soil and the increments to the soil due to fallout; (iv) the chemical composition of the rain water and the soil solution; and (v) the leaching efficiency of various solutions containing cations and anions.

Before the mathematical model can actually be applied to the problem of determining the distribution of strontium with depth at a given place, precise information on these factors is needed. While information on the water surplus at any time or place is relatively easy to obtain from the climatic water balance, and information on fallout is available from those stations at which pot collectors are being operated, and in highly generalized form elsewhere, information on some of the other quantities is not as readily available. For instance, even though soil samples are taken by the Health and Safety Laboratory of the New York Operations Office of the AEC at 17 different places in the United States, these are limited to one sample a year at a site and generally to only two layers (0 to 2 inches and 2 to 9 inches) in the soil. We do not know much about the seasonal or monthly variation in soil concentration of strontium or in its real variation with depth.

Information on the cation-exchange capacity of many different soils is available in the literature, but these data have never been assembled in a map, while information on the variation of cation-exchange capacity with depth is not at all readily available. Detailed information on the chemical composition of rain water and of soil solutions is practically nonexistent.

The future course of this study and its possible practical application will depend on the course of world events in the next several years. If weapon testing should be discontinued, either through international agreement or through unilateral decision, and if no further strontium-90 burden is added to the present stratospheric reservoir, fallout will soon reach very small levels and contamination of the soil will end. The strontium-90 in the soil will then serve as a tracer which will be of unparalleled value in studies of leaching, soil development, and ground-water hydrology.

If weapon testing should be resumed, or if a nuclear war should break out and soils all over the earth should be seriously contaminated, the natural processes of soil purification through leaching would proceed at different rates in different areas. After only a few years some soils would be decontaminated to a point where they would produce food suitable for human consumption. Soils in other areas would remain contaminated for many years and presumably would have to remain under quarantine. New sets of land values would develop, and a wholesale redistribution of any remaining population would occur. As the work begun under this research study continues, it will yield a body of principles which will apply regardless of the direction of future events.

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Science and Foreign Affairs

Recent scientific and technical advances have had a dramatic effect on international relations.

G. B. Kistiakowsky

My theme is the impact of science and technology on foreign policy. Let me try to single out, if I can, what I believe to be the important aspects of this relation between science and world affairs.

I need not devote much space here to demonstrating the proposition that the advances of science gradually, sometimes suddenly, are altering the relations between nations and peoples. Of course, it is the technology which is the carrier of change, but it is basic science, the acquisition of knowledge, that constitutes the seed from which man makes technology grow. The advances of science, in this sense, made our political isolation from the rest of the world impossible after World War II, just as they earlier made economic isolation impossible. In military affairs, perhaps, were visible the most dramatic and fast-moving changes, as technological developments took us from TNT to H-bombs, from artillery to bombers to ballistic missiles, from cavalry patrols to early-warning radar—all changes that tended to shrink the world and increase the mutual dependence and vulnerability of nations. If, for a moment, I may revert to the language of my chemist days, humanity but a century ago was in the condition of a steady-state reaction, whereas now it is in the midst of a non-steady, branching, chain process and science is the chain carrier. Public policy, whether domestic or foreign,

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must recognize this transformation, cope with the problems it generates, and use it as appropriate for the goals of our society.

The need to adjust public policy to changing human conditions, of course, is not new. What is new today is the rapidity with which the developments of science are altering the human conditions, the rapidity with which policy, particularly foreign policy, must adjust to the changes being wrought by the pace of scientific advance. Not only must it adjust; policy must prepare for, must predict, the impact of scientific discovery and must also in some sense attempt to guide it.

I return to this below. Let me explore now some other aspects of the relation of science to foreign affairs that are, I think, unique to our age (at least their importance is unique) and that provide us with our greatest immediate opportunities, and some of our major problems. I am thinking here of several things: (i) the unparalleled and in many ways unexpected political importance to a nation of having the appearance of world scientific leadership (I use the word *appearance* advisedly); (ii) the effect international scientific activities have, and can have, on the relations between states; (iii) the importance of the technical component of some prospective arms-control measures; and (iv) the relation of science to technical aid for less-developed countries. Each of these is worth careful consideration, for they are not always understood and yet they must be understood if the government and the scientific community are to fulfill the obligations and opportunities ahead of us in these areas.

Scientific Leadership

First, that matter of scientific leadership and its political impact. Scientific and technological progress has acquired status as the symbol of strength because of its obvious relation to military power, as well as to productivity and the good life. This is in evidence within our borders and everywhere beyond. The striving to emulate American scientific and technological progress has become an ambitious and urgent goal for countless millions of people, including, I might note, the Soviet Union.

But unfortunately it is the technological spectaculars which the public at large and, often, the press, tend to use as the sole measure of scientific as well as technological prowess, and thus, of military power as well. Achievements in outer-space activities are, of course, the prime example of this. Perhaps a few comments about our space and missile program in this light are in order.

An intercontinental ballistic missile capability is not necessarily dependent on huge rocket booster vehicles capable of sending multi-ton payloads into space. By the general public, in this country and certainly abroad, this is not well understood. The Soviet Union, of course, has not been lax in attempting to confuse the issue. Our development of long-range rockets began late because our military planning was founded on air-breathing engines. To move ahead as rapidly as possible in ballistic missiles, we chose—and wisely I believe—to make our missiles as compact as possible to deliver warheads of adequate yield. We could do this with an ICBM with a thrust only one-half that of the Soviet ICBM's because of our advanced nuclear weapons technology.

In this we have been successful; first the IRBM's and then the Atlas missile were perfected and became operational. But as a result of our planning and preoccupation with smaller missiles adequate to do the military job required, the rocket vehicles we developed did not have sufficient thrust to send spectacular payloads into space. We did not begin work on large rocket boosters until it was too late to match past Russian performance in outer space. But, it is important to remember that the extra-large rockets are not required for our long-range missiles; hence, our deficiency in outer-space payload capability does not indicate an inferior military capability.

Another important fact must be kept in mind. That is that our scientific studies of outer space, accomplished with smaller rocket boosters, have enjoyed unprecedented success. Our scientific achievements in space have easily matched those of the Soviet Union, nothwithstanding the greater publicity given the Soviet technological spectaculars. This, I believe, is generally recognized by the world's scientific community. In addition, we are now making rapid progress toward practical applications in "near-outer space" for the benefit of all nations and peoples.

I do not suggest that we accept a secondary role in future outer-space activities requiring large rocket boosters. We cannot ignore the very real political implications of various spectacular accomplishments in outer space that have come to have symbolic meaning to the world at large. We are indeed moving ahead rapidly to develop boosters for space-exploration missions requiring very large payloads and are vigorously pursuing the man-in-space program. But we must accept the technical reality that, despite a vigorous national effort to develop such boosters, there are limits to the speed with which the gap can be closed, and these limits are largely set by technological factors. Meanwhile there are for us major opportunities to carry out sound and exciting programs in space science and technology that will redound to our national benefit in terms of enhanced prestige and welfare. For example, the development of meteorological satellites could prove to be of great benefit to all nations and could substantially contribute to our scientific and technological stature throughout the world.

To repeat, we cannot accept a secondary role in future outer-space exploration. But true leadership must be seen in the context of far broader efforts. We must be constantly aware that our strength lies in excellence spread over a wide scientific and technological base. It is a feature of an authoritarian form of society that its government can concentrate efforts in narrow fields. If the total strength of such a society is substantial, as is that of the Soviet Union, then what one might term temporary technological superiority can be achieved by that society in selected directions. So long as this superiority is temporary, so long as it does not permit a vital military advantage, and so long as it is not across a broad front, there is no need for alarm, but we must increase our efforts to cancel out imbalances that arise and are significant. On the other hand, we must not permit ourselves to be stampeded into overemphasizing one area at the expense of others. We must constantly bear in mind the sound military doctrine that the enemy should not be engaged on a field of his choosing. Rather, we must continue to move across the entire broad front of scientific and technological advance. Thus, as a nation, we will remain a world leader.

Scientific Activities and Relations between Nations

Let me turn to the second aspect of the relation of science and foreign affairs on my list—the significance of international scientific activities to the relations between nations. Here I think is perhaps the most important of the roles science and scientists can play in today's embittered and divided world—not a new role in the sense that international activities of science are part of the lifeblood of science, but new in its potential impact on political relations.

For science is today one of the few common languages of mankind; it can provide a basis for understanding and communication of ideas between people that is independent of political boundaries and of ideologies. For example, eventually these personal relationships, established with Soviet scientists who form a major portion of Russia's intellectual elite, can provide a bridge between our cultures and assist in bringing about an evolution of the militant aspects of Communist ideology.

Science also provides a sometimes unique opportunity for cooperative endeavors that can contribute in a major way to the reduction of tension between nations and, more positively, to close relations between the United States and other countries—all this, of course, in addition to offering a means of cooperative attack on problems of interest to all nations.

This has been recognized many times before, and I can point to many activities of the government and of private scientific bodies that further these goals: normal international scientific union activity, the IGY, the exchange agreement between the national academies of sciences of the United States and the U.S.S.R., the very recent McCone-Emelyanov agreement, the UN Atoms for Peace conferences, and many, many others. However, the question must be asked whether we are doing enough in this area, and particularly whether the government is sufficiently active in instituting projects of its own, in supporting nongovernmental activities, and in creating and maintaining the necessary conditions for effective international scientific activity. What are some of the issues that face the government in this area?

The most obvious is how to balance the resources for international scientific projects against domestic scientific needs and should the federal government be doing more itself internationally, or should it support private efforts only? In either case, can you justify support for international projects when there are good scientific projects in this country that lack adequate support? A good illustration of this problem is presented by the scientific program in Antarctica. The government had to face the question of setting the level of antarctic activity in the knowledge that supplying funds for that program would detract in some measure from the support of deserving programs within the United States. There are few guidelines for determining the appropriate level of scientific activity in Antarctica, just as there are few guidelines for determining the appropriate level of activity in specific scientific fields.

In fact, the problem of Antarctica is not dissimilar from that of outer space (except that we now have a treaty reserving Antarctica for scientific research). Political considerations are important in setting this program level also. These considerations relate to the stature and scope of our effort relative to that of other countries, particularly the U.S.S.R., and, in the past, in Antarctica, to the relation of research to possible territorial claims. And so, the antarctic program is set as an orderly, sound, scientific effort, but with political awareness that the scope and excellence of the U.S. effort there has more than scientific significance.

The question of appropriate means for carrying out international activities comes up time and again. Can these be handled through the scientific community, in the way the IGY was planned and organized by the ICSU? What is the appropriate role for the UN, for UNESCO, for NATO? Should it be a government-to-government project because of the resources required? And if so, are bilateral or multilateral arrangements to be preferred?

A recent example may be illustrative, if I may be pardoned for referring to space science once again. When the UN Outer Space Committee was established, the suggestion was made that the committee itself should be responsible for conducting outer-space research, or at least for planning research on an international scale. Notwithstanding our strong desire for international cooperation in space, this was thought to be clearly inappropriate. Because of the large resources required to provide boosters for space exploration, it was considered necessary to keep the final decisions regarding space flights in the government's hands. On the other hand, international scientific planning and cooperation was clearly desirable at the scientist level, without the complex governmental machinery of the UN, which would inevitably have to face political issues. Therefore, the UN committee will be concerned with the mutual exchange and distribution of information, the study of legal problems of outer-space, the conference on outer-space exploration, and the general encouragement of space science. The National Aeronautics and Space Administration will make formal agreements with foreign governments for scientific cooperation, but both the UN and NASA will look to the Committee on Space Research of ICSU for the scientific cooperation and planning necessary to bring about effective international scientific collaboration.

The issue of bilateral versus multilateral agreements is one that is also of much interest at the present time, in view of the recent U.S.–U.S.S.R. agreement on peaceful uses of atomic energy. Notwithstanding the very real gains we may achieve through increased contacts with the Soviet Union, we must avoid any series of moves that would create a U.S.–U.S.S.R. scientific axis. Thus, it was carefully stated in the agreement with the U.S.S.R. that any joint projects would be carried out under the aegis of the International Atomic Energy Agency, where all member countries could participate. Clearly, what may be now the finest high-energy physics facility in the world—the European Organization for Nuclear Research (CERN)—should be included in activities under the agreement.

A receptive climate for international scientific activities requires government action too, or in some cases, lack of government action (in a positive sense). Science must not be sacrificed to political expediency, or ignored for political expediency, because this would be like canceling one's life insurance on account of temporary financial straits. We must be ever certain that science is adequately represented in those areas where policy will impinge on science, so that considerations of science will be included in policy formulation. International scientific activity, for example, has moved historically without regard for political boundaries, and this is one of its great strengths. This traditional nature of science must not be negated or forgotten, as it all too often is when restrictions are placed on the free movement of individuals among nations. Nothing will erode our basic traditions and our scientific leadership, and our influence, more quickly than a tendency to sacrifice basic long-term beliefs for short-term political considerations.

Moreover, the needs of science must

be adequately represented in international as well as domestic policy formulation. Radioastronomy recently almost came to an untimely end, simply through the negotiation of an international treaty on frequency allocations without adequate recognition of the needs of this young science for listening "windows." Through the good offices of the National Academy of Sciences it was possible to bring scientists and the appropriate government officials together, in time to establish a U.S. position for the Geneva International Telecommunications Union conference compatible with the needs of the radioastronomers.

International scientific activities thus carry with them many problems for government, but their benefits far exceed those problems. To achieve the benefits, however, requires that we be alert to the opportunities and that we be prepared to make some of the necessary policy decisions and commitments of resources.

Technical Components of Arms-Control Measures

I mentioned above, as a third new element in the relation of science to foreign policy, the importance of the technical components of prospective arms-control measures.

The negotiations on nuclear-test cessation have shown the importance of scientific and technological factors in the formulation of national policy in this area. These factors had to be evaluated by *ad hoc* groups that found a dearth of experimental data on which to base their conclusions. A similar *ad hoc* approach had to be employed regarding certain phases of the conference on the problem of reducing dangers of surprise attack, in which I participated more than a year ago. The *ad hoc* approach is not very satisfactory but the fact that scientific advice and evaluation were used in both these attempts to reduce military tensions is, in itself, important. It is a sign of the changing attitude and of the growing awareness on the part of policy makers that technical considerations and knowledge are essential for the formulation of sound concepts for arms-limitation measures, just as they are in formulating development plans for military hardware.

The success of future negotiations to relieve tensions by arms-limitation agreements will depend in some measure on understanding of the capabilities of proposed multilateral monitoring systems and on understanding of the inherent limitations of any monitoring system in a world of rapidly advancing technology. The limitations of technical analysis need also to be fully understood. There is no doubt, for instance, that the reliability of monitoring systems is largely a technical question. But the adequacy of such systems, from the point of view of national security, is not. It is a politico-military question. Similarly, deterrence is not a scientific concept but a politico-military one. And we must realize that political issues or disagreements cannot be resolved by technical agreement on facts; the political questions of national interest remain. I think these issues should be understood by the public as they are being understood by the policy makers. Especially we, as scientists, must understand that we can make but one of several contributions that are essential for the formulation of sound national policy.

Science and Technical Aid

I come now to the fourth, and last, of my list of "new" relations between science and foreign policy, which I called the relation of science to technical aid for less-developed countries.

The foreign aid programs supported by the United States are powered by a matrix of motivations made up of altruism, a belief that it is to our best interest to strengthen independent nations, and a desire to contain menacing philosophies. Motivation notwithstanding, it is evident that any program, any experiment, will fall short of success unless it is soundly conceived, soundly planned, and soundly executed.

In helping to achieve a sound aid program, we, as scientists, must not think in terms of developing only the more advanced scientific capability of other nations, which is often a reflection of our own standards and comfortable abundance. We must try to strike a balance between basic needs and sophisticated development. This requires an appreciation of the way in which science and engineering develop within a nation. In many lands the history of science has not been written beyond the prologue. We must, for instance, be aware of the long-term relation between primary and secondary school education and advanced research institutions.

We do little good by providing only for esoteric research facilities when a nation lacks roads, general practitioners, and machine operators. Of course, we do a disservice also when we ignore the advanced educational institutions that set a nation's standards, provide its teachers, offer a future for gifted citizens, and bring prestige to a nation or a region.

I would like to digress a moment to commend to your attention a recent report prepared by the National Academy of Sciences–National Research Council for the International Cooperation Administration, entitled "Recommendations for Strengthening Science and Technology in Selected Areas South of the Sahara." Our committee stimulated the undertaking of this important study, to be viewed as an experiment. It is an outline of the way in which assistance of a technological type should be designed to be properly utilized. It is an intelligent and realistic attempt to strike the necessary balance between basic needs and sophisticated wants, within a framework of limited resources, from within and without an area. It is also an attempt—a very successful one I believe—to show how a scientific approach can be used in the early planning stages of aid programs.

The reading of the report will have a sobering and disturbing, if not a frightening, effect on thinking individuals. It treats of selected areas of sub-Saharan Africa, of a land mass equal to that of the United States with a population one-half that of our nation —and this is only part of sub-Saharan Africa. It is an area which, within our lifetimes, will be transformed into a multiplicity of independent nations which, collectively, will greatly influence world affairs. Particularly disturbing in this study are the revelations of extreme shortages that still exist in this region—the nearly complete lack of public health measures and medical services, of communications and transportation, of the means for earning an income, of even the most elementary education facilities. Clearly, these embryonic nations need educated people in large numbers to provide not only civil servants but an understanding electorate to carry them along the path to democracy. But how can the needs for higher education, for doctors, for engineers, for political scientists, for so many other specialists be properly balanced against the need to provide even the most primitive health measures, to provide teachers for the many millions of illiterates, and to train the artisans and skilled laborers without whom the standard of living cannot rise? Against these multiple desperate needs, indigenous efforts, our aid, and the aid of others appear so utterly inadequate that one becomes fearful lest decades will pass before the level of education and the standard of living will rise enough to make democracy viable. The question then comes to mind: Will the awakening of latent desires allow democracy the time it needs to develop—a need inherent in its evolutionary nature—or will this region fall prey to the legerdemain appeal of revolutionary authoritarianism, especially Communist ideology?

For a research scientist this report will have a sobering influence: it will point out to him that he is a luxury that can, and must, be afforded by an advanced nation like ours, whereas in Africa south of the Sahara, a nurse, an elementary school teacher, a technician—these are the luxuries.

Science impinges on aid to technologically more advanced nations also. Various government departments have for many years supported research overseas. By and large, these programs have been well run. Such programs raise some serious issues for consideration, however, for outside support of science in a given country affects the relationships between that government and its citizens and universities. Some programs, even those in support of basic research, are welcomed by many foreign scientists, yet seem an affront to others. We must, therefore, consider the effects of such programs on all who are concerned, and especially on the natural growth of the scientific communities in the recipient countries. Does such support, for instance, actually retard the development of a healthy relation between science and government in other countries? What commitments are we making for continuity of support once foreign scientists have become dependent on U.S. support—commitments from which it may be impossible to withdraw or which may cause hardship should withdrawal be necessary? What is the effect of our support on the pattern of research in a given country? And is the manner in which our support is given in this area best calculated to further good relations between the scientific communities of other countries and the United States?

We are not the only ones who are aware of these problems. In its most recent annual report, the United Kingdom's Advisory Council on Scientific Policy, addressing itself to just these questions, had this to say about U.S. research support: "Whilst we warmly welcome this substantial financial support for research in this country, we recognize that research grants, and particularly specific contracts, of this magnitude (one and a quarter million pounds annually) must have a considerable influence on the general pattern of research undertaken. We, therefore, consider it desirable that the various bodies concerned with the financing of research in our universities and other institutions should be aware both of the extent and the purpose of these numerous United States research grants and contracts. We are glad to be able to record that the United States authorities have fully appreciated the position and have shown themselves ready to cooperate with us . . ."

Of course, there are no general answers to most of the specific questions raised, for they vary with the country concerned and with the manner in which our support is given in each country. But these questions need to be asked—and answered—before support is provided. These programs cannot be operated independently of foreign policy considerations.

The Scientist's Role

I have attempted here to outline some of the ways science can contribute to foreign policy, and the effect of policy considerations on science. But to integrate the scientific with the political, economic, military, and other factors that make up foreign policy operations requires, above all, competent people who understand the relationship of science to these other factors.

If we appreciate our responsibilities, we, as scientists, may well have an important role to play in the future in the policy-making process. I think it will be a role different from the one to which we have become accustomed. I think it will demand a new breed of public servant, although I am at a loss to find the appropriate name for him. The term *political scientist* has been pre-empted for a use very different from what I have in mind. I am sure that none of us would want to be called "scientific politicians," and few indeed would dare to lay claim to "scientific statesman." But there is a significance here that is far more important than finding the right name. The role I foresee demands that this new breed of citizen-scientist shall be continually aware that the scientific community must accept its appropriate share of the responsibility for the intelligent and successful resolution of the challenges facing the world.

Another kind of individual must be recruited, too—an individual with training in science in addition to the usual disciplines of the foreign service. The general presumption is that science is so specialized that the only way to provide scientific contributions to policy formulation is to obtain advice from practicing scientists on an *ad hoc* basis as needed. I submit that as valuable as such advice is, it does not fill today's requirements for a continuing and intimate involvement in the policy-making process of competent people who also understand science and its significance to policy, and who could therefore work effectively with the practicing scientists supplying the specialized *ad hoc* studies.

Perhaps science and engineering graduates should be attracted for regular careers in the foreign service and in our other overseas programs. I believe we must also provide a better scientific background for nonscientists in the international affairs field, and that this, perhaps, is the most important measure of all. Essential to these efforts is the development of an academic field of teaching and research in the interrelationship of science and foreign affairs, in order to provide education in and better understanding of the underlying significance and opportunities of this relationship.

These are not easy tasks or tasks that can be accomplished overnight. We cannot push a button and mass-produce diplomats in striped pants and laboratory coats, in the way that we produce toasters, automobiles, and television sets.

In discussing international relations, the American historian Julius Pratt states: "Neither the tools of diplomacy nor the tools of force can be suddenly improvised for use in crisis. They must be kept in a state of readiness for use. The success of a nation's foreign policy will depend, in part, upon the efficiency and the readiness of the instruments with which that policy is pursued." We, as scientists, must do all we can to help keep the tools of our diplomacy and the tools of our force in efficient readiness.

We have entered a new era, an era of scientific revolution, as C. P. Snow terms it, in which science and technology are transforming our way of life and the relations between nations. As practicing scientists, we cannot stand aside and simply watch this process, regardless of where it takes us; we must and we can use science and technology to achieve the humanistic goals of our free society. Let us learn to take greater advantage of the opportunities science offers us to contribute to the striving for peace in international relations and to improve the lot of man throughout the world.

Preparation of High School Science Teachers

The AAAS Cooperative Committee on the Teaching of Science and Mathematics recommends the adoption of certification standards.

The concern for better preparation of teachers in the field of science and mathematics (hereafter referred to in this report as the sciences) has been growing during the last several years. Very recently this concern has been intensified considerably as the result of new developments both nationally and internationally. A statement was made by the Cooperative Committee of the AAAS in 1946 with reference to recommended minima for the preparation of science teachers in content material (*1*). In that same report a general statement was given with reference to the breadth of preparation that was to be desired (*2*).

The members of the Cooperative Committee are J. W. Buchta, American Institute of Physics, chairman; Wayne Taylor, Academy Conference of the AAAS, vice-chairman; Bernard B. Watson, Operations Research Office, Johns Hopkins University, Bethesda, Md., secretary; Leonard Olsen, American Association of Physics Teachers; Thornton L. Page, American Astronomical Society; C. L. Agre, American Chemical Society; Theodore Woodward, American Geological Institute; Richard L. Weaver, American Nature Study Society; John W. Cell, American Society for Engineering Education; Arthur L. Howland, Association of Geology Teachers; Alfred B. Garrett, Board of Directors of the AAAS; Fred H. Norris, Botanical Society of America; John R. Mayor, director of education, AAAS; Harry F. Lewis, Division of Chemical Education, American Chemical Society; W. E. Restemeyer, Engineers Joint Council; Phillip S. Jones, Mathematical Association of America; Brother G. Nicholas, National Association of Biology Teachers; George G. Mallinson, National Association for Research in Science Teaching; Bruce Meserve, National Council of Teachers of Mathematics; Robert T. Lagemann, National Science Teachers Association; and Harold E. Wise, Section Q (Education) of the AAAS.

This report contains minor revisions of the subcommittee report which was published in April 1959 in *School Science and Mathematics*. Many of the suggestions that were gathered as the result of the wide distribution of the original report have been incorporated in this final report. The major change involves an increase in the number of hours in the area of earth science (now referred to as "related science").

Purpose

It seems that it is now time (i) to re-examine our original statements, (ii) to take cognizance of the impact of those events that have transpired in the last ten years on the requirements for the preparation of science teachers, and (iii) to make additional recommendations which result from the demands of the changing circumstances.

It is well recognized that changes in state certification laws may not always be made quickly. It is our hope, however, that this information and these recommendations, even though not immediately written into certification codes, will be studied by college and university departments of education, teachers colleges, state departments of education, certification bureaus and accrediting agencies, school administrators who select science teachers, colleagues in subject matter areas, and finally by those students and teachers who are preparing to do a more effective job in teaching science in our secondary schools.

New Developments To Be Considered

Several important factors have influenced the type of recommendation we now make on the course content that prospective teachers should have.

1) *The rapid changes that have occurred in a number of the sciences in the last decade.* Astronomy, biology, chemistry, geology, mathematics, meteorology, and physics have all advanced considerably in the last ten years. Word of new advances spreads by newspapers, magazines, public lectures, and television. This stimulates the curiosity of students who then seek answers to many questions. Teachers must be prepared to stimulate further the interest in such questions, to provide sound answers for them, and to direct effective reading at the level of the student's background. The course work taken by the teachers should prepare them to keep abreast of the new developments which are often highly complex, to answer questions about them, and to direct discussion of them.

2) *College entrance with advanced standing* (*3*). A concerted move was made (beginning in 1954) by a number of the colleges and universities of this country to work with secondary schools in developing college-level courses for their most able students. In the resulting program, for example, mathematics starting in the 10th grade leads to calculus in the 12th. In chemistry, the time-equivalent of at least three semesters permits instruction at the college level, with college texts. Thus students qualify for sophomore courses on college entrance, thereby reducing duplication. In physics similar programs have been available, but unless calculus is also taken, the policy has been to recommend advanced mathematics instead of advanced physics, thus making it possible for the student to start his sophomore physics (using calculus) during his freshman year in college. Similar programs have been in effect in biology, English, languages, and history. This program, expressing confidence in our secondary schools, places