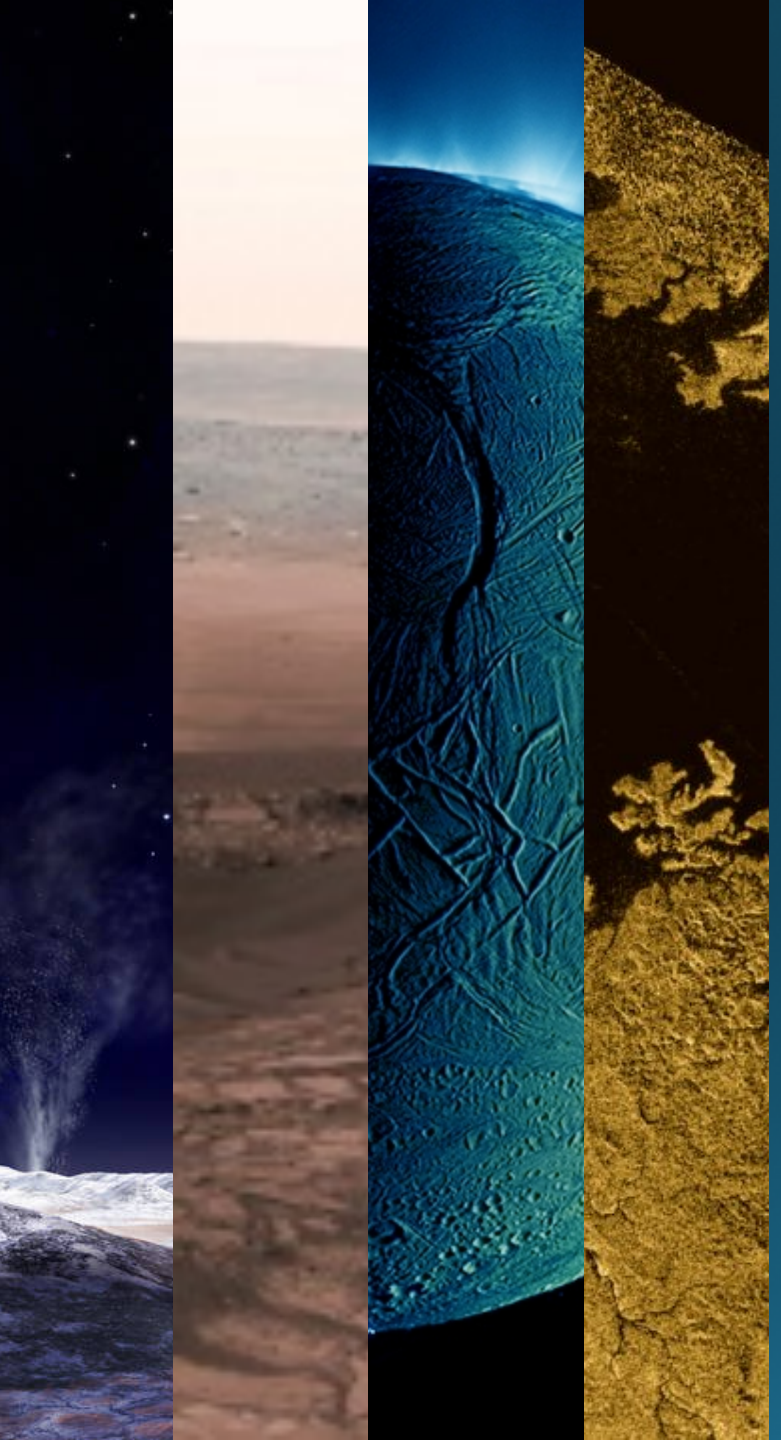


Life Detection Instrumentation in a Golden Age of Astrobiology

Stephanie A. Getty

Solar System Exploration Division

NASA Goddard Space Flight Center

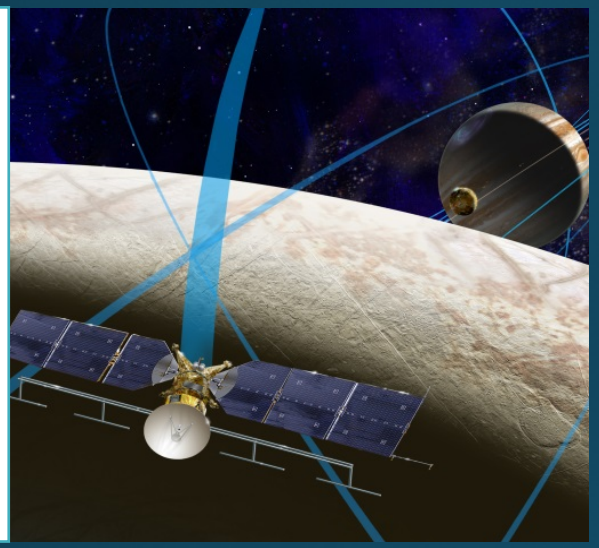
The past decade has seen…

- 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

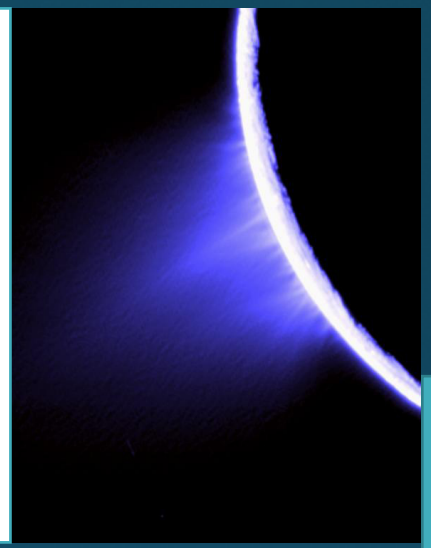
A Golden Age for Astrobiology!

Dawn @ Ceres ongoing

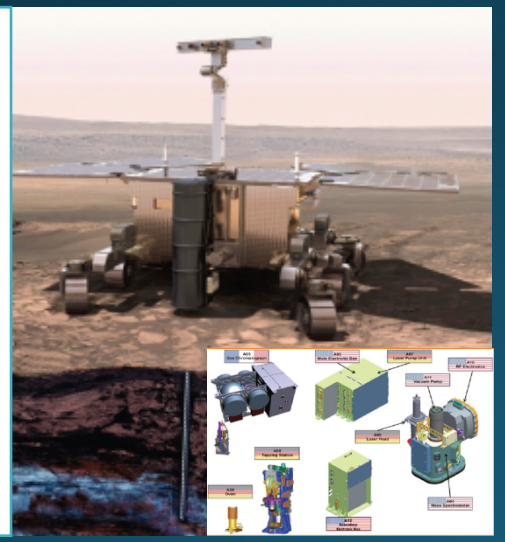
Europa Clipper launch 2022-ish



ELSAH @ Enceladus NF-4 Tech Demo



ExoMars launch 2020



Dragonfly @ Titan launch 2024-ish

Europa Lander launch mid-2020s

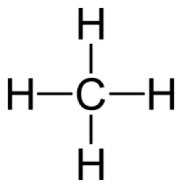
Ocean Worlds Program

New Frontiers Ocean Worlds

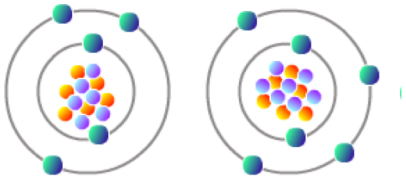
(Congressional Support!)

The Challenge: Identifying Life

Reasonable Doubt (or processed beyond attribution) — *Suggestive* — Life Signature

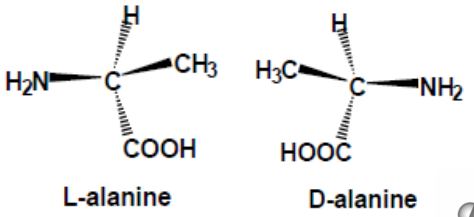


Food

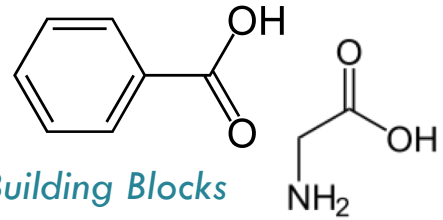


Isotopes

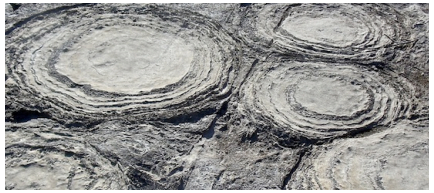
Cell-like Structures



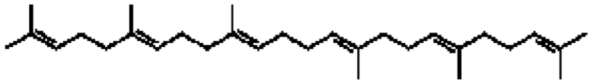
Enantiomeric Excess



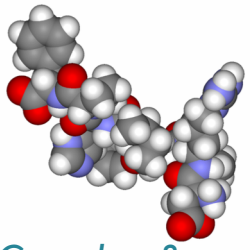
Building Blocks



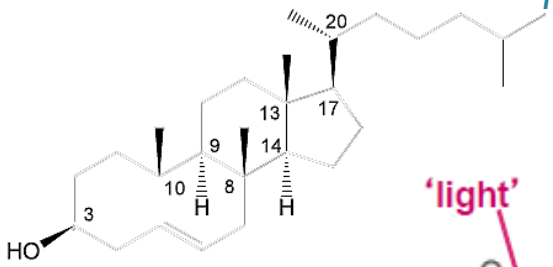
Biofabrics



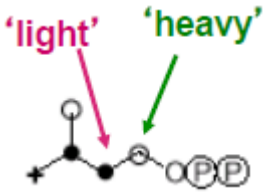
Structural Preferences



Complex & Informational Polymers



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/CIDA 2004-11
MPS

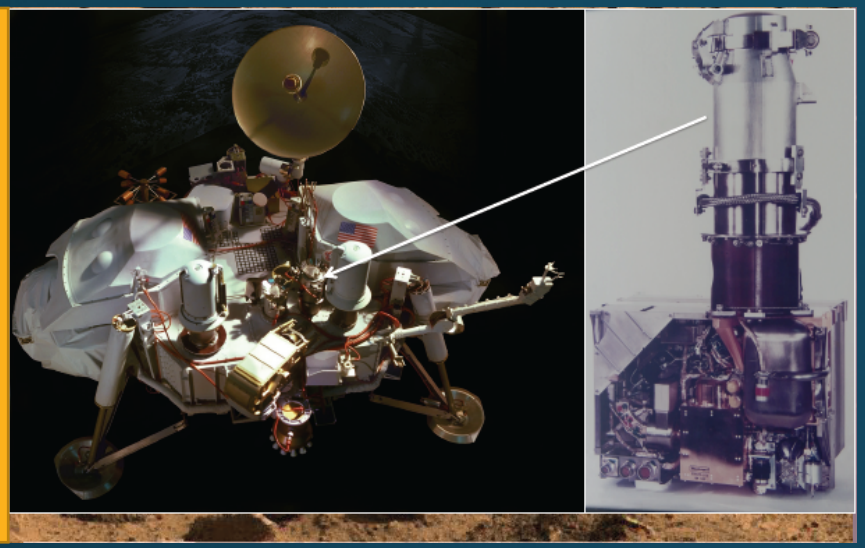
Cassini 1999-2017
GSFC, U Mich, SwRI

LADEE/INMS 2013-14
GSFC, Univ of Michigan

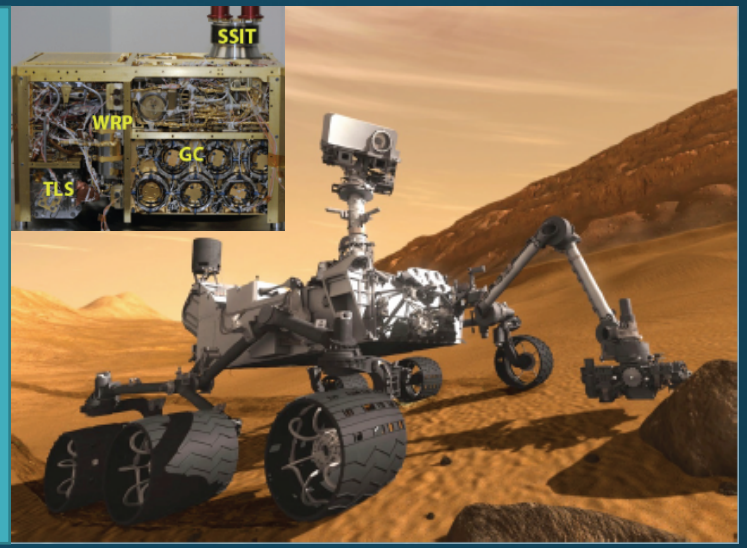
MAVEN NGIMS 2014-present
GSFC, University of Michigan

Europa Clipper 2024-ish
SwRI

Viking Landers Mars 1976-1980/82
MIT, Beckman, Perkin Elmer, & team

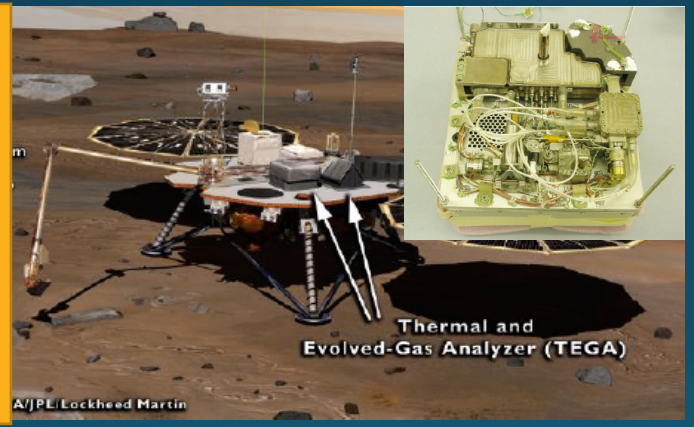


MSL/SAM Mars surface 2011-present
GSFC, U Paris, JPL, U Mich, and team

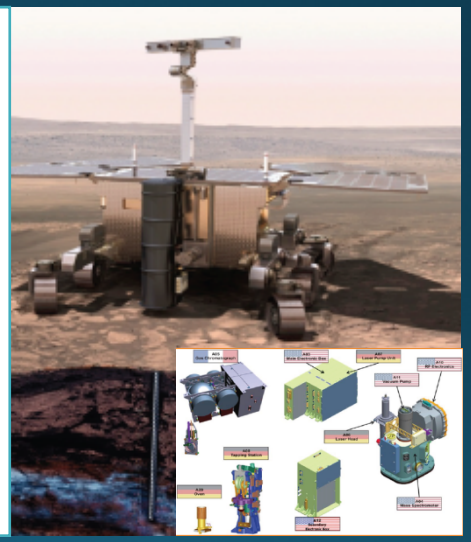


Cassini/Huygens Probe Titan 2005
GSFC, LISA, U Mich, and team

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

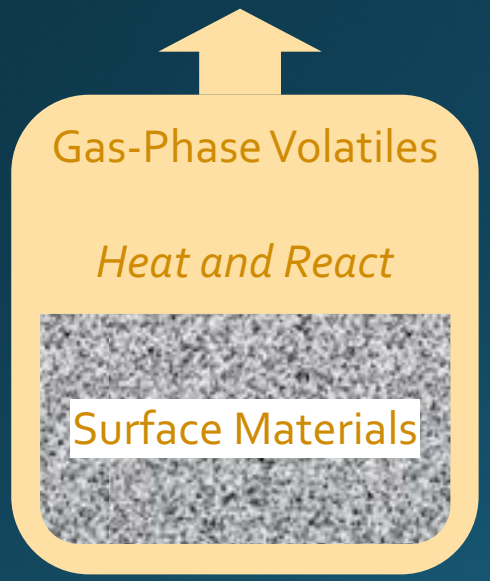


ExoMars/MOMA Mars surface 2020
MPS (Ger.), GSFC, LISA (Fr.), & team

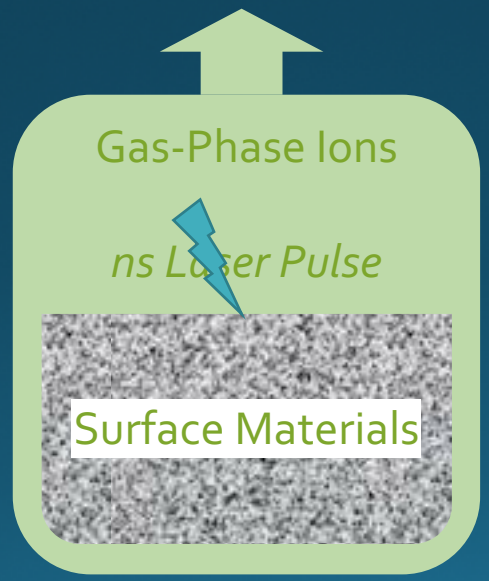


Organics Analysis for Life Detection

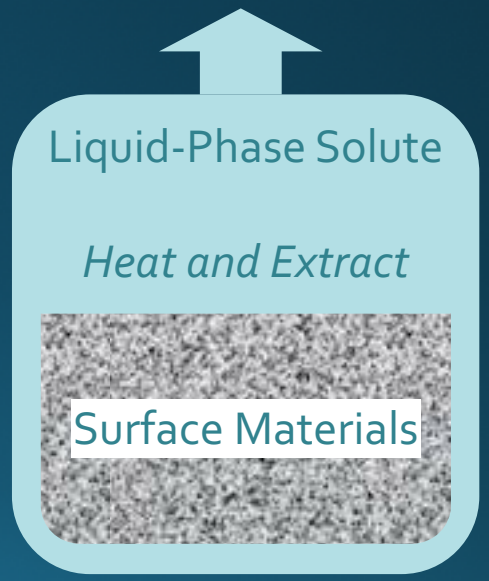
SENSITIVITY.....requires careful handling of the sample



Derivatization + Heating



Laser Desorption/Ionization



Liquid Extraction

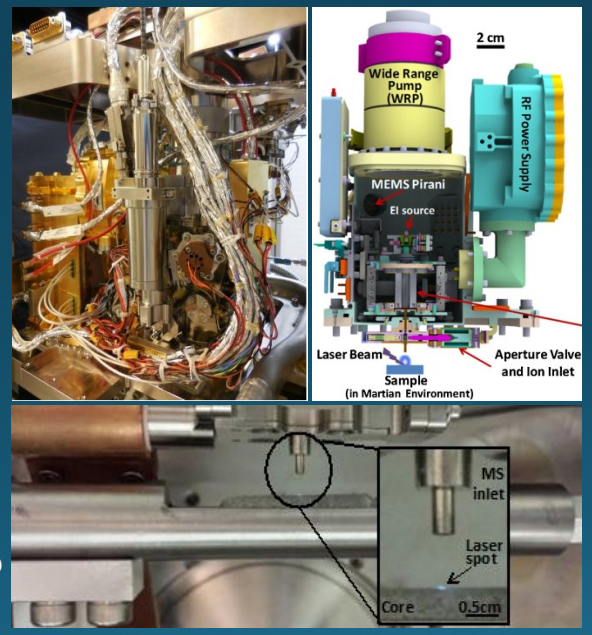
Organics Analysis for Life Detection

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

e.g., SAM, MOMA

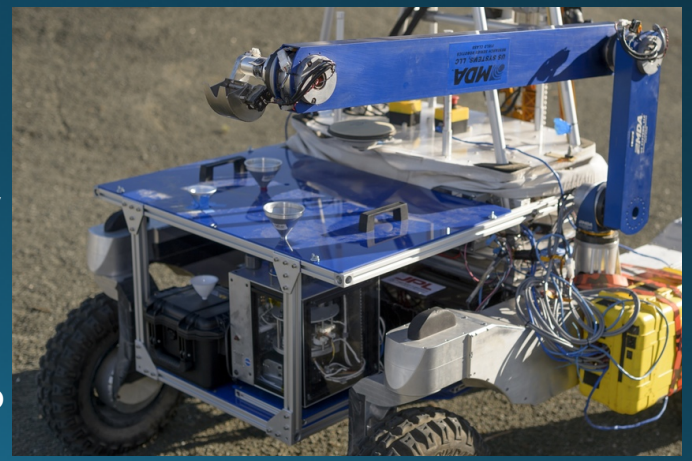
Derivatization + Heating

e.g., MOMA and future



Laser Desorption/Ionization

e.g., ARADS/SCWE



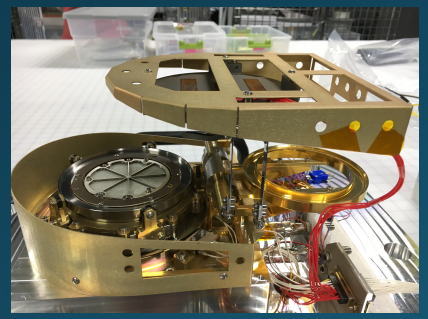
Liquid Extraction

Organics Analysis for Life Detection

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

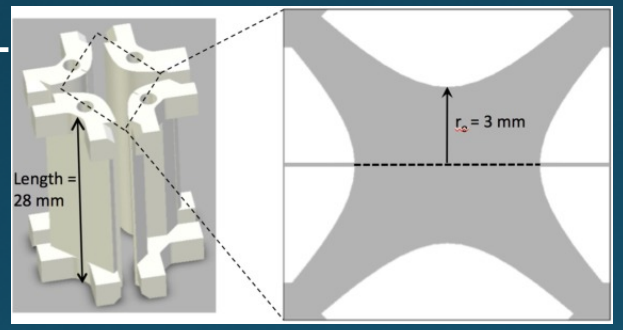
MASPEX Cryotrap

[future] Enrichment Cell

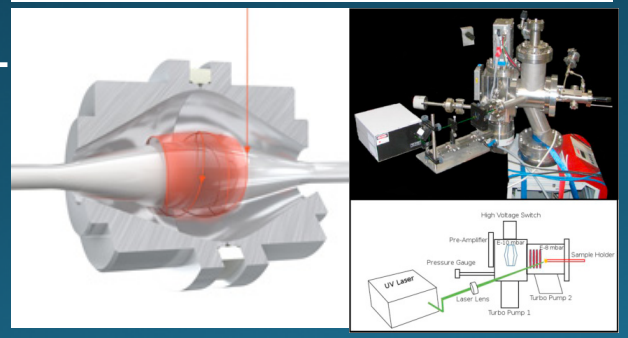


Preconcentration

MOMA Linear Ion Trap

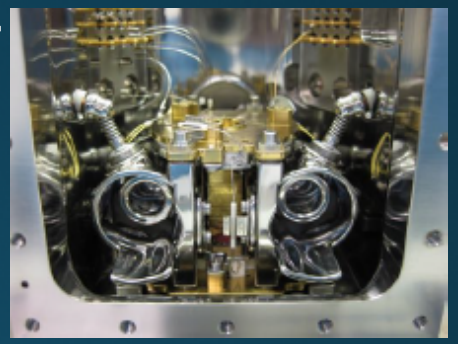


[future] CosmOrbitrap

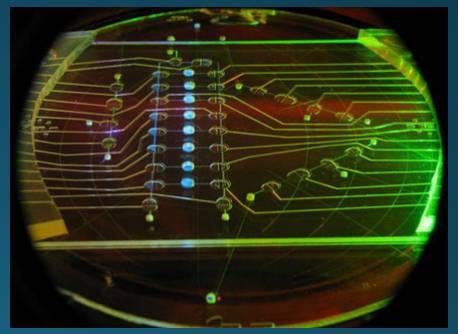


Ion Accumulation

[future] Dual Ion Polarity



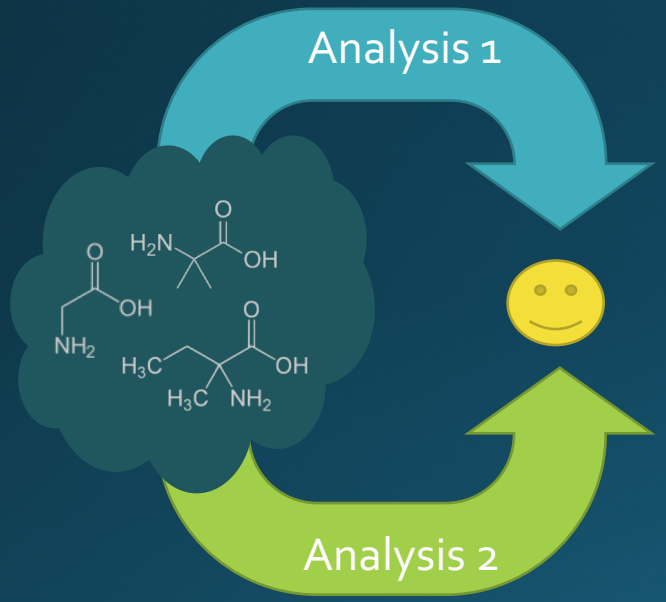
[future] CE-LIF



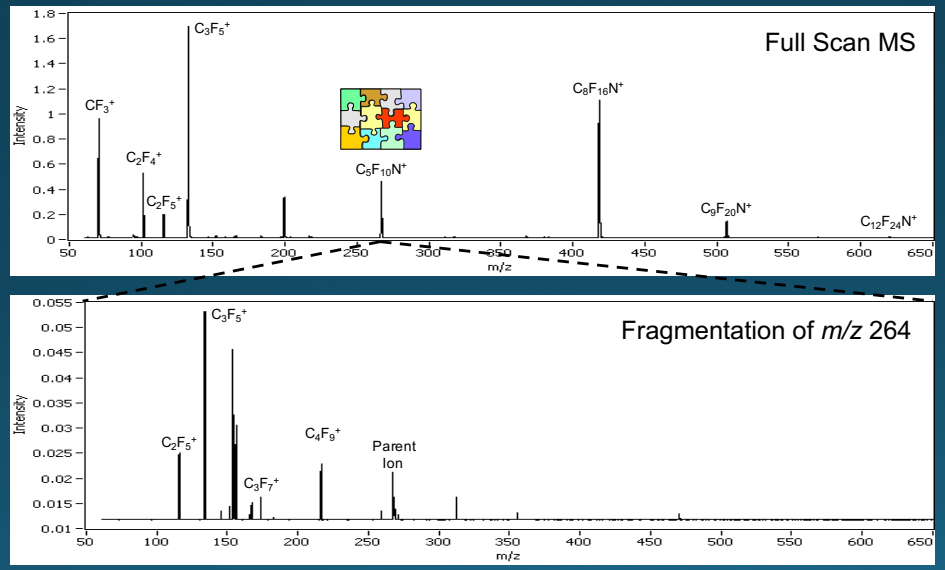
Detector Optimization

Organics Analysis for Life Detection

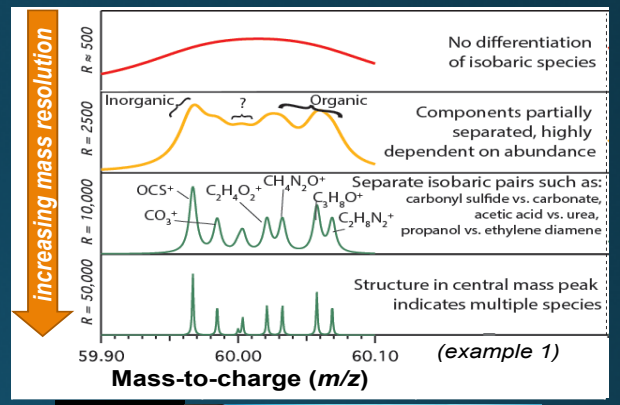
ROBUSTNESS.....requires careful assignment of the data features

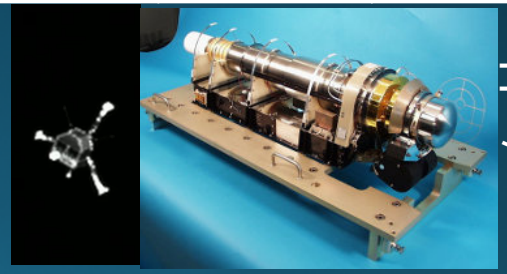


Redundant Measurements



Tandem Techniques





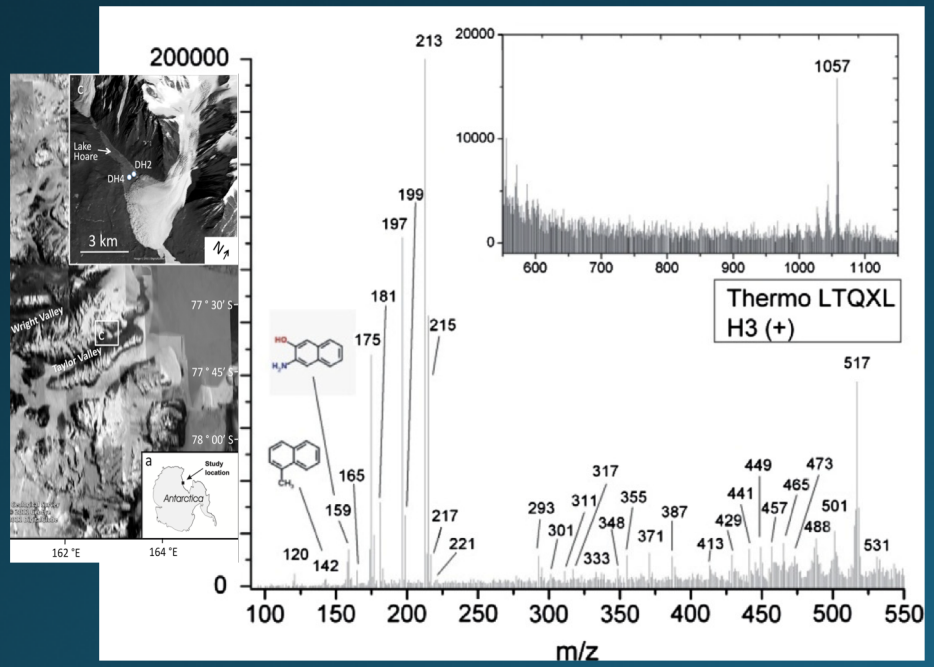
Rosetta/ROSINA
Clipper/MASPEX

High Resolving Power

Organics Analysis for Life Detection

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

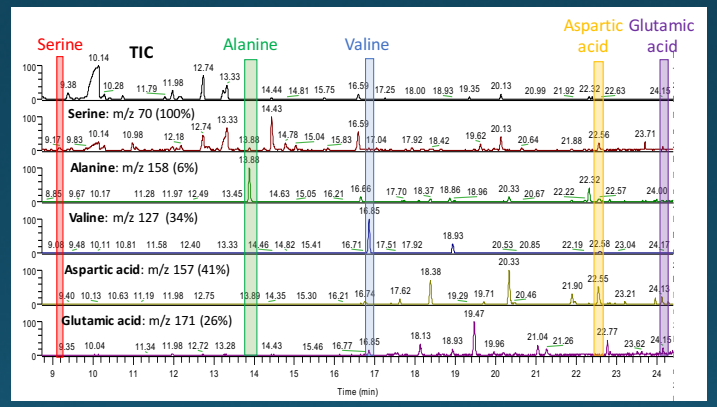
J.L. Bishop et al. / Icarus 224 (2013) 309–325



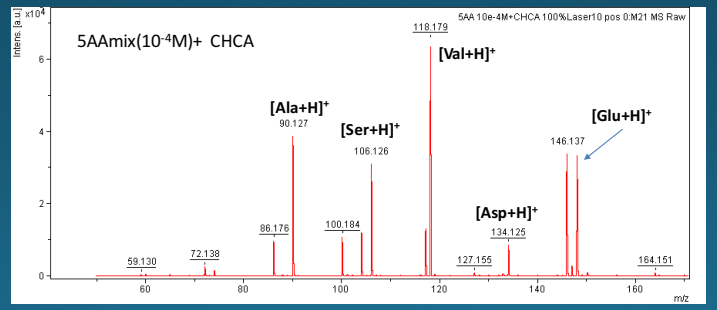
Instrument [e.g., Mass] Range

Non-polar to Polar

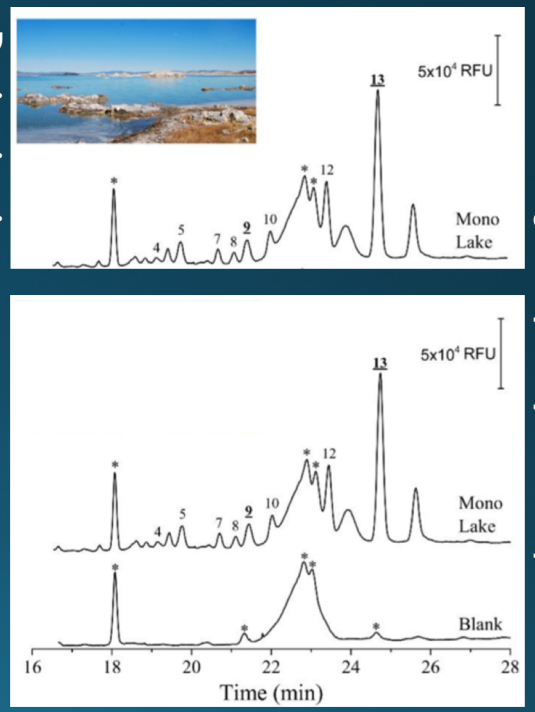
Non-volatile to Volatile



Derivatization-GCMS



MALDI-MS



Liquid Separation e.g., Capillary Electrophoresis

Complement of Measurements

Organics Analysis for Life Detection

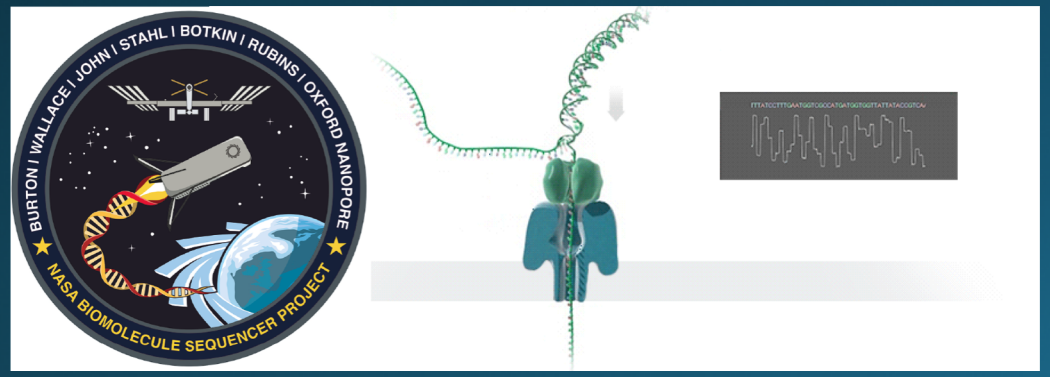
New Directions

	Volatilization	Isobaric & Chiral Separation	Ion Formation	Mass Identification	Structural Identification
e.g., MOMA	Derivatization & Pyrolysis	Gas Chromatography	Electron Ionization & Laser Desorption	Mass Analysis	Tandem MS
	SENSITIVITY	*ROBUSTNESS*	*SENSITIVITY*	*ROBUSTNESS*	*ROBUSTNESS*
	RUGGEDESS	*RUGGEDESS*	*RUGGEDESS*	*RUGGEDESS*	*RUGGEDESS*
Future Capability	Mobilization	Isobaric & Chiral Separation	Ion Formation	Mass Identification	Structural Identification
	Solvent/Water Extraction	Liquid Separation	Electrospray Ionization	Mass Analysis	Tandem MS
	SENSITIVITY	*ROBUSTNESS*	*SENSITIVITY*	*ROBUSTNESS*	*ROBUSTNESS*
	RUGGEDESS	*RUGGEDESS*	*RUGGEDESS*	*RUGGEDESS*	*RUGGEDESS*

New Advances in Life Detection

Oligonucleotide Sequencing

International Space Station
August 2016



Oxford Nanopore Technologies/MinION

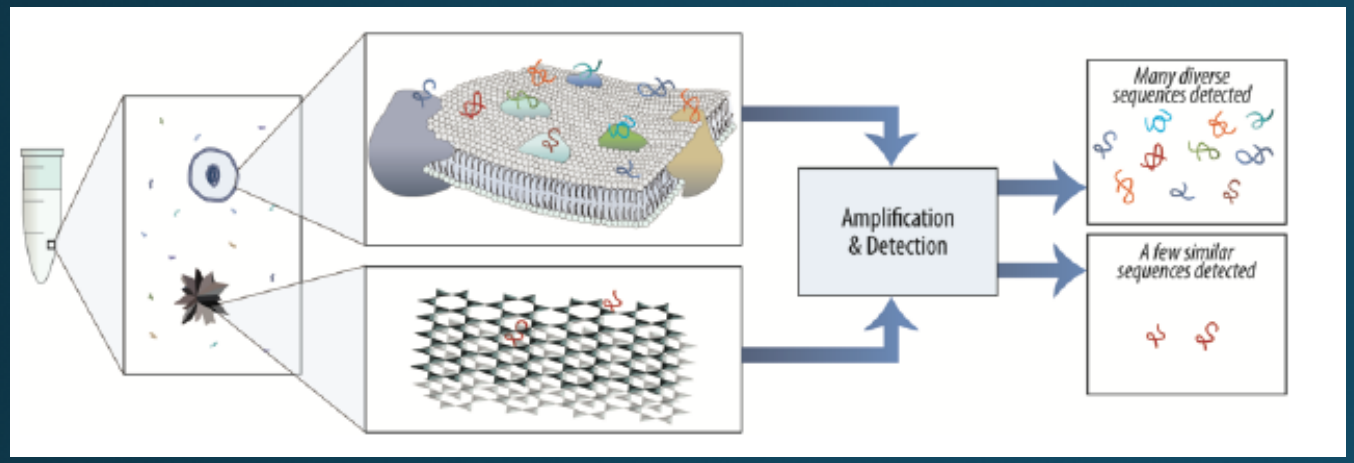
Field Testing

Antarctic Dry Valleys
(S. Johnson et al.)

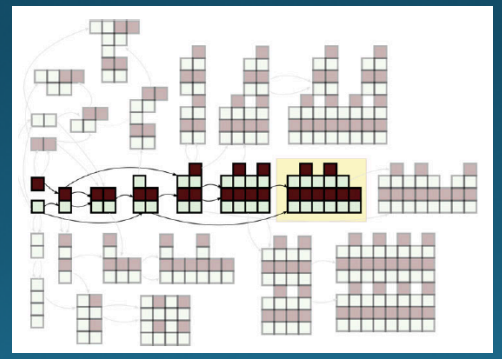
Atacama Desert
(K. Bywaters et al.)

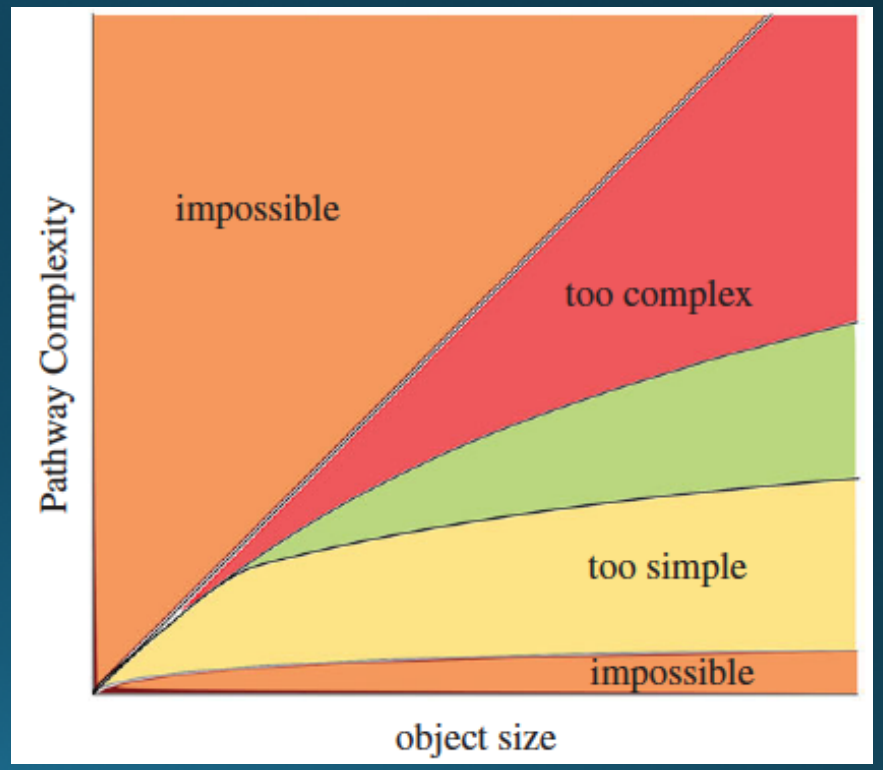
New Advances in Life Detection

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