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:

Though the meteorite argument NASA uses is widely believed, the NRC Mars Sample Return study in 2009 said that the argument is invalid (close the splash to go straight to the page), page 48

https://www.nap.edu/read/12576/chapter/7#48

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

And then later on the same page in the NRC's 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."

This study is in NASA’s citation list, but the reader is not told that the NRC in 2009 refuted NASA’s meteorite argument, or given any reason why we should ignore the NRC refutation of their argument.

We can see why NASA’s argument is invalid by considering the example of the invasive freshwater diatom "Didymo" in New Zealand which 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, there could be life on Mars perfectly adapted to live in an ephemeral briny seep which forms in the late evening / early morning, and rarely transfers to other seeps protected from UV in dust storms, perhaps only succeeding at this every few millennia. As with the diatom example, there is no need for it 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. While 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”.

The argument ***does*** work for Phobos - 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.

We will see that a minor elaboration is needed to take account of photosynthetic life, which can burn up during re-entry - but it doesn’t change their conclusion.

However the JAXA / Sterlim team say that their argument does ***not*** apply to the Mars sample return missions. :[5](https://nap.nationalacademies.org/read/25357/chapter/2#5)) (click the X on the splash screen to go straight to the linked page):

*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.*

So, the argument presented in the EIS remarkably is refuted on page 5 of the first cite they present when they talk about ejection from Mars.

This meteorite argument is widely believed by space settlement enthusiasts but as we see, it is not actually valid. Zubrin published it as an Op Ed for the Planetary Society with no peer review

He got an immediate reply in the next month. Margaret Race put it like this:

I noticed a slight oversight in the JAXA analysis. 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 it also turns out that the martian meteorites we have all come from at least 3 meters below the surface of Mars https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1945-5100.2002.tb01033.x

There the normal temperature is below -70 C

https://www.researchgate.net/publication/7390930\_Adsorption\_Water-Related\_Potential\_Chemical\_and\_Biological\_Processes\_in\_the\_Upper\_Martian\_Surface#pf3

They all also come from the high southern uplands with craters found for most of them now, the reason being that the air is thinner there so ejection is easier.

https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2005JE002600

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.

This suggests it would also 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 then ends up deep below the surface).

Phobos's moons would seem to be unrestricted category V for sample return missions at least so long as we are careful not to dig deep there – or if we do dig deep, add extra ionization radiation to samples from deep below the surface. In the forwards direction with the same restrictions they would be unrestricted Category II similar to the Moon.

But 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. This is not a study for backwards contamination so they don’t look into capabilities of extant martian life adapted to the dust storms for billions of years but if there is life there it may well be adapted to spread in dust storms even more so than terrestrial life.

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

Also, if life is returned the sample return studies are emphatic that there IS potential for large scale harm to the environment or human health. It is likely low but not demonstrably zero. Many astrobiologists have expressed this concern going back to Lederberg and Sagan. Their views are not cited in this report.

Sagan, C., 1973, The Cosmic Connection - an Extraterrestrial Perspective

https://www.e-reading.life/bookreader.php/148581/Sagan\_-\_The\_Cosmic\_Connection\_\_\_An\_Extraterrestrial\_Perspective.pdf

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.

Lederberg, J., 1999b. Parasites face a perpetual dilemma. ASM News, 65(2).

https://profiles.nlm.nih.gov/ps/access/BBGNMX.pdf

“Whether a microorganism from Mars exists and could attack us is more conjectural. If so, it might be a zoonosis to beat all others [infectious disease that jumps to humans]. On the one hand, how could microbes from Mars be pathogenic for hosts on Earth when so many subtle adaptations are needed for any new organisms to come into a host and cause disease? On the other hand, microorganisms make little besides proteins and carbohydrates, and the human or other mammalian immune systems typically respond to peptides or carbohydrates produced by invading pathogens. 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."

It's the same for the NRC study which NASA do cite.

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

… 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”

https://www.nap.edu/read/12576/chapter/7#48

Though NASA’s EIS cite this study they don’t cite this section which refutes the conclusions of their sterilizing subcommittee.

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.

We don’t need to contain gene transfer agents or ultramicrobacteria in a BSL-4 but 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

As a result of not alerting the reader when the cites contradict its own conclusions and omitting other cites like the 2012 size limit update and the 2015 MEPAG review, 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.

This means that the public weren't given the opportunity to comment on a scientifically valid EIS.

As to why and how that happened that is for NASA to investigate and I hope they can ensure that a mishap like this never happens again!

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.

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