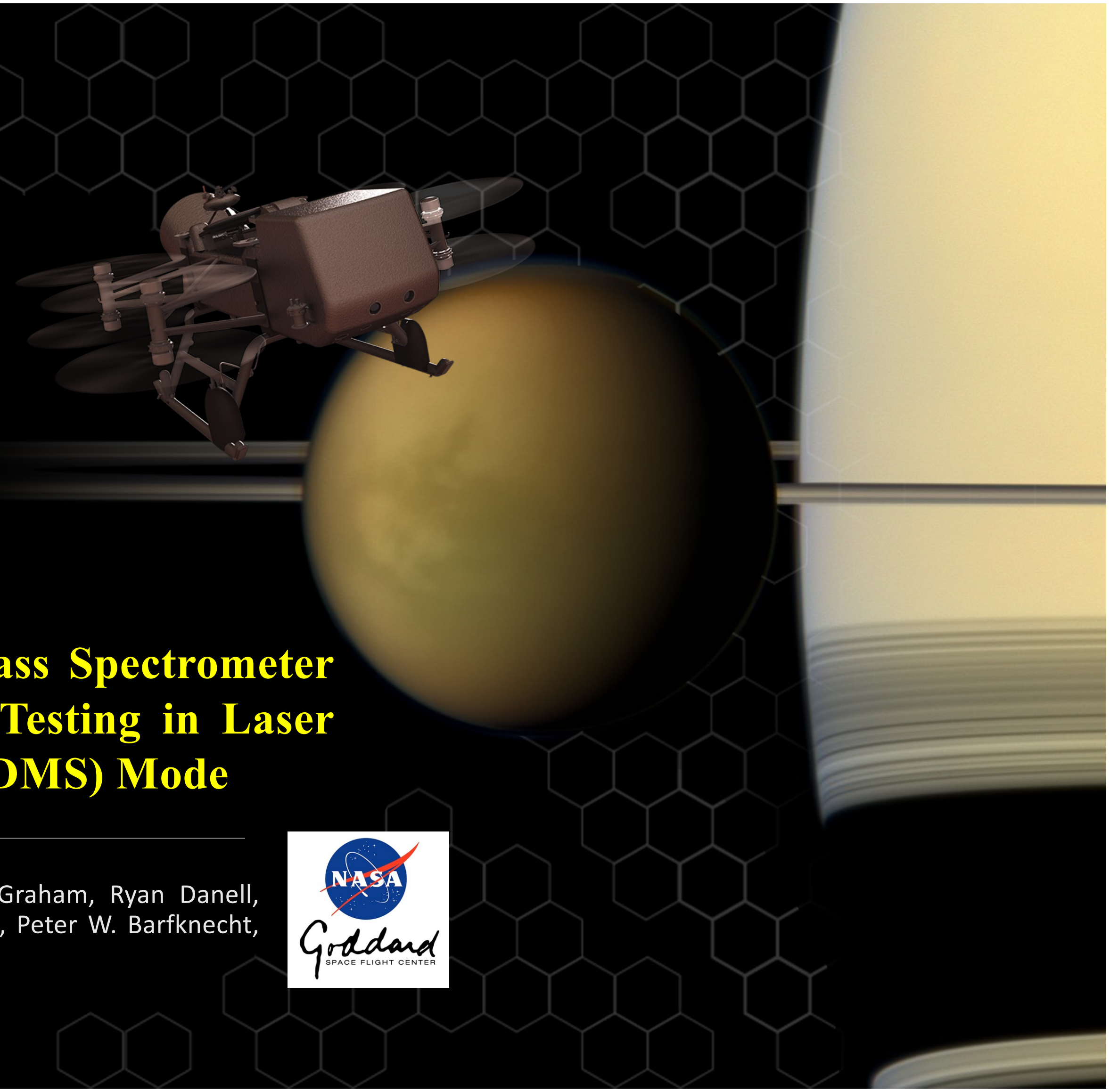
DRAGONFLY

A relocatable lander to explore Titan's prebiotic chemistry and habitability



Development of the Dragonfly Mass Spectrometer (DraMS) and Cryogenic Sample Testing in Laser Desorption Mass Spectrometry (LDMS) Mode

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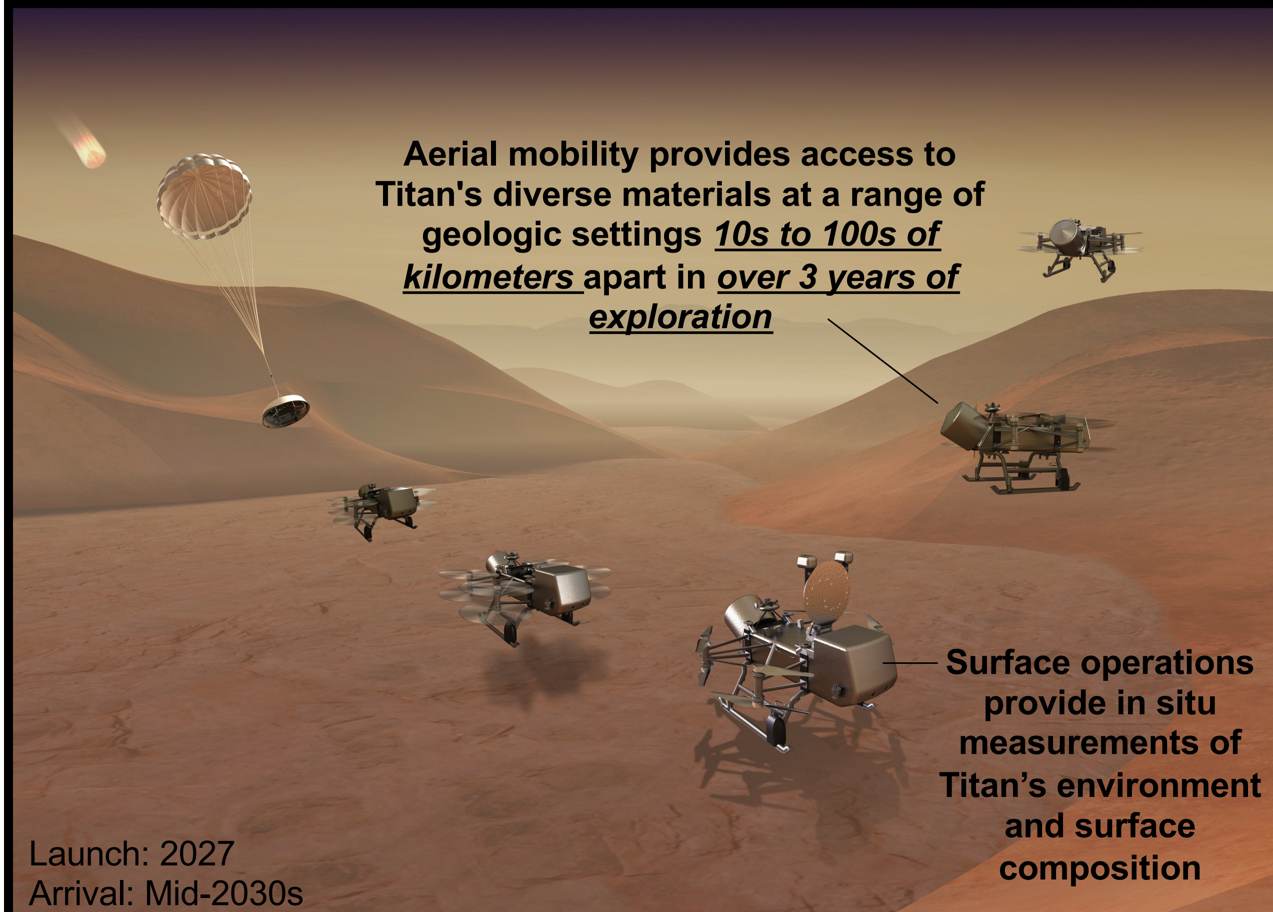
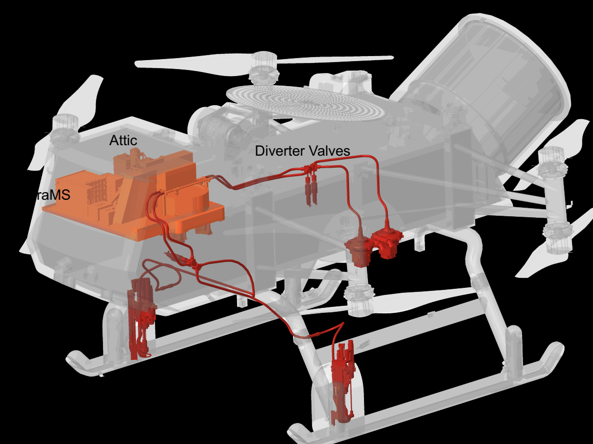
NASA Goddard Space Flight Center

Dragonfly: A relocatable lander to explore Titan's prebiotic chemistry and habitability



Dragonfly Mass Spectrometer will analyze chemical components and processes that produce biologically relevant compounds

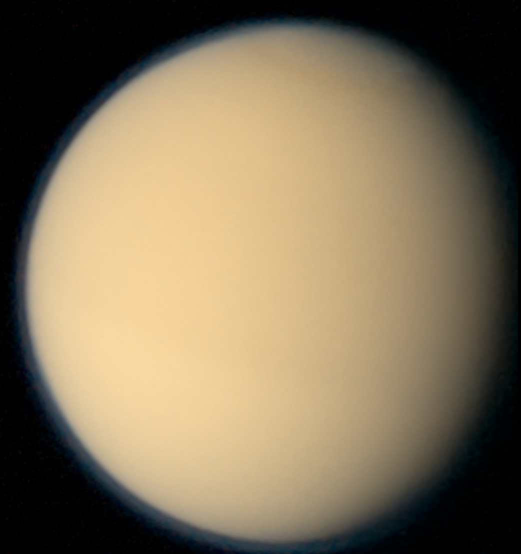


DrACO uses drills and blowers to pneumatically transfer surface material to DraMS for detailed chemical analyses

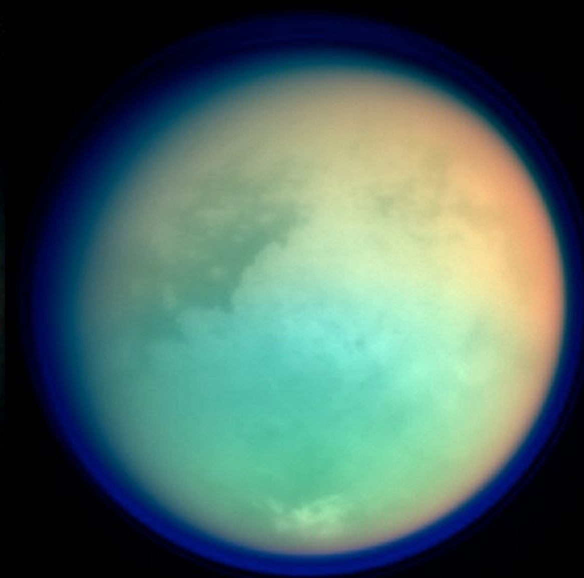
Why Titan?

- We do not know how life came to form on Earth and cannot go back to study our own prebiotic history
- Places elsewhere in our Solar System provide pieces to the puzzle of the chemical processes that led to life
- **Titan** has similarities to early Earth and may hold clues to understanding our chemical origins

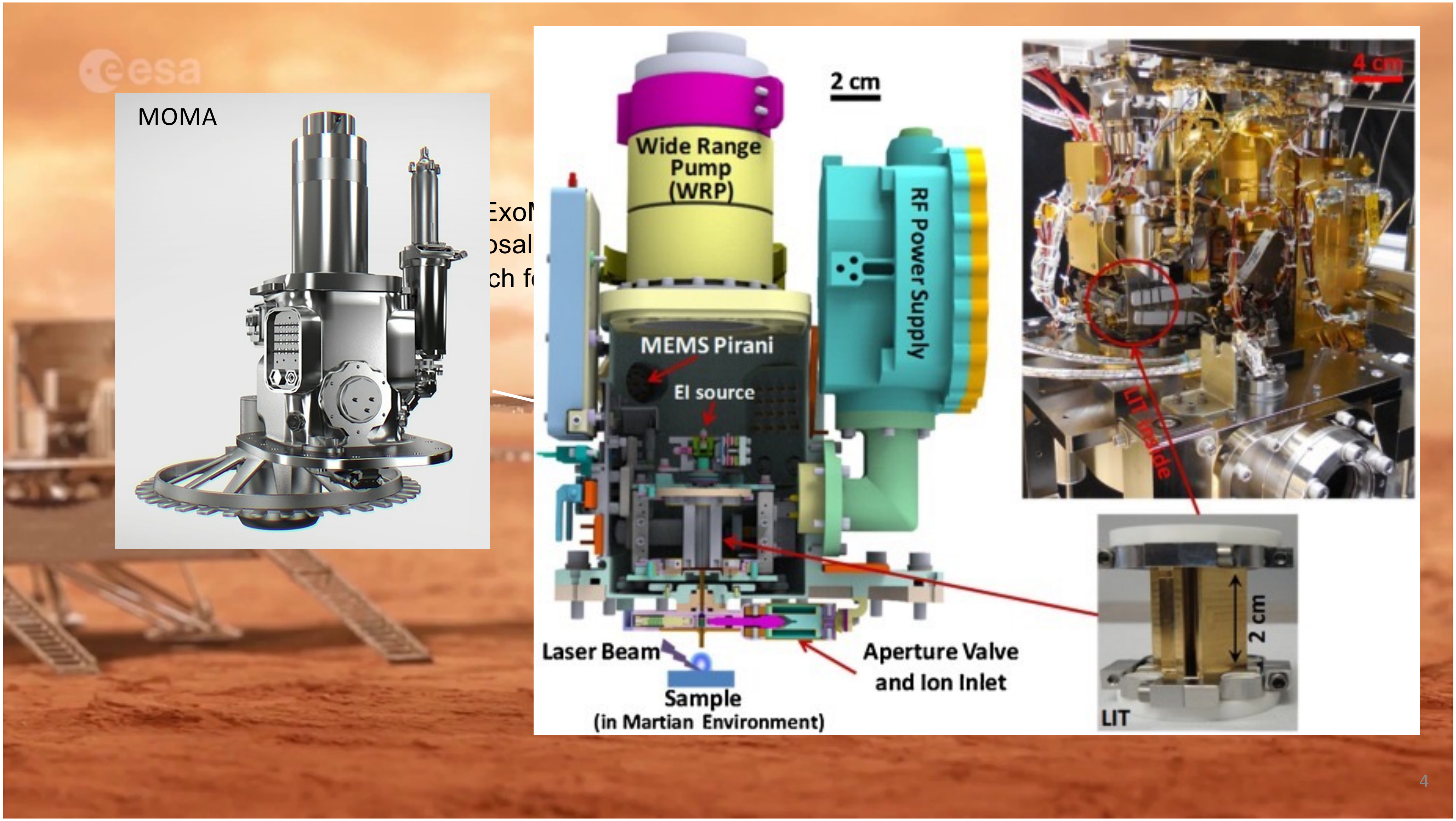
- Diameter: 5,150 km (3,193 miles)
- Surface gravity: 1.35 m/s2 (0.14 g)
  - 14% of gravity at Earth’s surface
  - 83% of gravity at Moon’s surface
- Surface pressure: 1.5 bar
  - 1.5× pressure at Earth's surface
- Surface temperature: 94 K (–179°C, –290°F)
  - Bedrock composition: water ice
  - Atmospheric composition: nitrogen, few % methane



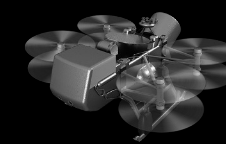
Voyager 2
23 August 1981

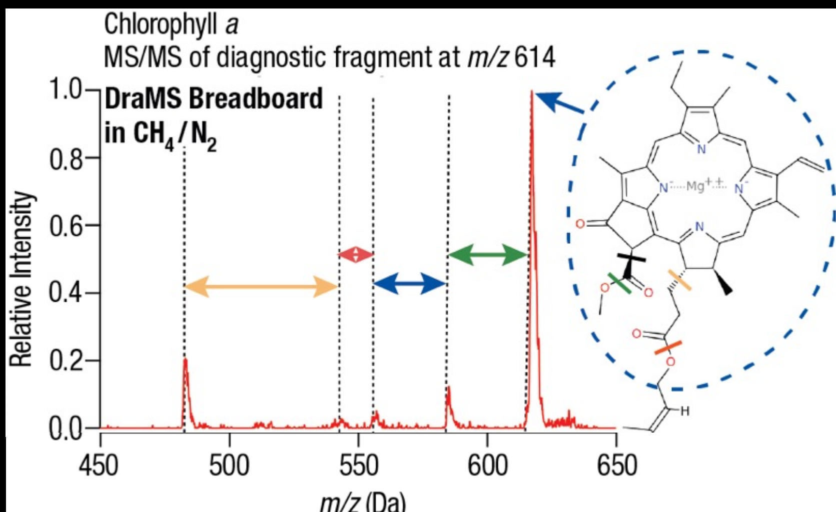


Cassini
26 October 2004


MOMA
2 cm
Wide Range Pump (WRP)
RF Power Supply
MEMS Pirani
EI source
Laser Beam
Sample
(in Martian Environment)
Aperture Valve and Ion Inlet
4 cm
LIT inside
2 cm
LIT

DraMS Molecular Analysis of Surface Materials





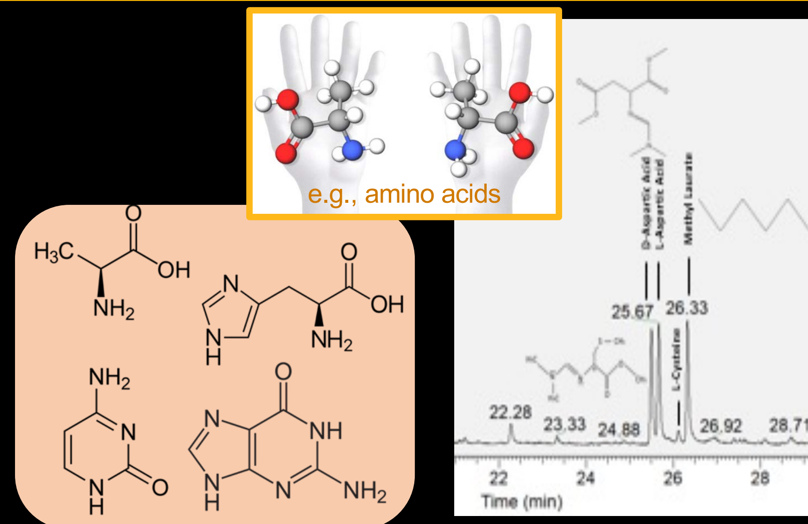
LDMS Mode

Broad Survey Mass Spectrometry

Organic inventory of high molecular weight organics

Preferential patterns and structural elucidation

Minimal sample processing



GCMS Mode

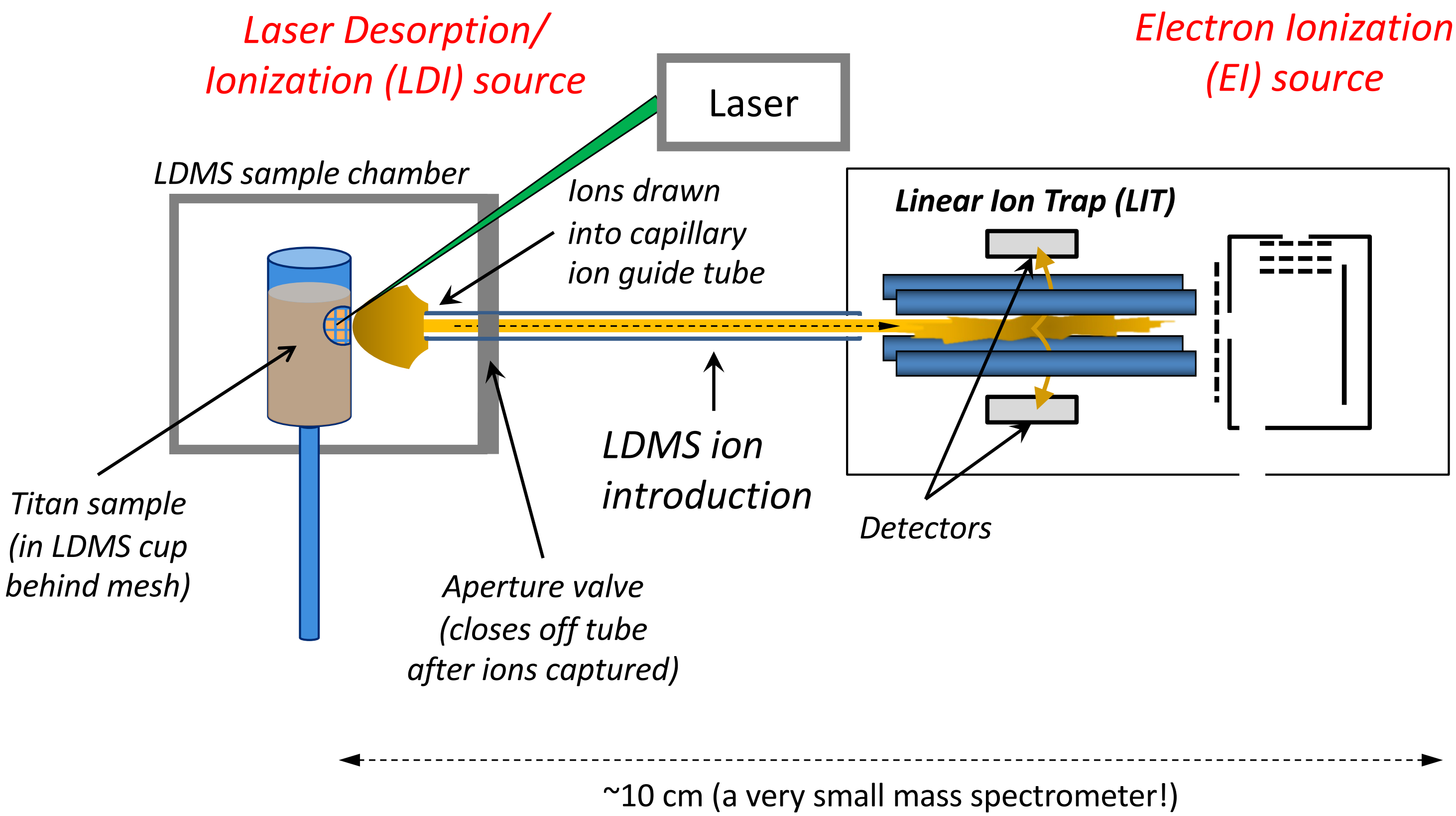
Sensitive and Selective MS

Gas chromatography targeting potential biomolecules

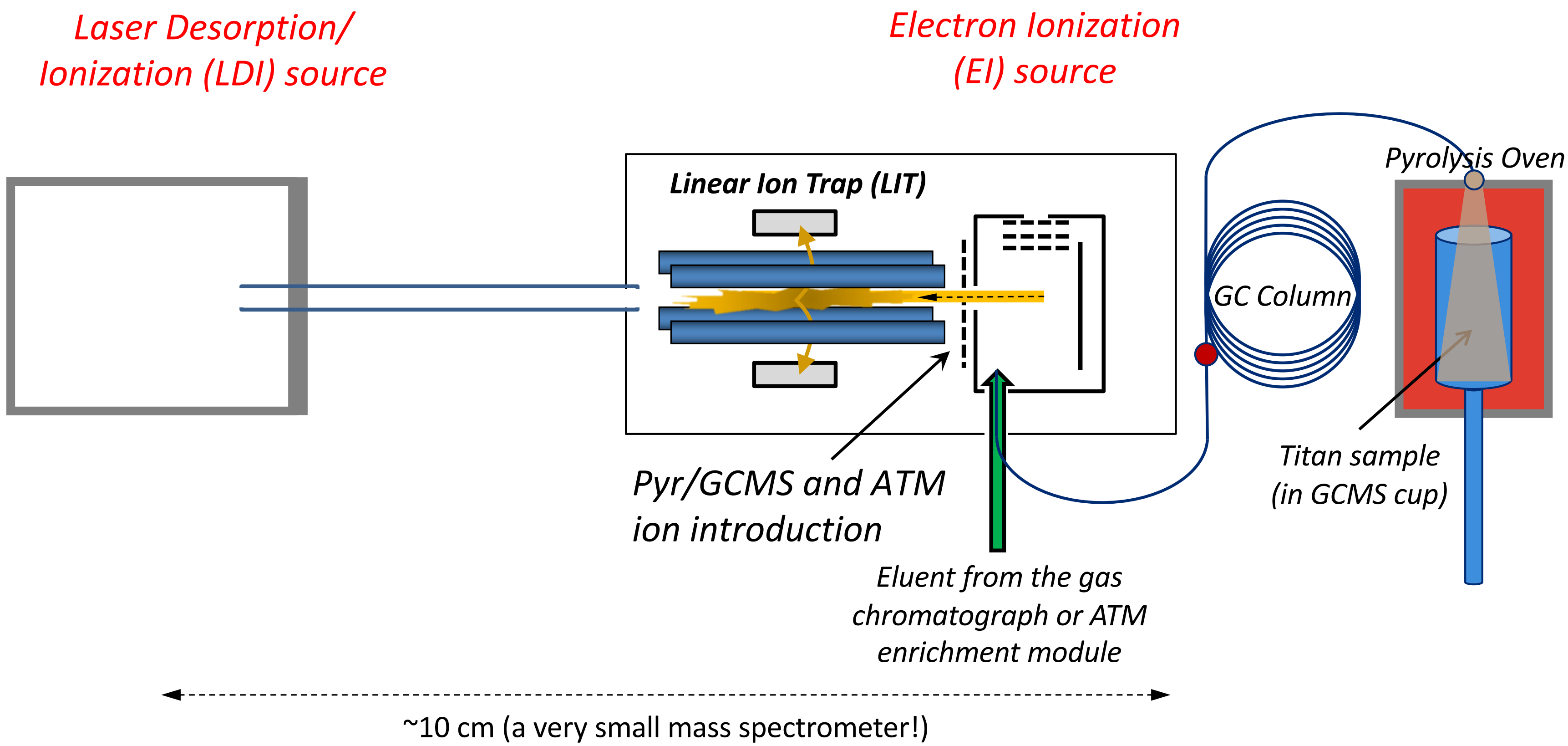
Search for enantiomeric excess

Derivatization options provide flexibility

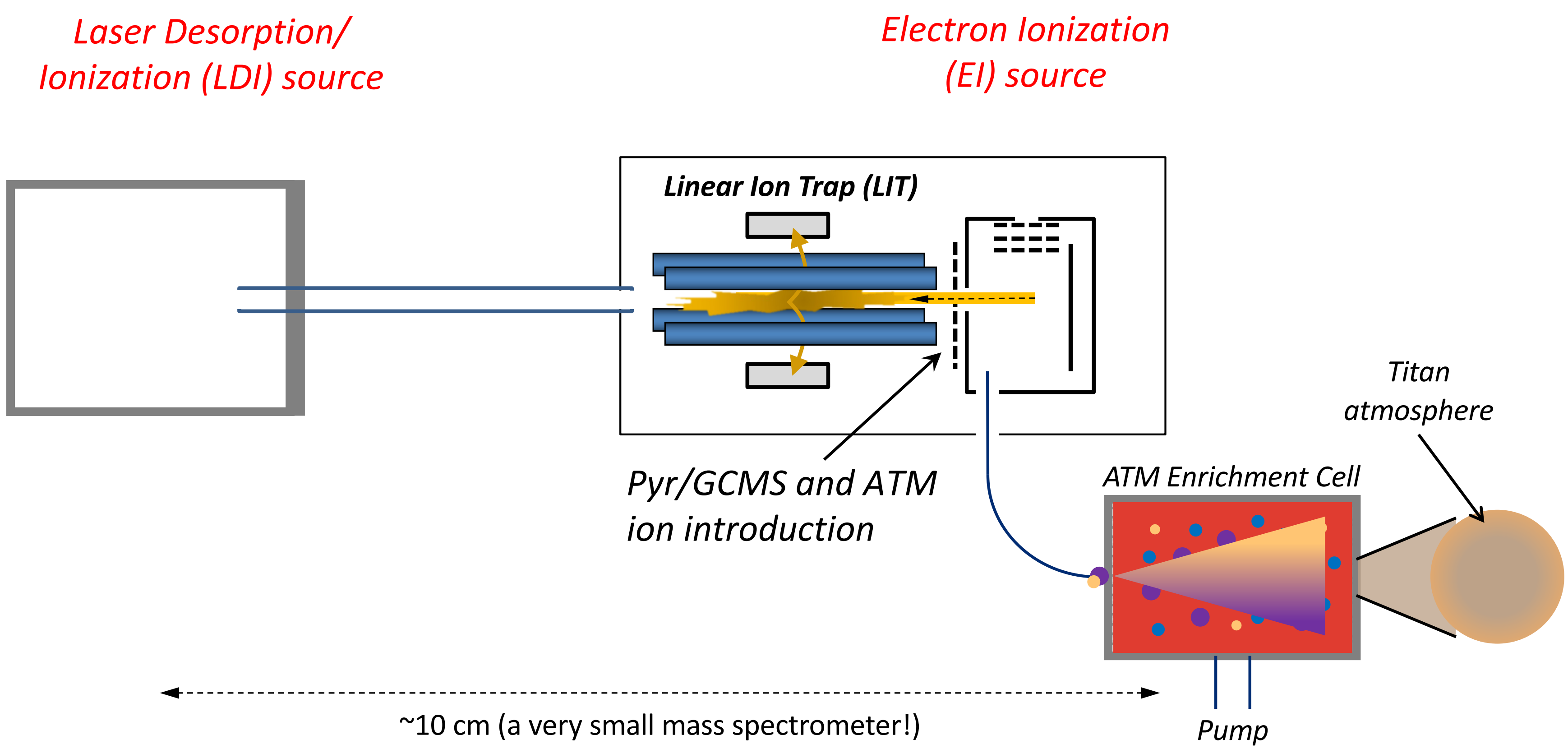
Modes of Operation (and Sequence of Events)

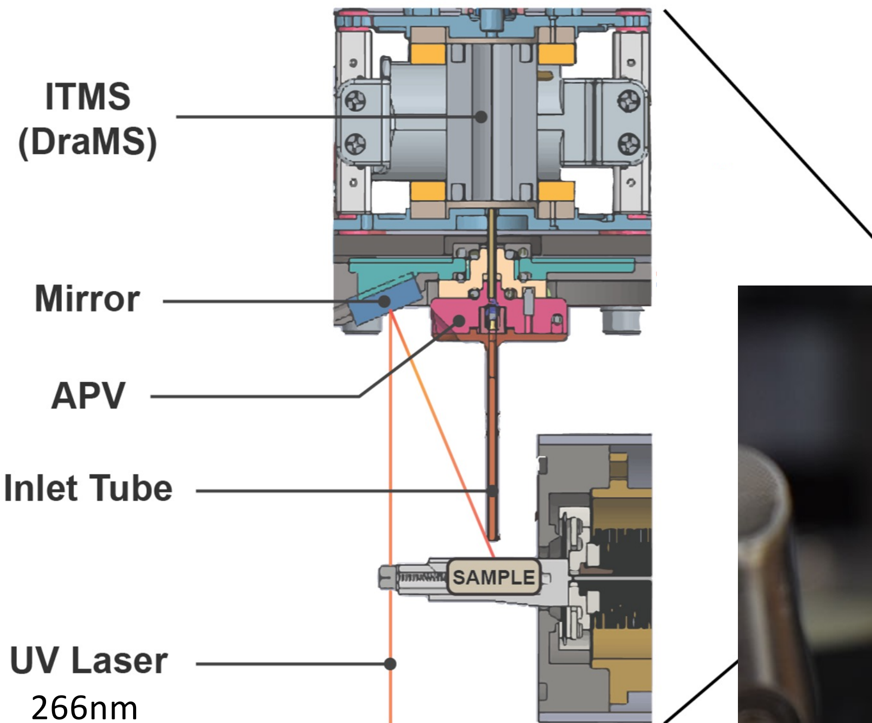


Modes of Operation (and Sequence of Events)



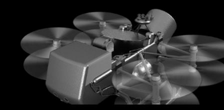
Modes of Operation (and Sequence of Events)



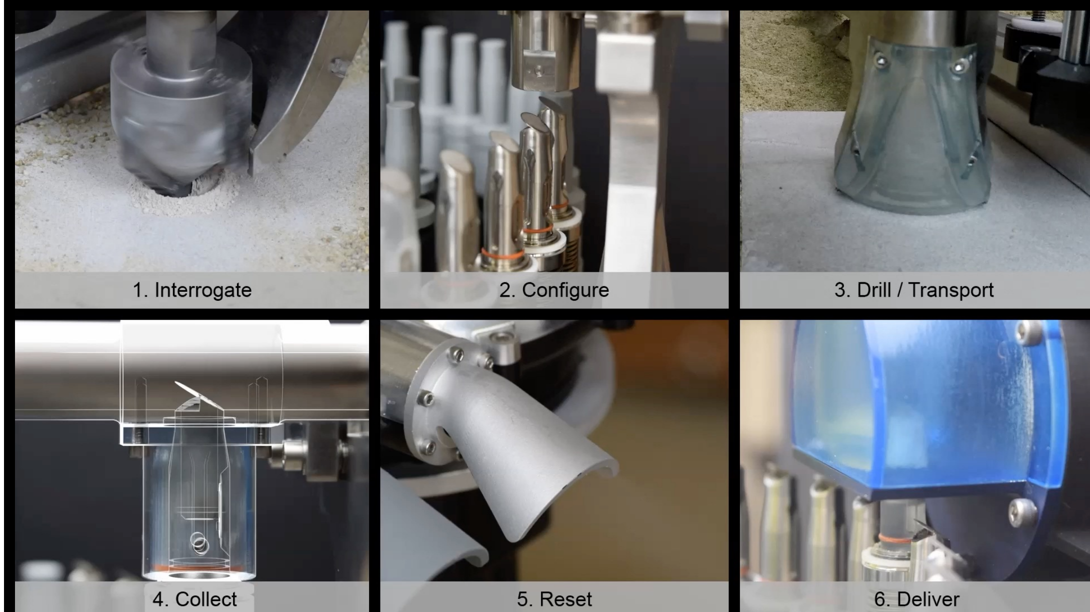


DRAGONFLY

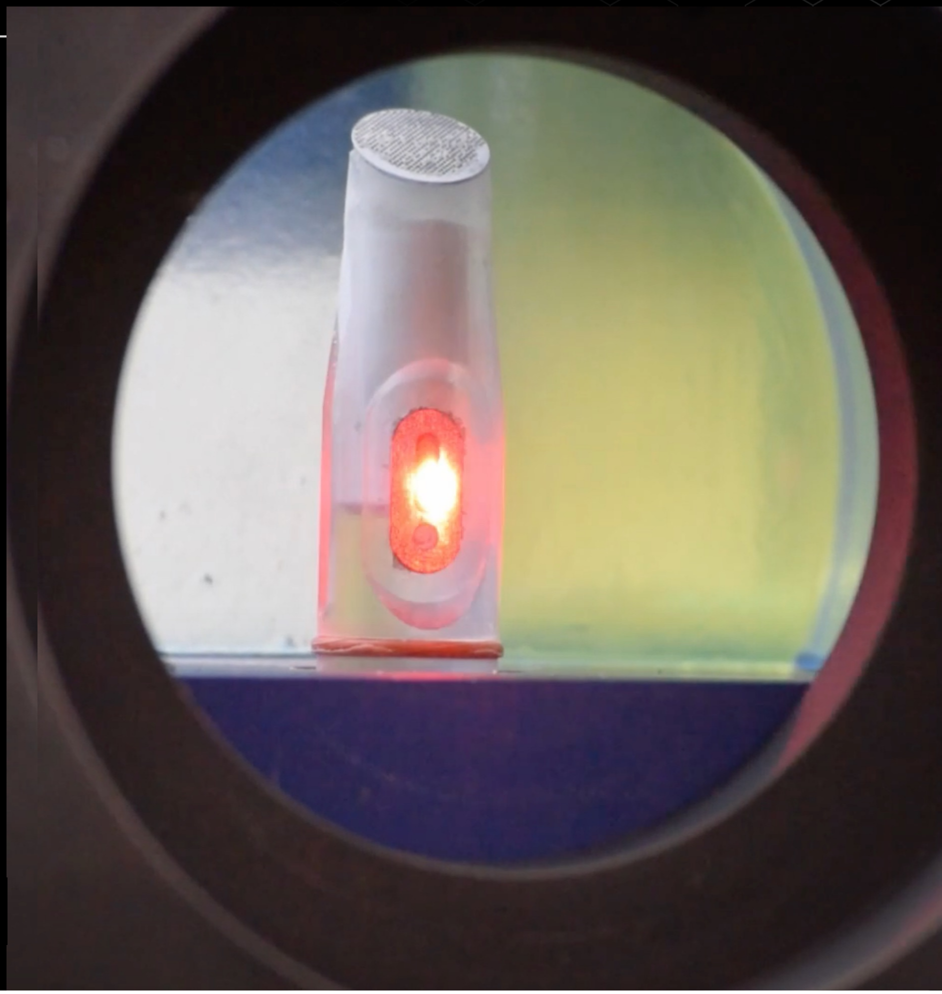
Acquisition of Titan’s solid surface materials in a cryogenic environment

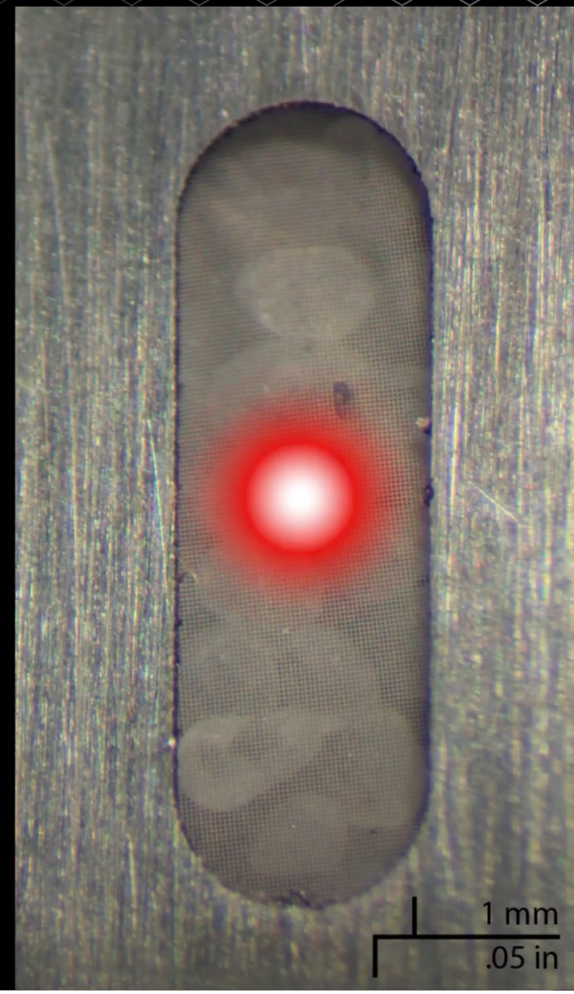


- DrACO: Sample surface materials for detailed chemical analyses with DraMS

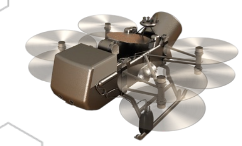


DraMS LDMS

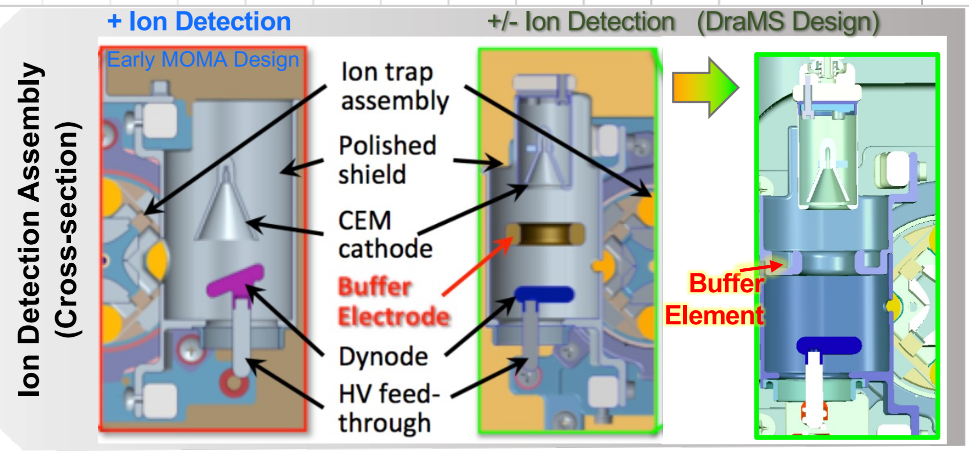


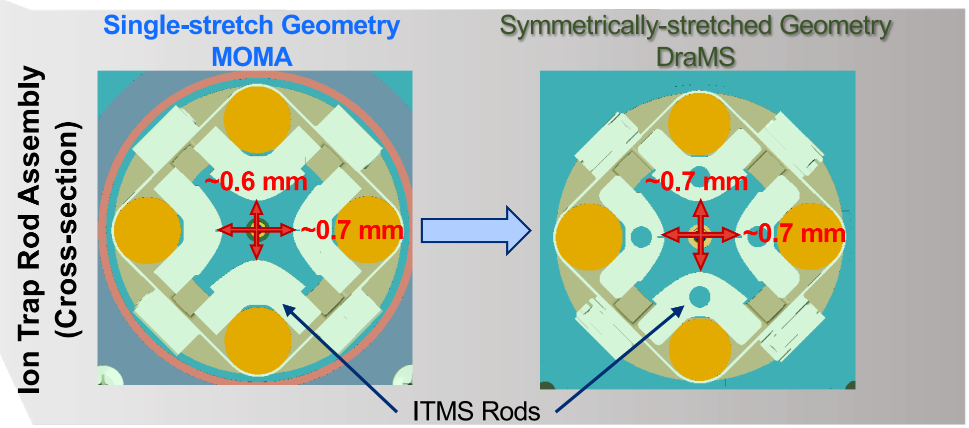


Key DraMS ITMS changes from MOMA

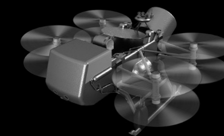


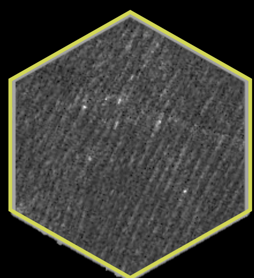
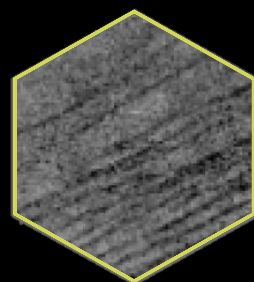
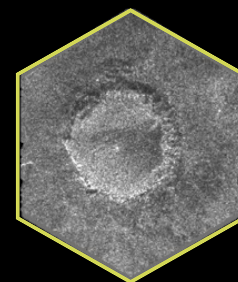
- Ion detection assembly:
  - Additional **(buffer) element** and switchable polarity dynode HV delivery to enable **positive and negative ion detection in LD mode**.
- Ion trap rod assembly:
  - Symmetrically-stretched rod assembly for improved mass spectrometric performance.

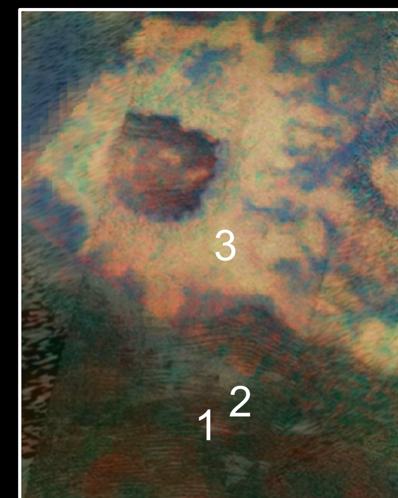




What kinds of samples will we get?



1. Dunes	2. Interdunes	3. Impact melt
		



Less altered → Organic Processing → More altered (Hydrolysis)

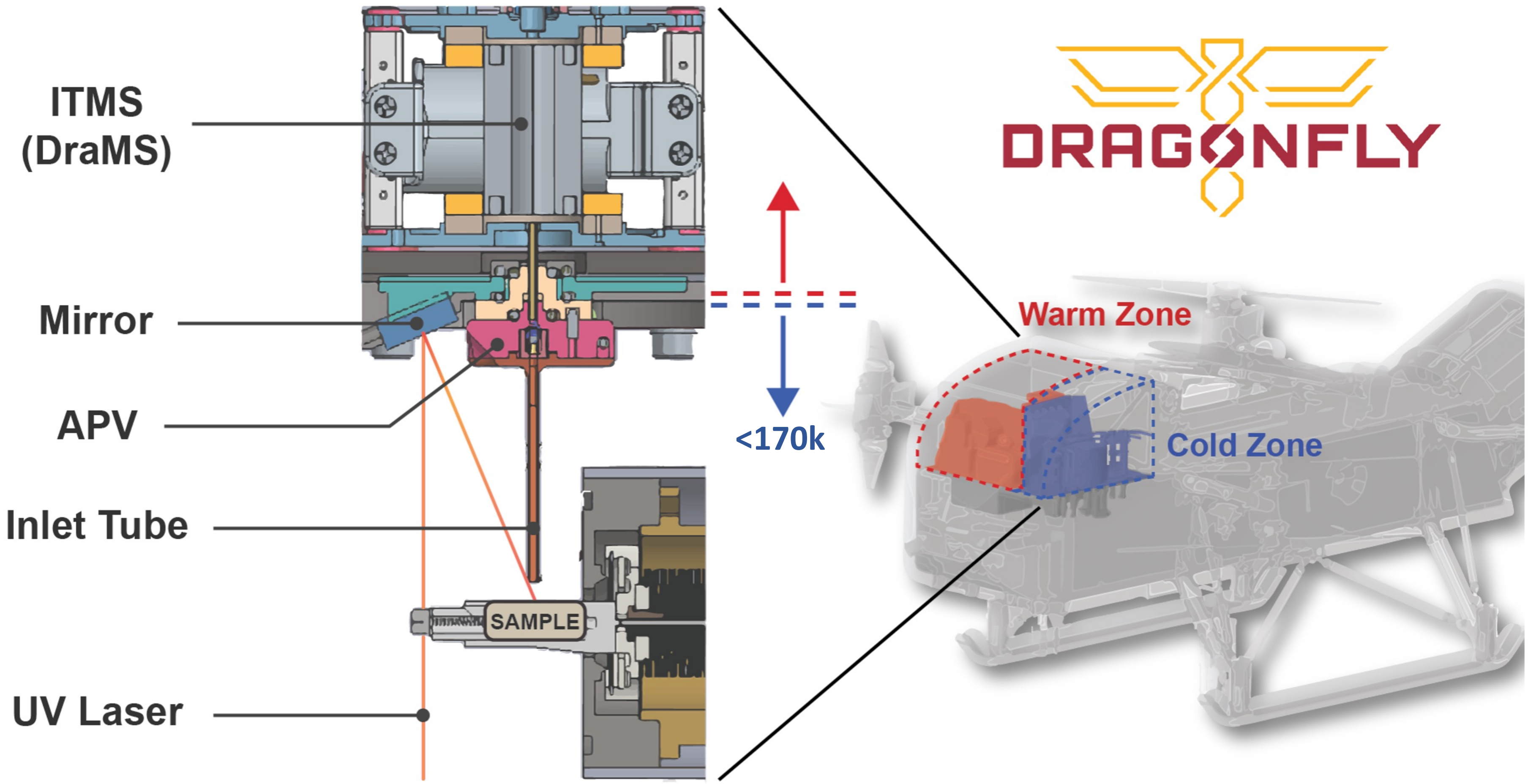
Lower Ice* Content → Ice* content → Higher Ice* Content

Lower likelihood of salts* → Possible Salt* content → Higher likelihood of salts*

*Ice = Water ice with up to 33% NH_3

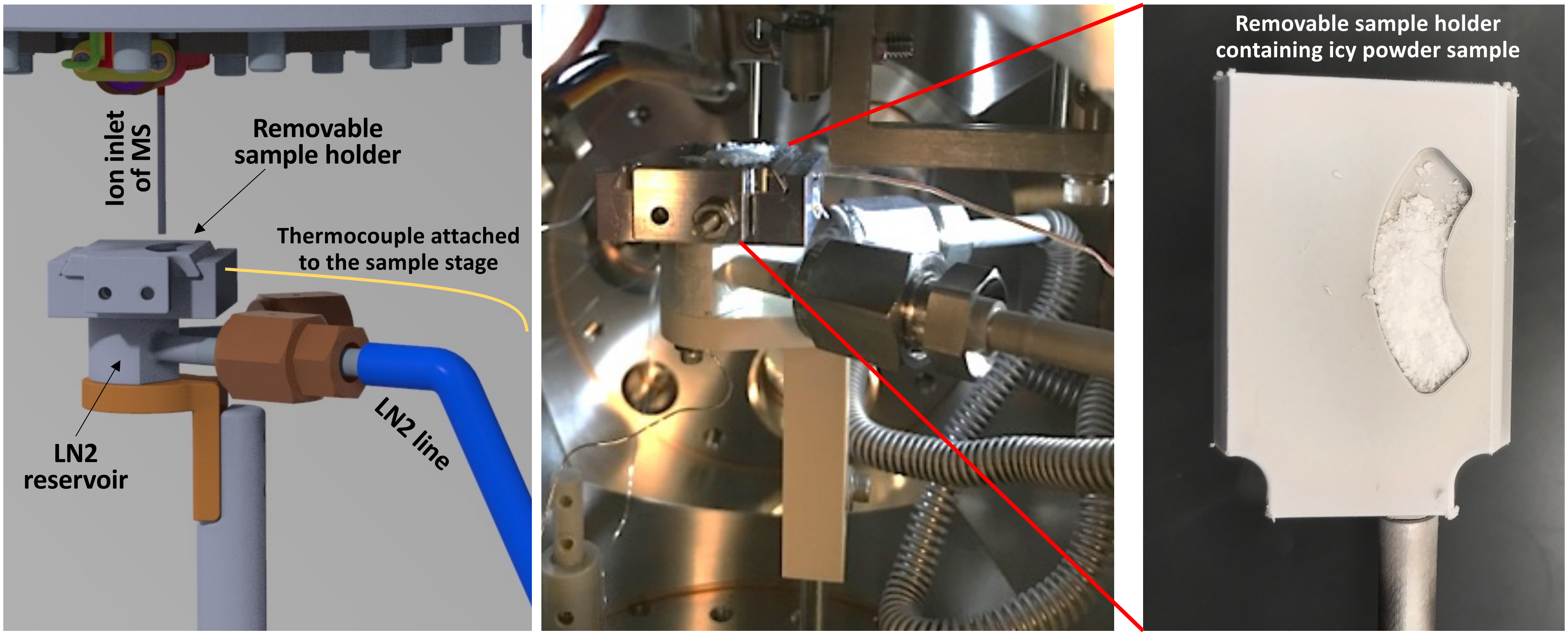
†Salts = few wt% NaCl, $MgSO_4$, KCl, …

Cryo-LDMS Dragonfly



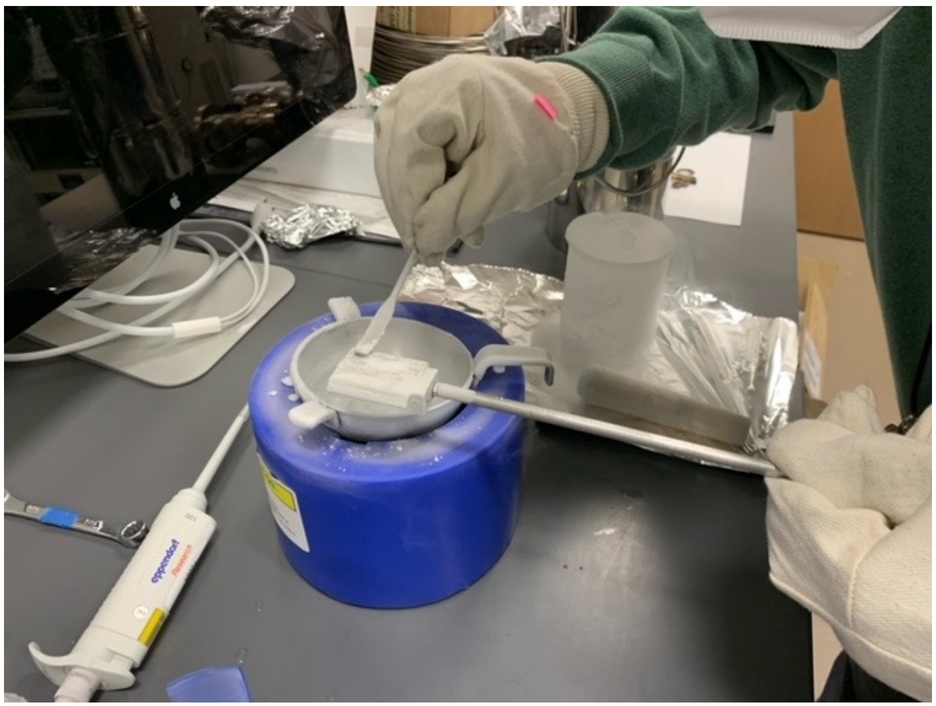
Cryo-LDMS Breadboard

The Cryo-temperature controlled the sample stage and sample holder for Cryo-LDMS

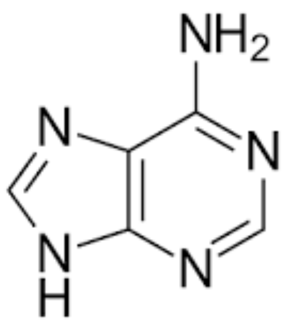


Cryo-LDMS sample prep:

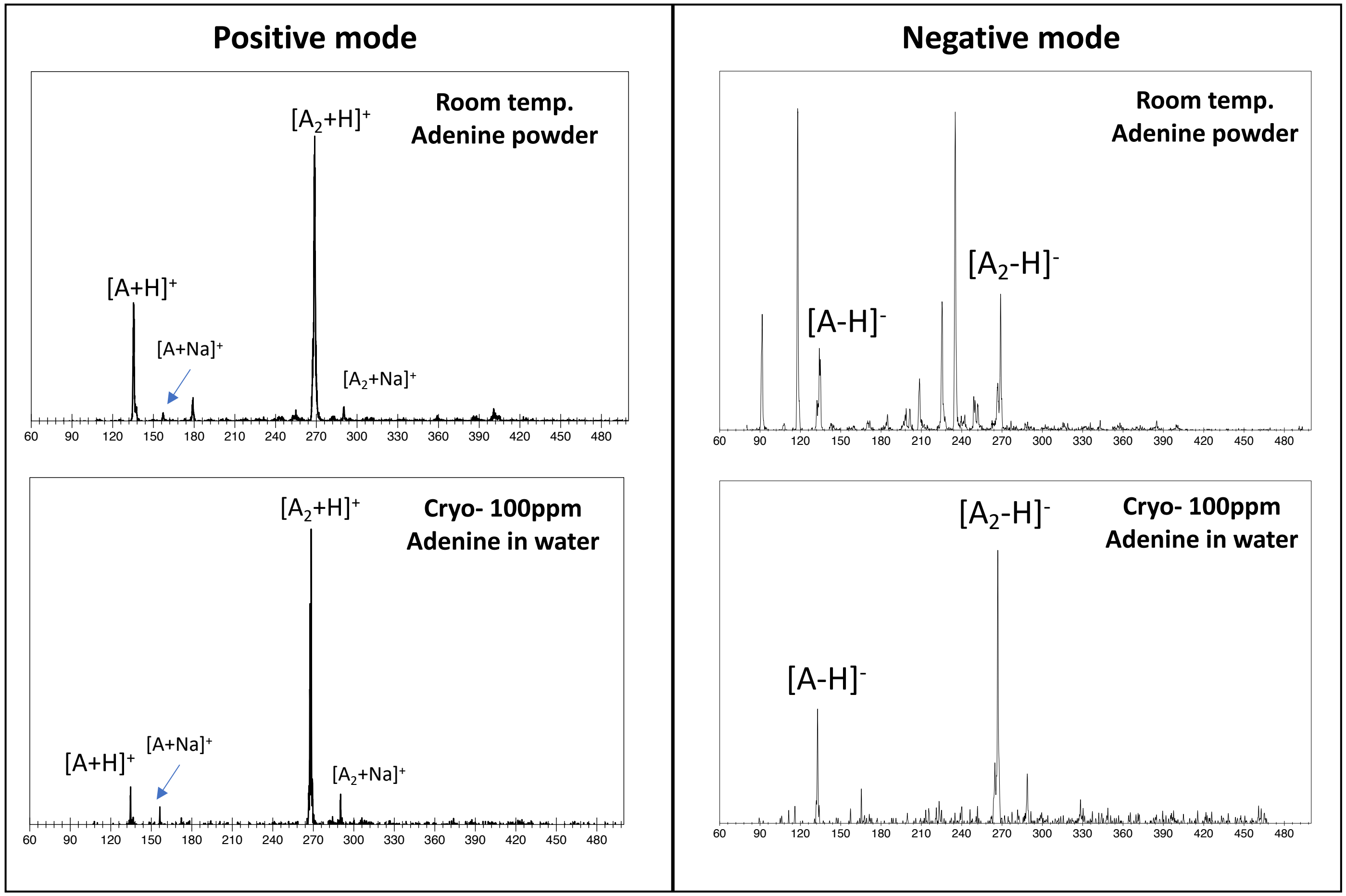
- Sample prep: (1)drop organic solution into LN2; (2)grind the ice to fine powder; (3)transfer the powder to the pre-cooled sample holder; (4)insert the sample holder onto the sample stage.
- It took ~20min to reach ~155K (~-120^{0}C).
- Fill the chamber with Titan atmospheric mix (sub-ambient (~25torr) pressure of 2.9% CH_4/N_2 gas mixture) then perform LDMS.
- Monitor the temperature by controlling the LN2 injection. The temperature was maintained between 155K-175K.



Cryo-LDMS Results:

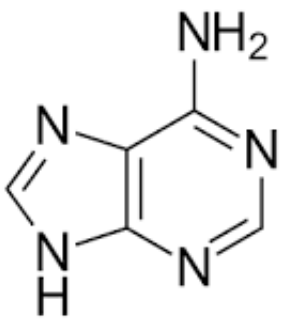


Adenine
m/z=135



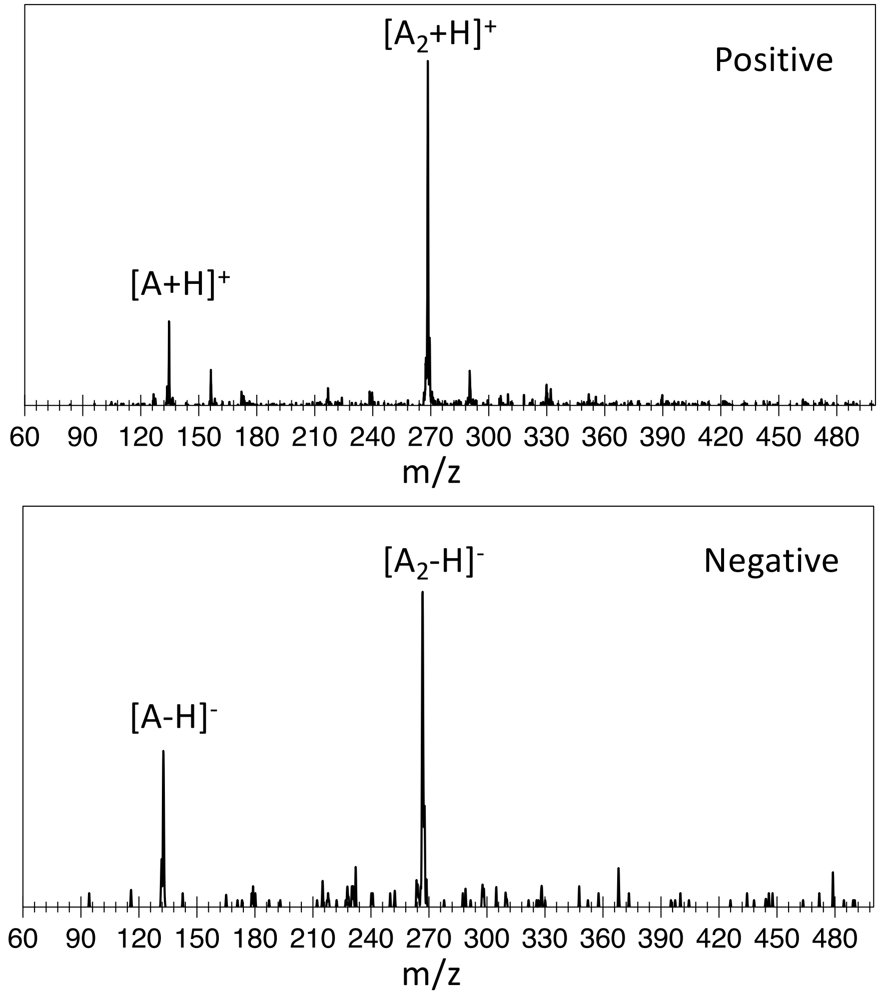
- ***LDMS of samples at cryogenic temperature works!***
- ***ppm level sensitivity to aromatic analytes in a water ice matrix is achievable.***

Cryo-LDMS Results:

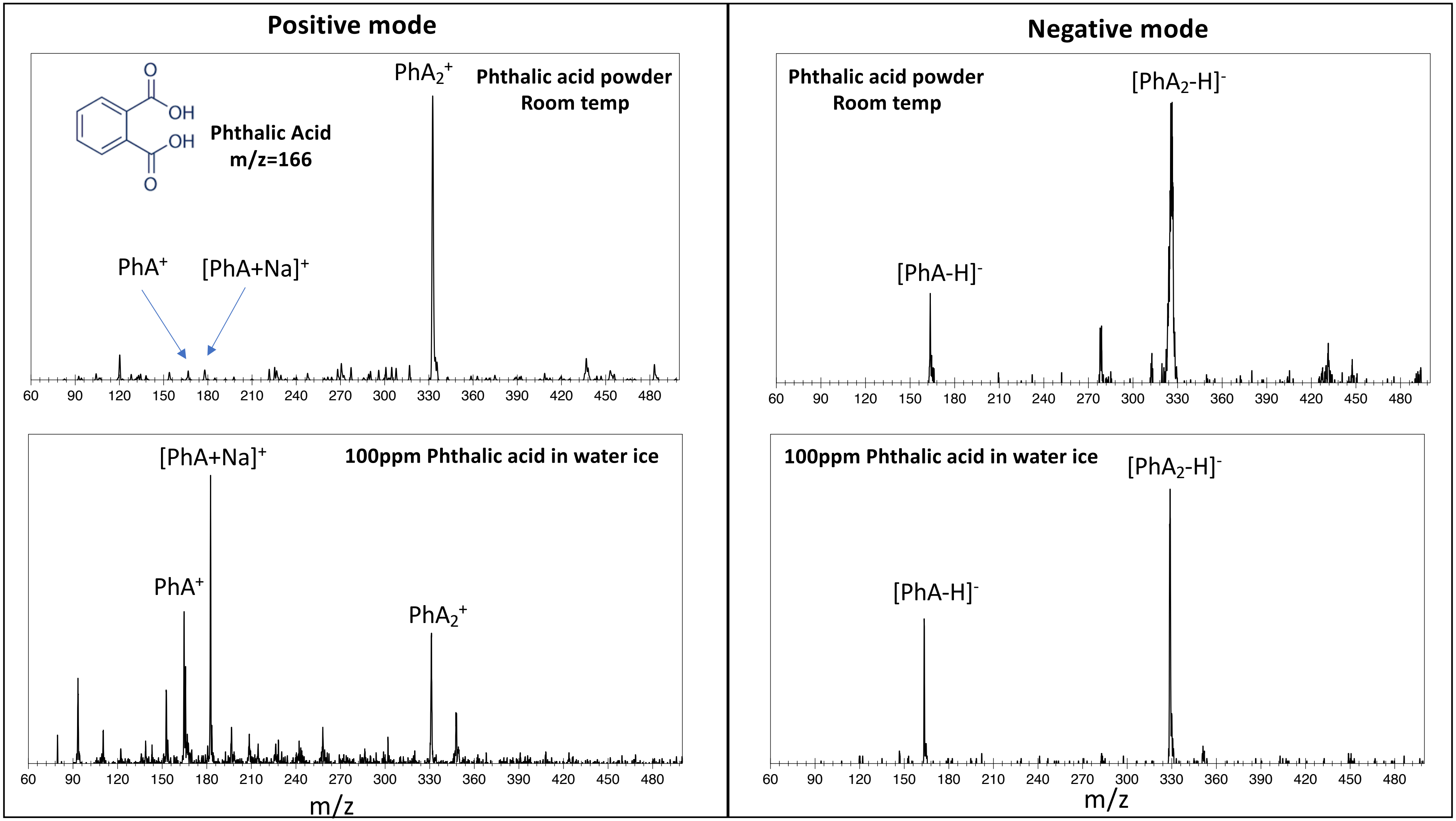


Adenine
m/z=135

Cryo 100ppm Adenine in **15% NH_3-H_2O ice**



Cryo-LDMS Results:



Summary

- DraMS will analyze powdered cryogenic surface materials, obtained from Titan's 94K surface, that may comprise a water ice or water-ammonia ice matrix.
- DraMS maintains collected samples below 170K to minimize any thermal alteration prior to analysis, particularly for the LDMS mode.
- To model and verify this capability in advance of the full instrument environmental testing, we have developed a cryogenic sample preparation protocol and prototype instrument setup. This prototype has allowed us to verify fundamental LDMS operation at cryogenic temperatures and to further investigate potential spectral and performance deltas when performing LDMS at these very cold temperatures.
- Continue to improve the sample preparation and analyze more samples, including organics insoluble in water, samples containing minerals and salts.

Acknowledgments:
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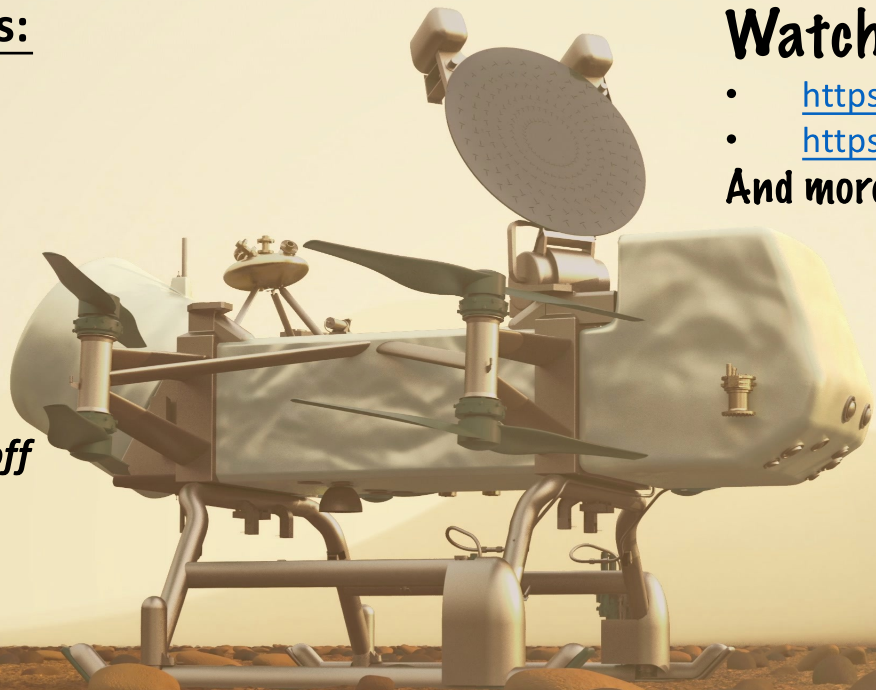
Melissa G. Trainer
and DraMS team



Watch *Dragonfly* Movies!

- https://svs.gsfc.nasa.gov/13562
- https://www.youtube.com/watch?v=XbglDa3rzBk

And more at https://dragonfly.jhuapl.edu/

Thank you!