BRIEFING ON MARS EXPLORATION

HEARING
BEFORE THE
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES
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September 29, 1976:

BRIEFING ON MARS EXPLORATION

WEDNESDAY, SEPTEMBER 29, 1976

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2 p.m., in room 2318, Rayburn House Office Building, Don Fuqua, chairman, presiding.

Present: Representatives Fuqua, Winn, and Emery.

Mr. FUQUA. The subcommittee will be in order.

On behalf of the Committee on Science and Technology, and particularly the Subcommittee on Space Science and Applications, we want to welcome you, Dr. Hinners, the Associate Administrator for Space Sciences, and also Jim Martin, Viking project manager who has been working with this program for about 8 years, and we are also pleased, as we have said many times, with the success the Viking program has had.

So many times it has been the manned programs that have created excitement and thrills for the people of this country. I think the Viking program has regenerated that spirit of man's adventure, whether it be manned or unmanned, and I think it is one of the most effective and spectacular things, particularly it having happened in this Bicentennial year, and also I think it certainly equates with our Apollo manned program and other successful manned programs we have had, so, Mr. Martin, you have not been here to hear the accolades we have given you before.

You are here now, and I want to say we are happy to have you here.

We have business on the floor now. We were tied up until about 4 o'clock in the morning, it is kind of like the night before launch, when you have a delay.

I know you are familiar with that. We are trying to close this session of Congress, and a lot of people have other things to do, but we do have our staff people here and others who are very much interested in the success of the Viking program.

Mr. Winn, do you have a statement?

Mr. WINN. I do not believe so, Mr. Chairman. I am anxious to hear their report.

Mr. FUQUA. So I will be happy to hear from you, Dr. Hinners.

Dr. HINNERS. I will be brief, Mr. Chairman.

As you know, I periodically come to you asking for approval for new projects, and to explain our progress, how we are doing, what our situation is, our schedule.

All of this ultimately leads to the return of data, in this case mission success, and it is with really great appreciation that we introduce some of the Viking program team that pulled it off. They have some of their data here to show you what has happened with Viking, what the results are.

It has been 8 years that they have been with this project, both the management headed by Jim Martin here, and all of us who have also labored designing the experiments, testing them, assuring that they would work when they got to Mars.

One of our scientists here today, Dr. Thomas A. Mutch, has an article in this publication which says one measure of the NASA program of space exploration may be that when this article is printed, it may be out of date. So it is with Mars.

Today we are going to give you the information before it is printed.

Thank you.

Mr. Fuqua. Thank you very much.

STATEMENT OF JAMES S. MARTIN, JR., VIKING PROJECT MANAGER, LANGLEY RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Martin. Mr. Chairman, it is our pleasure to be here this afternoon.

Viking has been a most exciting mission, and we look forward to this opportunity of giving you a short summary of some of the scientific results.

We have had a team of people that made all of this happen. It has not been an individual effort, it has been a team effort.

In 1974 we had something on the order of 10,000 people working on the project, and we have had 800 members of the flight team in Pasadena for this past year.

It has been a very exciting time, a very tough time, and I can appreciate your staying up until 4 a.m., because we have had to do that a few times.

The mission is still going on. We have two orbiters in orbit around Mars, and we have two landers on the surface of Mars, all four of these vehicles are active.

We are commanding each of them about every other day, and we will continue the active mission until early in November.

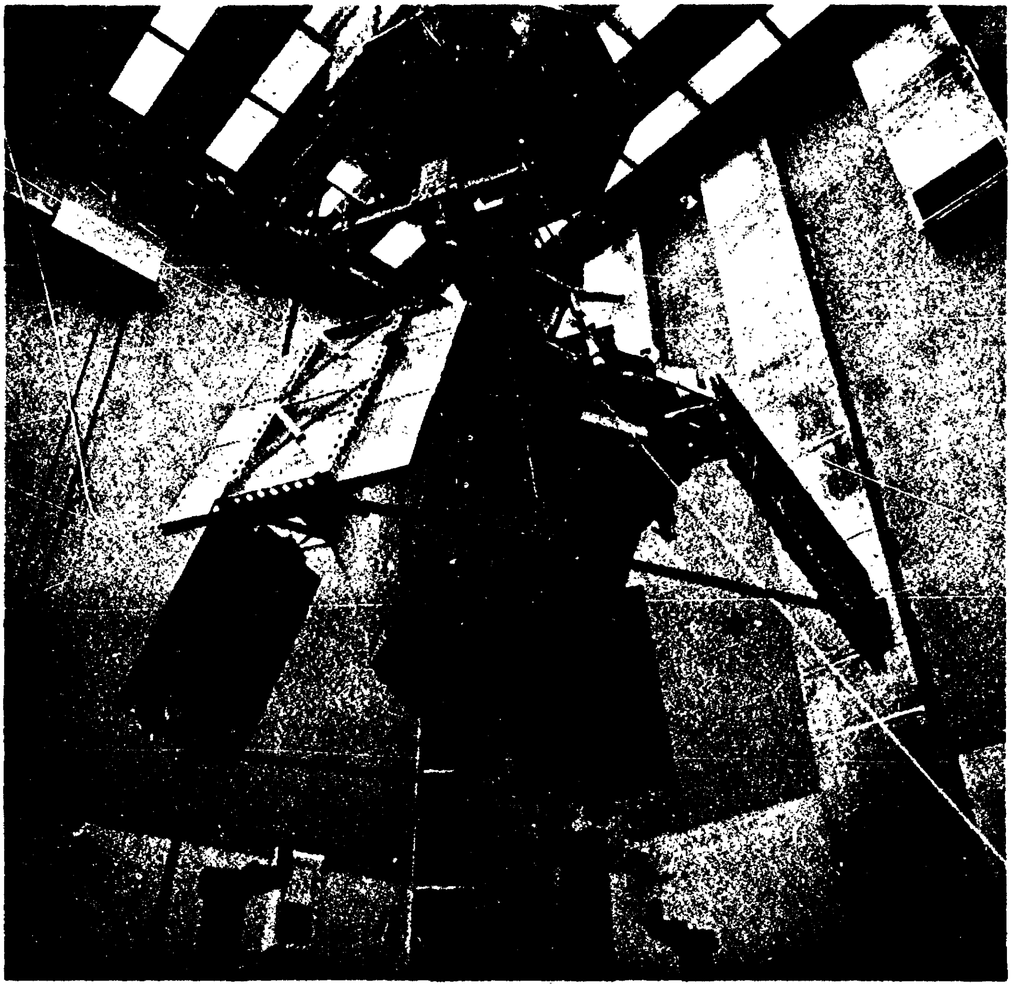


FIGURE 1

I would just like to show you a couple of slides, the first one is a picture of the orbiter [fig. 1], which is now orbiting Mars, and which was the mother ship for the mission during all of the cruise period.

The orbiter weighs about 5,500 pounds, has a wingspan of about 30 feet, and it is the relay station at Mars for most of the lander data. In addition, it is performing science observations.

I should mention the orbiter was designed and built at JPL in Pasadena.

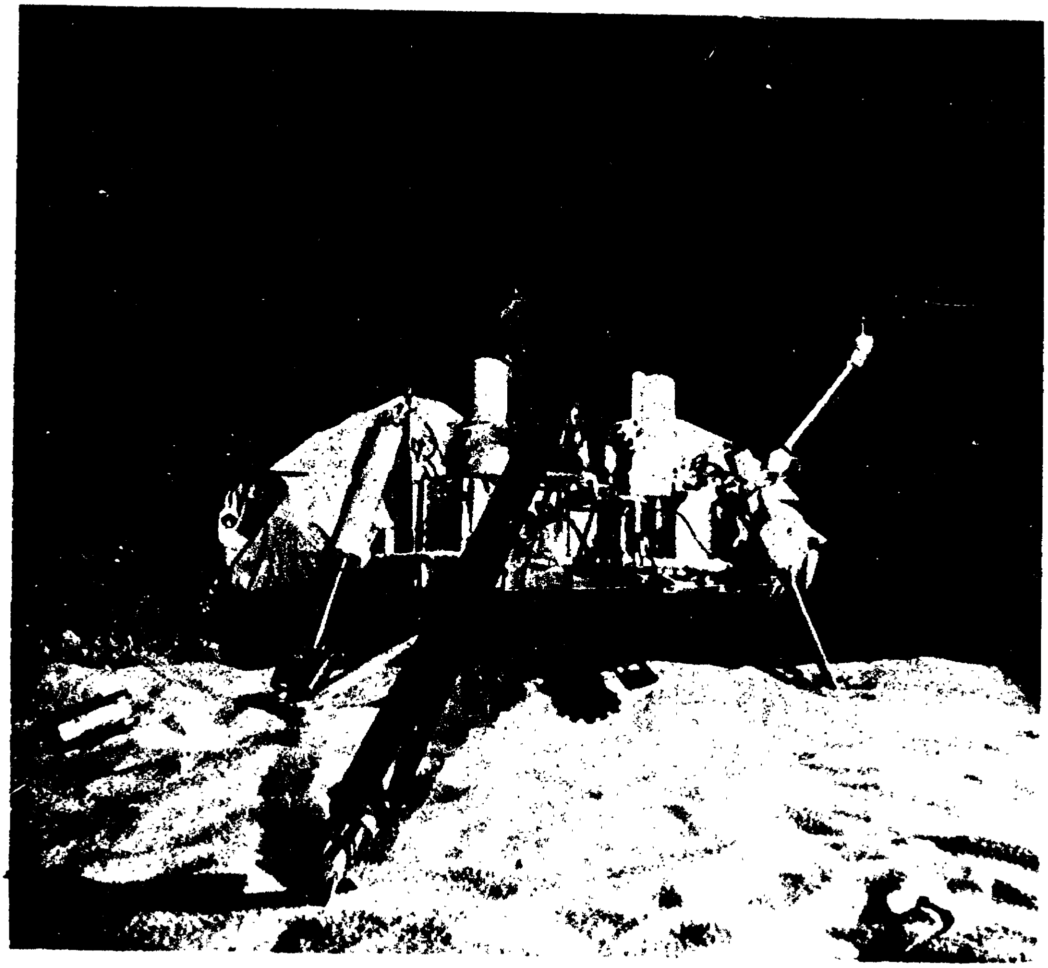


FIGURE 2

The next slide is of the lander as it sits on the surface [fig. 2], with the soil sampler boom out in front, and the meteorology boom on the right.

This lander is a truly remarkable robot that was designed and built by the Martin Marietta Corp. in Denver.

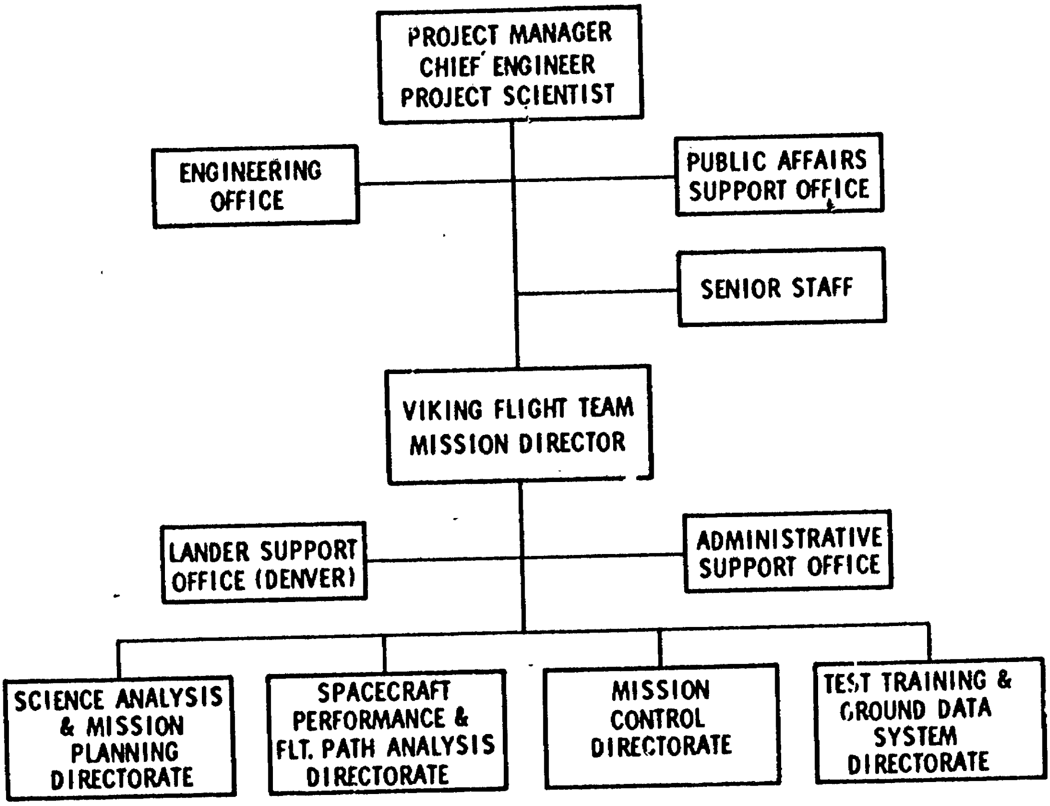


FIGURE 3

The next slide is a diagram of our great team that has been flying this mission [fig. 3].

One of the points I would like to make is that we decided about 2 years ago, because of the multiorganizational elements of this project, that we would put together a flight team that does not have any institutional ties in the sense that Langley and NASA run the flight team, but rather the people come from JPL, from the Martin Marietta Corp., and from other subcontractors. I would like to just mention the fact that the flight team director, Mr. Tom Young, is here in the audience today. He is from Langley.

The principal elements reporting to him, the science analysis and mission planning director, is headed by Gentry Lee from the Martin Marietta Corp.

The spacecraft performance and flightpath analysis director is Dr. Pete Lyman from JPL.

The mission control is headed by Mr. M. J. Alazard from JPL, and the test training and ground data systems director is Marshall Johnson from Langley. So we have had a mixture throughout this organization of Government, industry, and university people.

It has worked extremely well.

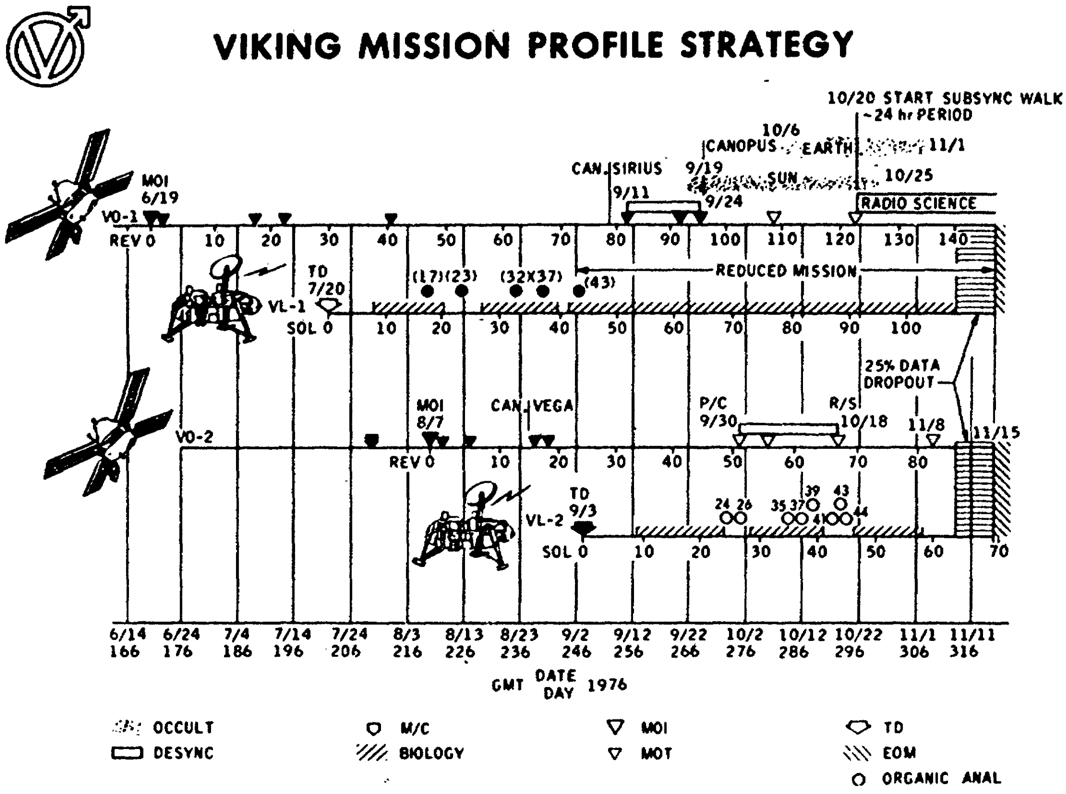


FIGURE 4

The next slide. This is an overall mission strategy [fig. 4].

You can see that the first orbiter went to the planet on June 19, and we landed on July 20.

You mentioned the Bicentennial year that we are in. We were shooting for July 4 for a landing, but Mars did not cooperate.

Mr. FUQUA. They did not know about the Bicentennial.

Mr. MARTIN. They did not know.

The original landing site we picked out looked too rough.

I am quite happy we moved on. The first lander has been operating now for some time, and is in what we call the reduced mission phase, because we are concentrating our efforts at the moment on the second lander.

The second lander came down on the 3d of September, and is now well into its activity. We are on or about the 24th lander day on the surface of Mars, and we will continue now out to about SOL–62.

We run into a conjunction of when Mars, the Sun and the Earth are all lined up in November. We expect to lose communications with all four vehicles for a period of about 3 to 4 weeks, and we expect to reestablish those in December, and we hope to continue the mission for a Martian year, which will carry us into the summer of 1978.

I would like now to introduce, if I may, the first speaker, Dr. Thomas A. Mutch from Brown University. Dr. Mutch heads the lander imaging team, and he will speak about some of the lander photographs.

STATEMENT OF DR. THOMAS A. MUTCH, LANDER IMAGING TEAM DIRECTOR, BROWN UNIVERSITY

Dr. MUTCH. Thank you very much.

In the few moments I have, I would like to just show you a sampling of the pictures we acquired.

I cannot describe the science systematically, but I can indicate some of our conclusions.

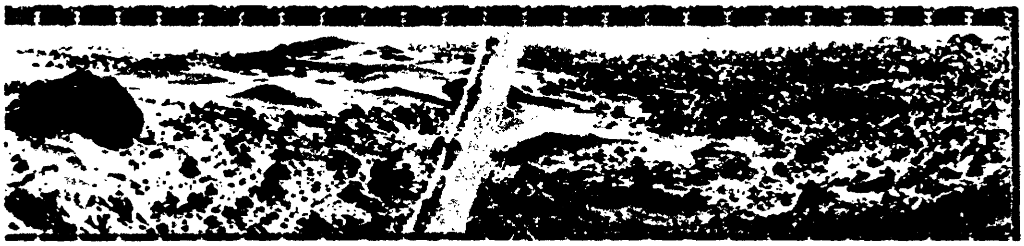


FIGURE 1

Miy I have the first slide [fig. 1] This is a picture taken with the first lander spacecraft, as are the next few pictures, and it shows a series of sand dunes, or drifts, about 2 feet high, and 10 to 20 feet from the lander.

This documents to some degree that Mars is a desert environment with sand, which is stationary, it has been somewhat eroded, and it is not actively moving.

We look forward to the prospect of some movement of sand, later in the year when dust storms come to the planet Mars.

I draw your attention to this large rock right here, because the Sun is behind that rock, you cannot see the surface detail.

FIGURE 2

In the next slide [fig. 2], you will see with the Sun from a different angle, you can see a lot of coarse texture on this rock.

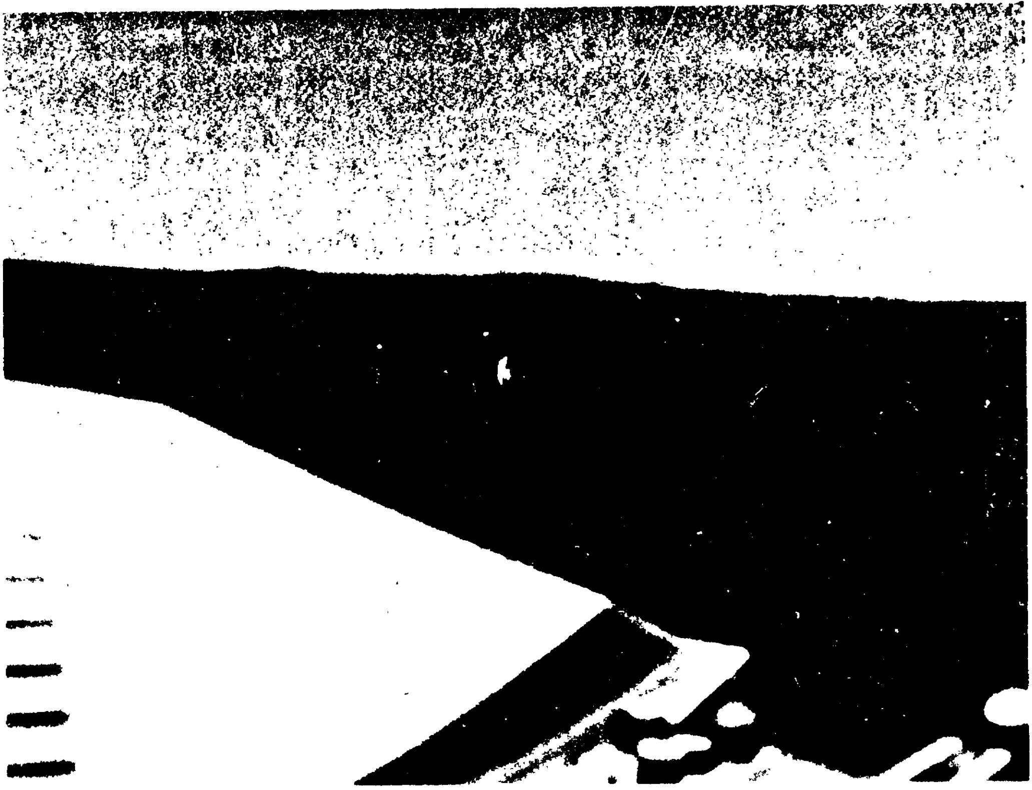


FIGURE 3

It looks like a very coarse-grained rock, and you can see some suggestions of a crown of material, which is more clearly shown on the next slide [fig. 3]. This is a colored picture of that same field of view, and here you can see the dark rock, the same rock we have seen in the preceding two pictures, about 6 feet across, but here it has a crown of fine-grained sediment, the same sediment which covers most of the surface.

The atmosphere itself is rather bright, brighter than we anticipated, and that is due to the scattering from the small dust particles which are suspended in the atmosphere, and as you go higher, the sky becomes darker as the skyline is less.

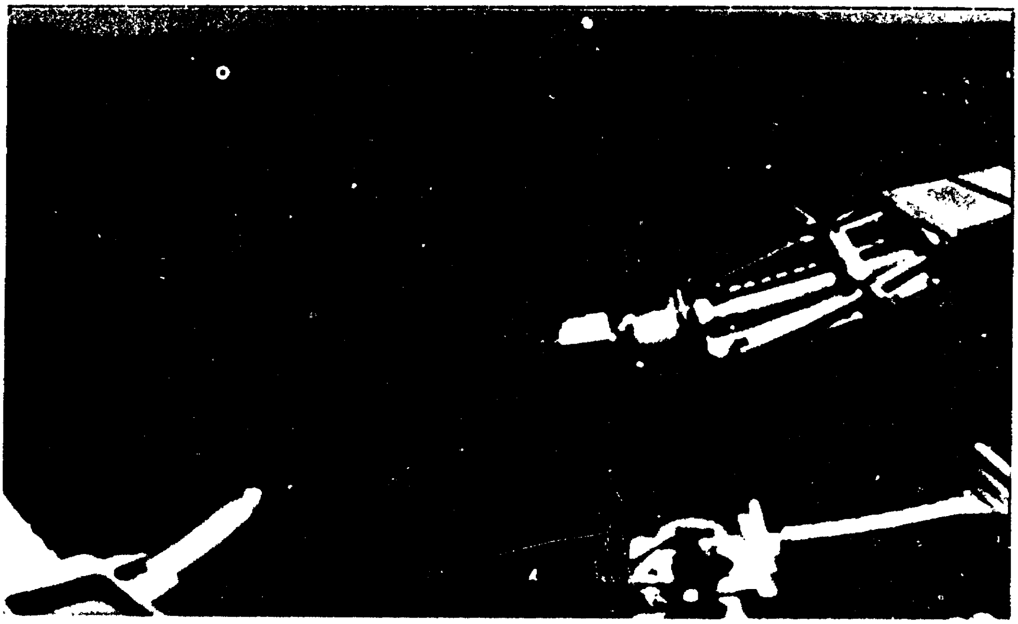


FIGURE 4

The next slide shows you a rather typical day in the life of Viking [fig. 4].

The cameras are often used as a diagnostic tool to confirm that certain activities which have been successfully carried out.

Here you see the collector that leads to the spacecraft.

The arm is not now in the extended position. When it was in the extended position, it dug these little trenches out here, and this material was brought into the Viking lander, and was analyzed by the biology instruments, and the organic and inorganic experiments.

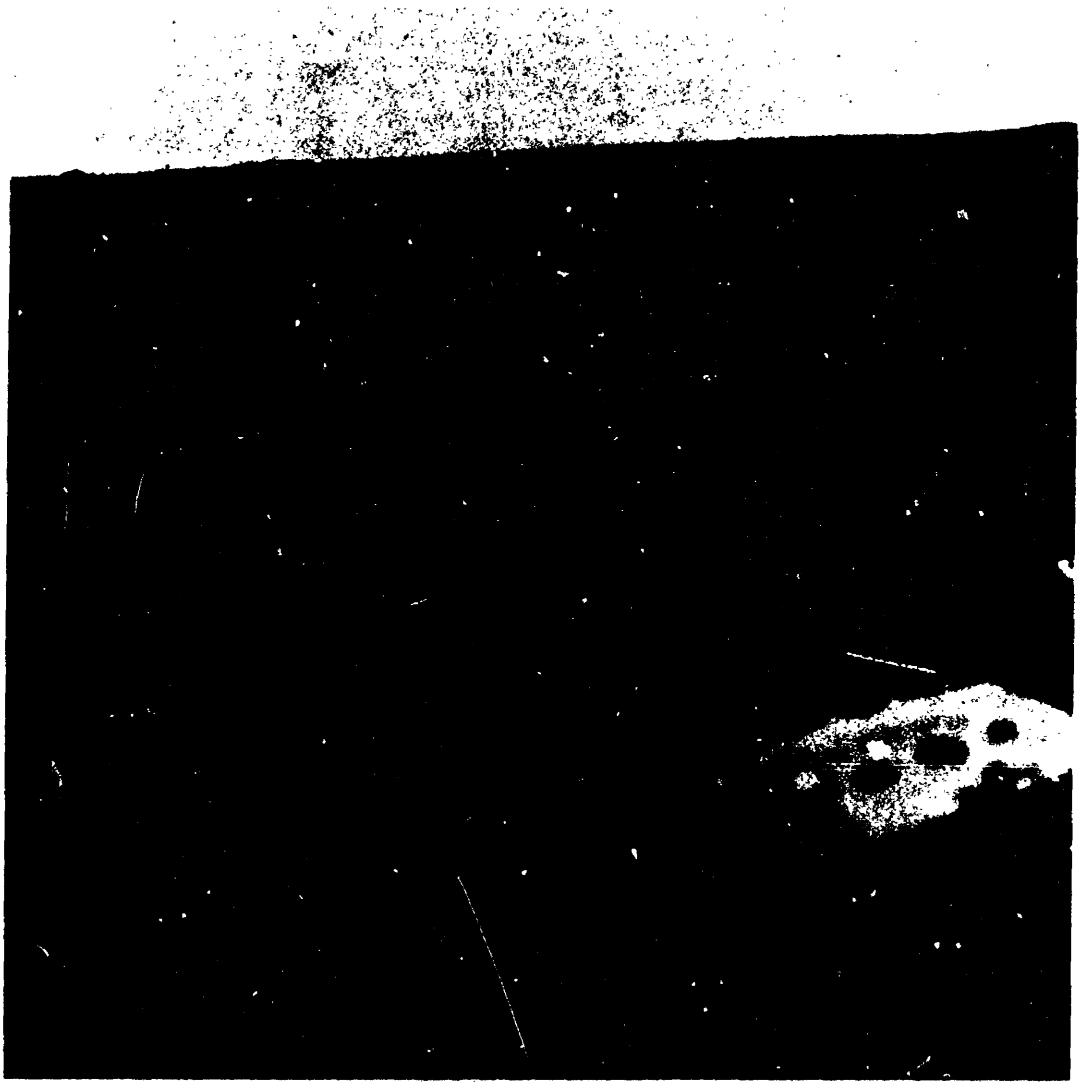


Figure 5

The next picture shows you a rather spectacular view of the surface, the color of the dunes [fig. 5]. Viking I took this just 15 minutes before sunset, when the Sun was only 2 to 3 degrees above the horizon, right over in here.

I might comment on all of these blocks you see here, they are probably due to the throw out of ejected material, but in this case, we cannot rule out the possibility they might have been deposited by a giant flood, and then at the second landing site, they could have been possibly deposits by floods, so we have a great deal more analysis to do.

FIGURE 6

The next picture is an interesting one [fig. 6]. It is taken 1 hour after the preceding picture, and if you will recall, the previous picture was a Sun element picture.

The Sun was a few degrees above the horizon. At this time the Sun is about 5 degrees below the horizon, right here, and not in the field of view, as you might anticipate, and the scattered light coming from the Sun, below the horizon, scattering up through the atmosphere, through the very fine grain material produces this kind of halo effect, with a spectacular sunset, with various shades down here.

This is scientifically useful, because it tells us about the particles in the atmosphere.

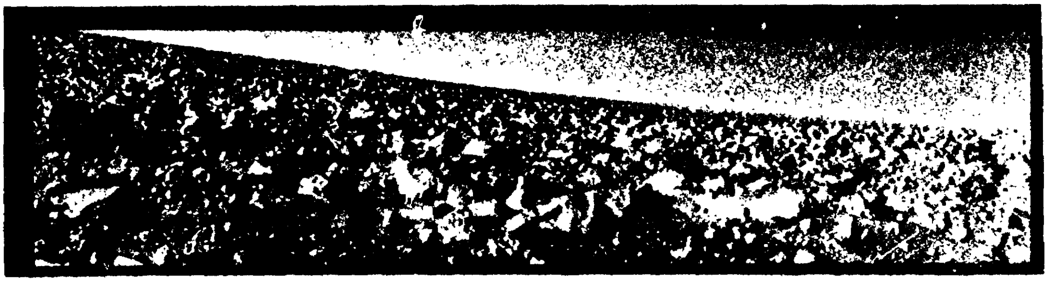


FIGURE 7

The next slide is taken from the second Viking, and you can see it is an extremely rocky scene [fig. 7], even though we had anticipated from the pictures taken in orbit that it might have fewer rocks.

There are circular boulders that indicate former volcanic activity.

You also see a small rock, for some distance, and may well have been related to the former presence of water, either flowing along the surface, or freezing.

Finally, although the dunes are not prominent here, they are rather specta-faceted objects of a fine sediment which have some very frightening reflective faces, and it appears to have been a stabilized dune.

The next slide shows you the color of the rendition here [fig. 8], as perhaps a little more vivid than the actual scene, but it is approximately correct, and then you see the bright atmosphere with the brightest region being close to the horizon, a very, very rocky field of view.

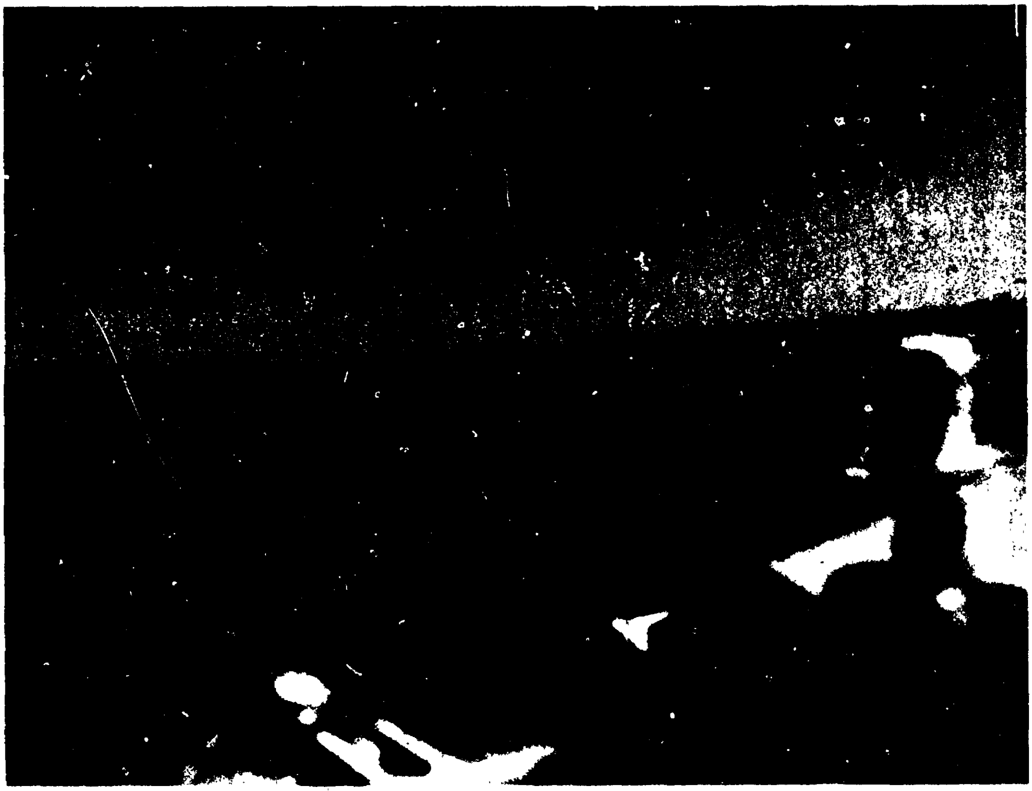


FIGURE 8

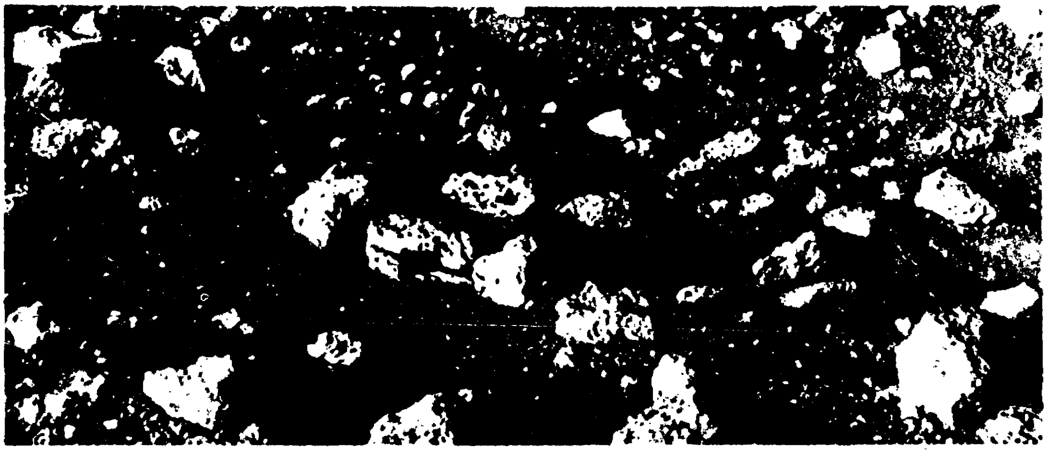


FIGURE 9

The reddish color is probably due to the presence of crystals of carbon dioxide, and this indicates that at some former time, Mars was probably water rich in environment, with the potential for oxidization and hydration of minerals.

I have one last slide [fig. 9]. This is a rather complicated one, and I cannot give it the justice it deserves.

First of all, I draw attention to this little area, which is only a few inches across, right in there, that bright appearing area.

It was determined that was an area which we were particularly anxious to sample because of the surface, and just last Saturday we successfully threaded our way through here, and acquired a sample right in here, without hanging up on the obstacles on either side, and this is a considerable accomplishment, and one which we are rather pleased with. That sample is now being analyzed by the system.

Finally, you might note that this is imaging data, camera data, just as in imaging data over here.

What we did, when we got to the end of the picture, and the camera kind of moves across the scene, we continue to scan in only a vertical direction.

This, if you will, is sort of a motion detection, and this is the first scan through that particular place, and you see successive lines, and this is the last line, so if there is any motion in the scene of any sort, you would see this recorded here, because these bars would look irregular as you come across.

Instead, they look very regular, and this indicates at this particular time of the year there is no movement of sand in the field.

Later we expect to use the same facility, which we call single line scan to document what we expect, and that is the movement of some sand across the surface as the winds are higher.

That concludes my presentation.

Mr. MARTIN. Thank you, Dr. Mutch.

The next speaker will be Dr. Harold P. Klein from the Ames Research Center.

Dr. Klein is head of the Viking biology team.

STATEMENT OF DR. HAROLD P. KLEIN, AMES RESEARCH CENTER DIRECTOR, VIKING BIOLOGY TEAM

Dr. KLEIN. Thank you very much.

If there are any questions, Mr. Chairman, as we go along, feel free to ask them.

If I may, I would like to read my statement, in order to save everybody some time.

Before the two Viking landers reached the surface of Mars, many people thought that pictures from the surface might reveal the presence of life on that planet.

We quickly learned that this was not the case, at least at the two landing sites where we are. So the question of whether or not Mars contains living organisms is now squarely up to the three biological experiments onboard the landers.

For 9 weeks now, Lander I has been conducting experiments concerning this very difficult problem. Lander II has been active for a scant 3 weeks.

During this period, the biology instruments have been operating almost flawlessly, and we can be virtually certain that the data we have received is not artefactual.

Several years of testing, using terrestrial soil samples, pure cultures of micro-organisms, and even lunar samples, led to the development of empirical criteria for each of the biological experiments.

The labeled release experiment was developed by Dr. Gilbert Levin in Baltimore, and it is one in which a small drop of water, containing a mixture of radioactive carbon-containing compounds, is introduced onto a sample, and the resulting sample is then incubated for several days, or even weeks.

As one or more of the added nutrients is decomposed by living systems in the sample, radioactive carbon dioxide is given off as a waste product, and the release of carbon dioxide is monitored by a miniature radioactive detector.

AIKEN SOIL
LABELED RELEASE EXPERIMENT

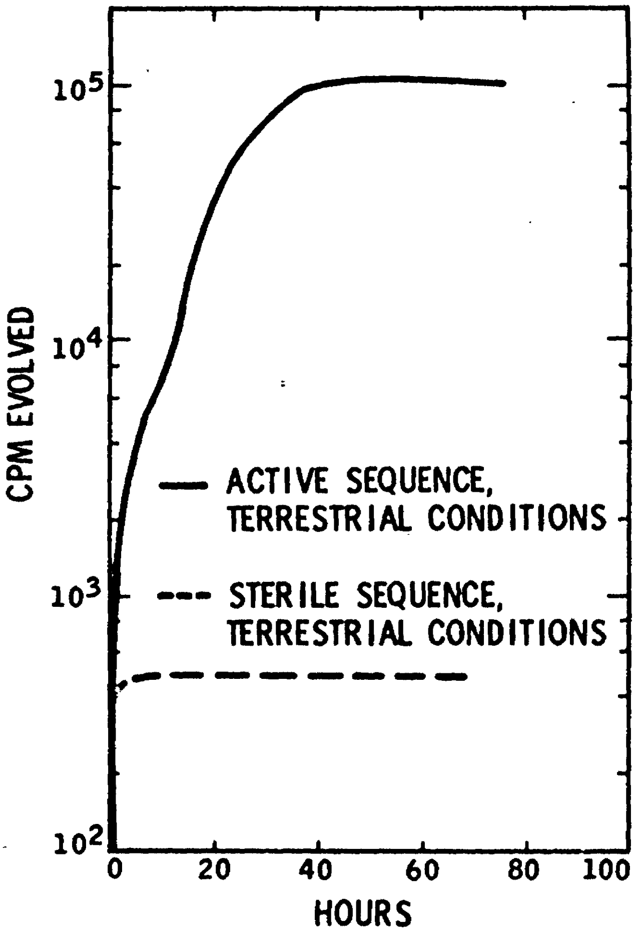


Figure 1

The first slide [fig. 1] shows results using an average terrestrial soil sample. You will see that radioactive gas is rapidly given off, this is time in hours plotted against the radioactivity and the process then levels off at some level of accumulated radioactivity.

When the same kind of soil is first sterilized by heating, and then tested in the same system, the response is much lower.

Notice that in this graph, we are using a logarithmic scale, and that the response is at least 100 times greater before sterilization than after sterilization.

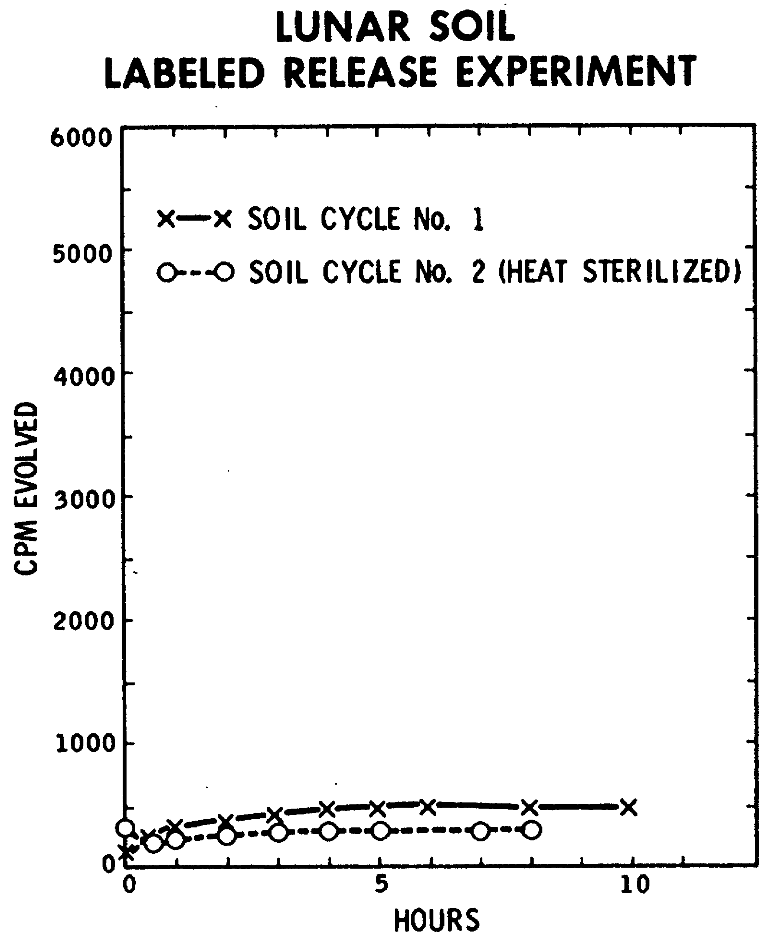


FIGURE 2

Soils known to be inherently sterile, that is, without any living things in them, give results as shown on the next slide [fig. 2], which happens to be from an experiment using lunar material.

You will see here that there is practically no response and that there is very little difference between the sterilized or nonsterilized lunar samples.

Now, from studies like these, we established the criterion that all soils that contain organisms, that is, that contain life, release at least 10 times as much radioactivity as the same soils do after they are sterilized.

MARS SAMPLE
LABELED RELEASE EXPERIMENT

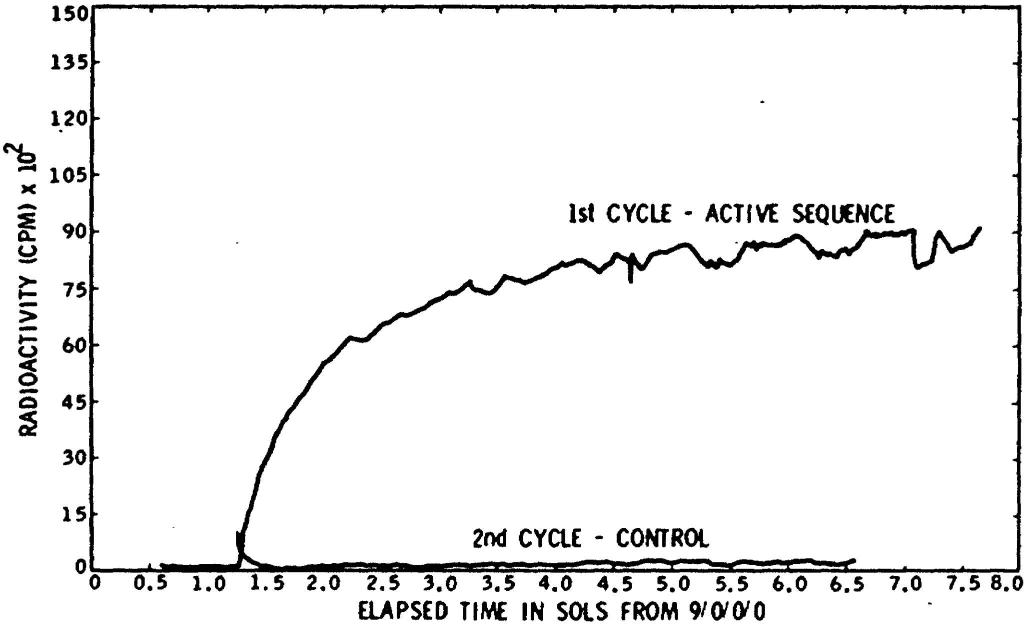


Figure 3

Now, when this experiment was first performed on Mars, as seen on the next slide [fig. 3], we were rather surprised. When the radioactive nutrient was added to Martian soil, we saw an immediate and formidable release of carbon dioxide.

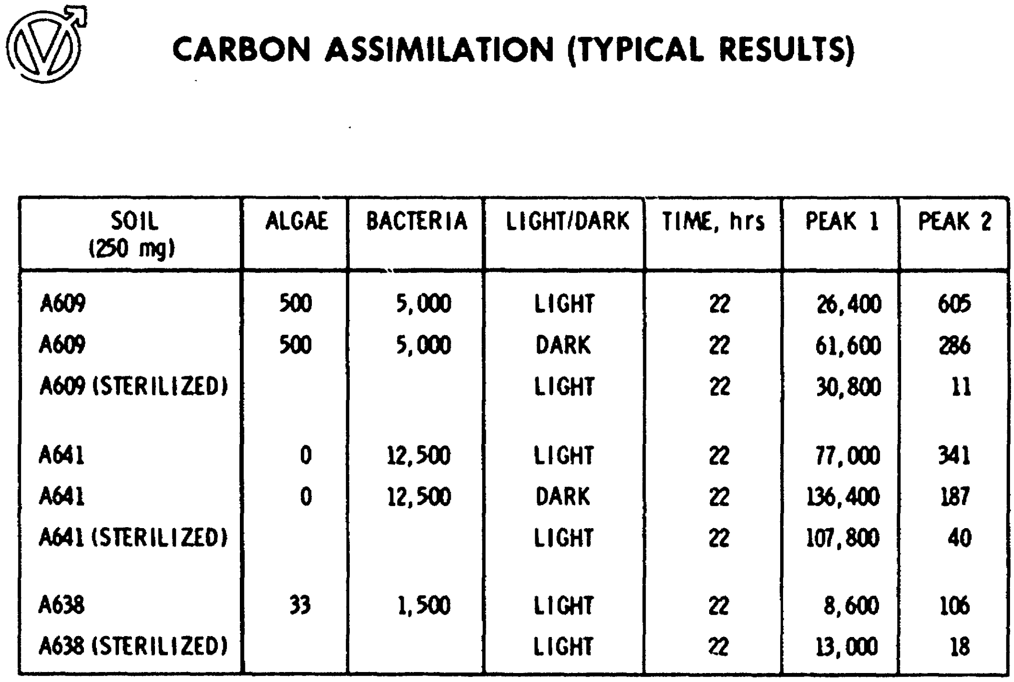
After the reaction had subsided several days later, we made the decision to heat-sterilize a second sample of Mars, to see whether we could decrease this signal. As you see from the lower curve, when we heat sterilized the soil and ran the experiment over again there was practically no response. Since the nonsterilized soils gave much more than 10 times the level of radioactive signal than the sterilized soil gave, this meets our original criterion for a so-called positive result.

I should note that analogous active responses were obtained again on fresh samples of soil on Lander I, and also the first time we tried this 2 weeks ago on Lander II. Thus, we now have three separate samples giving us this very active release of carbon dioxide by Martian soil.

The second experiment, that of Dr. Norman Horowitz of Cal Tech, is one in which a soil sample is incubated in the light, in the presence of a mixture of radioactive carbon dioxide and carbon monoxide.

Here the scientific question is whether either of these two gases is transformed into organic material during the period of incubation.

This process is carried out vigorously by photosynthetic organisms, and weakly by other organisms, on Earth. The essential data for this analysis is obtained during two periods of counting by another radioactivity detector.



CARBON ASSIMILATION (TYPICAL RESULTS)

SOIL (250 mg)	ALGAE	BACTERIA	LIGHT/DARK	TIME, hrs	PEAK 1	PEAK 2
A609	500	5,000	LIGHT	22	26,400	605
A609	500	5,000	DARK	22	61,600	286
A609 (STERILIZED)			LIGHT	22	30,800	11
A641	0	12,500	LIGHT	22	77,000	341
A641	0	12,500	DARK	22	136,400	187
A641 (STERILIZED)			LIGHT	22	107,800	40
A638	33	1,500	LIGHT	22	8,600	106
A638 (STERILIZED)			LIGHT	22	13,000	18

FIGURE 4

The two counting periods are referred to as peak I and peak II.

Peak I reflects some of the inherent physical and chemcial properties of the soil being tested, and peak II is a measure of the synthesis of organic matter from the starting gases.

On the next slide [fig. 4] are some results from a series of terrestrial soils that were tested. These happen to be antarctic soil samples, soils with measurable, but low, populations of micro-organisms.

The essential point from these studies is that we developed two criteria, for determining the positiveness of a sample.

The first is that the count of peak I, as compared to the peak II number, turned out to be less than 500 to 1, when we had a positive sample, and, second, that sterilization always reduced the peak II, from a high number to a low number, as you see in these cases.

I want you to notice particularly this set of numbers at the bottom of the table where the peak II is about 100, and after sterilization there was a drop to 18.

When we conducted this experiment on Mars for the first time, we obtained numbers very similar to this last pair at the bottom: a peak I of 7.400 and a peak II of 96. This set of numbers satisfied our first criterion which requires a ratio of peak I to peak II of less than 500 to 1. Then when we heat-sterilized the Martian sample, and ran it again in the light, the numbers this time yielded close to 7,400 for peak I and only 15 for peak II. Thus the second criterion for positiveness was also met.

PYROLYTIC RELEASE, VL-1

EXPERIMENT No. CONDITIONS TEMPERATURE	1 LIGHT, DRY, ACTIVE 17 ±1°	2 LIGHT, DRY, CONTROL 15 ±1°	3 LIGHT, DRY, ACTIVE 13° - 26°
PEAK 1, CPM ABOVE BACKGROUND	7421 ±59	7649 ±60	6713 ±58
PEAK 2, CPM ABOVE BACKGROUND	96 ±1.15	15 ±1.29	27 ±0.98

FIGURE 5

Now, these results are shown in the next slide [fig. 5], and also included are results on the first lander in which we tried to duplicate the first experiment.

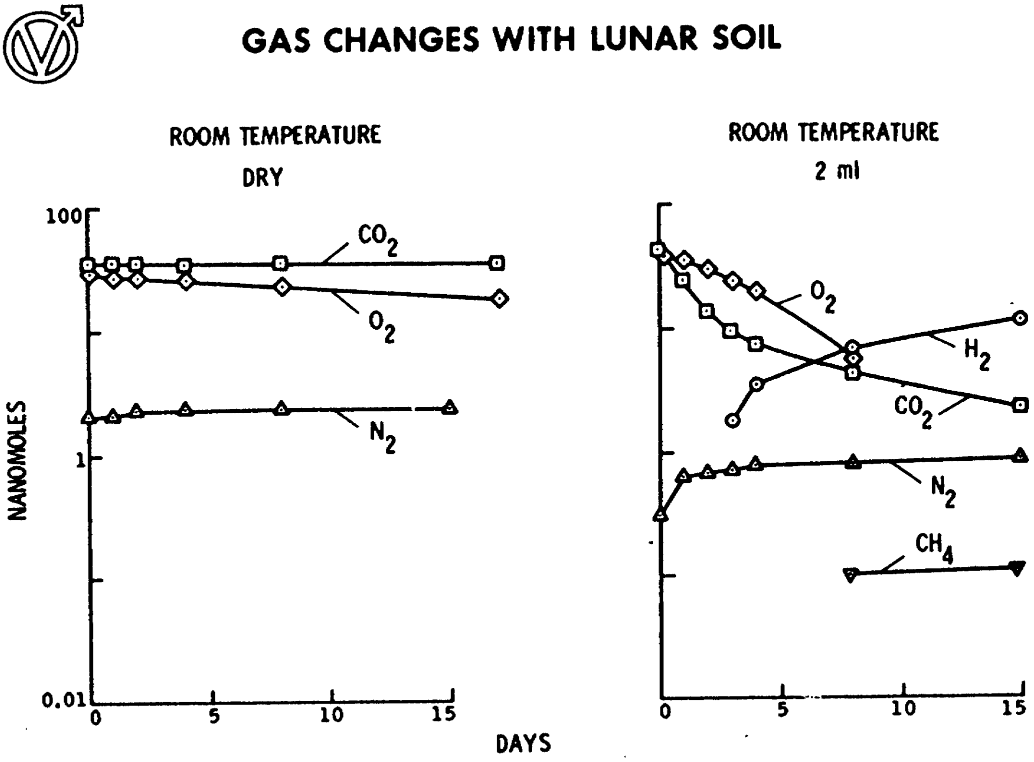
Unfortunately, during this third analysis, a set of thermoelectric coolers did not operate on the equipment for several days, and consequently, as you see from the table, the incubation temperature reached high levels, casting some doubt on the validity of this analysis as an exact duplication of the first one.

Nevertheless, even this last sample did just barely meet the 500-to-1 criterion for a positive.

Now, the one experiment on Mars for which the data obtained so far do not meet our predetermined criteria for a positive result is the gas exchange experiment of Vance Oyama, of the Ames Research Center.

This third experiment measures changes in the nature and amounts of gas in the atmosphere over an incubating soil sample in the presence of a solution of nutrients.

Much prior testing of this experiment demonstrated that many minerals, many inorganic materials in the soil, can react with water, which is used in this experiment, and that when these materials react with water, certain gases can be absorbed or given off. Therefore, the criteria for a positive result in this third experiment go beyond simple changes in gas composition.



GAS CHANGES WITH LUNAR SOIL

Figure 6

I will not go into these criteria at this time, but I will show an example on the next slide [fig. 6] of gas changes brought about nonbiologically. This happens to be a case in which lunar soil was assayed by this experiment. When the soil was made wet, there was an immediate absorption of oxygen from the atmosphere, and there was a rather immediate evolution of hydrogen gas. This process continued for several days, and then finally leveled off. These are however, inorganic reactions, none of them are to be interpreted as a biological process.

Now, when we performed this experiment on Mars, and first added water, the moisture did not cause a release of hydrogen as we see here, but instead oxygen appeared almost immediately. This very significant observation—of the release of oxygen from Martian soil when you wet it—was noted again at the Viking II landing site, although the amount of oxygen released was somewhat less.

Now, the importance of the finding that oxygen is released when you wet it, is that this told us that the surface material on Mars is unlike that of the Earth or of the Moon.

Mars apparently contains highly reactive oxygen-rich chemicals, which react with water to give off oxygen. Compounds of this type may also react directly with organic compounds, causing these compounds to be oxidized, at least in part, to carbon dioxide.

Clearly then the results in the first experiment I described, the labeled release experiment, now must be looked at in a new light. One need only postulate that solar or cosmic radiation induces on Mars the formation of reactive oxides, and that these reactive oxides may decompose the added nutrients, to explain all the results we have seen in the labeled release experiment.

Similar radiation-activated compounds could also possibly be involved in the second experiment. Thus the two experiments which gave positive results by our original criteria cannot be said to be conclusive at this time.

Mars has thus forced us to develop additional criteria beyond what we developed before we got to Mars, and for the remaining months of this investigation, we have modified our experiment strategy in an effort to resolve the ambiguities, and on the last slide, I want to show the total biology investigation time line, continuing through the conjunction period that was mentioned earlier, and on into the early part of the next year.

I do not have time to take you through this chart step by step, but I do want to mention some of the key features in this overall strategy and how we are trying to unravel the problem.

Mr. Fuqua. We have a rollcall going on, but we have a few minutes, if you would speed it up.

Dr. Klein. I have 1 more minute.

First, we are going to begin, in the next week, a cold sterilization.

This experiment could definitely rule out the presence of living organisms.

Second, we are developing a new sequence for the second experiment, which again could rule out life.

Third, during the first quarter of next year, we are proposing to do some cold incubations, in which we could get results that would strengthen the case for living systems on Mars. Finally, we are running some very long incubations which will allow very slowly-metabolizing systems, to accumulate enough products to be recognized as a living process. So in conclusion, we have a long way to go yet with these biological experiments.

We have to be patient and to try all of the procedures we have left in our arsenal. I believe that by the time we complete all these projected tests, we will be much closer to a solution to the enigma that confronts us now.

Thank you.

Mr. Fuqua. Noel, is it possible to try to accelerate.

We do have a few minutes, and I am afraid when this rollcall is over, we have a conference report coming up that affects the committee, and some of us may not be able to come back.

Mr. Martin. I would like to ask Dr. Gerald Soffen just to say a few words about some of the other sciences.

STATEMENT OF DR. G. A. SOFFEN, PROJECT SCIENTIST, VIKING FLIGHT TEAM

Dr. SOFFEN. Mr. Chairman, it is nice to see you again.

I simply would like to make a few points that I think take home the message of Viking. The points on this viewgraph illustrate the major discoveries we have made to date.

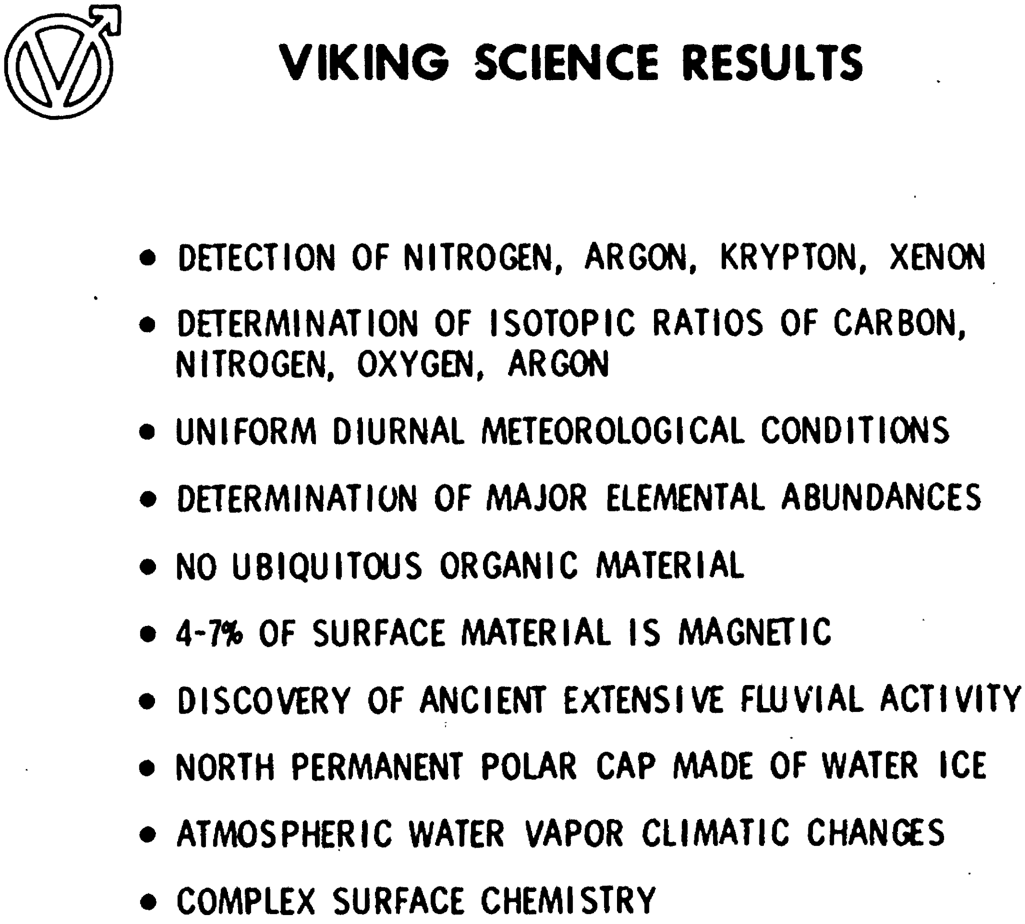
I will highlight in the few minutes I have here what I consider to be the things that Viking will end up being remembered for. I have listed at the top of this chart [fig. 1], and you can read as well as I can, those gases so important in reconstructing the atmosphere. One of the major things that distinguishes Mars from the Earth is its atmosphere. You have heard many words on the interest that the atmosphere has to those who are dealing with it.

I have also listed the changes in meteorological conditions that we observed with the meteorology experiment.

We find Mars right now to be a very benign planet.

We have looked for organic materials on Mars. To date we have not found anything.

That is the key to understanding, that biology is very coupled to the chemistry on the surface of Mars.



VIKING SCIENCE RESULTS

- DETECTION OF NITROGEN, ARGON, KRYPTON, XENON
- DETERMINATION OF ISOTOPIC RATIOS OF CARBON, NITROGEN, OXYGEN, ARGON
- UNIFORM DIURNAL METEOROLOGICAL CONDITIONS
- DETERMINATION OF MAJOR ELEMENTAL ABUNDANCES
- NO UBIQUITOUS ORGANIC MATERIAL
- 4-7% OF SURFACE MATERIAL IS MAGNETIC
- DISCOVERY OF ANCIENT EXTENSIVE FLUVIAL ACTIVITY
- NORTH PERMANENT POLAR CAP MADE OF WATER ICE
- ATMOSPHERIC WATER VAPOR CLIMATIC CHANGES
- COMPLEX SURFACE CHEMISTRY

FIGURE 1

We have measured the inorganic elements on Mars, but to date we have not found any organic materials.

We have measured magnetic materials, we have found 47 percent of it is magnetic, and one of the great controversies that has ranged over Mars in the last years is whether matter was magnetic on the surface.

The pictures we have coupled with the atmospheric tests, and we have for once ended that argument.

We now know there have been these great fluvial flood areas. We have seen them, and, in fact, they are consistent with the gaseous analysis that permits quite a bit of water to flow.

In the last few weeks we have made a major discovery on what the polar cap is made of.

You may remember that Mars has a permanent cap, and there was argument whether that is dry or with water; we now know it is water.

There is 10,000 times as much water locked in the polar cap as there is in the atmosphere.

We have seen some of the changes in the climate of the atmosphere, and as you heard from Dr. Klein in the last few minutes, there is a rather active chemistry on Mars that has baffled us, but that is the way science is, sometimes you open new questions.

Mr. FUQUA. What is the 47 percent of surface material as compared to Earth?

Dr. SOFFEN. On Earth, the thing that is unusual here, we see Mars as red, and, therefore, very oxidized.

To find this much magnetic material indicates that it is completely oxidized.

Mr. FUQUA. Is there an atmosphere on Mars?

Dr. SOFFEN. It is about one-hundredth of terrestrial atmosphere.

The thing that distinguishes the atmosphere, it changes on a seasonal basis.

Some of it is being frozen at the South Pole, and that is another discovery.

Mr. MARTIN. There is reason to believe, because of the finding, and particularly because of some of these gases and isotope ratios, that some millions of years ago, there was a much thicker atmosphere on Mars, perhaps approaching that of Earth.

Dr. SOFFEN. One particular interest of the stratosphere is trying to understand our own atmosphere, we are trying to understand the effects of the solar wind on Mars, to try to understand the Earth's atmosphere.

Mr. FUQUA. Is Mars an older or younger planet?

Dr. SOFFEN. We do not know the answer to that. That is one of the key questions that remains for the future.

Mr. MARTIN. Do we have time for one more speaker?

Dr. Carl Sagan, who is a member of the lander imaging team, and a member of the advisory staff.

Dr. Sagan?

STATEMENT OF DR. CARL SAGAN, MEMBER OF THE LANDER IMAGING TEAM

Dr. Sagan. Thank you very much. I will try to be very brief.

We are in the midst of the Viking mission, and it is still hard to get a true perspective on it; but I think it is already clear that it is a mission of historical proportions.

The amount of information we have already acquired from Mars through Viking exceeds the entire previous history of knowledge of the planet. Just to give one of many examples: 12 years ago, not so long ago, the smallest things that could be seen on Mars were about 100 miles across. The Viking lander permits us to see things that are less than a tenth of an inch across.

It is an improvement by a factor of 100 million in our ability, and the planet. Just to give one of many examples: 12 years ago, not so there are comparable improvements in non-imaging data.

The number of Viking firsts is extraordinary. I will not mention any of them in particular, because of the shortness of time—let me just say that they provide a set of perspectives on our own planet which many of us believe provides in itself a practical justification for the expenditures of funds on Viking.

There are many problems about our own planet which cannot be studied, because the problems are global in scope, and what is necessary is to perform experiments on other planets. Obviously we do not want to perform global experiments on the Earth, because we do not know enough to make such experiments safely.

The neighboring planets provide natural experiments on questions of weather, of climatology, and plausible results can be of immense practical benefit.

The question of life on Mars is, as you have heard, an open question.

There are contrary and confusing and even enigmatic results. What I would like to stress though is that the least interesting case is still of major importance.

The least interesting case is that the inorganic chemistry on Mars duplicates the many essential steps of biological chemistry on the Earth.

If that is true, similar processes must have occurred on Earth, before there was life on this planet. That means we are very likely learning important information about the origin of life on Earth, even if Mars is lifeless. We do have with the Viking extended mission a chance to learn a great deal more. I would say without even knowing whether the answer is an exotic biology, or an exotic chemistry, we have learned a great deal about life on Earth from our exploration of Mars.

How can we exploit the atmosphere that Viking has provided for exploration, discovery, and public excitement for science?

We have landed in only two places on the planet. We have looked close-up at only one ten-millionth of the surface area of the planet. We know from orbit that the planet is extraordinarily heterogenous and interesting, much more interesting than the places we landed on.

We chose those places because of their blandness and because of safety reasons. We know there are many other places more interesting: we know of fluvial tectonic, volcanic, and perhaps glacial processes on Mars, but we have not examined them close-up. The answer is clearly to land in a safe place, and then to move to an interesting place. That is one of the reasons why a rover mission system, to many of us, is an obvious follow-on to Viking.

Such a mission, for example, could rove to its own horizon every day. You can see a thing of interest in the distant horizon, rove to it before the day is done, look at it close up, and then go to the next interesting thing, and that could continue for traverses hundreds of kilometers in length.

Mr. FUQUA. In some of the photographs we have seen, particularly on Viking II, there have been some rather large rocks and boulders. Could a vehicle be designed in a practical way to be able to rove and not tip over?

Dr. SAGAN. The answer seems almost certainly to be yes. There are two methods you would use.

One is that the machine itself would have hazard avoidance techniques. The simplest of these are common in tabletop mechanical toys.

There are some that will wander over the table, bump into something, and turn around. Others in effect know not to run off the table.

That technology is pretty much in hand, and in really difficult cases, it can ask for advice from Earth.

Mr. MARTIN. That was work done in support of the lunar rover program on Apollo, that developed tracks, almost like caterpillar tracks.

There has been a scale model built, and I believe it would crawl over these kind of surfaces, rocks of say up to a foot high, without even bothering——

Mr. FUQUA. But some are taller than a foot high.

Mr. MARTIN. You would have to avoid the very big ones, but I believe we can see our way to program that vehicle to go around those, and then as Carl mentioned, have some simple features, hazard avoidance, that would stop the machine if it ran into something like that.

Mr. FUQUA. Have you talked to Dr. Hinners about this?

Mr. MARTIN. Well, yes, I have talked to Dr. Hinners at some length.

Dr. SAGAN. We did a study at Langeley in 1974, using some of the information that Marshall Space Flight Center had developed on Apollo.

It appears to us to be quite feasible. We do have a third orbiter, right now in storage, and I would just like to add too that I believe we have some very important unanswered questions.

We probably need a different complement of science. For example, I would like dearly to drill down into the ground, and see what is down there, a matter of a few feet, away from the ultraviolet light, and maybe down into the permafrost area.

For understanding about life on Mars, exploring the past history on its climate, and for the relatively inexpensive exploration of another world, the rover is the obvious mission of choice.

Mr. FUQUA. Any questions?

Mr. EMERY. No questions.

Mr. FUQUA. I do apologize for the time problem that we have run into.

It is very exciting.

What is your price estimate on the rover?

Dr. HINNERS. We are in the midst now of looking at options for follow-on programs, what they might be.

Of course, we are under our OMB restrictions on discussing this. We would have to have something to come back to you and discuss it at another session.

Mr. FUQUA. I do want to thank you. I am sorry to cut this short. It does not in any way diminish our interest, and the importance of a very fine mission that you gentlemen have performed, and we are keeping our fingers crossed. After a bumpy start, the Viking landers seem to be working well, and again, I want to congratulate you, Mr. Martin, and all of the people on the team for a very fine job that you have done, and I hope you will relate to the rest of the members of the team our congratulations for a job well done.

Mr. MARTIN. Thank you, Mr. Chairman.

We appreciate the opportunity to be here. I just want to mention we brought with us a package of materials which includes copies of Science, that have all of the science data that we have covered today.

Mr. FUQUA. Yes, I have seen them. They are very good.

Mr. MARTIN. Thank you, sir.

Mr. FUQUA. Again, I apologize for cutting you short in your presentation, and I do appreciate very much the success of your mission.

I look forward to hearing more from you in the future.

The subcommittee stands adjourned.

[Whereupon, the subcommittee was adjourned at 2:50 p.m.]

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