Development of a Miniature Dual-Source Linear Ion Trap Mass Spectrometer for the ExoMars Rover Mission

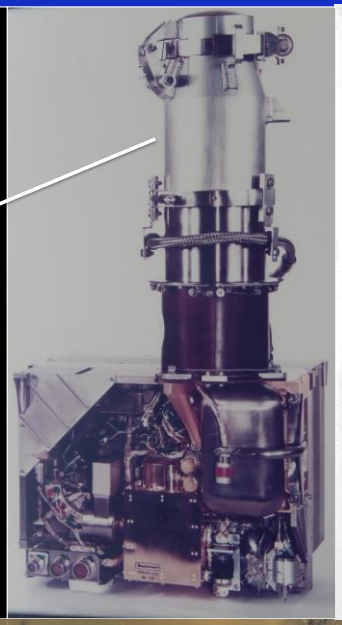
Will Brinckerhoff
Friso van Amerom
Ryan Danell
Veronica Pinnick
Ricardo Arevalo, Jr.
Xiang Li
Stephanie Getty
Andrej Grubisic
Lars Hovmand
Paul Mahaffy
Fred Goesmann
Francois Raulin

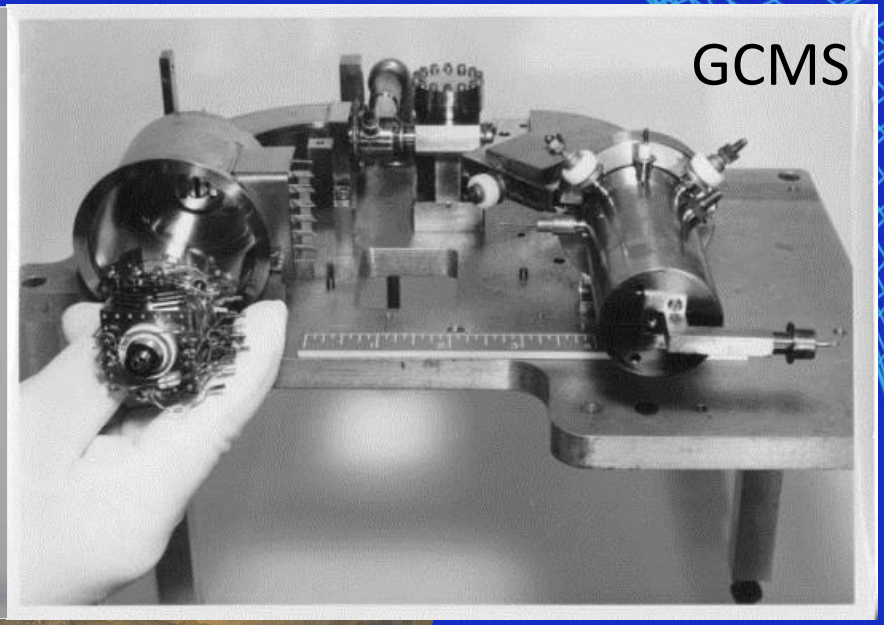
and the whole MOMA Team!

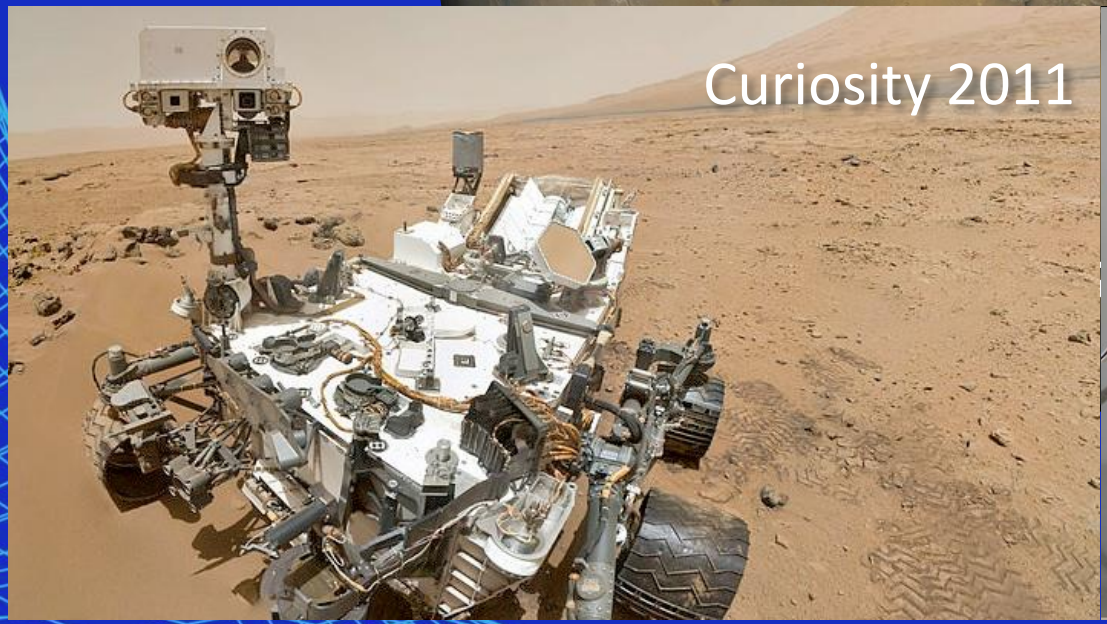
HEMS 2015 : Monday, September 14

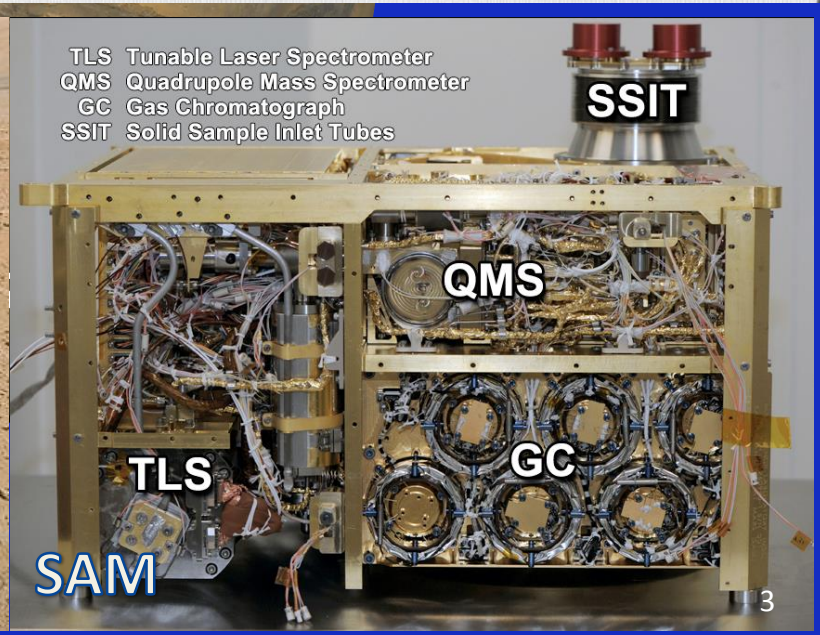
The Planet: Mars

The Planet: Mars

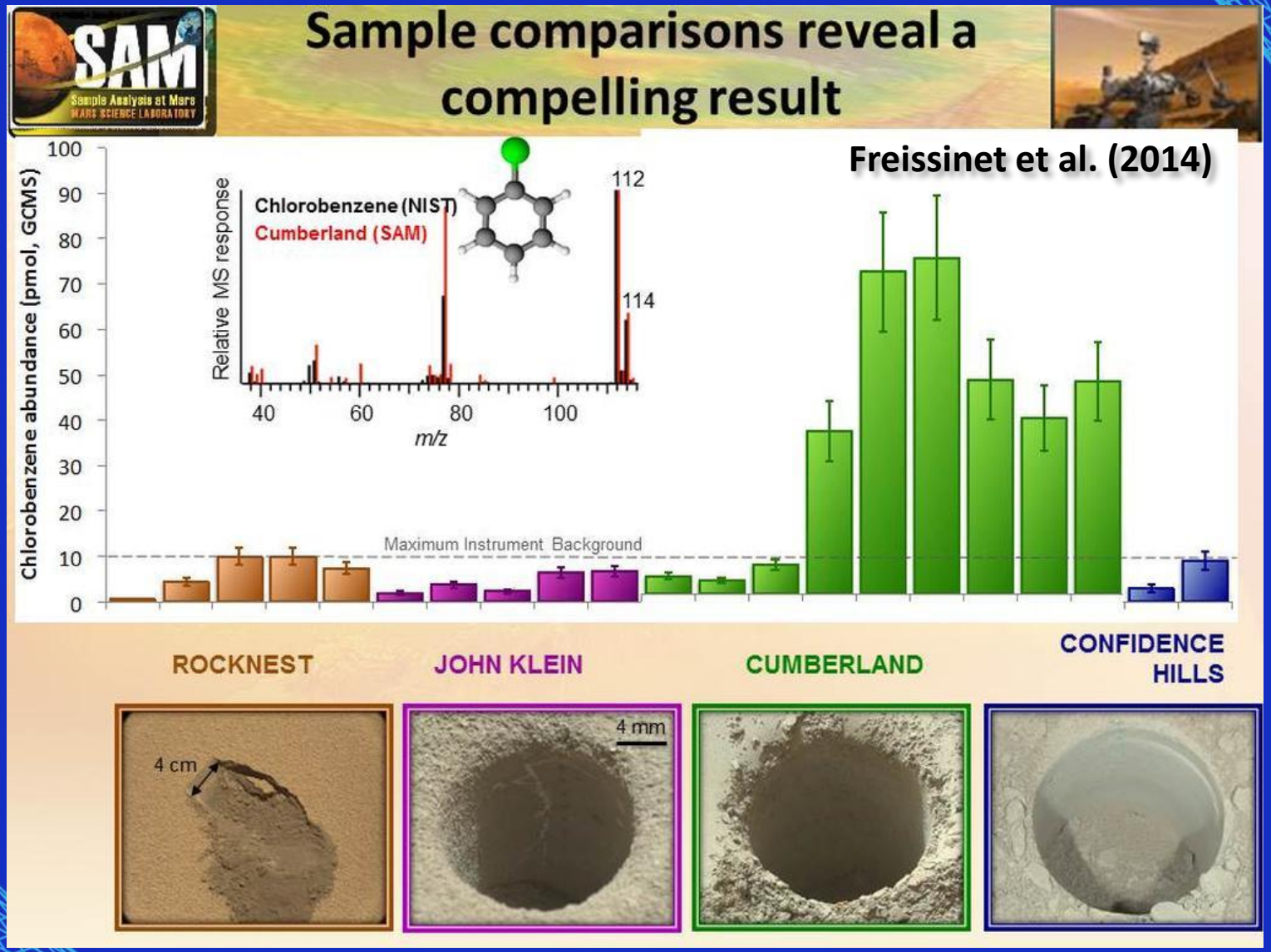








There's organics in them thar hills!



The Mission: ExoMars

ESA-Roscosmos mission

Launch: May, 2018

Mass: 310 kg

Power: solar arrays

Duration: 218 sols

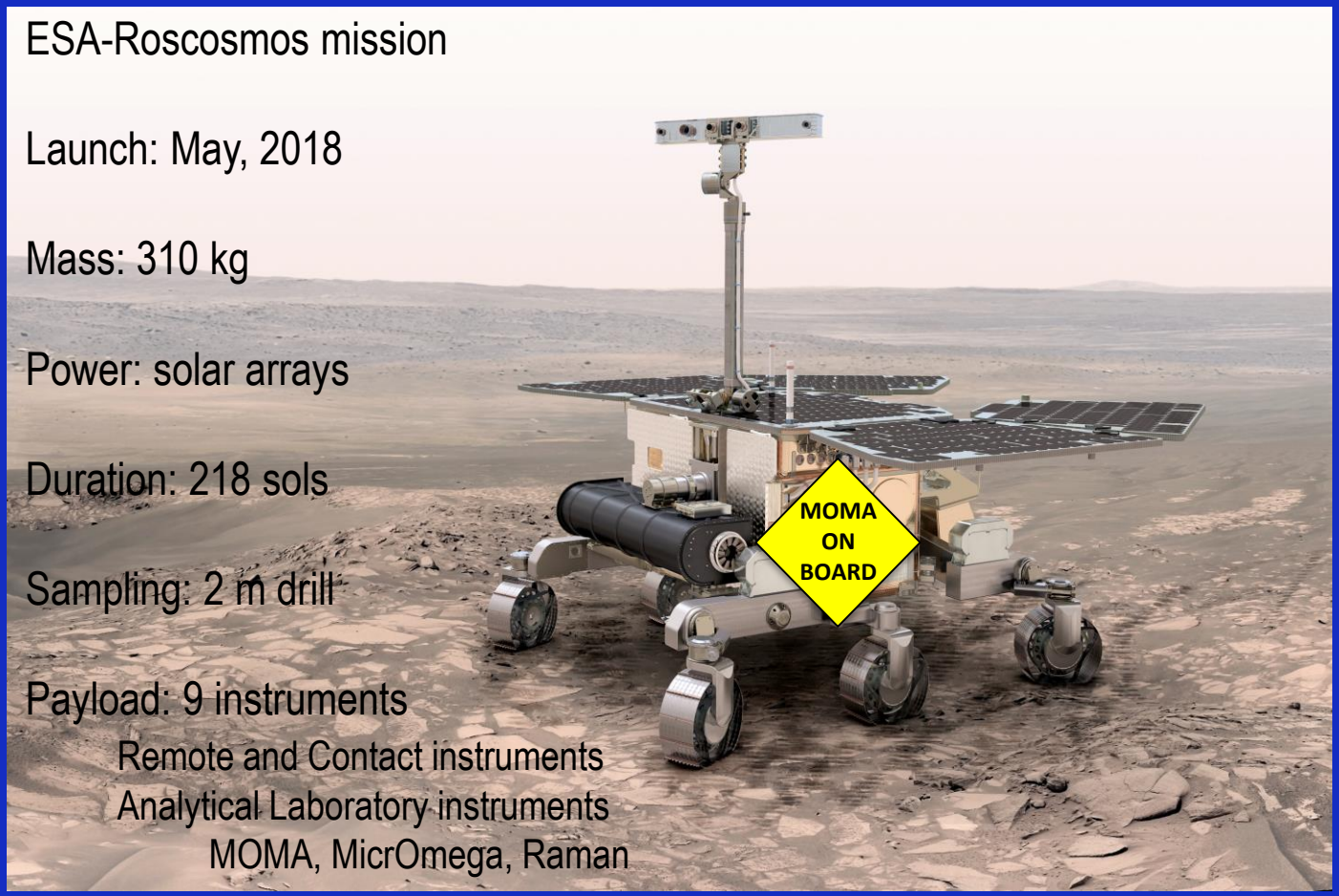
Sampling: 2 m drill

Payload: 9 instruments

Remote and Contact instruments

Analytical Laboratory instruments

MOMA, MicrOmega, Raman



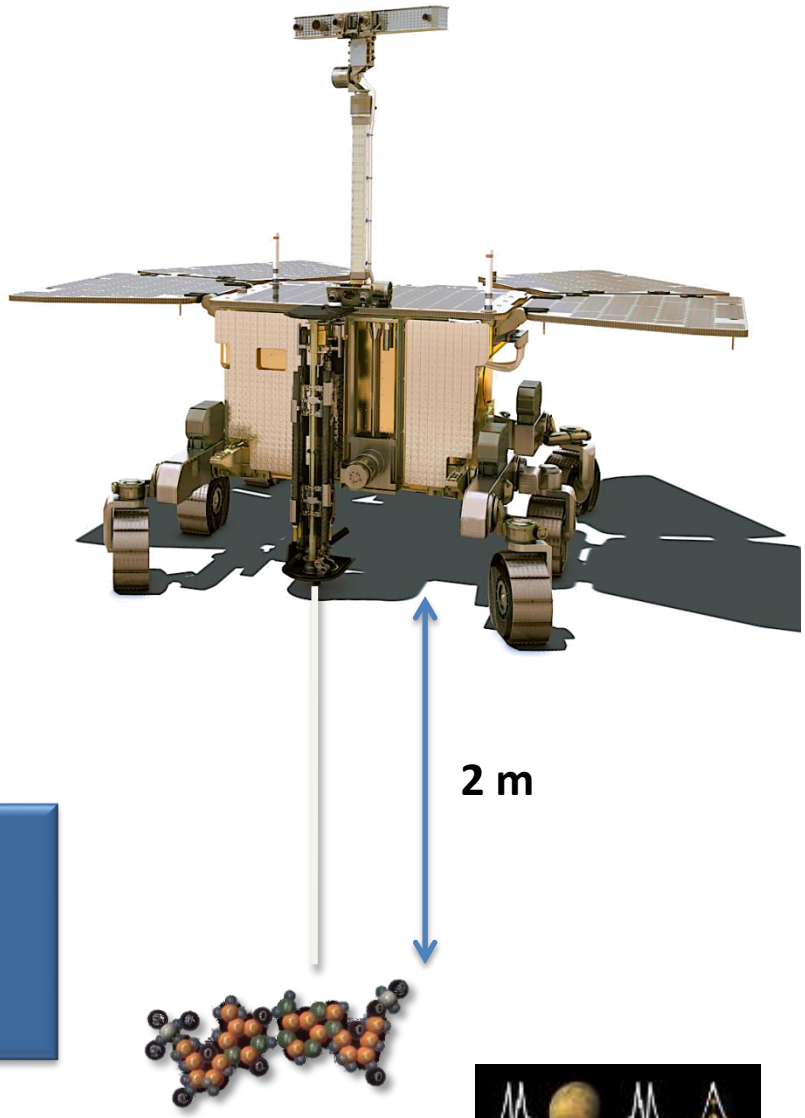
ExoMars with MOMA Enables Critical Mars Science!

Search for signs of past or present life?

- Complex organics with *nonrandom, repeating structures* (e.g., biopolymers)
- Organics do not exist in isolation: potential mixture of abiotic/meteoritic and biogenic
- *Chirality* (handedness) as a biomarker

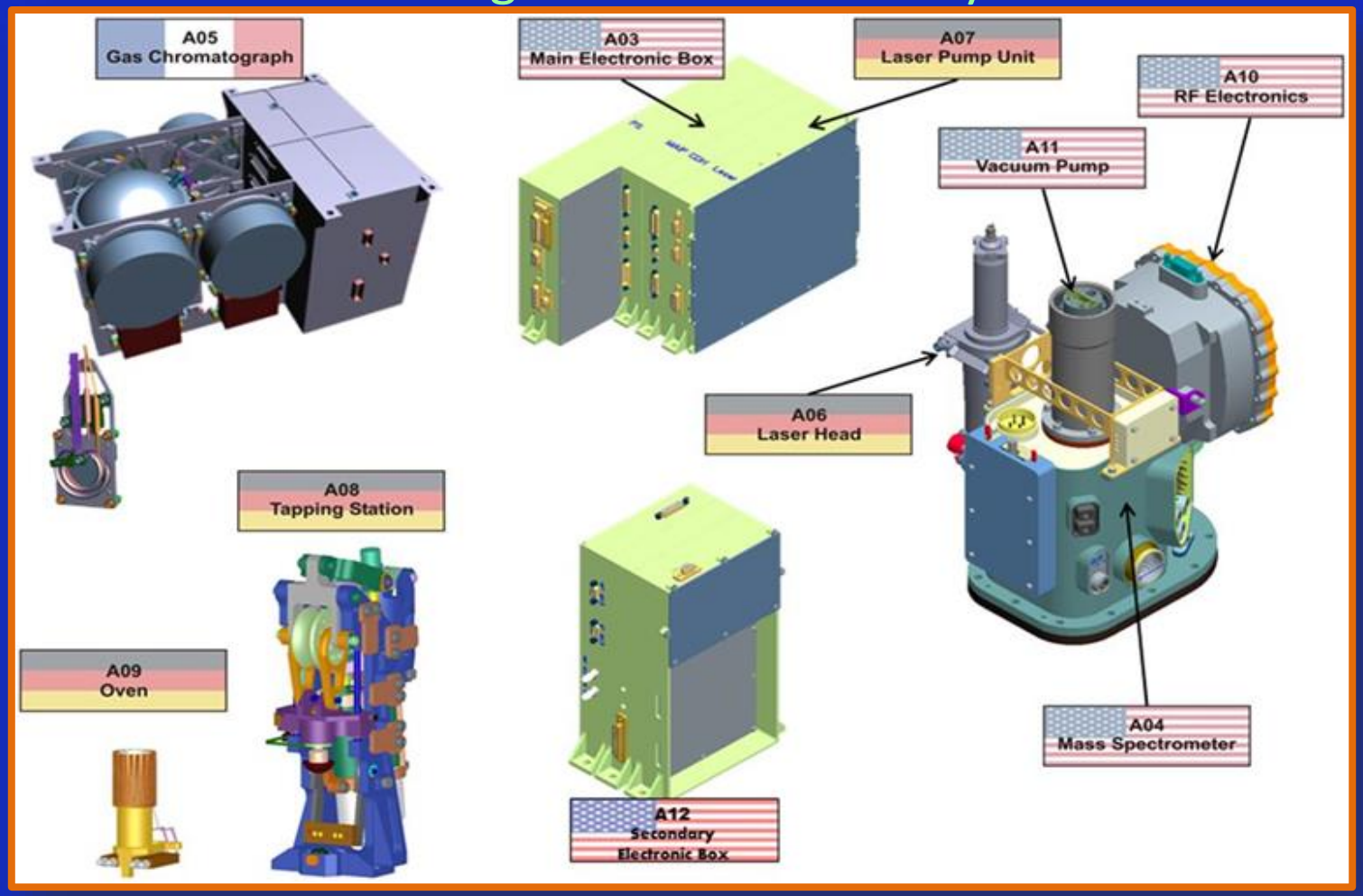
The surface of Mars is bathed in ultraviolet and cosmic radiation, potentially leading over time to the degradation of complex organics in the uppermost surface layers.

MOMA provides both *pyrolysis/gas chromatography and laser desorption MS* analysis of samples from as deep as 2 meters, potentially revealing a gradient of organics!



The Mass Spectrometer: MOMA

Mars Organic Molecule Analyzer



Total Mass: 11.5 kg MS + Electronics: 7.5 kg

MOMA Factoids

- Analyzes molecular composition of crushed samples acquired by drill
- Pyrolysis to 1000 C breaks down minerals and releases volatiles (including organics)
- Derivatization agent (in some ovens) for less volatile bulk analysis
- Pulsed UV (266 nm) laser desorption for surface analysis of nonvolatile organics

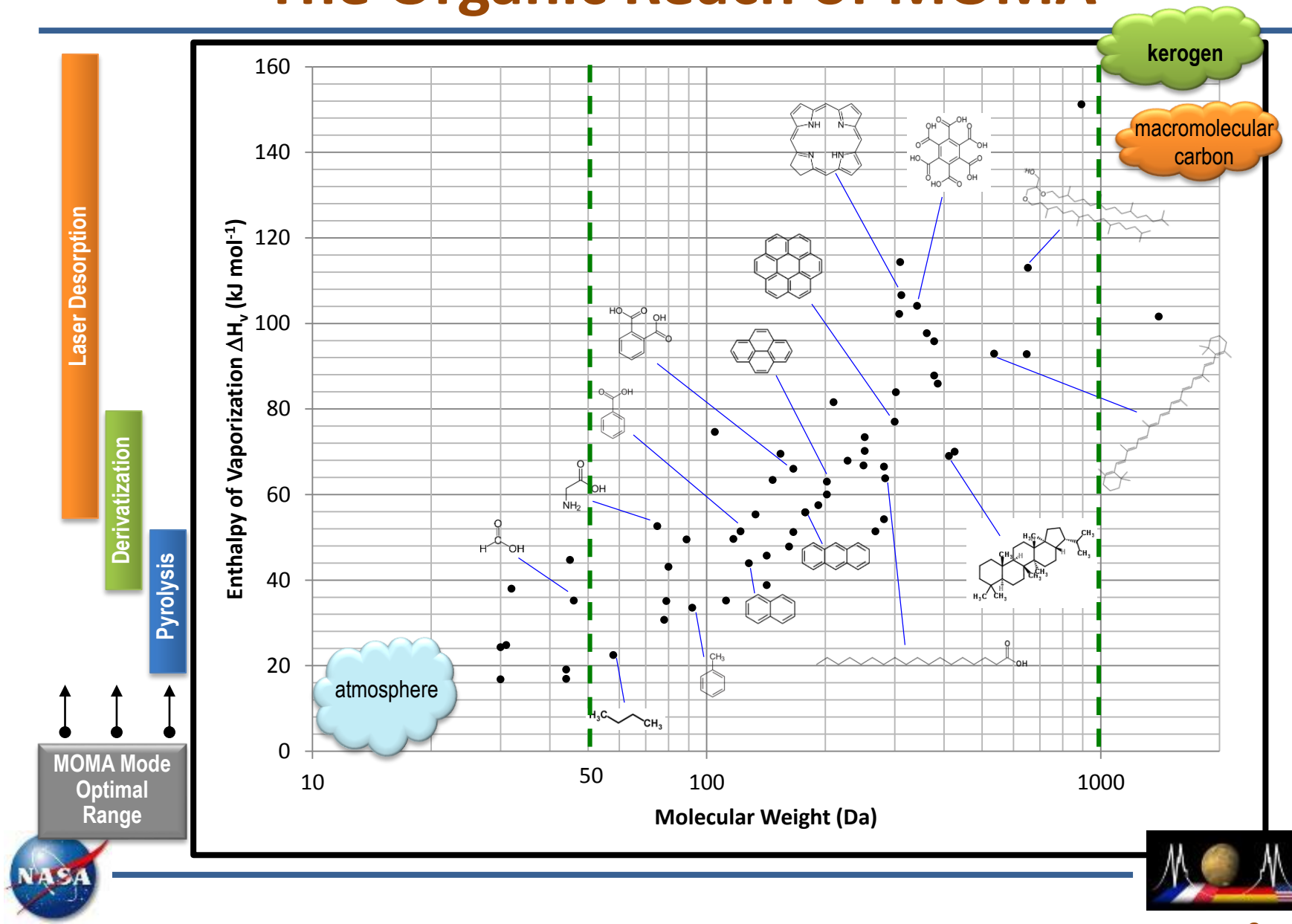
MOMA PI	**Fred Goesmann**	**Max Planck Institute, Germany**
MOMA Co-PI	**Francois Raulin**	**University of Paris, France**

Delivery of MOMA flight model to rover integration: mid 2016

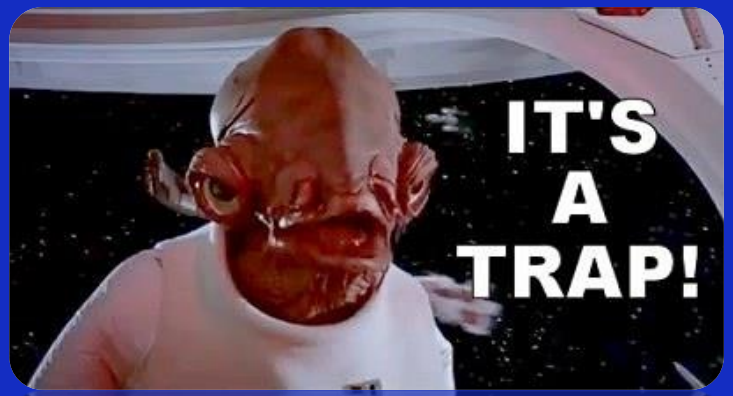
Delivery of rover to spacecraft integration: late 2017

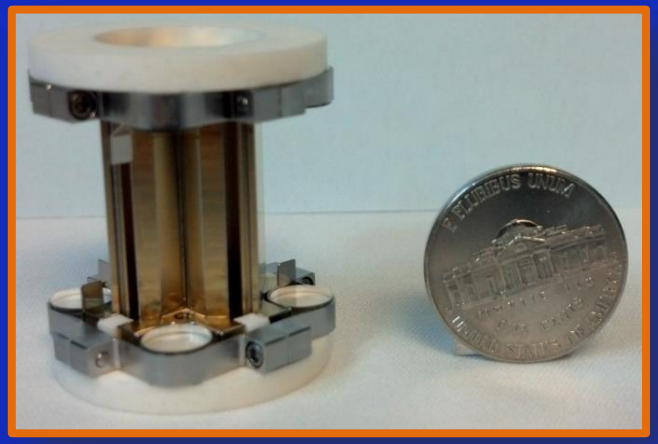
Launch from Baikonur Cosmodrome: May 7, 2018 (18 day window)

The Organic Reach of MOMA



The Mass Analyzer: LIT



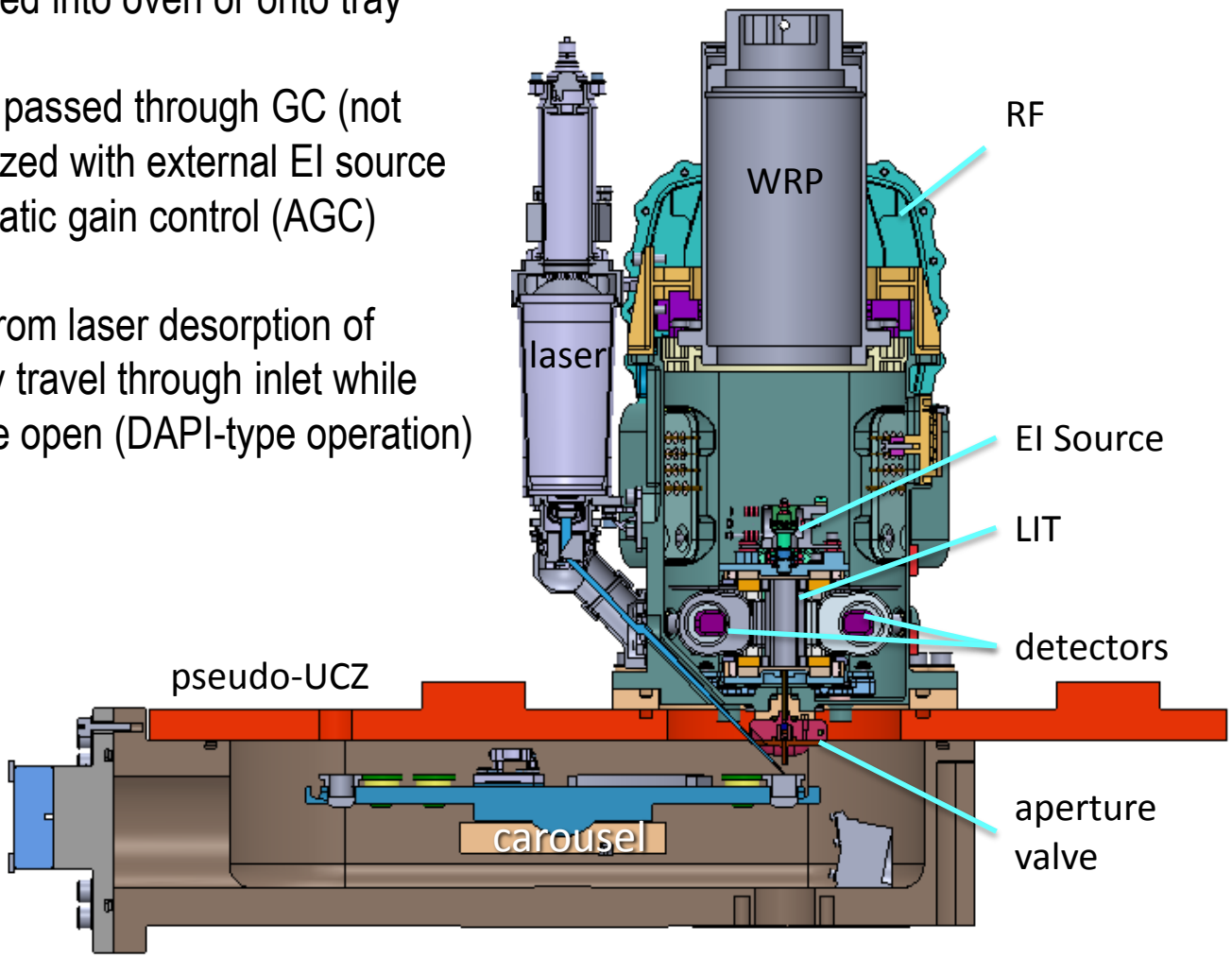


- Linear Ion Trap (LIT)
- Hyperbolic rod assembly
  - L = 2.8 cm
  - r_o = 3 mm
  - Volume ~ 25% of Thermo LXQ
- Top endplate for EI injection
- Bottom endplate for LDI injection
- Longitudinal slits for ion ejection

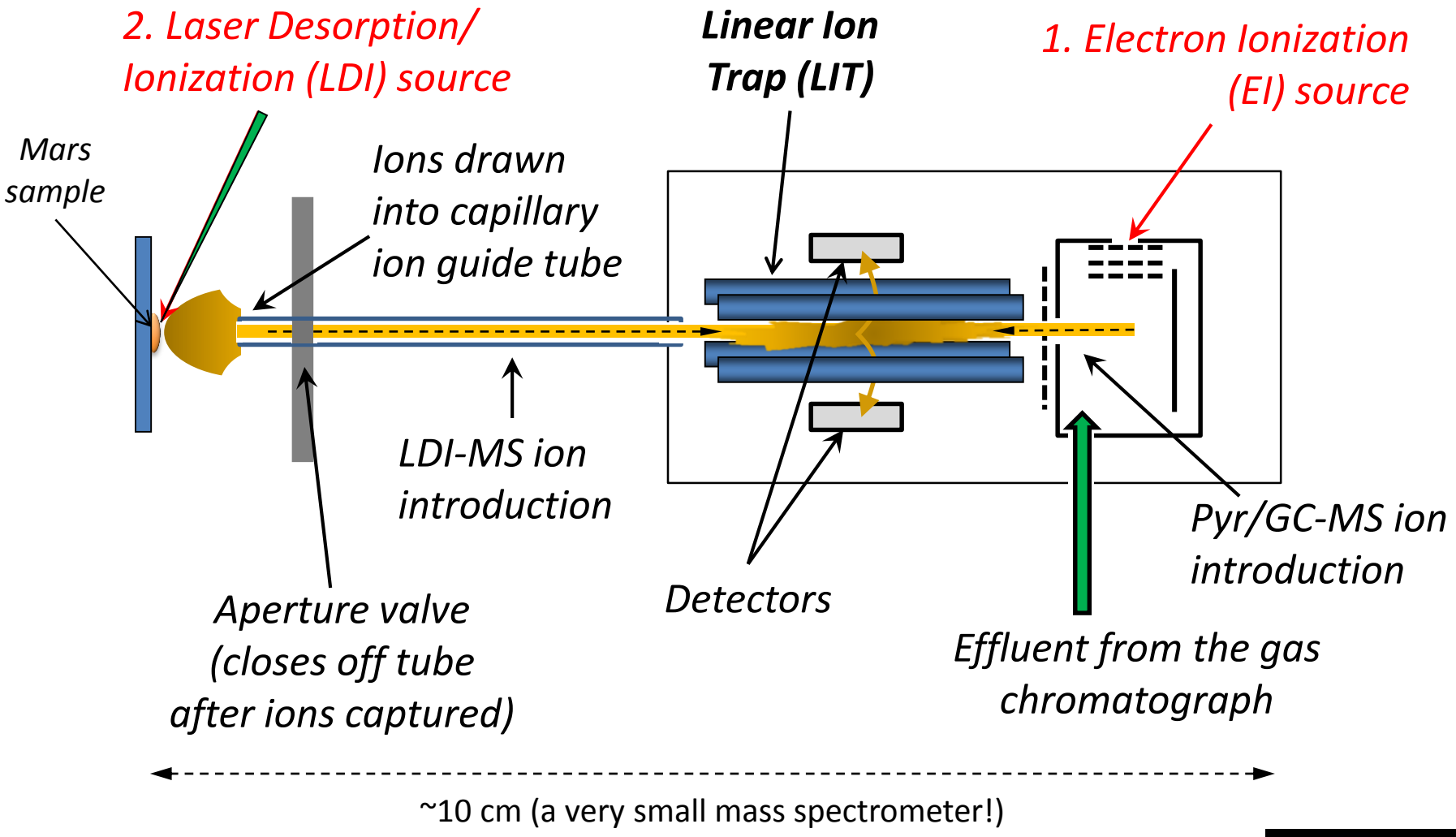
V_{pp} = 1.2 kV **Ω = 1 MHz** **Mass Range: 50-1000 Da (and beyond)**

MOMA-MS Configuration

- Samples loaded into oven or onto tray
- Pyrolysis gas passed through GC (not shown) is ionized with external EI source
- GCMS automatic gain control (AGC)
- Prompt ions from laser desorption of sample in tray travel through inlet while aperture valve open (DAPI-type operation)

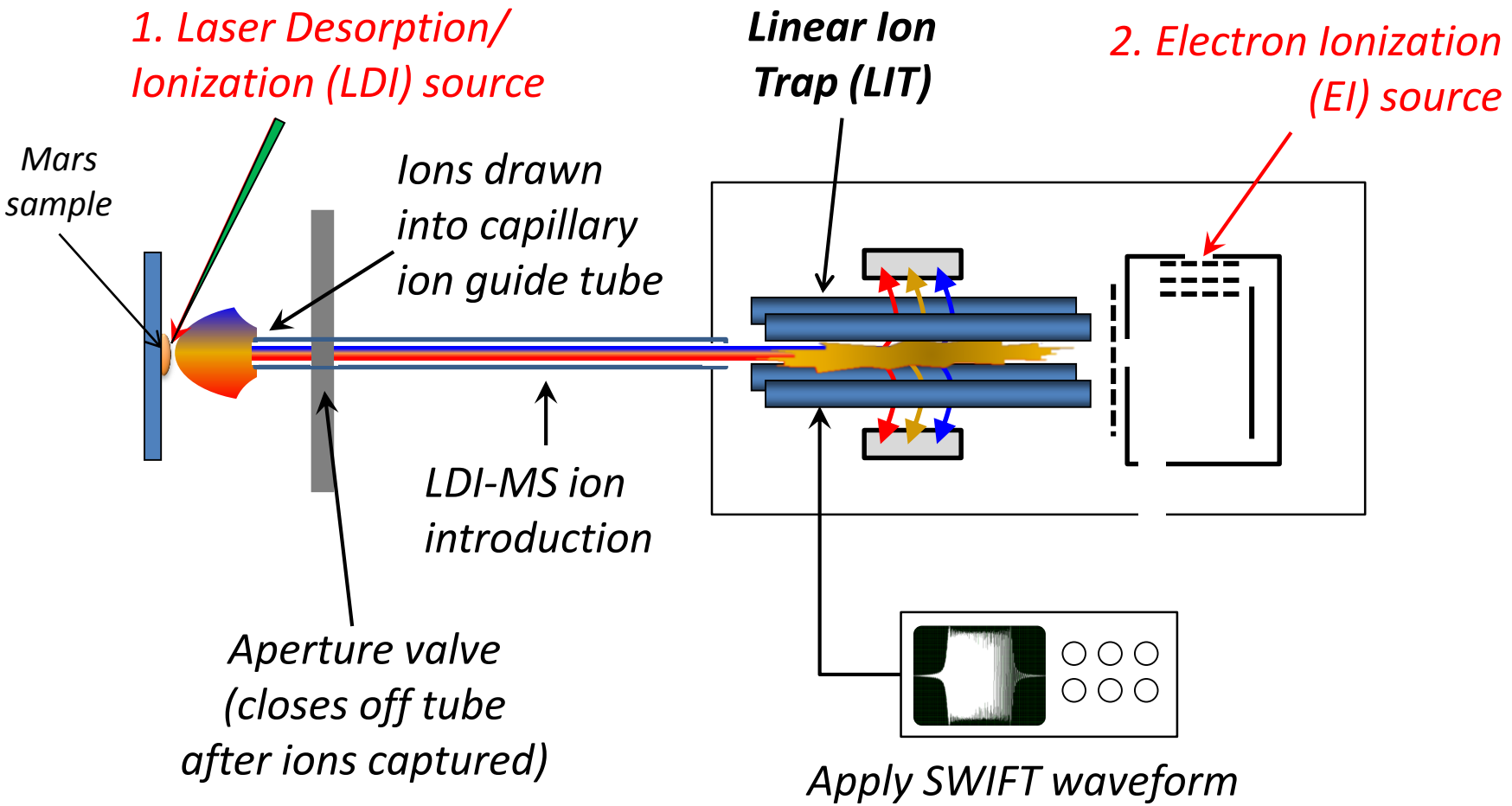


Dual-Source Linear Ion Trap MS

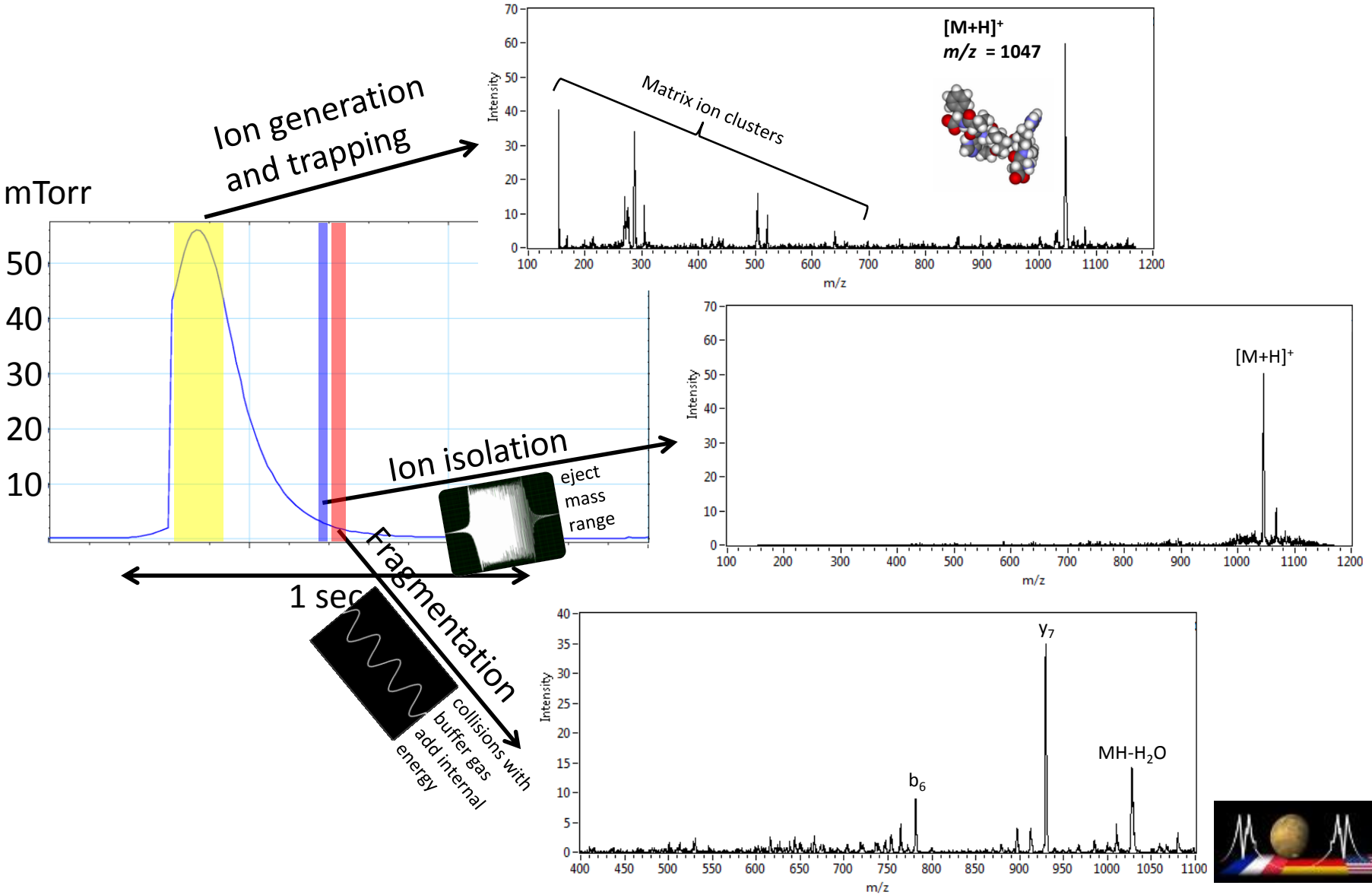


DAPI concept following: Gao, L.; Cooks, R. G.; Ouyang, Z. *Analytical Chemistry,* **2008**, *80,* 4026-4032.

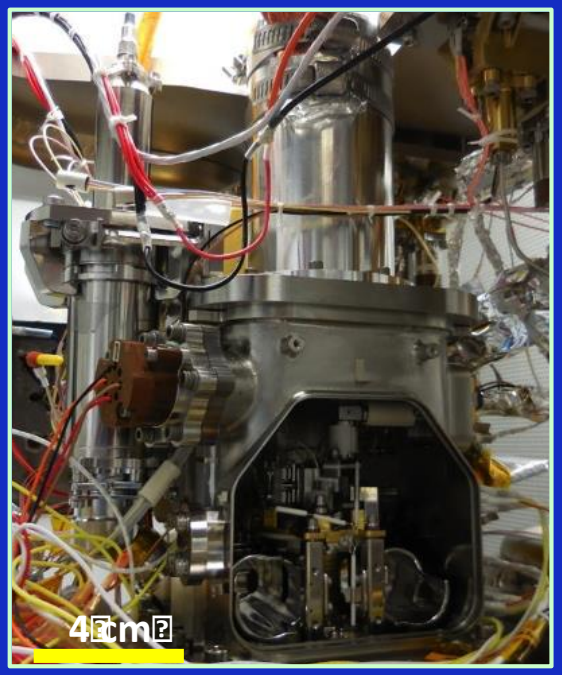
SWIFT Isolation for Charge Control



MOMA MS/MS Operation



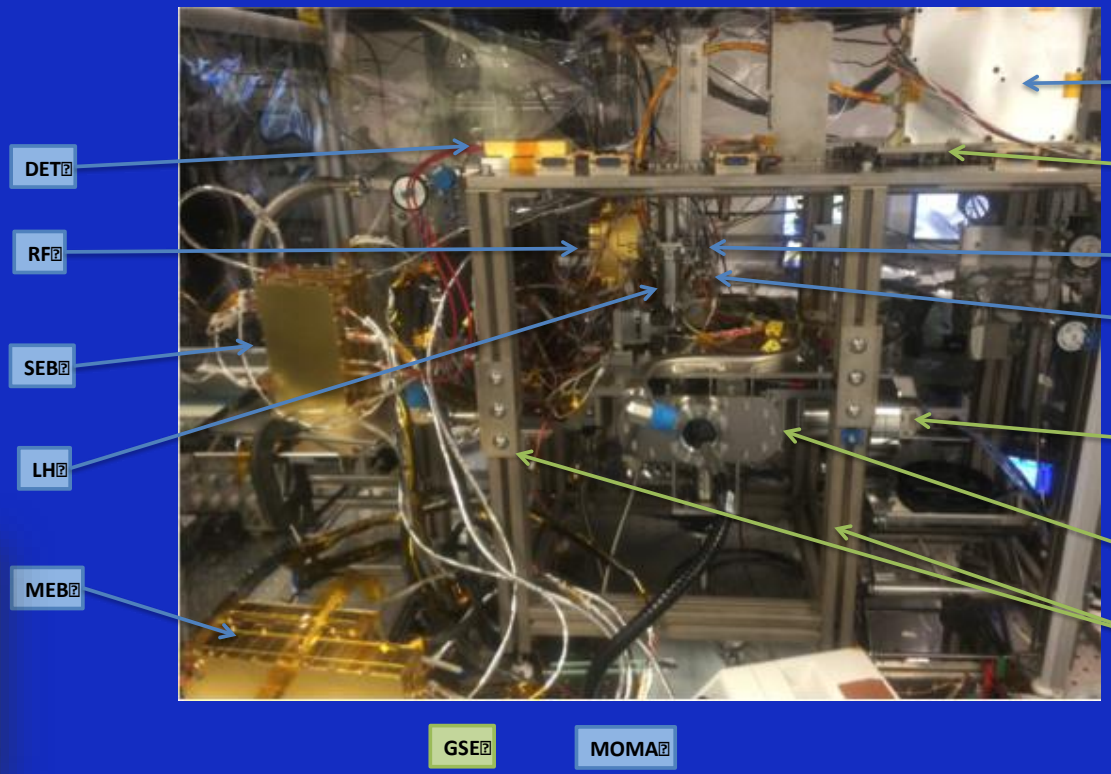
Engineering Test Unit (ETU)



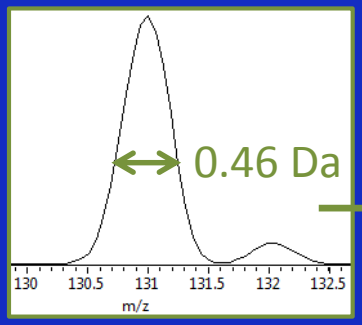
Ion trap MS in housing (detector flange removed), with wide-range pump and pulsed laser prototypes

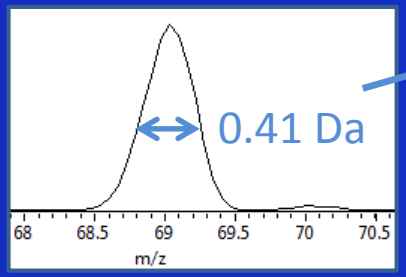
Aperture Valve

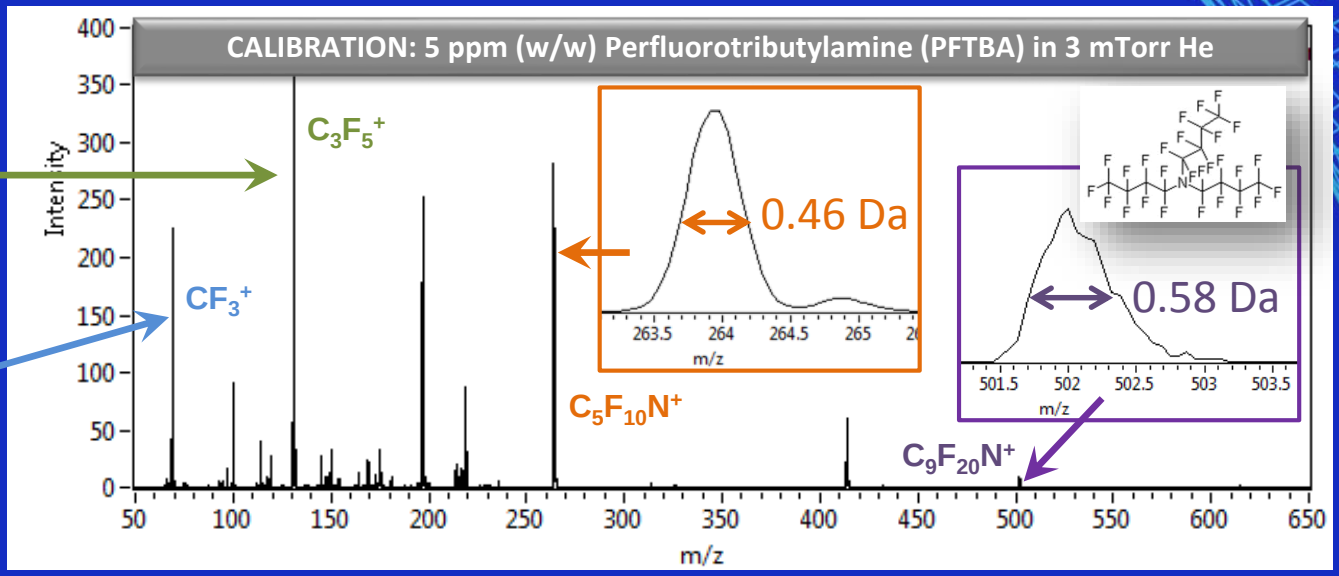
- ETU in "Flat Sat" configuration
- Built identical to flight model
- Supported by "rover-like" mechanical GSE:
  - pseudo ultra-clean zone (carousel)
  - pseudo analytical lab drawer (chassis)
- Pathfinder for flight operations

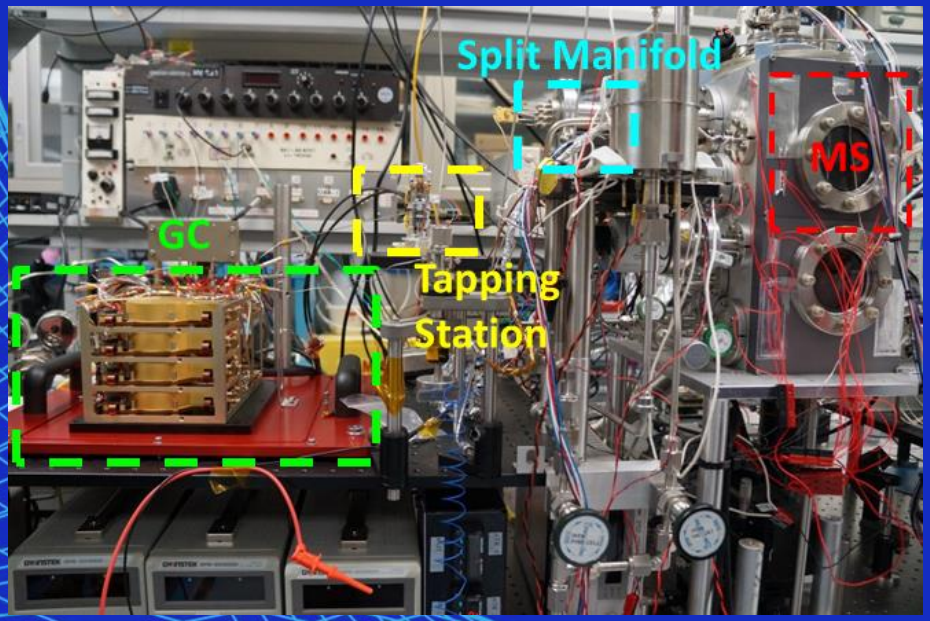


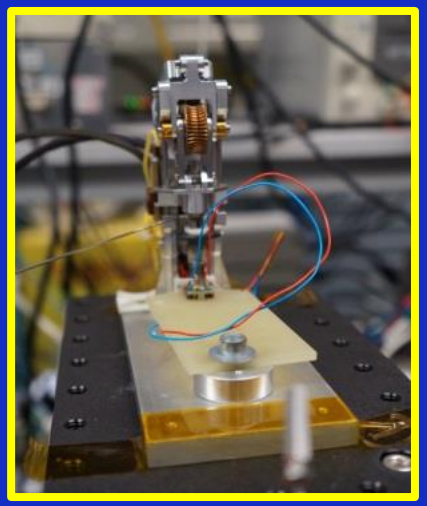
Test Spectra - 1



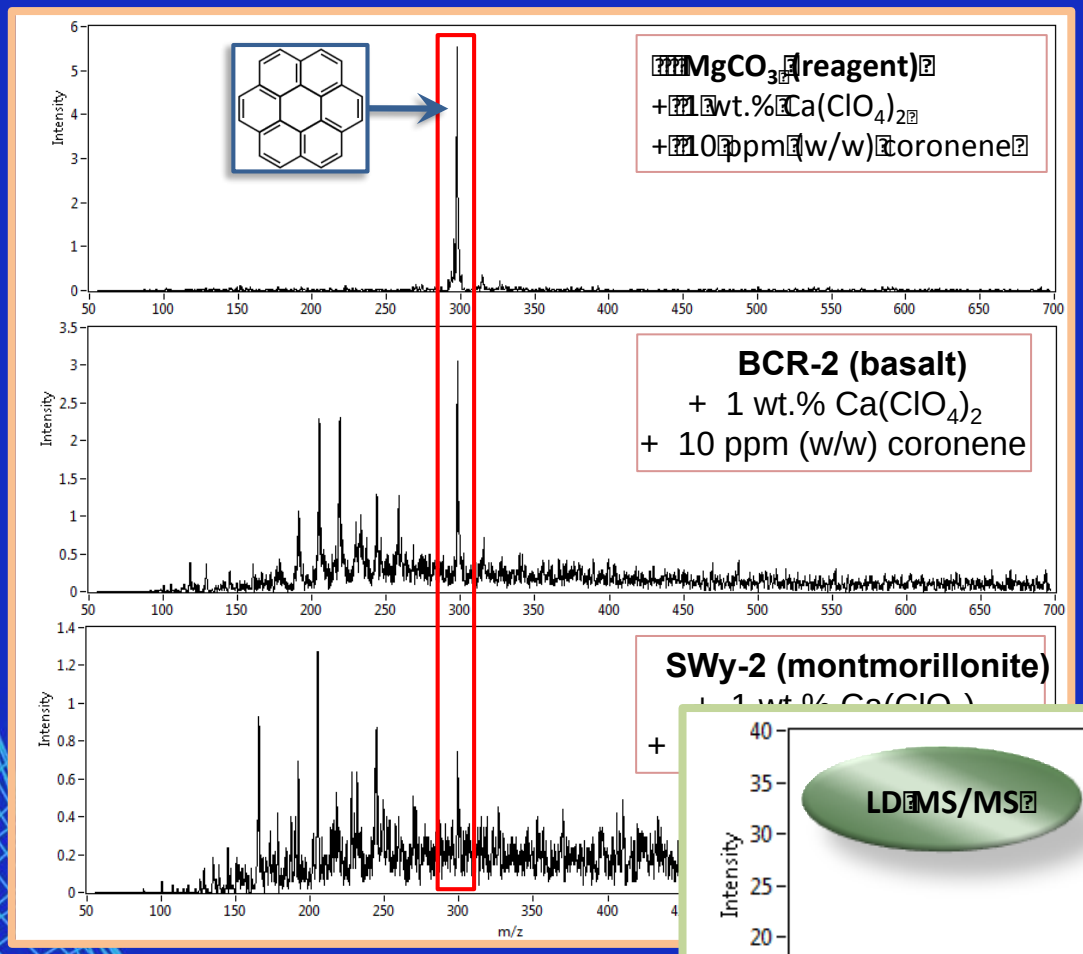






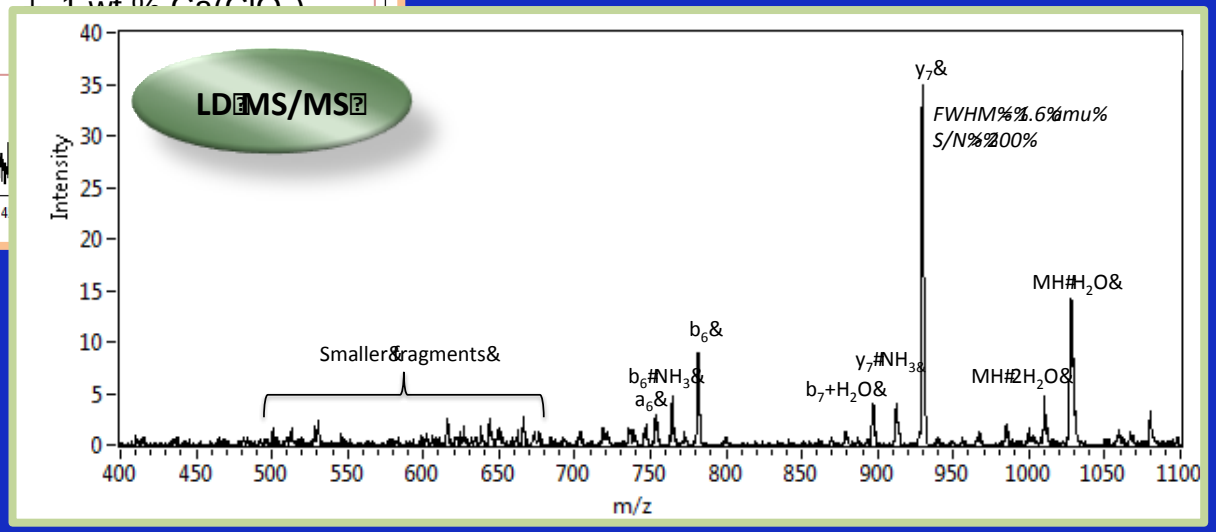


Test Spectra - 2



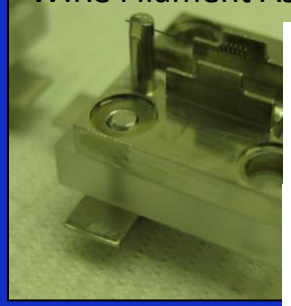
MOMA can detect heavy organic compounds in the presence of perchlorates.

MOMA can analyze molecular structure using MS/MS.

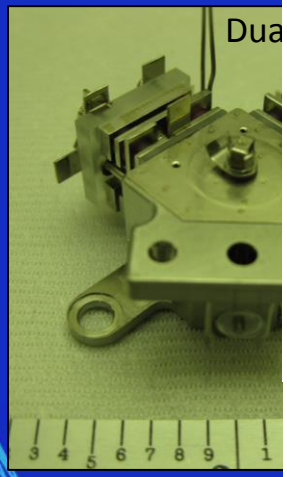


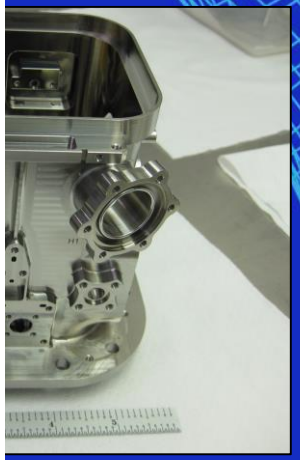
Fight Hardware Photo Gallery

W:Re Filament Assembly



Trap Electrode Assembly

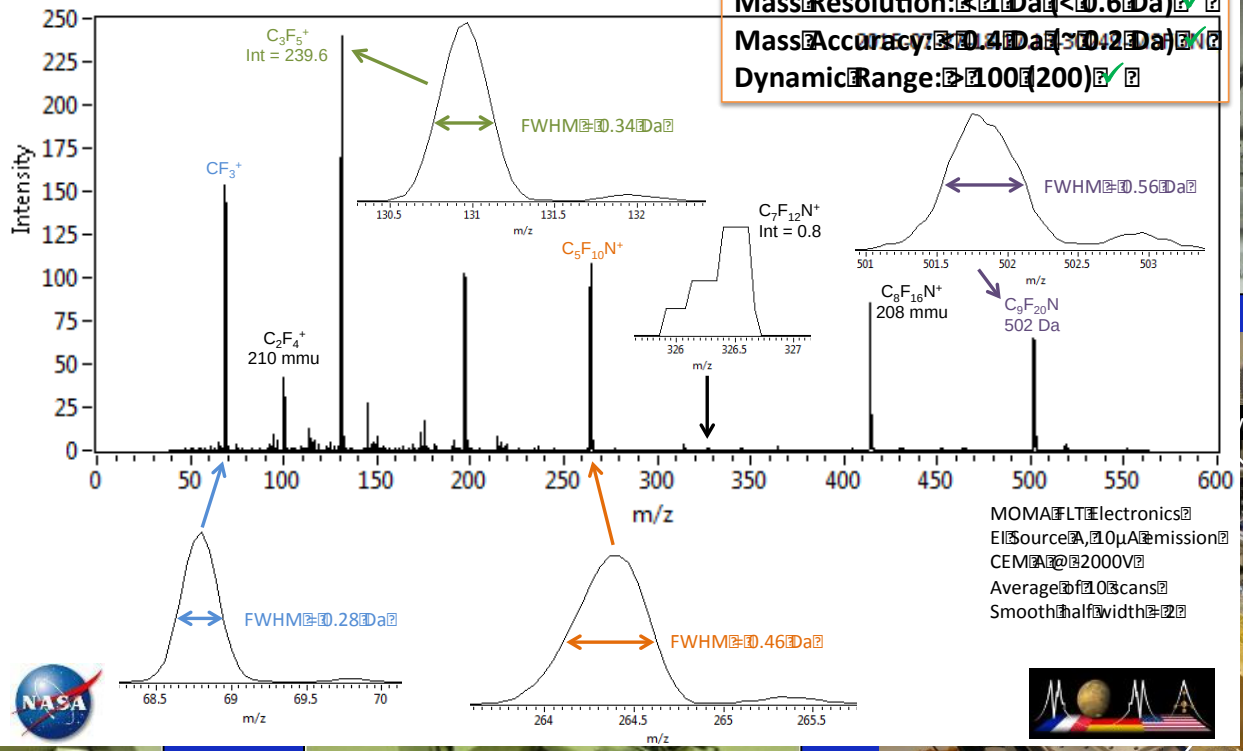




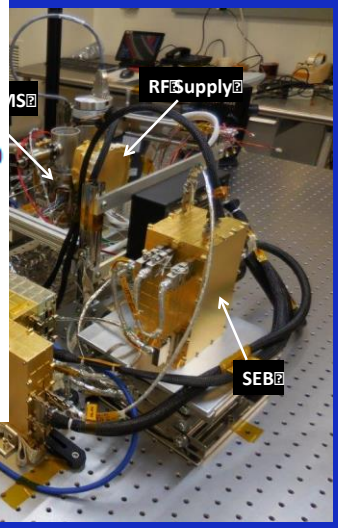
MS Performance Verification: FLT EI Mode Data

5ppm PFTBA in He @ 3mTorr

Mass Range: 50 - 500 Da ✓
Mass Resolution: < 1 Da (< 0.6 Da) ✓
Mass Accuracy: < 0.4 Da (< 0.2 Da) ✓
Dynamic Range: > 100 (200) ✓

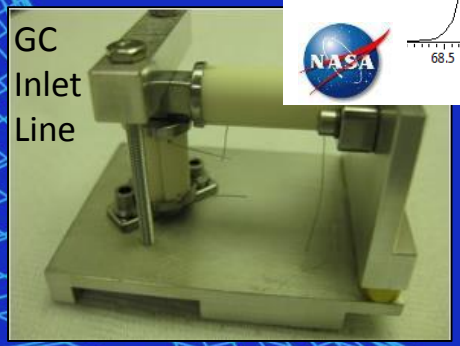


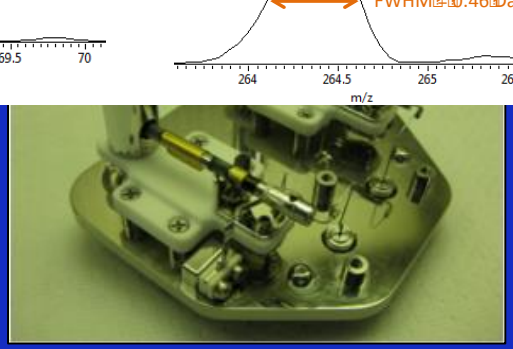
MOMA FLT Electronics
EI Source A, 10µA emission
CEM A @ 2000V
Average of 10 scans
Smooth half width = 2



Flight in "Flat-Sat" Config

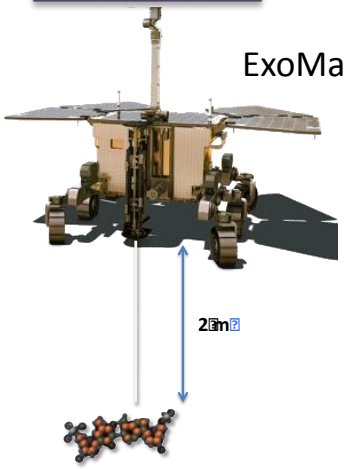
GC Inlet Line





The Last Slide

Unique Sampling Approach



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Unique Measurement Capability

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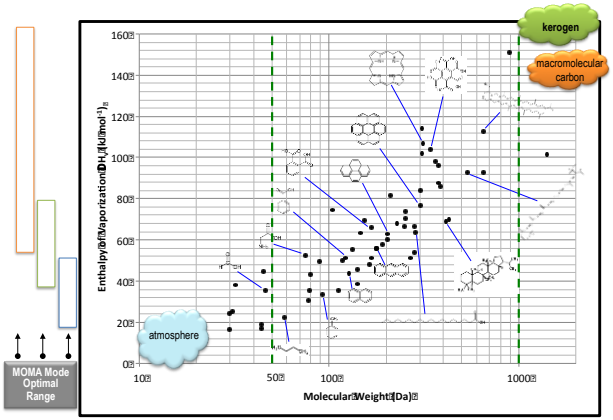
Enormous opportunity to advance our knowledge of organic preservation and potential for life on Mars!

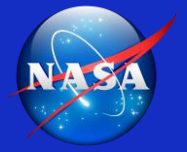


Wish us luck!

MOMA Team Members (partial list)

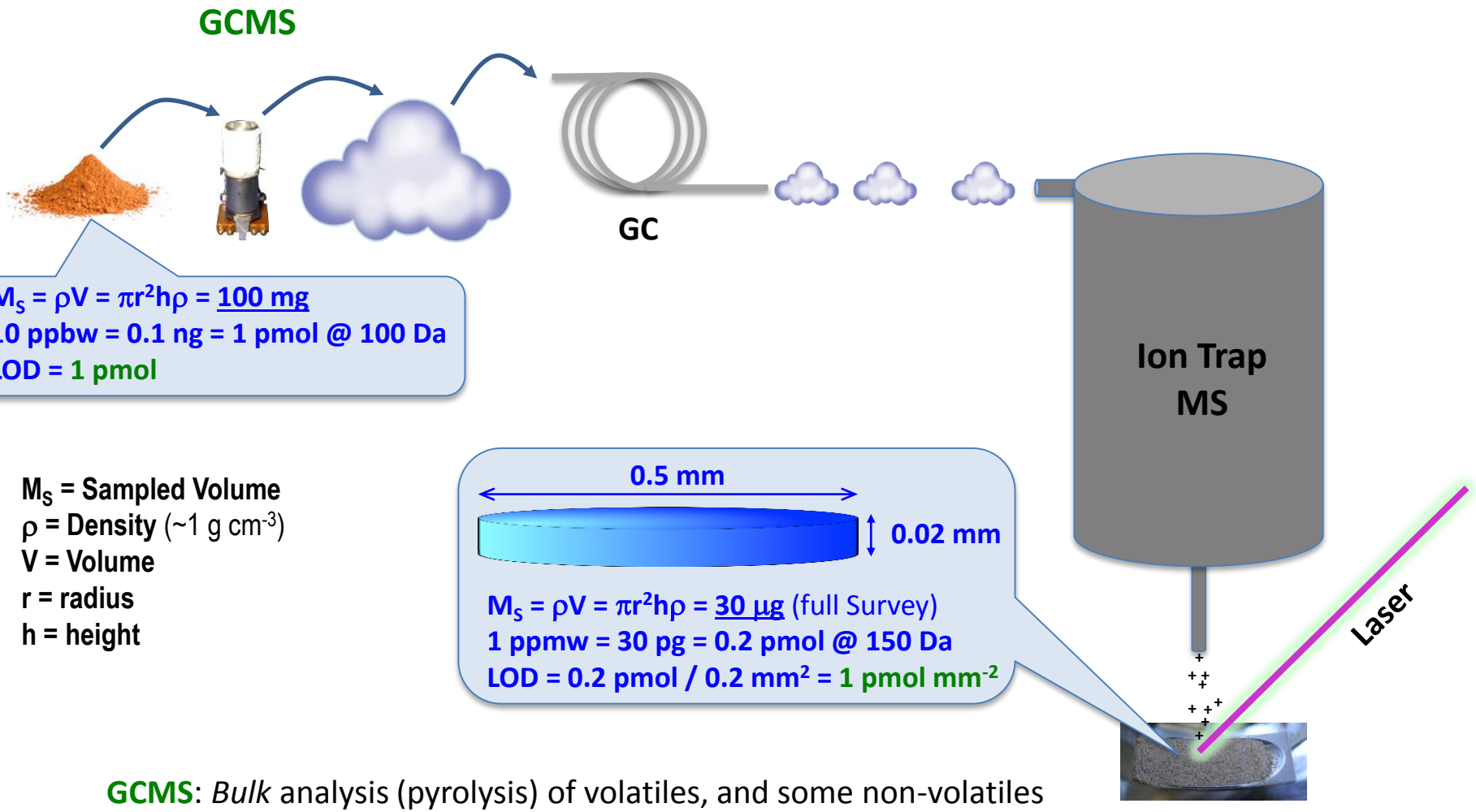
R. Arevalo, R. Danell, F. van Amerom, V. Pinnick, L. Hovmand, X. Li, S. Getty, P. Mahaffy, A. Grubisic, D. Glavin, C. Freissinet, F. Goesmann, O. Roders, E. Steinmetz, E. Miettinen, H. Steininger, W. Goetz, M. Earnst, F. Raulin, N. Grand, C. Szopa, A. Buch, A. Buettner, M. Hunnehukl, J. Neumann, P. Wessels, T. King, F. Jaeger, B. Ottens, Z. Gonnsen, A. Melak, P. Kimvilikani, R. Hoffman, F. Tan, S. Meyer, M. Barciniak, S. Battel, K. Arnett, R. Miller, S. Rogacki, D. McClaeb, V. Holmes, D. Harpold, C. Gundersen, G. Ramu, C. Budinoff, D. Steinfeld, E. Lyness, T. Nolan, J. Hengemihle, C. Johnson, B. Pratts, Z. Chu, A. Southard, D. Carrigan, M. Noreiga, R. Wilkinson, R. Arvey, R. Perry, J. Canham, T. Dear, E. Weidner, T. Capon, L. Marbley, L. Morgan, A. Ersahin, E. Wingard, J. Volpini, E. Lalime, R. Pratts

Support from NASA's Mars Exploration Program, M. Schulte (Science) and D. Lavery (Executive)



Backup Slides

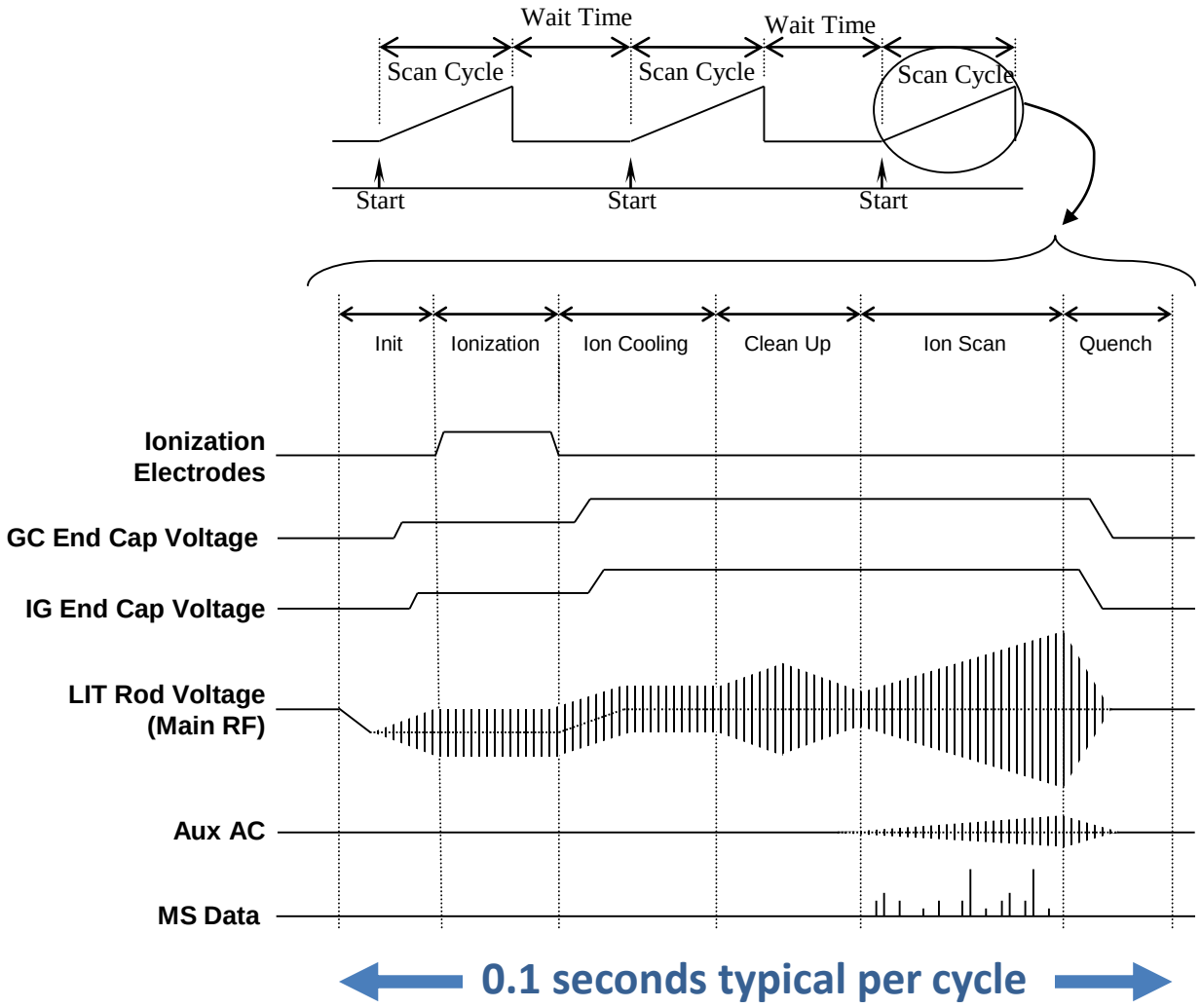
Dual Source Mass Spectrometry



GCMS: *Bulk* analysis (pyrolysis) of volatiles, and some non-volatiles using derivatization agent

LDMS: *Surface* analysis (laser desorption/ionization) of non-volatiles

Pyr/GC-MS Mode of Operation: Timing Diagram



LDI-MS Mode of Operation: Timing Diagram