Abzu: A Mission to Uncover the Origin of Ancient Organics on Mars *in situ*.

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Overview: In the search for evidence of life on Mars, preserved organic matter may be one of the best indicators of past life. Previous missions to the red planet have discovered trace quantities of organic matter or broad indications of the presence of organics, but molecular structures diagnostic of origin have been obscured by processing in preparation for analysis, and small sample sizes prevent detection of molecules that are low in abundance. We present Abzu, **a mission concept with a life-detection forward strategy** that builds on prior exploration of Mars and complements the efforts of Mars Sample Return.

Abzu will utilize a community-reviewed "high-confidence" approach to life detection, characterizing organic molecules and potential biomarkers with a limit of detection 4-5 orders of magnitude improved over previous missions, using non-destructive extraction techniques demonstrated on tens of thousands of terrestrial and meteorite samples. Additionally, Abzu will sample below the top 20 cm to overcome the most destructive effects of radiation, as the dose of ionizing cosmic rays diminishes with increasing depth, and solar UV photons are concentrated at the near surface.

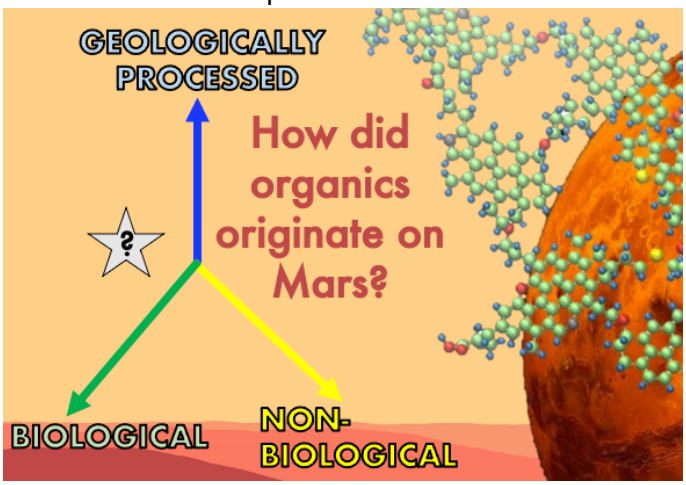

Figure 1: The goal of the Abzu mission is to understand the origin of organic matter on Mars and search for evidence of life in anciently habitable terrains.

Goal: To determine the composition and source of organic molecular signatures in surface and subsurface ancient aqueous environments on early Mars. Were identified organic molecular signatures synthesized biotically – indicating the emergence of life on Mars?

Objectives: Identify and classify organic compounds or groups preserved in the Martian environment to determine their source origin (**Fig. 1**). Determine whether the patterns in preserved Martian organics indicate synthesis such as:

- exogenously delivered material (e.g., meteoritic infall)
- endogenous abiotic synthesis (e.g., igneous, hydrothermal, electrochemical reduction)
- biotic synthesis
- a mixture of the above, environmentally processed (e.g., solar and cosmic radiation, soil oxidants, aeolian erosion & transport, transient aqueous activity)

Target Destination: Mars surface

Mission Architecture Platform: Lander

Target Solicitation: Discovery, mid 2030s launch

Molecular Target: Organic molecules with the highest preservation potential in billion-year-old sedimentary deposits (lipids, hydrocarbons, and insoluble macromolecular material)

Expected Measurements:

- Contextual imaging and lithologic assemblages
- Presence and structure of preserved organics
- Molecular structures, conformations, and patterns in acyclic and cyclic lipids and hydrocarbons

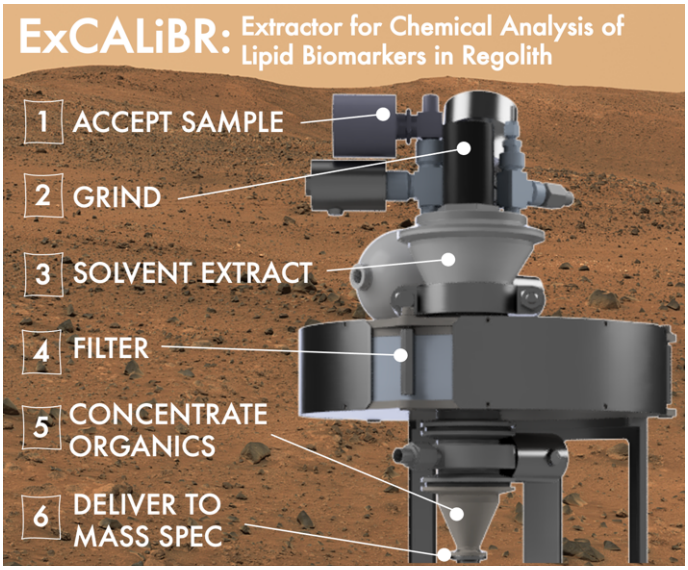

Figure 2: ExCALiBR instrument uses 5 sample processing steps to provide a mass spectrometer with unadulterated, concentrated lipids from Martian regolith. ExCALiBR can be deployed to characterize the origin of organics on Mars.

Central Payload Element: Sample processing and analysis based on best-practice laboratory techniques for complex, natural samples. Abzu's payload adapts laboratory lipid characterization techniques that have been used successfully in terrestrial laboratories for ~70 years on tens of thousands of samples (**Fig. 2**). The Extractor for Chemical Analysis of Lipid Biomarkers in Regolith (ExCALiBR). ExCALiBR's unique approach was selected for lipid extraction for the baseline payload on the future Mars Life Explorer (MLE) mission by the recent planetary decadal survey.

Conservation and Concentration of Origin-Diagnostic Molecular Information: Optimized sample acquisition, preparation, & analysis is utilized that conserves molecular features and patterns that are diagnostic of origin/synthesis. On Earth, molecular analyses of organics-lean samples from many Mars analog environments, particularly ancient settings, requires extraction and concentration from large sample masses (~10s of cc) in order to detect low-abundance biomarkers. By scaling sample mass up to 25 cc, Abzu improves limits of detection compared to past *in situ* techniques, providing the best chance to characterize a wider suite of organics that would otherwise be undetectable in small samples.

Technology Challenges:

- Challenges include sampling from depths greater than ~5 cm, particularly depths beyond 20 cm down to about 1 meter.
- Implementing stringent decontamination procedures, particularly on the sample acquisition system and sample handling system.
- Techniques for characterization that overcome challenges to the successful detection of lipids and hydrocarbons *in situ*, including interference by inorganics (e.g., perchlorates and other salts), molecular complexity, limitations on their solubility, heterogeneous distributions, and low abundance.

Landing Site Requirements: Region with accessible early Mars mudstone exposures, long exposure to liquid water (surface and subsurface), high potential for concentration, accumulation, and preservation of organics, catchment basin with evidence for aquatic or marine deposition from multiple sources, evidence of geologically fresh surfaces, and expansive, topographically smooth terrain.