will not differentiate into cells of that type. If the metabolic level becomes optimal in these cells later, when other group of genes are active, then these other genes will direct the synthesis of proteins that will specify differentiation into cells of another kind.

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Space Science and the Universities

Educational and research programs contribute to manpower and advances in the space sciences.

Frederick Seitz

There is a curious dualism in the mobility of man and his culture throughout history in that the species is distributed in essentially all places that are even remotely habitable, in spite of the fact that the average individual basically prefers to remain fixed. Most human beings spend their lives within a few miles of their birthplace, usually marrying someone from just around the corner. Yet in spite of this, man has managed to get to every spot or crevice of the earth's surface that he can reach by muscle or machine. Moreover, individuals have wandered far afield in spite of hardships. Man's motives in moving from one region to another, either in small missions or in large groups, are varied. Let me list a few of the principal ones.

Motives in Exploration

First, and perhaps most important, is the drive for self-preservation. It is this, for example, which brought the Eskimos to the Arctic wastes, Patagonians to the bleak tip of South America, and Bushmen to South Africa.

Second is the desire for trade. This led to the establishment of the Amber Route between the Mediterranean and the Baltic many thousands of years ago, and led the Chinese to develop the caravan routes across the Gobi Desert to Persia and Rome. This trade enriched Rome with silks but depleted it of gold. The same desire for trade brought the Phoenicians to England and around Africa, and ultimately brought Columbus to the New World.

Third is the desire for adventure or booty, which drove Alexander across Persia to India, Marco Polo to far-off Cathay, and Pizarro to Peru.

Then there are motives of military strategy, such as those which caused Hannibal to cross the Alps with his elephants to attack Rome from the north and caused Henry the Navigator to seek a route around Africa, thereby outflanking the Arabian citadels in the Near East.

Desire for prestige may play a very important role; it is this which led national teams to penetrate the polar regions and led Hillary to the top of Mount Everest.

Then there may be religious motives, such as those which led Livingstone to the heart of Africa, the Puritans and the Quakers to the New World, and the Italian Jesuit Matteo Ricci to Peking, where he lived the life of an expatriate 400 years ago.

Finally, there is the desire for unusual knowledge, one of the strongest of driving forces in one group of human beings. This quest for knowledge drove many men to the heart of Africa to search for the source of the Nile, drove others across the Arctic wastes to the Poles, and drives still others in bathyscaphes to the ocean depths.

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Clearly, most men who have made unusual journeys have been spurred on by a combination of these motives. We know, for example, that the Celtic tribes wandered back and forth across the face of Europe in the first millennium B.C., goaded by many motives which must have included those I have mentioned. Similarly, a combination of these motives has been the force behind most of the expeditions to the Antarctic in the last 50 years and the trips of the atomic submarines between the Atlantic and the Pacific, under the polar ice sheet.

The exploration of extraterrestrial space, in which mankind is deeply engaged at present, is a continuation of the pattern of migration that has prevailed throughout history, with one remarkable difference. Technology has now reached a point where our machines can attain sufficient velocity to overcome the earth's gravitational pull and hence has opened to us the possibility of exploring the outer atmosphere and the regions between the planets. Fortunately, the distances and speeds involved in space exploration are short as compared to a human lifetime, so long as we keep to the nearby planets, falling within the general time framework of great terrestrial explorations of the past.

The motives which drive us to explore space are complex, involving most of the motives I have given for exploration in general. The only one missing is the desire for wealth or booty, although in this connection I might remind you that Representative Gross of Iowa stated last year, during the hearings on the NASA budget, that he hoped we would find that the moon is made of gold, since we would need it by the time the first men land there, at the end of this decade!

I think we must view this period of exploration as an essential part of the human journey, tied to whatever meaning our human existence has. The only major debatable issue seems to be the rate at which the exploration proceeds. The President has decided that we must lead in space—that nothing less will suffice. Our investment in the space effort in any year or decade must be decided on the basis of a complex balancing of all the factors involved and will continue to be a matter of public discussion and debate. If we are to lead, this investment will be high as compared to our investment in most other science programs.

Promise of New Knowledge

In considering the role which the university will play in all of this, we automatically focus on the issue of knowledge, for the university is one of the places where new knowledge is generated through research. It also has, almost uniquely, the role of transmitting advanced basic knowledge in a systematic way from one generation to the next. For the university to ignore space exploration in its broadest sense would be as unthinkable as for it to ignore the corresponding problems concerning terrestrial affairs. Conversely, as I emphasize later, those concerned with space exploration cannot afford to ignore the universities. I can think of no aspect of university activity relating to science or technology which is not involved in a fundamental way in the space effort. In this connection I need only remind you that one of the most active bodies in the National Academy of Sciences at present is the Space Science Board of the National Research Council, which played a key role in the organization of NASA and is now the principal outside advisory body for that agency. It is composed of scientists and engineers from essentially every discipline represented within the Academy. Most of its members are from academic life.

Let me mention the principal areas in which we can hope to gain, from our efforts in space, the kind of knowledge with which the university is normally and rightly concerned. I will begin with applications and will turn later to science.

First of all, in the area of space technology there are matters relating to the traditional fields of engineering. If we take the view that engineering is concerned with the practical aspects of power conversion, communication, and control, with properties of materials, and with structures, and that the highest art in the field of engineering is the tying together of these aspects in specific applications through invention and design, it is clear that space technology offers an almost unlimited challenge.

Similarly, if man is to spend long periods in space, it will be necessary to obtain specialized knowledge concerning his responses to his space environment, and this will become part of the body of traditional knowledge in medicine, the behavioral sciences, and engineering.

Finally, there will be sociological, legal, and economic problems associated with space exploration. Their solution will contribute to traditional disciplines and will soon be fitted into the body of academic knowledge.

When we turn to the basic sciences, there are, first of all, matters to be investigated relating to the earth's upper atmosphere, which is influenced very directly by the emanations from the sun (the solar wind). Related to such studies is investigation of the thin and highly ionized solar atmosphere through which the earth travels. It is clear that we will not have a comprehensive and practical understanding of our atmosphere as a whole until we have a clearer picture of events 160 kilometers or more above the surface of the earth. Tied in with all this, of course, is study of the Van Allen belts, which are a focus of interest in various fields of science and technology.

Then there are matters relating to the inorganic composition of satellites, such as our moon, and the planets—that is, what might be called their local geology. (In this connection I should mention that the term *geo*, for earth, is taking on a much broader meaning these days—the chairman of the Academy's Space Science Board is a geologist by profession.) Geologically speaking, our planet consists of a metallic core surrounded by a coating of less dense metallic oxides, usually thought of as being divided into an outer crust and an inner mantle. The basalts and heavier minerals lie nearest the metallic core. The continents are granitic "islands" which float, surrounded by the oceans, on a basaltic base. The actions of the water of the surface and of the atmosphere and the oxidizing atmosphere itself have produced highly individualistic features, such as the sedimentary deposits and the weathered and eroded features of the topography.

To what extent are these characteristics peculiar to our planet? Since the moon does not possess an atmosphere and probably does not have a metallic core, it obviously has its own individuality. Moreover, the moon bears a clear imprint of billions of years of direct exposure to space, and thus it is a kind of enormous fossil from which we may learn much of the ancient past.

The information gathered by radio astronomy and by the recent Mariner probe of Venus has given us a much clearer picture of the topography of Venus than we had previously. Venus seems to differ from the earth in many important respects. For example, it seems to have a dense, continuous cloud cover and a surface temperature several hundred degrees above the boiling point of water. Mars seems more like the earth today, in temperature and in having an atmosphere transparent to light. However, we still wonder about the details of its atmosphere and surface.

Related to all of this are questions about the composition of the atmospheres and the clues which physical features give concerning the formation of the planets.

The third great new area of scientific study centers about the extraplanetary astronomical observations, of the type ordinarily made with telescopes and related instruments, that become possible once the observer is above the atmosphere. The vistas for research are almost unlimited. The observer will no longer be hampered by atmospheric turbulence and by absorption by the atmosphere, which blacks out everything except a small region in the visible spectrum and a few octaves in the radio-frequency range, usually called the radio-astronomy window. One can expect a vast extension of knowledge, on matters ranging from details of the sun's surface to the structure and composition of distant nebulae, once this type of observational astronomy is begun in earnest.

The fourth area of study concerns the basic laws of physics, particularly those that come under the designations of special and general relativity. Exciting new investigations become possible when one is dealing with variations in velocity and distance of gravitational field somewhat larger than the variations ordinarily observed on the earth, such as may be encountered by an artificial terrestrial or solar satellite of highly eccentric orbit.

Finally, we turn to the area of biological science, which to my mind is by far the most intriguing of the fields to be investigated in space exploration. If we find no significant signs of life anywhere else in the solar system, as we might guess, offhand, would be the case, we can be fairly certain that life as we know it originated on the earth and evolved, according to the traditional concept, from complex molecules suspended in the ancient seas of the earth a billion or more years ago. On the other hand, if we do discover signs of life elsewhere, a host of stimulating questions will arise: Are life forms elsewhere basically like those on earth in the sense that the same amino acid building blocks are used in their structure? If they are, can we determine whether life originated elsewhere in the solar system or universe and was transported here? Or did life perhaps start on our earth and become dispersed at an early stage in its development? If, on the other hand, it turns out that life forms elsewhere in the solar system are inherently different from those on earth—that is, that the chemical building blocks are radically different—what will we be able to say about the ease with which life can be formed in other environments? I myself can think of no other problems, except possibly those related to the origin and evolution of our own species, that are even remotely as exciting as these. I should add that there is evidence which suggests that the hydrocarbons found in some meteorites are closely related to those found in archaic deposits of biological origin on earth. This, in turn, faintly suggests that some forms of life resembling our own may have existed outside our own atmosphere.

Impact on the University

It is clear, then, that man's adventure in space will stimulate many branches of university work in a quite natural and automatic way. In some instances this will mean no more than the addition of interesting new studies of a specialized kind in traditional disciplines; in others, it will lead to major research programs which may involve sizable teams of workers.

One may reasonably ask to what extent the universities can expect to become radically reoriented. The answer seems fairly simple. The effect on each institution will be somewhat individualistic and will depend upon the particular interests of the staff and students, but, on the whole, it will not be vast. In general, the major universities will not be conscious of major revolutions. Institutions which are already well grounded in the fundamental aspects of the subjects which underlie space science and technology will quickly make the necessary adaptations. Here and there a faculty member will take on the problems in his field related to space science or technology as a specialty and assemble a team for developing a research program or a new curriculum, becoming deeply involved in a personal way. Occasionally, a large segment of a department involved in science, engineering, sociology, or psychology will decide that its department should become a major center for such study (for example, the department of physics at the University of Iowa has devoted much of its attention to the instrumentation of satellites and the interpretation of the results obtained from the instruments). Some universities will form interdisciplinary groups, perhaps of the biological, physical, and engineering sciences, in order to evolve programs which draw upon a diversity of talents.

I believe the greatest impact of the space program will be on the engineering colleges, not so much because of the unique character of the knowledge which is being acquired as because of the acceleration in the changing pattern of engineering, which would have altered much more slowly without the space program. While it is true that the basic equations of the engineer, such as Maxwell's equations or equations relating to dynamics and statics, will not be altered, the space effort has need of engineering knowledge of the most advanced and sophisticated type. While there will be great emphasis on routine reliability, there is also the utmost need for innovation. I believe those universities which take pride in their engineering schools will now have added reason to re-examine the relative emphasis which they place upon work leading to the doctor's and to the bachelor's degrees. They will also have cause to re-examine the traditional departmental structure, which represents an inheritance from the earlier days of engineering, when specialization occurred at the undergraduate rather than the graduate level. This structure may be poorly suited for the period ahead, if the fields of engineering are to have maximum flexibility in the face of challenges of a highly sophisticated type. Moreover, it seems clear that almost any aspect of space research carried on within a university will require close cooperation between the engineering department and departments in the physical sciences, such as astronomy, geology, or physics. The need for such coordination should accelerate the development of interdisciplinary laboratories, for work in engineering and science, to be used for both graduate and postgraduate research programs.

It is hardly necessary to add that the universities can make an enormous contribution to the space program. At the very least, the output of graduates is indispensable if the program is to accelerate and be sustained in the way which is envisaged. These graduates must have the best preparation our academic system can give them. Furthermore, the history of science in the United States demonstrates quite clearly that strong university participation in a field of research, whatever it may be, helps to assure the health of that field. There are many reasons for this. First, a certain proportion of the most gifted individuals find a university, with its freedom and flexibility, the most suitable environment in which to work. Then, too, the presence of many promising students in a formative period adds a particular freshness and vitality to research. This is not to say that excellent work is not done elsewhere, in industrial, nonprofit, or "in-house" laboratories. But any program that does not take maximum advantage of the capability of scientists within universities will not advance in the most effective way possible.

University–NASA Interaction

This brings me to a major problem which is in the minds of all of us at present. What degree of interaction between the agency sponsoring our space program and the universities is most desirable? The problem is obviously a very complex one and is not subject to any exact analysis. Perhaps one would like to ignore it, and yet it cannot be ignored, precisely because of the enormous demands the space program will make upon the universities, in the next 10 or 20 years, for highly trained manpower as well as for correlated research and knowledge. It is safe to say that, in the coming generation, a large proportion of our best-trained students in science and technology—perhaps a fifth—will end up in some part of the space program if it continues to be the object of urgent national interest. For their own good, the space agencies must make certain that the universities are viable and that the students they turn out have been given the maximum opportunity to develop their capabilities, at least in the areas of academic work essential for the space program.

Let me make a side remark. We all meet many individuals who regard the national space program as an unmitigated evil which saddles our country with a heavy financial burden and diverts our best technical minds from more important tasks. I hope I have made it clear that I feel the general goals of the space program are a natural continuation of the human adventure. For our society, particularly Western society, to ignore this challenge is unthinkable! The only debatable issues are the rate at which we will proceed and the sacrifices we will make to meet this challenge. Having witnessed the colossal waste of technical manpower that occurred in our country during the Great Depression, I must say that the present period of what some term technical overemployment stands out in very healthy contrast. I feel that the overall evolution of science and technology in the United States will be far more rapid if we have a healthy space program than it will be if we do not, provided we continue to recognize both the good and the bad effects the program may have on our economy and social structure and do what we can to mitigate the latter. The impact of the space program on our universities is one important facet of the problem which merits watching.

If we examine the policies of the various agencies which support science and technology in a way that has a direct effect on the universities, we find considerable variation. Let me review some of the more important examples.

First, there is the National Science Foundation, which is *not* mission-oriented and considers its key role to be that of providing support to universities in most major areas of science and engineering through grants. The National Science Foundation does not play a very direct role in guiding the flow of students into employment, although its indirect influence is enormous.

The National Institutes of Health resembles the National Science Foundation in that it has broad responsibility for supporting research directed toward the improvement of the national health. It differs from the National Science Foundation in that it also operates in-house laboratories, which, interestingly enough, have suffered seriously from losses in personnel to the universities and nonprofit laboratories which are supported by grants from the Institutes. Doubtless the money furnished for research by NIH is having a significant impact on the number of students who choose the life sciences instead of medicine as a profession. Despite the aforementioned losses of personnel in the indispensable in-house laboratories of NIH, there is little doubt that the policies of NIH have done a great deal to bring the country's best minds and talents to bear on the essential problems of public health.

In the years that immediately followed World War II, various agencies of the Department of Defense, particularly the Office of Naval Research, felt called upon to support university research in breadth and depth, on the principle that a healthy intercourse between the universities and the research agencies and facilities of the Department of Defense would benefit both and thereby provide maximum support to the Department's mission. In the intervening years, the Department of Defense has interpreted its mission more and more narrowly, having apparently adopted the general view that day-to-day association with university science was overemphasized in the past, and that the National Science Foundation and NIH are doing enough to maintain a healthy research atmosphere in the universities insofar as the needs of the Department of Defense are concerned. There are a few areas in the Department which have retained the original policies, but they are few and are under growing pressure to reform.

It is still true, I should say, that a very large number of university graduates end up working for Department of Defense contractors or in Department of Defense laboratories and agencies, so the Department inevitably depends to a considerable extent on the health of the universities.

Immediately after its establishment in 1947, the Atomic Energy Commission adopted policies toward the universities somewhat like those the Department of Defense agencies had at the time. That is, the AEC began to support the universities in breadth and depth, recognizing that this policy would in the long run be of mutual benefit. Over the years, the Atomic Energy Commission has not deviated significantly from this policy. Unlike the Department of Defense, the AEC has, on the whole, tended to strengthen and reaffirm its original policy on a broad front. It is true that the contracting procedures of the AEC are rather more complex and cumbersome than those of some of the other agencies. This, however, is a detail, and adjustments can be made in due course.

Since the space agencies, including NASA, are much more mission-oriented than either the National Science Foundation or the National Institutes of Health, I see little reason to expect them to provide the same general type of support to universities that NSF and NIH provide, unless evidence arises to show that certain specialized areas are being grossly neglected. It is clear that more appropriate bases for comparison are provided by the Atomic Energy Commission and by the Department of Defense. It is particularly important that NASA make such a comparison at this time, while it is in the process of establishing its own policies. There are two good reasons for this: (i) the quality of NASA's own effort will depend significantly upon the quality of the product of the universities, and (ii) NASA presumably has a long life ahead of it and may well determine the course of many aspects of science and technology in our country, not the least of which may be the vigor and effectiveness of some aspects of university life.

On the whole, I strongly recommend that NASA consider adopting policies relative to the universities more nearly like the present policies of the Atomic Energy Commission than like those of the Department of Defense. I realize that NASA, unlike the AEC, operates its own in-house laboratories directly instead of depending upon contractors, but this, I feel, is a detail in the larger picture, since the large contract laboratories of the AEC are, in a sense, also in-house laboratories. What strikes me as the most significant consequence of the differences in the policies now followed by the AEC and the Department of Defense is that a very large number of university scientists and engineers have a sense of direct responsibility for the program and welfare of the AEC, whereas the trend is in the opposite direction for the Department of Defense. I find very few scientists or engineers under 40 in universities who feel the sense of close communion with the Department of Defense that my own generation did in the corresponding age period. I believe an important part of this difference stems very directly from the fact that the Atomic Energy Commission has continued to support university research broadly and in depth while remaining well within the framework of its mission, whereas the agencies of the Department of Defense have tended to become more and more selective and restrictive. This gradual withering of the bonds between the Department of Defense and the universities can be justified only if one assumes that the very indirect channels which now exist are adequate. Such an assumption strikes me as being exceedingly dangerous. I think the policy adopted by the Atomic Energy Commission is a far more conservative and reliable one in the long run.

Conclusion

In brief, then, it is my hope that, once this period of organization and adjustment is over and NASA has become established, it will adopt policies resembling those of the Atomic Energy Commission, to the extent that its frame of reference permits. This, I feel, will assure a long and intimate period of communication between NASA and the universities, with optimum benefits to both. I see no reason why the establishment of such a policy should affect the in-house laboratories of NASA adversely. On the contrary, it seems to me that such a relationship will result in the NASA laboratories' obtaining the services of an appropriate number of the most talented graduates of the universities.

News and Comment

Test Ban: Testimony on Technical Aspects To Help Senators Decide if Treaty Is a Boon or a Bane

No issue in foreign policy is more entangled in scientific and technical considerations than that of arms control, and recent progress toward a limited test ban treaty has changed the questions somewhat but by no means eliminated the technological context of debate.

Devising an inspection system which would satisfy both sides was a chief technical difficulty preventing a comprehensive test ban and, when political circumstances altered, this technical Gordian knot was cut by excluding underground tests from the ban. Nuclear devices can be tested in the atmosphere and above it, underwater, and underground, and the last environment has persistently presented the greatest difficulties for detectors. The new test ban treaty simply forbids tests where they can be monitored more successfully.

The treaty is signed, sealed, but not quite delivered, because of the requirement of ratification by the Senate. Full-dress combined hearings before the Senate Foreign Relations and Armed Services committees and Senate members of the Joint Committee on Atomic Energy began Monday, with Secretary of State Dean Rusk, an advocate of ratification, as the first witness. Monday afternoon, the Armed Services preparedness subcommittee, in closed session, heard Edward Teller, an anti-test-ban advocate of long standing. It is clear from the pre-hearing statements of senators and the early testimony that the hearings will cover scientific and