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Space Medicine From the Perspective of Space Geophysics

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I AM INDEED HONORED to be present at the opening ceremonies of this great scientific group—The Aerospace Medical Association—and to be asked to give this Louis H. Bauer Lecture which opens its 34th meeting.

In categorizing aerospace activities, and the ever-present problems that must be solved in the advancement of aerospace capabilities, I tend to think of these four major classes:

1) Engineering of the vehicles including their power and fuel, their control and communications, and the organization of their payload. In this category we must include the engineering research needed to make the vehicle a viable mechanism, and the search in the catalogue of an evolving science for added vehicular capability.
2) Operation of the vehicle from its launching to its landing (or the recovery of its data or payload) involving the total organization of operational procedures, training, safety, and effectiveness for accomplishment of its mission within the known capabilities and limitations of its operational control.
3) The objective of the vehicle, particularly as a tool to explore previously inaccessible aspects of nature. As our aerospace capability has advanced, it has opened, one after another, new vistas of scientific opportunity that have revolutionized major aspects of scientific knowledge. Exploitation of scientific opportunity offered by aerospace capability is a major aspect of aerospace development.
4) Finally, optimum adaptation to the vehicle of the humans that must direct and control it; and, more generally, their adaptation to the space environment. Man evolved in a two dimensional framework tied to the surface of a particular planet—Planet Earth—which offers a relatively narrow range of environments. Aerospace adds a third dimension to man's existence, and with that new dimension, altogether new orders of velocity, acceleration, temperature, and a host of other new ecologic limits. Where before, man's range of adaptation involved no serious limits, our new world of aerospace finds man's adaptive capability as a limiting parameter. Consequently, not only man's gross physiological and psychological response to extreme environments must be understood, but also the detailed response of the biophysical and biochemical elements of man's structure must now be elaborated, since these, taken together, provide his total response. Thus, through a detailed comprehension of the underlying responses of each element of man's organization to extremes of environment, we can hope to perceive means of broadening his adaptive capability.

While aerospace medicine is necessarily concerned with all four of these classes of aerospace problems, aerospace medicine has direct responsibility for development of the fourth category—man's optimum adaptation to the new dimension—space. This is a mighty and a critical responsibility. Here is where aerospace medicine and my own field of geophysics join, for you must have scientific knowledge of the environment, if man's adaptation to it is to be successful.

As a nation, we must be grateful to the leaders of medical, biochemical, biophysical, and biological science generally for their foresight in organizing the Aerospace Medical Association. Through this Association, it has been possible to focus serious attention on the wide range of questions that underly, both macroscopically and microscopically, the major problems of man's successful adaptation to extreme environments. As an obvious consequence, man's adaptability to ex-

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tremes of environment will be steadily enlarged. But beyond this, from the detailed knowledge of the constituent elements of human limitations, must come an inevitable "fallout" of knowledge relating to man's general health, stamina, and longevity. I salute the Association and its members for their clear acceptance of the responsibility for this fourth great class of aerospace problems—the responsibility for the performance of man, himself, in his excursion into the third dimension.

In discussing aerospace problems today, I will turn primarily to the problems of space exploration. This is not to denigrate the problems of aviation—after all as a naval aviator for 37 years, these are very close to my heart. But after all, this is the 34th annual meeting of the Association, so I would suspect that at least the first 25 meetings were devoted almost wholly to problems of aviation. As a consequence, we have seen aviation flourish until it has become an integral part of our lives—the safest and most effective of all forms of transport. Certainly aviation is still far from its ultimate potential in our civilization. Many problems await solution. Yet the basic problems of aviation are now pretty well understood, for aviation has acquired some stability. Its success has set the stage for the next stage—our conquest of space.

Since the problems of space are as yet largely unexplored, and little understood, there is naturally discussion of almost unlimited scope as to how to do the job. What are the real objectives? Are they worth while? Are we spending too much? Or too little? Can we afford these expenditures at the present level? Or at any level? How much can we justify them? Should we race Russia to the Moon? What are the consequences if we don't, or if we lose? Has man any business in space? Couldn't the space job be done cheaper, more effectively, and more safely with scientific instruments alone? Aren't we trying to go too fast? Or too slow? What do we expect to accomplish in space anyway? and so on, and so on.

Well, just what are our real objectives in space? In detail, and nonemotionally, we would classify these into three categories:

a) Scientific
b) Civil applications
c) Military applications.

In the immediate future, certainly the scientific opportunities in space are dominant. This morning we have time to scan these opportunities only superficially, but they are outlined in detail in the report of the Space Science Board of the National Academy of Sciences.* Space offers a wide variety of opportunities to explore nature's secrets in altogether new ways, otherwise quite inaccessible to science.

The Earth, itself, is seen in quite a new light when explored from space. Its shape, its gravitational and magnetic fields, its atmosphere and the meteorology of that atmosphere, its coupling into the interplanetary medium as it courses in its orbit around the Sun—these and many other aspects of Planet Earth are coming into much sharper focus as we advance our eplorations into space. Already we have quite new and much more sophisticated ideas of the organization of the Planet on which we live, and the opportunities for extension of this knowledge through satellite technology are enormous.

"Empty" interplanetary space itself turns out to be filled with all sorts of "crud," traversed with a steady and significant "solar wind" with its associated electric and magnetic fields. The "storms" of the solar chromosphere can be observed both more directly, and through their consequences as they pass through space, from vehicles operating above our insulating atmosphere. Our knoweldge of solar physics and its consequences in interplanetary space is advancing to a new level of comprehension.

Our access to the universe through space telescopes placed above our insulating atmosphere promises a new era in development of the sciences of astronomy and astrophysics. For the first time we can see the universe in its full splendor, from the longest to the shortest wavelengths of light and energy. Without doubt, our knowledge of the organization of the universe and of its matter, is due for an explosion with the advent of large space telescopes. As we explore the universe we are brought close to the problem of the very basic character of the gravitational force that binds it together.

But perhaps the most exciting opportunity is the prospect of direct scientific exploration of the Moon and the planets. Our Earth is the result of only one aspect of planetary evolution. Therefore, the generality of our scientific conclusions is very restricted until we can see other aspects of this physical evolution of the solar system. So we need to study the geology and geophysics of the planetary bodies, their atmospheres, the consequences of their different parameters of size, mass, density, gravitational field, rate of rotation; their atmospheric densities, composition, convection and circulation under these differing basic parameters. Above all we are insatiably curious about the forms of life that may have evolved in significantly different environments, a matter to which I will return in a moment.

Looking back at the six years of our "space era" we cannot but be gratified at the scientific progress already evident, even though the more difficult and really important experiments still lie ahead. But the results of space science in the next seven years, until the end of this decade, should be far more striking, since we are now getting a firm hold on science-in-space. The more important experiments will culminate with increasing rapidity as time goes on. Truly, from the point of view of the scientist, this space age is an exciting age!

Turning from science we come to the civil applications of space. Most obvious are the potentials of space communications. I remind you that at the moment we now are limited to about 150 channels of narrow band communications across the Atlantic. Each channel costs more than a million dollars. With the coming of satellite relay, this number of channels will be increased indefinitely, and at about one-tenth the cost when used to full capacity. Now, naturally, the cost won't drop all at

* See "Science in Space" by Lloyd Viel Berkner and Hugh Odishaw, McGraw-Hill, 1961.

once—it will take a long time to build up world use of this new opportunity to the point of fully utilizing this new communication capacity. Of course, world wide dialing, radio and television of high quality can now be foreseen. But the implications of unlimited long-range communications capacity extend far beyond this—to highly integrated industrial systems in forms we now find it difficult to imagine. After all, the generation of business depends on communications.

Likewise we all know of the promise of the Tiros, and the forthcoming Nimbus satellites, in their impact on meteorological science and forecasting. The whole world can be brought into view, every storm watched from genesis to decay, the variability of the cloud cover measured, and a variety of measures undertaken that improves meteorological work enormously. Perhaps you have heard of the "Reaper" satellite that will collect and relay information from free floating balloons at fixed levels in the atmosphere and floating buoys on the surface of the sea imbedded within the weather everywhere over the Earth. The civil potentialities of these advances in meteorological science and consequent forecasting, climatology, and perhaps even control, are enormous.

Beyond the immediate applications of space devices is the fallout from the new technology of space in the creation of new industry and employment. Space pushes our technology of materials, of fuels, of electronics, of control, of navigation to their very limits. Out of these technological advances related to space are arising a whole series of revolutionary industrial opportunities that are not related to space at all, but which advance the general sophistication of society. As space expands the limits of our technology, the whole community benefits from the consequent technological progress.

In speaking of civil applications, we cannot forget transportation. It is a far cry from Shepherd's first rocket flight to regular high-speed military or civil transport from point to point. Yet the groundwork has been laid, however crudely. The future use of rockets for quick point to point transport now is as certain as we now know scheduled 600 mph air-transport had become after the demonstration at Kitty Hawk. Yet less than fifty years ago, few men had the knowledge, imagination, and courage to predict what is now a major, useful, and reliable industry. (We might also recall parenthetically that many more men at that time, some of them among the so-called "leaders," were free to predict that aviation had no future at all except as a rather foolish and amateurish hobby that sensible men would ignore.) Without question technological problems of regular rocket transport are enormous. But there is no known natural or scientific dictum that stands in the way of transport on an efficient and regular basis. So we can confidently predict that fast rocket transport will come eventually to give us 20-minute trans-Atlantic schedules. As scientists we can predict nothing but failure about any system that violates the laws of nature as we know them. But within these limits, we reserve the right to ignore the gloomy predictions of the ill-informed arising out of their fears of a complex, but scientifically sound future technology.

Finally we turn to military applications in space. Here we see a whole spectrum of potentials—early warning, reconnaissance, surveillance, intelligence, electromagnetic warfare, and interception, inspection and destruction of unfriendly missiles and satellites. Certainly satellites could be used as weapons carriers, though this seems a retrogressive application of the well-known point-to-point rocket techniques. The point is that an enemy can employ space techniques in a variety of ways that are inimical to our national interests. Therefore we must have the military capability not only to duplicate these techniques ourselves but also to police them when employed by an enemy.

Now when we look at this catalogue of scientific, civil, and military potentialities of space, they look pretty impressive. But there is another motivation in space exploration that is so important, it can't be ignored. That is the aspiration of men to reach out to the stars, to accomplish what men have not accomplished before. This is the very deep driving force within man, responsible for his evolution from the animal, an innate force that has caused him to rise to unparalleled social accomplishment. Now in our highly complex society I would readily admit that this primitive motivation, to master the unconquered, arising out of aspiration, can, by auto-suggestion, be brain washed into submergence below the prosaic level of day-to-day responsibilities. Following Monsieur Coué, such men religiously repeat at each opportunity "Day by day, in every way, I am convinced that our effort in space can't amount to anything, and at great cost too!" And after a time they get to believe it.

But the great bulk of the peoples of the world have not yet acquired this particular brand of sophistication. They appreciate and share our aspirations to reach to the stars, and find a satisfying excitement now that this seems almost within reach. This is the primitive instinct that has made man great. I cannot forget a night in the Mid Eastern desert when an Arab grasped my sleeve and pointed excitedly to the sky, exclaming "Look, mister, look—American Sputnik."

Because of this very primitive and deep seated instinct to conquer the unconquered, the space race between the U. S. and the USSR is inevitable. Men everywhere see, in the conquest of space, the peaceful demonstration of the superiority of one of the two competing systems of economic organization—capitalism vs. communism. The conquest of space has become a symbol of the challenge to each system to demonstrate its superiority—to "put up" or shut up! Now you may deplore this situation as foolish, or ungentlemanly, or costly, or unintellectual, but that's the way it is, and you'd better accept it if you want to retain our free system. The Russians recognize it with, 1st Sputnik, 1st hit on the Moon, 1st man in space, 1st photograph of back side of the Moon, 1st try (failed) to reach planets, 1st shot at Mars, and—the heaviest payloads—all spectaculars! (I would add parenthetically, moreover, that it may be better for both sides to shoot some dollars into space than to shoot them at each other!)

So, in addition to the scientific, civil, and military values of space, the conquest of space has, at this time, acquired an enormous political value. The nation that can win and retain space superiority will have won the equivalent of a war in demonstrating the superior viability of his system in the eyes of the world.

Well, say the skeptics, why not accept the space race purely for the political race that it is, and forget all about the science and so on. See how much money you could save! This, I submit, is a most superficial and unrealistic attitude. First of all, exploration of space means, by definition, the scientific exploration of space —the precise measurement and definition of what you have found, and accomplished. I point out that each Russian space spectacular has been accompanied by attempts at real scientific objectives. Without the employment of the most advanced conceivable science as the tool for exploration, the space race would degenerate into an athletic contest—a phony recognizable by all peoples. There is no advantage to winning a "phony-war." The scientific objectives are real and powerful by themselves; but they are also an integral part of the political objectives. Moreover, support of the required space science is only a "drop-in-the-bucket" compared to total costs. Our country saw a closely analogous situation in colonial days, when in the 1760's the race to measure the transit of Venus assumed political importance. Then as now purely scientific objectives were also unavoidably integrated with political objectives. Incidentally, our scientific success, then, gave us no small measure of confidence in our independent capabilities during our quarrel with King George III.

But aside from the importance of the scientific exploration of space both for scientific and political reasons, there is another impelling reason for maintaining space-science at a high level. A straight engineering approach to space exploration will work until you encounter a serious failure arising from natural causes you don't clearly understand. Then you are brought to a shuddering and expensive halt. Common sense dictates that we must extend our scientific understanding of space as far as possible prior to every step. Then the probability of disastrous and unretrievable failure is vastly reduced *for we will understand the space medium with which we deal!*

In balancing these complex policy goals—the scientific, the civil, the military, and the political—our government with its Space Council and Space Agency, acting together with the Congress, proceeded with surprising maturity in formulating our basic space policy in 1961. That policy puts reasonable emphasis on each aspect of the program. That policy recognizes the civil opportunities for deployment of space capability in communications, in meteorology, in navigation, perhaps later in transportation. It comprehends the spur of an advanced technology, essential in creating an advanced educational and industrial posture. It foresees the ultimate return of the space investment in generation of new industry and employment. The policy recognizes that no leading nation can allow its military posture in space to deteriorate, particularly during the contest with communism. The policy recognizes that no space program could hope to achieve its goals successfully without emphasis on science, not only to circumvent failure, but also to make our space goals the real goals of *scientific* exploration. The policy recognizes the imperative need to keep American space-science at the forefront. Above all, that policy realizes that success in space, out of the sum of these elements, represents a recognizable level of technological dexterity from which the world will judge the efficacy of our capabilities. Now particularly, it realizes that should the Soviet Union possess a real and significant advantage in this capability, it might readily be encouraged into irresponsible international adventure perhaps leading to war, out of a false sense of superiority and rash over-confidence engendered from such unique successes in space. Therefore, to prevent unique Soviet success, the contest for every major space objective becomes unavoidable. In annunciating this policy, our government generated certain goals directed toward a properly balanced program. These goals embraced the scientific, civil, military, and political objectives. Among them, and quite properly, was the objective to land a man on the Moon. This was essential, since the Russians had earlier indicated their intention of proceeding vigorously toward this objective, and it was a sound scientific goal.

But in recent months there has been a growing tendency on the part of some to view this as the only goal of our space program. This force to reduce and to warp the original goals, thus degenerating the space program to a mere athletic contest, could be extremely damaging to the whole Western position. Such action would ultimately lead to failure of the program.

As in all great social problems, it is impossible to unravel the complex interrelations between science-in-space, the civil and the military objectives, and the political goals. You cannot say that one is worth this much, another that much, etc., and the sum of given parts should represent the total cost—or the total value. Each part of the package has strong reflections and interactions with the others—so we cannot avoid commitment to the whole package. The only control available to us is the rate at which we can proceed. Our space leaders now say that our budgets are geared to "optimum" rate; that is the rate at which successive essential steps can reasonably and efficiently be taken without risking disastrous failure. The rate is geared to a reasonably rapid test of ideas that can retain the interest of the "first team" of scientists and engineers. The only room for argument is about the application of the word "optimum" to specific programs embraced in our total space effort. Here, as always there is plenty of room for constructive discussion.

The NASA and the DOD have both acted with mature consideration in balancing these policy objectives. Quite clearly, they are endeavoring to maintain the delicate balance between science, engineering, and application, leading to optimum speed and effectiveness toward the political goals. There has been close consultation with the Space Science Board of the National Academy of Sciences on the basic scientific framework that constitutes an effective space program. But a critical danger always lurks in the background that must be matched closely. Since to do a Moon program at all, we must have a vehicle, budget cuts would tend to skin the cream of science off the top. As we have said, this would ultimately deteriorate the program to an athletic contest, and end, either in complete failure for lack of ability to circumvent unforeseen roadblocks, or in failure with respect to both the scientific and the real political goals. So we, as scientists have a responsibility to undertake quite critical analyses of the effects of such budget changes on the ultimate goals. I am sure the Administration and the Congress welcome our assistance in this complex program.

Let me turn then to one final policy matter. Many have said "Why send man on such a dangerous mission?" Wouldn't it be better to use instruments? Can't instruments do everything that men can do, and a lot cheaper? A man in space takes a huge weight in his life support systems—just think what you could do with instruments of the same weight.

Of course, the preliminary surveys *are* planned with scientific instruments to define the frame of reference in a variety of parameters. Out of this knowledge, later and more sophisticated studies will be conceived and conducted. But as we approach these more advanced studies we need means of broad comprehension of which studies will be most productive in a relatively unknown horizon. We need a skilled interpretation of the broad situation from which alternative courses of action can be weighed objectively. If we were to try to design an instrument to exercise this broad comprehension, I suspect it would look surprisingly like a man. And we don't know how to make such an instrument! So we have little alternative at the more sophisticated experimental level but to use man, himself. Again, we see that political and scientific objectives overlap!

But here I would enter one caveat. In its report, last summer's Study Group of the National Academy of Sciences recommended that young, hut highly skilled scientists be included in the program for astronaut training. I believe this to be essential if space exploration is to be deeply scientific and not phony. Failure to do this in my opinion will be a major national "butch," for science is not something that you learn in a few lessons, like flying an airplane! And there is no reason why highly skilled scientists cannot be trained to take their place on the astronaut team.

To do a genuine job, the astronaut team must be a well rounded team including great scientific skills. So we should get on with training some scientist-astronauts without delay. From my reading of the Russians, I am positive they will do so. Our failure to provide the maximum scientific comprehension on the astronaut teams—a comprehension whose critical observations can steer future space science into the really effective channels—would greatly strengthen the argument of those who would do the job with instruments alone.

In looking at our whole space program critically, one cannot but conclude that our nation has approached and undertaken the program with great intelligence. Certainly there are details on which any one of us feels strongly that corrective action is needed.

Here we have the opportunity to be heard, and to have our case weighed. But considering our late start, considering the complexity of the problem and difficult technologies to be mastered, the program has been planned with extraordinary foresight. It seems to me that many of the critics of the program appear unduly harsh, and, I must say singularly uninformed in spite of positions of national leadership. Particularly in scientific circles, broad criticism seems appropriate only after a most thorough study and mastery of the situation. I would hope that in the critical discussion of some of the alternative details of the space program, we do not seem to indict the whole program without considerable knowledge of it.

Before we leave the area of policy, one other comment seems appropriate. We hear it said "Just think of what we could do with 20-billion dollars if it were turned to man's immediate welfare—medical research, housing of the poor, and so on." Thinking men recognize this argument as specious on a number of grounds. The same argument can be used against expenditures for war, or betting on horse racing, or against liquor and chewing gum. More deeply, we live in a dynamic civilization in which some aspects of technology must always lead the others. Failure to press these technological differentials will bring technology to a halt, and our space program is the greatest spur to technology today. Moreover, we cannot ignore the broad technological fall-out that is creating altogether new industry, employment, and broadening the national tax-base. Beyond this, in satisfying man's primitive aspirations to conquer the unconquered, we spur him to greater effort. Only one per cent added effort will pay for the whole space program, and there is no doubt that the program exercises a mighty influence in advancement of both education and industry. The point is that the poverty is far more likely to disappear when men work vigorously under strong motivation.

But enough of policy. Let us turn in conclusion to the exciting prospect of exploration of the Moon and the planets. What will we find when we get there? What will be the environment in which our instruments, or man himself must function? Will we find life—in known forms or in new forms? What experiments are most important? What precautions must be taken?

Geophysicists are now examining into the environmental aspects of the Moon and the planets with real vigor. The accelerated geophysical studies of the Moon and planets undertaken, since our national decision on space exploration in 1961, are beginning to culminate in a variety of scientific discussions. During this month of April I have attended three major scientific meetings packed with critical discussions of the environmental problems of space. Work on the Moon is progressing to the point where we ought to be ready for manned flights by the time technology permits. But the intervening unmanned flights are of the greatest import in settling major environmental problems that can be decided in no other way. Therefore, the scientific unmanned flights immediately ahead should under no circumstances be abandoned.

Looking fifty years ahead it seems likely, indeed probable, that we will have established an advanced expeditionary base on the Moon to acquire a whole series of scientific and exploratory advantages.

The environmental problem of Venus is now raging. There is wide discussion on how the seemingly conflicting evidence is to be interpreted. Is the surface hot or cold, is there water or no water, what is the nature of

Venus' cloud-cover? What is its meteorology, does the planet rotate, does it have a magnetic field, is it viable for life? These questions and a dozen other major questions are now being formulated in terms of critical experiments to be done in the future so that the environmental situation on Venus can be defined. Certainly no thought of a manned expedition to the surface of Venus can be conceived until its environmental situation is far more clearly defined.

Mars is a viable planet, and a most interesting planet for exploration. Its temperature range, and atmospheric conditions seem at this time to make manned exploration eventually possible. Mars seems to have some water vapor but no appreciable oxygen in its atmosphere. It seems to have a meteorology with occasional dust storms, and frost or ice collects at the polar regions during the winter. It may change color somewhat with seasons.

Does Mars have life? The answer is probably yes, but in primitive forms. The spectra of carbohydrate molecules is suspected from its surface. Moreover, we are now reasonably sure that life on the Earth evolved to the level of the organized cell, replete with photosynthesis and respiration before oxygen appeared in our atmosphere. Indeed, for early evolution to this cell level, atmospheric oxygen is forbidden in significant quantities. We know that only after photosynthesis was available in great abundance could oxygen appear in our atmosphere at all.

So the absence of Martian atmospheric oxygen certainly does not forbid Martian life. However, the absence of high oxygen levels seems to tell us that higher forms of life in abundance are improbable at this time. This may well be related to a shortage of water, with its widespread support of photosynthesis which could give Mars an oxygen atmosphere as life evolved more abundantly and to higher forms.

The probability of studying the biophysics and biochemistry of life under an entirely isolated ecological situation is clearly a major scientific opportunity. In their gross aspects we might expect strange organisms, but basically we would expect their elementary organization and structure to be somewhat similar to that found on Earth. This expectation is based on our knowledge that the character of the atoms, themselves, places some critical limitations on the forms of the nucleotides, the enzymes, and the resultant proteins that nature can produce anywhere. But within these limitations, a tremendous range of vital questions can be asked. What are the basic differences in biophysical and biochemical activity? Will new forms of genetic combinations be found? Will unknown amino acids, enzymes, or distinctive proteins be evident? In a radically different ecology, how will natural selection function? Will altogether new trace elements be employed in the synthesis of quite new living products? Will Martian photosynthesis be found in its Earthly prototype, or has nature on Mars found quite new methods of employing sunlight to supply the energy needs of its organisms? Could in this way higher forms of life exist without much water or without producing much oxygen? What will these life forms look like, and how do they compare and differ from those on Earth?

Quite clearly, Martian organisms, evolving in isolation from the Earth, will have no initial or natural resistance to attack from terrestrial organisms. Likewise, in the same way, terrestrial organisms are open to possible attack by the Martian variety. Consequently, you in aerospace medicine have a particularly difficult job of dealing with terrestrial contamination of Mars, and Martian back-contamination on the Earth. This requires that each step in the exploration of Mars be done with the utmost care, advanced planning, and circumspection. Every aspect of the problem of contamination and of back-contamination must be thoroughly examined and debated in advance in the scientific literature. Extensive experimental programs on contamination controls and standards are essential. The immense power offered to science of all time in examining life on Mars must not be destroyed for all time by the careless or impetuous action of the ignorant. Here, advanced and public examination and debate of the problem in the scientific literature is our best defense.

Certainly, the prospect of critically examining life on Mars is the most exciting and potentially profitable vista of space exploration.

But looking beyond, can we visualize visiting other Planets? Certainly Mercury is far too hot, and the crushing force of gravity on Jupiter is unthinkable. But a satellite of Jupiter such as Triton, not much different from our Moon, might be within our ultimate reach. Certainly the exploration of Jupiter or even Saturn may thus ultimately come within the reach of later centuries.

What about the stars? Here, within the limits of our scientific knowledge we can be quite positive. No known source of energy can carry us much beyond the limits of our planetary system, more especially within the life span of a man. Certainly, this life span relative to a terrestrial frame of reference can theoretically be enhanced indefinitely as the space vehicle closely approaches the velocity of light. But we just don't have any source of energy even distantly available to do this! So our study of the universe by space methods at least for the next few centuries, or at least until some entirely new and unanticipated scientific discovery, is forbidden by science, and must depend on the powerful new methods of space astronomy, probably ultimately based on the Moon.

I conclude by joining you in the sense of excitement for the mighty space objectives you have ahead. We have not discussed the difficult physiological problems of adaptation of man to his vehicle. We have not thought of the psychological problems of the necessary ease and reliability of command of the vehicle, or of the confidence that must be engendered in the space explorer if he is to face the most difficult problems of all time without, just plain "going to pieces." We have not discussed the problems of those men as they must go calmly about making critical and reliable observations and recording them in the face of a cruel environment. These, and a hundred others, are your problems. It is to you men of aerospace-medicine that we look for the human adjustments necessary, within the limits of human capability, for our nation to anticipate successful space exploration with reasonable equanimity.