What are the best ways to look for extinct or extant life on Mars? Thinking outside the box

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What Viking May Have Missed

It was claimed that the GC/MS instrument did not detect organics above part per billion (ppb) level.

However, the detection limit for amino acids is now known to have been in the 10s of ppm range.

A bacterial cell has a dry weight of 10^{-13} grams.

Amino acids are the major organic component of cells.

At ppm level, amino acids from ~10^{7} cells per gram of Martian soil would not have been detected!

Thus, Viking did not necessarily rule out the possibility of Martian biology!

Modern day GCMS systems have better sensitivity than Viking for some compounds but not for amino acids.

Glavin, D. P. et al., "Detecting pyrolysis products from bacteria on Mars" *Earth. Planet. Sci. Letts.* 185, 1-5 (2001)

Options for searching for evidence of life on Mars

- **Fly missions focused mineralogy and elemental analyses along with broad surveys of organic carbon using Viking style GCMS instrumentation. These studies will <u>not</u> directly search for molecules of possible biological origin.**

- **Fly instruments that are capable of carrying out state-of-the-art analyses for key biomolecules. Modern analytical methods have advanced far beyond Viking-type GCMS analysis and can detect key molecules with sensitivities in the sub-10^{-15} mole range.**

What molecules do we look for?

"The expected commonality of chemistry in life's processes assists in life detection because it predicts that terrestrial types of biochemicals are useful targets for analysis even in an extraterrestrial setting." N. R. Pace, The universal nature of biochemistry, *Proc. Natl. Acad. Sci. USA* 98, 805-808 (2001)

- **Target molecules should be ones that play a central role in biochemistry as we know it.**

- **Although the core classes of molecules (amino acids, nucleobases, etc.) may be similar to terrestrial life, their overall molecular makeup could be different.**

- **Searches should be general enough to detect molecules that are not identical to those used in terrestrial biology.**

The molecules of life

On a weight bases, protein-bound amino acids are the most abundant single class of molecules in a typical bacterial cell. The next most abundant are the nucleobases associated with RNA and DNA (~1/10 as abundant as amino acids).

Dry weight composition of *E. coli.* (g/cell)

protein	**1.6×10^{-13}**
RNA	**6×10^{-14}**
DNA	**0.9×10^{-14}**
lipids	**2.6×10^{-14}**
soluble fraction	**0.8×10^{-14}**
other	**2.4×10^{-14}**
Total	**2.8×10^{-13}**

From T. D. Brock, D. W. Smith, M. T. Madigan, *Biology of Microorganisms*, Prentice Hall, 1984

Astrobiology Science and Technology for Exploring Planets (ASTEP)

New Science-driven analyses emphasizing field campaigns:

- **Demonstration/Validation of instrument concepts**

Central Theme:

- **Test in extreme environments which might be representative of those on Mars**

Approach:

- **Develop in situ instrumentation with femtomole (10^{-15} moles) analytical sensitivity for targeted key molecules**
- **Use methods such as chiral analyses to distinguish between abiotic and biotic origins**

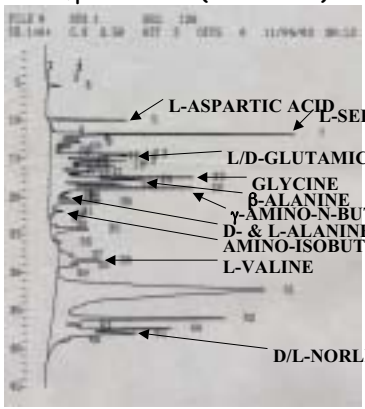
Only those instruments that demonstrate the detection of key target molecules such as amino acids in field-based studies at the required level of sensitivity should be considered for spacecraft payload packages.

Atacama Desert as Martian Soil Analog Chemical Laboratory

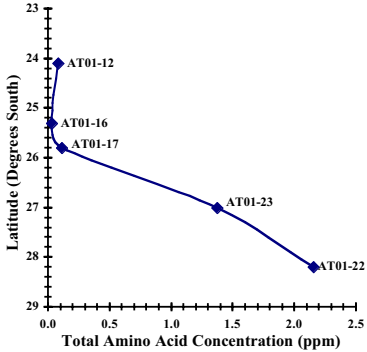
- **Chilean Atacama Desert is one of the driest sites on the planet (<0.5 mm H_2O/year).**
- **The transect from Lat 24˚ to 28˚ South at 69.5˚ West has been extensively studied.**
- **Some areas have unusual surface oxidation chemistry and organic soil concentrations at lab blank levels. Other areas show readily detected microbial and higher life forms.**

Laboratory Based Chiral Amino Acid Analyses of Atacama Samples

Sample AT01-22 (28.2° South)



Latitudinal Variation of Total Concentration of Amino Acids



Viking-type GCMS analyses of these same samples failed to detect the presence of amino acids, expect possible traces of ethylamine from alanine decomposition in sample AT01-22 (Navarro-González, personal communication).

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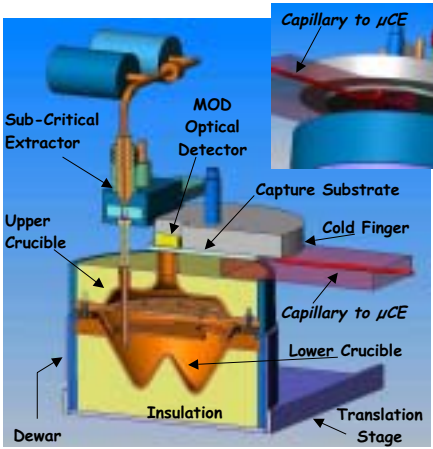
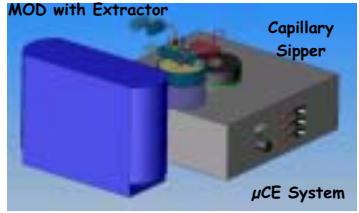
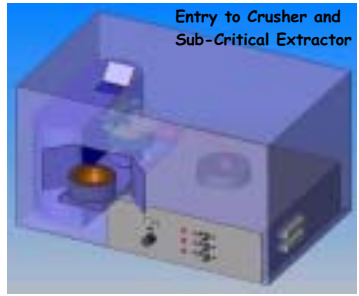
Integrated MOD/μCE Field Prototype







This instrument package will soon be tested at field sites such as the Atacama desert. This instrument concept was recently judged as 'excellent" and will be considered as part of the instrument payload on the ESA 09 ExoMars mission.

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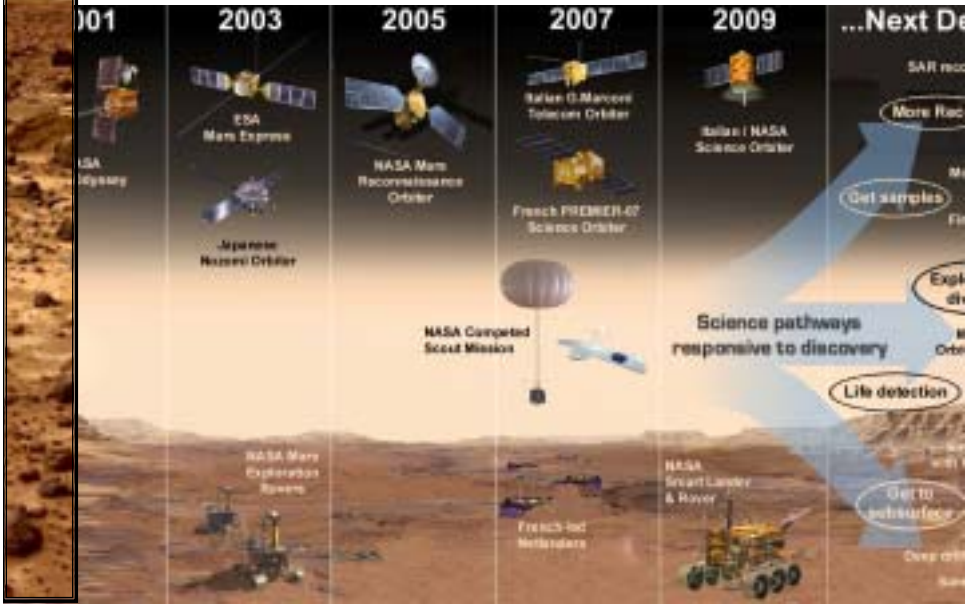
Mars Exploration Program



The molecules of life

Amino acids in a typical bacterial cell. In some bacteria, D-aspartic acid, D-glutamic acid and D-alanine are present but the overall D/L ratio for these amino acids is < 1.

Amino acids in *E. coli.* (g/cell)*

aspartic acid	1.9×10^{-14}
glutamic acid	3.1×10^{-14}
serine	1.2×10^{-14}
glycine	3.0×10^{-14}
alanine	2.2×10^{-14}
valine	1.0×10^{-14}
total listed amino acids	1.2×10^{-13}

***The listed amino acids account for ~75 % of the protein-bound amino acids**

The molecules of life

On a weight bases, amino acids are the most abundant single class of molecules in a typical bacterial cell. The next most abundant are the nucleobases associated with DNA and RNA.

Amino acids in *E. coli.* cells (g/cell)*

aspartic acid	**1.9×10^{-14}**
glutamic acid	**3.1×10^{-14}**
serine	**1.2×10^{-14}**
glycine	**3.0×10^{-14}**
alanine	**2.2×10^{-14}**
valine	**1.0×10^{-14}**
Total	**1.2×10^{-13}**

***Nucleobases, mainly from RNA, are about 1/10 as abundant as amino acids**