Life Detection Instrumentation in a Golden Age of Astrobiology

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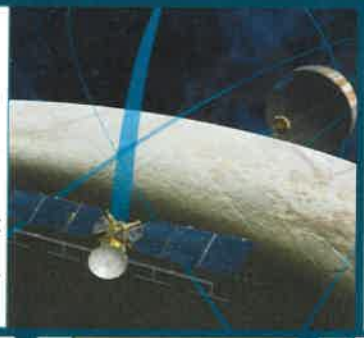
The past decade has seen…

- 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!

Dawn @ Ceres ongoing

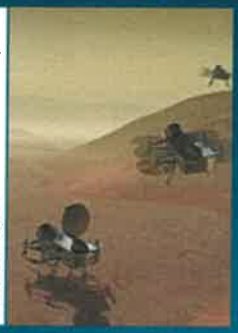
Europa Clipper launch 2022-ish



ELSAH @ Enceladus NF-4 Tech Demo

ExoMars launch 2020

Dragonfly @ Titan launch 2024-ish



Europa Lander launch mid-2020s

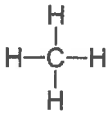
Ocean Worlds Program

New Frontiers Ocean Worlds

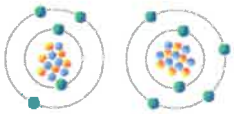
(Congressional Support!)

The Challenge: Identifying Life

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

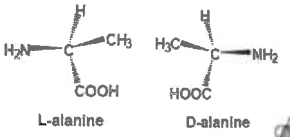


Food

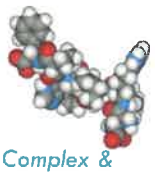


Isotopes

Cell-like Structures

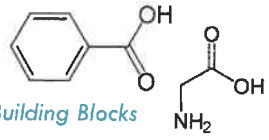


Enantiomeric Excess



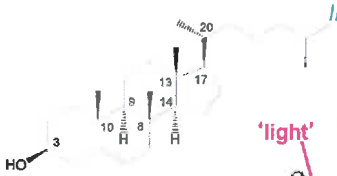
Complex & Informational Polymers

Structural Preferences

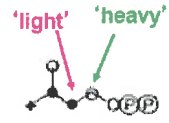


Building Blocks

Biofabrics



Structural Selectivity



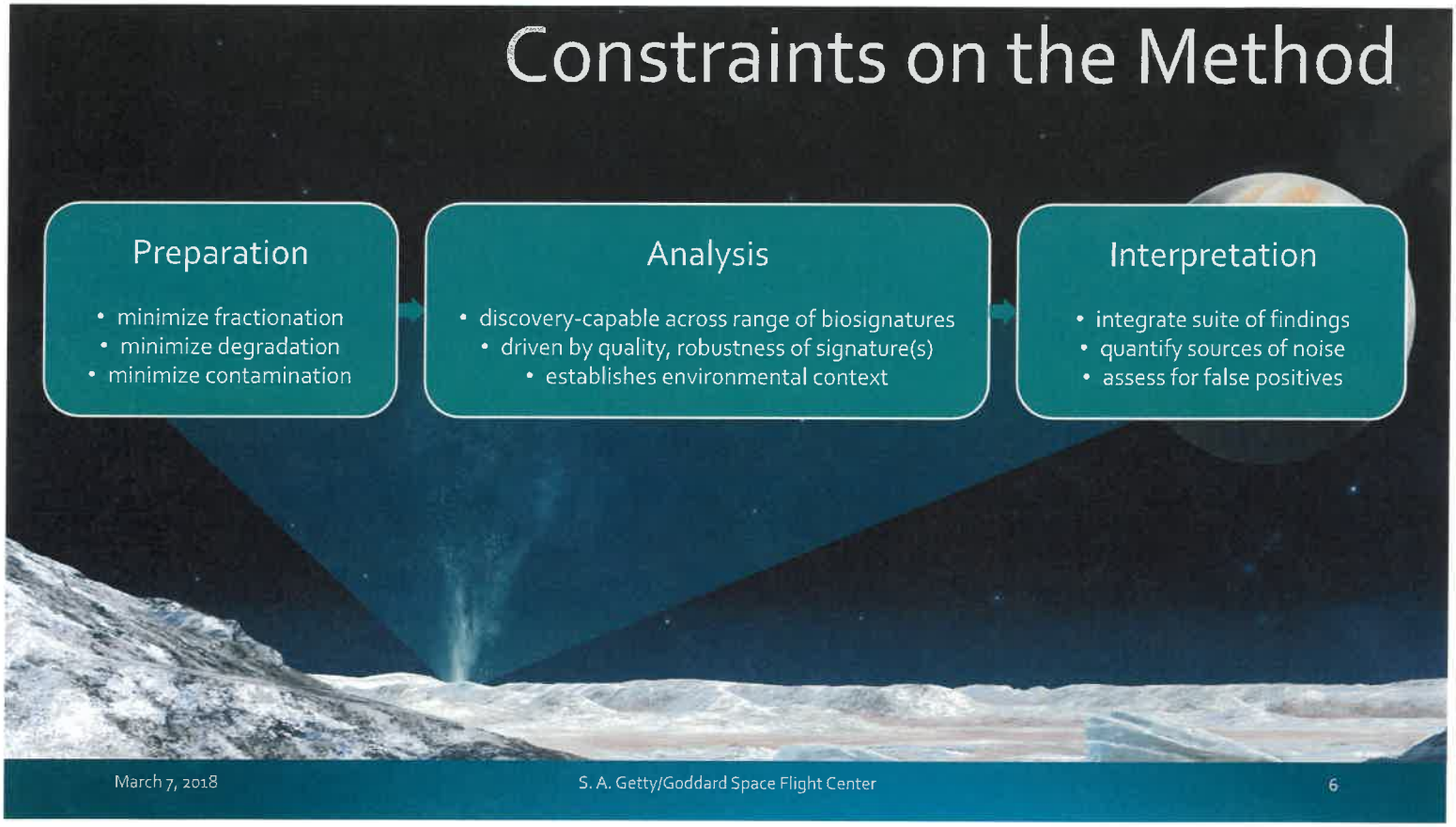
Isotopic ordering

- ✓ **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

S. A. Getty/Goddard Space Flight Center

March 7, 2018

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

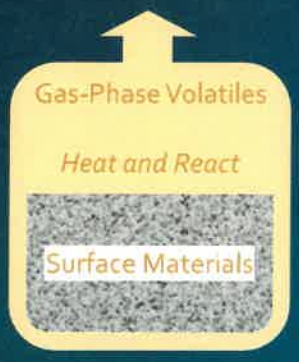
Cassini/Huygens Probe Titan 2005
GSFC, LISA, U Mich, and team

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

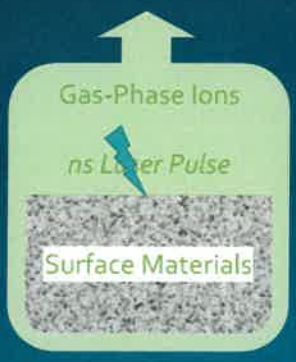
ExoMars/MOMA Mars surface 2020
MPS (Ger.), GSFC, LISA (Fr.), & team

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

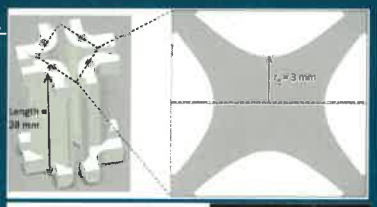
SENSITIVITY.....requires careful handling of the signal

MASPEX Cryotrap

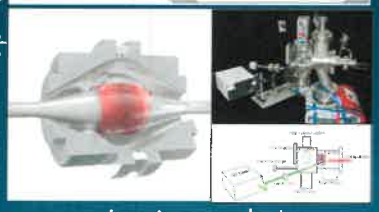
[future] Enrichment Cell

Preconcentration

MOMA Linear Ion Trap



[future] CosmOrbitrap



Ion Accumulation

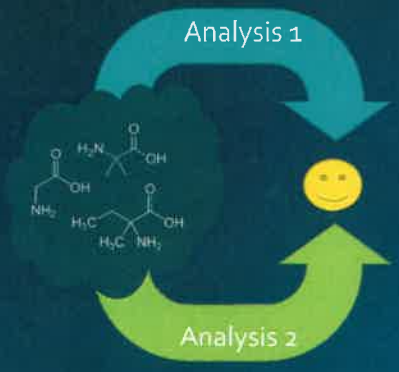
[future] Dual Ion Polarity

[future] CE-LIF

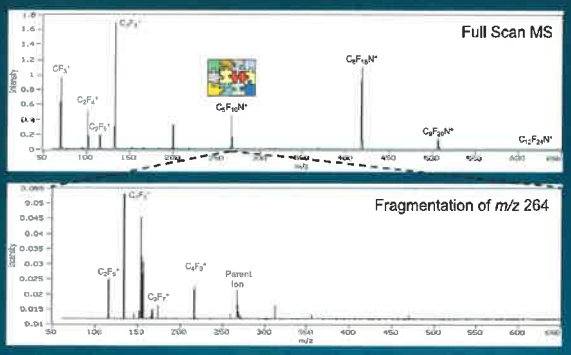
Detector Optimization

Organics Analysis for Life Detection

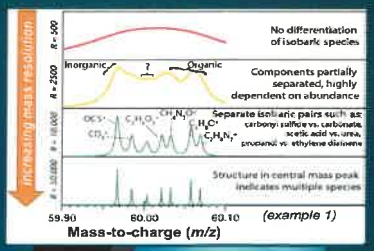
ROBUSTNESS.....requires careful assignment of the data features



Redundant Measurements



Tandem Techniques



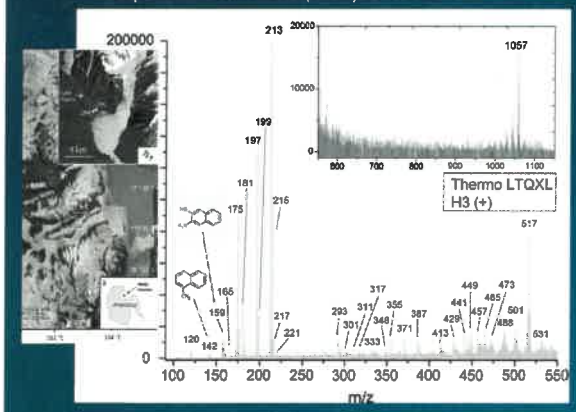
Rosetta/ROSINA Clipper/MASPEX

High Resolving Power

Organics Analysis for Life Detection

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

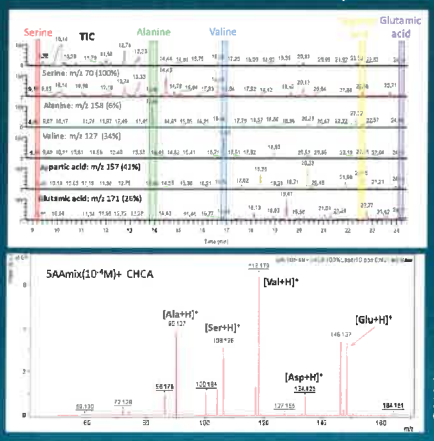
J.L. Bishop et al. / Icarus 224 (2013) 309–325



Instrument [e.g., Mass] Range

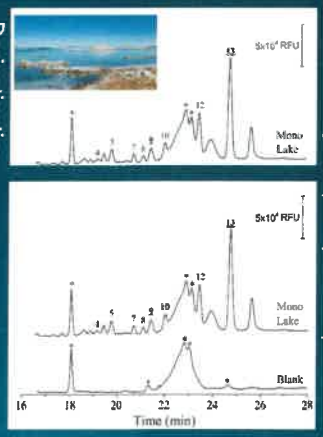
Non-volatile to Volatile

Non-polar to Polar



Derivatization-GCMS

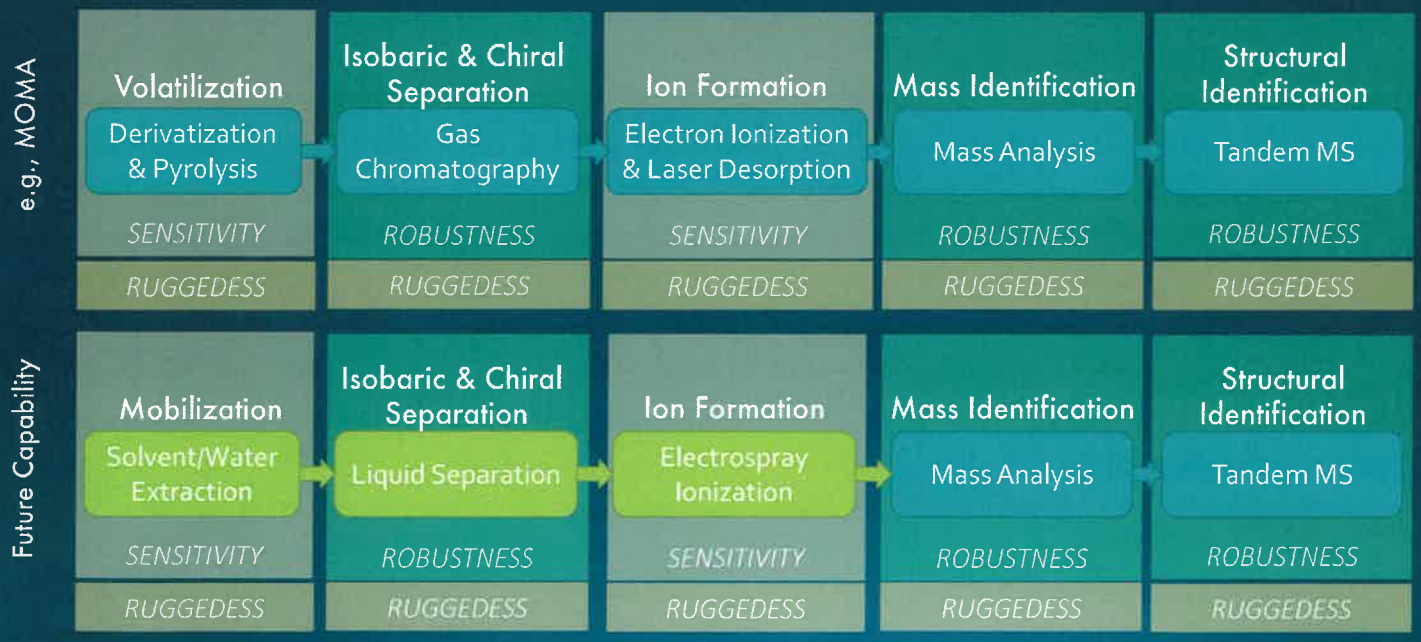
MALDI-MS



Liquid Separation e.g., Capillary Electrophoresis

Complement of Measurements

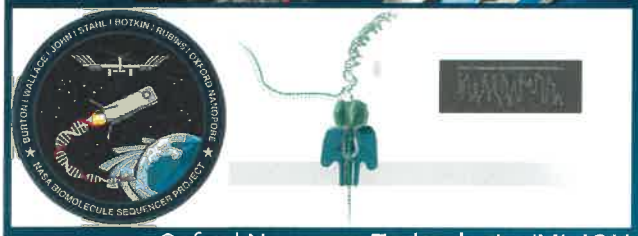
Organics Analysis for Life Detection
New Directions



New Advances in Life Detection

Oligonucleotide Sequencing

International Space Station
August 2016



Oxford Nanopore Technologies/MinION

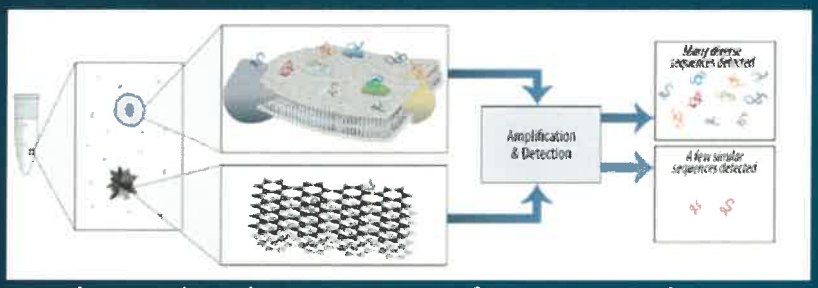
Field Testing

Antarctic Dry Valleys
(S. Johnson et al.)

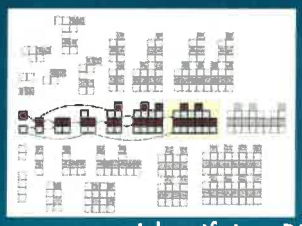
Atacama Desert
(K. Bywaters et al.)

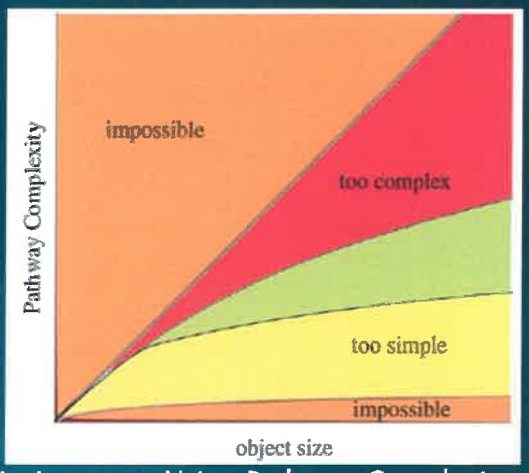
New Advances in Life Detection

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