**Short abstract (central points, 2,000 characters)**

**Graphical abstract**

**Abstract (long version)**

**UPDATE – new streamlined NEPA process means NSAA can hope to completeEISspring / summer 2023 with no more review if the EIS is not challenged**

**Public comment on NASA’s draft environmental impact statement in 2022**

**Introduction**

**NASA agrees we need to protect Earth’s biosphere from Mars samples,** thoughbelieve the surface of Mars is too inhospitable for life today

**However it is hard to find even one astrobiologist who would agree with**inconfidence that the Martian surface is too inhospitable for microbial life, andastrobiologists say there is a significant possibility of present day life even in Jezero crater

**NASA’s attempts to protect Earth in 1969 for Apolloweretoinadequaterepresentatives of the National Academy of Sciences and Public Health Servic**e NASA overruled these objections, saying that they didn’t have time to make thechanges

**This time NASA won’t be able to overrule objections by other agencies**, because ofNEPA legislation introduced in 1970

**With the technology not yet ready**, 9 years for the build, and 2 years to train technicianNASA can’t guarantee when they will be ready to receive unsterilized samples

**Objections could lead to new design requirements – such as newtechnologyquarantine requirements** – and this restarts the clock for the build

**Reviews by other experts or objections by the public during the legal process couldto a requirement to contain nanobes even smaller than the 0.05 microns limit as small as 0.01 microns, based on novel biochemistry such as mirror life** toimpractical “no appreciable risk of harm” standard – so NASA has to be prepared in case offinal decision that the required technology doesn’t yet exist

**If NASA start the build before the end of the legal process theybuildingfacilitysamples when the final decision is that they can never return to Earth orrequirehigher containment standards than current filter technology can achiev**e ESAlaunching spacecraft that can’t return samples to Earth directly

With this end to end requirement, 2028 is the earliest date for NASA to provide detailedand schedule with engineering details, which they are required to do before the build startsso 2039 becomes the earliest date for a sample return with delays beyond 2039**[SECTION OUT OF DATE DUE TO NEWER STREAMLNED NEPA PROCESS]**

**First proposed solution: to sterilize samples** – the extra radiation added to thealready received on Mars is not likely to impact on geological studies, and any sterilizedlife would remain recognizable

**Second proposed solution: to return unsterilized samples of astrobiologicaltosafe orbit above GEO for telerobotic study** then return sterilized sub-samples immediately

**Sketch for a third proposed solution - to aim for 100% containment of anyexobiology** with a facility in a nuclear bunker protected by a high temperature oil sumpat 300°C, with samples inside the facility studied remotely by telerobotics

**Perseverance’s sample tubes weren’t sterilized 100% leading to risk of falsethat may prevent distribution of unsterilized samples from containment** – estimated 8 nanograms maximum organic contamination per sample tube are equivalent to 81 ultramicrobacteria or 160 million hypothetical RNA world mirror nanobes

**Potential for major cost savings if samples handling decisions are made beforelaunches their spacecraft** – such as building a sterilization capability intospacecraftpermit it to return the samples direct to Earth – or removing the heavy aeroshell for theEntry Vehicle as unnecessary weight

**Proposals to sterilize all the samples or return to above GEO could bewithpossibility of risk to Earth’s biosphere** and minimal legal process

**Mars has a higher potential for habitability today than the Moon as understood in 1969**

**Could Mars be habitable but lifeless, perhaps with life in the past?** Cockell’sscenario which leads to possibility of uninhabitable habitats andreducelikelihoodreturning extant life

**Proposed solution of a self sustaining barely habitable Swansong Gaia whichexplain current conditions on Mars**, and increase potential for past life to continue topresent and of viable life returned in the sample

**A prebiotic Mars, lifeless for billions of years, could still develop protocells,geneOstwald crystals etc** – theorized forms of “almost life” and life precursors of great interestus - value of sterile containers to sample potential uninhabited habitats

**Proposals to modify the ESF lander and sample selections to increase potentialreturning viable present day or identifiable past life** with samples of the dirt, dust fromair during dust storms, and compressed large samples of Martian air collected100%containers by the fetch lander – and to use Marscopters to search for freshly excavatedcraters for Perseverance to sample

**Some Mars colonization enthusiasts argue that no planetary protectionneedehowever their arguments aren’t accepted by NASA** and wouldn’t be persuasive forgeneral public, other agencies or justices

**Scenario based approach to explore the consequences if Earth or Marsabiosphere involving two forms of biochemistry or alien species from theplanet**such as mirror life, RNA world nanobes, early life cells that cooperate rather thanbefore modern evolution, fungi and molds that our immune systems don’t recognize,adomain of life that is largely beneficial to terrestrial ecosystems similarly to the archaea

**How to complete astrobiological knowledge gaps rapidly with future teleroboticfrom Mars orbit**

**Perseverance’s mission within the wider context of an ambitiousprogramexploration and potentially settlement in our solar system**

**Modern legal processes didn’t exist at the time of Apollo - no legal precedent formodern restricted sample return**

1969 Apollo procedures didn’t protect Earth even according to theCommitteeBack Contamination (ICBC) that advised NASA – can we learn from their mistakes?

Comet and asteroid sample returns are legally straightforward - either sterilizedcollection - or Earth has a similar natural influx

Controversial 2019 report by Stern et al. recommended classifying parts of MarstoApollo 11 lunar requirements - no sterilization in the forward direction (Category II) Earth’s biosphere still protected in the backwards direction (restricted Category V)

2020 Review committee modified recommendations of 2019 report, saying our knowledgenot yet sufficient to classify parts of Mars as suitable for an unsterilized Category II missionthe forward direction – agrees on need to protect Earth in backwards direction

Similar situation in 2014 / 2015: 2014 report said maps can identify areas of Mars ofprotection concern in the forwards direction then 2015 review modifiedrecommendations, saying maps can’t yet be used – due to knowledge gapssurvivalterrestrial life in dust storms and potential for life to survive in microhabitats hard tofrom orbit

All agree Mars sample returns need to be treated as restricted Earth returnpotentialadverse changes to the environment of Earth

**Could Stern et al’s classification be a possible future scenario once we understandbetter – that we need to protect Earth from Mars but not Mars from Earth, indefinitelWe will find that in an alternative history the Moon could have been classified asApollo 11 indefinitely, and Mars potentially could be too**

Carl Sagan’s hypothesis of a subsurface habitable layer on the Moon at a depthtensmeters – which could risk backwards contamination of Earth – and originally therethought to be a low risk of forwards contamination

Decision to stop sterilizing missions to the Moon in 1963 because any forwardwas expected to be localized – even if there were habitats below the surface

Scenario of localized forward contamination on Mars depends on whether terrestrial lifebe transported in dust storms

Scenario of localized forward contamination by terrestrial life, but with Martian lifeablespread in Martian dust storms using spores adapted to Mars and more resilient thanspores

Scenario of no possibility of forward contamination because Martian life occurs inhabitats inaccessible to terrestrial life

All possibilities remain open: no need for sterilization to protect Mars, while Earthtoprotected indefinitely – or no protection either way - or protection indefinitely both ways -need to sterilize spacecraft to protect Mars indefinitely with no need toEarthastronauts from returned materials

Scenario of no present day life on Mars could give unique opportunity to studyhabitats on another terrestrial planet, and microbes accidentally introduced to anplanet in the wrong sequence could make Mars less habitable for colonists – need totime for study first

**How we understood the Moon in 1969 compared to Mars today - Mars with aatmosphere and liquid water, is more favorable for life than the Moon was thought toback then**

Views of astrobiologists on the possibility of present-day life on or near the surface of Mars

Suggested sources for native life in equatorial regions such as Jezeroincludemicrohabitats such as salty brines, and spores in windblown dust – while the dust andare not likely to be transferred to Earth via asteroid impacts

**First restricted (potentially life bearing) sample return since Apollo, but needsstricter planetary protection than was realized for Apollo – especiallydiscoverystarvation mode nanobacteria that pass through 0.1 micron nanopores**

By European Space Foundation study (2012), particles larger than 0.05 microns inare not to be released under any circumstances

The three proposed methods of containing samples in a Mars sample receiving facility, BSLin a clean room, clean room in a BSL-4 and triple wall - with examples for each design

EURO-CARES sample return facility design filter requirements are out by an ordermagnitude, due to unfortunate typo - ESF study’s probability of less than oneaisunsterilised particles of 0.01 microns (NOT 0.1 microns) – and ESF requires 10containment for particles of 0.05 microns

HEPA and ULPA filters are not tested for such small particles as 0.05 microns andrequired to contain them

Example of best available nanofilter technology from 2020, not yet commercially availablfilters out 88% of ambient aerosol particles at 0.05 microns - far short of the ESFto filter out 100% at this size – though this standard can be met with nanoparticles inunder high pressure

Challenges for maintenance for future 0.05 micron compliant nanoscale filters todesigned for sterilization before any potential extraterrestrial biology is known, and mayeasily damaged and hard to replace without risking release of nanoparticles

ESF study’s recommendation for regular review of the size limits

**Scientific developments since 2012 that may be considered in a new review of thestudy’s size limits – life with a simpler biochemistry such as minimum size RNAcells without DNA or proteins could potentially lead to a requirement that release ofa particle of 0.014 microns is not acceptable under any circumstances**

Could the postulated RNA world nanobacteria 0.014 microns in diameter spreadEarth’s environment (or other simpler forms of life)? Answer seems yepossiblwithadvantages to the postulated nanobes of the shadow biosphere hypothesis

Priority to decide on minimum size of released particle for filter requirements early inprocess and to outline future technology to achieve this standard

Discussion of potential large scale effects from mirror life could lead to a call for nearof containment, as for some experiments in synthetic biology

The 2012 ESF study in their discussion of precautionary principle said we need torisk using best available technology because if we require no appreciable risk of harmmission has to be cancelled – considerations of large scale effects couldtoneedrevaluate this conclusion

Clarifying this question of which version of the precautionary principle to use withcriterion that “we cannot take even a small risk with a billion lives”

Uhran et al recommend an advanced planning and oversight agency set up two yearsthe start of the legal process - Rummel et al recommend it should include expertslegaethical and social issues – while the ESF recommends an international framework shouldset up, open to representatives from all countries

**NASA procedural requirements for mission planners to develop a clear visionproblems, show it’s feasible and cost-effective, develop technology withdetails and show it will meet requirements before build starts – because ofcosts involved in modifying designs at later stages in the build**

Examples of how sample return facility requirements might change during theprocessmore stringent filter requirements than for BSL-4 – quarantine to be replacedteleroboticsand required safety levels far higher than the one in a million “gold standard” for a BSLfacility

Minimum timeline: 2 years to develop consensus legal position, less than one yearcomplete EIS, 9 years to build sample return facility and 2 years to train scientiststechnicians in its use

Need for legal clarity before build starts - NASA has reached keypoint A for the budgetentire program, but not for the facility – they can’t know what they will be legally requiredbuild for the facility – perhaps they can pass keypoint A without legal clarity keypointrequires detailed engineering knowledge of what to build

Need for legal clarity before launch of ESA’s Earth Return Orbiter, EarthVehicle,NASA’s Mars Ascent Vehicle

Legal process likely to extend well beyond 6 years with involvement of CDC, DOANOAOSHA etc., legislation of EU and members of ESA, international treaties, andorganizations like the World Health Organization – NASA don’t seem to be prepared foror even mention potential international ramifications [unless their EIS gets usedbypassstage altogether]

**The legal process and public debate for NASA’s mission as precedent formission to return a sample too – perhaps as soon as 2030 – with sterilization asolution for a country that wants to be first to return a sample**

NASA can’t accelerate the legal process to return an unsterilized sample before 2039butcould “win” this race with a sterilized return or a return to a safe orbit with sterilize– leading to China and other nations doing the same

**Public health challenges responding to release of an extraterrestrial pathogenunfamiliar biology**

Failure modes for sample containment

**Complexities of quarantine for technicians accidentally exposed to sample materials**

Vexing issue of authorizations to remove technicians from quarantine to treat lifemedical incidents in hospital

Example of a technician in quarantine with acute respiratory distress andsimilarLegionnaires’ disease – a disease of biofilms and amoebae that adventitiously infect– and sometimes mentioned in planetary protection discussions

Arbitrariness of technician’s quarantine period for an unknown pathogen – Carl Saganthe example of leprosy which can take 20 years or more to show symptoms

How do you quarantine a technician who could be a life-long symptomless super-spreaderan unknown Martian pathogen?

Martian microbes could participate harmlessly or even beneficially in the humanbut harm other terrestrial organisms when the technician exits quarantine - example ofZinnia on the ISS

What if mirror life becomes part of the technician’s microbiome?

Potential for mirror life on Mars and survival advantages of mirror life competingterrestrial life that can’t metabolize mirror organics

Similar considerations apply to astronauts returning from Mars - in some scenarios suchmirror Martian life, astronaut quarantine would be insufficient to protect Earth’s biosphere

A laboratory with the samples handled telerobotically as a solution to all thesequarantine issues – however the other problems remain and the safest way to dois in an orbital facility with the robotics controlled remotely from Earth

**Zubrin's arguments in: "Contamination from Mars: No Threat" - not likely to bein legal process - response of planetary protection experts in "No Threat? No Way"**

**These complexities arise due to need to contain almost anyexobiologysimplest solution to sterilize the samples**

**Sterilized sample return as aspirational technology demonstration for aastrobiology mission – with the six months return journey used to sterilize the sample**

Level of sterilization needed to protect Earth’s biosphere is similar to ~10 million yearsMartian surface ionizing radiation - and would leave present day life and past liferecognizable - if recognizable without sterilization

Suggestion to use low power nanoscale X-ray emitters for sterilization during the sixreturn journey from Mars

Experimental data on effects of sterilizing doses of gamma radiation – preservesgeological interest of rock samples - need to test effects of X-rays

**Why it’s a major challenge to find samples from Jezero crater to help decidequestions in astrobiology until we can send in situ life detectionmostbiosignatures will be degraded beyond recognition – nearly all organicsMarsexpected to be abiotic - past and present day life is expected to be low inand patchy in distribution – and all this is especially challenging if Martian lifedeveloped photosynthesis or nitrogen fixation**

Most Martian organics are expected to be from non living processes even if Mars hasday life and had abundant past life – and most organics found so farCuriosityPerseverance resemble meteorite organics

Curiosity’s detection of organics depleted in Carbon 13 could be from biologicallymethane which then interacted with UV in the atmosphere - but samples of thosewould give no other biosignatures to distinguish between the hypotheses

If Perseverance returns samples similar to the Curiosity carbon 13 depleted organicorTissint meteorite or ALH84001, this won’t resolve the question of whether they wereby life – a more unambiguous sample is needed

The processes on Mars expected to destroy most surface organics from past life

Possibility that past life in Jezero crater life, or even modern Martian life, neverphotosynthesis

Alternative to photosynthesis - chemosynthesis – perhaps using hydrogen sulfide orincluding hydrogen from radiolysis in rocks – with much lower levels ofthanphotosynthesis based ecology

Possibility that past life in Jezero crater or even modern life never developed nitroge– or if it did, that nitrogen fixation was never taken up by microbes in oxygen richlayers

**Present day and past life may be patchy or inhabit millimeter scale features**

If Mars has present day life - it’s likely to be in low concentrations as for hyper-ariddeserts, and may colonize temporary habitats slowly over thousands of years

We don’t know which geological contexts on Mars best preserve past life (if it’s there)Martian processes can destroy organics, or wash them out, and even a thrivingecosystem might leave no biomass, for instance in acidic conditions

Need many example samples as we study factors that lead to lifeless samples

**Mars sample tubes weren’t sterilized 100% out of concern by engineers that acontainer might not be able to open on Mars - higher levels of sterilization neededdetect life unless Perseverance returns life with recognizably different biologyabundant exceptionally well preserved life**

Achieved levels of sterilization yield a 0.02% probability of a viable cell in at least onetube, so if a single viable microbe is found in one of the tubes, proof of detection oflife can only achieve 3.09 sigma

Estimated achieved level of maximum 0.7 nanograms for each tested biosignature and 8 nanograms total organic contamination in every gram of returned rock sample – with nofor chlorophyll or carotenoids, amongst the most robust biomarkers for ancient lifeMarwhich could also get into the tubes, for instance through the cyanobacteria found inroom samples

Perseverance’s estimated achieved levels of 8.1 nanograms of organic contaminationgram of returned rock sample is more than the amount of organics in 81 ultramicrobacteria, or 160 million hypothetical minimal volume RNA worldandequivalent to the organics found in trillions of terrestrial amino acids – lifeinstruments that astrobiologists hope to send to Mars can detect a single amino acid ingram of sample

We can expect to find novel species and genera from terrestrial contamination in thetubes – in a ribosomal survey of samples taken from the clean room used toPerseverance, 4 species were found that didn’t closely resemble any previouslyterrestrial ribosome – and 41 species only detected through their smallsubunitexample of the genus Tersicoccus first found in clean room samples

The permitted contamination will make it challenging to prove Perseverance’s samplesNOT have Martian life in them and make it harder to spot genuine Martian microbesclosely resemble terrestrial biology – they will need to contain exceptionally wellpast or present day life - or we need to collect additional samples in more sterilewith the sample fetch lander

**Could Perseverance’s samples from Jezero crater in the equatorial regions ofcontain viable or well preserved present day life?**

Puzzles from the Viking landers – why some think Viking detected life already in1970sevolved gases in the labelled release experiment offset from temperature fluctuations bymuch as two hours, more typical of a circadian rhythm than a chemical reaction

Could spores from nearby habitats explain the Viking results?

Detection by Curiosity rover of liquid water with enough water activity for life though toofor terrestrial life - as ephemeral perchlorate brines in the Gale crater sand dunes -conditions are predicted in Jezero crater dunes

How Martian life could make perchlorate brines habitable when they only have enoughactivity for life at -70 °C – biofilms retaining water at higher temperatureschaotropicpermitting normal life processes at lower temperatures – andbiochemistryultratemperatures

Some Martian brines could be oxygen-rich, permitting aerobes or even primitive spongesother forms of multicellularity - Stamenković‘s oxygen-rich briny seeps model

Life could also exploit enhanced humidity in micropores in salt deposits - but these mayrare in Jezero crater

Melting frosts - and potential for a temperature inversion to trap a near surface coollayer at dawn as the air warms, perhaps permitting thin films of water to form briefly

Experiments with black yeasts, fungi and lichens in Mars simulation conditions suggestcould use the night time humidity directly without liquid water

Surface conditions of ionizing radiation, UV radiation, cold and chemical conditions don’tout the presence of life

Sources of nitrogen on Mars as a potential limiting factor – potential for Martian life tonitrogen at 0.2 mbar – and “follow the nitrogen”

**Could Martian life be transported in dust storms or dust devils, and if so, could any ofstill be viable when it reaches Perseverance?**

Native Martian propagules of up to half a millimeter in diameter (including sporeand hyphal fragments) could travel long distances with repeated bounces (saltation) - ifcan withstand the impacts of the bounces

Martian propagules could evolve extra protection such as a shell of agglutinated ironparticles to protect themselves from UV

Martian life could also use iron oxides from the dust for protection from the impact stressesthe saltation bounces - or it might use chitin - a biomaterial which is extremely hard andelastic and is found in terrestrial fungi and lichens

Potential for spores and other propagules transferred from distant regions ofsimilarlytransfer of spores from the Gobi desert to Japan – if little dust from a nearby habitat withorder 1000 viable spores per gram is blown to Perseverance’s site during a dust storm,could still return several cells per gram

Proposed surface microhabitats on Mars outside Jezero crater – droplets on theofPhoenix lander, brines that form rapidly when salt overlays ice at high latitudes, cavesvent to the surface, fumaroles, and fresh water melting around heated grains of dustin polar ice layers through the solid state greenhouse effect – these could achievedensities of life and be a source for propagules in the dust

Searching for distant inhabited habitats on Mars through presence or absence oforiginally living cell per gram – a rough first estimate assuming uniform mixingMars for a first estimate requires life to cover between 114,000 and 1,140 squarewith densities of life in the dust similar to an Antarctic RSL analogue in cell count, butthan a tenth of a square kilometer if any reach a billion cells per gram – thesecanhigher if any source habitats with high densities of cells are closer to the rover withmixing

Could local RSL’s be habitable and a source of wind dispersed microbial spores? Bothand wet mechanisms leave unanswered questions - may be a combination of both orwet and some dry

**Could Perseverance find recognizable well preserved past life?**

Searches for macrofossils of microbial mats or multicellular life - Knoll criterion andof recognizing life by its structures

Difficulties of recognizing microfossils even with associated organics – example of ALH84001

Perseverance could detect distinctive biosignatures like chlorophyll and carotenoids - butfor exceptionally well preserved present day life, and chiral excesses and C12 / 13 ratiosoccur in meteorites

**Modern miniaturized instruments designed to detect life in situ on Mars - could alsoused to examine returned samples in an orbital telerobotic laboratory**

**Sampling recommendations to improve chances of returning presentlifunambiguous past life, and material of astrobiological interest - including air //sampling additions to ESA’s Sample Fetch Rover and modifications ofcaching strategies**

Near certainty of a young crater of 16 to 32 meters in diameter less than 50,000 yearswithin 90 days travel of the landing site - to sample for past life less damaged byradiation

Probability of a new crater within reach of Perseverance forming during the mission tonewly exposed subsurface organics

Dating young craters from orbit through fresh appearance with sharp rim -absenceinterior craterlets or few craterlets

**Recommendation:** use of Marscopter and Perseverance to help identify young craterssharp rims to help sample subsurface organics excavated by meteorites

**Proposal:** send a presterilized marscopter with the ESA fetch roverpickpebblesastrobiological interest if any are found and return to a new sterile container broughtMarsMID EDIT

Exposure of organics through wind erosion - for samples of less degraded past life

**Recommendation:** Extra sample of air and airfall dust to search for Martian life,forward contamination issues for terrestrial microbes, dust dangers for astronauts, andreturn a random sample of wind-eroded rock from distant parts of Mars

**Proposal:** magnets could be used to enhance dust collection

**Proposal:** to use the sample return capsule as a dust collector – keep it open toatmosphere before adding the sample tubes

**Proposal:** by Jakosky et al from the 2020 NASA decadal survey to combine a dustwith a compressed sample of the Martian atmosphere

Value to astrobiology of returning the temporary brine layers found by Curiosity at depths ofto 15 cms in sand dunes

**Recommendation:** modify ESA’s sample fetch rover to grab a sample of the neartemporary brine layers from sand dunes - Perseverance may be able to do this too

**Evidence of past seas with deltas, while modeling suggests habitability offrequently changes in brief episodes of warmer conditions**

Evidence of temporarily more habitable Mars backs up the modelling including evidencethe Zharong rover of substantial amounts of water in Utopia Planitia about 700 millionago – would life survive in a planet with these frequent changes of habitability or does itextinct easily, and if so does it re-evolve?

**Suggestion of a self perpetuating “Swansong Gaia” maintaining conditionsabove minimal habitability for billions of years - as a way for early life tothrough to present day Mars**

Swansong Gaia hypothesis – that Mars would have far more CO₂ without life life itself keeps Mars barely habitable by growing and taking CO₂ out of the atmosphereMars gets more habitable

Interactions of nitrogen cycle with Swansong Gaia - if life returns more nitrogen toatmosphere when Mars is wetter, the Swansong Gaia cycle is reinforced

**Nitrogen fixation scenario 1:** Martian life never developed nitrogen fixation Swansong Gaia effect

**Nitrogen fixation scenario 2:** Martian life has nitrogen fixation and also denitrificationreturn nitrogen to the atmosphere, similarly to life on Earth – strong Swansong Gaia effect

**Nitrogen fixation scenario 3:** Martian life has nitrogen fixation butdenitrificationSwansong Gaia effect varies in effect depending on deliveries of nitrogen by comets

**Nitrogen fixation scenario 4:** Martian life behaves like the life in terrestrial hyperari– nitrogen fixation and denitrification but denitrification stops in theconditionsstrongest Swansong Gaia effect

Warming from methanogens limited by Swansong Gaia feedbackphotosynthesisproduces oxygen which turns much of the methane to CO₂ and also fixes the CO₂

Self limiting consortiums of methanogens, methanotrophs, and Fe(III)-reducingconverting underground aquifers to calcite, and so maintaining a subsurface barelySwansong Gaia hydrology

Could seasonal oxygen excess in spring and summer and deficit in winter be asignal of photosynthesis maintaining a Swansong Gaia homeostasis on Mars?

Swansong Gaia maintains a homeostasis, though at a much lower level of habitabilitythe original Gaia hypothesis – not the same as Kleidon’s “anti Gaia” which makes arapidly uninhabitable

Potential limits on the biomass of a Swansong Gaia on Mars using the amounts of freeand H₂ in the atmosphere

Testing the “Swansong Gaia” hypothesis through looking for evidence of cyclesMarsmaintain this homeostasis

**Recommendation to return a sample for teleoperated ‘in situ’ study toGeosynchronous Equatorial Orbit (GEO) in the Laplace plane, where particles in asystem would orbit**

Why we can’t return the sample to the ISS, the Earth-Moon L1 position or to the Moon doesn’t break chain of contact – Earth Moon L1 is gravitationally unstable - and atoMoon isn’t currently permitted under COSPAR

High orbits such as semi-synchronous orbits may work well if the sample is kept well outthe way of existing satellites

Advantages of GEO – nearly as far from Earth as from the Moon in terms of delta v much less latency for telerobotics and easier of access for payloads than the Moon

Easier to avoid satellites in GEO because of low relative velocity

An orbit within the Laplace plane above GEO contains debris in event of an offexplosion or other events

The Laplace plane is easy of access via low energy transfer of an Earth Return VehicleMars to above GEO using either a Distant Retrograde orbit or LL2 halo orbit as intermediary

A robotic spaceship from Earth can rendezvous for preliminary study of the returnedabove GEO

**If life is found, preliminary studies can continue telerobotically in orbitGEOinstruments designed for in situ life detection on Mars**

Advantages of telerobotic study above geo over terrestrial study

Possibility of early discovery of extraterrestrial microbes of no risk to Earth suchprDarwinian life as suggested by Weiss – if microbial challenge experiments show theyquickly destroyed by pervasive terrestrial microbes

Permitted levels of contamination could make it impossible to proveoflifePerseverance’s sample tubes – leading to an unnecessary requirement toPerseverance’s samples indefinitely

Early discovery of a familiar microbe from Mars such as chroococcidiopsis is not enoughprove the sample is safe – as familiar life can have new capabilities

Discovery of a familiar microbe like chroococcidiopsis does not prove all life insamplefamiliar – if terrestrial life originated on Mars, it could have extra domains of life that neverto Earth

Potential to discover multiple biochemistries such as mirror and non mirror life in thesample – perhaps evolved in disconnected early Martian habitats – or unfamiliar lifewith familiar life transferred from Earth to Mars in the past

Possibility of discovery of high risk extraterrestrial microbes needing extreme caution

**Potential for early discoveries of Martian life from samples of Martianpreserved in ice at the lunar poles - likely pre-sterilised by natural processesto protect Earth**

Suggestion by Crotts of a subsurface ice layer on the Moon deep enough for liquid waterby Loeb of a subsurface biosphere on the Moon

**Could Martian life have got to Earth on meteorites? Our Martian meteorites comeat least 3 m below the surface in high altitude regions of Mars**

Larger impacts could send material to Earth - but unlikely to transfer fragile surface dirt,and salts

**Could life get transferred from Earth to Mars? With Earth’s high gravity andatmosphere the challenges are far greater but may be more possible in the earlysystem with impacts large enough to blow out part of Earth’s atmosphere**

Report by the National Research Council couldn’t discount the possibility of pastextinctions caused by Martian life - could the Great Oxygenation Event be an example?

Whether or not chroococcidiopsis caused the Great Oxygenation Event – it gives aexample of a way life from another Mars-like planet could in principle cause largechanges to an Earth-like planet

**Scenario: evolution on Mars evolves faster than on Earth because ofoxygenatmosphere and frequent freeze / thaws of oceans, leading to life of the samecomplexity as Earth or even greater, and with multicellularity evolving early**

**Potential diversity of extraterrestrial life based on alternatives to DNA such as RNPNTNA, additional bases and an additional or different set of amino acids**

**Many ways present day Martian life could harm terrestrial organisms**

Mars could have opportunistic fungi – these kill 1.5 million people on Earth every year

Martian life could be a pathogen of Martian biofilms sufficiently closely adapted toprotists on Earth – or it might be ignored by the white blood cell phagocytesliveintercellular spaces of our lungs

Our antibiotics target specific enzymes and processes so might not work withmartian life – meanwhile related life might have naturally evolved accidental antibioticsthe Shewnella algae which seems to be the origin of the gene thatresistancequinolones – a new non naturally occurring synthetic antibiotic

Ways that our immune system may not notice an alien biochemistry without theantimicrobials or immune responses for alien opportunistic pathogens and other diseases

Could a Martian originated pathogen be airborne or otherwise spread human to human?

Microplastics and nanoplastics as an analogue for cells of alien life entering ourunrecognized by the immune system

Exotoxins, protoxins, allergens and opportunistic infection

Accidental similarity of amino acids forming neurotoxins such as BMAA whichserine – a putative cause for the motor neurone disease LouGherig’s disease or ALS

Martian microbes better adapted to terrestrial conditions than terrestrial life,ofefficient photosynthesis

Example of a mirror life analogue of chroococcidiopsis, anitrogenpolyextremophile

Example of mirror life nanobacteria spreading through terrestrial ecosystems

Possibility of extraterrestrial Martian life setting up a “Diminished Gaia” on Earth

Worst case scenario where terrestrial life has no defences to an alien biology -survive by ‘paraterraforming’ a severely diminished Gaia

Worst case where alien life unrecognized by terrestrial immune systems spreads toall terrestrial ecosystems

**Could Martian microbes be harmless to terrestrial organisms?**

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

Even if introducing martian life is largely beneficial, it could still be harmful inecosystems or have mixed effects with some harms and some benefits

A simple titanium sphere could contain an unsterilized sample for safe return to Earth’seven with the technology of 1969 - but how do you open this “Pandora's box”?

**Which variation on the precautionary principle is appropriate for a Mars sample return?**

Formulating Sagan’s statement that “we cannot take even a small risk with aliveascriterion for the prohibitory version of the precautionary principle

A requirement for similar levels of safety to those used for experiments with syntheticwould lead to the Prohibitory version of the Precautionary Principle and makesample return impossible with current technology and current understanding of Mars

Origins of the one in a million “gold standard” – as originally proposed it was 1 in 100and EPA uses numbers between 1 in 10,000 and 1 in 10 million – withdiscretion - no magic number can substitute for informed and thoughtful consideratioworking with the public

What counts as "no appreciable risk"? Needs to be decided by ethics not science, butcan help clarify discussion - idea of expected number of people severely affected

Adaptive approach - return an unsterilized sample to Earth’s biosphere only when youwhat is in it

**Proposal:** a sketch for a biosafe laboratory on Earth designed for 100%ofnanoscale mirror life using telerobotics, a sump heated to 300°C with heat and vacuumlight oil, and built in heat sterilization at end of life of the facility - could this be a safe wayopen “Pandora’s box”?

**Early life or life precursors on Mars, such as protocells or Woese’s pre cellcould be very vulnerable in the forwards direction - legal protection is weak,strengthened by the laws for backwards protection of Earth**

**The study “Safe on Mars” in 2002 proposed a mission similar to Perseverance towhether it is safe to send astronauts to Mars – however with themoreunderstanding of Mars, Perseverance’s sample won’t prove that astronautssafeJezero crater**

To check safety of Mars for astronauts requires widespread in situ biosignature anddetection, and in situ tests of dust for spores and other propagules

There is an asymmetry here - even discovery of extraterrestrial life of no risk to EarthJezero crater - such as pre-Darwinian life easily destroyed in microbial challengesterrestrial life wouldn’t immediately prove the whole of Mars is safe for humans - whilesingle sample of a biohazard such as mirror life COULD be enough to prove Mars unsafe

Several studies by astrobiologists concluded we need capabilities tolifesitforreasonable chance to resolve central questions of astrobiology – if they are correct, thisalso be necessary to show Mars is safe for Earth’s biosphere and for astronauts

Sample return as a valuable technology demo for astrobiology – and proposals to keepfirst sample returns simple, a scoop of dirt or skimming the atmosphere to return microndust samples

**Resolving these issues with a rapid astrobiological survey, with astronautsrovers from orbit around Mars**

Value of telerobotic exploration for a planet with complex chemistry developedbillionsyears – need for forward protection of uninhabited habitats

Scenario of a pre-biotic uncontaminated Mars of great scientific valuemicrohabitatsautopoetic cells, Ostwald crystals breaking the mirror symmetry of organics, orgeneadsorbed on mineral particles with impenetrable membrane caps, but not yet quite life

Arthur C. Clarke’s story “Before Eden” exploring the theme ofextinctionextraterrestrial life in the forwards direction

Suggestion to develop design specifications for 100% sterile rovers for fastastrobiological surveys throughout the solar system based on research for Venusrovers

Ultra cleaning with carbon dioxide snow sterilization – final 100% sterilization stageprcleaned components that doesn’t need high temperatures but can remove even traceof organics from surfaces – especially useful for microsats and microrovers / gliders

**Mars not habitable for humans in any ordinary sense of the word - lessthanplateau higher than Mount Everest, so high our lungs need a pressure suit to functionnot significantly more habitable than the Moon**

Dust as one of the greatest inhibitors to nominal operation on the Moon - and likely ontoo

**Planetary protection as an essential part of an ambitious, vigoroustoexploration - starting with exploration and settlement experiments on the Moon**

The Moon has some potential for commercial exports – while there is nocasecommercial exports for Mars - and extant life on Mars, especially ofbiochemistry,potentially be of great commercial value

Discovery of extant life on Mars could lead to long term interest in the planet,orbiting colonies using sterile robots as our mobile eyes and hands to explore the planetorbit via telepresence, and perhaps develop it commercially too, making ithabitableMartian life

This could be a stepping stone to human outposts or colonies further afield such asCallisto or Saturn’s Titan, and settlements in self contained habitats throughout thesystem, spinning slowly for artificial gravity and built from materials from asteroids and comets

**Conclusion - legal process is both understandable and necessary**

References (some quotations included to assist verification)

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Outline - and what’s new in this article