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SCIENCE EDUCATION
in the
SPACE AGE

PROCEEDINGS

A National Conference held in Los Angeles, June 1–4, 1964, for State Department of Education Science Supervisors and members of the Subcommittee on Institutes and Conferences of the American Association for the Advancement of Science Cooperative Committee on the Teaching of Science and Mathematics.

Sponsored by the
National Aeronautics and Space Administration
in cooperation with the
U.S. Office of Education
Department of Health, Education, and Welfare

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FOREWORD

This is a compilation of the speeches and reports of a national conference on science education as it relates to developments in the space sciences, held in Los Angeles, June 1–5, 1964.

The Conference was conducted under the sponsorship of the National Aeronautics and Space Administration in cooperation with the U.S. Office of Education. Its program was planned by a committee representative of the Council of State Science Supervisors, the Subcommittee on Institutes and Conferences of the American Association for the Advancement of Science Cooperative Committee on the Teaching of Science and Mathematics, the U.S. Office of Education, and the National Aeronautics and Space Administration's Headquarters and Western Operations Office. The NASA Western Operations Office served as host and was in charge of conference arrangements.

The purposes of the Conference may be summarized as follows:

> To provide State Science Supervisors, scientists of the Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics, and the science education staff members of the U.S. Office of Education opportunities to learn more about NASA's scientific objectives and programs and educational services.
>
> To provide NASA's headquarters, field installations, and Spacemobile educational personnel an opportunity to gain insights into what actions educators participating in the Conference feel that NASA can appropriately undertake in bringing space science information and understanding to the schools.
>
> To provide all Conference participants an opportunity to establish person-to-person relations in order to facilitate mutual assistance in space science education, and to gain through mutual discussion greater understanding of emerging science education problems.

The papers and reports of these proceedings are arranged in the order of their listing on the Conference program. Their compilation was the responsibility of Frederick B. Tuttle, Deputy Director, Educational Programs Division, Educational Programs and Services Office, NASA.

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OPENING REMARKS

James V. Bernardo *Director*
Educational Programs and Services Office
NASA Headquarters, Washington, D.C.

Good morning!

At the outset, may I extend to you the best wishes of the NASA Administrator, Mr. James E. Webb, and also the greetings of Mr. Julian Scheer, his Assistant for Public Affairs. I am honored and pleased to preside at this opening session of our Conference.

The Industrial Revolution, which began with the advent of Watt's steam engine, has been the dominant economic and social force for about 200 years. It is now being challenged by another force, one which has been characterized as the Third Revolution—the Knowledge Revolution.

George W. James, an economist at the Battelle Institute, suggests the hypothesis that in recent years we have shifted from a society based on natural resources to one based on human resources. This is an interesting theory, and may be worth examining further.

New business is constantly being sought, not chiefly through volume-production improvements but through technological breakthroughs. This transition involves an emphasis shift from natural resources to ideas, from factories to universities.

I'd like to cite some statements which strengthen this theory. They appeared in the April 1964 issue of *News Front*, the management news magazine:

1. Education now generates at least one-fifth of the U.S. growth rate.
2. The "knowledge industry" accounts for nearly one-third of the entire economy, and is growing twice as fast.
3. U.S. business spends $17 billion yearly to educate its personnel, or one-third as much as is spent on the nation's public and private school system.
4. More than one-fourth of the nation is engaged in education (51 million students and 2 million teachers).
5. Investment in education has increased the output of the economy, and the income of those educated is equal to a return on the investment of about 10 percent, according to the Chase National Bank.

Dr. Clark Kerr, president of the University of California, has stated that we are just now perceiving that knowledge may be the most powerful single element in our culture. He has pointed out that science-based industries sprouting up around a university campus form the nucleus of a new kind of city—the "ideopolis" or "city of the intellect."

It is generally agreed that the rapid advances of science and technology have posed serious educational problems. They have induced changes at a tremendous rate, and it is this almost incredible rate of change that is becoming a dominant fact of our time. One of the powerful and dynamic forces which has caused much of this acceleration is the exploration of space. Man's accomplishments in space have unlocked the human imagination; they have increased man's spirit of adventure and pioneering; and they have presented him with one of the greatest challenges of all time—the break away from the confines of his own planet.

The remarkable revolution of knowledge has not been limited to science, for the need to strengthen the humanities and arts at every level has been recognized, and curricular reforms are tending to bring them ever closer—and this is a good sign.

Most important is the necessity for a strong and unrelenting pursuit of excellence in our educational programs. My colleagues and I feel that space science and technology, coupled with consideration of their social and economic impacts, provide an excellent catalyst. There can be little excellence if there is no interest and desire. Space information, responsive to a natural interest and enthusiasm of our young people, provides considerable motivation, considerable stimulation, to achieve high standards in the substantive areas.

President Johnson, on November 14, 1963, said: "Today the full complex of our society—business, labor, education, and government—are working together in a resolute and determined commitment to realize the potential of the space frontier."

During this conference, I am sure that we will see, again and again, the sure signs that, as a nation, we are on course, pushing ahead to explore the universe, with unprecedented teamwork and unison of effort by labor, management, education, and government.

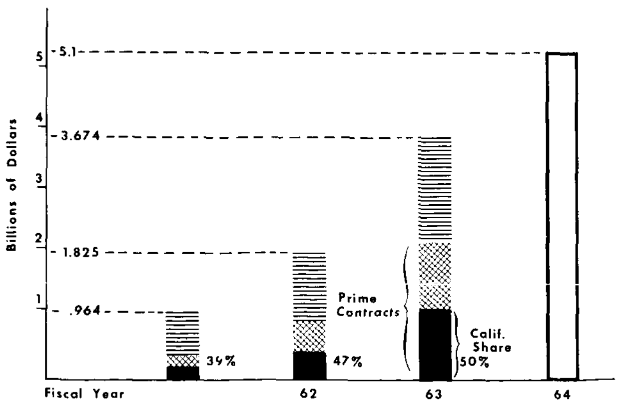
GREETINGS FROM THE NASA WESTERN OPERATIONS OFFICE

Robert W. Kamm *Director*
NASA Western Operations Office
Santa Monica, Calif.

I'd like to welcome you from several points of view:

First of all, welcome to the State which is now first in population in the United States. Anyone from New York here? Welcome to the State which has the greatest concentration of aerospace industrial capability, both large and small, of any in the United States. Welcome to the State which has the greatest percentage of defense spending of any in the United States. And welcome to the State which has 50 percent of NASA's business. And also welcome to the State which takes great pride in its educational installations and systems, and which we feel rates second to none in its great colleges and universities.

The last two reasons, of course, are why we are having this joint conference here in California this week, and is also why our Western Operations Office, and our Educational Programs activities, are here. During this week you will have the opportunity to see what some of our major contractors are doing. I'd like to give you just a few statistics to show you what California is doing for NASA:



CALIFORNIA'S SHARE OF NASA'S PRIME CONTRACTS-VALUE OF AWARDS

Fig. 1

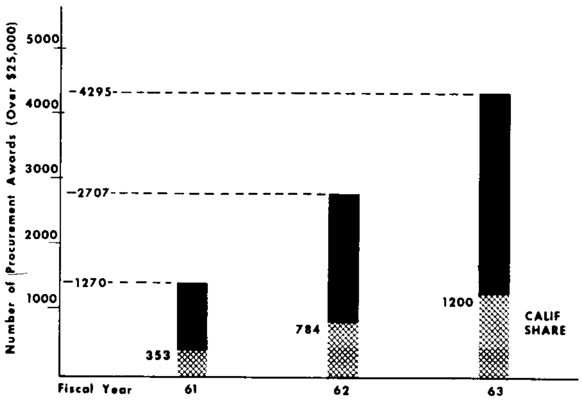
This slide (fig. 1) shows California's share of NASA's prime contractors in the past few years. The budget has grown from just under a billion dollars in fiscal year 1961, to 5.1 billion for this fiscal year. NASA's prime contracts to business as shown represent about two-thirds of the total budget. The lined areas at the top of the bar chart include NASA's administrative operations costs, including payroll; and also substantial awards made to other governmental agencies, such as Corps of Engineers for site construction, and the Air Force for boosters. The budget for the operation of the Jet Propulsion Laboratory is also included. That's about $200 million for this fiscal year. Obviously a substantial portion of these dollars are also spent in California.

Solid areas at the bottom of the chart represent the dollars awarded in NASA prime contracts to California firms. These range from 39 to 50 percent of the total dollars awarded to prime contractors. Statistics to date for fiscal 1964 show that these figures are running at about the same 50 percent level as for fiscal 1963.

California also has a dominant role in subcontracts. For example, 12 of NASA's major contractors and their first- and second-tier subcontractors reported that California received 45 percent of their subcontract dollars during the first 6 months of 1963.

An indication of the number of separate contracts and, therefore, roughly the number of contractors involved, is given on the next slide (fig. 2). Total NASA procurement actions were 1,270, 2707 and 4295 for fiscal years 1961, 1962, and 1963. California received 353 awards in fiscal 1961, 784 in 1962, and 1,200 in fiscal 1963. And here again the data do not include contracts placed for NASA by other government agencies, nor subcontracts placed by the Jet Propulsion Laboratory. Also, awards under $25,000 were excluded.

These figures show why NASA is so interested in the State of California. We have, as I am sure you know, two of our major centers in California: the Ames Research Center just south of San Francisco, and the Flight Research Center at Edwards Air Force Base—about 100 miles away from here.



CALIFORNIA'S SHARE OF NASA'S PROCUREMENT AWARDS

Fig. 2

Our Western Operations Office is here to represent Headquarters in this area, and also to provide on-the-spot representation for our centers and program offices in working with these hundreds of NASA contractors. To do this, we have a diversified staff of technical experts, of contract managers, of financial experts. We are paying to the local contractors through our office about $150 million per month—that's *per month.* We have lawyers and patent attorneys, public information specialists, and all the others required to deal with contractors.

In the educational programs field we work as an extension of our Headquarters' Office of Educational Programs. Art Costa, the head of our office, has worked hard in lining up this agenda, and I sincerely hope that the various sessions and the field trips are going to help all of us here get a better insight into the problems and a better means of handling the big challenge before us: the proper orientation of "Space Science Education."

THE NASA MISSION

Donald R. Mulholland *Deputy Director*
NASA Western Operations Office
Santa Monica, Calif.

I would like to add my welcome to you in behalf of NASA here on the west coast; and I hope that the week you spend here discussing and examining some of the fruits of the space program as it has progressed to this point in time will be a pleasant experience.

Since most of you are primarily associated with educational activities, I assume that you might first benefit from some background history of NASA. It is not unusual to find that many people do not well understand our history. For example, it is not generally recognized that the organization which manages our space program had its real beginning in 1916.

President Wilson and his Cabinet concluded that the airplane was likely to become an important part of this country's military and commercial fabric, and that the endeavor would be of such magnitude that the Government should undertake basic research in the fields of aerodynamic structures and propulsion to meet the need. Thus, the Congress in 1916 established the National Advisory Committee for Aeronautics—NACA; and over the years, fine NACA Research Centers were built up at Langley Field, Va.; Cleveland, Ohio; and at Moffett Field and Edwards, Calif.

Forty-one years later—in 1957, the space age was born with the launching of the first sputnik. It seemed unbelievable that an object was actually racing around our world—an artifical moon.

In November of that year President Eisenhower, like President Wilson, took action to organize this country's resources to meet this new challenge: a challenge which again would obviously have a gross effect on the future of the whole world—and perhaps other "worlds" as well.

President Eisenhower created a Scientific Advisory Committee headed by Dr. James R. Killian, president of MIT. This committee of specialists sought to determine our national objectives and requirements for the exploration of space. It sought also to recommend a basic framework in which the role of science and technology would provide assured long-term success in this new area of obvious importance.

After extensive study, the Killian Committee submitted its report to President Eisenhower in March of 1958, recommending the creation of a special agency to conduct an aggressive civilian-oriented space program. This was endorsed by the President and submitted to Congress on April 2, 1958; and in July of that year Congress enacted the Space Act, creating the National Aeronautics and Space Administration—NASA.

NASA pursued its assigned objectives under the direction of Dr. T. Keith Glennan, president of Case Institute of Technology, who was named its first Administrator; and Dr. Hugh L. Dryden, formerly Director of NACA, who was appointed as Deputy Administrator. The old National Advisory Committee for Aeronautics formed the nucleus of the new organization, with a transfer of its more than 8,000 personnel along with its research laboratories. This seemed to be the most logical first step in organizing such a vigorous space program. NACA's research had led to rocket propulsion and to the very threshold of space by the end of World War II, as demonstrated by the famous X-series of rocket research aircraft. In fact, the latest of that series, the X-15, is still making headlines as its achievements continue.

During the "getting organized" period, which took over a year, several space projects were authorized and assigned to military organizations to get them underway. These had been closely followed by NACA during the initial period, and were transferred to NASA jurisdiction when the new organization was formed. This mass transfer included five space probes, three satellite projects, and several rocket engine programs. For example, Saturn had been under ARPA direction and Army management; Centaur came from the Air Force; and the Tiros meteorological satellite from the Army Signal Corps.

Other organizational elements were added to NASA to increase its capability. The Development Operations Division of Redstone Arsenal under Dr. Wernher von Braun became the NASA Marshall Space Flight Center. The Goddard Center was formed from a nucleus of Naval Research Laboratory personnel. The Jet Propulsion Laboratory, which is owned by the Government but staffed by the California Institute of Technology, was transferred from Army jurisdiction to NASA.

These initial steps were illustrative of actions which were to continue gearing America's talent and resources into a single management structure for the scientific exploration of space and peaceful application of the newly developed space technology. Later the Manned Spacecraft Center at Houston was formed; and now an Electronics Center near Boston is planned.

The launch of the many satellites and deep-space probes has sparked a chain reaction of events. No end to this chain reaction, called the "space age," yet appears in sight. Men everywhere now look at the universe with practical eyes and ever-increasing hopes.

Many concerned Americans heaved a great sigh of relief when Explorer I, the first U.S. satellite, was successfully launched into orbit in January of 1958. It carried an International Geophysical Year experiment conducted by Prof. James A. Van Allen of the University of Iowa, which made the most important discovery of the IGY: the radiation belts which carry his name. Then a dramatic encore, Vanguard I, was launched in March of that year. This was the first satellite to employ solar-powered batteries.

When the Congress of the United States brought NASA into being, the act declared that: "It is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." Four major national goals were established:

1. To conduct the scientific exploration of space for the United States. (Scientific satellite programs.)
2. To begin the exploration of space and the solar system by man himself. (Manned space flight.)
3. To apply space science and technology to the development of earth satellites for peaceful purposes to promote human welfare. (Weather and communications satellites.)
4. To apply space science and technology to military purposes for national defense and security. (Department of Defense.)

The great effort by American engineers, scientists, and technicians in carrying forward our entire space program will do much more than place a man on the moon. The vast effort now underway will provide the basis for the greatest technological harvest man has ever known. Accurate weather forecasting as well as reliable international TV can be foreseen; but even greater scientific and engineering breakthroughs are inevitable and will surely have a profound effect on economic, social, and material benefits throughout the world. As we plan the exploration of space, we become more convinced that our effort to meet this historic challenge has just begun.

Looking into the future, we must all become aware of our increasing personal and professional responsibilities. The exploration of space is truly a social force which is rocking the world. As professional educators, we cannot ignore this force. Every educator as well as every educational institution has a responsibility for the success of our national effort to explore space. Our schools, colleges, and universities are now called upon to produce a body of scientists and engineers of unexcelled competence. Some of these graduates will enter Government service with NASA. Some will join private industry, and some must remain in our schools, colleges, and universities—where they will continue to advance knowledge and produce new talent.

The opportunities for developing new fundamental knowledge and technical applications may very well exceed those which have existed in the atomic and nuclear physics fields during the past years. A vigorous academic program covering appropriate aspects of the space endeavor must be pursued. Such a program must enjoy a workable relationship with the Federal Establishment; but it is important that it preserve the essential virtues of educational institutions—that is, a devotion to scholarly and scientific inquiry, and a primary concern for the guidance and education of students.

American scientific achievements in space have been many since the dramatic flight of Explorer I which discovered the Van Allen radiation belts. As educators you must remain abreast of the achievements which will be rapidly changing the teaching of the various disciplines. It appears to be a characteristic of scientific space activities that they cease to be front-page news soon after they are launched, even though this is the very moment that their contribution to knowledge begins. The difficult task of piecing together the "cosmic jigsaw puzzle" of space engages many highly skilled persons throughout our scientific and educational community. It is a time-consuming and exacting job which only rarely merits newspaper attention. Yet these scientists are learning about the basic nature of the universe, earth-sun relationships, the shape of the earth, the structure of the atmosphere, the history of the earth, and of the solar system.

With the challenge clearly existent, I hope that all of you here at this conference will greatly benefit from the discussions, lectures, and exchange of ideas which will take place throughout this week.

THE NATURE AND PURPOSE OF THIS CONFERENCE

Frederick B. Tuttle *Deputy Director*
Educational Programs Division
NASA Headquarters
Washington, D.C.

NASA Headquarters Project Director for the Conference and Vice Chairman, Conference Planning Committee

In assembling a conference such as this, NASA has, from the point of view of its own interests, two purposes. The first is to bring greater understanding of America's space science program to possibly the most important element in America's scientist community; namely, yourselves—who hold positions of responsibility for the future progress of science education. NASA's second purpose is to provide to those of us who are responsible for and are participating in the NASA education program an opportunity to gain and share ideas with science educators such as yourselves.

In inviting the U.S. Office of Education to cooperate with us in planning and conducting this program, we of NASA wanted to assure for the Conference a broader dimension than our own purposes, as stated above, would imply. We wanted to provide a setting—a frame of reference—for discussion of the problems of space science education and of science education in the emerging space age. The nature of our discussion of science education will be presented by Dr. E. S. Obourn at the conclusion of my talk.

In the process of planning this Conference, those of us on the Planning Committee (and we had an active, responsible, and congenial group) had one all-embracing purpose: to organize a Conference that could lead participants to greater understanding of space science developments and of space science education, Grades 1 through 16. We have no point of view to espouse, no bill of goods to sell. We hope to provide an opportunity for each of us to learn, not only from the especially invited guest lecturers in science but also from each other.

The program we have organized for the 5 days of the Conference comprises three elements: One is scientific, with general session speeches and discussions, and field trips; another is pedagogic, with general session speeches and discussions, and roundtables; and the third is organizational, with periods devoted to separate sessions for discussion of the "in-house" business of each organization represented at the Conference.

I have alluded in general terms to the participating groups of educators here assembled. The nature and interest of each of the groups will be discussed at some length following Dr. Obourn's talk. However, I will say that seldom, if ever, has a Conference been held that is as representative of the Nation's leadership in science education as is this.

The members of the Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics number eminent scientists in their respective disciplines—men who have had such strong and constructive interest in science education that they have been chosen to hold leadership roles in the science education activities of their respective national societies.

The State Science Supervisors present are representative of the group that probably has more to do with the progress of elementary and secondary school science teaching than any group in this land. They are men and women selected for their roles because they are first and foremost master teachers and dynamic supervisors—authentic leaders in their respective States.

The U.S. Office of Education has over the years stood in the forefront of those calling for a revision of the science curriculum and for an increased interest in its importance. The Office of Education staff members who helped plan this Conference are representative of the Nation's best in elementary and secondary school science teaching.

We of NASA Headquarters, Center, and Spacemobile education programs are for the most part professional schoolmen, although some of us have backgrounds in publications. We have taught and administered in the colleges and lower schools. Most of us have science majors; but some of us have been selected for our backgrounds in the social studies. A number of us have been leaders for 20 years in the effort to bring to teachers sufficient understanding to integrate into their teaching recent scientific-societal developments.

In my discussion of the nature and purpose of this Conference, I have not indicated that we are hoping to arrive at conclusions and make recommendations. I have indicated that we hope to achieve mutual understanding in the fields of our several interests. Possibly, I can best illustrate our purpose by referring to two Biblical accounts: One is the Old Testament story of the Tower of Babel; the other, the New Testament account of the Lord's bestowing the gift of tongues on the Disciples when they were assembled on the Feast of Pentecost. In both cases, those present found themselves talking to each other in different languages. However, in the New Testament, Christ's Disciples were united by a common spirit. We of this Conference, drawn together from the science teaching of the elementary school to the university, from the life sciences to the physical sciences, will also find the problem of communications difficult. But we, too, are motivated by a common spirit—that of striving for insights and understanding as we pursue our common goal of better science education.

THE NATURE AND PURPOSE OF THIS CONFERENCE

Ellsworth S. Obourn *Specialist for Secondary Science*
U.S. Office of Education
Washington, D.C.
U.S. Office of Education Project Director for the Conference

Dr. Tuttle has provided a clear framework within which this Conference will carry on its deliberations. I am sure that these parameters which were reached after many meetings of the Advisory Committee, both in Washington and Los Angeles, are to be regarded as guides and in no way as limiting.

It has been a difficult undertaking to weld into a common linkage the diverse interests and concerns of each of the participating units. I would be remiss if I failed to recognize all of the other people who have made contributions to this endeavor.

We have high hopes that this Conference will weld the participating groups into a forceful unit which can make a significant and lasting impact on the improvement of science teaching in America. This Conference is above and beyond the interests of any one of the member groups: indeed its importance arches over the two sponsoring agencies and strikes deeply into the future welfare and security of our Nation. The future welfare and security of this Nation can be translated into at least three goals or targets which can determine action programs for the groups here assembled:

1. *The provision of a scientifically literate citizenry.* Presumably we are a highly literate Nation in terms of the old definition of literacy—symbolized by the three R's. We can say with considerable confidence what it is that constitutes literacy in each of these areas. But a new vector has been added to basic literacy: that of literacy in science and technology. Today this is practically undefined, and we know very little about the elements of which it is constituted. Today we graduate from public high schools many young people illiterate in science. This literacy must be provided by education in science in the public schools.

2. *The provision for scientific, engineering, and technical manpower.* This is another of the pervasive determinants for the teaching of science in the schools. Much has been done, and other new programs are now in progress, toward the identification of, and the provision for, science-talented youth. But we cannot afford to be lulled into a state of passivity regarding the future manpower needs of a society that is likely to be more scientifically and technologically oriented in the years ahead. Our national security and welfare can be adequately served only as we produce a higher and higher quality product from the science classes of our schools. The scientific manpower of tomorrow is in the public schools of today. For them we must continuously raise the sights to new and more promising targets. The introduction to the U.S. Science Exhibit, Seattle World's Fair 1962, states, "High on the list of prerequisites for being a scientist is a quality that defines the rich human being as much as it does the scientist: his ability and his desire to reach out with mind and imagination to something outside himself."

3. *The provision for the interdisciplinary infusion of science as a humane pursuit in the culture of our times.* C. P. Snow has pointed out the dichotomy between the various cultures that exist in our society. More recently, in a reexamination of his first position, he points out that this gap is

narrowing. With science becoming an increasingly dominant factor in the life of the Nation and the affairs of people, the school science program at all levels must reach out to join with other disciplines; this to insure that common elements in modes of inquiry among them, and the related conceptual schemes within each discipline, become integrated in the thinking and behavior patterns of the young people who complete the public schools. This must become an integral aspect of literacy in science for every boy and girl in this Nation.

This Conference offers a unique and challenging opportunity for exploring some of the diverse problems of science education, as it seeks to provide the leadership, the programs, and most important, the day-to-day classroom teaching in the public schools that can lead toward the goals through which the national security and welfare can be improved. Only as we keep these goals before us can the fullest potentials of this Conference be achieved.

More specifically, the Conference Planning Committee has sought ways to organize the special and common interests of the participating groups in the program that is before you. These common interests have been melded through the papers that will be presented, the panels that will react to them, and the discussion groups. The special interests have been provided for by time in the program when each group will discuss its unique problems and concerns. In the field excursions we will have the privilege of seeing firsthand some of the achievements of today's scientific, engineering, and technical manpower.

In closing, I would like to point out that NASA and other agencies, both governmental and nongovernmental, which are committed to the scientific future of this Nation *must not fail.* On these, and some others, the future well-being and welfare of this Nation rests. These can sustain and flourish only as the science programs in our common schools produce the cutting-edge research scientists, the engineers, mathematicians, technicians, and common laborers who can produce a scientific product unequaled and unexcelled.

Over and beyond this capability, the future of these agencies and the Nation rests upon a literate citizenry that will support and sustain a productive scientific endeavor. It is within these concerns that this Conference takes on its great challenge.

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THE NATURE OF THE SUBCOMMITTEE ON INSTITUTES AND CONFERENCES OF THE AAAS COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS AND ITS INTEREST IN SCIENCE EDUCATION

Ted F. Andrews *Head*
Department of Biology
Kansas State Teachers College
Emporia, Kans.
and Vice Chairman of the Subcommittee
on leave as consultant on Teacher Preparation,
Biological Sciences Curriculum Study
University of Colorado

Soon after the National Science Foundation began to bring scientists together to serve on evaluation panels or to meet as directors of various sorts of institutes, the physicists, chemists, geologists, biologists, and mathematicians recognized that improved liaison was needed. As the scientists and mathematicians began to discuss improvement of education in the sciences, it became obvious that many problems were common to all disciplines, and that many of these problems were most readily solved through scientists and mathematicians working in concert. The artificial boundaries that had become conspicuous among the various fields of science became more and more obscure as they learned of each other's research and science teaching problems. It was evident to certain forward-looking persons that science-teaching improvement programs could best be accomplished through the cooperative efforts of scientists from all disciplines.

The institute programs of the National Science Foundation provided the opportunity for several hundred scientists to assemble annually, or in some cases several times each year, to consider problems of educating teachers of science in the secondary schools and in the colleges. Many scientific societies and associations had, for many years, committees on education and science teaching. Naturally, members of these committees became active in the institute programs and, as a result, the committees were rejuvenated and impetus given to their activities. Many associations established new committees on institutes, which were to concern themselves with the enhancement of institutes to reeducate inservice teachers of science in the secondary schools of America.

In May 1961, Dr. Marsh White, who was chairman of the Committee on Institutes, Conferences, and Symposia of the American Association of Physics Teachers, a member society of the American Institute of Physics, conceived the idea of an Interdisciplinary Committee on Institutes and Conferences. Various scientific societies were invited to send a representative of their education committee to an informal meeting to be held in conjunction with a meeting of panelists convened by the National Science Foundation.

On June 3, 1961, the precursor group of the Interdisciplinary Committee on Institutes and Conferences met in Washington, D.C. Representatives of committees on education in the following associations and societies convened:

1. The American Chemical Society.
2. The American Association for the Advancement of Science.
3. The American Institute of Biological Sciences.
4. The Botanical Society of America.
5. The Mathematical Society of America.
6. The American Association of Physics Teachers.
7. The American Society of Zoologists.
8. The American Society of Microbiology.
9. The National Association of Biology Teachers.

In addition, many representatives of the National Science Foundation met with the association representatives to discuss such topics as:

1. What should be done about teachers participating in more than one institute? (This is still a pertinent and appropriate query.)
2. Are there important groups of key people who need training? Science supervisors? Junior high school science teachers?
3. Should relatively more attention be given in the planning of institutes and conferences on new curriculum developments?
4. Are there new fields or topics which should be given increased attention? How can interdisciplinary planning be made effective?
5. Are there new approaches which might be used to increase net efficiency in reaching more teachers? Fellowships? Internships?
6. Are there particular difficulties inherent in present procedures for submission and evaluation of proposals, distribution of institutes and operation of institutes? Is evaluation adequate?

The second meeting of this group, which in the correspondence was called the Intersociety Committee of Representatives from Educational Committees of Physics, Chemistry, Zoology, Botany, and Mathematics, was held in Washington, D.C., September 9, 1961. About a dozen persons met and discussed the following topics:

1. All areas of science can learn from each other; there is need to pool experiences in order to improve science teaching.
2. Education committees might be of more assistance in helping others to write proposals and encourage our memberships to submit better proposals.
3. How can quality of institutes be evaluated? Are there other innovations that might supersede or augment the institutes?
4. Preparation and distribution of brochures intended to increase interest in science teaching.
5. "Space science" is attaining increased status and may be included at the college level. In what ways can collegiate scientists assist in guiding the development of "space science"?
6. Multiterm institutes are needed to insure continuity in the institute participant's educational experiences.

Nearly a year passed before the third meeting was convened in Washington, D.C., at the Cosmos Club, August 1, 1962. Seventeen persons attended. Dr. Marsh White was elected Chairman; and Dr. Allyn Waterman, Secretary, of the Interdisciplinary Committee on Institutes and Conferences. Each association representative reported on the activities of the educational committee of the society he represented.

Dr. White arranged for the fourth informal meeting of scientists to be held in conjunction with a meeting of the summer institute panelists in Washington, D.C., July 1963. Eleven attended the meeting and formally organized the Interdisciplinary Committee on Institutes and Conferences (ICIC). Dr. White served as moderator of the discussion and temporary chairman until an Executive Committee of five persons was elected:

Chairman: Allyn Waterman (Zoologist), Williams College.

Vice Chairman: Ted F. Andrews (Biologist), Kansas State Teachers College.

Secretary: Robert L. Silber (Chemist), American Chemical Society.

Marsh W. White (Physicist), Pennsylvania State University.

E. A. Cameron (Mathematician), University of North Carolina.

Following adjournment of the summer institute panelists sessions, the Executive Committee met to discuss future plans. It was decided by the Executive Committee that ICIC could appropriately be affiliated with the AAAS Cooperative Committee on the Teaching of Science and Mathematics, a committee that had been in existence since 1941. The secretary, Robert Silber, contacted Dr. Alfred Garrett, Chairman of the

AAAS Cooperative Committee, to discuss the relationships of ICIC to the AAAS Cooperative Committee.

On Feb. 25, 1964, by action of the AAAS, the Interdisciplinary Committee on Institutes and Conferences became an official subcommittee of the AAAS Cooperative Committee on the Teaching of Science and Mathematics. Hence, the ICIC has had an official affiliation with the AAAS since February 1964.

The objectives of the AAAS Interdisciplinary Subcommittee on Institutes and Conferences are stated as follows:

1. Encourage scientific societies to develop programs to improve science teaching.
2. Provide liaison among the educational committees of the various scientific societies.
3. Promote symposia at national meetings.
4. Promote college curriculum changes.
5. Stimulate colleges and universities to develop more appropriate institutes.
6. Suggest interdisciplinary institutes, conferences, and symposia for well-qualified college instructors.
7. Recommend institutes for college instructors from small, underprivileged colleges.
8. Encourage colleges and universities to incorporate in their institutes, conferences, and symposia experiences on methods and techniques of teaching modern curricular materials.
9. Encourage dissemination of information on need for additional and different programs of education in the sciences.
10. Suggest development of science career opportunity brochures, especially science teaching.

During this conference on "Science Education in the Space Age," sponsored by NASA, 22 representatives of the Interdisciplinary Committee on Institutes and Conferences participated in the panel discussions and met as a group to discuss the future activities of ICIC. Since the ICIC is a subcommittee of the AAAS Cooperative Committee, the group decided to elect a chairman, vice chairman, and secretary. The following were elected:

Chairman: Dr. J. Robert Harrison, Department of Zoology, Miami University, Oxford, Ohio.

Vice Chairman: Mr. Robert Silber, American Chemical Society, Washington, D.C.

Secretary: Dr. J. W. Buchta, American Association of Physics Teachers, Washington, D.C.

The ICIC Committee, under the chairmanship of Dr. Harrison, devoted attention to the following general areas of discussion:

1. Present status of institutes and conferences. Representatives of ICIC agreed to obtain from NSF and AEC, data on institutes and conferences financed during the past 5 years.
2. In what ways can NASA contribute most effectively to education in the sciences?
3. What contributions can basic sciences make to the programs sponsored by NASA?
4. The need for increased support for updating instructors in colleges, especially as regards content and philosophy of the new curricula.
5. Future activities of the ICIC.

The Chairman, Vice Chairman, and Secretary of ICIC will meet on October 12, 1964, in Washington, D.C., with the AAAS Cooperative Committee on the teaching of Science and Mathematics to report on the results of the deliberations of the NASA-sponsored conference on "Science Education in the Space Age," and on the recommendation resulting from the discussions of ICIC.

THE NATURE OF THE U.S. OFFICE OF EDUCATION AND ITS INTEREST IN SCIENCE EDUCATION

Robert E. McConnell *Acting Regional Representative*
Region 9
U.S. Office of Education
San Francisco, Calif.

The U.S. Office of Education has an interest in all levels of education: elementary education, secondary education, collegiate education, and graduate education. The Office is organized into three bureaus: Educational Research and Development, International Education, and Educational Assistance Programs.

There are provisions and personnel in these bureaus to render several types of services. Principal among these are the publishing of the results of studies and surveys, the furnishing of consultants to all educational groups, the supporting of research, and the administration of financial assistance programs.

The Office carries on its work through publishing its research findings, studies, and survey reports; through participating in conferences; through speaking and writing; through consultation and fieldwork; through contracting with colleges, universities, State offices of education, other public or private agencies, organizations, groups, and individuals to conduct research; through aid to college students; and through administering financial assistance programs as stipulated by the Congress.

It has long been engaged in gathering statistics, making surveys, doing research, consulting in the modernizing of curricula, and helping upgrade school personnel. In recent decades the Congress has appropriated increasing amounts to assist in financing special programs in education such as research, vocational and technical education, schools in federally affected areas, counseling and guidance, science, foreign languages, financial aid to college students, and so on.

There is one project to which I should like to refer at this point: This is title III of the National Defense Education Act of 1958. It provides for *two* kinds of assistance to schools in their efforts to improve instruction in science, mathematics, and foreign languages.

The first is financial assistance to purchase equipment and to remodel facilities. About 83 percent of the funds have gone for science and mathematics equipment and facilities and teaching materials. The other 17 percent has supported the foreign languages.

In the first 5 years under NDEA, the Federal Government had allotted \$172.2 million for equipment and remodeling projects in local public schools. In the same 5 years, 250 loans totaling \$3.3 million were made to private schools.

Each Federal dollar that is allotted to the States for these purposes in the public schools must at least be matched by a State or local dollar. From this, one can conclude that about \$350 million have been spent in this improvement program. This is an enormous accomplishment.

The second kind of aid has gone to State supervisory services. In the first 5 years under this act, \$10.3 million in Federal funds went into the improvement of supervisory and related services and administration of State plans.

Before 1958, only a few States employed specialists in science and mathematics. There were possibly only a half-dozen specialists, but now there are 75 or 80. In all 3 programs in 1958 there were only 33 State specialists, but now it is reported that there are 238.

Although the quality of education in the United States is high by any standard, our school system needs constantly to be revitalized. Curricula and teaching material are always in need of modernizing. Likewise the education of teachers and professors needs constantly to be updated. An important phase in the updating of education is the incorporating of the results of research and experimentation into the teaching material at all levels of education. The Office has a stake in all of these ventures.

Within recent weeks the Bureau of Research and Development has been reorganized. The science, mathematics, and engineering specialists have been assigned to the Division of Research, and more specifically to a Branch of Curriculum Improvement and Demonstration. While the role of the science specialists has not been fully defined, it is quite likely that their field contacts will be extended to include more activities in science education research.

The U.S. Office of Education is vitally interested in this Conference on Science Education in the Space Age. It is pleased to cooperate with NASA in holding this national meeting for its own personnel and for State supervisors of science, the personnel of NASA, and members of the Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics. I personally consider it a privilege to participate in this conference.

The purposes of the conference as we see them are:

1. To explore further the important role of science education in our Nation's space effort.
2. To develop plans for modernizing science teaching through the incorporation of space-related material into school programs. The need to enrich courses of study is always present.
3. To draw closer the person-to-person professional relations that exist between and among the members of the participating organizations.
4. To provide opportunities for members of the participating organizations to work on their specific problems.
5. To provide NASA's education staff an opportunity to discuss those problems of science teaching related to NASA's educational programs.

I trust that all of you are eager participants and that we may all have a stimulating and profitable conference. This should be an opportunity for everyone to grow in his perception of the problems of education in space-related science.

THE NATURE OF THE COUNCIL OF STATE SCIENCE SUPERVISORS AND ITS INTEREST IN SCIENCE EDUCATION

Franklin D. Kizer *Supervisor of Science*
State Department of Education
Richmond, Va.
and Immediate Past President of the Council of State Science Supervisors

It is my happy privilege to respond on behalf of the Council of State Science Supervisors, sometimes familiarly known as "CS ^{3}."

I wish to express the appreciation of the membership to NASA, for making it possible for us to meet with such a distinguished group of scientists and educators. We have been looking forward to this meeting for more than a year, and we are extremely pleased that it has materialized in this location.

Many of the State Science Supervisors' positions began with the NDEA Act of 1958; however, several of us predate NDEA. As our titles imply, with few exceptions we have a leadership responsibility for science education in our State department of education. Our primary duty is to assist our chief State school officer in every way possible—and more especially in the many phases of science education. Now, science education at the State department of education level includes many phases. Some of these are:

New curricula for the space age.
Laboratory facilities and equipment.
Teacher certification.
Textbooks.
Supplementary materials.
Use of natural and human resources.
Safety.
Evaluation.

I must clarify one point: Our title of "Supervisor" is a misnomer. We are primarily consultants—not inspectors; advisers—not dictators. We render a spectrum of assistance to local school science teachers.

In our State we work with the local schools and science teachers through the school district superintendent, who is usually the legal authority for the operation of the entire school program on the local level. We are expected to advise and interpret the policies of the State board of education, possess encyclopedic knowledge of all national science curricula; be able to recite from memory a myriad of sources of information for materials, equipment, new books, professional societies, aids to teachers, films, programs, summer NSF scholarships; and conduct inservice programs for the teachers and administrators. We even have to protect the teachers from the antivivisection and humane societies which object to students using laboratory animals in their science experiments and investigations.

Most of us were given the responsibility by our respective chief State school officers of scheduling the NASA Spacemobile in our State. This has been a very pleasant assignment for my staff in Virginia, and we are looking forward to many months of association with NASA and the Spacemobile supervisors and lecturers in a continuous development of a space education resource program to meet our science curriculum needs.

Now for the CS ^{3}, which is a new isotope in science education. Its history? Purpose? Members? Organization?

In March of 1963, the organization, the Council of State Science Supervisors, officially came into existence—with a constitution, officers, and dues. This was the result of about 2 years of study and planning by State science supervisors from the various States.

I had the honor of serving as the first constitutional president, and of representing the council on the planning committee for this Conference.

The Council of State Science Supervisors is a positional organization. The membership consists of any member of the staff of the department of education of any of the States, the District of Columbia, Puerto Rico, or a territory of the United States, who is designated by his chief State school officer as having specific responsibility for science education.

The purpose of the Council of State Science Supervisors is to strengthen the leadership role of the State Science Supervisors in the development of effective programs of science instruction in the various States through such means as—

1. The exchange of ideas and the dissemination of information among the membership in such matters as State programs, experimental studies, and other items of general concern to the membership.
2. The study of designated problems pertaining to the work of the State Science Supervisors.
3. Cooperation with other organizations interested in the improvement of science instruction.

It is my pleasure to introduce to you the officers of our association: President, Severo Gomez, Texas; president-elect, Lewin Wheat, Maryland; and secretary-treasurer, Gene Maguran, West Virginia. Our official publication is the *Capsule*. Committees are organized to facilitate the handling of our business and recommend to the membership suitable reactions on proposals requested by other groups.

Our dues are $5 per year! We are solvent. Our budget is balanced with a surplus. We do not envision any financial difficulties which will prohibit us from carrying out our objectives and purposes.

We welcome an opportunity to cooperate with all groups interested in science education. We will evaluate all proposals fairly. However, we will not commit our membership to programs that require a financial obligation or that will exclude any State from participation. We are united for the promotion of leadership among all State Science Supervisors.

Again we thank Fred Tuttle; Art Costa; Mrs. Archie Owens, Science Supervisor of the Los Angeles Public Schools; NASA; the Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics; the U.S. Office of Education; the industries, and all others who have had a part in making this Conference possible. We are looking forward to the general sessions, the roundtable discussions, the field trips, and all other activities of the Conference which will update our education and assist us in greater development of our leadership roles in science education. We are delighted to be here! And on behalf of our chief State school officers, we express our appreciation for your kind and generous invitation. Thank you.

THE NATURE OF NASA'S EDUCATIONAL PROGRAMS AND SERVICES OFFICE, AND ITS INTEREST IN SCIENCE EDUCATION

Aaron P. Seamster *Director*
Educational Programs Division
NASA Headquarters, Washington, D.C.

Each of the three distinguished gentlemen who preceded me has told us about his own organization and of its interest in science education. I am pleased and grateful to have the opportunity to present a statement for NASA's Educational Programs and Services Office.

The Space Act of 1958 established NASA as a research and development agency uniquely concerned with development of information for use in advancement of the aeronautical and space activities of the United States. The first of eight prime objectives listed in the act directs that these activities "be conducted so as to contribute materially to . . . the expansion of human knowledge of phenomena in the atmosphere and space."

The information function of the agency is spelled out further and more explicitly in the act's direction "to provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

These directions of the act are explicit stimulation for the NASA educational programs and services; but these activities also are reflections of tremendous public demand for information about the Nation's civilian space program, combined with the fact that NASA is a sole source of such information.

Every level of organized education, and virtually every level of the general public, has directly or indirectly requested NASA to help satisfy an astonishing thirst for information about space science and technology.

In the discharge of this educational responsibility, NASA has developed the Educational Programs and Services Office, which works through established education institutions and interested organizations to provide a long-range program for the United States. The Office has been organized into two divisions: The Educational Programs Division and the Educational Media Division.

The Educational Programs side of the family is responsible for working directly with schools, colleges, State departments of education, other Federal agencies, professional educational associations, and other organizations interested in education. The small staff of professional educators, with experience and qualifications covering a broad educational spectrum, provides assistance as requested and as appropriate.

They are presently carrying out a six-point program of activities as follows:

1. *Professional Education Conferences*

This meeting is the finest example of this particular program. We hope that this Conference on Science Education in the Space Age will not only be of interest but of value to you in your important work; and that it will also contribute in some measure to America's leadership in space.

2. *Youth Activities*

This is our effort to encourage young people to participate, through school and nonschool organizations, in space-related activities designed to familiarize them with developments in the space sciences and technologies. This category includes Science Fairs, Youth Science Congresses, model rocketry, spacecraft model building, Boy Scouts, and other youth programs pertinent to the U.S. program in space.

3. *Teacher Education Courses, Institutes, Seminars, and Workshops*

This activity is to encourage and assist State departments of education, school districts, professional associations, and particularly institutions of higher education, to provide opportunities for preservice and inservice elementary and secondary school teachers to gain greater understanding of developments in space sciences. They may include seminars, workshops, courses, and institutes, conducted in summer session and during the regular school years. They also may include assistance, as requested by the sponsoring institution, that ranges from providing audiovisual and reading materials, arranging for field trips, and making available resource lecturers, to helping the sponsoring institution organize and conduct the activity.

4. *Development of Instructional Resources*

This activity is to advise and assist elementary and secondary schools, and the institutions preparing teachers for these schools, in adapting and updating courses of study with appropriate space-related information. Activities in connection with this program may include initiating or encouraging others to initiate the development of carefully selected resources units such as curriculum bulletins, course syllabi, as well as reading and audiovisual materials.

5. *Adult Education Courses, Lecture Series, and Conferences*

This activity has as its purpose the encouraging and assisting of adult education organizations, publicly or privately supported, to offer courses that bring to their enrollees information about the space programs. This program may include assistance, as requested, such as providing audiovisual and reading materials, arranging for trips to NASA centers, and making resource lecturers available.

6. *Lecture-Demonstration Program*

This activity provides a systematic means for meeting the requests of schools for lectures and demonstrations in assembly halls and classrooms about NASA's activities and their results. Some lecture-demonstrations may be undertaken by NASA scientists, administrators, and education staffers; but the large majority of such assignments go to the space science lectures of the Spacemobiles. The Spacemobile program has been tremendously effective and successful, both domestically and abroad. You will, as this Conference progresses, be meeting and working with people involved in this program, so I will take no more time on it now.

The Educational Media Division, the other half of the family, is engaged in developing and providing resources such as motion pictures, television and radio tapes, and a wide variety of publications. These resources, designed basically to serve the needs of the educational community, have extensive collateral use in communication with the general public.

In order to carry out the programs just outlined, NASA Headquarters relies heavily on its Center Education Officers [introduce Center Education Officers at this point].

May I close by saying that NASA's educational programs are operating with a limited budget and mission. We are trying to bring space age understandings, or space science, if you will, to schools, elementary and secondary, and to teachers at these levels, both preservice and inservice. We are all schoolmen, like yourselves, dedicated to providing services to those who are concerned with the development of an increased supply of scientists, engineers, and technicians for future needs, and to achieve in our country a science-literate citizenry able to understand and act intelligently in the face of many problems emerging from an age of science and technology, and the Knowledge Revolution.

THE PAST, PRESENT, AND FUTURE OF SPACE EXPLORATION

Joseph Kaplan *Professor of Physics*
University of California at Los Angeles
and Chairman of the U.S. National Committee
for the International Geophysical Year

I am particularly pleased to be here today. Obviously, I will not be able to speak on all aspects of the topic, the "Past, Present, and Future of Space Exploration," which would turn out to be a great deal.

I think it is appropriate that today is the day (June 1, 1964) that the IGYUS National Committee for the International Geophysical Year is offically being dissolved, after a little more than 10 years of existence. As many of you know, the Committee for the IGY played a role in the exploration of space; and I, personally, both historically and by connection with teachers and others, perhaps played a longer historical role. My first professor in physics, as a graduate student, was Joseph S. Ames,[1] after whom the Ames Laboratory was named. He is the man who conceived the idea of creating an executive agency to deal with a particular type of scientific problem. The old NACA, the National Advisory Committee for Aeronautics, was thus dreamed up and organized by Joseph S. Ames—hence the NASA Ames Laboratory of today. Professor Ames was the first chairman of the Committee. So back in 1924, even as an undergraduate, I became aware of the fact that there are some professors of physics who may not be around every day in the week.

Ames was a hard man to get to know. He had an assistant, a very distinguished-looking janitor, who wore his castoff clothes. When Ames went to lecture, the janitor, wearing a morning coat with striped trousers, would open the door for him. When I got to know Ames, I asked him what he did in Washington, and he told me about NACA. As many of you know, NACA was to change the "C" to "S"—to become NASA, the National Aeronautics and Space Administration. This executive agency now has a much larger area of activity; and I think Ames might have been pleased that he taught me a little more than physics because of the problem of knowing what the Nation should do about the space program. When I was the Chairman of the U.S. National Committee for the International Geophysical Year, naturally we gave some thought to it. Later on, I want to talk to you a little about international problems as they're related to space research. This is what I have called a new dimension of science—a fourth dimension—which relates to the fantastic impact that science has had on our international relations. And may I say that I believe that perhaps NASA is accomplishing as much or more in international relations from a scientific point of view than any other agency of the U.S. Government. I take some pride in this because the head of NASA's International Office, Arnold Frutkin, is a graduate of the IGY. A great many people got their taste for international programs in science during the International Geophysical Year.

Space science (I don't care what you call it; the point is, it gives a new dimension to a kind of science) is inspired by the fact that we can get into space and do things that we couldn't do before. I think the greatest things being accomplished in this area are the fantastic things that are happening to the engineers because of the demands of the scientists. The opportunities that

[1] Dr. Joseph Sweetman Ames (1864–1943); Chairman, National Advisory Committee for Aeronautics, 1927–39; president, The Johns Hopkins University, 1929–35.

have developed are really quite remarkable, and later on I will prove to you that it is worth $20 billion to go to the moon. The price tag can be extremely small, even at $20 billion; but this is something that unfortunately many people who talk about space don't emphasize. I made this point to the American Association of Psychiatrists at a major banquet in New York. I'll discuss it further later.

Let's look at the opportunities of science in space. We need to go back 35 or 40 years, which is the span of my own experience in the programs which are related to upper atmospheric physics. Sitting in front of me is my old friend, Don Loughridge,[2] who can remember when Kinsey [3] and I first came to the University of Washington, at Seattle, in 1928. That was the first institution we visited on the west coast; and while there we talked about the upper atmosphere. What were the opportunities in upper atmospheric research—which is the forerunner of space research—back in 1928? In my own case it opened up a vista of science which affected my whole career in thinking and enjoyment of science from the essentially frontline professional point of view. The first real inspiration that I got out of the upper atmosphere wasn't so much in relationship to its composition or transmission of radio signals, as the realization that the understanding of radio propagation and the upper atmosphere in the thin ionosphere might some day result in the development of techniques which would make the world small, and influence world politics.

I gave the Sigma Xi lecture at the University of Washington in 1948. As I went into the auditorium, a man asked me, "Is this where the lecture on geopolitics is going on tonight?" "No," I said, "I'm the lecturer. It's really geophysics." On second thought (the man was a professor of political science), I said, "Come on in. You're liable to learn something." He did come in.

A very early aspect of upper atmospheric physics in 1928 was known as "the light of the night sky." Professor Page [4] will recognize the term. The only people of an international organizational point of view who recognized that there was such a thing as the "light of the night sky" was the International Union of Astronomy. The Union had a Commission on Meteors and "the Light of the Night Sky."

Some of the astronomers in America were interested because they were already concerned about bigger telescopes and the possibility that this chemiluminescence, like the light of the firefly, this chemical reaction going on in the upper atmosphere giving rise to radiation, might interefere with astronomical obeservations. So, the first really good inspiration that I got for staying in this field wasn't obtained in the physics department—not even from Karl Compton [5] at Princeton, where I spent a year as research fellow, but from my old friend, Dr. Babcock,[6] the older Babcock at Mount Wilson. I visited and talked with him about some of my first ideas about this radiation. The radiation from the night skies is very peculiar, and weak, particularly when you had to photograph it with the kind of spectrographs that we had in the 1920's. You opened the slit real wide to get any light in, then you took a long exposure, and got a spectrum that you could explain any way you wanted to—and nobody could argue with you. That was "the light of the night sky" which inspired me to go into upper atmospheric physics.

Interestingly enough, the one aspect which was clearly understood, or at least measured, was the radiation due to atomic oxygen in the upper atmosphere; the so-called green auroral line. This was something you could get hold of; but the rest of the spectrum you couldn't. There were no photographic plates then for the infrared. So we didn't understand most of the spectrum. But Dr. Babcock told me, "Kaplan, you're going into a great field." And I stayed in it, and that's what got me started in geophysics.

It also got me into astronomy. You couldn't look up at the sky and then stop there; so I helped my old friend, Dr. Leonard,[7] here at UCLA, who was a one-man department of astronomy. He dreamed about meteors and meteorites at a time when most of his colleagues said that it wasn't a science. "Who's interested in meteorites?" they asked. Today, we can answer the question, but we couldn't then. Even the relatively small and limited aspects of upper atmospheric physics which

[2] Dr. Donald H. Loughridge, Palos Verdes Estates, Calif.; Regional Counselor for California, American Institute of Physics, and Conference participant.

[3] Dr. Edgar Lee Kinsey, professor of physics, UCLA.

[4] Thornton Page, professor of astronomy, Wesleyan University Visiting Professor at UCLA, and Conference participant.

[5] Dr. Karl Taylor Compton (1887–1954), professor of physics, Princeton, 1919–30; president, MIT, 1930–48.

[6] Dr. Harold Delos Babcock, physicist, Mount Wilson Observatory, Carnegie Institute (Retired).

[7] Dr. Robert Walton Leonard, professor of physics, UCLA.

existed in those days provided a frame of reference for teaching—at least on the advanced level—and for research problems which were limitless.

I joined the American Astronomical Society to learn more and was made a member of a commission of the International Astronomical Union. In this, I had my first taste of what international scientific cooperation can be. This was a good forerunner of my involvement in the International Geophysical Year.

The 1920's were pretty primitive times for looking up at the sky. Man was looking up, but not very far, and not with particularly good tools. He hadn't gotten very far off the ground. High-altitude balloons weren't known then, in the 1920's, and rockets weren't even dreamed of—until a few people like Von Karman [8] came along right after the war to organize practically the whole aerospace industry.

I recall our attempts to understand what solar radiation was like in the ultraviolet, because the ultraviolet radiation which is absorbed by the earth's atmosphere gives it most of its properties. We were off with regard to the intensity of solar radiation in the regions able to ionize the atmosphere; we were off by a factor of 10 to the 8th, if I remember right.

If you looked up at the sky and put a radio signal up there, then figured out the number of electrons you needed to reflect it back, you knew what happened. The stuff went around, and then had to have something to bring it back. Then you made some guesses about the kinetics going on up there—how fast these electrons recombine. And then in tracing back to the original cause, you were off by a factor of 100 million in your knowledge of the sun—which, after all, was the cause of it all.

So it didn't take very much imagination later for a few of us—after World War II—to promote the use of rockets for scientific research. The payoff from that was fantastic. It was relatively cheap: a byproduct of military research in many ways; and it was produced through the purely scientific research of a small cadre of people who were able to use rockets technically. It's a small area when you think of it; but in another area, the payoff was equally great. One of the things that becomes apparent very quickly—out of a number of problems—when you head up a thing like the International Geophysical Year, is that you must plan a good program. After all, everybody looks at it; and, hopefully, all the good scientists that you can get will participate in it. And, they're critical. You can't afford to help waste the time of good scientists on big programs just because they're big. You have to make sure that the programs are good.

A particularly intense problem in the case of the IGY was the one of going to the Congress—to a congressional committee, which in this case happened to be the one that dealt with the budgets of the National Science Foundation and of the National Aeronautics and Space Administration. The problem was in going to the committee and explaining why it was that we wanted $43 million in cash, and about $500 million for rockets and other things, such as Antarctic programs, and for a thing called geophysics—with no idea in most of our listeners' minds of what geophysics was.

Another problem was that of educating the public, or creating "scientific literacy," a term that I think I used quite a lot in those days—and which has been used increasingly.

Now, if you're in the business of speaking to the general public about science—to people who have to make decisions—whether the President of the United States, a Congressman, the head of the Budget Bureau, or the National Science Board; the one thing you have to make sure of is that you have to tell the truth. You can't exaggerate.

From the point of view of bringing science to the public, and to students at all levels, I don't believe that anything compares with the development that took place after the IGY Committee eventually had either the foresight or the courage or the foolhardiness to propose to the President of the United States that a satellite be part of the IGY program. I could spend the rest of the afternoon, if I had a good enough memory, telling you of some of the debates that went on in this area. As a matter of fact, I could take you back 10 years and tell you of some of the debates that went on as to the desirability of having an International Geophysical Year. I could tell you of debates that usually started with people who said, "Good science has been brought into the laboratory by individuals. You can't argue with that. Why don't we just go home and forget the whole thing." This occurred. One of the men who said that is *today* one of the greatest propagandists for international cooperation in science. As a matter of fact, he is

[8] Professor Theodor Von Karman (1881–1963); professor of aeronautics and Director of Guggenheim Aeronautics Laboratory, California Institute of Technology.

now so far ahead of me in this respect that he frightens me by the techniques he would use to bring the cooperation about.

You can imagine the debates we had when someone came along and said, "It's ridiculous to try to understand the relationship of the sun and the earth—and to try to understand it on the basis of instrumentation, sophisticated as it is, carried by rockets which go up for perhaps 6 or 8 minutes and then turn around and come down. You've got to go up there and stay there." We did have to increase the time in space, so we started what I christened the LPR program of the IGY. For a while we classified it "secret." All that meant was that we didn't tell anybody else about it, that we were interested, and that we were afraid. The LPR meant "long playing rocket."

Out of the LPR program, I got the reputation of being a hi-fi fan—long before I even owned a reproducing instrument. Anyhow, I got by; and the elementary purpose of the rocket or the first satellite was simply to make some simple measurements in the high atmosphere. This was primarily to look at the sun in a continuing manner, so we could find out what kind of radiations came from there, how they varied, etc. This is still a basic purpose of the NASA scientific program—obviously one of the great purposes. We already dreamed a little bit about looking back toward earth, at the weather. This has now been done. And out of this look at the weather is coming another large and very exciting program, which I won't have too much time to tell you about. We also mentioned the possibility of going to the moon. We were very much concerned that the program of sending an IGY satellite up to make these measurements during the IGY would cost $20 million. You see, the whole budget was $43 million, and the idea of spending half of it to launch the rockets alternated with programs advanced by people who were interested in the solid earth and the more conventional things.

Well, $20 million just showed our naivete, because by the time one of the companies learned that you shouldn't fire rockets after you cleaned them out with river water—that you should use clean water to wash out the rocket casing before you assembled it—about $100 million had gone down the drain. The price went up, but even at the highest price it wasn't too bad. Later on I'll tell you what I told the psychiatrists.

I hope I've shown you, without going into detail, that the outstanding aspect of the space program to me—as I've watched it—is the fantastically broad opportunity on literally every level of national existence in the scientific and technical field.

Let's look for just a few minutes at another aspect: I refer to recent reporting in England concerning a meeting of COSPAR, the Committee on Space Research. This is a committee of the International Council of Scientific Unions, sort of a United Nations kind of organization, a group of nongovernmental groups of scientists—nongovernmental—that's the important point. COSPAR is a committee of that group, and COSPAR brings together the representatives of some 10 scientific unions, which illustrates the depth and breadth of the science program in space. The leaders of COSPAR obviously would be those people who have been in upper atmospheric and space-related research for a long time. They are the geophysicists, primarily, and radio scientists, and the astronomers. But coming in, and coming in rapidly, are the life scientists, the biologists, and the physiologists—people who are concerned with the behavior of man in space. And then we pass on, down the line, where we find the theoretical and applied mechanics people; for example, those who are interested in the problems of the structures, of sound, etc.

Before I end up with a remark or two about the larger and better known program that we have, I want to sound an element of possible danger in this whole area of the space sciences—and the impact of the space sciences on universities. I can barely touch on this, although this again is a problem of intense interest to myself on the international level. Very soon after the launching of the first satellite, Explorer I, and the rapid development of the space program, departments of engineering started to change their names. Departments of aeronautical engineering quickly became departments of aeronautics and astronautics, etc. Institutes of aeronautical sciences first became institutes of aerospace sciences—and now there are rocket societies, or something else, in combination with astronautics and aeronautics. There's been a tendency, perhaps overplayed in American universities—including my own institution, in the institute of geophysics—even to begin to design curricula, so to speak, in the space sciences. This may be a dangerous tendency—and it may be a necessary one. Perhaps it's a sign of increasing age on my part, but I'm a little fearful of the effect of this rapid development, and the possible havoc it could raise with the really fundamental educational program, regardless of what the level is—going down even into the elementary grades. We will have to be very careful of the effect on the rigorous disciplines of the basic departments, such as chemistry, physics, and mathematics; and, of course, astronomy, meteorology, and geophysics.

It's perfectly all right to use the fascination of space and the things involved in it to interest young persons in science; but to go further than that, and to ruin their opportunity to learn, to learn the fundamentals so that they can survive in a rapidly changing period, I think is a mistake. We were discussing the length of time it takes to get a Ph. D. I entered Johns Hopkins as a freshman in 1921 and got a Ph. D. in 1927, with an undergraduate degree in chemistry. I was here as an assistant professor in 1928, 7 years later. You can't figure out what did it, maybe my father did who claimed it was his brains I'd been using all the time—and I won't quarrel with that—but I'm willing to bet that if one could prove what did it, it was a remarkable man[9] in my senior year in highschool who taught me to use the calculus; to understand, to appreciate it, to love it, and use it. When I went to Johns Hopkins, I wasn't satisfied with *Kimball's College Physics*, good as it was. I went to the library, and I found books that used the calculus. The only trouble I had was that the professors couldn't understand it, particularly the chemists. So I quit and became a physicist. It was a very uncommon thing in 1924 to find a chemist who understood calculus. They had one out here in Berkeley, but he was far away, and I'd never heard of California.

An embarrassing thing happened in my senior year. I wrote a thesis in physical chemistry, and the teacher sent it back with an "A," and a notation that said, "I don't understand a word of it."

The point is, with all the space programs around, that the fellow who teaches you calculus when you're 15 years old may have a lot more to do with your future than the man who forces you into a lot of fragmented subjects and tries to make a professor or a Ph. D. in space science out of you. Now, I may be wrong in this. I'm fighting the same battle at the international level, and it's very interesting that the toughest part of that fight will come up in about 10 days in London, at a meeting of COSPAR.

In forming COSPAR, we felt there was need for a kind of top-level bureaucracy in the world of scientists. If the United Nations asks some questions about space, the COSPAR scientists can give some answers. There also is need for some sort of a group that could bring together a committee if the chemists or astronomers object to our putting a lot of junk up in the high atmosphere. We would then have an internationally recognized, able, spokesman. COSPAR has become that.

The business of exploding hydrogen bombs in the high atmosphere in the naive hope that something of use might be learned never appealed to me, but nobody listened. It caused a lot of hassle. We need these international bodies. We need a lot of good scientists to get together internationally to plan on a level that normally would be given over to so-called bureaucrats. We need the men who are in the laboratories to come out and plan. This is what happened during the International Geophysical Year. This is why the program turned out to be a good program; not because I was chairman. I helped get the money for them. The IGY turned out to be a good program because good people came out of their laboratories and planned.

When that happens, you don't like to bring them to Washington or even to Florence, Italy, and have them just sit around and plan and worry about this and that. Whenever scientists come together they talk to each other; they tell each other what they've discovered—and we call those things "symposia." But the first thing you know, the older scientists who are good, come together, and they bring their younger scientists. And one of the tragedies of COSPAR is that now it's in trouble, because some of the other unions like mine—the geophysicists—have said, "We used to hold those symposia, but now you've trapped all the good young people. What's the reason for our existence?"

Well, maybe there is no reason for their existence. Maybe I'll be the last president of the International Union of Geodesy and Geophysics. Maybe there's no reason for the existence of the physics department for all I know; and Dr.

[9] William H. Wilhelm, teacher and head, Department of Mathematics, Baltimore Polytechnic Institute, 1907–37, Baltimore, Md., City Schools.

White [10] and I may be among the last professors of physics. I'm in the middle of the same problem on the international level. Are the modern problems of science and society such that the interdisciplinary approach is really needed? And that the specialist is a thing of the past?

Does the success of COSPAR indicate this trend? COSPAR is a relatively young committee—I helped write its charter at the Royal Society of London in 1961—and yet it's one of the most successful and able of international entities. More countries are joining it all the time. They are willing to put out relatively large amounts of money in dues—much larger than required of astronomers or geophysicists for their organizations. Is the interdisciplinary trend reflected by the large universities now organizing curricula, establishing institutes, and erecting buildings for space sciences?

I just want to say one more thing. I've probably given you a little feeling for the fact there is another dimension for science; namely, international scientific cooperation. In the case of the IGY, this type of cooperation accomplished a great deal, and actually went over into other areas. One of the most notable of these was the signing of the Antarctic Treaty, which resulted in a very fine program whereby about 12 nations are now working in the Antarctic, with no thought as to atomic testing or warplanes—at least not on the surface. There is good scientific cooperation.

And there are some new programs in the making. A proposal for a special committee on water is coming up next week in London. Probably some hydrologists will object because it costs a lot of money and is too glamorous. It may also involve the thinking of experts from other disciplines. This is the sort of thing that frightens the narrowly limited specialist because he sees his field disappearing. So in that way, I think there is some analogy with the glamour and attraction of the space program. This is all in the making; we are in the middle of it, and it's quite important.

Now, when I told the psychiatrists about the moon program, it was really relatively simple. I wish we could have gotten it at a cheaper price; but then, the price turned out to be relative small. My talk was before the late President Kennedy called for international cooperation in some of the more expensive space programs. As you know, he called for this toward the end of his life. His last major speech was at the centennial of the National Academy of Sciences, and it was entitled, "Science and International Cooperation." Parts of it were reprinted in the weekly journal of the AAAS.

I have pointed out that there are two aspects to the space program in general—and particularly to the program of landing a man on the moon. One aspect is the bringing of scientific literacy to people. No matter how you try, I don't think you can take what in most sciences might be a very exciting point to the specialist and bring it to the public and get them excited about it. There is no personal experience with it. The great appeal of astronomy certainly must be related to the fact that when people look up at the sky, they see stars. Man has wondered about these things. Space has that same interest. The ultimate developments of space, its glamorization, and the accomplishment of great engineering feats at whatever cost, will bring scientific literacy to the public. Don't underestimate the value of that. In my opinion, the business of developing a small group of people who understand science and work in its various fields, and on the other hand leaving the rest of the world ignorant of science, is a dangerous trend. A solution to this difficulty is an important thing.

I recognize in the space program a demand for far more accurate data with regard to collision mechanism among atoms and molecules, the excitation of spectra, and the rate of formation of neutral atoms out of ions and electrons. These are wonderful studies for the physicist, because he can do a lot of nice experiments.

But I come back to what is clearly my favorite subject; I still think that one thing we might buy with large enough programs are those that demand international cooperation; programs that have to be done, and which help develop a peaceful world. Those kinds of programs are coming along. Water development is one of them. Pakistan will have to cooperate in this, even with Israel, if they get thirsty enough. They aren't thirsty enough yet; and this canceled the international meeting on refrigeration, because Pakistan wouldn't give a visa to an outstanding refrigeration engineer from Israel. But if you get thirsty enough, you'll do business with Israel. In time, a scientist from the United Arab Republic will get together with an Israeli. They'll be on the same

[10] Dr. Marsh W. White, emeritus professor of physics, Pennsylvania State University; past Chairman, Interdisciplinary Committee on Institutes and Conferences; and Conference participant.

committee and will work together. Cooperation like this seems to me to be inherent in the space program, and maybe it will be dramatized by the moon program.

It's a lot easier, of course, to cooperate when you're worried about the nomenclature of the upper atmosphere than when you're worried about the ways of digging a hole in the ground and locating oil and things like that.

The way I justified the moon program to the psychiatrists was that "peace is worth $20 billion and then some." They applauded and I sat down. I never did find out if they thought I was really crazy; but that was the answer, and a year later I still think that was the correct answer.

One of the more ridiculous exercises one can go through is to criticize NASA, or the late President Kennedy, or President Johnson, or anybody else, because of the high cost of the moon program, and the impossibility of justifying that cost in terms of the spinoff of technological devices. I'd rather spin off peace.

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PANEL FOLLOWING DR. KAPLAN'S ADDRESS

Robert L. Silber *Educational Secretary, American Chemical Society*

The following panel of interrogators, chaired by Robert L. Silber, Educational Secretary, American Chemical Society, queried Dr. Kaplan after his address: Marsh W. White, emeritus professor of physics, Pennsylvania State University and past Chairman of the Interdisciplinary Committee on Institutes and Conferences; Luke E. Steiner, professor of chemistry, Oberlin College, and chairman, Division of Chemical Education, American Chemical Society; and J. Robert Harrison, professor of zoology, Miami University, Oxford, Ohio, and chairman, Education Committee, American Society of Zoologists.

The text below is a somewhat shortened transcript of the discussion:

MR. SILBER.—Thank you very much, Dr. Kaplan, for this panoramic view of "The Past, Present, and Future of Space Exploration." Dr. Kaplan neglected to bring out in his remarks that in spite of his many activities, he still manages to teach a class of science nonmajors at UCLA. I think that is a real tribute to a great teacher as well as an experimenter.

DR. WHITE.—When one listens to a talk by Dr. Kaplan, hoping to be able later to ask some intelligent questions or to make some intelligent remarks, he finds that he is so intensely interested in the lecture that he has difficulty in remembering that one of his assignments is to comment on the lecture. I have a couple of comments, however, which I believe are pertinent. Dr. Kaplan viewed with some misgivings the courses and curricula concerned with various aspects of space science. He was particularly concerned, I believe, that these courses would attract students away from basic courses in the individual sciences. Now, if a considerable number of bright, young men and women who could be trained in the basic sciences—including, of course, mathematics—are wooed away to begin courses in the space sciences, we may not be doing the cause of space exploration a real favor. I wonder if this statement is in line with your thinking?

DR. KAPLAN.—I really haven't made up my mind. At UCLA there was a proposal in the Institute of Geophysics that a curriculum be established in geophysics, not in space science but in geophysics itself, to the extent of having a Ph. D. in geophysics. Formerly we got all of our geophysics students in other fields such as geology and astronomy; and a man getting his doctor's degree could get it in physics and do his thesis under someone in geophysics, or in an aspect of geophysics which had acquired a good physicist. The same thing could happen to an astronomer or an engineer, and so on. This was the basis on which I first proposed and helped to organize the Institute of Geophysics. The institute has now turned away from that, and I think this is a dangerous trend. I am afraid that the trend may be motivated by the element of glamour. On the other hand, part of my thinking is motivated by a similar trend on the international level. It is good to have a COSPAR that doesn't represent space, or the sciences, as such. So sometimes—as maybe 24 hours from now—I'll be intensely on the side you state. Then perhaps I will indicate that we should have both, and that we should tolerate a few people who want to know a little bit about a lot of things; hopefully thinking that some new approach to science will come out of that.

DR. WHITE.—NASA is depending upon our ability to produce scientists and mathematicians and engineers, for the successful accomplishment of its major mission. Actually, a larger number of these people are needed than we have been able to produce to date. Now we know that to accomplish the NASA mission, the findings of the Killian Committee and various other groups indicate that we will have to have approximately twice as many trained scientists and engineers by 1970 as we have today. Do we have any prospect of doing this? The statistics seem to indicate that we are leveling off in the production of physicists. We certainly are not turning out very many mathematicians, especially at the Ph. D. level; and the enrollment in engineering, we all know, is not only leveling off but has been declining for several years. Do you see, therefore, any probability of being able to meet this manpower challenge?

Dr. Kaplan.—The outstanding young leaders in space science today, most of whom I know both nationally and internationally, did not come out of the so-called space science course. One of the best young men, for instance, in chemical aeronomy (the chemistry of the high atmosphere) is a man who went through the Physics Department of UCLA. He did a chemical kinetic spectroscopy-type problem, with more modern measuring techniques than some of the oldtimers used on a gas related to the outer atmosphere. This gas is nitrogen, which I've used for 35 years to train people. I took him to some international gatherings where he met people whose names he had seen in the literature; and I had him give a paper at an international meeting before he even had his Ph. D. Later he got his Ph. D., and is now one of the leaders in the field. The question now arises, "Can you train many people of that kind?" I believe the answer is "No"—that it's a losing battle.

I started out as a chemical engineer, and I've been on a lot of Ph. D. committees in engineering. I've watched the candidates over a period of about 15 years; and just the other day a man came to me who was extremely interested in high pressures and the affect of high pressures upon water. I listened to the kinds of things he knew—the mathematics he had to use, physics he would have to use, and so on. And I must say that this man skirted around very well on the frontlines of all of these areas. There was a mathematician there, a physicist, and three engineers—and there he was on the frontline of aerodynamics, mathematics, and physics. He was knowledgeable in the kinds of things that during the war Teller and Oppenheimer and people like that did—because at that time, the engineers weren't ready. Now the man I have been talking about is the kind of engineer that NASA is going to be looking to—and you just can't produce that kind of an engineer overnight. So I think the answer is "no," but the goal is wonderful and the net result may even be worth $20 billion!

Dr. Steiner.—It has been a long time since I listened to a speech which has left me as speechless as I am now. I had expected that I would have several questions, but I found that most of them were answered during the course of the address. I do want to bring in a slight change of focus, if I may. We have centered pretty much on subject matter, and usually after I think about curricula long enough, I begin to think about the poor student. Undoubtedly, under such a program as this, there is a great need for technicians, engineers, and scientists. Now, college students have various capabilities; various degrees of interest, and theory, and practicality. The problem, then, is what kind of an education to give them that will be good for a lifetime? Maybe the objective posed by the question isn't so good though, because it is fairly evident that things are always changing. So perhaps one should not expect to educate a man for a lifetime, but to turn out people who can be expected to progress with the changes in life, people who can quickly grasp changes in scientific knowledge, and just as quickly change their points of view, and yet have the resilience to be creative throughout their entire lifetime. The question then becomes, "Should we educate people in the basics, or train for application?" It certainly appears to me that students should be given an education that is as basic as possible. There is an area which was touched upon lightly, but which I find most interesting—and that has to do with scientific literacy. This goes back to what people learn, beginning with kindergarten and sometimes even earlier. I was wondering, Dr. Kaplan, if you could give us your opinion of what kind of science teaching is most appropriate at the beginning levels?

Dr. Kaplan.—I practice a little bit of that kind of teaching three or four times a year to very large groups of junior high and high school students. They are brought together from some 15 schools at a time. I don't talk about specific problems of science so much, but rather try to illustrate various points by talking about careers in science. About 500 students have started in 2 sections in this elementary physics course and some 400 will finish. They will solve problems such as "Derive the pressure formula in terms of the kinetic theory of gases." Solve it, understand it, and have some feeling for the impact of kinetic theory, where one considers the theory of Nature in terms of its ultimate atomic and electrical constitution. At least one good experiment would be to take something of common experience, say the starting and stopping of an automobile. At an early stage of life, the student should be taught some of the quantitative aspects, to build up his knowledge and interest in mathematics. When I was in high school in Baltimore, I was assistant manager of a grocery store. For some reason or other, I got to wondering why things were packaged in a certain way. Then I began to wonder why drops were approximately round and so on. Then I was intrigued to find out that there was a method of mathematics which could give me the answer as to why drops were round. You see the connection there with Nature. Later, when I got to know Irving Langmuir very well, I was elected chairman of a committee of which he was a member. This was a wonderful experience, because he told me of a number of things that he had done because of his intimate love and relationship with Nature. So, I think that you can teach a fairly sophisticated level of acquaintative appreciation if you narrow your sights to one important phenomenon. In Physics 10, I would teach only the kind of physics needed to understand why the specific heat of a diatomic molecule is greater than that of a monatomic gas. The students would understand that well, because heat is around them, and so on. I think it takes a lot of experimentation on the part of teachers.

Dr. Harrison.—You stressed international impact. Why has there been no local or national impact to speak of? I have a feeling that perhaps a lot of what we hear, rather than being intelligent education in a true sense, is really propaganda.

Dr. Kaplan.—Our moon program is essentially for the purpose of national prestige. It would be for a propaganda purpose—and no one, I am sure, even in NASA, would deny that. I think a lot of people would like to find a formula to try to get out of that frame of mind. And I think that we would have done a lot better if we had done the hard, tough experimental work to make our people feel safer, more at home, and relaxed in the kind of world in which they are startled every day by some achievement. We have done very well, incidentally, in communication and educational techniques. Educational television, for instance, is an extremely good tool. We recognize all of these things; and I think that by this time we could have accomplished a lot more in this field and done the Nation much more good from the prestige point of view. I believe that we could accomplish a great deal more, for example, if we could export the techniques of doing away with illiteracy—and particularly in this field. We've done a great deal, and this may come as a surprise to you: there is more interest on the part of science writers in America in getting good science writing before the public than there is in England. Some of our science writing in our newspapers is a lot better than in the *London Times* or the *Manchester Guardian*. And here I used to be under the impression that the only good science writing was in England. There is a lot of good science writing in the United States, and there has been for a long time and will continue to be. So, if I had had my choice, I would have said, "Slow down the moon program"; and I would have moved in on this other problem, the broad problem of scientific literacy. Solving this problem will require a very high order of talent of all kinds—not necessarily of the top levels of the university or the Academy of Sciences, but a high order of talent wherever it may be. For example, you've got to let a high school teacher recognize that he is a great teacher and can inspire the youngsters. And I say give him all the opportunities that I give one of my students to go to international meetings of the American Physical Society, Astronomy Society, and what have you, so that he can learn from a lot of people. Give that to a few hundred or so, or even to a few thousand, high school teachers and see what happens. They will make a point of bringing out what is important and what isn't.

Dr. Thornton P. Page, a member of the audience.—I was interested in Dr. Kaplan's remarks about education. Can't we capitalize on the glamour of astronomy, physics, and so on, in the teaching of science? Why should we be so worried about capitalizing on this?

Dr. Kaplan.—That is a very timely question. I am really not worried about it; I am a little bit concerned. The thing that bothers me goes on in between. The United States is very good at using this glamour, and now, in fact, we have got other countries using it. There is a European organization for space research that's learned this from us. However, I find that practically everyone on the other side of the Atlantic is opposed to this. They are not accustomed to applying glamour tactics to science. They want to stay with the old-fashioned techniques of science. So, what I'm concerned mostly about is not that one approach is wrong and the other's right, as I think we need to take advantage of both. What I'm really concerned about is how to do both in order not to be kicked in the teeth either by my side for not delivering the goods, or by the more conservative people for taking something away from them.

Dr. Page.—Then in regard to our teaching of science at the lower levels, do you agree that this field of motivation is ideal? Is this what you want?

Dr. Kaplan.—I think that this would be perfect, provided you teach good science in response to the appeal.

Dr. Page.—That last comment also deserves a response because, undoubtedly, physics is one of the things that you consider good science. Can you tell me what physics is, and can you tell me how long the term "physics" has been popular? I learned only recently that physicists have been called physicists for less than 100 years.

Dr. Kaplan.—Well, in terms of life as we see it, this is fairly long. The electron was discovered only 5 years before I was born, and consider what has happened since. I think it is a little longer than that. In my own career at UCLA, I felt that the Astronomy Department should be a more than one-man department and I was able to expand into geophysics, and so forth. In the modern university one can get away from departmental lines, but the tendency is not very great. I think you will meet physicists and chemists who are genuinely concerned that the glamour programs do take away from the budget. I have lived with that sort of thing at the University of California since Ernest Lawrence invented the cyclotron. And I would say that the net result of his invention on physics at Berkeley can hardly be said to oe bad. But I also remember when there were those who said, "This glamorous invention will ruin the rest of physics by taking away."

Mr. Silber.—Several years ago, a conference of chemists and physicists was convened to explore the idea of whether or not they could develop a course at the college freshman level that would combine physics and chemistry. This was an interesting experience. At the beginning of the meeting, the physicists sat on one side of the room and the chemists on the other. As each physicist rose to speak, he would say, "now this physics-chemistry course," and when a chemist rose, he would say "now this chemistry-physics course." The conference fortunately was 4 days in length, and by the end of the conference physicists and chemists were speaking to each other—and even sitting side by side. And some were beginning to believe that they might be able to put the two courses together. This points out some of the problems involved, not only within our own discipline but between disciplines. And when we bring all of these disciplines together in a meeting and let them be exposed to other kinds of disciplines or semidisciplines—and then to other aspects of whole problems—then you can begin to see what actually is involved. I think that from this discussion we may have found three basic problems:

1. Where do we get trained people for science, or space-science, and how do we train them?

2. What do we teach?

3. How do we interpret science or space-science programs to the public?

I would like to express my deep appreciation to Dr. Kaplan. Thank you very much. I would also like to express my appreciation to the interrogators, Drs. White, Steiner, and Harrison for their very pertinent questions.

TRENDS IN SCIENCE EDUCATION AT THE COLLEGIATE LEVEL

Allyn J. Waterman *Professor of Biology*
Williams College
Williamstown, Mass.

As has been noted many times over in this past decade, science is enjoying a phenomenal increase in knowledge—both factual and interpretive. So fundamental have been the implications of this increase that many colleges have in recent years begun reevaluations of the educational process at the college level—from the contents of the first science course on through the curricular organization of the department.

A staggering amount of information is flowing down from research sponsored by NASA at its centers, and from universities and private industry. How can this material be handled, and how can it be integrated and synthesized with the science of the past rapidly enough to reach teachers and their students without delay—and without disturbing the educational balance of the liberal arts program? How can the total be presented in the curriculum of today and integrated with the other sciences in cooperative endeavors that may result in mutual benefit? In addition, there are the problems of teacher training and updating, plus the task of taking care of the exploding student population.

To complicate the problem, students are entering college better prepared as a result of the new mathematics and improved science teaching in the high schools.

What are undergraduate colleges doing about this? The trend is for experimentation to find solutions to a host of correlated problems. It is reported that there is a growing tendency for science education to be given at a somewhat more specialized and sophisticated level, with more quantitative overtones and accompanying interpretation, than used to be the case; for more integration between the scientific disciplines; and for the material of science to be presented in such an interesting and dynamic fashion that it has appeal for even the nonscientist.

Rather than speak in generalities of the trends in science education, I have selected a number of descriptive examples for presentation in the hope that these may focus attention upon actual phenomena in the educational revolution in science teaching. This survey is not complete, nor in the time available is it intended to be. Almost any one of the following topics deserves all the attention we can give it. If this paper has a biological overtone, I hope you will overlook it. After all, the educational problems of one science are the problems of any science; and I am better acquainted with those in my own area.

Curricular Revision and Changes in Course Content

Many educational institutions are currently engaged in curricular revisions in the general area of undergraduate science, while others are interested in and aware of the need for reevaluation but have not yet made the initial moves. Biology, for example, is in the throes of a revolution as well as entering upon an era of unprecedented productivity. Modernization of the biology curriculum, and of any science for that matter, is a pressing necessity. The experimental programs now being studied are based on new standards attuned to the times.

A stimulating development, still in its initial stages and subject to modification in the future, is the intermediate level "CORE" program for all students—irrespective of specialty. It is felt that future scientists need a common store of knowledge and skill within their specialty beyond that ordinarily expected of undergraduate majors. The so-called CORE program may consist of two-or-more-year courses beyond the first, or introductory, course—to be taken in sophomore to senior years, and around which are arranged elective courses. There is much discussion in progress in some disciplines as to the constitution of the CORE program.

CORE programs in biology are in existence in a number of institutions across the country, including Chicago, Harvard, Johns Hopkins, Purdue, Stanford, Wesleyan, and Williams—just to mention a few. At two conferences—one held at Berkeley, Calif., last February with representatives from most of these institutions and the other in St. Louis, in May, with participants from many colleges and universities, under the auspices of the Commission for Undergraduate Education in the Biological Sciences (CUEBS), the CORE curriculum, and introductory courses in biology were discussed.

The following lines are quoted liberally from a report prepared by Prof. Carl Swanson [1] of Johns Hopkins at the Berkeley conference:

"New concepts, approaches, techniques, and instrumentation have drastically altered the structure of science: its image is characterized by change rather than stability. The rate of change, in fact, is so great that, except in a few universities (and colleges), the emerging ideas rapidly outmode and outstrip the physical facilities for teaching and research (let alone the supply of teachers). How to handle a student population eager to learn and to be a part of this scientific revolution; how to train teachers of the future as well as to update present teachers overwhelmed by the volume and developing intricacies of their subject areas; and how to realine biology with chemistry, mathematics, and physics which themselves require a different kind of training and performance by both teacher and student, are topics being discussed by teachers, administrations, education committees of the biological sciences, commissions appointed by the sciences, American Institute of Biological Sciences, and others."

According to Dr. Swanson, "Adequate curricula must reflect the sense of progress which currently infects biology as well as the current state of factual knowledge, if student enthusiasm is to be properly sustained. The new curricula presented at the CUEBS Conference place a greater emphasis on the unity, and less on the diversity, existing among organisms. This has resulted in a reduction in the number of course offerings and the substitution of a CORE program designed to guide the student, in integrated fashion, from the level of molecular organization to those of populations and organismal behavior. Characterized by a sequential ordering of content material, organisms are not surveyed in a phylogenetic sense, but analyzed as appropriate examples of the phenomena of biological organization under scrutiny.

"The need for revised curricula and the pertinence of CORE programs stem from the changing character of biology as a whole. As a result of this changing emphasis in content, stress is placed upon, but not limited to, cell biology, biochemistry, and molecular genetics. Programs differ in organization, their beginning and their ending, but all encompass the same general material in presenting the student with a sound knowledge of the current dynamic state of biology.

"The establishment of CORE programs has inevitably altered the teaching structure of biology departments. The phylogenetic survey has become dispensable at least at the elementary level, and its place taken by courses which require a more substantial preparation in chemistry and physics. In certain introductory courses, particularly those in which nonmajors are not segregated from the majors in biology, the necessary background in physical science is presented along with biology. The old morphology, systematics, and phylogeny have been minimized, dropped, lost their identity through merger with other courses, or been shifted to more advanced, elective, status. Much duplication has been eliminated. Along with this there has been noticed a greater sense of unity among participating staff, broadening of staff interests, more flexible teaching procedures as well as contact between staff and undergraduates, and improved laboratory exercises. Undergraduate students have been much more strongly stimulated, and their exposure to biology has been immensely richer and more rewarding. The increased en-

[1] Swanson, Carl. *Undergraduate Curricula in Biology.* Unpublished report of a conference held at Berkeley, Calif., Feb. 21–22, 1964, under the auspices of the Commission on Undergraduate Education in the Biological Sciences. Dr. Waterman is a member of the Commission's Panel on Instructional Personnel.

rollments give evidence of the signficance of these changes to the student.

"The introductory courses in these CORE programs are felt to be on the whole superior, and equally well adapted for any student, irrespective of his interest or field of major. The public image of contemporary science, as conveyed, for instance, by the more ambitious magazines and newspapers, calls for modern and substantial curricula in schools of higher education. This need is even more urgent than in the physical sciences, if only because the general public is just beginning to appreciate the significance of biology in contemporary society."

Another type of reorganizational phenomenon in progress among biology departments, probably less so in the physical sciences, is that of course consolidation. This is happening in biology to courses such as comparative anatomy and embryology (the more descriptive courses), and also to the separate disciplines of elementary zoology and botany, to form integrated courses through these mergers. Probably such changes foreshadow more profound curricular modifications.

Undergraduate Education in the Sciences

In *Science Education News*[2] for December 1963, published by the American Association for the Advancement of Science, there is a report of what some of the groups organized by national scientific societies, under National Science Foundation support, are doing in the area of undergraduate education. Among these are, to summarize:

1. The Committee on Educational Policy in Agriculture has recommended a model baccalaureate curriculum in agriculture which includes basic sciences, social sciences, and humanities; as well as instruction in agricultural fields.

2. The Commission on Undergraduate Education in the Biological Sciences—CUEBS, of which I am a representative—one of the two commissions most recently established for the study of undergraduate science programs, has as its primary purpose the encouragement of significant curricular experimentation. A changed and changing biology is emerging and this "modern" biology is as yet imperfectly represented in too many college curricula. The result appears to be a growing "disparity between the actual condition of the discipline and the image of it in many classrooms."

The Commission is turning its attention to an identification of the problems that must be solved in order to meet the difficulty just mentioned, and will develop plans for solving this problem. It is considering the introductory biology course, education of biology teachers, summer institutes for college teachers, ways of assuring adequate training in physics, chemistry, and other fields to students studying biology at the freshman and advanced undergraduate levels, better ways of teaching biology to students who will not make it their area of specialization, and other matters. I am currently engaged in organizing a summer institute for college teachers of the first course in undergraduate biology to be given in the summer of 1965 at Williams College.

3. The Advisory Council on College Chemistry came into being to improve undergraduate instruction in chemistry and to facilitate communication of the importance of good teaching and good teaching ideas in this field. Initial activities have sought to stimulate experimental programs and to seek support for such work, to provoke discussion of the problems of large freshman courses, teacher development, development of courses in science for nonscientists, teaching aids, the curriculum and advanced courses, the graduate student as a teaching assistant, and other areas.

Much is being currently carried on in the field of chemical education by the American Chemical Society through its headquarters staff, its board and Council Education Committees, and its Committee on Professional Training; and through the activities of its Division of Chemical Education. Information is disseminated through the *Chemical and Engineering News*, the *Journal of Chemical Education*, and the ACS News Service.

4. The Commission on Engineering Education operates under the direction of leaders from education and industry. Its three major committees are primarily endeavoring to stimulate the best ideas and encourage their development, to increase the capabilities and efficiency of engineering faculty, and to improve educational methods and materials. The Commission is cooperating with other groups, such as the Committee on the Undergraduate Program in Mathematics, and the Agency for International Development.

5. The Association of American Geographers is concerned at present with the improvement of

[2] *Science Education News*, "Undergraduate Education in the Sciences," December 1963.

college undergraduate geography courses—particularly as they pertain to liberal education, and the reorganization of programs to bring them up to date with modern developments in the field as well as with changes in modern education as a whole. This project represents the first organized effort at the national level to evaluate the role of geography in undergraduate and general educational programs. A national conference will be held, followed by a number of regional conferences to discuss a variety of topics.

6. GEO-Study (Geological Education Orientation Study) is an enterprise of the American Geological Institute supported by the NSF. Its objectives are to analyze the present status of education in the geological sciences, to identify significant trends and develop new ideas and concepts for improvement of geological education, to provide guidance by predicting changing requirements, to consider ways and means of aiding faculties to meet changing requirements, and to effect the broadest possible involvement of the geological profession.

It is planned to establish a Commission on Education in the Geological Sciences as an action agency of the profession to encourage fruitful developments and experimentation in undergraduate geological education. A steering Committee has recommended immediate establishment of panels on interdisciplanary cooperation, professional development, role of geology in liberal education, and content and sequence of courses for the major.

7. The Committee on the Undergraduate Program in Mathematics (CUPM) is an action committee of the Mathematical Association of America. With financial support from the Ford Foundation and the NSF, the Commission is working through five panels; i.e., Teacher Training, Mathematics for the Physical Sciences and Engineering, Pregraduate Training, College Teacher, and Mathematics for the Biological, Management, and Social Sciences. The work of the panels has consisted largely of conferences leading to a set or sets of recommendations and course guides describing desirable college mathematics curricula for the area represented by the panel. Reports of some are available.

This year CUPM will attempt to produce a recommended general mathematics curriculum for a contemporary liberal arts college. Information has been spread by publications, and meetings of the Mathematical Association, the Bureau of College Consultants, and the NSF Institutes for Sciences and Mathematics Teachers. It has also employed various devices to encourage, support, or commission the writing of experimental text materials in certain areas where commercial texts do not exist.

A new Advisory Group on Communications has been formed. Several factual surveys have been conducted: production of Ph. D.'s in mathematics and their undergraduate origins, mathematics course offerings in colleges, and the current state of mathematics in the colleges. The Consultants Bureau visits colleges and discusses matters of curriculum, library holdings, recruitment of staff and students, and so on, with mathematics departments and administrations.

8. The Commission on College Physics, established by the American Association of Physics Teachers, is dedicated to the improvement of undergraduate instruction in physics at all levels from the introductory course through the senior year of the physics major. It recognizes that such improvement can be made only by departments and individuals responsible for physics teaching, and that major action must come from colleges, universities, and professional physics organizations; and so considers its own function to be that of acting as a "nerve center" for curriculum development.

The Commission is preparing a set of detailed outlines of physics courses for general educational value, encouraging study of a 1-year introductory physics course suitable for scientists and engineers, and stimulating thought about one or more course developments in physical science for persons who desire college experience in this subject but who have very little mathematical preparation. It is cosponsoring a national conference to explore the problems and possibilities inherent in Curriculum S, a curriculum proposed to provide courses beyond the introductory level for undergraduates who have goals other than that of being a professional physicist, one which publishes a newsletter, and one which is concerned with teaching aids such as college-level physics films; and is preparing a series of paperbacked books for supplementary reading.

Independent Study, or the Honors Approach

Independent study or honors programs are receiving much attention. These vary in different institutions, but all have in common the principle of special study for the strongly motivated, superior, or even the hardworking student. They may dominate the junior and/or senior year, take the form of honors courses or an honors thesis, and even be initiated as early as the freshman year. In the 11th edition of the series, *New Dimensions in Higher Education*, 1963, U.S. Department of Health, Education, and Welfare,[3] there is explored the "potentialities of honors programs and of the honors approach in relation to high-ability students who are preparing to teach. It is recognized that honors programs in general are distinguished by the breadth, depth, and sense of inquiry which are considered important elements in working successfully with students whose talents transcend the average."

Actually the honors program is not new; it has been employed in colleges and universities for several decades in one form or another. Dean Lindley Stiles of the School of Education, University of Wisconsin, considers honors programs as possible "cases of excellence in the dry and strife-torn deserts of teacher education." [4]

Changing Methods of Instruction

In the face of developing shortages of well-trained teachers, there is evolving deep interest in audiovisual facilities as a means of relieving faculty shortages, and there is an increased need of physical facilities to care for an expanding student population, the instructional load of the instructor, and other necessities. The use of closed-circuit television for expanded lectures and lecture-demonstrations has been effective. From talks concerning ways of increasing the student's responsibility for learning a greater portion of the course content on his own has emerged the audiotape for use with an adequate laboratory manual, "automated" lectures stored on audiotape for loan to students through the college library—even accompanied by visual displays for parallel projection, and the "teaching machines" and "programed textbooks."

One advantage of these techniques is the availability of material to students on more than one occasion. With some of them, the type of material must be very carefully selected; and they are most closely applicable to factual and descriptive material which does not require "live" instruction. They all place greater responsibility upon the student and in turn permit the teacher to reach more students with routine material, utilizing his teaching effort more productively.

Scientific Communication

There is developing an acute literature information problem in the different areas of science. This has been recognized by the AIBS, the Cooperative Committee for the Study of Science and Mathematics, and other commissions; and committees have been appointed to recommend action. Studies are being made: (1) of the development of specialized information centers for the storage and rapid retrieval of information in specific areas of science, along with the application of automation and mechanization as related to storage and retrieval; (2) to improve the flow of fundamental and applied information from the research center to the student and commercial user; (3) to coordinate with other groups working in the communication fields, for the purpose of devising ways of cooperation in more effective dissemination of information.

Science Education for the Nonscientist or Nonmajor

Increasing concern is being shown over the new demands of education concerning the kind and amount of education in science that should be given to those who do not plan to enter scientific careers. As reported in *Science Education News* [5] of the AAAS for December 1963 . . . at one of the recent conferences on science for the nonscience concentrator, Dr. Gerald Holton of Harvard's Department of Physics said he favored a "specially developed, hard-hitting, substance-centered physical science course combined with mathematics—one which uses major formative cases in the development of physical science as a skeleton on which to base case studies in depth." This might help the student to "find his talents, become at home in his universe, understand his relations to his fellow men, see where we stand between our past and our likely future, and become more certain of the functions of knowing and believing."

Any other field of science could use these same words; they do not apply peculiarly to physics. Actually what is wanted for the future scientists at the undergraduate level and what is wanted for the nonscientist is said not to lie too far apart

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[3] Haswell, Harold A., and Cornett, R. Orin. "Talent and Tomorrow's Teachers, The Honors Approved," *New Dimensions in Higher Education*, Foreword, No. 11, 1963, pp. V and VI.

[4] Stiles, Lindley. "Oases in Excellence," *New Dimensions in Higher Education*, 1963, pp. 65–69.

[5] Op. cit., p. 1.

basically; the problem is to reach some accord on content.

Science Education News goes on to say that the undergraduate of our crowded century might make use of science subjects to sharpen his individual talents, if courses were written to disclose the intellectual appeal which science has for scientists and if the sciences were shown to the undergraduate in their proper aspect as adventures of the human mind. Several commissions appointed by their societies have this problem on the agenda.

At a conference on chemistry for nonscience majors, supported by the NSF and sponsored by the Division of Chemical Education, the conclusion was also reached that "such a course should be rigorous, with every effort made to limit the number of items covered so that those included could be studied intensively. It must be organized and taught in such a maner that a student will develop curiosity, will acquire a reasonable amount of chemical information, and will be required to exercise critical judgment."[6] Modern first-year science courses are developing along these lines.

Mushrooming Subject Areas

There are particular areas of the individual scientific disciplines that have muchroomed during the last decade, ever more so in the last 5 years. This tendency may augment in the future rather than decline as knowledge continues to accumulate in peculiarly active areas, and this poses certain problems for the curriculum. One example is well illustrated in biology by the subject of animal behavior. Many schools are hiring people specifically trained in this area. There is also the tendency for those offering full programs in animal behavior to unite with those teaching similar topics in the fields of phychology and physiology.

Textbooks

Teachers tend to follow the available textbooks, and other teaching materials. When these are slow to emerge, then it is only reasonable to expect that the alterations of perspectives of a science as well as of curricula, course content, and instructional techniques will filter through educational circles all too slowly.

Without textbooks paralleling new developments for the teacher to use as a basis and teaching guide as well as a source of information, such corrective and improved measures presented in institutes and conferences for updating teachers will meet only a portion of the problem and also reach too few teachers. For example, there exists at present a wide gap between the classical approach to biology as taught in many schools, and still making up the bulk of material in many textbooks, and the fascinating new developments, principles, and concepts filtering down from the experimental laboratories of universities and research institutions. Nor do recent college textbooks, on the whole, help to bridge the gap between the improved teaching of modern biology in the high school and the contents of the first course in college biology.

Subject material considered previously to be the prerequisite of the university may now even be included in college courses, if not in high school science. The more progressive high schools often supply the same or even a more advanced background than was formerly given in general science or first-year college biology courses. Enormous differences exist in this respect, with some high schools at the average college level and some colleges probably not a great deal better than the progressive high school level. Institutions of higher learning are faced with the fact that entering students from high school may have a more up-to-date knowledge of modern science, a development which is making the former scrutinize their curricula and particularly the contents of the first course.

There are enormous differences in the way textbooks are used by teachers. A case is cited where a biology textbook, used mainly for a 1-year college course of biology at freshman or sophomore level, is also adopted by some high schools; while in some colleges that same text is considered far too advanced for undergraduates. In one case at least, it is used as the basis for the Ph. D. examination. While there is a tendency for educational commissions to encourage textbook writing in areas not covered by commercial activities at the college level, they produce little writing themselves.

First Course in a College Science

There is no general agreement as to what constitutes the best freshman-sophomore course in any science. The contents of such courses are changing as science teaching in the high schools improve, and as more knowledge moves down from upper

[6] Garrett, A. B., *et al.* "The College Chemistry Course for Nonscience Majors." *Journal of Chemical Education*, Vol. 38, No. 5, June 1961, pp. 253–254.

courses. In turn, this is provoking a closer look at college curricula.

It is reported in the *Chemical Engineering News*[7] that "the quality of the background of students enrolling in first-year college chemistry courses in the United States is generally better than 5 years ago as more and more teachers have taken advantage of the programs supported by the National Science Foundation." The widespread use of the materials developed by the Chemical Bond Approach and the Chemical Education Materials Study groups will provide more entering undergraduates with better backgrounds in chemistry. Similar programs in mathematics are bringing in students with introductory calculus or prepared to study calculus in the freshman year. The undergraduate college must be prepared to take advantage of these developments.

In biology, the Encyclopaedia Britannica Film Series covers five major areas of ecology, heredity and adaptive change, plant life, animal life, and physiology at the high school level. The textbooks developed by the Biological Sciences Curriculum Study (BSCS) are complete in themselves and are based on the assumption that for most high school students this may be their only formal acquaintance with the subject. There are three versions, emphasizing: the molecular, the community and population, and an up-to-date approach to the whole of biology. The AIBS Film Series also contributes to the improved teaching at this level.

These programs, along with the general updating of high school physics, have made it possible for colleges to give more advanced material in the first-year science courses. Topics taught previously in upper courses are being introduced into the lower level course, and in some sciences the laboratory experiments are becoming more quantitative. Here is where interest in a science is often stimulated.

First-year science courses in college are organized in a variety of patterns and taught in different ways, depending upon the interests of the institution and its staff. A new type of biology course is developing, one that combines elementary courses previously specialized for particular student interests, and is organized along the lines of modern biology. Faculty members of a whole department may be involved in the course, both lecture and laboratory, and each instructor covers his own speciality. While varying somewhat from one institution to another in the subjects covered, these for the most part may include: organismic and systematic biology, cell physiology, reproduction and development, molecular or microbiol genetics, biochemistry, plant sciences, ecology, cytology, population studies, and evolution. Animal behavior may be included.

The first-year course offers a special challenge in several respects: it may not only be the single experience in the science for some undergraduates, but there is a tendency now for well-qualified students to bypass part or all of it through advanced placement procedures, excellent scholarship record, or special examination. The latter is favored in institutions with "CORE" or stem-sequence curricula, where the student may enter upper courses directly. Some favor the elimination of this biology course entirely.

Interdisciplinary Studies

Here is a peculiarly difficult problem, complicated by already crowded schedules of the students, along with the uncertainty as to how far a specialization in two sciences ought to go. For example, how much biology should be included in the program of the future biophysicist or biochemist? There is a growing need for interchange of information and background experience, especially in borderline areas.

As mentioned above, the establishment of CORE programs in biology has altered the teaching structure of departments, with certain courses being replaced even at the elementary level by others requiring a more substantial preparation in chemistry, mathematics, and physics. In the modern biology courses, even in those in which nonmajors and majors are not segregated, the necessary background in the physical sciences and mathematics is presented along with biology. Questions are asked such as: should biochemistry be taught by a biologist or by a biochemist? Should the biochemist be a member of the biology department, the chemistry department, or another department to include biochemists and biophysicists? There appears to be a tendency for the necessary physical and mathematical materials to be given by biologists with such training, rather than by joint appointments with these departments. Biochemists may be encountered commonly in

[7] "Modern Texts are Needed to Update College Chemistry Courses; Freshmen Often Ready for Quantum Chemistry, Thermodynamics," *Chemical Engineering News*, Vol. 42, No. 7, pp. 42–44. Feb. 17, 1964.

biology departments, where as biophysicists are not. A need for the latter is developing.

Particularly difficult is the problem arising from the apparent tendency of scientists in one discipline to persist in the belief that what is good for their majors is also good for any science major. A biologist must follow a program culminating in a year of organic chemistry (often preceded by 2 years of chemistry), and he also needs math and physics (probably more than he usually can get into his program). These courses are generally set up for majors in those respective departments.

How to give biology students the necessary physical science and mathematical experience in a reasonable period of time and still maintain the balance of the liberal arts program is a problem which is far from solution. Instead, it is becoming more difficult to solve—with the changing emphasis and rapid accumulation of knowledge. The problem is said to be even more acute when one considers the education of secondary and elementary teachers who will teach science.

Faculty Research

It is generally recognized that there is no dichotomy between teaching and research; that there is no better way for a scientist and teacher to remain active and abreast of developments in his field and up to date in his teaching than to participate in research. Some college administrations have learned, or are learning, this fact and are encouraging their faculty by reducing teaching loads as far as possible.

Outside help for research is now available to college teachers from the national foundations, and some departments have modest funds for this effort. Large student enrollments, too many courses assigned to one teacher, low budgets, lack of facilities, and other factors—both administrative and personal—have restricted such activity.

Today teacher updating is one of the most pressing problems facing education, and one which is being vigorously attacked by foundations, educational committees of the scientific societies, and other types of organizations. In experimenting with curricula and course content, there is always the danger in the college or small university of losing sight of this primary problem.

Conclusion

Your attention has been called to several of the major current trends in science education at the collegiate level, to the variety of different groups interested and active in this area, and to factors responsible in one way or another for these trends. The listings are not complete, nor are they intended to cover all facets of the problem. Scientists and educators recognize that science education at all levels—from the intermediate to the collegiate—needs improvement to keep abreast of the changing times.

We should all ask ourselves: "What should we be doing to further the change?" The problems are known; specific solutions for some of them have already been instituted in educational programs or are in the experimental and blueprint stages. Many interested scientists and educators are already involved both at the experimental level and in the effort to bring about more concerted and widespread action. Reading objectives of the various educational committees and commissions, and of specially appointed groups, one is struck with the common general purpose running through all of their reasoning. To read one report is to read them all. There is not unanimity, nor should this ever be expected, considering the diversity of interests, backgrounds, special teaching problems, materials, and types of training. But all are seeking to identify significant trends, to develop new concepts and programs for improved teaching, to encourage more interest so more people can be involved in quicker time, and to bring about cooperation and interdisciplinary action among the sciences and institutions as well as between scientists and educators.

NEW PROGRAMS AND DIRECTIONS IN SCIENCE EDUCATION AT THE SECONDARY SCHOOL LEVEL

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Overview.—During the century 1840–1940, science—either directly or through related technology—brought about a revolution in circumstances and conditions of living in man's relationship to Nature and to the universe. In the period since 1940, the rate of change has been explosive. The mind of man has penetrated the nucleus of the cell and the nucleus of the atom, and man himself has loosened the bonds of gravitation and entered space.

The vistas of the conceptual sweep of modern science have been caught in the following quotation from Dr. Warren Weaver,[1] of the Alfred P. Sloan Foundation:

> ". . . we are just in the process of gaining a scientific picture of the total ascent of life. By far more vast and significant than the Darwinian view, this modern evolutionary doctrine begins with the elementary particles of the nuclear physicist and moves through the whole range of the atomic and molecular world up to the nucleic acids which, in their capacity to reproduce pattern and to pass on coded information, seem capable of forming the primitive basis for a living organism. From this point it is conceivable to move on to the gene, the chromosome, the cell, and ultimately, human life. Whether or not man is the present climax of this ascent is itself now under question: we have radar-listening devices, directed at inconceivably distant parts of the cosmos, seeking to determine whether there are other and possibly more advanced beings there, trying to communicate with earth-bound man.
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> "When the sights are set as high as this, the view transcends all the compartments of science. This is not, in any exclusive sense, physics or biology or chemistry or astronomy. This is the whole of science, engaged with a problem of majestic dimensions.
>
> "The sweep and the depth of such a view of matter, man, and the universe fairly suggest what science really is—not a trivial business of tricky hardware, not the phony bubbling retorts of the advertisements, not strange men with white coats or beards, but the response, at once poetic and analytical, of man's creative mind to the challenge of the mystery of matter and life."

Broad Purposes of Education in Science.—The reform movement to improve the teaching of science in the schools of the United States has grown out of a deepening awareness on the part of many people of the basic role of science and technology in the present and future welfare and security of the free world. To safeguard these for the future, quality education in the sciences becomes imperative and mandatory.

It would seem that the following purposes guide and motivate all phases of the reform movement in science teaching in the United States:

1. To provide an education in science for all citizens that will insure a level of scientific literacy commensurate with the demands placed on the society by science and technology.
2. To provide specialized education in science

[1] Weaver, Warren. *A Great Age for Science.* New York, Alfred P. Sloan Foundation, 1961.

for those who will constitute the creative scientific and engineering manpower for the future.

3. To provide full educational opportunities for the pursuit of science as a humane endeavor in a society in which it plays a significant role.

The movement to improve the teaching of science in the schools of the United States has been charted largely in terms of the broad purposes stated above. Implementation has been directed toward providing a supply of excellently educated scientists, engineers, technicians, and retrained workers, as well as toward raising the level of scientific literacy of all citizens.

The Public Understanding of Science.—The public understanding of what science is, how it operates, and the circumstances which make it prosper, has become increasingly important as its influence in the lives of people has increased. As has been pointed out previously, science has become so heavily involved with major political and social issues of the day that for a citizen or his representative in government to vote with wisdom, there must be some understanding of science and the scientific enterprise. The citizen must understand science so that he can "use" its processes of inquiry, methods, and attitudes to help him make intelligent decisions in all aspects of living. In short, science needs to become more a way of life with all people.

The basic reason for understanding has been well stated in the following quotation by Dr. Warren Weaver:[2]

> "All citizens would be given a richer inner life if they could have a chance to appreciate the true nature of science and the scientific attitude.
>
> "For science is not technology, it is not gadgetry, it is not some mysterious cult, it is not a great mechanical monster. Science is an adventure of the human spirit. It is an essentially artistic enterprise, stimulated largely by curiosity, served largely by disciplined imagination, and based largely on faith in the reasonableness, order, and beauty of the universe of which man is a part."

Providing Science Manpower.—The basic elements upon which estimates of the scientific manpower needs of the United States are based lie well within the scope of our national welfare and security. The United States has sustained an economic progress that is based on the unprecedented rate of growth of scientific research and development since World War II. This progress has occurred in the face of an expanding population, increased competition in world trade, and higher living standards—all of which have demanded further developments. During this transition to a technologically based society, the scientifically literate as well as the scientifically illiterate have called for advancement in the field of medicine. Problems in chronic disease, disability, mental health, aging, and environmental health have received and will continue to receive increased attention.

The world has witnessed apprehensively the extensive and sophisticated research and development for military purposes. Further demands on the science manpower pool of resources have been made by the complex nature of space exploration and the advances in the uses of atomic energy.

Educational institutions in the United States have felt a shortage of qualified instructors in certain fields of science and engineering becoming acute as the postwar population bulge enters college. It was not long ago that management in industry and government relied mainly on people trained, or with experience, in business, law, or finance. Today, with developments in science and technology changing the shape of industry and government, and with the policies of industry and government affecting the course of science and technology, management has demanded its share of people trained in science and engineering. These problems, among others, have brought about national challenges; challenges that create urgent and accelerating requirements for a scientific and technical manpower.

Emphasis on Quality and Excellence.—In implementing reform in science education, there has been a strong emphasis on reform to get a product of excellence from the secondary schools. This emphasis has necessitated a reexamination of some of the elements that constitute quality; and then an attempt to find the weaknesses in the traditional materials and procedures which failed to reach the newly defined standards of quality and excellence.

There seems to be fairly general agreement among the scientists and school personnel who have produced the new resources for reform that the older view of merely purveying information *about* science is no longer acceptable. There is evidence to indicate that today the view is widely accepted that science at all levels must be learned firsthand,

[2] Ibid., p. 64.

and that its *process* element is as important as its *product* element. It seems reasonable to believe that to reach the level of quality and excellence desired, the pupil must have continuous opportunity in the classroom to practice the intellectual skills associated with the various processes of inquiry in order to conceptualize the content of science.

The growing concern on the part of those responsible for producing new resources for reform in science teaching, with an emphasis on the process element of education, has resulted in an elevation of laboratory or practical work to a new level of importance in science teaching. Some of the old recipe-following procedures formerly used in laboratory teaching have given way to a newer emphasis on open-ended problems, whereby the student goes into the science laboratory with a problem which challenges his interest perhaps more than verifying the specific heat of lead or the coefficient of linear expansion of brass as in an earlier day.

Few directions are given the student. He is expected to propose reasonable hypotheses and then proceed to design and carry out a controlled experiment to test his belief. As this investigation develops, the teacher may ask the student to state the assumptions which lie back of any inferences he has made and perhaps to repeat the experiment under other suggested conditions. The results of the experiment may be inconclusive and may lead to further experimentation.

Without further elaboration on classroom techniques, it is evident that such an emphasis on firsthand experimental work demands that laboratory time be flexible. It is also evident that if time is to be provided to propose and test hypotheses, to go perhaps down a blind alley to a dead end and then back out to take a fresh look and a new approach, the old ground-to-be-covered concept has to be modified or more time provided for the laboratory study of science. In the majority of science classes, the trend has been toward teaching fewer science concepts in greater depth.

The Role of the Teacher in Implementing Reform.—The reform movement in science in the United States was confronted at the outset with the problem of updating and improving the background preparation of the teachers of secondary science. In 1953, some of the first supplementary training programs for secondary school science teachers were started, with support by the National Science Foundation. This endeavor, along with other efforts to improve the quality of science teaching, is so indispensable and easily one of the most important factors in the implementation of reform in school science that it will be discussed in greater detail later.

Local Action: Key to Reform.—U.S. Commissioner of Education Francis Keppel remarked in a recent address:

> "We must recognize first of all that the quality of education depends upon what happens to individual students in individual classrooms, and that the actual improvement of our schools is initiated and supported through local action and as a result of individual attitudes. At the same time, we must recognize that the educational enterprise is a public trust and a public responsibility, and that the answer to finding ways to finance its improvement lies in concerted public action. In private institutions as well as in public ones, this concerted action is a composite of individual concern, individual effort, and individual action."

Reform movements which have made lasting impact on public education usually have been closely associated with local schools. The production of courses of study in science is one example.

Practically every State has produced a course of study or study guide for each of the high school sciences. Many also have courses of study for the junior high school and for the elementary schools. In many school districts of a State, especially those comprising small towns and rural areas, the State course of study in science is used as a guide to instruction.

On the other hand, in urban and suburban areas, and in consolidated school districts, it is common practice to use local courses of study or curriculum guides in science and other fields. These guides are usually prepared by selected teachers working as a committee with a local supervisor or curriculum consultant. In such cases, the State guide may be used as a model, or the endeavor may be carried out quite independently.

While models and guidelines for various reform movements may be produced by groups of experts, such endeavors make an impact only as they are accepted by local school administrators, supervisors, and teachers, and finally modify the day-to-day classroom activities of the teacher.

Summary: Problems and Issues—Trends and Outlook.—How does one differentiate between problems of the future and issues of the present? How can one identify and separate those trends which hold promise from those which do not? Hans Margolius once said, "Only in quiet waters things mirror themselves undistorted. Only in a quiet mind is adequate perception of the world." Certainly those who are deeply and directly involved in the present reforms would have a most difficult task if asked to be impartial in predicting the role to which history will relegate their efforts.

It is clear that a revolution is taking place in education in science and mathematics in the United States. There is heartening evidence that this reform is spreading to the humanities and the social sciences. As this revolution is complex and involves all levels and disciplines, as well as all the aspects of the social and educational structure, no categorization of the concomitant problems, trends, and issues can prevent a great deal of overlapping. Categories relating to the public (the average citizen), the materials of science, and the professions (relating to personnel most intimately involved) have been used.

The Public.—Any problems relating to the average citizen in a democratic society can be attributed in part to the relationships of the people to the educational system, inasmuch as the goals of education in general are determined by the needs, hopes, and aspirations of that society. However, certain problems seem to center currently with the public in general—and through the public are reflected in the school. It should be the whole of society, through its philosophers, scientists, artists, political scientists, inventors, and other thinkers, that ultimately determines the goals and ends of education for its members. Ordinarily, education and educators cannot create these goals; they can only implement them. In these times of rapid change this fact must sometimes be reiterated, for there are those in the United States who sincerely seek improved education for their fellow citizens, but at a more rapid pace than it can be achieved, even through the current dynamic reform movement.

Two near-opposites in public reaction constitute one of the most pervading problems in efforts to improve science education. While on the one hand, too many people simply do not care whether the school science program is updated, others will vehemently insist that their local school is using a "modern" course, react as though a complete revolution has been achieved, and be complacent about any continued improvement. Change for the sake of change, with too little regard for proved quality and demonstrated worth, guides too large a portion of those in positions of responsibility at the various levels in the education structure.

The secondary school level was the first to be attacked in the current movement. Probably this was due mostly to the fact that this is the first level at which the disciplines are taught as separate courses. It became immediately evident that, in order to be most effective, such change should involve all levels. However, such wholesale changes are simply not likely to be accepted by local-level teachers, administrators, and citizens. It is one thing to say to local school people that, for example, their high school chemistry needs complete revision, and quite another to say, or even intimate, that their entire structure, 1 through 12 and beyond, might need careful scrutinizing and revision. Even though those intimately involved in the reforms are convinced (by their direct experience) that broad, all-level reform is needed immediately, two things preclude such a possibility. First, the personnel for such a job are simply not immediately available, and secondly, almost all schools and districts must, to a certain extent, go through their own stages of trying limited reforms in order to be convinced of the broader needs.

Of every 10 youngsters now in grade schools in the United States, 3 will not finish high school and only 4 will continue their education past the 12th grade. In 20 years, the six who have a high school education or less will outnumber at the polls the other four. Scientific literacy among the adult population is highly praised but poorly defined. What constitutes the best science education for the majority who will not go on to college? Although the literature abounds with documentation of educational strife on this point, no clear answer is now evident. Meanwhile, 26 million young people will terminate their education in the coming decade. How best to educate them, to the best of the Nation's ability, to live in the unknown world of 1985, is today one of the most urgent problems facing the Nation's professional educators—scientist as well as educator.

Materials.—The need for greater numbers of capable scientists to become involved in the creation of new materials for science education of both school and college level is acute, but lethargy and lack of dedication to such "school work" still cause

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scientists to remain aloof in their research citadels. A number of new courses and curricula designed to take advantage of the new preparation afforded school students are being developed and tested at various colleges and universities, and many of these and others to follow will be made available to other institutions. The scientific communities are all concerning themselves more and more with mechanisms, such as special written materials, equipment, and aids to instruction by which college faculty can keep abreast of modern developments in their fields.

The Professions.—Much has been written and spoken about the dichotomy of scientists (and other subject matter specialists) and educators (professional pedagogists) which developed during the past four decades. The improvements which have been made thus far have resulted from joint endeavors by scientists and educators as this dichotomy is fast being delegated to history.

The most important aspect of the revolution is probably not the new courses themselves—they will be superseded before long—but the new attitude of the scientific and teaching communities toward science education. Courses in science are now regarded as a proper subject for research and development by both of these communities, and many capable people including some of the Nation's best minds are willing to devote time to carrying on such investigations. As students come better prepared from the elementary schools, new opportunities and obligations will be created for the high schools and, similarly, for the colleges.

There is an immediate need for basic redirection by many of those who have been concerned with research in science education. So long as such research is directed primarily into various descriptions of the status quo, or otherwise inwardly directed (for example, studies of existing texts and tests to determine comparability), there can be little basis for future planning. A cursory look at recent publications in this field would uncover dozens of suggestions for improved research, but few scientifically conducted studies which provide answers to them. A very brief sampling of such needs (suggestions) are listed below:

1. *Public policy.*—What level of scientific literacy is essential for intelligent, responsible citizenship in the modern, technological society that is the United States today? How can one teach, measure, and evaluate such scientific literacy?

2. *Curriculum.*—Should science be integrated into a CORE curriculum, or should it be taught in separate courses at different levels: What *is* the optimum time quota to be allotted to science at each level—elementary, intermediate, secondary?

3. *Learning.*—What is creativity? How can it be accurately identified or engendered in students? How does the teacher best give the non-science student a proper appreciation of pure science and the research scientist?

4. *Methods.*—How can teaching aids, such as television, radio, films, filmstrips, slides, teaching machines, newspapers, and periodicals, be used most effectively to achieve the objectives of science teaching at each level, and for pupils of varying abilities?

The National Association for Research in Science Teaching has published a list of dozens of unresolved issues in certain fields relating to science education; scientists and scholars involved in the present reform movements could identify dozens more. A few investigators are beginning to undertake the task of attacking these unresolved problems and issues. Indications are that such scholarly research will tend to become the rule rather than the exception in coming decades.

The Future.—It has been previously intimated that it is rather difficult to be clinically honest in appraising a revolution when one is living within that revolution. The direction in which lies the ultimate solution or situation of science education in the United States, or the distance in time to an ultimate solution, might best be determined by a disinterested observer. There is no question but that there are ample indications that increasing numbers of citizens are interested in the success of these efforts to improve science teaching, to insure increasingly better education in the sciences for both the scientist and citizen.

TRENDS IN SCIENCE EDUCATION AT THE ELEMENTARY SCHOOL LEVEL

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The revolution that has produced new designs in science education, and curriculum modifications in high school science programs, is now moving into the elementary schools. To date there are about 12 K–9 science projects being supported by the National Science Foundation. A number of other programs are being developed with funds from other national and local sources. This presentation will refer only to those programs supported by the NSF. Since the junior high school programs have implications for the elementary programs, I will include them in this presentation.

Because these programs will be introduced into thousands of classrooms in the near future, it is important that we review the reasons for the revolution that we find taking place. One of the primary reasons for this movement is the ever-increasing rate with which the nature of our society is changing. Since several speakers have elaborated on this point, I would like to just read a quotation from Alfred North Whitehead:

". . . our rate of progress is such that an individual human being, of ordinary length of life, will be called upon to face novel situations which find no parallel in his past. The fixed person, for the fixed duties, who, in older societies was such a godsend, in the future will be a public danger."

The exponential rate at which knowledge is expanding has also been mentioned. Continually, we read or hear statements like:

"Half of the prescriptions being written today could not have been written in 1950."

"The atom has over 32 particles instead of 3."

"150,000 research studies were completed in the last 6 months."

"Ninety percent of all scientists that ever lived are living today."

"Half of the jobs in which today's youngsters will be employed in their productive years do not exist today."

There is little doubt regarding the changing nature of our world and the explosion of knowledge. The implications of these developments are quite clear. No longer can we afford to train the child to live in today's world. In a few short years, today's world will not exist. If the maturing child is to remain literate in these rapidly changing times, education for him must continue throughout his lifetime.

In examining the school situation we find a rather alarming situation. A number of studies show that many youngsters drop out of school by the end of the eighth grade. Most students who continue do not take more than 1 year of science in the high school. It is apparent that the major burden to develop scientific literacy in all children rests on the elementary school science program.

If we examine some typical programs today, what do we find? Many, if not most, adhere basically to the notion that science is an organized body of factual information. Developers of these programs feel that by organizing the knowledge of science properly, we can systematically cover the field as we go through the years. Traditional textbooks are beautifully geared to this kind of a curriculum. By the end of the 12th grade, the student is supposed to have covered the field and is assumed to be scientifically literate. Most of us and those citizens walking the streets are products of this coverage. What degree of literacy can we claim for our citizenry?

The 12 elementary science projects supported by the NSF are in different stages of development. Some have been in progress since 1958. Others are just getting started. In reviewing these programs, I am presenting only that information which is pertinent to curriculum and classroom instruction. My editorial comments are based on personal prejudices developed during observations of these programs which are being tried in Oregon:

1. *The AAAS Commission on Science Education, Stanford University.*—The 1963 summer conference produced four experimental booklets, each containing about 18 to 20 exercises for grades K–3. Eventual plans call for the development of a K–16 science program. The AAAS materials stress the processes of science. This is in marked contrast to the traditional subject-matter coverage. The scope of the AAAS program includes studies in space/time, numbers, measurement, classification, prediction, and inference. The present design is structured to the point where exercises are studied in sequence. This, it seems, reduces the flexibility of the program and may tend to discourage the teacher from capitalizing on the spontaneous interests of children. Although this criticism can be made of all textbook-oriented programs at both the elementary and secondary levels, it is especially significant at the primary level where much of the activities are adapted to the interests of children.

2. *Earth Science Curriculum Project, University of Colorado.*—This project will attempt to develop an earth science course at the ninth-grade level. No materials are available at this time. The intentions of the project are to pattern the course after the new programs in biology, chemistry, and physics.

3. *The Elementary School Science Project, Utah State University.*—This project is developing lessons for grades 1 and 2. No materials are available at this time.

4. *The Elementary Science Study, Watertown, Mass.*—The instructional materials from this project place very little emphasis in a sequential or continuing program with respect to grade level. ESS is not attempting to develop a national curriculum, but is supplying a variety of carefully tested materials which the local curriculum director may use to meet the needs of the local school system.

A sampler containing selected blocks or units will be available for trial in a limited number of schools this fall. Some of the block titles are Butterflies, Cells, Gases, Kitchen Physics, Molds, and Playground Physics. These blocks were developed by examining the flow of ideas, questions, and observations of children. As in other studies, heavy emphasis is on the style of teaching, which presents scientific content through student experimentation.

5. *Junior High School Science Project, Princeton, N.J.*—This project started as a geology course, but the interrelatedness of the activities with the other science disciplines prompted the project to title their materials "Time, Space, and Matter." The course attempts to help teachers and students gain an understanding of the nature of the earth through a series of firsthand experiences. There is no textbook for the course. The student manual contains many empty pages on which student observations and inferences are noted.

6. *The Minnesota Mathematics and Science Teaching Project (Minnemast) University of Minnesota.*—The objective of Minnemast is "to produce coordinated mathematics and science curriculum for grades K–9, and mathematics, science, and methods courses for preservice education of teachers."[1] Their preliminary materials are not available for distribution at this time.

7. *PSSC Junior High School Physical Science, Watertown, Mass.*—This project developed preliminary materials in 1963. The purpose is "to develop a 1-year course in physical science for use in junior high schools. The student laboratory work is of primary importance. To emphasize this, the laboratory instructions are incorporated in the body of the texts; the results are not described. The equipment has been designed in such a way that the students can perform the experiments in ordinary classrooms."[2] No materials are available at this time.

8. *School Science Curriculum Project, University of Illinois.*—This project also hopes to develop improved science curricula in grades K–9.

[1] American Association for the Advancement of Science and the Science Teaching Center, *Second Report of the Information Clearing House on New Science Curricula.* University of Maryland, College Park, Md., Mar. 1, 1964, p. 28.

[2] Ibid., p. 33.

About eight units have been developed, but none is available at this time.

9. *The Science Curriculum Improvement Study, University of California.*—The materials in this project are being designed for grades K–6. Three units at the primary level are available. They are *Interaction and Systems, Material Objects*, and *Relativity of Position and Motion.*

10. *Study of a Quantitative Approach in Elementary School Science, State University of New York, Stony Brook, N.Y.*—The intent of this project is "to develop a science curriculum for grades 1 through 6, which stresses measurement and quantitative analysis appropriate to the grade level. We hope to establish age and grade levels for abilities in quantitative understanding illustrated by tested projects."[3] The major writing for this project will start in the summer of 1964. No materials are available at this time.

11. *University of California Elementary School Science Project, Berkeley, Calif.*—This project is in the process of developing a number of curriculum materials on basic science for the elementary school. One block or unit, *How I Began*, is available.

12. *The University of Illinois Elementary School Science Project, Urbana, Ill.*—This project has produced instructional materials in the area of astronomy. In this program children learn about astronomy in a way similar to the way in which astronomers have learned about the universe through measurement, charting, and experimentation. Descriptive astronomy is kept to a minimum. The materials have been designed for the upper elementary grades. Three booklets are now available, *Charting the Universe, The Universe in Motion*, and *Gravitation.* Other books in development are: *The Message of Starlight, The Life Story of a Star*, and *Galaxies and the Universe.*

An examination of these programs shows a degree of diversity among the different projects. The materials of some programs are highly structured, and are directed toward establishing a sequential curriculum which the local school district would follow quite closely. Others are developing flexible materials which would enrich any existing program at different grade levels. Some projects are developing materials which cover a broad range of topics, the selection of which may be made by local school personnel. Others are designed to study one topic for the entire year.

Along with these diverse characteristics, the programs have several similarities. They make no attempt to cover systematically the broad range of topics or concepts which we find in most curriculum documents from State departments of education. The activities in these programs are centered in those areas where the child can make empirical observations to one degree or another. In general, the child is able to participate in depth studies and to experience the processes which are inherent in discovering knowledge of the world around him. The emphasis is on uncovering the field of science by digging deep and making a first-hand examination of the understructure or foundation of the field. This understanding of the nature of science is necessary if children are to understand the inevitable changes and innovations of the future, and if they are to remain scientifically literate.

It is possible that by studying only a few areas, many traditional topics are never studied. There might be fear that students will not have a broad enough background for everyday general living. As Dr. Kaplan and Dr. Andrews indicated, all sciences have conceptual schemes in common. When the field of science is uncovered, there are basic threads that seem to hold the entire field together. For example, a basic understanding of the nature of matter and energy helps us to understand phenomena in a number of different studies. An understanding of matter and energy is basic in understanding reactions in chemistry, changes in weather, heating of substances, and metabolism in organisms. It is possible that matter and energy may be studied as matter and energy, or as rocket propulsion, or in any number of other topics.

The emerging programs seem to have another common characteristic: the programs make no attempt to prepare students for traditional high school science courses, which, in turn, are geared to many traditional college science courses. The programs are attempting to provide a more basic education for all pupils.

All of the programs require active participation by the child. They are not limited to reading about or talking about something. As many senses as possible are used with each activity. For example, it is one thing for the teacher to demon-

[3] Ibid., p. 48.

strate that a white powder contains starch, by mixing it with an iodine solution; and it is quite another thing to have five, six, or eight white powders available, with instructions for the children to find ways to identify them. This activity involves many chemical tests. Children will taste, smell, feel, and observe. Such an activity also requires a considerable amount of thinking.

All of the national programs attempt to design activities so that the child will perceive basic concepts and relationships in science for himself. This process involves techniques of accurate observation, measurement, analysis or relationships on the basis of similarities and differences, the identification of frames of references, and other skills which are not innate within the child but develop through practice. If learning is to be for life, the child will need to develop self-learning skills. This does not mean that everything must be discovered by the child, but, certainly, there is much more room for discovery in the classroom than we find today. The activities in some of the programs are excellent in this regard.

To one degree or another the activities of the new programs tend to utilize investigations which are naturally suited to children. The importance of this natural interest cannot be overemphasized, because of the high positive correlation between interest and learning. There is an attempt to liberate the innate curiosity in children. Plutarch understood this over 2,000 years ago when he said, "The child's mind is not an urn to be filled, but an ember to be kindled." I don't think that we can be satisfied to say that this curiosity should be liberated. It must be liberated. Each child needs to develop a love for learning that continues through life. I don't think this is idle talk. There are many examples where this is being accomplished in classrooms by creative teachers with creative instructional materials. Because of the inquiring nature of many activities, the new programs offer many opportunities to liberate the child's curiosity.

In contrast to a textbook-centered program, the core of instruction in all of the programs is to involve the child in activities and experimentation. All of the programs incorporate into the instructional materials those activities which require the child to participate in the procedures which help him discover knowledge for himself. The processes of science have become as important as the content.

In many Oregon classrooms, teachers have been using the preliminary materials which have been available. Although each program can be criticized on one basis or another, in general, there is agreement that the new elementary science programs are a considerable improvement over traditional programs. Teachers are no longer concentrating only on the information that is being taught. They are also becoming aware of the behavioral changes taking place in children, such as the ability of children to attack a problem. Teachers are observing more enthusiasm, independence, and responsibility among children. In those instances where the teachers were disappointed, it was evident that the teacher was using the newer materials without fully understanding the philosophy and intent of the programs. If new programs are to be introduced, the most important factor will be the orientation and inservice training of the classroom teacher. However, as in classroom teaching, the ability of a teacher to verbalize the philosophy of a program is not necessarily an indication that teaching behavior will be consistent with the stated philosophy. I should add that an inservice program is effective only to the point that it can change the behavior of teachers.

As persons interested in science education, it is our responsibility to understand the revolution that is taking place in elementary school science, and its impact in developing scientific literacy in young children. I think the time is past to sit back with a "wait and see" attitude when breakthroughs are being made in all phases of contemporary living. In our rapidly changing world we cannot afford to wait for the one "right answer" which apparently does not exist in curriculum. I think we need to develop the same experimental mindedness which has developed these new programs and which characterizes all progress.

NATURE AND POTENTIAL OF SCIENCE EDUCATION IN THE SPACE AGE *(A summary of a panel discussion)*

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The following summary of the panel discussion and audience reaction following the presentation of trends in science education at three educational levels—higher, secondary, and elementary—was prepared by the panel recorder, Lewin A. Wheat, Supervisor of High Schools (Science), State Department of Education, Baltimore, Md., and secretary-treasurer of the Council of State Science Supervisors. Members of the panel included: W. Earl Sams, Consultant in Education, State Department of Education, Sacramento, Calif., panel chairman; Robbin C. Anderson, Professor of Chemistry and Director of Academic Year Institute, University of Texas; Elva Bailey, Head, Educational Programs and Services, NASA Goddard Space Flight Center, Greenbelt, Md.; Mary M. Blatt, Science Adviser, State Department of Public Instruction, Harrisburg, Pa.; Robert K. Henrich, Spacemobile Lecturer, Educational Services, NASA Ames Research Center, Moffett Field, Calif.; and Mr. Wheat, panel recorder.

The discussion centered on the many problems involved in bringing about changed methods in science teaching in accordance with the needs of our times.

In brief, the major points of concern were:

1. Implementation of newly developed science education programs.
2. Provision of time and opportunities for orientation and development of teachers within the new programs.
3. The need for a total program providing science education of value to all of America's youth.

Reactions to the presentations, to comments, and to the questions raised all contributed to a general exchange of ideas on the nature and potential of science education in the space age.

The following questions and comments indicate in more detail the thoughts and ideas evoked by the discussion:

Questions

If there is a shortage of scientists and engineers, where will these additional people come from?

How do we provide teachers with time to assimilate new developments and implement them into common practice?

Is there such a thing as "science and process readiness"?

Should the use of science textbooks be eliminated from elementary grades?

Comments

There is a need for better science education at lower levels, especially in the intermediate grades. Special emphasis should be placed upon the introduction of science at an early age.

Current secondary chemistry and physics enrollments are down, while those in biology have increased.

There is a too frequent tendency for educators to look for *the one* solution. Current emphasis on process teaching is a blacklash to the years in which such teaching was lacking.

The science curriculum is what really happens when the teacher is in the room with his class. We must gear the science program away from ruts and so organize it to maintain, develop, and enhance the interest of youngsters.

Honor programs with the selection of desirable problems offer individual training, a new approach, and a significant contribution to science education.

There is a need to build into educational training and budgeting, ways to keep teachers up to date.

Some new techniques worth considering in coping with new developments are team teaching, effective use of the master teacher, increased number of periods, and use of laboratory assistants.

Grades 1–5 were cited as that period when the child's learning is most rapid.

Some definite structure or grade placement of materials for the science program is necessary at the local level.

Broad guidelines for science programs are seen as necessary at the State level.

Emphasis was placed upon the need for providing science education programs for all, not just the upper 10 percent.

The philosophy of the new curriculum programs in science is seen as vital not only to those pupils of high ability who plan to specialize in science but also to all children.

The articulation of vocational and industrial education with science is felt desirable and necessary.

Curriculum development programs are seen as rejuvenated curriculum, rather than completely new.

A most important problem for future research will be on how people learn.

THE IMPACT OF SPACE TECHNIQUES ON MODERN SCIENCE

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National Aeronautics and Space Administration

It is traditional, I suppose, when thinking of space activities, to call to mind giant rockets and complex spacecraft. In keeping with such tradition, most speeches on the subject include spectacular pictures of rockets taking off, spacecraft going into orbit, and lengthy discussions of the engineering and operational problems of space flight and space research.

This evening, however, with your permission, I shall refrain from showing you any such pictures. Instead, it is my intention to dwell entirely on science. I wish, during the few minutes ahead, to convey to you some idea of the power of space techniques in solving important scientific problems, and in expanding the horizons of many important scientific disciplines.

With this audience I need not argue the point that science is a coherent, disciplined activity of scientists searching for new knowledge and new concepts. In this light, space science is simply science done in space or by means of space techniques. It is nothing mysterious, and it is most certainly not separate from the rest of science. Rather, it is a very active part of the total body of science.

At the same time, that body of scientific activity that we call space science is playing both an exciting and a far-reaching role in modern science. Rockets, satellites, and deep-space probes now make it possible to solve many important and vexing problems that would not yield to classical techniques. Furthermore, the rocket approach is greatly expanding the horizons of a number of classical disciplines. Finally, the wealth of information that is pouring in from space observations has had the effect of bringing together into a very effective partnership a number of disciplines that hitherto had tended to go their separate ways.

To phrase these points in different terms, space techniques have reawakened a general interest in the broad scheme of things, in geophysics, the solar system, and the universe in general. This reawakened interest marks a return to what used to be referred to as "natural philosophy." The implications of this new outlook are tremendous. The perspective of the natural philosopher is one that is comprehensible to the thoughtful layman as well as to the scientific specialist. Thus, renewed interest in natural philosophy brings with it the possibility of closer ties between the scientist and his contemporaries in other fields of endeavor. The potentiality for enriching our Western culture may well be the greatest treasure to be garnered from modern space activities.

The truth of the foregoing comments becomes more apparent when one considers the role of the various scientific disciplines in space research. I could review these for you by listing the various traditional disciplines, recounting one by one the role that these play in our exploration of space, and the influence of space exploration upon them. However, I believe that such an approach would tend to be rather dull. Instead, I have chosen to group the various disciplines into seven different broad areas of recognizable importance. These are listed on figure 3. It should be emphasized that this grouping is an arbitrary one. On the other hand, it turns out to be a very natural listing in view of the way in which space science has developed over the past half-dozen years.

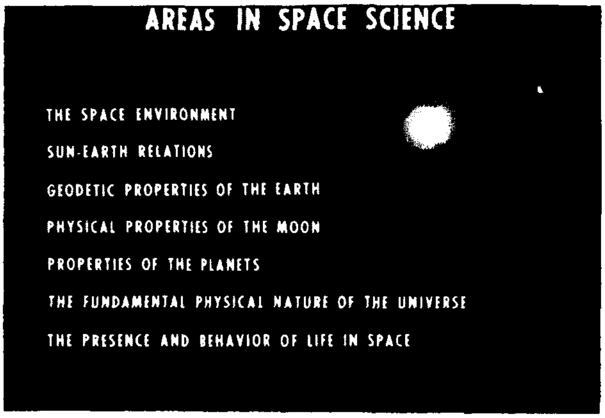


Fig. 3

Satellites and deep-space probes have made it possible to measure and observe quantities and phenomena that simply cannot be observed at the surface of the earth. As a consequence, we now know much about the interplanetary medium, the earth's environs in space, the outer reaches of the earth's atmosphere, the influence of the sun upon these that had never before been suspected.

With satellites and deep-space probes, the scientist is in a position to study the sun intensively in a broad range of wavelengths; to investigate the earth from a new perspective and vantage point; and, more importantly, to investigate in detail the influence of the sun upon the earth and its atmosphere. This area of sun-earth relations is obviously one of practical as well as scientific importance.

Most intriguing is the fact that by sending satellites away from the earth, out into space, it is possible to investigate the internal structure of our planet. As will be discussed in more detail later, this avenue of study has yielded a number of very important results.

We are only now beginning our direct investigation of the moon and the planets. In the course of time, the deep-space probe will carry instruments to these bodies of the solar system to make direct observations and measurements of their physical, chemical, and gravitational properties. As this research unfolds, the field of geophysics will expand from a field encompassing only one body of the solar system to one encompassing many. The advantages of being able to compare observations on other planets with those on earth should be tremendous. The student of the solar system should be able to get a much better handle on the problem of the origin of our planetary system.

The field of cosmology does not by any means suffer from lack of imagination. On the other hand, it does suffer greatly from the lack of quantitative data on the basis of which to choose from among various possible theories, and on the basis of which to extend theory. With orbiting telescopes above the earth's atmosphere, where measurements can be made in all wavelengths ranging from the gamma rays through the radio spectrum, the scientist can view the sky in a manner simply not possible from the ground. This advance in astronomical observation should greatly further our efforts to explore the fundamental physical nature of the universe. Already, preliminary measurements have indicated the power of the orbiting astronomical observatory.

Let us explore this point a little further. For most of its history, astronomy has had to observe in the visible portion of the wavelength spectrum. Only very slight extensions of this optical window into the ultraviolet at one end and the infrared at the other end were available to the astronomer. Thus, the astronomical theorist has had to construct his theories on the basis of a very narrow portion of the total spectrum of wavelengths. This very theory itself, however, indicates that the most important information about the birth, evolution, and demise of stars and galaxies is to be found in other portions of the spectrum. The opening of the field of radio astronomy a few decades ago has borne out this conclusion. Now, radio astronomy has discovered a galaxy from which energy appears to be radiating at an incredibly high rate. Also, sounding rocket observations made by the NASA Goddard Space Flight Center have shown that very hot stars are radiating in the ultravoilet much less intensely than theory had predicted. It is clear that present theories will have to be modified and extended. And it is just as clear that additional data will be required in order to point out the path toward the correct theory.

The presence and behavior of life in space is, I think, one of the most exciting areas of space research. Of particular interest is the possibility that some life forms may be found on the planet Mars. The philosophical implications of such discovery need not be dwelt upon. Scientifically, the opportunity to compare such life forms with terrestrial life should be most illuminating. Even if life is not to be found on Mars, the investigation of organic-type compounds that may have been formed in the Martian environment may still prove to be highly illuminating in the problem of seeking the origin of physical life.

These few remarks on the various areas of activity in space science today serve to indicate in a general way the manner in which space techniques are strenghthening the hand of the classical scientist, and simultaneously broadening his horizons. I should like, in the rest of this discussion, to strengthen these points by taking a specific discipline and exploring with you how this discipline is being affected by space science. The field that I have chosen is that of geophysics. I think you will agree with me, after we have reviewed some of the space science results in the area of geophysics, that a tremendous revolution, or perhaps vigorous evolution, is in progress. But it should be kept in mind that this vigorous evolution is not confined to geophysics. Rather, the discussion is intended to be illustrative of the type of expansion that is going on in many areas of science today.

It is my hope that I may succeed in establishing two important points: First, I wish to show how space techniques aid traditional geophysics in a very powerful way. Secondly, I should like to point to how space research necessarily broadens and extends the whole context of geophysics.

Although I shall illustrate these points by exhibiting some results that have been obtained from satellites and space-probe research, it is not my purpose this evening to review such results in detail. Rather, I hope to bring to your attention the power, versatility, and very present availability of space techniques for application to the discipline of geophysics.

The Solid Earth.—Even the solid earth is subject to study by space techniques. Indeed, one of the most intriguing aspects of the space science program is that by sending satellites out into space, one may learn a great deal about the figure and structure of the earth.

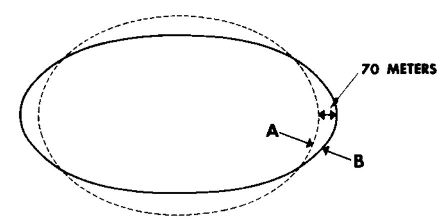
A satellite in orbit is influenced by gravity, air densities, and even by solar radiation. By observing the influence of these quantities on the satellite orbit, these separate quantities may be measured.

The earliest deductions from satellite observations were atmospheric densities at orbital altitudes, which will be discussed a little later. Having measured air density and solar radiation effects, one is then in a position to separate them out from the gravitational influences. This enables one then to obtain quantitative measures of the various harmonics in the expansion of the earth's gravitational potential. These quantities in turn have important implications for the distribution of matter within the earth, and for the internal strength of the earth's mantle.

First results improved the estimate of the equatorial bulge. Principal names here are those of O'Keefe and Kaula of the Goddard Space Flight Center; Kozai, Smithsonian Astrophysical Observatory; and Newton, Johns Hopkins Applied Physics Laboratory. The measured flattening ratio turned out to be (fig. 4):

DISCREPANCY IN FLATTENING RATIO

EXAGGERATION= 5 X 10^5



A. FIGURE OF HYDROSTATIC EQUILIBRIUM (Flattening=1/299.8)
B. OBSERVED FIGURE (Flattening=1/298.2)

Fig. 4

$$\frac{1}{(298.2 \pm 0.2)}$$

This corresponds to a bulge at the equator of 70 meters greater than one would expect for a perfectly plastic earth rotating at the present rate. It is the bulge a perfectly plastic earth would exhibit for the rotation rate of 50 million years ago when the earth was rotating faster, with a day of about 23½ hours.

Other departures of the geoid from the figure of hydrostatic equilibrium have also been determined from satellite observations, particularly from Vanguard I (fig. 5). Longitudinal variations have been measured from the orbits of Vanguards II and III, the Echo I rocket casing, and the Geodetic Satellite ANNA I among others. The second-order longitudinal variation gives an equatorial ellipse with a difference of axes equal to 80 meters.

These departures from the hydrostatic figure for a purely plastic earth imply strength in the earth's mantle, characterized by O'Keefe as roughly equivalent to that of an ordinary brick wall, capable of supporting stresses as great as 2×10^7 dynes/cm^2.

Collecting all the results to date together on the gravitational variations yields a figure of the earth which shows a hump in the western Pacific near Indonesia and the Philippines, and a depression in the Indian Ocean, as shown schematically in figure 6.

These results may be seen more quantitatively in the next figure (fig. 7). The geoid heights are given here in terms of feet above or below the reference figure, the location of which is indicated by the zero contour lines. The presence of the depression in the Indian Ocean and the hump near the Philippines is clear from these contours. Now these results, although interesting in themselves, lead to further important lines of thought.

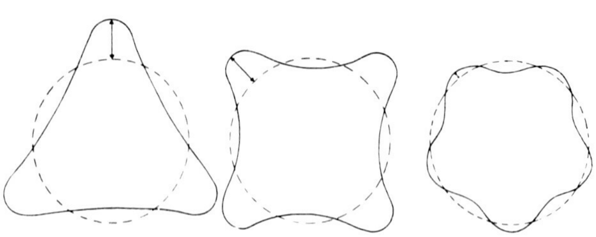
For example, the average heat flow through the earth's crust is about 60 ergs per square centimeter per second, which is 0.1 percent of the visible solar energy incident on the earth. In the vicinity of the Indian Ocean depression, however, the total heat flow is on the order of 80 ergs per square centimeter per second. On the other hand, at the elevation in the Western Pacific region, the heat flow is about 40 ergs per square centimeter per second.

These facts would be consistent with a very slow convection in the earth's mantle, of about 1 centimeter per year or less, which in turn might offer the following explanation of the hump and depression found in the geoid. This convection would exhibit an upward motion in the Indian Ocean depression and a downward motion in the Western Pacific hump. The upward motion in the Indian Ocean area would carry with it less dense material, which in turn would have a lower total gravitational attraction. As a result, the waters in the Indian Ocean area would descend—as has actually been found to be the case. In contrast, the downward motion in the Western Pacific area would leave that region with cooler, more dense, hence gravitationally more attractive, material. This excess gravitational attraction would draw together the waters of the Western Pacific into a hump—as has also been found to be the case.

Earth's Atmosphere and Ionosphere.—The earth's atmosphere is a very important area of geophysics. It is one of the earliest to be explored by space techniques; namely, with sounding rockets. Prior to the advent of the sounding rocket, balloons, sound ranging on large explosions, meteor studies, auroral observations, and similar techniques were used for an indirect probing of the upper atmosphere. With the discovery of the ionosphere in 1925, radio waves became an important upper atmosphere probe. With the advent of the sounding rocket, the upper atmosphere field has burst into activity (fig. 8), literally pouring forth results into the literature.

HARMONICS OF THE GEOID

VERTICAL EXAGGERATION = 2 X 10^5



3RD (17 METERS) 4TH (11 METERS) 5TH (2 METERS)

Fig. 5

GRAVITATIONAL ANOMALIES

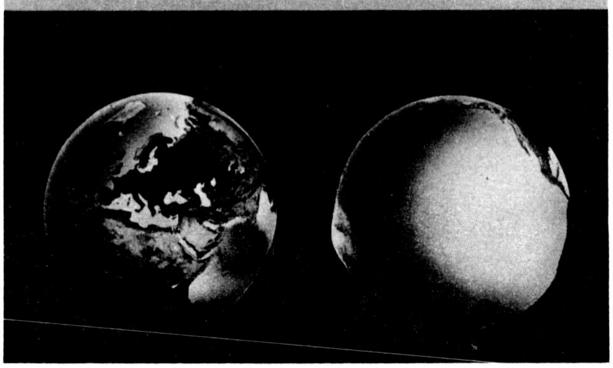


Fig. 6

GEOID HEIGHTS

GEOID HEIGHTS FROM SATELLITE OBSERVATIONS

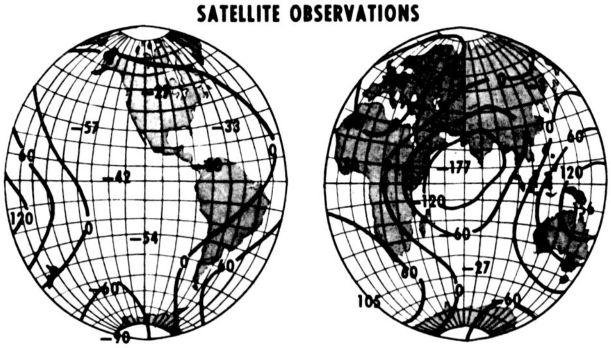


Fig. 7

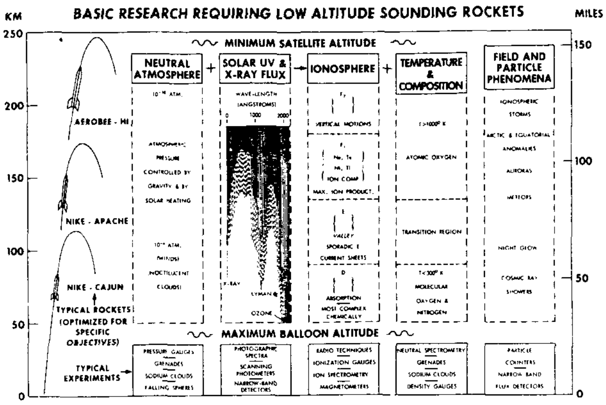


Fig. 8

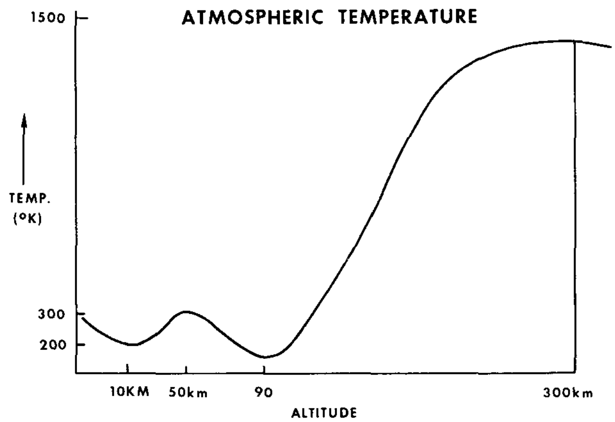


Fig. 9

The sounding-rocket program laid the groundwork for the present satellite and space-probe research. Indeed, the sounding rocket continues to provide a mechanism for testing out equipment and the design of experiments before they are carried out in the more expensive spacecraft. Also, the sounding rocket continues to be a good means of entering the very difficult field of research from satellites and space probes.

A wealth of information on the earth's upper atmosphere has accumulated from the space program. I shall not attempt to review these results in great detail. It may, however, be of interest to take a quick look at the general picture as it appears at the present time.

The curve shown in figure 9 is the result of a synthesis from a very large collection of data. Actually, the temperature varies with time of day, sunspot cycle, and geographic location. The story of upper air temperature is a fascinating one, in which the names of Priester and Jacchia play a leading role.

Theory by Harris [3] and Priester [4] is shown in figure 10. The solid portion of the curves was based on data available from rockets and satellites at the time that the theoretical calculations were made. The dashed portions constitute extrapolations both backward and forward in time. Since the publication of these curves, a number of years have passed and additional data have become available. With slight corrections, these data have borne out the theory very well.

Electron density in the upper atmosphere is also a parameter of major importance. Early

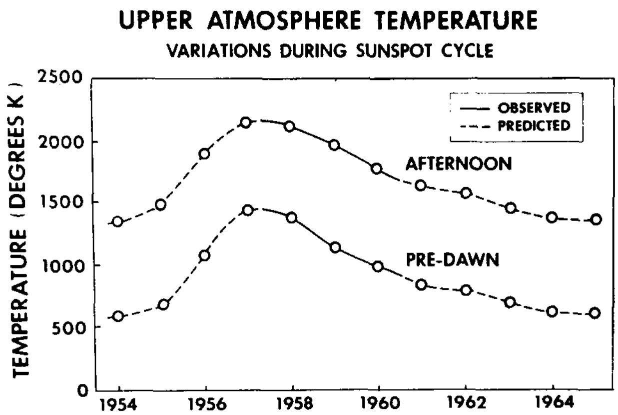


Fig. 10

work by Seddon [5] and Jackson [6] led to the clarification of a number of confusing problems that did not yield to ground-based ~~operations~~ observations. A considerable advance was made with satellites by the Soviets and by Bourdeau of the Goddard Space Flight Center. Bourdeau's work with the Explorer VIII satellite yielded a tremendous wealth of new data.

Another important parameter in the upper atmosphere is chemical and ionic composition. Both direct and indirect measurements have been made by a number of workers. An interesting byproduct of the ionospheric measurements mentioned above has been the revelation of a helium layer in the upper reaches in the atmosphere. The presence of this layer of helium was predicted by Nicolet on the basis of theoretical work. Its actual presence became clear in the Explorer VIII data.

[3] Dr. Isidore Harris, NASA Goddard Space Flight Center.
[4] Dr. W. Priester, NASA Goddard Space Flight Center.
[5] Dr. J. C. Seddon, NASA Goddard Space Flight Center.
[6] Dr. John E. Jackson, NASA Goddard Space Flight Center.

Figure 11 shows electron density measurements obtained by Bauer and Jackson of the Goddard Space Flight Center in a rocket launching conducted at the Wallops Island launch facility in Virginia. The individual points represent the measured values of electron density. The curves drawn on the figure were calculated on the basis of two different sets of assumptions. One assumed an atmosphere changing from predominantly atomic oxygen in the few hundred kilometer levels, to one in which hydrogen dominates. The second represents an atmosphere changing from predominantly atomic oxygen to one in which helium predominates. As may be seen, the experimental data initially follow the atmosphere that changes into the helium layer, while at the very top there appears to be a tendency to follow the hydrogen curve.

The conclusion then is that in the vicinity of 1,000 kilometers, the helium layer makes its appearance. On the other hand, above 2,500 kilometers, hydrogen becomes the dominant constituent. Additional data that have been obtained since these early results show that the level at which the helium layer first appears, and also the thickness of the helium layer, vary with the phase of the sunspot cycle.

The earliest structure parameters of the earth's atmosphere to be measured by means of rockets were pressure and density. In figure 12, Robert Jastrow [7] has pulled together various observational data into a density versus altitude curve. Note that as one goes toward 3,000 kilometers' altitude, the densities drop toward those to be expected in interplanetary space.

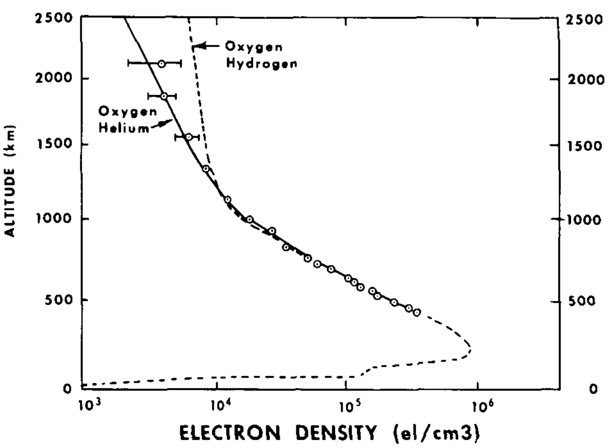


Fig. 11

One would expect, therefore, the earth's atmosphere to come to an end essentially by merging with interplanetary space. In other words, except for its gravitational field, the earth would not be expected to have much of an influence on the interplanetary medium beyond something less than one earth's radius altitude. This, however, is not the case—because of the earth's magnetic field, which extends the earth's influence into space for many earth's radii throughout what is called the earth's magnetosphere.

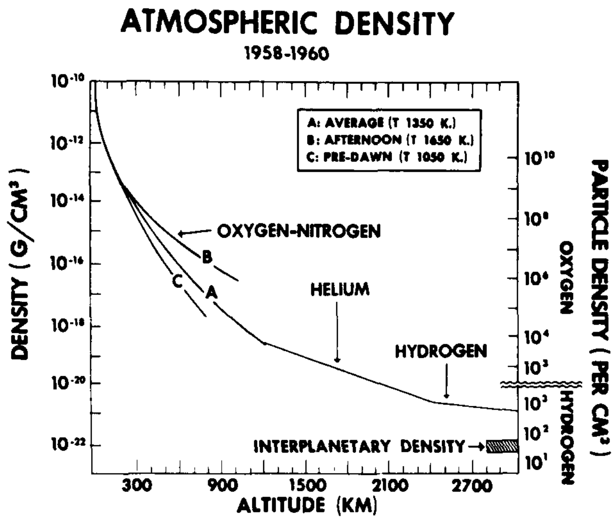


Fig. 12

The Earth's Magnetosphere.—The undistorted magnetic field of the earth would look very much as shown in figure 13. That is, it would be the field of a magnetic dipole. Such a field, of course, is capable of trapping charged particles that find themselves within the magnetic field lines with too low an energy to escape.

Indeed, trapped particles were found by Van Allen [8] in his discovery of the radiation belts. Since that discovery in 1958, during the International Geophysical Year, a whole series of sounding rockets, satellites, and deep space probes has extended our knowledge about the magnetosphere tremendously.

Our present-day space probes are capable of providing an extended survey of the earth's magnetosphere, because of their long lifetimes and extended orbits. This may be seen by reference to figure 14.

[7] Dr. Robert Jastrow, Director, NASA Goddard Institute for Space Studies, New York, N.Y.

[8] Dr. James A. Van Allen, Iowa State University.

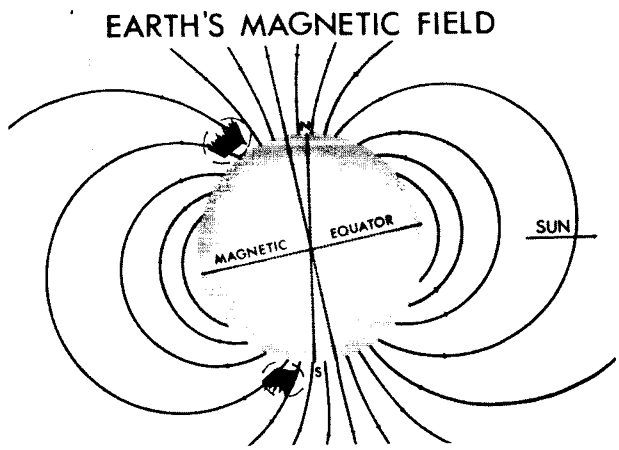


Fig. 13

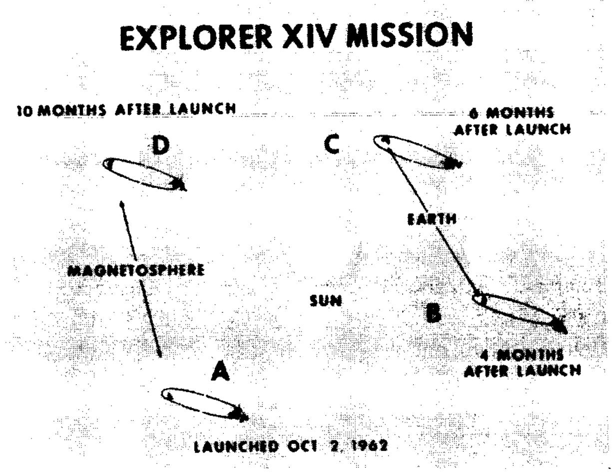


Fig. 14

In this picture, the earth's magnetosphere is shown as having a teardrop shape, with the blunt end toward the sun and a tail extending away from the sun. Accumulation of the data from space probes and satellites has shown clearly that this is the shape into which the magnetic field is distorted by a wind of particles emanating from the sun. Thus, as the earth revolves around the sun from position A to B to C to D in the course of the year, the absolute orientation in space of the tail of the earth's magnetosphere varies, since it always points away from the sun.

On the other hand, the plane of the orbit of the satellite about the earth would remain essentially fixed in space, although actually there would be some minor variations in its orientation. As the earth revolves around the sun, and the satellite's orbital plane remains essentially fixed, the effect is to make the satellite's orbit sweep through the different reaches of the earth's magnetosphere. Hence, if the satellite can continue to work throughout the course of a year, it is possible to explore the earth's magnetosphere with the satellite's instruments from the blunt forward edge of the magnetosphere facing the sun around through the elongated tail and back again.

With this picture in mind, then the next picture (fig. 15) can be understood. It represents some of the coverage of the earth's magnetosphere provided by satellites and deep-space probes launched during the past half-dozen years. The satellite Explorer XVIII continues to operate successfully, and in the interval since the picture here was drawn, has swept on around through the magnetosphere well beyond the single quadrant shown.

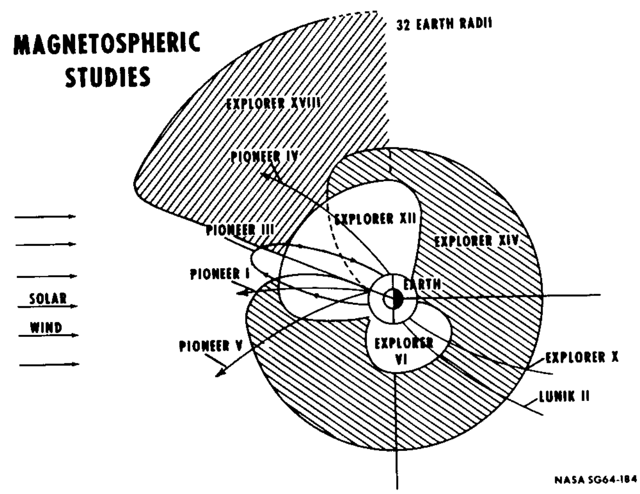


Fig. 15

As a result of observations made in satellites and space probes, by Van Allen, Simpson,[9] Winkler,[10] Sonett,[11] Heppner,[12] Ness,[13] Rossi,[14] and Bridge;[15] and of theory worked out by Parker,[16] Gold,[17] Kellogg,[18] Dessler,[19] and others, a very fascinating picture of the earth's magnetosphere has developed.

[9] Dr. J. A. Simpson, University of Chicago.
[10] Dr. John Winkler, University of Minnesota.
[11] Dr. Charles P. Sonett, Space Technology Laboratory.
[12] Dr. James Heppner, NASA Goddard Space Flight Center.
[13] Dr. Norman F. Ness, NASA Goddard Space Flight Center.
[14] Dr. Bruno B. Rossi, MIT.
[15] Dr. Herbert Bridge, MIT.
[16] Dr. Eugene Parker, University of Chicago.
[17] Dr. Thomas Gold, Cornell University.
[18] Dr. W. W. Kellogg, National Center for Atomic Research, Boulder, Colo.
[19] Dr. A. J. Dessler, Rice University.

This picture, however, did not come easily. In the initial observations, basically only the concept of a belt emerged. Then the idea of two separate belts appeared, only to decline later when more complete measurements showed the entire magnetosphere to be filled with radiation. In the measurements by Explorers III and IV, the pronounced influence of solar activity upon the radiation belt was demonstrated.

Then as measuring techniques improved, the extent of the magnetosphere began to be more clearly defined, and the sharpness of the magnetosphere began to emerge.

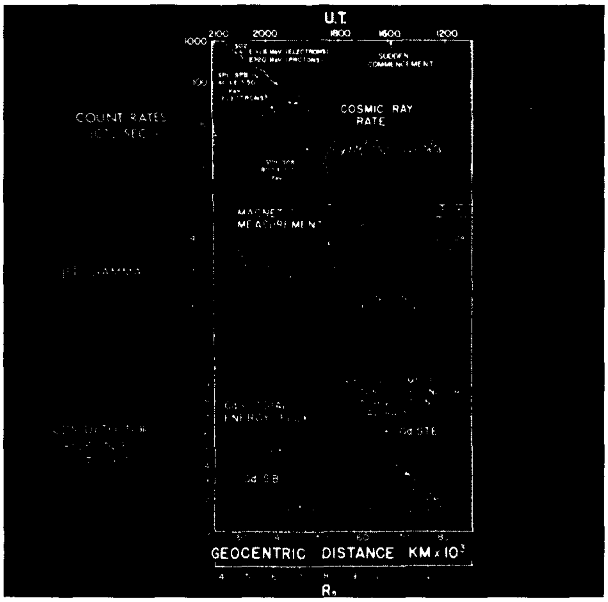


Fig. 16

Figure 16 shows particle measurements by Van Allen, and magnetic field measurements by Cahill,[20] made on Explorer XII. The dashed line down the middle of the picture is inserted to call attention to a marked change that occurs as one crosses the line from the left portion to the right portion. The distance from the center of the earth is shown at the bottom of the picture, both in kilometers and in numbers of earth's radii. As can be seen in the bottom segment, the counting rate of low-energy particles remains reasonably stable at distances closer than eight earth's radii to the earth, while at distances greater than eight earth's radii, the counting rate jumps markedly. As has now become clear, this indicates the presence of a solar wind blowing against the earth's magnetic field but unable to penetrate into the magnetosphere. In the top portion of the picture, the energetic particle counting rate is quite high at distances closer than eight earth's radii; but at distances greater than eight earth's radii reduces to essentially the cosmic ray counting rate. The energetic particles at less than eight earth's radii are taken to be the particles trapped in the Van Allen radiation belt.

In the middle set of curves is shown magnetic field measurements made by Cahill. The field intensity is seen to depart from the theoretical inverse third power curve shown as the solid line. The departure amounts to a building up in intensity as the eight earth's radii line is approached. Upon crossing the eight earth's radii line, the field intensity drops down to a low level and remains there. The slight buildup in intensity over the theoretical curve is what one would expect if a solar wind were indeed blowing against the earth's magnetic field and compressing it. The α and ψ curves are the direction angles of the magnetic field. These are seen to be quite steady in the region of space ~~beyond~~ within the magnetosphere.

Thus, taking all these pieces of evidence together, it would look as though the eight earth's radii line marks the edge of the earth's magnetic field; that is, the edge of the magnetosphere.

Figure 17 shows intensity contours within the radiation belt obtained by Van Allen on Explorers XII and XIV. One can see from this slide how the radiation belt contours appear to crowd closer to the earth on the antisolar side than on the solar side. Also, there can be seen intensity contour lines on the antisolar side that appear to move off to very great distances from the earth. Thus, one

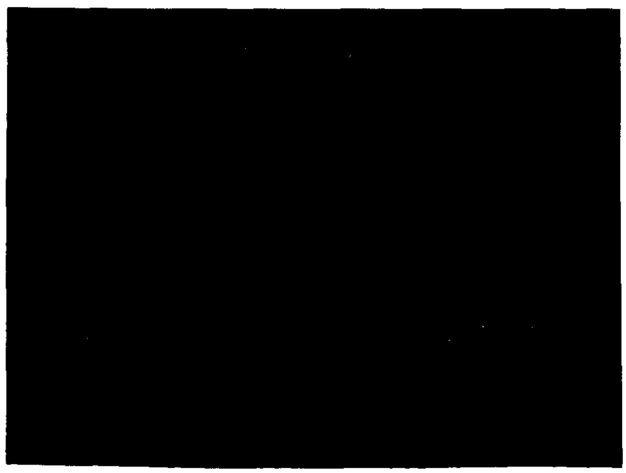


Fig. 17

[20] Dr. Lawrence Cahill, University of New Hampshire.

sees here a clear indication in these data that the earth's magnetic field does indeed have a tail toward the antisolar side. This intriguing suggestion appeared in data obtained by Heppner, Bridge, and Rossi, in measurements made on Explorer X sometime earlier.

The recent results obtained from the Explorer XVIII satellite, called the Interplanetary Monitoring Platform, have greatly extended our knowledge of the outermost reaches of the magnetosphere. Explorer XVIII was instrumented to measure both high-energy and low-energy particles, solar and magnetospheric plasmas, and magnetic fields. All the data are consistent in supporting very clearly the picture of a magnetopause, transition region, and shock wave between the magnetosphere and interplanetary space. I will not attempt to review all these data, particularly since it took a whole day for the experimenters themselves to go through the host of results they had to report. Instead, I shall present two figures loaned to me by Dr. Norman Ness, who carried out magnetic field measurements on Explorer XVIII.

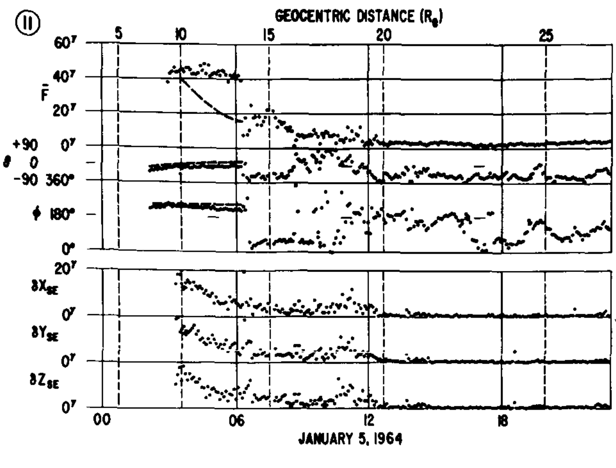
The first of Ness' figures (fig. 18) corresponds to orbit No. 11 of Explorer XVIII. Shown here at the top are the magnetic field intensity out at 10 earth's radii from the earth and beyond, together with the field direction angles. The data are similar to those of Cahill shown on an earlier picture. The buildup in field intensity as one approaches 13 or 14 earth's radii is clear, with a marked divergence from the theoretical field intensity shown in the dashed line. The steadiness of the direction angles is also apparent. To the right of the picture, beyond 20 earth's radii, the steady low value of the interplanetary field is also apparent, as is the appreciable variability of the direction angles. What did not appear on Cahill's data, however, is the disturbed region between 13 and 20 earth's radii. Here both the field intensity and the direction angles of the magnetic field vary widely.

The picture that has developed from data such as these is that the region of disturbance between 13 and 20 earth's radii is one of turbulence. The outermost boundary of this region marks the onset of a shock wave in the solar wind, while the innermost boundary marks the edge of influence of the earth's magnetic field. This boundary of the earth's magnetosphere has been given the name "magnetopause."

This picture is very clearly illustrated by Dr. Ness in plotting the data from a large number of orbits from Explorer XVIII on a single picture (fig. 19). The position of the shock wave, the magnetopause, and the turbulence region between them is clearly shown in these data.

Note that the turbulence region is narrower along the line toward the sun than that at 90° from the line toward the sun. Missing here are data on the antisolar portion of the earth's magnetosphere. Additional data have been obtained in the interval since those data shown on this figure were acquired, and are under vigorous study.

There is, of course, a host of questions that one has in mind about the tail of the earth's magnetosphere. One of these questions relates to how far into space this tail extends. There have been some suggestions that the magnetospheric cavity might reach as far as the moon. Conversely, one asks what effect the moon might have upon the



Magnetic field data from orbit No. 11 January 5, 1964 illustrating outbound traversal of magnetopause boundary at 13.6 R_e and shock wave boundary at 19.7 R_e.

Fig. 18

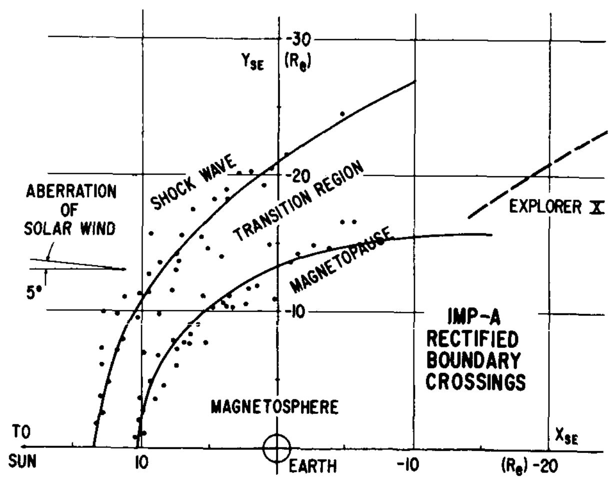


Fig. 19

solar wind, what sort of cavity does it carve out of the wind?

Ness' data give some insight into the extent of these effects. He has detected in his observations the effects of the moon on the solar wind, and has shown this schematically in figure 20. At the lower right-hand corner of the figure, the shock wave and magnetopause of the previous picture are reproduced. The trajectory of the Explorer XVIII satellite, affectionately called IMP for Interplanetary Monitoring Platform, is shown reaching well beyond the shock wave. At the outermost portions of the orbit, the wake of the moon in the solar wind is detected.

New Fields To Plow.—The foregoing discussion reveals, I believe, in an impressive way the diversity of areas of interest to the geophysicist that exist in the present space science activity. It shows how space techniques can be applied to some of the traditional problems of geophysics, such as the earth's figure, internal structure, and atmosphere. It goes further to show how traditional geophysics has actually been extended in its horizons by the discovery and subsequent exploration of the earth's magnetospheric trapped radiation.

But that's not all. The space program promises vast new fields for plowing. I refer to the entire solar system. Indeed, the domain shown in figure 21 is the new kingdom of the geophysicist. The techniques and capabilities for carrying instruments, and ultimately the geophysicist himself, to the far reaches of this new domain are now in existence. The opportunities are limitless. It but needs those interested to avail themselves of the opportunities.

In the field of education, teachers are needed who can inspire in some of their students the desire to follow up on those opportunities; and in the rest of their students an appreciation of the importance of understanding these things to the further development of our culture, and of man himself.

MOON AND IMP (ORBIT 5) POSITIONS, DECEMBER 1963

VIEW ON ECLIPTIC PLANE

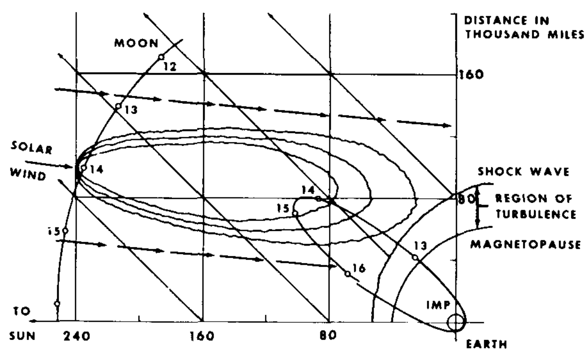


Fig. 20

THE SOLAR SYSTEM

Fig. 21

THE ORIGIN OF LIFE IN THE UNIVERSE

Cyril Ponnamperuma *Acting Chief*
Chemical Evolution Branch
Exobiology Division
NASA Ames Research Center
Moffett Field, Calif.

In the 1958 Reith Lectures, A. C. B. Lovell,[1] Professor of Radio-astronomy of the University of Manchester and Director of the Jodrell Bank Experimental Station, described the problem of the origin of the universe as the greatest challenge the human intellect has ever faced. Along with the problem of the origin of the universe, the question of the origin of life and the origin of intelligence may be regarded as the three most fundamental questions of all science. It is my purpose this morning to outline how modern science is endeavoring to find a solution to the problem of the origin of life.

While the problem of the origin of the universe is staggering to the human mind in its very concept, the solution to the problem may come from a surprisingly simple, one-shot observation or experiment. The theory based on the evolutionary model of a universe arising from Abbé Lemaître's primeval atom will stand or fall when an astronomer's penetrating gaze has compared the spatial density of galaxies 50 million light-years ago with those of 10 billion light-years ago. The rival cosmological concept of continuous creation demands the appearance of hydrogen at several billion trillion tons per second in the observable universe. This concept will be satisfactorily proved when a nuclear physicist can demonstrate that energy can be converted into hydrogen at the rate of one atom per year, in a volume as big as a New York skyscraper.

When we contemplate the origin of life, the enormity of the problem is equaled only by the complexity of the possible solutions. "The evolution movement," wrote Bergson, "would be a simple one, and we should soon be able to determine its direction if life had described a single course like that of a solid ball shot from a cannon. But it proceeds rather like a shell, which suddenly bursts into fragments, which fragments, being themselves shells, burst in their turn into fragments, destined to burst again, and so on for a time incommensurably long. We perceive only what is nearest to us, namely the scattered movements of the pulverized explosions. From them we have to go back, stage by stage, to the original movement."

Even the formulation of this problem is perhaps beyond the reach of any one scientist, for such a scientist would have to be at the same time a competent mathematician, a physicist, and an experienced organic chemist. He should have a very extensive knowledge of geology, geophysics, and geochemistry; and, besides all this, he should be absolutely at home in all the biological disciplines. Sooner or later, this task would have to be given to groups representing all these faculties and working closely together theoretically as well as experimentally. Such was the view professed by Bernal[2] in 1949. However, today we have reason to be more optimistic. For the first time in human history, the sciences which arose as separate disciplines are seen fused together, and our own genera-

[1] Lovell, A. C. B. *The Individual and the Universe.* London, Oxford University Press. 1958.

[2] Bernal, J. D. *The Physical Basis of Life.* London, Routledge, Kegan Paul. 1951. p. 10.

tion has witnessed the birth of such sciences as biophysics and molecular biology.

Three factors have made the scientific approach to the question "how did life begin" possible, not only theoretically but also experimentally:

1. Astronomical discoveries of the century.
2. The triumph of Darwinian evolution.
3. Recent biochemical advances.

The humanist may be indignant that a problem so profound should be regarded as belonging to the laboratory; but the experimental scientist is optimistic that his investigations will someday unravel this great mystery.

The astronomical discoveries of the century have relegated our earth to the corner of a universe made up of billions of stars. The study of the heavens, by present-day telescopes, has revealed more than 10^{20} stars. Like our own sun, each one of these stars can provide the photochemical basis for plant and animal life. Two factors become abundantly clear: (1) that there is nothing unique about our sun, which is the mainstay of life on this planet; and (2) that there are more than 10^{20} opportunities for the existence of life on other planets. In the light of numerous possible restrictive conditions, a conservative estimate made by Harlow Shapley [3] shows that there must be at least 10^{8} planetary systems suitable for life. The astronomer, Su-Shu Huang,[4] however, considers that 5 percent of all planets can support life: there are 10^{18} possible sites for the existence of life. In the light of these considerations, the question of the origin of life assumes cosmic proportions.

This conclusion, which astronomers have reached by the rigorous analysis of scientific observations, was already prophetically described by the Italian, Giordano Bruno, in the 16th century: "Sky, universe, all-embracing ether, and immeasurable space alive with movement—all these are of one nature. In space there are countless constellations, suns, and planets; we see only the suns because they give light; the planets remain invisible, for they are small and dark. There are also numberless earths circling around their suns, no worse and no less inhabited than this globe of ours. For no reasonable mind can assume that heavenly bodies which may be far more magnificent than ours would not bear upon them creatures similar or even superior to those upon our human Earth."

The Space Science Board of the U.S. National Academy of Sciences,[5] in an authoritative document, set the search for extraterrestrial life as the prime goal of space biology: "It is not since Darwin and, before him, Copernicus, that science has had the opportunity for so great an impact on the understanding of man. The scientific question at stake in exobiology is the most exciting, challenging, and profound issue not only of the century but of the whole naturalistic movement that has characterized the history of western thought for over 300 years. If there is life on Mars, and if we can demonstrate its independent origin, then we shall have a heartening answer to the question of improbability and uniqueness in the origin of life. Arising twice in a single planetary system, it must surely occur abundantly elsewhere in the staggering number of comparable planetary systems.

"If pursued thoroughly, this search for life elsewhere will inevitably demand that man must get into space himself. We shall, of course, get on with the job—using remotely controlled life-detection systems even before this venture is fully possible. But we shall never be satisfied with negative results from our instrumental life-detectors, because they are intrinsically hampered in their scope by our current ignorance of the nature of whatever extraterrestrial life there may be. Furthermore, should these preliminary sallies give positive results, the urgency for man to get there will only increase. Therefore, while the intellectual appeal of the extraterrestrial life question stands out above all else in space biology, it seems inevitable that the size of the man-in-space project (in terms of dollars and manpower) will exceed that of all other aspects of space biology."

There is a distinct possibility of our finding an answer to the question of the existence of life in our own planetary system, by an inspection of the planets with our immediate or remote sensors. Outside our planetary system, one way by which we can answer the question is by making radio contact with other civilizations in outer space. The odds against success in such an attempt are literally astronomical. "There is one race of men; one race of gods; both have breath of life from a

[3] Shapley, Harlow. *Of Stars and Men.* Boston, Beacon Press. 1958.

[4] Huang, Su-Shu. *American Science,* 47, 397. 1959.

[5] *A Review of Space Science Research.* National Academy of Sciences. National Research Council Publication 1079. 1962. Ch. 9.

single mother. But sundered power holds us divided, so that one is nothing, while for the other the brazen sky is established their sure citadel forever," wrote Pindar in the "Sixth Nemean Ode."

However, we have yet another possibility in the experimental approach to the problem. As the laws of chemistry and physics are universal, the retracing of the stages by which life appeared on earth would give strong support to the theory of its existence elsewhere in the universe. Laboratory experiments on earth can reveal which materials and conditions available in the universe might give rise to chemical components and structural or behavioral attributes of life as we know it.

The Darwinian theory of evolution has postulated the unity of the earth's entire biosphere. According to Darwin, the higher forms of life evolved from the lower over a very extended period in the life of this planet. Fossil analysis has shown that the oldest known forms of living systems may be about 2 billion years old. Life, indeed, had a beginning on this planet. Geochemical data tell us that the earth is about 4½ billion years old. A question immediately arises as to the history of our own planet between its birth 4½ billion years ago and the emergence of life. This idea was uppermost in the mind of the physicist Tyndall,[6] when in 1871 he wrote in his *Fragments of Science for Unscientific People:* "Darwin placed at the root of life a primordial germ, from which he conceived that the amazing richness and variety of the life now upon the earth's surface might have been deduced. If this hypothesis were true, it would not be final. The human imagination would infallibly look beyond the germ and, however hopeless the attempt, would enquire into the history of its genesis. . . . A desire immediately arises to connect the present life of our planet with the past. We wish to know something of our remotest ancestry. . . . Does life belong to what we know as matter, or is it an independent principle inserted into matter at some suitable epoch, when the physical conditions became such as to permit of the developmentof life?" The consideration of biological evolution thus leads us logically to another form of evolution; namely, chemical evolution.

Recent biochemical discoveries have underlined the remarkable unity of living matter. In all living organisms, from the smallest microbe to the largest mammal, there are two basic molecules. Their interaction appears to result in that unique property of matter which is generally described by the word "life." These two molecules are the nucleic acids and protein. While each one of these molecules is complex in form, the units comprising them are few in number. The nucleic acid molecule consists of nucleotides strung together like beads along a chain. The nucleotides, in turn, are made up of a purine or pyrimidine base, a sugar, and a phosphate. In the protein molecule, 20 amino acids link up with one another to give the macromolecule. A study of the composition of living matter thus leads us to the inescapable conclusion that all living organisms must have had some common chemical ancestry. A form of evolution purely chemical in nature must of necessity have preceded biological evolution.

The evidence which is available from practically every field of science thus leads us to the idea that Nature is a unity which can be divided into categories merely for human convenience. The division of matter into living and nonliving is perhaps an artificial one, which is convenient for distinguishing such extreme cases as a man and a rock, but would be quite inappropriate when describing a virus particle. Indeed, the crystallization of a virus by Wendell Stanley[7] almost 30 years ago precipitated the need for revising our definition of the terms "life" and "living." These sentiments were powerfully expressed by Pirie[8] in an essay entitled "The Meaninglessness of the Terms Life and Living." He compares our use of the terms "living" and "nonliving" to the words "acid" and "base" as used in chemistry. While sodium hydroxide is distinctly alkaline, sulfuric acid is a powerful acid. However, in between, there is a whole variation in strength. The chemist has overcome the confusion arising from the use of the two terms, "acid" and "base," by inventing the nomenclature of "hydrogen-ion concentration." He is thus able to describe all the observed phenomena in terms of one quantity. Thus, a liquid may have a pH of 4 or a pH of 8. We may have to invent a similar quantity in order to avoid any vagueness that might arise in applying the term "life" to borderline cases such as the virus.

Chemical evolution may be considered to have taken place in two stages: From inorganic chem-

[6] Tyndall, John. *Fragments of Science for Unscientific People.* London, Longmans, Green & Co. 1871.

[7] Stanley, W. *Science,* 81 : 644, 1935.

[8] Pirie, N. W., in *Perspectives in Biochemistry,* eds. J. Needham and D. R. Green, Cambridge, Cambridge University Press. 1937. p. 11.

istry to organic chemistry, and from organic chemistry to biological chemistry. The first stage of chemical evolution perhaps began with the very origin of matter. In a series of cataclysmic reactions during the birth of a star, the elements of the periodic table must have been formed. About 15 billion years later, when the solar system was being formed, the highly reactive elements which occur in living organisms probably existed in combination with hydrogen—carbon as methane, nitrogen as ammonia, and oxygen as water. Four and a half billion years ago, when the planet earth was being born from the primitive dust cloud, the rudimentary molecules, which were the forerunners of the complex biological polymers of today, were perhaps already in existence. Within this framework, life appears to be a special property of matter, a property which arose at a particular period in the existence of our planet and which resulted from its orderly development.

The idea of life arising from nonlife, or the theory of spontaneous generation, had been accepted for centuries. One had only to accept the evidence of the senses, thought the ancients: worms from mud, maggots from decaying meat, and mice from old linen. Aristotle had propounded the doctrine of spontaneous generation in his *Metaphysics*. He had traced the generation of fireflies to morning dew, and the birth of mice to moist soil. His teaching was accepted by the long line of Western thinkers who had turned to him as the final authority in matters metaphysical and physical.

The ancient Hindu scriptures described life as having originated from nonliving matter. The *Rig Veda*, for example, pointed to the beginning of life from the primary elements, while the *Atharva Veda* postulated the oceans as the cradle of all life.

Newton, Harvey, Descartes, van Helmont, all accepted the idea of spontaneous generation without serious question. Even the English Jesuit, John Tuberville Needham, could subscribe to this view, for *Genesis* tells not that God created plants and animals directly but that he bade the earth and waters to bring them forth.

The world's literature is full of allusions to this popular belief in spontaneous generation. Virgil in his *Georgics* tells us how a swarm of bees arose from the carcass of a calf. Lucretius in *De Natura Rerum* refers to the earth as the mother of all living things: "With right it followeth then that earth hath won the name of Mother, since from earth have all things spring." Recall *Antony and Cleopatra*, act II, scene VII, where Lepidus tells Mark Antony "Your serpent of Egypt is bred . . . now of your mud by the operation of your sun—so is your crocodile."

In the middle of the last century, Pasteur, by a series of brilliant experiments, demonstrated that living systems could not arise out of nonliving material. Pasteur dealt the death blow to the theory of spontaneous generation which was based on incompetent observation and the willingness to accept the superficial evidence of the senses.

Unfortunately, Pasteur's work gave rise to the misconception that the problem of the origin of life could not be approached by scientific methods. The question of life's beginning was, therefore, considered to be unworthy of the attention of any serious scientific investigator. But a little thought makes it transparently clear that what Pasteur disproved was the growth of microorganisms from sterile starting material. It is indeed a very different thing from what we are concerned with in chemical evolution—the gradual formation of organic compounds over hundreds of millions of years, and the slow emergence of replicating systems.

The story of Louis Pasteur is often told to beginning students in biology as a triumph of reason over mysticism. But today we know it is perhaps the contrary. The reasonable view is to believe in spontaneous generation—though in a restricted sense.

Among those who speculated on the conditions necessary for the origin of life, Charles Darwin was a pioneer. In a letter to a friend, he wrote: "If we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present that a proteine compound was chemically formed ready to undergo still more complex change. . . ." This was too outrageous a declaration for the conservative thinking of Darwin's contemporaries. At the height of the controversy over the origin of the species, little or no attention was paid to the remote question of the origin of life.

The great impetus, however, to the experimental study of the origin of life began with the

Russian biochemist, Oparin.[9] Already in 1924, a preliminary booklet was published by him in Russian, pointing out "that there was no fundamental difference between a living organism and brute matter. The complex combination of manifestations and properties so characteristic of life must have arisen in the process of the evolution of matter." According to Oparin, "At first there were the simple solutions of organic substances whose behavior was governed by the properties of their component atoms and the arrangement of these atoms in the molecular structure. But gradually, as a result of growth, and increasing complexity of the molecules, new properties have come into being and a new colloidal chemical order was imposed on the more simple organic chemical relations. These newer properties were determined by the spatial arrangement and mutual relationship of the molecules. In this process biological orderliness already comes into prominence."

Independently of Oparin, Haldane[10] in 1928 had speculated on the early conditions suitable for the emergence of terrestrial life. "When ultraviolet light acts on a mixture of water, carbon dioxide and ammonia, a variety of organic substances are made, including sugars, and apparently some of the materials from which proteins are built up. Before the origin of life they must have accumulated until the primitive oceans reached the constituency of a *hot dilute soup*."

Twenty years after the appearance of Haldane's paper, Bernal[11] of the University of London theorized before the British Physical Society in a lecture entitled "The Physical Basis of Life." "Condensations and dehydrogenations are bound to lead to increasingly unsaturated substances, and ultimately to simple and possibly even to condensed ring structures, almost certainly containing nitrogen, such as the pyrimidines and purines. The appearance of such molecules makes possible still further syntheses. The concentration of products is an absolute necessity for any further evolution. One method of concentration would of course take place in lagoons and pools which are bound to have fringed all early coastlines, produced by the same physical factors of wind and wave that produce them today. A much more favorable condition for concentration, and one which must certainly have taken place on a very large scale, is that of adsorption in fine clay deposits. It is therefore certain that the primary photochemical products would be so adsorbed, and during the movement of the clay might easily be held blocked from further possibly destructive transformations. In this way relatively large concentrations of molecules could be formed."

A starting point for any consideration of the origin of life must turn round the question of the cosmic distribution of elements. Astronomical spectroscopy reveals that with surprising uniformity the most abundant elements in our galaxy are, in the order of rank, hydrogen, helium, oxygen, nitrogen, and carbon. Hydrogen, oxygen, nitrogen, and carbon are indeed the basic constituents of living systems. The table on the composition of the sun illustrates the distribution of these elements very clearly (fig. 22).

COMPOSITION OF SUN

HYDROGEN	87.0 %
HELIUM	12.9
OXYGEN	0.025
NITROGEN	0.02
CARBON	0.01
MAGNESIUM	0.003
SILICON	0.002
IRON	0.001
SULPHUR	0.001
OTHERS	0.038

Fig. 22.—Composition of the sun.

The present rarity of the terrestrial noble gases with respect to their cosmic distribution indicates that a primary atmosphere of the earth was almost completely lost in early times, and that the present atmosphere is of secondary origin. The chemical compositon of the secondary atmosphere must at first have been very similar to that of the primary atmosphere. Because of its high rate of escape,

[9] Oparin, A. I. *Life, Its Nature, Origin, and Development.* Edinburgh and London, Oliver & Boyd. 1961.
[10] Haldane, J. B. S. *Rationalist Annual,* 148. 1928.
[11] Bernal, J. D. Op. cit. p. 10.

most of the free hydrogen must have been lost, and the principal constituents of the atmosphere must have been water vapor, ammonia, and methane. It is this atmosphere of water vapor, methane, ammonia, and small amounts of hydrogen which will be considered in this discussion as the primitive atmosphere of the earth.

The energies available for the synthesis of organic compounds under primitive earth conditions are ultraviolet light from the sun, electric discharges, ionizing radiation, and heat. It is evident that sunlight was the principal source of energy. Photochemical reactions would have taken place in the upper atmosphere and the products transferred by convection. Next in importance as a source of energy are electric discharges such as lighting and corona discharges from pointed objects. These occur close to the earth's surface and hence would more efficiently deposit the reaction products in the primitive oceans. A certain amount of energy was also available from the disintegration of uranium, thorium, and potassium 40. While some of this energy may have been expended on the solid material such as rocks, a certain proportion of it was available in the oceans and the atmosphere. Heat from volcanoes may also have been effective. In comparison to the energy from the sun and electric discharges, this was, perhaps, not too widely distributed and its effect may have been only local, on the sides of volcanoes for example.

Most of these forms of energy have been used in the laboratory for the synthesis of organic molecules. Simulation experiments have been devised to study the effect of ionizing radiation, electric discharges, heat, and ultraviolet light on the assumed early atmosphere of the earth. The analysis of the end products has often yielded, very surprisingly, the very compounds which we consider today as important for living systems.

Among the first experiments specifically designed to test some of the theories on the origin of life were those of Calvin and his associates [12] in Berkeley. In 1951 they radiated water and carbon dioxide in the Berkeley cyclotron and obtained appreciable yields of formaldehyde and formic acid. Although in this experiment carbon dioxide was used as the source of carbon, instead of methane, it established very clearly that materials of biological significance can be synthesized non-biologically. It may be pertinent here to recall that in 1829, Wohler synthesized urea from ammonium cyanide and disproved the theory long held by Berzelius and others that a "vital force" was necessary for the production of organic compounds.

A classic experiment in this field was performed in 1953 by Stanley Miller,[13] who was then a graduate student of Harold Urey at the University of Chicago. When methane, ammonia, water, and hydrogen were subjected to a high-frequency electric discharge, some amino acids were produced. A more complete analysis showed a variety of organic products.

Miller's experiments on the mechanism of the synthesis of amino acids by electric discharges indicated that a special set of conditions was not required to obtain amino acids. Any process or combination of processes that yielded the two very basic carbon compounds, formaldehyde and hydrogen cyanide, would have contributed to the accumulation of amino acids in the oceans of the primitive earth. Therefore, whether the aldehyde and hydrogen cyanide came from ultraviolet light or from electric discharges is not of fundamental importance, since both processes would have contributed to the amino acid content. It may be that electric discharges were the principal sources of hydrogen cyanide, and that ultraviolet light was the principal source of aldehyde; and that the two processes complemented each other.

The work of Sidney Fox [14] of Florida State University has centered around the thermal model of biochemical origins. Although this model limits itself to a single form of energy, a somewhat coherent picture seems to emerge.

When a mixture of methane, ammonia, and water in the gas phase is passed through a heated tube containing alumina at about 1,000° and the reactants absorbed in water, amino acids are formed. Fourteen of the amino acids which commonly occur in protein have been synthesized by this method.

If the 18 amino acids usually present in proteins are heated to about 200° C., polymers can be obtained. These random polymers have been described as proteinoids. When hot saturated solutions of these polymers are allowed to cool, huge numbers of uniform, microscopic, relatively firm

[12] Garrison, W. M., Hamilton, J. G., Morrison, D. C., Benson, A. A., and Calvin, M. *Science*, 114: 416. 1951.

[13] Miller, S. L. *J. American Chemical Society*, 77: 2351. 1955.

[14] Fox, S. W. *Nature*, 201: 335. 1964.

and elastic spherules separate. These are usually 1.5 to 3 microns in diameter. For each milligram of solid, approximately 10^7 to 10^8 microspheres can be formed. Fox's work had thus led him to a theory of the origin of organized units. He considers them suitable models for the evolution of the cell.

In the experiments in our own laboratory,[15] we have adopted the simple working hypothesis that the molecules which are fundamental now were fundamental at the time of the origin of life. We are analyzing "the primordial soup" described by Haldane. The various forms of energy which are thought to have been present in the primitive earth have been used by us in a series of experiments.

In the experiments with methane, ammonia, and water, electron irradiation was used as a convenient source of ionizing radiation, simulating the K^{40} on the primitive earth. The results of this investigation clearly establish adenine as a product of the irradiation of methane, ammonia, and water. It is the single largest nonvolatile compound produced. The apparent preference for adenine synthesis may be related to adenine's multiple roles in biological systems. Not only is it a constitutent of both the nucleic acids DNA and RNA, but it is also a unit of many important cofactors (fig. 23).

The apparatus used for studying the effect of electric discharges on a primitive atmosphere is illustrated in figure 24. In a typical run of 150 hours, 65 percent of the methane was converted into organic material which could be recovered in ether and water solution. In the water-soluble fraction, adenine was identified.

As formaldehyde is formed by the action of electric discharges or ionizing radiation on a mixture of primitive gases, it was used as the starting material for synthesis in a further series of experiments. A preliminary separation into groups of sugars seems to indicate that by far the highest yield is of the pentoses and hexoses. Among these, the two sugars present in RNA and DNA, ribose and deoxyribose, were identified.

In a third series of experiments, hydrogen cyanide was used as the starting material. This again is one of the primary products when a mixture of methane, ammonia, and water is exposed to electric discharges, or ionizing radiation.

The use of hydrogen cyanide as starting material is also strengthened by the theory that comets may have been responsible for the accumulation of relatively large amounts of carbon compounds on the primitive earth. The CN band is generally the first molecular emission to appear on the tails of comets during the travel of these bodies towards the sun. It is also the band with the largest degree of extension into the comets' heads. It is possible

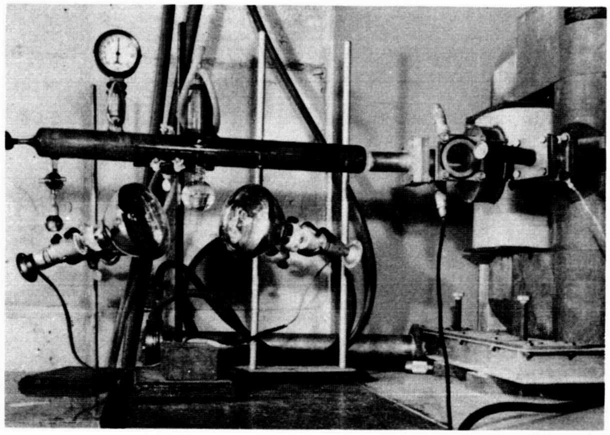


Fig. 23.—Electron irradiation of methane, ammonia, and water.

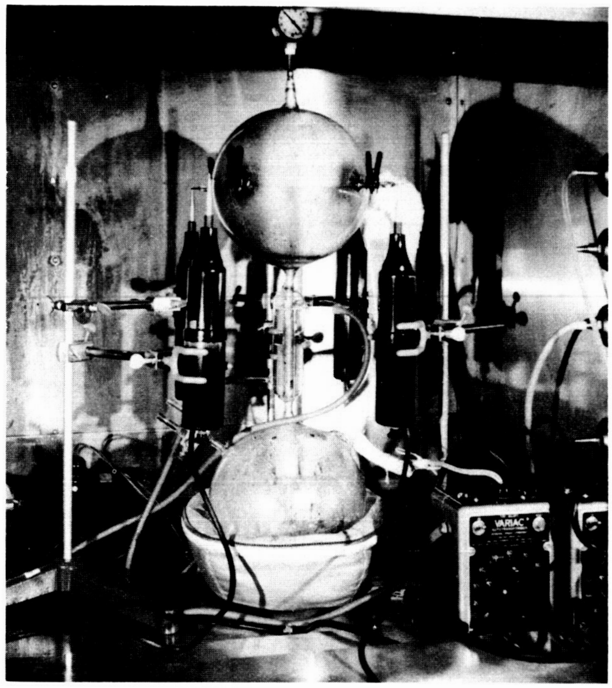


Fig. 24.—Electric discharge through a mixture of gases resembling the earth's primitive atmosphere.

[15] Ponnamperuma, C., Lemmon, R. M., Marriner, R., and Calvin, M. *Proc., U.S. National Academy of Science*, 49: 737. 1963.

that the heads of comets contain frozen free radicals which are volatilized by radiant heat from the sun. It is also possible that they contain frozen molecules which are vaporized and photodissociated into radicals by solar radiation.

About 40 million comets are now reckoned to be present in the solar system, and it has been calculated that about 100 comets have collided with the earth since the formation of our planet some 5×10^9 years ago. The amount of cometary material trapped by the earth during its first 2 billion years can be calculated to be about a thousand billion tons. Most of the cometary material must have been retained by the magnetic and gravitational fields of the earth. Hydrogen cyanide or its reaction products may thus have been found in fairly large concentrations, either locally or distributed through the earth's primitive atmosphere.

When hydrogen cyanide is exposed to ultraviolet light, a large number of organic molecules are formed. Among these we have identified adenine and guanine, which are constituents of the nucleic acid molecule.

In the experiments already described, we have established the formation of the purines adenine and guanine—and the sugars ribose and deoxyribose. It was therefore of interest to see whether the same sources of energy which were responsible for the synthesis of the purines and sugars could be instrumental in the synthesis of nucleosides and nucleoside phosphates leading up to the synthesis of the energy source adenosine triphosphate.

It has been suggested that the earth's primitive reducing atmosphere was at least slightly transparent around 2,600 A, and that the activation of purines and pyrimidines by ultraviolet light in this region was a possible step in the formation of nucleosides and nucleotides. In our laboratory [16] we have satisfactorily duplicated these conditions and established the synthesis of adenosine, adenosine monophosphate, the diphosphate, and ATP—the energy source of all living systems.

Recent developments in the science of quantum biochemistry have thrown new light on some very significant aspects of chemical evolution. It is a striking fact that many of the molecules which are essential to living systems are conjugated systems exhibiting the phenomenon electronic delocalization. In the nucleic acids, for example, the purines and pyrimidines are conjugated systems. Although the proteins do not, at first sight, appear to enjoy this property, a closer look shows us that the matrix of hydrogen bonding which exists in a protein molecule provides a certain measure of electronic delocalization. In the high-energy phosphates, there is interaction between the mobile electrons of one phosphoryl group with those of another. The porphyrins, for example chlorophyll and haem, which are of paramount importance in living systems, are highly conjugated molecules.

Even this meager consideration of electron delocalization leads us to the following conclusions:

1. Evolutionary selection used the most stable compounds.

2. On account of electron delocalization, these compounds were best adapted for biological purposes.

3. The possibility of life as we know it was made more probable by the appearance of these compounds.

The choice of conjugated systems is perhaps the most important quantum chemical effect in biochemical evolution.

Carbon and silicon appear in the same group of the periodic table, and both need four electrons to reach the configuration of the nearest inert gas. On account of this superficial and apparent similarity between carbon and silicon, the question of a "silicon biology" has often been raised in discussions on the origin of life. However, a careful consideration seems to indicate that such a prospect is very unlikely.

One answer to the question is forthcoming from a consideration of cosmic abundance. Carbon is certainly more prevalent than silicon in the universe. Another reason arises from the fact that hydrogen, carbon, nitrogen, and oxygen have been utilized in living systems, since they are the smallest elements in the periodic table and can achieve the stability of inert gases by the addition of one, two, three, and four electrons. Small atoms form tight and stable molecules. They can also form multiple bonds. In comparison to carbon, silicon forms weaker bonds with itself and other atoms. Silicon does not form multiple bonds, and the result is the formation of large polymers, like quartz, which are unwieldy and also remove any available silicon from circulation. A further reason for the unsuitability of silicon for life processes arises

[16] Ponnamperuma, C., Sagan, C., and Marriner, R. *Nature*, 199: 222. 1963.

from the fact that silicon compounds are fairly unstable in the presence of water or oxygen.

Optical activity has often been suggested as a very distinctive characteristic of molecules present in living systems. In living organisms, all syntheses and degradations involve only one enantiomorph. Molecules are either lefthanded or righthanded. While a start with one form or the other would have been self-perpetuating, it is difficult to understand how the initial choice was made. Physical forces such as circularly polarized light, the surface of asymmetric crystals, or spontaneous crystallization cannot account for the overwhelming tendency to produce only one form rather than the other.

A reasonable explanation appears to be that the structural demands of large molecules required the use of one form rather than both. The use of one optical isomer rather than mixtures would undoubtedly confer great stability on the polymers. This still does not answer the question of how the initial choice was made. Professor Wald [17] describes how he once discussed this matter with Einstein, and this was Einstein's reply: "You know, I used to wonder how it comes about that the electron is negative. Negative-positive—these are perfectly symmetric in physics. There is no reason whatever to prefer one to the other. Then why is the electron negative? I thought about this a long time, and at last all I could think was: it won in the fight!"

The most plausible solution appears to be that the single optical isomers were selected on the basis of stability of the structures of higher order. The final choice was arbitrary. This is a case of natural selection at the molecular level. It accords with the evolutionary scheme: "We are the products of editing rather than authorship." It will be most interesting indeed if the sampling of martian life reveals the presence of d-amino acids rather than l-amino acids. If we were to sample all life in the universe, we should hopefully end up with an equal distribution of l- and d-amino acids.

The decrease in entropy produced when a highly organized system results from less-organized matter has often been raised as an obstacle to the evolution of life from nonlife. The second law of thermodynamics applies to chemical and physical systems which are isolated in the sense that energy does not cross the boundary of the system. In such systems, entropy tends to increase or the state of the system becomes progressively more random.

A feature of the evolution of living organisms and of many processes taking place within living organisms is that in them entropy appears to decrease at the expense of a greater entropy increase in the environment. This point was clearly made by Schroedinger [18] in his book *What Is Life*. Living systems are not isolated. Energy does cross the boundaries of the system. This state of affairs is consistent with the second law.

There is no reason to doubt that we shall rediscover, one by one, the physical and chemical conditions which once determined and directed the course of chemical evolution.[19] We may even reproduce the intermediate steps in the laboratory. Looking back upon the biochemical understanding gained during the span of one human generation, we have the right to be quite optimistic. In contrast to unconscious Nature which had to spend billions of years for the creation of life, conscious Nature has a purpose and knows the outcome. Thus the time needed to solve our problem may not be long. It is unnecessary to belabor the difficulty of the task or the immensity of the prospect for any man's philosophic position. It is superfluous to discuss the skeptical and provincial viewpoint that would shrink from pursuing it, for what is at stake is the chance to gain a new perspective of man's place in Nature—an entirely new level of discussion on the meaning and nature of life.

Over 500 years ago, Copernicus in *De Revolutionibus Orbium Coelestium* reversed the scientific thinking of his time about man's place in the physical universe. A hundred years ago, Darwin's theory of evolution destroyed age-old beliefs of the uniqueness of man by tracing his origin from the brute. Today, we are gradually learning to accept the Oparin-Haldane hypothesis that life is only a special and complicated property of matter, and that basically there may be no difference between a living organism and lifeless matter.

[17] Wald, G. *Annals, N.Y. Academy of Science,* 69 : 352. 1957.

[18] Schroedinger, E. *What Is Life?* New York, Doubleday. 1956.

[19] *A Review of Space Research.* Op. cit.

THE SPACE AGE SYNDROME OF THE HUMAN MALE

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The medical dictionary says that a syndrome is a concurrence of symptoms. For the purpose of this discussion, we will need to equate emotion with symptoms. In fact, this is very nearly a description of middle age, when one exchanges the emotions for symptoms. An even better description of middle age is that time when the broad mind and the narrow waist exchange places!

What exactly is a "Space-Age Syndrome?" Well, this conference certainly is a part, but there is very little solid data for assessments. Tonight you will just have to grant me poetic license to say, "I think" or "This is the way it seems."

The first symptom—and we learn a little bit about ourselves in considering this—is one which is not only of paramount interest to biologists, but to all humanity. If, indeed, a space capsule were to go off course and land in the thick of the Amazon jungle, the very first thing that the astonished Amazonians would want to know about those organisms inside would be their sex.

Now, why call this a symptom of the space age rather than of any age? Because, thus far, there has been a really very male domination. It is true that the Russians orbited a lady, but between the U.S.S.R. and ourselves, there have thus far been 12 people sent aloft and only one has been a female. Our present count in the United States is 30 astronauts on the ready, and not one is a female. The anthropologists haven't given us a plausible explanation for this, unless it is owing to woman's natural conservatism and innate commonsense. Perhaps, the gratifications she seeks are more earthy and practical. And then our costume designers are engineers and they haven't yet provided a space suit that will even differentiate between a male and female, let alone flatter the figure.

There is an old dictum for describing this competition between the sexes—and that is that the easiest way for a woman to achieve the full benefits of a man's job is to marry him! Now, there is a fundamental disadvantage that career women face in our society, and we'll hear about this in our discussion. It makes their roles exceedingly difficult. The disadvantage is that they must deal chiefly with men.

Another symptom of the space age is age itself—that is, we cannot gratify the avid interest of youth. We find our severest critics among the working adults, where careers remain outside the pale or influence of space activity; and we face a "ho-hum" indifference from the elderly.

Wherever the economy finds vigor as a result of space activity, there is enthusiasm. Where it doesn't, there are very sharp questions. Partly, this situation awaits more dramatic demonstration of the general benefit. It awaits that day when material and services attributable to space-supported research begin to appear on the consumer market, and you can identify them.

An effort underway to accelerate this so-called "transfer" is something which a number of you attended in the way of a symposium at UCLA on Tuesday of this week. I think we gave it an unfortunate title. Maybe we frightened away the kind of people that we wanted to have there by calling it a "Symposium and Workshop on the Transformation of Knowledge and Utilization of Technology." That's kind of a jawbreaker.

Well, that leads us to another Space-Age Syndrome—which is education. This enterprise is second only to construction as the largest industry in the United States; and it appears that education might well replace construction in the next decade. But, despite the swelling throngs on the campuses of colleges and universities, where the construction crane is as familiar a landmark as "Old Main," we are not so much concerned with this incessant growth as we are with the self-pruning development known as the high school dropout. We are so convinced that higher education is essential to a contributory role in society, that we regard the dropout as a threat to the stability of the entire system. Remember just a few years back when it was fashionable and so-called progressive to refer to science as interdisciplinary? Now the boundaries between the major disciplines are so obscure that you've got to hyphenate your specialty two or three times to establish your field of competency: like physiological-psychology, magneto-hydrodynamics, or thermo-nuclear physics.

The entire fund of knowledge, said now to be doubling every 10 years, poses the image of a Ph. D. who does not subscribe to continuing education as being, within 20 years, hardly superior to the dropout.

Education also approximates the construction industry for its characteristically sparse research into its own processes.

It is part of the Space-Age Syndrome that the toiler's spade has become known as the "idiot stick," and that physical labor, along with routine work, is being automated into scarcity at an almost disorganizing rate. An encouraging corollary is the gratifying opportunity as well as the requirement to use more of one's mental ability in whatever position is secured. This development subscribes to the late Norbert Weiner's entreaty about "The Human Use of Human Beings."

When the giant strides are made into the ways and means of rapid learning, when much of the needed research is done—why should it not then be possible to rotate through the professions?

And, before leaving this subject of education, I should probably add to the symptoms we are discussing the pressures being brought on the public school teacher. With the publicity that is given to space science these days, the poor teacher is bombarded with questions about relativity, celestial mechanics, exobiology, fission and fusion, and a lot of confusion. It is symptomatic that the Education Division of NASA holds workshops for science teachers who are beginning to feel overwhelmed, so they can regain their sense of superiority.

To hear from someone else on this subject, let me quote from Clark Kerr, president of the University of California. I took this down over the telephone recently and we incorporated it into a little brochure:

"The basic reality for the university is the widespread recognition that new knowledge is the most important factor in economic and social growth. We are just perceiving that the university's invisible product, knowledge, may be the most powerful single element in our culture, affecting the rise and fall of professions and even of social classes, of regions, and even of nations. Because of this fundamental reality, the university is being called upon to produce knowledge as never before—for civic and regional purposes, for national purposes, and even for no purpose at all, beyond the realization that most knowledge eventually comes to serve mankind. And, it is also being called upon to transmit knowledge to an unprecedented proportion of the population."

Next is the symptom on communications. The communication satellite is the space-age symbol of this phenomenon. We seem to want to know everything that is going on everywhere; and what may too easily follow is the possibility to control everything that is going on anywhere. An interpenetration of cultures has already occurred to the extent that the New York Academy of Sciences already lists 600 differently constructed artificial languages. Certainly this is symptomatic. And I suggest to anyone here that if they are searching for a manifestation of real scholarship, try constructing an artificial language.

So we have a sharing of experiences becoming worldwide and almost instantaneous—either rhetorical or direct. When Echo II was launched early this year, it was seen by more millions of people than any artificial object in all previous history. Now, as the stage is being set for a worldwide audience, what exactly will we wish to say? And, how can we say it so it won't be misunderstood?

That which follows easily after the subject of education is the symptomatic acceleration of knowledge. The UNESCO figures tell us that somewhere in the world a communication concerning chemistry is published every minute; every 3 minutes a report on physics; and a report on medicine, biology, and electronics every 5 minutes.

And these reports flow largely from 115,000 different research laboratories. Thus, we're faced with the circumstance wherein a literature search may find a quicker and less expensive answer than actual research, but beginning with expert advisement that the research has not yet been done.

We had a professor from UCLA talk to us about the developing transformation of the knowledge industry, and yet this is already an old story to the managers of research and development. They talk about $100,000 as being the breakoff point, where it might be less costly to reinvent than to go through this morass of material. Because whatever it is you plan to use, you're going to have to test and confirm.

Still research grows and grows, until it has become the most rapidly expanding business in America. At its present rate of growth, it will equal the entire gross national product in another 60 years. Naturally, there's a leveling off in sight; and this is due, among other things, to the rising cost of research. So costly is the equipment and personnel, that over 80 percent of the present research and development is dependent on Government support. Where indeed is the private organization which could afford to develop atomic energy, or the fuel cell, or to explore space? Research and development for the Government, and research and development for private organizations, are altogether different breeds of cat.

The development of management systems such as PERT are essentially means of control so that you get some dollar's worth of result, or some assurance that you are not being lavishly wasteful with your money. But, there are actually no good mensurations to adjudicate the performance of research and development that is done for the Government. Private corporation success finds its criteria in the marketplace. So, we're kind of reversing the old dictum that necessity is the mother of invention. Now, we've got a kind of motherless child—we're trying to find use for the inventions that have already occurred in order to create new jobs, to dispel technological unemployment, and to increase the increment of the gross national product.

Back to our syndromes. Our jurists are contributing symptoms today just by asking questions as "Who owns space?" "How far does sovereignty extend?" and "Shall flags be raised on other planets?"

Militarists alarm us by saying such things as "whoever controls space can rule the world." Some support for this logic is implied in the race for space.

Anthropologists establish symptoms by pointing to launch vehicles as the cultural symbols of our era, vying with the cathedrals and the pyramids of times past.

Sociologists, economists, businessmen, and politicians are so impressed with the rate of change that they characteristically use or abuse the term "revolution." This is a symptom that is likely to remain with us for another generation.

We continually refer to the revolution of rising expectations, the human rights revolution, the cybernation revolution, the research revolution, the managerial revolution—and not the least of these, the revolution in biology.

On the front page of the *Los Angeles Times* this week was an article referring to the remarks of a biology professor at Johns Hopkins University. The professor said that married couples in the future will need special permits to have children; that the population explosion is the most dire threat next to the thermonuclear explosion.

When we put a number of these symptoms together into a Space-Age Abner, we find that we have a youngish male, very much on the move, with a lot of education and an appetite for a great deal more. He is identified with most of the revolutionary things that others point to. He is highly paid, but he is more at home with ideas than he is with dollars. He represents the creative man overtaking the organization man. And, he is wrestling with the greatest intellectual challenge the human has ever faced: that of trying to account for the origin of the universe and the evolution of life. He wonders how and if he will need to explain himself and his civilization to others out there. At the same time, he is somewhat confident that he won't find anything superior in intelligence: he is rather resigned to encountering lower forms, like algae and lichen. And yet the bizarre forms of life that he has examined here allow him to expect almost anything. This sort of undertaking sets him apart from his neighbors and groups him with the learned elite. They're respected, but they are not altogether appreciated—even in their own community. The theologians are not certain how to approach him. They wonder whose information would be best for the other to have.

To this Space-Age Abner, even the eternal verities like sunrise and sunset will dissolve into an indexing that identifies them by planet and by solar phase. He could never look at the moon in the sky like lovers or the shepherds of old because he sees the moon now as a port of call and a Rosetta Stone that needs decoding. He thinks seriously about the agelessness of traveling with the speed of light when time and distance interfuse; he seeks means to escape, not just the earth, but the solar system itself so he can climb to the edge of this galaxy.

How many in total can we refer to as Space-Age Abners? There are some 70,000 scientists and engineers employed in space programs. There are thousands more teachers whose interests and efforts draw them in. But the degree of involvement is purely a speculative one: let's say 100,000 at the outside. So, in the United States, this becomes one person in 2,000.

For most people throughout the world, and in this country, their heads are much closer to their feet. Food and shelter are more urgent than literacy. Disease and despair shield their eyes from the glitter of space accomplishments. But if we were to address ourselves to an order of need, first things first internationally, there is some question whether mankind would yet be to the common level of manufacturing the ukulele.

The Space-Ager is concerned about this, though hardly victimized. Indeed, the struggle that goes on in the Universe is in his breast. And the Great Universe, as it enjoys definition and meaning, is in his own mind.

NASA'S SCIENTIFIC AND TECHNICAL INFORMATION PROGRAM

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The Scientific and Technical Information Division of NASA conducts an aggressive program: (1) to acquire the world's scientific and technical literature of interest and pertinence to aerospace programs; (2) to organize this literature and bring it under bibliographic control rapidly; and (3) to both announce and disseminate the literature to all appropriate audiences in the shortest possible time.

In order to carry out this program, the Scientific and Technical Information Division has contracted with Documentation, Inc., of Bethesda, Md., to acquire, process, and announce the world's technical *report* literature— that body of information which is considered informal or unpublished. Similarly, by cooperative arrangement with the American Institute of Aeronautics & Astronautics, New York City, the world's *formally published* literature, i.e., learned journal articles, scientific meeting papers, monographs, books etc., is acquired, processed, and announced. The output from these two contractors appears in the two abstract journals, *Scientific and Technical Aerospace Reports* (Star), and *International Aerospace Abstracts* (IAA). The IAA reports appear on the 1st and 15th of each month, and the Star reports on the 8th and 23rd. The journals are identical in categories of information covered; and in their subject, author, corporate source, and accession number indexes; and both provide quarterly, semiannual, and annual indexes. During calendar year 1964, it is anticipated that the two journals will announce and abstract in excess of 40,000 discrete items.

To complement and enhance the printed indexes in the abstract journals the Scientific and Technical Information Division produces multiple copies of magnetic tapes on which are stored index entries in much greater depth than is feasible on a printed page. These tapes are provided to NASA research centers and contractors, and to academic institutions such as Indiana University, Wayne State University, and the University of Pittsburgh, which are conducting technologically oriented programs under contract with NASA.

In furtherance of the concept of speed of announcement and abstracting, every item received appears in an issue of the abstract journal within 4 to 6 weeks of receipt. In consonance with the principle of rapid dissemination of pertinent information, during the period while incoming new material is being processed for announcement, it is simultaneously microfilmed, reproduced on single film sheets(approximately 4 by 6 inches, which carry 60 pages of images), and distributed to all official recipients[1] 6 to 10 days in advance of the mailing dates of the abstract journals. Thus, a scientist or engineer who scans a current issue of the abstract journal and finds an abstract of an article or report of specific interest knows with certainty that the entire report in microfilm *is already available* for his use within his own organization.

A recent development that is being employed to provide needed information to scientists and en-

[1] NASA centers, NASA contractors (including colleges and universities), other Government agencies, and the 12 Federal Regional Technical Report Centers.

gineers while filtering out extraneous materials is our system of Selective Dissemination of Information. Through utilization of this system, all of the index points of every report are recorded and stored on magnetic tapes; and participating scientists and engineers [2] are assisted in recording the range of their professional interests and needs by employing the same indexing vocabulary. Thus "profiles" are created of the contents of each document; and interest "profiles" of each man. Computers compare these profiles very rapidly and facilely, and whenever the two profiles match (based upon a predetermined number of matching terms), the participant is automatically notified of the existence of a document *at the place where he is employed.*

In addition to the services mentioned above, the Scientific and Technical Information Division provides two series of bibliographies: an on-demand bibliography service, and continuing bibliographies in the aerospace field. Rapid translation service is also furnished. The Division operates a Technical Publications service which is responsible for the issuance of all of the formal NASA publications series, but additionally concentrates on the repackaging of scientific and technical information. In this case, "repackaging" is used to denote the assembly of highly specialized technical information for broader, interdisciplinary audiences, or for lay audiences; to quickly assemble and publish papers presented at scientific meetings and symposia that are of interest to aerospace audiences; and to issue data compilations, handbooks, and state-of-the-art surveys.

The dissemination of aerospace technical literature alluded to earlier encompasses the NASA family of research centers and NASA contractors, other Government agencies and their contractors, and, perhaps more significant for this audience, some 150 college, university, and major public libraries throughout the United States, which have requested either all of the NASA information products, tools, and services, or selected portions that they desire.

[2] NASA staff in Headquarters and centers, and selected USAF scientists and engineers.

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THE NASA POLICY FOR GRANTS AND RESEARCH CONTRACTS WITH INSTITUTIONS OF HIGHER LEARNING

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It should be made clear in any discussions involving NASA's educational responsibility that NASA is a mission-oriented agency. Behind our support of research, encouragement of graduate training, and attempts to improve the facilities in which research is conducted upon university campuses, is the motivating force of a number of objectives which we are charged by law to pursue. Some of them, such as "the expansion of human knowledge of phenomena in the atmosphere and space," and "the preservation of the role of the United States as a leader in aeronautical and space-related science and technology," are broad and far reaching in their implications.

Obviously, we cannot hope to accomplish such objectives without tapping the intellectual resources of the university community; but it must be made clear and kept constantly in mind that our activities are not primarily altruistic or eleemosynary in origin. No agency could be more aware of and more interested in the importance of education, in the broadest sense, to its successful functioning; yet aid to education is not part of our mission. Such a constraint is not necessarily disadvantageous. It may, in fact, encourage a concentration of interests and energy which, within its proper scope, generates a thoroughly wholesome identification with and concern for the problems of the ultimate customer. This point is mentioned here with emphasis to help clarify the reasons behind our methods of operation in the eyes of those who may be more accustomed to dealing with quite differently chartered agencies, such as the National Science Foundation or the Office of Education of the Department of Health, Education, and Welfare. We seek to complement and extend in depth, within our own broadly defined regions of interest, the invaluable efforts of such agencies. If we succeed, the Nation will have the benefit of an interrelation of roles of not only Federal agencies and universities but of the agencies themselves—which can serve the public interest of us all.

While admitting that "aid to education" is not part of our mission, we can however, through constructive methods of operation, secure the maximum direct contribution of the Nation's university community—and as a byproduct, strengthen the established academic framework. This we have accomplished, within the limits of our resources, both through the Sustaining University Program and in our other relationships with universities. Our policy in all our university activities is to work within the existing university structure and not to foster activities tending to weaken the university or pull the researcher away from teaching. In turn, we expect the university to bear its share of responsibility and devote an appropriate portion of their material and human resources to the national space effort.

SUMMARY REPORT OF ROUNDTABLE DISCUSSIONS AND CONFERENCE PROGRAM

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It is my pleasure this morning to synthesize some of the main ideas brought out in the roundtable discussions and to conclude with a look to the future in terms of the thinking we have heard expressed during this week.

Summary of the Roundtable Discussions [1]

The ideas and conclusions that evolved out of the roundtable discussions seem to fall under various topics or discussion areas. Some of the topics are of interest to all of the participating groups in this Conference, while others are of more particular concern to one or another of our groups. I would like to begin with those items which are of interest to all, and then move on to areas of particular interest to specific groups: the Council of State Science Supervisors, the AAAS Subcommittee, the U.S. Office of Education science staff, and the NASA education staff with Spacemobile lecturers.

Roundtable participants agreed that the space age places a heavy requirement on the educational system in three major areas: first, the training of technologically qualified space engineers and scientists; second, the improving of public understanding; and third, the strengthening of the basic areas of education in science and mathematics. NASA's education program has an obligation to serve the great public interest in space and to cultivate it to the enhancement of science and mathematics generally.

It was generally agreed that the public needs to have greater understanding of the nature of science and greater appreciation of the exploration of space. In connection with these aims, the following questions were raised: What does the average citizen need to know to be considered scientifically literate? What are the attitudes of the average citizen toward science and toward space exploration in particular? How can we educate to produce a greater degree of scientific literacy?

Everyone seemed to agree that space science involves all the sciences and that the processes and skills of space science are the same as they are in all other areas of science. In other words, scientific activity in so-called space science calls for skill and observation, experimentation, measurement, and creativity just as it does in any one of the science disciplines. It was pointed out, however, that space science research has developed new and different devices and instrumentations, most of them in very recent years. It was also noted that space science research and related technological activity have resulted, to a unique degree, in teamwork by scientists representative of the various science disciplines.

Curriculum.—To meet the needs both for an informed citizenry and for a scientific, engineering, and technical manpower pool, it was generally agreed that space science should not be isolated in

[1] The roundtable discussions were held Wednesday afternoon, June 3, 1964. Each roundtable was composed of 8 to 10 conferees, who discussed science pedagogy, including NASA's educational mission. No effort was made to reach formal agreement or to produce recommendations. Essentially, the purpose of the roundtables was to provide a medium for sharing ideas for acknowledged leaders in science teaching who were representative of elementary and secondary schools and colleges and of the several science disciplines.

the curriculum. Rather, space science should be incorporated and interwoven into the existing curriculum in all grades, elementary through college. An effort to integrate space science into the curriculum involves not only updating curricula in existence for years but also enriching curricula that are still in the formative or beginning stages, such as BSCS, PSSC, Chem Studies, and others. However, it was also pointed out that in the junior high program, an earth science course is emerging to replace or to accompany the general science course. In some schools, earth science is joined to space science and the course labeled, accordingly, "Earth-Space Science."

Participants at the roundtables concurred on the principle that NASA should not conduct large-scale curriculum revision projects, such as those undertaken by the National Science Foundation or the several professional associations, but they also emphasized that NASA is in a unique position to provide materials that inspire, suggest, and assist efforts by schools at all grade levels to update their teaching in terms of space age developments and, further, that it should undertake such curricular assistance efforts as requested. Some participants suggested that in addition to providing schools with materials for science classes, NASA should perform the further service of supplying materials for the guidance counselor on careers, and even for the social studies teacher on social and technological implications.

Studying the hypotheses and the research findings of scientists investigating the phenomena of space provides students with opportunities to apply, reinforce, and identify concepts in other disciplinary areas or frameworks. To many of the educators present, such use of space science provides a splendid opportunity for the students in elementary and secondary schools, particularly the latter, to experience and to understand the general applicability of these concepts. The roundtable participants, however, also made clear that to introduce space science into the schools necessitates appropriate instructional materials. Such instructional materials are not now available, either for laboratory use or for individual study and homework. The point was stressed that if these instructional materials could be made available in the near future, they might be integrated, in an organic sense, with the broad-scale, comprehensive curriculum projects now being undertaken in physics, chemistry, mathematics, earth science, and biology.

Teacher Education.—It was agreed that all teachers need to perceive the social implications of space exploration in order to capitalize on the interest which youth has in this field, whether it be in the teaching of language arts, social studies, mathematics, or science. It was also stressed that preservice teachers—those who are preparing to teach—need more information regarding basic scientific and mathematical principles involved in space science. It was pointed out that NASA could and should help enrich the standard science courses of the several disciplines by providing textual and audiovisual teaching materials, possibly laboratory apparatus, and, where available, visiting resource speakers to enrich the standard science courses in the several disciplines. It was recognized, however, that space understandings can be taught more effectively and with less duplication of effort through the required standard courses of the several science disciplines than through any added course labeled "space science"; and that, further, the strictures of a 120- to 150-hour teacher preparation program would permit only a few to enroll in such an added course in any event.

Participants also agreed that high school teachers should be well grounded in the techniques of research. Knowledge of the techniques of research is becoming increasingly important for teachers who follow the new science curricula, for they must be able to design and supervise open-end "experiments" for use of pupils in their classrooms.

The subject of the noncredit or the elective-credit space science workshop or course for inservice teachers, usually a course of an introductory or general nature, stimulated lively discussions. Suggestions were made that seminars, courses, workshops, or institutes of a similar nature, but with more advanced content and directed to scholars with considerable science background, be offered. These, it was thought, should be staffed by specialists representative of the several space science disciplines and conducted for a semester or more rather than for a 2- or 3-week period in the summer. Another suggestion was that space science workshops or institutes be conducted for outstanding secondary school students.

State Science Supervisors.—It was agreed that the role of the State science supervisor will be increasingly important and will require additional supervisory personnel as well as relief from certain routine chores and from redtape. The science supervisor must find more time to spend on the professional tasks involved. Such tasks include coordination of space science activities at all levels, preparation and dissemination of information, visitation to schools, planning facilities, and examining and reviewing curricula, materials, and resources such as texts, audiovisuals, and Spacemobile presentations. It also involves participation in conferences and meetings such as this one, and the sponsoring, encouraging, and evaluating of experimental science programs in the school districts served. Finally, it includes the highly important task of working with scientists at the colleges and universities to help bring their competencies and contributions to the schools.

The relationship of the State science supervisor to the NASA Center Education Director was noted as one that could be mutually helpful. Toward that end, however, a close and continuous contact should exist between State science supervisors and NASA science educators. Also, the NASA Education Director, through the science supervisor of each State, should keep that State's education authority informed of his office's science education activities within its area. Effective two-way communication of this kind would result in better understanding of NASA's services by administrators, supervisors, teachers, and parents. It would also provide occasion for real depth in NASA's aid to State and local curriculum efforts and to State and local teacher-education efforts, and in NASA's assistance through reading materials, audiovisual instructional materials, and consultant and speaker resources, including Spacemobile presentations.

In the case of Spacemobile presentations, it was pointed out that State science supervisor-NASA Education Director relationships could make such presentations more productive in an education sense by (1) effecting teacher and pupil orientation to the Spacemobile service and Spacemobile lecturer orientation to the school; and (2) by helping provide and encourage classroom followup of the lecture-demonstration in order to take advantage of the motivation to learning that the lecture creates.

College Science Teaching.—The roundtable participants who discussed questions of science teaching at the collegiate level considered the following: keeping up to date with developments in their disciplines; reorienting the college courses; providing space-science instructional resources for college courses; and supporting research in space-related areas.

There was repeated emphasis on the importance of institutions of higher learning being kept up to date on the latest technical and scientific information emerging from rapidly expanding areas of research. (The Conference program included a representative of NASA's Office of Scientific and Technical Information at a later session to explain NASA's efforts to answer this need of the colleges.)

There was recognition of the need for college course revision in the light of increasing numbers of secondary school graduates who are now entering college with advanced backgrounds in science and functional research orientations to the use of the science laboratory. It was pointed out that colleges are giving serious thought to the questions of science teaching to meet the needs not only of these graduates but also of coming generations of secondary school graduates generally, in terms both of the introductory and advanced college course curriculum content and of the preparation of the college teacher, himself.

Another element in the college discussion was the relationship of the college science course content to the needs and problems of industry and particularly of engineering. It was pointed out that college and industry people should work closely together to relate, where educationally sound, industrial application to the science teaching program. It was also noted that colleges must stress the fundamentals and, by so doing, develop students who are capable of adapting to the changing conditions and demands of industry.

The need for additional college science laboratories was also discussed, as was the necessity for keeping college textual and audiovisual teaching materials up to date. It was suggested at one point that the Spacemobile lecture-demonstration, if conducted by a lecturer with sufficient depth in the appropriate discipline, might be a useful resource.

Finally, there was discussion of the importance of NASA's supporting space-science-related research at the college level, i.e., in schools that do not offer the doctorate in the sciences, in order to encourage and assist faculty and students in the several science disciplines to gain greater understanding of space science.

The Spacemobile.—The roundtable participants recognized the value of the Spacemobile as an instrument of science education. They urged that the Spacemobile lecture be continuously scrutinized for accuracy, that it be evaluated to insure that the best and most modern science education research is applied, and that it be related to themes and understandings which are being developed in modern science curricula. The lecture, for example, should reflect the increasing emphasis in today's science teaching on student involvement, particularly in the processes of scientific inquiry. Greater emphasis, it was suggested, should be placed on science as such than on propaganda, technology, or gimmicks.

Some participants felt that the lectures should have less content which is merely factual or technologically oriented and suggested that they be revised with the help of scientists representing other disciplines and of educators particularly qualified in learning theory.

In addition, the lecturer should have a good science background in order to serve as a resource person in science classes and should be encouraged to use his own, individual talents and background in science and to develop Spacemobile lectures and classroom presentations around his particular scientific specialty. He could then relate this specialty to the bigger picture in the totality of space exploration and thereby emphasize the interrelatedness of space exploration.

In the discussion on the desirability of relating the Spacemobile lecture to science curricula now being developed, it was pointed out that the lecture can enhance, extend, and apply the themes and large understandings, such as change, interrelatedness, force and motion, and so on, which students are currently conceptualizing through the various national science curriculum projects. This alinement with modern science curricula, as a matter of fact, should characterize *all* the NASA educational services. Workshops, teacher education materials, films, and publications should all help focus attention on the basic principles of science as they relate to space exploration. These, in turn, will enable teachers to make better use of and to capitalize on the interest of students in aerospace science and to relate this interest to each of the other science disciplines.

Out of the roundtable discussions came important challenges. How can space science stimulate all of the sciences—including oceanography, geology, and botany? How can it stimulate the schools to develop scientists, engineers, and technicians who possess the competence and the creativity to meet and solve space science problems? And, finally, how can the schools develop a citizenry sufficiently knowledgeable to cope with the societal problems that these developments in the space sciences present?

Summary of the Conference Program

I would like now to review the total Conference program and try to pick out some of the salient thoughts and ideas—and project them ahead just a little in terms of what we face as educators.

The theme of this Conference is "Science Education in the Space Age." I confess to being concerned about this; I sense a fallacy in the idea of educating for an age. As we look back over the history of man, we find that he has progressed through a continual series of ages in developing our modern culture. We note that each of these ages is characterized by certain unique materials, products, and technology. Each has been compounded and built one upon the other; and all are still in effect today. We are still in the Stone Age, since products and materials made of cement, ceramics, and plaster are widely used. We exist in the Age of Bronze, iron, and steel, for these, as well as a myriad of new materials and alloys, are used for everything from aluminum in candy wrappers to zirconium in atomic reactors. We are still in the industrial age as we see ever greater expansion on the automobile, the electronics, and the missile industries, and the thousands of smaller industries which are emerging. We exist in the air age. Here we are today, planning to leave very soon and to be home on the other side of the Nation in just a matter of minutes. I would like to point out, as a bit of side interest, that it is very fitting that we are meeting in this hotel today, because the whole concept of the fly-in conference, where large hotels would be built adjacent to airports and people could come in and find all of their needs, was first put forth in a book, *Aviation in the Modern World*, by Mr. James Bernardo.[2] We exist in the atomic age as men strive to harness the energy of the atom to do the world's work.

[2] Bernardo, J. V. *Aviation in the Modern World*, New York, E. P. Dutton, 1960. 352 pp. (Mr. Bernardo is Director, Educational Programs and Services Office NASA Headquarters, Washington, D.C. A Conference speaker.)

And man added the dimension of infinite vertical movement as he entered the age of space.

It is significant that the length of time between each of these ages has been diminishing over the years. The stone age lasted for many thousands of years. The bronze age lasted about 1,000 years. The industrial age started about 100 years ago and the air age started about 50 years ago. The atomic age was born about 25 years ago, and we will soon celebrate the sixth anniversary of the space age.

We can notice that each new age is coming upon our culture with increasing rapidity. Major technological revolutions occur at shorter and shorter intervals. At this rate, if you will allow me to make a prediction, our society in a few years will be experiencing a major new age every few months.

Education in the space age, therefore, is a conception which is inadequate to cope with the dynamic changes which will be taking place in our future society. I think that Dick Brenneman [3] helped us to take a look at some of the bigger problems last night. By the time the children and youth of today's space age assume their role in adult society, they will encounter an entirely new age. By that time, our present knowledge and facts will have proved inadequate. The jobs and careers we think of today will no longer exist, but will be replaced by others as yet unclassified. The world will require new skills, aptitudes, and knowledge. How, then, should we today prepare our youth for living in the world of tomorrow? Herein lies the main topic for our consideration—a topic whose significance must not be blurred by adults who are still thinking in terms of the horse-and-buggy age.

I could take a great deal of time listing for you the kinds of problems related to space which our children may be facing. There is the problem of military control of space. There is the problem of who is going to control the commercials on international television. A tremendous problem of the future lies in the life support and protection of astronauts as they travel through space for extended periods of time; can they withstand long periods of weightlessness, radiation, and isolation? I could point to the need for new sources of energy to send our rockets deep into space and to power our space stations. I could go on and on. There are a host of technological problems related to the age in which our students will be involved.

Some of the students who are in your schools today will be working on, contributing to, and solving many of these problems. These and similar problems will be solved in their lifetime. It will take great skill, scientific knowledge, and tenacious research. Experiments will be conducted and projects undertaken and billions of dollars spent by private industries and governmental agencies. Soon weather will be controlled; we will have instantaneous international television, and telephone communications; the world's deserts will flower; the seas will be harvested; new energy sources will be exploited; the near planets will be explored; diseases will be conquered; and life will be lengthened and enriched. All of these challenges will dominate the attention, tease the curiosity, and intrigue the intellect of future generations. These are important social and technological problems facing us. Some will continue to be problems for years to come.

Beyond these, however, I think we can see a situation arising which will bring on even more profound problems than the ones I have just mentioned. As we look to the future, we can see that the problems which will face these children and youth—problems of a social and philosophical nature—will grow out of the *effect* that technology has on society, rather than out of the technological questions, themselves.

I would like you to think with me, if you will, in terms of three explosions. The word "explosion" has always given man a sense of awe, of cataclysm. The effects of the three explosions I am thinking of will be to present some of the biggest problems of our coming generations. The fuses have already been lit and our time is running out.

The first explosion I'd like to draw your attention to is the nuclear explosion. You are probably thinking immediately of nuclear explosion in terms of an atomic or hydrogen bomb, each in itself a terrifying problem. But *this* nuclear explosion has to do with the nucleus of the atom and the nucleus of the cell, and the nucleus of the universe. In the 20th century, man has invaded the nucleus of the atom. He has begun to release its energy, to understand its structure, and to dissect its parts.

[3] Richard H. Brenneman, Technology Utilization Officer, NASA Western Operations Office, Santa Monica, Calif. A Conference speaker.

Dr. Ponnamperuma [4] has shown us that in this century man has deciphered the living cell, recreated its components, and anticipated its control. Also, Dr. Newell [5] helped us see that in this lifetime we will probe the secrets of the universe as man asks where it all came from and where it is all going.

The results of this nuclear explosion will have tremendous effects on our society. As we discover how to control thermonuclear reactions and as this energy is applied and used on a wide scale, we will find that nuclear energy will be used as a primary source of power. The atoms and molecules themselves will be used as timekeepers, as computers, and as storehouses of information.

With the energy of man being replaced by the energy of the atom, we will have increased mechanization and automation to a much greater extent than we have now. Life is going to be revolutionized because people will have much less work to do. This problem, implicit in an industrial civilization, will reach ever greater proportions as more and more nations of the world harness nuclear energy to do their work, and I think Dr. Kaplan [6] helped us to see this.

The problem, then, as a result of the nuclear explosion, is that at some point we must decide what people are going to do with their leisure time. There is some speculation today that improper use of leisure time is contributing to juvenile delinquency and crime. It must be pointed out, however, that with leisure time we are also able to read more, to pursue other cultural activities, and sports, travel, and hobbies. Thus the question arises, will more leisure time leave man's mind free to think constructively and creatively, to contemplate and appreciate the esthetic aspects of his environment—or, will it allow his values to become decadent and amoral? This question is then followed by another: How can science contribute to the consumer's appreciation of and relatedness to his environment?

I think Dr. Ponnamperuma showed us that the invasion of the nucleus of the atom will soon be overshadowed by man's penetration into the nucleus of the living cell. I think we are moving to a time when it will be within our power to modify and to adapt living cells and ultimately living creatures. And when we can do that, the potential, whether for good or evil, will be enormous. As we understand the composition of the nucleic acids that control the living cell, man can alter the nucleic acid molecule in such a way as to produce the kind of cell desired. We will, of course, control cancer and virus diseases and congenital birth defects. But the question arises, if you can alter a human cell, can you alter a human being? And if so, toward what end?

Also, the exploration of space will soon lead to the solution of some of man's age-old questions about the origin of the universe and the possibility of life on other celestial bodies. Are we prepared to find the answers? We may find some evidence which disproves or substantiates some of the current scientific theories.

Dr. Ponnamperuma again helped us see that scientific knowledge has upset man's complacent thinking of the past. For years, men traveled under the delusion that the earth and the mind of man were the center of the universe. A major revolution occurred in man's thinking when he found himself to be inhabiting a relatively small speck of matter, circling a rather inconspicuous star, in one of thousands of galaxies.

Man's thinking met another revolution as he was faced with the idea that life did not occur by spontaneous generation, but rather that it had evolved throughout the centuries, adapting to the environment and mutating by chance to produce this current state in the evolutionary process.

And now we are approaching another revolution in man's thinking, as science sheds new light on the theories of the origin of the universe and the possibility of extraterrestrial life. Will children of this space age be prepared for the revolution in thinking which is going to take place in their lifetime?

And so, from these nuclear explosions, we see a society that may be becoming increasingly overly mechanized, standardized, and more fully automated. We see an affluent society with many conveniences, high standards of living, and increased leisure time. We see a society increasingly steeped in cold, scientific realism.

In this situation, the individual needs a sense of personal self-realization more than ever before, To live richly and sensitively, he needs a sense of

[4] Cyril A. Ponnamperuma, Acting Chief, Chemical Evolution Branch, Exobiology Division, NASA Ames Research Center, Moffett Field, Calif. A Conference speaker.

[5] Homer E. Newell, Associate Administrator, Office of Space Science and Applications, NASA Headquarters, Washington, D.C. A Conference speaker.

[6] Joseph Kaplan, Professor of Physics, University of California at Los Angeles; and Chairman, U.S. National Committee for the International Geophysical Year. A Conference speaker.

direction and an integrity of purpose that can be derived only from values he himself has formulated or discovered and accepted. He needs to develop the ability to react with esthetic and moral discrimination to the array of stimuli that bombard him constantly in the fast-paced culture of modern America. Without such discrimination, the child's future vocation is likely to have little meaning beyond the bare provision of material things, and his leisure time is apt to bring mere escape from the routine of daily living. I think he needs spirituality, morality, and esthetic appreciation, each as basic to the humanity of man as are intelligence and physical well-being.

The second explosion I'd like to discuss with you is the population explosion. The last time I was in Washington with my wife, I noticed a huge electric clock in the lobby of the Department of Commerce building which tells the story of U.S. population changes. There is one birth every 7.5 seconds, and one death every 19 seconds. One immigrant enters every 1.5 minutes, and one emigrant leaves every 23 minutes. We have a new population gain of one person every 10.5 seconds, more than 8,000 people every 24 hours, or about 3 million every year. Roughly speaking, the population now doubles every 45 years. If current patterns of growth continue, the U.S. population will rise to 200 million by 1966, and to 260 million by 1980. By the year 2000, the population will reach 350 million.

Furthermore, the most rapid rate of growth of the world's population is *not* in the United States but in many of the newly emerging nations. We must realize, then, that the majority of the world's future population will be non-Caucasian and non-Christian.

The problems facing our children, however, will not be so much with the housing and feeding of this population, for by then new sources and processes of food production will be developed, the moon could be populated, and the ocean depths inhabited, if need be. The problems of living with the population explosion, coupled with the nuclear explosions, however, may result in an increasingly impersonal and mechanistic society. This poses the questions: Can creativity and individualism continue to be important in the growth of civilization, or will we give way to conformity and homogeneity of the masses? Can our children continue to value human dignity in this vast prolific sea of humanity? Can they respect and value the rights, property, privileges, and potentials of others when living in such proximity? Our responsibility, then, is to develop in children of this space age the ultimate concern for other groups and individuals.

The third and last explosion I'd like to discuss is the explosion of scientific knowledge. The amount of knowledge available today is expanding at a fantastic rate. This is because of the persistent application of scientific procedures, not only to the nucleus of the atom, the cell, and the universe, but to the whole compass of human experience. It is multiplied by the invention of instruments to conduct inquiry with range and precision. Modern facilities for travel and instantaneous communication have made available the major part of the world's store of knowledge to anyone who wishes to use it. Extensive libraries and museums have contributed to the accumulation and storage of vast treasures of knowledge.

The explosive growth of the world's population has given rise to the number of workers in the fields of inquiry. It has been estimated that there are about seven scientists alive today for every eight who lived since the mid-17th century. Or, to put it another way, 85 to 90 percent of all modern scientists are alive today, working to push forward the frontiers of knowledge; and with increasing technology they *are* pushing it forward with greater range and skill. At the rate we are going, we can estimate that by the year 2500 scientists will outnumber other persons by eight to one.

In addition, each of these numerous scientists is writing and publishing his research results. The flood of literature is threatening to drown all of us in a sea of articles, papers, books, reports, and IBM cards. Twenty-four hours from now there will be some 4000 more newly published monographs in science. Even we in NASA have been accused of planning to reach the moon not by our rocketpower, but by stacking our publications one atop the other.

In recent years we have heard it said that communication among scientists, or rather the lack of it, is one of our biggest problems. Each scientist is becoming more and more specialized in his own highly developed field of inquiry. No longer are there just chemists or geologists, but rather each one is doing research in a narrow, particular area of endeavor.

It is obvious that the Nation needs intelligent scientists, creative engineers, and competent technicians if it is to maintain its leadership in world affairs. An even bigger problem, however, exists in the fact that the requirements of this modern society make it imperative that not only scientists but all citizens in a democracy attain minimum literacy in the natural and physical sciences. They need to understand science if they are to comprehend the natural and social world in which they are to live and if they are to grasp its implications. The problems which will face society cannot be approached wisely or effectively without a reasonable understanding of their scientific aspects. Citizens cannot be expected to furnish wise support or make adequate decisions unless they are given a chance to understand. Here is one basic difference between our democratic form of government and communism. The citizen in a Communist regime has no say in the decisions about such matters and, therefore, does not need to be informed. This makes the education of our young people of today vital to our future democratic way of life.

In addition, it is interesting to contrast against this phenomenal increase in knowledge and the emphasis on the need for knowing the fact that the human being's capacity to learn has not correspondingly increased; as a matter of fact, the swift pace of life with the trauma and strains of an affluent, overpopulated, mechanized society may well diminish the ability to learn by comparison with the calmer age, the calm mind that George Katagiri [7] mentioned.

The problems here, then, are in deciding what shall the schools teach, what knowledge is worth knowing, and how we can free the learner's capacity to learn.

Herein lies the challenge to educators: All of us here are charged with educating this space age youth for living in the world of tomorrow.

We heard Doctors Katagiri, Waterman,[8] and Obourn [9] talk about many of the scientific agencies and institutions that are working on curriculum studies to help identify what is worth knowing from each of the structures of science, and what techniques should be used, and how they may be used to increase the learner's capacity to learn. We know that there are some 25 of these projects which are currently in use or have been completed today. Each one of these projects attempts to identify the methods of inquiry, the modes of thought, and the structure of each one of these disciplines. Hopefully, as students encounter new information, they will have learned to synthesize and internalize it because they have internalized broad-based or conceptual schemes. These include instruction in the big ideas, the pervasive threads, and the unifying themes known as the structure of the discipline. In this way, it is hoped that students will gain an understanding and use of the methods of the scientist; that they will develop an appreciation for the nature of science as a discipline; and that they will be able to grasp the basic principles underlying science. By mastering the tools of the scientist's thought, it is hoped, students may relate new information as they confront it and organize it into meaningful ideas. It is believed that organizing facts in terms of principles and big ideas is the only way to reduce the quick rate of loss in the human memory.

It is very encouraging to see such progress made in the disciplines of science and mathematics. However, man does not solve all of his problems by scientific thought alone. Indeed, the problems outlined here, facing our space age children today, are far too complex to be relegated to solution solely by the scientific method.

I think we need to call upon all of our modes of thoughts—empirical, esthetic, moral, and logical—in order to solve these kinds of problems: logical thought, which is the basis for mathematics and languages; empirical learning, which is based largely on the natural sciences; moral thought, based on literature, history, religion, and our heritage; and esthetic thought, based on music and the fine arts. We need logic to answer the quest for truth, but we need moral thought as the basis for our scientific actions. We need esthetics to satisfy the spirit, and we need empiricism to evaluate our progress toward the betterment of mankind. We must give children balanced experience in all these areas of intellectual activity if we are to develop well-rounded, well-educated adults capable of coping with the explosions of their age.

I'd like to fit a little story in here: Two astronomers were watching the planet Mars from their observatory. Suddenly the planet disintegrated

[7] George Katagiri, Consultannt on Science Conservation and Outdoor Education, State Department of Education, Salem, Oreg. A Conference speaker.

[8] Allyn J. Waterman, Professor of Biology, Williams College, Williamstown, Mass. A Conference speaker.

[9] Ellsworth S. Obourn, Specialist for Secondary School Science, U.S. Office of Education, Washington, D.C. A Conference speaker.

with a cataclysmic explosion. A huge mushroom cloud billowed out into space. One astronomer turned to the other and said, "See, I told you there was intelligent life on Mars."

As we educate for the space age and the next age, I'd like to borrow a passage from the recent report of the NEA's Project on Instruction, *Schools for the '60's:* "Our task of education is profoundly complex. Man has rocketed his kind into space. He has brought back into pulsating life a human being already pronounced dead. He has fashioned in his own likeness robots that remember, file, sort, and then answer in moments problems that would tax a hundred men for a thousand days. But men still cheat and steal and kill as they did a thousand years ago, and in the stone age thousands of years before that.

"These are not always trapped men or hungry men or threatened men who cheat and steal and kill. Some men pronounced learned cheat because they are vain. Some men pronounced holy steal because they are greedy. Some men pronounced wise kill because they have established no identity with their fellow men. The people who soon may bring down upon our world a holocaust are—or will have been—the most educated of all time."

No man is just educated—he is educated *for* something, for some purpose or for many purposes.

We have succeeded well in teaching man to swim the seas like a fish. We have educated him to fly in the sky like a bird. He has succeeded in soaring into space like a demigod, and now we must educate him to walk the earth like a man.

REACTION TO THE 1964 SPACE SCIENCE EDUCATION CONFERENCE

Severo Gomez *Division of Guidance and Supervision*
Texas Education Agency, Austin;
and President of the Council of State Science Supervisors

For approximately 5 days we have been bombarded with the thinking of some of the fine minds of our times—those of men in science and engineering; and men and women in science education. Our minds have been energized by this bombardment to a realization of the role we all must play in the scientific enterprise.

In addition to listening to our learned friends, we have had the opportunity to exchange ideas among our respective groups, to discuss problems of mutual concern, interest, and responsibility. We have been fortunate to witness some of the activities in which space scientists are engaged and to hear about some of their research projects and experimentation.

We are told that—

We should concern ourselves with synthesizing and integrating new knowledge with the science of the past.

The main objectives of science education are to—

Develop a scientifically literate citizenry.

Provide the manpower necessary for activities in science and technology.

Express science in terms of human enterprise, or humanity.

We can't prepare children to live in today's world because today's world won't exist very long. And this goes along with the ideas expressed that space science is not a separate discipline; that it is the application of all the science disciplines in space, and that the only way children can be prepared for today or tomorrow is to be helped to understand the fundamental concepts and principles of science phenomena. In essence, that we need to get out of the bead-counting techniques of teaching in the elementary school.

Later, our attention was called to the nonunified curriculum and to some areas of science applied to space. These ranged from "the space environment" to "the presence and behavior of life in space." If I may react here, I wonder if we may refer to this nonunified curriculum not as one of an interdisciplinary nature but that of an interdependent one.

We heard of the importance of inservice training and how the elementary teacher is afraid of science. In our experiences as State supervisors, we find this not to be true. The elementary teachers are the most eager to learn; and consequently, do learn, and improve their instruction tremendously. The higher one goes into the grades, the greater the sophistication of the teachers, and the greater the difficulties in an inservice training program.

We learned from this Conference that we need each other—our talents, our resources, our facilities—for the interdependent disciplines and for the activities which occur in extraterrestrial environments.

We, as State supervisors, are perhaps nearer to the actual happenings in science education in the elementary and secondary schools than any other group here. But we need your assistance. Of the Office of Education, we ask for your talents, your materials, your guidance. Of NASA, we ask a continuing effort in informing our schools of activities in space through written materials which may supplement curricula, through informative films, lectures, workshops, and so on. Of the NASA Spacemobile lecturers, we specifically ask not to be satisfied with exciting a group of students for an hour or two, but to assist us in motivating the instructional and supervisory leadership at the local level so that the interest and desire to learn about science does not end as the Spacemobile drives away.

In our visits to the industries involved in aerospace activities, we saw many technicians and technologists. Their role is an important one. Little has been said about them at this Conference. We find many students in our schools who will assume positions such as these. We ask that you assist us in reaching this group. They are of vital importance to our activities. These are the individuals that need not be scientists, but need to be scientifically literate and technically skilled.

We have referred to space science as the interdisciplinary science. I choose to say that the interdependence of the disciplines is exemplified in activities dealing with the extraterrestrial. But to simplify matters, let us say that actually the fundamental discipline is physics—which may be the classical physics, geophysics, biophysics, chemophysics, meteorophysics, oceanophysics, astrophysics, etc. Whatever it is, let me in my final charge ask for the assistance of the college science educators and educationists. In my State, more than thirty 4-year colleges and institutions produce scientists and science teachers. However, in each of the 3 school years, 1960 through 1963, only five physics teachers were trained. And of the five trained each year, only two chose to teach in the State. A colleague of mine says that in his State, only three physics teachers have been trained in the last 6 years. You heard Dr. Owen Kiernan, Commissioner of Education for Massachusetts, say that only 3 students prepared themselves for physics teaching among the June 1964 graduates of Massachusetts' 50 colleges. We hear so many times that high school students enter college with little or no knowledge of physics; and we hear it of other disciplines. We ask of you in the colleges to help us in this problem. Don't force our biology-trained teachers to attempt to teach physics. Encourage some of your talented students with potentialities for teaching to pursue the teaching profession at the secondary level. Let us have a fair share of these young people.

The level at which the new curricular materials can be used was discussed. May I say that science instruction cannot be segmented into K–3, or 6, or 9, or 12—that for some it may be K–9, but for many it should be K–20. In many cases, for example, BSCS biology has assumed its normal position at the 10th grade. Why? Because of what has been going on at K–9. Our concern is just as great for 13, 14, 15, etc., as it is for K–12.

To conclude, may I, on behalf of the Council of State Science Supervisors, thank everyone responsible for this Conference. It was quite fruitful. Thanks to NASA—to Messrs. Tuttle, Costa, Bernardo, Kamm, and the rest. Thanks to NASA's Headquarters Office and Western Operations Division, and finally thanks to the U.S. Office of Education and its excellent staff.

REACTION TO THE 1964 SPACE SCIENCE EDUCATION CONFERENCE

Lola J. Eriksen *Science Specialist*
Arts and Humanities Branch
U.S. Office of Education
Washington, D.C.

In reacting to the NASA/USOE Conference on behalf of the U.S. Office of Education, I would like to comment upon the nature of the Conference constituency, the organization of the program, some possible areas for future planning, and some implications for science education.

As we look at the backgrounds of the delegates who make up this Conference, we note diversity: State science supervisors, university faculty members concerned with science education, and Government agencies; namely, NASA and USOE. Our being together has done much to improve the understanding of our respective roles, as well as to promote means of working together. This has been a helpful and stimulating situation, for we have had to look beyond the horizons of our respective responsibilities and have sought solutions for mutual problems.

As we look at the program, we note that there has been a real effort to help us upgrade our scientific backgrounds. We have examined the past, the present, and the future of space exploration. We have looked at physical science as it applies to space, and we have been guided into examining theories of life in the universe. Our field trips have provided unexcelled opportunities for us to talk first hand with scientists in industry who are doing basic research. Many of us have been amazed by the nature and diversity of scientific research undertaken by the industries we have visited. We have also viewed the picture of education in science. We have had an opportunity to share information about our respective educational programs, and we have examined trends in science education. A panel guided our thinking on the nature and potential of science education in the space age. We tackled problems of science education in our roundtable discussions, and had our thinking challenged by sociological implications of science education. The result has been a broad view of this whole area of education.

As we examine the organization of the Conference, we note a balance in the type of activities scheduled. There were papers and other formal presentations, roundtable discussions, organization group meetings, field trips, and opportunities to chat over the coffee cups. The program was balanced by conferees listening and actively participating. The variety of activities provided for high degrees of stimulation and interaction.

Now let us look at some possible areas for consideration in future conference planning. It might be helpful to place greater emphasis upon the total spectrum of science as opposed to "space science" as a discipline. We recognize that virtually all of the scientific disciplines relate in one way or another to so-called "space science." This is not a separate field of science but rather a unifying theme.

Another possibility for the future might be greater coordination of the activities of component groups so that specific activities might complement the work of other groups. If each of the organization groups represented were to consider within a membership session the same topic area, it might be fruitful to note respective viewpoints and suggestions. The success of personal interaction among the participants in the roundtable sessions might indicate that an increased number of discussion group sessions would be fruitful. At this level, the interaction between representatives with various backgrounds led to some highly stimulating and provocative discussions.

Additional intergroup sessions, including NASA staff and science supervisors, and OE personnel and State Science Supervisors might be fruitful. It could be to the advantage of all present to learn about science education activities in the various States.

The success of this meeting may suggest the need for sponsorship of regional meetings, utilizing a somewhat similar type of program organization and conferee representation. Wider participation within geographic regions should further stimulate science education, as well as be conducive to increased intergroup cooperation.

As we examine the implications of this Conference, let us look first at the problem areas which have been posed. We have examined the role of science in the curriculum, noting that the orientation of present science offerings is still largely directed toward college preparatory students. We have noted that information about science is no longer accepted as *the* primary goal in science education. The process aspect of science has achieved new recognition; and hence, there needs to be teaching directed toward understanding the nature of the process. This may also mean the teaching of fewer concepts but more selective ones, as well as teaching to a greater degree of depth. Because of the vast diversity of scientific knowledge and the problems inherent in science teaching, it would seem that there is a real need for the development of State guidelines to assist local school districts.

The whole aspect of science teaching needs consideration. This would include greater attention to research into the nature of the curriculum, the kinds of resources available, the methods used, as well as attention to aspects of creativity and the learning process.

The role of the supervisor is a key one in science education by virtue of the nature of the subject and its rapidly expanding body of knowledge. It is through direction offered by supervisory personnel that the key to science instruction at the local level may be found.

Because of the factors mentioned, preservice and inservice teacher education in science is of even greater importance than in decades past. In addition, the emphasis upon process has resulted in elevation of laboratory instruction to a new level of importance; so there needs to be teacher training for this as a goal, not incidental consideration. Another implication is in relation to credit for inservice teacher education. The science courses needed by many elementary teachers are not those which presently are offered for graduate credit—for many of these teachers have little or no background in the sciences.

As we look at the sociological aspects, we see another implication for science education. We need to provide a full educational opportunity for the pursuit of science as a human endeavor. There is great need for public understanding in the area of science. We have not yet determined the level of scientific literacy needed for an informed citizenry in our science-oriented culture. We need to examine carefully the role of science in general education.

Another implication for our consideration here is an examination of the relationships between educators, the scientific community, and Government organizations. We recognize the need for cooperative efforts, particularly at regional and national levels. This Conference, itself, is a testimony to this type of endeavor, as have been some of the new curriculum developments in the sciences.

Another implication from this Conference is further consideration of the role of higher education. We recognized that it is no longer feasible for educators to develop new science curriculums without cooperating with scientists. New emphases in science, as well as the necessity for general scientific literacy of all citizens, necessitate a reevaluation of current undergraduate offerings. In addition, the same factors necessitate a change in the methods of instruction in higher education. The lecture-demonstration approach is no longer satisfactory as a total vehicle for conveying understanding of both the nature and content of science.

If one thing has impressed each of us as a result of our experiences here this week, it has been the team effort that characterizes research in space-related sciences. This implies a great need for an interdisciplinary approach to the science curriculum.

As we look at manpower implications, we realize that the popular appeal and dramatization of certain aspects of technology have resulted in adequate responses to manpower needs such as engineering—at least in the space-related industries in southern California! However, we also recognize that with a science-technology-oriented society, manpower always will remain a problem. The decline of the number of students majoring in science is of real concern. We need to be cognizant of the manpower problems related to science education.

A further implication of our deliberations is in the great extent of scientific information accumulated. As we noted previously, this has resulted in a trend toward the selection of fewer concepts to be taught, with an emphasis in depth.

On one of our industry field trips, a number of us had the privilege of observing a testing operation which provided 48 separate items of information—each consisting of 4 digits of recordable data. This was recorded instantaneously, fed into an IBM computer, and recorded on punchcards. This information was then automatically processed on tabular sheets and the cards fed into machinery which graphed the data, all within 3 minutes of completion of the testing operation. The research director informed us that the project engineers then had 27 minutes to study the graphs, analyze the data, make necessary changes in the testing operation, and be ready for a repeat performance. When we saw what industry has done to facilitate the recording and organizing of test data, it was a bit overwhelming. It sometimes takes months, in education, for data processing, and graphing by hand.

We have here an example of one of the reasons for the great growth in scientific information, in comparison to growth of other aspects of our culture. We need to think about the implications this holds for us. Vast sums of money have been expanded for research in pure science, while relatively little has gone into research in science education; i.e., into solving the pedagogical problems of curriculum and method confronting those who wish to improve the teaching of science in the elementary and secondary schools and colleges. Perhaps, the time has come for foundations, Government agencies, and State and local departments of education to consider seriously supporting research efforts in science education.

As we have deliberated this week, our concerns have been, in the final analysis, in changing the behavior of the student. We see implications for our total program of education, for the structure of the curriculum, for the methods used in teaching, for the selection and training of our teaching personnel, as well as for the relationship of science to the total educational offering. As we have been told, the reform movements which have made lasting impact on public education usually have been closely associated with local schools. Thus our challenge is to move in the direction of seeing an impact upon the local school program of science education. However, as Dr. Brenneman pointed out, "We don't make sufficient use of the knowledge we have." We need to consider what we know about the nature of science and our purpose in teaching it, and to evaluate what we are doing in relation to our goals.

The Space-Science Education Conference has been an outstanding opportunity for professional interchange, and coordination of activity. May each of us return to his respective responsibility in science education with an increased zeal, a fortified background, deepened professional association, new ideas for strengthening our personal impact on the most important of products—the citizens of tomorrow. May we also return with a vision that sees more clearly the science education goals on our professional horizons.

REACTION TO THE 1964 SPACE SCIENCE EDUCATION CONFERENCE

Allyn J. Waterman *Professor of Biology*
Williams College
and Chairman of the Subcommittee on Institutes, Conferences, and Symposia of the AAAS Cooperative Committee on the Teaching of Science and Mathematics

Mr. Chairman, ladies and gentlemen:

My colleagues on the Subcommittee join me in thanking NASA and the USOE for the privilege of meeting with you during this Conference. We greatly appreciate being drawn into your discussions, and the active roles assigned to us. This has been a rare event. Not in my memory, have representatives of governmental services, science supervisors, and teachers of science at the grass-roots level of science education been brought together in such a sympathetic atmosphere for deliberation over, and mutual discussion of, our common problem; namely, that of education in the sciences and the training and updating of science teachers in this period of mushrooming developments in all of the sciences.

There seems to be distinct unanimity of opinion here with respect to most of the problems that must be faced. These problems are not peculiar to any one group, to any one level of science education, or to any one scientific discipline. Reasonable solutions commonly result from joint effort. With the discussions which have developed in this Conference, it appears to us that there is now a foundation for entering into a series of *action conferences.* Speaking as a biologist, this cross-fertilization of ideas and programs cannot help but promote hybrid vigor.

The speakers who have preceded me this morning have succinctly and ably summarized our reactions to the subject matter of the Conference. In these few minutes, I thought I would tell you something of the activity of the Subcommittee during its several meetings the last few days. In the Monday–Wednesday sessions, such topics as the following were discussed:

1. Present status of institutes, conferences, and symposia for high school and college teachers of science, with special reference to the backgrounds, needs, and purposes of participants; type of institutes held to date.

2. The future direction of institutes, conferences, and symposia. Interdisciplinary action appears to be called for. Guidance and financial assistance are needed to reach more teachers, and to modernize all levels of scientific education and all subject areas.

3. Ways in which NASA might contribute to such programs for the training and updating of teachers of science, mathematics, and engineering. Value of NASA and the USOE to the Subcommittee—we came here with this as one of the topics uppermost in mind. With effort being made to improve curricula and upgrade teachers in secondary and elementary schools, along with generous funding of the science disciplines at the graduate and research program levels, there appears to be a gap in teacher education; that is, a need for updating teachers at the undergraduate collegiate

level. We appear to be neglecting this vital area of scientific education. Who has the obligation and responsibility of updating college science teachers? Here is an area which would profit immensely from any assistance that the Educational Division of NASA could contribute.

4. Contributions that the basic sciences might make to the educational programs sponsored by NASA; for example, to the Spacemobile program as consultants, participants, or as representatives on advisory committees.

5. Organization and purposes of our Subcommittee. A slate of new officers was elected, with Prof. J. Robert Harrison, Miami University, Oxford, Ohio, as Chairman. Discussion topics included: present activities of the educational committees of the sciences, and problems of interdisciplinary education.

6. Problem of communication between NASA and college or university programs and scientists, especially in the area of aerospace science and its role in the curriculum. Additional topics taken up included: publication channels of aerospace scientists, research grants, and education programs such as the Spacemobile program.

The present deliberations of the Committee have been most provocative. From these, after careful discussion, have emerged two suggestions approved unanimously by this group:

1. NASA might establish groups of consultants representing science, mathematics, and engineering at regional and national levels to work with the Educational Advisory Committee and the Director of the Educational Program Division of NASA. This could provide the NASA Education Project and the science faculties of institutions of higher learning an avenue of communication and an opportunity for mutual service.

2. NASA might hold conferences of science, mathematics, and engineering representatives from colleges and universities to explore the educational implications of space programs.

The Interdisciplinary Committee will be pleased to cooperate at any future time in educational efforts, in meetings like this one, or by any other means. We feel that it is important that the Committee meet again with all of the groups here represented.

Thank you again for including us in this Conference.

ACKNOWLEDGMENT AND CONFERENCE ADJOURNMENT

James V. Bernardo *Director*
Educational Programs and Services Office
NASA Headquarters
Washington, D.C.

Well, folks, I believe you'll agree—this has been a mighty busy week. I hope we came close to realizing the purposes as stated at the outset. I trust too, that the Conference has been not only interesting but of value for all of us.

There have been so many people involved in planning and implementing the program that I would risk injustices by naming names. I'd like, then, in behalf of NASA, to express deep-felt gratitude and appreciation to the entire Planning Committee and WOO's Local Arrangements Committee for their unstinting efforts, and to the aerospace industries for providing us with wonderful field experiences.

To all of the participating groups:

The State Science Supervisors,

The AAAS Subcommittee on Institutes and Conferences,

The Spacemobile teams, and

The U.S. Office of Education, may I say, it has been a great pleasure, a privilege, and an opportunity for us—to have joined with you in this undertaking. I feel that we have come to know and understand each other better, and that the exchange of knowledge and ideas has been fruitful. It is hoped that we may continue our professional and personal relationships for mutual benefit, to the end that we may continue efforts to improve science education in this great land of ours.

With very best wishes to all, I now declare this Conference adjourned.

Thank you.

APPENDIX A

CONFERENCE REGISTRATION LIST

Ugo Amelio, Spacemobile Lecturer

Melvin D. Anderson, Acting State Science Supervisor, State Department of Public Instruction, Des Moines, Iowa

Robbin C. Anderson, Director of Academic Year Institute and Professor of Chemistry, The University of Texas, Austin, Tex., and Chairman of the Committee on the Teacher and His Work, Division of Chemical Education, American Chemical Society

Ted F. Andrews, Chairman, Department of Biology, Kansas State Teachers College, Emporia, Kans., and President, National Association of Biology Teachers

Lloyd H. Aronson, Spacemobile Lecturer

Harold R. Bacon, Spacemobile Lecturer

Elva Bailey, Head, Educational Programs and Services, NASA Goddard Space Flight Center, Greenbelt, Md.

John R. Bannister, Spacemobile Lecturer

Jay K. Beck, Spacemobile Lecturer

Fred M. Bell, Spacemobile Lecturer

Warren J. Bell, Science Consultant, State Department of Education, Topeka, Kans.

A. P. Bennett, Director of Instruction, State Department of Education, Jackson, Miss.

James V. Bernardo, Director, Educational Programs and Services Office, NASA Headquarters, Washington, D.C.

Olive S. Berg, State Supervisor, Elementary Education, State Department of Education, Pierre, S. Dak.

Richard C. Berne, Jr., Spacemobile Lecturer

Albert L. Berry, Supervisor of Science, State Department of Education, Frankfort, Ky.

Robert D. Binger, Supervisor, Science Education, State Department of Education, Tallahassee, Fla.

G. W. Blankley, Spacemobile Lecturer

Mary M. Blatt, Science Advisor, State Department of Public Instruction, Harrisburg, Pa.

G. K. Bradford, Science Supervisor, State Department of Education, Columbus, Ohio

Richard H. Brenneman, Technology Utilization Officer, NASA Western Operations Office, Santa Monica, Calif.

Kenneth E. Brown, Specialist for Secondary School Mathematics, U.S. Office of Education, Washington, D.C.

Stanley P. Brown, State Supervisor of Mathematics, State Department of Education, Augusta, Maine.

J. W. Buchta, Editor, *The Physics Teacher*, Washington, D.C.; and Secretary, Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics

H. V. Bullock, Science Coordinator, State Department of Education, Atlanta, Ga.

Robert E. Bush, Spacemobile Lecturer

Jack Callow, Spacemobile Lecturer

Edwin Y. H. Chinn, Program Specialist, Science Education, State Department of Education, Honolulu, Hawaii

Nathaniel H. Cole, Supervisor, Science and Mathematics, State Department of Education, Juneau, Alaska

Everett E. Collin, Educational Programs Officer, Educational Programs Division, NASA Headquarters, Washington, D.C.

Raymond R. Corey, Spacemobile Lecturer

Arthur L. Costa, Chief, Educational Programs Division, NASA Western Operations Office, Santa Monica, Calif.

John R. Craig, Research Programs Manager, NASA Office of Grants and Research Contracts, Washington, D.C.

Richard N. Crone, Spacemobile Lecturer

Hampton Crowder, Science Consultant, State Department of Education, Oklahoma, City, Okla.

William L. Curry, Spacemobile Lecturer

B. Michael Donahoe, Educational Specialist, NASA Western Operations Office, Santa Monica, Calif.

Kiaran L. Dooley, Director of State-Federal Relations, State Department of Public Instruction, Bismarck, N. Dak.

Albert H. H. Dorsey, Science Supervisor, State Department of Education, Columbia, S.C.

Kenneth W. Dowling, State Supervisor of Science, State Department of Public Instruction, Madison, Wis.

Harold D. Drummond, Chairman, Department of Elementary Education, University of New Mexico; Member, NASA Educational Advisory Committee

Albert F. Eiss, Assistant Executive Secretary, National Science Teachers Association, Washington, D.C.

William G. Elliott, Supervisor, Science and Mathematics, State Department of Public Instruction, Pierre, S. Dak.

Arlen C. Erickson, Spacemobile Lecturer

Lola J. Eriksen, Specialist for Elementary and Secondary School Science Education, U.S. Office of Education, Washington, D.C.

Don Fandre, Spacemobile Lecturer

Paul S. Feinstein, Assistant to the Director, Scientific and Technical Information Division, NASA Headquarters, Washington, D.C.

Richard H. Fleming, Chairman, Department of Oceanography, University of Washington, Seattle, Wash.

Harold A. Foecke, Specialist for Engineering Education, U.S. Office of Education, Washington, D.C.

Clark W. Fowler, Science Supervisor, State Department of Public Instruction, Helena, Mont.

James M. Garner, Supervisor, Science Programs, Office of State Superintendent of Public Instruction, Olympia, Wash.

Lloyd E. George, Spacemobile Lecturer

Alfred B. Garrett, Vice President for Research, Ohio State University; and Chairman, Cooperative Committee on the Teaching of Science and Mathematics, American Association for the Advancement of Science

E. A. Gibson, Jr., Spacemobile Lecturer

Severo Gomez, Science Consultant, Texas Education Agency, Austin, Tex.; and President of the Council of State Science Supervisors

William J. Gruver, Specialist, Science, U.S. Office of Education, Washington, D.C.

William D. Guthrie, Science Supervisor, State Department of Education, Trenton, N.J.

Hiram R. Haggett, Educational Programs Officer, Office of Public Affairs, NASA North Eastern Operations Office, Cambridge, Mass.

J. Robert Harrison, Professor of Zoology, Miami University, Oxford, Ohio; Chairman, Education Committee, American Society of Zoologists; and Chairman of the Subcommittee on Conferences and Institutes of the AAAS Cooperative Committee on the Teaching of Science and Mathematics

Edward J. Hart, Supervisor of Science Education, State Department of Public Instruction, Dover, Del.

Robert A. Hawkins, Spacemobile Lecturer

Robert D. Helton, Spacemobile Lecturer

Robert K. Henrich, Spacemobile Lecturer

John A. Hooser, Science Consultant, State Department of Education, Jefferson City, Mo.

Stephen Hopkins, Assistant Director of the Department of Science, Board of Education Offices, Washington, D.C.

Eugene E. Horton, Chief, Educational Programs and Services, NASA Manned Spacecraft Center, Houston, Tex.

Theresa A. Horvath, Assistant Education Services Manager, NASA Lewis Research Center, Cleveland, Ohio

Hendrik R. Hudson, Spacemobile Lecturer

Garth A. Hull, Educational Services Officer, Public Affairs Office, NASA Ames Research Center, Moffett Field, Calif.

Paul L. Hunsberger, Spacemobile Lecturer

Paul DeHart Hurd, Professor of Education, Stanford University; and Member of the NASA Educational Advisory Committee

Richard Jahns, Dean, College of Mineral Industries, Pennsylvania State University; and Chairman, Education Committee, American Geological Institute

Ellwood A. Johnson, Spacemobile Lecturer

Guy E. Johnson, Jr., Spacemobile Lecturer

Lloyd K. Johnson, Specialist for Secondary School Science, U.S. Office of Education, Washington, D.C.

Lloyd E. Jones, Jr., Spacemobile Lecturer

Robert W. Kamm, Director, NASA Western Operations Office, Santa Monica, Calif.

Joseph Kaplan, Professor of Physics, University of California, at Los Angeles; Chairman, U.S. National Committee for the International Geophysical Year; and President, International Union of Geodesy and Geophysics

George Katagiri, Consultant on Science, Conservation, and Outdoor Education, State Department of Education, Salem, Oreg.

Robert L. Kent, State Science Supervisor, State Department of Public Instruction, Indianapolis, Ind.

Owen B. Kiernan, Commissioner of Education, State Department of Education, Boston, Mass.

Arnold K. King, Vice President for Institutional Studies, The University of North Carolina; and Chairman, NASA Educational Advisory Committee

Franklin D. Kizer, Supervisor of Science, State Department of Education, Richmond, Va.; and immediate Past President of the Council of State Science Supervisors

Robert F. Knutson, Spacemobile Lecturer

Robert E. Krebs, Specialist for Secondary Education, U.S. Office of Education, Washington, D.C.

George J. Lewis, Spacemobile Lecturer

Clarence B. Lindquist, Specialist for Mathematics and Physical Sciences (Higher Education), U.S. Office of Education, Washington, D.C.

Donald H. Loughridge, Palos Verdes Estates, Calif.; Regional Counselor for California, American Institute of Physics

Curtis C. Love, Supervisor of Science, State Department of Education, Little Rock, Ark.

Frank Lucarelli, Spacemobile Lecturer

Paul W. Lampkin, Spacemobile Lecturer

W. Bemon Lyon, Education Consultant in Science, Mathematics, and Modern Foreign Languages, State Department of Education, Montgomery, Ala.

Gene A. Maguran, Sr., Science Specialist, State Department of Education, Charleston, W. Va.; and Secretary-Treasurer of the Council of State Science Supervisors

L. Frank Mann, Consultant in Secondary Education, State Department of Education, Sacramento, Calif.

Arthur H. Maynard, Spacemobile Lecturer

Joe P. Minor, Supervisor of Instruction (Science), State Department of Education, Austin Peay State College, Clarksville, Tenn.

Roscoe Monroe, Spacemobile Lecturer

Donald R. Mulholland, Deputy Director, NASA Western Operations Office, Santa Monica, Calif.

George K. McBane, Science Specialist, State Department of Education, Santa Fe, N. Mex.

Leland S. McClung, Chairman, Department of Bacteriology, Indiana University; and Chairman, Education Committee, American Society for Microbiology

Bernard R. McColgan, Spacemobile Lecturer

Robert E. McConnell, Acting Regional Representative, Office of the Commissioner, U.S. Office of Education, Regional Office, San Francisco, Calif.

Robert B. McCurdy, Spacemobile Lecturer

James McGrath, Spacemobile Lecturer

Arthur J. McMahon, State Supervisor of Mathematics, State Department of Education, Providence, R.I.

William J. Nagle, Spacemobile Lecturer

John X. Nesbit, Spacemobile Lecturer

Gordon Nesler, Spacemobile Lecturer

Homer E. Newell, Associate Administrator, Office of Space Science and Applications, NASA Headquarters, Washington, D.C.

William Nixon, Spacemobile Lecturer

Herman J. Oberle, Spacemobile Lecturer

Ellsworth S. Obourn, Specialist for Secondary School Science, U.S. Office of Education, Washington, D.C.

Jeri Ochab, Spacemobile Lecturer

Timothy B. O'Connell, Jr., Spacemobile Lecturer

Thornton P. Page, Visiting Professor, Department of Astronomy, University of California at Los Angeles; and immediate Past Chairman, AAAS Cooperative Committee on the Teaching of Science and Mathematics.

Frank Patti, Spacemobile Lecturer

Robert Perry, Spacemobile Lecturer

Richard S. Peterson, State Specialist of Science Education, State Department of Public Instruction, Salt Lake City, Utah

Albert Piltz, Elementary School Science Specialist, U.S. Office of Education, Washington, D.C.

Harold P. Pluimer, Science Consultant, State Department of Education, St. Paul, Minn.

Cyril Ponnamperuma, Acting Chief, Chemical Evolution Branch, Exobiology Division, NASA Ames Research Center, Moffett Field, Calif.

Philip N. Powers, Director, Engineering Experiment Station, Purdue University, Lafayette, Ind.; and Chairman, Special Committee on Relations with NASA and Education, American Society for Engineering Education.

William E. Restemeyer, Professor of Applied Mathematics and Electrical Engineering, College of Engineering, University of Cincinnati

Roland J. Revello, Spacemobile Lecturer

Richard W. Rice, Spacemobile Lecturer

Daniel J. Roberts, Spacemobile Lecturer

Julian F. Rogers, Spacemobile Lecturer

Robert Ryder, Spacemobile Lecturer

W. Earl Sams, Consultant in Secondary Education, State Department of Education, Sacramento, Calif.

Dorris L. Sander, Director of Elementary Education, Department of Education, Cheyenne, Wyo.

Ray W. Schiltz, Spacemobile Lecturer

Aaron P. Seamster, Director, Educational Programs Division, NASA Headquarters, Washington, D.C.

Glyn H. Sharpe, Consultant, Science and Mathematics, State Department of Education, Denver, Colo.

Rt. Rev. Msgr. Joseph F. Sharpe, Superintendent, Secondary Schools, Los Angeles Archdiocese, Los Angeles, Calif.

Jack D. Shattuck, Spacemobile Lecturer

H. Maine Shoun, Director, Title III, State Department of Education, Boise, Idaho

Robert L. Silber, Educational Secretary, American Chemical Society, Washington, D.C.; and Vice Chairman, Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics

Leonard Skov, Administrator of Title III, NDEA, State Department of Education, Lincoln, Nebr.

John L. Snyder, Director of Education, American Geological Institute, Washing, D.C.

Wendall N. Spreadbury, Jr., Spacemobile Lecturer

Frank E. Sorenson, Chairman, Department of Educational Services, University of Nebraska; and Member, NASA Educational Advisory Committee

Luke E. Steiner, Professor of Chemistry, Oberlin College; and Chairman, Division of Chemical Education, American Chemical Society

Philip R. Surgen, Spacemobile Lecturer

Evan A. Sweetser, Consultant in Mathematics and Science, State Department of Education, Montpelier, Vt.

Lester D. Taylor, Chief Science Consultant, State Department of Public Instruction, Springfield, Ill.

Y. A. Taylor, Supervisor of Science, State Department of Public Instruction, Raleigh, N.C.

Hugh Templeton, Supervisor, Science Consultant, State Education Department, Albany, N.Y.

Ina S. Thompson, Consultant in Elementary Science Education, State Department of Education, Tallahassee, Fla.

C. C. Trillingham, County Superintendent of Schools, Los Angeles County, Los Angeles, Calif.

Christopher Trump, Spacemobile Lecturer

Frederick B. Tuttle, Deputy Director, Eductional Programs Division, NASA Headquarters, Washington, D.C.

Henry Van Engen, Professor of Mathematics/Education, Department of Mathematics, University of Wisconsin

Lester R. Velez, Spacemobile Lecturer

Howard I. Wagner, Director of Science Education, State Department of Education, Concord, N.H.

Richard O. Ward, Spacemobile Lecturer

Allyn J. Waterman, Professor of Biology, Williams College; and immediate past Chairman, Subcommittee on Institutes and Conferences of the AAAS Cooperative Committee on the Teaching of Science and Mathematics

Gordon L. Wenger, Spacemobile Lecturer

Herman S. Weinstein, Director, Educational Services, Washington, D.C.

Lewin A. Wheat, Supervisor of High Schools (Science), State Department of Education, Baltimore, Md.; and Vice Chairman of the Council of State Science Supervisors

Marsh W. White, Emeritus Professor of Physics, Pennsylvania State University; and Past Chairman, Interdisciplinary Committee on Institutes and Conferences

Lee E. Wickline, Specialist for Secondary School Science, U.S. Office Education, Washington, D.C.

Walter Wiesman, Chief, Educational Liaison Branch, NASA Marshall Space Flight Center, Huntsville, Ala.

J. Donald Wood, Supervisor of Instruction (Science), State Department of Education, Nashville, Tenn.

Peter E. Yankwich, Head, Division of Physical Chemistry, University of Illinois; and Member of the Advisory Council on College Chemistry

APPENDIX B

CONFERENCE SCHEDULE

SUNDAY, MAY 31, 1964	
1:00 to 7:00 p.m.	CONFERENCE REGISTRATION
2:00 to 9:00 p.m.	PRECONFERENCE MEETINGS
2:00 p.m.	MEETING, CONFERENCE PLANNING COMMITTEE
3:30 p.m.	MEETING, BRIEFING SESSION FOR CHAIRMEN AND RECORDERS OF ROUNDTABLE SESSIONS
7:00 p.m.	THE SPACEMOBILE LECTURE-DEMONSTRATION WITH DISCUSSION—All conference participants invited. Presiding: Ellwood A. Johnson, Lecturer, NASA Spacemobile, Educational Services, Washington, D.C. Lecturer: Donovan Fandre, Lecturer, NASA Spacemobile, Educational Services, NASA Western Operations Office, Santa Monica, Calif.
MONDAY, JUNE 1	
8:00 to 9:00 a.m.	CONFERENCE REGISTRATION
8:30 to 12:00 noon	FIRST GENERAL SESSION Presiding: James V. Bernardo, Director, Educational Programs and Services Office, National Aeronautics and Space Administration, Washington, D.C. GREETINGS FROM THE NASA WESTERN OPERATIONS OFFICE Robert W. Kamm, Director, NASA Western Operations Office, Santa Monica, Calif. THE NASA MISSION Donald R. Mulholland, Deputy Director, NASA Western Operations Office, Santa Monica, Calif.
10:00 a.m.	THE NATURE AND PURPOSE OF THIS CONFERENCE Frederick B. Tuttle, Deputy Director, Educational Programs Division, National Aeronautics and Space Administration, Washington, D.C. Ellsworth S. Obourn, Specialist for Secondary School Science, U.S. Office of Education, Washington, D.C.

MONDAY, JUNE 1—Continued

10:30 a.m.

THE NATURE OF THE SUBCOMMITTEE ON INSTITUTES AND CONFERENCES OF THE AAAS COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS AND ITS INTEREST IN SCIENCE EDUCATION

Ted F. Andrews, Chairman, Department of Biology, Kansas State Teachers College, Emporia, Kansas; and Vice Chairman of the Subcommittee

THE NATURE OF THE U.S. OFFICE OF EDUCATION AND ITS INTEREST IN SCIENCE EDUCATION

Robert E. McConnell, Acting Regional Representative, Office of the Commissioner, U.S. Office of Education, Regional Office, San Francisco, Calif.

THE NATURE OF THE COUNCIL OF STATE SCIENCE SUPERVISORS AND ITS INTEREST IN SCIENCE EDUCATION

Franklin D. Kizer, Supervisor of Science, State Department of Education, Richmond, Virginia; and immediate Past President of the Council of State Science Supervisors

THE NATURE OF NASA'S EDUCATIONAL PROGRAMS AND SERVICES OFFICE AND ITS INTEREST IN SCIENCE EDUCATION

Aaron P. Seamster, Director, Educational Programs Division, National Aeronautics and Space Administration, Washington, D.C.

12:00 to 2:30 p.m.

SECOND GENERAL SESSION— LUNCHEON

Presiding: Robert L. Silber, Educational Secretary, American Chemical Society, Washington, D.C.; and Vice Chairman of the Subcommittee on Institutes and Conferences

THE PAST, PRESENT, AND FUTURE OF SPACE EXPLORATION

Joseph Kaplan, Professor of Physics, University of California at Los Angeles; Chairman, U.S. National Committee for the International Geophysical Year; and President, International Union of Geodesy and Geophysics

Interrogators: J. Robert Harrison, Professor of Zoology, Miami University; and Chairman, Education Committee, American Society of Zoologists

MONDAY, JUNE 1—Continued

12:00 to 2:30 p.m.

Luke E. Steiner, Professor of Chemistry, Oberlin College; and Chairman, Division of Chemical Education, American Chemical Society

Marsh W. White, Emeritus Professor of Physics, The Pennsylvania State University; and Past Chairman, Interdisciplinary Committee on Institutes and Conferences

3:00 to 4:30 p.m.

GROUP SESSIONS

Subcommittee on Institutes and Conferences
Chairman: Allyn J. Waterman, Professor of Biology, Williams College, Chairman of the Subcommittee

U.S. Office of Education
Chairman: Mr. Obourn

National Aeronautics and Space Administration Headquarters, Field Installations, and Spacemobile
Chairman: Mr. Seamster

Council of State Science Supervisors
Chairman: Mr. Kizer

TUESDAY, JUNE 2

8:00 to 11:15 a.m.

THIRD GENERAL SESSION

Chairman: W. Earl Sams, Consultant in Secondary Education, State Department of Education, Sacramento, Calif.

TRENDS IN SCIENCE EDUCATION

At the Collegiate Level
Mr. Waterman

At the Secondary School Level
Mr. Obourn

At the Elementary School Level
George Katagiri, Consultant on Science, Conservation, and Outdoor Education, State Department of Education, Salem, Oreg.

9:15 a.m.

BREAK

9:30 a.m.

NATURE AND POTENTIAL OF SCIENCE EDUCATION IN THE SPACE AGE—A panel to interact with speakers and the audience

Chairman: Mr. Sams

Robbin C. Anderson, Director of Academic Year Institute, and Professor of Chemistry, The University of Texas, Austin Tex.; and Chairman of the Committee on the Teacher and His Work, Division of Chemical Education, American Chemical Society

Elva Bailey, Head, Educational Programs and Services, NASA Goddard Space Flight Center, Greenbelt, Md.

9:30 a.m.	Mary M. Blatt, Science Advisor, State Department of Public Instruction, Harrisburg, Pa.
	Robert K. Henrich, Coordinator for Spacemobiles, Educational Services, NASA Ames Research Center, Moffett Field, Calif.
	Recorder: Lewin A. Wheat, Supervisor of High Schools (Science), State Department of Education, Baltimore, Md.; and Vice Chairman of the Council
11:00 a.m.	FIELD TRIP BRIEFING Presiding: Mr. Costa
11:30 to 4:30 p.m.	TOURS OF AEROSPACE INDUSTRIES
11:30 a.m.	TOUR 1: Douglas Aircraft Co., Santa Monica, Calif. Robert M. Wood, Assistant Director, Research and Development, Science and Future Systems, *host*
11:30 a.m.	TOUR 2: The Garrett Corp., Los Angeles, Calif. John Bold, Manager of Press Relations, *host*
11:30 a.m.	TOUR 3: Hughes Aircraft Co., Malibu Research Laboratories, Malibu, Calif. John M. Richards, Customer Relations, Aerospace Group, *host*
1:00 p.m.	TOUR 4: Northrop Space Laboratories, Hawthorne, Calif. Lee R. Thornton, Executive Advisor to Vice President, General Manager of Business Administration, *host*
11:30 a.m.	TOUR 5: TRW Space Technology Laboratories, Redondo Beach, Calif. Herbert Rosen, Public Relations Manager, *host*
11:30 a.m.	TOUR 6: University of California at Los Angeles, Symposium, Cafeteria and Royce Hall, Westwood, Calif. B. Michael Donahoe, Educational Specialist, NASA Western Operations Office, *host*
6:00 to 7:00 p.m.	SOCIAL HOUR
7:00 to 10:00 p.m.	FOURTH GENERAL SESSION—DINNER MEETING Presiding: Alfred B. Garrett, Vice President for Research, The Ohio State University, Columbus, Ohio, and Chairman, Cooperative Committee on the Teaching of Science and

7:00 to 10.00 p.m.

Mathematics, American Association for the Advancement of Science

INVOCATION

Rt. Rev. Msgr. Joseph F. Sharpe, Superintendent Secondary Schools, Los Angeles Archdiocese, Los Angeles, Calif.

BANQUET WELCOME

C. C. Trillingham, County Superintendent of Schools, Los Angeles County, Los Angeles, Calif.

GREETINGS FROM THE NATIONAL SCIENCE TEACHERS ASSOCIATION

Albert F. Eiss, Assistant Executive Secretary, National Science Teachers Association, Washington, D.C.

THE IMPACT OF SPACE TECHNIQUES ON MODERN SCIENCE

Homer E. Newell, Associate Administrator, Office of Space Science and Applications, National Aeronautics and Space Administration, Washington, D.C.

WEDNESDAY, JUNE 3

8:30 a.m. to 1:45 p.m.

GROUP SESSIONS

Subcommittee on Institutes and Conferences

Chairman: Mr. Waterman

U.S. Office of Education

Chairman: Mr. Obourn

Council of State Science Supervisors

Chairman: Severo Gomez, Science Consultant, Texas Education Agency, Austin Texas; and President of the Council

National Aeronautics and Space Administration (Spacemobile)

Chairman: Herman Weinstein, Director, Educational Services, Washington, D.C.

National Aeronautics and Space Administration

Chairman: Mr. Bernardo

10:00 a.m.

LOS ANGELES CITY SCHOOLS SCIENCE CENTER

Tour for Council of State Science Supervisors

Presiding: Mr. Kizer

2:00 to 4:00 p.m.

ROUNDTABLE SESSIONS

Table 1

Chairman: W. Earl Sams, Consultant in Secondary Education, State Department of Education, Sacramento, Calif.

Recorder: Clarence B. Lindquist, Specialist for Mathematics and Physical Sciences (Higher Education), U.S. Office of Education, Washington, D.C.

WEDNESDAY, JUNE 3—Continued

2:00 to 4:00 p.m.

Table 2 Chairman: Thornton P. Page, Visiting Professor, Department of Astronomy, University of California at Los Angeles

Recorder: John X. Nesbit, Coordinator for Spacemobiles, Educational Services at NASA Marshall Space Flight Center, Huntsville, Ala.

Table 3 Chairman: Everett E. Collin, Education Programs Officer, National Aeronautics and Space Administration, Washington, D.C.

Recorder: William E. Restemeyer, Professor of Applied Mathematics and Electrical Engineering, College of Engineering, University of Cincinnati

Table 4 Chairman: Albert Piltz, Elementary School Science Specialist, U.S. Office of Education, Washington, D.C.

Recorder: Eugene Horton, Chief, Educational Programs and Services, NASA Manned Spacecraft Center, Houston, Tex.

Table 5 Chairman: Evan A. Sweetser, Consultant in Mathematics and Science, State Department of Education, Montpelier, Vt.

Recorder: Richard C. Berne, Coordinator for Spacemobiles, Educational Services, NASA Langley Research Center, Hampton, Va.

Table 6 Chairman: Henry Van Engen, Professor of Mathematics/Education, Department of Mathematics, The University of Wisconsin

Recorder: Y. A. Taylor, Supervisor of Science, State Department of Public Instruction, Raleigh, N.C.

Table 7 Chairman: L. S. McClung, Chairman, Department of Bacteriology, Indiana University

Recorder: Curtis C. Love, Supervisor of Science, State Department of Education, Little Rock, Ark.

Table 8 Chairman: B. Michael Donahoe, Education Specialist, NASA Western Operations Office, Santa Monica, Calif.

Recorder: Gene A. Maguran, Sr., Science Specialist, State Department of Education, Charleston, W. Va.

Table 9 Chairman: James M. Garner, Supervisor, Science Programs, Office of State Superintendent of Public Instruction, Olympia, Wash.

Recorder: Theresa A. Horvath, Assistant Education Services Manager, NASA Lewis Research Center, Cleveland, Ohio

2:00 to 4:00 p.m.

Table 10 Chairman: Richard Jahns, Dean, College of Mineral Industries, Pennsylvania State University

Recorder: Robert D. Binger, Supervisor, Science Education, State Department of Education, Tallahassee, Fla.

Table 11 Chairman: Lee E. Wickline, Specialist for Secondary School Science, U.S. Office of Education, Washington, D.C.

Recorder: John L. Snyder, Director of Education, American Geological Institute, Washington, D.C.

Table 12 Chairman: Harold P. Pluimer, Science Consultant, State Department of Education, St. Paul, Minn.

Recorder: William J. Gruver, Specialist, Science, U.S. Office of Education, Washington, D.C.

Table 13 Chairman: Melvin D. Anderson, Acting State Science Supervisor, State Department of Public Instruction, Des Moines, Iowa

Recorder: Bernard R. McColgan, Coordinator for Spacemobiles, Educational Services, NASA North Eastern Office, Cambridge, Mass.

Table 14 Chairman: Peter E. Yankwich, Head, Division of Physical Chemistry, University of Illinois

Recorder: Herman J. Oberle, Lecturer, NASA Spacemobile, Educational Services, NASA Ames Research Center, Moffett Field, Calif.

Table 15 Chairman: Walter Wiesman, Chief, Educational Liaison Branch, NASA Marshall Space Flight Center, Huntsville, Ala.

Recorder: Richard S. Peterson, State Specialist of Science Education, State Department of Public Instruction, Salt Lake City, Utah

4:00 p.m. GROUP SESSION

Meeting of Round Table Chairmen and Recorders

Presiding: Mr. Tuttle

THURSDAY, JUNE 4

8:00 to 9:15 a.m. FIFTH GENERAL SESSION

Presiding: Garth A. Hull, Educational Services Officer, Public Affairs Office, NASA Ames Research Center, Moffett Field, Calif.

THE ORIGIN OF LIFE IN THE UNIVERSE

Cyril Ponnamperuma, Acting Chief, Chemical Evolution Branch, Exobiology Division, NASA Ames Research Center, Moffett Field, Calif.

9:15 a.m. FIELD TRIP BRIEFING

Presiding: Mr. Costa

9:30 a.m. to 4:30 p.m. TOURS OF AEROSPACE INDUSTRIES

TOUR 1: Aerojet-General Corp., Azusa, Calif.

James F. Lloyd, Manager, Public Relations, Von Karman Center/Downey Plant, *host*

TOUR 2: North American Aviation, Inc., Space and Information Systems Division, Downey, Calif.

John H. Kearney, Public Relations Coordinator, *host*

AiResearch Manufacturing Company, The Garrett Corp., Torrance, Calif.

James A. Wolfinger, Senior Preliminary Designer Engineer, *host*

TOUR 3: Jet Propulsion Laboratory, Pasadena, Calif.

Richard R. Wilford, Senior Representative, and Robert Miller, Representative, Public Education and Information, *hosts*

TOUR 4: Rocketdyne Division, North American Aviation, Inc., Santa Susana Facilities, Chatsworth, Calif.

John R. Ulf, Public Relations Coordinator, *host*

Lockheed-California Co., Rye Canyon Plant, Saugus, Calif.

Donald T. Perkins, Scientific Advisor for Spacecraft Organization, *host*

8:00 to 9:30 p.m. SIXTH GENERAL SESSION

Presiding: Hugh Templeton, Supervisor, Science Consultant, The State Education Department, Albany, N.Y.

THE SPACE AGE SYNDROME OF THE HUMAN MALE

Richard H. Brenneman, Technology Utilization Officer, NASA Western Operations Office, Santa Monica, Calif.

FRIDAY, JUNE 5

8:30 to 10:00 a.m.

GROUP SESSIONS

Subcommittee on Institutes and Conferences

Consultants: Paul S. Feinstein, Assistant to the Director, Scientific and Technical Information Division, NASA Headquarters, Washington, D.C.

John R. Craig, Research Programs Manager, NASA Office of Grants and Research Contracts, Washington, D.C.

Meetings of NASA Field Installation Education Representatives with Spacemobile Space-Science Lecturers and State Science Supervisors

Science Supervisors from—	Education Directors from—
New York, Connecticut, Rhode Island, Maine, Vermont, New Hampshire, Massachusetts	North Eastern Office
Southern California, Nevada, Utah, Arizona, Hawaii	Western Operations Office
Florida, Puerto Rico, Virgin Islands	Headquarters and John F. Kennedy Space Center
Pennsylvania, West Virginia, Delaware, New Jersey, Maryland, Washington, D.C.	Goddard Space Flight Center
Northern California, Idaho, Montana, Oregon, Wyoming, Washington, Alaska	Ames Research Center
Kentucky, Virginia, North Carolina, South Carolina	Langley Research Center
Texas, New Mexico, Oklahoma, Kansas, Nebraska, Colorado, North Dakota, South Dakota	Headquarters and Houston Manned Spacecraft Center
Ohio, Indiana, Illinois, Iowa, Wisconsin, Minnesota, Michigan	Headquarters and Lewis Research Center
Alabama, Georgia, Tennessee, Missouri, Arkansas, Louisiana, Mississippi	Marshall Space Flight Center

FRIDAY, JUNE 5—Continued

10:15 a.m.	SEVENTH GENERAL SESSION Presiding: Mr. Seamster Summary Report of Round Table Discussions and Conference Program Mr. Costa Reactions to the 1964 Space Science Education Conference Mr. Gomez Lola J. Eriksen, Specialist for Elementary and Secondary School Science Education, U.S. Office of Education, Washington, D.C. Mr. Waterman Acknowledgments and Conference Adjournment Mr. Bernardo
12:30 p.m.	CONFERENCE ADJOURNS
1:30 to 4:30 p.m.	SPACEMOBILE WORKSHOP Presiding: Mr. Collin

SATURDAY, JUNE 6

8:30 a.m. to 12:00 p.m.	SPACEMOBILE WORKSHOP Presiding: Mr. Collin

APPENDIX C

CONFERENCE COMMITTEES

NASA EDUCATIONAL ADVISORY COMMITTEE

Arnold K. King, Vice President for Institutional Studies, University of North Carolina. *Chairman of the Committee.*

Harold D. Drummond, Chairman, Department of Elementary Education, University of New Mexico.

Paul De Hart Hurd, Professor of Education, Stanford University.

Frank E. Sorenson, Chairman, Department of Educational Services, University of Nebraska.

Fletcher G. Watson, Jr., Professor of Education, Harvard University

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ERRATA

Page 54: Second line, column one, should read "2 X 10^7 dynes/cm^2" not "2 X 10^7 dynes cm^2."

Page 55: Third line, column two, should read "did not yield to ground-based observations" not "did not yield to ground-based operations."

Page 58: Twenty-fourth line (end of first paragraph), column two, should read "within the magnetosphere" not "beyond the magnetosphere."