

Life Detection Instrumentation in a Golden Age of Astrobiology

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The past decade has seen...

- ❖ The first detection of organics on Mars
- ❖ Oceans at Enceladus and Europa
- ❖ Evidence of subsurface water/ice on Titan
- ❖ Correlation of geological activity with abundant organics on Ceres
- ❖ Advancing understanding of the limits on habitability in Earth's extrema
- ❖ Explosion of exoplanet detections, on the cusp of characterizing environments

A Golden Age for Astrobiology!



March 7, 2018

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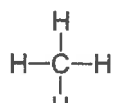
The Challenge: Identifying Life

Reasonable Doubt

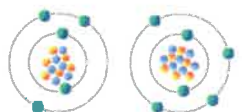
(or processed beyond attribution)

Suggestive

Life Signature



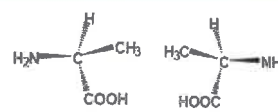
Food



Isotopes



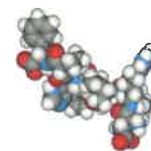
Cell-like Structures



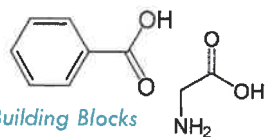
L-alanine

D-alanine

Enantiomeric Excess



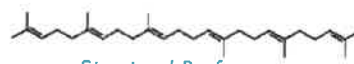
Complex & Informational Polymers



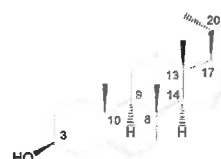
Building Blocks



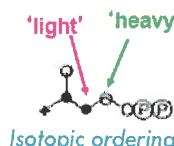
Biofabrics



Structural Preferences



Structural Selectivity



Isotopic ordering

✓ Multiple life signatures provide high confidence

✓ Abiotic signatures provide important context

Constraints on the Measurement

The chance of encountering a sign of life

SENSITIVITY

The environmental factors working against a detection
operational
programmatic

RUGGEDNESS

Preserving integrity during the acquisition and analysis

ROBUSTNESS

Constraints on the Method

Preparation

- minimize fractionation
- minimize degradation
- minimize contamination

Analysis

- discovery-capable across range of biosignatures
 - driven by quality, robustness of signature(s)
 - establishes environmental context

Interpretation

- integrate suite of findings
- quantify sources of noise
- assess for false positives

Explorer 17 Earth (1963)
GSFC and Cons'd Sys Corp



Apollo 17/LACE 1973
UT Dallas



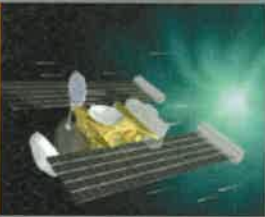
Pioneer Venus/ONMS 1978-92
GSFC, University of Michigan



Galileo Jupiter probe 1995-2003
GSFC, University of Michigan



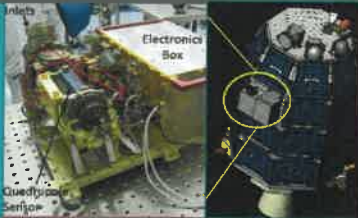
Stardust/NCIDA 2002-11
MPS



Cassini 1999-2017
GSFC, U Mich, SwRI



LADEE/INMS 2013-14
GSFC, Univ of Michigan



MAVEN NGIMS 2014-present
GSFC, University of Michigan



Europa Clipper 2024-30th
SwRI

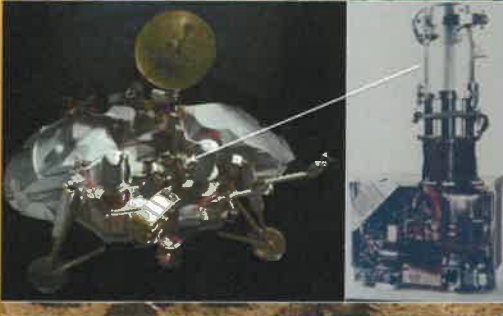


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Viking Landers Mars 1976-1980/81
MIT, Beckman, Perkin Elmer, & team



MSL/JAM Mars surface 2011-present
GSFC, U Paris, JPL, U Mich, and team



Cassini/Huygens Probe Titan 2005
GSFC, LISA, U Mich, and team



110-0 km
3rd Parachute
(2h13min)

Phoenix Lander/TEGA 2008
UT Dallas, U Arizona, JSC



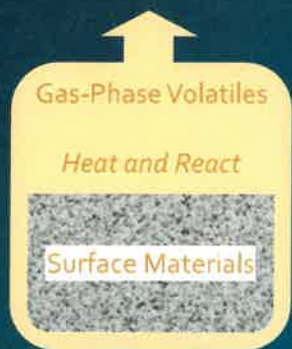
Thermal and Evolved Gas Analyzer (TEGA)

ExoMars/MOMA Mars surface 2020
MPS (Ger.), GSFC, LISA (Fr.), & team



Organics Analysis for Life Detection

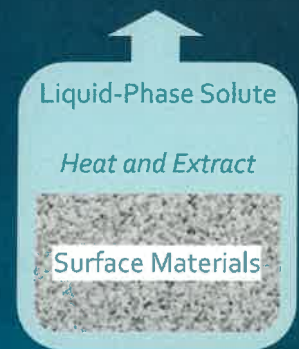
SENSITIVITY.....requires careful handling of the **sample**



Derivatization + Heating



Laser Desorption/Ionization



Liquid Extraction

Organics Analysis for Life Detection

SENSITIVITY.....requires careful handling of the **sample**

e.g., SAM, MOMA



Derivatization + Heating

e.g., MOMA and future



Laser Desorption/Ionization

e.g., ARADS/SCWE



Liquid Extraction

Organics Analysis for Life Detection

SENSITIVITY.....requires careful handling of the **signal**

MASPEX
Cryotrap

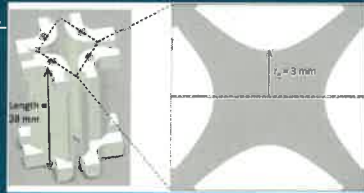


[future]
Enrichment Cell

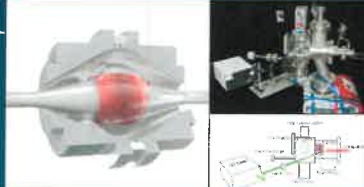


Preconcentration

MOMA
Linear Ion Trap



[future]
CosmOrbitrap

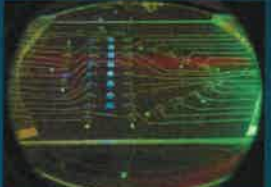


Ion Accumulation

[future]
Dual Ion Polarity



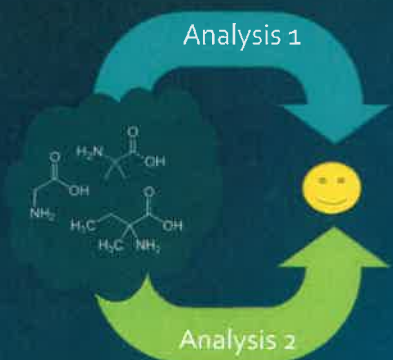
[future]
CE-LIF



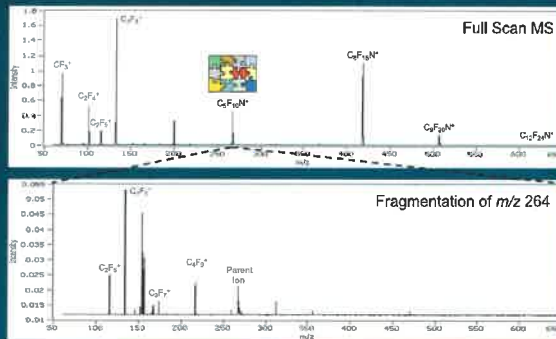
Detector Optimization

Organics Analysis for Life Detection

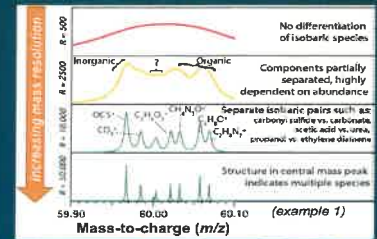
ROBUSTNESS.....requires careful assignment of the data features



Redundant Measurements



Tandem Techniques



High Resolving Power

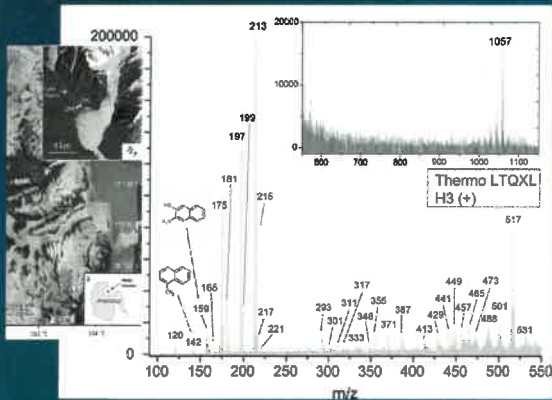


Rosetta/Rosina
Clipper/MASPEX

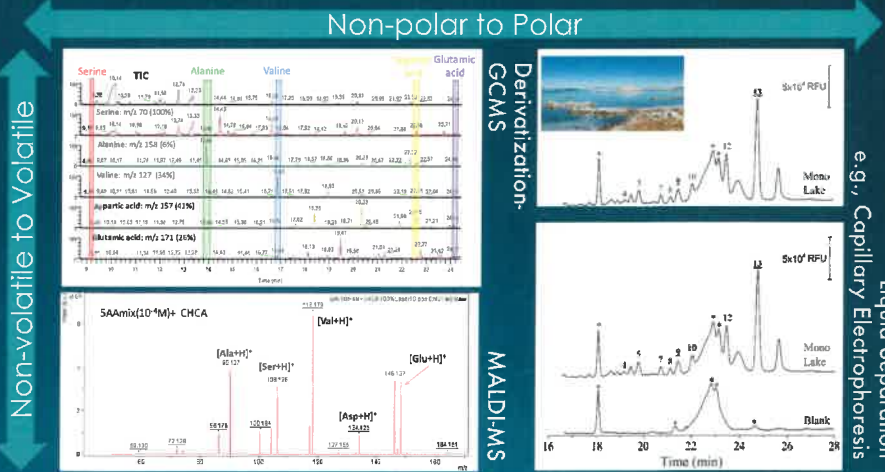
Organics Analysis for Life Detection

RUGGEDNESS.....requires ability to learn from non-idealities

J.L. Bishop et al. / Icarus 224 (2013) 309–325



Instrument [e.g., Mass] Range
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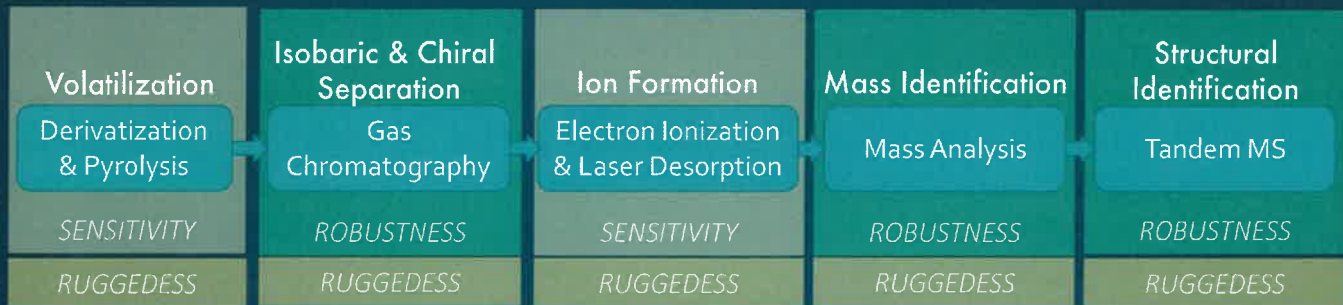
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Complement of Measurements

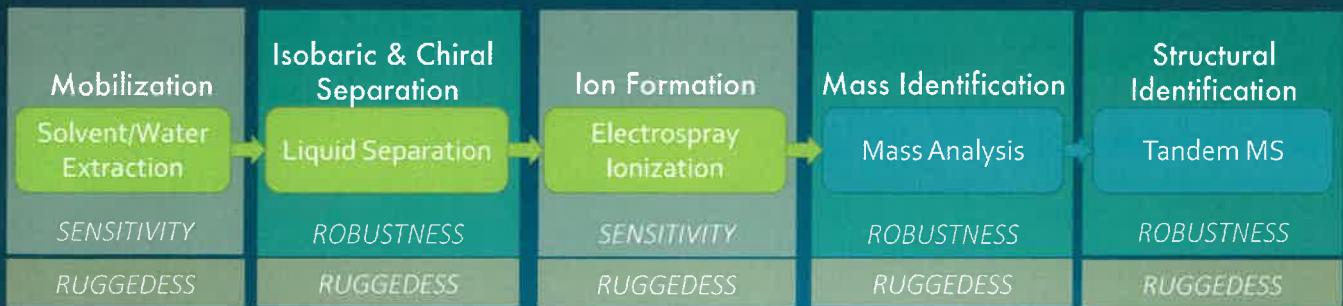
Organics Analysis for Life Detection

New Directions

e.g., MOMA



Future Capability



New Advances in Life Detection

Oligonucleotide Sequencing

International Space Station
August 2016



Oxford Nanopore Technologies/MinION

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Antarctic Dry Valleys
(S. Johnson et al.)

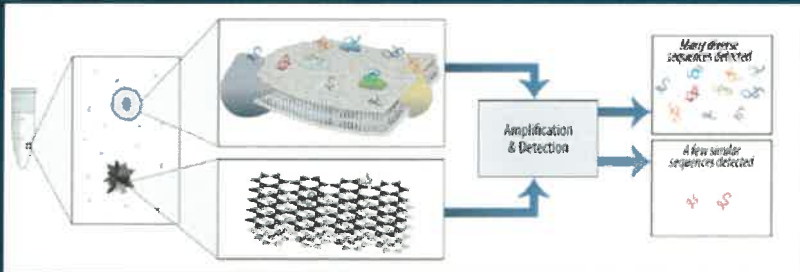


Atacama Desert
(K. Bywaters et al.)

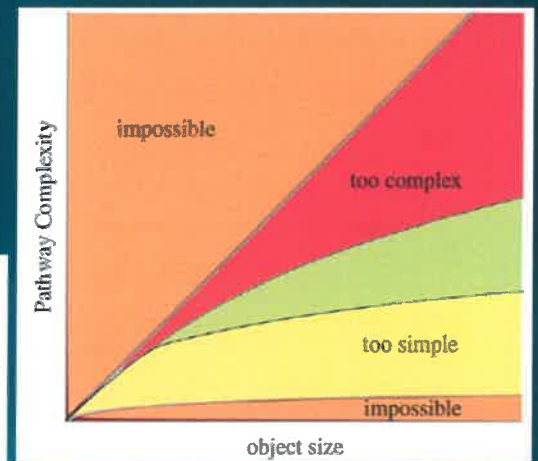
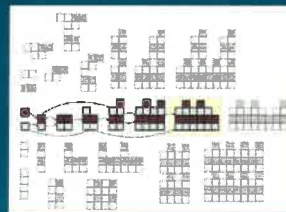
Field Testing

New Advances in Life Detection

Agnostic Approaches to Identifying Life Signatures



Template-mediated Fingerprinting of Nonterran Polymers
S. Johnson et al. (2018) LPSC 2294



Identifying Biosignatures Using Pathway Complexity
Marshall et al., (2017) *Phil Trans Royal Soc* 375: 20160342

Closing Thoughts

There is a healthy interplay between

experiment ✦ analog work ✦ theory

Advances are underway in identifying complementary suites of Earth-informed, but not Earth-centric, life signatures

Portfolio of previous instruments reveals a general approach toward universal detection that will serve well the search for life

Targeted developments can leverage and supplement these instrument types to target theoretically robust agnostic biosignatures