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University-Industry Interaction Patterns

Past models are analyzed, some recent experiments described, and recommendations for the future given.

Rustum Roy

The research enterprise in the United States has been developing a pronounced lacuna in the areas of "applied science" or "applied research" (*1*). It has been my contention—since long before the shutdowns at U.S. Steel, RCA, Ford, Zenith, and others—that U.S. industry is increasingly withdrawing from fundamental research, even from research applied to its own problems, the support it had been giving for two decades. This gap must now be filled by universities, since no other performers are in sight. However, in order to do so, there must be a higher *general* level of effectiveness in the interaction between universities and industry in this country than has ever existed before. In this article, I examine briefly the situation in university-industry interaction, or coupling, in the recent past and describe viable models for the greatly enhanced interaction that is, in my opinion, essential to the well-being of national research and development (R & D).

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Standard Patterns of University-Industry Interaction

The taxonomy of the methods of university-industry scientific and technical interaction is not very complicated. The practices involved are standard; innovators are few and far between, since the person who can survive in a hostile environment from both camps is extremely rare. For several decades there have been only two or three universally acceptable mechanisms through which an entire university or a particular department could interact with industry. These mechanisms, summarized schematically in Fig. 1, are easily recognizable. The use of university faculty as consultants in industry is a time-honored and extremely effective way by which (given normal luck) the results of research and new ideas may be transmitted in one direction. There are innumerable examples of faculty consultants playing important roles in industrial developments. In the other direction, toward the university, flows (in addition to a fee) the most important benefit: a feel for the significance of problems on the scale of "value" to industry, relevance to the public's needs, and so on. It is my contention that in consulting, at least for large companies, the consultant gains as much as he gives. Such personal contacts occasionally, but not frequently enough, lead to interchange of samples and sharing of facilities, to the benefit of both industry and the university. Very often the latest results of government-supported research in the consultant's laboratory lead to new ideas that prove valuable to the company employing the consultant. The only problem with this method is its neglect: it is remarkable not how many, but how few, of the engineering and science faculty consult at all. While we have all read about abuses of the consultation privilege, an informal survey of science and engineering faculty all over the country would suggest that fewer than 10 percent of them spend 1 day a month in consulting. (Excessive consultation is a bogeyman, since every department head or dean has complete control of the matter.)

A second standard method of university-industry interaction is the research project funded by industry within a university laboratory or department. This is a highly desirable method of interaction. A high degree of monitoring and interaction is demanded, chiefly because the industry contact man must continually justify and resell the project to his superiors at every budget hearing. However, changes in management and attitude within industry have led recently to many projects of too short a duration for optimum results; also, funding is typically less than optimal. A company will often start an in-house 2-man-year effort in a new area, at a cost of, say, $80,000 per year, but it is extremely rare to find a $50,000 industrial project at a university, even though the same level of effort could be purchased with no costly investment in future white elephants of equipment or commitments to personnel. On the other side, in hard times industry cuts off external support first, without studying the effectiveness of research. Another observation is that universities which have been "too well" funded from federal sources, especially by block grants, tend to stop looking for industrial research support, which is harder to get.

The project research supported by industrial research associations is usually better with respect to longevity and level of funding, but concomitantly they provide for much less intense interaction with particular industries. The long-lived contracts of the American Petroleum Institute or the American Iron and Steel Institute with several universities are among the best known of this kind of interaction.

A third form of contact (it hardly deserves to be called "interaction") is the industrial fellowship. This is typically a tax-deductible, corporate gift to the university; it is extremely valuable as general support for a department or laboratory but in itself involves no research interaction whatsoever. Indeed, the psychological and emotional attitudes generated by the corporate "gift" are highly dangerous for research interaction. Many a research manager in industry subscribes to the idea that university departments are looking for handouts rather than delivering value for money; furthermore, the existence of a fellowship from his own company to any part of the university often seems to relieve him of any sense of obligation toward, or partnership with, the research arm of that university. It should be clearly understood that fellowships from corporate headquarters are gifts to the university. If they are to be a means of interaction, they could be transferred to the research vice president, who could then use them as a means of nucleating research interaction.

Postwar Attempts at Interaction

The two golden decades of science funding in the United States, 1948 to 1968, were not notable for inventiveness at the industry-university interface. These were the decades of the government-university honeymoon. However, as the flow of money across this interface climbed past the $2 billion mark, some crumbs and spin-off did accrue to industry-university partnerships. One can identify two notable classes of experiments in university-industry coupling.

The first is the "industrial associates" model; Fig. 2 presents schematically the concept behind schemes of this type. The rationale was a healthy step away from the fellowship idea: it was based on the premise that a university is a large resource base of talented manpower (and to some extent specialized equipment) which could be utilized by industry in a collective-consultation mode. The university collects a fixed annual fee for membership in the associates. Members are given special access to the resources of the entire university and receive "most-favored-nation" treatment in regard to specific parts of university departments or laboratories. Special seminars and conferences are occasionally arranged for the membership, and the company itself has a further intangible benefit in belonging to a prestigious club around a prestigious university. For its part, in addition to the $20,000 to $25,000 fee, the university receives relatively vague management advice on directions for the future. The Massachusetts Institute of Technology and Stanford University versions of this model are among the best known and most highly developed.

The government can be very much involved in furthering and supporting industry-university coupling efforts. The efforts recorded above are strictly binary efforts between the parties involved; I turn now to the second class of university-industry interaction, where the government appears in the role of a broker.

In the mid-1960's, C. F. Yost, director for materials science at the Advanced Research Projects Agency, made an effort to generate a rather specific, goal-oriented program wherein one university and one company were joined in a team effort wholly paid for by the federal government. The theory was that, if the federal government provided the funds for research on a fairly broadly defined objective, the special capabilities of each of the two participants could be coupled so as to interact continuously and efficiently in reaching such goals. Three such contracts were let to three teams of two members each. There was considerable variation in the parameters that most persons within the three teams regarded as important (for example, geographic separation of the team members), and very interesting data on coupling efficacy could probably be gained by studying them. The contracts were terminated at the end of about 5 years, and no formal assessment of efficiency has been attempted. The general impression in the materials science community is that efficiency was not high.

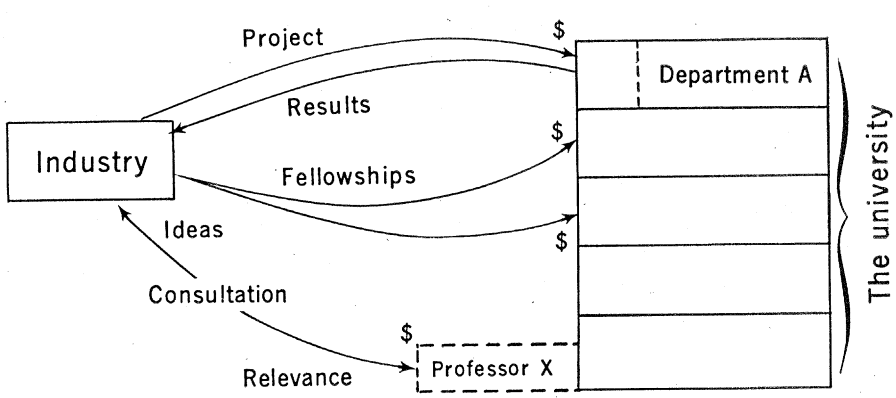

Fig. 1. Schematic representation of the traditional mechanisms whereby the university interacts with industry. The three most common are the research projects, wherein a particular department or unit takes on a specific task with the costs borne by the company; fellowships, gifts from the corporation to the university, often designated for particular departments, with no quid pro quo required; and consultation, the use of faculty (outside their departmental functions) to provide expert advice (in addition to the fee, the faculty member and, thence, the university gain a better understanding of relevance of current research to industry's problems).

In fact, a variation of this model of coupling is fairly widely used—in end-item contracts where an industry is the prime contractor and part of the research is subcontracted to a university. The Department of Defense (DOD) and, later, the National Aeronautics and Space Administration have utilized what is essentially this model. Given reasonably long-term funding, the university can operate quite effectively in this mode; indeed, this may be the most generalizable of all the models available.

Other Recent Developments

We have noted that, during the late 1950's and early 1960's, while the flow of government funds to universities increased very rapidly, the degree of university-industry interaction remained constant or declined. Only a few universities and their corporation partners attempted any new approaches to this problem of linking their two research efforts more closely. Among these approaches were industrial coupling or liaison programs, applied research programs with definite industrial significance, and multi-performer, programmatic funding with a defined objective.

The theory behind the industrial coupling or liaison programs (ICP, ILP) resembles the industrial associates in some ways but differs sharply in others. First, it selects a single technological area encompassing, or within, a department, an interdisciplinary laboratory, or an institute in which the university has especially high competence relative to the industries involved.

Second, it creates continuing interaction between a few persons in industry and the university. Thus applied research objectives of the company (specifically, those that can utilize either the facilities or the results of the large research programs funded by the federal government) are introduced into the thinking of the faculty and students. The company in effect inherits a basic research laboratory that is funded by the federal government and conducting research in an area of direct interest to the company. Where communication is effective, ICP or ILP is an ideal way of utilizing the federal basic research dollar by having results of the research flow quickly (that is, 2 years faster than via the literature) and *personally* to the most interested users.

Third, the ICP or ILP model utilizes the above two conditions to create the best resource for performing joint research on specific problems funded either by the company itself or by various government agencies. The interchange of personnel through visits, telephone calls, consultant relationships, and the regular use of the university's specialized instrumentation by company personnel, is the most important result of this kind of coupling. The "fee" for joining such a group is typically $3000 to $5000 a year, the amount often becoming part of a larger project sponsored by the company.

This kind of arrangement, which appears to have so many advantages, is still relatively rare on U.S. campuses. In the major area of materials technology, fully developed versions appear, among other places, at Pennsylvania State University, Lehigh University, and Case Western Reserve University. Interestingly enough, none of their specialties overlaps—nonmetallics, metals, and polymers, respectively. A department-based example is found in the chemistry–chemical engineering program at Stanford University. The flow of information, ideas, and so on is summarized in Fig. 3.

A second approach to coupling university-industry research is applied research programs with definite industrial significance. Over the last several years, an interesting model has been developed by the Pennsylvania Science and Engineering Foundation (PSEF). The rationale behind funding at the state level was to take advantage of federal programs that establish competence at universities and to use these competences for creating new technologies and, thence, jobs, within the state.

The PSEF funds, at a university that has a special competence, a project in which a particular industry (or industries) has shown a definite interest, which that industry has helped design, and which that industry certifies has the potential of improving its competitive position, developing new products, and so on. The greater the participation by the company, the greater the chances of PSEF funding. The state thus assures itself of vigorous coupling if the company puts its own funds (in cash, kind, or personnel) into the project. This model also assures some "productivity" and continuing outside assessment.

The aspect of such ventures which is always questioned first, concerns the proprietary rights to any inventions that result. Regrettably, this aspect is often used as a red herring to avoid such experiments. In practice, few difficulties are encountered, and these can be avoided by a key administrative invention. In all cases, the results of research supported by public monies is in the public domain and would be included, where appropriate, in regular reports, student theses, scholarly articles, and so on. In many cases, the university work is kept relatively basic, while the company concerned operates within its own laboratories a parallel applied program that is intensively coupled (by personnel exchange, visits, and so on) to the university work. The company then

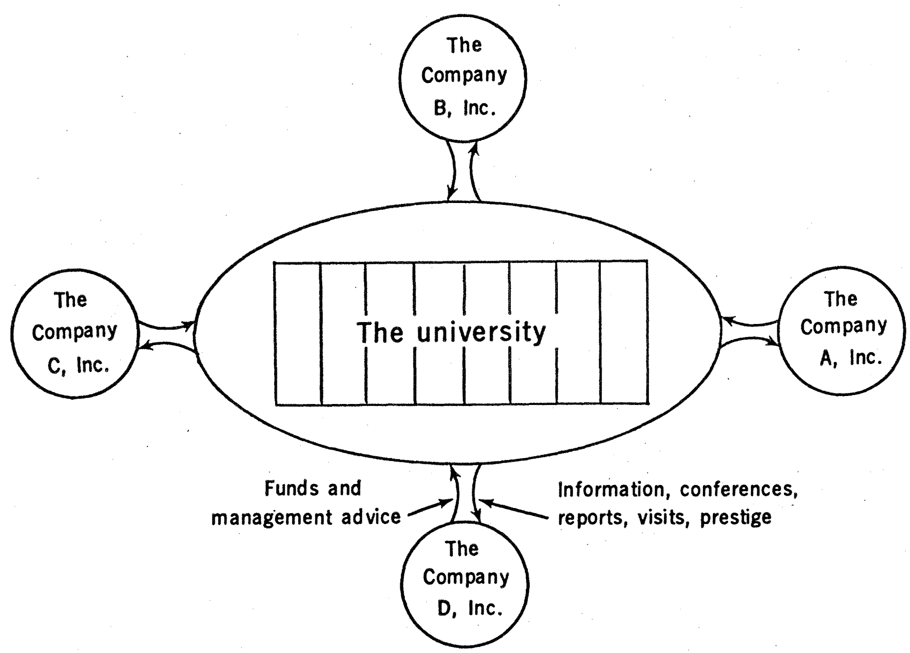

Fig. 2. Schematic representation of a university-wide industrial associates program.

builds quickly on any new ideas or results from the state program. The company gains a time advantage thereby and can establish its proprietary position in-house. In other cases, which provide perhaps the best general solution, the company establishes a (proprietary) project at the same laboratory where state support exists. The company is thus able not only to utilize the results of the PSEF-funded research in its own laboratories, but to enable the university team to pursue those specific outputs of the PSEF-funded work that are of special interest to the company's business, with appropriate proprietary safeguards. This model is shown schematically in Fig. 3. In such cases, the company builds a pyramid—with a large base of federally funded basic research to establish the high competence of the group, followed by a smaller applied program supported by the state, and finally a specific applied program supported by industry.

The third approach to coupling university-industry research is multi-performer, programmatic funding with a defined objective. I have noted that DOD has occasionally effected considerable university-industry coupling via the prime contractor–subcontractor relationship in its contracts. Occasionally, the system established to operate such contracts provided a very good model for a pattern that appears to have promise for the future. While the overall objective was military, it was usually translated into general *scientific* objectives. (An example is the set of contracts to develop coatings for refractory metals, such as tungsten, in order that these metals could withstand temperatures above 1600°C—a requirement necessitated by their use in leading edges of supersonic airplanes.) The definition of the problem was often refined further in a first meeting at which the contractor's representatives gathered with each of the subcontractors, including those from universities, and with a few nationally known authorities in the field who acted as consultants. After such a session, each component of the system was coupled to the prime contractor through occasional contact, reports, sample exchange, and so forth. Occasional larger meetings completed the system.

An adaptation of this style is now being developed, and some of the programs started within the engineering division of the National Science Foundation provide examples of it. The model in use here can best be seen in terms of Fig. 4. First, the selection of the area of technology to be worked in is based on an analysis of the economy or technology by various public bodies, such as a committee of the National Academy of Sciences, and advice from industrial and university research leaders. The key (potentially) nucleating step is then taken by convening a "workshop" of some 30 to 50 representatives from both large and small industries directly involved in the field and the universities (and government laboratories) working in related areas. At this workshop, the group has several tasks:

1) The group must determine whether there is a science-technology "gap" in the particular area which is not now being adequately covered within the United States by industry (and the universities).

2) If there is such a gap, the group, or a part of it (mainly representing industry and the agency), works on defining the specific problem areas most in need of research.

3) A report embodying the group's principal recommendations on basic problems of significance to industry is then prepared and widely distributed to industry and the universities.

4) The agency obtains authorization to commit itself to a coherent program with substantial funding ($0.5 to $2.0 million per year) on an increasing schedule for a period of 4 to 5 years.

5) Proposals for research in the areas outlined in numbers 2 and 3 above are invited, and an interlocking research program is constructed by selecting several of these. Industry has a secondary input into the system here by helping evaluate such proposals for "relevance," in addition to peer group review of the proposals for quality.

6) The results of the continuing work are not only published and circulated as annual reports, but semiannual meetings are held, in which industry and university research workers discuss their results in a rather new give-and-take situation. Here, not only finished work, but work in progress is discussed in an atmosphere of peer group criticism. This is quite novel for academic science. Furthermore, wasteful research can be avoided in cases where workers in industry can offer information or suggestions indicated by their unpublished work. Obviously they cannot determine what the university investigators may choose to do in light of their advice. However, the agency representative can be sensitive at this point in distinguishing between a wasteful duplication and a subtly different and innovative approach on the part of the university. There should be no covering up of the fact that the role of the agency manager here is a distinct departure from previous National Science Foundation practice, but no different from the practice of several DOD agencies.

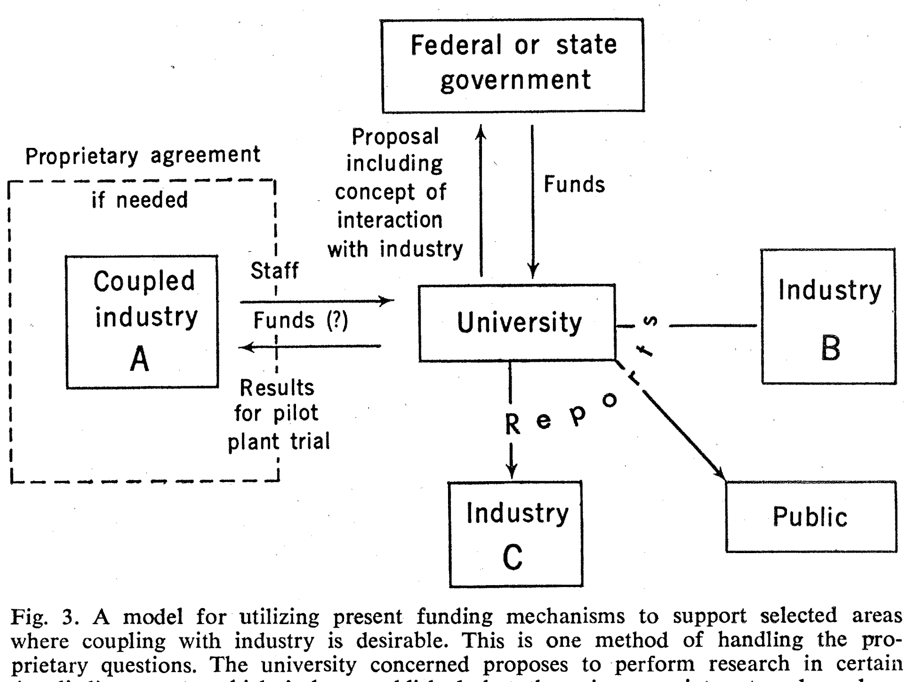

Fig. 3. A model for utilizing present funding mechanisms to support selected areas where coupling with industry is desirable. This is one method of handling the proprietary questions. The university concerned proposes to perform research in certain (applied) areas in which it has established that there is some interest and need on the part of the industry. Part of this interest may be the existing or proposed special proprietary relation with a specific industry. Thus the federal or state government supports a certain basic program. With this base established, the university sets up specific proprietary relations with a specific company.

Indeed, the agency manager has the advantage here of having a relatively disinterested body of experts from industry to advise him; again, he has to be careful to avoid taking single opinions, since a particular company's interests may conflict with the work in a particular university laboratory.

7) The meetings are expected to generate many interacting pairs, in addition to the collective interaction. In other words, after a year or two it would be expected that particular industries and particular universities would exchange samples, skills, instrumentation, and so on. Indeed, intensive study and evaluation of its own products would almost certainly benefit American industry. Further, proprietary research arrangements of the kind mentioned earlier (Fig. 3) might be set up separately between the industry and a selected university, whenever needed.

Summary

The nation is entering a period when the R & D output must be increased, probably without major increases in resource allocation. Obviously, in this situation, either efficiency or productivity must be increased. Perhaps one of the most wasteful aspects of the national R & D system (and one that received little attention during the golden era of the 15 percent per year expansion) has been the very weak coupling between the university, on the one hand, and industry (or government), on the other. It is a serious error to allege about such coupling that "it has never worked," that the objectives and reward structures of the institutions are such that it cannot work, and so on. The fact is that coupling has never been tried seriously. History shows that the total dollar effort in research that *required* coupling or that had coupling as its main objective was on the order of $10 million per year (that is, much less than 0.1 percent of the research money spent on U.S. campuses). At the same time, there is little doubt that the experiments which must and will be tried in the immediate future call for innovations in management and changes in the attitude and structure of many universities. In conversations with administrators who have had experience with such programs, I have found strong suggestions of very mixed responses from the universities. In light of these responses, and if effectiveness is a goal, it would be better for those universities that are more wedded to disciplinary research, to single principal-investigator work, *not* to participate in these new efforts. We need much greater diversity in the styles of university life, and it would be healthy for the academic enterprise if some universities retained a greater degree of detachment from society, while others consciously decided to interact more with it, through the private sector, and made the changes necessary to do so. If initial funding is restricted to those universities that consider university-industry or university-government research a worthy objective and that have a proven track record and a favorable administrative and reward structure, the new programs may well establish a major new pattern of national R & D.

In an effort to identify some of the features that contributed to the success of one particular effort at coupling—that of high-voltage capacitator development, undertaken by Pennsylvania State University and Erie Technological Products—PSEF, through its executive director, R. Laughlin, held discussions with representatives of the university and the industry. Together they developed the following criteria for successfully translating university-industry research into products:

1) Demonstrated scientific experience, capability, and competence, plus a novel approach or idea.

2) Demonstrated previous performance of the university sector in industry-related work (either consulting or research contracts).

3) Proximity or ease of communication between the units involved.

4) Industry employees working in the university at least part time.

5) Strong university management, since performance is evaluated by atypical criteria.

To these criteria I would add, with maximum emphasis, the "Abelson doctrine" (*2*)—that performance should be a much more important criterion than promise in awarding contracts. The "relaxation times" of university structures are measured in decades. For a government administrator to think that he can, for a few hundred thousand dollars a year, effect changes in the disciplinary or departmental structure of a university with no previous record of performance is sheer foolishness. Perhaps a quarter of our major institutions have the philosophy, willingness, and performance necessary for interacting with industry. To invest initial money outside these groups would be to invite failure.

My "analyses" of the fragmentary reports and the occasional records, as well as my observations, lead me to suggest that, besides considering the question of which universities are suitable, we should consider experimenting with a variety of patterns simultaneously, in order to discover, within, say, 5 years, which ones offer the best hope of success. Among these patterns, the following appear to me to be most promising:

1) The multi-performer, coherent area program described above.

2) The single university coupled to an industry association. Here we envisage two models: The first, a large project funded jointly by the government and the association in a suitable, interdisciplinary laboratory on the campus; the second, a physically separate laboratory, with long-term funding, *near* the campus, responding through a board of directors to both the association and

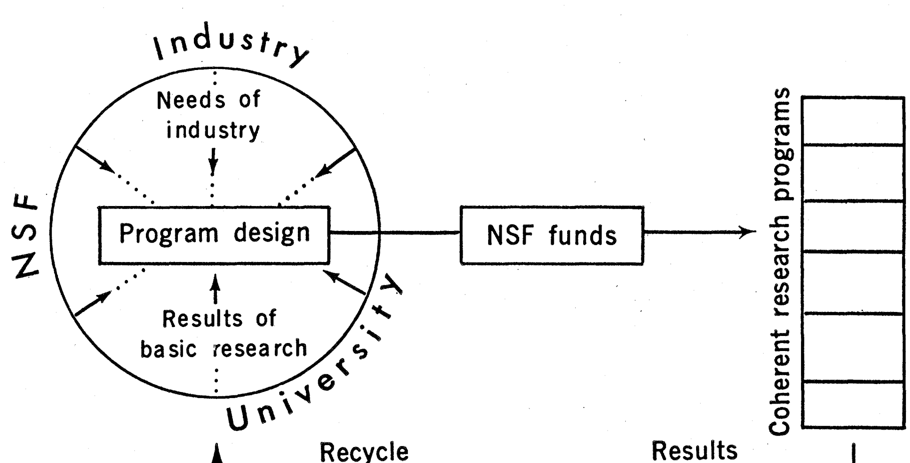

Fig. 4. Model for multi-performer research program coupled to a specific formal or informal industry association. Such a model is being used by NSF with the cutting tool and grinding materials industry.

the government. A typical version of the latter model might involve a laboratory attached to a major university with established breadth and strength in a particular area, funded, partly by industry and partly by government, at $2 to $3 million annually. Such laboratories could probably not always be fully integrated with the campus, since they would need to do work, such as pilot plant studies, that is not closely tied to the academic program. A semiautonomous operation on the campus, fully utilizing the faculty and capabilities of the university and contributing to the research effort, would probably be best.

3) The single university coupled to a single industry, with industry participating in the funding as in the PSEF model described earlier. (Of course, two or three industries could be involved instead of just one.)

4) The pattern given above, with an *additional* proprietary, two-way contract between the industry and the university.

5) The prime industrial contract (with several university subcontractors on a long-range, joint contract) directed toward nonmilitary technology.

The government agency managers should have had experience with both industrial and university systems, either through participation in them or through dealing with them as contractors. Remarkable prejudices build up—sometimes against, sometimes for —the approach most familiar to the administrator.

The field of university-industry interaction needs more widespread and thorough discussions among those who have been in it, and a small conference or two to bring such people together is overdue. Except for discussion, major funding is the only item lacking in the great experiment to harness together the research establishment troika.

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3. Many of these themes have been developed in conjunction with service on various state and federal agency committees, among them the Materials Advisory Panel of the Governor's Science Advisory Committee in Pennsylvania. I am indebted to many colleagues, especially I. Warshaw, deputy division director for engineering, National Science Foundation, for many hours of stimulating discussions; the opinions expressed are my own.

NEWS AND COMMENT

Theodore Roszak: Visionary Critic of Science

Berkeley, California. What is sometimes referred to as the antiscience movement is so hard to define that one suspects it is an abstraction to express the fact that science is under attack from a number of disparate quarters. One of the most ambitious of such attacks is the critique put forward by Theodore Roszak in two recent books, *The Making of a Counter Culture* (1969) and *Where the Wasteland Ends* (1972). Roszak differs from other social critics, for example Charles Reich, in that he sees science as the root cause of society's maladies—"Science is not, in my view, merely *another* subject for discussion. It is *the* subject." He is also among the most radical of science's critics in that it is not technology, pollution, or any consequence of scientific activity he is objecting to, but science itself—its methods, its view of the world, and its dominant role in western culture. Roszak's views on science would commend themselves to attention by their scope, if by nothing else.

A historian by training, Roszak teaches at the California State College at Hayward but lives in Berkeley, a few blocks away from the countercultural sidewalks of Telegraph Avenue. In person he is soft-spoken, with a way of looking that suggests more the inner vision of the mystic than the ardor of "the foremost spokesman of antiscience," a label recently affixed to him by the London *Observer*. Roszak rejects the description. "I am certainly not antiscientific," he told *Science*, "in the sense that I want to throw science out of the culture. But I am antiscience in that I want to question the cultural dominance of science, I want to put it in a somewhat more subordinate place in society, to ground it in a sensibility drawing on the occult, mysticism, the Romantic movement. . . ."

What is the position from which Roszak seeks to dethrone science? In *The Making of a Counter Culture*, a largely sympathetic description of revolt movements among the young, Roszak denotes the culture being countered as the technocracy. The technocracy epitomizes the trends in urban-industrial society which Roszak dislikes—its complexity, its power in relation to the ordinary citizen, its dependence upon an elite corps of technical experts who justify themselves by appeal to scientific forms of knowledge. But science is not just the privileged knowledge that keeps the technocrats in power, it also forces upon society its own way of looking at the world, which Roszak describes as the "myth of objective consciousness."

Roszak means myth not so much in the sense of something which may be false but as an expression of a particular view of the world. Objectivity is the bedrock upon which the natural sciences are built. Since it is science to which modern man refers for a definitive explication of reality, objectivity has become "the commanding lifestyle of our society. . . . The mentality of the ideal scientist becomes the very soul of society."

The myth of the objective consciousness, Roszak argues in the book, sustains the technocracy and distinguishes it from the counterculture. Objectivity leads to alienation, whereas the counterculture draws upon the sense of community. Objective consciousness "*is* alienated life promoted to its most honorific status as the scientific method. Under its auspices we subordinate nature to our command only by estranging ourselves from more and more of what we experience. . . ."

Roszak compares the scientist's role in society with that of the ancient Egyptian priesthood which used its monopoly of the calendar to command the awed docility of ignorant subjects. Scientific knowledge is, in practice, inaccessible to the public at large, which accepts on trust what the experts say. But the experts, at some stage along the way, have been bought out by "ruling political