SUMMARY

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PART I: PERCEPTIONS OF THE NATURE OF BASIC AND APPLIED SCIENCE

It was pointed out in Dr. Stokes' paper and ensuing discussion that we should question the traditional view that pure research and applied research are placed at other ends of a continuum. This one-dimensional view can seriously impair understanding. In fact, it is argued that each of the paired concepts of "basic" and "applied" research is a type in its own right, and neither is the polar opposite of the other. The double dichotomy is represented by jointly defined types by the cells of a four-fold figure shown in Dr. Stokes' chapter.

Quadrant I includes research that seeks pure understanding without a particular problem or a particular social need in

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view; projects for which the term "pure research" would be appropriate.

Quadrant II includes research that seeks to address a need by extending basic scientific understanding to discover how that need can be met.

Quadrant III includes research that seeks a clearly defined goal by developing knowledge that may be of little scientific importance, but will achieve the goal set forth.

Quadrant IV emphasizes the fact that "basic" and "applied" research are logically distinct concepts and that the categories represented by Quadrants I-III are more than an elaborated version of the familiar dichotomy of basic and applied research. This cell, reserved for research that is undertaken neither to advance basic scientific understanding nor to develop knowledge for an applied purpose, is by no means empirically empty. There are cases, for example, where the real motive for launching a research project to solve a social problem was the sponsors' desire to reduce pressure for creating a government program to deal with the problem.

The research community has paid a price for incorporating too simple a view of the relationship between basic and applied science in its organizational arrangements. The complementary misperception, that what is basic is *not* applied and what is applied is *not* basic, has taken a toll. No one with first-hand research university experience can miss the ease with which many faculty, who are engaged in basic research as defined within their disciplines, accept the corollary idea that they are therefore *not* engaged in applied science. Those who accept this view may pay lip service to the possibility that fundamental advances of science will lead later to worthwhile applications. But pursuing these is often seen as a task for others, who may be thought to have a somewhat lower scientific status. How much more satisfactory the relationship of the physics and engineering faculties might be if their research missions were explicitly understood to overlap. (Stokes)

The chapter on perception of basic and applied sciences in Japan by Drs. Abe and Tezuka explains that basic research is carried on in universities, applied research is carried on in national research institutes, and research and development is carried on in the private sector. The tradition to give weight to basic research in Japan was initiated during the last quarter of the 19th century with the establishment of the chair system at the Imperial University. The elite students who received their higher education at the Imperial University became leaders in private companies, in the civil service, or in the universities as professors. The Japanese formulated their system in accordance with the university system of Germany, then the world center of learning.

Therefore, in Japanese universities, up until today, there was a strong tendency to respect basic science, while in Japan's private companies, where the focus of research is geared toward development, the top leaders were conscious of the importance of basic learning. The sectors of research in Japan today are applied research, as well as research and development. The further the research continues, the more the basic aspects are needed. In particular, when high levels of technology are implemented, very often basic research is pursued.

Laboratories in the private sector do not pursue basic research as a primary goal. However, they do produce some basic research achievements as by-products of their research goals. *[This supports Dr. Stokes argument that the distinction between basic and applied research is often artificial.]*

The system of lifelong tenure works positively for research workers in *(Japanese)* company laboratories because the rotation in service provides workers with the mobility and with the opportunity for diversification. In the universities, the lifelong tenure system seems to have a negative effect, because faculty are assigned to narrow, unchangeable duties which are prescribed to their chairs. Theoretically, the mandate attached to the chair binds the chairholder to the same research specialization for life. Although the chair system serves higher education very well, it deprives faculty of the opportunity for mobility and for diversification; it does not encourage the personal development of the chairholder as a researcher.

Consequently, researchers in company laboratories can adjust more easily to changing, current research needs than researchers in university laboratories. Another consequence is difficulty for cooperative research between university and company laboratories. Cooperation is maintained mostly on the basis of personal contacts and through the provision of young researchers from universities to companies. Questions of patents, different levels of research, and different systems of funding have made complete cooperation between private companies and universities impracticable. *(Both the questions of patents and the questions of industry-university cooperation are treated in separate sections of this book.)*

To clarify the distinctions between basic and applied research Dr. Langenberg explains that the word "research" represents a range of human activity that has as its objective the acquisition of new knowledge and understanding. To some, including most scientists and scholars, "new" means new to all humanity, not previously understood by anyone. To others, new means new only to the inquirer; for such persons research may simply mean consulting a reference library. In this chapter *[Dr. Langenberg]* assumes the former definition of research.

A standard tool of human thought is subdivision, classification, and labeling. This is an essential tool, because the ability of the human mind to comprehend complex things is limited. Big problems must usually be attacked one bite-sized chunk at a time. But, like any tool, this one must be used with care and due regard for its limitations. For example, it is common to classify research by field or discipline, e.g., mathematics, physics, biochemistry, oceanography, economics, etc. Such a classification is reflected in the very organization of many institutions concerned with research, such as universities and government agencies. Yet, in practice, we are often forced to recognize the importance of research that does not fit neatly into a disciplinary classification. We then call it interdisciplinary research and seek ad hoc ways to support and perform it, frequently against great impediments created by the disciplinary classification system itself.

Another common way to classify research is as "basic" or "applied." The severe limitations of such an either-or classification, applied to so complex an enterprise as research, are apparent to almost everyone associated with the enterprise. Nevertheless, it has its uses, and is used. It is therefore essential that its users understand its capabilities and disabilities as thoroughly as possible.

The most important point to come from consideration of the several ways one might categorize research is that any classification which yields a single, two-valued parameter (basic or applied) must be incomplete and may be dangerously misleading. There is a fundamental difficulty in attempting to characterize research in this way or even by a continuous but one-dimensional scale with, say, basic on one end and applied on the other. Research is a human activity, a rather personal and individual human activity, moreover, and therefore exhibits all the complexity and multiple varied characteristics one expects of a human activity. To attempt to characterize it simply and starkly as basic and applied is about as accurate as characterizing a human being using nothing but the words big or small. One is reminded of the problem of characterizing a physical event. This at least requires specifying its time and place, and that requires four numbers. One number simply won't do. This line of thought leads one to suggest that some serious consideration be given to the question of how one might devise a multi-parameter scheme for characterizing research. As a management tool it would, depending on one's point of view, suffer from the defect of increased complexity or have the advantage of reduced oversimplification. But if modern managers can understand and practice matrix management, they can surely cope with a matrix classification of research.

PART II: POLICIES OF RESOURCE ALLOCATION IN BASIC AND APPLIED RESEARCH

The subject of Japan's approach to university-industry cooperation was addressed by Drs. Inose, Nishikawa, and Uenohara. They state that: The pattern of the university-industry collaboration in Japan seems to be quite different from that in the United States. In Japanese national universities, which perform a major portion of academic research, no part-time consulting activity has been done for industry as professors are considered to be full-time government employees. In the United States, business ventures are often found which center around universities and which involve university professors and graduate students as active participants. Such agreements are very scarce in Japan. Although there are a number of research contracts between Japanese industries and universities, the amount of funding has been relatively small and has not covered stipends.

There are, however, significant collaborations between Japanese industries and universities. Quite a few industries provide generous support to university research activities by providing computers, instruments, experimental systems, materials, and devices free of charge or at a very low price. For instance, inter-university computer centers for nationwide service, at a price 60 percent to

80 percent lower than the list price. At no cost to the university, electronics manufacturers often provide university professors with exploratory semiconductor devices fabricated in their facilities, or experimental systems built by their plants in accordance with the professor's specifications. At a very low charge to the university, a good amount of software for computer network architecture or data base management has been designed, produced, and tested by industries in collaboration with the universities. Industries allow professors to use their testing facilities for highly-powered machinery, large structures, etc., free of charge.

University professors often join as project leaders, advisors, or investigators on large, government-sponsored projects, such as pattern information processing, large-scale integration, direct steel manufacture by nuclear heat, integrated traffic guidance, optoelectronic instrumentation for production, etc. These projects are carried out mainly by industry. Professors who join such projects are usually permitted to use, free of charge, expensive facilities installed in government research institutions and in industrial laboratories and, after the completion of the projects, some of these facilities are given to the universities.

Dr. Radnor explains in his chapter that: While R & D personnel frequently resist the idea, the extent and the nature of the relation between a government agency's mission and its R & D programs is a legitimate concern of policy-makers. Without sufficient and proper information on this question there is no hope that they can participate in a productive manner in the critical decisions having to do with budget sizes and allocations. They do not (as many R & D personnel sometimes, and wrongly, wish) abdicate these responsibilities to the R & D leadership. Instead, they often make very arbitrary and frequently destructive decisions to change, cut, or even increase overall and individual R & D program budgets. It is to R & Ds interest to improve the quality of the knowledge with which they work in making such decisions.

It is assumed in this type of analysis that a meaningful set of prioritized national goals can be defined for a sector as the criterion base for evaluating the relevance of the R & D programs. We saw that this was not so, especially for those fields where discrepancy was likely and hence the need greatest. This should not have been surprising. Goals are political statements that are changeable, conflicting, often deliberately ambiguous, and inconsistent—especially in highly politicized and immature fields such as education and law enforcement. Different leaders and other influential persons espouse different goals at different times; the goals vary across institutions, government levels, etc. A consensus that produces a clear direction for R & D is rare. Agencies are generally poor at formulating goals and at translating them into program plans. Therefore, the following tends to abound: high-sounding, unprioritized, and meaningless generalities; skillful ex-post facto rationalizations of programs to meet vague goals; and management styles that combine very general direction with detailed interference.

It follows that just because discrepancies are observed in the goals-R & D programs relation, the "blame" should not be laid automatically at R & Ds door. They cannot be expected to follow leadership that is not given. But should R & D wait for leadership or provide its own? What is R & Ds role and responsibility? *These are questions that must be addressed and should concern us all.*

PART III: PRACTICES OF GOVERNMENT FOR BASIC AND APPLIED RESEARCH SUPPORT

In the chapter by Drs. Bartocha and Cziesla, it is pointed out that: one must be conscious of the difficulty in making a sharp distinction between basic and applied research as, quite often, research has basic as well as applied aspects. Statistical data must therefore be used carefully. In this paper use is made of data from the Division of Science Resources Studies of the National Science Foundation (NSF) which are internally consistent. These data provide a basis for analyzing the roles played by different government agencies and performers and how the support for the various fields of science has changed.

The majority of *[U.S.]* federal funding for basic research (about 95%) is provided by six agencies: The Department of Health and Human Resources (HHR), the National Science Foundation (NSF), the Department of Defense (DOD), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the U. S. Department of Agriculture (USDA). The most pronounced change during the last decade is the increased share of funds for the Department of Health and Human Resources, which rose from about 30 percent to more than 37 percent.

Research, particularly basic research, is part of the normal activity of many university science faculty members. The combination of doing research and providing advanced education and training has become an essential part of the United States research system. Almost all basic research conducted in universities and colleges is performed in institutions which grant doctoral degrees.

This effort relies heavily on federal support. Over the last decade, about 70 percent of basic research funds in this sector were provided by the federal government and accounted for about one-half the federal obligations for basic research. The considerable stability in the proportion of federal funds over the last decade is also apparent in the distribution by field of science. Differences, however, can be observed in the rate of growth for particular fields. Environmental sciences and engineering research have enjoyed the most rapid growth whereas social sciences have only moderate growth.

In discussing policies and practices of government support for basic and applied science, Drs. Abe, Inose, Nishikawa, Shimo, and

Tezuka, point out that during the past century, since the Meiji Restoration, the Japanese government has taken the initiative to support basic and applied science. They argue that this has come about because of Japan's recognition of the need to catch-up with the industrialized and advanced nations. They point out that: In 1960, research workers employed by industrial companies numbered 42,000 and their ratio to the total number of researchers country-wide was 36.3 percent; in 1980 researchers numbered 173,200 and the ratio to the total number of researchers country-wide was 47.2 percent.

The number of research workers in universities also increased, but at a slower pace than in the industrial companies. The number grew from 15,800 in 1960 to 31,900 in 1980, but the ratio decreased from 50.6 percent in 1960 to 44.1 percent in 1980.

The number of research workers at national and public research institutions grew from 15,800 in 1960 to 31,900 in 1980, but the ratio decreased from 13.4 percent in 1960 to 8.7 percent in 1980.

Thus the larger groups of scientific research workers in Japan are those of the universities and of the industrial companies. To date, the two groups have been roughly the same size. This balance, however, is starting to shift toward the industrial companies.

A second consideration, looking specifically at university researchers *[in Japan]* is the rapid growth in the number of faculty members in health sciences, the more moderate growth in engineering, agricultural science, and other sciences, and the decline in the humanities and social sciences.

The health field faculty members increased from 13,121 in 1961 to 54,812 in 1980, indicating a growth of 4.1 times in only 20 years. Humanities and social science faculty members remained relatively stagnant while engineering and agricultural faculty members increased steadily from 11,583 in 1961 to 36,355 in 1980, marking growth of 3.14 over 20 years. The increase in science faculty members, at the rate of 3.34 times, was quite comparable.

Furthermore, in view of the triple structure of Japanese universities (national, municipal, and private), the comparatively larger contribution of national universities in science is noteworthy.

National universities have 14.9 percent of science faculty members as opposed to 8.7 percent in all other universities. In the more "policy-oriented" research institutions of the national universities and the research institutes for joint use, the number is even higher: 29.2 percent and 60 percent respectively.

MITI *(Ministry of International Trade and Industry)* has been responsible for supporting much industrial R & D activities. There are two types of government support: 1) Contract, where in principal the government pays the whole cost of the project; and 2) Subsidy, where the government bears, in general, 50 percent of the cost.

Some of the major projects are: Super High-Quality Computer; Desalination of Sea Water; Electric Vehicles; Pattern Recognition Processing System; Flexible Manufacturing System; Opto-Electronic Measurement and Control System; and High-Speed Computer System for Science.

Through the use of subsidies, MITI supported super LSI technology in the form of a four year project ended in 1979. The government spent 29.5 billion yen to subsidize 40 percent of the total cost of the R & D. The project involved five major electronics companies.

MITI also supports a four year project started in 1978 in cooperation with the Boeing Aircraft Company of the United States to develop a new 200 seat passenger airplane. The Japanese government will pay 16 billion yen (50 percent of the total R & D cost) to help the Japanese companies engaged in this project.

Another example of overseas R & D cooperation is the new jet engine program. Since 1980, Japanese companies have been cooperating with Rolls-Royce of the United Kingdom in an eight year project.

In the final chapter of this part, Dr. Schlie examines the theoretical basis for government support of R & D. He explains that: There is a widespread perception that the United States economy is declining and that this is significantly related to a decline in the United States technological performance relative both to our past record and to our current economic competitors. Recent lackluster rates of economic growth, high rates of inflation, and stagnating employment are now part of our national consciousness and have had a substantial impact on the outcome of the 1980 presidential election.

Economic indicators, such as balance of trade, market share, and productivity, provide more specific and worrisome details. In the 1970s, the United States had a trade balance deficit for six of the ten years. A large part of the deficit was due to oil imports, but industrial performance also was not very encouraging. The R & D-intensive trade balance, reflecting traditional United States export strength in technology-based manufactured goods, had been positive and had steadily increased since 1960. However, in 1976 this indicator leveled off and in 1977, the latest year for which data are available, it declined slightly. In three of the six deficit years, there was an overall deficit in manufactured products; in major trade categories, the United States had gone from being a net exporter to a net importer of automobiles, telecommunications apparatus, and inorganic chemicals.

[The present U.S.] administration does not generally accept the notion of market imperfections or failures as they relate to direct federal involvement in the commerical stages of technology development. It is clear that the reliance for international technological competitiveness of United States industry will be placed on the private sector and the free market.

Also, it is clear that the major domestic priorities of this administration will focus on macroeconomic policies that are designed to stimulate United States industry. Major attempts to spur economic growth and decrease inflation are underway—significant federal budget cuts and tax breaks that have been enacted into law—including accelerated depreciation and tax credits for R & D. A major effort is also being made to reduce the federal regulatory burden placed on industry. Micro-policies aimed at assisting or supporting specific industry sectors, in any way, will not be utilized.

On the other hand, the more traditional forms of government support for R & D appear to be accepted, albeit within a general policy of tight budget constraints. In spite of extreme proposals by economist Milton Friedman to the contrary, basic research in the National Science Foundation has not been severely cut back; R & D budgets for defense-related purposes have been greatly increased; in general, commercialization activities on the "D" end of the R & D spectrum and ancillary activities have been reduced or even eliminated, but research has emerged relatively unscathed.

National security may also present acceptable rationale in the future for a further federal role in the technological upgrading of our national industrial base. The only certain reality may be that things will change.

PART IV: COOPERATION OF UNIVERSITIES AND INDUSTRY IN BASIC AND APPLIED SCIENCE

The industry-university cooperation was addressed in this volume in three separate chapters. Drs. Senich and Kaatz point out that: In spite of the important federal support for basic research *[in the United States]*, a number of factors are currently forcing government, industry, and academia to focus on more collaborative efforts. There is a general and increasing concern about technological change *and other societal change factors*. For universities these factors include: diminishing general financial support; increased competition for federal research funds; decreases in enrollment; fewer career opportunities in universities;

outdated university research facilities; and the increasing federal emphasis on accountability for support. Inflation, taxes, and the increase in government regulations has led industry to look for ways to increase their science base without increasing in-house R & D expenses.

One of the oldest and most widely practiced mechanisms for knowledge transfer between university and industry is the consulting relationship. Typically, a company contracts with a university faculty member to provide information or training in a specific area for a short period of time. The extent of corporate funding of such activities varies considerably within and across industries, as does the extent of faculty involvement across disciplines and universities. The rationale for consulting then becomes the enhancement of teaching effectiveness. In some disciplines consulting is important to academic advancement. For example, faculty members in a college or school of architecture are commonly encouraged to do consulting in order to gain pedagogically useful information on current industry practices and procedures.

Faculty consulting is a formally recognized activity and is generally governed by specific regulations. These regulations, however, may be honored more in the breach than in practice. In the establishment of a policy on faculty consulting relationships many factors are considered. Features found common to *[most U.S.]* universities are:

1. consulting without compensation as public service; and
2. consulting with compensation as professional development.

The fundamental problem in achieving industry-university research linkages is meeting industry needs while preserving the spirit of free inquiry by university faculty. Research into the nature of our universe is primarily performed by the university within the context of its purpose. The university provides rewards for basic research by its faculties, since its immediate value to industry is likely to be very small.

University faculty who shift their research interests more toward the "how?" question, in response to industrial needs, do so at the risk of some cost in academic standing. This, then, is a primary barrier to closer United States industry-university research linkages. The *[NSF]* ISTI program serves to address this barrier by experimenting with alternative institutional arrangements through which the results of basic research are more quickly seized upon by industry.

Approaching United States university-industry cooperative projects in the chapter by Drs. Gerstenfeld and Colton, they emphasize that: Universities are major performers of the research that is transformed by industry into technological advances. The flow of information between campus and industry is an important element in both scientific and technological advance.

A variety of experiments have begun during the past several years in the United States to strengthen industry and university relations. These experiments will test the effects of cooperation between universities and industry to stimulate industry R & D activities that show promise of long-term social, educational, and private economic benefits.

Some of the difficulties in achieving university-industry cooperation are discussed and include rewards, orientation toward time, research direction, peer group loyalty, departmental structure, risk, and communication.

Suggestions for achieving successful industry-university programs are presented. University researchers must receive enough release time so that at least fifty percent of their efforts can be directed toward a particular cooperative project. Projects should be guided by small, joint committees consisting of members from the sponsoring firm(s) and from the university. Faculty must be free to publish findings, perhaps with a short review time allowed the firm to assure that no confidential information is divulged. In the case of multi-company sponsors, the project selections are particularly pertinent so that areas of commonality *[must]* be found and a multiplier effect achieved. At the working level, selected faculty and industry counterparts must be able to develop a person-to-person relationship beyond the two institutional commitments.

PART V: PATENT POLICIES FOR GOVERNMENT-SUPPORTED RESEARCH

In the chapter by Dr. Ganz there is a review [of] the issues of United States patent policy as it concerns inventions made under federal government funding of universities and similar non-profit organizations. The starting point *[specifies]* what objectives one is seeking to accomplish through this component of federal patent policy.

The Patent and Trademark Amendments of 1980 that was recently passed establishes uniform federal policies with respect to inventions made by non-profit organizations, universities, and small businesses under government-supported research and development programs. Prior to the passing of this bill, federal government agencies sometimes took title to the patented inventions made under their grants and contracts, whereas in other cases they let the contractor retain any resulting patents and insisted only upon a royalty-free license to use the underlying inventions for governmental purposes. Under this latter "license" policy, the contractor in effect has an exclusive right to the civilian market exploitation of its inventions. Under the "title policy," on the other hand, it lacks such assurance.

The primary objectives of the bill, as repeatedly stated in hearings and other discussions, are to promote industry development and commercialization of inventions made with government support and to promote increased cooperations and collaboration between the non-profit and commercial sectors. Ultimately, it will add to greater productivity in the United States, provide new jobs, create economic growth, foster increased competition, make government research and development contracting more competitive, and stimulate a greater return on the dollars spent each year by the government on its research and development programs.

Patents do make a difference. There now exists a fairly solid knowledge for understanding how patent policy affects industrial firms. With respect to universities, we are in less well-chartered waters.

The process in *most* cases of converting scientific advance into new products and processes is complex and time consuming. Studies of *major* twentieth century innovations indicate that the time interval between its inventions and its commercial use averages between ten to twenty years. We would be overly optimistic to expect the full impacts of this patent reform to produce economic returns in the short run.

Drs. Toyama and Hasegawa explain that the current patent system in Japan is based on the patent law enacted in 1899 and extensively ammended in 1960. This chapter states that ...the basic policy in Japanese Patent Law is that the patent right generated by an inventor should belong to the inventor except in the case of inventions of an employee. Most universities whose research activities are supported by government, particularly in natural science, are national universities. Therefore most researchers who receive government support are government officials.

...research activity of a university professor differs greatly from work done at a research institute of a private corporation. The latter is usually done under directed supervision to achieve the specific goal of the institute, while a university researcher can conduct his research freely. After analyzing the characteristics of a university professor's research work, the conclusion was reached that the patent right to an invention resulting from his research should not be transferred to the government in principle, but that an inventor does have the obligation to transfer that right in special cases *[such as]* when an invention results from applied research that was done with the substantial support of special government funds; and when an invention results from applied research, using government's facilities secured particularly for the implementation of specific research.

Patent policies are discussed in this volume in several different chapters. Mr. Bremer explains that: In general there is agreement in both the *[United States]* government and the private sector that considerations basic to patent policy should be based upon certain fundamental premises. The inventions in scientific and technological fields resulting from work performed under *[U.S.]* government contracts constitute a valuable national resource. The use and practice of these inventions and discoveries should stimulate inventors, meet the needs of the government, recognize the equities of the contractor, and serve the public interest. The public interest, in a dynamic and efficient economy, requires that efforts be made to encourage development and civilian use of these inventions. Both the need for incentives to draw forth private initiatives to this end and the need to promote healthy competition in industry must be weighed in the disposition of patent rights under government contracts. Where exclusive rights are acquired by the contractor, he remains subject to the provisions of the antitrust laws. The public interest is also served by sharing the benefits of government-financed research and development with foreign countries to a degree consistent with our international programs and with the objectives of United States foreign policy. There is growing importance attached to the acquisition of foreign patent rights in furtherance of the interest of United States industry and the government. The prudent administration of government research and development calls for a government-wide policy on the disposition of inventions made under government contracts. The policy must reflect common principles and objectives to an extent consistent with the missions of the respective agencies, and must also recognize the need for flexibility to accommodate special situations.

In a report prepared by the Japanese Science Council from the Ministry of Education, Science and Culture (MESC) the handling of patents for the inventions of university professors is discussed. This chapter tells us that: University professors play a leading role in intellectual creativities; however, there has not been a uniform interpretation and application of provisions for the employee's inventions. Various universities have resorted to different ways. One reason for this lack of uniformity is that there has been the basic question of whether or not university professors' inventions could be handled exactly in the same manner as ordinary employee inventions. It can be said also that university research activities and university professors' inventions have been varied, making it extremely difficult, technically, to handle them uniformly.