



# Is a Mars Sample Return Mission too Risky? A Public Hearing Case Study

by

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*“You have to remember two things: One is that the Viking Landers landed in what would be more or less desert areas of Mars in order to find a very safe place on which to land, and so that kind of reduced the probability of finding organic material on the planet should it be there. Secondly, the sensitivity of that GCMS we sent there over twenty years ago is far less than the sensitivity that we are talking about here that we are applying with our Earth-based techniques.”*

—Wesley T. Huntress, Jr., Associate Administrator for Space Science at NASA Headquarters at the 7 August 1996 NASA *Life on Mars* Press Conference.

*“I’ve been shot down for my thoughts concerning life on Mars by people who kept saying the truth is in the simple explanation. For a long time, it was easier to explain my results with chemistry, which argued against life. But now, it appears the chemical explanation may be too complicated, and that life may be the simplest answer.”*

—Dr. Gilbert Levin, designer of the labeled release experiments carried on the Viking landers, *Chemical Innovation*, 2001, 31, 12-16.

*“Perhaps Martian samples can be safely returned to Earth. But I would want to be very sure before considering a returned-sample mission.”*

—Carl Sagan, *Cosmos*, p. 129.

## **Background and Setting**

In 1976, the National Aeronautics and Space Administration (NASA) landed Viking 1 and Viking 2 probes on the surface of the planet Mars with the express intent of searching for signs of life. While one of the “life detection” or microbiology experiments seemed to strongly suggest the presence of possible microbial life, a sensitive analytical device known as a gas chromatograph-mass spectrometer (GC-MS) failed to detect the presence of any organic material in Martian soil. This surprising result, especially in wake of evidence of organic material in lunar soils collected by the Apollo missions, suggested that organic molecules derived from meteoric material (which impact Mars continually) that should be present in the Martian soil were somehow being destroyed. A hypothesis was developed to explain the absence of these organic molecules by an “oxidation mechanism” that would decompose organic molecules into simpler substances, such as carbon dioxide. This also implied that life based on carbon could not exist on Mars. However, in over two decades of searching, no “oxidants” have ever been found on Mars. In addition, several of the assumptions that argued against life on Mars have been shaken by new discoveries, including the ubiquitous presence of microbial life in even the most

inhospitable Earth environments, telescopic evidence of water on the Martian surface, and the presence of organics in Martian meteorites. Thus, a re-examination of the original Viking experiments and data have regained a spotlight in the media.

As early as 2011, NASA plans to launch a probe to the planet Mars, collect Martian soil samples, seal them in a canister, and then return them to the surface of the Earth. Proponents of the so-called Mars Sample Return Mission assert that acquiring soil samples on Mars and studying them in Earth-based laboratories is the most effective way to remove the ambiguity surrounding the interpretations of Viking data, and would permit direct microscopic observation of the soils for the presence of putative Martian microbes. Opponents of the Mars Sample Return Mission passionately believe such a mission could be extremely dangerous to the Earth's ecosphere, and possibly lead to a global public health epidemic or even extinction of the human species. Opponents of Mars Sample Return point to examples in fictional literature of the disastrous consequences of extra-terrestrial contact — H.G. Wells' *War of the Worlds* and Michael Crichton's *The Andromeda Strain* — in an attempt to influence public opinion to kill funding for the mission. Proponents of the Mars Sample Return Mission tend to argue that even if life does exist on Mars, their opponents exaggerate the risks to life on Earth, and maintain that possible “back-contamination” is remote.

In this scenario, fictional Senator Mark O'Neil, Chairman of the United States Senate Standing Committee on Commerce, Science, and Transportation, has convened a public hearing on the Mars Sample Return Mission. Budget deficits and increasing criticism from the international community have forced the committee to reconsider the mission. The setting is the United States Senate Floor in Washington DC sometime in the early 21<sup>st</sup> century. The Senators have brought three expert witnesses on a panel to testify in this public hearing on whether to continue funding for the Mars Sample Return Mission. The first expert is Dr. Heinrich Grossman, a physicist and the Planetary Protection Officer for NASA, who strongly supports the mission. The second expert witness is Dr. Floyd Dow, a professor of biochemistry from the University of California at Los Angeles and scientific consultant to the International Committee Against Mars Sample Return (*ICAMSR*). The third expert witness is Dr. Elizabeth Cruz, a geologist with NASA's Ames Research Center. Dr. Cruz takes a more neutral viewpoint, somewhere between that of Dr. Grossman and Dr. Dow. The scene opens with Senator O'Neil initiating the questioning of Dr. Grossman.

**Image Credit:** Image of Mars taken by the Hubble Telescope on June 26, 2001. Upon its release date (July 5, 2001), this photograph was considered in many circles to be the “best” photograph ever taken of the Red Planet from an Earth-based telescope. NASA and The Hubble Heritage Team (STScI/AURA). Acknowledgment: J. Bell (Cornell U.), P. James (U. Toledo), M. Wolff (Space Science Institute), A. Lubenow (STScI), J. Neubert (MIT/Cornell). Image and further details can be viewed at [http://hubblesite.org/news\\_and\\_views/pr.cgi.2001+24](http://hubblesite.org/news_and_views/pr.cgi.2001+24).

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## Hearing Transcript

SENATOR O'NEIL: Dr. Grossman, could you tell us what your job function is at NASA?

DR. GROSSMAN: As Planetary Protection Officer, it is my job to certify all missions in which spacecraft launched from Earth are planned to be returned.

SENATOR O'NEIL: And in the case of the Mars Sample Return Mission, you have certified the mission, is that correct?

DR. GROSSMAN: That is correct, Senator. I find no substantive reasons to prevent the Mars Sample Return Mission from taking place. The risk of "undiscovered" Martian life posing hazards to life on Earth is, at best, miniscule.

SENATOR O'NEIL: Upon what basis do you make that assessment?

DR. GROSSMAN: First of all, in the critical Viking gas chromatograph-mass spectrometry, or GC-MS experiment, no organic compounds were detected in the Martian soils. Organic compounds are molecules containing hydrogen and carbon. Now organic molecules don't necessarily have to result from biological processes — but on Earth all organisms are based on organic molecules. No organics — no life.

DR. DOW (SHOUTING): Excuse me Mr. Senator, but Dr. Grossman is NOT giving you the whole picture on the Viking GC-MS results.

SENATOR O'NEIL: In your view what is being left out, Dr. Dow?

DR. DOW: The Viking GC-MS experiment was flawed. First, Martian soils were heated in an oven to 500 degrees Celsius. These molecules became vaporized, and were carried by the gas chromatograph, or GC, through a long column by hydrogen gas. I have a diagram of the device. [Dr. Dow puts up an overhead, a diagram of the GC-MS device, a copy of which is included at the end of this transcript.] Now the mass spectrometer, or MS, part of the device only functions at low pressure, so the hydrogen carrier gas must be separated from any organic molecules prior to introduction into the MS. This is done using the hydrogen separator here in the diagram. The problem, sir, is that the hydrogen separator on the Viking landers was made of a palladium-silver alloy.

SENATOR O'NEIL: What is, in your opinion, the problem associated with a palladium-silver alloy?

DR. DOW: As stated in the Ph.D. thesis of John Lavoie, Jr., a student of Dr. Klaus Biemann, the Principal Investigator of the Viking GCMS experiments, "it seems appropriate to also mention the fact that many sulfur and iodine-containing compounds may poison the palladium surface of this device, which will severely reduce hydrogen permeations. At high concentrations such compounds can permanently inactivate the palladium." Senator, the levels of sulfur in Martian soil are 50 to 100% more abundant than they are on Earth.

SENATOR O'NEIL: Dr. Cruz, what do you have to say about the GC-MS experiments?

DR. CRUZ: Well, both of our experts are correct. The Viking GC-MS didn't detect any organic molecules, and sulfur could potentially inactivate the hydrogen gas separator, essentially making it impossible to inject organic molecules into the mass spectrometer. I, for one, am fairly certain that organic molecules should exist on Mars, sir. GC-MS analysis of lunar soil samples collected in the Apollo missions clearly show that when heated to 1000 degrees Celsius, anywhere from 0.1 to 10 parts

per million is due to complex organic molecules. We planetary geologists explain the presence of organics on the moon as coming from impacts of comets and meteors, which contain such molecules. Mars, which is close to the asteroid belt, is certainly bombarded with such debris even now. There should be organic molecules there.

SENATOR O'NEIL: But clearly the Viking missions didn't detect any organic molecules, Dr. Cruz. Assuming the GC-MS devices were working, how do you explain that?

DR. CRUZ: Sir, NASA Ames research analysis of the meteorite ALH84001, which possesses all the characteristic signatures of isotopic composition consistent with an origin on Mars, clearly shows polyaromatic hydrocarbons, or PAHs, a class of organic molecules, deep within the rock. The organic material inside the meteorite contains no detectable amount of carbon-14. Sir, the half-life of carbon-14 is about 5700 years. Our techniques for detecting carbon-14 are very sensitive, Senator. The lack of carbon-14 deep within ALH84001 and other identified Mars meteorites subsequently found to contain PAHs suggest the PAHs didn't come from contamination due to organics on Earth. It is without question that at some point in its geological history, conditions on Mars were such that organic molecules were present.

SENATOR O'NEIL: Drs. Grossman and Dow, do you agree with Dr. Cruz's assessments?

DR. GROSSMAN: The scientific community is in general agreement about the non-Earth origin of the carbon in ALH84001 and the other Martian meteorites.

DR. DOW: I agree completely with the others.

SENATOR O'NEIL: But are there any other mechanisms that might explain the absence of these organic molecules in the Viking GC-MS, besides equipment failure?

DR. GROSSMAN: Well, yes. The judgment of the Viking scientific team was that the failure to detect any organics, which we agree should be present, was due to a mechanism of oxidation of the organic molecules in the soil into simpler species like carbon dioxide. We believe the high ultraviolet radiation on the surface of Mars can produce powerful oxidizing species that break down the organics.

DR. DOW: No one has found these "powerful oxidizing species" in the soil or in the atmosphere of Mars! The argument is a red herring. The oxidant hypothesis has failed the test of time.

SENATOR O'NEIL: Dr. Cruz, is Dr. Dow correct? Have powerful oxidizing species been detected in Martian soils or atmosphere or not?

DR. CRUZ: Dr. Dow is correct, sir. NASA scientists have failed to detect any such oxidizing species in the atmosphere. More recently, we have shifted our attention to species that might be formed in soils and would be difficult to detect from Earth. A recent experiment by Albert Yen's group at the Jet Propulsion Laboratory produces such oxidizing species when exposing soil to ultraviolet radiation under Martian atmospheric conditions.

SENATOR O'NEIL: So these oxidizing species might be destroying organic molecules?

DR. CRUZ: That's right. It is also consistent with Dr. Stephen Benner's explanation of why no organics were detected by the Viking GC-MS.

SENATOR O'NEIL: Dr. Cruz, could you enlighten us on Dr. Benner's hypothesis?

DR. CRUZ: It's very simple actually. What he discovered was that under certain oxidizing conditions, PAHs and other hydrocarbons produce salts of benzenecarboxylic acids, and perhaps oxalic and acetic acids. Such products are oxidation-resistant and stable. They are also nonvolatile, which is a key point. The Viking GC-MS was designed to analyze only volatilized organics produced by heated soil samples. Dr. Benner's results indicate that a whole class of organic compounds may have been missed during the Viking analyses, whether produced by biological or nonbiological processes.

DR. DOW: Dr. Cruz is exactly right. In addition, there are questions as to whether the Viking GC-MS device was sensitive enough to detect organic molecules at concentrations below 1 part per billion. If microbial life exists on Mars, it wouldn't be a stretch to say organics would be present at concentrations below 1 part per billion. That's what we see when we test Antarctic soils containing microbial life.

SENATOR O'NEIL: Dr. Grossman, do you concur?

DR. GROSSMAN: It is possible the Viking GC-MS did not have the requisite sensitivity.

SENATOR O'NEIL: Well, from my perspective there are a number of theories that can explain the Viking GC-MS results. Dr. Dow, you're the biochemist. Tell me why the Viking GC-MS results are so important.

DR. DOW: Aha, we get to the crux of the problem! Senator, the Viking GC-MS results were used to call into question the "positive" results of Dr. Gilbert Levin's labeled release experiment, which indicated possible — indeed, in my opinion probable — life on Mars.

SENATOR O'NEIL: Explain for us, Dr. Dow, the labeled release experiment.

DR. DOW: Gladly. Labeled release was an experiment designed to test whether there was any evidence of microbial metabolism in Martian soil samples. It is inherently 10,000 times more sensitive than the Viking GC-MS. If something's alive, it has to eat something else, or take in gases and light to synthesize molecules needed to maintain it. What Dr. Levin did was to provide organic nutrients labeled with carbon-14 in a solution that was applied to the soil samples. If there were living organisms present, they would consume the nutrient and eventually give off radioactive carbon dioxide as a waste product. Interestingly, the labeled release detector showed carbon-14 labeled carbon dioxide being given off in seven of nine experiments taken on Viking.

DR. GROSSMAN: Two of the experiments showed nothing. You can't explain that away!

DR. DOW: Perhaps those two samples contained no microbes.

DR. GROSSMAN: The Viking team concluded that the labeled release results could be explained by a catalytic reaction that takes place in the Martian soil, leading to carbon dioxide release. Dr. Dow and I have argued this point many times. Carl Sagan and others showed that certain clays could catalyze this carbon dioxide release.

DR. DOW: Clays can do this, yes. That doesn't mean the Martian soil is similar to the clays examined by Sagan. Dr. Grossman, you know better! At any rate, Senator, the most compelling evidence in the labeled release experiment has not been discussed. When a soil sample was heated to 40 degrees Celsius, close to our body temperature, radiolabeled carbon dioxide was released. But when the same sample was subsequently heated to 160 degrees Celsius, it showed no indication of labeled carbon dioxide being produced. There is only one reasonable interpretation of this result — heating to 160 degrees Celsius killed the microbes. A catalytic mechanism doesn't explain that result away. It is a clear sign of life.

SENATOR O'NEIL: Dr. Cruz, what is your interpretation of the labeled release experiments? Is Dr. Dow correct?

DR. CRUZ: A metabolic interpretation of the labeled release results is the simplest explanation, though not necessarily the only one. A chemical interpretation is much more difficult to support when one considers the results of the heated soil experiments. It isn't proof of life on Mars, but it is a compelling argument.

SENATOR O'NEIL: Very interesting. But in order for life on Mars to exist, doesn't there have to be water present? Where is the water?

DR. DOW: That is the nail in the coffin to Dr. Grossman's premise! When Viking went to Mars, we didn't know there was any possibility of water on the surface. However, NASA scientists, using high-resolution images taken by the Mars Orbiter, found gullies on Martian cliffs and crater walls that could have been formed by liquid water seeping to the surface in the geologically recent past.

SENATOR O'NEIL: Dr. Cruz, you're the geologist. Is this true?

DR. CRUZ: Well, there is no question that Mars Observer did take images of the surface that appear to be gullies formed in the recent geological past. Water could have come to the surface and formed the gullies. However, I would not be surprised if liquid carbon dioxide could have caused the same phenomenon.

DR. GROSSMAN: And you accuse me of exaggeration, Dow! He's an alarmist, Senator. I think you can see that.

SENATOR O'NEIL: I see our time is getting short. Could each of you make a final statement regarding your positions before we are forced to call this hearing to a close? Let's start with you, Dr. Grossman.

DR. GROSSMAN: Thank you, Senator, for allowing me the opportunity to testify before you today. Not one firm indication of microbial life on Mars exists. At best, the Viking results suggest a remote possibility of microbial life on Mars. There is no evidence to suggest such microbes, if they exist, are pathogenic. Furthermore, NASA has established strict quarantine procedures to prevent the accidental release of Martian soil samples. The risk of back contamination is small; the chance that extant microbial life is a pathogen is even smaller. The risk to Earth's ecosystem is minute. Yet you can see from our testimonies that there is a great deal of disagreement over the interpretation of the Viking experiments. Resolving those ambiguities by studying Martian soil samples in sophisticated Earth labs is the most compelling reason I can think of to justify a Mars Sample Return Mission. For the sake of the spirit of human exploration and discovery, it is my sincere hope that you will not choose to eliminate funding for the Mars Sample Return Mission.

DR. DOW: I cannot disagree more with Dr. Grossman's position. The evidence presented in this hearing clearly establishes the problems with the Viking GC-MS analysis, and the hypothesis to explain the absence of organic molecules by an exotic oxidation mechanism has not stood the test of time. Organic molecules are on Mars, and with future missions, we will hopefully detect them. The flawed Viking GC-MS results cannot explain away the results of the labeled release experiments, which give a strong indication of metabolism occurring in Martian soils. Dr. Grossman suggests there is a chemical explanation, but that is a much more complex argument than the simplest explanation that microbial life is there. Finally, we have experimental evidence and theoretical calculations to support the presence of water on Mars's surface, not in the distant past, but in the recent geological past. Some call me an

extremist, or an alarmist. But I say there is plenty of evidence to support extant microbial life on Mars. Perhaps such microbial life is totally harmless to humans. That does not mean Martian microbes could not affect other organisms and possibly wreak havoc on the food chain. Senator, I have two children. If there is even a remote chance that microbes exist on Mars, isn't it a risky scheme to bring Mars soil back to Earth? Even Carl Sagan said we must be sure Mars is devoid of life before we bring back a soil sample. Dr. Sagan is no longer with us, but I trust if he were here today he would agree with me. The Mars Sample Return Mission is risky. Is anyone in this room willing to risk their children's lives for this knowledge? If so, please stand up.

SENATOR O'NEIL: Dr. Cruz, I would appreciate your final thoughts.

DR. CRUZ: I think you can see my two colleagues are passionate about their positions. However, I am first and foremost a scientist and my view is, I believe, objective. What is known today was not known at the time of Viking. Organic molecules should be on Mars's surface from impact events, but we haven't detected them. Likewise, the oxidants proposed to destroy such molecules haven't been found either, and the Benner hypothesis suggests that even if oxidation is occurring on Mars now, a whole class of organic molecules wouldn't have been detected by the Viking GC-MS. The labeled release results taken on Viking are compelling, and certainly suggest the potential for microbial life on Mars. I believe it is far too early to speculate on the likelihood of water on Mars' surface. I believe, however, that time may resolve that issue. Is there life on Mars? I don't know. It is possible, but it hasn't been proven to my satisfaction. If there were microbial life on Mars, would I want to bring it back to Earth? Probably not. I saw the movie *The Andromeda Strain*. Trust me, I don't want to see nukes used to destroy the area where the sample landed if anything were to go wrong.

SENATOR O'NEIL: Well, thank you all for your scientific perspectives. The Committee will discuss your testimonies. This hearing is now adjourned.

## Study Questions

1. What evidence does Dr. Grossman use to suggest that life does not exist on Mars?
2. How does Dr. Dow call into question the Viking GC-MS analysis? What counter-evidence does Dr. Grossman use to attack Dr. Dow's hypothesis?
3. What is Dr. Cruz's evaluation of the likelihood of organic molecules on the surface of Mars? How do her colleagues respond?
4. How does the Benner hypothesis fit into the discussion of the Viking GC-MS results? Is it important?
5. Ultimately, why do the Viking GC-MS results play such a large role in the controversy of possible life on Mars?
6. Dr. Dow relies heavily on the labeled release results to support his position. How well do the labeled release results support the existence of microbial life on Mars? Are there any explanations? Are they believable?
7. The possible existence of water on Mars's surface appears to be an important piece of the puzzle. What lines of evidence does Dr. Dow use to support the existence of water on Mars's surface? How do Drs. Cruz and Grossman respond? Are any of their counter-arguments compelling?
8. Why might the presence/absence of liquid water on Mars's surface have no bearing on whether microbial life exists on Mars or not?
9. None of the experts presented statistical evidence to back up their claims of "risk." How might simulations have helped the senators evaluate the element of "risk"?
10. For those who have read the book and/or watched the movie *The Andromeda Strain*, what possible correlations do you see between it and the proposed Mars Sample Return Mission?
11. Based on the information presented, what should the senators do? What alternatives might the scientific staff at NASA consider that might be more politically palatable according to the pressures set forth in the section "[Background and Setting](#)?"



# Viking Gas Chromatograph-Mass Spectrometer (GC-MS)

