A Workshop on the Research Policy of the United States

The Soviet Union openly and repeatedly proclaims that its goal is to become the world leader in all key branches of basic and applied research. China has the same goal. Each of them aims to displace the United States from what one Congressman recently called its "unquestioned world leadership" in scientific and technological research. Both the Soviet Union and China are cheering themselves on in this research race with the Marxist dictum that the capitalist nature of society in the United States will throttle the growth of its science and technology. Although not an official participant in this race, India is developing its own science and technology while closely watching China's, and while being closely watched by Pakistan. West European countries, competitively conscious of each other's science and technology since the early 19th century, and even before, are making statistical comparisons of their continent's overall research potential with that of the United States and of the Soviet bloc. The smaller countries are in intense research competition with each other. Egypt is keeping its eyes firmly on the growth of basic and applied research in Israel—and vice versa. Philippine senators, shocked to see their country ranked 19th scientifically on a list of 21 countries, held nationwide hearings to find what to do about it. Thus, the worldwide research race is on among the large nations and among the small nations, among regions and among blocs united by power or similar political and social philosophies. In every instance the participation in this emulation rests on the belief that the social growth and the very existence of the political entity in question depends essentially on how it develops and uses its basic and applied research, its science and technology. Success in the armament race, the space race, the economic growth race, and in the race toward better or greater societies will be decided in the long run by the success in this research race.

There seems to be much less awareness among the entrants that the future relative distances between the competitors in any given category depends very strongly on how much objective public information each of them produces about their own and their rivals' science, technology, and social change, and on how effectively each acts on this information. From a comparative study of the methods used and the amount produced, and of the quality and the social use made of this information in various countries, one should be able to tell much about their science and technology in the years immediately ahead.

The United Sates is at present an especially interesting case study of this kind, for it is now the largest producer of social science information and conjecture on the interaction of science, technology, and society. During the past 40 years the United States more than any other country, has been continually devising new groups, organizations, and institutions to identify and study key problems in this field and to transform them into national policy problems. It has developed a broad spectrum of workshops in universities, government, industry, and other social institutions, working to assemble, systematize, and transform hunches about outstanding problems and raw information data about them into possible national policy actions. This book, **The Impact of Science on Technology** (Columbia University Press, New York, 1965. 231 pp. $6.75), is the second report made by one of a dozen such research policy workshops, the Seminar on Technology and Social Change, organized by Columbia University in 1962. The book, which is edited by Aaron W. Warner, discusses from a broad variety of points of view the increasingly important, and what some in the United States consider neglected, social problem of the national research policy of the United States: the relation of basic research and civilian technology and the institutional and policy changes required for effective social action on it.

Although the substantive investigation of this problem in the seminar is extremely interesting and illuminating for anyone anywhere who is interested in research policy, the seminar's method of work as a research policy workshop deserves special attention outside the United States. Its organization and method of work, as presented in the book, was along much the same lines as the first one, held in 1963 and reported in *Technology and Social Change*, edited by Eli Ginzberg.

This time informal papers are presented by seven "men of affairs who have had specific but different experience mediating the interaction between science and technology." This specific experience of the seven in either performing or administering basic or applied research, technological innovation, and their research policy and related national policy activities is to some extent described in the papers themselves and in the introduction by Christopher Wright of the Columbia University Council for Atomic Age Studies. The seven include, from academic life, I. I. Rabi, Nobel prize winner in physics from Columbia University and Harvey Brooks, dean of the Harvard University School of Engineering; from government, H. Holloman, assistant secretary of Commerce for Science and Technology and Congressman John Brademas, a member of the Committee on Education and Labor; three are leaders of important research institutions: Alvin Weinberg, director of Oak Ridge National Laboratory, R. Halford, dean of the Graduate School of Columbia University, and F. de Hoffmann, the president of the General Atomic division of the General Dynamic Corporation. I believe that three of the seven are currently members of the President's Science Advisory Committee. It is very difficult for a foreigner to determine whether the seven do represent or do not represent a given school of thought or a current trend in the thinking of the research policy community on the subject of science and civilian technology. Even if we assume that they do represent one such particular point of view—there were, for example, no overt spokesmen for military research—I think that the seminar's method of work tends to consider the problem itself from a very broad approach, for each of the seven papers is followed by an equally

long discussion in the form of more than 200 brief questions and answers, comments and counter-comments (which constitute almost one-half of the book) by an audience of about 60 persons. About one-half of the audience were economists, political scientists, or sociologists, one-fourth were representatives of business enterprises, and one-fourth were government officials or leaders of research establishments and universities. The seven papers and the discussion identify, and in some cases explore, the principal theme of the seminar for institutional and national policy implications. The book concludes with a systematic summation and identification of themes and problems requiring further inquiry or systematic research by the chairman of the seminar, Aaron Warner, professor of economics at Columbia University. Among the numerous reports that I have seen, from various countries on similar seminars, symposia, and conferences dealing with particular aspects of national research policy, this report impresses me as being outstanding by virtue of the method used and the skill displayed in concentrating throughout on the main theme while exploring all the implications and interactions that the theme may have with the total social system of the United States and its goals.

After considering the seminar as a group processing of raw information on problems and ideas on one major research policy problem in the United States, one has to ask how the seminar will contribute to the improvement of information about, and actions on, the relation of science and technology in the United States. Perhaps the most impressive methodological trait of the seminar is that there is a continual striving by all the participants to transform the know-how knowledge, the conjectures and generalizations of practical men of affairs, into a scientific field of endeavor. Every participant in the seminar, including those prone to believe that generalizations about science and its interactions with society are not possible, is continually, on almost every page and line, identifying problems and hypotheses on the interactions of science and society which should be further studied and tested in a systematic way by various branches of the social sciences. The problems raised can and no doubt will supply themes for numerous research projects and Ph.D. degrees. The fact that at this, as in most other such seminars and research policy workshops in the United States, there is always a large and active participation by the social scientists is a strong indication of the general trend in the United States to develop as objective information on the interactions of science and society as the present state of the social sciences permits.

In the United States, in Europe, in the Soviet Union, in India, and elsewhere there is an increasing demand for what Derek Price recently called "The scientific foundations of science policy" [*Nature* **206**, 233 (1965)]. I read the report of the Columbia seminar at the same time that I read the book *The Basic Laws of Development of Natural Sciences* (1963) by the Soviet historian of science, M. M. Karpov, who speaks of the great practical, national policy value of work to discover such "laws." And what struck me in reading the report is that the whole of it was imbued with an objective, critical approach to the problem of science and technology in the United States. Starting with the implicit assumption that war is not imminent and that the development of the civilian technology is a must for the economic and social growth of the United States, the various participants advance the idea, bolstered by a certain amount of factual evidence, that at present "military and space activities in large measure determine the character of advanced technology in the United States." Numerous speakers then advanced the thesis (I must confess that to me it is a new thesis) that the United States is lagging behind some European countries in technological inventiveness and innovation in the civilian field. This thesis is then explored and considered critically in an objective, scientific spirit from various points of view. As a matter of fact, the seminar proceedings read almost as an illustration of what Karpov calls a fundamental law of the development of science, the law of "criticism and struggle of opinions," which he describes in part as follows:

> The struggle of different opinions arises from the very process of scientific knowledge. The differences of opinions between scientists irrevocably arise, first of all, in those branches of knowledge where few facts and data have been accumulated. This brings about the rise of simultaneously existing different hypotheses and theories and to the struggle among them within the bounds of a materialist world view which goes on until sufficient facts are accumulated negating one of them.

In practicing this "law," while studying the important problem of science and technology, the participants of the seminar fulfilled one underlying condition. For, although, as is to be expected and desired, each participant in his contribution showed signs, sometimes explicitly stated, of professional and institutional bias, all participants were to a rare degree free of conscious ideological and political constraints. As the experience of the Soviet Union in some branches of the natural sciences and in the whole of the social sciences still shows, this "law" ceases to be valid if the problems in any branch of knowledge and research, and especially in social phenomena, are considered under direct political and philosophical constraints, such as the "materialist world view." This seminar examined every possible cause and aspect of the thesis that the United States is lagging in technological innovation. Although more factual data on this would have been welcomed, the participants did not beg any problems or questions pertinent to its theme because of ideological, class, or political considerations. This seminar seems to me to be an outstanding illustration of the advantages held by those societies where the study of social problems is independent and free of political and ideological biases and norms.

The proceedings of this seminar, conducted in a freely exploring, academic atmosphere, lead to a wide range of approaches and recommendations for policy actions. Whether the problems raised with respect to science and technology will be transformed into social problems—that is, problems accepted as such by wider sections of the public and then transformed into political problems and policy actions —is a matter of conjecture, especially in a country like the United States. The seminar did make considerable effort to determine the nature of the social forces that must be taken into account in bringing about this transformation. Thus, Holloman points out that, in general, "The limitation to the exploration of space or to the development of weapons is the limitation of our technical and scientific capability. There are few social, political, or economic problems directly involved. In the case of meeting civilian needs, on the other hand, the limitations to the applications of technology involve such things as political factors, social resistance to change, the cost of the social and economic displacement brought

about by the change, the understanding of the people, and the character of the change that has to take place"—and that in particular "the growth and improvement of the private sector of our economy are increasingly limited by non-technical, social factors."

The Chinese and the Soviet writers, even the most objective among the latter when expressing their thoughts publicly, maintain that even when such problems are scientifically analyzed, these nontechnical, social factors in general and the ownership relations in the United States economy in particular will prevent their solution in the interest of the broad sections of the population of the United States, and will thus act to prevent the development of science and its utilization. One can adduce a certain amount of evidence confirming this point of view, even from the proceedings of this seminar—for example, that so far the government has done nothing to influence directly one way or another the research activities of enterprises connected with the civilian needs. But this would give only one, and a smaller, part of the picture. First of all against all such evidence one can accumulate much more of a contrary kind showing that in recent times in the United States the social institutions and relations of production, including the question of definition of "ownership" of means of production, has undergone consistent change in the direction of a wider social approach. Furthermore, the problem of developing civilian technology and innovation is becoming a social problem through the influence and the activities of numerous research policy workshops like this Columbia seminar. Finally there is as much awareness in the United States as there is in the U.S.S.R. of the importance of success in the research race. The national importance of not lagging in this race is a very vital factor causing the leaders of all institutions, including business, to take a realistic appraisal of national problems, including the problem of science and civilian technology. It seems to me that in policy workshops like the Columbia seminar the United States has an extremely powerful weapon for the solution of the problems basic to the research race.

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Communications Systems: Current Research and Reviews

Advances in Communication Systems: Theory and Application. vol. 1. A. V. Balakrishnan, Ed. Academic Press, New York, 1965. x + 316 pp. Illus. $11.50.

This book is the first volume in a new series designed to provide a record of significant current research and critical reviews in the broad field of communication systems. "The emphasis of the series is upon criticism. The purpose of each contributor is to place each new theory in its proper perspective within the overall scientific schema." I feel that there is a need for such a series and that the stated goals are appropriate. However, the first volume is rather uneven, and the goals are only partially attained. The book consists of six independent articles that will be reviewed in the order in which they appear.

A. V. Balakrishnan's "Signal selection theory for space communication channels" (31 pp.) is in two equal parts. The first half, consisting of a general discussion of mathematical models of the Gaussian channel and a description of the signal selection problem, is poorly written. There are misstatements (for example, that the limiting noise due to zero-point fluctuations in optical systems is white Gaussian). There is also considerable undefined notation and imprecisely defined concepts. The second half contains an interesting direct proof of the optimality of the simplex configuration. The paper contains only four references, and no reference is made to many classic works in the field (for example, Shannon's 1959 paper on bounds on communication performance). In no sense are the results placed in "proper perspective within the overall scientific schema."

David Braverman's "Theories of pattern recognition" (23 pp.) is a concise well-written description of the communication theoretic aspects (largely adaptive decision theory) of pattern recognition. It is primarily of an introductory nature indicating the various approaches taken and illustrating these by simple examples.

In contrast to the first two papers, which discuss general theories, R. W. Sanders's "The digilock orthogonal modulation system" (16 pp.) describes an actual system "which has found practical application," but unfortunately none of the applications are mentioned. Neither theoretical results nor performance data are given, and the references are rather inadequate. Although the paper is generally well-written, it is rather compressed, surprisingly so since one purpose of the series is to remove "the space limitations of the journal format."

J. C. Springett's "Telemetry and command techniques for planetary spacecraft" (50 pp.) seems closest to the stated goals of this series. It describes the communication system for the Jet Propulsion Laboratory's planetary probes, with particular emphasis on the use of pseudonoise codes for synchronization. The phase-lock loop receivers are described, a simple theory outlined (references are given to more complete theories), and performance data given. Publication here is welcome because much of the material has been available previously only in the laboratory's reports.

Rudolf A. Stampfl's "Communication from weather satellites" (95 pp.) also describes specific systems (Tiros and Nimbus), but here the emphasis is on the complete satellite system rather than on only the communications. Engineering information is provided, not only on the television and infrared sensing systems and the frequency modulation telemetry, but also on orbits and coverage, attitude sensing, antennas, and system operation and performance.

The final paper, "Information theory of quantum-mechanical channels" (82 pp.) by H. Takahasi, contains considerable new and significant results not previously published. A quantum analysis of a "four-port" in which the input consists of a source and an external system and the output contains a receiver and an absorber is presented. Assuming only linearity between input and output, Takahasi derives (among many things) the probability distribution of the receiver output considering signal and noise input. The results are applied not only to lossy channels but also to ideal amplifiers. This is not easy reading (a quantum mechanics background is assumed and the reader must be prepared for statements such as "the well-known matrix form of the annihilation operator . . .") but may well become essential reading for those interested in theoretical quantum elec-