

**Current title:** NASA and ESA are likely to be legally required to sterilize Mars samples to protect the environment through to 2039, or until proven safe – technology doesn't yet exist to comply with ESF study's requirement to contain viable starved ultramicrobacteria, and legal process followed by build and training of technicians takes at least 17 years - proposal to study samples remotely in a safe high orbit above GEO with miniature life detection instruments – and immediately return sterilized subsamples to Earth

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## Abstract (long version)

NASA plans to return samples from Mars by 2031. They believe there is no surface life in Jezero crater, but also agree Earth has to be protected, on the remote chance there is native Martian life in these samples. Martian life might survive as a swansong biosphere from a more habitable early Mars, perhaps in microhabitats such as are commonly found in Mars analogue deserts on Earth.

The Apollo sample return procedures were decided internally with no legal process. During internal review, experts in its Interagency Committee from Public Health Service and the National Academy of Sciences told NASA that their plan for the astronauts to exit the capsule to a raft on the open sea would not protect Earth. However, NASA overruled their objections on the grounds that their recommendations would postpone the launch date. The procedures were first made public on the day of launch of Apollo 11.

This would not be permitted today. We have many laws to protect Earth's biosphere that didn't exist in 1969.

The European Space Foundation study from 2012 says

*"release of a single unsterilized particle larger than 0.05 µm is not acceptable under any circumstances".*

This is to contain starvation-stressed nanobacteria which can pass through 0.1 µm nanopores. Such a technology doesn't exist yet, even as experimental filters in laboratories. The 100% requirement is far beyond requirements for HEPA and ULPA filters as is the 0.05 µm requirement.

A Mars sample return facility is estimated to cost ~\$500 million. Before starting any project costing over \$250 million, NASA has to commit to Congress that its cost and schedule is adequate. They can't know this until the end of the 6+ years legal process, which can change

build requirements. Adding 11+ years to complete the build, this paper finds an earliest date of 2039 to return unsterilized samples. Further delays to the 2040s are likely.

However, samples can be sterilized at a level sufficient for planetary protection while preserving evidence for past life, geological dating and structure, and ability to detect present day life. A sterilized sample returned to Earth becomes an unrestricted sample return; a relatively simple process under the Outer Space Treaty.

Perseverance's primary objective is past life, rather than present day life. For past life sterilization would make little difference to its astrobiological interest since most samples have been subject to surface ionizing radiation for tens of millions of years.

However, this paper recommends that the ESA fetch rover adds a dust sample, originally planned for Perseverance. This could be used to search for dust-storm resistant Martian propagules which could be transported in Martian dust storms. It can be combined with a large volume compressed atmosphere sample to greatly increase sensitivity for biosignatures in the atmosphere.

This paper also recommends the ESA fetch rover is modified to dig an extra sample of dirt to return the brine layers Curiosity discovered centimeters below the surface of sand dunes. This could help resolve the puzzling Viking lander results and help to finally answer the question, "Did Viking detect complex chemistry or native life in the 1970s?"

This could greatly increase the interest of the mission for the search for present day life on Mars. If there is a significant chance of viable present-day life in these samples, we suggest returning them to a satellite in a stable inclined orbit above GEO in Earth's Laplace plane or "ring plane". This orbit has many advantages for protection of Earth, the Moon, and other satellites. Sterilized subsamples can be returned to Earth immediately for geological studies, and preliminary astrobiological work.

Should signs of life be found, either in the sterilized samples or in orbit, scientists can send miniature life detection instruments to the orbiting satellite. Astrobiologists have designed many such instruments to search for life in situ on Mars and can test them in the satellite. An orbit above GEO is close enough so that they can be teleoperated with close to zero latency. Decisions about what to do next depend on what they discover.

If no life is found, the samples can be sterilized then returned to Earth. Sadly, this paper finds that the permitted levels of contamination of the sample tube, though low, are likely not low enough to permit an easy definite disproof of the presence of viable life in the samples. However ionizing radiation to the levels needed to sterilize the samples would preserve the biological interest of past life.

This article examines specific worst-case scenarios for Martian life, such as a blue-green algae with everything flipped as in a mirror: DNA spirals counterclockwise, and amino acids,

carbohydrates, and sugars, are all in their mirror forms. Ordinary terrestrial life can't use these mirror organics.

Synthetic biologists have started a step-by-step process to flip a terrestrial cell to mirror life. They warn of a risk that this mirror life could gradually transform parts of terrestrial ecosystems to indigestible mirror organics, giving it a competitive advantage.

Synthetic mirror life will need containment to a higher level of safety than conventional biosafety laboratories. To keep Earth safe, mirror cells will depend on chemicals only available in the laboratory.

If we discover native Martian mirror life, we might need to leave it in orbit to achieve a similar level of safety, since it would not be designed to be safe on Earth.

This paper uses scenarios to examine possible effects from returned Martian life. In some of the scenarios, Martian life is harmless or even beneficial. However, in worst case scenarios Martian life can never mix safely with ours. In many scenarios, quarantine might also be insufficient to protect our biosphere from microbes in the microbiomes of astronauts returning from Mars.

Our future possibilities, and opportunities, depend on what form Martian life takes. Answering this seems a top priority for space colonization enthusiasts, and astrobiologists alike.

Perseverance can't resolve this question even if it does return viable life since any sample would just be a first indication of life in a small number of sampled locations in Jezero crater, or samples from elsewhere via spores that got to it in dust storms. Normal life could coexist with mirror life elsewhere on Mars. Familiar terrestrial species could coexist with unfamiliar species with novel capabilities. However, future astronauts in orbit around Mars may be able to give answers quickly with rapid astrobiological surveys of proposed potential habitats, controlling surface robots to do these astrobiological surveys with no risk to Earth using low latency telepresence.

This article concludes that the complex laws already in place to protect Earth's biosphere are both understandable and necessary.