INTERACTION BETWEEN SPACE EXPLORATION, SCIENCE, AND TECHNOLOGY

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Introduction

It is a great privilege to have the opportunity of spending a day in the Twin Cities where one may sense a keen awareness of the vital role of science and technology in our modern world. This community is widely recognized as one of the most rapidly growing regions in combining the resources of the University, industry, and the local and state governments to accomplish economic growth.

In view of the circumstance which triggered this banquet, I wish first to pay tribute to the directors of the Hill Family Foundation, founders of the Louis W. Hill Space Transportation Award, who in 1958 could see in the first artificial satellite of the earth the forerunner of a space transportation system. Next I would like to thank the officers and members of the Twin Cities Section of the American Institute of Aeronautics and Astronautics for making arrangements for this meeting and for the activities of the day, which have provided a welcome diversion from the desk in Washington.

Then I would like to recognize the University of Minnesota as an active and valuable ally of the National Aeronautics and Space Administration in the scientific exploration of space. I am sure that you are

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as familiar as I am with the great contributions of Professor A. O. Nier and his associates in the application of the mass spectrometer to the study of the composition of planetary atmospheres; with Dr. E. P. Ney's pioneering investigations of air glow and the zodiacal light; with Professor J. R. Winkler's massive contributions to the study of cosmic rays and of radiation trapped in the earth's magnetic field; with Dr. W. R. Webber's measurements of the fluxes and energy spectra of solar protons; and with Dr. P. J. Kellogg's theoretical studies of the interaction of solar particles and the earth's magnetic field, leading to a better understanding of the relationship of the sun to the earth and of physical phenomena in ionized gases. In recent weeks we have been discussing with Dr. William G. Shepherd, Vice President for Academic Administration, several other areas in which the University may be of assistance, and in fact there was an announcement of one such additional area last week.

I would also like to take this occasion to express appreciation to our industrial partners, including the contributions of Minneapolis-Honeywell in the areas of guidance and control; the Schjeldahl Company, which fabricated the Echo spacecraft, largest spacecraft ever launched into space and perhaps seen by more people in the world than any other satellite; and Control Data Corporation, supplying equipment and services for computation and data processing, and ranking twenty-fourth among NASA contractors listed according to net value of direct awards. In addition to those mentioned, there are numerous other industrial companies in this region participating in the space program in smaller contracts and in first- and second-tier subcontracts.

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The Changing Technological Scene

Last year I had the pleasure of participating in the selection of the contents of a time capsule which was buried at the World's Fair and intended to be opened in the seventieth century. It contained many items to illustrate our modern technology, many being articles in common use and others being products related to transportation, atomic energy, and other areas of science and technology. Among the items selected were an electronic watch, a Polaroid camera, antibiotics, computer memory units, a plastic heart valve, samples of superconducting wire, a ruby laser rod, normal and irradiated seeds, desalted sea water, a permanent magnet, birth control pills, transistor radios, freeze-dried foods, an electric toothbrush, and tranquilizers. The field of space exploration was represented by such items as solar cells, miniaturized electronic circuitry from the Vanguard satellite, samples of the aluminized mylar material from which the Echo balloons were fabricated, and the first photographs of the moon taken by Ranger VII. The many recently developed objects in this list are dramatic evidence of the rapid pace of change in the technological scene.

Let us consider the development of technology in a few areas during the past century. As a first example, consider power. In the earliest days of our republic, human labor furnished a quarter, and labor of animals half, of the energy required for life. In 1900 each man, woman, and child in the United States had two horsepower working for him day and night. At the present time the figure stands at ten horsepower.

With less than ten percent of the world's population, we in the United States control almost half its supply of power, and as a result our standard of living is seven times the average of the rest of the world. Had we lived like this in the Periclean age of Ancient Greece, we should need the exhausting labor of ten billion slaves to provide the benefits.

It has been only twenty-two years since Fermi and his group of scientists and engineers produced the first self-sustained chain reaction in a nuclear reactor. Today we see the beneficial effects of this energy source in the fields of medicine, agriculture, industrial processes, electric power generation, and propulsion.

Next let us look at communication. Fundamental to all of man's activities is his ability to communicate rapidly with precision. One measure of our ability to communicate used by the communications engineer is the number of bits of information that can be transmitted per unit time. Until the nineteenth century, communication was by signal fires, mirrors, drums, runners, pigeons, wind-driven ships, post riders, and sentinels who relayed shouted messages. By the latter half of the century man had achieved the ability to transmit a few bits of information per minute from coast to coast and across the sea. There were about a million telephones in 1900. Today in Washington, D.C., alone there are almost that many telephones, and you can rent over fifty million dollars worth of telephone equipment for a dime. Many of us did not go to moving pictures as children for there were none. Today radio and television reach into every corner of the land. About five thousand bits of information per second must be transmitted for intelligible voice communication, and some ten to one hundred million bits per second for high-quality television. Through satellite technology developed by NASA, we will soon be linked more closely to other people of the world. All of us have been thrilled by the high-quality vidicon pictures transmitted to us by Ranger as it plummeted to the moon's surface. The Ranger photographs have been selected by Dr. Watson Davis, director of Science Service, as one of the ten outstanding accomplishments of last year.

As a final example, consider the development of transportation initiated by the airplane. In 1900 the airplane concept was not taken seriously. The noted scientist Simon Newcomb wrote in 1903: "May not our mechanicians be ultimately forced to admit that aerial flight is one of that great class of problems with which man can never hope to cope and give up all attempts to grapple with it?" But men like Langley and the Wright brothers were already at work on the problem, and the first powered flight came the same year. As children we saw man in his first flights, soaring a few hundred feet off the ground and at much less than one hundred miles an hour. Today we span our continent in four hours and cross oceans in jet transports and are working earnestly to provide air transportation at supersonic speeds.

Four years after our first satellite launching we placed John Glenn in orbit, and within eight years from his flight we expect to place American explorers on the moon's surface and return them safely to earth. Such has been the remarkable progress of the technology of transportation in the new oceans of air and space as man escapes his former confinement to the surface of the earth.

Scientific Research, the Catalyst of Change

In man's early history there was mostly technology and little science. The origin of science can be traced far back in the distant past. Aristotle is quoted as saying that true science is the search of nature in the spirit of true scientific curiosity. For hundreds of years science was mainly a purely intellectual activity involving little of what we now call experimental science. Much has been written about those objectives of science which relate to gaining an understanding of the entire universe in which we live, of the excitement of studying the unknown, and of the contribution of science to man's intellectual and spiritual life. However, we are here concerned more with the interaction between science and technology. Charles Singer writes (A History of Technology, Oxford University Press, 1956, page 274): "In our own time technology has become almost synonomous with the application of scientific knowledge to practical ends. To us it seems that science is the source, the parent of technology. Up to about 1500 and perhaps much later, it would be more accurate to say that technology was the parent of science, but from the rather indeterminate period usually called the Renaissance, natural phenomena came to be more and more systematically observed."

According to Walker (Modern Technology and Civilization, McGraw-Hill, 1962, page 14): "Most historians and many scientists are agreed that in important respects the relation [between science and technology] is reciprocal. Advances in 'pure' science are rapidly reflected in new technological revolutions. . . . The mounting debt of science to technology is not always as fully realized. Without the telescope, a technological invention, the science of modern astronomy would have been impossible. Without the microscope the modern sciences of zoology, biology and bacteriology would not have developed. But the cases are endless and to be found in nearly every department of modern science and modern technology. One of the latest and most striking debts of science to technology lies in the field of mathematics and physics. Progress in both is now dependent in part on the high speed automatic computer. The computer in turn owes its development to information theory and the researches of the mathematician. The systematic development of new technical inventions out of the expanding stores of scientific knowledge only became conspicuous in the 19th Century."

We might add to Walker's list the fact that without the rocket we could not now be pursuing science by sending instruments and men into the space environment.

It has long been realized that there is a time lag between a discovery or new theory in science and its application, but this lag is growing shorter and shorter. Conic sections are said to have been discovered by Apollonius of Perga in the third century B.C., when they were of intellectual interest only. They were applied to the problems of engineering in the seventeenth century. Paracelsus discovered ether and its anaesthetic effects and Valerius Cordus gave the formula for its preparation, yet it was centuries later before it was used as an anaesthetic.

Non-Euclidean geometry, worked out by Riemann as an essay in pure mathematics in the nineteenth century, was used by Albert Einstein in the twentieth century in his theory of relativity. It was in Descartes' time that the application of conic sections to the orbit of planets was first noticed. Later these curves were used to compute paths of projectiles, in searchlight reflectors, and cables of suspension bridges. Chlorinated diphenylethane was synthesized in 1874, but its value as the insecticide DDT was not recognized until 1939. The photoelectric cell was used by Hale in pure science investigations in 1894, and twenty-five years later it was used to make motion pictures. There was a lag of forty years from Maxwell's publication of the laws of the electromagnetic field to the first radio experiments of Marconi, ten years from the discovery of the neutron to the first nuclear reaction, and six years from the invention of the transistor to the first transistorized amplifier on the market. Judging from this record, some of the discoveries and advances of space science should feed back into our lives within a decade. Others may await some other critical piece of information before they fit into the jigsaw of nature. Each piece of information serves as a building block for steady progress.

It took a thousand years to develop in empirical stages the guns that were used in World War II. After that, it was less than two decades until we were able to fire guns in the laboratory that were ten times faster. This progress was made possible because the gas dynamic laws of expansion became better understood especially due to the advanced mathematical methods supported by highly developed experimental techniques. This was achieved without having the improvement of guns as the objective.

Interaction of Science, Technology, and Social Need

There is a mistaken impression in some circles today that scientific and technological development always proceeds by an orderly process in which, first, there is a basic concept or theory, followed by experimental verification, leading to further theoretical and experimental investigations and applied research, followed finally by application to some social need. Actually, of course, the situation is not so simple; the situation is a dynamic one with continual interactions between theory, experiment, application, and social need. In my reading of the history of scientific development, I have been impressed time and time again by the almost dominant role of the specific social environment in which the scientist and engineer work, which in most instances seems to be a prerequisite for the intensive development of the scientific concept itself as well as the ensuing technology. One or two examples will illustrate.

Most of the work for which Pasteur is famous originated in the social needs of the community in which he worked. Beginning in 1854 he addressed himself to the reason for unsatisfactory results obtained in the fermentation of beer, and in 1857 showed that the troubles arose from small organisms which interfered with the growth of yeast cells responsible for fermentation. Later he turned his attention to similar problems in the production of good wine. Later, under great social pressure, he studied the small organisms responsible for certain diseases of the silkworm, of cattle, of chickens, and of dogs and man. Thus social needs provided the incentive for and the support of Pasteur's scientific work in solving the "problems of the infinitely small."

Another classic story begins with the work of James Maxwell starting about 1850 and already briefly referred to. In 1865 and 1873 he described the propagation of electromagnetic waves and suggested that light was a phenomenon produced by the travel of electromagnetic waves in the ether. I believe the first experimental demonstration of electric waves was by Hertz in 1883, who invented an oscillator to produce such waves. There was some limited further theoretical and experimental development by scientists such as Lodge and Righi in the last two decades of the nineteenth century. Marconi began a study of the application of electric waves to signaling in 1895 and succeeded in sending signals across the Atlantic in 1901. I think it is now obvious to everyone that this application by Marconi to a practical social need marked the beginning of greatly increased support for theoretical and experimental research in this field, that it marked the foundation of very large industrial developments, and that there has been a very great social impact.

These cases are of course the traditional ones that everyone quotes. There are many others such as the development of probability theory and modern statistics from the "social need" of the members of high society in France interested in gambling.

We believe that activities in the exploration of space, a modern social need recognizable from the passage of the National Aeronautics and Space Act and the appropriation of large sums of money by the Congress, provide that essential environment to accelerate greatly the growth of theoretical and experimental science in many areas. It is true that this accelerated growth in science and technology is essential to the on-going development of space capability, but of deeper significance is the complex dynamic interaction between science, technology, and space exploration, which is essential to the growth of science, technology, and space exploration. In this case, as in the cases previously cited, to use an analogy from bacteriology, there has to be a nutrient solution (money and employment opportunities) to feed the scientific and technological effort, and as soon as this environment is provided, many latent efforts in science and technology begin to assert themselves and move forward.

I believe that this interpretation of certain aspects of the space program is more significant and meaningful than the current concepts of technology utilization and technological spinoff as incidental or serendipitous benefits of space exploration.

Some Aspects of Current Space Activities

Current space activities not only represent applications of scientific results already available and stimulate the advance of almost all fields of science carried out in laboratories on the ground, but open up completely new breathtaking vistas through the new opportunities for making scientific measurements in the high atmosphere and outer space. One of the oldest and most fundamental problems challenging scientists is the structure of the universe--the abundance of the elements in the cosmos, the evolution of the stars and galaxies, the formation of the sun and planets, and the origin of the earth. All the information we had about the universe prior to 1957 came to us in the form of waves radiated from the surfaces of stars that reach our telescopes and spectrographs. Unfortunately most of this star radiation is absorbed in the atmosphere and a pitifully small fraction reaches our instruments. Everything else is lost to us in observations at the surface of the earth. Under these handicaps, astronomers with great ingenuity have learned much about the composition of the stars, their life histories from the time of birth in the chance condensation out of the gas and dust of interstellar space, to their eventual destruction in the explosion of the Supernova. Now for the first time in the history of science we have the means to put a telescope above this atmospheric curtain and our instruments can then take in the entire breadth of radiation. Moreover, we can send our instruments now to the nearest planets and probably in a few years to the outer reaches of the solar system. An unmanned astronomical observatory for use in a satellite in space is nearing completion and is scheduled for first launch during the latter part of this year. Within the past year we launched the second Orbiting Solar Observatory for studies of the sun and the first Orbiting Geophysical Observatory for studying the earth. These observatory satellites carry many instruments and are made possible only through the cooperation of many experimenters in universities, industries, and government laboratories. Many smaller satellites were launched for scientific purposes, to make measurements within the ionosphere and of the ionosphere from above, to measure electric and magnetic fields and the charged particles which are present in the neighborhood of the earth, the density of air present at various heights and the flux of micrometeoroids. The second

Ariel satellite was launched in cooperation with Great Britain, carrying experiments by British scientists for the measurement of galactic radio noise, of atmospheric ozone, and of micrometeoroid flux. An Italian satellite for the measurement of the local density of the upper atmosphere was launched by an Italian crew in the cooperative San Marco project. The crew was trained by NASA, and the satellite was placed in orbit by a Scout rocket from Wallops Island. Thus Italy became the third country other than the U.S. or the U.S.S.R. to launch a satellite of its own.

During the last few months, Ranger VII and Ranger VIII have transmitted back to earth thousands of television pictures of the lunar surface of extraordinary quality. Details of the moon have been photographed at two general locations with a thousand times the clarity of earth telescopes. In each case the vehicles were impacted on the moon very close to the intended targets. On November 28 Mariner IV was launched to fly by the planet Mars. The vehicle will make its closest approach to Mars--about 5400 miles--on July 14, 1965; and if the equipment continues to work properly, we will for the first time obtain 21 pictures of the planet Mars about 50 to 100 times better than any taken from the earth's surface.

As we pursue investigations in basic science in the space program, we are also developing areas of application such as meteorology and communications. These, as much as anything else we do, will serve to knit closer together the peoples of this earth in a bond of better understanding of each other's problems and of mutual assistance and benefits that will come with better weather predictions. During the past three years seven successful communications satellites have been launched of three types, namely: passive, i.e., Echo; low-altitude active, including two Telstars and two Relays; and two synchronous satellites, Syncom II and Syncom III. These satellites have been used to demonstrate transcontinental and transoceanic communication in all of its forms, including telephone, teletype, and television. You may recall the transmission of the Olympic Games from Tokyo to the Western World by means of Syncom III. Syncom III was placed in a synchronous equatorial orbit in August 1964. It was positioned so accurately that it drifts westward only one mile per day and north and south of the equator less than six miles per day--all this at an altitude about 22,500 miles above the earth's surface. The experimental work carried out by these satellites forms a foundation for the operational system to be established by the Communications Satellite Corporation in cooperation with many other nations.

Manned space-flight activities will resume this month with the first manned flight of the Gemini carrying two astronauts. Gemini is to be used to develop earth-orbiting rendezvous techniques, to study the behavior of men and equipment in extended flights under conditions of weightlessness, to begin the study of extravehicular operations in space, and to serve a variety of manned missions of interest to NASA and the Department of Defense.

Manned flights will continue with the Apollo three-man capsule, which eventually will take man to the moon. The broad purpose of the

Apollo program is the establishment of a national competence for manned space flight out to distances of the moon, including the industrial base, trained personnel, ground facilities, flight hardware, and operational experience. The use of this capability for manned flight to the moon and return and for further space explorations out to distances of the moon is intended to bring about United States leadership in space. We then will be in a position to do whatever our national interests require in the further study and use of this new environment.

I intend to make my principal report to you on the status of the Apollo program through the use of a film at the end of this talk. Thus I will merely mention here that two new launch vehicles are under development to provide the desired capability. The first is the Saturn IB, whose first stage uses a cluster of eight up-rated H-1 engines and is a developed and redesigned version of the present Saturn I first stage. You will recall that eight successful flights of the Saturn I have been made. The upper stage of Saturn IB will utilize one J-2 liquid hydrogen-liquid oxygen engine of 200,000 pounds' thrust in the S-IVB stage. This launch vehicle will be able to place a payload of 35,000 pounds in a 105-nautical-mile orbit. It will be man-rated and make its first flight in 1966, carrying the Apollo three-man capsule in earth orbit.

For the mission of landing on the moon, a still larger booster is under development, the Saturn V. The first stage uses a cluster of five F-1 engines, each with a thrust of one and a half million pounds, giving a total thrust of seven and a half million pounds. The second S-II stage utilizes five J-2 liquid oxygen-liquid hydrogen engines with a total thrust of one million pounds, and the third stage is the S-IVB already described. The first flight of the Saturn V is scheduled for the 1967-68 time period. This large launch vehicle, 33 feet in diameter and 276 feet high less the spacecraft, is able to put the Apollo space capsule, the instrument unit, and the S-IVB stage--a total weight of 280,000 pounds--in a 105-nautical-mile earth orbit.

The flight missions which I have mentioned are undergirded by a program of advanced research and technology, carried out in in-house government laboratories of NASA and other government agencies, but also in cooperation with industry and the universities under contract. The work ranges from basic research to applied research and advanced technological development, and there are literally thousands of projects which cannot be described here in detail. However, I may attempt to give some idea of the scope by mentioning the broad classifications of our grants and research contracts with universities and nonprofit institutions. The fields covered are

Physical sciences (physics, chemistry, and mathematics)

Engineering sciences (energetics, electromagnetics, fluid mechanics, materials technology, mechanics, system analysis and control, flight operations)

Cosmological sciences (planetary sciences, astrophysics, astronomy)

Socio-economic studies

Scientific investigations in space (sounding rockets, scientific satellites, lunar and planetary exploration)

Satellite applications investigations (meteorology, communications)

Vehicle systems technology (advanced vehicle systems, booster recovery systems)

Supporting activities (tracking and data)

Space operations technology (manned space flight)

Space propulsion technology (solid rocket systems technology, liquid rocket systems technology, nuclear systems technology, space power systems technology)

Flight medicine and biology (biotechnology, operational aspects of in-flight experiments)

Basic medical and behavioral sciences (physiology, metabolism, radiology, psychology and sociology)

Space biology (effects of space environment on biological phenomena, extraterrestrial life)

Research today has progressed from the early days of unrelated investigations of a comparatively few individuals working on subjects that interested them. Now we have the organized effort of large groups on programs whose goals are set by the joint thinking of university scientists, research staffs, aircraft designers, aircraft users, space vehicle designers, and space vehicle users. It is this collaboration of scientist, designer, and user which makes our aeronautical and space research so fruitful and permits so rapid a rate of progress. And these developments, taken together, signify that our planet will become small in the eyes of man, as small as Europe became in the sixteenth and seventeenth centuries.

The future lies bright before us. I am reminded of a Life Magazine editorial in 1963 (May 17 issue) which said: "Never was there so much for talented men to do whether in politics, science, art, business, or even speculations on the nature of man. The same could have been said of Europe near the end of the Fifteenth Century when the Renaissance was opening new doors to human thought and experience. A time of challenge always produces skeptics and naysayers; Isabella of Spain had advisors who tried to talk her out of financing Columbus's voyage. But the bold spirits of that time did venture into the unknown and they turned their age, already exciting enough, into an era of unprecedented exploration and discovery which changed the history of the world."

The progress we have made in aeronautics and space, with the support of the Congress and the people, is tangible enough for all to see. I feel that we are at the beginning of a great new surge in science and technology stimulated by their interactions with each other and with social needs, nourished by the resources and needs of space exploration. Many more tangible benefits lie before us. I join with Wilbur Wright in affirming that "it is not necessary to look too far into the future, we see enough already to be certain that it will be magnificent."

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