STEVEN MULLER

RESEARCH UNIVERSITIES AND INDUSTRIAL INNOVATION IN AMERICA

Ever since the mid-1970s, a belief that the future well-being of the American economy depends on a renewed national commitment to technological and/or industrial innovation has become more pronounced and widespread. Those who profess this belief usually invoke the innovative character of past American economic development and then assert that in recent years the United States has begun to lose the role of international leadership in industrial, scientific, and technological innovation. In this context the idea also is advanced that American research universities have been vital contributors to innovation in science and technology in the past, and therefore a successful recommitment to such innovation depends essentially on leading participation by American research universities. As usual, when a majority of the public subscribes to beliefs and ideas, there is some truth in them—but no one simple truth. Some reflections on the relationship of the modern American research universities to innovation in science and technology may help to sift out reality from unwarranted assumptions and reduce some confusion.

THE FOUNDATIONS OF THE CONTEMPORARY UNIVERSITY

It is certainly true that the contemporary major research universities are distinguished by a great emphasis on science, and increasingly on technology as well. But the extent to which these universities are the fountainhead of innovation in science and technology is at least arguable. And on the record, major research universities have not been a major—not even a significant—direct source of new products for the marketplace. The major research universities do perform research, but they remain primarily teaching institutions, and their chief role is to develop and train human talent. The vital link between the major research universities and the advancement of science and technology in the United States, therefore, can be discovered mainly in the pool of talent which the universities both harbor and produce.

Today it is difficult to remember the only very recent origin of much that is taken for granted in the contemporary American university. As of now, for example, no one would argue that the whole university is dedicated to the spirit of free inquiry. Yet the fact is that this tradition is scarcely more than a century old—precisely as old, by no coincidence, as the scientific character of the modern university. In its beginnings, the university, of course, was already committed to knowledge and truth, but the knowledge was received knowledge, and the truth revealed rather than discovered. For centuries, the university as an institution was tied inextricably to established religion and served primarily to refine and transmit established knowledge and to train human minds to function within the confines of God's word and established faith.

Thus, in the early nineteenth century, when Wilhelm von Humboldt achieved the reform of the Prussian university by insisting on freedom of teaching and learning, he had in mind a highly specific concept of freedom: freedom from religious orthodoxy. And—as important—learning took on a second meaning beyond the original definition of absorbing all that was already known: learning began to mean inquiry as well. It is useful to note that von Humboldt's reforms were of course achieved only with the support of the Prussian government, and the statesmen of Prussia supported him explicitly because they wanted to foster their state's industrial development. The Prussian government perceived the linkage between scientific training in the universities and the application of science to and in industry, and so they sponsored the emergence of the research university. Ideas that had earlier been heresy—that truth required proof rather than faith, that knowledge could be advanced by discovery, that to question the wisdom of the past was not only legitimate but indeed necessary, and that facts were so objective that *no* known fact was sacred—were ideas now embraced within the university. Professors and their students were set free to search for the new and to seek proof for discovery.

In the United States the modern research university was not fully established until the opening of The Johns Hopkins University in 1876, with an explicitly acknowledged debt to the ideas of von Humboldt. Within a few years thereafter, graduate research programs began to sprout throughout American higher education, atop the established collegiate foundations. Even before then, however, the government of the United States had also perceived the linkage between the education of talent and national development. The

Karl Wilhelm von Humboldt (1767-1835)

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Morrill Act, enacted during the Civil War in 1862, fostered the establishment of colleges specifically to educate talent in the agricultural and mechanical arts so that farming and production could spread more effectively across a whole continent. The land-grant colleges were not founded as research universities, even though they later became such, but the emphasis on the practical and its application in their founding set their professors and students free from the old rigidity of religious orthodoxy and received knowledge as well.

The devices that symbolize the industrial and technological revolutions of the nineteenth and twentieth centuries—whether one thinks of the steam engine, the cotton gin, the automobile, the telephone, the telegraph, the radio, the airplane—were not developed within or by the university. Indeed, the more venerable of these devices were invented before the university as an institution had itself been transformed by science. But the application, maintenance, and continued refinement of such devices throughout the American economy depended upon a pool of trained talent which was—and is—a product of the American research university. That statement requires amplification. But before that amplification can be most effectively performed, it is necessary to observe a major second stage in the evolution of the major research university in the United States—its mobilization into national service.

TRANSFORMATION BY MOBILIZATION

Until World War II, the American research university as an institution became progressively more scientific, but it did not grow hugely in size, nor did it develop significant new ties to the industrial community. The most interesting evolution of the period occurred so quietly and naturally that no one ever seems even to have remarked upon it: namely, the employment of doctors of philosophy by industry. Before the 1890s, there were, in effect, no American Ph.D.s in existence, and the degree was introduced to mark the highest level of advanced preparation for an academic career. However, well before the outbreak of World War II, industry had research departments and laboratories, and, to staff these, employed Ph.D.s and used professors of science and engineering as consultants. Thus, the high quality of the research done, for example, by American Telephone and Telegraph, General Electric, and E.I. Dupont de Nemours & Company did not depend on close relationships to one or more particular universities as such, but rather on the fact that their leading scientists were drawn from the most advanced university graduates and had the same level of training as future professors.

With the outbreak of World War II, inevitably the mobilization of the whole nation also included the universities but went far beyond the traditional call of students to the colors and the enlistment of physicians, nurses, and other specialists into service. Technology played an unprecedented role in the war effort. Not only were university specialists called to work on technologically sophisticated projects, but universities were requested to sponsor new laboratories to do research for military purposes. Nor was this a short-term effort. While the war as such ended in 1945, it was followed immediately by the so-called cold war and the Korean War; and, in fact, the period of national mobilization lasted fully for at least thirty years—until the closing of the Vietnam War. To a significant extent, mobilization still persists into what is now a fifth decade. In addition to university laboratories, new government laboratories were established in large number and variety, and more and more these too drew for research staffing on the Ph.D.s coming out of the university graduate schools.

As defense technology kept widening to include space, chemical and biological warfare, electronics, and virtually all materials, the concept of the national interest irresistibly expanded to include the whole range of science and technology within the university. Public investment by government in the growth and development of university science and technology came to be regarded as a perfectly natural—indispensable—ingredient of national security. First millions, soon billions, of dollars annually were appropriated for this purpose. At the same time, access to higher education

was being expanded by means of a succession of congressional enactments and appropriations. As a result, existing colleges and universities grew greatly in size, and new colleges and universities were established. In the quarter century between 1945 and 1970, American higher education more than tripled in size and capacity, and within the major research universities the federal government became the established patron of advanced research and training over the entire range of fields in science and technology.

THE GOVERNMENT-UNIVERSITY PARTNERSHIP IN RESEARCH

Selected aspects of the way things were done in the process, or of the way in which matters turned out, appear worthy of comment. For example, it can be noted that the interaction between representatives of government and the university community began in the 1940s on an extraordinarily high level of mutual trust and commonality of purpose. World War II was—at least after Pearl Harbor—a "popular" war in the United States. Subsequently there was widespread consensus that the best way to counter Stalinist expansionism and avoid renewed global war and the use of nuclear weapons was to create effective deterrent capacity. Cooperation in the national interest was not then controversial. In other words, motives were not initially in question. As a result, problems that might otherwise have led to long and vexed negotiations were settled quickly and effectively in order to get the job done. An enduring network of personal connections between individuals in government and those in university science grew in this agreeable climate, and those helped to lubricate relationships later when some friction began to develop.

It must be assumed that the high degree of mutual trust at the outset had much to do with the easy adoption of the peer review systems in the distribution of increasingly vast amounts of government sponsored research. There is, in retrospect, a near miraculous purity in the concept that the best way to assure the funding of good science is to allow good scientists to review applications and select the best. And—most of all—it is worth noting that it was possible for government to deal directly with university scientists and technology experts themselves, with only relatively minor involvement on the part of the universities or institutions. It is more than doubtful whether university administrations could have motivated professors to cooperate with government nearly as effectively as was in fact the case, where the motivation arose within the professional initiative combined with the appeal of the national interest that largely swept the institutional university along in its train.

In the well-known story of the growth of government sponsored university research, the involvement of industry is seldom mentioned or emphasized. While this may be easily explained because industry involvement was indirect, it is a grave distortion not to recognize explicitly the major stake on the part of industry in the burgeoning government-university partnership. Even if one were to look only at national defense in a narrow sense, it is obvious that the ever more sophisticated and complex national defense systems—developed with the advice of university specialists—called for an ever greater range of sophisticated and complex products—products procured by government and produced by industry. The wider the range of government needs—beyond weapons systems and into, for example, space and communications technology—the greater became the involvement of diverse industrial enterprises in providing the means growing out of research and development. It is, of course, true that in response to the situation, more and more of the affected industries began to set up elaborate research and development programs of their own—also often with government assistance. But here too the staffing of these industrial research and development programs depended on the availability of university trained talent—talent at the core, trained at the doctoral level. The great investment on the part of the federal government in university science and technology, therefore, produced not only ideas and techniques that resulted in industrial contracts, but also—and with far greater total impact—provided the funds and facilities within universities to train great new numbers of highly advanced technologists and specialists, who found employment in industry and government, as well as within the university system itself.

To the extent, however, that the federal government was not only the principal sponsor of science and technology in the major research universities, but also the principal consumer of so much of the applicable result, it can be remarked that the need to *market* ideas and techniques was generally—and notably—absent. To a large extent, government was willing to sponsor basic research, i.e., the conduct of scientific inquiry for its own sake and where an applicable outcome was neither promised nor expected. However, where the government sponsored targeted research, the government was also likely to be the consumer or purchaser of the result; hence there could also be a certain indifference as to whether the result was ever purchased or consumed—that decision was, after all, up to government. There was *competition*—among investigators for research support and among industrial enterprises for procurement contracts, but there was very little marketing.

UNIVERSITY ATTITUDES TOWARD RESEARCH

In this connection it should also be pointed out that research as a *product* is not—or, at least not yet—an acceptable notion even within the contemporary American research university. To understand this, it is useful once again to go back to Wilhelm von Humboldt and the germinal reform of the Prussian university which he achieved. Von Humboldt spoke not only of freedom of teaching and learning, but also of the identity of research and teaching. His credo was that in-

The Johns Hopkins University (JHU) downtown campus, ca. 1885. Levering Hall, the Administration Building, Hopkins Hall, and the Chemistry Building are at left and the Biology Building is at right.

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quiry was an indispensable part of teaching: only someone engaged in inquiry was best qualified to teach, and learning involved engagement in inquiry as much as absorption of subject matter. The twin identity of research and teaching has since become—and remains—gospel within the American research university. And this twinning needs to be understood in light of the fact that the university has been—and remains—primarily a teaching institution. When a major American university styles itself as a research university, what is meant is that its teaching mission is distinguished by a research component of the highest quality. What is not meant is that the university is primarily a research institution. Research without teaching is still as heretical an ideal within the contemporary American university as teaching without research.

To understand this confluence of teaching and research within the university supports the notion that the university as an institution is generally ill-suited to perform research: it is the professor *at* a university who performs research, not the institution. The key relationship which evolved as government became so prominent a sponsor of research was—as noted earlier—between government and individual professors identified as principal investigators. The inner logic of this arrangement lies in the linkage of research and teaching as well as in the freedom of inquiry: only the researcher/teacher could appropriately determine the proper mixture of inquiry and instruction that is inevitably a cardinal feature of an academic research project. Thus, on the face of it, a particular university can be identified as "doing" on the order of $100 million annually of federally sponsored research, and it is accountable to government and the public for the whole of it. But in reality so great a total is merely the accumulation of hundreds of individual projects, solicited and executed under the guidance of principal investigators, normally unrelated to each other, and scattered throughout the university. A major research university is one whose faculty is composed of many persons of such distinction so as to be able to bid successfully for research awards—grants and contracts awarded by government in the name of the institution but awarded in fact to the principal investigators. Universities did not and do not *assign* research to members of the faculty any more than they assign the courses to be taught. Instead, professors select the research they wish to do just as they select the content of their teaching, and, if funded, they thereby put the university into that particular research activity. When professors—principal investigators—move from one university to another, their research awards follow them and do not remain at the university of origin. As a result, a university widely known for research of a particular kind could—and does—suffer loss of competence with the departure of a principal investigator, whose arrival at a different university would then lend to it the distinction lost by the institution from which the move originated.

There were—and continue to be—some exceptions to this prevailing situation in that some universities did set up special laboratories, dedicated to particular lines of inquiry, which sought and received support as such, i.e., not on the basis of individual grants and contracts. In most instances, however, there was a controlling reason for such action by the university: the need for secrecy. When government insisted on secrecy in the national interest, the university faced—and still faces—a dilemma. On the one hand, it is obvious that certain types of research involving national security require the protection of secrecy lest they aid foe as well as friend; on the other hand, secret research is anathema to academic practice. Precisely because of the fundamental credo that research and teaching are inextricably linked, research that—for reasons of secrecy—cannot be related to instruction is academically illegitimate. Academic research *must* serve—or at least be capable of serving—as a teaching base and, therefore, *must* be open. By definition, then, secret research cannot be academic research. To resolve this dilemma, universities willing to engage in secret (classified) research set up nonacademic laboratories, physically isolated from the rest of the campus, in which secrecy could be maintained—but at the sacrifice of the academic mission. At the same time a decision was reached that individual faculty members could engage

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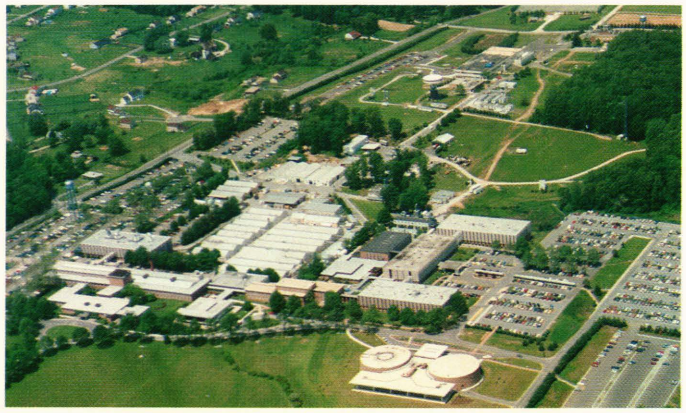


The JHU Applied Physics Laboratory, Laurel, Md (1984)

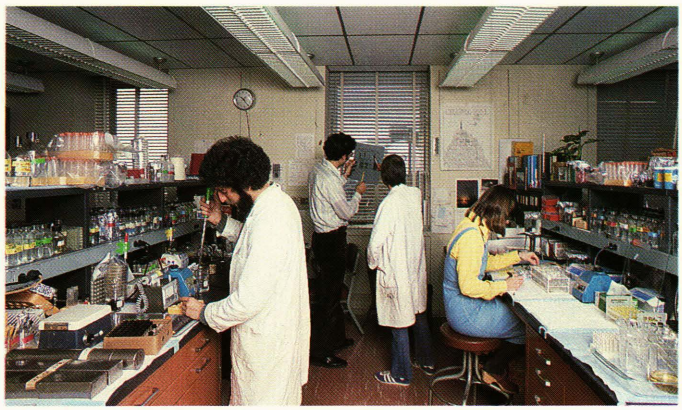
in secret research as a matter of individual choice, but *not* on the campus. Professors can, in other words, serve as consultants on secret or classified projects, but only if the work they did on such a basis was located outside the academic campus and as long as their laboratories and offices on campus remain entirely open. This mode of operation made it possible to achieve some academic linkage between an off-campus secret research project sponsored by a university and the same university's academic departments. By means of joint appointments, an investigator primarily engaged in secret research can come onto the academic campus as a part-time faculty member, at least to teach, but possibly to perform nonclassified research as well; a regular faculty member can leave the academic campus and engage in secret research at the classified project site, serving as a part-time consultant.

CORROSION IN THE GOVERNMENT-UNIVERSITY RESEARCH PARTNERSHIP

In the course of the 1970s, a gradual sea change occurred in the relationship between the federal government and the major research universities—a sea change hard to define both because it took place gradually and because so much on the surface remains the same, but also it was sufficiently severe so that, in effect, it seems to mark the end of an era. A series of circumstances coincided to produce this effect. First, the constant dollar level of federal government appropriation to support university research in science and technology ceased to rise, and on occasion had even fallen, not only from one year to the next but over several years in succession. A form of the cold war continued; the nation's investment in national security remained extremely high; even the countrywide mobilization in the national defense remained a constant of sorts. But as far as the universities were concerned, the context of federal research support changed from growth and renewal to contraction. And this came about in combination with the end of that earlier sustained period of growth in student and faculty numbers. Overall, most of the level of effort reached in the past still continues, but the steady acceleration of support of the previous twenty-five years has halted.

Of greater importance may be the fact that substantial corrosion has appeared in the process of government-university research interaction. This is not surprising in that it is only a natural occurrence when a relationship goes on for so protracted a period, but an understanding of this reality merely explains problems without attenuating them. To a signficant degree, the initial trust and shared common purpose between government and the university community have been substantially dissipated for all sorts of reasons. The unpopularity of the Vietnam War produced sharp differences between government and the majority of the academic community. The sheer volume of federally sponsored research became so great that inevitable problems appeared in the auditing and accountability for so huge and diverse an annual effort. With the enormous growth of the professoriate over a quarter of a century came some dilution in quality. Where, early on, a relatively small elite of faculty members at relatively few institutions had dominated the interaction on the university side, there were now much larger numbers of persons from many more institutions involved, and the quality of peer group evaluation became somewhat arguable in the process. Over time, just enough instances of poor fiscal management and/or questionable performance occurred to corrode some degree of faith and confidence. And, after all, a process dependent on annual appropriations from so highly political a body as Congress could not expect indefinitely to remain miraculously untainted by political consideration. Additional corrosion therefore occurred when, on occasion, Congress began to tie strings and ribbons to federal grants and contracts. Recently, there has also been a tendency—still unchecked—to make some awards on political grounds by simply and blatantly operating outside the regular process of research proposals and peer-group review.

Other considerations entered the picture as well. Quite apart from inflation, the absolute cost of pursuing research has become steadily greater as the technology of research itself became ever more complex.



Industry-sponsored biochemical research

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The scientist doing equations on a blackboard—as fixed symbolically in the public eye by the ineradicable image of Einstein in his study—has been superseded by the research team operating with a vast laboratory array of instruments whose cost and complexity are awesome. And furthermore, the range of science and technology far outstrips even the most all-inclusive definition of national security, and the result is that real argument is now possible as to the priority for research support when weighed against the whole array of other public priorities.

THE INDUSTRY-UNIVERSITY PARTNERSHIP

In the wake of this major revision in the relationship between government as principal sponsor of research in science and technology and major research universities, a still increasing effort developed to establish a new level of direct partnership in research between the university and private industry. No one has ever suggested that private industry should eventually replace the federal government as principal research sponsor; nor has it been assumed that federal research sponsorship would cease. But the assumption that federal research support in constant dollars would at best level off and perhaps also be less comprehensive has led the university to be interested in industrial research sponsorship as a supplement to—not substitute for—federal support. As for industry, the trigger comes in the field of biotechnology and genetic engineering, whose results in many instances have greater promise for commercial rather than national security development. (However, this interest may well be of llimited duration. Recognizing the potential in these fields for the production of pharmaceuticals, foods, and chemicals and, initially, the almost total absence of in-house expertise in industrial laboratories, industry turned to universities and their faculties for knowledge and expertise. As in-house expertise is hired or developed, this dependence on outside university expertise will diminish and may, within a few years, be of only minor importance.) By the beginning of the 1980s, therefore, discussion among representatives of universities and private industry began to be intensive and continuous. A number of large industrial commitments for sponsorship of university research received national publicity, accompanied by a host of smaller scale, less well publicized commitments of great diversity. It appears extremely likely that direct university-industry partnerships in research will continue to proliferate. However, this new linkage has significant limitations and problems. Some have already been widely discussed; others, less so. An interesting and useful way to appraise them may take the route of comparison with the process of research sponsorship by the federal government.

Partnership grows out of mutual interest. And as noted, the foundation of the partnership between government and the universities lay in shared devotion to the national interest—specifically to national security in time of war. The analogous shared concern between industry and the universities appears to revolve substantially around financial gain: most fundamentally, profit for industry, research support for the university. How sound is that analogy? It can be argued well that financial gain represents at least as much of a mutual incentive as partriotism or even that gain can exceed partriotism in intensity. However, it may be more difficult to argue that financial gain as motive can parallel patriotism in serving as the basis for mutual trust. That, in turn, may be particularly relevant to the potential of industry-university relationships because of the dichotomy involved in university participation. As was and is true in the government-university partnership, the operative university partners are the researchers themselves—the principal investigators. In the partnership with government, the basic assumption was not only that everyone within the university shared a common commitment to the national interest, but—especially at the outset—financial gain beyond the mere generation of support for research scarcely was perceived as a factor; the concept of profit did not usually enter into consideration.

In the partnership with industry, however, profit does enter into consideration, either actually or poten-

tially. On the one hand, it would be unfair if a corporation made large profits from an application of university based research and there were no sharing whatever with the university partner. On the other hand, insofar as the university partner is both the individual researcher and the institution, how is profit shared between these two? At first blush one might think that this question is easily answered by drawing on a long history of institutional patent policies that represent both a tradition and experiential base for profit sharing on the part of the industry as well as for profit sharing between principal investigator and university institution. But in practice there is the complexity involved, for example, in stock ownership by professors and/or universities as institutions and in profit sharing by corporations with scientists who serve only as consultants on an individual basis and not as participants in a university sponsored relationship.

It is not relevant at present to explore this and other complex entanglements further; however, it should be noted that a great degree of mutual trust is more apt to develop and be sustained over protracted periods by the generation of common concern based on patriotism than by those based on financial gain. In fact, without excessive cynicism one must note the effort to evolve a common industry-university concern much more analogous to wartime devotion to national security, as at least a complement to the profit motive. The common concern invoked in this view is technology transfer—a phrase that stands for the common humanitarian impulse to strive to make the benefits of applied research available to the public as rapidly and effectively as possible. (This was the impulse governing Professor Frederick Gardner Cottrell when he established Research Corporation as a nonprofit technology transfer agency in 1912.) More recently this concept has also been directly related to the national security—by referring precisely to the discussion of economic innovation with which this chapter began. Patriotism, as well as profit, can be invoked by the argument that the welfare—and security—of the United States depends on sufficient technology transfer directly from university to industry in order to assure not only that discovery results in new benefits to the quality of human life in the best and quickest manner, but also to assure that American industry thereby remains so consistently innovative as to reclaim and retain world leadership.

The profit potential in this context then becomes a desirable but secondary enhancement of a more noble primary goal. And even those who might be reminded—skeptically—of the now famous old assertion that "what's good for General Motors is good for the country" may find it difficult to deny that there is truth in the argument that university research relates positively to innovation in industry. Obviously, however, any argument linking industrially sponsored university research to American national purpose is awkward to justify when the sponsoring corporation is a major multinational enterprise based abroad. And the fact is, of course, that at least a few of the most prominent new linkages between particular industrial corporations and American research universities have involved foreign, rather than American, enterprises.

POTENTIAL HAZARDS

There are other problems that emerge when industry-university research relationships are compared with the government-university research partnership, particularly those relating to the absence of overriding national interest as basic justification. On occasion, for example, industry would like to impose secrecy on research, but for proprietary purposes rather than by reason of national security. Universities, committed (as already indicated) to the inseparability of teaching and research, cannot appropriately accommodate industrial interest in confidentiality any more than government interest in secrecy. Ideally, therefore, confidential industrial research should be carried on by professors only off-campus, in industrial laboratories, just as was and is done with secret government research. But the presence of the profit motive makes the easy parallel more difficult to apply. What happens, for instance, when the principal investigator is also the entrepreneur? What happens when the university as an institution stands to profit through a contractual arrangement or as an investor? Are patents the answer? It is generally assumed (most conveniently) that the time required to obtain a patent is just about as long as that required for the publication of a piece of research. But will this result in an erosion of time-consuming testing because of a rush to publish? And what happens if the research in question involves unpatentable techniques that are best protected as trade secrets?

Questions such as these raise the more fundamental issue of whether the anticipation of financial gain will tend inevitably to draw professors away from the concept of research as pure inquiry toward the goal of research for profit. Earlier, goal oriented research had become something of an issue in the course of the government-university research relationship. Often, however, because the goal was classified, the research took place away from the university in any event. In the case of other goals, such as "the war on cancer," the goal was so broad and humane as to cause no problem.

Financial gain is more suspect, particularly because the university as an institution is as directly involved as the principal investigator. In the case of government sponsored research, it is assumed that the university as an institution has only a minor interest in the substance of any particular piece of research being done as long as it is not secret and as long as the principal investigator who solicited support is appropriately funded and committed. But will university administrators, representing the interests of the university as an institution, remain in such a position of benign indifference when there is a prospect of financial gain for the institution? Will there, in other words, be a tendency by the university to push professors not merely to perform research and obtain support for doing

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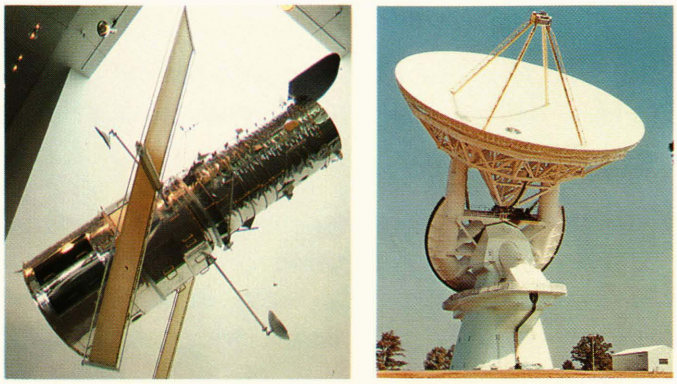
This line of inquiry compels recognition of another relevant difference between the government-university and industry-university relationships. As noted earlier, the essence of the government-university relationship was government sponsorship through a process of open application by principal investigators whose applications were subject to a peer review process. Relationships between industrial corporations and universities increasingly have taken on an entirely different form. First, the diversity of industry and of the professoriate is so great that some sort of brokerage was required to match potential sponsors and investigators; university administrations began to play the role of broker. Second, a marketing approach emerged—a corporation marketing its interest in sponsorship and a university marketing its interest in receiving sponsorship. Third, instead of a nationwide application process and competition by application, corporate research sponsorship with a university tends to be negotiated on a one-on-one basis, and in most cases it contains no form of peer review. Fourth and finally, the result for the universities was a new and highly competitive race for industrial sponsorship in which university administrators were actively marketing the skills of their professors. It is against this background that questions are asked as to whether or not the university as an institution will attempt to impart guidance to principal investigators when the factor of financial gain is present.

FUNDAMENTAL ISSUES FOR INDUSTRY-GOVERNMENT-UNIVERSITY RESEARCH INTERACTIONS

Problems of this kind are significant and awkward, and they continue to be both explored in practice and debated in the abstract. They are, however, dwarfed by two other considerations that may be even more fundamental and as yet have received very little discussion. The first of these derives from further consideration of the enormous cost of research instrumentation in the universities. As noted earlier, the aggregate sum required for adequate instrumentation already appears to be growing beyond even the capacity of the federal government to sustain at public expense. And large as the collective resources of private industry may be, they fall short of the resources available to government; and in fact, no way exists (nor is likely to be found) for a *collective* application of industrial resources to support research in the universities. Even industry-by-industry collective collaboration is hamstrung by antitrust legislation; company-by-company approaches are the rule. At the moment, such approaches appear to be feasible only as long as the application of corporate resources remains a marginal supplement to a much larger volume of support from government. It follows, however, that the significant future decreases in government research support are not likely to be offset by a sufficient increase in support from industrial corporations. Instead of industrial resources rising to balance out shrinking federal allocations, a more likely prospect would be that major reductions in federal support for instrumentation and its installation and maintenance would make university laboratories *less* attractive to corporations because, rather than complementing government support, available corporate resources would become submarginal under these circumstances.

The future requirements of support for instrumentation have practical consequences for the universities, for industry, and for government. For the universities, assuming that the twin pressures of need and practical possibility will, over the long run, impose their own logic, the most likely answer would appear to lie in the type of sharing that has already evolved in the field of high-energy physics. Just as, for example, only a finite number of nuclear accelerators exists and just as these are governed by consortia of institutions so as to provide access to investigators across the entire discipline, so it seems probable that truly large-scale instrumentation resources in other scientific and technical fields will evolve along similar lines. The university or universities in conjunction with which such resources are located will, on the one hand, develop

The future requirements of support for instrumentation will impose their own logic. The most likely answer would appear to lie in the type of sharing that has already evolved in the field of high-energy physics....It seems probable that truly large-scale instrumentation resources in other scientific and technical fields will evolve along similar lines.



Space Telescope (left) and National Radio Observatory (right) operated by the Association of Universities for Research in Astronomy for NASA, and by Associated Universities, Inc., respectively.

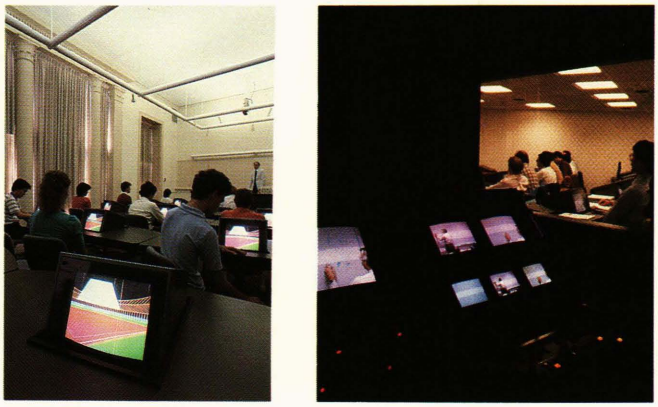
special strength in the relevant particular area of inquiry; on the other hand, colleagues from the rest of the university world will also have access to the facility and its resources.

And, at a different level, universities will need to consider more effective sharing of resources with colleges that operate on the undergraduate level only. The issue in this respect is not research—professors located in colleges will already have access for research purposes to highly advanced instrumentation resources at major research universities—but teaching. The universities draw on the collegiate sector for their graduate and professional students. Universities thus have an interest in preventing the decline of instrumentation in undergraduate colleges to the point where college graduates would be so underprepared in science and technology as to be dysfunctional in graduate and professional schools. As a result, universities will see the need to share the most expensive and sophisticated instrumentation with colleges for teaching purposes. There are new lines of sharing within higher education that as yet have barely begun to appear.

As for private industry, corporations dependent on science and technology have an unavoidable stake in the adequacy of instrumentation and the quality of research in the major research universities. The *essential* linkage between the universities and industrial innovation and vitality consists of people-related as opposed to product-related research. The article of faith within the university community which insists on the inseparability of research and teaching is not merely sacrosanct—it is practical wisdom as well. To the extent that its consequence puts limits on the direct applicability of university research precisely because that research must also serve a teaching mission, those limits are an asset rather than a liability. Both government and industry are inescapably dependent on a flow of talent which the universities produce. To a large degree, the quality of government and industry in the age of technology is determined by the quality of available talent; the stream of the most highly trained, specialized, and scientifically and technologically advanced talent flows out of the university pool.

Industry recognized long ago that innovation in science and technology depended on the creation of industrial laboratories. These laboratories, rather than university laboratories, are the proper and best source of product development. But industrial laboratories are staffed by university graduates. Under ideal circumstances, universities are the source of graduates trained in the methods of inquiry with state-of-the-art instrumentation, who are eligible to be hired by industry for its laboratories. Technology transfer occurs as well informed and highly skilled human talent moves constantly out of teaching laboratories into applied research laboratories. Nor is this a one-way street. New techniques and results from industrial laboratories move over into the teaching laboratories of universities, not only by the maintenance of personal contacts, but also because university scientists already consult sufficiently with industry to stay current with industrial advances in science and technology. Under less than ideal circumstances, universities would lack the resources for the adequate and most up-to-date preparation of graduates in science and technology; the pool of the most highly trained talent would then be not fresh but stale. At the worst, industry would itself have to offer the ultimate in advanced training if industrial laboratories alone were to offer advanced instrumentation no longer available in university laboratories for research and teaching.

If this is the correct perspective, then at least a good deal of the prevailing industrial and public fixation on the *substance* of university research appears to put the accent on the wrong syllable. The most fruitful outcome of the now protracted experience of government sponsorship of university research has been in fact the splendid enhancement of the nation's pool of most highly developed talent, not the research results obtained in any single instance or in aggregate. Clear recognition that universities exist to teach and that the contemporary university must do research in order to teach—not do research for its own sake—provides the best guidance for future courses of action. Such recognition implies that government, industry, and the universities fully share a common purpose: to assure the



TV-audio linkage between classrooms at the JHU campus (left) and APL (right) 17 miles apart.

Clear recognition that universities exist to teach and that the contemporary university must do research in order to teach—not do research for its own sake—provides the best guidance for future courses of action....Industry should move to a more fundamental emphasis on the preservation and enhancement of the teaching mission of the university.

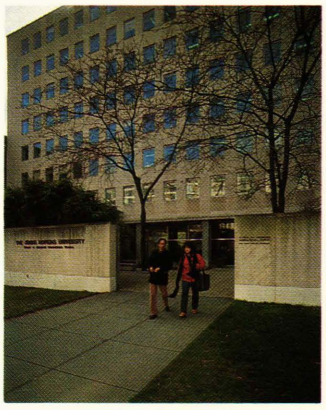
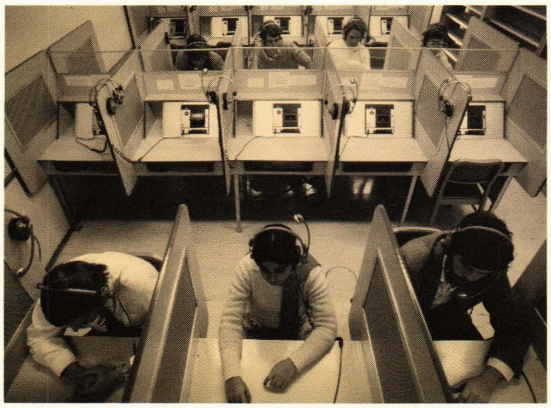
ability of the universities to attract, nurture, and prepare human talent at the most advanced level of science and technology so that the goals of government and industry will not be impeded for lack of human resources. Industry, therefore, should move beyond the current emphasis on the possibility of product development directly from university laboratories to a more fundamental emphasis on the preservation and enhancement of the teaching mission of the university. In practical terms this would mean supportive concern by industry with the continuation of public investment by government in the strength and quality of university research—and hence, teaching—in science and technology and less effort on the part of corporations to leverage the prospect of financial gain for universities into pressure to unhinge university research from the teaching mission so as to move it closer to a more goal oriented character with directly applicable results in view.

The future of innovation in the American economy does indeed depend on the American university. The dependence, however, rests far less on the results of university research per se than on the indispensability of research to the training mission of the university. The university's role in the development of human talent transcends by far the university's role in discovery—or, explicitly, the goal oriented quest for discovery. It follows, then, that the future of both national security and national prosperity depends significantly on a continued investment in university science and technology, supported by both government and industry, with the primary emphasis on the development of human talent.

AMERICAN SHORTCOMINGS: INNOVATION, PRODUCTIVITY, OR MARKETING?

Tempting as it is to end here, some brief concluding observations may be useful on the innovative character of American society in comparison to other national societies. On the one hand, there *is* evidence that the United States has no monopoly among the countries of the world on innovation in science and technology. On the other hand, there is no evidence that to date the United States lacks the ideas or the talent to retain world leadership in the advancement of science and technology, provided that adequate resources are supplied. The record of recent international economic experience shows little evidence that other national economies are more innovative than that of the United States insofar as the substance of science and technology is concerned. What that record does reveal, however, is that other nations have been and remain more innovative and successful in production, manufacture techniques, and international marketing of new products than the United States. Japan, for example, in addition to superior production and quality control, appears to be applying a genius for the identification and exploitation of world markets through a combination of highly innovative and effective product development and marketing far more than striving for original discovery in science. In contrast, American industry continues to draw on original discovery but may be falling behind in international market share. For this there may be several reasons. First, American corporations may be too comfortable with a domestic market of continental size which for decades has been familiar, as well as sufficient to sustain profits and growth. Second, American corporations have relied heavily on foreign employees when selling abroad, not only on the assumption that indigenous citizens of other lands will get the best reception within their domestic markets, but also because American talent familiar in depth with foreign markets is in extremely short supply. Third, there has been a reluctance to invest in new manufacturing facilities and an inability to control quality of product.

The simple fact appears to be that aside from innovation in the manufacturing process, American corporations need to cultivate foreign markets more effectively on a global scale and, in the process, rely more on American talent that knows the area, its culture and history, and, above all, its languages. To the extent that this is true, American universities may have a major contribution to make to national economic


The JHU School for Advanced International Studies (left) and its Language Laboratory (center) in Washington, D.C. The JHU-Nanjing University Center for Chinese and American Studies is at right.

American universities may have a major contribution to make to national economic prosperity through foreign language and area studies.... Their ability to provide human talent familiar in depth with any and all areas of the world may need greater recognition and support in the context of national prosperity.

prosperity, not only through teaching and research in science and technology, but also through foreign language and area studies for far greater numbers of students than have participated in the past. It is not true that worldwide marketing is a new concept for American industry, but it may be true that worldwide marketing falls short when it is executed and supervised by Americans who speak only English and on behalf of products designed primarily for an American market. The major research universities in America are among the most cosmopolitan, least parochial institutions in the country. Their ability to provide human talent familiar in depth with any and all areas of the world may need greater recognition and support in the context of national prosperity within a global economy. The earlier research partnership between government and the universities included language and area study centers and fellowships, long and successfully supported by the National Defense Education Act. It is worth considering whether American industry has a major stake in reviving and supplementing that experience as well.

In summary, then, the power and strength of American industry in a global economy depends both on future innovation *and* the capacity to market the results worldwide. Innovation in this era of science and technology depends on numerous factors—one of which without doubt is human talent of appropriate high quality. The American university has become the proper training ground for such talent by virtue of the effective linkage of scientific research to its traditional teaching mission. Thus, industry and government have a joint stake in university research, less for the sake of applicable results than for its indispensable educational function. And if there is truth in the thought that American industry may be more deficient in marketing than in innovation, the universities have the capacity to contribute to the solution of that problem as well.

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