Extracted from *Managing Technology for Profit,*
A Small Business Guide

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R&D Strategies for Business

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When Zeus refused mortals fire, the Greek god Prometheus defied Zeus and gave fire to mankind. Zeus' rage and punishment were terrible, but Prometheus was freed by the great hero Hercules whose strength ensured that the world would once more benefit from Prometheus' compassion. Such ancient alliances are the tales of mythology, but these case studies of ongoing, successful, and completed business ventures are real-life examples of how technology-based strategic alliances are structured and how they work

R&D STRATEGIES FOR BUSINESS

GLOBAL COMPETITION—THE U.S. PERSPECTIVE

The U.S., and most developed nations, are undergoing radical changes that affect their ability to compete both domestically and internationally:

- Erosion of their manufacturing industries and a shift from basic smokestack and rural economies to service and specialty product industries.
- Impact of global competition. The same technology that created the 747 also created the ability to move large amounts of goods and services anywhere in the world within 24 hours.
- Increasing demands on their education systems to produce more scientists and engineers and to accelerate R&D at universities and colleges and in the public and private sectors.

In a survey published by *Research & Development* magazine in the late 1980s, two-thirds of the CEOs of America's top 476 industrial companies said that the U.S. is falling behind other nations in R&D. The corresponding published trade figures for technology-related industries, supported by R&D, suggest they're right. And, except for the advent of China, plus some developments in telecommunications, this picture has changed little in the last 5 years.

U.S. Trade Imbalances
Technology Intensive Industries

Industry	*Surplus/(Deficit) ($US billion,Cumulative 1996)*
Aircraft, airplane parts	10.3
Professional, scientific, control instruments	4.3
Synthetic plastics	4.2
Specialized machinery	3.3
Medical and pharmaceutical products	1.9
Organic chemicals and products	1.4
Power generating equipment	(0.2)
Rubber tires and tubes	(0.6)
Metalworking machinery	(0.7)
Paper and paperboard	(1.1)
Watches and clocks	(1.1)
Iron and steel mill products	(3.7)
TV, VCR, and sound equipment	(5.5)
Electrical machinery	(9.5)
Fibers and textiles	(14.6)
Motor vehicles and parts	(26.4)

Let's talk about how China is changing the picture—for the worse. In 1994, the U.S. imported nearly $39 billion in goods from China while exporting only $9 billion, for a trade deficit of $30 billion. In 1995, it was estimated that China would ship $48 billion in goods to the U.S. for a trade deficit of $36 billion. China is rapidly becoming America's most lopsided trading partner.

Japan, however, is still our major technology competitor. The U.S. continues to lose ground to Japan in communications equipment, consumer electronics, business machines, autos and motorcycles, machine tools, scientific instruments, semiconductors, and steel. The U.S. Trade Delegation, led by Mr. Michie Kantor, has identified seven sectors—cars, car parts, semiconductors, computers, supercomputers, telecommunications, and construction—in which the U.S. would like to improve its trade balance. Meanwhile, Japan has targeted fiber optics, biotechnology, optical computing, synthetic fibers, composite materials, superconductor technology, and aerospace as promising technologies for market domination.

Overlying all this is the simple fact that the end of the cold war has shifted the basis for the relationship with Japan. The U.S. alliance with Japan, built on the need to contain communism in Asia, anchored the relationship even when trade tensions threatened to drive them apart. Economics and technology have now emerged as the dominant issues.

Technology, then, has become the currency of industry and has created a global economy. In the process, technology has become one of the principal drivers of competition, playing a major role in changing industries as well as in creating new ones. Technology is the great equalizer, eroding the competitive advantage of even the most well-entrenched company and propelling newcomers to the forefront. Sony's use of the transistor to gain market dominance in the key sound equipment industry over the U.S. giants—RCA, General Electric, and Zenith—is one example. Technology is continually changing the rules of the game.

Technology transfer is the buzz word of the second half of the 1990s, with Japan often quoted as an example of an economic miracle built on technology. For a total cash outlay of about $8 billion, post-war Japan acquired the cream of U.S. and European technology. A united Europe in 1992, a resurgent united Germany, and the opening up of the Communist bloc is accelerating the impact, and the need, for new technologies in the 2000s. The rules of the game will change even faster.

State and federal governments are trying to get into the technology game both directly and indirectly. The federal government, under its theme of making America more competitive, has passed legislation that allows businesses to acquire intellectual properties (read embryonic technologies) from U.S. government labs and universities. The state of Michigan has poured millions of dollars into its Michigan Modernization Service program for small and medium manufacturers. The problem isn't money—the U.S. traditionally still outspends Japan by 2 to 1 on R&D investment. The problem solution is in the people and the need to be market, customer, and demand driven—Japan produces no product without a large target consumer market!

In turn, business has learned that it is often substantially cheaper to license, or buy, a new development than to invest in costly in-house R&D. However, the private sector still views the government sector with suspicion. We have a long way to go to break through the bureaucratic red tape and create the essential partnerships.

Technology is the great equalizer, eroding the competitive advantage of even the most well-entrenched company and propelling newcomers to the forefront.

Because we live in a time when there are more scientists and engineers alive than ever before, we have a veritable flood of technologies—witness the increase in patent applications worldwide. In fact, there's more technology than the private or public sectors can possibly fund for investment purposes and remain globally competitive. (This is not well appreciated by most entrepreneurs when approaching corporate partners and government for support and interest.) The same excess of scientists and engineers further compounds the problem by shortening the technology window.

Witness the exponential increase in the rate of innovation. From the steam age, to the industrial revolution, to World War I, it took, on average, around 100 years for technology to have an impact. In today's society, that window has shortened to some 7 years in most industries and 14 months for computer software. Professionals and technicians who were once educated for life now find their skills obsolete within 5 to 10 years with projections of 50 percent of our current workforce skills obsolete by the year 2000—a skills drought.

The influence of technology on the skills drought is best evidenced by an example with the simple average auto mechanic. In her past life, when she was Secretary of Labor, Elizabeth Dole, in an article published in the *Intercom Journal of the Society of Technical Communication*, August 1990, noted that in 1965 "the average mechanic needed to understand 5,000 pages of service manuals. With this knowledge the mechanic could be reasonably certain of fixing any car on the road. Today, the average mechanic would need to comprehend 465,000 pages of technical text to accomplish the same task."

Good science has always been good business. A 1989 study, by *Business Week* magazine, of 897 companies in 19 industries demonstrated that the strongest R&D firms, regardless of size, had average growths of 11 percent in sales and 18 percent in profits. In manufacturing, the respective figures were 16 and 31 percent. The study was based on average R&D funds per employee to remove bias from major firms.

With the increasing costs and sophistication associated with R&D, how can business and industry respond to the challenges of innovating new products and processes to remain competitive in the world scene? How can smaller nations like Australia, with less developed manufacturing bases, and larger nations like the U.S., with a declining manufacturing base, remain competitive? How can small business, with significant less resources, gain access to the vital R&D and new products critical to its growth and survival?

In these case studies, we'll examine several potential new business initiatives that respond to these challenges. In particular, we'll talk about several personal cases, that I'm familiar with, showing a trend toward using external R&D and novel business arrangements to make businesses competitive. We'll talk about ants (small business) and elephants (Fortune 500 businesses), high-tech companies, government and industry alliances, university and industry programs, and we'll conclude with the future role of the not-for-profit research institutes as servant to business, industry, and government.

CERAMIC RESEARCH INC.—THE ANT AND THE ELEPHANT

Ceramic Research, Inc. (CRI), is an example of an R&D start-up company funded with seed venture capital to develop and commercialize unique technology. Typically, an R&D start-up company is formed to develop and retain intellectual property rights (patents and know-how) relating to a specific technology. Seed venture capital from one or more sources is provided to the owner of the base embryonic technology in return for a significant shareholding in the company. If the R&D is successful, such rights or shares may subsequently be sold to third parties, or used to leverage additional rounds of financing to market and sell products from the research.

An R&D start-up company is formed to develop intellectual property rights relating to a specific technology.

In late 1989, CRI signed an agreement with the DuPont Company (Wilmington, Delaware) to transfer patent rights and technical information on a novel laser-based process that could be used to produce ceramic fibers for various applications. The agreement was the result of a 3-year search. The search brought inquiries from more than 100 Fortune 500 and Japanese companies—Boeing, Alcoa, and Sohio among them. The overwhelming response required that they methodically select the right partner, including arranged meetings and presentations tied to secrecy agreements to protect both parties interests. CRI is an example of how research, technology, venture capital, Fortune 500 companies, and international business interests were successfully combined. The strategy used to attract the interest of DuPont and some other major companies contains some valuable lessons.

The CRI story is also the story of why and how an ant sought and found an elephant for a partner. In dealing with an elephant, one is confronted with three major problems: how to attract the elephant's attention, how to get the elephant up on its feet, and, critically, how to make sure the elephant goes in the right direction once it is up and running.

Why ceramics? Most people associate ceramics with fine china or clay pottery of brittle, brightly colored materials. However, there is another class of ceramics, known as fine or advanced technical ceramics, which is causing a quiet material revolution in a number of industries. Fine ceramics are lighter, stronger, and harder than steel. Fine ceramics are destined for application in everything from aerospace vehicles to automobile engines, from batteries to integrated circuits, from medical diagnostic devices to cutting tools. Not since the advent of plastics has there been such materials with such promise of affecting us all. DuPont typically understated corporate interest by commenting that

"DuPont's purpose for acquiring CRI's technology was to assess the commercial feasibility of the technology as part of DuPont's commitment to high-temperature materials."

CRI's original charter was to fund the R&D to confirm the feasibility of the idea to use a laser to produce fine ceramic materials. As a small business, CRI faced the typical problem of how to investigate the novelty of a new idea without its own R&D capabilities. CRI hired its uncle, Midwest Research Institute (MRI), one of the US's leading not-for-profit research institutes, to provide the necessary support and services—it's always cheaper to buy specialty services. Using MRI's staff and facilities, CRI was able to internally demonstrate the feasibility of the CRI process. The process was named after the company.

The early R&D work produced sample quantities of carbon, silicon, silicon carbide, silicon nitride, and boron fibers with varying degrees of success. Materials produced from single component materials, such as boron, were pure and strong, but materials produced from multicomponent mixtures, such as silicon nitride, were more fragile. CRI was not convinced that the process was viable since a number of key technical questions relating to chemistry and laser processing remained unanswered. The story could have ended right there on an inconclusive note, but fate played her card.

About this time, I joined MRI Ventures—one of the partners in CRI and the for-profit subsidiary of MRI. Originally trained as a chemical engineer, I had led a business team for Union Carbide Australia to develop and license a novel separation process worldwide. I was given the job of evaluating the commercial viability of CRI's technology and recommending a course of action to CRI's board.

I was encouraged by the initial research results and particularly so since CRI had produced ceramic fibers in a simple and crude apparatus without input from the industries who might in the future buy, or use, ceramics produced by the CRI process. The inventor had just plugged his crude apparatus into the wall, turned on the juice, and made fibers. Like many R&D companies, CRI was working in a vacuum, not only unaware of the value of its technology, but more importantly, the opportunities and business it could create for major companies. I also discovered that CRI was dragging its feet on filing the essential worldwide patent applications to protect the novel intellectual property that CRI had developed.

We also concluded that CRI needed a partner to help evaluate, develop, and commercialize the CRI process. It was a simple decision not to seek additional venture capital for CRI and to go it alone since the ceramics industry was dominated by major Fortune 500 and overseas companies. Money alone, lot's of it, would not buy CRI a ticket to the ceramics game and solve its market entry problems. CRI could not feasibly establish the necessary engineering, marketing, and distribution resources to compete with the majors. What did we want in a partner? We decided to look for a partner with the following characteristics:

- Corporate objectives that included long-term commitment, allocation of resources, and growth through advanced ceramic materials technology
- Previous history and experience in commercializing new process technologies
- Availability of, or access to, strong R&D scientific and engineering skills
- Ability to specify fiber properties essential to specific industrial applications
- Ability to measure and characterize mechanical, chemical, and electro/optical properties of advanced ceramics
- Ability to formulate and test composites for industrial applications including life cycle and strength tests
- Ability to test material properties of ceramics at elevated temperatures including microstructural, creep, and fracture analyses under load
- Strong process design and engineering skills to support R&D efforts, to evaluate scale-up data, and to prepare both prototype and commercial plant designs

People skills were key in commercializing the opportunity! It was essential that CRI's partner not be averse to technology originating from outside the company (the so-called not-invented-here factor). It was also essential that the partner's group leaders be experienced in working in joint venture opportunities. A free interchange of ideas and information is crucial to ensure a successful technology transfer.

We thought that the CRI opportunity might appeal to businesses in these three categories:

- Producers of advanced engineering materials or electronic semiconductor substrate products who wanted to protect or expand their current technology base and markets or who desired to integrate into new markets
- Companies seeking to acquire or to license an advanced ceramic materials technology to establish or sustain a competitive business opportunity in engineering materials, electronics, optical, or semiconductor industries
- Suppliers of raw materials for advanced ceramic materials who wished to integrate into the actual manufacture of ceramic fibers or electronic substrate materials

We recommended to CRI's board that CRI might commercialize the technology by one or more of the following business strategies:

- A joint venture company could be formed to develop, manufacture, or sell products in fields of advanced engineering materials, new electronic materials, or new optical and medical fiber products. CRI would contribute proprietary technology rights, inventor access rights and full R&D support services through Midwest Research Institute. The partner would contribute R&D capital, resources, and industrial experience to direct joint ventures into profitable markets. Equity would be divided based upon contribution with guaranteed future rights split to protect each partner's business interests.

- An option/license/acquisition agreement could be granted for specific uses under pending patent and proprietary know-how rights with a technical support agreement. Various options could be built in to match the various stages of developments of the technology including an option to joint venture at a later stage.

- A combined technology collaboration, patent, and know-how cross-licensing agreement could be negotiated with options to future rights to satisfy and protect each party's future business interests. CRI would expect the partner to contribute to the cost of transferring the technology to the partner.

The board seemed pleased (probably relieved) by the plan, installed me as president of the start-up, and sent us naively on our way to commercialize the technology.

A mini business plan, which we describe as a "business opportunity," was prepared. This document described the CRI technology, the potential markets, the R&D status, and suggested business options. It was mailed to a select list of 150 companies worldwide. Press releases announcing the opportunity were also mailed out to targeted media. The response was overwhelming. Over 100 companies responded immediately, among them Japanese companies clamoring for more information. Feast had overtaken famine. Overnight, we had gone from being technology-driven to market-driven.

To process the responses, we designed a simple five-step program aimed at getting to know the respondents and providing the essential information to allow both parties to reach a conclusion within an 18-month time frame.

1. Respond to their initial interest

2. Arrange a two-way nonconfidential discussion

3. Arrange a confidential technical and economic presentation

4. Agree to produce and permit samples to be analyzed to confirm potential applications of interest to the prospective partner

5. Engage in commercial negotiation leading to a successful partnership

About the same time, I visited Japan to meet with several major companies, including Nippon Steel, Sumitomo Chemicals, Denka, Mitsui, Hitachi, Mitsubishi, and Toshiba. They were all interested mainly in consumer-related new material opportunities in electronics and components. Most people fail to realize the simple trick of getting to the Japanese markets' attention: they are almost solely focused on consumer-related markets.

Through the following year, CRI hosted visits from Boeing, Alcoa, BP America (ex-Sohio), PPG, DuPont, Alcan, General Electric, Englehard, Corning, and others. Two confidential reports were presented to prospective partners as part of the presentation. One report was prepared describing the process technology and the other ballpark investment figures and operating data. The reports were presented under secrecy agreements with each company. The minimum secrecy period was 5 years. The 5-year period was designed to allow CRI sufficient time to process its patent applications and stake out its claims.

I also used the long-term secrecy provision to secure a serious commitment from each company. These long-term obligations, coupled with the detailed confidential reports, required the prospective partner to think long and hard, at a reasonably high management level, before accepting this lengthy period of confidentiality. CRI's disclosures would effectively taint each company's in-house-related R&D efforts. CRI's disclosure thereby created a competitive niche for CRI and for its prospective partner.

Within 6 months of starting its marketing program, CRI entered stage four of the program and commenced making samples for certain key companies. CRI's partners clearly defined the properties and specifications that they needed to respond to the opportunities within their industries. CRI's role was to meet those challenges, thereby, entering the "D" phase of R&D.

CRI also had to respond to another challenge. The principal scientist and inventor left MRI about this time and I had to negotiate a consulting arrangement with him. Technical support for CRI was supplied by the inventor and by staff scientists at MRI.

This was a time of rapid development of the technology and confirmation of the often quoted maxim: "In science, the credit goes to the man who convinces the world, not to the man to whom the idea first occurred."

CRI's first major success was to produce continuous, pure boron fibers that were rated at a strength in excess of 1 million psi—a major breakthrough. The strength and lightweight properties of this new material made it ideal for several immediate aerospace applications, including Reagan's Orient Express, the successor to the Space Shuttle.

This important development also encouraged Boeing Aerospace Company to negotiate an option agreement to secure potential rights for aerospace applications. Under the terms of the agreement, Boeing was given the right to duplicate CRI's equipment in their facilities and to embark on its own aerospace composite R&D.

Boeing fell into a major category on the original opportunity list: "Companies seeking to acquire or to license an advanced ceramic materials technology to establish or sustain a competitive business opportunity in engineering materials, electronics, optical or semiconductor industries."

I knew that it was fundamental to developing technology that a company must also be able to evaluate, or characterize, the materials it produced. Boeing was expert in the composite field and was able to direct CRI's R&D program in this market. CRI agreed to perform additional R&D in Kansas City for Boeing, as well as to provide technical support. It was clear from the outset, however, that Boeing was in the aerospace business, not in the materials business. Boeing never intended to actually manufacture fibers from CRI's process technology. A manufacturing party still had to be found.

Courting the Elephant. So, Boeing and CRI embarked on the next stage—to find a partner. Through various contacts, CRI developed a list of potential partners that included several heavyweights, i.e., 3M, DuPont, Morton-Thiokol, and Alcan.

Meanwhile, CRI continued to produce samples for evaluation by its prospective partners. Separately, the prospective partners sent business teams to Kansas City and an extensive due diligence began. CRI and the prospective partners studied several elements:

- CRI's technology, including process, apparatus, and future products
- Potential economies of the CRI process
- Market size, niches, and characteristics for projected opportunities
- Fit with existing in-house new business development plans
- Properties and qualities of the sample materials being produced by CRI
- CRI's patent position and potential effectiveness in protecting future markets from serious competitors
- Nature and terms of the proposed arrangement

While it was clear that each prospective partner sought to "control" the technology, their interests in materials and business strategies were different.

Boeing's sponsored partner produced a scenario to develop the technology through boron fibers because of their unique application in the aerospace and defense industries. The other partners chose silicon carbide and zinc selenide fibers as materials upon which to justify their interests to their respective management. Recognizing that CRI had only produced very limited quantities of material for evaluation, the partners had to exhibit a large degree of faith before deciding to negotiate for rights to the technology.

Clearly, the fortunes in the technology game belong to those whose vision of the future allows ample opportunity to change direction when the market calls. DuPont's nylon and Kevlar fibers are examples of materials that found markets that weren't in the original vision of the inventors. The territory represented by patents and intellectual property must be staked out with this expanded vision in mind.

In developing technology, a company must be able to evaluate the materials it produces.

The strategies the potential partners proposed to develop the technology varied from joint R&D proposals, to licensing of CRI's technology and patents, to assignment of CRI's technology and patents.

During that year, I traveled extensively, meeting with the individual partners to analyze the relative merits of each proposed arrangement. It became increasingly clear that DuPont represented the best choice.

Why DuPont? Since the 1930s, DuPont had led the way in developing processes to produce new materials. In each succeeding decade, DuPont had invented the polymer melt spinning, dry spinning, gap spinning, cold drawing, and fiber sintering processes that were necessary to produce polyester, nylon, and Kevlar fibers. What's more, certain key people at DuPont recognized that CRI's patent position could become a veritable patent machine—protecting far into the future the materials markets that DuPont/CRI might develop. The other candidates did not appear to be so far-sighted in this vision. They wanted to focus on known, shorter-term applications and did not seem to grasp the breadth of CRI's technology. I pushed for DuPont as CRI's preferred partner.

Finally, about 18 months later, CRI and DuPont executed an assignment agreement. CRI assigned its basic technology and patents to DuPont for an initial payment involving seven figures, plus a continuing royalty stream based on a percentage of the sales value for products resulting from CRI's patent. CRI also agreed to put DuPont in business by selling it basic research equipment that would be installed in DuPont's Wilmington facility. In turn, DuPont agreed to assume responsibility for CRI's patents and to embark on a multimillion dollar, multiyear program aimed at the commercialization of CRI's technology.

PYROLYSIS MATERIALS RESEARCH CONSORTIUM—AN INDUSTRY/GOVERNMENT LINKED CASE STUDY

Let's turn our attention now to a different case study, in fact, a combination of case studies involving an industrial consortium of Fortune 500 companies and small businesses, with several disciplines, to develop and commercialize a U.S. government-derived technology.

In 1989, MRI Ventures formed an industrial consortium to commercialize a novel process for producing phenolic-based adhesive materials. Wood waste products—sawdust from saw mills and bark from pulp mills—can be used to produce feedstocks for phenolic adhesives. These materials are used in the production of plywood, composite boards, and molding compounds. The adhesives may also be used in engineered plastics and in new applications such as composites for automobiles of the future.

The Technology. Since 1986, the U.S. Department of Energy's (DOE) Office of Industrial Programs has funded the development of a biomass conversion program at the Solar Energy Research Institute (SERI) (now the National Renewable Energy Laboratory). This program led to the development of a novel pyrolysis process to produce high yields of complex phenolics/neutrals (PN) oils from wood waste. The PN oils are recovered by a novel separation process to extract the phenolics-rich fraction from the oils. Additional research has defined a number of applications for these biomass-derived phenols in formulations for phenol-formaldehyde (PF) resins. The process won an R&D 100 award.

Market. In 1989, the PF resins market worldwide totaled 3 billion pounds with plywood resins accounting for over half the market and the balance being for insulation and molding compounds. Based on preliminary cost projections of 10 to 27 cents per pound, it appeared these SERI biomass-derived materials could be substituted for phenol costing 40 cents per pound in PF resins.

High risk, early stage technology requires a multiple partner concept.

Given the high risk, the early stage nature of the technology, the need for more than one engineering discipline, the need to scale-up the process, including the design of the fractionation scheme, and the need to evaluate the oils, adhesive formulations, and the resin molding compounds, we determined that a multiple partner concept was essential in lieu of a single-licensee approach. We selected a consortium as being the most effective commercialization route. This partnership approach was endorsed by the industrial review committee, who recommended the consortium be promoted to the industry at large.

Applicable Law. Under the prevailing Bayh Dole PL-9620 law, MRI, as the contractor for DOE's SERI facility, could elect title to inventions and the associated patents. In the case of this biomass technology, the basic patent rights were elected and transferred to MRI Ventures, its commercial subsidiary, for commercialization. MRI further agreed to transfer its future rights under this government-funded R&D program to MRI Ventures as the R&D and the technology developed.

Creating Interest. Interest in participating in the consortium was sought from the industry at large by a 500-plus direct mailing piece to selected companies and trade associations worldwide, together with worldwide news releases to all major technical publications and newspapers. Given the origin of the technology from a U.S. government laboratory, all interested companies were invited to participate in the consortium, but with a preference given to U.S. industry.

MRI Ventures designed the consortium to be driven by industry to ensure the practical application of the resulting technologies—a market-driven approach. The members of the consortium would share the results of a major R&D effort for a fraction of the total cost with incentives to develop additional technologies. R&D risk would be substantially reduced both in cost and time because of the collective capabilities of the individual members.

Our initial approach was to invite DOE to be part of the consortium, but it was later determined that this was not the most advantageous form for the consortium, particularly from the industry's point of view. Confidentiality and patent and technical data rights issues were complicated if the DOE was included. Subsequently, a Memorandum of Understanding was negotiated between DOE, SERI, MRI, and MRI Ventures in which DOE gave its blessing to the formation of the consortium. In turn, in a unique twist, the industry parties elected to go ahead on trust with the draft agreements!

Member Characteristics. What did we look for in inviting companies to participate? We sought U.S. companies; commitment to adhesives-related businesses; in-house R&D in adhesives production or use; market and applications knowledge; adhesives, foams, or composites formulation know-how and process design and development capability; and production, marketing, and distribution of related products.

Our Approach. In June 1988, MRI Ventures produced a business plan that outlined the formal structure of the consortium, its collaborative nature and the R&D mission. The plan also included an optional license agreement and a draft acceptance letter of intent. At the onset, it was clearly recognized by both government and business that the documents were on the leading edge and would be subject to review and revision. While the broad objectives were spelled out in the agreements, certain management, patent, and licensing issues remained to be negotiated.

This plan was forwarded to the 30 companies that had responded expressing additional interest. In August 1988, invitations were mailed to 18 companies who possessed the requisite capabilities inviting them to attend a review meeting at SERI that September. Concurrent with the September meeting, individual technical presentations were made by SERI's biomass technical director and research staff to many of the participants who expressed interest in the consortium. Additional information and updates were continuously mailed to companies as questions were raised during this period.

In May 1989, formal comments and approval of documents for establishment of the consortium were received from DOE. DOE's comments were redrafted into a final proposal and circulated in early June 1989, to the 15 companies that were still interested in the consortium.

The Members. After some 16 months of effort, the consortium was formed: Allied-Signal, Inc.; Aristech Chemical Corporation; Georgia-Pacific Resins, Inc.; Plastics Engineering Company; Pyrotech/Interchem Industries, Inc.; and MRI Ventures, Inc.

In a unique situation, the private sector companies joined the consortium largely on trust. At the time of final execution, the final documents were still in the "original" draft form!

MRI Ventures was licensor and served as the consortium's managing partner and administrator for the other members. The members of the consortium who were invited to participate were chosen so as to represent all aspects of the commercialization process, including current phenol producers, resin manufactures and users, companies interested in building and scaling up the technology, resin sellers and distributors, and companies experienced in development and management of patent portfolios.

Funding. To provide some idea of the funding involved in the consortium, DOE expended approximately $7 million over the 5 years of the consortium. Such funding depended upon appropriations from the Office of Management and Budget. On the industrial side, member fees during the consortium's 5-year term totaled over $560,000 with additional in-kind industry funding in excess of the government's original funding.

Such in-kind R&D included the design and scale up of the pyrolysis reactor, the actual production and fractionation of the pyrolysis oils, the incorporation of the oils into adhesive formulations, and the application and development of products arising from the oils and the formulations themselves. In addition, the consortium considered in-kind research to evaluate alternative feedstocks beyond wood chips, including bagasse, as well as investigating the other fractions present after the PN oil is separated out. On the commercial side, in-kind contributions included market research of the products and their application to industry, as replacement for phenol, the technical evaluation and licensing of the technology, and general technical and business support.

Term. The consortium's initial 5-year term and its continuation during this period was subject to achieving annual technical and business milestones as recommended by the industry members to MRI Ventures. Each of the milestones carried an associated performance standard.

Member Duties. Each member of the consortium was expected to provide a representative to serve on business and technical review committees to advise MRI Ventures, develop commercial applications through direct and in-kind R&D, evaluate the technical and commercial feasibility of the technology and its application within the industry, suggest consultants and subcontractors if additional expertise outside the current membership was required to develop or commercialize the technology, assist with management of the patents and intellectual properties to maximize member benefits and potential license returns, and propose suitable licensing policies based on industrial experience.

Given the novel nature of the technology and its multiple products and uses, MRI Ventures relied heavily on recommendations from industry as to a fair and reasonable licensing policy.

Member Benefits. As part of the consortium documents, MRI Ventures agreed to contractually obligate itself to make the rights available only to the members of the consortium. Membership had its privileges–including participating in a major research effort at minimum risk and cost. Also, members were playing a key role in developing new technology that may have a significant impact both on phenol production and downstream products such as adhesives and molding resin compounds. They received proprietary reports and briefings on potential breakthrough technologies that could impact these industries.

Each member had an option to acquire a license to patents surrounding the base technology.

At the same time, they were assessing the impact of the technology on their current business interests, as well as potentially improving the economics of existing phenol processes and the production of phenolic resin adhesives and formulations. In addition, the potential also existed to develop new products and markets because of the unique properties of the resins. Furthermore, the consortium served as a network that allowed strategic relationships of mutual interest to be built. Each member of the consortium had an option to acquire a license to both the current and future patents, inventions, and know-how surrounding the base technology. Also, members could invent new technologies and intellectual properties as a result of their own in-house and supplementary in-kind research.

Management. The consortium was not a legal entity in its own right and was designed as a unique hub and spokes. MRI Ventures served as the hub, or managing member, while the other members served as the spokes. This is a unique approach under prevailing laws governing technology transfer from a U.S. government laboratory.

MRI Ventures provided the common link between the business and the technology, while managing cooperative R&D effort between parties with diversified interests: the government, SERI, MRI, and industry. This link allowed industry to obtain simplified access to government-derived technology and was brought about because MRI Ventures was the sole repository of the intellectual property rights. As the owner of the technology and the licensor of the basic patents and know-how rights to the other members, MRI Ventures served as licensor and protector of the technology. Given the sensitive and competitive nature of several members of the consortium, MRI Ventures also served as a conduit to disseminate R&D and business information to and between the members—protecting both individual and collective interests. The consortium was registered with the Federal Trade Commission (FTC) and the U.S. Justice Department under the National Cooperative Research and Development Act. Since the consortium was not a legal entity unto itself, MRI Ventures served as the contracting party when it was necessary to retain consultants for and on behalf of the consortium.

Barriers to Cooperative R&D. In forming the consortium, we had to address a number of critical issues that continue to impact future government/industry R&D in the U.S. These issues include exchange of information, cost sharing, patent and technical data rights, and establishment and maintenance of private and public sector relationships.

In exchanging information, two key questions were asked: To what extent can government and industry interact technically to discuss program details from government-sponsored research? and How can industry protect its competitive interest by preventing the disclosure of its proprietary information from Freedom of Information (FOI) requests?

On the one hand, the function of government research is to engage in research that is either in the national interest or is of sufficiently high risk to not be of serious immediate interest to the industry. On the other hand, industry's investment in developing and commercializing new government-derived technologies must be protected by minimizing the dissemination of information to potential competitors.

The initial approach was to have DOE participate in the consortium. However, if DOE had been an actual member of the consortium, the potential existed for third parties (including potential competitors) to request information produced in-kind at the industry facilities. Clearly this was not in the best interest of the industry partners and was viewed as a disincentive. Conversely, of course, it is necessary to provide reports demonstrating the proper use of government funds in furthering R&D.

As a condition for providing continued cost-shared R&D funding for the biomass program, the Office of Industrial Programs required industry matching funds. While the direct effect of cost-shared funds with industry is not a problem, an indirect problem can be caused because of the effect of patent and technical data rights of the cost-shared research that was performed at a government laboratory. If DOE SERI shared any of the R&D costs with the consortium, under current law, DOE owns all technical data. Such technical data cannot be protected from an FOI request from a potential competitor.

This led to the creation of two separate R&D programs: the maintenance of the existing DOE program and the consortium program. The DOE SERI program continued with the research "R" and industry developed "D" technology in key applications and product use areas. While the base technology was protected by patents, the base SERI research technical information was not considered to be as valuable as the technical information for the applications and products developed by the members.

Hence, securing patent and data rights (know-how) can be a major barrier to establishing industrial interest in government-funded R&D. Under current law, not-for-profits, small businesses, and universities can elect title to inventions that become patents from government-funded programs. Big business requires a waiver to obtain such title. Technical data, except for a brief period of time during the patenting process, resides with the government and, hence, cannot be protected. The ownership of technical data for inventions developed at government laboratories resided within the government. Clearly, the commercialization of technology requires protection of the know-how that is developed as a part of the industrial manufacturing and scale-up process.

An even greater barrier is philosophy and the actual relationship between the private and public sector. Government, with its mandate to act in the common interest of its constituency, and industry with a need to develop and protect markets, clearly have views that are very often at opposite ends of the spectrum. In many instances, industry has refused to work directly with the government, sighting the potential competitive risk as being too great to justify the required business investment. Conversely, the 12 civilian government agencies, including DOE, have developed an extensive library of intellectual properties that can and should be used to support industry and to inspire the U.S. competitive position in world markets—the common goal. Under the current political and regulatory climate, a license is required by business to obtain the rights to such technology and the process is often lengthy and difficult.

PLASTICS COMPUTER INTEGRATED MANUFACTURING (PCIM) CONSORTIUM

Now we'll take a look at PCIM, a program launched by a research institute in Michigan. The approach was to link the supply side (multi-university) with the demand side (multi-industry) in a consortium driven by industry needs to integrate computers into the plastics molding injection industry.

The emphasis was on a "try-before-you-buy" plan to introduce computer integration into plastics manufacturing—injected molded plastics in particular. Each consortium member received the results of a $1 million R&D program for a fraction of the total cost.

PCIM was typical of the rationale for investing in developing R&D capability that can be divided into four broad and partially overlapping categories: investing for the future industry; meeting regional needs; advancing the industrial, business, and manufacturing capabilities; and strengthening applied science and engineering education.

Implementing CIM systems can help companies respond to a rapidly changing worldwide marketplace.

CIM Background. Computers and related technology play an ever-increasing role in manufacturing and the issue of computer-integrated manufacturing (CIM) is being embraced by companies developing strategies for the future. CIM can be one or more systems or techniques that a company applies to their operation. CIM systems include just-in-time, total quality management, group technology, manufacturing resource planning, statistical process control, simultaneous engineering, robotics, computer-aided design/computer-aided manufacturing, and computer controls.

Implementing CIM systems can help propel forward-thinking companies past the competitors by allowing them to respond to a rapidly changing and demanding worldwide marketplace. CIM can be used to effect specific components of a company's short- and long-range strategic plans requiring state of the art and breakthrough technologies to maintain and improve quality production and products. The plastics industry, with its rapid growth and many applications, expressed the need and desire to use CIM systems as they can be applied to the industry.

Just as important as the development and application of CIM technology was a workforce trained to effectively implement CIM. Studies showed that 50 percent of the skills of the current workforce would be obsolete by the year 2000. This would require substantial training and development of new skills to keep pace with the ever-changing industry and marketplace standards.

Three critical areas that contributed to the underuse of computed-integrated production in plastics injection molding were identified as education and training enabling current employees to use existing computer-integrated technology and new technologies as they were developed, an understanding of how to efficiently apply computer integration to injection molding at the factory level, and being able to determine at what point and to what degree integration is cost effective.

Consortium Model. A bicycle is perhaps the best analogy to describe how the consortium works. On the standard bicycle, the front wheel steers, the rest of the vehicle follows, and the rear wheel provides the power to move the vehicle ahead.

Relatively simple roles, with clearly defined functions, were applied in a similar way through the Research & Technology Institute of West Michigan. Nine plastic manufacturing firms—3M, ADAC Plastics Inc., Batts Inc., Cascade Engineering, DuPont, IBM Corporation, Moldflow Inc., Prince Corporation, and Wright Plastic Products Inc.—were invited to form the front wheel to ensure the future of their industry by investing in applied research, technology deployment, and training. The frame for this new vehicle was completed by building the back wheel with three West Michigan academic partners—Western Michigan University, Ferris State University, and Grand Rapids Community College. Thus, the strategic alliance, known as the Plastic Computer Integrated Manufacturing (PCIM) Consortium, was born.

The PCIM Consortium leveraged the individual disciplines from the participating schools to target and participate in research, development, training, and application of CIM to the plastics injection molding industry.

The PCIM Consortium was driven by the needs of the industry. PCIM provided the information and tools to improve the productivity, marketability, and thus, profitability of the plastics injection molding companies, their suppliers, customers, and equipment manufacturers. The PCIM Consortium Research and Development Plan specifically targeted the evaluation, application, and deployment of CIM systems, architecture, advanced injection molding equipment, and secondary production processes; investigation of new plastics injection molding materials and composites, equipment configurations, and specific operating conditions, throughputs, cycle times, and controls; and training in CIM and state of the art plastics injection molding equipment operation and techniques.

Unique Features. The consortium brought together the resources, faculty, staff, and capabilities of three educational institutions under the coordination and management ability of a research institute (with no vested commercial interests) with the leadership and direction of industry.

The consortium R&D program was built around a functioning CIM cell to address the equipment, processing, manufacturing, and training issues facing plastics manufacturers. The equipment for the cell was paid for with a grant from the State of Michigan. This type of cell, not available in the U.S. at the time, combined the facilities, faculty, equipment, and expertise of three educational institutions to form a cohesive, fully-operational, state of the art industry unit.

The PCIM consortium cell combined a 250-ton injection molding machine, peripheral equipment such as conveyors, robots, feeders, dryers, monitoring equipment computers, and operators to form a unique, fully-automated system with total state of the industry plastics injection molding capability. The cell could be accessed from remote locations through local area networks and could demonstrate multiplant applications and capabilities, allowing industry the opportunity to direct research efforts and father critical data:

- Preview, test, and determine individual cell component functions, utilities, and performance
- Determine ease-of-operation, installation, troubleshooting, wear, process and product quality control, and cost effectiveness
- Observe real-time production and access comprehensive data on the latest technology—prior to making capital equipment decisions
- Develop training protocols to fully use current equipment

The cell used interfaceable equipment and allowed for incorporation of emerging equipment with the potential to interface with injection molding equipment.

Member Benefits. What benefits did the members derive? Consortium benefits included the following:

- Appointing one representative to serve as a member of the PCIM Consortium Advisory Committee that reviewed, directed, and drove the research plan
- Accessing all technical information and data including annually published business and biannual research reports for the consortium
- Exposing new ideas, components, and state of the technology techniques within an automated environment—and from other members

- Accessing demonstrations, seminars, and training sessions conducted by the PCIM Consortium R&D and management teams addressing CIM for plastics injection molding
- Consulting with academic experts in plastics processing
- Networking with other manufacturers, vendors, or suppliers to discuss common applied research needs and developing strategic relationships
- Nonexclusive rights to license to any patent rights developed during the term of the consortium
- Rights to separately fund additional research in areas of proprietary interest to a member company (additional research was performed under separate agreement with the member through R&TI and the member school)

Deliverables. What did the consortium members get for their money? They received reports on research tasks conducted as part of the PCIM Consortium Research Plan and updates through R&D task reports, university and college training program offerings, focus reports on research conducted on CIM cell as selected by the PCIM Consortium Advisory Committee, seminars and demonstrations offered by the consortium, and state of the industry forums.

Cost and Duration. How much did it cost? Each company paid a fee of $50,000 for a 3-year program in a series of annual payments of $15,000 the first and second year and $20,000 the third year. Each company received the results of the entire program estimated to represent an R&D effort of $1 million, but only paid a fraction of the cost.

What distinguished this consortium from more prevalent business alliances was its fundamental approach to problem solving. The research institute acted as a facilitator to link the demands of business and industry with the best available researchers in affiliated universities and research laboratories. With PCIM, business and industry, as the front wheel, steered the consortium and set the agenda for the research. Members of the rear wheel, represented by the academic researchers, provided additional know-how, technical skills, and resources to power the consortium towards answers sought by business and industry.

This response to the demands of business and industry was a critical factor that guided the consortium. Business needs proven technologies as much as it needs innovations. What it doesn't want, nor can it afford, is to fund esoteric research without practical application.

Business needs proven technologies as much as it needs innovations.

The research institute managed the research effort and guided the consortium. It served as the consortium's managing partner and administrator for all the members—it had no vested interest in competing with any of the members of the consortium. It also served as a repository for any new innovations that might be of commercial value to its business partners. This made it easier to deal with one entity in transferring those rights (and knowledge) to industry.

Part of the mission of regional research institutes is to assist business and industry in deploying technologies to keep them competitive in the global marketplace. The significant advantage, and the distinctive difference between the PCIM Consortium and other alliances, was the response to business. Business and industry leaders set the course for the R&D conducted by the PCIM Consortium. Business understands the myriad problems it faces on the front line of competition daily. It understands the areas in which it must perform better. What it was lacking was a vehicle to carry out an effective program for technical improvement.

PCIM became a novel business strategy for companies to solve common problems, implement new technologies, and fight off foreign competition in plastics manufacturing.

So, why would plastics companies seemingly competing with each other want to cooperate and share information? The answer comes from understanding strategic alliances. A strategic alliance is a communion of resources to pursue business opportunities of like or mutual interests. Firms involved in PCIM, while sometimes directly competing with each other, still understood the need to improve their technical abilities, see ways to continuously improve, and fight foreign competition.

To make PCIM work, we developed the structure for the consortium, created a collaborative and cooperative environment among members, identified and clarified the R&D mission, established goals and time lines for accomplishing the mission, and then recruited the researchers to conduct the applied research.

On the one hand, PCIM was a strategy to upgrade existing processes and deploy new technologies used in plastics manufacturing. On the other hand, PCIM was a novel business strategy—a tool to solve problems in the most efficient manner possible. PCIM participants were able to maximize their investments in research and development by pooling resources and knowledge to yield the greatest return for the lowest risk.

For example, the cost benefit ratio on basic R&D improves significantly in a consortium. An initial per company investment of $50,000 compounds with the contributions of other consortium members. In the case of PCIM, the individual investment yielded the benefit of a $1 million research project with all members sharing in the information obtained at a minimum 20/1 leverage. This is a definite benefit for consortia members, but only one of many ways that it differs from other alliances.

PCIM represented a fundamental shift in the ways of doing business, especially for smaller companies who have been unable to bankroll substantial R&D projects. Yet, these same companies, who have grown over time by being innovative and creative, understand that continued R&D efforts are their lifeblood and opportunity for the future.

The PCIM business strategy focused on the problems in the industry. It was not research for the sake of research. In these difficult economic times, business and industry cannot afford the luxury, nor do they have the desire to fund basic research work without having an idea of the potential outcome and probability of success.

Consortia offer the opportunity to breathe life into companies. They are flexible, cost-effective tools that meet the challenges posed by foreign competitors and respond to the needs of business and industry. They are a strategy that companies, even small businesses, can adopt to move their business to new levels of performance in these competitive times.

The PCIM model can help other industries guide their future progress. Once business and industry establish an R&D agenda, a "disinterested party" can recruit the best brains available from colleges, universities, or government laboratories to address industry-defined problems. From this, budgets, schedules, and time lines are developed to ensure that projects won't get lost in space or orbit out of control. Or, that the bicycle won't fall apart or end up in the ditch.