



Limits of Life (LoL) Session

1. Peter Doran: Overview (and definition) of the limits of life (5 mins)
2. Petra Rettberg: Mars Special Regions (7mins)
3. Lyle Whyte: Limits of cold temperatures for microbial life (7 mins)
4. Emily: Limits of water activity (7mins)
5. Discussion

Limits of Life

- Establish limits of life with regards to various environmental factors so we can establish data-based projections of where Earth life has a high and low probability of inoculating a solar system body
- For Planetary Protection forward contamination considerations we are largely concerned with the limits of terrestrial life
- We focus on the limits with regard to replication/growth, not just survival/metabolism
- Synergistic effects remain a significant knowledge gap

<i>Factor</i>	<i>Extremophile</i>	<i>Earth environments</i>
High temperature	Thermophile or hyperthermophile	Submarine hydrothermal vents, terrestrial hot springs, deep subterranean environments
Low temperature	Psychrophile	Ice, permafrost, Antarctic dry valleys
High pressure	Barophile or piezophile	Subseafloor, deep subterranean environments such as the Mariana Trench
High pH	Alkaliphile	Soda lakes
Low pH	Acidophile	Acid mine drainage, hot springs
High salinity	Halophile	Brines, evaporite deposits
Desiccation	Xerophile	Antarctic dry valleys, deserts
Ionizing radiation	Radioresistant	High-radiation environments (from radioactive waste, nuclear reactors, cosmic rays, gamma rays, X-rays)
UV radiation	Radioresistant	High deserts, upper atmosphere
Toxic element concentrations	—	Acid mine drainage, hot springs

Domagal-Goldman et al. (2016). The Astrobiology Primer v2.0. Astrobiology.

Where we are at

- Two MEPAG SAG's (SR-SAG and SR-SAG2) went over in exhaustive detail the limits of life on Earth in order to help establish where there might be Special Regions on Mars (places where Earth life could potentially take hold).
- The first SAG established that while other factors are important, we can just concern ourselves with temperature and water activity.
- It was established in multiple products of these efforts that this analysis should be revisited every 2 years (the last was 10 years ago)

MEPAG = Mars Exploration Program Analysis Group

SAG = Special Analyst Group

SR-SAG = Special Regions SAG

- Since then the PPOSS project proposed that the Special Regions temperature and water activity limits should be used in the COSPAR policy as a general tool for PP
- COSPAR PP Policy prepared by the COSPAR Panel on Planetary Protection and approved by the COSPAR

Bureau on 3 June 2021

5. **Environmental conditions for replication**

Given current understanding, the physical environmental parameters in terms of water activity and temperature thresholds that must be satisfied at the same time to allow the replication of terrestrial microorganisms are:

- Lower limit for water activity: 0.5
- Lower limit for temperature: -28°C

PPOSS = Planetary Protection of Outer Solar System

Questions to consider for Discussion

- Are there important studies we've missed in the recent literature
- Should we formalize the updating/reviewing of Mars SR and LoL and on what repeating cycle?
- It's been 10 years, time for new workshops?
- Do we handle Mars SR and LoL separately now that we are using LoL outside of Mars SR in the policy?
- Should there be a high temperature limit for life for PP use (e.g. for Venus/Mercury)?