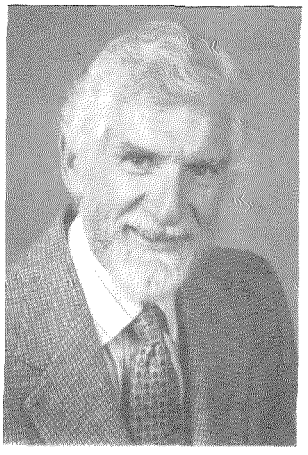
Universities and Industry in Collaboration

Three managers of industrial research and one from academia discuss their real-life experiences in university-industry research relationships.

Martin Cooper
Vice President and
Director of Research
and Development
Motorola, Inc.



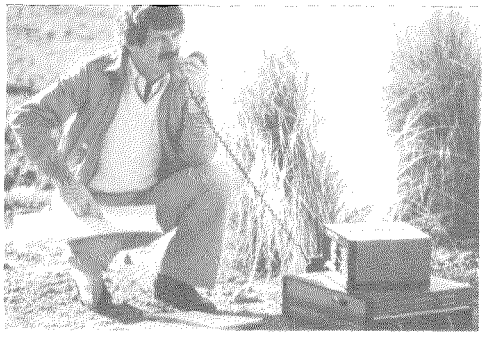
A REFRESHING initiative has recently been emanating from most of the universities that Motorola deals with, urging stronger ties between academia and industry. The sincerity of this initiative would be less questionable if the threat of severe cutbacks in government-funded university research did not also exist. Nevertheless, industry and universities do have mutual problems. The survival of our corporations is contingent on an increasing flow of graduates who are educated in the fundamentals of science and technology and who have reasonable facility in using modern problem-solving tools. The primary product of the universities is, of course, their graduates. And the market for the product is limited to the schools themselves, to government of various kinds, and to industry. I don't want to minimize the importance of government, but this nation depends on industry to produce the goods and services that are the material substance of our society. So I want to discuss Motorola's experience in bringing these reluctant bedfellows — universities and industry — together.

Universities and colleges generally agree that their first purpose is to educate. Secondly, they like to do research, partly to keep the faculty interested and because, in schools like Caltech, research is a very important part of the educational process.

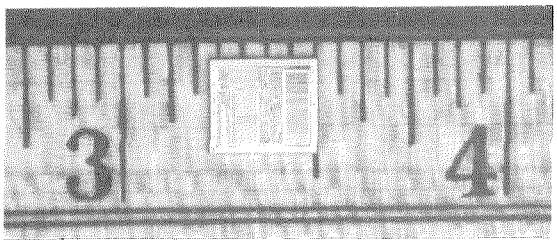
Industry also sees the schools as a source of educated engineers and scientists, and as a source of inspiration. We like to get some sense of direction in our long-range technology expenditures, and people who live in the university environment spend a lot more time thinking about what is going to happen in 10 or 15 years than those of us who have to meet this year's profit and loss requirements.

Motorola's primary funding to universities and colleges comes from the Motorola Foundation, which is purely charitable. We prefer to direct our funds to those schools that have some relationship to Motorola and that in some ways will encourage continuing dialogue between the academics and our people. The funds themselves, however, are not specifically directed; they are pure contribution. We have an industrial liaison program with MIT, and we also have a continuing grant to MIT. We are an Industrial Associate at Stanford, and we are a participant in their Center for Integrated Systems. We are doing some research at the University of Iowa. At Caltech we are an Industrial Associate and a member of the Silicon Structures Project.

Some aspects of our university relationships have not been very successful. One thing we do, for example, is to hire prospective teachers away from the schools whenever we get the chance.



Motorola, Inc.'s Falcon Mini-Ranger (left) is used for accurate electronic determination from remote locations of the position of vehicles such as dredges or offshore drilling platforms. The company's MSF5000 Base Station (below) provides superior system performance as the core of a radio system.



Motorola's MC6800 eight-bit microprocessor offers an entire computer – the equivalent of 70,000 transistors – on the surface of a single chip of silicon.

We short-sightedly offer salaries in excess of what the universities can offer. If an individual is not a dedicated educator, he'll come to work in industry. We are beginning to try to correct that situation by encouraging the financing of students who will remain in school and in teaching roles, but this alone will not solve the problem.

Our industrial liaison efforts have not been fully successful. Our people just won't be driven into productive relationships with the universities that we select; rather, they tend to concentrate on their current work. Do we have interactions with the universities by individuals? Absolutely. They almost always result from the fact that somebody in a university is working in a specific area of interest to one of our engineers or scientists. Of their own volition, they get together and establish successful relationships.

The other major failure, of course, is that we all just ignore the problems. We assume that the schools are going to manage, that they are going to produce the students that we need, and that one way or another we will all survive.

There have also been some successes. The Motorola Foundation contributes several millions of dollars every year to universities in a totally unrestricted way, and we hope this is done somewhat intelligently. We also directly fund some research. One of our scientists, for example, invented a technique that is not in our field of interest. To establish whether it was worth investing in further, we sought somebody who could carry it through at least the first stages of research. We found such a person at the University of Iowa, and we have a very successful interaction between those who created the idea and that university. We have some fine relationships between our semiconductor division at Phoenix and the materials organizations at Northwestern University and the University of Illinois. We also get involved in programs where universities perform related research and development as, for example, at the new Center for Integrated Systems at Stanford.

I have only recently learned about the power electronics program at Caltech. Its purpose is to create generalized applications directly usable by industry. It is the kind of collaborative program that industry should be reaching out for, but not everyone in industry has the foresight to invest in long-range programs.

The final successful type of program is the funding of related R&D, though I call it the "illusion" of related R&D. An example of that has been the Silicon Structures Project here at Caltech, in which Motorola was a participant for several years. The concept of that program — joint research in Very Large Scale Integration — was extraordinary, and the mechanism for creeping up on the long-range problems was structured so that there were also short-term benefits, particularly in terms of inspiration. One element of the Silicon Structures Project was having the industrial particpants live full time at Caltech, generally for a period of a year. We hoped each of these people went back to his industrial organization carrying with him the concepts, the philosophy, and the understanding of what is happening in the university.

Let me address some suggestions to industry, beginning with a proposal that our technologists be given at least some advisory capacity in the university funding programs. The chief value industry can get out of this funding is opening channels of communication — so that when one of our people has a problem, he has somebody in the university that he knows and trusts. Being able to call that person has direct value.

I also suggest that we encourage our technologists to visit universities. One of the mechanisms we have discovered for this is to hold seminars on university property. Once you get a group of technologists into the university environment, it's easy for them to meet people in their field. I just recently had a meeting of several hundred members of our science advisory board — technologists from throughout Motorola — right here at Caltech. The meeting was superb, the facilities were excellent, and a number of collaborative introductions were made that are going to persist.

That leads to one other suggestion, which is not to expect much in the way of short-term results. The money invested in university collaboration is a long-range investment; it is unproductive to fall into the trap of expecting usable product designs or software, and it is a waste of the university resource.

We also have some suggestions for the universities. I believe that the biggest challenge in American society is that of productivity. This is a long-range problem, but it has to be addressed at all levels. Every example I have given you of Motorola's university programs addresses productivity, though in very narrow areas. Yet our productivity problems are of a very general nature and have to be addressed everywhere. Collabora-

tive programs that address the issue of productivity should be increasingly attractive to industry.

Other university problems involve the questions of publication and proprietary rights. The progressive universities are starting to figure out ways to allow those of us in industry who elect to make investments in them to maintain some kind of rights in the results of research. But many do not and also require that all research be fully published. That is a great inhibitor for industry. We are reluctant to invest in research that is likely to benefit our competitors.

I would also suggest that universities restrain their tendency to overpromise, appealing to the long-range views of whomever they approach in industry rather than promising short-term results. Both industry and the universities must attack these problems, and it is in the best interests of all of us in the United States for us to learn to work together on solutions. □

Louis Fernandez
Vice Chairman
Monsanto Company

MUCH HAS BEEN written about the internal problems with which universities must wrestle when they decide to collaborate with industry, but there has been less focus on the price many companies must pay in order to consider collaboration with an academic institution.

At Monsanto we do a great deal of soul searching before we seriously consider collaboration with a university. There are three main hurdles: the patent department, senior management, and our research and development staff.

The patent department concerns itself with the issue of secrecy, which is pivotal to whether a collaboration can work. From the university's point of view, of course, the secrecy issue appears threatening because of the need for academicians to publish, to attend meetings, and to talk about their work. From the perspective of our patent department, the issue is equally threatening. What if a breakthrough occurs and is publicized before we have time to secure adequate patent positions? What if Monsanto invests a great deal of money to finance a breakthrough to which other companies have immediate access? An invention is, after all, the least expensive part of the innovative process. For every dollar we spend to invent something, we will invest many hundreds more before that invention reaches the marketplace. The big economic risk for Monsanto comes not in supporting research, but when we decide to pour concrete and build manufacturing plants to produce new materials. Without adequate patent protection, no company can afford to invest the large amounts of money required to bring a new product to commercialization. Our patent department wants to ensure that we get that kind of protection from an academic collaboration.

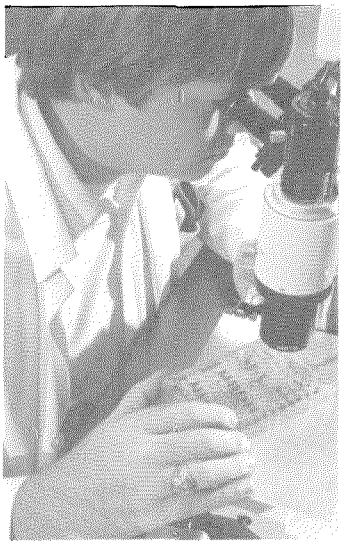
For senior management, the big question is the same, no matter where the research is done: Will the potential rewards from the agreement be commensurate with the investment that is required? We have to justify to our board of directors any major research expenditures. If we cannot demonstrate the potential value in such an investment, the board simply will not approve our going ahead — not for research inside the company and certainly not for research outside.

Finally, we have to face the question of internal problems with our own R&D staff. Industrial scientists work for a salary, and their inventiveness is rewarded with promotion, higher salary, or occasionally with a prize. Nonetheless, making a great invention is not likely to make a company scientist rich. In many academic institutions, on the other hand, individual scientists can earn royalties on their inventions. It doesn't take too much imagination to see that a collaboration which produces significantly different rewards for the various scientists involved could lead to major morale problems within the company.

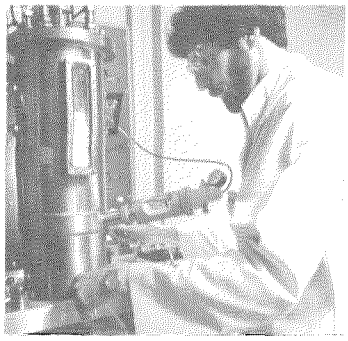
Moreover, for a corporation, the very existence of an outside research project has the potential for causing internal problems. No R&D department at Monsanto has the amount of funding or staffing that the department heads believe it deserves. Imagine trying to convince those people that their internal projects will not get more funding because we plan to go outside with some of that money.

Considering the issues of secrecy, investment value and morale, what, then, encourages us to go ahead?

In the first place, academic institutions often possess skills that are extremely valuable for industry — too valuable to wait 10 or even 20 years for a company to develop internally. Second, our experience in small collaborative programs gives us some idea of how an arrangement with an



Monsanto Company's interest in biological sciences has been increasing over the last decade, and the company scientists use many vehicles for their research. Above, plant tissue is prepared for culturing. Below, hybridoma cells are studied under a stereo microscope.



Fermentation is a vital component in effective large-scale production of commercial biotechnology products. Here, a Monsanto scientist records conditions under which biological materials are produced in the molecular biology laboratory fermenters.

academic institution could work and where problems might arise. We know we must have partners whom we can trust; with whom we can work together in real collaboration, not just someone we can hire to do a task.

In the early 1970s, Monsanto scientists began to see the value of building up an expertise in the biological sciences beyond what we had in the agricultural chemicals area and in doing so fairly rapidly.

The result was a 1974 agreement with Harvard Medical School through which Monsanto unabashedly opened a "window on biology." The agreement runs for 12 years and is concerned generally with seeking the molecular basis for organ development. The principal Harvard investigator had previously been a Monsanto consultant, and the program involves collaborative work in Monsanto laboratories as well as in Harvard laboratories. In 1979 we accelerated our search for biological knowledge by taking three major steps: We announced the formation of a molecular biology staff within the company; we entered into a joint program with Genentech to develop animal growth hormones; and we began to investigate ways we might use biotechnology as a vehicle to enter the health care business.

The same year, Monsanto hired a new senior vice president of research and development, Howard A. Schneiderman, who came to us directly from academia. At once he began to look for ways that Monsanto science and academic science could be of mutual benefit to each other. He naturally turned to our very close neighbors at Washington University with the result that, in 1982, the two institutions entered into a five year, $23.5 million agreement with Washington University Medical School for biotechnology research. The purpose of this agreement is to fund basic research and to make discoveries that will ultimately lead to new therapeutic materials in the health care field.

Like the Harvard agreement before it, our program with Washington University has received a lot of attention in the press, in industry, in academia — even in Congress. And certainly at Monsanto.

We have done everything we possibly can to assure the success of this program. Building on our experience of the past, we have developed broad guidelines we feel are important for a truly cooperative agreement between an academic and industrial institution. The Monsanto-Washington University agreement is a good example of Monsanto's views on industry-academic collaboration.

First of all, we had to deal with an issue of great sensitivity on both sides — the tradeoff between security for patent purposes and the academician's right to publish. In this case, Monsanto has the right to a 30-day look at papers prior to their being submitted for publication and then, if patentable material is included, a chance to put off submission for a short period longer to provide time to file the proper patent applications. We feel, and Washington University agrees, that this arrangement should prove satisfactory to both institutions. Any contract must include some mechanism for dealing with a proprietary situation.

Second, we believe the arrangement should be between institutions rather than individuals. This prevents the kind of distortion that happens when one individual receives large sums of money that are not available to his colleagues. According to the Monsanto-Washington University arrangement, if major royalties should accrue to the university as a result of our work, a third of them will go to Washington University, a third will go to the individual scientist's department, and a third will go to his laboratory — but not to any individual investigator. This situation has an obvious advantage for Monsanto as well as for the university, where faculty members remain on a par whether they are working on Monsanto-funded programs or in other areas. The academic scientists will also remain on an equal level with Monsanto scientists with whom they are collaborating, thus avoiding the morale issue of one group of scientists having the possibility of becoming rich while the other does not.

In the third place, the collaboration should be a real partnership, a relationship of equals. A company cannot expect success in this kind of relationship unless it has in-house skills in the particular area of the agreement. Monsanto has in-house expertise to bring to this arrangement; we have further insured the partnership by forming an oversight committee to administer funds for the individual research projects. The committee is made up of four people from Monsanto and four from Washington University. This means that a specific research project will not go forward unless both Monsanto and the university endorse it. Washington University decides what kind of research it wishes to engage in; Monsanto selects from that menu of options the projects in which it has an interest. This way, we are not trying to tell them what to do, but rather which aspects of what they do are worthwhile for us.

Finally, to assure the scientific credibility of the program, we recognize the need for scientific peer review. The science, which is, after all, the whole point of the collaboration, must be assessed by objective, informed outsiders at regular

intervals, thus assuring university officials that the efforts are of proper quality and assuring Monsanto's senior management that the work is progressing apace. Moreover, an outside panel — along with a tightly worded contract — can help insure that the research undertaken is being carried out in the arena in which it was originally intended. It will be of no use to academic scientists, and be a misuse of corporate dollars, if academic-industrial collaborations turn into development programs for new products.

Development is clearly the role of the industrial company, not the university. To ask academic researchers to do development work — other than specific tests of the type often carried out in engineering schools or clinical testing in medical schools — would be a gross mismanagement of funds, time, and an American resource.

The driving force for our collaboration is the biological revolution, accompanied by the very exciting advances in chemistry and physical measurement. As with any revolution, old technologies will be displaced, and companies like mine will find themselves needing to retool. We feel that relationships with academic institutions will speed our ability to do this retooling. We will piggyback on university skills as we build up our own skills and heighten our ability to bring important new products to the people of the world. If our collaboration works the way we believe it will, it will not just be Monsanto and Washington University that will benefit from this undertaking, but it will also be society at large.

A successful academic-industrial collaboration can bring new products to consumers, but it can have another result as well. America's technological strength is being challenged as individual companies, like Monsanto, find themselves competing with whole nations in the international arena. In the United States it is difficult, because of various legal restraints, for companies to collaborate. If, however, a company were to look around and ask what other existing institutions could enhance its technological capability, the first answer would be universities. These great institutions with enormous scientific skills are an obvious key to the question of how we can be more competitive internationally. In countries like Japan and West Germany, we see a much closer interface between business and academe. That relationship shows up in new high-technology products and a keen edge against American competition. A West German or Japanese type of relationship may not be appropriate for us. But we can have one that is uniquely American. Under the right circumstances, we are natural partners. And the results of such partnerships hold great promise. □

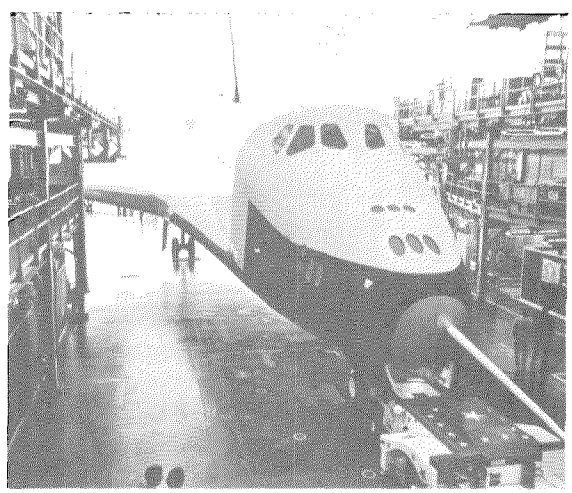
John F. Tormey
Director (retired)
Corporate Technology Policy
Rockwell International Corporation

AT ROCKWELL INTERNATIONAL there are two major routes by which money could go to a university. One is through the Rockwell Trust, and the other is via a Rockwell normal business expense. In the latter case there are three ways that an individual division president or engineering vice president or his designee can disburse money to a university. He can use direct money out of his contract; he can use money out of his overhead; or he can fund the research through an IR&D project. He really doesn't have to consult with anybody before he acts except his own conscience, and his profit and loss statements.

Funding for direct contracts with a university — open contracts for services, say, to perform some analytical work — belongs to the business side. So do such expenses as hiring consultants, continuing education, and directed experimental research, as well as all of our Industrial Associates programs.

Out of the charitable side, or the Trust, come major and minor grants, gifts, undergraduate scholarship programs, a graduate fellowship program (through which we fund 26 PhD fellowships across the country), chairs, buildings, matching funds, and equipment. The corporation has a

The Space Shuttle (left) is one of Rockwell International's best-known products, but the company has many others. Below, for example, a machinist monitors five-axis milling of a titanium casting of a pumping element for a marine propulsion system.



reasonable but finite amount of money in the Trust, and only a portion of it goes into education; there are also the arts, the community, and health and welfare to be considered. And the education share also covers our commitments to liberal arts establishments as well as technical institutions. Among the reasons why the Trust would bestow a charitable grant to a particular university are good will, minority responsibilities, being a good neighbor in the community, acquiring employees, being a patron of science and engineering, and, finally, a direct self-interest in the particular technology of the school itself.

The case study I would like to follow here is a major grant involving both our direct technical interest and our role as patron of science and engineering — a direct grant to Caltech of a half million dollars. The period of the grant is from 1982 to 1987, and it is divided into two parts — half to a study of turbulence, and the other half to a particular field of research in semiconductors.

The establishment of this grant came about in ten steps, and there were random resistances in the smooth flow from step to step that took a little time to overcome. First, there was the prelude: those years of industrial associations with Caltech during which very little money surfaced — attending meetings like the Research Directors Conference, and lectures and annual alumni meetings, reading publications, using the library, and so on. But we didn't get past this "getting to know you" point until Robert Anderson, the chairman of the board of Rockwell, who is also a member of the Caltech board of trustees and a member of the visiting committee of the Division of Engineering and Applied Science, created a *stimulus*. A couple of years ago Mr. Anderson suggested that we in engineering do something specific about a research grant to Caltech. This stimulus got a group of executives to come to Caltech to *get acquainted* in a formal sense. This took quite a while (about four months) — not because I couldn't bring the Caltech faculty to bay, but because I couldn't corral my own associates. I had to gather together four divisional line executives and bring them to Pasadena. I think we cancelled a meeting six times. Finally, there was a superb summit meeting here at Caltech. I must say that the Caltech faculty who were at that meeting were at their best — charming, informed, and stimulating. We had a magnificent breakfast, a magnificent lunch, magnificent scientific discussions; and, as Rockwell got together afterward, there were such expressions as, "Who *were* those guys? This is a *great* school. Let's do *something*." This was one of the *key* meetings. I recall every line and nuance of it.

Then I put together a series of "*how abouts*," going around to the various vice presidents to get their suggestions for about 12 topics in technology that were of strategic concern to Rockwell across the board. Following this I met with Roy Gould, chairman of the division of engineering and applied science at Caltech. He and I went over the list, which he subsequently took to his department heads for their review. Within two weeks I received a very nice letter from Professor Gould with a package of Caltech "*how abouts*" — seven of theirs matching seven of ours. Then I sat down with the corporate vice president of engineering, and we picked two, one on turbulence and one on semiconductors.

The operation didn't proceed much beyond this point until the *money arrived*. As you might expect in corporations, it's all relatively harmless to this point. But finally the money was made available from the Trust; I had it in my hand and could begin "soft" discussions. Since Trust money is charitable (it is not expended for things that chiefly benefit the giver), I did not enter into "hard" negotiations with Caltech. On the other hand, I couldn't simply assign Caltech the money without *some* gentlemen's understanding of what they were going to do. Hence the word "soft."

As part of the "soft" discussions, I arranged with the Caltech development people to set up meetings for me with appropriate Institute staffers. I visited the public relations office, the contract office, the financial office, and so on. They understood that it was going to be a gentlemen's understanding, and so we talked through these things on how it was going to be done.

The key element was simply a personal letter between the provost and myself. (The research fields and the principal investigators were already spelled out in one-page papers submitted by each of the two faculty members.) Our letter covered such matters as starting period, contribution times, publicity (no one would rush to press without telling the others), published reports and other communications (we would get the first copy of any published report and a letter once a year just to let us know they were still alive), access, and visitation.

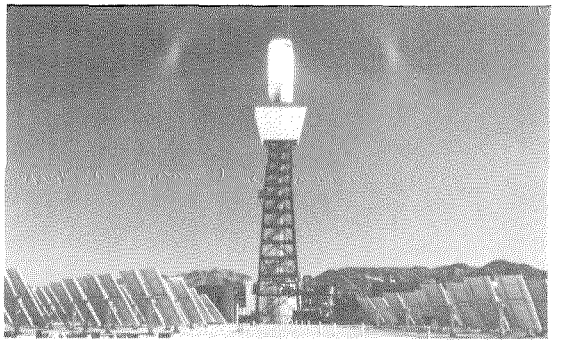
The letter also covered access to records, which had been a cause for uneasiness among my financial associates. They said, "Gee, you can't let them have half a million dollars without giving them a book on how to report the costs back to us." So I came and talked to the Institute accounting people and asked if we could see the Caltech accounting records on that particular project if we wanted to find out how the money was being spent. They said, "Of course." I decided

that we would trust Caltech to apply the same rigor to our money that it would to its own.

We also wanted to identify four Rockwell scientists in each of the two fields as liaison scientists for the program. For me, these technical matchups were crucial to the success of the grant. We tried to pick people with good academic backgrounds — not necessarily Caltech PhDs, but those who might be comfortable in an academic atmosphere. Before I brought our people over, I came to the Caltech faculty involved and said, "Fellows, this is the most important part; everything else is paperwork. You've got to be ingratiating to my people; don't intimidate them or they won't come back." They all promised to behave.

Now we are well into the first year of these two research grants. As you might expect, and as I *knew* would happen, my people are still a tad uncomfortable coming to Caltech. This is not their turf, and although everything has been done to make them feel comfortable, it just takes a while. This is the biggest resistance for us.

This was an experiment for us because our company has never done precisely this before. We're delighted that it has worked out so well: it was relatively painless. The whole thing took about nine months altogether. What are the benefits to us? We're intermixing people; we're lifting the horizons of our people. We hope that occasionally we'll pick up a competitive edge, and we'll get experience in grants so that we can do the same thing with other universities in the future. □



Rockwell's Rocketdyne Division developed the central receiver boiler and the thermal storage unit for Solar One, the country's first solar electrical generating plant.

John D. Roberts
Institute Professor of Chemistry
Caltech

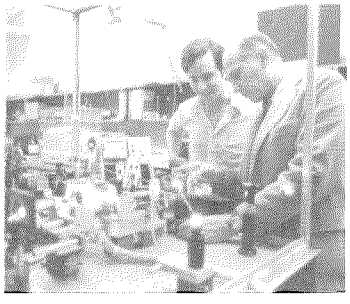
THE BENEFITS to industry and universities from mutual collaboration are obvious, but problems come along with those benefits, and I should like to discuss some of them from the academic point of view. In no particular order of importance, I list five such areas of difficulty below:

1. Should any group have preferred access to students and postdoctoral fellows with respect to consideration for employment?
2. How should we handle patent rights?
3. How should we handle proprietary information? In the purest sense, such information has no place on university campuses, but, pragmatically, it is often generated in applied research in commercially competitive areas.
4. What restrictions, if any, should there be on the publication of results?
5. How can we in the universities preserve necessary balance in our programs? Industry has rather suddenly discovered that there are rapidly developing new areas such as biotechnology, integrated optics, and computer science, in which industry is far from up to speed. Because they wish to establish positions in these areas as rapidly as possible, many corporations are very willing to pump money into university research and have their personnel participate directly in it. But it is important for each university to preserve balance in its programs (and especially set aside resources to nurture those areas where the next potential breakout may only be a gleam in a young professor's eye). One way to help achieve and maintain balance would be to have each restricted-purpose gift accompanied by an unrestricted grant to use at the university's discretion.

As a consultant for DuPont for 33 years, I do know something about how industrial research is carried out, and in the course of that relationship, my DuPont colleagues and I carried out collaborative basic research that led to several publications. My DuPont collaborations were interesting because *no* money changed hands. Each party got something it wanted, with mutual saving of time and money.

This was done under the old system where university research was financed primarily by the government, in part through corporate taxes. Cor-

In the academic community, both students and professors occupy the labs. Above, undergraduates in Caltech's new Mead Chemistry Laboratory. Below, Amnon Yariv, Myers Professor of Electrical . . .



. . . Engineering and professor of applied physics, and graduate student Tom Koch make adjustments on a dye laser and amplifier system used to study ultrafast processes and switching phenomena in semiconductors. . . .

. . . One important result of all this effort becomes visible each June as students don caps and gowns and attend commencement.

porations paid those taxes to the government, the government selected the areas for support. All industry benefited in the most general way.

No one likes to pay taxes, and taxes have been and are being reduced, but government spending for research in real dollars has also been reduced. To maintain the level of basic research the country needs to keep the economy vital in the long run, therefore, requires new sources of money. At the present time, as Martin Cooper points out, universities are knocking at industry's door. Some of the less-favored universities are in such straits, in fact, that they are willing to act as low-cost research institutes, in competition with Battelle or SRI International, for example, working on specific industrial projects. In my view, this is not a good use of universities.

I like Mr. Cooper's idea of "illusory" objectives in supporting university research, that is, for industry to benefit by inspiration and ideas as well as by fostering education of students in important fields — but to have no more than the illusion of directly benefiting by gaining exclusive patent rights to breakthrough inventions.

The publication problem is an important one. As a member of the National Academy of Sciences Panel on "Scientific Communication and National Security," I heard a lot about this problem as it relates to possible transfers of critical technology (ideas or hardware) to the Soviet Union. I recommend reading that report, which holds that simultaneous submission to journals and the sponsors should suffice for national security purposes. The industry representatives on the panel strongly supported this view. It seems that industry in general would like to have access to DOD-sponsored research promptly, but then some parts of it would argue for substantial delays in publication for industry-sponsored research where patent rights might be involved. The difference in viewpoint creates problems for universities.

What should industry-university partnerships be like? From our point of view, the best possible partnership would be a general and very open one with all of the companies interested in our work. Nonetheless, we understand that many corporations who give money for specific purposes will have rather natural proprietary feelings about open dissemination of results to those who did not support the work.

Let me point out our concern that too tight partnerships could well lead to perceptions that ideas, research programs, and students can be bought and sold on university campuses. Such perceptions could lead to serious problems for us in another direction. Many corporations contribute general support to the Institute through the Industrial Associates program. A few make additional large general contributions with no strings attached. To a degree, when we take on collaborative projects involving restricted access or patent rights from other companies in areas in which our donor companies are also interested, we may be inhibiting their right of access to ideas, results, and students. We are creating an internal conflict of interest. We must take great care in making relationships not to foster undue channeling of research and not to prejudice the collegial environment. With our very small groups, that environment plays an important role in our success.

If large enough contributions were possible, the ideal system for us would be to have corporate support largely channeled into Industrial Associates type programs. All of the corporations involved would thus be partners together. The universities could fulfill their educational mission through dissemination of their results in conferences and by individual visits, with neither side holding back. Unfortunately, as John Tormey has made so clear, it can be hard to get corporate research personnel to make the use they could and should of such visits, even when the research is in relatively specific areas of interest.

The Rockwell arrangement was fun to negotiate, and you will note that it calls for no patent rights and no restrictions on publication. It does foster our strength in areas in which Rockwell has a deep interest. This is another very useful model for collaborative research with industry, and it has many advantages. The one possible problem is that of creating some unbalance in our programs, a difficulty which might become serious if several other companies decide they want to push the same research areas here.

Clearly, a new world of industry-university relationships is with us. As yet there is great diversity, and as yet no standard well-tested model for industrial support of university research has emerged. Any search for one may be fruitless, because of the differences in objectives, concern for proprietary rights, financial resources, and research sophistication of the industries involved. Properly set up, with understanding of each participant's interests and limitations, collaboration in research can be expected to lead to great mutual benefit. Collaborations based on one side seeking specific answers to specific proprietary problems, however, and the other seeking financial support to keep academic wheels turning without proper consideration of educational objectives can only be expected to lead to mutual dissatisfaction. □