement is crucial to success.

Pine states that a modular design is virtually a prerequisite for products to be produced inexpensively but singly to suit individual tastes.<sup>15</sup> In Japan, Matsushita offers bicycle buyers 11 million options, based on a modular system. Before Propeller’s modular saddle, most horse riders would be forced to purchase a good enough compromise from a narrower range of standard saddles. Poor saddle fit also caused back problems in about 60 percent of horses with which they were used.

A few top competitive riders would be fortunate enough to be able to obtain custom saddles suited to themselves, their mount, and their chosen event, but doubtless at high cost and following a long wait. Now more riders can surely do so. We will see this idea illustrated further in the extended case below of a DVD rental kiosk developed by Eduardo Alvarez and IDEO.

Another interesting example that exhibits the power of modularity is the development of a broadened product line for DeWalt Tools by Altitude, a Boston-based design firm. Using DeWalt's standard rechargeable battery pack (component sharing) in a worksite radio and battery-charger combination, Altitude produced what has become a design classic.

### Thinking Beyond the Toolbox

When DeWalt, a leading US power tool manufacturer, asked Altitude to conceive new product ideas for the professional worksite, the recommendation — a radio — was certainly unexpected. But after intensive work and hundreds of creative collisions, the design team thought of combining the DeWalt brand with entertainment. With an industrial sound generator featuring an integrated battery charger, rugged controls, and a protective roll-cage, the designers developed a new *category* of radio.

Altitude researchers conducted in-depth and extensive interviews in the construction industry to understand what workers in steel-toed boots valued in a radio and discovered that there were significant

opportunity gaps between incumbent products and the consumer's needs. Contractors were destroying and replacing three to four portable radios a year in their harsh worksite conditions. DeWalt's radio needed to communicate visually that it was "worksite tough" but wouldn't monopolize scarce power outlets. Integrating a charger that fits all of DeWalt's battery packs helped build fanatical loyalty and spurred sales of other DeWalt products.

"The Worksite Radio/Charger was a defining product for our DeWalt brand and for the entire cordless category," explains Bob Welsh, the company's global director of industrial design. "It has since become an unmistakable icon in the construction industry." Sales exceeded expectations, boosting profitability, achieving high margins, and selling for years with minimal price erosion. In fact, the Worksite Radio/Charger remains the most successful product launch in DeWalt's history. It illustrates how targeting specific market niches can facilitate the discovery of customer needs.

### **Transparent interfaces**

An early question raised in the research for this book was whether the movement of the innovation and design process toward networks of actors (as shown in Exhibit 1.3) would open a producer of products and services to wider competition and predation. In fact, it is inevitable. Resistance will simply slow the pace of change for the firm trying to maintain a proprietary design and raise its costs, painting the firm into a corner. By the same token, customers will prefer to buy products that do

not necessarily lock them in to a single vendor or set of services or software.

For modular design to deliver its maximum benefit, the interfaces between modules must be transparent and open rather than closed and proprietary. Transparent interfaces create a mixed blessing by opening up the supply chain for modules to greater competition. This makes the producing firm more vulnerable to outside influences and predators, but at the same time gives it and its customers a wider range of choices and increases the rate at which technology can advance and the breadth of its potential application. Notable examples in which a firm offering a superior but closed design have lost in a competitive race to firms with inferior but open designs include Sony's Betamax versus VHS video recorders, Apple's Macintosh versus the IBM personal computer, and Boeing's early suspended engine pod design, which allowed many jet engine choices, versus competitors' engines integrated in wing designs. In each case, the design that allowed more competition, and also more implicit partners, won the larger share of sales.

### **Open standards and open source innovation**

Von Hippel contends that the locus of innovation is shifting toward user communities over time, and that if this is true it is a matter of great interest and relevance for the future. "Innovation communities," he writes, "can increase the speed and effectiveness with which users and also manufacturers can develop and test and diffuse their innovations. They also can greatly increase the ease with which innovators can build

larger systems from inter-linkable modules created by community participants.”<sup>16</sup>

“Open source software development is perhaps the most prominent example of the community-based model. Although often viewed as an anomaly unique to software production, the community-based model extends well beyond the domain of software. Innovative communities have been influential in product categories as diverse as automobiles, sports equipment, and personal computers.” — Sonali K. Shah<sup>17</sup>

We know that design contests have been around for quite a while, but what is truly new is the global scale on which companies can now reach out to the best and brightest. For example, LEGO allows programmers from outside the company to access the code that controls its Mindstorm toy robot, leading to an increased range of activities the robot can perform, in ways the company never imagined.<sup>18</sup> Core 77, the industrial design site, teamed up with watchmaker Timex for a global design competition called Timex 2154: The Future of Time (celebrating Timex’s 150<sup>th</sup> anniversary). Designers from more than 70 countries explored and visualized personal and portable timekeeping 150 years into the future, resulting in more than 640 entries. Winners can still be viewed online, and in the Timex Museum.

In the same vein, Illy Cafe teamed up with *Domus* magazine in April 2004, asking students and designers under the age of 35 to create new ways of enjoying coffee (“create a place for meeting, discovery

and encounter”). Over a ten-month period, 704 entries were received, roughly half coming from outside Italy. The best fourteen projects were exhibited in Milan. The winning concept is an escalator that functions both as a coffee machine and an art show. Coffee is served at the bottom of an escalator. On the way up, customers sip their coffee and enjoy a brief art exhibition. At the top of the escalator, they throw their plastic cup into a recycling machine that instantly molds it into a ticket for an art exhibition or show.

In South Korea, mobile carrier KTF has held a contest to design new cell phones based on a “Cell Phone of Sensibility” theme, with a focus on usability and style. In late 2005, 19 winners were announced, and a few of them may see their creations end up in Korean stores relatively quickly. Another approach involving outside experts can be found at Procter & Gamble, which launched its dedicated Connect + Develop program (mentioned in Chapter 1) with the goal of having at least half of its new products derived from ideas generated by non-employee experts.<sup>19</sup> Beside its own research and development employee base of 7,000, the company now has access to millions of potential innovators. The results so far are everything from Swiffer Wet Jet, Olay Daily Facials, Crest Whitestrips, and Night Effects to Mr. Clean Autodry, Kandoo baby wipes, and Lipfinity.

In some respects, one might view the process of networked design and brokering that we describe as part of a broader movement toward more widespread participation in the creative process in all its aspects!

**The design and innovation system in Boston**

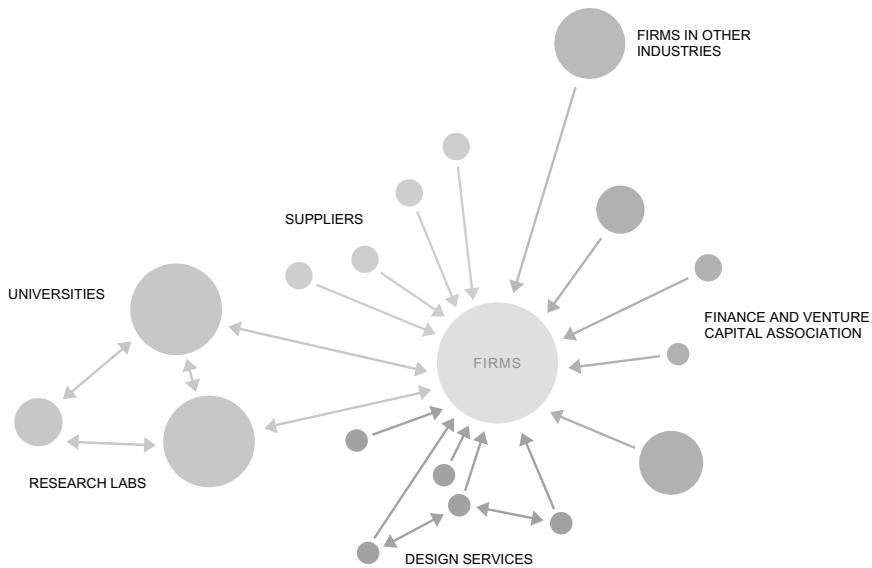
We said in earlier chapters that there is a growing trend toward networks of firms participating in the innovation process, and that a growing number of these are design firms. Our survey in the United Kingdom showed evidence of an astonishing concentration of designers in and around London. Design and innovation are markedly an urban phenomenon. Recent evidence from others' research shows that, all things being equal, clustered suppliers seem to lead to greater efficiency. Larger and more diverse clusters of firms seem to provide more scope for the combination of resources, brokering of ideas, and the collision and synthesis of different currents of invention. Thus, we believe that the importance for the creative process of firms' proximity to one another is greatest when the information they require is tacit or rapidly changing.

These arguments indicate that we should expect more spinoffs and more rapidly growing clusters when greater technological opportunity is coupled with low appropriability. The greater the number and the lower the cost of communication channels, the greater will be the number of ideas and innovations that tend to be created. Hargadon and Sutton, from a case study of the design firm IDEO, suggest that design firms act as technology brokers by introducing solutions where they are not known and in the process create new products that are original combinations of existing knowledge from different industries.<sup>20</sup> They contend that designers exploit their access to a broad range of technological solutions with organizational routines for acquiring, storing, and retrieving this knowledge, and that organizations that face many

different problems develop routines that will be broadly useful in solving future problems.

Boston has been a home for radical and innovative ideas from its very beginning. Founded by religious dissenters, Boston has been a source of revolutionary thought in realms as varied as governance, human rights (the abolition of slavery and universal suffrage), science, medicine, and the arts. During the past two centuries, the focus of this ferment and energy has expanded to innovation and manufacturing in various fields of design and technology. Rapidly growing clusters of new ventures in information technology, software, electronics, medical instruments, and biotechnology have supplanted earlier communities of firms in the realms of tools and machinery, furniture, textiles, defense, and scientific instruments. There are large and growing communities of firms in finance and financial services, design services, intellectual property law, and others that support this dynamic, as well as large universities and hospitals with major laboratories and research programs. In recent years, biotechnology has been a major focus of growth, especially in venture capital investment.<sup>21</sup> Today, more than 400 of the United States' approximately 2000 new firms in biotechnology are located around Boston, a disproportionate number (per capita) equaled only in California. This complex is shown schematically in Exhibit 4.2.

We show in the exhibit that there is an incredibly rich texture of communication links among all of the actors in the Boston innovation and design complex though this is possible only to suggest. We surmise that the more actors there are in a complex, the more diverse and varied



**Exhibit 4.2.** A schematic of actors in the Boston design and innovation cluster.

are these actors. Further, the richer the degree of communication links among them, the greater will be their propensity to innovate. This is certainly borne out by a comparative study made by Rickne of firms developing medical implant technologies and devices in Boston, Cleveland, and all of Sweden.<sup>22</sup> Areas with greater diversity and connectedness would enable and encourage many more creative collisions and combinations than would be the case in areas sparsely populated with technology-based firms or having firms that are sparsely connected. Based on this hypothesis, one would expect less innovation in Cleveland and in Sweden than in Boston; in fact, that is what the data suggest.

Hargadon and Sutton contend that when connections are made, existing ideas often appear to be new and creative as they change form, combining with other ideas to solve the problems of different users.<sup>23</sup>

Brokers, in their view, benefit from disparities in the level and value of particular knowledge held by different groups, and derive value by enabling the flow of resources between otherwise unconnected groups within a larger network. In their analysis, technology brokering is visible at the level of firms and industries, but it takes place through the actions of teams and people.

### **Enabling Innovation Through Knowledge Brokering**

To recognize the potential value of a technology and adapt it to disparate products, designers must be familiar enough with a technology to generate analogies appropriate for current designs. Links to many industries provide designers with access to a broader range of technological solutions than they would see working in a single industry.<sup>24</sup> A case study of Thomas Edison's early laboratory in Menlo Park suggested that he created a setting, and ways of thinking and working, that enabled his inventors to move easily in and out of separate pools of knowledge, to keep learning new ideas and to use ideas in novel situations.<sup>25</sup> Researchers suggest that there are four tactics to enabling innovation through knowledge brokering: explore new territories, learn something about everything, find hidden connections and make prototypes that work.<sup>26</sup>

As one might expect, the Boston area provided us with a great variety of design firms from which to select examples for our study. We interviewed leaders at Product Genesis, Bleck Design Group, Herbst Lazar Bell, Product Insight, Altitude, Design Continuum, Manta Product

Development, Synectics, IDEO, and 9<sup>th</sup> Wave, as well as at the MIT Media Laboratory and its associated AgeLab.<sup>27</sup> Each of the companies is a product development firm. In addition to offering industrial design services, these firms have a suite of additional services for their clients. Although varying from firm to firm, the expanded services include mechanical and electrical engineering and analysis, software programming, product and marketing strategy, rapid prototyping, and manufacturing. In the course of the work, one of our authors, Eduardo Alvarez, developed an idea for his own business and worked for an additional year with IDEO to develop the idea and several prototypes for test. He has since raised seed capital, started the company, and launched the product in one national market. This experience is described below as an extended case study of VIGIX.

### **VIGIX Inc.**

Our case begins with the objective of creating a truly fulfilling customer experience. The VIGIX idea is to create a network of small-footprint kiosks — in convenience stores, supermarkets, office buildings, airports, and elsewhere — from which movies and games are sold and rented on physical media (DVDs and memory cards) and through direct downloads. The product was developed in partnership with IDEO, among the world's most prestigious design firms.

For the entrepreneur and his new company, the pursuit of customer delight has been the focus of product development. Two

principles — simplicity and excellence — guided the design team as it first identified the requisite and most valuable elements in the perception and customer experience when renting a movie and only then turned to creating the technology and operational procedures to achieve the product objectives.

The product features include convenience, ease of use, and reliability. Small kiosks make it possible for VIGIX to be in convenient and non-traditional locations. Each kiosk offers only the 40 new titles most people are looking for, and a simple graphic user interface allows the customer to watch a video clip of the movie and see the customer rating the movie earned in theaters.

To ensure product competitiveness, the team designed a very simple kiosk. Movies are returned by mail with the provided postage-paid envelope, eliminating the need for a complex robotic arm to take DVD returns and restock them in the machine — as in competing kiosks. Having the customer mail the DVD eliminates the need for a much larger, higher-cost kiosk that requires more maintenance. The VIGIX kiosk is less than half the size of its competition, can be installed by one person, and is easily moved (and thus deployed in the market). High reliability is assured because there are no moving parts. Using a unique patented technology, the kiosks are restocked by a simple cartridge swap that can be done by anyone, with no training. Cartridges are restocked centrally, where the company can enforce strict quality controls, but restocking the kiosks is done by outside companies such as UPS.

VIGIX also enhances the customer's delight with its system for ensuring that titles customers want are available at the kiosks. Availability of titles can be checked at a website that duplicates the screen the customer sees when choosing a DVD at the kiosk. Customers can locate the kiosk closest to them and reserve titles.

#### *The Design Process*

The VIGIX team employed brainstorming, storyboarding, focus groups, customer observation, surveys, market tests with several prototypes, and a deep analysis of current and future competition to define the most valuable elements in customer perception and experience when renting a movie. The designers began by storyboarding situations in which convenient movie rental would make a big difference in the customer experience. Exhibit 4.3 shows a weekend car trip of a family with young kids. The kids soon become impatient and begin to fight. When dad spots a gas station with the VIGIX logo, he stops and rents a movie for the minivan's DVD. The unpleasant situation in the car is transformed. Later, dad drops the movie, in its return envelope, in a mailbox.

Visualizing such scenarios helped the team understand several important factors. For example, the scenario could be true only if there were a pervasive network of kiosks. When the product developers approached the largest US convenience store chains, they learned that the kiosks would have to be very small and stand alone in aisles, not against already used walls, if they were to have any chance of being



**Exhibit 4.3.** Story board of the envisioned customer experience in the early stage of the design process.

put in these stores. The kiosk would have to look good from the front *and* the back.

The VIGIX example begins with an ideal design or concept as we have defined it above. In this case, the team has been perceptive in seeing that the customer is not only the final consumer, but also that the vendor in whose premises the rental kiosk must reside and be serviced matters. The designers have stressed simplicity and ease of use and service in every phase of the kiosk's operation from installation through the customer interface and replacement of stock. Simplicity seems especially important, as the kiosk's host — the vendor — will be on the front line of any complaints from users, which must be kept to a minimum.

That the kiosk has built-in ease of response to meet varying demographics and changing demand seems a vital advantage over competitors, as does the entrepreneur's acute use of competitive intelligence and consumer testing in specifying the design. The product team has combined



**Exhibit 4.4.** The Vigix kiosk.

hardware, software, and web-based services in much the same way as the successful Apple iPod formula. Further, the team has used various visualization techniques — in this case, a storyboard, alternative scenarios, sketches, and models — to enhance communication and produce an elegant integration of various concepts.

A fascinating aspect of the case is that it has led to a patented breakthrough in vending machine technology and operation, which should have much broader appeal and application than in this product alone. The VIGIX kiosk and services have been tested and at this writing have been launched in an attractive market.

The VIGIX example highlights two aspects of the design process — *visualization* and *modeling* — that we have found to be central in design inspired innovation. The VIGIX designers relied upon both visualization and modeling to develop the kiosk. In Chapter 8, we discuss these aspects in considerable detail.

### Synthesis and integration

How can a designer understand what the customer really needs? Our research finds that strong contact with the ultimate customers is one of the most common practices of successful product design organizations. Every leader of a design firm we talked with is an information enthusiast. They promote awareness of the world through collaborative communication with universities, encouraging their employees to teach, attending conferences, hiring freelancers and consultants, attending trade shows, and so on. Even with these practices, however, defining customer needs is a hard problem to crack. The more innovative the idea, the harder it is to determine customer needs, because there may be little or no information or culture around the future product. In other words, the information needed is almost entirely latent and unspoken, or tacit in academic jargon.

The design of a product is an exercise in blending both tacit and explicit knowledge to solve a problem. As Ed Gilchrest from 9<sup>th</sup> Wave Design noted during our conversation, the real asset “is the knowledge in the designer’s head.”<sup>28</sup> In other words, the knowledge that is codified or explicitly represented by a product is not as valuable as everything else a designer knows. The designer knows about the “why” and “how” of solving the design problem as well as the final answer. When the next design problem is presented, the designer may be unable to apply the same answer, but may very well be able to apply expertly the methods and reasons learned to find a creative *new* answer. Roger Bohn suggests eight stages of knowledge, ranging from complete ignorance (stage one)

to complete knowledge (stage eight). When the most important knowledge is in the workers' heads, knowledge is at stage two — it is expertise based.<sup>29</sup>

Tom Allen was one of the first to describe the striking differences in communication patterns among scientists in contrast to those among engineers.<sup>30</sup> Scientists communicate in a markedly more formal and codified manner than do engineers, relying primarily on journals. Engineers operate more in the world of tacit communication and trade-offs. Informal conversations, drawings, models, and prototypes are the less precise bread and butter of engineering work. It is not surprising that working closely together enhances both the quality of communication and the results of engineering work.

The design of the Douglas DC-3 aircraft, including producing the prototype, involved only fifty people working together in one building for less than a year. The result was so good that the prototype was sold as production model number one! One of the first five DC-3s produced was removed from commercial service after five decades of service and now resides in the Smithsonian Air and Space Museum as one of the great design classics of all time.

The tacit nature of product design knowledge is fundamentally why face-to-face communication has been especially important in ensuring knowledge “blending.” As individuals work together, they are able to build a rapport that facilitates knowledge transfer. Because personal communication is an essential part of tacit knowledge transfer, co-location would seemingly be critical to knowledge transfer between designers.<sup>31</sup> Product development firms recognize that knowledge transfer takes place both ways during product design collaboration. Product Genesis said this transfer begins with the initial

interaction between the client and the firm.<sup>32</sup> Communication during design collaboration is the fundamental means of transferring knowledge.

“It is hard to transfer the full complexity of a technology ... If the receptor knows very little, he can do very little even with the simple idea, because he cannot generate the mass of detail that is required to put it into execution. On the other hand, if he knows a great deal and is capable of generating the necessary details, then from just a few sentences or pieces of technology he will fill in all the rest. That is why it is hard to transfer technology to the Third World and very hard not to transfer it to Japan.”<sup>33</sup> In simple terms, the more similar the knowledge that two people have within a product domain, the more easily additional knowledge can be transferred between them. Davenport and Prusak also observed that a major factor in effective knowledge transfer is a common language about the knowledge domain.<sup>34</sup>

In a case study that looked at how knowledge transfer could be facilitated between a contracting company and a supplier, Tunisini and Zanfei found that the first investment that had to be made was the skill-intensive and time-consuming process of developing a shared language.<sup>35</sup> Product Genesis reinforced this idea in our conversations by saying that the key to knowledge transfer was the language used. When the firm embarks on a new product development engagement with a client, Product Genesis ensures that all participants understand a glossary of project-specific terms.<sup>36</sup>

By changing how designers work, technology advancements have changed the knowledge intensity of their output. A computer model’s representations with links to enterprise-wide databases and other design models mean it contains much more actionable knowledge about the product and the design than drawings once did. As a result, the ability

to learn from models has increased. Product Insight noted that its designers learn a great deal about clients' products from the clients' computer models.<sup>37</sup> Most product development firms we interviewed described how the Internet and effective search engines have made design research simpler, faster, and more productive, widening their sources of design knowledge for possible inclusion in the product.<sup>38</sup>

Sometimes in a complex project such as the design of a new car, an abstract model is insufficient, even if it is a vivid three-dimensional computer rendition. What is called for is a full-scale physical model, even though that may be extraordinarily costly. One of the present authors and seven of his students were involved from beginning to end in the development of the Chrysler LH platform, a basis for many of the company's current models. The project was so vital to Chrysler at the time that the company went to the length of devoting an entire large separate building to the LH team. All of the needed design and engineering groups were arrayed around the perimeter of the building. The prototype of the new design was placed in the center of the building so that it became the center for communication and a persistent reminder of the status of all of the design work and its integration. In Carlile's terms, the prototype was a "boundary object," a physical representation that helps solidify problem definition and focus discussion and coordination between members and sub-groups of the entire team.<sup>39</sup> Noehren extended Carlile's work on product development teams by showing that there was a statistically significant correlation between the frequency of boundary object usage by a product development team and the success of the project. Noehren also noted that models provide a more effective product development team communication focus than drawings.<sup>40</sup> This will be discussed further in Chapter 8.

The LH prototype was built from both standard and sometimes one-of-a-kind parts. An engineer working on the prototype in the center of the building was immediately obvious to all around. Others who were curious or simply walking by could observe any and all changes to the prototype and the manner in which these might affect or interact with their own parts of the project. As a result, the LH platform was one of Chrysler's most effective designs and was completed in record time.

The effectiveness of a boundary object in communicating knowledge about a design is a consideration in the location of design work. The more explicit the specification and information needed, the more mobile the process can be. Technology has changed the ability of designers to communicate through computer models and virtual three-dimensional representations. With manual drafting and drawings, the knowledge of the design resided in the designers' and analysts' minds. The drawing was a mute device for communicating a fraction of the knowledge about the product. Communication and effective knowledge transfer are influenced by having a common language, co-location and trust building, the use of boundary objects, and design process technology.<sup>41</sup>

Another change pointed out by the product development firms is the ability to create rapid prototype models directly from the computer model of the product. Firms we interviewed recognize intuitively that the prototype is an effective means of communicating knowledge about the design — it is a better boundary object. When prototypes are combined with virtual simulations made possible through advanced software linked to the engineering model, extensive knowledge is available about the configuration, behavior, and functioning of a product.

The complexity of many of today's technology products requires that input from many different disciplines be integrated into a final solution. Product development teams provide a way to "fuse" different ideas from different people working on the same problem, which ultimately is a major source of knowledge.<sup>42</sup> Design knowledge is not just in the designer's head, but is also in the heads of all those who helped in the integration of the solution. The integration of many different types and sources of knowledge in the context of a specific design problem is a significant contributor to a product's knowledge intensity, which, in turn, influences the degree of collaboration required for its completion. As the knowledge intensity of the product increases, the amount of collaboration necessarily increases. Ultimately, collaboration, of which communication is a part, is the knowledge transfer instigator between the supplier and the customer corporation.

Evolving design and engineering software and hardware enable a large complex integrated system, such as a commercial aircraft, to be designed and analyzed in a virtual three-dimensional environment. Entire manufacturing processes and factory flows can be simulated directly from the design models. Embedded within the models are data linked back to knowledge-based engineering software used to conceive the design and links to master lofted surfaces that span many parts. With the latest application releases, critical dimensions and tolerances can be portrayed in space. Changing the shape or parameters of a design feature can be propagated quickly through the computer model to modify any related features.

According to von Hippel, "Today, user firms and even individual hobbyists have access to sophisticated programming tools for software and sophisticated CAD design tools for hardware and electronics."<sup>43</sup> These

information-based tools can be run on a personal computer, and they are rapidly coming down in price. As a consequence, innovation by users will continue to grow even if the degree of heterogeneity of need and willingness to invest in obtaining a precisely right product remain constant."<sup>44</sup>

The integration of many different requirements and technologies into a single product can be the significant differentiator between a successful and a poor product. Iansiti points out in his study of technology integration in the computer industry that the integration choices made during design, and not the technologies selected, can determine success.<sup>45</sup> In one case, the overall system performance of two mainframe processors was compared along with their fundamental component technologies. One processor achieved significantly better performance despite 10 of its 12 fundamental technologies being worse, and the remaining two on a par with the other processor. Better integration decisions were made by the first firm to develop a faster processor with poorer technologies.<sup>46</sup> Iansiti later shows how technology integration is an enabler for an organization to "view the entire product and production systems as a coherent whole, balancing the potential of individual technologies with the requirements of the context of application."<sup>47</sup>

### **Integration Influences Collaboration and Knowledge Transfer**

Consider the design of a fairing to enclose the radar on an aircraft. Peter Grant offers this as a good example of how integration can influence the collaboration and knowledge transferred.<sup>48</sup> Designing this product requires the integration of knowledge about materials and processes, structural analysis, weight analysis, aerodynamic flow, electromagnetic behavior, manufacturing processes (including cost), joint and attachment

configurations, maintenance procedures, and potential damage scenarios (such as bird or lightning strike). Most of this knowledge is codified in many different forms, but how and why to select the various types of knowledge and integrate it is the uncodified designers' job. When the fairing is complete and installed on an aircraft, its external simplicity belies the knowledge intensity resulting from this complex design integration. If the design of such a fairing is contracted, integration knowledge necessary for the design will be transferred through the interactions of the corporation and the supplier. Sufficient collaboration must occur for the firm's needs to be understood by the design supplier for design execution.

The fairing design example also points to the impact of modularity on knowledge transfer. If the company so desires, the fairing design could be contracted with an outer defined surface, a mating interface definition, a weight and cost limit, and impact and electromagnetic requirements. Less knowledge about the rest of the aircraft would then be transferred to the supplier. However, for the corporation to develop this information requires sufficient specific knowledge and systems integration skills.

In a review of the literature on networks of innovators, Powell and Grodal conclude that the difficulty of transfer is high and the certainty of results low for tacit knowledge, while the opposite is true when knowledge is highly codified and formal. This leads them to suggest that "there is a medium range of knowledge codification where the value of the innovative output exceeds the costs of knowledge transfer and recombination."<sup>49</sup>

Our interviews suggest that the middle range is exactly the space in which design firms are most active and most effective.

Increasingly, design firms are providing more than the finishing touches. In a few cases, they are providing the total contract provision of innovation from start to finish. Most work lies in between these two ends of the spectrum. We develop this much more fully in the following chapter, based on our interviews in Sweden.

### The MIT AgeLab

Work at the Massachusetts Institute of Technology AgeLab, created in 1999, is a good example of how designers are pushing the boundaries of product development to “invent new ideas and creatively translate technologies into practical solutions that improve people’s health and enable them to ‘do things’ throughout the lifespan.” The AgeLab’s efforts also illustrates the integration of product and service, hardware and software, into technologies and innovative delivery that “can have a significant impact on the quality of life for older adults, their families and caregivers.”

The AgeLab works in transportation, housing, health, communications, work and retirement, services, and decision-making around aging and caregiving. One example involves older drivers and new in-vehicle technologies. Collaborating with US, German, Japanese, and Italian automakers, a research team at the AgeLab is conducting extensive research on the design integration of intelligent transportation systems and their promise to promote lifelong safe driving. This includes

an exploration of cognitive workload and the adaptation of new technologies to the driving tasks of operators over 50 years of age.

In the area of wellness and “self-empowered health,” AgeLab designers have developed an Electronic Pill Pet that uses play and emotion to remind older adults to take their medications. And a Smart Personal Advisor transforms shopping for food and consumer health products into an informed activity. The advisor, mounted on a grocery cart, uses the consumer’s personal diet information to provide guidance at the point of decision.

These are only a few of the projects at AgeLab, where design-inspired innovation is seen as “the opportunity to invent the future of healthy, active living.”

## Endnotes

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<sup>1</sup>E. von Hippel, 2005.

<sup>2</sup>A. Lehnerd, 1987.

<sup>3</sup>M. De Rond, 2003.

<sup>4</sup>J.M. Utterback, 1994, Chapter 9.

<sup>5</sup>A. Phillips, 1971. Cited in Utterback, 1994, Chapter 4.

<sup>6</sup>R.E. Miller and D. Sawers, 1970.

<sup>7</sup>M. Iansiti, 1997.

<sup>8</sup>Lecture by Russell Ackoff in James M. Utterback’s class at MIT, Cambridge, Massachusetts, 25 April 1989. Based on R. Ackoff, 1981.

<sup>9</sup>For further details, see Lehnerd, 1987; see also M.H. Meyer and A.P. Lehnerd, 1997.

<sup>10</sup>For a more recent example involving heart monitoring devices, see M.H. Meyer, P. Tertzakian, and J.M. Utterback, 1997.

<sup>11</sup>K.T. Ulrich and S.D. Eppinger, 2004.

<sup>12</sup>K. Pavitt, 2005.

<sup>13</sup>Pavitt, 2005.

<sup>14</sup>Pavitt, 2005.

<sup>15</sup>B.J. Pine II, 1993.

<sup>16</sup>von Hippel, 2005.

<sup>17</sup>S.K. Shah, 2005.

- <sup>18</sup>LEGO Mindstorms Robotics Invention System 2.0 Software.
- <sup>19</sup>L. Huston and N. Sakkab, 2006.
- <sup>20</sup>A.B. Hargadon and R.I. Sutton, 1997.
- <sup>21</sup>Massachusetts Technology Collaborative, *Index of the Massachusetts Innovation Economy*, 2005.
- <sup>22</sup>A. Rickne, 2000.
- <sup>23</sup>Hargadon and Sutton, 1997.
- <sup>24</sup>Hargadon and Sutton, 1997.
- <sup>25</sup>Hargadon and Sutton, 2000.
- <sup>26</sup>A.B. Hargadon, 1998.
- <sup>27</sup>Transcripts and summaries of the interviews can be found in E. Alvarez, 2000.
- <sup>28</sup>E. Gilchrest, Interview at 9<sup>th</sup> Wave. Southbury, MA: 4 March 2000.
- <sup>29</sup>R.E. Bohn, 1994.
- <sup>30</sup>T.J. Allen, 1977.
- <sup>31</sup>T.H. Davenport and L. Prusak, 1998.
- <sup>32</sup>B. Vogel, 2000.
- <sup>33</sup>R. Gomory, 1983. Cited in D. Leonard, 1998.
- <sup>34</sup>Davenport and Prusak, 1998, p. 98.
- <sup>35</sup>A. Tunisini and A. Zanfei, 1998.
- <sup>36</sup>B. Vogel, 2000.
- <sup>37</sup>J. Rossman, Interview with Product Insight. Acton, MA: 8 March 2000.
- <sup>38</sup>According to Gianfranco Zaccai, leading firms such as Continuum have, for years now, applied design research based on qualitative analysis of human behavior and perceptions in contextual settings; this means that the user/customer actually becomes part of the cluster. This is a key first step which informs meaningful brainstorming, envisioning, and storytelling. In essence, the designer/researcher becomes the medium through which the user/customer/stakeholder communicates their expressed aspirations. Eventually, probing into different aspects of human behavior associated with different product categories, the “users” also inform the design community’s tacit knowledge.
- <sup>39</sup>P.R. Carlile, 2002.
- <sup>40</sup>W.L. Noehren, 1999.
- <sup>41</sup>Carlile, 2002.
- <sup>42</sup>Davenport and Prusak, 1998, pp. 49–50.
- <sup>43</sup>von Hippel, 2005.
- <sup>44</sup>von Hippel, 2005.
- <sup>45</sup>Iansiti, 1998.
- <sup>46</sup>Iansiti, 1998, pp. 79–81.
- <sup>47</sup>Iansiti, 1998, p. 119.
- <sup>48</sup>P.L. Grant, 2000.
- <sup>49</sup>W.W. Powell and S. Grodal, 2005, p. 76.