3) The message is read in the correct groups of three by starting at some fixed point.

4) The code sequence in the gene is colinear with the amino acid sequence, the polypeptide chain being synthesized sequentially from the amino end.

5) In general, more than one triplet codes each amino acid.

6) It is possible that some triplets may code more than one amino acid—that is, they may be ambiguous.

7) Triplets which code the same amino acid are probably rather similar.

8) It is not known whether there is any general rule in accordance with which such codons are grouped together, or whether the grouping is mainly the result of historical accident.

9) The number of triplets which do not code an amino acid is probably small.

10) Certain codes proposed earlier—such as comma-less codes, two- or three-letter codes, the combination code, and various transposable codes—are all unlikely to be correct.

11) The code is probably much the same in different organisms. It may be the same in all organisms, but this is not yet known.

Finally, one should add that in spite of the great complexity of protein synthesis and in spite of the considerable technical difficulties in synthesizing polynucleotides with defined sequences, it is not unreasonable to hope that all these points will be clarified in the near future, and that the genetic code will be completely established on a sound experimental basis within the next few years.

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Space Science

The future holds exciting possibilities for scientific research by man in space.

Homer E. Newell

Today, as never before, our world is conscious of its position in space. Rockets, satellites, and deep space probes are demanding the attention of the thoughtful citizen, as these devices play their role in the greatest adventure of mankind, that of reaching out into space, beyond man's traditional home.

A major, indeed inseparable, part of this activity is what has come to be known as space science. The range of this scientific activity is extremely broad, encompassing the earth, the moon, the sun, the planets, the stars, the galaxies, and the vast intervening spaces. Although space science focuses on those researches and investigations that are carried out in rockets, satellites, and deep space probes, it is, as every scientist recognizes, absolutely inseparable from the rest of scientific activity. Thus, as we look back into the past, we find the roots of the present program of science in space in the ground-based investigations of the very same subjects that now comprise space science.

In other words, space science is not a new subject. The objects of interest and investigation are the same as they always have been. The new elements in space science are the spacecraft, with its scientific instruments, and the rocket that launches the spacecraft to its vantage point far above the ground.

Past

Space science has a past that is as illustrious as its present is exciting and its future is promising. One need only point to the tremendous accomplishments of ground-based astronomy to prove this point. Throughout most of its history, astronomy has been limited to the very narrow range of wavelengths in the visible portion of the spectrum, plus small extensions into the ultraviolet and the infrared. The addition of a portion of the radio wavelength spectrum to ground-based observation was a recent event in astronomical history. Yet in spite of these limitations, which theory indicates to be very great indeed, a remarkable body of astronomical knowledge and theory has been built on the knowledge that has been obtained from ground-based observations.

Closer to home, but still inaccessible to the observer, the earth's upper atmosphere also received the attention of the ground-based scientist. Supported by observations of meteor trails, aurora, and airglow, by reflections of sound waves, by radio echoes, and by theory, the upper-atmosphere researcher did good detective work. Subsequent direct measurements by sounding rockets showed that the investigators were indeed on the right track. They were,

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however, hampered by the very wide range of chemical and ionic species and processes that could be assumed to occur in the upper atmosphere and ionosphere. Only direct measurements could reduce the possibilities to manageable proportions.

As for interplanetary space, the ground-based researcher had no way to make observations of these regions. Extensions of the solar corona, the zodiacal light, and the Gegenschein provided only faint clues to the population of these vast spaces. With considerable ingenuity, the cosmic-ray physicist attempted to use the cosmic rays as one means of learning about magnetic fields in interplanetary space. But without some new approach the task of studying the interplanetary medium was exceedingly difficult if not insuperable.

The much needed boost in these fields was provided by the research rocket, at first in the form of a sounding rocket. With the advent of this powerful research tool, rapid strides were made in a number of directions.

Prior to the era of the artificial earth satellite, the principal advances made in high-altitude rocket research were in the investigation of the earth's atmosphere up to a few hundred kilometers. In the course of a decade a tremendous body of new information was acquired on the structure and composition of the high atmosphere and the geographical and temporal variations in this structure and composition. In the ionosphere, the electron content was measured, and ionic species and photochemical and ionization processes were identified. Their distribution with height and geographic position and their variation with time of day and season were determined. Data on the aurora and altitudes and intensity distributions for various wavelengths in the airglow were obtained. Upper-air winds and their seasonal variations were measured.

Cosmic rays were among the first objects to be investigated by means of sounding rockets. Although the time of flight of the rocket was a matter of minutes, and thus statistical samplings were poor, nevertheless a considerable advance was made in determining the cosmic ray flux above the atmosphere, in obtaining additional data on composition, and in supplementing the very extensive work already being done by means of balloons. It was in the course of such cosmic ray investigations that Van Allen observed very high counting rates in the auroral regions; from this he was led to the discovery of the Van Allen radiation belt through instruments placed in the early IGY satellites.

In spite of its limited flight time, the moderate-altitude sounding rocket made possible important advances in the investigation of the solar spectrum. The spectrum of the sun was observed and photographed in the ultraviolet. Solar x-rays were measured, as was their variation with solar activity. The altitudes at which the solar ultraviolet and x-ray wavelengths were absorbed in the earth's atmosphere were determined. From values for solar intensities measured above the atmosphere it was possible to make small corrections in the evaluation of the solar constant.

Even the stars were observed by means of sounding-rocket instruments. Pioneering work by the Naval Research Laboratory revealed hitherto unobservable ultraviolet sources in the sky. These exciting discoveries were pursued with vigor, but the very limited observing time afforded by the sounding-rocket flight imposed a limitation on the ability of the researcher to exploit the opportunities to observe the sky in the ultraviolet wavelengths. The need for extended observing periods turned attention to the promising capability of the artificial satellites that had come into being during the International Geophysical Year.

Present

Space science is now in an era of unmanned rockets, satellites, and deep space probes. The sounding rocket remains, and will continue to be, the most effective of these tools for investigating that region of the earth's atmosphere that lies between balloon altitudes and the heights at which satellites orbit the earth. A big brother of the sounding rocket, called the geoprobe, is used for sorties out into the earth's magnetosphere and will undoubtedly long continue to be used for special experiments and for preliminary checks on satellite and deep-space-probe experiments. But it is the artificial satellite that removes the severe limitation on observing time that exists with the sounding rocket and the geoprobe. The artificial satellite makes possible observations of a global character extending over long periods and reaching out to lunar distances. The deep space probes enable man, for the first time in history, to establish contact with the moon and planets, as did Mariner II in its recent close-at-hand observations of the planet Venus. Gains are being made all along the space frontier, in geophysics, astronomy, and interplanetary physics.

Geophysics. At the turn of the century it was supposed that the upper atmosphere was very quiet and undisturbed. Only those few individuals who were experimenting on, and theorizing about, these regions of the atmosphere knew that this was not so. Several decades ago this picture of the upper atmosphere began to give way. Sounding rockets have played a significant role in determining the true state of affairs. The most recent investigations have been by means of grenade explosions at high altitudes and observation of sodium vapor clouds ejected from sounding rockets (*1*). Strong turbulence is usually found in the region below 105 kilometers. Wind shears—that is, regions in which winds of different velocities and directions are found very close together—appear in the altitude range of 100 to 107 kilometers. These wind shears sometimes exhibit a change in wind speed of 220 kilometers per hour with change in altitude of less than 1 kilometer.

Early wind measurements made with sounding rockets revealed that the winds of the upper atmosphere follow a seasonal pattern. For example, in the latitude of Fort Churchill, Manitoba, winds are strong and from the west in the winter and considerably weaker and from the east in the summer. There are similar seasonal variations at the latitudes of The White Sands Proving Grounds and Cape Canaveral. The most recent results also indicate that daily systematic changes are superimposed on such seasonal patterns. For the region from 80 to 130 kilometers, enough data are accumulating to permit the hope that it will one day be possible to predict these winds on a seasonal basis, in much the same way that jet streams are now predicted for the lower atmosphere.

For a long time it was not possible to determine at what height the composition of the atmosphere changed significantly from that found at sea level, if it did change. There were good theoretical reasons for expecting changes to occur in and above the E region of the ionosphere, but the wide range of possibilities made it impossible to determine the actual state of affairs. Now, with data from rocket and satellite measurements, particularly those obtained by Bourdeau and his colleagues (*2*) of the Goddard Space Flight Center and by Hale and Hanson (*3*) of Lockheed

Missiles and Space Company, it is possible to represent the major properties of the upper atmosphere, as shown in Fig. 1 (*4*). Up to about 120 kilometers the atmosphere has a composition basically that at sea level, consisting principally of nitrogen and oxygen molecules. Between 120 and 1000 kilometers, atomic oxygen becomes the predominant constituent. Above 1000 kilometers there is a layer in which helium predominates, and above that, a region in which hydrogen is the principal constituent.

The density curve corresponding to this distribution of atmospheric gases corresponds to an average temperature in the upper atmosphere of 1350°K (Fig. 2) (*5*). There is, however, a diurnal variation in temperature. For the 1959 time period this variation runs from about 1800°K in mid-afternoon to about 1000°K in the hours just before dawn. Moreover, all three of these values have been shown by Priester to have a definite correlation with solar activity. For example, Priester predicts that at the low point of the present solar cycle, in 1964, the predawn temperatures in the upper atmosphere will be 500°K, as compared to almost 1500°K for times near the solar maximum.

The decline in atmospheric density with altitude is exponential. As a consequence, at 1000 kilometers the density has fallen to a value comparable to the density of the interplanetary medium. One would, therefore, normally expect the limits of the earth's atmosphere to appear at about this altitude. That this is not the case is due to the fact that the earth has a magnetic field which, as Van Allen discovered early in 1958, traps electrons and protons to form the radiation belts.

These trapped particles constitute an extension of the earth's atmosphere to form what is now known as the magnetosphere.

Figure 3 shows the form that the magnetosphere would take if the dipole component of the earth's magnetic field were not subject to external influences. However, as shown by measurements made in Explorer X and in later Explorer satellites, the earth's magnetosphere does not have the perfectly symmetrical shape that is shown in Fig. 3. Instead, it is distorted, much as shown in Fig. 4.

This is the shape that one would expect the earth's magnetosphere to assume if it were being subjected to a solar wind of charged particles. Such a solar-plasma wind would compress the magnetosphere on the side toward the sun, while blowing it out on the side away from the sun. The existence of this solar wind was confirmed by observations made by the Mariner II spacecraft.

We are all aware that man has altered the natural environment in the earth's magnetosphere with high-altitude nuclear tests. The high-altitude nuclear explosion Starfish produced an artificial belt that increased the radiation levels in the magnetosphere during July 1962. Measurements made from the satellites Ariel, Telstar, and TRAAC permitted construction of the flux chart shown in Fig. 5.

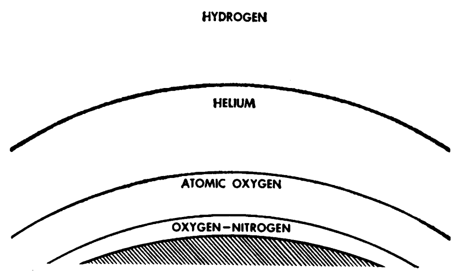

Fig. 1. Composition of the atmosphere.

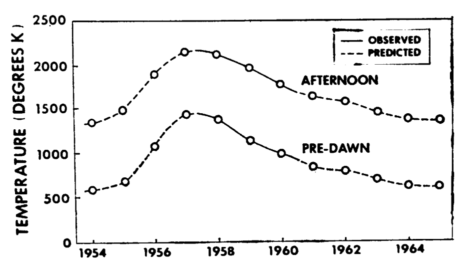

Fig. 2. Variations in temperature of the upper atmosphere during the sunspot cycle.

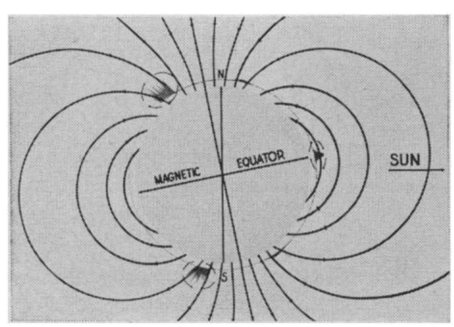

Fig. 3. Schematic drawing of the earth's magnetic field as it would be if the magnetosphere were not distorted by external influences.

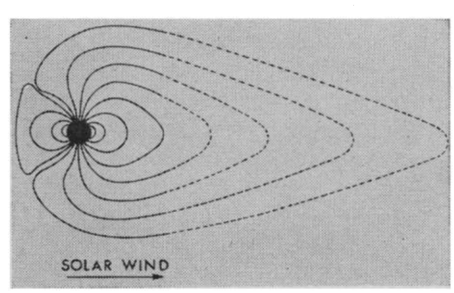

Fig. 4. The shape of the magnetosphere as distorted by a solar wind of charged particles.

Some controversy exists concerning the flux levels at great distances from the earth (distances greater than 2 R_E). Data obtained by Injun I and observations made more recently by Explorers XIV and XV suggest a smaller radiation belt, as shown in Fig. 6. The decay of the radiation belt is being monitored by several NASA satellites. Data not yet published give evidence of additional artificial belts created near two earth radii in October 1962. Presumably, these belts were caused by a nuclear test conducted by the U.S.S.R.

Astronomy. In a sounding-rocket experiment performed by Stecher and Milligan of the Goddard Space Flight Center (*6*), an Aerobee rocket was flown with instruments aboard to obtain stellar spectra in the ultraviolet wavelength region. A number of stars of different spectral types were observed at wavelengths from 1600 to 4000 angstroms. Observational results and expected intensities in the ultraviolet for a star comparable to the sun showed satisfactory agreement. Also, agreement was good for earlier, hot stars down to wavelengths of about 2600 angstrom units. Below 2400 angstrom units, however, for the hotter stars there arises a fundamental disagreement between observations and theory. This disagreement is very clearly shown in Fig. 7.

The Orbiting Solar Observatory I demonstrated effectively the power of the satellite as an astronomical research tool. Figures 8 and 9 are schematic illustrations of spectral data from the satellite; Fig. 9 shows changes in the solar ultraviolet spectrum associated with solar activity (*7*). For the astronomer and the solar physicist, the data from Orbiting Solar Observatory I provide a tremendous amount of information (*8*).

Some of the results obtained from the flight of Mariner and its 14 December passage by the planet Venus (*9*) may be summarized as follows.

1) *Interplanetary.*

There is always a solar wind. The wind is steady for long periods of time. It does, however, fluctuate appreciably from time to time (*10*).

The transverse magnetic field—that

is, the field component normal to the direction to the sun—lies typically between 3 and 5 gamma. Both the transverse and the radial fields fluctuate at times by factors of 5 to 10. The absolute value of the radial field is not yet known. There is some evidence of a 27-day periodicity in the radial field, suggestive of a correlation with solar rotation. The direction of the transverse field is hard to determine; it has been observed to swing through almost 360° in relatively short periods (*11*).

Cosmic dust has a flux that is lower, by several orders of magnitude, in interplanetary space than near the earth (*12*).

2) *Planetary.*

All the instruments functioned as the spacecraft passed the planet, but reduced and interpreted data are not yet available for many of the measurements. The magnetic field showed no rise to within 5 gamma, the sensitivity of the magnetometer at that time. With certain assumptions, Coleman and his co-workers conclude that the source strength of Venus's dipole field is less than 5 to 10 percent that of the earth's. A weak field at 21,000 miles from Venus could have been obscured by the solar wind.

Interplanetary physics. The remarkable terrestrial effects associated with solar activity, particularly solar flares, lead to the conclusion that the medium of interplanetary space must be constantly stirred and churned by solar particles and fields. This conclusion was supported by observations from Pioneer V and Explorer X, and recently by measurements from Mariner II.

Data such as these are being fitted together by the theorists to form the picture of activity in interplanetary space shown schematically in Fig. 10.

The more or less steady solar wind that constantly blows through interplanetary space is greatly modified by solar storms. When a flare is at the right position on the sun's surface, clouds of charged particles are ejected in a direction such that they reach the earth and interact with its atmosphere. The energy carried by these particles averages less than $1/10^6$ that of the sun's visible light, but among its effects are communication blackouts and disturbances, magnetic storms, auroral displays, and violent changes in the intensity of the Van Allen radiation. Under normal conditions, it appears, the interplanetary space consists of extremely slow moving electrons and protons at low concentrations, perhaps five per cubic centimeter, and a still smaller number of energetic cosmic rays, normally at a concentration of less than one such energetic particle per cubic meter. When the solar flare occurs, a tongue of plasma, or relatively slow moving charged particles, erupts from the surface of the sun and moves across interplanetary space at a speed of about 1600 kilometers per second. At this rate the plasma cloud reaches the earth in about one day. It drags with it the lines of solar magnetic force, which are frozen into the cloud and forced to move with it, in accordance with the laws of Maxwell. The lines of magnetic force have their roots on the surface of the sun in the vicinity of the flare, but as the plasma tongue moves out they are drawn out with it. As the magnetic lines of force become distended they lose their strength, and by the time they reach the earth they are some 500 times weaker than they were at the surface of the sun. However, the magnetic field

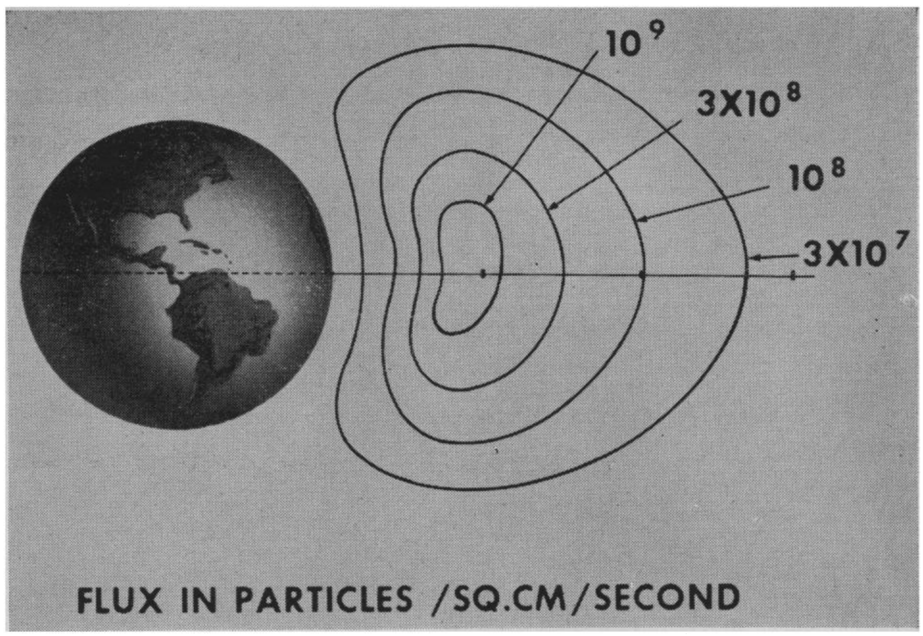

Fig. 5. Artificial radiation belt produced by the high-altitude nuclear explosion Starfish, in July 1962, as estimated by Hess and Nakada, 16 July 1962.

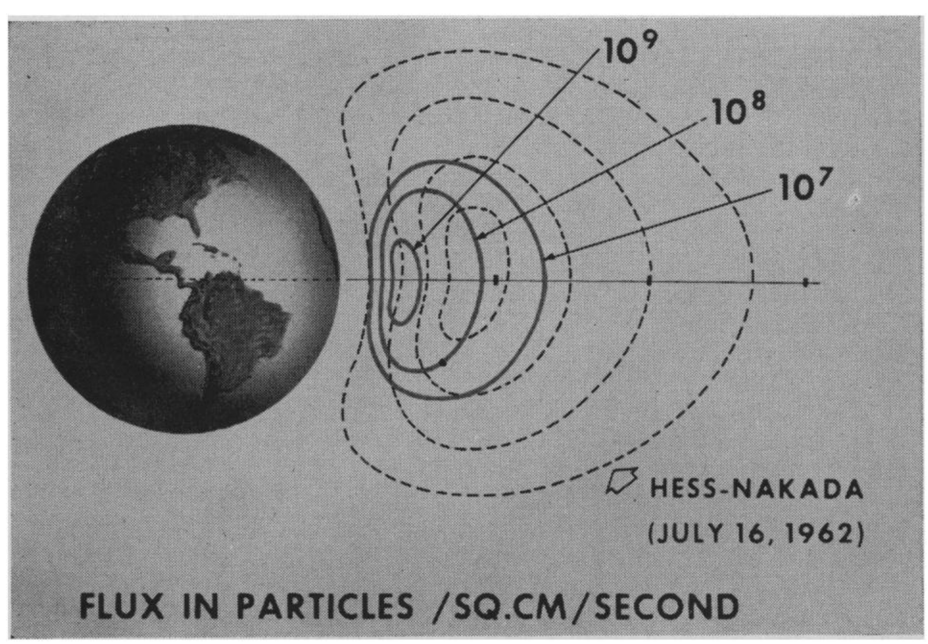

Fig. 6. Artificial radiation belt produced by the high-altitude nuclear explosion Starfish, in July 1962, as estimated (solid lines) from observations by Injun I, Explorer XIV, and Explorer XV, compared with the radiation belt as estimated (dashed lines) by Hess and Nakada.

within the plasma tongue is still sufficiently strong to screen the earth partially from the cosmic rays which normally bombard it; this explains the decrease in the cosmic ray intensity during magnetic storms, known as the Forbush decrease.

Also, when the earth is enveloped in a tongue of solar plasma (Fig. 10), solar protons have a direct channel to the earth. Because streams of energetic protons would be a hazard to the crews of lunar spacecraft, the periods during which the earth is enveloped by a solar plasma tongue are a matter of serious concern in the man-in-space program.

Manned space flight. At present the U.S. manned space flight program is primarily an engineering endeavor. It is, however, laying the groundwork for future activities in space. One of the most important of these will be manned scientific exploration of the solar system.

Future

I turn now to what I believe is the truly new frontier of space science: man himself making scientific studies in space. It has been decided that the United States will press forward vigorously with a manned flight program, with the objective of placing a U.S. astronaut on the moon within this decade. Thousands of people are now working with determination to accomplish this.

It is important, therefore, to consider carefully what man will do out there in space. It is especially important for the scientific community to give serious and careful thought to this question. There are tremendous scientific opportunities to be seized by the man in space.

At this stage, the scientific community has an opportunity to help decide what man will do in space and, in particular, what he will do when he gets to the moon. If the scientific community does not give this matter its attention, and does not proffer its suggestions and advice, its views will be missed. But this will not bring things to a halt. Someone else will make the scientific decisions.

Let us review some of the possibilities for man in space that are even now apparent.

Scientific exploration. It is clear that the very first thing man will do in space, on the moon, and on the planets, will be to explore. Whether systematized or not, whether planned or incidental, every look he takes—every glance—will be exploration. And if he is an accurate observer, all of it will be science. Each bit of information, each observation, each mention of a new phenomenon or object, will be seized upon avidly by the scientific community. After this initial scientific exploration, specific investigations, based on the first-look results, will be designed and carried out. Later there will be many practical applications, both civilian and military, of the new space knowledge and technology, and of man's ability to move about in space.

Man in orbit. Man in orbit acquires a new perspective for viewing the earth. Small beginnings in the area of scientific observation from orbit have been made by the Mercury pilots. As confidence and ability develop, the man in an earth-orbiting satellite will be able to devote more and more attention to observing weather patterns, the airglow, the aurora, the zodiacal light, the Gegenschein, the sun's corona, and other astronomical phenomena.

At some time in the development of the space program it will be important to send scientists aloft to do their own observing. It is important, therefore, that the scientific community begin to consider carefully not only what scientific tasks are to be done in orbit but also how they are to be done, and by whom. If scientists themselves are to go into orbit they must receive appropriate training for survival and for performing their duties as members of the spacecraft crew, as well as for carrying out their scientific investigations under the unusual conditions of space and space flight. At some appropriate time such scientists must be introduced into the NASA astronaut training program.

So far, more thought seems to have gone into the question of research a man might do on the moon than into that of research he might do in a satellite orbiting the earth. This is due in part to President Kennedy's commitment of the nation to the landing of a man on the moon within this decade. It is due in part to the fact that the moon is clearly an explorable body in the same sense that the earth is. One can easily see, in the mind's eye, men walking around, looking, poking here and there in search of interesting and important finds, picking up specimens for later study in the laboratory, taking pictures, making field tests, drilling holes, implanting instruments and automatic observing stations, and in general doing the many things that a geophysicist might do on earth. It is also due in

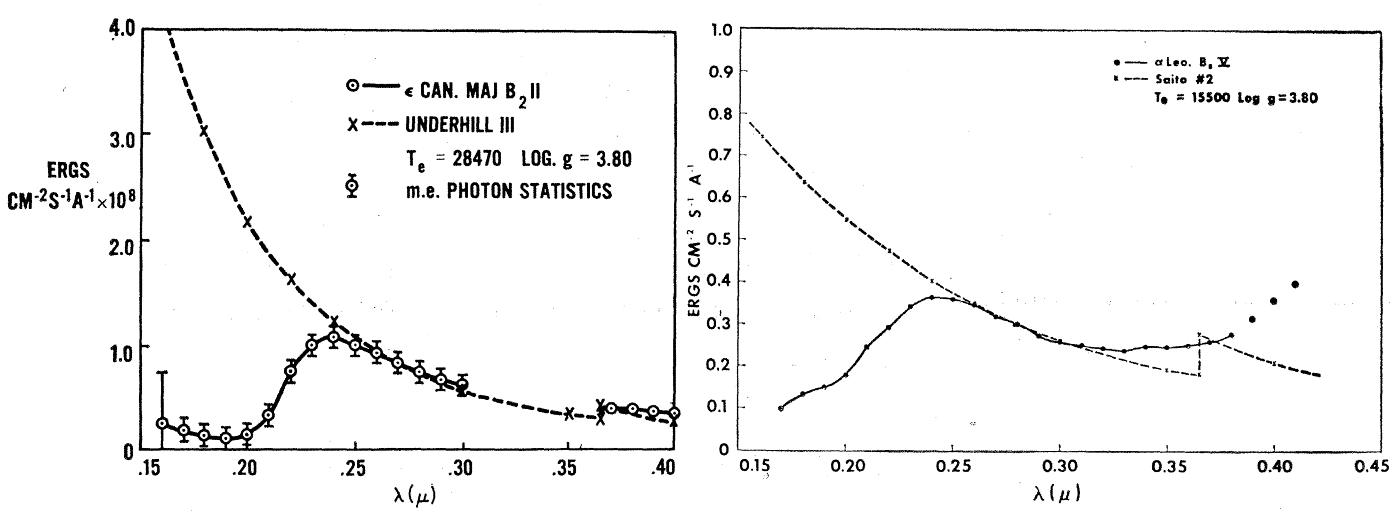

Fig. 7. Plots of spectral data in the ultraviolet region, obtained from Aerobee rocket flights, for Epsilon Canis Majoris (left) and Alpha Leonis (right), showing disagreement between observational results (solid lines) and predicted results (dashed lines) at wavelengths below 2400 angstroms. [Stecher and Milligan (6)]

part to the fact that many of the questions of current scientific interest concerning the earth and its atmosphere, the sun, and other astronomical matters are already being attacked with vigor and promise by means of unmanned satellites and probes.

But a number of valuable scientific observations to be made by a scientist in orbit are already visualized, and it behooves the scientific community to pursue the subject with vigor. I mentioned earlier some of the geophysical and astronomical observations that a man in a satellite might make. In addition, man himself, in orbit, is an important subject of scientific study. Indeed, when large manned laboratories can be put into orbit there will be opportunity to conduct, under conditions of careful control and of close personal attention, biological experiments on the effects of weightlessness and on radiation, new periodicities, and other conditions strange to terrestrial life. In such a laboratory, fundamental and applied research on closed ecological systems would be carried out under the very conditions under which the systems would be required to operate. Systems to be used on manned planetary missions will have to operate for years without failure. In an orbiting laboratory such a system could be given a life test that would be fully meaningful and in which one could place some confidence.

When man has learned to move about freely in space, especially when he is able to move around outside of the spacecraft or space station that serves as his home base in space, there will be many activities that he can pursue. One of these will be engineering and construction in space.

One can foresee the need to assemble large laboratories, huge antenna systems, stations to serve as staging areas for interplanetary flight, and even space vehicles for making flights to the planets and into deep space.

It may be necessary to form the reflecting surfaces for astronomical telescopes under the conditions of weightlessness under which they are to operate, so as to eliminate distortions that would be introduced by forming them on the ground under a gravitational force of 1g and then launching them into orbit.

In view of the tremendous cost of constructing the huge observatories and laboratories of the future, it may well prove to be far cheaper to provide human maintenance and repair crews in space than to rebuild and launch a

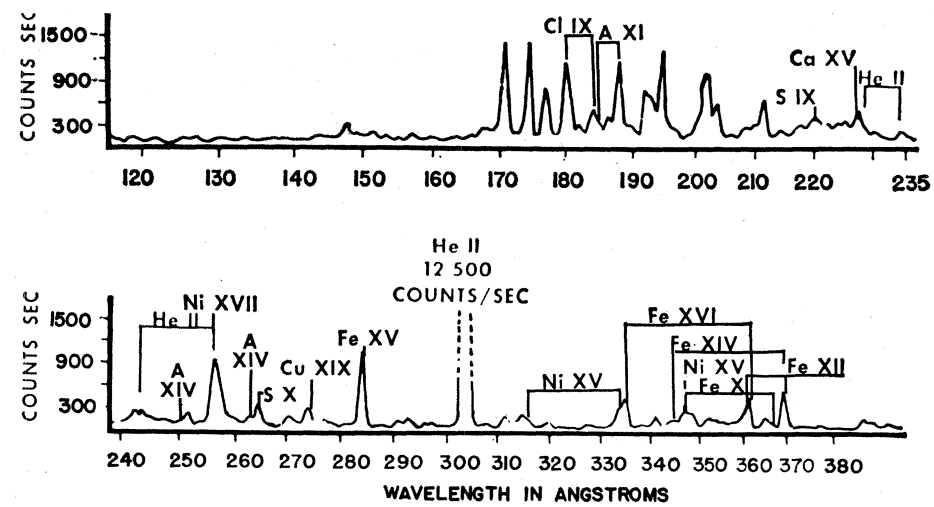

Fig. 8. Solar spectrum and possible resonance lines of ionized atoms. [J. Lindsay]

new satellite every time an old one has ceased to function. In fact, in many cases it may not be just a matter of maintenance and repair. By replacing instruments in an orbiting observatory it may be possible to update, at relatively low cost, a basically expensive facility.

The ability to engineer, inspect, build, maintain, renovate, and carry out complex logistics operations in space will also have military value. In time, engineering in space will constitute an important segment of manned operations in space for military purposes.

Man on the moon. We know that the solar system was formed about 4.5 billion years ago, but we do not know how it was formed. The investigation of its origin is a project of the greatest

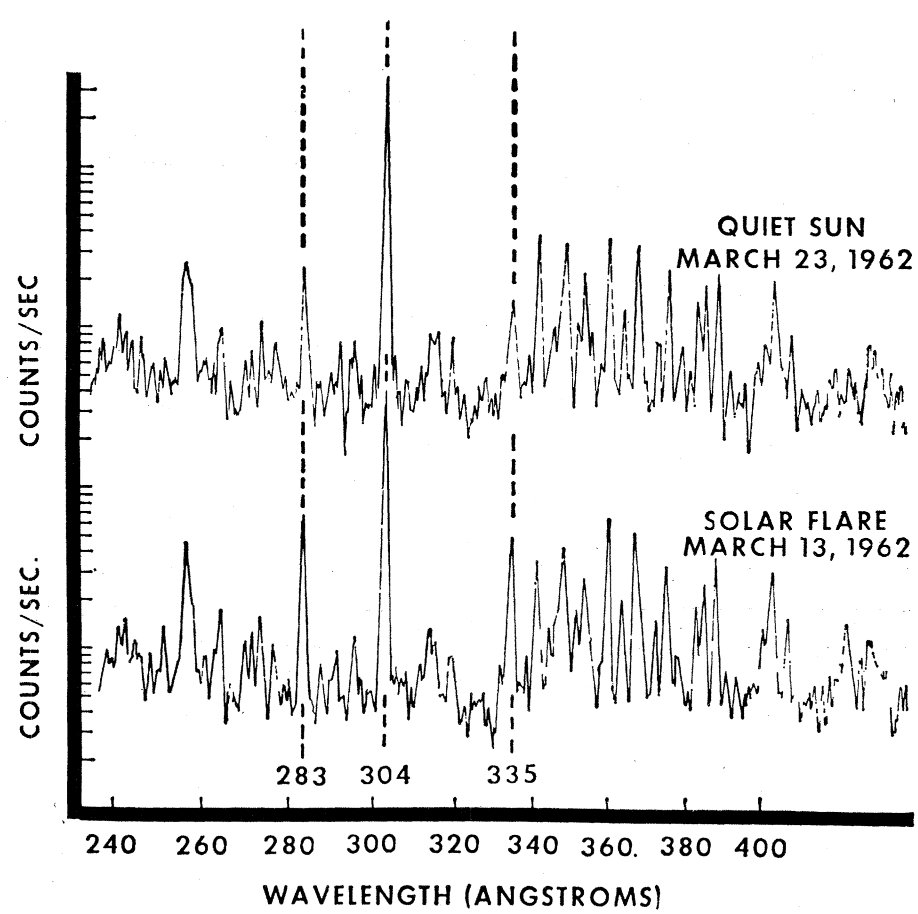

Fig. 9. Variations in the solar spectrum in the extreme ultraviolet. [J. Lindsay]

scientific interest, one to which the exploration of the moon can contribute significantly. The moon will play a special role because it is a body whose surface has preserved the record of its history for a much longer period than the surface of the earth, and probably the surfaces of Mars and Venus, have preserved the records of theirs. On the earth, the atmosphere and the oceans wear away surface features in 10 to 50 million years. Mountain-building activity turns over large areas of the surface in about the same time. There is little left on the surface of the earth of the features that existed several hundred million years ago. But the moon has no oceans and very little atmosphere to destroy the surface. Also, the moon's surface, through a telescope, shows few signs of the mountain-building activity which distorts and defaces the surface of the earth.

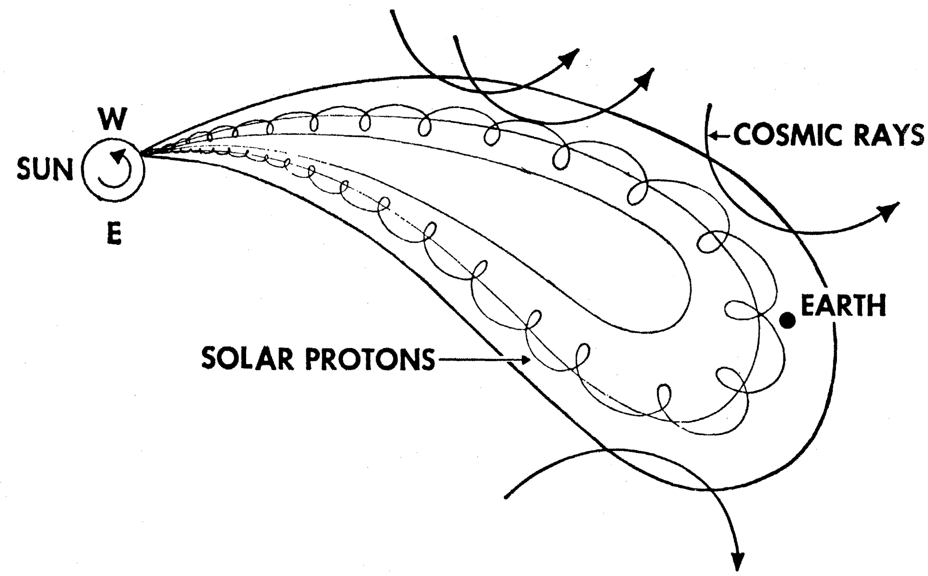

Fig. 10. Propagation of solar disturbances from the sun to the earth (After-Forbush decrease). [Jastrow (*4*)]

Thus, the moon's surface will carry us back very far into the early history of the solar system, perhaps not back to the birth of the sun and planets, but certainly billions of years back—much farther back than the 10 to 50 million years to which we are limited on the earth.

Not only the surface but also the internal structure of the moon may provide a clue to the early history of the solar system and the birth of the planets.

One of the theories concerning the creation of the planets, popular until recent times, held that the solar system was created during a near-collision between our sun and another star, in which the gravitational forces between these two massive bodies tore huge streams of flaming gas out of each. As the intruding star receded, the masses of gas which happened to be near the sun were captured by it into orbits in which they eventually cooled and solidified to form the planets. If the solar system was in fact formed in this way, then the moon and planets must have been molten at an earlier stage in their histories. In that event, the iron in their interiors would have melted and run to the center to form a dense core.

Another theory holds that the planets were formed out of pockets of condensation in the dust surrounding our sun during the early stages of its existence. We know that stars themselves are almost certainly formed in this way, by condensation of pockets of interstellar gas and dust which happened to be somewhat denser than their surroundings. It seems likely that additional subcondensations could have developed in the tenuous matter surrounding the sun before the central condensation had proceeded to its final stages, and that the moon and planets were eventually formed from these subcondensations.

Large bodies like the earth have enough radioactive uranium inside them to produce melting of iron simply through the heat generated in nuclear decays. Therefore, the existence of a dense core of iron in the interior of the earth does not prove the validity of the collision theory, or disprove the theory of condensation. However, the moon is smaller and colder and will provide a much better indication than the earth as to which of the two theories on the origin of the solar system is correct.

Obviously, the necessary observations and measurements cannot all be made just through man's standing on the moon and looking around. But a giant step will have been taken when the first scientist on the moon does look around, begins to see which are the most likely answers, and determines the most promising courses to follow. Before that time some data will have been obtained by means of unmanned spacecraft, Rangers and Surveyors, but the full power of the lunar science effort will not be brought to bear until man and instrument together tackle the problems to be solved.

This subject was discussed at length at the Space Science Summer Study conducted by the National Academy of Sciences at the State University of Iowa, under NASA sponsorship in the summer of 1962. Most of the participants felt that the first scientist-astronaut to be landed on the moon should be a geologist. His first job should be to look—and think. There was considerable discussion about the qualifications of this first scientist on the moon. It took a Darwin, it was pointed out, to make the voyage of the Beagle the historic success that it was. One might say that the difference between sending a run-of-the-mill scientist, or a nonscientist given special supplementary training in science, to the moon to look around and sending a Darwin there is a difference of many, many orders of magnitude in the returns to be realized from the venture. Of course, the problem is to find a Darwin who is able, and willing, to become an astronaut.

How man will pursue scientific investigation on the moon is a question worthy of much thought. One approach is that already mentioned—to send scientists to the moon. Another is that of training the astronauts to look for anticipated objects and phenomena and to see and accurately report the unanticipated ones. Still a third approach might be to have an astronaut-scientist team, in which the astronaut on the moon is linked with the scientist on the earth by radio and television. In two-way conversation the astronaut receives guidance from the scientist, who sees through the television what the astronaut sees. By questioning the astronaut, the scientist can get additional details about objects that appear to be of special significance.

At any rate, the scientific observer on the moon will have plenty to keep him busy. First, he will examine the surface, note the various geologic formations, select samples to bring back to earth, and take pictures. Eventually (probably on a later trip) he will make measurements of surface properties, radioactivity, temperature and heat flow, seismic activity, and so on, with instruments that he has brought with him. At some point he will begin to use the moon as a base for a variety of observations, some of them not necessarily of the moon itself. Studies of the librations of the moon can provide a great deal of information about its internal structure. Other astronomical investigations may well concern the sun and stars. The far side of the moon would be an ideal site for a radio-astronomy observatory. Also, observations of the earth from the moon, particularly of atmospheric phenomena, might be of great value.

At first, such observations from the moon may well be made with automatic or semiautomatic equipment placed on the moon by the men who go there, supplementing observatories landed by unmanned spacecraft. Eventually, however, manned bases, including scientific observations, will probably be established.

When man does build on the moon he will do so under conditions very different from those on earth. Gravity will be only one-sixth the value on earth, while the lack of an atmosphere, bombardment by meteoritic particles, the constant interplanetary radiations, the tremendous range of temperatures, dust that may be more than just a nuisance, and unusual conditions of electrostatic charging will confront him with problems that will tax his ingenuity and skill to the utmost.

When manned lunar bases or observatories go into operation it will be necessary to maintain supply lines. The required logistics and operational support will make an antarctic expedition look like a grade-school exercise by comparison.

All of this will require, of course, an adequate scheme for protecting the men involved from the radiations of space.

Interplanetary space. Much of the investigation of interplanetary space will doubtless be done best by instrumented space probes. Nevertheless, man, as he traverses space on his way to the moon or the planets, will have an opportunity to search for the unexpected. Most of his observational opportunities will be in the area of astronomy. The zodiacal light, the Gegenschein, the sun's corona, the atmospheres of the planets, the bodies of the solar system—all will come under new scrutiny. In addition, man will make observations on himself under conditions of isolation not producible in any other fashion.

Man on the planets. The experience gained in manned exploration of the moon will serve as a basis for undertaking the manned exploration of the planets. There will be different considerations—the much greater distances that must be traversed, the longer times that man must spend in the lonely voids of space, and the existence of atmospheres around the planets.

Certainly one of the most exciting possibilities in space exploration is the possibility that indigenous life may be found on some other planet. The most likely candidate is Mars; balloon observations in the infrared have detected emissions from Mars characteristic of the carbon-hydrogen bond.

When man reaches out toward the planets, who can say where it will all end? Manned bases, manned observatories, landings on the satellites of planets (such as satellites of Jupiter or Saturn), and unmanned orbiting observatories about the various planets are in the realm of possibilities for the far distant future. At present all such thoughts are in the nature of speculation. But, in view of the formidable manned space flight program that we have undertaken, such speculation can ultimately be useful. Properly controlled and guided, it can lead to the development of the ideas essential for progress.

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