First for anyone who doesn't know about it, NASA are planning to return its Mars samples of rock and some dust / soil to biosafety level 4 facilities (BSL-4). The samples are in tubes on Mars. They want to return them some time around 2033.

Their plan to return them in a BSL-4 was fine from 1999 through to 2012.. However, in 2012 the European Space Foundation did a major report which concluded that a sample return mission has to contain the very small microbes we now know exist called ultramicrobacteria which can get through a very tiny 0.1 micron nanopore and still be viable. A BSL-4 can't contain ultramicrobacteria and doesn't have to, but extraterrestrial ultramicrobacteria, perhaps independently evolved, do need to be contained according to the ESF. So, why doesn't NASA mention this important study and its conclusions in their draft EIS and why do they still plan to use a BSL-4 facility?

The chance of returning life on those mainly geological samples is low. The chance it is dangerous if returned is also likely low. To give an idea of the order of risk I use Margaret Race's analogy of a smoke alarm. The risk of a fire in your house is so low most people don't panic about it. But you still install smoke alarms just in case.

Life from terrestrial deserts is harmless to us and perhaps martian life is too. But there are many ways it could be harmful, in minor or even major ways. Life could have developed capabilities on Mars that Earth life doesn't have such as resistance to UV or ionizing radiation or ability to flourish at very low temperatures in freezers. It could produce accidental toxins similar to ergots disease, botulism or tetanus, it could be a fungus or mold that can harm our crops or ourselves, or it could be some independently evolved life with a different biochemistry and our ecosystems might not work the same way if half the microbes are based on a different type of biology with chemicals perhaps that terrestrial life can't use or are poisonous to it.

I am reasonably familiar with the literature on this topic since I've been working for the last two years on a preprint on planetary protection NASA and ESA are likely to be legally required to sterilize Mars samples to protect the environment until proven safe ... specifically on planetary protection for NASA's Mars sample return mission.

You can get a first idea of this article by skipping through the sections as most of the titles are written like mini abstracts making it easy to drill down into the section of interest to you. Then within many of the sections the main points are summarized in graphics. You can see my annotations of NASA's draft EIS here: NASA_EIS_annotated.docx - if you have Word you can download it either from that page or via this direct link. NASA_EIS_annotated.docx (for download) or as a zip to see the annotations with formatting and graphics - the online version only shows them as plain text.

See also Why Doesn't NASA Respond To Public Concerns On Its Samples From Mars Environmental Impact Statement?

NASA aren't responding to public concerns including my comment in May alerting them to the ESF study which is why I wrote these blog posts - and the general public has to be behind this project for it to succeed

Skip to next section or Skip to discussion of NASA's draft EIS

I have tried contacting NASA about the European Space Foundation study, and got no response including via public comment on their proposals in May.

. Public comment by Robert Walker, May 16, 2022

The draft EIS still doesn't mention this study and has no mention of my comment in the section on comments from the public. I tried emailing experts but so far no response or they just say to contact NASA and they will answer but they aren't responding.

I continue to try emailing experts and I also wrote this blog post as an open letter to interested experts and the general public.

If you are an expert or know such an expert please pass it on and try to get an answer.

The general public need an answer. There are many people raising issues in the comments on the draft EIS and this concern isn't going to go away if NASA continues to ignore these comments.

As Rummel at al wrote:

> *"Broad acceptance at both lay public and scientific levels is essential to the overall success of this research effort."*
>
> See: A draft test protocol for detecting possible biohazards in Martian samples returned to Earth.

The general public has to be behind this mission for it to succeed. Not just space engineers, geologists and space colonization enthusiasts. I am not seeing that at present.

If it gets through NEPA it may well be stopped by the presidential directive to consider alleged large scale or long term effects.

Open letter to NASA, experts and the public - are you aware of NASA's draft EIS? The public needs answers and NASA aren't providing them - the risk is likely low for this mainly geological mission but it is like not providing smoke detectors for a house for billions of people

Skip to next section or Skip to discussion of NASA's draft EIS

Dear NASA, planetary protection experts, anthropologists, and other interested members of the public.

Are you aware of NASA's draft Environmental Impact Statement? They propose to treat the returned samples as like any human disease or toxic chemical handled in a Biosafety level 4 (BSL-4) facility. But a BSL-4 is NOT designed to contain all possible forms of extra-terrestrial biology that we might find on Mars. The European Space Foundation made that clear in 2012 when they set a size limit of 0.05 microns, well below BSL-4 capabilities. But NASA aren't listening to the public comments asking them to take more care.

The way it's drafted, it's likely none of the other agencies in the USA show an interest, because NASA's EIS claims there is no significant risk of environmental effects, and no more risk to human health than any other toxic substance we know how to handle.

The chance of returning life in these largely geological samples is probably low. And if they do return life, the chance this life causes large scale effects on Earth's ecosystems or environment or large scale and long lasting human health impacts is also likely low, though according to the National Research Council study in 2009, not demonstrably zero. But these samples could contain life and it would be a precedent for other countries that may return samples far more likely to contain life.

A BSL-4 laboratory such as NASA proposes to use is NOT designed to contain even the smallest terrestrial microbes, the ultramicrobacteria. In 2012, the European Space Foundation said a Mars Sample Return Facility needs to contain those minute organisms if we return them from Mars. We can't assume that ultramicrobacteria from Mars will be harmless to Earth. More on that below.

The ESF also said this needs periodic review - perhaps extra-terrestrial life with a novel biochemistry can be even smaller? Early life ribocells without proteins or DNA theoretically could go through even a 0.2 micron nanopore and recent research makes them more plausible.

… the ESF-ESSC Study Group recommends that values on level of assurance and maximum size of released particle are re-evaluated on a regular basis.

The release of a single unfertilized particle larger than 0.05 microns is not acceptable under any circumstance

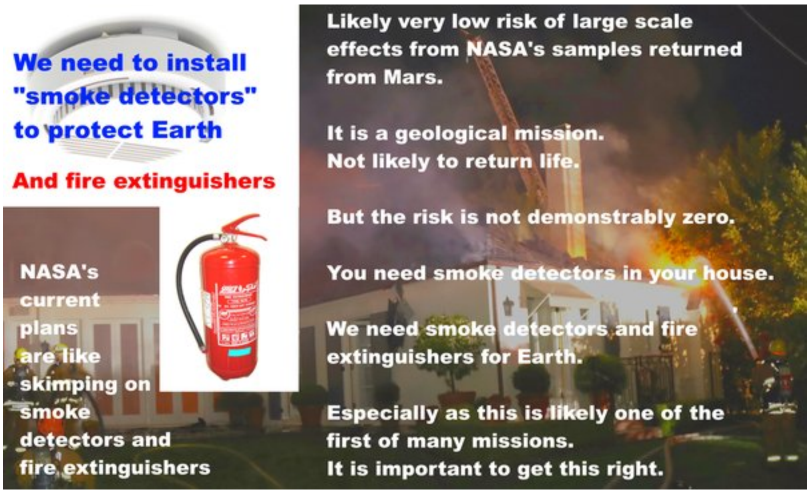
WELL BELOW Biosafety 4 limits - we don't have ANY air filters yet that can do this

Page 48 of 2012. Mars Sample Return backward contamination–Strategic advice and requirements

Margaret Race, senior research scientist at SETI, uses a good analogy in a reply to Robert Zubrin, president of the Mars society and a space colonization enthusiast

"He's confident in our impressive technological prowess; he's raring to go and doesn't want anything to slow down or stop our exploration of Mars - especially not burdensome regulations based on very small risks and scientific uncertainty. Yet when he suggests that there's no need for back contamination controls on Mars sample return missions, he's advocating an irresponsible way to cut corners. If he were an architect, would he suggest designing buildings without smoke detectors or fire extinguishers?

From her "Hazardous until proven otherwise" in., "No Threat? No Way" in the Planetary Report, Nov / Dec 2000



Text on graphic: We need to install "smoke detectors" to protect Earth.

The risk of large scale effects from NASA's mission is likely very low - indeed unlikely it returns life at all but it's not demonstrably zero.

The risk of a fire to your house is also low.

We need the smoke detectors just in case. Especially for a "house" for billions of people.

Especially as we likely have many future missions like this from many countries.

Background graphics:

. Smoke detector.JPG - Wikimedia Commons

And this photo of a fire from the Los Angeles fire department, “Smoke alarm saves residents of a Bel Air home”

And fire extinguisher File:Fire-Extinguisher.JPG - Wikimedia Commons

I believe NASA has to stop its environmental impact statement for the Mars sample return mission and start work on it again with a new statement to do it properly. The main issues with it are

- **Out of date science** - aim to use a Biosafety level 4 facility which can’t contain the exceedingly minute ultramicrobacteria which the ESF in 2012 said needs to be contained - ultramicrobacteria aren’t normally a biosafety risk but ultramicrobacteria from Mars could be especially with some new unusual biology.
- **Requires actions in the BSL-4 laboratory to do “safety testing” with unsterilized samples on Earth which won't even work** - when there is so much by way of DNA, amino acids and other biosignatures of terrestrial life in the sample tubes it is going to be impossible to prove there is no martian life in it, and so, impossible to prove its safe.
- **The sample return likely is safe, unless present day life is right up near the most optimistic ideas of how abundant it could be, but there will be no way to prove it’s safe**, and all the samples will have to be sterilized anyway before they leave the laboratory.
- **NASA’s EIS doesn’t look at a sterilised sample return, which should be considered because it keeps Earth 100% safe** and especially with their high contamination levels would make almost no difference to astrobiology either and almost none to geology
- **NASA’s EIS incorrectly says that credible evidence says Mars has been uninhabitable for millions of years**
- **NASA’s EIS argues incorrectly that there is no significant risk of environmental effects and human health risks are no more than for any other toxic substance or human infectious disease,** when the 2009 study says the risk of large scale effects on humans or the environment is likely low but not demonstrably zero
- **NASA’s EIS incorrectly says that credible evidence says Mars has been uninhabitable for millions of years**
- **As a result of all this it is likely that other agencies that should look at it because of the risk of large scale effects will ignore it.**
- **Mission could be made far more interesting by adding bonus dirt dust and gas samples returned in STERILE containers** so they aren’t contaminated with all those biosignatures, and returning them to a location away from Earth’s biosphere such as above GEO with still zero risk to Earth
- **Why take even a small risk when you can take a zero risk** with virtually the same science and lower cost? Especially when it’s a precedent for other countries who may return samples more likely to have life in them and possibly before NASA?
- **Even the “astrobiology upgrade” added to a sterilized sample return is also likely lower cost for NASA if anything than its planned mission** because most of the costs for instruments etc would surely be taken on by interested universities and labs keen to send them to orbit to look for life in the samples - and with most of the extra costs incurred in the 2030s when we already know the samples are safely back in orbit - while the bonus astrobiological samples could make it far more interesting.

It does all this by misrepresenting its sources. For example, it claims that credible evidence says Mars has been uninhabitable for millions of years when its source for this sentence is about the search for local habitats in seemingly uninhabitable worlds.

It's mainstream that microbes returned from Mars have the potential to cause large scale effects and could harm us, and that we need to protect Earth until we know what's there. There are numerous papers. But NASA's draft EIS doesn't cite the literature correctly. That baffles me.

For a shorter less technical summary see:

. NASA Please Listen To Public Concerns About Life In Samples From Mars - Your plan is like Building A House Without Smoke Alarms

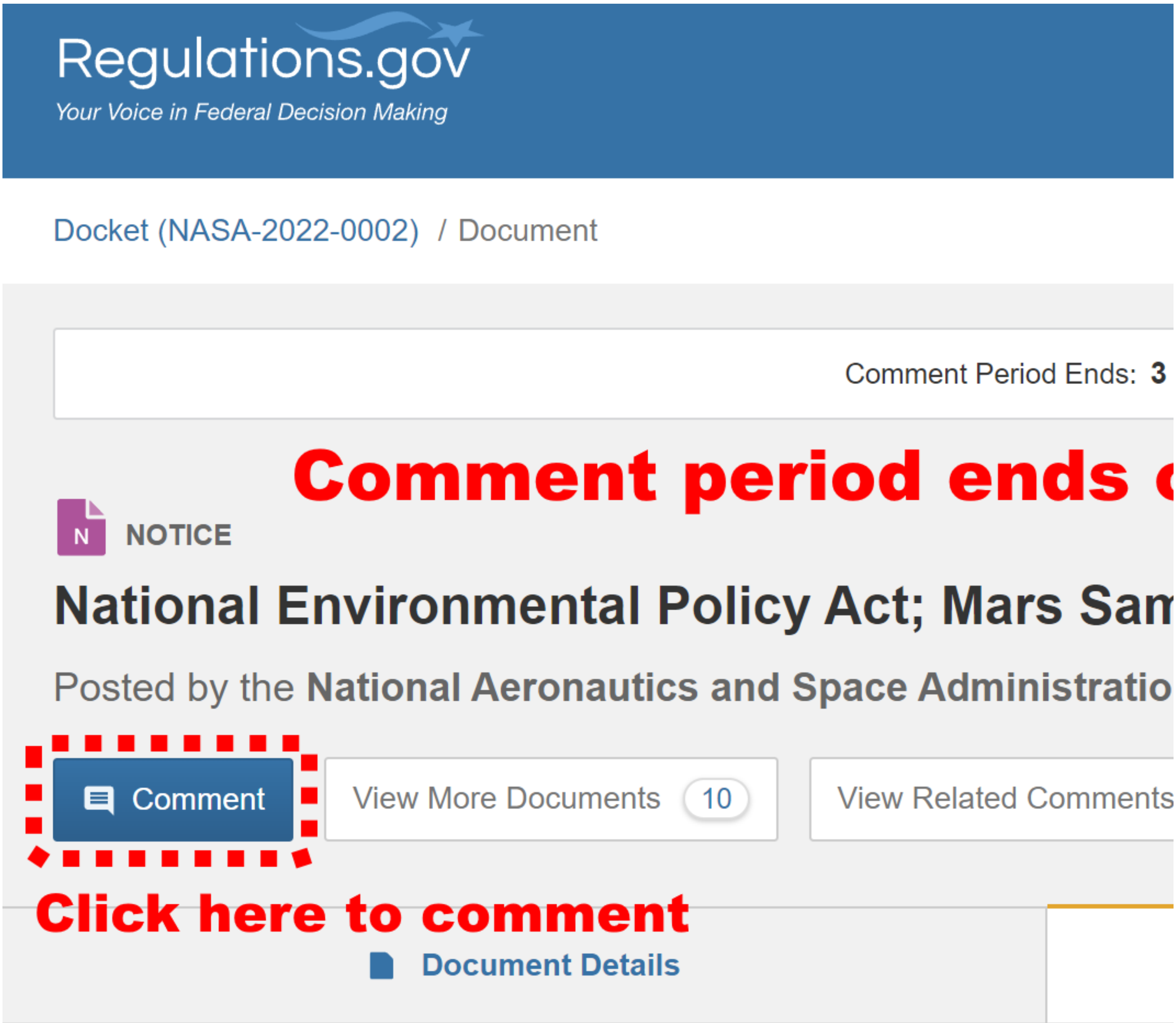
For space colonization enthusiasts see my:

. Dear Space Explorers - Yes We Do Need To Protect Ourselves And Earth From Any Microbes In Mars Rocks As We Explore

Everyone - do comment if you have thoughts about the project - go here, and click on the blue button to the left:

. National Environmental Policy Act; Mars Sample Return Campaign

You don't need to be an expert. It's a request for public feedback as for any big project like building a reservoir or an oil pipeline.



Text in red: Comment period ends on 20th December

(blue button to the left, circled with a red dashed line)

Click here to comment

Page is here: National Environmental Policy Act; Mars Sample Return Campaign

I have a couple of sections of background now - comments on what Carl Sagan said about the topic brought up to date and a section about habitability of present day Mars.

Experts may want to skip to the section where I talk about the statement itself. Though if you have the time the next two sections may be of some interest too.

Carl Sagan - we do need to protect Earth from life on Mars - we need to do a vigorous program of unmanned Martian exobiology and terrestrial epidemiology before we can return samples unsterilized or send human astronauts to Mars

Skip to next section or Skip to discussion of NASA's draft EIS

For any of you who haven't read this passage then I thought it would be a good introduction. I also comment on each paragraph based on how it relates to the Mars sample return mission.

This is from Carl Sagan's book published in 1973, The Cosmic Connection - an Extraterrestrial Perspective.

> **Carl Sagan:** The second objection to manned missions to Mars is more subtle. It is equally an objection to automatically returned samples from Mars, like the Soviet Union's Luna series for automatic sample return from the Moon. This is the danger of "back contamination." Precisely because Mars is an environment of great potential biological interest, it is possible that on Mars there are pathogens, organisms which, if transported to the terrestrial environment, might do enormous biological damage – a Martian plague, the twist in the plot of H. G. Wells' War of the Worlds, but in reverse. This is an extremely grave point. On the one hand, we can argue that Martian organisms cannot cause any serious problems to terrestrial organisms, because there

> has been no biological contact for 4.5 billion years between Martian and terrestrial organisms. On the other hand, we can argue equally well that terrestrial organisms have evolved no defenses against potential Martian pathogens, precisely because there has been no such contact for 4.5 billion years. The chance of such an infection may be very small, but the hazards, if it occurs, are certainly very high. Wholesale exterminations of native populations in Santo Domingo and Samoa and Tahiti occurred during the early days of sailing- ship exploration for just such reasons. Among the gifts carried by Columbus to the New World was smallpox.

Back then he thought there was no biological contact. Nowadays we think that some very hardy microbes like b. subtilis might be able to get here on meteorites, but this isn't proven. However what matters for invasive species are the ones that can't get here for whatever reason. We have no samples of the surface dust, ice or dirt and we have invasive diatoms in New Zealand that can't even get from one freshwater lake to another without human help. So it is a huge assumption to assume that any life that can hop in dust storms from one briny seep on Mars to another living millimeters below the surface of the dirt has to also have the capability to get to Earth on a meteorite resisting the shock of ejection, the extreme cold and vacuum of interplanetary space, the fireball of re-entry - and to make matters harder the meteorites we have come from at least three meters below the surface of the very inhospitable high southern uplands of Mars where the air is thinner so that rocks can be ejected more easily. Yet martian life from briny seeps below the dirt may be able to get here in a sample tube like a tiny spaceship for a microbe, which even preserves some of the martian atmosphere at Mars atmospheric pressure.

As Carl Sagan said you can still argue both ways. Our immune system has never been challenged by extraterrestrial biology. But some forms of extraterrestrial life such as molds or fungi might just need our immune system to not recognize it to start growing, for instance in our sinuses, or lungs, and our bodies are essentially porous to microbes. There are many defences including natural antibiotics but these depend on specific cellular processes of terrestrial microbes that they disrupt that might not work with independently evolved cells from Mars.

> **Carl Sagan:** It is no use arguing that samples can be brought back safely to Earth, or to a base on the Moon, and thereby not be exposed to Earth. The lunar base will be shuttling passengers back and forth to Earth; so will a large Earth orbital station. The one clear lesson that emerged from our experience in attempting to isolate Apollo-returned lunar samples is that mission controllers are unwilling to risk the certain discomfort of an astronaut – never mind his death – against the remote possibility of a global pandemic. When Apollo 11, the first successful manned lunar- lander, returned to Earth – it was a spaceworthy, but not a very seaworthy, vessel – the agreed-upon quarantine protocol was immediately breached. It was adjudged better to open the Apollo 11 hatch to the air of the Pacific Ocean and, for all we then knew, expose the Earth to lunar pathogens, than to risk three seasick astronauts. So little concern was paid to quarantine that the aircraft-carrier crane scheduled to lift the command module unopened out of the Pacific was discovered at the last moment to be unsafe. Exit from Apollo 11 was required in the open sea.

His point there about quarantine applies still today to technicians. If a technician did get very sick and was at risk of dying after exposure to martian samples - what is the plan next? There is no way ethically we can let them die when we don't even know yet what the cause is, or even if we know it is a martian microbe did it. They would still be rushed to hospital. So what is the quarantine for?

It also brings out another point. We can expect flight engineers to be focused on success of the mission. They don't have an objective unbiased view on all this. Their decision making isn't necessarily going to be reliable on planetary protection. This is not a decision for scientists, it is a decision for the general public about acceptable levels of risk and risk / benefit calculations.

> **Carl Sagan:**There is also the vexing question of the latency period. If we expose terrestrial organisms to Martian pathogens, how long must we wait before we can be convinced that the pathogen-host relationship is understood? For example, the latency period for leprosy is more than a decade. Because of the danger of back- contamination of Earth,

This also is something that hasn't been addressed since then, that we don't know a quarantine period. But it's worse than that. Carl Sagan doesn't mention typhoid Mary - a life-long symptomless superspreader of typhoid. A technician could be a host to an opportunistic pathogen that's harmless to them but kills other humans. I also use the analogy of the Zinnia plants killed in the ISS by an opportunistic pathogen of crops brought there in an astronaut's biome - we can't protect Earth from pathogens of crops, and the pathogen concerned, a fungus, not unlike what we could find on Mars didn't harm the astronaut but rarely kills immunocompromised people on Earth. We might all be immunocompromised relative to a fungus using a biochemistry terrestrial immune systems have never encountered in the billions of years of evolution.

Then my final example is life that evolved independently. Like Hachimoji DNA with 8 bases instead of 4 which synthetic biologists created. It needs chemicals only available in the laboratory to make those 4 extra bases so it can't escape. But martian native hachimoji might be able to make extra bases from ordinary organics. It might have a different vocabulary of amino acids, it might translate the genetic code into amino acids in a different way. Or it might have evolved from scratch as mirror life, just set off the long path of evolution with the early life organics in the opposite mirror sense from terrestrial life. Its DNA spiraling the other way, and starches, proteins everything flipped as in a mirror. If so it would very likely have the isomerases able to turn non mirror organic food into mirror organics to eat it. There are a few terrestrial microbes that could transform mirror organics back to ordinary organics but for most terrestrial microbes it would be indigestible. Over decades to centuries terrestrial organics might gradually be transformed to mirror organics. Eventually terrestrial microbes would evolve to transform it back again. It might end up with a mix of equal amounts of both types of organics but either way it's unlikely our ecosystems can continue to function as they do now with either half or all the organics inaccessible to terrestrial life. I don't think humans would go extinct. It would happen slowly and we would be able to grow crops in enclosed habitats as for space colonies. Over time we'd paraterraform Earth. With future technology enclose entire tropical rainforests, coral reefs and other ecosystems with protective greenhouse like coverings to keep out the mirror life but it would be a severely diminished natural ecology - until eventually over millions of years new forms of multicellular life evolved to cope with mirror life.

I also found many scenarios where life from Mars is harmless or even beneficial, where it has more efficient photosynthesis and can make better use of regions where there are high levels of UV or low levels of nutrients and large areas of the deep ocean get covered in algae used by terrestrial life and the coldest driest deserts become far more habitable. And it could be like the archea, an entire domain of life that has largely harmless or beneficial interactions with the other domains.

But we don't know and until we know what's there I think we need to assume we are returning the worst case scenario of mirror life.

> **Carl Sagan:** I firmly believe that manned landings on Mars should be postponed until the beginning of the next century, after a vigorous program of unmanned Martian exobiology and terrestrial epidemiology. I reach this conclusion reluctantly. I, myself, would love to be involved in the first manned expedition to Mars. But an exhaustive program of unmanned biological exploration of Mars is necessary first. The likelihood that such pathogens exist is probably small, but we cannot take even a small risk with a billion lives. Nevertheless, I believe that people will be treading the Martian surface near the beginning of the twenty-first century.

This is the main point. This " vigorous program of unmanned Martian exobiology and terrestrial epidemiology." hasn't yet started. There are many potential habitats for native life on Mars and we haven't yet sent life detection instruments to any of them or even tried to detect life in the dust yet. Astrobiologists have designed many life detection instruments that do sample preparation and analysis automatically, tiny instruments we could send to Mars some weighing only a fraction of a kilogram but we haven't yet sent them to the planet and our spacecraft haven't been sufficiently sterilized to look in the places where life is most likely.

Also though the hope of space explorers is that Mars life turns out to be harmless or even beneficial to Earth - we can't know that. It is a possible outcome of that vigorous program that we find something on Mars that can never be returned safely to Earth. There is a reason we have to check for it. And if we have to check that means a possible outcome is that martian life is not safe for Earth. In science fiction we get to imagine what we would like to have on Mars and a science fiction adventure story needs the life on Mars to be harmless to Earth for plot reasons, for most ideas for science fiction about Mars. But the reality doesn't depend on the imagination of science fiction authors.

The National Research Council said on page 48 of their 2009 report on planetary protection for a Mars sample return (just click the X close button to close the banner for other ways to access the report to visit the page)

> **National Research Council (USA)** The committee found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero

This is a situation where what Carl Sagan said applies:

The likelihood that such pathogens exist is probably small, but we cannot take even a small risk with a billion lives.

This is a decision for the general public about ethics and what are acceptable risks and risk / benefit. It is not a decision for scientists or flight engineers.

The chance that NASA returns life in this particular mission may be low but it sets a precedent for future sample returns including the Chinese return which may even happen sooner, due to NASA's high prestige. It's important to get this right.

This mission can be made 100% safe with a presterilized sample return - and the interest for astrobiology greatly increased with bonus samples of dirt, dust and atmosphere collected in CLEAN sample containers with not a trace of terrestrial organics (which we know how to do) returned also sterilized or else for remote analysis in a safe orbit above GEO within reach for hundreds of life detection instruments sent there on the Ariane 5 maximum payload over 7 tons to above GEO - but due to a technical and possibly illegal overnarrow scope the current impact assessment can't consider a presterilized sample return

The sad thing is, the mission can be made 100% safe with a presterilized sample return. Due to a technicality the draft EIS is not able to consider this alternative, they require samples to go through "safety testing" which wouldn't actually work as we'll see due to the presence of multiple biosignatures from terrestrial contamination, all samples will need to be sterilized anyway before they leave the BSL-4. It can do virtually all the same science with presterilized samples yet the EIS doesn't consider this option. Such an over-narrow Purpose and Need may even be illegal by a 7th Circuit decision in 1997.

Also it could be made far more interesting for astrobiology by adding samples of dirt, dust and the atmosphere collected in 100% sterile containers on Mars which could be sent there on the ESA fetch rover, ideally including the salts that Curiosity found that form very cold temporary briny seeps in the early morning and late evening on Mars in some seasons of the year. This could be of interest for habitability and prebiotic chemistry even if it doesn't have martian life. The dust meanwhile would sample distant regions of Mars - we detect microbes from the Gobi desert in Japan brought there by the dust storms. The same could be possible on Mars if it has distant habitats that may be more habitable than Jezero crater and it's also possible martian life over billions of years is adapted to survive transmission via dust storms which block out 99% of the UV. If we don't find life then we get a first estimate of how rare it may be on Mars, though of course it is not enough to prove there is no life even in Jezero crater with just one sample. Also we get a first idea of any chemistry on Mars perhaps including prebiotic chemistry that could tell us about conditions on a planet that hasn't had life evolve yet.

These bonus samples could be returned sterilized and would still be of great interest, any modern life would be recognizable without the noise of forward contamination from terrestrial life. Or I suggest they could be returned to a safe orbit above GEO close enough to send over 7 tons there in one payload on the Ariane 5, probably more by the 2030s, which is enough for hundreds of life detection instruments as a result of the extraordinary miniaturization of technology in the last two decades, and these can do end to end sample preparation and analysis today so they don't need humans present. This would minimize forward contamination of the samples and there are many issues with human quarantine which I'll touch on in this blog post, how do you keep out a pathogen of crops for instance, like the one that killed two Zinnia plants on the ISS, brought there on an astronaut's microbiome?

There is likely little life on Mars similarly to Mars analogue deserts on Earth and it may well be harmless - but there are scenarios where it could be harmful especially if based on a different biochemistry or because of adaptations to survive on Mars - in most science fiction it is imagined as harmless for plot reasons but we can't know in advance that the real world is like that

Skip to next section or Skip to discussion of NASA's draft EIS

There is little life in Mars analogue deserts on Earth such as the arid core of the Atacama desert or the McMurdo dry valleys in Antarctica, and the rover isn't searching for life. So it is probably not that likely to return life and the chance it returns life that's harmful to human health or the biosphere is likely very low. To give an idea of the order of risk I use Margaret Race's analogy of a smoke alarm. The risk of a fire in your house is so low most people don't panic about it. But you still install smoke alarms just in case.

If there is life on Mars it is like life in the driest coldest deserts here. We do find life almost everywhere and terrestrial microbes use biofilms as a home to live in otherwise inhospitable places, for instance to retain water and protect from UV etc. Also, life on Mars would be likely to be a polyextremophile (microbe able to live in diverse extreme environments) like Chroococcidiopsis which is extraordinarily versatile and is one of our top candidates for life that could survive on Mars from Earth. It is found on Antarctic cliffs, in hot dry deserts, tropical reservoirs and seas, and it has so many and such diverse metabolic pathways it has even been found over 100 meters below the sea bed.

Microbial life in our deserts is harmless to us and quite possibly martian life is too, but we don't know this yet. What about independently evolved life, perhaps mold with extra bases like Hachimoji DNA which has four extra bases, safe in labs as it depends on chemicals only found in a lab, but Martian 8-base life would likely work fine on Earth. Or even life that evolved independently from scratch as mirror biology with mirror chemicals, DNA spiraling the other way, proteins, sugars, all as if reflected in a mirror? Or photosynthetic life that is more efficient because it evolved to cope with martian dust storms or molds that can thrive at much lower temperatures than terrestrial molds, for instance in freezers, or microbes that produce chemicals that are accidentally toxic to us or our crops like ergot disease, botulism or tetanus. Or pathogens of biofilms that use the same methods to infect human lungs like legionnaires disease or molds or fungi that bypass the natural antibiotics that protect us as they use a different cell wall structure and maybe multiply in our sinuses like Aspergillus species. And yes some hardy microbes might get here via meteorites but what matters are the ones that can't.

Until we know what is there we can't assume that life from Mars is safe. In science fiction the heroes and heroines are almost never harmed by martian microbes but that's because that's needed for the plot, or in the case of movies, for the script. It's not based on any experience of extraterrestrial life. s

MORE BACKGROUND - MARS LOOKS DRY BUT MAY HAVE LIFE

Skip to next section or Skip to discussion of NASA's draft EIS

However though Mars looks completely dry, it has some briny seeps just below the surface of the sand dunes in places. In Jezero crater they probably form only briefly in the early morning and late at night but in other places they can last longer. Most of the brines are far too salty for life and they take up the water at night - but at times they take up enough water for life as we know it to be possible except that it is then very cold, -70 C because the atmosphere gets most humid when it is very cold.

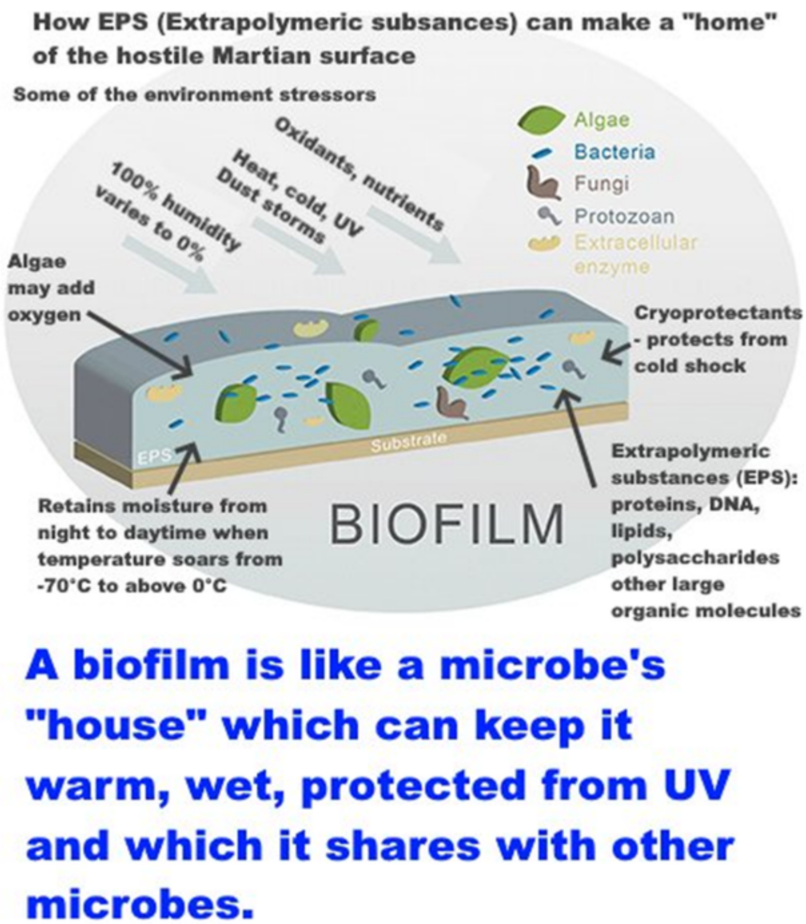
Modern Mars looks totally inhospitable from space – but it has a thin atmosphere and Curiosity found very cold salty brines that sometimes form overnight in Gale crater – the same process should happen in Jezero crater – though too cold for terrestrial life these brines might be habitable to biofilms that retain the water through to daytime when it gets warmer.

[Arrow points to Gale crater]

These brines may also be habitable to Martian life if it can withstand lower temperatures.

Image from How to Search for Life on Mars,

However we get life in very inhospitable places using biofilms where microbes work together in a community to make a kind of microbial home that is wetter or has more organics or protected from UV or in other ways more habitable. Possibly even Jezero crater might have these little biofilm homes especially for Martian microbes that adapted and evolved on Mars for billions of years.



How EPS (extrapolymeric substances) can make a "home" of the hostile Martian surface.

Some of the environment stressors

100% humidity varies to 0%

Heat, cold, UV, dust storms

Oxidants, nutrients

Algae may add oxygen

Retains moisture from night to daytime when temperature soars from -70°C to above 0°C.

Cryoprotectants - protects from cold shock

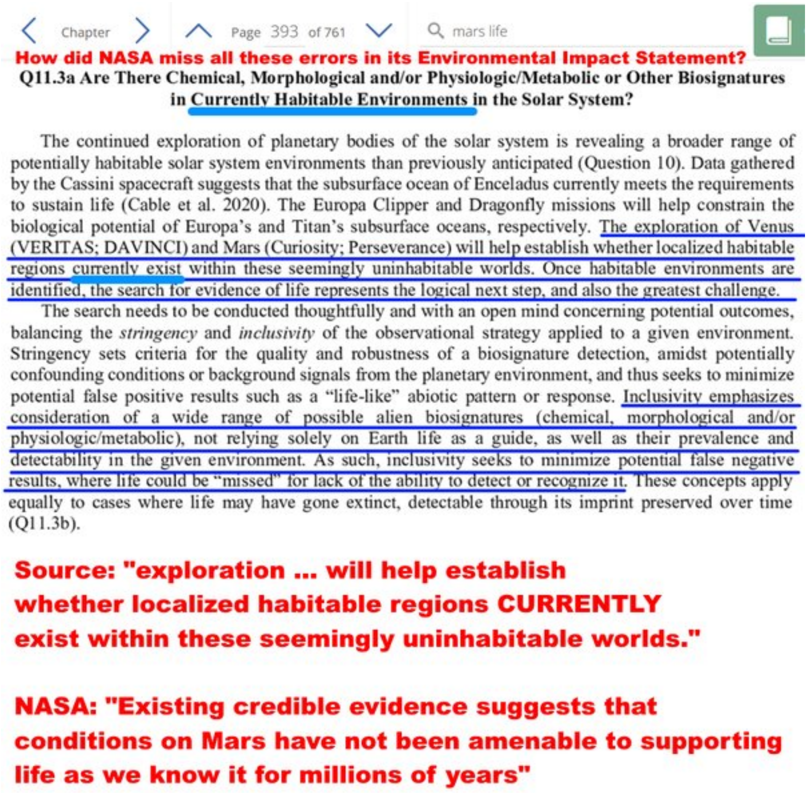
Extrapolymeric substances (EPS): proteins, DNA, lipids, polysaccharides, other large organic molecules.

A biofilm is like a microbe's "house" which can keep it warm, wet, protected from UV and which it shares with other microbes.

So you get many different ideas about how possible or not present day Mars life is. If you go by the most optimistic it's possible that Perseverance returns life, perhaps as viable spores in the dust. If you go by the least optimistic there may be almost no life or none at all, there may well be habitats, but perhaps life went extinct millions of years ago or spreads so slowly it never got to them and only lives deep below the surface today. So those are basically the two main streams of thought in modern astrobiology, life deep below the surface or not there at all, and life much more common - but even the most optimistic would say it's still rare, patchy, a few patches here and there in a vast desert, sometimes a thin biofilm, sometimes a few thousand cells per gram of dirt - that's by analogy with the most inhospitable deserts on Earth which are probably roughly as habitable as the most hospitable deserts on Mars.

NASA'S EIS CLAIMS MARS HASN'T BEEN SUITABLE FOR LIFE FOR MILLIONS OF YEARS - ITS CITE IS ABOUT THE SEARCH FOR CURRENTLY HABITABLE ENVIRONMENTS ON MARS - HOW COULD THIS EVEN GET THROUGH NASA'S INTERNAL REVIEW PROCESSES?

Skip to next section



Q11.3a Are There Chemical, Morphological and/or Physiologic/Metabolic or Other Biosignatures in Currently Habitable Environments in the Solar System?

The continued exploration of planetary bodies of the solar system is revealing a broader range of potentially habitable solar system environments than previously anticipated (Question 10). Data gathered by the Cassini spacecraft suggests that the subsurface ocean of Enceladus currently meets the requirements to sustain life (Cable et al. 2020). The Europa Clipper and Dragonfly missions will help constrain the biological potential of Europa's and Titan's subsurface oceans, respectively. The exploration of Venus (VERITAS; DAVINCI) and Mars (Curiosity; Perseverance) will help establish whether localized habitable regions currently exist within these seemingly uninhabitable worlds. Once habitable environments are identified, the search for evidence of life represents the logical next step, and also the greatest challenge.

The search needs to be conducted thoughtfully and with an open mind concerning potential outcomes, balancing the *stringency* and *inclusivity* of the observational strategy applied to a given environment. Stringency sets criteria for the quality and robustness of a biosignature detection, amidst potentially confounding conditions or background signals from the planetary environment, and thus seeks to minimize potential false positive results such as a "life-like" abiotic pattern or response. Inclusivity emphasizes consideration of a wide range of possible alien biosignatures (chemical, morphological and/or physiologic/metabolic), not relying solely on Earth life as a guide, as well as their prevalence and detectability in the given environment. As such, inclusivity seeks to minimize potential false negative results, where life could be "missed" for lack of the ability to detect or recognize it. These concepts apply equally to cases where life may have gone extinct, detectable through its imprint preserved over time (Q11.3b).

How did NASA miss all these errors in its Environmental Impact Statement?

Source: "exploration ... will help establish whether localized habitable regions CURRENTLY exist within these seemingly uninhabitable worlds."

NASA: "Existing credible evidence suggests that conditions on Mars have not been amenable to supporting life as we know it for millions of years.

, MSR DRAFT Environmental Impact Statement 1–6

I don't know how it is even possible for something like this to get through NASA's internal review processes, but I can only describe what I found in the draft EIS. If you find any mistakes in this however small do let me know, at support@robertinventor.com

MY ANNOTATED VERSION OF NASA'S DRAFT ENVIRONMENTAL IMPACT STATEMENT

Skip to next section

You can see my annotated EIS here as an online word document: NASA_EIS_annotated.docx - you don't need Word to read it though sadly it leaves out formatting and graphics from the comments. Also, sadly I couldn't get the page numbers to match in Word so you need to search for the text to find the same passage in my annotated version.

If you have Word you can download the pdf either from that page or via this direct link. NASA_EIS_annotated.docx (for download) or as a zip (only slightly smaller) which then has all the formatting and graphics.

BASED ON THE INVALID USE OF THIS CITE, ANOTHER INCORRECTLY USED CITE, AND A MISAPPLIED METEORITE ARGUMENT, THE EIS SAYS POTENTIAL IMPACTS WOULD NOT BE SIGNIFICANT - THE 2009 NRC STUDY THEY THEMSELVES CITE ELSEWHERE SAYS THE RISK OF EVEN LARGE SCALE EFFECTS ON THE ENVIRONMENT IS LIKELY LOW BUT NOT DEMONSTRABLY ZERO

Skip to next section

Based on

- this invalid use of cites to show that Mars is currently uninhabitable
- another argument which we'll see is invalid that it won't be in Jezero crater if it is elsewhere on Mars, and
- an argument from martian meteorites saying martian life can get here faster and better protected in a meteorite, in case there is life in Jezero crater
- NASA's EIS says potential environmental impacts would not be significant.

Here I compare what the EIS says with what the National Research Council said in 2009

You can visit the page here: page 48 (just click the X close button to close the banner for other ways to access the report to visit the page)

What the National Research Council said:

The committee concurred with the basic conclusion of the NRC's 1997 report *Mars Sample Return: Issues and Recommendations*[26] that the potential risks of large-scale effects arising from the intentional return of martian materials to Earth are primarily those associated with replicating biological entities, rather than toxic effects attributed to microbes, their cellular structures, or extracellular products. Therefore, the focus of attention should be placed on the potential for pathogenic-infectious diseases, or harmful ecological effects on Earth's environments.

The committee found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero. Changes in regulations, oversight, and planetary protection controls over the past decade support the need to remain vigilant in applying requirements to protect against potential biohazards, whether as pathogenic or ecological agents. Thus, a conservative approach to both containment and test protocols remains the most appropriate response.

A related issue concerns the natural introduction of martian materials to Earth's environment in the form of martian meteorites. Although exchanges of essentially unaltered crustal materials have occurred routinely throughout the history of Earth and Mars, it is not known whether a putative martian microorganism could survive ejection, transit, and impact delivery to Earth or would be sterilized by shock pressure heating during ejection, or by radiation damage accumulated during transit. Likewise, it is not possible to assess past or future negative impacts caused by the delivery of putative extraterrestrial life, based on present evidence.

What NASA's draft EIS says:

unlikely to pose a risk of significant ecological impact or other significant harmful effects should there be a sample release. The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgement that the potential environmental impacts would not be significant.

> **What the National Research Council said**: The committee found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero
>
> Although exchanges of essentially unaltered crustal materials have occurred routinely throughout the history of Earth and Mars, it is not known whether putative martian microorganisms could survive ejection, transit and impact delivery to Earth or would be sterilized by shock pressure heating during ejection or by radiation damage accumulated during transit. Likewise, it is not possible to assess past or future negative impacts caused by the delivery of putative extraterrestrial life, based on current evidence.
>
> **What NASA's draft EIS says:** The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgment that the potential environmental impacts would not be significant.

Though the draft EIS does cite the 2009 study it doesn't cite that section about the potential for large scale effects which would contradict its own assertion that there is no significant risk of any environmental effects.

, MSR DRAFT Environmental Impact Statement 3-16

There are NUMEROUS mis-cites / mistakes like this throughout the EIS.

NO MENTION OF THE 2012 EUROPEAN SPACE FOUNDATION STUDY WHICH REDUCED THE SIZE LIMIT TO 0.05 MICRONS - WELL

BEYOND BSL-4 - I ALERTED THEM TO THIS IN MAY BUT THE EIS STILL DOESN'T MENTION IT

Skip to next section

Relevant section of the Environmental Impact Statement:

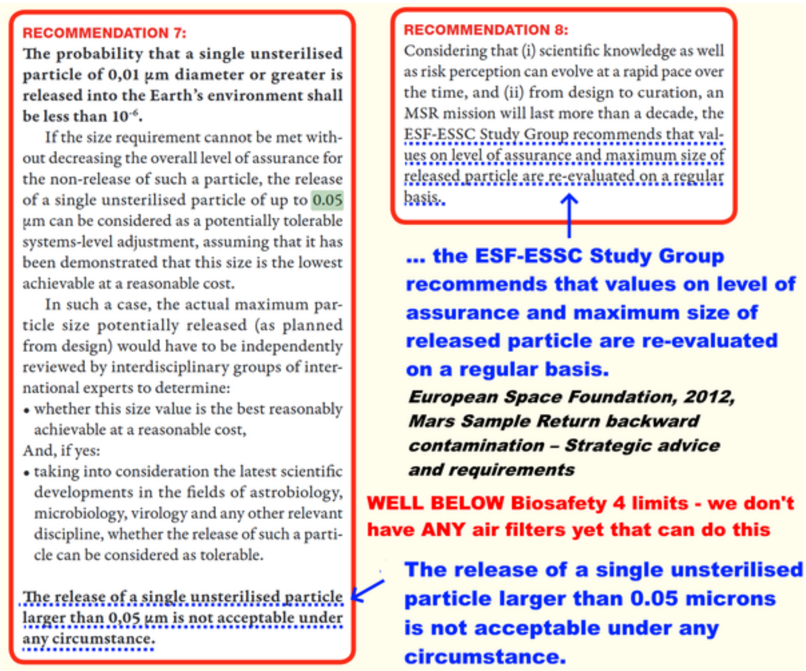
> **The material would remain contained until examined and confirmed safe or sterilized for distribution to terrestrial science laboratories. NASA and its partners would use many of the basic principles that Biosafety Level 4 (BSL-4) laboratories use today to contain, handle, and study materials that are known or suspected to be hazardous.**
>
> **S-4, in the subsection "Flight Elements" of the summary**
>
> . MSR DRAFT Environmental Impact Statement

This is my public comment to them in May - they show no indication that they read it.

> **Are you aware of the ESF Mars Sample Return study (Ammann et al, 2012:14ff)?** It said "The release of a single unsterilized particle larger than 0.05 µm is not acceptable under any circumstances". This is to contain starvation limited ultramicrobacteria which pass through 0.1 micron filters (Miteva et al, 2005). Any Martian microbes may be starvation limited.
>
> **This 100% containment at 0.05 microns is well beyond capabilities of BSL4 facilities.** Even ULPA level 17 filters only contain 99.999995 percent of particles tested only to 0.12 microns (BS, 2009:4).
>
> It IS possible to filter 0.05 micron particles from water, under high pressure. One study used carbon nanotubes loaded with silver. It eliminated polioviruses at 0.03 microns in diameter (Kim et al, 2016) (Singh et al, 2020:6.3).
>
> However, this technology doesn't seem to exist for aerosol filters.
>
> …
>
> . Public comment by Robert Walker, May 16, 2022

My first sentence alerted them to the 2012 European Space Foundation study which said that a particle of 0.05 microns must not be released under any circumstances.

The ESF also said we need periodic review and another review is certainly needed a decade later.



> … the ESF-ESSC Study Group recommends that values on level of assurance and maximum size of released particle are re-evaluated on a regular basis.
>
> The release of a single unsterilised particle larger than 0.05 microns is not acceptable under any circumstance
>
> WELL BELOW Biosafety 4 limits - we don't have ANY air filters yet that can do this
>
> Page 48 of 2012. Mars Sample Return backward contamination–Strategic advice and requirements

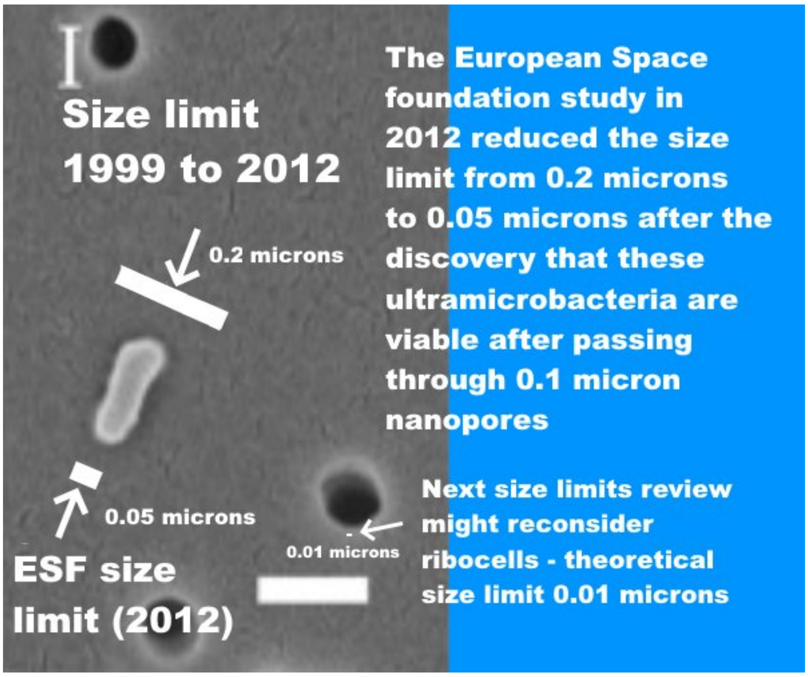
I checked the papers on filters and 0.05 microns is beyond the capability of even the best experimental air filters today. The best I found at that particle size was 88% reduction using 6 layers of filters. A BSL-4 facility isn't equipped to contain ultramicrobacteria and doesn't need to. HEPA and ULPA filters aren't even tested down to that size range.

SIZE LIMIT MAY BE REDUCED BELOW 0.05 MICRONS ON REVIEW

Skip to next section

Also I think the next size limit review might reduce the 0.05 microns even further, with interesting recent research on the practicality of ribocells, which have only RNA enzymes, replicate more slowly but could theoretically pass through a 0.02 micron nanopore. Early life has to be less complex and might have used very small cells.

At 0.01 microns, ribocells could set up a shadow biosphere with the competitive advantages of high surface area to volume ratio and too small to notice for protozoan grazing as for the shadow biosphere hypothesis.



Size limit 1999 to 2012: 0.2 microns

ESF Size limit (2012): 0.05 microns

The European Space Foundation study in 2012 reduced the limit from 0.2 microns to 0.05 microns after the discovery that these ultramicrobacteria are viable after passing through 0.1 micron nanopores

Next size limits review might reconsider ribocells – theoretical size limit 0.01 microns

SEM of a bacterium that passed through a 100 nm filter (0.1 microns), larger white bar is 200 nm in length

. Passage and community changes of filterable bacteria during microfiltration of a surface water supply

NASA haven't responded to my May comment either directly or in the section of the draft EIS responding to public comments, and the draft EIS still doesn't mention the 2012 ESF study or the 0.05 microns limit. Also NASA's EIS doesn't give a reason to ignore the ESF limit or a reason not to cite the ESF study. The EIS just doesn't show any indication that the ESF study exists.

IF YOU AGREE SOMETHING NEEDS TO BE DONE, DO SHARE THIS LETTER - AND DO COMMENT ON THE DRAFT EIS

Skip to next section

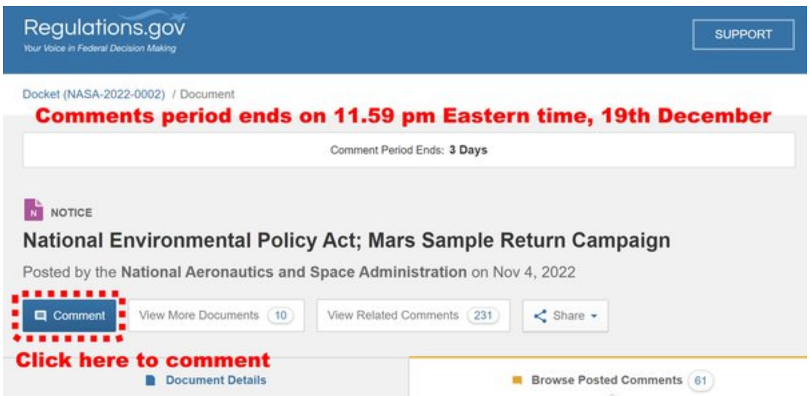
Hopefully by now you agree with me something needs to be done. If I have made any mistake in this however small please say!

Everyone - after reading this if you agree

Do share this page with others.

Do also comment on NASA’s comment page here:

. National Environmental Policy Act; Mars Sample Return Campaign



Text in red: Comment period ends on 11:59 pm Eastern time, 19th December

(blue button to the left, circled with a red dashed line)

> Click here to comment

This is where you go to comment:

. National Environmental Policy Act; Mars Sample Return Campaign

Remember NEPA want to hear from the general public, not just experts. This is your chance to have a say. It closes for comments on December 20th. You don't need to be an expert. It's a request for public feedback as for any big project like building a reservoir or an oil pipeline.

If you are an expert on planetary protection for Mars sample returns, or closely related topics (e.g. astrobiology) and want to do something about it - do contact me, support@robertinventor.com . My main idea so far is to ask experts to sign a letter to NASA about it. The draft of the letter is at the end of my academic analysis of the draft EIS . It's not yet ready for signature, as I will see what experts think about how best to take this forward or if the text needs to be changed. Do say if you are interested sign the letter, or have other ideas about how to take this forward.

Anyway lets look at NASA's draft EIS some more, there is lots more to say.

ENVIRONMENTAL IMPACT STATEMENT CLAIMS NO SIGNIFICANT RISK OF ENVIRONMENTAL EFFECTS AND NO UNUSUAL HUMAN HEALTH RISKS - BY MISREPRESENTING ITS SOURCES

Skip to next section

NASA'S EIS claims that potential environmental impacts would not be significant

> **3.4.1.2.2 Environmental Consequences**
>
> **The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgement that the potential environmental impacts would not be significant.**
>
> **3–15**

and no unusual human health risks. For the sample recovery

> **Given implementation of these precautions and given that Mars materials are not expected to have significant pathological impacts if released into the Earth's biosphere, on-site mission preparation (to include testing, rehearsals, and landing site preparation), EES landing, and EES recovery operations are expected to have minimal direct and/or indirect impacts on human health at the UTTR, the Det-1 location, or in general.**
>
> **3–18**

Yet when considering the possibility of studying the samples with humans in orbit they say there is concern about potential health impact 2-26):

> **Additionally, a positive result from the SSAP (Site Safety Assessment Protocol) represents a potential hazard to crew health within a small, enclosed system, plus a contaminated facility that will eventually need to be returned to Earth (or will fall to Earth if there is a system failure).**
>
> **2–26, section 2.3.1.1 Programmatic Alternatives**

So it is rather inconsistent, they claim a potential hazard to crew health if the samples are studied in orbit, but minimal hazard to human health in case of an accidental release once the samples are returned to Earth.

They claim that the risk of accidental release from a BSL-4 are minute and can be described as zero.

> **While not completely analogous,the results of previous NEPA analyses for BSL-4 facilities have concluded that the hazards associated with the operation of BSL-4 facilities are expected to be minimal. Analyses performed in support of recent NEPA documents conclude that the risk from accidental release of material from a BSL-4, even under accident conditions that include the failure of protective boundaries (e.g., reduced effectiveness of ventilation filtration systems) are minute and can be described as zero (NIH/DHHS 2005).**
>
> **An alternative release path resulting from the contamination of workers leading to direct contact with others (members of the public) was also analyzed. Qualitative risk assessments for this mode of transmission have shown that the risk to the public is negligible. (NIH/DHHS 2005, DHS 2008)**
>
> **3–14**

Of course this is not true. The risk of release from a BSL-4 is small yes but it is not correct to describe the risk as zero. There are sometimes accidental releases from BSL-4 facilities.

These are usually through human error rather than issues in the lab design or protocols. Example, in 2003 in Taiwan, SARS was released from a BSL4 facility through human error. The technician found a spill in a cabinet and instead of filling it with hydrogen peroxide and waiting for some hours as was the normal procedure, he wiped it with ethanol, and put his head into the cabinet to do this. He did this because the standard procedure would make him late for a conference

. The Good, the Bad and the Ugly: a review of SARS Lab Escapes

There were several breaches of containment during the Apollo sample handling.

For instance, two technicians had to go into isolation after a leak was found in a sample handling glove for Apollo 11

. When Biospheres Collide: A History of NASA's Planetary Protection Programs. page 485

. When Biospheres Collide: A History of NASA's Planetary Protection Programs. page 241

FLIGHT ENGINEERS SHOULDN'T MAKE DECISIONS FOR HUMANITY ABOUT WHAT LEVEL OF RISK IS MINUTE ENOUGH TO DESCRIBE AS ZERO

Skip to next section

The "gold standard" for a BSL-4 is to aim for a one in a million chance, though we still get escapes with only 50 labs so far so that isn't actually achieved mainly because of human error.

However because of the potential for large scale effects on human health and on the environment, some would say we shouldn't take even a one in a million chance. This is not something for flight engineers to decide.

Carl Sagan said of a Mars sample return:

> *The likelihood that such pathogens exist is probably small, but we cannot take even a small risk with a billion lives.*

In context:

> *I reach this conclusion reluctantly. I, myself, would love to be involved in the first manned expedition to Mars. But an exhaustive program of unmanned biological exploration of Mars is necessary first**. The likelihood that such pathogens exist is probably small, but we cannot take even a small risk with a billion lives.** Nevertheless, I believe that people will be treading the Martian surface near the beginning of the twenty-first century.*
>
> (Cosmos)

As Randolph put it (Randolph, 2009:292).

> *The risk of back contamination is not zero. There is always some risk. In this case, the problem of risk - even extremely low risk - is exacerbated because the consequences of back contamination could be quite severe. **Without being overly dramatic, the consequences might well include the extinction of species and the destruction of whole ecosystems**. Humans could also be threatened with death or a significant decrease in life prospects*
>
> ***In this situation, what is an ethically acceptable level of risk, even if it is quite low? This is not a technical question for scientists and engineers. Rather it is a moral question concerning accepting risk.** Currently, the vast majority of the people exposed to this risk do not have a voice or vote in the decision to accept it. Most of the literature on back contamination is framed as a discourse amongst experts in planetary protection. Yet, as I've already argued, space exploration is inescapably a social endeavor done on behalf of the human race. Astronauts and all the supporting engineers and scientists work as representatives of all human persons.*
>
> **…**
>
> In this situation to treat persons with dignity and justice means that everyone should have the opportunity to voice their opinion concerning whether humans should accept the risk.

This shouldn't be decided through a statement in a draft Environmental Impact Statement saying

> **the risk from accidental release of material from a BSL-4 … are minute and can be described as zero**

ANALOGY OF SYNTHETIC LIFE WITH LIFE FROM MARS SUGGESTS WE NEED CONTAINMENT ORDERS OF MAGNITUDE SAFER THAN A BSL-4 IF MARTIAN LIFE IS INDEPENDENTLY EVOLVED

Skip to next section

Since we could return independently evolved life from Mars, a better analogy for life from Mars is synthetic biology. This already permits the creation of inheritable synthetic life such as life with hachimoji DNA

. Hachimoji DNA and RNA: A genetic system with eight building blocks.

. They make sure that this is safe by designing nucleotides that depend on chemicals only available in the laboratory.

Synthetic biologists have suggested that a safety mechanism to contain synthetic life should be many orders of magnitude safer than any contemporary biosafety device. Schmidt put it like this:

> *The ultimate goal would be a safety device with a probability to fail below 10^{-40}, which equals approximately the number of cells that ever lived on earth (and never produced a non-DNA non-RNA life form). Of course, 10^{-40} sounds utterly dystopic (and we could never test it in a life time), maybe 10^{-20} is more than enough. The probability also needs to reflect the potential impact, in our case the establishment of an XNA ecosystem in the environment, and how threatening we believe this is.*
>
> ***The most important aspect, however, is that the new safety mechanism should be several orders of magnitude safer than any contemporary biosafety mechanism.***
>
> . Xenobiology: a new form of life as the ultimate biosafety tool

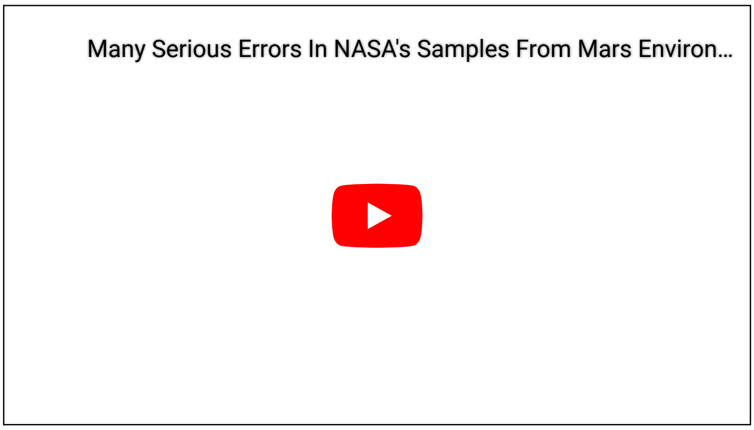
MY VIDEO SUMMARY, BLOG POST, ACADEMIC ANALYSIS AND ANNOTATED ENVIRONMENTAL IMPACT STATEMENT

Skip to next section

I summarize some of the main mistakes in my blog post on Science 2.0: Many Serious Mistakes In NASA's Samples From Mars Environmental Impact Statement - Proposals For A Way Forward

And I did a video for the blog post here:

Video:



Click to watch on Youtube: [Many Serious Errors In NASA's Samples From Mars Environmental Impact Statement - A Way Forward]

I did an annotated version of the EIS here

. [NASA_EIS_annotated.docx]

For the first comment search for "These same principles" then click on the speech bubble to the right. That then shows up all the comments and you can click through them. You can use the comments list to find the passages I highlighted as of special concern, and then read my comments on them. Sadly the web version shows the comments as plain text leaving out formatting, hyperlinks and graphics. But you can use the … menu to download it.

You can also download it directly here:

My preprint about the EIS is here.

. So many serious mistakes in NASA's Mars Samples Environmental Impact Statement it needs a clean restart - omits major impacts – uses old science later overturned – statements cited to sources that say the opposite – no response to significant public concerns – "Purpose and need" should permit a sterilized return as a reasonable alternative action - and size limit needs a new review first, a decade after the ESF in 2012 reduced the size of particle to contain from 0.2 to 0.05 microns

That detailed preprint is long as I wanted to be thorough.

However, you can get an idea of the main issues from the first page of the contents list and click through to get the basic points. Indeed I have written the section titles like mini-abstracts, so you can get an idea of the basic points by just reading the section titles. It's organized so you can drill in to whatever depth you like on any topic I cover.

NASA'S EIS SAYS THAT IF THERE IS LIFE ON MARS IT ISN'T NEAR THE SURFACE ON JEZERO CRATER BY CITING THE 2014 RUMMEL ET AL STUDY CLAIMING A CONSENSUS - BUT THEY OMIT THE REVIEW IN 2015 WHICH MODIFIED MANY OF ITS CONCLUSIONS SO IT IS NOT A CONSENSUS

Skip to next section

This is what they say:

> ***Consensus opinion within the astrobiology scientific community supports a conclusion that the Martian surface is too inhospitable for life to survive there today, particularly at the location and shallow depth (6.4 centimeters [2.5 inches]) being sampled by the Perseverance rover in Jezero Crater, which was chosen as the sampling area because it could have had the right conditions to support life in the ancient past, billions of years ago (Rummel et al. 2014, Grant et al. 2018).***
>
> **S 2–4**

Their source is not a consensus position.

Rummel, et al., 2014. *. A new analysis of Mars "special regions": findings of the second MEPAG Special Regions Science Analysis Group (SR-SAG2)*

Even as that 2014 report by Rummel et al was in publication, NASA and ESA commissioned a review which overturned many of its findings.

The NASA EIS relies on Rummel, et al., 2014.

It is a **serious omission** to not mention

Board, S.S., 2015. Review of the MEPAG report on Mars special regions.

That's because it reversed or corrected many of its findings including the ones they rely on for that statement.

As for their second cite, Grant et al, it is kind of random. It's not about planetary protection, it is about the geographic features of the landing site with a very brief mention of planetary protection referring to other papers and Grant et al's only cite on planetary protection is for the possibility of creating a temporary habitable region if a spacecraft accidentally impacts on the surface.

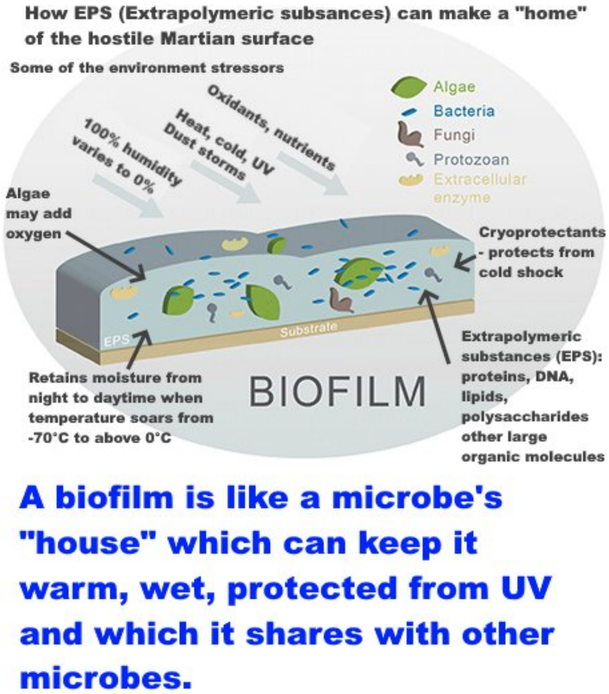
EIS DOESN'T CONSIDER SPORES AND PROPAGULES IN DUST STORMS OR BIOFILMS OR LOCAL MICROHABITATS - A BIOFILM IS LIKE A MICROBE'S HOUSE IN AN OTHERWISE INHOSPITABLE ENVIRONMENT - OR THAT MARTIAN LIFE AFTER BILLIONS OF YEARS EVOLUTION ON MARS MIGHT BE BETTER AT LIVING THERE THAN TERRESTRIAL LIFE

Skip to next section

So the EIS doesn't consider

- local habitats not visible from orbit in regions that seem uninhabitable on a larger scale
- capabilities of biofilms to make a home for microbes in inhospitable surroundings.
- transfer of life in dust from other parts of Mars.

These are all identified in the 2015 review as knowledge gaps about Mars.



> How EPS (extrapolymeric substances) can make a "home" of the hostile Martian surface.
>
> Some of the environment stressors
>
> 100% humidity varies to 0%
>
> Heat, cold, UV, dust storms
>
> Oxidants, nutrients
>
> Algae may add oxygen
>
> Retains moisture from night to daytime when temperature soars from -70°C to above 0°C.
>
> Cryoprotectants - protects from cold shock
>
> Extrapolymeric substances (EPS): proteins, DNA, lipids, polysaccharides, other large organic molecules.
>
> A biofilm is like a microbe's "house" which can keep it warm, wet, protected from UV and which it shares with other microbes.

I got the metaphor of a "house" from this paper:

> If biofilms can be metaphorically called a "city of microbes" (24), the EPS represent the "house of the biofilm cells." The EPS determine the immediate conditions of life of biofilm cells living in this microenvironment by affecting porosity, density, water content, charge, sorption properties, hydrophobicity, and mechanical stability (6).
>
> . The EPS matrix: the "house of biofilm cells".

The EIS also doesn't consider the possibility of Martian life having capabilities Earth life doesn't have after adapting to conditions on Mars and transfer in dust storms for billions of years.

THE EIS JUMPS FROM STUDIES THAT SAY IT IS POSSIBLE SOME VERY HARDY MICROBES GOT FROM MARS TO EARTH TO A

CONCLUSION THAT FOR ANY LIFE IN JEZERO CRATER IT IS EASIER TO GET HERE INSIDE A METEORITE THAN RETURNED IN A SAMPLE TUBE - WHAT MATTERS ARE SPECIES THAT CAN'T GET HERE IN METEORITES (IF ANY EVER HAVE)

Skip to next section

NASA's EIS goes on to say that if there is life in Jezero crater it can get to Earth faster and better protected in a meteorite than in their sample tubes. They rely on cites that just say that there is a possibility that some hardy life gets here on meteorites, such as b. subtilis, not proven of course.

But for panspermia we only need one martian species to get here. For the natural contamination standard we need ALL martian species to get here.

NASA's EIS doesn't explain that for sample return what matters are any species that can't get here in a meteorite. I use the example of a barn swallow which isn't an invasive species in the Americas because it can fly across the Atlantic while the starling is invasive because it needed humans to get there. For microbes, the diatom "didymo" is an invasive species in New Zealand and can't even get from one freshwater lake to another without human assistance.

There may be many species on Mars that can live perhaps in biofilms in the salts, using the water that forms at night even in Gale crater where Curiosity detected brines briefly forming in the dunes or elsewhere on Mars. They may be adapted to get blown in the dust storms, maybe with protective coatings, but could never get to Earth in a meteorite as we have no samples of Martian dust or dirt. These species might not be able to get 3 meters below the surface in the southern uplands, where the temperature is a uniform -70 C and where our meteorites come from and then get on ejecta, survive the fireball of exit from Mars, the shock of ejection and fireball of entry to Earth.

MOST PHOTOSYNTHETIC LIFE WOULD GET HERE VERY RARELY IF AT ALL

Skip to next section

Charles Cockell found that even the blue green algae chroococcidiopsis, remarkable extremophile as it is, would rarely get here that way. In a re-entry test of chroococcidiopsis attached to a heat shield not only chroococcidiopsis but all the organics were destroyed at the distance below the surface where it would typically penetrate to. He concluded that while it might be possible for some photosynthetic life to get here on a meteorite in the past, it's not a common event. Also chroococcidiopsis is very sensitive to the shock of ejection and would only survive in the 2% of rocks ejected at the very lowest end of the shock range. For all we know, some species of martian surface life could be easily damaged by the shock of ejection like Chroococcidiopsis or more so.

2009 NATIONAL RESEARCH COUNCIL STUDY WHICH THE EIS CITES SAYS THE POSSIBILITY EVEN OF LARGE SCALE EFFECTS THOUGH LIKELY LOW IS NOT DEMONSTRABLY ZERO

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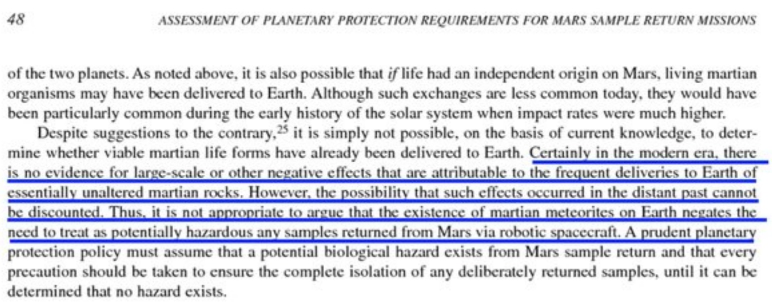
As the experts among you will know, the 2009 NRC Mars sample return study which the NASA EIS cites said we have to treat Mars samples as a potential risk. They said that though there don't seem to be examples of large scale effects in the recent past due to microbes from Mars they can't rule it out for the distant past. They said it's not appropriate to argue from the martian meteorites to say we don't need to take precautions to protect Earth.


48 *ASSESSMENT OF PLANETARY PROTECTION REQUIREMENTS FOR MARS SAMPLE RETURN MISSIONS*

of the two planets. As noted above, it is also possible that *if* life had an independent origin on Mars, living martian organisms may have been delivered to Earth. Although such exchanges are less common today, they would have been particularly common during the early history of the solar system when impact rates were much higher.

Despite suggestions to the contrary,[25] it is simply not possible, on the basis of current knowledge, to determine whether viable martian life forms have already been delivered to Earth. Certainly in the modern era, there is no evidence for large-scale or other negative effects that are attributable to the frequent deliveries to Earth of essentially unaltered martian rocks. However, the possibility that such effects occurred in the distant past cannot be discounted. Thus, it is not appropriate to argue that the existence of martian meteorites on Earth negates the need to treat as potentially hazardous any samples returned from Mars via robotic spacecraft. A prudent planetary protection policy must assume that a potential biological hazard exists from Mars sample return and that every precaution should be taken to ensure the complete isolation of any deliberately returned samples, until it can be determined that no hazard exists.

> *Certainly in the modern era, there is no evidence for large-scale or other negative effects that are attributable to the frequent deliveries to Earth of essentially unaltered Martian rocks. However the possibility that such effects occurred in the distant past cannot be discounted*
>
> *... Thus it is not appropriate to argue that the existence of martian meteorites on Earth negate the need to treat as potentially hazardous any samples returned from Mars by robotic spacecraft.*

They said the possibility of large scale effects appears to be low but not demonstrably zero But this is what the National Research Council said in 2009: :48

National Research council: **CONCLUSIONS**

The committee concurred with the basic conclusion of the NRC's 1997 report *Mars Sample Return: Issues and Recommendations* [26] that the potential risks of large-scale effects arising from the intentional return of martian materials to Earth are primarily those associated with replicating biological entities, rather than toxic effects attributed to microbes, their cellular structures, or extracellular products. Therefore, the focus of attention should be placed on the potential for pathogenic-infectious diseases, or harmful ecological effects on Earth's environments.

The committee found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero. Changes in regulations, oversight, and planetary protection controls over the past decade support the need to remain vigilant in applying requirements to protect against potential biohazards, whether as pathogenic or ecological agents. Thus, a conservative approach to both containment and test protocols remains the most appropriate response.

A related issue concerns the natural introduction of martian materials to Earth's environment in the form of martian meteorites. Although exchanges of essentially unaltered crustal materials have occurred routinely throughout the history of Earth and Mars, it is not known whether a putative martian microorganism could survive ejection, transit, and impact delivery to Earth or would be sterilized by shock pressure heating during ejection, or by radiation damage accumulated during transit. Likewise, it is not possible to assess past or future negative impacts caused by the delivery of putative extraterrestrial life, based on present evidence.

NASA's draft Environmental Impact Statement: The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgement that the potential environmental impacts would not be significant.

> **National Research Council**: The committee found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero
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>
> **NASA's draft EIS:** The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgement that the potential environmental impacts would not be significant.

Though the draft EIS does cite the 2009 study it doesn't cite that section about the potential for large scale effects which would contradict its own assertion that there is no significant risk of any environmental effects.

, MSR DRAFT Environmental Impact Statement 3-16

GREAT OXYGENATION EVENT AS EXAMPLE PAST LARGE SCALE TRANSFORMATION WHICH COULD BE CAUSED BY LIFE FROM ANOTHER PLANET - AND MIRROR LIFE AS EXAMPLE RISK TO CONSIDER FOR MARS

Skip to next section

They don't give an example of past large scale effects that could be due to martian life, but the great oxygenation event is an obvious one. If photosynthetic life did originate on Mars and got here after some early large impact on Mars it could be an example of a major transformation of our atmosphere and ocean by life from Mars. Whether photosynthetic life did or didn't come from Mars it shows the potential of life with a novel capability to transform the environment of Earth - turning it into a planet with oxygen rich oceans and atmosphere.

I've used the example of mirror life in my preprint on planetary protection for NASA's Mars sample return mission. Astrobiologists say we can't assume we are looking for familiar life on Mars and some think that the reason we have normal and not mirror life is just blind luck. If so, and if Mars has independently evolved life it could be a 50-50 chance that it is mirror life. So the chance of mirror life there seems low but not that low, depending on how likely it is that life evolved independently on Mars and on why Earth doesn't have mirror life already. Mars could also have both forms, independently evolved mirror and non mirror life co-existing.

Mirror life is a logical combination of

1. some astrobiologists think that it is just "luck of the draw" that we ended up with ordinary life rather than mirror life, 50 -50. See: The origin of homochirality
2. evolution could easily have happened independently on Mars and if so might have evolved as mirror life from early life all the way

Some terrestrial microbes do have the enzymes needed to transform mirror organics into normal organics to use it. See:

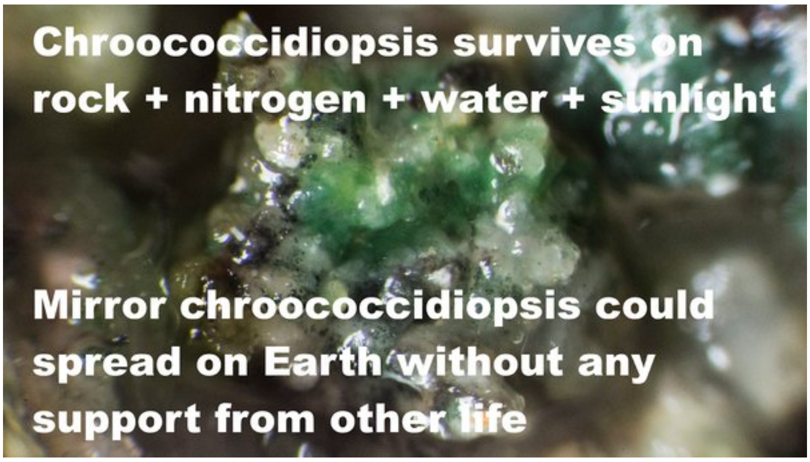
. Raineyella antarctica gen. nov., sp. nov., a psychrotolerant, d-amino-acid-utilizing anaerobe isolated from two geographic locations of the Southern Hemisphere

Most terrestrial life couldn't make use of mirror organics such as starches, fats, proteins.

2007. An adventure in stereochemistry: Alice in mirror image land

Mirror life on Mars would be sure to have the necessary enzymes to be pre-adapted to use normal non mirror organics because of all the ambidextrous meteorites, comets and abiotic organics on the surface. So if we returned mirror life, it would likely take a while to evolve and adapt to terrestrial ecosystems, then it would likely slowly over decades and centuries transform all terrestrial organics to mirror organics. Because it can eat ordinary organics and ordinary life can't use its mirror organics.

One top terrestrial microbe to survive on Mars is chroococcidiopsis, a primary producer, blue-green algae, lives anywhere from tropical reservoirs to Antarctic cliff faces and Mars could have similar. But maybe mirror blue-green algae.



Chroococcidiopsis survives on rock + nitrogen + water + sunlight

Mirror chroococcidiopsis could spread on Earth without any support from other life.

Photograph shows chroococcidiopsis in a cave at Ares Station, Cantabria in the Iberian peninsula – with a transparent covering of other microbes – it can live on its own or in colonies with other life and it can also live inside rocks. Photo by Proyecto Agua on Flickr

Only a very few species of terrestrial microbes can metabolize mirror organics and though many microbes might eventually evolve or take up the capability from other microbes, few longer lived species could do that. They wouldn't transform into mirror life. They would be normal organics but with the ability to digest mirror organics by flipping it into normal organics.

Right now an early life proto mirror cell would be too vulnerable. So it couldn't evolve again from scratch. But highly evolved mirror life from Mars might be able to compete fine In the mirror life scenario the organism itself is mirror life throughout ALL its chemicals are mirrored including the DNA, proteins, enzymes etc. It has to evolve independently to same complexity as modern life.

As to why we don't have mirror life now - it could have evolved early on, and it's a bit of a mystery why we have only the one form of life. Also can be ambidextrous life in theory, Joyce's enzyme is chirality indifferent. However now, billions of years later,, it isn't easy to "flip a cell" - all the molecules have to be flipped not just DNA or enzymes or proteins. It will likely take a decade of careful experiments.

There are various theories about why we have only normal not mirror life. With luck of the draw, it's just that early life evolved one way, gradually got better and it is so hard to evolve from scratch, that the mirror form never got underway in time, by chance.

. The origin of biological homochirality .

A living cell is like an intricate machine with lots of interlocking asymmetric parts. You can flip the whole thing in the mirror and it will still work. But flip a few components and it will just jam up.

It's rather remarkable that synthetic biologists think they can flip a cell. The big problem is how it can continue to function when only half is flipped and the other half isn't. But they think they solved that problem in theory though many practical problems for next decade.

This is a researcher into synthetic mirror life outlining a worst case scenario of what could happen if mirror life escaped from a laboratory with the necessary enzymes to flip terrestrial organics. He says we have to make it dependent on lab chemicals so it can't do that.

. Mirror-image cells could transform science-or kill us all

I don't think mirror life would kill us all in reality. But it would be an environmental effect as great as the Great Oxygenation Event and once started likely unstoppable. The worst case scenario here is that in future generations humans have to paraterraform Earth and live in habitats kept clear of mirror life and preserve our natural ecosystems in enclosed habitats with normal organics in the soil and water instead of it all mirror organics. We could probably preserve almost all terrestrial species, with vast habitats and the technology of tomorrow, and coral reefs, seagrass, kelp forests and other regions of the sea too but in this worst case scenario, outside those habitats nearly all higher life would be gone and would gradually re-evolve over millions of years to handle mirror organics.

But it would be severe legacy for the next generation if they had to cope with that due to us returning it from Mars - in that worst case scenario.

PERSEVERANCE COULD CAPTURE LIFE FOR INSTANCE IN ITS REGOLITH SAMPLES - AND THE TUBES AREN’T FULLY STERILIZED SO THERE IS NO WAY TO TELL IF IT IS MARTIAN OR TERRESTRIAL LIFE

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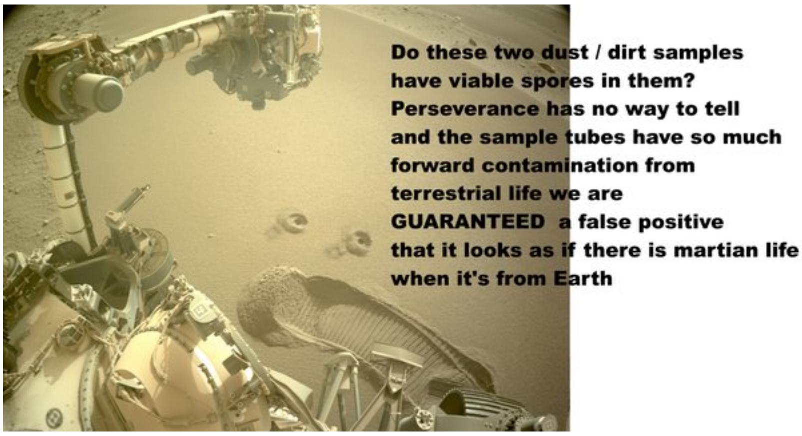
Perseverance is not looking for life, so NASA will only return it if we go by the astrobiologists who are most optimistic about life on Mars or if they are very lucky. But Perseverance does have two samples of regolith that include dirt and dust and it's not impossible those have a few viable martian microbes per gram. There's no way Perseverance could test for life in its tubes and even if it could, the sample tubes aren't 100% sterilized and have significant levels of terrestrial organics.



> Do these two dust / dirt samples have viable spores in them? Perseverance has no way to tell and the sample tubes have so ,much forward contamination from terrestrial life we are GUARANTEED a false positive that looks as if it is martian life when it's from Earth.

THE EIS MAKES IT A "PURPOSE OR NEED" TO RETURN UNSTERILIZED SAMPLES FOR "SAFETY TESTING" - WHICH EXCLUDES THE REASONABLE ALTERNATIVE OF A STERILIZED SAMPLE RETURN WHICH DOESN'T NEED SAFETY TESTING - A TEST CASE OF AN APPARENTLY SIMILAR OVER NARROW NEEDS AND PURPOSE IN 1997 LEAD TO THE WHOLE ACTION VACATED SO IT COULDN'T GO AHEAD

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Then NASA's draft EIS makes it a "purpose or need" to return unsterilized samples for "safety testing".

> *An important aspect of this is that many critical measurements can only be done on samples that have been through intricate sample preparation processes, and most of those processes are not able to be automated.*
>
> ***These same principles regarding the importance of using terrestrial laboratories to enable the best scientific return also apply to the care and attention to detail that would be required to conduct a proper and comprehensive sample safety assessment in a proposed SRF.***
>
> ***3–3***

So the purpose and need section says that the samples have to be returned to Earth to do a comprehensive sample safety assessment.

If we check the submitted alternatives, this is an argument they use to rule out the alternatives to "no action" proposed during scoping.

> **Section 2–3 (Alternatives considered but not carried forward)**
>
> ***Alternatives must be able to accommodate the equipment required to conduct the proper analysis to meet MSR Campaign objectives (which include not only science but also a properly rigorous assessment of the biological safety of the samples).***
>
> 2–24

So they use the narrow scope of the needs and purpose to exclude any alternative that doesn't permit a safety assessment of the sample to detect if there is life in it or not before it is returned.

The issue here is that there is no need for a safety assessment if all samples are sterilized before they reach Earth's biosphere.

A sterilized sample return would preserve almost all the geological interest of the study by their own assessment. They don't do this, the only alternative to return to a biosafety laboratory on Earth is "no action".

I am not a lawyer and I welcome comments from lawyers on whether my understanding here is correct.

But if I understand right, they shouldn't define the purpose and need so narrowly.

As a result it doesn't even mention the reasonable alternative of a sterilized sample return.

I think this is actually illegal in the USA under a 1997 decision of the 7th circuit that it isn't permitted to define the purpose and need so narrowly as to rule out reasonable alternatives.

This is the judgement, which is often referred to in later cases:

> **One obvious way for an agency to slip past the strictures of NEPA is to contrive a purpose so slender as to define competing "reasonable alternatives" out of consideration (and even out of existence). The federal courts cannot condone an agency's frustration of Congressional will.** If the agency constricts the definition of the project's purpose and thereby excludes what truly are reasonable alternatives, the EIS cannot fulfill its role. Nor can the agency satisfy the Act. 42 U.S.C. § 4332(2)(E)
>
> 7th Circuit, 1997 Simmons v. U.S. Army Corps of Engineers

In that test case the Justice vacated the action, i.e. ruled that it can't go ahead. They wanted to build a reservoir but wrote the Purpose and Need section so narrowly as to exclude the possibility of considering two smaller reservoirs in place of one larger reservoir. That was enough for them to lose their case and they weren't permitted to build any reservoir - not based on two smaller reservoirs being better. Just based on them improperly excluding two smaller reservoirs from consideration.

It would take an expert in US environmental law to say for sure but this does seem to suggest considerable legal jeopardy for NASA to define its purpose and need so narrowly. Has a lawyer looked at this?

In any case if it does go to the courts, there is surely no way that NASA could win the case because of all the other mistakes. So it would be a case of what the Justice decides. Hopefully just to restart with a new EIS and fix the mistakes?

SAFETY TESTING WOULDN'T WORK ANYWAY - BECAUSE THERE IS SO MUCH FORWARDS CONTAMINATION, THE LEVEL OF CONTAMINATION FROM TERRESTRIAL LIFE IS SO GREAT IT CAN NEVER PASS THIS TEST

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The safety testing couldn't work anyway.

NASA's draft EIS refers to the study on safety testing from COSPAR. But in the abstract this says it's difficult and not practically possible to test any martian life for its effect on a new environment and that the only safety testing they looked at is to test to see if there is life there at all.

> *During the Working Group's deliberations, it became clear that a comprehensive assessment to predict the effects of introducing life in new environments or ecologies is difficult and practically impossible, even for terrestrial life and certainly more so for unknown extraterrestrial life.*
>
> *To manage expectations, the scope of the SSAF was adjusted to evaluate only whether the presence of martian life can be excluded in samples returned from Mars.*
>
> *If the presence of martian life cannot be excluded, a Hold & Critical Review must be established to evaluate the risk management measures and decide on the next steps.*
>
> . COSPAR Sample Safety Assessment Framework (SSAF).

However the sample tubes weren't sterilized 100%. NASA expect returned rock samples to have 8.1 nanograms organics from terrestrial contamination per gram of returned rock sample, and up to 0.7 nanograms of each biosignature. They don't have a break down of which biosignatures were most abundant in their modeling but a gram of rock could contain 0.7 nanograms of their most abundant biosignatures, perhaps DNA, and similar amounts of glycine, alanine etc with up to 0.7 nanograms for each biosignature they tested. ppb is the same as nanograms per gram in this table:

To determine a final return sample cleanliness value, each of the vectors above was assessed using analysis results, test results, theoretical modeling, or a combination of the three. Predicted results are given in Table 6 for rock core samples.

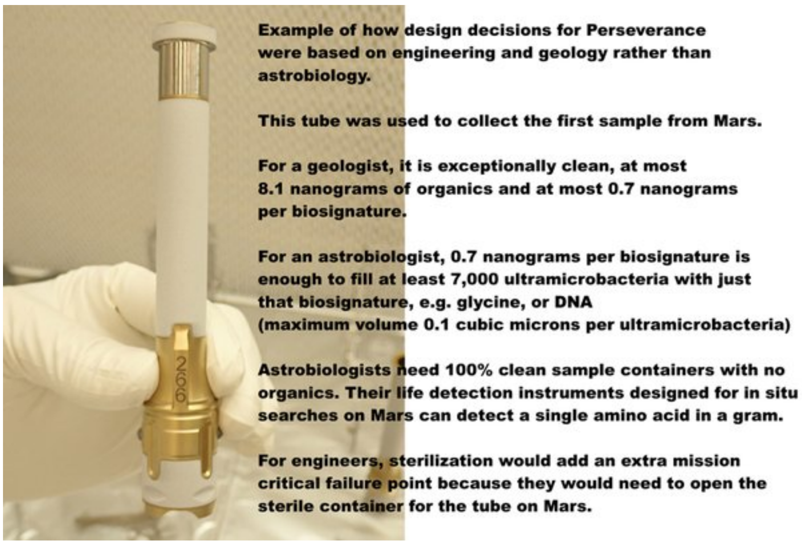
Table 6. Mars 2020 Return Sample Contamination Cleanliness Predicted Results for Rock Core Samples

Contamination Class	Requirement	Best Estimate	Notes
Viable Organisms	<1E-3	4.80E-06	Probability
Total Organic Carbon	10 ppb baseline 40 ppb threshold	8.1 ppb	
Tier 1 Compounds	1 ppb	0.7 ppb	
Tier 2 Compounds	10 ppb	<10 ppb	

This is from table 6 of:. Mars 2020: mission, science objectives and build. In Systems Contamination: Prediction, Control, and Performance 2020

So that works out as:

- 8.1 nanograms of organics per gram of returned rock sample.
- 0.7 nanograms per gram for each of the biosignatures they tested (e.g. DNA)
- 0.00048% chance of a single viable microbe per tube
  – this means a 0.02% chance that at least one tube has a viable terrestrial microbe in it.



> **Text on image:** Example of how design decisions for Perseverance were based on engineering and geology rather than astrobiology.
>
> This tube was used to collect the first sample from Mars.
>
> For a geologist, it is exceptionally clean, at most 8.1 nanograms of organics and at most 0.7 nanograms per biosignature.

> For an astrobiologist, 0.7 nanograms per biosignature is enough to fill at least 7,000 ultramicrobacteria with just that biosignature, e.g. glycine, or DNA (maximum volume 0.1 cubic microns per ultramicrobacteria)
>
> Astrobiologists need 100% clean sample containers with no organics. Their life detection instruments designed for in situ searches on Mrs can detect a single amino acid in a gram.
>
> For engineers, sterilization would add an extra mission critical failure point because they would need to open the sterile container for the tube on Mars.

So if they use Kminnek et al's recommended method for safety testing, all the samples will test positive for biosignatures and go to hold and critical review. I looked at what could come next, for critical review, and technicians couldn't try to cultivate martian life because as psychrophiles the doubling time would likely be months to years or more.

Also most terrestrial microbes can't be cultivated. One of the reasons for the "uncultivable majority" is that in labs the medium is too rich for them though they do very well in nutrient poor environments. Most martian life would be adapted to nutrient poor environments. Another reason can be dependence on chemicals provided by other life in biofilms and martian life is likely to use biofilms.

They couldn't use gene testing because the Perseverance clean room samples turned up many species only known by a small subunit of the ribosome rna and of those four of the species were not closely related to any known terrestrial species. We can be sure there will be many species found similarly when the samples are thoroughly analysed. This is normal, the issue of microbial "dark matter".

As far as I can tell all the samples would go to hold and critical review until we find out more about Mars by other methods.

SO BSL-4 DOESN'T PROTECT EARTH, THE SAFETY TESTING IS IMPOSSIBLE, ALL THE SAMPLES WILL NEED TO BE STERILIZED FOR THE GEOLOGISTS ANYWAY - AND THERE IS ALMOST NO CHANCE OF INTERESTING ASTROBIOLOGY - SO WHY NOT JUST STERILIZE THEM ALL ON THE WAY BACK AND KEEP EARTH 100% SAFE WITH A LOWER COST MISSION TOO WITHOUT THE UNNECESSARY, EXPENSIVE AND INEFFECTIVE PRECAUTIONS NASA WANTS TO DO?

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So, I don't see the point in the BSL-4. It doesn't protect Earth, it will be hard to do the studies geologists want to do in a BSL-4. NASA themselves found that sterilization makes virtually no difference to most geological studies, and they will have to sterilize all the samples removed from the labs anyway because they will all be in "hold and critical review" indefinitely.

Then there is almost no chance of interesting astrobiology from samples contaminated with so much terrestrial life, and Perseverance has no life detection instruments so it can't expect to find the heavily degraded organics of past life. The astrobiologist papers I've seen all say it has to be able to spot multiple biosignatures in situ to have a chance of returning the likely very rare rock samples there that may have evidence of past life.

Meanwhile present day life isn't even an objective and it's not trying to search for microhabitats in Jezero crater. There are several suggested microhabitats that are relevant to Jezero crater such as biofilms exploiting the brines Curiosity detected, photosynthetic life exploiting the night time humidity directly and life in micropores in salt deposits which concentrate humidity to make the micropore more habitable than the surrounding atmosphere - and Jezero crater has near 100% night time humidity. But they aren't looking for present day life, and can't detect it in situ. Given how patchy life is in terrestrial deserts near the dry limit for life the chance they return it is very low unless there is present day life almost everywhere - and even if there is life in the regolith samples, the chance that it can be distinguished from the terrestrial contamination seems so low as to be almost nonexistent.

So I don't think astrobiologists will be concerned about sterilizing all the samples. With near certainty, it's just going to be another study that proves what we already know, that Mars in the past was habitable for life, in a little more detail. For astrobiologists, the mission "as is" is a technology demo for a future more interesting sample return for astrobiology using in situ life detection to search for biosignatures on Mars before returning samples.

OR WE CAN MAKE IT FAR MORE INTERESTING BY ADDING BONUS SAMPLES OF DIRT, DUST AND ATMOSPHERE IN 100% STERILE CONTAINERS

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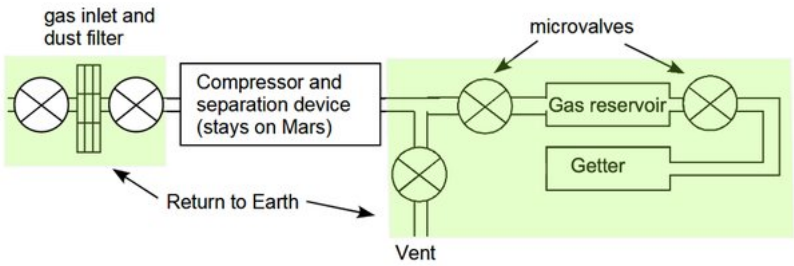
But we could make it far more interesting by returning a sample of the dirt, dust and atmosphere in 100% sterile containers using an atmospheric compressor as for MOXIE to compress the atmosphere to return about a fifth of a gram of atmosphere to analyse for trace gases like the methane and anything else of biological interest. This is a suggestion by Jakosky et al. Then run in a cycle the compressor can then collect dust from dust storms to find either spores of Martian life adapted to spread in the dust, or dead life just as we detect microbial life from the Gobi desert in Japan. Depending on how habitable the most habitable regions on Mars are, and how exposed to the dust storms we could detect life at a considerable distance from Jezero crater at concentrations of thousands of dead or viable spores per gram or more diluted to one spore per gram by the time it reaches Jezero crater.

This is how it works.



First it uses the getter to remove evolved gases from the container wall. Then it closes one microvalve and opens another to get an atmospheric sample. Finally it closes both microvalves to the gas container and opens the vent to run more atmosphere through the compressor to collect dust in the filter

. Scientific value of returning an atmospheric sample from Mars.

Then we could return a sample of dirt, ideally including the salts that Curiosity found. Even if there is no life there it would help us to simulate surface processes and microhabitats more accurately in our Mars simulation chambers. It could also resolve the old question of what Viking found and especially the offset of 2 hours for the evolved gases from the diurnal temperature maximum. If that wasn't life then we still need to know what complex chemistry lead to that effect.

Also even if there is no life on Mars - we have nowhere on Earth with habitats that have had organics for billions of years but no life. So, anything we find in potential microhabitats on Mars could tell us a lot about prebiotic chemistry. If there was complex prebiotic chemistry happening in the Viking experiments that's interesting for astrobiology too. It might give us insight into processes that happened before life evolved.

We could adapt the ESA fetch rover to dig up an extra sample of dirt to add to a sterile container and put in the orbital sample capsule.

This shows the sample collection tool for the ESA fetch rover and shows how it resembles the digging tool for Viking and could be adapted to take a sample of dirt from the surface after it has already picked up and stored the geological samples.

NASA could greatly increase the interest of this mission for astrobiologists by digging a scoop of dirt and returning it in a STERILE container.

Perhaps this gripper could double as a scoop somehow?

The digging tool, lower center, was used by Viking to scoop up material from the surface soil for the Viking experiments , Mars - Viking 1 Lander

Inset: Frame at 17 seconds from video of an artist's impression of the ESA fetch rover collecting a sample left on the surface by Perseverance

NASA could use this to return a sample of dirt in a STERILE container.

If this is feasible, then ESA's Sample Fetch Rover could grab a small amount of dirt from the region around the Mars Ascent Vehicle, to a depth of five or ten centimeters or so and load it into the return container after adding the samples from Perseverance's cache.

Analysing this extra sample may help resolve questions about the Viking results and if Viking did find life, it could return that life for study.

Then we could add the gas compressor / dust collector to the same container, compressing the gas and collecting the dust in different compartments.

If the sterile container for the astrobiology bonus samples doesn't open on Mars it would be mission critical for the astrobiology samples, but it wouldn't be any problem for the Perseverance samples, so geology focused researchers and engineers should be okay with it. While for astrobiologists it is a risk worth taking to get samples in sterile containers.

ALL GEOLOGY SAMPLES STERILIZED BEFORE THEY GET TO EARTH - AND ASTROBIOLOGY ONES TOO BUT ARE MUCH MORE INTERESTING RETURNED IN A TRULY STERILE CONTAINER

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If we could get agreement to do this, the idea is that all the geology samples are sterilized before they reach Earth's biosphere. The bonus astrobiology samples could be sterilized too on the return journey and still be interesting, so that's the simplest bonus samples mission. If there was viable life in the sample before sterilization it could still be recognized as such and returned in sterile containers, and for the bonus samples, the biosignature testing would be meaningful. It would still be able to find short unaltered sequences of genetic material, robust large biomolecules like chlorophyl, chiral imbalances in amino acids, visible structures like cell walls and nuclei, and unusual concentrations of particular long chain organics, such as proteins or whatever else it uses recognizably different from the random selection found in meteorites.

OR WE RETURN THE ASTROBIOLOGY SAMPLES TO A SAFE ORBIT ABOVE GEO - AND STUDIED REMOTELY VIA THE AMAZING MODERN MINIATURE LIFE DETECTION INSTRUMENTS

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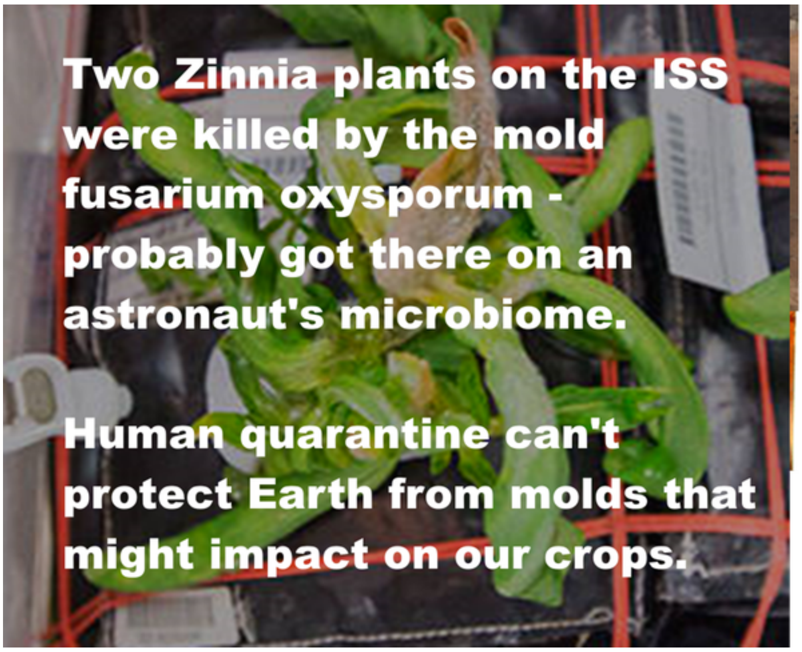
However especially given the likely small but not zero chance of life in the sample, we might want to try reviving the life and want more intact present day life - so we could also return them to a safe stable orbit. I have proposed the Laplace plane above GEO - there even light debris from spacecraft cladding or after an explosion would still be in stable orbits as a result of the competing pressure of light and gravity. So it would be very safe for Earth's biosphere.

I looked at human quarantine for the idea of returning to a human occupied space station but this won't work. One of my examples is about the two Zinnia plants that died in the ISS due to a mold that's an opportunistic plant pathogen brought there probably in the microbiome of one of the astronauts. This mold fusarium oxysporum sometimes causes sickness in immunocompromised humans and very rarely is fatal but was harmless for the young healthy human astronauts on the ISS.



Text on graphic: Two Zinnia plants on the ISS were killed by the mold fusarium oxysporum - probably got there on an astronaut's microbiome

Human quarantine can't protect Earth from molds that might impact on our crops.

Mold growing on a Zinnia plant in the ISS. The mold fusarium oxysporum is thought to have got to the ISS in the microbiome of an astronaut

. Draft genome sequences of two Fusarium oxysporum isolates cultured from infected Zinnia hybrida plants grown on the international space station. Genome announcements, 6(20).

. Two of the four infected plants died , How Mold on Space Station Flowers is Helping Get Us to Mars

It would be impossible to keep a pathogen of terrestrial plants out of the terrestrial biosphere with quarantine of technicians or astronauts.

This shows us human quarantine can't protect Earth from crop diseases, or from opportunistic pathogens such as molds that are symptomless for most people but kill a few. It also can't protect against diseases with life-long symptomless carriers like typhoid Mary or diseases of other animals plants, insects etc.

Also, if the sample contains, say, mirror life ribocells or ultramicrobacteria those could be harmless as a small component of the human microbiome but slowly turn all terrestrial organics to mirror organics as they spread and adapt to live on Earth. With these and many other examples in my paper I plan to submit to astrobiology journals concludes that human quarantine can't protect Earth from Mars samples unless we know what it is specifically that we need to protect against, which of course we can't know at this stage. I am confident this part of my preprint will survive peer review.

This is that preprint I've been working on for two years or so now.

- NASA and ESA are likely to be legally required to sterilize Mars samples to protect the environment until proven safe – the technology doesn't yet exist to comply with the ESF study's requirement to contain viable starved ultramicrobacteria proven to pass through 0.1 micron nanopores - proposal to study samples of astrobiological interest remotely in a safe high orbit above GEO with miniature life detection instruments – and immediately return sterilized samples to Earth

So instead we can return to a satellite where astrobiologists study the dust, dirt and atmosphere using instruments they designed to search for life in situ. These can do sample preparation and detect a single amino acid in a gram, or can do end to end gene sequencing.

They have developed a miniature scanning electron microscope, near field superresolution optical microscope to go beyond the optical resolution limit, synchronized raman spectroscopy to take spectroscopic measurements of features of microbes, and an off axis holographic microscopic imager that lets the researchers refocus the image after return to Earth. That last one is especially interesting if we find life that can be grown in a medium as it can get sharp images of swimming microbes in a solution by refocusing after the image is taken. They have developed many more such instruments. This is because of the extraordinary shrinking in size of the instruments used in biological research in the last 20 years.

So, unlike geology, the astrobiologists can do a lot of their work in space remotely even on Mars and can do it above GEO with much less latency. With Ariane 5 we have sent spacecraft of over 7 tons to above GEO. These instruments weigh fractions of a kilogram up to a few kilograms. We can send between hundreds and thousands of these instruments to above GEO in one payload.

Text added to ESA graphic Mars Sample Return overview infographic,showing current proposed timeline from Fact Sheet Proposed Action, MSR PEIS Fact Sheets and time until the facility is ready to receive sample

Text on graphic:

Mars may resemble Earth's coldest driest deserts: small niches for life adapted to extreme conditions, perhaps habitable at microbial scales only.

Earth is protected from a Mars sample return by numerous laws to protect Earth's biosphere that didn't exist in 1969.

Solution 2: study in a safe orbit above Geostationary Earth Orbit (GEO) first.

Humans never go near the satellite.

Samples stay above GEO.

No risk to Earth's biosphere.

Astrobiologists study samples in orbit much as they would do controlling a rover on Mars.

Sterilized subsamples can be returned immediately.

How to keep Earth 100% safe with minimal impact on science or cost – technology doesn't exist to contain ultramicrobactieria.

So we can

1. sterilize all samples or

2. check for life first - to do this, return samples to a safe orbit above GEO to study remotely with miniature instruments like those designed by astrobiologists to search for life on Mars.

With 2. we can return sterilized sub-samples from the orbital facility immediately.

In 2, a return to the ISS doesn't break the chain of containment with Mars and COSPAR decided the Moon must be kept free of contamination for future astronauts and tourists. Above GEO solves both these issues.

1. and 2. both have simple legal processes.

By NASA regulations, build can't start until technology is decided. Build estimate: 9+ years + 2 years to train technicians.

Earliest date ready: 2023 + 11 = 2034

However, the technology doesn't exist yet for the 2012 European Space Foundation requirement of 100% containment of 0.05 micron particles even a decade later. This limit may also be reduced further on review.

Also from NASA's point of view - these are all expenses for the 2030s and not only that, they are expenses that universities would be likely to take on similarly to the way they fund large terrestrial telescopes. For NASA it would add very little to the mission cost.

I think even this expanded mission with extra samples might turn out to cost less for NASA than their proposed mission. The sterilized sample return surely would, as it would eliminate all their expensive, elaborate and ineffective precautions and be 100% safe for Earth and the samples could be sterilized on the journey back using nanoscale X-ray emitters.

So I think the current draft EIS needs to be stopped. It needs peer review and the size limits study before they can go ahead and preliminary investigation of the timescale, feasibility and cost for the technology to contain samples at the new size limit whatever it is, likely somewhere between 0.05 and 0.01 microns.

They need to consider sterilized sample return and hybrid missions like the one I describe as alternatives and not exclude them through an overnarrow needs and purpose.

TO EXPERTS ON THE TOPIC - ARE YOU INTERESTED IN SIGNING A LETTER TO NASA?

Skip back to top

If you agree on these points, would you be interested in signing a letter saying so, which we could publicise in some way and also send to NASA - perhaps attached to the public comments before it ends 5 days from now.

You can find the draft of the letter towards the end of my preprint here

. So many serious mistakes in NASA's Mars Samples Environmental Impact Statement it needs a clean restart - ...

It says several other things which I think all astrobiologists would agree on but it's just a draft and we can work on it if it needs changes.

Or do any of you have other ideas of how we can proceed?

Also do send this on to anyone else who might be interested a

If I have made any mistakes in any of this please say. So far nobody I contacted has found any mistakes that they mentioned to me. I found some minor errors myself and fixed them. If anyone finds mistakes I will fix them.

Thanks. Best wishes,

Robert

My background and my preprint about planetary protection for NASA's Mars sample return mission (work in progress, hope to submit it soon)

I have a reasonably understanding of the literature they cited because I've been working on that paper NASA and ESA are likely to be legally required to sterilize Mars samples to protect the environment until proven safe ... specifically on planetary protection for NASA's Mars sample return mission since 2020.

I trained as a mathematician, not as an astrobiologist, but astrobiology is very multi-discipline. I think what I bring most to the topic was to bring together results and ideas across the vast range of many different disciplines spanned by the subject. I was invited to give a talk on astrobiology to a small conference in Oxford where some of the world's leading astrobiologists also spoke. My presentation for that conference is here "Super Positive" Outcomes For Search for Life In Enceladus and Europa Oceans - Robert Walker

I was encouraged to write a paper on astrobiology by an astrobiologist friend some years ago. That lead to the my original preprint. It grew and grew and is more like a thesis in length now. I'm not sure what I'll do but plan to submit it or parts of it to astrobiology journals.

I also have a blog on Science 2.0 where I write blog posts on many topics and have often blogged about planetary protection in the past.

For some of my blog posts at Science 2.0 on this topic of protection of Earth for a Mars sample return:

- . Will First Mars Astronauts Stay In Orbit - Tele-operating Sterile Rovers - To Protect Earth And Mars From Colliding Biospheres?
- . Let's Make Sure Astronauts Won't Extinguish Native Mars Life - Op Ed
- . Likely 2040 Before Mars Samples Returned Safely, Legally -Yet Not Likely To Return Life - Needs To Be Detected In Situ First
- . Protecting Mars - And Earth - From What - And Why Bother? Our Inheritance Of Unopened Astrobiological Treasure Chests

And here is my free self-published online book on planetary protection for the general public, where I expand on many of these themes.

- . OK to Touch Mars? Europa? Enceladus? Or a Tale of Missteps?

Here is the link again to my other two posts on NASA's plans:

For a shorter less technical summary see:

. NASA - Do Listen To Public Concerns About Life In Samples From Mars - Your Plan Is Like Building Us A House Without Smoke Alarms

For space colonization enthusiasts see my:

. Dear Space Explorers - Yes We Do Need To Protect Ourselves And Earth From Any Microbes In Mars Rocks As We Explore

My longer version of this blog post:Many Serious Mistakes In NASA's Samples From Mars Environmental Impact Statement - Proposals For A Way Forward

My preprint about the EIS is here.

. So many serious mistakes in NASA's Mars Samples Environmental Impact Statement it needs a clean restart ...

Annotated EIS here as an online word document: NASA_EIS_annotated.docx - you don't need Word to read it though sadly it leaves out formatting and graphics from the comments.

If you have Word you can download the pdf either from that page or via this direct link. NASA_EIS_annotated.docx (for download) or as a zip (only slightly smaller)

Do comment yourself if you have thoughts about the project - go here, and click on the blue button to the left of the page to add a comment:

. National Environmental Policy Act; Mars Sample Return Campaign

You don't need to be an expert to comment. It's an opportunity for feedback from the general public as for any big project like building a reservoir or motorway. Also it's not restricted to the public in the USA - you are asked to give your country of origin in the feedback form as indeed is proper for such a mission.

This is my latest comment:

> I'm trying to get some attention to this. NASA have you found out yet that the European Space Foundation study in 2012 said that we need to contain the very tiny ultramicrobacteria? There is no sign that you have any knowledge of it in the draft EIS. You don't cite this study and your plans involve a biosafety level 4 facility - which CAN'T contain such tiny microbes. We don't need to on Earth but ultramicrobacteria from Mars, perhaps mirror life for instance, are another matter.
>
> Our best air filters are able to stop some of them but at that size they don't use nanopores, they rely on brownian motion, random jostling of air molecules to knock them out of the air stream onto the filter. I didn't find much by way of %s but one study using six layers of filters was able to block out 88%. That is NOWHERE NEAR the European Space Foundation requirement that "The release of a single unsterilised particle larger than 0.05 microns is not acceptable under any circumstance"
>
> Your draft environmental impact statement doesn't even mention this important study and you don't seem to have seen my comment alerting you to it. So you haven't chosen a BSL 4 because somehow you've found a way to contain these particles. It is apparently because you are unaware the requirement even exists. This limit also needs periodic updates which you haven't done.
>
> This is not right. And your statement says that the risk of release from a BSL-4 is minute and can be described as zero - but we do get accidental releases from BSL-4s. It's for the public to decide if that risk can be described as zero not mission planners who are not likely to have an impartial objective view

of the matter.

Then, you say that the potential environmental impacts would not be significant. But the National Research Council in 2009 "found that the potential for large-scale negative effects on Earth's inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero".

You use that meteorite argument but it's invalid. The NRC say "Thus it is not appropriate to argue that the existence of martian meteorites on Earth negate the need to treat as potentially hazardous any samples returned from Mars by robotic spacecraft."

Then finally you say that samples have to be returned to terrestrial labs for "safety testing". But the study by Kminnek et al which you cite would find the abundant biosignatures in the Perseverance contamination (0.7 nanograms per signature per gram) and they would all go into "hold and critical review" so it would achieve nothing.

But based on that you then don't even consider a sterilized sample return which would achieve virtually all the same science and keep Earth 100% safe even from e.g. mirror life ultramicrobacteria. There may be some legal jeopardy in doing what you did too - a 1997 test case by the 7th Circuit lead to a project to build a reservoir being stopped altogether because they defined the Purpose and Need so narrowly as to exclude the reasonable alternative of two smaller reservoirs. And whether or not it's legal, it's not ethically right to use a narrow Purpose and Need to exclude looking at a sterilized return.

I also suggest you add bonus astrobiology samples of dirt, dust and atmosphere in STERILE containers sent with the ESA fetch rover. That could hugely increase astrobiology interest. Also - astrobiologists have designed miniature end to end sample preparation through to life detection instruments to send to Mars. We could send hundreds to thousands of them to above GEO in a single Ariane 5 launch of over 7 tons, and study the astrobiology samples safely there, and return the geology samples pre-sterilized to Earth.

So that's a reasonable alternative too.

See attached files for more details.

Please reconsider this decision. It can't be right to have as the only option to take these elaborate but ineffective precautions which can't contain ultramicrobacteria and not consider alternatives that can keep Earth 100% safe and even achieve better science that way.

I find it hard to understand how this got through your internal review processes? How did your reviewers miss the ESF study? But I have to comment on the draft EIS as it is and this is what I see and it is unfinished, missing many things.

John Rummel once wrote that “Broad acceptance at both lay public and scientific levels is essential to the overall success of this research effort.”

I am not seeing that here and without the public behind you at some point it is likely to fail which would be a great shame.

Also, it can be made far more interesting with those bonus samples in fully sterilized containers. The levels of contamination that are ultra low for geological past habitability studies are just not good enough for astrobiology as you'll find out. They will just have to say they see lots of biosignatures of life in the rock and regolith samples that could be from either Earth or Mars with no way to tell.