We must contain any life in Mars dirt that can’t get into meteorites

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NASA / ESA, and separately, CNSA (China) plan to return samples from the Mars surface. Meanwhile JAXA (Japan) plan to return samples from Phobos. We need to protect Earth from any life in these samples.

JAXA categorized samples from Phobos as an unrestricted sample return, needing no precautions. They reason any life on Phobos withstood ejection from Mars, and samples returned from the top few centimetres experienced similar conditions to the journey of a meteorite to Earth from the last impact on Mars 700,000 years ago.

JAXA warn that their conclusion doesn’t apply to samples collected on the Mars surface. NASA’s draft EIS didn’t notice this caveat. NASA also plan to return unsterilized samples to a BSL-4, which can’t comply with the 2012 ESF size limit review.

These missions can be made 100% safe for Earth with virtually no loss of science by sterilizing samples with the equivalent of 500 million years of Mars surface ionizing radiation before they reach our biosphere. These 100% safe missions can be greatly enhanced with bonus samples of dirt and dust returned in sterile containers to a martian gravity centrifuge in an unmanned satellite above GEO to start Sagan’s “vigorous program of unmanned exobiology”.

It seems necessary to publish a short review of central results in the planetary protection literature of the last several decades for the attention of NASA / ESA and China as they prepare for their missions. NASA haven’t responded to attempts to alert them to these issues via email or via public comments on the draft EIS, and the comments period is now closed.

Let’s start with the meteorite argument. NASA argues that:

First, potential Mars microbes would be expected to survive ejection forces and pressure (National Academies of Sciences, Engineering, and Medicine and the European Science Foundation 2019), …

The natural delivery of Mars materials can provide better protection and faster transit than the current MSR mission concept.

The NRC Mars Sample Return study in 2009 refutes this argument on page [48](https://www.nap.edu/read/12576/chapter/7#48) concluding:

“The potential hazards posed for Earth by viable organisms surviving in samples [are] significantly greater with a Mars sample return than if the same organisms were brought to Earth via impact-mediated ejection from Mars"

And then in the discussion of large scale effects

"... 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."

NASA’S first cite NAS, 2019, is an assessment of planetary protection for Japan’s mission to return samples from Mars’s innermost moon Phobos. JAXA conclude there is no need to take special precautions for samples returned from Phobos because (amongst other reasons) they have already survived ejection from Mars.

However JAXA specifically say their argument does ***not*** apply to the Mars sample return missions. :[5](https://nap.nationalacademies.org/read/25357/chapter/2#5))

*MSR material might come from sites that mechanically cannot survive ejection from Mars and thus any putative life-forms would de facto not be able to survive impact ejection and transport to space. Such mechanical limitations do not apply for material collected on Mars.*

*Therefore, the committee finds that the content of this report and, specifically, the recommendations presented in it do not apply to future sample return missions from Mars itself.*

The martian dust and dirt for instance couldn’t mechanically survive ejection, as it would just burn up in the atmosphere if it reached escape velocity.

So, the argument presented in the EIS is refuted on page 5 of the first cite they present when they talk about ejection from Mars. They don’t alert the reader to this discrepancy.

Some very hardy microbes such as b. subtilis, might rarely be able to survive transfer from Mars to Earth in a meteorite. But this doesn’t prove all or even any martian life has got to Earth from Mars. Barn swallows in the Americas don't prove it was okay to introduce starlings, which can't cross the Atlantic and are an invasive species in the USA.



For a microbial example, the invasive freshwater diatom "Didymo" (*Didymosphenia geminatum)* in New Zealand can't get from one freshwater lake to another on the same island without human help. It could never get from Earth to Mars and indeed, if there are diatoms on Mars (not impossible for instance in the lakes found beneath the polar ice) they will be independently evolved.

Similarly microbes could be perfectly adapted to live in Martian biofilms in ephemeral brines which we know form in the late evening / early morning in Gale crater and likely also in Jezero crater, and rarely transfer to other seeps protected from UV in dust storms, perhaps only succeeding at this every few millennia. There is no need for life adapted to these cold brines to have adaptations to extreme shock, vacuum, ability to live in rocks deep below the surface and so on that would let it get to Earth on a meteorite.

Meanwhile, a sealed sample tube is like a miniature spaceship complete with a small amount of martian atmosphere not unlike the wet diving gear for “Didymo”.

This argument does work for Phobos however. The Jaxa team correctly said that it is safe to return samples from Phobos because

1. all our martian meteorites left Mars at least 700,000 years ago for the most recent impact. See table S4 of <https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2020JE006523>
2. So long as JAXA recover material just from the top few cms on Phobos it had similar levels of ionizing radiation to meteorites currently arriving at Earth from the last impact on Phobos 700,000 years ago.
3. life ejected from Mars can get to Earth protected from the fireball of re-entry so long as it isn't in the surface layers.

There may be a slight oversight in the JAXA analysis on that last point. They argue that they can ignore the effect of the fireball of re-entry to Earth since microbes would be protected if just below the surface of the rock. This is normally a valid argument but it doesn't work exactly as stated for photosynthetic life.

The astrobiologist Charles Cockell attached photosynthetic life to an aeroshell for re-entry at a typical depth for chroococcidiopsis and found that not only the life but all associated organics were destroyed on re-entry. He concluded

... Thus, the planetary exchange of photosynthesis might not be impossible, but quite specific physical situations and/or evolutionary innovations are required to create conditions where a photosynthetic organism happens to be buried deep within a rock during ejection to survive atmospheric transit.

https://www.researchgate.net/profile/Charles\_Cockell/publication/5937888\_The\_Interplanetary\_Exchange\_of\_Photosynthesis/links/0c960530632bf30e20000000.pdf

However, all our martian meteorites were thrown up into space after glancing collisions into the Elysium or Tharsis regions, high altitude southern uplands [(Tornabene et al, 2006)](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510#m_-5454762008349871800_m_-1972427842941295334_kix.a4ip5t4d8249). The atmosphere is thin, making ejection to Earth easier. The rocks we have all come from at least 3 meters below the surface [(Head et al, 2002:1355)](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510#m_-5454762008349871800_m_-1972427842941295334_4ut9kfm5zz3j),  The subsurface below about 12 cms has a uniform temperature of around 200°K or -73°C ([Möhlmann, 2005:figure 2](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510" \l "m_-5454762008349871800_m_-1972427842941295334_b_M%C3%B6hlmann_2005)).   The youngest ejection age is 700,000 years for EETA 79001 B and oldest ejection age 18.15 million years see table S4 in [(Udry et al, 2020)](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510#m_-5454762008349871800_m_-1972427842941295334_b_udry_2020)

Head, J.N., Melosh, H.J. and Ivanov, B.A., 2002. [Martian meteorite launch: High-speed ejecta from small craters](https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1945-5100.2002.tb01033.x). *Science*, *298*(5599), pp.1752-1756.

*Page 1355: Nishiizumi et al. (1986) found that all cosmogenic nuclide data indicate that the shergottites were ejected from>3 m depth. This conclusion was supported by Reedy (1989) stating that the Shergottite-Nakhdite-Chassignite group meteorites (SNCs), especially the shergottites, must have been buried >5 m in any previous parent object (corresponding to a shielding depth of >I500 glcm²)*

Möhlmann, D., 2005. [Adsorption water-related potential chemical and biological processes in the upper Martian surface](https://www.researchgate.net/publication/7390930_Adsorption_Water-Related_Potential_Chemical_and_Biological_Processes_in_the_Upper_Martian_Surface#pf3). *Astrobiology*, *5*(6), pp.770-777.

Tornabene, L.L., Moersch, J.E., McSween Jr, H.Y., McEwen, A.S., Piatek, J.L., Milam, K.A. and Christensen, P.R., 2006. [Identification of large (2–10 km) rayed craters on Mars in THEMIS thermal infrared images](https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2005JE002600): Implications for possible Martian meteorite source regions. *Journal of Geophysical Research: Planets*, *111*(E10).

Udry, A., Howarth, G.H., Herd, C.D.K., Day, J.M., Lapen, T.J. and Filiberto, J., 2020. [What martian meteorites reveal about the interior and surface of Mars.](https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2020JE006523)

So, for the last 20 million years, meteorites have been ejected only from those very dry high southern uplands where life is unlikely in present day Mars except for in geothermal hot spots, heated caves etc.

Life 3 meters below the surface is not likely to have photosynthetic life unless it is polyextremophile and also able to live without light - and even if capable of photosynthesis, at those depths it would have no reason to be on the surface of ejected rocks.

So the JAXA argument seems to be valid for at least the last 20 million years and so also, its conclusion that it is safe to return samples from those moons. Life deposited on Phobos over 20 million years ago has had about 24% of its amino acids destroyed.

By a similar argument it may be safe for Earth to send astronauts to Phobos so long as they don't dig deep, or they sterilize any materials that are returned from deep below the surface of Phobos (sterilization advised as there would be a very short transit time from Mars to Phobos of a rock that ends up deep below the surface).

However, we can't say the same about the Martian surface at this time. Though Jezero crater seems uninhabited from orbit, extremophiles live in Mars analogue deserts on Earth in biofilms in microhabitats that you can only discover by close examination.

Also life from distant areas on Earth can be transferred in dust storms with life from the Gobi desert detected in Japan https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD029597

The same may happen on Mars especially since the dust storms block out the sun bringing darkness and greatly reducing UV exposure.

These are both mentioned as knowledge gaps in the MEPAG review of 2015

"The SR-SAG2 report does not adequately discuss the transport of material in the martian atmosphere. The issue is especially worthy of consideration because if survival is possible during atmospheric transport, the designation of Special Regions becomes more difficult, or even irrelevant."

https://nap.nationalacademies.org/read/21816/chapter/4?term=dust#12

“Special regions” there means regions where forwards terrestrial contamination is possible with viable life that could propagate on Mars. The MEPAG study and MEPAG review are studies for forwards rather than backwards contamination so they don’t look into capabilities of extant martian life which may have adapted further to the dust storms for billions of years.

SR-SAG2 is the 2014 study that the EIS relies on to say there won't be life on Jezero crater if elsewhere on Mars and they don't cite this 2015 review which overturned that conclusion.

The 2015 MEPAG review also warns about use of maps and says that local microenvironments can be habitable in regions that seem to be uninhabitable on larger scales. This also applies to Jezero crater and means we can’t know it is uninhabitable everywhere without detailed local study looking for microhabitats.

Physical and chemical conditions in microenvironments can be substantially different from those of larger scales. Although the SR-SAG2 report considered the microenvironment (Finding 3-10), the implications of the lack of knowledge about microscale conditions was only briefly considered.

The 2015 MEPAG review also has a long section on biofilms and the ability of microbes to modify microhabitats by surrounding themselves with “extrapolymeric substances” - proteins, polysaccharides, lipids, DNA and other molecules.

These EPS can modify the microhabitat and make it much more habitable for microbes and help them cope with stressors in the environment. See page 11:

https://nap.nationalacademies.org/read/21816/chapter/4#11

NASA’s biggest omission in this EIS is that they don’t cite the European Space Foundation study in 2012 which reduced the 1 in a million threshold to 0.01 microns from 0.2 microns due the discovery of horizontal gene transfer to distantly related archaea a million times faster in sea water than previously thought Page 19 of

https://science.nasa.gov/science-red/s3fs-public/atoms/files/ESF\_Mars\_Sample\_Return\_backward\_contamination\_study.pdf

Surprisingly, it is now estimated that GTA transduction rates are more than a million times higher than previously reported for viral transduction rates in marine environments. Clearly, GTAs are a major source of genetic diversity in marine bacteria.

The ESF also said a particle of 0.05 microns or larger shouldn’t be released under any circumstances because of the discovery that ultramicrobacteria remain viable after passing through 0.1 micron nanopores. Page 21

“the release of a particle larger than 0.05 μm in diameter is not acceptable in any circumstances”

From the ESF study itself the previous size limit review was in 1999 so NASA are relying on science from 23 years ago when it says a BSL-4 is sufficient to contain the samples. The ESF review itself said we need periodic review of their conclusions so a new size limit review is certainly needed a decade later before NASA should consider doing a proper scientifically valid EIS. This might well take account of the rapid developments in study of the potential for extremely tiny early life cells such as ribocells. These could use the far smaller, and less efficient ribozymes in place of ribosomes. They may reproduce more slowly but the small size with a high surface to volume ratio would be an advantage in low nutrient conditions on Mars. This would also help them to avoid protozoan grazing – Mars could have anaerobic protozoa and the brines on Mars could also be oxygenated.

We don’t need to contain gene transfer agents or ultramicrobacteria in a BSL-4, never mind ribocells. Also, these requirements go well beyond any current air filter technology in recent air filter reviews like this one. Here bear in mind 100% containment is needed at all sizes from 0.05 microns upwards and at all sizes from 0.01 microns upwards we need to make sure the chance of a single particle released is less than 1 in a million for the lifetime of the facility.

<https://www.mdpi.com/2079-6439/10/2/15/pdf?version=1644317375>

NASA’s draft EIS also claims no significant risk of environmental effects for life returned from Mars.

**What NASA’s draft EIS says:**The relatively low probability of an inadvertent reentry combined with the assessment that samples are unlikely to pose a risk of significant ecological impact or other significant harmful effects support the judgement **that the potential environmental impacts would not be significant.**([NASA, 2022eis](#b_NASA_2022eis): 3-3):

**What the National Research Council said in 2009**: The committee found that **the potential for large-scale negative effects on Earth’s inhabitants or environments by a returned martian life form appears to be low, but is not demonstrably zero**

Although exchanges of essentially unaltered crustal materials have occurred routinely throughout the history of Earth and Mars, it is not known whether putative martian microorganisms could survive ejection, transit and impact delivery to Earth or would be sterilized by shock pressure heating during ejection or by radiation damage accumulated during transit. Likewise, it is not possible to assess past or future negative impacts caused by the delivery of putative extraterrestrial life, based on current evidence.  
[(Board et al, 2009: 48).](#kix.xed3c1hm3p4k).

NASA’s sterilizing subcommittee said the risk of a direct pathogen of humans is near-zero  [(Craven et al., 2021)](#b_Craven_et_al_2021)

Since any putative Martian microorganism would not have experienced long-term evolutionary contact with humans (or other Earth host), the presence of a direct pathogen on Mars is likely to have a near-zero probability.

They don’t cite the terrestrial examples of microbes pathogenic to humans and not adapted to us such as Legionnaire’s disease, a disease of biofilms and protozoa that can use the same methods to infect human lungs. There could be diseases of anaerobic protozoa on Mars which could infect human lungs which would seem like a biofilm to it and the macrophages could seem like large protozoa or they could invade the intercellular spaces in our lungs.

They don’t mention opportunistic fungal infections. We have specific protections in our immune systems targeting three main genera of fungi that infect humans such as Aspergillus. These kill 1.5 million immunocompromised people a year. We might all be immunocompromised against a new genera of fungi from Mars. There are many such examples of ways martian life could be harmful to humans, or to our crops or ecosystems – as well as harmless or beneficial - which I plan to cover in a future paper (Walker, ).

Joshua Lederberg, who got his Nobel prize for his work on microbial genetics was a key figure in the early work on planetary protection [(Scharf, 2016)](file:///C:\Users\rober\Downloads\chester.docx#kix.t6u255axqlml). He first began to give it his attention in 1957 [(Lederberg, 1959)](file:///C:\Users\rober\Downloads\chester.docx#kix.sewr7np8b4ap). He put it like this [*(Lederberg, 1999b)*](file:///C:\Users\rober\Downloads\chester.docx#kix.ar87fg72xwf2):

*“Whether a microorganism from Mars exists and could attack us is more conjectural. If so, it might be a zoonosis [infectious disease that jumps to humans] to beat all others*

He argues that our immune system and defenses are keyed to various chemicals produced by Earth life. such as peptides and carbohydrates. Mars life might use different chemicals.

*Thus, although the hypothetical parasite from Mars is not adapted to live in a host from Earth, our immune systems are not equipped to cope with totally alien parasites: a conceptual impasse."*

In the best case (for us), the Martian microbes are unable to make anything of terrestrial biochemistry and give up. However, in the worst case, it’s our defense systems that are mystified. The microbes don’t resemble Earth life and so our defenses don’t recognize the attackers as life or attempt to do anything about them.

Carl Sagan put the same reasoning in different words like this [(Sagan, 1973:162)](file:///C:\Users\rober\Downloads\chester.docx#kix.urfjjsuep509):

*"This is an extremely grave point. On the one hand, we can argue that Martian organisms cannot cause any serious problems to terrestrial organisms, because there has been no biological contact for 4.5 billion years between Martian and terrestrial organisms. On the other hand, we can argue equally well that terrestrial organisms have evolved no defenses against potential Martian pathogens, precisely because there has been no such contact for 4.5 billion years. The chance of such an infection may be very small, but the hazards, if it occurs, are certainly very high.*

In the same book Carl Sagan wrote [(Sagan, 1973)](#kix.urfjjsuep509)

*Because of the danger of back-contamination of Earth, I firmly believe that manned landings on Mars should be postponed until the beginning of the next century, after a vigorous program of unmanned Martian exobiology and terrestrial epidemiology.*

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

The sterilizing subcommittee also looks into the potential for martian life that might transform the environment of Earth and uses examples of extremophiles that can’t live in our normal habitat to motivate the idea that martian life wouldn’t be able to live on Earth.

There are many described extremophiles that may survive in environments that are extreme to human or animal life (e.g. extremes of temperature or pressure) but do not survive under conditions in our normal habitat (Merino et al. 2019). Thus, it is plausible that any Martian microbe, after it arrives on Earth, would not be viable on Earth due to a lack of its required Martian nutritional and environmental conditions. … Based on these factors, a very low qualitative probability of biological risk can be assumed.

However, though this is true of some extremophiles, it is not true for some martian life analogue polyextremphiles such as chroococcidiopsis, a blue green algae which is one of the best terrestrial candidates for a microbe to flourish on Mars due to its remarkable ability to repair even many double strand breaks in its DNA.

Chroococcidiopsis can flourish almost anywhere from Antarctic cliffs to the Atacama desert [(Bahl et al, 2011)](#kix.axc3vj9odk3) or from Sri Lankan reservoirs [(Magana-Arachchi et al, 2013)](#kix.ejspgahn01jm) to the Chinese sea [(Xu et al, 201q26:111)](#kix.2o5rxmoxb588). As a prime producer it can survive on just rock, water, light, fixing CO2 and nitrogen from the atmosphere. It is an ancient polyextremophile with numerous alternative metabolic pathways it can utilize, including nitrogen fixation, methanotrophy, sulfate reduction, nitrate reduction etc [(KEGG, n.d.)](#kix.pj8o7osp4x21), even able to grow in complete darkness using a hydrogen-based lithoautotrophic metabolism including viable populations 750 meters below the Atlantic sea bed [(Li et al, 2020)](#kix.xaj0jr23elda).

The perception that microbial life from Mars would be safe for Earth seems to be a minority view amongst microbiologists [(MacGregor et al, 2001)](#b_MacGregor_2001)

It may be helpful to add a fully worked out example of large scale harm that many astrobiologists would find plausible, polyextremophile mirror life. A mirror form of Chroococcidiopsis.

Synthetic biologists are working on a plan to gradually flip ordinary to mirror life over a period of a decade or so - but this needs great care. They warn that escape of mirror life could cause major transformation of the terrestrial biosphere by locking up organics in unusable mirror forms. This is possible if it can somehow obtain the isomerases to transform organics into mirror organics that it could eat.

*Kasting “It would quickly consume all the available nutrients,” he says. “This would leave fewer or perhaps no nutrients for normal organisms.” …. As the CO₂ in the ocean was incorporated into inedible mirror cells, they would “draw down” CO₂ from the atmosphere … in about 300 years the bugs would suck down half of Earth’s atmospheric CO₂. Photosynthesis of most land plants would fail. “All agricultural crops other than corn and sugar cane would die,” … “People might be able to subsist for a few hundred years, but things would be getting pretty grim much more quickly than that.” After 600 years, we’d be in the midst of a global ice age. It would be a total evolutionary reboot—both Kasting and Church think mirror predators would evolve, but whatever life existed on Earth by that point wouldn’t include us..*

Bohannon, J., 2010. [Mirror-image cells could transform science-or kill us all](https://web.archive.org/web/20151124042506/https:/www.wired.com/2010/11/ff_mirrorlife/). Wired,

If there is life on Mars, whether mirror or normal, it will likely have the isomerases to metabolize organics of opposite sense already - because unlike on Earth nearly all the organics will be abiotic, whether indigenous or infall, so both chiralities. Only a few terrestrial microbes currently have that capability though the others might develop it fast. So we might end up with a mix of normal and mirror organics, or mainly mirror organics or some other mix.

I think we would survive. We already have almost self-sustaining space habitats designed in principle like the early Russian BIOS-3

Johansson, M., [Living in Space,  Comparative Study of one Conventional Life Support System and two Biological Systems](https://web.archive.org/web/20070824071621/http:/www.physics.irfu.se/Publications/Theses/Johansson:MSc:2006.pdf)

 Also, we could enclose large areas of Earth with its tropical jungles, coral reefs etc (a bit like the confusingly similarly named Biosphere II).

But it would be a severely diminished world to leave to the next generation.

Even if life has got to Earth from Mars or vice versa, Mars could have a shadow biosphere of life with a different biochemistry that hasn't got here (my own example) as for the hypothesis of a terrestrial shadow biosphere of nanobes ([Cleland, 2019](https://mail.google.com/mail/u/1/#kix.isfv99lfhkt8), pp [213](https://books.google.co.uk/books?id=eqCsDwAAQBAJ&pg=PA213)- [214](https://books.google.co.uk/books?id=eqCsDwAAQBAJ&pg=PA214)) which could co-exist with modern life.

 Cleland, C.E., 2019. [The Quest for a Universal Theory of Life: Searching for Life as we don't know it](https://books.google.co.uk/books?id=eqCsDwAAQBAJ)(Vol. 11). Cambridge University Press.

We didn't find these nanobes, but they are biologically credible, because such small cells have an advantage in an environment with low nutrient concentrations, as they have a larger surface to volume ratio, and so take up nutrients more efficiently. They would also avoid protozoan grazing [(Ghuneim et al, 2018)](https://mail.google.com/mail/u/1/#kix.6av2wm9nvy6g).

Ghuneim, L.A.J., Jones, D.L., Golyshin, P.N. and Golyshina, O.V., 2018. N[ano-sized and filterable bacteria and archaea: biodiversity and function](https://www.frontiersin.org/articles/10.3389/fmicb.2018.01971/full). Frontiers in microbiology, 9, p.1971.

See section Selective Pressures for Small Size

If Mars has early life nanobes, even with less sophisticated biology, they might be able to compete in a shadow biosphere on Earth. That leads to the idea of maybe mirror life ribocells, or very small primitive cells that could compete on Earth due to being really tiny and with the extra benefit that they are inedible to terrestrial life.

These are just examples to help illustrate a point as the sample return studies don’t give much by way of examples.

Another central argument in the draft EIS is that Mars is lifeless anyway and that they are doing the sample return precautions just out of an “abundance of caution”. The draft EIS says that “conditions on Mars have not been amenable to supporting life as we know it for millions of years” ([NASA, 2022eis](#b_NASA_2022eis): 1-6):

Existing credible evidence suggests that conditions on Mars have not been amenable to supporting life as we know it for millions of years (iMARS Working Group 2008, National Research Council 2011, Beaty et al. 2019, National Research Council 2022).

But their most recent 2022 source for this “existing credible evidence” says the opposite from their summary.

Their source says that exploration of Mars will help establish whether localised habitable regions currently exist. It refers to Mars as “seemingly uninhabitable”, not “uninhabitable. See: ([Smith et al, 2022](#b_Smith_et_al_2022): [393](https://nap.nationalacademies.org/read/26522/chapter/16#393)) (click on X button on banner to go straight to the page)

Section title: “Are There Chemical, Morphological and / or Physiologic / Metabolic or Other Biosignatures in **Currently Habitable Environments** in the Solar System

The exploration of … Mars (Curiosity, Perseverance) will help establish whether localised habitable regions **currently exist** within these seemingly uninhabitable worlds.

[Emphasis on “currently” mine]

NASA’s draft EIS doesn't have the scientific credibility one expects of NASA. It also doesn’t have the credibility that is actually required of a NEPA EIS.

Birnbach, I., 1997. [Newly Imposed Limitations on Citizens' Right to Sue for Standing in a Procedural Rights Case](https://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1496&context=elr). Fordham Envtl. LJ, 9, p.311.

* **First, the regulations require a 'rigorous analysis' of alternatives to the proposed plan, including a 'substantial treatment' of these alternatives in comparison to the proposed plan.**

NASA's EIS doesn't have rigorous analysis of ANY alternative except "no action". They should include reasonable alternatives such as a presterilized sample return or delaying the mission until it can be done safely.

* **Second, the regulations require an agency undertaking an EIS to 'insure [sic] the professional integrity, including scientific integrity, of the discussions and analyses in environmental impact statements.'**

From my analysis here, this EIS would fail peer review, by omitting important studies that overturn the results they rely on, and most strikingly by using cites that refute the sentences they are attached to without alerting the reader to this discrepancy. So it doesn't have scientific integrity.

* **Additionally, the regulations require that the analysis be undertaken with an 'interdisciplinary approach' to 'insure [sic] the integrated use of the natural and social sciences and the environmental design arts.'**

This hasn’t been done. For instance, Mars sample return studies emphasize the need to involve the public early on, not just in the USA either or a particular state but through fora open to representatives from all countries globally because negative impacts could affect countries beyond the ones involved directly in the mission.

[(Ammann et al, 2012:59)](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510#m_-5454762008349871800_m_-1972427842941295334_m_-7564448782541179972_m_20121669073991).

So the public weren't given the opportunity to comment on a scientifically valid EIS.

This can be made into a mission that is 100% safe for Earth with virtually no impact on the science by sterilizing the samples before they reach Earth using an ionizing radiation dose equivalent to 500 million years of surface conditions. This would reduce the amino acids 1000 fold with virtually no impact on the geological interest.

As for astrobiological interest due to no in situ life detection, because Perseverance can't drill to layers protected from surface ionizing radiation, and high levels of forward contamination, these samples are sadly of virtually no astrobiological interest.

Every billion years the amino acids on Mars are reduced a million fold by ionizing radiation. This is why astrobiologists want to drill on Mars to a depth of 2 meters and why the ExoMars mission had the capability to drill to that depth.

Also past life is likely to be patchy and hard to find, much of it washed out later or destroyed by the reactive chemicals or destroyed by ionizing radiation if exposed temporarily to surface conditions.

Then to complicate it further there's constant infall of organics from interplanetary dust, comets, meteorites and there's also in situ abiotic synthesis of organics.

Unlike the situation on Earth, even at the very high ends of habitability of Mars most of the organics will be abiotic. Past life because it is so readily destroyed. Present day life because it can only survive in occasional biofilms in microhabitats and likely grows very slowly with doubling times of months to millennia or more.

Without the ability to drill AND do in situ life detection, they are exceedingly unlikely to find past life. [(Bada et al, 2009:7)](https://mail.google.com/mail/u/1/?ui=2&ik=5fe299b9b7&view=lg&permmsgid=msg-a:r7390408788637707510#m_-5454762008349871800_m_-1972427842941295334_m_-7564448782541179972_m_20121669073991):

We feel that organic detection efforts over the next two decades via investment into advanced in situ robotic instrumentation are fundamental in support of a future intelligent MSR mission.

**Currently, MSR is regarded by much of the scientific community as largely weighted towards a technology demonstration as the rationale for good astrobiology will not be apparent until we discover more about our neighboring planet.**

 Bada, J.L., Aubrey, A.D., Grunthaner, F.J., Hecht, M., Quinn, R., Mathies, R., Zent, A. and Chalmers, J.H., 2009. [Seeking signs of life on Mars: In situ investigations as prerequisites to a sample return mission](http://mepag.jpl.nasa.gov/reports/decadal/JeffreyLBada_URS211530.pdf). Planetary science decadal survey White Paper, Scripps Institution of Oceanography, USA.

The mission could be made far more interesting by sending STERILE containers on the ESF fetch rover to return bonus samples of dirt, dust and atmosphere without forward contamination.

These could be studied above geostationary orbit, in Mars simulation conditions with a centrifuge for artificial gravity remotely. NOT talking here about a human occupied space station. Humans go nowhere near it because of issues of contamination both ways (the HEPA filters won’t keep out ultramicrobacteria in the forward direction too).

Instead it is a single satellite, the equivalent of just one geostationary satellite but placed far above GEO. Humans study the dust, dirt and atmosphere just as they would on Mars using in situ instruments designed for end to end sample preparation to analysis - these instruments already exist such as LD chip almost sent on Exomars but descoped, SETG, astrobionibbler, the chiral labelled release and others.

As a result of these many other mistakes by NASA, the public and NEPA have not had the opportunity to comment on a scientifically credible assessment.

We conclude that NASA must restart the process and work towards a scientifically credible Environmental Impact Statement which must involve the public at an early stage and it must surely examine reasonable alternatives that keep Earth 100% safe with virtually no loss of science, or even major gains in the science return.

We need to do this properly – not only for the NASA mission but also as a precedent for China and other countries like India, Russia perhaps at some point and so on.

For instance if NASA establish a precedent of returning the samples for pre-sterilization above GEO, other countries are likely to do the same or indeed, perhaps to collaborate in a multi-national astrobiology sample handling lab – in a similar spirit to the ISS but much simpler, as it would be smaller and unmanned.