This column provides examples of cases in which students have gained knowledge, insight, and experience in the practice of chemical engineering while in an industrial setting. Summer interns and coop assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of analytical tools used and the skills developed during the project should be emphasized. These examples should stimulate innovative approaches to bring real world tools and experiences back to campus for integration into the curriculum. Please submit manuscripts to Professor W. J. Koros, Chemical Engineering Department, University of Texas, Austin, Texas 78712.

INDUSTRY, ACADEME, AND GOVERNMENT

Building a New Relationship

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Every business is under increasing pressure to achieve outstanding financial results. At the same time, however, achieving those results is becoming ever more difficult. The reduction of international trade barriers combined with the appearance of strong, technology-based regional players has resulted in both increased competition and reduced profit margins. To compete in this new global marketplace, almost every large company in almost every industry has found it necessary to right-size or restructure their organization, or to re-engineer their work practices.

Although chemical industry research and development (R&D) spending is growing modestly, an increasing portion of R&D budgets is being dedicated to short-term technical support of existing businesses and environmental compliance. Most companies have reduced the amount of their R&D budgets dedicated to exploratory or long-range research at the same time the U.S. government is slashing both its defense and nondefense related R&D spending. For many of us, these were painful but necessary changes directed at reducing our costs and increasing our global competitiveness. Now, we must look to the future to improve the value our companies deliver to the customers and stockholders.

The chemical industry's traditional approach of doing essentially all of its own R&D must yield to a new paradigm in which the talents and resources of academe and government will be leveraged to produce results while containing costs. Some of what government spends on R&D should be channeled into areas of research that will have a long-term effect on improving the competitiveness of the chemical industry. Together, industry, academe, and government must unleash the pent-up power of our organizations and turn them loose to create uncommon value in the marketplace—a sustainable value that will provide an economic foundation for sustainable growth into the twenty-first century.

A new partnership between industry, academe, and government could provide a foundation upon which the value-creation process could be revitalized. In this paper, we will report on DuPont's recent experiences in establishing a new type of partnership between government, industry, and academe.

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GROWTH IN THE US CHEMICAL INDUSTRY

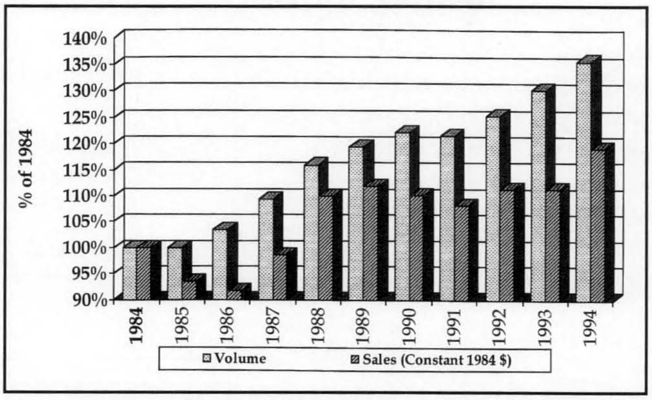

Figure 1. *U.S. chemical industry shipments and constant dollar sales indexed to 1984 (Source: 1995 CMA Data Book).*

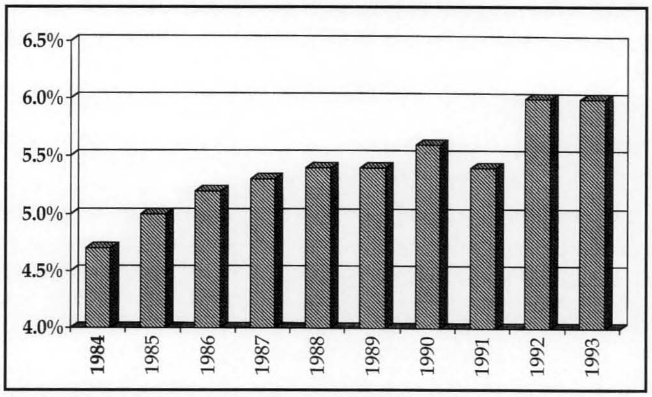

Figure 2. *Chemical industry R&D funding as a percent of sales. (Source: 1995 CMA Data Book).*

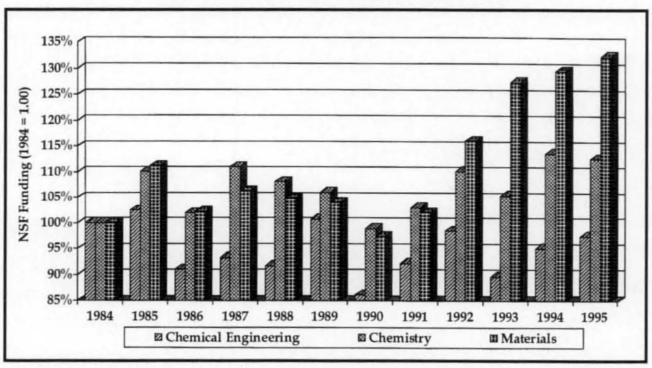

Figure 3. *NSF funding of areas of interest to the chemical industry.*

During the last decade, the U.S. chemical industry has steadily grown in terms of volume of product shipped and exported, but competitive pressures have steadily eroded prices, resulting in the dollar value of those shipments growing at a 1% annual rate, as shown in Figure 1. This is in stark contrast to the decades following World War II that were benchmarked by explosive growth fueled by the development and commercialization of synthetic polymers.

During the last decade, however, margins have eroded and profitability is at the mercy of the gross world product (the sum of the gross domestic products of the developed and developing countries). When the global economy is growing, industry returns are reasonable; when it's not, industry often does not earn the cost of capital. This is not a formula for long-term success. In R&D, this has meant that a larger share of the R&D dollar goes to customer support and regulatory expense while less of it supports development of new product chemistry and manufacturing processes.

Compared to defense-related industries such as aerospace and electronics, the chemical industry has received a very small portion of government R&D money even though it has been a major and consistent net exporter. At DuPont, for example, current R&D expense is roughly the same today as it was a decade ago, without any adjustment for inflation, and all companies have cut employment to reduce costs, yet have seen little real growth. Underlying this trend is the simple fact that while volumes are up modestly, selling prices continue to erode at roughly half the rate of inflation. The net result is that there has been little real growth in total revenue and that growth has barely kept place with inflation.

The chemical industry is in the process of a major corporate transformation as it responds to this new environment. We have worked to meet this global challenge and to become more cost-competitive. Staying competitive is good—it is essential—but it will not create real, sustainable growth, and growth is critical both to industry and to our national economy. Companies that create value in the marketplace prosper and grow; they create jobs and opportunities for their employees; they provide products and services that help people live better and more comfortably; they make a contribution to society. Those companies that fail to create value wither and die.

If value creation is fundamental to business success, then what is value? We believe that all lasting value is created by new technology. If R&D is essential to sustaining the value-creation process, how is the chemical industry funding its R&D activities? Overall, R&D funding has increased from just over 4.6% of sales in 1984 to 6% in 1994 (see Figure 2).

The National Science Foundation (NSF) is a key source of academic R&D funding. While NSF funding for materials research has increased significantly during the last decade, funding for basic research in chemistry has, in constant dollars, increased only marginally, and chemical engineering funding has actually decreased (see Figure 3). This has had a major impact on the chemical industry since new chemistry is the engine that drives growth, and chemical engineering is the route through which value is captured. In the maturing chemical industry, new chemistry and engineering technology will become even more important as the low-cost, high-quality producers dominate the marketplace.

Industry, academe, and the federal laboratories have each developed a certain character as they worked to fulfill what has been their traditional role in the R&D community. This character can be summarized by the strengths and weaknesses of these respective entities in carrying out their mission. Tables 1-3 summarize those strengths and weaknesses as these organizations function to create value in the marketplace through the development and commercialization of new technology. Since funding sources have, for the most part, driven research priorities, industry, academe, and the federal laboratories have remained separate and distinct entities, with limited interaction.

INDUSTRY'S ROLE

The chemical industry itself has been the traditional source of chemical technology of commercial importance. Historically, the chemical industry has worked on major, proprietary developments without direct collaboration with either government or academe. The collaborations that did exist were focused on support of enabling technologies.

With significant research budgets dedicated to the development of new chemistry and the processes needed to manufacture the products resulting from this new chemistry, this traditional approach to research worked well; but as research expenditures dedicated to new product and process development shrank, innovation suffered. The result has been a dearth of major new products and nearly stagnant growth rates.

The historical role of the chemical industry in conducting its own proprietary research has resulted in a matrix of strengths and weaknesses of these research organizations, as can be seen in Table 1. The chemical industry has developed a significant capability to develop and commercialize new, high-value products given the ideas and the adequate technical and financial resources to do so. Recognizing that R&D budgets will remain under continuing pressure, the chemical industry must return to a balanced R&D portfolio that includes a focused fundamental R&D effort, one that leverages the capabilities of academe and government to gain maximum benefit at an affordable cost.

TABLE 1
R&D Strengths and Weaknesses of Industry

Strengths	*Weaknesses*
• Owns the problem	• High cost
• Knows data needs	• Resources may not be available when they are needed
• Has the resources	• Cannot afford state-of-the-art equipment in every area
• Knows the materials	• Limited focus
• Knows how to handle hazardous materials safely	• Reduced emphasis on fundamental research
• Can move quickly	

TABLE 2
R&D Strengths and Weaknesses of Academe

Strengths	*Weaknesses*
• Outstanding fundamental research capabilities	• Limited financial resources
• Lower cost	• Sometimes unresponsive
• Innovative and creative approaches	• Limited ability to manage hazardous materials
• At or near the leading edge of technology	• Uncertain continuity
• Centers of expertise	• Potential loss of proprietary information
• Source of future talent	

TABLE 3
R&D Strengths & Weaknesses of Federal Laboratories

Strengths	*Weaknesses*
• Highly skilled resource base	• Uncertain and variable funding strategies
• State-of-the-art equipment	• Slow to respond to urgent needs
• Outstanding continuity	• Proprietary information protection
• High degree of specialization	• High cost
• Outstanding fundamental research capabilities	

ACADEME'S ROLE

Academe has been the traditional source of fundamental scientific knowledge. Generally unconstrained by the need to produce commercial success, it has been able to focus on developing fundamental scientific knowledge and to work on issues of academic interest, independent of their commercial value. The result of academe's independence of commercial success was the development of extraordinary capabilities in the growth of fundamental science, summarized in Table 2. Academe also gained the reputation of being unresponsive to industry's needs and slow to respond to specific requests, especially if those requests did not also include copious funding.

With government funding of research and development coming under harsh scrutiny, it is likely that money from these sources will be, in the future, much less than it has been in the past. To continue supporting the research infrastructure in academe, new funding sources and structures will be required. The new paradigm for industrial research funding could have a major effect on academe. To take advantage of this opportunity, academe has been and must continue to look for new, innovative ways to leverage its capabilities into research areas of commercial importance. New alliances with industry are necessary for both to prosper.

FEDERAL LABORATORIES' ROLE

Federal laboratories have been a nontraditional source of commercial technology, but, recently, one of increasing importance. They have some of the most capable, specialized, and talented people available in the world in addition to state-of-the-art facilities, capabilities industry cannot afford to replicate. The strengths and weaknesses of the federal laboratory system are summarized in Table 3. Until recently there has been little incentive for the federal laboratories to collaborate with industry in developing products and processes of commercial importance, but with recent changes in both law and funding strategies, this situation is rapidly changing.

Cooperative research agreements, funds-in agreements (funds from industry to government), and the Advanced Technology Program are recent examples of government and industry cooperation. Unfortunately, the government's push to balance the federal budget has put these programs at risk. Like their industrial counterparts, some government leaders are willing to mortgage tomorrow by cutting fundamental research today.

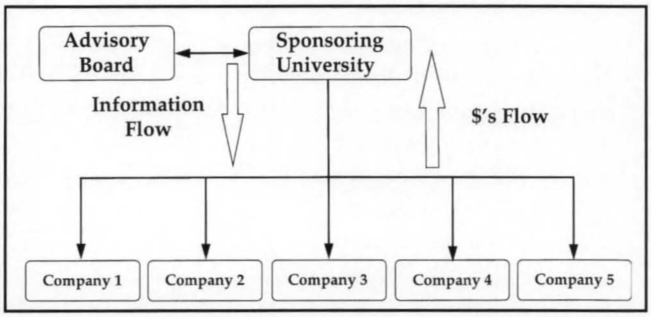

Figure 4. *The traditional consortia model.*

MEETING THE CHALLENGE: GOVERNMENT, ACADEME, AND INDUSTRY

To meet this challenge, government, academe, and industry must form a new partnership designed to kick-start growth and revitalize the industry. The traditional view of the roles of these three entities shows each pursuing research directed at their limited view of the world. There are many problems with this view: there is little collaboration, and much competition; everyone is competing for the same, shrinking pool of R&D dollars; the focus is on getting money, not getting results of commercial importance; there are clear duplications and voids; and all too often, solutions are looking for problems instead of problems finding solutions.

Together, government, academe, and industry need to use their strengths and minimize their weaknesses to develop the strongest research alliance possible and to deliver results of both scientific importance and commercial worth. In some cases, this may require redefining the traditional way they work together through new alliances and consortia. To use the unique strengths of industry, academe, and the federal laboratories, they need to focus on research of commercial interest, with industry assuming a leading role in the partnership. Proprietary right must be maintained by the sponsoring company which can realize a competitive advantage by getting the best people with the best equipment working on the most important problems and producing exceptional results in a very short time.

REDEFINING THE CONSORTIA

Many universities sponsor special-interest consortia that provide a focal point for companies with common technology interests. The companies benefit by sharing the cost of developing and leveraging information, while the university receives a much-needed revenue stream to fund their research efforts. This usually does not give companies access to many of the key academic experts in a particular field. Individual universities find themselves competing with each other for the limited funds available instead of collaborating to leverage their collective expertise in a given field to the mutual benefit of the companies they seek to serve. Companies can derive competitive advantage from these consortia only if they can apply the knowledge developed in a unique way since all members share equally in the information developed by the university-sponsored consortia. This traditional consortia is pictured in Figure 4.

By stating this limitation, we do not imply there is not great value in these consortia. For enabling technologies, those needed to run a business efficiently but whose application does not provide competitive advantage, these consortia allow cost and idea sharing. For higher-risk areas of interest, they permit companies to pool their resources, thus minimizing the cost of developing leading-edge technology. The sponsors of these consortia can still gain competitive advantage by applying the results of this research more effectively than do other members.

These consortia usually have an advisory board composed of representatives from both the university and the sponsoring companies. Consortia priorities are decided by a voting majority of this advisory board; thus, a new research program requires consensus of the advisory board. One member, with a narrow focus leading, perhaps, to a new product or process, cannot always get the needed work done under the auspices of the consortia. A member may also be reluctant to discuss concepts with the other consortia members, fearing that doing so may compromise any competitive advantage such a development may offer.

A key feature of the traditional consortia is the flow of money and information. Money flows from many companies to the sponsor of the consortia (usually a single university, although there are some multi-university sponsored consortia). The sponsor then performs or coordinates the research, compiles the results, and distributes the information back to the sponsoring companies. Although led by an advisory board, day-to-day operations of the traditional consortia are managed by the sponsoring university.

FORMING A NEW PARTNERSHIP

Recently, several companies have developed a new, reverse consortia model (see Figure 5) in which the sponsoring company, rather than the university, is at the core of the consortia. In this model, one or more companies sponsor the consortia and engage those universities and government laboratories having the needed expertise. The focus is, in general, more narrow than in the traditional consortia and is usually directed at, but not limited to, the development of specific product and process science and the technology needed.

Unlike the traditional consortia, the reverse consortia is formed to accomplish a specific purpose, and strategic direction is defined and controlled by the sponsoring company or companies. Participating organizations are not selected based on their willingness to contribute money, but on their specific expertise in the research area of interest. The composition of these contributing organizations may change as program goals are accomplished. Performance against established goals becomes a criterion for continuing participation. Like the traditional consortia, money flows from the corporations to the research institutions and information flows to the paying companies.

Since the sponsoring companies control the consortia, the developed technology can, and often does, remain proprietary. Also, since sponsorship is restricted, potential competitors can be excluded. The net result is that this new consortia model provides companies with the ability to engage the best research minds to achieve important business results and still build a competitive advantage. Concurrently, specialized research equipment resident in academe or at government laboratories can be leveraged to meet the business need. This new model melds together the best of each organization to form an entity of great strength and vitality with only a few weaknesses, as can be seen in Table 4.

DuPont has established several of these reverse consortia. Each is targeted at a specific goal (*e.g.,* improvement of existing asset productivity, development of engineering process control principles from analysis of biocontrol mechanisms, etc.). Potential participants (including professors and their students) are invited to submit research proposals that are then upgraded interactively until they are either accepted or rejected. Although the final decision rests with DuPont, consortia members collectively upgrade these proposals to meet the stated goals. DuPont then manages the projects and works with participating members on project milestones, timing, and resource requirements.

One of these reverse consortia, shown in Figure 6, is for the development of an exciting software integration tool called the Prosight Engineering Workbench. The Prosight development is a low-risk, high-return effort that requires many skills not resident in DuPont. We have formed a reverse consortia to acquire those skills and accelerate the product development.

We are developing Prosight in conjunction with Microsoft, Hyprotech, Interna, the University of Massachusetts, Carnegie Mellon University, and the University of Edinburgh. We envision Prosight as a tool our engineers will use to integrate

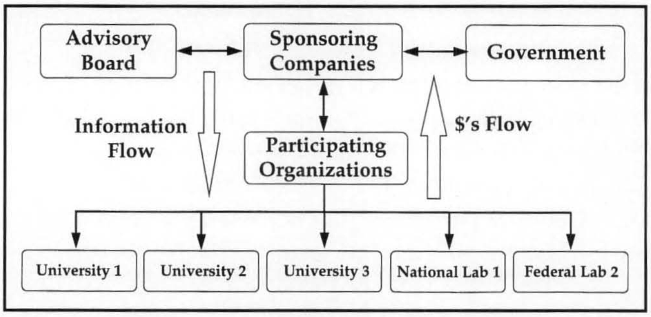

Figure 5. *A reverse consortia model.*

TABLE 4
Strengths and Weakness of the New Consortia Model

Strengths	*Weaknesses*
• Sponsor owns both the problem and the results of the research • Sponsor understands both the commercial needs and the materials • The best research and development minds can be employed to work on the problem • Access to leading edge and highly specialized technology and state-of-the-art equipment • The ability to get the right talent assigned to the program and to change the mix of assignments as the program progresses • More rapid completion of the program • Potentially lower cost than "in-house" development	• None of consequence identified

data and models from many different sources, facilitating the rapid incorporation of new and sophisticated modeling tools developed by academe or industry and making them almost immediately available to our process engineers and scientists.

This example of the new consortia model is producing remarkable results. In just eighteen months the Prosight Engineering Workbench moved from concept to first release—a remarkable achievement. Without the new consortia model, this development would have surely taken considerably longer and cost significantly more. Based on the initial success of the Prosight Engineering Workbench, discussions are underway with other chemical companies, and we anticipate that this effort will grow to a global, multicompany consortia in the very near future.

DuPont has not been the only beneficiary of this effort. Our university partners have adopted part of the product of this effort as a teaching tool to more effectively connect their instructional programs to industrial needs. Members of the university staff have coauthored papers with other consortia members, and students have had the opportunity to develop solutions to current, high-value industrial problems. This mutually beneficial relationship works because industry taps the talent of academe while, simultaneously, academe connects their efforts to important industrial problems.

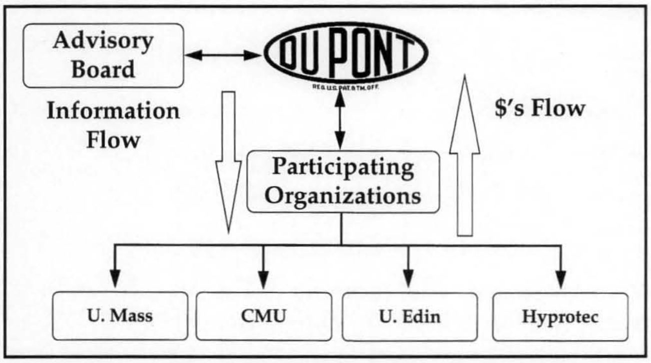

Figure 6. *The DuPont Process Synthesis and Optimization Consortia—Prosight Engineering Workbench Development*

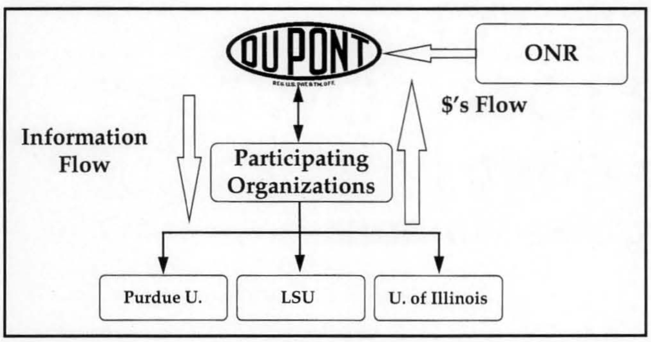

Figure 7. *Neurobiology: Process Control University Consortium*

A second example of the reverse consortia is neurobiological control. This grew out of another industry-academe relationship. Young prospective faculty members spent a year in industry before starting their teaching careers. This gave them an opportunity to develop a better understanding of industry and industrial research, to building industrial relationships that can last a career, and to be introduced to problems, separate from their thesis work, that could start them on a whole new area of research.

From this activity came the idea for another DuPont-sponsored consortia—the Neurobiology: Process Control University Consortium as shown in Figure 7. Unlike the Prosight Engineering Workbench consortia, this is a high-risk program that receives significant financial support from the Office of Naval Research (ONR). Its objective is to develop and use control systems based on neurobiological models (*e.g.,* the body's control of blood pressure) for commercial applications. By forming a cooperative consortia with ONR and academe, DuPont is able to minimize its risk while taking advantage of the results of this speculative research effort. If successful, this activity could lead to new and innovative ways of controlling industrial processes that could have applicability to problems far removed from the chemical process industry.

OTHER FORMS OF COLLABORATION

While the new consortia model provides an unique structure for extracting value from government-academe-industry collaborations, it is not the only approach. For decades, many companies, DuPont included, have had so-called "Year in Industry" programs that allowed professors to spend their sabbaticals working in an industrial research environment—these proved to be mutually beneficial relationships since both academe and industry benefited from gaining fresh insights into the way research could be conducted.

More recently, we have used these programs to provide specialized talent on focused research programs. As an outgrowth of this activity, we recently invited several graduate students to do their thesis work with us at the DuPont Experimental Station. Some of them worked on mutually agreed upon research and development programs upon which they based their graduate dissertations. The graduate students received firsthand industrial research experience while the company gained the services of young, energetic, talented people who brought with them novel approaches to our R&D needs. Ultimately, the students may also benefit by receiving an offer for full-time employment.

Several students not only made a significant and immediate contribution to our development needs, but they also went on to extend their research after returning to the university. Several visiting professors have continued their relationship with DuPont by providing ongoing consultation and by directing their graduate students into areas of research that have commercial significance to DuPont.

This effort also permitted visiting professors and graduate students to interact with both industrial engineers and professors and students from other universities. These joint efforts have resulted in ongoing working relationships that strengthened their individual research and fostered value for each other and the benefits of collaborative teamwork. Instead of viewing each other as competitors, members of this new consortia strive to achieve a common goal, competing only to achieve a higher quality of thought and result.

SUMMARY

The global competitive environment, combined with a change in funding of research and development in industry, academe, and government necessitates significant changes in the way these research organizations work with each other. The industry-sponsored consortia has been used with great success at DuPont and may form the model for other such relationships. To improve the competitive position of the U.S. chemical industry, we must keep looking for innovative ways to capture exceptional value in the marketplace from our limited research investment. Increasing the dialog between industry, academe, and government, and identifying areas of mutual interest and potential collaboration, is essential for improving global competitiveness. ❒