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

By *Robert Walker*
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Open letter to Space Colonization Enthusiasts. It is natural for enthusiasts who are keen on space colonization to think we need no protection for Earth. After all settlers on Mars in science fiction stories rarely run into issues. Even when they find life on Mars, somehow it is never hazardous for Earth. However science fiction is a product of the author's imagination and is never predictive. Even hard sci. fi. gets some things right and some things wrong. But we are in a world now where what used to be science fiction is becoming reality and it may not be quite as the visionaries saw it.

We need to work towards a consensus on planetary protection for Mars and Earth. I am not writing this to win arguments. I think we need constructive dialog.

This is to accompany my post about mistakes in NASA's environmental impact statement for a Mars sample. We need to do it much more carefully and get it right.

NASA need to consider as a "reasonable alternative" a sterilized sample return which keeps Earth 100% safe at minimal cost to NASA with virtually the same science return. The Perseverance samples, though clean for a geologist have so much terrestrial contamination that they are guaranteed false positives of life from Earth and they will NOT be able to tell if it is from Earth or Mars as most will be the unsequenced uncultivable majority of "microbial dark matter" - so it makes little difference to sterilize them. Any Martian life will still be recognizable exceot we likely can't even see it amongst all the life from Earth in the tubes.

NASA could also greatly increase its science return at very low extra cost with a sterilized return combined with samples in CLEAN sterile containers - astrobiologists may find much of interest in them even if they don't contain life. We can return these unsterilized astrobiology "bonus" samples to return to a safe orbit above GEO.

My blog post about it is here:

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

I'll give a quick summary of the main issues I found at the end of this blog post.

We have many different perspectives but in the process we need to work together towards a consensus position amongst space colonization enthusiasts (I count myself as one too) , also with NASA, and consulting with other agencies such as the CDC, WHO, Department of Homeland Security, NOAA, Department of Agriculture and Fisheries, etc.

Most importantly, we need to bring along everyone in the general public too. Otherwise everything is likely to take far longer. For the Mars sample return, as John Rummel put it,

> *"Broad acceptance at both lay public and scientific levels is essential to the overall success of this research effort."*

You might expect a consensus to involve compromise, perhaps with some protection for Earth, but not as much as the astrobiologists and planetary protection officers want or the general public with their focus on the environment rather than space exploration.

However in this case I propose for discussion an even stronger form of planetary protection, 100% protection. The idea is to work towards a fast exploration of Mars with human explorers in spectacular orbits around Mars to help us all move on together.

Why do potentially unsafe exploration, however low the risk, when we can to it as fast or faster, even at less cost, with zero risk?

We have many laws to protect the environment including international treaties that didn't exist at the time of Apollo. These mandate us to protect Earth's ecosystems from alien invasive species and that includes species that are not just alien to a particular country but also ones that are alien to the Earth as a whole. These protections are all new since Apollo. NEPA itself started the year after the Apollo 11 landing. We have to comply with them irrespective of any text in the outer space treaty.

It is not going to help anyone to try to bypass those laws. That's like building a house without smoke alarms. We need the smoke alarms just in case we risk a fire.

I think working together for the highest possible level of protection of Earth and Mars actually benefits space exploration, settlement and perhaps eventually colonization, by boosting public support and by increasing the possibility of finding radically new biology on Mars unaffected by terrestrial life.

We saw how quickly public interest waned after Apollo was presented as largely a "flag and footsteps" mission. That approach does lead to huge initial interest but after the first flag and the first footprints that is it over as far as the public are concerned. Follow up missions are like the second team to reach the summit of Everest. Everyone has heard of Hillary and Tenzing, but who outside of Switzerland has heard of Schmied, Marmet, Reist and von Gunten? Similarly how many have heard of Pete Conrad, Alan Beam and Richard Gordon, the Apollo 12 team?

I believe there is a way forward focused on maintaining the interest of Mars to the highest degree possible by exploring it in a way with zero chance of introducing Earth life until we reach the point where we can make properly informed decisions about whether we want to do this. This may seem counterintuitive at first but I hope after reading my arguments that you will see some interest in it.

I don't expect everyone to agree, but it may be a starting point for more constructive dialog than the subject had before. I believe there is much in the proposal here to interest a space engineer and colonization enthusiast and this approach in turn would benefit from the ingenious solutions to space engineering issues, which space colonization enthusiasts have applied already to ideas for rapid exploration of the Moon and of Mars.

There's a French phrase

> "Du choc des idées naît la lumière"

Which I understand translated means

> "From the clash of ideas springs forth light."

The result is not a compromise between the ideas. It is often something completely new.

This suggestion is based on my preprint:

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

TITLES OF SECTIONS LIKE MINI ABSTRACTS - SUMMARIZE WHAT THEY SAY IN THE TITLE

I write titles of sections like mini abstracts - you can get a first idea of the article by reading just the titles and looking at the graphics - then drill into any section of special interest.

SHORT FORM FOR INLINE CITES LINKING DIRECTLY TO THE CITED PAPER IF AVAILABLE ONLINE

I will mention a selection of some of the cites I use in the preprint. For these I will give just the author name, date, and linked title to the cited paper. For the full cites see the preprint. I will also sometimes link directly to pages on the internet via the text.

WE HAVE MANY EXAMPLES OF INVASIVE SPECIES ON EARTH THAT CAUSE PROBLEMS - FOR EXAMPLE BARN SWALLOWS CAN FLY FROM EUROPE TO THE AMERICAS BUT STARLINGS ARE AN INVASIVE SPECIES

Perhaps some species got to Earth from Mars or got from Mars to Earth. The most recent time a species could get to Mars from Earth is after the Chicxulub impact that ended the dinosaur era. There are miore opportunities in the other direction, once or twice every million years, but Mars has much less life than Earth if it does have life.

We don't have any examples yet, but maybe some day we find a familiar terrestrial species on Mars and prove it was exchanged between the planets at some point in the past.

But if we do find some life shared between the planets, it's not enough to show Martian life is safe on Earth. Many birds fly from Europe to the Americas. Examples include barn swallows and Arctic terns. But starlings don't. so the European starling is an invasive bird in the Americas.

Some microbes may be able to get from Mars to Earth - what matters for invasive species are the ones that can't.

Barn swallow - can cross Atlantic

Starling - invasive species in the Americas

Didymosphenia geminata invasive diatom in Great Lakes and New Zealand, can't even cross oceans.

Starling photo from: Starling - Flickr - TrotterFechan.

Barn swallow photo from A Barn Swallow in Flight

Didymosphenia geminata (Lyngb.) from: Species Profile - Didymosphenia geminata

So, in this analogy, although most birds can fly, not all flying birds can cross the Atlantic, so birds too can be an invasive species.

As an example, in 2012, starlings caused $189 million in damage to crops of blueberries, wine grapes, apples, sweet cherries and tart cherries in the USA.

Starlings also eat cattle feed and 1000 starlings can represent a loss of $200 to $400 in cattle feed. They can also transmit many diseaes to cattle via the feeding troughs and their excrement corrodes iron structures inclding motor vehicles and iron roofs. They are also involved in thousands of bird strikes.

. European Starlings

MICROBES CAN BE INVASIVE TOO - INVASIVE DIATOMS THAT CAUSE BAD ODORS AND CLOG UP TREATMENT PLANTS IN THE GREAT LAKES AND INVASIVE DIATOMS IN NEW ZEALAND

There are invasive microbes too. The diatom Didymosphenia geminata is an invasive species in New Zealand, possibly brought there on wet diving gear.

Text on sign: Your boat may now be carrying didymo. Please clean using approved methods. Protect our waters …

Image from: Didymo signage on Waiau river.jpg - Wikipedia

Didymo can’t even move from one lake to another in New Zealand without help from humans carrying it on wet gear. There is no way it could travel between planets. There are salt water diatoms too. But they couldn’t travel between planets on meteorites either. If there are diatoms on Mars they have evolved independently and can’t be directly related to terrestrial diatoms.

The long stalked version is an invasive species in the Great Lakes too with no records before 1990. It forms mats up to 20 cm thick which trap stream sediment. These can cover the bottom of the stream and smother native plants, insects, mollusks and algae. The short stalked version doesn’t form mats, and is presumed to be native to the Great Lakes.

. Schmidt, M., n.d. Species Profile - Didymosphenia geminata , aquatic non indigenous species, Great Lakes Information system.

So those are microbes that not only can’t get to Mars on a meteorite. They can’t even cross the Atlantic or get from one lake to another in New Zealand without human help.

Similarly, would a microbe adapted to microhabitats on the surface of Mars, living in the dirt, brines, or just beneath the crust of a rock, or in pores in salt, be more like the starling or barn swallow?

There might be reason to suppose a microbe on the surface of Mars would be more like the starling. We have no samples of the surface Martian dust, dirt, salts or ice and impacts would likely just scatter them in the atmosphere. Some of the microbes there might never have got here either.

Also there could be life on Mars with different capabilities from any terrestrial life, for instance there could potentially be nanobe mirror life unable to get to Earth on a meteorite co-existing with other species related to terrestrial life that does rarely get here. That’s like starlings co-existing with barn swallows in this analogy.

NOT TO DISCOURAGE SPACE EXPLORATION AND COLONIZATION AND IT IS POSSIBLE ANY MARTIAN LIFE IS ALWAYS OR OVERWHELMINGLY BENEFICIAL - RATHER THIS IS A CALL FOR INFORMED DECISIONS RATHER THAN HOPEFUL GUESSES

I am saying this not to discourage space exploration and colonization, but rather to suggest we need to know what we have on Mars before we can make the best decisions about what to do next. Those starling problems are actually quite good analogues for some of the potential risks from Martian microbes.

It’s possible Martian life is harmless. Or microbes from Mars can harm us indirectly. They could harm our crops, ecosystems, animals, or produce accidental toxins.

It is also possible they harm us directly. Legionnaire’s disease is a disease of biofilms and of protozoa that uses the same methods to infect human lungs and isn’t adapted to us. Many molds and fungi are harmful to immunocompromised patients and can kill them, and we may all be essentially immunocompromised to an alien Martian biology. More on this later in this post.

Or it could be that none of these things happen. There could be no life on Mars, it could be early life that can’t compete with terrestrial life, it could even be beneficial, enrich ecosystems, fertilize deserts, spread through the desert parts of oceans and inu the process only benefit local life (if lucky). I call that Enhanced Gaia”.

But we need to know, before we return life from Mars to Earth.

Other similar analogies for invasive species include the American mink which competes with otters and kills water rats in Europe, or rats, pigs and starlings in the USA or rabbits in Australia. The starlings and the rabbits were even transferred deliberately, also the minks accidentally, while rats came along for the ride unintentionally with human explorers.

NATIONAL RESEARCH COUNCIL SAID THEY COULDN'T RULE OUT THE POSSIBILITY THAT MARTIAN LIFE CAUSED PAST EXTINCTION EVENTS ON EARTH

The National Research Council looked into the question of whether Martian life transferred to Earth by panspermia could have caused extinction events in the past.

> ***"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, 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 negate the need to treat as potentially hazardous any samples returned from Mars by robotic spacecraft.***
>
> ***A prudent planetary protection policy must assume a 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."***

They didn't give any examples here. But there are many past extinction events that aren't fully explained yet.

MY OWN EXAMPLE SCENARIO - MIGHT MARTIAN LIFE BE THE REASON FOR THE GREAT OXYGENATION EVENT?

Amongst those big possible extinctions in the past is the Great Oxygenation Event when the oxygen content of the atmosphere and oceans rapidly surged. Why did terrestrial life only develop photosynthetic life half a billion years ago? Why haven't we had photosynthetic life since soon after life began on this planet?

This suggestion is from my preprint so hasn't been peer reviewed and I'm interested in comments on it for feedback.

The blue green algae Chroococcidiopsis is an amazing survivor which we can find almost anywhere on Earth, from the cliffs of Antarctica to warm tropical reservoirs in Sri Lanka, from the deserts of Arizona to 170 meters below the sea bed in the Atlantic. It has such a diversity of metabolic pathways it can grow without any light at all.

This is one of our top candidates for a terrestrial microbe that may be able to survive on present day Mars if there are suitable habitats for it, in cracks in rocks or below a thin layer of dust to protect from UV, and has been tested in Mars analogue environments on the exterior of the ISS.

It's also remarkably resistant to ionizing radiation and UV.

Pavlov et al suggested that perhaps it developed its ability to self heal from ionizing radiation damage on Mars.

. Pavlov, et al, 2006. Was Earth ever infected by Martian biota? Clues from radioresistant bacteria.

That's a minority view. Cyanobacteria originated in the Precambrian era. It could have developed these mechanisms back then, when, with no oxygen in the atmosphere, there was no ozone layer to shield out UV radiation.

> *QUOTE Since cyanobacteria originated in the Precambrian era, when the ozone shield was absent, UVR has presumably acted as an evolutionary pressure leading to the development of different protection mechanisms (Rahman et al., 2014) including avoidance, the scavenging of ROS by antioxidant systems, the synthesis of UV-screening compounds, and DNA repair systems for UV-induced DNA damage and protein resynthesis (Rastogi et al., 2014a).*

Casero, et al., 2020. Response of endolithic Chroococcidiopsis strains from the polyextreme Atacama Desert to light radiation.

But for the sake of illustration, supposing it did come from Mars. Then it could have been responsible for the Great Oxygenation Event.

THE GREAT OXYGENATION EVENT WAS GREAT FOR US - BUT IT MIGHT BE THE LARGEST EXTINCTION EVENT IN EARTH'S HISTORY - AND WHETHER OR NOT - IS CERTAINLY AN EXAMPLE OF A LARGE SCALE TRANSFORMATION OF EARTH'S BIOSPHERE

There's a lot of debate about whether this really was an extinction event. Lane suggested it wasn't and anaerobes just retreated to habitats that were still suitable for them, and there are many of those:

"Microbes are not equivalent to large animals: their population sizes are enormously larger, and they pass around useful genes (such as those for antibiotic resistance) by lateral transfer, making them very much less vulnerable to extinction. There is no hint of any microbial extinction even in the aftermath of the Great Oxygenation Event. The 'oxygen holocaust', which supposedly wiped out most anaerobic cells, can't be traced at all; there is no evidence from either phylogenetics or geochemistry that such an extinction ever took place. On the contrary, anaerobes prospered."

Lane, 2015. The vital question: energy, evolution, and the origins of complex life. page 49.

[phylogenetics is the study of evolutionary history and relations between species]

However there is some evidence for exceptionally large sulfur-oxidizing bacteria before the event which may have been driven extinct. They were, 20 to 265 microns in size, occasionally also in short chains of cells. This may be part of a diverse ecosystem that predated the GOE

"And this discovery is helping us reveal a diversity of life and ecosystems that existed just prior to the Great Oxidation Event, a time of major atmospheric evolution."

Czaja, et al, 2016. Sulfur-oxidizing bacteria prior to the Great Oxidation Event from the 2.52 Ga Gamohaan Formation of South Africa

Whether or not this was an extinction event - and whether or not the cyanobacteria came from Mars - this shows a way that life from another planet could in principle transform the terrestrial biosphere.

APPROACHING THE DIVERSITY OF WHAT WE MAY FIND ON MARS WITH SCENARIOS FOR WHAT HAPPENS WHEN THE TWO BIOSPHERES COLLIDE - WITH SOME SCENARIOS MARTIAN LIFE IS DEVASTATING TO EARTH'S BIOSPHERE - WITH OTHERS TERRESTRIAL LIFE IS DEVASTATING TO MARTIAN LIFE - AND WITH OTHERS THE TWO FORMS OF LIFE ARE HARMLESS TO EACH OTHER OR MUTUALLY BENEFICIAL - WE NEED TO KNOW WHAT WE HAVE ON MARS AS TOP PRIORITY

I use another example in my preprint, of mirror life. This is like ordinary life except you just flip everything so that the DNA spirals the other way, and all biochemicals occur in their mirror form. This suggestion that we could return mirror life from Mars is not yet peer reviewed and I haven't seen it previously discussed in the literature on a Mars sample return.

However the idea that mirror life could cause large-scale changes to our biosphere is mainstream - it's a reason for taking great care with our experiments in synthetic mirror biology. Synthetic biologists can engineer their microbes to be only able to replicate in laboratory conditions, for instance dependent on an nutrient they can't find in the wild. For a discussion, see:

Bohannon, 2010. Mirror-image cells could transform science-or kill us all

What I did in my preprint is to just combine that idea with the suggestion that mirror life is a viable alternative biology, that is not impossible for Mars.

If Mars currently has mirror life, it could lead to modifications of Earth's biosphere as extensive as the Great Oxygenation Event, If there is mirror life on Mars, there is no reason particularly why mirror life would be especially hardy or be able to get here via meteorite transfer. So this seems to be a real possibility. I'll go into that in more detail soon.

In my preprint I use a method of scenarios. Some scenarios for what we find on Mars such as mirror life would mean it is never safe to land humans on Mars or to return life from Mars to Earth.

In other scenarios it is safe for Earth for our astronauts to land on Mars but we risk making native Martian life extinct - that's especially so if Mars has early life similar to whatever predated terrestrial life. After all we have no examples of pre-DNA life on Earth, so, whatever it was, DNA based life made it extinct. Some suggestions such as Woese's "transformable cells" would be very vulnerable to terrestrial life - the genes compete but the cells don't, with all the cells freely exchanging genetic material with each other. Once terrestrial life infects a habitat like that, Martian life mightn't last long.

In other scenarios Martian life is safe for Earth. I give the example of the archaea there. That's an entire domain of life that is largely beneficial in ecosystems and for humans. It's possible the archaea have a role in toothache, along with other organisms, but they are largely harmless and beneficial with no infectious diseases that are caused by archaea.

Life from Mars may also be beneficial. On Earth, invasive species aren't always harmful. Indeed most species are beneficial.

Schlaepfer, et al., 2011. The potential conservation value of non-native species

That's for higher lifeforms. I tried sketching out some ways that new microbial species from Mars could be beneficial to Earth.

This again is from my preprint and not yet peer reviewed.

- Terrestrial photosynthesis is inefficient - it can't adapt to make optimal use of low light levels, and most of it rejects green light - more efficient photosynthesis from Mars could increase the rate of sequestration of CO_2 in the sea and on land, improve soil organic content, and perhaps help with reduction of CO_2 levels in the atmosphere
- Martian life could be better at nitrogen fixation, and phosphorous and iron mobilization and so improve our soils - and also inhabit areas such as the ocean far from the shore, which are desert areas for terrestrial life
- Martian life could increase species richness and transfer new capabilities to terrestrial life by horizontal gene transfer.
- Martian life could produce beneficial bioactive molecules as part of the human microbiome. These could include molecules that are antiviral, antibacterial, antifungal, insecticides, molecules that kill cancer cells, immunosuppressants, and antioxidants - we get all of those from beneficial microbes that are already in our microbiome.
(see: Borges et al, 2009. Endophytic fungi: natural products, enzymes and biotransformation reactions)

Though of course those could also cause problems, like the blooms that lead to eutrophic zones in the oceans, or the toxic algal blooms in the great lakes that can kill cows and dogs that eat them.

So we have to be careful here. Most likely they would be mixed, beneficial in some ways, maybe even most of the time in most ecosystems, but harmful in other ways.

I cover this in the preprint in the section:

Enhanced Gaia - could Martian life be beneficial to Earth's biosphere?

CHROOCOCCIDIPOSIS COULDN'T GET HERE ON A MARTIAN METEORITE FROM MODERN MARS - IT WOULD BE DESTROYED BY THE SHOCK OF EJECTION

If a microbe is to get from Mars, its first challenge is the shock of ejection. It gets suddenly accelerated from rest to escape velocity in a fraction of a second. This can destroy it through cell rupture or by DNA damage. All cells of Chroococcidiopsis are killed at 10 GPa of shock. See:

Nicholson, 2009, Ancient micronauts: interplanetary transport of microbes by cosmic impacts.

ALH84001 experienced a shock of ejection of ~35 − 40 GPa. The Nahkalites were least shocked at 15 to 25 GPa. This is still too much for Chroococcidiopsis. However, from modelling, some of the material is only lightly shocked, probably about 2% of the ejecta. See 6.3. Implications of ejection models on page 147.

See: Nyquist et al., 2001 Ages and geologic histories of Martian meteorites.

More shock resistant microbes can survive better. Of the order of 1 in 10,000 of microbes of b. subtilis and the photobiont and microbiont partners in the lichen X Elegans could survive 40 to 50 GPa.

However for Earth to be safe from invasive species from Mars we need ALL species that are there to get to Earth. In the invasive birds and mammals metaphor, Barn Swallows and Arctic terns can cross the Atlantic, Arctic terns even also fly through Australia, but sparrows, rabbits, pigs, rats and mink can't cross the Atlantic or the Pacific oceans by themselves.

We don't know if any Martian life has got to Earth from Mars. We don't know the capabilities of Martian life and it could be that none of it can withstand the shock of ejection or the many other challenges. But if some of them can get here it won't show that all Martian life is safe for Earth.

MARTIAN ROCKS COME FROM THE SOUTHERN UPLANDS WHERE THE AIR IS TOO THIN FOR EVEN EXTREMOPHILE LIFE - BECAUSE THE THIN AIR MAKES IT EASIER FOR IMPACTS TO SEND ROCKS TO EARTH - AND THEY ALSO COME FROM AT LEAST 3 METERS BELOW THE SURFACE - UNLIKELY LOCATION FOR LIFE EXCEPT IN VERY RARE GEOTHERMAL HOT SPOTS (SO FAR NONE FOUND ON MARS) AND LESS THAN A METER IN DIAMETER

The rocks we get from Mars all come from regions of Mars which are especially unlikely to have present day life.

First they all come from high altitude regions.

- All except ALH84001 were probably thrown up into space after glancing collisions into young volcanic flows in the Elysium Planitia or Tharsis regions, high altitude southern uplands. See McSween, 2002, The rocks of Mars, from far and near

  Most of them likely came from the Elysium Planitia region, while ALH84001 may well come from Gratter crater in the Memnonia Fossae which may have the older Noachian age surface materials needed for this meteorite - though it may also come from material that was thrown up from older deeper layers by a previous impact and then sent to Earth.

See page 22 of Tornabene et al, 2006, Identification of large (2–10 km) rayed craters on Mars in THEMIS thermal infrared images: Implications for possible Martian meteorite source regions
- They also all come from at least 3 meters below the surface. See page 1355 of:
Head et al, 2002. Martian meteorite launch: High-speed ejecta from small craters.
- We have candidate impact craters for some of them, so this is well established science.
- The temperature below about 12 cms is a near constant 200 °K or -73 °C. See figure 2 of Möhlmann, 2005, Adsorption water-related potential chemical and biological processes in the upper Martian surface units are multiples of 4.4 cms).

NOT IMPOSSIBLE THAT A LUCKY STRIKE COULD THROW UP LIFE FROM A SUBSURFACE CAVE OR EVEN A GEOTHERMAL VENT ON THE SLOPES OF OLYMPUS MONS - WHICH WAS VOLCANICALLY ACTIVE AND HAD MOVING GLACIERS 4 MILLION YEARS AGO - BUT FOR SAMPLES RETURNED TO BE SAFE FOR EARTH WE NEED ALL MARTIAN SPECIES TO GET TO EARTH NOT JUST A FEW LUCKY SPECIES

It is not totally impossible life could get into the Martian meteorites, but would require a high measure of luck. Some Martian volcanoes have been active in the geologically recent past, as recent as 2 million years ago. Olympus Mons also shows signs of glacial activity as recent as four million years ago which suggests it likely has ice protected beneath the dust on its slopes.

A lucky asteroid impact on Mars could throw up material from a subsurface cave, or a geothermal hot spot, or fumarole. But such events would surely be rare.

See Neukam et al., 2004, . Recent and episodic volcanic and glacial activity on Mars revealed by the High Resolution Stereo Camera.

So, it’s possible that some exceptionally hardy life has got here, even in geologically recent times. Perhaps life from geothermal vents after a lucky strike of a meteorite into a geologically active geothermal system on the flanks of Olympus Mons.

It’s not impossible that a lucky asteroid impact could send back life from Mars from a cave or a geothermal vent just below the surface, but most wouldn’t send any life this way.

Just as there are many species on Earth that could never get to Mars on a meteorite, if Mars has a diversity of microbial species, there are likely to be many species on Mars that could never get to Earth that way.

PERSEVERANCE COULD RETURN LIFE IN DUST OR BRINES - WE HAVE NO SAMPLES OF THESE FROM MARS ON EARTH AS THEY COULDN’T SURVIVE EJECTION FROM MARS OR RE-ENTRY TO EARTH’S ATMOSPHERE - IF VIKING DID FIND LIFE IN THE MARTIAN DIRT IN THE 1970S, THIS DIRT COULDN’T GET TO EARTH AFTER A METEORITE IMPACT

Perseverance is not likely to return life from the southern uplands. You mentioned the possibility that Viking discovered life on Mars in the 1970s. If it did, it might have come from dust storms from distant parts of Mars, protected from UV by the iron oxides in the dust, or it could be native Martian life, perhaps in biofilms adapted to use ultra cold brines found by Curiosity that form at times of close to 100% humidity at night. Mars adapted biofilms could retain the water through to the warmer daytime conditions.

We don't have any samples of Martian dust on Earth, or of those brine layers. Even with very large impacts, Martian dust and salts couldn't survive the journey from Mars to Earth. If they travelled fast enough to get through the atmosphere, they would burn up like shooting stars on ejection from Mars and on reentry to Earth.

We might also find photosynthetic live in cracks in rocks, or in a layer just below the surface of rocks as cryptoendoliths for protection from the UV, or else protected by thin layers of dust. But these would be destroyed by the fusion crust of re-entry to Earth.

INTERIORS OF MARTIAN METEORITES DIDN’T HEAT UP - BUT THE FUSION CRUSTS DID HEAT UP AND NO PHOTOSYNTHETIC LIFE WOULD BE LIKELY TO SURVIVE

The interior of some of our Martian meteorites didn't warm up significantly. However, like all meteorites they have fusion crusts which life couldn't survive and this would destroy any cryptoendoliths living just below the surface of any rocks sent from Mars to Earth.

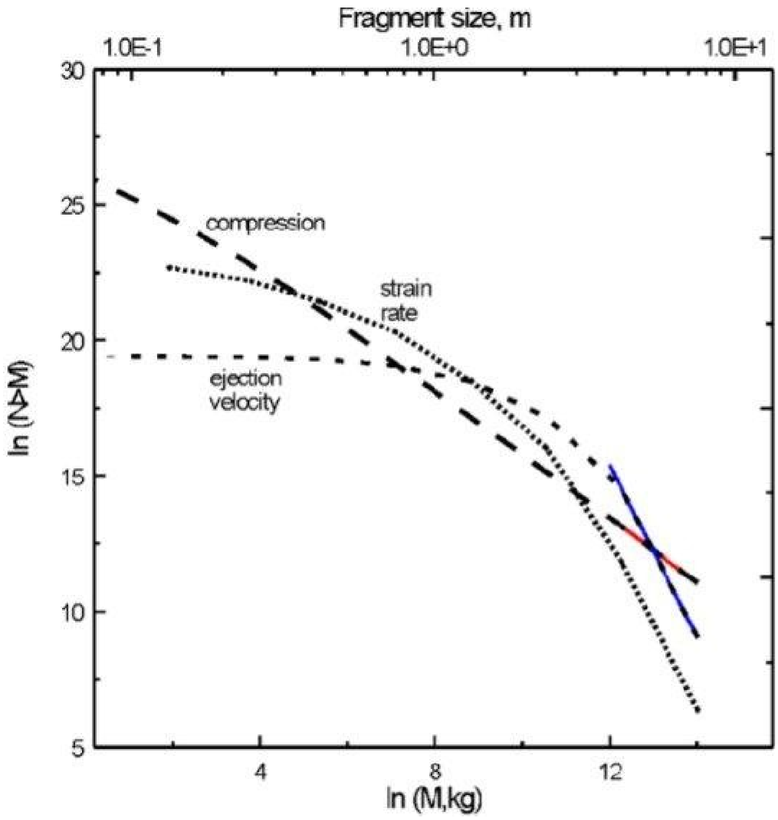
Some Martian photosynthetic life could survive in cracks below the surface but the plasma of the reentry fireball would penetrate those cracks, break up the meteorite and sterilize life in cracks too. This is backed up by experiments with materials attached toa re-entry heat shield.

MAXIMUM SIZE OF MARS METEORITES BEFORE THEY HIT EARTH'S ATMOSPHERE OF A FEW TENS OF CENTIMETERS

Fragments are less than a meter in diameter before they hit Earth's atmosphere. This is a model of the fragments ejected from Zunil crater, a plausible source crater for some of the Sherghoti meteorites.

> QUOTE Zunil is an excellent candidate for one of two source craters for the known basaltic shergottites with emplacement ages of 165–177 Ma and ejection ages of ~1.5 and ~2.7 Ma

In this figure, compression and strain independently constrain the maximum fragment size so for a rock fragment to reach Earth, it has to be within both those sizes and above the ejection velocity curve. The maximum size for this crater is 0.7 cm.



Page 366 of The rayed crater Zunil and interpretations of small impact craters on Mars

NUMBER OF MARTIAN METEORITES THAT HIT US PER YEAR FROM AN IMPACT ON MARS

This figure shows the percentage of meteorites that reach Earth over the first two million years. It's a near constant rate for the faster ejection velocities.

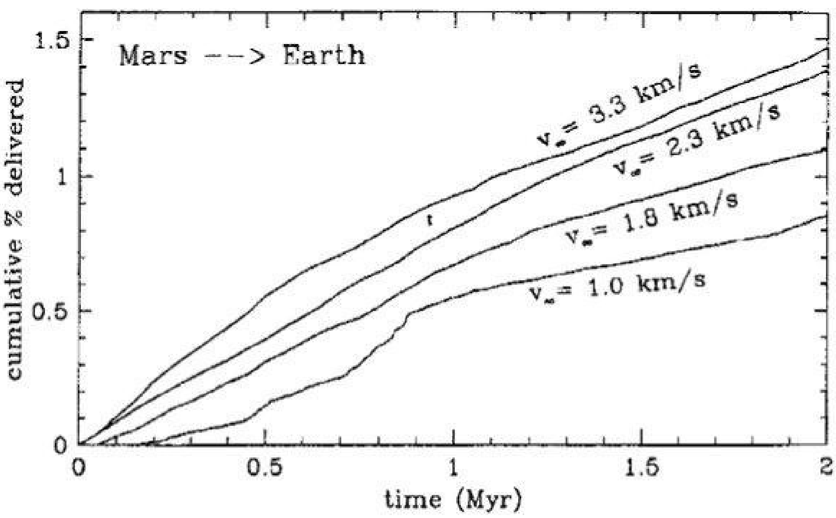


Figure from Mileikowsky et al, 2000, Natural Transfer of Viable Microbes in Space

They find that the meteorite reach Earth at a near constant rate for 10 million years and over that time 0.6% of the ejected fragments hit Eaarth.

Mileikowsky et al calculate (page 399) that

- 15 Martian meteorites hit Earth every year (based on observed numbers found in Antarctica)
- These come mainly from three impacts on Mars in the last 10 million years
- The flux is roughly constant for 10 million years after an impact (then falls off rapidly)
- So this estimate based on observed Antarctic meteorites gives ane estimate of a billion fragments per impact

[This will be an over estimate as there are fragments from older impacts as well]

- Scaling theory suggests 20 million fragments per impact (60 million total of which many don't escape Mars but fall back)
- Taking an intermediate figure of 100 million fragments in 10 million years.
- 0.6% works out at 600,000 fragments in 10 million years
- Or about 6 fragments hit Earth every century

The estimate from the numbers of martian meteorites found in the Antarctic ice increases that to 60 per century. The scaling theory estimate reduces it to a little over 1 fragment per century.

STERILIZATION BY COSMIC RADIATION - MOST SAMPLES WE GET WILL BE STERILIZED BUT SOME COULD SURVIVE AFTER THE SHORTEST JOURNEYS

Cockell looked closely at whether photosynthetic life could get to Earth from Mars. Cockell summarizing the literature says that tests with Bacillus Subtilis spores (which are very radioresistant though not quite as resistant as radiodurans) find that they can survive

- Up to one million years shielded by 1 meter of rock
- Up to 300,000 years behind 10 cm of rock
- Up to 100,000 years behind 3 cm of rock

Most photosynthetic life grows mms or cms below the surface

See

Cockell, 2008. The Interplanetary Exchange of Photosynthesis

Cockell concludes:

Thus, even if one assumed that near surface-dwelling photosynthetic organisms

somehow survived the dispersal filter of atmospheric transit during planetary ejection and

arrival at the destination planet, in most cases they would be effectively killed by cosmic

radiation during interplanetary transit, which, unlike UV radiation, will effectively penetrate to depths of a few millimetres or centimetres where such organisms would normally grow.

WE DON'T KNOW IF ANY LIFE GOT FROM MARS TO EARTH - THIS DEPENDS ON ITS CAPABILITIES TO WITHSTAND VACUUM AND SUDDEN SHOCKS, FIREBALL OF EXIT FROM MARS AND ENTRY TO EARTH'S ATMOSPHERE AS WELL AS IONIZING RADIATION

However we don't know for sure that any life has got from Mars to Earth. These experients are all based on terrestrial biology as that's all we have.

We don't know the capabilities of the Martian life. It doesn't need to withstand vacuum conditions to survive on Mars and it doesn't need to be able to withstand sudden shock.

Most terrestrial life including just about all higher forms of life wouldn't be able to get here on a meteorite from Mars.

Of those that could get here, most would be destroyed by the fireballs of exit from Mars or re-entry to Earth and ionizing radiation on the journey for all except the very shortest crossings or deep within very large rocks

MARTIAN LIFE WOULD LIKELY SURVIVE ON EARTH - LIKE BLUE-GREEN ALGAE FROM ANTARCTIC CLIFFS

Martian life would be likely to be able to survive on Earth. The Martian brines are highly oxidising, with perchlorates and hydrogen peroxides. They are so oxidizing that many terrestrial life forms would find hard to tolerate them. Recent research by Stamenković suggests the cold brines on Mars may be oxygenated too, even with the very low levels of oxygen, in the very cold conditions since oxygen is more soluble in cold water.

Then, though Mars gets very cold at night, in daytime it can sometimes reach above 20°C.

Microbes returned from Mars to Ear may be able to settle in on Earth as a "home from home" even more habitable for them than Earth.

An example here is Chroococcidiopsis, a blue-green algae found in Antarctic cliffs, also in the Arizona desert near JPL, but also is ubiquitous through Earth, found in the sea, in tropical water supplies, both wet, dry, hot, cold, it's a polyextremophile that has numerous metabolic pathways that let it survive almost everywhere, and it is one of the top candidates for a form of life that could survive on Mars.

Once it was well established, other mirror life could build up a microbial ecosystem based on this and in this way mirror life could start to spread through our ecosystems.

BEST CASE SCENARIOS - ARCHAEA AS A DOMAIN OF LIFE LARGELY BENEFICIAL -

In the best case scenario, Martian life is harmless to us. It might be an alien biology that is completely mystified by our biology. It might be unable to survive here. It might be a vulnerable early form of life that can't compete. There may be no life, only chemistry. Or it might be able to survive here but be almost entirely beneficial to humans and to our ecosystems. The archaea give a good example here of an entire domain from the tree of life that causes no sickness in humans, except possibly contributing to tooth decay and seems to be largely beneficial everywhere.

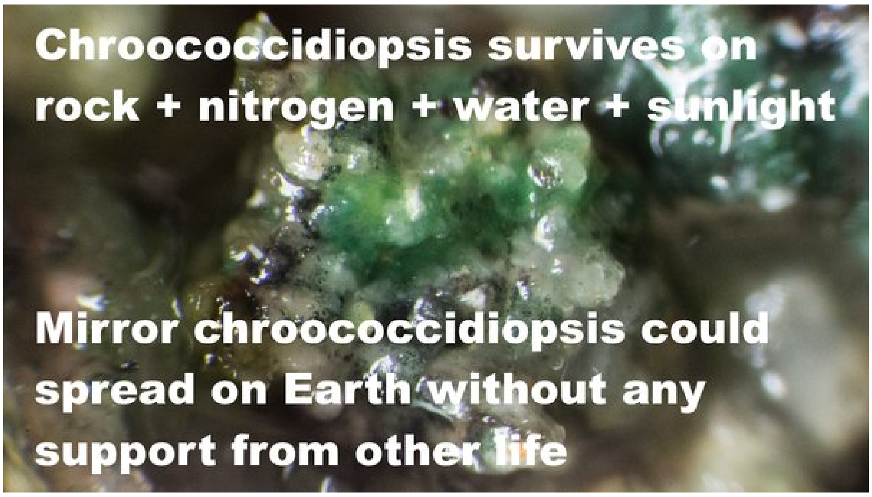
However we can also devise worst case scenarios where it's never safe to return Martian life to Earth.

EXAMPLE WORST CASE SCENARIOS FOR ECOSYSTEMS, MIRROR LIFE NANOBES - AND FOR ASTRONAUTS - ALIEN BIOLOGY MOLDS THAT WE ARE ALL IMMUNOCOMPROMISD TOWARDS

My clearest example here is chroococcidiopsis but flipped as in a mirror, DNA spirals the other way and all the organics are mirrored. Some terrestrial microbe can use mirror organics but no known multicellular life can subsist on mirror organics.

If Mars has mirror life, it's bound to develop the isomers that let it digest ordinary organics too because of the constant rain of organics from comets, asteroids and interplanetary dust.

Return that to Earth and it will gradually turn all the organics throughout all the ecosystems it inhabits into indigestible mirror organics.



Chroococcidioopsis 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

Humans would survive, and the process would likely take centuries, but we'd not be able to stop it and eventually would need to protect all our ecosystems in greenhouses and similar undersea habitats with the mirror life kept out as far as possible as well as mirror organics.

Then for a worst case for impacts on humans, some of our candidates for Mars are opportunistic human pathogens. I give a number of examples in my preprint including S. liquefaciens which has caused eye infections, urinary tract infections, bloodstream infections, abscesses, septic arthritis, and fatal meningoencephalitis amongst other effects.

. Serratia infections: from military experiments to current practice.

These are most hazardous to immunocompromised. But experts like Joshua Lederberg said that though in the best case they might be mystified by our biology, in the worst case, we might all be essentially immunocompromised to a Martian organism with an unfamiliar biology that no terrestrial life has ever encountered in its evolutionary history.

. Paradoxes of the host-parasite relationship

WE NEED TO FIND OUT WHICH SCENARIO WE FACE ON MARS TO GUIDE DECISIONS

There is simply no way to find out which scenario we face on Mars by hypothetical reasoning. We don't have enough information, with not even one other example of alien biology from a terrestrial planet. Instead we need to find out, we need the experimental data.

WORST CASE SCENARIOS FOR HUMAN SETTLEMENT ON THE MARS SURFACE MAY EVEN BE BEST CASE SCENARIOS FOR HUMAN SETTLEMENT ELSEWHERE IN THE SOLAR SYSTEM - AND MARS COULD STILL BE EXPLOITED FROM ORBIT AS WELL AS STUDIED SCIENTIFICALLY

These worst case scenarios for astronauts on the surface of Mars wouldn't be a reason to give up on space settlement. The opposite. If we do find even one of those worst case scenarios like mirror life on Mars, though we could never return it to Earth, the interest in Mars as a planet would be huge

Human explorers and settlers would have a very important role to play in orbit around Mars using robotic avatars on the surface rather similarly to characters in a computer game.

There are many other places we can settle including the two moons of Mars, the asteroid belt, closer at home the Moon, or in orbit around Mars, and further afield Jupiter's Callisto and Saturn's Titan are of especial interest. Titan is so cold that we may have no planetary protection issues there except to keep microbes clear of cryovolcanic eruptions if there are any.

If we work together on this we can reach a conclusion quickly which may need a rapid survey of Mars from orbit.

In the worst case in the forward direction we may also need to protect vulnerable Early life from terrestrial microbes, but again this can be an opportunity for space settlement.

We need to bring the public along in a much wider ranging mission. And I think myself that updates from humans living in a settlement on Mars with the same ochre skies and the same scene outside their window with occasional trips in rovers will not sustain interest for long.

While if we find interesting life on Mars, and we can keep it free from terrestrial life as we study it - there would be great interest - also far more economic benefit to Earth too. By-products from extremophiles already sustain a billion dollars a year industry and the economic benefits from novel life from Mars could be huge, so long as we protect both Mars and Earth in the process.

We can get some idea of the potential value of extraterrestrial life from the study of extremophiles which has lead to enzymes that are widely used (Sarmiento et al, 2015)

- in the $1 billion industry of enzymes for detergents - this is another application - they work at cold temperatures so removing the need for heating and saving energy.
- in the food industry, including bread making, fruit juices, for lactose free foods, for making syrups for wood pulp and paper processing
- in the textile, cement, cosmetic industries.
- in various research techniques for experts studying DNA and RNA

They are used to reduce costs, make the processes more eco friendly, reduce CO_2 emissions, enable more efficient faster processing, et.

The cold adapted enzymes are more active, so less of the enzyme is needed, and they can be used at lower temperatures, saving energy. The heat adapted enzymes are active and efficient at high temperatures, extreme pH values, high concentrations of the substrate, and high pressures. They are also highly resistant to organic solvents, and other things that stop enzymes working (denaturing agents). They are easier to separate during purification steps (because they don't break up) and they catalyze faster reactions.

Discoveries from study of a novel biochemistry could be far more radical than these enzymes, with implications for pharmaceuticals, understanding processes in medicine, agriculture, nanotechnology, and many other fields. They may form materials with novel properties too (many materials we use in everyday life are the results of biology).

Indeed, it's impossible to know what the results would be. These lifeforms if they exist, and any discoveries that would flow from them, are part of our natural heritage as human beings living in our solar system.

I believe if there is a risk of humans making Martian life extinct, we can best sustain scientific interest, public interest, and the economic value of Mars by protecting Mars, at least in the early stages of exploration.

DECISION WON'T BE MADE BY AUTHORS OF BLOG POSTS OR ARTICLES FOR THE POPULAR PRESS BUT AS A RESULT OF AN EXTENSIVE LEGAL PROCESS AND SUBMISSIONS BY SCIENTIFIC EXPERTS IN INDEPENDENT UNINVOLVED AGENCIES AND REVIEW BOARDS - AND POSSIBLY PRIVATE LEGAL ACTIONS BY OBJECTORS IF THE GENERAL PUBLIC AREN'T FULLY ENGAGED FROM THE START

The literature on the legal process for a Mars sample return is small but there are two articles by Urhan et al and by Race? These are the main ones I found:

- Race, M. S., 1996, Planetary Protection, Legal Ambiguity, and the Decision Making Process for Mars Sample Return
- Uhran, et al, 2019. Updating Planetary Protection Considerations and Policies for Mars Sample Return.

Also the article by Rummel et al. on the steps needed to prepare before the legal process starts

- Rummel, et al, 2002. A draft test protocol for detecting possible biohazards in Martian samples returned to Earth.

From these it is clear the legal process will be very extensive. It's also clear we need a consensus position that brings the public along with us BEFORE the legal process starts, or there are likely to be many delays.

These are peer reviewed, and written by mainstream authors. Rummel and Conley are both former NASA planetary protection officers and Race is a biologist working on planetary protection and Mars sample return at the SETI institute,

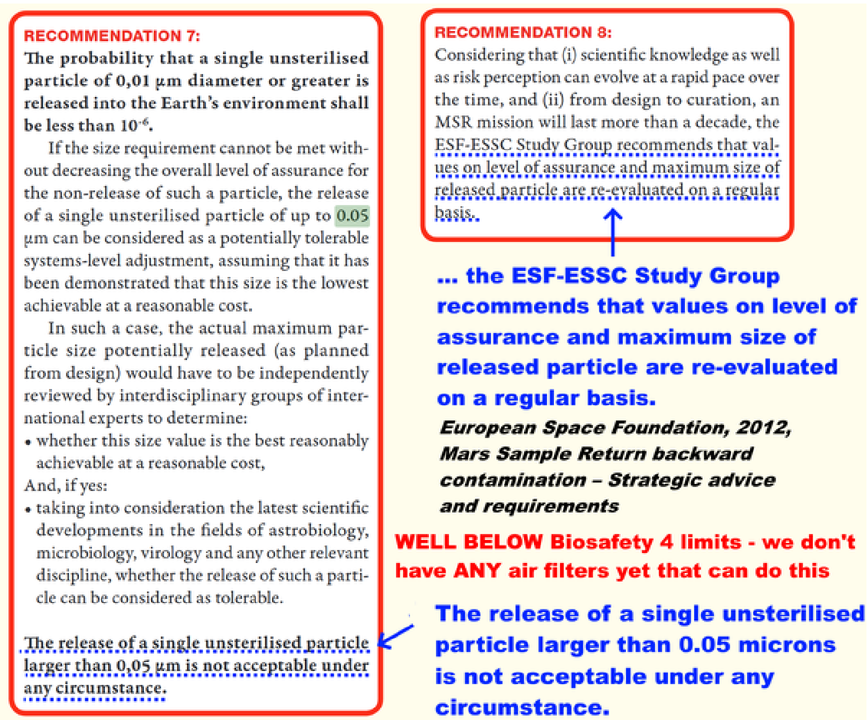
Also, everything they said checks out. If there is anything I'm missing here, by relying on them, do please say.

Based on Rummel et al's recommendations, we should also involve the experts of other uninvolved agencies.

NEED FOR NEW MARS SAMPLE RETURN STUDY BEFORE INITIATING NEPA PROCESS - AS 2012 STUDY IS OUT OF DATE

I believe we also need a new Mars Sample Return study as there were major changes between the 2009 study by the National Research Council in the USA and the 2012 study by the European Space Foundation in Europe.

- National Research Council. 2009. Assessment of Planetary Protection Requirements for Mars Sample Return Missions (Report)
- Ammann, et al, 2012. Mars Sample Return backward contamination–Strategic advice and requirements (ESF-ESSC Study Group on MSR Planetary Protection Requirements)



… 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

The 2012 study stresses the importance of regular review (page 21 of Amman et al, 2012).

Based on our current knowledge and techniques (especially genomics), one can assume that if the expected minimum size for viruses, GTAs or free-living microorganisms decreases in the future, and this is indeed possible, it will be at a slower pace than over the past 15 years

However, no one can disregard the possibility that future discoveries of new agents, entities and mechanisms may shatter our current understanding on minimum size for biological entities. As a consequence, ***it is recommended that the size requirement as presented above is reviewed and reconsidered on a regular basis.***

[bolding as in original cited text]

The minimum size requirement for filters to contain Martian biology was reduced from 0.25 microns to 0.05 microns / 0.01 microns in just three years from 2009 to 2012.

By 2022, a decade later, another review is certainly required.

Sadly the legal process is started without a new sample return study.

I don't think it will withstand legal challenges on the basis of inadequate analysis in an EIS - that the agency either failed to consider some of the impacts or failed to fully consider the weight of the impacts they did review.

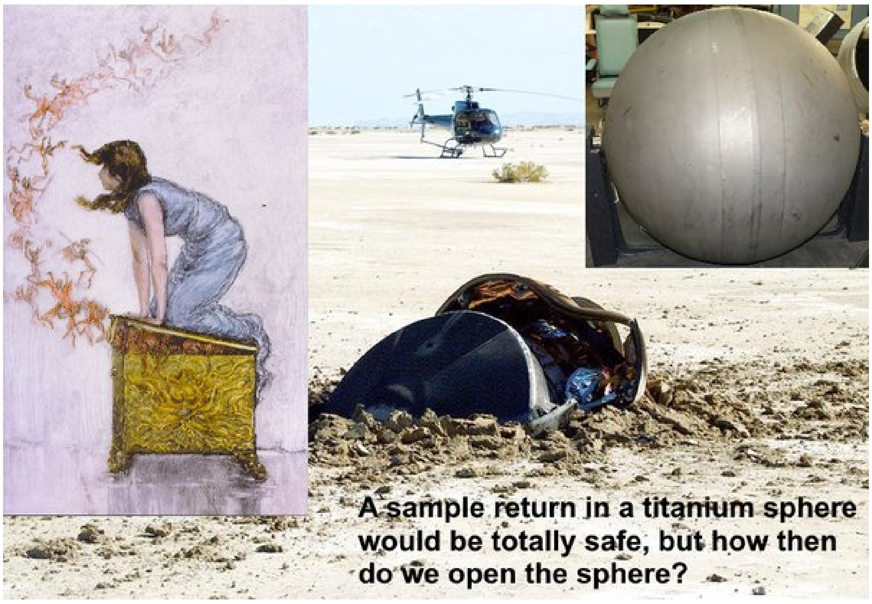
Plaintiffs can't claim damages, but the court can remand the case to the agency for further proceedings and may specify what those proceedings must include which can include stopping the mission altogether or other actions (perhaps in this case a sterilized sample return?)

- Congressional Research Service, 2021, National Environmental Policy Act: Judicial Review and Remedies

COULD WE DO 100% EFFECTIVE CONTAINMENT ON EARTH NOT BASED ON FILTERS - PROTECTED BY A HIGH TEMPERATURE OIL SUMP?

The basic idea is to return the unsterilized sample inside a titanium sphere. This much we can do and it would be safe, there wouldn't be any risk to Earth from a sample inside a titanium sphere. We could even do end of experiment sterilization without opening it by simply heating it up to 300 C and keeping it at that temperature for hours or weeks as needed.

The issue is, how can we then get it out of the sphere with 100% safety to study and what kind of facility could contain it?



A sample return in a titanium sphere would be totally safe, but how then do we open the sphere? Top right image shows a titanium sphere that survived re-entry. Top left image shows Pandora trying to close the box that she opened in the Greek legend.

Main image - Genesis return capsule on the ground after it crashed

NASA, 2005, NPR 8020.12D, Planetary Protection Provisions for Robotic Extraterrestrial Missions.

Top left, Opening Pandora's box

Church, F.S., n.d. Opened up a Pandora's box

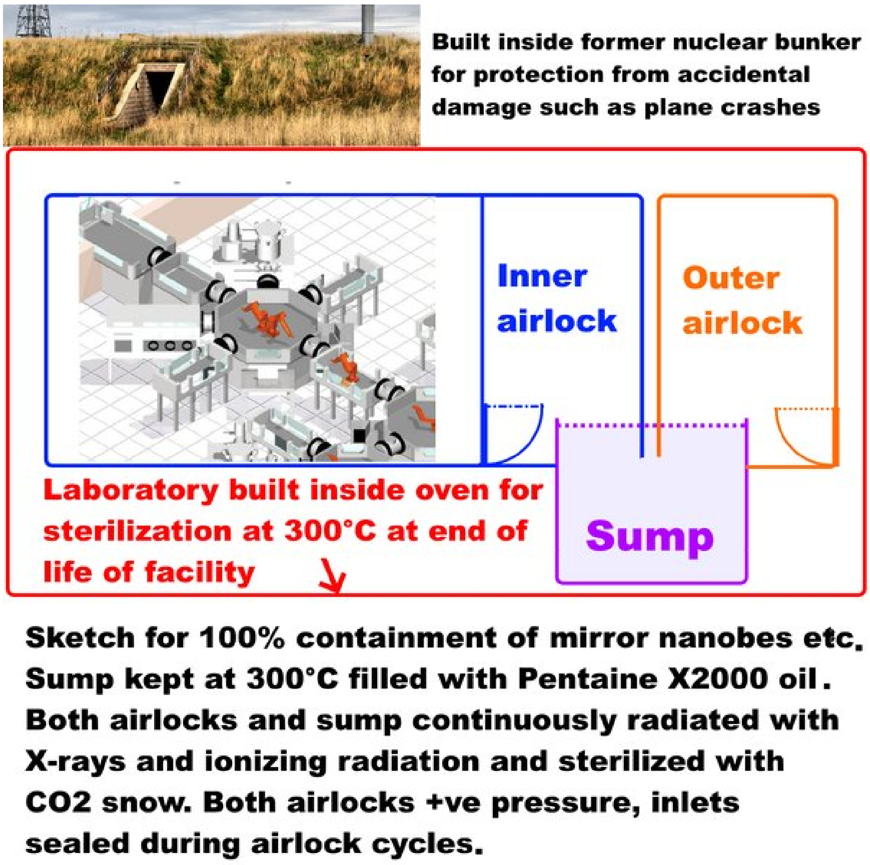
Top right - space ball after re-entry - probably from the equipment module of Gemini 3, 4 or 5.

Daderot, 2017, Oregon Space Ball, probably from the equipment module of Gemini 3, 4, or 5 mission, titanium

So the next step is that the sphere is brought to the facility which is built inside a former nuclear bunker, It is also built inside a large oven for end of facility lifetime complete sterilization, in case something is returned that can't be permitted to make any contact with Earth's biosphere, like mirror life.

Finally instead of a conventional airlock it has two airlocks at positive air pressure which are only connected via sump filled with vacuum stable high temperature light oil which is kept at 300 C and irradiated with ionizing radiation., That should keep in even mirror life nanobes

To make this sketch I use the LAS fully robotic floor plan for a Mars sample receiving facility placed inside an oven for end of laboratory lifetime sterilization of the facility and accessed via two airlocks and a sump for 100% containment of even mirror life nanobes.



Text on image: Built inside former nuclear bunker for protection from accidental damage such as plane crashes

Laboratory built inside oven for sterilization at 300°C at end of life of facility

Sump

Inner airlock, outer airlock

Sketch for 100% containment of mirror namobes etc. Sump kept at 300 °C filled with Pentaine X2000 oil. Both airlocks and sump continuously radiated with X-ays and ionizing radiation and sterilied with CO2 snow. Both airlocks +ve pressure, inlets sealed during airlock cycles.

Sketch of telerobitic facility Credit NASA / LAS, Hsu, 2009, Keeping Mars Contained,

Photo of Cultybraggan nuclear bunker

Clark, 2009, Cultybraggan nuclear bunker

The studies would have to be done telerobotically. I'd be interested in thoughts from engineers as to whether this is feasible. This might permit a very fast legal process as it would hopefully be clear to everyone that it will be safe.

The build of the facility could be started right away with confidence that it will be considered suitable when finished. Congress would need to approve the build as it does with all major funding requirements.

The other solution involves returning to a safe orbit outside of Earth's biosphere. This involves minimal legal process similar to the sample returns from comets or asteroids.

This assume that the samples are of biological interest. If not the simplest solution is simply to sterilize them.

SADLY THE PERESEVERANCE SAMPLES ARE NOT STERILIZED SUFFICIENTLY TO DETECT LIFE IN LOW

CONCENTRATIONS - AND THEY ARE SAMPLING ROCKS - NOT MUCH DIRT OR DUST EXCEPT ONE REGOLITH SAMPLE - WE COULD HOWEVER ADD A 100% STERILE CONTAINER TO RETURN A SIMPLE SCOUP OF DIRT IN THE SAMPLE FETCH LANDER

Some think there is a high chance Viking in the 1970s did discover life and if not I think it was very interesting chemistry. But sadly the current Mars sample return won't return a sample of the dust or dirt or the sub surface brines that Viking may well have sampled. Also the sample tubes aren't adequately sterilized to be able to prove that there is no life in them or to detect low levels of life - there is enough organics by my calculation for tens of thousands of ultramicrobacteria per tube and tens of millions of simpler RNA world nanobes (which could be hazardous to Earth as mirror life nanobes). In my literatue survey I found warnings from experts that insufficient sterilization can lead to false positives which could make it impossible to release the samples from contanment without sterilization and this seems likely to happen for Perseverance's samples.

So I suggest the sample fetch lander is modified to return a sample of the dirt, just collected using a scoop as for Viking, and collected into a 100% sterile container. The reason this wasn't done for Perseverance is that engineers worried that with their complex drilling machinery the container wouldn't open on Mars. But with geological samples already collected and a simple scoop collection method I think we could aim higher for a 100% contamination free sample of dirt, and I think we should also similarly have a 100% contamination free sample of the Martian atmosphere and of dust from dust storms.

If I see any mistakes in this do say!

EARTH WILL BE KEPT SAFE - AS A RESULT OF AN EXTENSIVE LEGAL PROCESS AND EXPERTS FROM MANY DIFFERENT AGENCIES - AND THE PUBLIC ALSO INVOLVED

The papers by Urhan et al and Race are peer reviewed and everything in them checked out. Urhan et al's second author is Cassie Conley, former NASA planetary protection officer. If what they say is correct, these things will be looked at very thoroughly.

Uhran, et al, 2019.. Updating Planetary Protection Considerations and Policies for Mars Sample Return.

As a result of the EIS process, numerous US agencies will make sure it is safe - who have nothing invested in the success of the space program - including the

- Department of Homeland Security,
- CDC (for potential impact on human health),
- Department of Agriculture (for potential impact on livestock and crops),
- Occupational Safety and Health Administration - for any rules about quarantine for technicians working at the facility
- Department of the Interior which is the steward for public land and wild animals which could be affected by release of Martian microbes
- Fish and Wildlife Service for the DoI who maintain an invasive species containment program and may see back contamination as a possible source of invasive species
- National Oceanic and Atmospheric Administration (NOAA)'s fishery program for sea landing in case it could affect marine life and NOAA fisheries
- Integrated Consortium of Laboratory Networks (ICLN)

INTERNATIONAL ORGANIZATIONS LIKE THE WHO, FAO, AND OTHERS WOULD ALSO BE INVOLVED AS WELL AS INTERNATIONAL TREATIES

Also several international organizations are likely to be involved such as the WHO (for potential impacts on human health globally if a new organism is returned that can be spread to other countries). If the worst case scenarios such as mirror life are seen as credible this would surely also involve the Food and Agriculture organization for potential impacts on global food supply and so on.

See:

Race, 1996, Planetary Protection, Legal Ambiguity, and the Decision Making Process for Mars Sample Return

Race says that experts will have challenges deciding in advance whether the sample should be classified as potentially:

• an infectious agent

• an exotic species outside its normal range

• a truly novel organism (as for genetic engineering)

• a hazardous material

The choices here would change which laws and agencies would be involved.

There are numerous treaties conventions and international agreements relating to environmental protection or health that could apply.

Including those to do with

• protection of living resources of the sea

• air pollution (long range pollution that crosses country boundaries)

• world health, etc

She also writes that many interntaional treaties would be involved based on work by George Robinson.

Meanwhile, since this is a joint NASA / ESA mission, it involves ESA. Most of the ESA member states are in the EU (ESA, n.d.) so the EU will get involved.

This leads to a separate legal process in Europe, starting with the Directive 2001/42/EC (EU, 2001). I haven't located any academic reviews for the European process, but as for the case in the USA, this would spin off other investigations which would involve the European Commission (Race, 1996).

In 1969, for Apollo 11, NEPA didn't exist. NASA did set up an interagency panel but their recommendations were kept secret and not made public before the mission. This panel asked NASA modify its plans, to keep Earth safe, but NASA vetoed them and all this happened in private discussions with no public involvement.

None of this would be permitted today. Today, NASA has no veto.

Any objections by the agencies would be made public and If any of these agencies think that NASA's plans don't keep Earth safe they can require NASA to change its plans or just stop the mission.

FEW THINGS COULD SUSTAIN INTEREST PUBLIC INTEREST MORE THAN LIFE ON MARS - OR END IT MORE QUICKLY IF WE MAKE THAT LIFE ACCIDENTALLY EXTINCT - FOOTPRINTS AND FLAGS ARE OF ONLY SHORT TERM INTEREST THAT FADES IN WEEKS

As you know there was huge public interest in the first footprints on the surface of the Moon, and the first flags. But after that the public moved on, "been there done that". I believe that the same would happen on Mars unless there is more to it than watching humans living on another planet with different coloured skies, and otherwise resembling a terrestrial desert.

I believe the more interesting Mars turns out to be, for humans, the more likely we can sustain human interest and funding. If we find life on Mars, especially life that is novel and of different biology from Earth life, that would sustain the most public interest of any discovery we could make there.

MARTIAN LIFE RETURNED TO EARTH COULD POTENTIALLY BE MORE LIKE INVASIVE AMERICAN MINK IN EUROPE, AND TERRESTRIAL LIFE ON MARS MORE LIKE INVASIVE RABBITS IN AUSTRALIA OR RATS, PIGS AND EUROPEAN STARLINGS IN THE AMERICAS

We do have candidate microbes that could survive on Mars such as chroociccidiopsis, a blue-green algae and a similar microbe on Mars could survive on Earth. We'll also find that chroococcidiopsis couldn't get here on a meterorite from Mars.

We do have invasive microbial species such as invasive diatoms in New Zealand lakes such as Didymosphenia geminata , probably brought there from the northern hemisphere damp sports equipment, and many invasive diatoms in the Great lakes including Stephanodiscus binderanus which clogs water treatment systems and creates foul tastes and odours in the water (see for example, Diatoms as non-native species)

WE NEED TO LOOK CLOSELY AT POSSIBLE SCENARIOS FOR MARS

So it is important to look closely at many different scenarios of what we can find on Mars. If there is a potential for Martian life, we need to know if it is at risk from terrestriial life brought from Earth. Also we need to be very confident that both the Earth and human astronauts are safe after a mission to Mars.

WE HAVE NOT ONLY A RESPONSIBILITY BUT A LEGAL OBLIGATION TO PROTECT EARTH'S BIOSPHERE THROUGH

MANY LAWS THAT DIDN'T EXIST AT THE TIME OF APOLLO - NOT THE OUTER SPACE TREATY

If there is even a small risk of returned life harming Earth's biosphere, we not only have a responsibility but are legally required to protect Earth. This is based on many laws to protect Earth's environment and doesn't depend on the Outer Space Treaty.

According to the best analyses I've seen, the legal process will take many years and any plans will be scrutinized by independent experts in all the affected agencies in the USA, also international treaties and the domestic laws of other countries will be involved too. We can't follow the streamlined procedures of the Apollo years any more because the law has moved on since then.

For details see Updating Planetary Protection Considerations and Policies for Mars Sample Return

So we don't need to have any concern on an individual level of risk to Earth's biosphere. Earth will be protected. But I think there is a risk of expensive mistakes in planning for space missions that don't take account of this legal complexity, perhaps based on the very different legal situation for the Apollo missions. As far as I can tell, by adding up the timelines, we couldn't complete the legal process in time to return an unsterilized sample from Mars before 2039. But there may be ways to speed this up, by returning a sample to a safe orbit outside of Earth or possibly a very safe sample return to Earth.

NEED TO BRING SCIENTISTS, THE PUBLIC AND SPACE COLONIZATION ENTHUSIASTS TOGETHER

I believe we need to bring the scientists, the public, and the space colonization enthusiasts together. There is a large constituency of space colonization enthusiasts on Mars and we can accomplish much more if we can go forward working together with each other to solve the many problems for human exploration of Mars.

I will go into your arguments in a moment, but first I will outline my vision for the future, which I hope is an inspiring alternative to the ideas of the Mars society and SpaceX for the near future.

MY VISION FOR THE FUTURE WHICH I BELIEVE WILL LEAD TO FAR MORE SUSTAINED INTEREST IN SPACE EXPLORATION AND SETTLEMENT - STARTING WITH EVEN MORE AMBITIOUS PLANETARY PROTECTION EXPLORING MARS FROM ORBIT IN THE SPECTACULAR HERRO ORBIT - EVEN MORE INTERSTING THAN THE ISS ORBIT AROUND EARTH

I suggest we start with missions from Earth doing in situ exploration of Mars, followed by humans exploring Mars from orbit in a very rapid astrobiological survey - similar to the one you vision but done with 100% sterile rovers. They would explore in orbit by telepresence.

As you'll know, this is an idea that's come up often in the Mars exploration literature:

Buzz Aldrin's plan:

- Aldrin et al, 2013. Mission to Mars (p. 173).

The Boeing "Stepping stones to Mars" mission:

- Hopkins et al, 2011, September. Comparison of Deimos and Phobos as destinations for human exploration, and identification of preferred landing sites
- Kwong, et al., 2011, September. Stepping stones: exploring a series of increasingly challenging destinations on the way to mars. In *AIAA Space 2011 Conference, Long Beach, CA* (pp. 27-29).

The HERRO mission

- Oleson, et al., 2013. HERRO mission to Mars using telerobotic surface exploration from orbit
- Valinia, et al., 2012. Low-Latency Telerobotics from Mars Orbit: The Case for Synergy Between Science and Human Exploration.

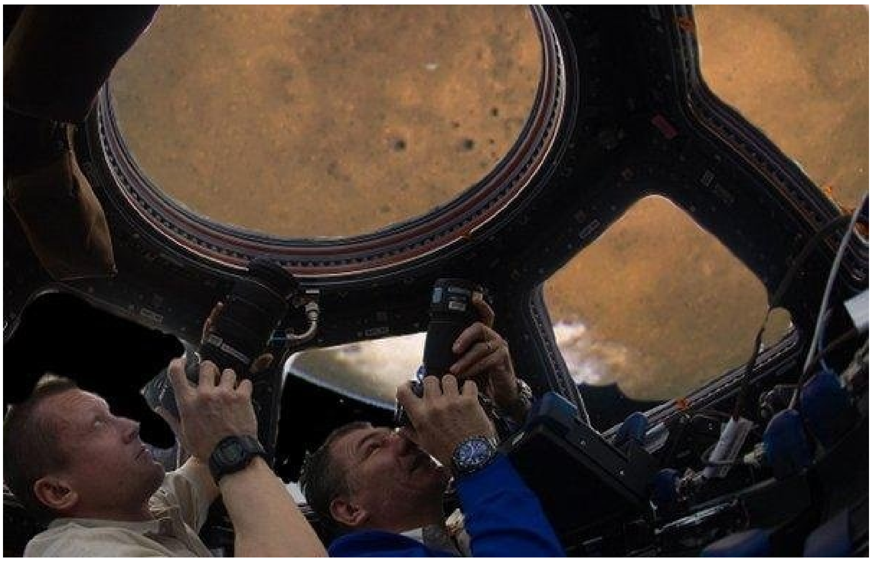
And Mars Base Camp

- Cichan et al, 2017. Mars Base Camp: An Architecture for Sending Humans to Mars

The easiest of all of these in terms of delta v. is the HERRO mission which could be the earliest, a sun synchronous near polar Mars orbit that's easty to get to from Earth.

The HERRO orbit is a spectacular one, comes in close to the poles of Mars twice a day, near to each pole, then skims the surface than away again until Mars recedes to a small disk in the distance and then repeats. The astronauts get a few hours every day of close telepresence exploring the surface directly via robots that work like avatars in a computer game.

This is what it might look like from inside the spacecraft



Composite of photo from the Cupola of the ISS (Coleman, C, 2011) and Hubble photo of Mars (Hubble, 2003

In this video, I use a futuristic spacecraft called the “Delta Flier” in Orbiter as that was the easiest way to do it in the program I used to make the video. Apart from that, it is the same as the orbit suggested for HERRO.

https://www.youtube.com/embed/BftmbvBd5m4?feature=oembed

Video: One Orbit Flyby, Time 100x: Mars Molniya Orbit Telerobotic Exploration in HERRO Mission

I think an orbital mission like HERRO is of far greater sustained interest both for the public and for the astronauts than a surface colony where you see the same view from your window every day - with not even much by way of changes, very little even by way of weather, and it takes hours to put on a spacesuit if you do it safely, to get out of doors. The first footprints and the first flag would be of interest but there is a limit to how much interest there is in seeing the same landscape outside the module window every day of the year, with the monotony only relieved by occasional dust storms or dust devils.

But the HERRO orbit would be much like the ISS, where the astronauts see constantly changing landscapes outside of their windows. This greatly adds to the public interest of the ISS.

The HERRO orbit is a bit like the lunar gateway polar orbit but approaches Mars twice a day instead of once every 7 days as for the Moon.

THEN SETTING UP A BASE ON PHOBOS, DEIMOS OR BOTH AS WITH BUZZ ALDRIN’S “MISSION TO MARS”

Humans could also explore Phobos and Deimos which also have ISS like orbits around Mars. There again, they see a different view every time they look out of their windows towards Mars.

This would be like Buzz Aldrin’s plan - from his “Mission to Mars” book.

As he summarized it briefly in this interview

There are a lot of things really should be done before the first

people go down and it is so much more efficient without going into details ... A project manager said what they did in five years could have been done in one week if we had human intelligence in orbit so that we could control things with a second time to life instead of 15 minutes

From his book, Aldrin and David, 2013. Mission to Mars (p. 173).

Phobos is a way station, a perfect perch that becomes the first sustainable habitat on another world. From that mini-world, crews on Phobos can run robotic vehicles on Mars more directly, in a much shorter communication delay time than commands sent from faraway Earth. Robotic stand-ins for astronauts will ready the habitats and other hardware on the Martian surface, in preparation for the first human crew to arrive on Mars. That’s my judgment. My theory right now is that somebody piecing together hardware on Mars through telerobotics on Phobos is the right person to later lead the first landing mission on the red planet.

Phobos and Deimos are, in a sense, offshore islands of Mars, discovered in 1877 by Asaph Hall at the U.S. Naval Observatory in Washington, D.C. They were tagged with names from Greek mythology: Phobos means “fear,” Deimos, “terror.” In the future these Martian moons are likely to symbolize just the opposite: courage and security.

By placing a crew-occupied laboratory/control station on either Phobos or Deimos, an assortment of probes, penetrators, and rovers can be controlled on Mars. Far more of the planet can be reconnoitered, more so than a landed crew could achieve. After all, Mars is vast. It’s a huge planet with a lot of real estate, some of it very hazardous in terms of crevasses, caves, steep hills, giant canyons, and high mountains. Better to lose a robot or two than have a person face a deadly predicament.

On one hand, robots are able to cope with the surly climes of Mars while carrying out boring, risky, or dull jobs. On the other hand, humans bring perception, speed and mobility, dexterity, and an inquisitive nature. Combining the two is opening up a new paradigm in space exploration. “Telepresence” makes use of low-latency communication links that can put human cognition on other worlds. Low-latency yields the appearance of “being there” in a way that is near real-time believable. The ability to extend human cognition to the moon, Mars, near-Earth objects, and other accessible bodies helps limit the challenges, cost, and risk of placing humans on perilous surfaces or within deep gravity wells.

MAINTAINING THE BIOLOGICAL VALUE AND INTEREST OF MARS WITH 100% STERILE ROVERS - MADE FEASIBLE BY ENGINEERING STUDIES FOR VENUS

Then I believe that to maintain the biological value and interest of Mars in early stages of exploration, we need 100% sterile rovers, We have that technology developed for Venus landers, a complete rover made with modern heat tolerant electronics that can run indefinitely at 300 C with active cooling. these electronics are widely used in electric cars, to monitor furnaces, for some jet engine parts and so on so they are well understood and robust.

For our Mars missions we could heat the rover for months during the journey to Mars then operate it at normal temperatures on Mars. There would be initial expense in the design, sourcing components for it and so on, but much of the work is already done for Venus and once done there would be little overhead after that. The expense of heat tolerant alternatives for all the components would be small compared to the overall cost of a space mission.

So, I actually advocate a far higher level of planetary protection than we have today. Hopefully you may find these ideas interesting even though you are not likely to agree with them initially.

PERHAPS EARTH LIFE ORIGINATED FROM MARS - IF SO IT’S NOT IMPOSSIBLE THAT PHOTOSYNTHETIC LIFE FROM MARS CAUSED WHAT MIGHT BE THE GREATEST MASS EXTINCTION EVER - THE GREAT OXYGENATION EVENT

Although we have no evidence of any transfer of life from Mars, one suggestion is that terrestrial life originated from Mars brought here perhaps on huge impacts in the early solar system.

If so Martian life helped form the Earth we have today and is even our distant cousin. But that doesn't prevent it causing mass extinctions here.

Suppose that photosynthetic life came to Earth from Mars half a billion years ago. It could have caused the great oxygenation event, which was hugely beneficial for our form of life. We don't know, but it's possible that it also made many previous species extinct, adapted to a world without oxygen.

IF LIFE HAS GOT TO EARTH FROM MARS IT DOESN’T MEAN ALL MARTIAN LIFE GOT HERE - FILTERED TO THE LIFE ABLE TO SURVIVE THE TRANSIT

Also if life has got to Earth from Mars, it doesn't mean that ALL Martian forms of life have got here. Instead it would be filtered to whatever is able to withstand the journey from Mars to Earth.

Martian life unable to get here could still be very hazardous if they did get to Earth.

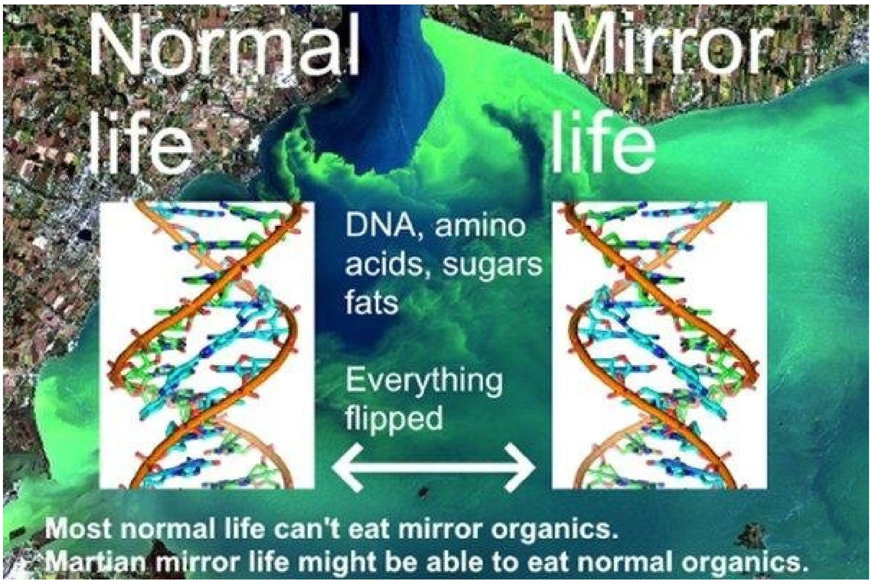
Example of a mirror-life blue-green algae - chemistry reflected in a mirror - likely to be able to metabolize both forms of life but only produce mirror organics

Let's take the example of mirror life blue-green algae. This is identical to terrestrial life but with all the chemistry reflected as in a mirror, DNA and RNA spiral the opposite direction and so on. Of all the alternative biochemistries this is the one with most agreement on. All the astrobiologists agree that mirror life would just work.

There are varying views about why we have ordinary rather than mirror life. Some think that there are reasons why normal rather than mirror life is favoured. But other experts say it is just the luck of the draw and could have gone either way.

, The origin of homochirality

Suppose Mars has mirror life and for whatever reason it hasn’t been able to get here on a meteorite. This could cause similar large scale changes to Earth’s environment.



Normal life, Mirror life, DNA, amino acids, sugars, fats, everything flipped. Most normal life can't eat mirror organics. Martian mirror life might be able to eat normal organics. Background image from NOAA, DNA spiral from Pusey et al, 2012, cites in preprint

We don't know why terrestrial life all has DNA spiralling the same way and most organics in only one form and not its mirror. It may just be chance and if so Martian life could have life with the DNA spiralling the opposite way - or both forms of life.

The Martian surface conditions would rapidly destroy organics from life over timescales of millions of years and most of the organics are likely to be from infall from space, in form of comets, asteroids, interplanetary dust and so on. So the organics are likely to occur in both forms, ordinary and mirror.

Some terrestrial microbes have the capability to metabolize mirror life but this very rare and no higher lifeforms can do this.

Life from Mars, whether the same symmetry as terrestrial life or mirror life, is likely to be able to metabolize both forms of organics as that would double the amount of organic material it can consume.

Not saying this is a likely scenario. But it can't be ruled out. This is new to my original preprint as far as I know but it should survive peer review.

It combines together

- Universal agreement that a cell with everything in its mirror form would still function.
- Research into attempts to convert terrestrial life to mirror life by gradually flipping components of a cell into a mirror one by one
- Research into biosafety levels needed for mirror life - they will make it safe by making it dependent on chemicals only available in the laboratory
- Detailed scenarios of what could happen if mirror life escaped on Earth without those precautions and if it had or acquired the ability to metabolize non mirror organics - it would gradually change all organics to mirror organics
- Astrobiologists say we shouldn't assume Martian life is based on terrestrial biochemistry when we search for it
- Some experts are of the view that the choice between life and mirror life was just a matter of chance, making it 50–50 that any independently originated Martian life is mirror life.

Based on all that, there has to be a possibility though likely very small that Mars could have mirror life and that the mirror life has never got to Earth.

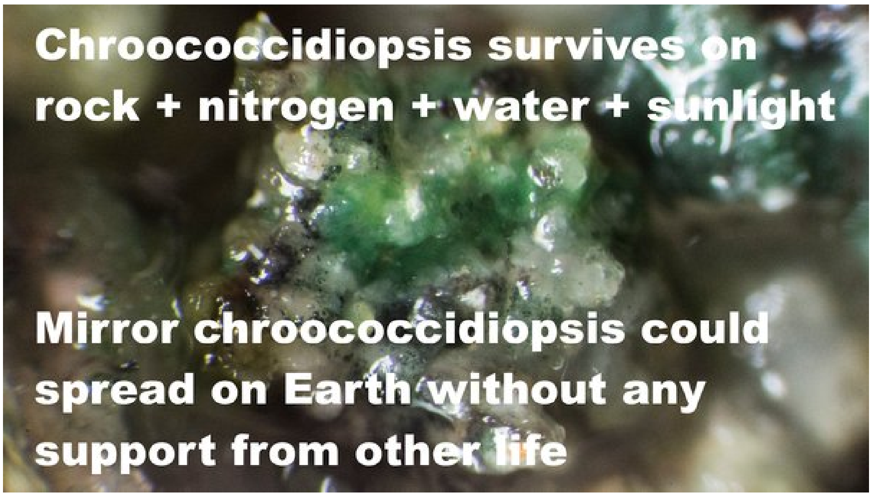
I cover this in my preprint about the draft EIS under

- If Mars has mirror life, returning it could potentially cause a similar large scale transformation of terrestrial ecosystems by gradually converting organics to mirror organics – an example worst case scenario

My clearest example here is chroococcidiopsis but flipped as in a mirror, DNA spirals the other way and all the organics are mirrored. Some terrestrial microbe can use mirror organics but no known multicellular life can subsist on mirror organics.

If Mars has mirror life, it's bound to develop the isomers that let it digest ordinary organics too because of the constant rain of organics from comets, asteroids and interplanetary dust.

Return that to Earth and it will gradually turn all the organics throughout all the ecosystems it inhabits into indigestible mirror organics.



Chroococcidioopsis 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

Humans would survive, and the process would likely take centuries, but we'd not be able to stop it and eventually would need to protect all our ecosystems in greenhouses and similar undersea habitats with the mirror life kept out as far as possible as well as mirror organics.

In this article we wouldn't actually all die because of that. After all we have figured out how to live in space even though nobody has built a space colony yet. For sure we can live in habitats on a world with mirror life indigenous outside our habitats.

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

Example worst case scenarios for ecosystems, mirror life nanobes - similar in size to a SARS-COV2 virus - as for the shadow biosphere hypothesis

Then it could be RNA life, which could permit very small nanobes similar in size to the SARS CoV2 virus which causes COVID or smaller. Indeed we have DNA based ultramicrobacteria which can pass through 0.1 micron filters, only double the diameter of the SARS - CoV2 virus. There was a lot of interest at one point in a shadow biosphere of RNA nanobes that could co-exist with terrestrial life.

. The Quest for a Universal Theory of Life: Searching for Life as we don't know it , pp 213 - 214

It would have some advantages, protean grazing would ignore it as too small, and the high surface to volume ratio is an advantage in nutrient poor environments.

. Nano-sized and filterable bacteria and archaea: biodiversity and function. See section: **Selective Pressures for Small Size**

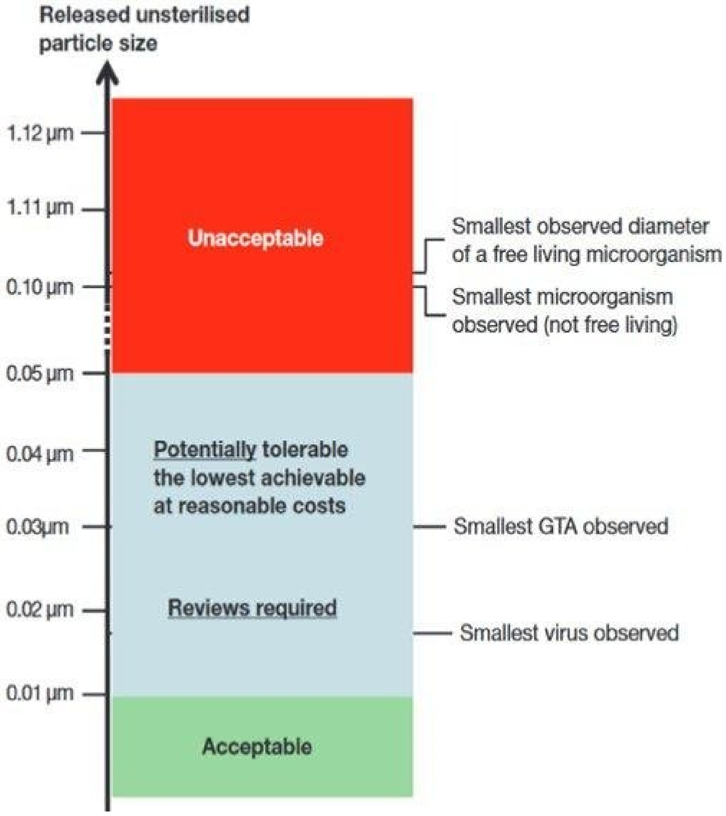
We never found that shadow biosphere. But early terrestrial life has to have been much simpler than DNA. Probably we did have early much simpler forms of life that could survive as much smaller nanobes than for terrestrial life, but terrestrial life made it extinct.

However we can't guarantee that terrestrial life would out compete mirror nanobes from Mars, after all it was a viable hypothesis for a shadow biosphere for Earth.MIRROR LIFE NANOBES MIGHT BE ABLE TO PASS THROUGH FILTERS NOT MUCH LARGER THAN 0.01 MICRONS OR 10 NANOMETERS - WE HAVE NO FILTERSE WITH ANYTHING LIKE THAT CAPABAILITY - WELL BEYOND HEPA FITLERS

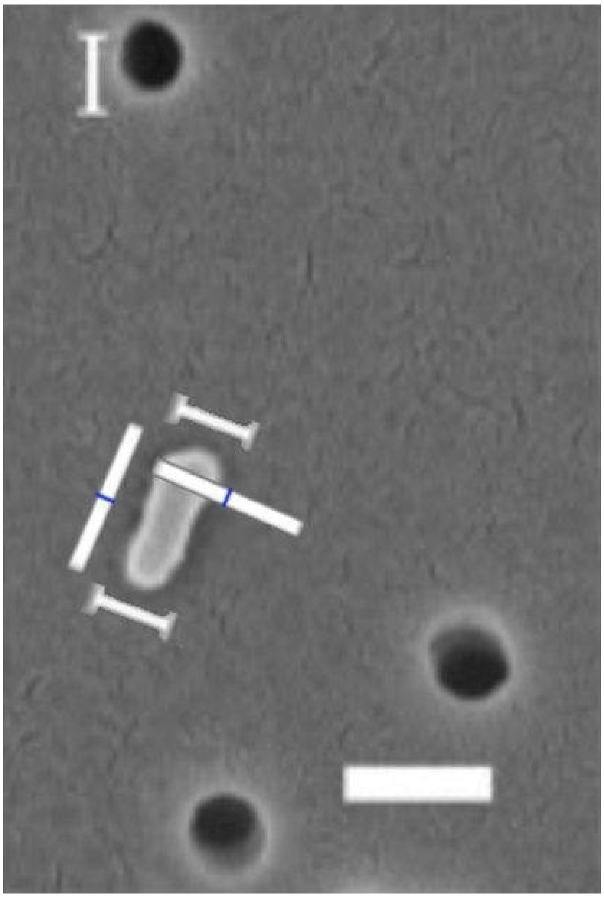
Mirror life nanobes may be able to pass through filters not much larger than 0.01 microns or 10 nanometers.

I did a search of the literature and we don't yet have filters able to filter out individual SARS CoV2 viruses. HEPA filters can filter out the larger droplets but not individual viruses. We do have filters that work under high pressure to filter out such small nanoparticles from water, but they are also delicate and high maintenance.

The 2012 Mars Sample Return study for the European Space Foundation said a mission needs to contain a 0.05 micron particle that not even one such particle should leave the facility.



They base this on experimental observation of terrestrial nanobacteria that can pass through 0.1 micron (100 nanometer) filters.



SEM of a bacterium that passed through a 100 nm filter (0.1 microns), large white bar is 200 nm in length (Liu et al, 2019).

The report concluded (Ammann et al, 2012:21)

> *"the release of a particle larger than 0.05 µm in diameter is not acceptable in any circumstances"*

That also is beyond current capabilities to filter out.

EXAMPLE OF MIRROR LIFE NANOBES GRADUALLY TRANSFORMING TERRESTRIAL ORGANICS TO MIRROR ORGANICS - THIS IS A SCENARIO EXPERTS WILL NOT BE ABLE TO IGNORE IN THE LEGAL PROCESS

This is an example of a worst case scenario. But we don't know what we will find on Mars so, until we do, we do need to consider all scenarios. We have no way to assign probabilities to them yet.

In this scenario, the Martian nanobes gradually turn all terrestrial organics to mirror organics. Most terrestrial life doesn't survive. Some prime producers like Chroococcidiopsis do survive as they can grow based on just sunlight, water, and a few elements from rocks. Others survive because they are able to metabolize mirror organics or quickly evolve that capability. Some smaller forms of higher life with short lifespans may be able to evolve the capability to use mirror organics.

But most terrestrial biospheres gradually go extinct. This would likely take centuries but over that time period we would need to gradually paraterraform Earth, cover the land and protected areas of the sea such as coral reefs with enclosures to keep out mirror organics and as much as possible of the mirror life, and artificially ensure that the organics within the ecosystems are of the right symmetry for terrestrial life to use. We might also be able to engineer terrestrial life to use mirror organics.

It's not an extinction scenario for humans but it is severe degradation of the Earth's biosphere in the short term, though long term it is enriched by the diversity of both mirror and non mirror life. Much like the great oxygenation event it would likely result in a more biodiverse world eventually but the short term effects would be very severe and last for millions of years, though we might be able to speed up the transition.

There is no way that experts are going to permit a sample return from Mars if thereis any possibility for such a scenario as this.

We need to prove that it is impossible first.

ASTRONAUTS WHO DISCOVER MIRROR NANOBES ON MARS COULD NEVER RETURN - SO WE NEED TO KNOW BEFORE WE SEND THEM THERE

We couldn't protect against this by quarantine. If astronauts found mirror life on Mars there would be no way to sterilize it from their habitats, or remove mirror life from the human microbiome. They would need to remain on Mars for the indefinite future and there might be no way to bring them back to Earth safely.

So it is important to know the answer to this BEFORE we send humans to the Martian surface.

MARTIAN ASTRONAUTS COULD ALSO BE HARMED BY A DISEASE OF BOFILMS LIKE LEGIONELLA WHICH IS NOT ADAPTED TO HUMANS

Martian life could also be hazardous to astronauts more directly. Yes there is no way that Mars would have diseases adapted to humans, however, legionnaire's disease is often used in the planetary protection literature as an example of a disease of biofilms which isn't adapted to humans. It "sees" our lungs as just another biofilm. It even infects the macrophages that try to eat it, which to legionella must seem like a large amoeba from a biofilm.

Legionella isn't a likely organism to find on Mars as it requires oxygen, though the oxygenated brines may make it more likely. But it's an example to show that diseases from Mars needn't be adapted to human hosts to harm us.

WE COULD ALSO BE HARMED BY FUNGAL DISEASES - ONE OF THE CANDIDATE MICROBES FOR MARS IS AN OPPORTUNISTIC INFECTION OF HUMANS - AND IF WE ARE ALL IMMUNE NAIVE TO MARTIAN LIFE WE MIGHT ESSENTIALLY ALL BE IMMUNOCOMPROMISED FOR A MARTIAN FUNGAL DISEASE

Another example like this, fungal diseases. For most people they are a minor nuisance, athletes foot, fungal toe nails, or the allergic reactions that lead to asthma or allergic rhinitis. But for immunocompromised, some fungi and molds can be deadly.

Our immune system might never have been exposed to anything resembling Martian life. If so we might all be essentially immunocompromised like the patients who sadly die of fungal diseases. One of the candidates for a terrestrial mold that could live on Mars is actually an opportunistic Martian pathogen in the immunocompromised.

WE NEED TO LOOK AT WORST CASE SCENARIOS - BUT MARTIAN LIFE COULD ALSO BE BENEFICIAL - EXAMPLE OF THE ARCHAEA - A WHOLE DOMAIN OF LIFE THAT IS LARGELY BENEFICIAL TO OTHER LIFEFORMS

I don't want to suggest that Martian life inevitably harms terrestrial biospheres. We need to look at that because it's important to consider worst case scenarios when we don't know what's there.

However in other scenarios Martian life is beneficial to Earth's biosphere. A good analogy here is the archaea, a complete domain of life that causes almost no problems for any of our biospheres or terrestrial life. It might be implicated in tooth decay but there is very little by way of archaea caused diseases or harm.

However we need to know what we have on Mars before we send humans there and return it to Earth, accidentally or intentionally.

MARTIAN LIFE COULD ALSO BE AT GREAT RISK FROM EXTINCTION BY TERRESTRIAL LIFE - FOR INSTANCE IN A SCENARIO OF TRANSFORMABLE EARLY LIFE CELLS WITH GENETIC COMPETITION BUT NO COMPETITION AT THE CELLUULAR LEVEL

Then Martian life could be early life that hasn't evolved far, especially if it has evolved recently. One hypothesis is that life may have gone extinct and re-evolve don Mars many times and we might find life there that isonly a few hundred million years old. Another possibility is that early life has survived all the way to the present but has barely changed.

Woese suggested that early life took the form of transformable cells. Their cell walls are essentially permeable to RNA indeed they might share it also via vesicles, and other methods such as are widely used in terrestrial microbes today for horizontal gene transfer. This leads to Lamarckian evolution. This could be very effective in the harsh conditions there with microbes in a biofilm cooperating maximally by sharing all the genetic information they have that could help adapt. It might not have any predators yet.

However such life would be very vulnerable to terrestrial life as the cells never needed to compete with each other and would be just eaten by terrestrial life. The life might be gone before we can study it.

LIFE INTRODUCED TO MARS COULD MAKE IT LESS RATHER THAN MORE HABITABLE - FOR INSTANCE PHOTOSYNTHETIC LIFE BY COOLING MARS COULD MAKE IT LESS HABITABLE - IT IS POSSIBLE THAT THIS ALREADY HAPPENED - HYPOTHESIS OF A SWANSONG GAIA (NOT YET HAD PEER REVIEW)

Another issue is that life we introduce to Mars could make Mars less rather than more habitable for humans, and indeed for native life too. Photosynthetic life on Earth helps keep it cool, by removing CO2. That helps make Earth more habitable but a cooler Mars is the opposite of what life needs there. In my preprint I make a new suggestion. It hasn't had peer review yet, but the suggestion is that photosynthetic life on Mars would help preserve it in a barely habitable state for billions of years.

This assumes that the volcanoes on Mars continue to release enough CO2 to keep it warm enough for liquid water continuously - but that photosynthetic life responds to any cO2 pulse by rapidly spreading over the surface and removing CO2 until it is barely habitable.

Sometimes the atmosphere would thicken and liquid water would be possible, but as soon as this happens life immediately starts removing CO2 bringing it back to its current barely habitable state.

Swansong Gaia hypothesis. Modern Mars looks sterile, but photosynthetic life might take CO_2

out of the atmosphere when it gets warm enough for liquid water, keeping Mars

barely habitable. This would work with a wide range of CO_2 emission scenarios

I call this the swansong Gaia hypothesis. Based on Jack O'Malley-James's idea of a swansong biosphere when a planet loses life but before it is completely extinct,but then a Gaia type feedback that maintains habitability for billions of years,like Gaia, but minimally habitable in a perpetual swansong biosphere state.

The idea itself isnt' new. The current Martian atmosphere average pressure at 0°C is remarkably close to the triple point for water of 6.1 millibars, the balance of pressure and temperature where ice, liquid water and water vapour can co-exist in equilibrium. In places it is below the triple point, in Hellas basin by one model it is 12.4 millibars and would boil at 10°C. In the Southern Uplands it is well above the triple point.

Perhaps this is not a coincidence.

The literature has several speculations about the idea that the Mars atmosphere could be self-limiting. with excess CO2 sequestered asa carbonates whenever the pressure gets higher. However the literature focuses on formation of carbonates by dissolving in water and other abiotic processes, including a suggestion that abiotic photosynthesis could help keep Mars perpetually in such a state. See for example:

- Kahn, 1985. The evolution of CO_2 on Mars.
- Haberle, et al., 2001. On the possibility of liquid water on present-day Mars

The only thing new about my suggestion of a self perpetuating Swansong Gaia is my suggestion that ibiotic photosynthesis combined with some other biotic processes such as methanogenesis contributes to the long term stability of the atmosphere, maintaining it at a perpetual almost minimally habitable state for billions of years, with occasional boosts in habitability after a big influx of CO2 and other gases such as hydrogen (which can increase the warmth by collisional)

The strenght of the feedback loop could be amplified when there is open water by native life with carbonate shells such as forams.

I also suggested another feedback that would strengthen the Swansong Giaia effect. Martian life might be like life in terrestrial deserts where nitrogen is returned to the atmosphere by denitfication when conditions are wetter, but in drier conditions in terrestrial deserts there is only nitrogen fixation and no dentrification, so nitrogen is only removed. As the climate gets drier perhaps a small amount of nitrogen fixation may still continue but the ntirogen levels will be low as with the current Martian atmosphere.

Methanogens might give an initial pulse of extra warming as the atmosphere thickens after a pulse of CO_2, for instance from a cometary impact or volcanic eruptions. However the photosyntehtic life would release oxygen to convert the CO_2 to methane and also fix the CO_2.

Then the methanogens might also themselves be self limiting as they retreat underground once the lakes are gone. . A consortium of methane oxidising and sulfate reducing bacteria can convert underground aquifers to calcite through anaerobic oxidation of methane.

- Drake et al, 2015, Extreme 13 C depletion of carbonates formed during oxidation of biogenic methane in fractured granite.

Subsurface methanogens might form layers of calcite that trap the emissions of methane below the surface. If this happens near the surface it could become another feedback that traps more methane the warmer the climate is.

IF MARS DOESN'T HAVE PHOTOSYNTHETIC LIFE THE LAST THING WE WANT IS TO SET UP AN ARTIFICIAL HUMAN CREATED SWANSONG GAIA THAT WOULD MAINTAIN IT PERPETUALLY AS A BARELY HABITABLE PLANET

The Swansong Gaia effect would increase the possibility of present day Mars having life. But it would make terraforming hard because the natural tendency would be for photosynthetic life to remove any CO2 that we try to release into the atmosphere, and for as long as the climate remains dry, the drier deserts over most of the surface mean nitrogen would be removed too.

If Mars is not in a swansong gaia state and if it has never seen photosynthetic life, the last thing we would want to do is to set up an artificial swansong gaia like this. So we might want to hold back on introducing terrestrial photosynthetic life while we work on trying to establish some other different end state artificially.

SOME CONSORTIA OF METHANOGENS CAN CONVERT SUBSURFACE AQUIFERS TO CEMENT

Then, some consortia of methanogens are able to convert subsurface aquifers to cement. This is another way that introduced life on Mars could make it less habitable to terrestrial life and to humans, that maybe a few decades after the first astronauts get there, all the sub surface aquifers calcify and can no longer be easily accessed as source of water - assuming there are subsurface aquifers near localized geothermal hot spots.

THESE ARE SCENARIOS ONLY - WE DON'T KNOW WHAT WE WILL FIND OUT BUT WE CAN GET THE ANSWERS FAST IF SPACE COLONIZATION ENTHUSIASTS, SCIENTISTS, MISSION PLANNERS AND THE PUBLIC ALL COME TOGETHER WITH THE SAME VISION

These are just scenarios, we don't know what we will find on Mars. But we can find out if space colonists and scientists and astronauts all come together to do a rapid astrobiological survey as I suggested.

WE NEED TO START WITH THE MOON AND LEARN HOW TO LIVE THERE - A MAJOR CHALLENGE BUT ONLY 2 DAYS

INSTEAD OF OVER 6 MONTHS EVAC AWAY FROM EARTH

The journey from Earth to Mars is very difficult and hazardous. Chris Hadfield has suggested that this is a task for the next generation of astronauts. First we need to show that we can survive on the Moon or in orbit around the Moon. Once we have the capability to send astronauts to the Moon to live there for 3 years with no resupply from Earth - this will make lunar settlement and exploration much lower cost and much easier to do - and then we can consider sending human to Mars.

We could send humans to Mars today but there is a significant risk that everyone dies on the journey there. For instance, after an Apollo 13 type accident as the spacecraft leaves Earth - the only way back wouldn't be just a few days around the Moon but a year or more via Mars.

Also for emergencies, then we have emergency evacuation from the Moon to Earth in 2 days. An EVAC from Mars would take at least six months and longer when the two planets are in unfavourable positions relative to each other.

OUR FIRST PRIORITY SHOULD BE THE MOON WHICH HAS MANY ADVANTAGES INCLUDING SUNLIGHT NEARLY 24/7 AT THE POLES NEAR TO ICE IN THE CRATERS OF PERPETUAL NIGHT

So - I don't think our first priority is to send humans to Mars, our priority should be the Moon which has many advantages including the ice in craters of perpetual darkness and the peaks of almost eternal light at the poles. Heat rejection is much easier at the poles too, and solar power is present almost year round 24/7. and with no dust storms to block it. The vacuum of the Moon is a benefit not a problem. For instance we can make solar panels deposited directly on the surface under vacuum conditions with pressures so low as to be impractical to achieve in commercial factories on Earth.

We don't need the CO2 of the Martian atmosphere for human habitats as CO2 is normally a waste gas. If we import some of our food, and don't grow it all ourselves, the CO2 builds up and has to be scrubbed.

MEANWHILE PREPARE FOR MARS - INCLUDING IN SITU ROBOTIC MISSIONS AND THEN DEEP SPACE MISSIONS LIKE THE HERRO RAPID SURVEY FROM ORBIT AROUND MARS

Meanwhile we prepare for the first human missions to Mars. That includes more in situ robotic missions there and searching for life directly on Mars as you suggest in your article.

Once we have learnt to live on the Moon and are ready for deep space missions we can send humans to the HERRO orbit on Mars where they could greatly accelerate the pace of discovery and discover as much in a year as would take ten years or more from Earth, through telepresence, operating the many assets we would have on the surface by then and bringing more of their own, miniature robots and gliders and hopping bots and marscopters throughout Mars controlled by telepresence from orbit.

PROPOSAL (NOT PEER REVIEWED): WE COULD RETURN A MARS SAMPLE SAFELY TO EARTH WITH PRESENT DAY TECHNOLOGY USING A TITANIUM SPHERE, WHIPPLE SHIELD, BALLUTE, BLACK BOX FLIGHT RECORDER TECHNOLOGY, NUCLEAR BUNKER AND OIL SUMP WITH TEMPERTAURE AND VACUUM STABLE LIGHT OIL KEPT AT 300 C

As for right now, we do need to protect Earth. In my preprint I propose a way we could return samples safely to Earth, and I go into that in my preprint.

There may well be ways to do this that are lower cost and simpler. But this is to show that it is possible, which I believe it is.

This is a sketch of the sample receiving facility for my proposal.

Shows the LAS fully robotic floor plan for a Mars sample receiving facility placed inside an oven for end of laboratory lifetime sterilization of the facility and accessed via two airlocks and a sump for 100% containment of even mirror life nanobes.

Sketch of telerobitic facility Credit NASA / LAS. Hsu, 2009. , Keeping Mars Contained

Photo of Cultybraggan nuclear bunker, Clark, B., 2009, Cultybraggan nuclear bunker

My suggestion, not yet peer reviewed, is to return first in a low energy ballistic transfer to a high orbit above GEO. I suggest in the Laplace plane where the Earth's ring particles would orbit if we had a ring system. This is a very safe orbit, as it turns out that any debris even after an explosion of the spacecraft couldn't reach Earth' surface.

We then enclose the sample in a titanium sphere surrounded by Whipple shields or other micrometeorite shielding - and then in a ballute. The ballute isn't needed for planetary protection but is to achieve a gentle reentry with minimal temperature changes and a soft landing.

This is all done telerobotically, no humans go up there but we see from many missions including deploying the James Webb telescope that we can do very complex missions telerobotically.

It then returns to a terrestrial desert as with the current plans - but then it is enclosed in fireproof material as for a flight recorder black box. The micrometeorite shielding might be able to double as fireproof protection or we add extra layers after the sample container is returned maybe foam protection.

Now we know it's safe even in a helicopter crash. So now we transfer it to a nuclear bunker.

The sample receiving facility would be built inside a giant oven for end of life sterilization - since we have to be ready for the possibility of mirror nanobes that can never be released ot Earth's biosphere even when the facility is decommissioned.

We can keep Earth protected by using a sump for anything moved in or out of the facility - consisting of vacuum and heat stable light oil kept at 300 C when materials are moved in or out, and also with cobalt 60 gamma ray sterilizers in the sump to prevent any possibility of life getting out of the sump when it is in cooler conditions.

We then study it telerobotically inside the facility - the advantage of returning it to Earth is so that we can put heavy machinery inside, even particle accelerators if we wish to.

There are many details would need to be thought through such as how to maintain it while keeping Earth safe. I go into some of this in my preprint.

This is just a suggestion and engineers could surely improve on it or find better ways to do it but I do believe it may be possible to achieve 100% safe sample return to Earth with care.

SIMPLEST WAY TO KEEP EARTH SAFE IS BY STERILIZING THE SAMPLE ON THE RETURN JOURNEY

The simplest way to keep Earth safe is to just sterilize the sample on the journey back from Mars. We could use nanoscale X-ray emitters to do that, from my calculations this could feasibly be powered by solar power.

PROPOSAL (NOT PEER REVIEWED): OR RETURN TO RECEIVING FACILITY IN THE LAPLACE PLANE - WHERE EARTH’S RING SYSTEM WOULD ORBIT IF WE HAD ONE

We could also return the sample to a receiving satellite in the Laplace plane well above GEO and do all the study there.

That’s one of the main topics of my paper:

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.

Figure 1: Text added to ESA graphic (Oldenburg, 2019) showing current proposed timeline (NASA, 2022mpfs) 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.

SADLY THE SAMPLE TUBES ARE NOT SUFFICIENTLY STERILIZED TO EVER PROVE THAT THERE IS NO LIFE IN THE SAMPLES - ENOUGH ORGANICS FOR TENS OF THOUSANDS OF ULTRA MICROBACTERIA PER TUBE AND TENS OF MILIONS OF SIMPLER RNA WORLD NANOBES

Sadly the Mars sample tubes are not sterilized sufficiently for us to ever prove there is no life from Mars in them and it will also be hard to detect Martian life in low concentrations in the samples. There's enough permitted organics for tens of thousands of ultra macrobacteria in each tube [check number] and tens of millions of those hypothetical RNA world Martian nanobes.

I made it that the permitted organic contamination is enough for 81,000 ultramicrobacteria or 160 million hypothetical RNA world mirror nanobes per tube. See the section in my preprint:

Also nearly all organics on Mars are likely to be non life, abiotic, from meteorite and comet infall, so it will be very hard to find the small signal of Martian life there.

PROBLEM OF MICROBIAL DARK MATTER - WE DON'T HAVE A CENSUS EVEN OF ALL THE RNA AND DNA THAT WE SENT TO MARS IN THE PERSEVERANCE SAMPLE TUBES - WHICH LIKELY CONTAIN MANY GENES FROM SPECIES WE HAVEN'T YET SEQUENCED

We don't have a census of the DNA or RNA in the sample tubes. That's impossible because of the problem of microbial dark matter. Every time we do a survey of clean rooms the isolates contain numerous RNA sequences and DNA sequences that aren't recognized as belonging to any known microbe.

This is the problem of Microbial Dark Matter. Yes we would recognize a known sequence, we'd recognize anthrax from Mars, but of course that's not a likely Martian organism.

If we find chroococcidiopsis on Mars we'd be able to tell if it is a known strain from Earth. But there are many strains of Chroociccidiopsis with differing capabilities. Any microbe in this species from Mars is likely to be adapted in many ways - for instance it might have developed the capability to metabolize mirror organics from meteorites and comets, and it might have developed even greater ionizing radiation resistance than Chrooiccidiopsis if it has evolved separately on Mars. It likely hasn't got to Earth in the last 20 million years to the oldest ejection ages of our martian meteorites since none of them come from likely sources for ap hotosynthetic lifeform (at 3 meters or more below the surface)

Most likely if we do find a strain of chroococcidiopsis on Mars, it hasn't got to Earth for tens or hundreds of millions of years, indeed if it got here at all it probably got here well before the great oxygenation event half a billion years ago since Mars didn't have much by way of lakes or seas at that time and there would be the same problem of transfer of surface layers as today.

So - unless it comes from Earth as contamination in our spacecraft, any martian choroococcidiopsis most likely has evolved for many tens or hundreds of millions of years on Mars and so is not likely to be identical to any known strain on Earth and its capabilities would be unknown.

But more than that we have the problem of microbial dark matter. These are microbes that can't be cultivated in the laboratory for various reasons. I will summarize some of the details from this 2015 overview of the topic.

Solden et al, 2015, The bright side of microbial dark matter: lessons learned from the uncultivated majority

They may depend on other microbes for their amino acids and even nucleotides, they may not have much by way of ribosomes to make proteins and some use strands, phyla to extract nutrients from other bacteria in biofilms.

Others have very long generation times of six months or more, which makes it hard to sequence in a laboratory. This is very relevant to Mars. Others only survive in nutrient poor situations. They do very well in natural conditions but when you put them in a laboratory on an agar solution they die quickly. Some produce hydrogen as a biproduct and they depend on other microbes to remove the hydrogen or they die.

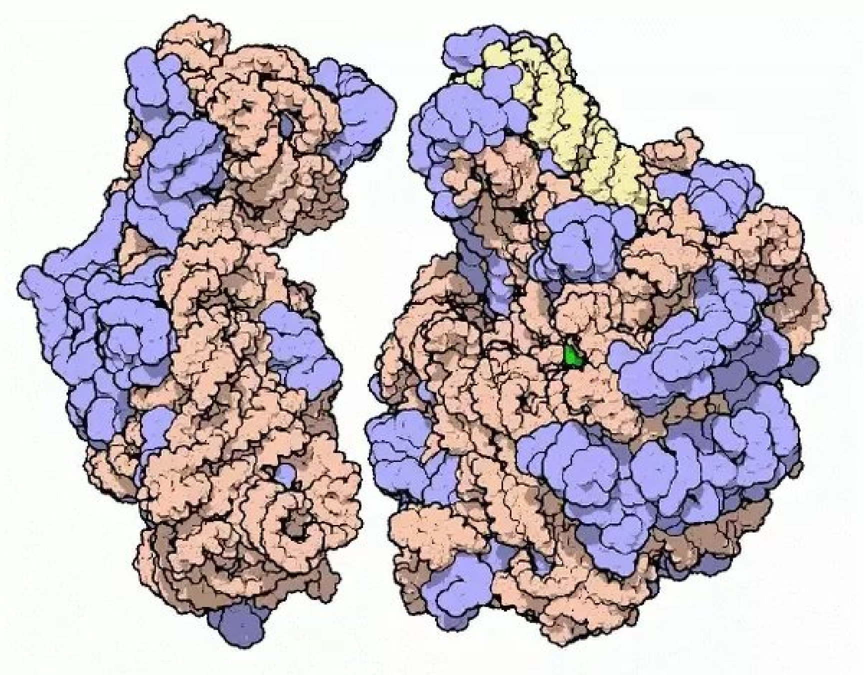
MANY ENTIRE PHYLAE ARE ONLY KNOWN THROUGH A SMALL rRNA FRAGMENT OF THEIR PROTEIN FACTORY - SPECIFICALLY THE rRNA COMPONENT OF THE 16S RIBOSOME SUBUNIT

Many entire phylae of microbes are only known through fragments of RNA from their ribosomes, specifically from an RNA strand in the smaller of two subunits that fit together to make their protein factory or ribosome. This is used as a marker to get an estimate of the diversity of the phyla of microbes that can't be cultivated and most of which aren't yet sequenced.

This shows how the large and small subunits fit together.

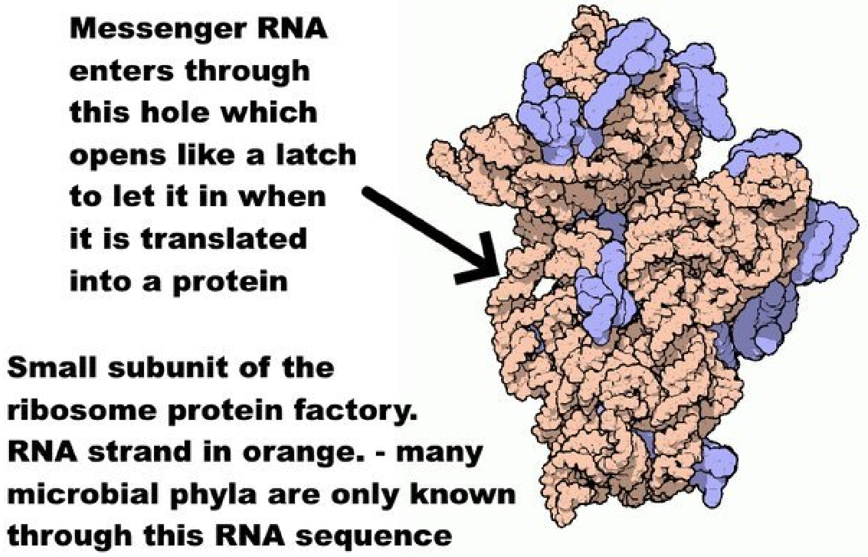
The RNA strands are shown in red.

The small unit is called the 16 S subunit in the papers.



You can see animations of them spinning here PDB101: Learn: Videos: Ribosomal Subunits

Here is a particular view on it which shows the hole that the mRNA enters through as it is translated into proteins.



> Messenger RNA enters through this hole which opens like a latch to let it in when it is translated into a protein.
>
> Small subunit of the ribosome protein factory.
>
> .RNA strand in orange. - many microbial phyla are only known through this RNA sequence

Graphics and details from here

. Goodsell, D., 2000 PDB101: Molecule of the Month: Ribosomal Subunits

As of 2016 there were at least 89 phyla of bacteria and 20 of archaea that are recognized only by RNA databases of the small ribosome subunit, though the true count of phylae for the bacteria could be far higher with estimates of up to 1,500 bacteria phylae.

. Solden et al., 2016. The bright side of microbial dark matter: lessons learned from the uncultivated majority

Now that we have single cell genomics there are partial and sometimes complete gene sequences for many of the phyla but these represent only a small fraction of the total species in each phyla. We know very little about them and they may use novel metabolic pathways that we haven't yet studied.

This part of the ribosome is very stable

This remains the situation as of 2022. Most of the microbial biomass hasn't yet been cutulrured and the genetic sequences can't be used to characterize them.

> QUOTE The majority of microbial genomes have yet to be cultured, and most proteins identified in microbial genomes or environmental sequences cannot be functionally annotated. As a result, current computational approaches to describe microbial systems rely on incomplete reference databases that cannot adequately capture the functional diversity of the microbial tree of life, limiting our ability to model high-level features of biological sequences.

Hoarfrost, et al, 2022. Deep learning of a bacterial and archaeal universal language of life enables transfer learning and illuminates microbial dark matter

THE PERSEVERANCE CLEAN ROOM HAD MANY UNCULTIVABLE SPECIES, 36 OUT OF THE 41 SPECIES IDENTIFIED BY THEIR 16S RIBOSOME SUBUNITS WERE FOUND IN ONLY ONE LOCATION - AND 4 HAD RIBOSOMES THAT DIDN'T CLOSELY RESEMBLE ANY PREVIOUSLY KNOWN RIBOSOME

In a 2021 study of clean room samples from the clean room used to assemble Perseverance, , 16 genera could be cultivated and 51 genera could not be cultivated as identified by this ribosome subunit.

They found 49 identified species using 16S mRNA sequencing.

Of those there were 4 novel species that had less than 98.7% similarity to any previously sequenced 16S RNA ribosome subunit.

36 of the species were unique, found in only one of their samples.

> QUOTE The 130 NSA isolates were represented by 16 bacterial genera, ofwhich 97% were identified as spore-formers via Sanger sequencing. … The 16S rRNA gene-targeted amplicon sequencing detected 51 additional genera not found in the NSA [ASA standard spore assay] method.

> Sanger sequencing of the full-length 16S rRNA gene on the NSA isolates from the 98 samples resulted in 130 isolates, belonging to 16 genera and 49 species
>
> When analysed spatially, 36 of the 49 identified species were not ubiquitous and isolated only once in a given SAF location
>
> … four isolates representing potentially novel species as they had ≤ 98.7% sequences similarity to the 16S rRNA sequence of any validly described species

Hendrickson et al, 2021, Clean room microbiome complexity impacts planetary protection bioburden.

IF THIS LEVEL OF DIVERSITY CAN BE GENERALIZED TO THE TUBES, EACH SAMPLE TUBE COULD CONTAIN UNIQUE 16S SUBUNITS NOT FOUND IN ANY OF THE OTHER SAMPLE TUBES AND OUT OF 38 SAMPLE TUBES THREE OR FOUR OF THEM MAY CONTAIN SUBUNITS THAT DON'T CLOSELY RESEMBLE ANY RIBOSOMES SO FAR KNOWN ON EARTH, ALTHOUGH ORIGINATING FROM EARTH

This doesn't mean that these were the only novel species, just the ones they found in that particular survey. Also it doesn't mean they sequenced them either. All they have is the sequence of the 16S RNA ribosome subunit.

Hendrickson et al, 2021, Clean room microbiome complexity impacts planetary protection bioburden.

So we can be pretty certain that the sample tubes have DNA or RNA from microbes that can't be cultivated and they may very well have 16S ribosome subunits that don't closely resemble any ribosomes previously sequenced.

Also the sterilization wasn't sufficient to rule out viable microbes. The requirement was a 0.1% chance of a viable microbe per tube. They believe they achieved a 0.00048% chance of a viable microbe per tube. This would make the chance that at least one tube contains a viable terrestrial microbe around 0.02% which would mean that if just one tube yields a viable microbe, it won't be possible to conclude that it is Martian without further analysis. 0.02% corresponds to 3.09 sigma which would not be enough to prove life from Mars for a discovery of such importance.

COULD JUST TREAT THIS AS A TECHNOLOGY DEMO - AND STERILIZE THE SAMPLES - AS A PRECURSOR FOR FOLLOW UP IN SITU STUDIES

The chance of finding life seems so small it might be easier to treat this as a technology demo and just sterilize the samples. There is almost no chance of detectable past life either as it would quickly be sterilized beyond recognition by ionizing radiation unless rapidly buried and unearthed just as rapidly.

Astrobiologist have written many papers saying we need in situ exploration and detection of life on Mars and have designed many instruments we can send to Mras to do that.

WAYS TO INCREASE CHANCE OF RETURNING LIFE - LOOKING FOR YOUNG CRATERS RECENTLY EXCAVATED MATERIAL FROM ANCIENT MARES

However there are ways to increase the chance of returning life. First, we can look for young craters that have recently excavated past life on Mars. I suggest we can use the Marscopters to help iwth that. I calculated that there shoudl be craters within easy reach of Perseverance that have happened in the last few tens of thousands of years excavated to a depth of meters. Tehre is even a small chance that we spot such an impact with before and after images during hte mission itself.

FOR PRESENT DAY LIFE - A DUST SAMPLE COMBINED WITH AN AIR SAMPLE - CAPABILITY DROPPED FROM PERSEVERANCE

For present day life - I recommend we add a dust sample - and an atmospheric sample, capabilities dropped from Curiosity.

This is not my own suggestion, but it's a proposal in a paper that doesn't seem to have had much attention that I'd like to highlight.

We already have an atmospheric compressor on Mars for Moxie, compressing air for the test on splitting CO_2 to generate oxygen on Mars.

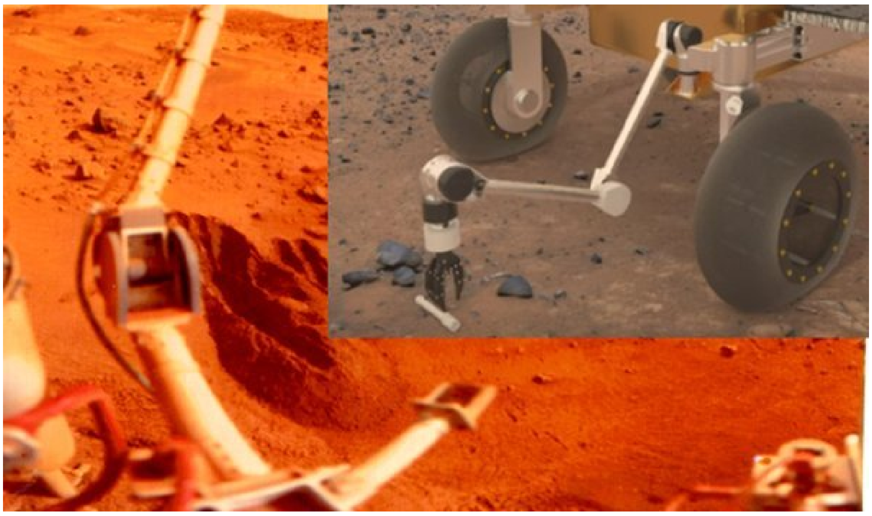
The idea is to first compress Martian air into a sterile container which will let us return a far larger sample than we will have in the sample tubes and let us detect trace concentrations of organics in the Martian atmosphere. This needs a dust filter to keep out the dust, but we then keep it running after collecting the air sample, even through Martian dust storms, just exhausting the ir back to the atmosphere. This could give us a big sample of dust from Mars.

If there is life on Mars it's likely evolved propagules that can spread through the dust storms, and even low concentrations in distant areas of Mars could send detectable propagules to Jezero crater. We detect propagules such as hyphal fragments from the Gobi desert in Japan.

ALSO DUPLICATE VIKING - RETURN A SCOOP OF DIRT - AND IDEALLY ALSO THE BINE LAYERS DISCOVERED INDIRECTLY BY CURIOSITY

Then as a top priority I think we need to duplicate Viking and just scoop up some dirt. we need to try to bring back some of the briny salt layers detected by Curiosity. Whatever Viking found, either biology or complex chemistry - we need to resolve that mystery.

These are capabilities we could add to the spacecraft sent to receive the Mars samples. And - unlike the sample return from Perseverance - these could be designed to be 100% sterile. They are bonus samples. So - we can wrap them up in a covering, which was the main issue with sterilizing the sample tubes 100%. Engineers worried that if it was sterilized and enclosed that they might not be able to open the container on Mars. But with the aim to detect present day life it is top priority to have 100% sterile containers to collect them. We can't do anything about the sample tubes for Perseverance but we can ensure a 100% sterile container for the atmospheric / dust / gas bonus sample and a 100% sterile scoop of soil sample too.



This would greatly increase the astrobiological interest. If we are lucky we strike gold right away - if Viking did indeed discover life. But if it discovered complex chemistry then in this way, we end up with a far better understanding of surface conditions that can help guide future missions.

CAN RETURN THE GEOLOGICAL SAMPLES TO EARTH IN THEIR SAMPLE TUBES, STERILIZED AND THE ONES OF ASTROBIOLOGICAL INTEREST TO A SAFE ORBIT ABOVE GEO, UNSTERILIZED

The level of contamination is so high for astrobiology, though very small for geology that there isn’t any real loss to astrobiology by just sterilizing all the geology samples. The geologists also say it makes little difference to their experiments.

So, why not just sterilize all the geology samples. Then collect the astrobiology samples in sterile containers with no traces of organics. These need to be opened on Mars (or on the way there). If they don’t open that is mission critical for the astrobiology samples but it has no impact on the geology. Since it is the only way to get interesting astrobiological samples the astrobiologists should be okay with this too.

COCKELL’S SUGGESTION OF UNINHABITED HABITATS - THESE ALSO NEED TO BE PROTECTED AT LEAST INITIALLY AS OUR ONLY OPPORTUNITY WITHIN LIGHT YEARS TO DISCOVER WHAT HAPPENS TO A TERRESTRIAL PLANET AFTER BILLIONS OF YEARS WITHOUT LIFE

Cockell has suggested that Mars may have uninhabited habitats. That could also be the situation on Europa's ocean or Enceladus's ocean. These would be habitable for terrestrial life but there is no life in them because Mars never evolved life.

In that situation - then we still need to protect Mars from terrestrial life. this is our only opportunity within light years to study a planet that started off like Earth but either never developed life or it went extinct.

What we find there may be chemistry yes, but complex chemistry that developed over billions of years. For instance we might find Ostwald crystals, a theory for how RNA might have formed originally. We might find protocells, cell like structures that don't actually have life. We might find cells that can reproduce, but imperfectly, not yet with the accuracy needed to call it life.

Anything like this might be very fragile and easily destroyed by introducing Earth life. I'm not suggesting we keep Mars pristine indefinitely, but that we need to know what is there first and study it. We could easily lose a wonderful opportunity that our descendants could only duplicate once they have the capability to send similar missions to planets orbiting nearby stars.

IF THERE WAS NO POSSIBLIITY OF LIFE ON MARS, WE COULD TREAT IT LIKE THE MOON AND MOST ASTEROIDS BUT THAT DOESN’T SEEM TO BE THE CURRENT SITUATION

If Mars was totally lifeless and no life was possible there like the Moon or most asteroids then we could treat it like the Moon. But at present it doesn't seem to be like that based on the data so far.

NASA in press briefings often seem to be confident that there is no life on the surface of Mars but as you have suggested and many astrobiologists have also said, we don't know this. There is a distinct and significant possibility for life there that is living on the edge, perhaps as I suggested a Swansong Gaia - or maybe recently evolved or it recently got to the surface from below. Or it might be complex chemistry - whatever it is, our top priority is to find out what is there.

Based on that we can then make informed decisions about what we do next.

ONE POSSIBLE FUTURE SCENARIO IS A MARS THAT HUMANS CAN NEVER VISIT WITH NANOBE MIRROR LIFE - PARADOXICALLY THIS MIGHT BE MOST STIMULATING OF ALL FOR SPACE SETTLEMENT AND MAYBE EVENTUAL COLONIZATION IN OUR SOLAR SYSTEM - MANY DESTINATIONS TO LIVE OTHER THAN MARS AND A MARS WITH MIRROR LIFE COULD STILL BE EXPLOITED TELEROBOTICALLY FROM ORBIT

And one scenario for the future is a Mars that humans can never visit, with nanobe mirror life, for instance. In my view this is the most exciting of all. It would stimulate space exploration more than any other with a huge importance for settlements in orbit around Mars to study it. It could also be exploited. We could mine Mars, maybe for mirror organics, maybe for products of life, and export them to orbit sterilized as necessary all done via telerobotics to keep humans and Earth safe.

I think this possibility, would be stimulating for human colonization both int he short and the long term and not as disappointing as it might seem. There are many other places for humans to explore and perhaps colonize, including the moons of Mars.

I suggest that Callisto in the Jupiter system has great potential once we can go further afield, with ice, organics, rock, outside Jupiter's ionizing radiation and protected from solar storms. Saturn's moon Titan is also of great interest. The cold is far easier to protect against than vacuum. Terrestrial life couldn't survive on Titan except perhaps in the water "lava" of cryovolcanoes so it might have minimal planetary protection issues.

Once we have the capability we could perhaps have settlers there too, the only atmosphere in our solar system of similar pressure to Earth, it has more benefits than one expects when you look closely. Then with stand alone space settlement spinning slowly for artificial gravity the whole solar system is habitable with large thin film mirrors out to Pluto and beyond.

BY BEING MORE RIGOROUS ABOUT PLANETARY PROTECTION WE STIMULATE A FUTURE WITH MORE OPPORTUNITIES FOR SPACE COLONIZATION - AND A FUTURE WITH MORE ASSETS ON MARS THAT WE CAN USE IF SPACE COLONIZATION OF MARS IS FEASIBLE

By being even more rigorous about planetary protection we might actually stimulate a future with more opportunities and interest for space colonization than if we try to bypass it and not take those precautions. And if we do end up having human colonization of Mars we would have many assets on the surface already and we would have a much greater understanding of the planet and what we can and can't do there.

THE MAIN ISSUES WITH NASA'S CURRENT ENVIRONMENTAL IMPACT STATEMENT

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.

As I mentioned at the start, please see my:

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

Then, I've got an open letter to experts and the general public here where I've focused it very strongly on the particular passages in the Environmental Impact Statement of most concern that I want to draw everyone's attention to,

. NASA - Your Samples From Mars Need A Better Than Biosafety Level 4 Facility - NOT Designed To Contain Even Earth's Tiniest Cells

That page also links to my annotated copy of the Enviornmental Impact Statement and a detailed academic analysis I did.

Then I did this blog post here for the general public.

. Many Serious Mistakes In NASA's Samples From Mars Environmental Impact Statement - Proposals For A Way Forward

And video here:

: Many Serious Errors In NASA's Samples From Mars Environmental Impact Statement - A Way Forward

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

Science Education & Policy

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