The Problem of Scientific Surprise

Progress report on efforts to pin down an elusive estimative problem.

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Unforeseen Soviet achievements in science and technology have shown in recent years that means should be found whereby intelligence estimates can better anticipate the results of Soviet research and development, forestalling scientific and technological surprise and providing lead time for our own research and development programs. Precision or certainty in the prediction of Soviet advances can of course not be expected, but it may be possible to develop methods of using the information we do obtain on current Soviet scientific activity to gain some insight into the likelihood of future achievements. In 1957 a series of studies aimed at developing such methods, essentially a search for indicators, trends, and patterns that might make it possible to foresee at least certain kinds of scientific and technological innovations with some measure of accuracy and reliability, was begun.

Three approaches to the problem have been made-one through identification of promising frontier areas and prominent trends in worldwide scientific research; one through the analysis of environmental and sociological factors in past major achievements first of Western science and then of Soviet science; and one through analysis of projected Soviet research programs. The results of these studies to date point to a practical methodology for improving upon estimates of what will and what will not be achieved within the next two decades in many fields of science and technology; but the attempt to find methods for predicting where and by whom discoveries will be made has been much less successful.

The findings of the studies made along these three approaches are given individually below.

Frontier Areas and Trends Worldwide

The best source for identifying promising frontier areas, important objectives, and prominent trends in the world of science is the judgment and speculation of leading scientists themselves. For this study, therefore, authoritative and detailed projections and forecasts by scientists as to trends and future possibilities were collected from world scientific literature in all basic fields. Annual reports and general survey or review articles were found to be richest in such material. The published judgments thus assembled were supplemented with a survey by interview of the views of some 50 scientific leaders in the United States.

The resulting composite of opinion served to identify not only a number of general trends-such as that toward mathematization and theoretical explanation of phenomena in all sciences and that toward interdisciplinary studies-but also the major problems, goals, and speculations in many subfields of the basic physical and biological sciences, subjects such as gravitation, anti-matter, plasmas, computers, non-linear mechanics, chemical theory, fast reactions, climate control, molecular biology, control over heredity and growth, brain function, and environmental research. Many of the ideas that were speculative in 1957 are being realized in research today. It is one thing, however, to state research goals in a field and anticipate advances, quite another to specify when the goals will be reached or by whom the advances made. Although, for example, scientists of all countries are seeking a satisfactory theory of elementary particles and believe a solution not far away, it may be in the United States, in the USSR, or in some other nation that it is first achieved.

Sometimes it may be possible to establish a link between the likelihood of future scientific achievement in general and the prospects for Soviet science in particular when specific Soviet research objectives are known or can be surmised. Plans to build certain kinds of scientific facilities or experimental installations or instruments may both indicate objectives and help define capabilities for reaching them: U.S. scientists can estimate, for example, what can and what cannot be achieved by such-and-such Soviet accelerators. The Soviets anticipated in 1955 that their accelerator research might result in the discovery of the anti-neutron, a discovery which they indeed, as well as the West, were able to announce in 1956. These considerations, however, bring us to our third approach, the study of projected Soviet research programs, which will be discussed later.

A negative outlook for scientific advance, the unlikelihood of achievement, can also, when identified, at least narrow the field for the prognosticator. The

development of an "antigravity machine," for example, is pretty well ruled out on theoretical grounds. As mathematically put by a physicist, "Gravity change has only one sign. This immediately negates the possibility of a shield for gravitation forces." On the other hand, stubborn adherence to questionable theory may itself create a negative outlook for achievement: the long persistence and strong influence of the Lysenko-Michurin theory of genetics has been considered by many Western scientists a sufficient basis for expecting few important results from Soviet genetics. A negative influence is also exerted by the lack of adequate research equipment or personnel-say optical and radio telescopes, electron microscopes, specialized computers, space vehicles, oceanographic ships, theoreticians-and if we have reliable information about these we have a basis for estimating what cannot be achieved by a country. The Soviet lack of digital computers may have retarded work in some secondary fields of research.

Another indicator of the likelihood of important scientific advance is a major data collection effort in a particular field; observational discoveries, new theories, and practical exploitation are likely to follow. For example, the intensive IGY collection program for space data led to our discovery of the Van Allen radiation belt and that for oceanographic data to the Soviet discovery of the Lomonosov range under the Arctic. The extensive Soviet efforts to collect climatological data could bring important advances in the understanding of climate change and its control.

Environmental Factors

The environmental or sociological approach to a methodology for predicting scientific advances began as an academic study of the recent history and sociology of science.[1] Case histories of major advances in four areas of Western science were analyzed in an attempt to identify influences within the research environment that might have been decisive in promoting them. It was concluded that many scientific discoveries have certain characteristics in common: they are likely to result, among other things, from new techniques, instruments, and methods of research, from the interaction and stimulation of other fields of knowledge, and from the concentrated efforts of a group of young but experienced scientists. The sociological circumstances conducive to scientific advance, however, seem to defy complete systematic analysis. Scientific creativity is affected by a number of elusive factors, including the ill-definable "state of the art," social and scientific prejudices and fads, the practical needs of the times, and other motivations, quirks, and intuitions within the mind of the scientist.

A similar study of environmental factors was attempted for Soviet scientific

advances; but so little data was available on the circumstances of specific Soviet discoveries and even on the general Soviet research environment that it was abandoned. The group making this study concluded, on the basis of the existing literature about creativity, that "that which is common among creative men does not appear in personality pattern, media used, products produced or environment provided. . . . There is nothing which lends support to the view that inventions can be predicted." They saw no prospect of foreseeing Soviet scientific discoveries even if information on Soviet research were abundantly available.

Projected Soviet Programs

The environmental approach to a study of Soviet science having thus been abandoned, the empirical relationship between published Soviet directives for research or projected programs otherwise revealed and corresponding announced achievements was explored. In many instances, for example in the development of certain nuclear reactors, accelerators, computers, and satellites, the Soviet intention to score an achievement had been made known in advance; but no systematic correlation between this rather obvious basis for prediction and ensuing successes had ever been attempted. Statements in the Soviet literature about projected research, whether official directives or indirect references, were there fore collected for ten years back in four important fieldspolymer chemistry, nuclear physics, semiconductor physics, and automation-and claimed achievements were checked against the planned program as thus pieced together.

As expected, the main difficulty in this study arose from the fragmentary picture of Soviet research formed by scattered official and semi-official statements about research interests and activities; in many fields these statements are insufficiently precise or complete to permit analysis for predictive purposes. It was not possible to arrive at statistical conclusions, much less validated rules for prediction, but some generalizations could be made. The data strongly suggested that Soviet directives and statements of research intentions and interests are a useful basis for anticipating specific research activities and resulting achievements. In fields in which the Soviets are behind the West and where the trends and objectives of research are clearly evident, the results can be foreseen with some confidence. In frontier areas that are undergoing very rapid and revolutionary change, however, it would be difficult to say much more than that the Soviets are likely to make original discoveries of some kind or other in directions in which they have a capability and have shown a strong interest. There seems to be no reason, at any rate, not to credit or even to discount stated Soviet intentions, at least in the fields covered by this study: Soviet scientific achievements appear to

follow closely their research plans.

Furthermore, there were no significant instances of announced accomplishments which were not preceded by the disclosure of research programs. Because the data for this study cannot be assumed to have been complete, it cannot be asserted that Soviet accomplishments are invariably preceded by the disclosure of projected research; but the weight of evidence in the case studies indicated that it would not be the usual Soviet practice to embark upon a research program without published announcement. The prediction of Soviet advances in science seems therefore to rest most heavily on detailed study of Soviet research programs and statements of intent.

Course for the Future

The development of a predictive capability with respect to Soviet science and technology can best proceed, it then appears, along the following lines:

Continued identification of the most challenging and promising scientific problem areas according to the judgment of leading scientists.

Detailed and systematic reconstruction and evaluation of the Soviet research program, with special attention to changes in direction and effort.

Study of Soviet capabilities and limitations for experimental and theoretical research.

Identification of the most promising Soviet creative scientists, especially young men, and their research interests and special capabilities.

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1 Summarized in R. R. Scidmore's "The Symptoms of Scientific Breakthrough," Studies IV 1, p. 73 ff.

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