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The Role of Universities in Industrial Research

Improving Industrial R&D – University Relations

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This report of a joint Industrial Research Institute – Engineering Research Council conference explores the current health of industry-university relations and suggests some approaches for future actions.

New problems and changing priorities require that we reexamine the traditional interfaces between academia and industrial R&D. The search by the Federal government and industry for ways to stimulate R&D and reduce the time it takes the results of R&D to reach the marketplace, makes this reexamination particularly pertinent at this time. Therefore, some thirty representatives of the Engineering Research Council (E.R.C.) and the Industrial Research Institute (I.R.I.) met for two days last April in Atlanta, Georgia, to examine the current problems of industry-university relations. In addition to two formal papers giving the views of industry and universities, six panel sessions addressed specific issues related to the problem.

Industry and University Views

Philip C. White, General Manager-Research of Standard Oil Co. (Indiana), in his paper (printed in full in this issue), said that industry looks to the university to fulfill seven needs. First, the advancement of scientific and engineering frontiers. Second, the production of well-trained graduates free of university bias. Third, universities are expected to perform specific research projects under contract with industry. Fourth, industry often needs independent studies which provide credibility to their own inquiries. Five, industry needs the universities to provide special technical services, facilities for testing and the making of surveys. Six, universities can also provide special expertise for consulting, for continuing education and the like. And lastly, industry expects the university to broadly carry on the total educational function.

There are, said White, certain actions which can be taken by industry to strengthen basic science and engineering. This would include informing universities close at hand of industry's current interests. It is also desirable to exchange personnel between universities and industry on some sort of sabbatical arrangement. Likewise, consulting can be a two-way street and White said he believes "that industry should have a stronger voice in deciding which major government research and development programs should be funded."

Industry does fund programmed research in universities, but there is always a limitation in scope and there are time and money limits as well as proprietary pressures in industry which do not transfer easily to a university. Moreover, if an industry needs consulting or testing there must be an obvious match with the universities' goals or things will not proceed smoothly.

Paul Ebaugh of The Penn State University, in his paper, "Objectives and Constraints (Real or Imagined) in University Research," said that the general path that universities follow were usually described in the universities' research policies. These policies might differ in detail, but in general, the functions of university research were to advance the frontiers of knowledge, both basic and applied, to vitalize and add relevance to its teaching, to encourage and stimulate a spirit of inquiry

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in the faculty, to train research workers and lastly, to serve the public by solving problems of general and public interest.

Now, added Ebaugh, there are well-defined criteria governing the acceptability of a sponsored research program in a university that could be determined by asking a number of questions. What are the interests and capabilities of the principal investigator? What are the interests and plans of the Department, College and University? Is it truely research and not product testing? What is the potential for contribution to knowledge and improvement of the capabilities of faculty and students, in other words, what is the impact on instruction? Are space, facilities, equipment and personnel available? Will the project be greeted with enthusiasm by the faculty and the students?

He pointed out that there are desirable benefits, not only in attracting high quality faculty and students, but in being assured that there was relevance in the studies and research of the faculty. Other advantages are in creating a favorable image with the public as being a university able and willing to serve. However, there are constraints imposed by the university calendar, the need for freedom to publish, the variability of patent policies and other factors such as schedules, travel funds, the requirement that sponsored research cover full costs, and the difficulty in expanding and contracting faculty as research projects start and finish.

Ebaugh said that the universities have, during the past thirty years, found ways of dealing with the Federal Government. And, although many of the requirements are onerous, the universities know how to deal with such constraints. This is not true with industry. Here there are great differences in the business procedures and there are many variations in the proprietary considerations, publication, disclosure and who owns the patents. But the biggest deterrent to getting started is in universities knowing what the needs of individual industries are and, from the industry point of view, in knowing the capabilities of universities.

Ebaugh ended his talk by pointing out that there are many workable agreements operating through projects, grants and fellowships, through industrial liaison programs or coupling programs. There are industrial consortia supporting research and development in specific areas. Now we have started to develop joint industry/university projects with Federal funding. He mentioned the problems of communications and said these could be solved by more publications or directories telling of capabilities and needs. Having more university representatives at industrial meetings and having more industrial visits to the compus will be helpful. He felt that the patent problems could be worked out if they were addressed early in the game. He suggested that better university stewardship of projects would be helpful and this could be done by making sure that the universities research administration was called into the consultations early so that a prospective project administrator and client company could delineate the business relationships before trouble arose.

Some Case Examples

R. M. Hexter, Chairman — Department of Chemistry, University of Minnesota who examined the problem from the point of view of a chemistry department in a large university. He felt that some of the problems lay on each side of the fence. Too many university professors at the graduate level are interested in only reproducing their own kind of professors. He mentioned also the disturbing effects of the business cycle when for one period there is a demand for chemists and a shortage of supply followed too soon by too many graduates and too few jobs. He also introduced an idea often mentioned throughout the conference, namely, that some of the most significant research is done by groups of people. In many such cases, because of the breadth of information needed, the group is not limited to a single department, but includes others in allied disciplines. Hexter thought that one of the ways to success was for a university to concentrate its available money in selected areas and use that money to provide "a margin for excellence."

W. J. Fabrycky, Associate Dean for Research, Virginia Polytechnic Institute, got down to brass tacks by producing examples of quickly moving a bright idea from the innovator to the shipping platform. He first spoke of an inventor who had an idea for an automatic valve that limits the hot water flow in an ordinary bathroom shower. The idea was brought to successful fruition by the help of a university professor who understood its mechanics and who helped move it into production. Because there was a lively demand, reinforced by the energy shortage, the concept quickly progressed to where now millions are on the market. A second example concerned a university professor who got his bright idea when the courts declared that independently produced equipment could be interfaced with that provided by the telephone company. This project, which involved faculty, students and an industry, and eventually some government funding through the National Science Foundation, did reach a successful conclusion in spite of difficulties and roadblocks because of the

dedication and entrepreneurship of one man.

E. P. Segner, Jr., Associate Dean of Engineering, The University of Alabama, told of their arrangements with the Foundry Educational Foundation that resulted in a special foundry building, a special curriculum, the production of students trained to go into the foundry industry and probably the raising of the general level of technology in that industry.

Philip L. Walker, Jr., Head-Material Science Department, The Pennsylvania State University told of an arrangement concerning the study of coal and carbon which in spite of its vicissitudes was now being viewed with great favor because of the materials and energy shortages. He pointed out that the program had produced a group of professors whose talents and knowledge were at the leading edge of scientific inquiry in this field. He said the necessary ingredients were interested professors with long-range continuing financial support who could form a group willing and able to solve practical problems in a single cohesive area of science. Since this support had been available at Penn State from the state government and cooperating industries, they were now ready and able to work on such problems as coal liquefaction and gasification with support from such diverse groups as Gulf Industries, The Office of Coal Research and the National Science Foundation.

Contracts and Grants

Camden A. Coberly, Associate Dean, College of Engineering, The University of Wisconsin, used two examples of contracts and grants that led to success: first, development of a sampling tube for molten metal in which temperature changes could be read to indicate the composition of the metal, and second, a system for recovering the material of used tires by freezing them and reducing the brittle rubber in a hammermill. The latter development had resulted in the founding of a new company. He claimed these examples of putting university research to work were successful because of a continuing interest by all those concerned.

Robert N. Faiman of the University of New Hampshire told of moving the University of New Hampshire into ocean research, establishing it as a Sea Grant college. Faiman said the kind of understanding that now exists between institutions and government agencies can be established with industry if both sides are willing to develop a mutual understanding of each other's requirements. He added "although most industry support has been viewed in the nature of gifts or grants of a charitable nature with little return expected except good will and an opportunity to recruit graduates, it is suggested that industry can and should consider universities as a source of professional and scientific expertise which can be drawn upon with a hard-nosed expectation of results through the establishment of clear contractural relations."

John C. Hancock, Dean of Engineering, Purdue University spoke of the Herrick Laboratories where they deal with problems of refrigeration, noise control and heat transfer as well as a power program supported by a consortium of industries. Both professors and graduate students are involved and the research can be used for thesis. He emphasized the need for effort, commitment and person-to-person communication.

Arland W. Pauli, External Research & Development of Deere & Company, told of a successful experiment where the company decided to develop a new planter and went to the agricultural engineers in a university and established a program of cooperative research. The success of the experiment, he said, depended upon a mutual interest, the need for the results of the research and effective communication and understanding between the two parties, industry and university professors.

Ross J. Martin, Director, Engineering Experiment Station of the University of Illinois, described four separate programs — one in electronics, another in fracture control, a third in electric power research and a fourth in engineering construction systems. An analysis shows that each was a center of excellence involving people working at the frontiers of knowledge in well-defined areas. As they became recognized, and their capabilities acknowledged, money began to flow in from industry as well as from government and business consortia.

Albert P. Sheppard, Associate Dean of Engineering of the Georgia Institute of Technology talked about a special arrangement they had had for a number of years with the Whirlpool Corporation. This started with the funding of graduate fellowships, but grew to a productive relationship between the industry research and engineering staff and the research-oriented faculty at Georgia Tech. Stepping stones in achieving this relationship involved engineering managers visiting the engineering school to discuss their problems and visits by the faculty to the research laboratories and plants of the industry. This had led to seminars, the establishment of a chair in manufacturing engineering and jobs for graduates in industry. The thrust of this analysis was the necessity for developing continuing and many faceted relationships between the two organizations.

Eric A. Walker, Vice President — Science and

Technology of Aluminum Company of America described a system which involved not only the support of professorships in universities, but a mechanism for university professors to talk with researchers in industry. The device used to achieve the latter is to tell a young industry researcher to visit the university which is doing the best work in his field, then provide him with a check, in Alcoa's case for $5,000, which the young industry representative can leave with the professor to help support a graduate student or to provide general support for the work, but to leave it only if he thinks the work being done is good and useful. Since most professors hope the industry representative will visit again next year with similar results, there is a real incentive to communicate and to establish a lasting relationship.

Proprietary Considerations

Henry B. Smith, North Carolina State University, spoke of the importance of having an agreed upon and written patent policy. This not only had to have the approval of the faculty, but ought to carry the imprimatur of the university administration. Usually, he said, this precludes secret research because the purpose of university research is to publish and put the research to work. This made a licensing agreement necessary and usually this had to be a nonexclusive right.

Willard Marcy, Vice President, Patents, Research Corporation pointed out that very little research is going to result in a new product unless someone can get a patent, thus protect his investment. He gave an example of a university which had developed a burn cure. Only after a company had been given an exclusive right to produce for a limited period was it possible to make the investment necessary to perfect and market the invention. Marcy pointed out that until very recently it was possible for the government to grant exclusive rights to manufacture, but this had now been challenged in the courts and thus, the problem of government-owned patents was again in limbo.

Rolf Buchdahl of the Central Research Department, Monsanto Company, told of a project involving the company and the University of St. Louis which had been funded by the Advanced Research Projects Agency of the Department of Defense. He felt that good communications could be achieved if there was a mutual desire by the individuals in both groups to obtain solutions to explicitly-stated technical questions. When there was no such desire, success was out of reach.

Consulting and Advisory Panels

Robert J. Tait, Associate Director, Engineering Experiment Station of Ohio State University, described an arrangement that provides a place where industry can go to find solutions to problems both large and small involving at the smallest end of the scale the calibration of a valve and at the other extreme, long-term contracts. He said they used the engineering experiment station as a business mechanism and always tried to suggest the best solution for the industrial customer, even if it involved going places other than Ohio State. This operation from modest beginning had now reached a point where in 1973 it approached a million dollar business.

Fred J. Benson, Dean of Engineering of Texas A&M University, described an electrical power institute sponsored by the electrical engineering department of the university which was borne of the lack of power engineering graduates. Through it a consortium of power companies started to finance an institute which would do research, they had developed a noise detector and a hot spot detector, both of which had been adopted by the utilities.

W. D. Kennedy, Vice President and Director of Research of Tennessee Eastman Company, described a wide-ranging program of contacts with universities, going all the way from university professors who were invited to lecture or to give seminars, to devise systems for the drying of grain, or for the measurement of river water quality. He inferred that the essential ingredients were knowing what each side wanted to do and then providing sufficient communication so that one could do it.

E. A. Baillif, Vice President, Research & Engineering Center, Whirlpool Corporation, spoke of considerations that led him to abandon the idea of appointing a technical board of directors for the company. He spoke also of the establishment of opportunity groups, groups involving both partners from the university and the company, who would take on a special topic and through the interplay of ideas develop something new. He pointed out that this cannot be achieved overnight, and for Whirlpool it was a relationship which had its beginning 20 years ago.

Hansford W. Farris, Professor of Electrical Engineering of The University of Michigan, spoke of the need for major corporations to have a technical board. There are some who have such a group consisting of high level people such as the vice president for research, the vice president of engineering, etc. who meet with the group of university individuals who know the corporation intimately and who understand its technical objectives. If carefully

done, said Farris, this can be a successful mechanism for cooperation.

Willie L. McDaniel, Jr., Director, Engineering and Industrial Research Station, College of Engineering, Mississippi State University, told of a successful operation between the Mississippi Power and Light Company and his university. In this, the university put together a cross-discipline group to study the temperature profile of a river. It took, he said, mutual interests with each side contributing, multi-disciplinary approach and a sound contract.

Industry-University Interchanges

Alexander Ross, Technical Director, M&T Chemicals, Inc., spoke of the efforts of the American Chemical Society to improve university–industry relationships. This involves the interchange of teaching and practicing chemists and work study programs similar to the British sandwich programs or American cooperative programs.

C. W. Theobold, Vice Chairman & Executive Director, Committee on Educational Aid, E. I. du Pont de Nemours & Co., Inc. examined a complicated research program undertaken by du Pont on a complex vinyl polymer. There were certain questions which had to be answered under the pressure of time, while other problems could be resolved at leisure. A team involving university representation sorts out the problems giving the long-range ones to the university. By proper integration, both parties were satisfied with the results.

Harold Witcoff of General Mills, Inc. spoke about the need for mutual understanding and thought this could be done by inaugurating a special course on the philosophy of industrial research. By concentrating on the needs of industry and mechanism by which research was done in industry, students could be better fitted to industry's needs.

David T. Zentmyer, Assistant Director of Research, Fundamental Research & Application, Armstrong Cork Co., spoke of a three pronged program: a sabbatical leave for an industrial scientist which sent him back to the university, a grant in aid program enabling a professor to work on a problem of company interest and a program by which the company contracted with the university. These combined to make consulting with university members relatively uninhibited and the attending of seminars given by both sides, relatively easy.

Entrepreneurial Centers

Dwight M. Baumann, Professor of Engineering Design and Executive Director of the Center for Entrepreneurial Development, Carnegie Mellon University, described a center which instructs students in entrepreneurship and provides a laboratory for practice, much as a teaching hospital provides a place for interns and research fellows to try their skills. By incorporating new businesses, or coming to the rescue of those which are floundering, students can get practical experience. The center is financed by a grant from the National Science Foundation. He gave practical examples of two winners.

George W. Howard, Director, Engineering Experiment Station of the University of Arizona described a joint effort which was not an outstanding success. This consisted of inviting an advanced development group of a corporation to establish itself on campus to make use of university expertise. It failed because there was not sufficient emphasis on planning, not enough consideration of the marketing problems and not enough communication with the manufacturing facilities of the corporation.

Vince Haneman, Jr., Dean of Engineering of Auburn University, gave four examples of successful academic entrepreneurships. He pointed out that there was some justification in the title "academic charlatan" for those who were successful in this game. He said the requisites for success are a need for the product, a man who will do the work and a realistic appraisal of what has to be done.

Through all of the talks there were themes which occurred and reocurred. The first and most prominent one was the need for some means of identification. How can industry look into the vast number of complicated universities and find out who knows what? How can the universities look at the equally complex array of industries and find out where the needs are, who is interested in what I am investigating and who will then make use of the information I discover? The ASEE does produce each year a listing of all the engineering colleges who are doing research and it gives some facts covering the number of people, the title of the discipline and the amount of money spent. But this is quantitative only and it gives no idea about the competence of the people, the specific questions they are trying to answer, or how successful they have been.

On this point, we would like to make an outrageous suggestion. The Michelin organization in France examines all prominent restaurants. After sampling their products it assigns them a rating in a published guide, awarding two forks to a good restaurant, three to an excellent one and four, only rarely, to the few that are outstanding. Would it be

possible for industry to report through some organization, perhaps the I.R.I., those places and those people who have responded well to an industry request, giving special recognition to those where they felt the money was exceptionally well spent? This would allow other industries to identify centers of excellence, excellence from the point of view of the user of the research. To many, any evaluation scheme must seem outrageous, but if we are to build up useful relationships industry must have some idea of where to go. Perhaps there could be a similar compendium telling what each I.R.I. member is interested in and whom a university should approach if it has a research project it would like to sell.

Obviously, closer relationships between these two organizations, E.R.C. and I.R.I. is needed and fortunately it is possible. It is also apparent that we need some relaxation of the rules of getting together; rules concerning business practices, patents, accountability, publication, etc. But these can be relaxed if there is early discussion and understanding and desire on both sides. It is apparent, too, that one of the essential ingredients of success is the formation of groups, "centers of excellence," that can be called upon for consultation, for research, for testing, for student recruits and for independent studies. One man may lead such a group but continuity and breadth is needed and this is more readily found in a group than in a single person.

Continuity must be reemphasized. Research, expertise, understanding and innovation cannot be turned on and off. In involves people's lives and the cooperation between industry and universities cannot be turned off by business cycles, nor unduly interrupted by either the university or the business calendar or a contract period.

In every example discussed the importance of communication was emphasized. Not between the President of the company and the President of the university, but by eyeball-to-eyeball communication between the person who is doing the research and the person who is going to use it. Frequent visits between the two, the movement of people back and forth by sabbaticals, by consulting arrangements, and by the movement of students from the university to the business organization all help. The key words which appear throughout these talks are indicative of the needs, "our need and interest," "effective commitment," "person-to-person lasting relationships," "understanding" and time and time again, "communications."

The Role of Universities in Industrial Research

What Industry Needs from Academia

Philip C. White and Curtis C. Wallin

Universities are of service to industrial R&D in seven areas. More effective action can result from closer cooperation and more interaction between industry and academia.

Improvement in industry-university research cooperation has been subjected to much scrutiny, thought, and exposition in recent years. Although the results have not been inconsequential, the problems have not yet completely yielded. This can be attributed primarily to two factors: (1) The inherent stubbornness of "people problems" in yielding to even good approaches for their solution. (2) The rapidly changing scenario which provides not only a moving target, but also a moving platform from which to launch many of our problem-solving efforts.

Before we discuss the needs of industry as they relate to university research, we will make a few observations about some of the changes that are taking place on the industrial research scene. These changes clearly have implications for the future of industry-university research relationships. The status of and demands on R&D departments within their business organizations are being battered in opposite directions by shock waves of change. The two primary forces at work are, first, the political and social climate which increasingly requires that industrial firms be capable of assessing, broadly, the effects of their technology and products on society. Mr. Cole, president of General Motors, gave a very convincing outline of this trend to not long ago *(1)*. The second force is the increasingly competitive condition which produces a management trend toward tighter, more profit-oriented, controls. There is more reliance on new products and technology developed internally, rather than acquisition for growth, a trend noted by Williams Sommers of Booz, Allen, & Hamilton *(2)*.

The first of these factors tends to broaden the scope and responsibilities of the research organization, leading it into a role as the technological focal point for all aspects of the firm's business. Four functions within this role which seem certain to continually increase in importance are:

1. To assess and solve problems of the effects on the physical environment of resource extraction, manufacturing operations, and product usage.
2. To be alert, and capable of responding, to changes in raw material and energy supplies, and to the need for conservation of both.
3. To assess possible problems which may arise for the consumer, or for society as a whole, through the use of company products or out of company operations.
4. To be the focal point for technological information, from both internal or external sources, needed for overall company planning.

The drive in the other direction, toward tighter managerial controls and greater relevance to the firm's business, stems from increasing recognition that economic survival depends on optimal and efficient use of assets, in physical, manpower, and know-how forms. Or, stated more specifically, with the highly sophisticated capabilities for modelling the effects of alternate business strategies now available, management can be expected to insist that technological effort be controlled in scope and

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direction to conform to the selected strategies.

In addition to these two major factors of change, there are a couple of others, external to industry, which bear on the relationship between industrial and academic research. On the manpower supply/demand situation, we are clearly entering one of those troughs in the supply cycle. It appears that unfilled demand for engineers, and some science disciplines, is likely to be with us for many years. Any steps to close the gap will be very welcome by industry. The second point is the retrenchment and shift in emphasis of Government-sponsored research. These new directions will have to be factored into the arrangements between industry and the universities to meet their respective needs.

All these influences no doubt have variable effects on different segments of industry. However, it seems almost certain that, as a generalization, we can expect industrial R&D to play a more central, yet technologically broader, role in the firm's planning and operations. At the same time, objectives will become more closely defined and cost/benefit judgments will be acted upon with greater confidence and regularity.

Needs of Industrial Research

What do these trends portend in terms of the needs that we in industrial research organizations see in our relations with the university community? The needs are not new, even though some of the influencing factors may be. They are:

1. Advancement of scientific and engineering frontiers
2. Well-trained graduates, free of anti-business bias
3. Specific research projects, done under contract
4. Independent studies to provide credibility
5. Appropriate technical services-testing, surveys, etc.
6. Available expertise for consulting, continuing education, etc.
7. The educational function-broadly

The first two, and the last, on this list call for broad support, by industry in general, by private foundations, and by the Government. Needs 3 through 6 are more normally amenable to a 1 to 1 relationship.

The need for advancement of scientific and engineering frontiers hardly needs explanation or defense, but the broader range of demands on industrial research will make it more dependent than ever on the university for this need. Examples of the tremendous impact this frontier-type research can have on industry and, through industrial application, on all of society are readily apparent in examples such as the foundation molecular biology has laid for the pharmaceutical industry's contributions to medical treatment, or the changes in electronics wrought by the transistor, based on better understanding of solid state physics. A classic example of this in the oil industry was the Geophysical Analysis Group at MIT in the mid-50's. Their work on analyzing Wiener's stationary time series led to a revolution in the digital computer processing of siesmic signals in oil exploration.

Also included in this advancement need is a type of research which is vital to all of society, and certainly very pertinent to industry's long-range interests. These are the broad multidiscipline studies, evaluations, technological assessments, and research on means of improving techniques for these. Here the diverse staff of a large university is ideally suited to the job. Here is one intriguing and very current example. Many of the new fossil fuel resources (low sulfur western coal, oil shale and tar sands, for instance) are located in remote, sparsely populated areas. As we develop these, new industries in new population centers will be required. We will need more than just advanced technology. The challenges of the environment, and the inevitable socio-economic-political impacts will require this very type of broad, interdisciplinary study. University teams will surely be major contributors.

These are two qualifications regarding this frontier information — both obvious, but deserving mention. The fields of study must have relevance, current or potential, to industrial application, and the findings, and often also their significance, must be communicated.

Second on our list of needs is that for graduates whose background and capabilities are well tailored for careers in industry. This implies a way of thinking as well as basic knowledge and skills. Future industry employees need broader perspectives from their training which will help them to understand what the competitive business world is like and the nature of the applied research or field engineering usually expected of them. They also need to be better trained in thinking their way through problems or projects thoroughly to a logical and meaningful conclusion. And they must be able to communicate convincingly when they have reached that sound conclusion.

Our third need is for specialized research investigations directed at specific objectives and funded by contract. It is one that is obvious and common, but it also is often a source of misunderstanding. The key requirement here is that the newest and most advanced scientific or engineering knowledge, available uniquely through academic researchers, by applied on target and carried out thoroughly to

a usable conclusion. Because of the increasingly tight managerial reins on R&D, the concept of cost/benefit will apply here, and it is encumbent on both parties to keep this in mind.

Another increasingly important need, for which industry must call upon the unique position and capabilities of the university, is for independent, nonbiased studies. These are often required to verify or establish safety, toxicology, long-term effects or value, and limitations on products or technology. Here both industry and the public benefit from the greater credibility of the independent approach and the university hopefully gains a challenging and income-producing assignment.

Industrial research departments also need help at times of a more routine nature and turn to an outside lab, either for particular capabilities or just for additional capacity. Frequently, a university can provide sampling, analytical techniques, data analysis services, literature surveys, etc., conveniently and with high competence. A direct arrangement between the two can benefit both.

A sixth need, the ready availability of highly expert help for problem-solving and in continuing education programs, will increase in importance as industrial R&D more completely fulfills its role as a technology center. It is certain that our industrial scientists and engineers will require constant renewal and extension of their knowledge over their career lifetime. For this, expertise is needed beyond that which we have in-house. As broader demands are placed on R&D, that expertise may more often be in the social sciences.

Finally, there is the need for universities to continue "the educational function". We include this obvious function in the list because we want to be sure we did not lose sight of it. The goods and services that business and industry are there to provide are those needed and in demand by an educated populace. There is an interdependence here that is critical. Moreover, if we are approaching, as many believe, limits in some of our traditional areas of growth, the academic community will face new challenges in educating us as to how we maintain the balance of that critical interdependence.

Industry's Actions and Constraints

We would like to now focus on what industry can do to increase the chances of satisfying those needs, and some of the constraints which affect our actions. Here the spotlight turns directly on industrial research management, as we take a look at principles we might follow.

If we want advancements on the frontier of science and engineering to be relevant to our business and be communicated, we cannot leave it to chance. We have to take some actions. The objective we should seek, in taking these actions, is very well stated, in my view, by The Engineering College Research Council *(3)*: "The college . . . should strive to be on the leading edge . . . in fields of collateral interest to companies, but the research should be faculty inspired and consonant with the university's educational goals."

First, we must take steps to actively seek out professors at local universities whose fields of expertise correspond with our research interests. With them, and their research students, we must arrange informal meetings, panel discussions, symposia, etc., in reciprocal visits designed for two-way flow to technical knowledge and viewpoints on objectives. This could do much to open lines of communication by carrying the story of our research and its objectives to the university staffs where there might be a mutual interest. The desired interweaving of information and ideas and attitude doesn't always take place too easily. Good leadership and some persistence will be necessary.

Second, we must review and revise our practices on hiring and sabbatical leave to promote easy temporary exchange of researchers between the university and industry. This implies sufficient incentives to promote enthusiastic participation in such exchanges by the best people on both sides.

Third is to expand local programs for the use of consultants, with exchange in both directions. Inherent here is a relatively high level of responsibility for useful results, but positive steps to induce broader diffusion of information and viewpoints within the respective staffs should be part of the programs.

Fourth, in broader research areas, which impact on entire industries or on society as a whole, industry voices are too often inadequately represented. If we are to enlist the best talents available to help in solutions to these most important research efforts, industrial researchers should be included to a far greater extent in Government and foundation-sponsored programs. Such men, who have successfully managed research for years against stringent time and financial constraints and harsh, practical criteria of success or failure, have a contribution to make to such programs.

If we carry out these actions, they will impact not only on the advancement process, but also on our closely related second need, well trained manpower, and even the availability of consulting expertise. For manpower training too, of course, money is critical: grants-in-aid for graduate students, and one some of us have used, direct facilty

awards for teaching excellence.

There is another critically important aspect of manpower, and that is better matching of supply and demand. What is needed is far from clear. We have recently cycled badly, apparently due largely to overreaction to short-term pressures by both sectors. Better, more stable employment and hiring practices, by both industry and Government, are clearly needed on the demand side. And communication of the best feasible demand projections, to everyone in the academic community, even down to the high school level, should help dampen the overreaction that swings the supply cycle so widely. Close cooperation here is a must.

The same is true for counteracting the antibusiness bias. Business has its faults, but they tend to be the exceptions and students at all levels need to have a more thorough understanding of the beneficial aspects that are the rule. We in industry need academic help in telling the true story.

Constraints on Industrially Funded R&D

First, where direct contracts are concerned, industrial firms cannot be expected to fund projects of fields of investigation which are not demonstrably connected to their business plans or interests. There is an inevitable conflict here with academic freedom. A professor should not accept a research contract unless he is willing to restrict the work he does, with those funds, to studies that fall within the scope of the contract. Grants-in-aid are another matter, and industry takes a much broader outlook as to the benefits received. However, in both cases, management must appraise the value of funds spent this way against other alternatives.

Coming now to our next three needs — specific projects, done under contract, independent studies for credibility, and services such as testing — we are dealing with funded work which is fairly rigidly programmed. Here is where we find constraints that affect our university relations.

The second constraint, when industry pays for a job to be done, whether by a university professor or anyone else, it expects the costs to match the estimate, and the completion date to be met. There are exceptional circumstances, of course, but they should be the exceptions. We cannot expect good business principles to be ignored for the sake of academic and research freedom.

The last constraint, one which frequently causes more difficulty than it should, is industry's need for protection of its proprietary position. The problem here is quite basic. It arises from the diametrically opposing viewpoints of the academic researcher and managers of industrial research. Both appreciate the intrinsic value of new scientific knowledge and/or technology. However, to the former, its value most often becomes realized when it is broadly communicated to fellow scientists, whereas, to the industrial manager, it is frequently a salable commodity or an asset that can provide a competitive edge. In either case, to him, control of its dissemination is vital to its value. Despite this dichotomy, there can be cooperation with a reasonable amount of "give" from both sides.

This surely applies in the often conflicting but related area of patent rights. Here it must be recognized that industry, when it pays for contract research, is doing so as part of its effort to enhance the "margin" on which its existence depends. Thus, a company's concern for patent rights is not only valid, but such rights are often the key to its willingness and ability to sponsor projects. It finds it hard, and often impossible, to accept an academic attitude which says, "If the work is done at the university, it is improper for an individual company to exploit that work for profit." A productive cooperative relationship between industry and university will by enhanced by an understanding that the role of profits is as fundamental to the former as the teaching of students is to the latter. The point is well made by an analogy from a recent talk by Herb Fusfeld *(4)*, which I quote: "Suppose I said that we want a university faculty to conduct research needed for a major program. However, in order that they make a full commitment, and that the university should not derive any secondary benefit from the funds allocated for this research, those faculty members and those departments will not be permitted to pursue any teaching activities or advise graduate students. You would not only rise up in justifiable outrage, but you might even present the proper arguments that such conditions would weaken the institution and prevent continuing research contributions in the long run."

One other constraint should be mentioned. Turning to a university for routine, technical service-type chores can be of mutual benefit, but only so long as the work is consonant with academic goals. If it is done just for income, a school opens itself to charges of prostituting its talents. In seeking consultants, industry should not confine itself to top experts. There is much to be gained, on both sides, by seeking out the promising younger faculty member, who is on his way up.

References
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4. From talk at meeting of National Association of State Universities and Land Grant Colleges, November 1973.