Nearly Forty Years after Viking: Are We Ready for a New Life-Detection Mission?

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*The Viking life-detection experiments, conducted nearly 40 years ago, are one of the great highlights and historic events of astrobiology. Until today they remain the only attempt at life detection on another planetary body. While the interpretation of their findings is still controversial, especially with regard to whether chemical reactivity, life, or possibly both were detected (*e.g., *Klein, 1999; Quinn and Zent, 1999; Benner* et al., *2000; Houtkooper and Schulze-Makuch, 2007; Levin, 2015), a scientific consensus has emerged that they were conducted too early, at a time when we did not understand the martian environment sufficiently. Life is intrinsically related to its surrounding environment, and we can understand life, and likely detect it, only if we thoroughly understand the environment. Since Viking, many other missions have been launched to investigate Mars, and our knowledge of the planet and its environment has increased exponentially. Is now the right time for another attempt to search for life on Mars? If so, how should we do it given the financial constraints? If not, what information do we still need before launching a life-detection mission to Mars or elsewhere? This roundtable discussion is an attempt to provide some insights on these questions by experts in the field.*

Dirk Schulze-Makuch: ***It is now nearly 40 years after the Viking life-detection experiments, which leads us to the question of whether we are ready for a new mission geared toward life detection. Steve, do you think we are ready?***

Steven Benner: Well, for this discussion to have any impact, we must address three realities: a scientific reality, a technological reality, and a sociological reality.

The sociological reality is that the United States government, to some extent, Europeans, certainly China, maybe also Russia, have the sociological motivation to launch a life-detection mission to Mars. Any one of them would love to have the political and social prestige of discovering life on Mars.

The technological problem, discovering life, is the same as we have always had, but better manageable because of miniaturization of electronics and other technological advances. Nevertheless, we do not have the ability to place a fully equipped craft or a fully staffed laboratory on the surface of Mars to aggressively explore for life and its context. On the other hand, technological problems of sample return prevent this from being a goal at this time.

But perhaps the most important is the scientific problem. We do not have a clear enough understanding of how life of any kind would manifest itself, to come up with a simple, technologically achievable instrument package that would produce results definitive enough to convince people who will seek to not be convinced. That is how science works; any claim of life discovery will be challenged. So it would be most productive for us on this panel to consider how that scientific problem can be addressed.

This was the problem in 1976. All the wet chemistry life-detection tests could, in some sense, be interpreted as positive. However, the mass spectrometry test was interpreted as negative because it did not find any substantial amount of organic material. We now know that interpretation is not necessarily correct in the form that it was phrased. So if you can address the scientific questions today, I think the technological and sociological questions will take care of themselves.

DSM: ***Steve, you brought a lot of issues up, and some of them we will definitely discuss later on. I would like to hear the panel's response to the question: are we ready for another mission? John, what do you think?***

John D. Rummel: If I were going to look at Mars and try to find those places where Earth organisms can live, which we just recently did and published in *Astrobiology* (Rummel *et al.,* 2014), I find that there are only a few places that are even close to supporting Earth life. But I think that some of them are certainly well within the scope of what we would like to find.

It is very technologically challenging to be able to take a clean spacecraft and land it on a slope to look at something like recurrent slope lineae. A place where liquid water or salt water may be flowing regularly on the surface of Mars would be the kind of place I would want to go—*if* it is warm enough and wet enough that Earth microbes could make a living there.

Aside from that, we have not found any other smoking guns. We have not found heat flow. We have not found subsurface water. And we do not land currently in places like Hellas Basin where you can get much more interesting precipitation issues and meltwater because of the increased atmospheric pressure. So I do think that we are close to being able to envision a life-detection experiment flying to the place where you would expect something similar to Earth life to possibly be. But we are a long way from actually being able to achieve that successfully. We have a lot of work to do in terms of how to land on Mars and put our bait into the appropriate fishing hole.

DSM: ***Okay. What do you think, Gil?***

Gilbert Levin: I think that science works on Mars just like it does on Earth. Since we had our labeled release experiment give a positive response, which has never been scientifically contradicted, the only thing that science would permit is that you go back and test that again. When you get a positive answer, you go back and seek to verify or disprove.

Now, no one disagrees that there was activity detected in the surface material of Mars. The dispute is over the source of that activity—chemical or biological. Therefore, it is very important to go back to that same area because you already have the response there. You want to check that response. My advice is to go back with a modified labeled release experiment that is capable of distinguishing life from chemistry.

I am very puzzled as to why this major scientific question has been allowed to sit idle, unattended, for four decades. So my advice is let us go back. I like the idea of a panel of experiments. That certainly can help. The idea of looking for metabolism instead of a snapshot of a simple molecule or a complex molecule is the way to go. That was the basis of the labeled release experiment.

Nothing really has been found on Mars in the 40 years since to preclude life, even terrestrial-type microorganisms, from growing there. So I say yes, let us go back.

DSM: ***Sam, what do you think? Are we ready?***

Samuel Kounaves: When I think about the question: are we knowledgeable enough to go back to Mars at this point? I would say I do not think we are. I think the discovery of 1% perchlorate by Phoenix, and then confirmation by the Mars Science Laboratory (MSL), shows how little we know about the surface chemistry of Mars.

How I feel right now is that we know enough about the surface chemistry to know that it is probably extremely hostile to life, and even organics, and that the only way we are going to be able to ever find a potentially habitable environment is to access deeper and deeper places, maybe meters or more underground.

We also need to know more about the surface chemistry, the inventory of organics and inorganics. We have not detected any reasonable complex biomolecules, even if MSL is given the benefit of the doubt, at this point.

The most recent data from all the perchlorate experiments shows that the surface is extremely highly oxidizing. We recently published a paper (Carrier and Kounaves, 2015) showing that perchlorate and other oxychlorines can be produced on chloride-bearing mineral surfaces without atmospheric chlorine or aqueous conditions, thus implying that oxychlorines and their highly oxidizing intermediaries are globally and temporally ubiquitous. Richard Quinn also published a paper in *Astrobiology* (Quinn *et al.,* 2013) showing that perchlorate radiolysis creates exactly the compounds you would need to create the exact results of the labeled release experiment and that there is no way you can create perchlorate without generating a tremendous amount of radicals—hydroxyl radicals (·OH) and chlorine radicals (·OCl). To expect anything other than some very simplistic organic molecules is not warranted by any of the data so far that we have seen.

So I do not think we are ready for a life-detection mission, but we are ready for a much more thorough exploration of the surface and especially the subsurface of Mars.

DSM: ***Victor, you are the principal investigator of the SOLID (Signs Of Life Detector) instrument. What is your opinion on this?***

Victor Parro: I think yes, we are ready to go back and try to look for life. Since Viking, we have learned much on the development of environmental microbiology. On Earth, we have learned that

microbes can live practically anywhere where liquid water is available. They do not need oceans. They just need water films, just a few molecules of water.
We know that they can metabolize at −15°C at high salt concentration. They can live bound to minerals in the deep subsurface, thousands of meters underground. We have found that there are places on Earth that are analogues to other environments that have been described on Mars. And we have nice examples like the Antarctic Dry Valleys, the Atacama Desert, cold salty springs in the high Arctic, Río Tinto, and the deep subsurface.
We now know much better the microbial metabolisms that might be operating in the different planetary environments, and perhaps this could help us develop new approaches for life detection—either for detecting biomarkers or new metabolisms.
For example, we know that microbes can use oxidized metals as an electron acceptor and their reduced forms as an energy source. They can use hydrogen as energy. They can reduce CO_2 to produce methane. They can respire sulfate, perchlorate, and nitrate. So there is now a great variety of anaerobic metabolisms known, and we should take advantage of this knowledge to design new methods for detecting life.
From the biological point of view, we are now much better prepared to search for life than we were in the 1970s, and we can design a set of experiments that can address this question.
DSM: ***There are organisms that can metabolize highly oxidizing compounds like perchlorates and hydrogen peroxide, although there is no question that the martian surface is, at the least, a very challenging environment. So that brings me to the question: what would you look for in a sample to identify life? And what type of life could we expect?***
SB: First, let me say that there is a distinction between kinetic oxidation potential and thermodynamic oxidation potential. There is no question that potassium perchlorate is a strong oxidant by any thermodynamic measure. However, perchlorate at low temperatures is actually very kinetically stable; thus, nobody worries about the destruction of organic molecules in a water solution of potassium perchlorate. In fact, classic physical organic chemistry experiments used 1 molar potassium perchlorate to keep ionic strength constant when setting an organic reaction, since perchlorate is so slow to react.
Certainly, the process by which perchlorate is made the first place from chloride ions and hydroxyl radicals involves species that are easily oxidizing organic materials. However, if an organic material is embedded in a crystal, such as sodium chloride, the sodium chloride will protect it against oxidation.
Also, Dirk, as you mentioned, it is conceivable that a martian life form could make a living by metabolizing perchlorate, especially if it has a contact between an oxidant mineral like perchlorate and then, say, a subsurface reducing mineral, a serpentine, a basalt.
I think the bigger question, however, is the one about where you go to look. The interesting places are often inclines. They are on slopes, and NASA does not like to land on slopes for obvious reasons. So what I would do is first try to decide what an accessible site is.
Now, I do not think the sociology will tolerate simply going back to the same place that we went in 1976 and rerunning Gil's experiment. I think we would have to add chirality to that experiment. This would be an easy thing to do with today's technology.
I would also try to look at some different compounds, replacing formate, for example, by a less easily oxidized species such as acetate or, for that matter, lactate or any of the amino acids that have chirality associated with them.
I would want to know more about the geological context because that way I could make a better guess as to how the life was making a living. I would love to find an outcrop of a reducing mineral near an oxidizing mineral such as perchlorate. Then I would go there looking for the metabolism that involves the interactions of that energetic mineral oxidant with an energetic mineral reductant.
JDR: It would be nice to have the food laid out in front of you, and then you could watch for something that eats it.
DSM: ***So what should we do, then? Should we look again, like Gil did, at the labeled release***

experiment of the Viking mission, look for proof of metabolism, or should we look for something else? Maybe Gil could interject here first.
GL: From my experience, any molecule that is cited as a biomarker is not going to stand up against Occam's razor, because everyone will say it is easier to imagine that molecule having been created abiologically than to invent life to have made it. So I think the best answer is the metabolic one, and I would include, however, that it would be very good to send a video-recording microscope to look for motion.

I think the combination of a video camera that could take up-close, high-definition images and metabolic experiments would be excellent. However, I do ask the question: do you really think we should abandon the 1976 results, which everyone agrees show there was something highly reactive in the surface of Mars? Should we not find out what that was? We know there is something there. So again, I say, does not science direct us to go back there?

SB: Gil, when you say motion, would you complete for my benefit the phrase? Motion in what?

GL: In a close-up sample.

SB: Yes, but would that sample be a liquid?

GL: Some people advocate putting that sample in water. I would not do that. I think water is the enemy of life on Mars, except in thin films, as was discussed.

SB: But suppose the sample is a solid. Would you say that you can look for motion in a solid?

GL: Yes, if there is something there, there is streaming, there is motion. If you get a microscopic view of a cell, you will see streaming.

DSM: ***Is that along the idea from the paper by Kasas*** **et al.** ***(2015)?***

JDR: The Kasas *et al.* paper is an interesting one in that first you attach your biological sample to your atomic force microscope, and then you go from there. That first step would be sufficient for most of us to declare victory and not go ahead and worry too much about the rest, at least for the initial sample.

SK: Also, in that paper they do not really talk about the limits of detection. If you go back to some older papers, they are talking about a film of yeast that has grown on there, and then the observed effect is from the film of yeast, not from single organisms. That is a major problem.

There are several other life-detection methods out there. There have been some recently published on microfluidic platforms, for example.

It is not the actual life detection that is the problem. For me, as an analytical chemist, it is everything that goes on before doing that—all the sampling, all the planetary protection, all the definitive analysis. Making sure that you have not gotten contaminants, making sure that it is not a false positive or a false negative, that is our biggest challenge right now, because we can detect life, probably, with a variety of methods. We should send an array of methods, not just one method or one instrument but a large array of chemical instruments that will look at both the wet chemistry and dry chemistry, and a good enough mission that would take on a wide variety of parameters and give us as close as possible a definitive answer.

I am not speaking for NASA, but I have spoken to NASA people, and there is not going to be a mission unless it can return reasonably definitive answers, neither positive or false negatives.

DSM: ***So would you prefer then an*** **in situ** ***approach or a sample return approach?***

SK: I think the best way to do this—and I have always said robotic missions would be good—but I now think the best type of situation for finding life on Mars is to set up a laboratory with humans, the instruments, and sampling equipment.

We have been looking on Earth for quite a long time, and we are still discovering life in places we did not expect it. So I think we need to be there and do a good study to get a definitive answer—look through microscopes, look through instruments, and drill down deep. And then maybe we will get a definitive answer about life on Mars in some underground ecosystem.

DSM: ***So an*** **in situ** ***approach, but with a human mission?***

SK: I think that it is the best way in light of how we do things here on Earth. And the probability of having a nondefinitive result from a robotic mission is high.

Look at the ALH meteorite. It could have been life, but we may never know. Look at MSL regarding the organics and previous missions. It is not definitive enough. So as great a discovery as life or signs of it on Mars would be, it has to have the most definitive answer we can conjure up with the right instruments.

GL: We have had something like 14 landers and rovers on Mars that were not chemically or biologically cleaned. And if we do send a human there and we find something, are not the naysayers still going to say that it is contamination? Particularly if we find terrestrial microorganisms, which I believe it would likely be.

SK: You are right. They are going to say that, but that is why it is going to have to be a really good, long-term mission with all the precautions and all the testing you can possibly do. And maybe at some point we will come to such conclusive evidence. But I agree with you. That argument will always be there, but that is what we have to deal with. We have to create the highest confidence level possible for positive tests.

JDR: I think that if the labeled release experiment could work in Utopia Planitia or in Chryse, which is one of the most boring places on Mars, then it should be able to work everywhere to find life.

The problem we have with setting up a lab for humans to do this work is that humans at this point in time have no capability on the martian surface whatsoever. They have less capability than the Apollo astronauts had, and the Apollo astronauts were in suits that could only last about three to five days on the surface of the Moon. So we do not have something that makes humans capable on Mars unless they are going to teleoperate rovers in real time.

I think we have to accept that the investments have not been made not only in extravehicular activity (EVA) capabilities but in EVA capabilities with any level of microbial cleanliness. And we have a lot of work to do on that.

DSM: ***It seems to me that everyone is betting on Mars as the place for a life-detection experiment. Does everyone agree that we should go to Mars? If we do a life-detection experiment then go to Mars and also test for metabolism? Are there any deviating opinions from that?***

VP: I think testing for metabolism is something we should do, but it should be part of a suite of instruments, because, for example, looking for metabolism, you are assuming that you are taking a sample with living microbes. But probably they are dead. So the proposal we have is to search for molecular biomarkers, polymers, because this is more robust in the sense that we do not need to get samples with living cells.

On Earth, very often we find dead biofilms or microbial clusters. But we can still detect biopolymers like exopolysaccharides and proteins, peptides, even some DNA in unclean samples. So I think in fact the dead microbial matter is far more robust than the living cells in many cases, and it is a good situation for searching for biomarkers in certain systems. Metabolic experiments, though, should be part of any suite of experiments.

GL: Well, perhaps I go to the extreme by saying, if you found DNA, there would be people who would say it was abiotically formed. Even though DNA sure sounds like a winner. But you have to admit, you are using judgment, not proof, because the Occam's razor finding that it is easier to produce DNA abiologically than biologically is uncontestable.

JDR: Occam does not have a sequencer, which is what you would use if you found DNA.

SK: But even if we found DNA, the argument would be that it was contamination.

GL: That is true.

VP: Well, not necessarily. It is not easy to contaminate your sensors with DNA. It would be, in my opinion, a very dirty preparation. What we are proposing is to get a kind of barcode or a complex biomarker profile. We are not talking about just, “Okay, we have the signal for DNA.” We are talking about obtaining different signals from, let us say, some polysaccharides, some proteins, some peptides—a complex pattern of detection, not only just one compound.

We have been using this system on Earth, and it works. But, of course, one never knows what would happen on Mars.
DSM: ***Let's say I gave you $5 billion to send three experiments to determine life in our solar system. Where would you send the mission, and what instruments would you take with you?***
SB: Well, I would certainly send it to Mars; it would be the most likely place to have life that we would recognize easily, even if it has a different chemistry than the chemistry that supports Terran life. But it also happens to be a reasonably close, reasonably gravitationally tolerant, place to go.
To specifically answer your question about life, I would attempt to identify it in the environment with sources of free energy. If you are below the surface, presumably you do not have the use of the photons from the Sun, and you might not want to have them anyhow, because on Mars, the sunlight has many high-energy photons that would tend to destroy organics.
But I would be looking for the mineral that is going to form a redox partner with, say, the perchlorate. Then I would look at the morphology of the minerals, because we have enough experience with locales on Earth where life is eating away at rocks, and we have a reasonable idea of what we might look for. Now, Gil is correct. We certainly would want to look for metabolites or organic molecules that are in that mixture. And the goal would be to do more than just look for metabolism, that is, chemical transformations, but rather to look for intermediates that join together to create metabolism. A goes to B, B goes to C and from there to D, and so on, in real biological systems. This is almost universal; you expect a certain relationship in terms of their free energy in the compound A, B, C, D. This provides metabolic meaning to more than just a collection of molecules.
Then again is the fundamental problem of analytical chemistry always involving sample preparation. You have to decide how you are going to process the rocks to get organics off the surface. This requires highly clean solvents, whatever you choose to use, and very clean instruments as well.
So my view of this would be, I would look for a manifold of organic species by analytical chemistry at the part-per-billion level where we are looking for more than just chemical structures but also chirality.
DSM: ***Does anyone else have suggestions regarding the instruments we should send to Mars?***
SK: What I would suggest, not because I am a chemist, but clearly we need both organic and inorganic samples. I would want to know what species are there in terms of oxidizing materials. Then I would use a variety of instruments, such as supercritical extraction fluid-type instruments instead of thermal-type instruments to look for organics, and several biomarker detectors—an array of instruments that would look at a variety of parameters.
I agree with Steve. The sample prep would have to be really well done in terms of guaranteeing the minimal amount of contamination from Earth.
GL: In respect to contamination, I would just like to get on the record, the approach I have argued for would be to put the instruments, many daggerlike instruments, darts, so to speak, in a box, heat-sterilize the box, then bolt it onto the lander. After landing, the instrument would be activated by shooting these darts out through the roof of this little box and landing them at least 100 yards away upwind from the spacecraft and having communication by FM radio so there is no possibility that contamination from the landed spacecraft could have influenced the result.
SB: Well, at the part-per-billion sensitivity level, you do not sterilize by heat.
JDR: No, you are going to have to clean it off and kill the dead bug bodies, get rid of those. But in general, the concept of putting a clean payload on a not-so-clean rover has some merit. If you can actually use one rover to get yourself into a place where you can take a clean sample, then you can do the analysis. But, you know, when I look at our title of this panel, "Nearly Forty Years after Viking: Are We Ready for a New Life-Detection Mission?" the answer that usually comes up is yes, but to the plumes of Europa and Enceladus is where we should go. Because that is where whatever is coming out is *obtainable* from orbit, and they are not just images of potential methane plumes, et cetera. And I do think we have life-detection possibilities in orbit around Mars right now, or soon with the ExoMars Trace Gas Orbiter.

But the plumes of Europa and Enceladus are something that are accessible with current technology and, in fact, the samples, although they are not necessarily prepared the way we would want, are something that we could grab and analyze with an orbital spacecraft.
DSM: I think that is a very good idea, although with Enceladus there is a lot of radiation, as well, and Europa, even more radiation. So anything that you catch would probably be modified by radiation very quickly.
But let me get back for a moment to Mars. If you would go to Mars and look for life, you probably would want to land in one of those special regions where there are a lot of requirements, which make the mission really expensive. So how do we deal with that if we go with a life-detection mission to one of the special regions?
JDR: If you are going to spend the $5 billion mentioned, you need to go study Mars and not study the Earth that you brought with you. So I do think that it is money well spent.
One has a lot of choices with respect to special regions, and if one is thinking about something like recurrent slope lineae on the surface, then one has the choice of roving to them and not landing on them. One has the same sorts of considerations with respect to subsurface water if we ever find something. Certainly, there are ice places, and caves are a great place to go, too.
The question is, would you ever really want to go to a special region with a dirty spacecraft and then study your own contamination? I do not think most people would find that scientifically compelling.
GL: In preparation for the labeled release experiment, we spent years trying to find a special region on Earth where there was no life. We could not do it, and I happen to believe that Darwin works on Mars just like on Earth. So if life ever got a foothold there, I think over the eons of time it would have evolved to occupy that planet just like it did on Earth, and that is why I never bother getting in arguments about where to land. I do not care where they land it. I just want them to land it.
SK: I just want to point out something here, that I have heard this argument about life all over Mars and on Earth. The problem is that life enjoys niches where it is favorable for it, and on Earth most niches are favorable. But even on Earth you can find niches that are absolutely not. Is there life coming out in molten lava? No, because life as we know it cannot survive at such temperatures in such places.
So on Mars, I am convinced pretty well that life perhaps emerged at the same time as on Earth, and there is probably a subsurface ecosphere where the niche is just right—the temperatures are good, the water activity is good. But then, like on Earth, you reach niches on the surface where it is bathed with lethal radiation, lethal oxidants, and that is not a niche that is inhabited. There is life everywhere on Earth because the niches are very friendly almost everywhere. But that does not mean it is true on other planets.
VP: Concentration here really matters, because it is not the same to go to some places where you can find 10^6 cells per gram, for example, at a place where there is only less than 10^3. We have problems on Earth, for example, with the drilling projects, to get an insight into the life that is there, because the concentration of cells is very small. So I think it is important to go places where we are confident that we would find some amounts of certain biomarkers.
DSM: ***So how should we go forward? Should we design single life-detection experiments that are piggybacked on other planetary missions, or should we really try to have one mission be dedicated to life detection only?***
SK: In my opinion, a single life-detection experiment on a mission is doomed to provide nondefinitive results. I think that it would be a big mistake. It needs to be a mission with multiple instruments and approaches, more than Viking and others have provided so far. Otherwise, it is doomed to nondefinitive results.
GL: I agree. I certainly think it should be a multipurpose mission.
VP: Right. I think all of us agree that one important thing that has never been studied deeply is the wet chemistry on Mars. The technology is relatively cheap and can be done. To start to follow the martian wet chemistry probably would be interesting, by sending several missions with a suite of experiments

that can cover biomarkers to metabolisms to even some geochemistry.
This type of mission always will be successful because it will always provide some feedback to Earth. This type of new program to follow the wet chemistry might render good results.
GL: And included in that should be looking for methane. That is really an exciting possibility and not too difficult to do.
DSM: ***So from this discussion I take it that everyone is actually concerned about extant life and not only about extinct life. Is that correct, or does someone have an opinion that we should look more for fossilized life in some kind of a quartz layer on Mars or something like that?***
GL: I think we should look for both.
JDR: I think searching for ancestors is a lot easier than searching for extant life, because they do not have to like the current environment on Mars to be there. So it is a much less toothy problem.
I do think it should be done, and what we have seen with Curiosity is a lot of capability to characterize ancient environments but not a whole lot of understanding of taphonomy on Mars, which is something that we have a lot to learn about.
DSM: ***We seem to have a consensus that we would like, if we feel the time is ready, to have one mission with several instruments dedicated to life detection. So how do we do that politically? How can we push that through with NASA or ESA to make that happen?***
JDR: I think you can do that by constructing your arguments and going to the appropriate Mars meetings and showing them to the participants. I do not think you can point to gaping holes in the physical-chemical characteristics of the current martian environment and have somebody be very comfortable with an experiment like the labeled release experiment that is trying to deal with metabolism when we do not know anything about certain aspects of the chemistry of Mars.
But we are much further along than we were before, thanks to Phoenix, thanks to Curiosity, thanks to Steve and to the Mars Exploration Rovers. Viking did a splendid job of demonstrating that there is a phenomenology there that needs to be explained. I think going back and explaining it is something that should be done—a labeled release–type package should be part of that—to determine whether or not you have actually got the same phenomenology in a place that you can explain.
This is the sort of thing that these days can be done on a budget like the Discovery program. The mission that is going to Mars in 2016 is done as a Discovery project. So if you make a good case and you present a spacecraft and the appropriate instruments together with all the systems engineering, all the schedules, and all the planetary protection that is necessary to do that job, you can send that mission today.
You can do that job in a program that already exists by convincing your colleagues that it is worthwhile, convincing engineers that you can do it and have it operate.
SK: One of the arguments I hear the most often, though, is on the subject of organics. We are looking forward to organics being detected by Curiosity perhaps. But since that has not happened, and may never happen if that contamination is always a question mark, detecting organics is a very critical step. We could send a smaller suite of instruments now that we know the chemistry of the surface. If there are no organics of any substantial complexity, or if the organics all look like they are chondritic infall, that is not going to help. If we identified organics that looked to have come from more complex biosystems, that would certainly trigger a search for life.
GL: Well, if Curiosity ever does its wet extraction organic analysis, we may get those data. I have been staying tuned to hear about it, but that has not happened.
SK: The fact that there were contaminants inside the chamber from the derivatization agent is always going to give people pause unless there is some methodology that can convince the community that there is no chance that those contaminants or that the gas chromatograph (GC) contaminants or the materials are not contributing to it.
GL: It might be possible to subtract those contaminants from the results. But at any rate, the result might be negative, and that would settle the issue. I agree—find complex organics, or go home.

VP: Also the gases that the gas chromatograph–mass spectrometer (GCMS) system yields always render more molecules, and one never knows exactly the original nature of the molecule or the complex structure of these molecules.
DSM: That reminds me of what Gerald Soffen said at the end of the Viking experiments—no bodies, no life, no organics found. Of course, that has now been in question, and there were probably organics there. But I think Sam has a good point. It would be very difficult to convince the community without being 100% sure that there is at least a reasonable suite of organics there that could possibly support life.
JDR: Unfortunately, I think organics fall under the same problem as looking for DNA or other things. There is such a very small expectation that the surface of Mars may be a place where things can stay alive. And it is not going to be a place you go to and find a plethora of organisms. It is not a deep-sea hydrothermal vent. It is rather the opposite.
So I think we really do need to continue to look for those sorts of places that are particularly good for preserving living organisms, if they were there in the first place, and even ancestors. And that is why a place like recurrent slope lineae is important. We have never been to a place on Mars that is wet, not at any depth that we know of. A lot of ice, but wetness is something that we have not explored yet. And if we can find a wet spot, then I would say that is the place to go.
GL: Viking found a wet spot. Viking lander 2 took the temperature at its footpad as the Sun rose. The temperature rose to 273 K, and then it stopped for the rest of that determination. Now, that is a pretty good fingerprint for liquid water. We know the surface gets up to 273 K, so at that place, at least, there was a film, at least, of liquid water.
SK: There is a problem with the presence of liquid water on Mars, and that we have pointed out in a recent publication of a reanalysis of the Phoenix data. I do not know if you are aware of it, but we identified the perchlorate parent salt as being calcium perchlorate, which should not be possible in a solution where we also found soluble sulfate. This implies that the surface around Phoenix has probably been dry since the Heimdall Crater formed 500 million years ago. This implies that Mars has been extremely arid, even at the thin-film water levels, for 500 million years in that area, and which is also pretty close to Viking's location. The data is contradictory to what we would have expected. But it is simple chemistry. Calcium perchlorate plus magnesium sulfate in water does not end up as calcium perchlorate, because you will precipitate out gypsum or anhydride or epsomite.
GL: If I have to choose between two sets of data like that, one the kind of theoretical, the other being straightforward, the signature for liquid water, I would have to go with that.
JDR: Well, I think the straightforward signature for liquid water is probably a little more than Viking 2 gave us. I would love to have seen Viking 2 actually dig farther down and find the ice layer that we estimate is there just about 9 inches below where they got.
GL: Agreed.
JDR: We are in a data-poor environment, but what Sam points out about the Phoenix mission is very true. We do not really understand some of the ices on Mars, where they got to, how they got into the forms that they are in. There is a lot about Mars that we are not really dealing with very well having to do with obliquity cycles and how they affect what you find in the near subsurface. So we have a long way to go, but I still think—find a wet spot. Let us not get misty-eyed over the old wet spot that we think we found, but let us get one that actually shows flow features.
GL: Right, but the main thing I am waiting for is that wet chemistry analysis for organics. Even though it might be questionable, I would love to see what it says.
SK: I would, too, but I do not think we are going to see it until they can figure out a way to get rid of the contamination and the questions.
DSM: ***Can we design an experiment to exclude those false positives so that if we go somewhere, to the lineae, like John suggested, which I think Gil likes, too, we can find chemistry indicative of life?***
SK: So, how do we know they are false positives? I think identifying and excluding them definitively is probably going to be the biggest challenge. It would take the $5 billion figure you mentioned to

basically design, validate, sterilize, and put together the experiment with a large array of instruments to ensure no false positives.

GL: I think a good piece of that $5 billion ought to be spent on controls. There is nothing more important.

SK: Absolutely.

GL: And labeled release had these wonderful controls, and I think they ought to be further exploited, because that is the way to get to certainty.

SK: As an analytical chemist, I agree, that is exactly right. You hit it right on the head. Controls and blanks and dependable, definitive results from those blanks and controls compared several times—repetition, repetition.

JDR: And then fly the mission. As in “do not put any ducks on board, but go looking for ducks.” They quack. They waddle. They have feathers. I think you could actually do this on a Discovery payload basis, and that opportunity will come around again.

I think it is going to take a lot of careful advocacy, and a very carefully crafted evidence chain about why you would deal with this with a mission, now that you can go ahead and make measurements that can possibly shed light on this question.

I think that its time is coming. And if you can do it on Mars, you can do some of this on Europa, too.

GL: Another important thing that has happened since Viking is that we have learned how to miniaturize the technology like mad. So we could cut costs way back.

DSM: And there is definitely a huge impetus from the public, because what excites people is finding life. If you can galvanize this kind of energy, and maybe resources, too, then that could be a way forward.

JDR: It is a challenge, but I think it is one that people are stepping up to, and I am glad we are discussing it here.

DSM: ***Are there any closing statements from the panel?***

JDR: I would like to point out that while the labeled release experiment is not totally understood at this point in time, no one has ever ascribed the results of the labeled release experiment as emanating from spacecraft contamination. Viking set the gold standard for a clean spacecraft in the 1970s. I think we can do a better job than that in the 21st century, and if we can do that with a spacecraft that still operates, then we will have a good chance to go ahead and address these questions, and the best places are Mars, Europa, or Enceladus.