*Keynote Address**

DR. S. FRED SINGER
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INTRODUCTION

G. C. TEWINKEL, *Past President, ASP*

Our Convention is honored this year in having as its guest speaker Dr. S. Fred Singer, Professor of Physics, University of Maryland.

I find that his work has been associated with such nebulous topics as: The Upper Atmosphere; High Altitude Sounding Rockets; Geophysical Research with Artificial Satellites; Primary Cosmic Rays and their Origin; Environment in Space Vehicles; Orbits of Rockets and Space Vehicles; Theory of Relativity; Origin of Meteorites; Ionospheric Currents; Magnetic Storms and Aurora; and Radiation Belts.

Dr. Singer has earned for himself distinction as one of the most brilliant of our space scientists. He designed satellites before there were any. He predicted the existence of radiation belts which later were discovered by Dr. Van Allen.

Dr. Singer was commended by President Eisenhower for outstanding achievement in the development of satellites for scientific purposes. He was the recipient of the Distinguished Alumnus Award by Ohio State University in 1958. He was selected as one of the Ten Outstanding Young Men of 1959 by the U. S. Jr. Chamber of Commerce.

It is my pleasure and honor to present to you Professor Singer of the University of Maryland.

DR. S. FRED SINGER

INTERESTING PROBLEMS IN OUTER SPACE

PRESIDENT Tewinkel, President Karo, Ladies and Gentlemen of the Consecutive Meeting, I am very pleased and honored to be invited to deliver this Keynote Address today.

After spending considerable time in thinking about the subject I decided that since very soon you will have finished exploring the Earth, there then will be only one place to go, and that is out into space. Therefore, I will touch on some of the interesting problems that exist in outer space for photogrammetrists, surveyors, cartographers and mappers; in other words, for people who have the background and professional interest which you have.

I am not an expert in many of the new instruments and new techniques, but I can talk about what I personally think are some of the exciting problems that exist in outer space, particularly in connection with the planets, what their scientific importance is, and why it is so vital that measurements be made.

The start will be the Moon—our nearest neighbor—sometimes called a satellite of the Earth, because it in fact revolves around the Earth. But sometimes it is also called a twin planet of the Earth.

The origin of the Moon is unknown. There are generally two types of theories. One is that the Moon was captured by the Earth but was formed independently. The other is that the Moon was formed close to the Earth, within its gravitational field. Later I will tell you how careful measurements of the features of the Moon make possible deciding between these two possibilities. For historical reasons it should be mentioned that there are also theories which claim that the Moon came out of the Earth after it had been formed; I fear those theories do not stand up very well under the laws of physics.

It seems fair to start with the problem of the back side of the Moon—the hidden side—because therein lies the only photogrammetric

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achievement made in space so far. As you know, it was made by a Russian scientific group in one of the lunik rockets, October 7, 1959. They were able to photograph the back side of the Moon using a camera with two focal-lengths, 200 and 500 millimeters. They were able to obtain pictures of 10 millimeters and 25 millimeters in diameter, which they took on 35 millimeter film.

It is a very important achievement. But from a technical point of view, the measurements were not ideal. In the first place, the distance to the Moon was quite large—of the order of 65,000 kilometers—during the time that the camera was operating. And secondly—and this is probably the most serious—they made their observations when the back side of the Moon was fully illuminated by the Sun. Therefore, no shadows could be observed. It is extremely difficult to observe any surface detail of the Moon when it is viewed under full illumination.

The spectacular lunar pictures which you always see are those taken during half-moon, because then the craters and the mountains throw shadows, and the relief stands out particularly well. In fact, the most successful picturing of the Moon that I know of is a composite, the two halves of the Moon taken with the Sun first on one side, and then on the other side. When joined together, the whole of the Moon surface is seen in relief.

In spite of the fact that these pictures were taken under fairly unfavorable conditions, they did achieve some results which they analyzed. I should briefly discuss the technique because it has not been too well expounded. It has only recently been released by the Russians in a Russian journal. Also, it was discussed at a conference which the Russians organized last December in Leningrad.

As I mentioned, the pictures were taken on 35 millimeter film. They were developed in the vehicle itself using very much standard types of processing techniques. The negatives were dried, and then scanned with a slow television type of scanner. This has the advantage of getting the resolution of the photographic process without having to recover the pictures. You can transmit them to the ground by telemetering. A further advantage is that you can take your time about transmission. Because you can scan as slowly as you like, you can get fairly high resolution. In other words, the resolution of the television system, while of course not as good as the photographic resolution, is better than televising directly.

Unfortunately their techniques were not perfect. In the first place, from reading over their original paper, it appears that the negatives themselves were not particularly good; there were little imperfections in the film; the development may not have been carried on properly; the contrasts were not always right.

Secondly, there was radio interference. While pictures were transmitted several times from the probe to the Earth, there was radio interference; as a result noise was introduced into the picture.

I think it extremely interesting how they finally reduced the data which they received on the Earth. I will spend a little time on that, because I am sure the action will interest you.

They took the precaution of having the analysis made by three separate, independent groups—one in Leningrad, one in Moscow, one in Kharkov. These groups did not communicate with each other. They only compared their final results. This is quite important in order to get a completely unbiased picture.

I mentioned before that not much surface detail is visible because the Sun was shining full on the Moon. They could however see surface detail very well near the edge—actually the northwest rim—where many of the lunar features were already known.

You are probably aware of the fact that the Moon "librates," so that we can see a little around one edge of the Moon when it is turned one way, and then around the other edge when turned the other way. They were able to observe the edge features of the Moon quite well, and showed that the features continued around into its hidden side.

But then they ran up against the following problem. There are on the Moon, roughly speaking, two types of features. These are the so-called maria, the oceans—of course they are not really oceans, but are so-named—and the mountains. The contrast between them is quite large. They have different reflecting powers. Furthermore, there are also small features on the Moon which have a rather low contrast.

Their first problem was reducing the extreme contrast without destroying the moderate contrast. They went about this in a very fine way. Essentially the need is a dynamic compression of the picture. They prepared what is called a photographic mask. The technique is quite new to me; perhaps it has been used by others, but I suspect not. They then constructed a positive which was washed out, and purposely blurred it by printing out-of-focus. They made it with very low contrast. Then they superimposed this positive on the negative and produced another print. In this way they were able to reduce the dynamic range—the contrast range of the picture. They could reduce the extreme contrast without destroying the moderate contrast.

This technique worked well but unfortunately they had other problems.

I mentioned the noise in the transmission. The only way they could get rid of that was by superposition of many of the transmissions. They superimposed some dozen of these on each other, and were then able to see which features of the Moon survived. Those that survived were believed to be real features; those that did not survive were suspected to be noise introduced into the transmission.

The third technique which they finally used is also interesting.

I mentioned that the pictures were transmitted by radio techniques to the ground where they were recorded on magnetic tape. So essentially what they had on the ground was a magnetic tape record of the pictures. Instead of turning this record back into light, as before, they treated the magnetic tape electronically. They decided to work at a particular level of intensity corresponding to light intensity, and then amplify the magnetic tape signal around this level. Thus they increased the contrast at a particular density region. Of course, everything that was very bright got brighter and showed no resolution at all; and everything that was dark got darker. But this did not matter, because they had the magnetic tape available and could run it over and over again. So gradually they increased the contrast at each level. They were able to resolve things of extremely low contrast by this process of electronic amplification.

I mention these factors to indicate that a considerable amount of effort went into analyzing these pictures. They were able to resolve something like 250 surface features of the Moon. Of the total they considered perhaps 200 to be reliable and the rest of doubtful validity.

Unfortunately, this effort while very fine and pioneering, did not settle any fundamental problems about the Moon. It showed, as expected, that the back side of the Moon is more or less like the front; that there are craters, maria, and all the features that we know exist on this side of the Moon.

But perhaps I should make clear that all of the back side of the Moon has not yet been photographed. There is still an unexplored region which has not yet been seen. There is still tremendous need for looking at the back side of the Moon with much better resolution and at a time when the Sun is so situated that one can see the relief and the details much better than in the past.

Leaving this problem for a moment, I would like to discuss another one, concerned with the Moon. That is how does one prepare a contour map? This has just been done, incidentally, by Baldwin who wrote a book called "The Face of the Moon." He is republishing it with new data.

If you want to know the altitude of a point on the Moon, in order to construct a contour map, there are two ways of doing this, in principle. One is to study what is called the terminator. That is, you look at the line where the illuminated portion ends and the dark portion begins—this is the terminator line. Of course, you will see shadows. You measure the length of these shadows. You know the altitude of the Sun. Therefore, you can estimate the heights of various surface features. This method has been found to be quite unsatisfactory and of very little accuracy, because, as you probably know better than I, the terminator line is very indistinct, due to the low altitude of the Sun.

A much more precise method is the one based on the libration of the Moon. I touched on this earlier.

Because of the lunar bulge, the Moon does not show us the same face all the time; it actually oscillates slightly. This oscillation amounts to about 14 degrees. So one can really see more than half of the Moon.

If the Moon were a perfect sphere, and if you picked a point on it—let us say one marked by a small crater—you could calculate exactly where this point is going to be during the libration. If the Moon is not a perfect sphere, then this point, as it librates, will not be at the exact place that you expect.

This, briefly, is the principle of measuring altitude, or deviation from the spherical surface, using the libration.

You must pick a lot of very good surface features on the Moon, observe them carefully and mark their position as the Moon librates. Then you have to make a lot of calculations.

This in fact has been done quite recently. We now have a contour plot of the front side of the Moon. I would say it is good to maybe a thousand foot altitude. It shows, in fact, that the maximum depressions occur, as you would expect, in the maria—the so-called oceans—and the maximum altitudes occur on the mountains. The difference between these two—the maximum range—is of the order of 30,000 feet, which is a considerable distance.

It is interesting that the altitude resolution is now about as good as the resolution of surface detail on the Moon.

Leaving this problem, and going on to a perhaps more exciting problem—the craters. They tell us something of the history of the Moon.

I believe the paramount view today, and the one which I think is the correct one, is that most, if not all, of the craters originate through the impact of large bodies, such as meteorites or asteroids, which hit the Moon. As they hit they produce an explosion which blows off material and generates a crater.

One mystery about the craters is that they seem to be nearly circular. Why is that? The fact that they are circular led people earlier to think that these were extinct volcanoes. But now we know that meteorite impacts will also produce circular craters. The reason, I think, is quite interesting. It has nothing to do with the idea that the meteorite may come in nearly vertically. Even if at a fairly large angle, it will still produce a circular crater. The reason is that the meteorite is quite small compared to the size of the crater. The Arizona meteor crater, for example—the meteor body itself—may be only of the order of one per cent of the size of the crater. This crater is due to a large explosion which essentially does not depend on the direction of the meteorite's momentum as it comes in. The explosion, therefore, always leaves a circular crater.

But are the craters really quite circular? This matter has just been studied by a colleague of mine at the University of Maryland, Professor Ernst Öpik. He seems to detect a slight ellipticity. I will try to explain why he undertook this study.

The Moon is not a perfect sphere. Its libration tells us that. In fact, the Moon has a bulge, which points towards the Earth. It is a so-called triaxial body. The bulge is produced by the tidal force of the Earth's attraction. The Moon at one time was very much closer to the Earth. The tidal force therefore was then much stronger. This bulge may be a fossil bulge that was produced when it was close to the Earth, some billions of years ago, and "frozen in" because the Moon is not perfectly elastic.

If the craters were formed a long time ago, you would expect to observe an ellipticity and that the axis of this ellipse would point towards the tip of the bulge.

Think of the Moon as a sphere with circular craters on it. If you pull out a point on it, so as to create a bulge, the craters will become distorted. Therefore, it is very important to look for their distortion. This is what was done, and it was found that the ellipticity is very, very small and may in fact be zero.

I suggest that here is a very good job for photogrammetry, and it is a very important job, too, because the present photographs do not establish at all whether or not this ellipticity exists. I would like to point out for you the consequences of the presence or absence of this ellipticity.

If the ellipticity pointed to the bulge really exists, this would indicate that the craters were formed at a time when the Moon was still very much closer to the Earth than now —some billions of years ago. If you trace the Moon's history, going back in time, it comes closer and closer to the Earth. And this has been done first by Sir George Darwin and more recently by a German astronomer who has calculated that some four billion years ago the Moon must have been about three Earth radii away instead of today's sixty Earth radii. Going back still further, he calculated that the Moon was then captured by the Earth gravitationally—it was just an independent body which came along. This was a rather complicated process which we do not need to go into now. Eventually its orbit was changed into a circle and then this orbit began to expand. That is where it is today.

You can see that at three Earth radii, the Earth's tidal force on the Moon would have been very, very much greater than it is today. In fact, if you calculate the effect of this tidal force, you can figure the deformation of the Moon to be so great that all of the craters would have been broken up and destroyed. Yet we see today that all the craters are quite perfect; they have a nice, smooth rim.

This leaves one of two conclusions. Either the Moon did go through this kind of capture process, some four billion years ago, and the craters were all formed afterwards, so that they came out to be nice and smooth. Or the Moon was never captured at all. In order to decide between these two possibilities, one needs to measure the ellipticity of these craters.

Let me go back to the first possibility again, to show what is wrong with it. It would seem very strange for the Moon to be captured by the Earth and not to have any craters on it at all until after the capture and the Moon had gone out for some distance. Therefore, it seems a little more reasonable to think that the Moon was actually formed from loose material which happened to be going around the Earth at a distance of five to eight Earth radii; that it coalesced into a body; then that this coalescence process—the last part of it—actually produced the present craters, because the impacts would have been energetic enough to give them.

To be consistent with this picture, which, as I mentioned, was put forward by my colleague Prof. Öpik, one would expect these craters to have a very small ellipticity directed towards the bulge.

I think that I may have talked enough about the Moon. Of course, one could talk about it for hours. I only wanted to illustrate some of the problems, to show that they are really basically interesting and intriguing, and that they demand a great deal of technical and scientific skill for their solution.

Perhaps I should say a few words about the planet Mars. There the problems are quite different.

Mars has an atmosphere. It has some water vapor. It has erosion. It is a planet which resembles the Earth much more than the Moon does, and therefore it will be more familiar to some of you and will be more amenable to the techniques that are used on the Earth.

There are several features about the Martian surface which I will mention very quickly. Like the Moon there are regions which are called the "maria"—the oceans—but they are certainly not filled with water. Then we have "continents," which are higher than the maria. And white polar caps. The continents are generally reddish-yellow, the maria seem to be dark grey, and the polar caps, white.

It is thought that the maria—the depressions—derive their color from either their peculiar soil or from vegetation. The arguments which favor the hypothesis of vegetation, to which I also subscribe, are the following. There are tremendous dust storms on Mars—not all the time, but quite often. You would expect that after some time this yellow dust should have covered the maria, so that they would be filled up, so to speak, and their surface features would have disappeared. In fact, they do cover the maria, but these dark areas seem to come back again and again. So they must have some kind of regenerative power, the sort of power one associates with hardy plants, such as lichens—a sort of combination of moss, fern, and algae. It is therefore now believed quite widely that lichens do in fact exist on Mars. There may be other vegetation.

An additional piece of evidence which I might mention is spectroscopic. People have measured the infra-red spectrum of Mars and found the absorption bands in it which correspond to the bands in organic molecules, thereby indicating that some kind of organic molecules do exist on Mars. These absorptions come from the maria; they seem to be definitely associated with these dark areas.

The topography on Mars is fairly smooth. There are no violent mountains and no deep ridges, as we have on the Moon. But there may be quite large differences in level. We do not know. We cannot apply the techniques that we use for the Moon to measure the contours of Mars.

There seem to be interesting little spots, white spots, on Mars. These may be due to water vapor, which is condensed hoar frost, in other words. Frost would tend to condense out from lower regions, so there must be some modulation in the plateau. Maybe there are low regions and high regions. The maria are thought to be depressions in low regions.

You probably have heard about the haze on Mars. Actually there are three types of hazes, or clouds. There is the so-called blue haze; it is not blue at all; it is a type of smoky haze. In the blue region of the spectrum you cannot see the surface of Mars. To see the surface, you must use red light. And since we always use sunlight, which contains red light, you can see Mars best if you use a red filter. So much for the "blue" haze. The yellow haze, of course, is due to dust storms. It is of quite a different origin than the blue. The white haze, when and if it does exist, probably consists of ice crystals. It occurs very rarely. It always occurs near the terminator line. It may indicate just the freezing out of the little bit of water vapor which is in the Martian atmosphere.

These are the main problems that we are going to run into on observing the surface of Mars.

Perhaps I should close this discussion of Mars with one remark about the famous canals. I think there is no doubt that such things as narrow black markings really exist.

They radiate from circular features which are called the "oases." Their origin, of course, is not known. But the most reasonable assumption, taking what we know should exist, is that the oases are meteor craters and that the radiating dark lines may be just cracks in the surface. The question is why are they dark. It may be that the exposed soil is a little more fertile than the surrounding sand, and that vegetation has started to grow in these cracks. So what we see, again, is the dark vegetation in the same way.

But all this, as you know, is highly speculative. and real observations will have to be made, not necessarily from the surface of the planet, but from fairly close to it and with much better photographic equipment than now available, before we can settle some of these problems.

I shall pay only lip service to one more planet before closing—Venus. That is very easy as there is nothing that can be observed about the surface of Venus, because it is completely surrounded by clouds.

But even though this planet is eliminated I have the feeling that even after we run out of problems on the Earth, there are plenty of challenging problems in space, particularly on the Moon and on Mars.
