EarthDate

Life on Mars?

The official mission logo for NASA's Viking program. The Viking landers carried the first experiments designed to search for life on the surface of Mars.

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Is there life on Mars? That's the question NASA wanted its first Mars mission to answer – in 1976.

They designed their remarkable Viking rover -- well before modern computers -- to collect and test soil samples, 140 million miles from Earth.

First, Viking added a nutrient solution to the soil, looking for carbon dioxide that microbes would produce if they consumed it. And the test showed a small amount!

Next, Viking incubated the sample to see if microbes, if present, could produce organic matter. A tiny amount was detected! But the third test would be conclusive. The rover incinerated the soil to gasify its compounds, then used a spectrometer to evaluate them. If there were organic matter, it would surely show up. But it didn't.

At the time, the answer was: no life on Mars.

Several decades later, subsequent missions, using different tests, did find signs of microbial activity. So NASA went back to review the Viking data. With 50 years of new understanding, many scientists now believe that salt compounds in the Martian soil, when heated, would have destroyed any organic matter. Meaning Viking's gas test may not have been designed or understood correctly.

Today, there's still no solid proof that Mars has microbial life. But new -- and half-century old -- tests haven't ruled it out either!

I'm Scott Tinker.

Background: Life on Mars?

Synopsis: The 1976 Viking landers carried out the first experiments designed to search for life on Mars. Puzzling and conflicting experiments led NASA to report that the results were caused by unusual Martian soil chemistry. Fifty-years later, new discoveries about Mars are prompting scientists to reconsider the conclusions about life on Mars and elsewhere.

Vikings on Mars

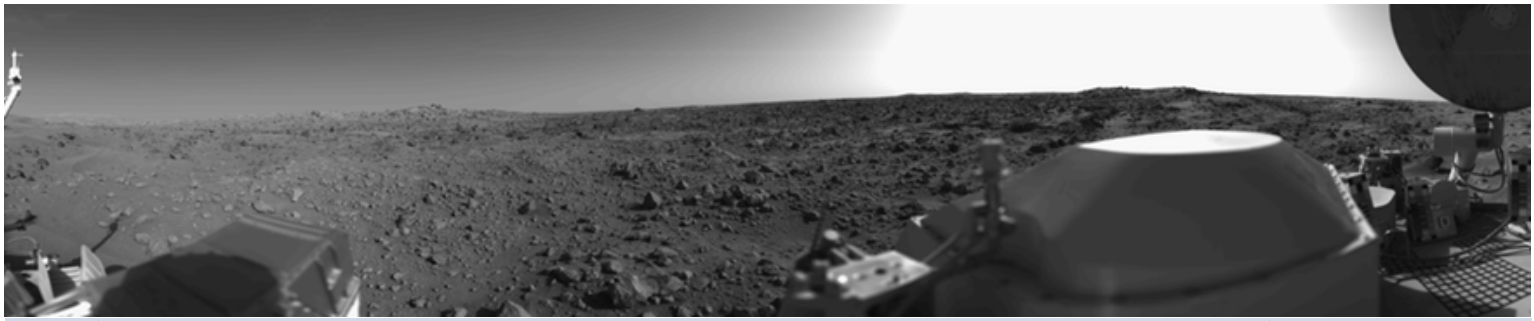
- In the summer of 1976, Earthlings got their first-ever, close-up look at the surface of planet Mars.
- NASA's Viking 1 and 2 orbited the Red Planet and sent high-resolution images of the Martian surface.
- Both orbiters circled the planet for about a month before detaching landers at two different locations on the surface, becoming the first spacecraft to land successfully on the Martian surface.
- The landers were charged with many objectives including studying the chemistry, biology, weather, magnetic properties, and physical conditions of Mars' surface and atmosphere.
- But the big question on everyone's mind was "Is there life on Mars?"

Viking Lander Observations

- Both landers monitored and collected weather data at the landing sites, and recorded cyclical, yet extreme conditions.
- At the landing location of Viking 1 in the Chryse Planitia (Golden Plains) region, temperatures only reached 7°F (-13.9°C) during the day and plummeted to -107°F (-77.2°C) at night, during Mars summer.
- When compared to suitable living conditions on Earth, these temperatures were deemed unsuitable for life to exist.
- Measurements revealed intense ultraviolet radiation at the surface and extremely dry soil.
- Mars appeared to self-sterilize, with harsh conditions and an oxidizing soil chemistry containing reactive compounds that can destroy organic molecules needed for life.
- These reactive chemicals could also interfere with experiments designed to detect traces of organic material.

Testing for Life

- While the amazing images and information about the physical properties of Mars were wondrous, the most anticipated findings were from experiments designed to test for signs of life.
- Labeled Release Experiment
  - The goal of the experiment was to test Martian soil for signs of microbial metabolism. Metabolism is a set of chemical reactions living organisms use to break down nutrients for energy. In many microbes, this process releases carbon dioxide as a waste gas.



Viking 1's first panoramic view from the surface of Mars in 1976. The blurred structure at left is the housing for the lander's soil-sampling arm, and the distant horizon features are about three kilometers (1.8 miles) away.

Credit: By "Roel van der Hoorn (Van der Hoorn)" - Own work based on images in the NASA Viking image archive., Public Domain, https://commons.wikimedia.org/w/index.php?curid=2407343

Background: Life on Mars?

- Viking placed a soil sample in a sealed chamber and added a nutrient solution labeled, or tagged, with radioactive carbon-14.
- If microorganisms were present, they would consume the nutrients and then release radioactive carbon-14 carbon dioxide, which the instrument could detect.
- The experiment detected this radioactive carbon dioxide in untreated soil and both Viking landers, located 4000 miles apart, gave similar, repeatable, and positive results.

- Pyrolytic Release Experiment.
  - The experiment was designed to test whether Martian microbes might build organic material from carbon in the atmosphere.
  - "Pyrolytic" refers to heating a sample to high temperatures to break down materials and release gases for analysis.
  - A sample of Martian soil was exposed to light, water vapor, and a simulated Martian atmosphere containing radioactive carbon-14 tagged, carbon monoxide and carbon dioxide.
  - If photosynthetic microorganisms were present, they should incorporate the radioactive carbon into organic matter (increasing biomass) through carbon fixation.
  - After incubation, the soil was heated to release any newly formed organic material. The instrument detected a small radioactive signal, and the initial assessment showed a "small but significant formation of organic matter occurred."
- Gas Chromatograph – Mass Spectrometer (GC-MS) Experiment
  - This instrument can identify the chemicals in a gaseous sample. It first separates the different gases in the sample and then measures the mass of their molecules to determine what compounds are present.
  - The Viking GC-MS heated Martian soil samples to 248°F (120°C) to drive off gases loosely trapped in the soil, especially CO_2 from the Mars atmosphere, that might have stuck to the sample container or soil itself.
  - It then heated the sample to 1166°F (630°C) to vaporize any organic compounds for analysis. The gas chromatograph can only test gases.
  - Scientists expected to detect organic molecules, which should exist on Mars from meteorites and cosmic dust that have accumulated over billions of years.
  - Instead, the instrument detected a second burst of carbon dioxide along with small amounts of methyl chloride and methylene chloride.
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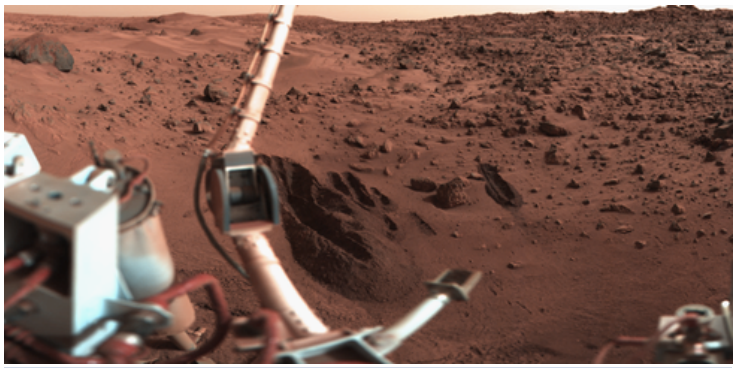
  - Scientists suggested that a strong oxidizing chemical in the Martian soil might have destroyed organic compounds before they could be detected.
  - The chlorinated compounds (methyl chloride and methylene chloride) were initially thought to be contamination from cleaning solvents on Earth, because similar chemical had been detected during tests before the spacecraft reached Mars.



The Viking 1 lander's sampling arm dug trenches in the Martian soil while collecting samples for the lander's chemistry and biology experiments. Some trenches were made deeper to study soil that had been less affected by solar radiation and surface weathering.

Credit: By "Roel van der Hoorn (Van der Hoorn)" - Own work based on images in the NASA Viking image archive, Public Domain, https://commons.wikimedia.org/w/index.php?curid=5796686

Interpreting the Results

- Two of Viking's biological experiments, Labeled Release and Pyrolytic Release, produced results that could be interpreted as evidence of microbial activity.
  - The increase in CO_2, with the C-14 marker, indicated metabolism occurred in the Labeled Release experiment.

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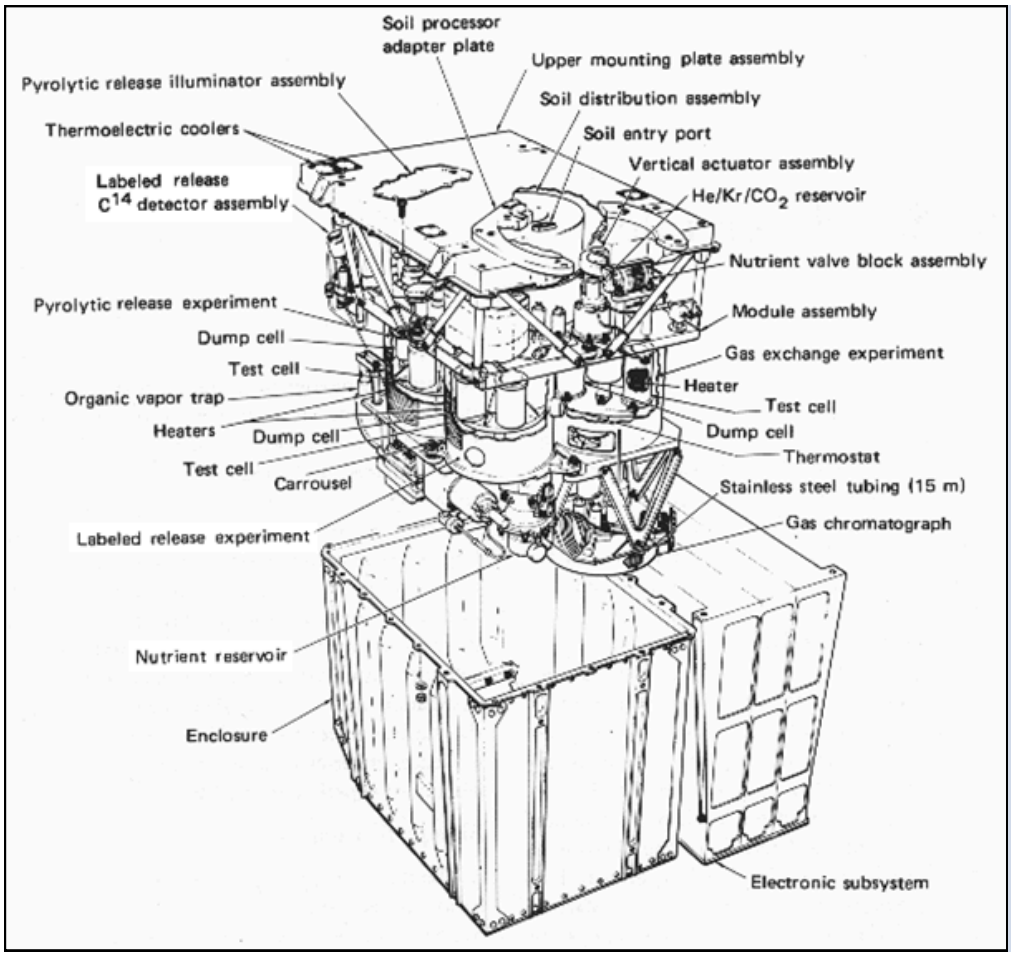

About the size of a square foot, the Viking biology experiment package contained the instruments used for the Labeled Release, Pyrolytic Release, Gas Exchange, and Gas Chromatograph tests.

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- The absorption of C-14 in the Pyrolytic Release experiment would imply that photosynthesis occurred.

- However, the GC-MS experiment did not detect organic molecules in the Martian soil.
- Meteorites and cosmic dust often contain organic molecules formed in space, and billions of years of impacts should have delivered at least trace amounts of these carbon-based compounds to the Martian surface.
- Because no organics were detected, the Viking science team concluded that the reactions seen in the biology experiments were most likely caused by unusual chemical reactions in the soil rather than living organisms.
- They suggested that a powerful oxidizing compound, possibly a type of peroxide, could have caused the release of the radioactive carbon dioxide, oxygen, carbon fixation signals.
- Based largely on the GC-MS results and this interpretation, NASA concluded that the Viking mission had not found evidence of life on Mars, and that the results were most likely caused by unusual soil chemistry.

Revisiting the Viking Results

- Decades after the Viking missions, newer Mars missions discovered that organic molecules do exist on Mars. The Curiosity (2012) and Perseverance (2021) rovers have confirmed their presence, often preserved within rocks.
- Scientists also discovered that Martian soil contains perchlorate salts, highly reactive chemicals that can break down organic molecules.

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- When organic molecules are heated in the presence of perchlorates, they can produce carbon dioxide and chlorinated gases such as methyl chloride, similar to the compounds detected by Viking's GC-MS instrument.
- Laboratory experiments showed that organics mixed with perchlorates could produce exactly the gases Viking measured, suggesting the instrument may have detected the breakdown of organic molecules rather than their absence.
- Some researchers have also suggested that adding liquid water during the Viking experiments may have harmed any microbes present, since possible Martian organisms could be adapted to extremely dry conditions and rely on salts that absorb moisture from the atmosphere. (See the EarthDate episode on Antarctic Dry Valleys).
- Because of these discoveries, scientists now realize that Viking's results may have been influenced by Martian soil chemistry in ways they did not yet understand.

Science in Progress

- When the Viking landers arrived on Mars in 1976, scientists designed their experiments based on what they knew about life on Earth. Living organisms require liquid water, carry out metabolism, and use carbon-based chemistry.

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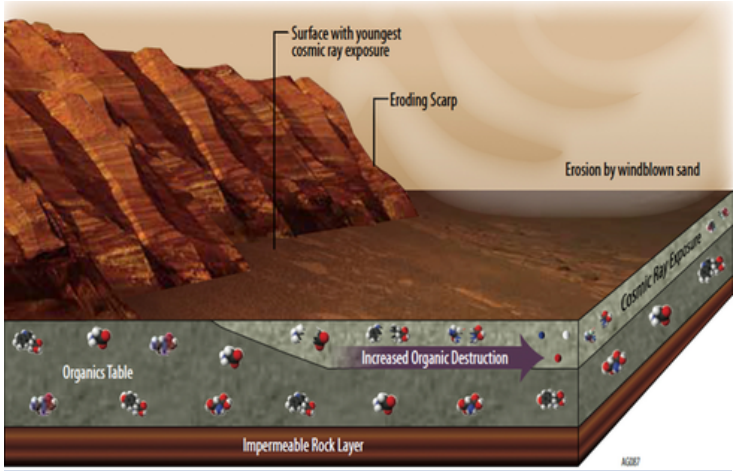

Organic molecules on Mars can be altered or destroyed by cosmic radiation, ultraviolet light, and oxidizing chemicals in the soil, making them difficult for spacecraft instruments to detect.

Credit: By Courtesy NASA/JPL-Caltech, Attribution, https://commons.wikimedia.org/w/index.php?curid=38278651

- But Mars proved to be more chemically complex than scientists realized at the time.
- As new missions and new discoveries reveal more about the Martian environment, scientists are revisiting the Viking data with fresh perspectives.
- This is how science progresses. Researchers interpret results using the best knowledge available, and new discoveries can change how earlier evidence is understood. In other words, science is rarely "settled."
- Fifty years after Viking landed on Mars, its puzzling experiments are still helping scientists learn how to search for life beyond Earth and reminding us that life, even on Earth, can thrive in places once thought impossible.

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