HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

Development and Testing of a Sample Cup for Laser-Based Instruments

Session 104: Astrobiological Technologies I
2019 Astrobiology Science Conference
June 24, 2019

Presenter:
J. Tighe Costa
Exploration Technologies Group
Honeybee Robotics
jtcosta@honeybeerobotics.com

Co-Authors:
Andrej Grubisic[1], Joseph Sparta[2], Xiang Li[1], Marco Castillo[1], Vincent Holmes[1], Cuyler Crandall[2],Bernice Yen[2], Fredrik Rehnmark[2], Melissa Trainer[1], Ralph Lorenz[3], Kris Zacny[2]

[1]NASA Goddard Space Flight Center
[2]Honeybee Robotics Exploration Technologies Group
[3]Johns Hopkins Applied Physics Laboratory

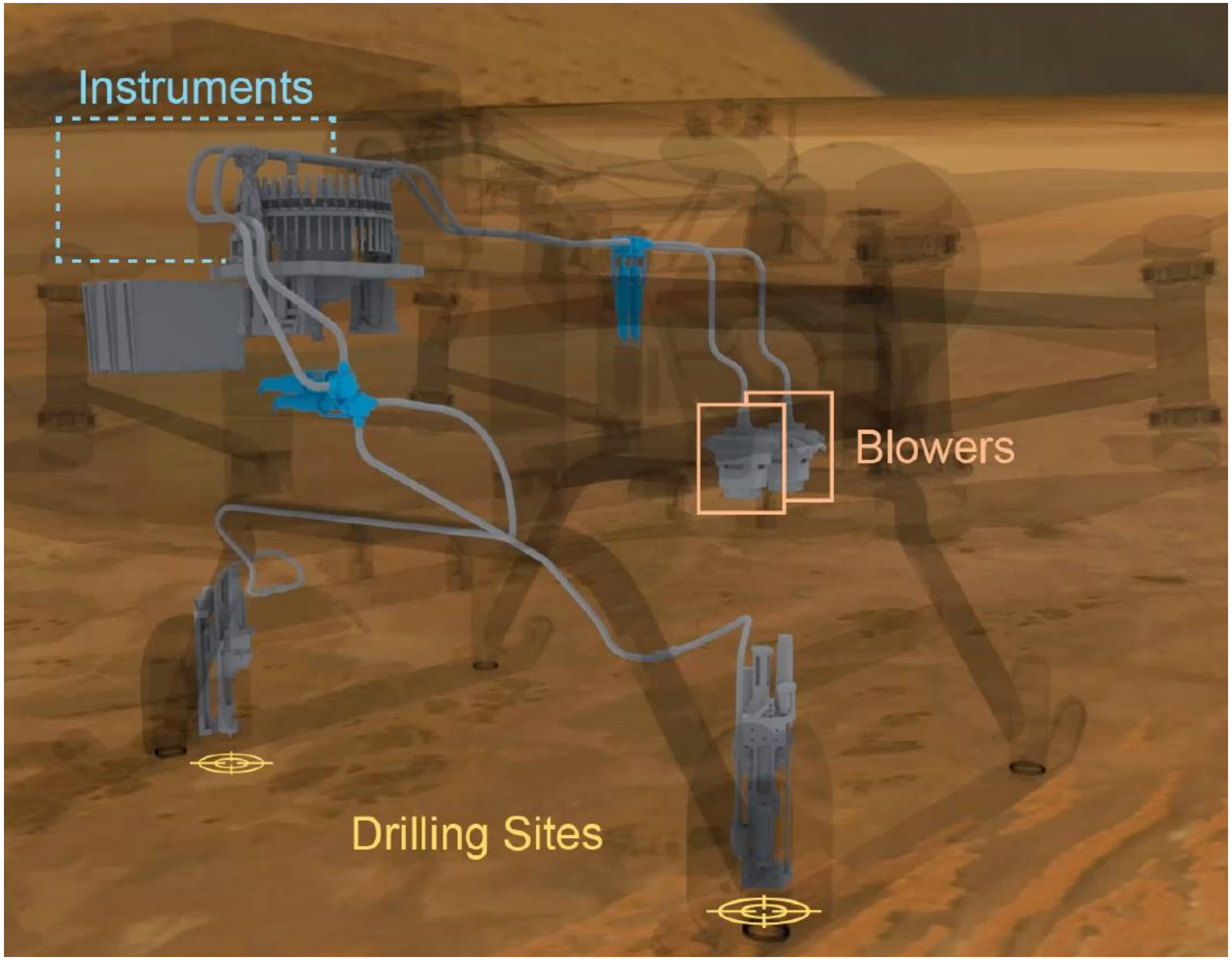
Context

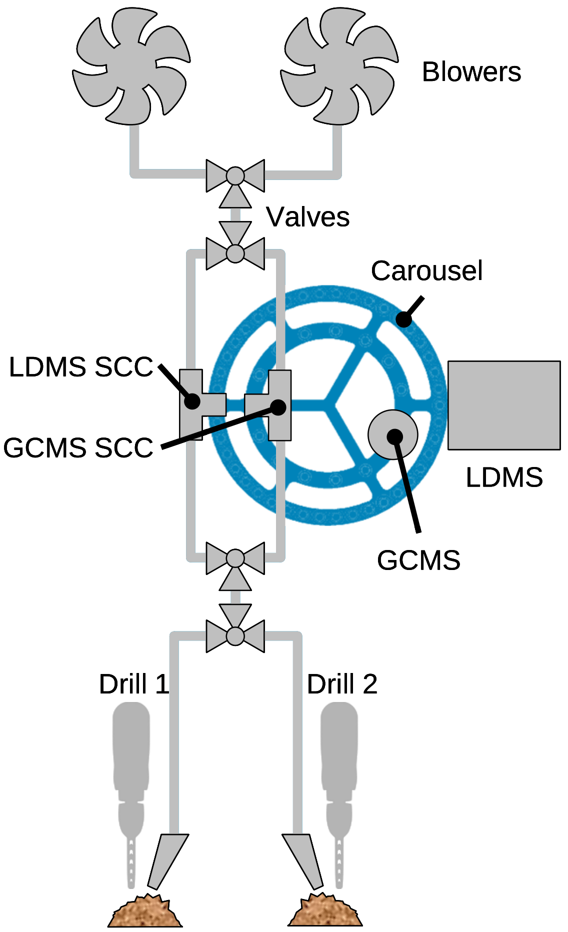
DRAGONFLY
Flights of Exploration Across
Saturn's Moon Titan
NASA
APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY
http://dragonfly.jhuapl.edu

Introduction

Pneumatic system transports sample inside the vehicle

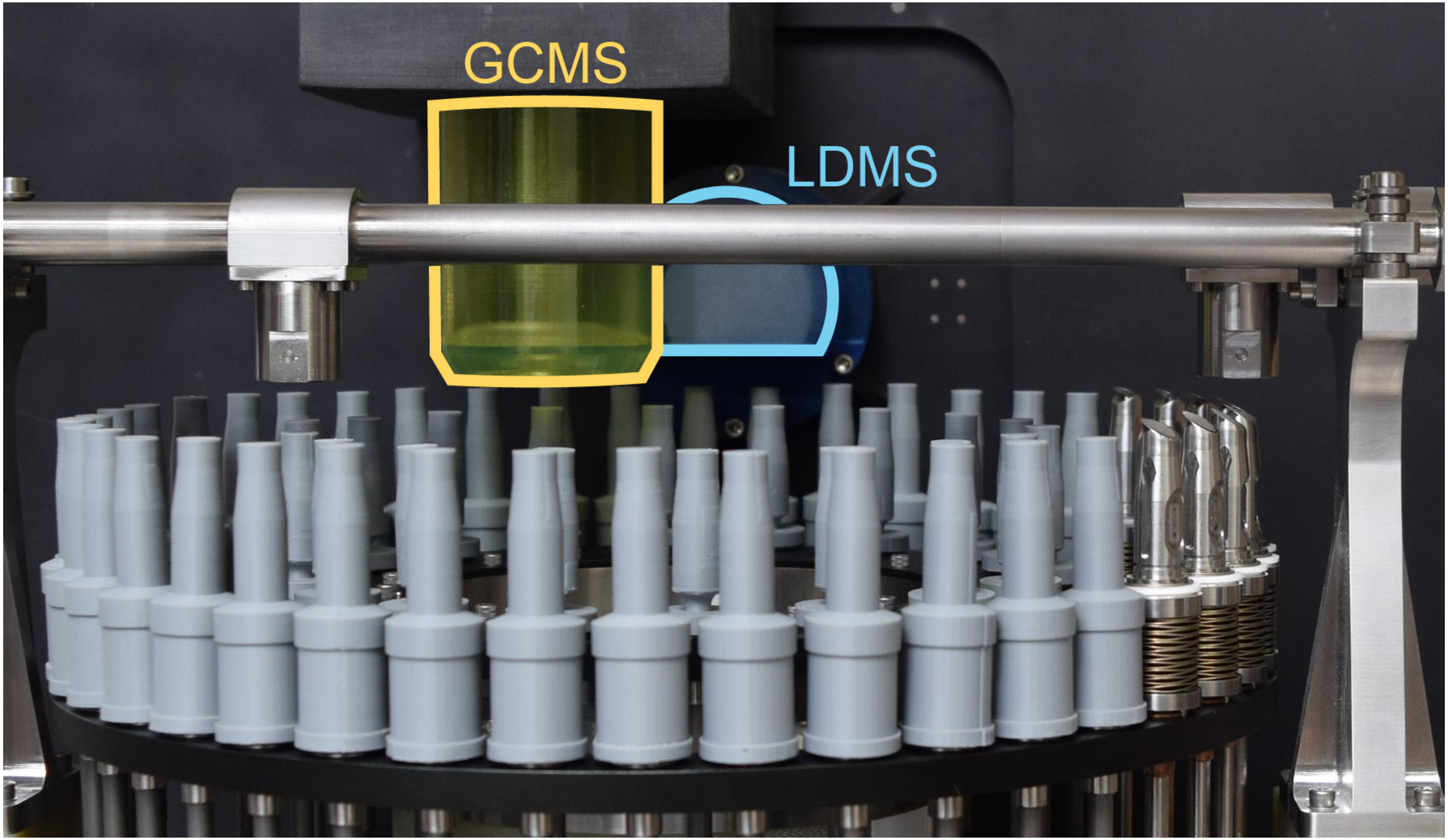
Carousel delivers sample to the instruments





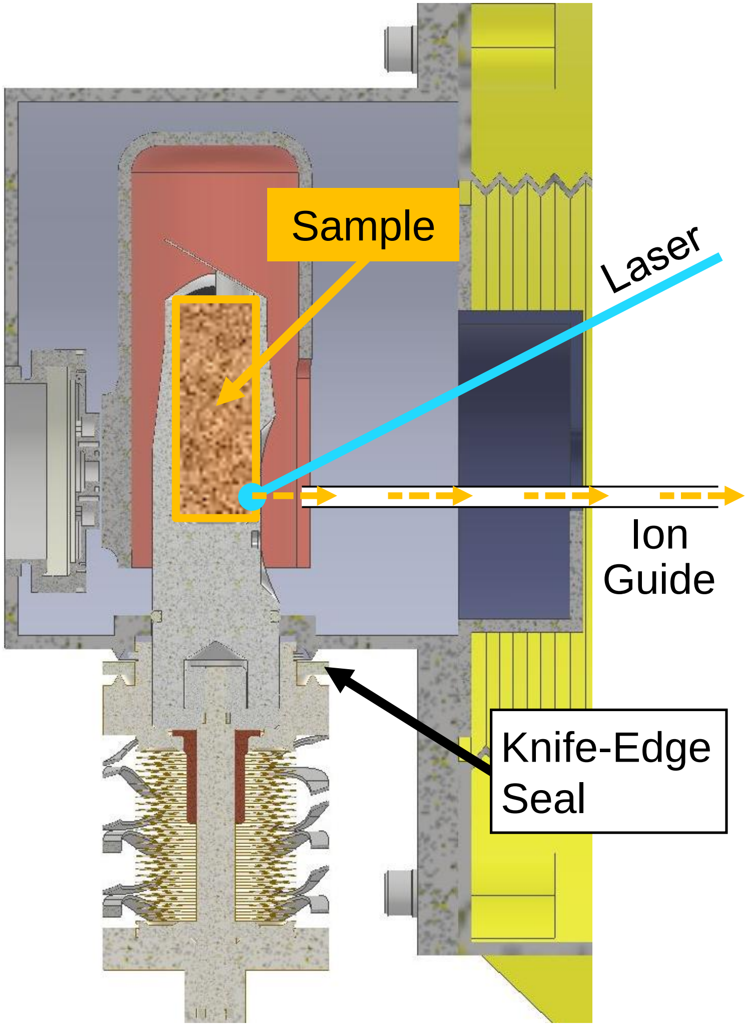
Carousel

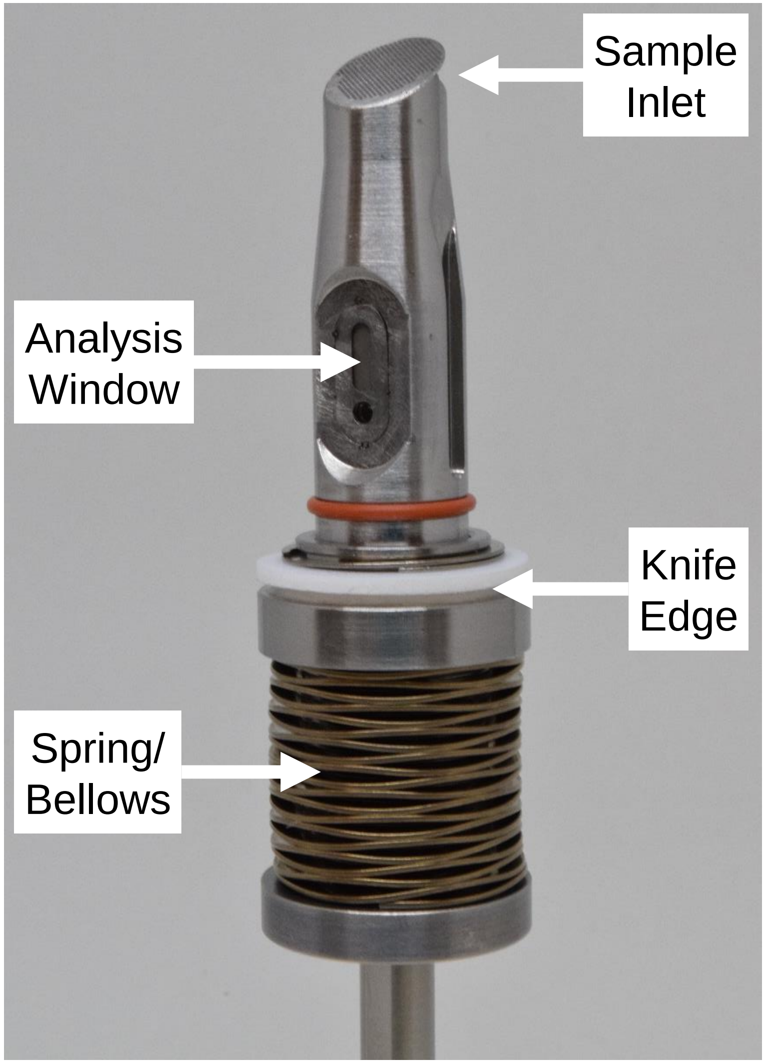
Sample delivery to two instrument modes: **GCMS** (18x cups) and **LDMS** (40x cups)



LDMS Sample Cups

Sample cups perform two functions: **collection** and **presentation**



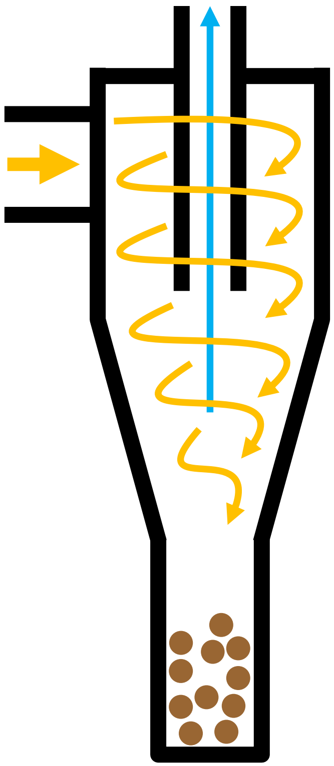


Methods of Collection

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

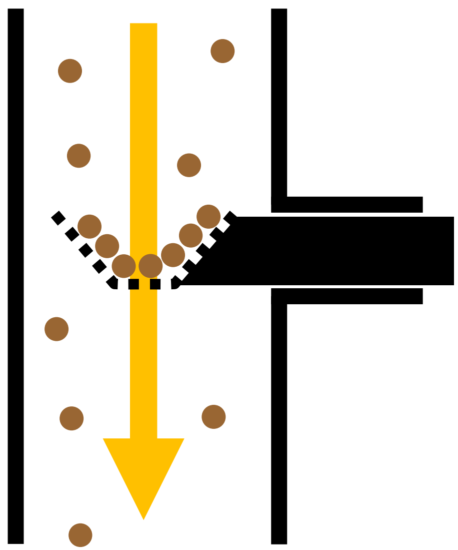
Cyclone

Particles collected from dirty-flow vortex by hitting walls



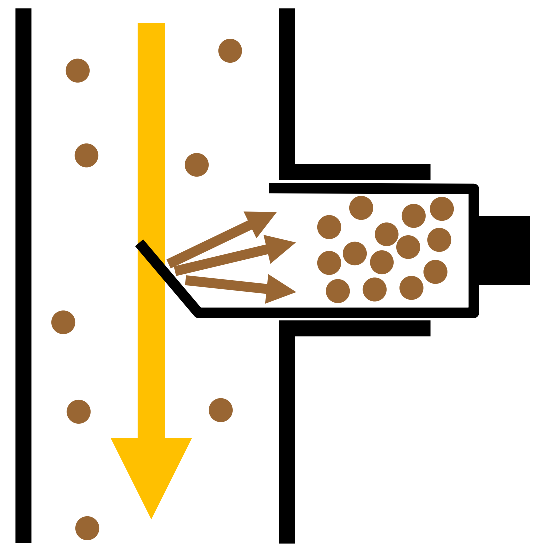
Tea-Strainer

Particles collected from dirty flow by building up in filter



Deflector Cup

Particles collected from dirty flow by deflecting out of flow



Sample Clean Flow Dirty Flow

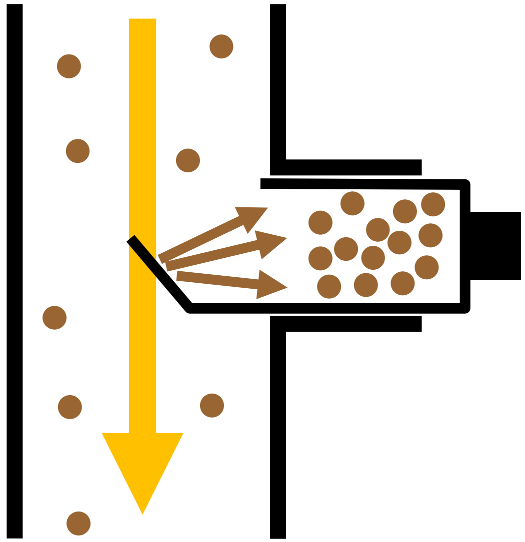
Why Choose a Deflector Cup?

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

Cross-Contamination	Excess sample passes through system
	Readily scalable for single-use sample cups
Self-Metering	Yes (cannot over fill sample cups)
Sample Bias	Collected particle size depends on mesh
	No preference for cohesiveness
	Bias towards collecting first particles
Collection Efficiency	Inefficient (<5%)
System Impact	Dirty blower or positive pressure system
	Finite/moderate sample quantities
	Does not preserve stratification of sample
	Gravity agnostic collection

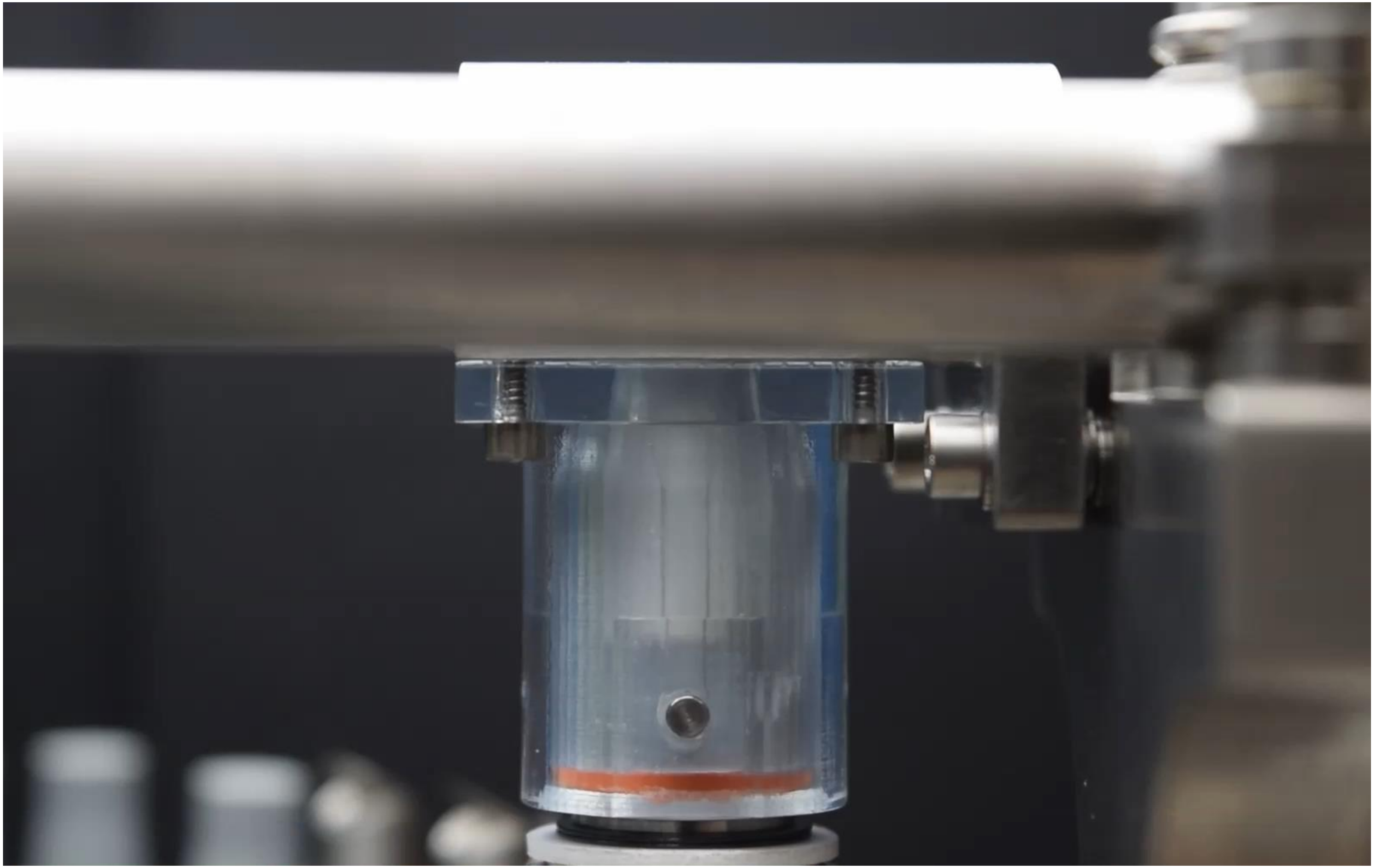
Deflector Cup

Particles collected from dirty flow by deflecting out of flow



Sample Clean Flow Dirty Flow

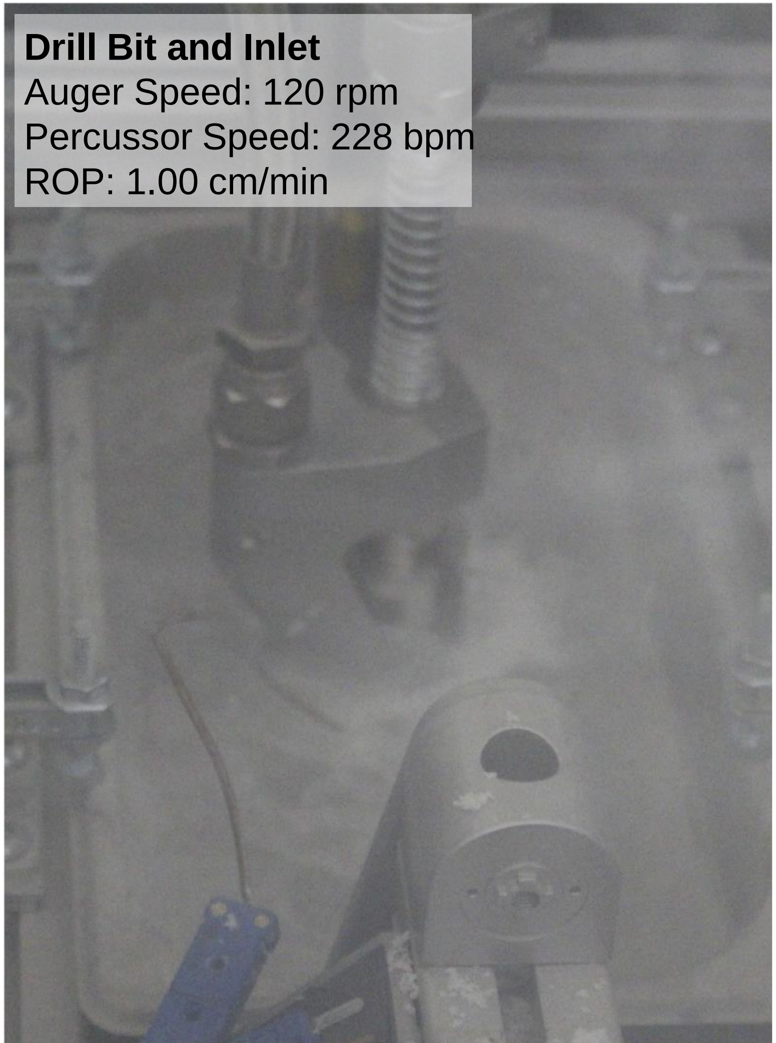
Collection in Action

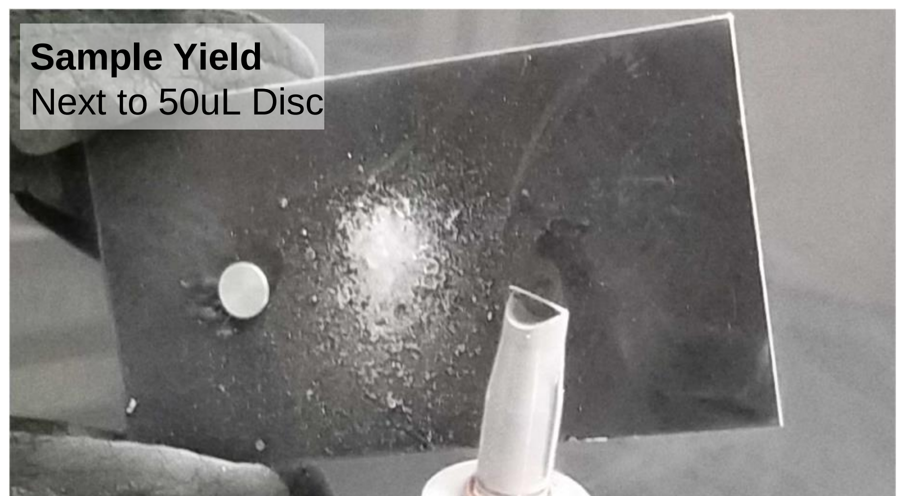


Testing in a Relevant Environment

Testing in a Relevant Environment

Successful collection of water-ice, ammonia-ice, paraffin wax, and silica sand





Testing at Earth STP

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

469uL (94%) Average Fill
54uL (11%) Std. Dev.

Simulants selected cover wide range of material properties:

- Particle density
- Particle size
- Particle shape
- Cohesiveness/stickiness

Glass Beads
40-80um

17cc Ingested
367uL Collected

Wheat Flour
<100um

17cc Ingested
417uL Collected

Paraffin Wax
<1000um

17cc Ingested
523uL Collected

Coal
<1700um

17cc Ingested
523uL Collected

Walnut Shells

150-175um

17cc Ingested
438uL Collected

833-1000um

17cc Ingested
470uL Collected

Silica Sand
250-500um

17cc Ingested
440uL Collected

Beach Sand
707-833um

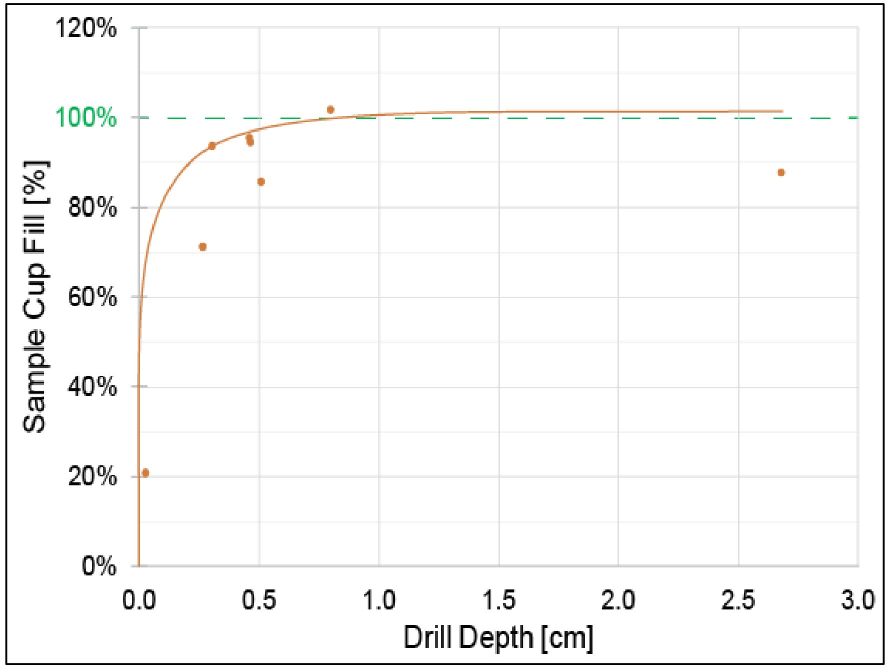
17cc Ingested
523uL Collected

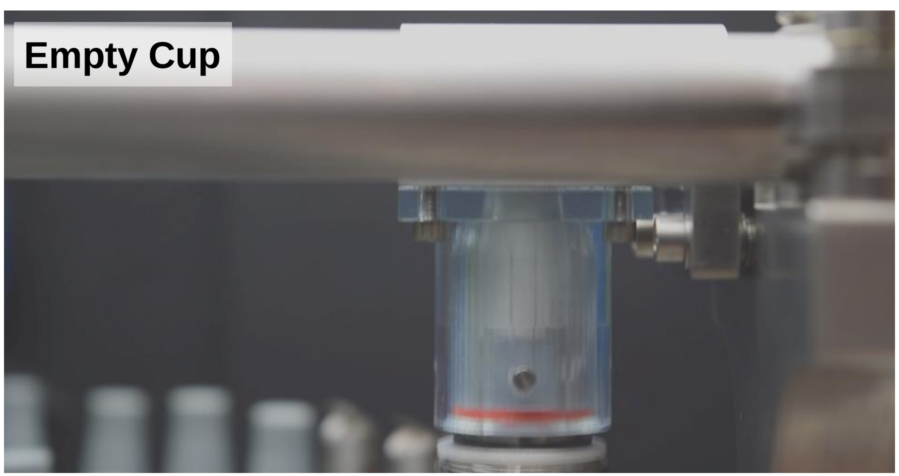
10:1 Sand:Oil
250-500um

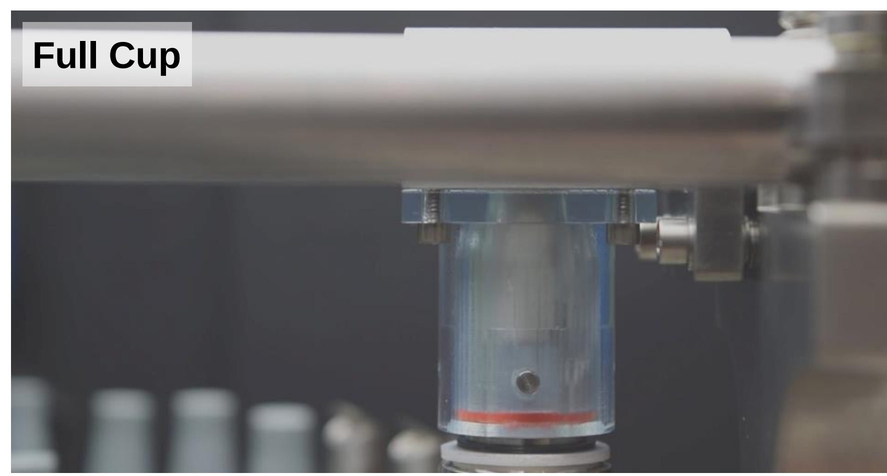
22cc Ingested
523uL Collected

Depth-to-Fill Testing in Limestone

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation



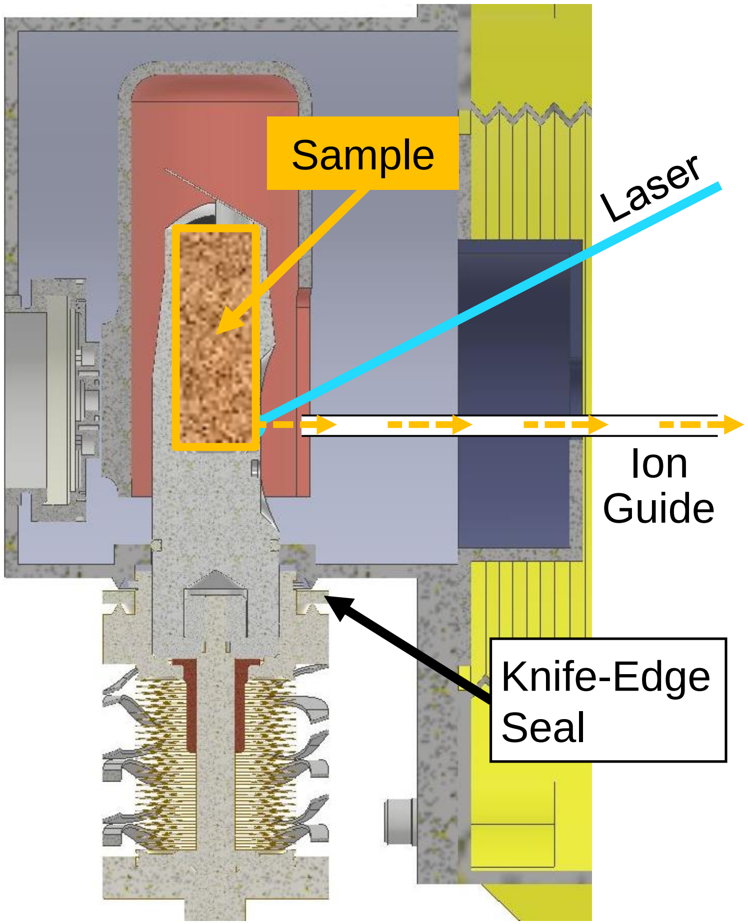




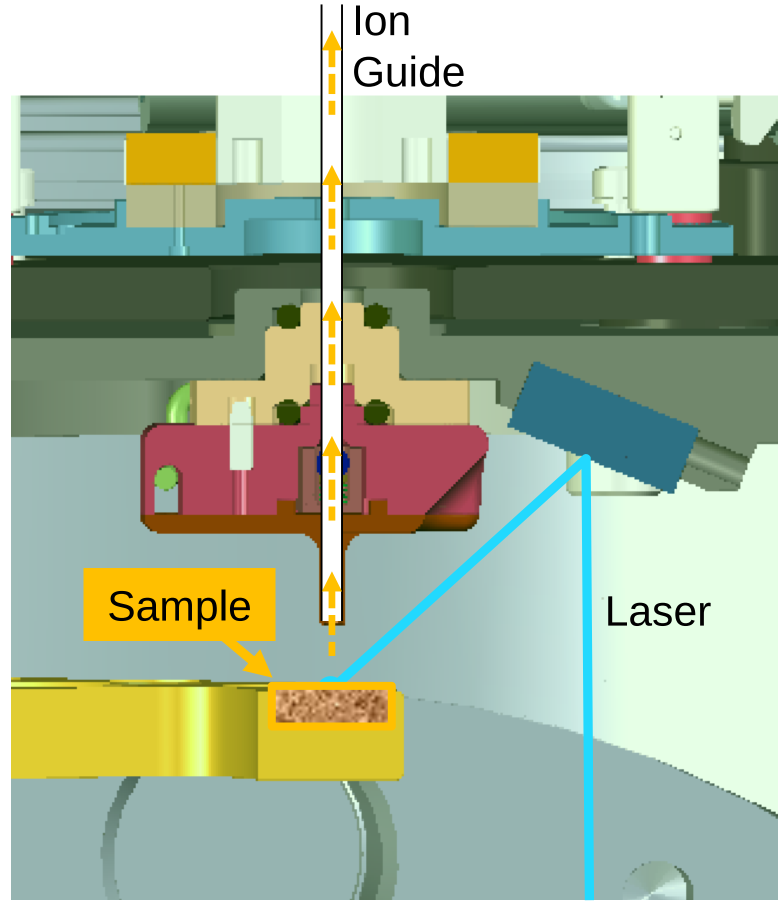
Sample Presentation Requirements

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

LDMS requires **surface of sample to be flat** and in laser **line-of-sight**, and to be able to **perform analysis at multiple locations**



Sample Presentation on Vehicle



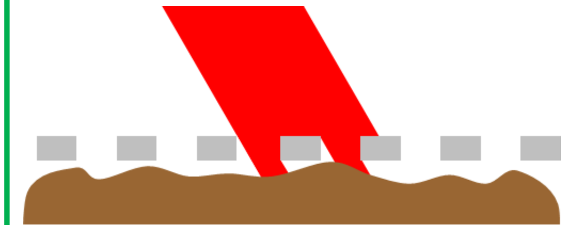
Sample Presentation in Lab

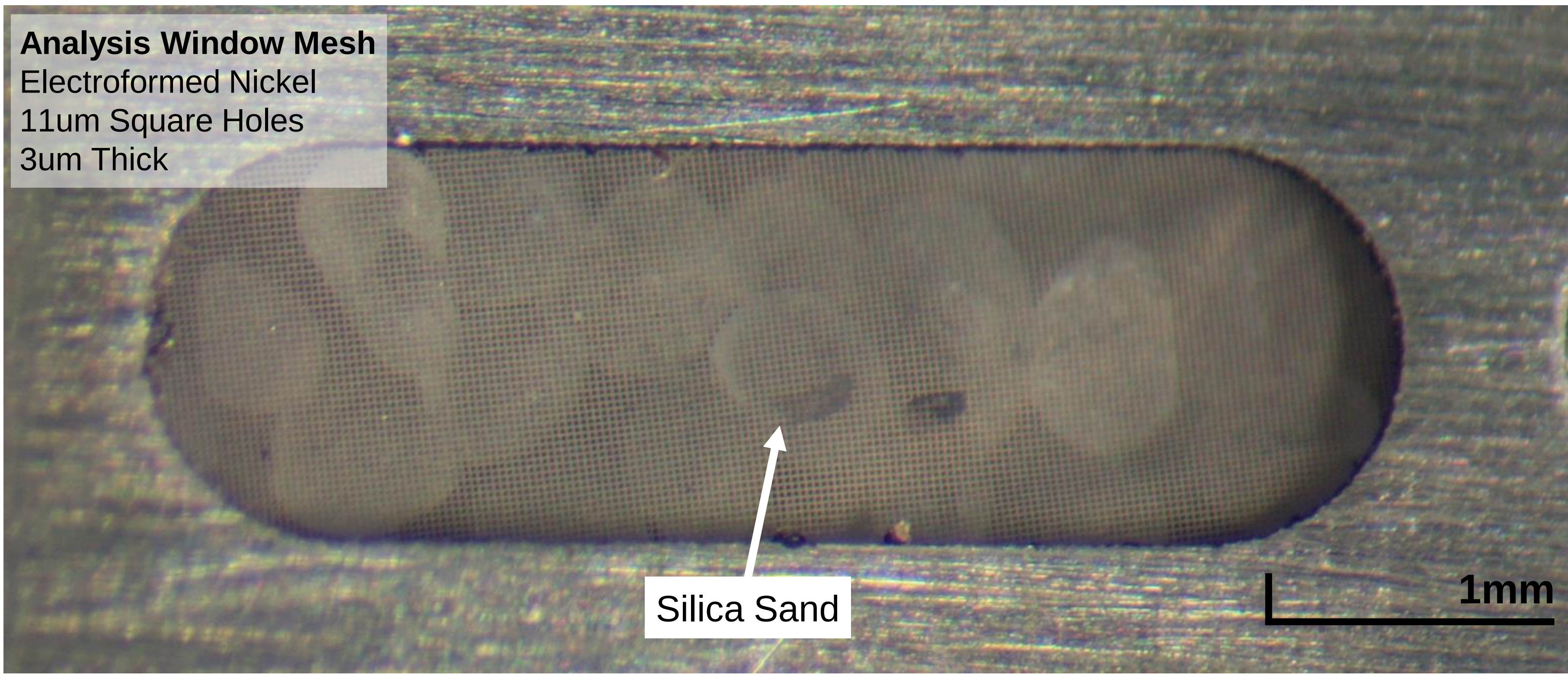
Analysis Window

Thin mesh, large holes
(LDMS preference)

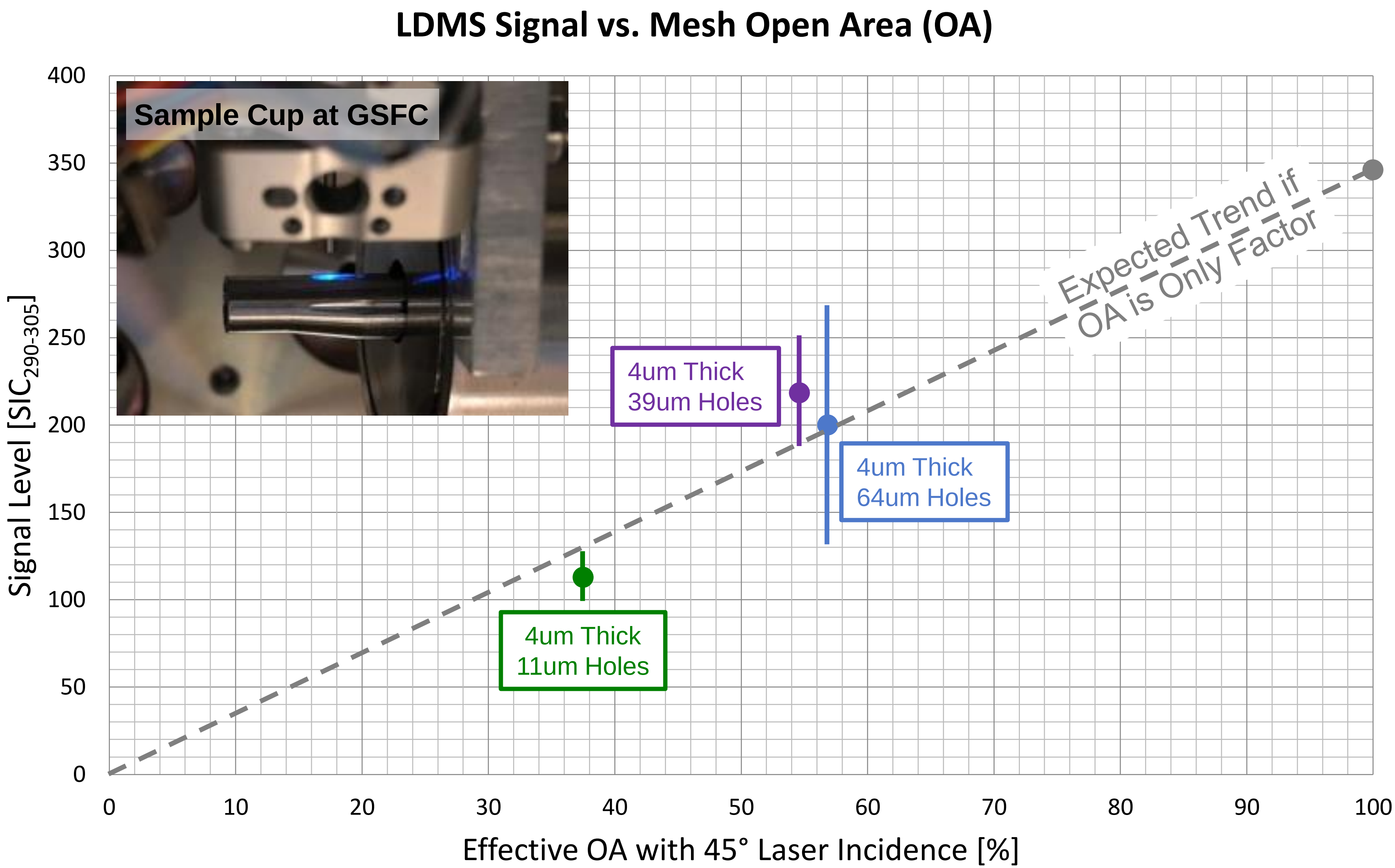
Thick mesh, small holes
(pneumatics preference)

Thin mesh, small holes
(compromise)



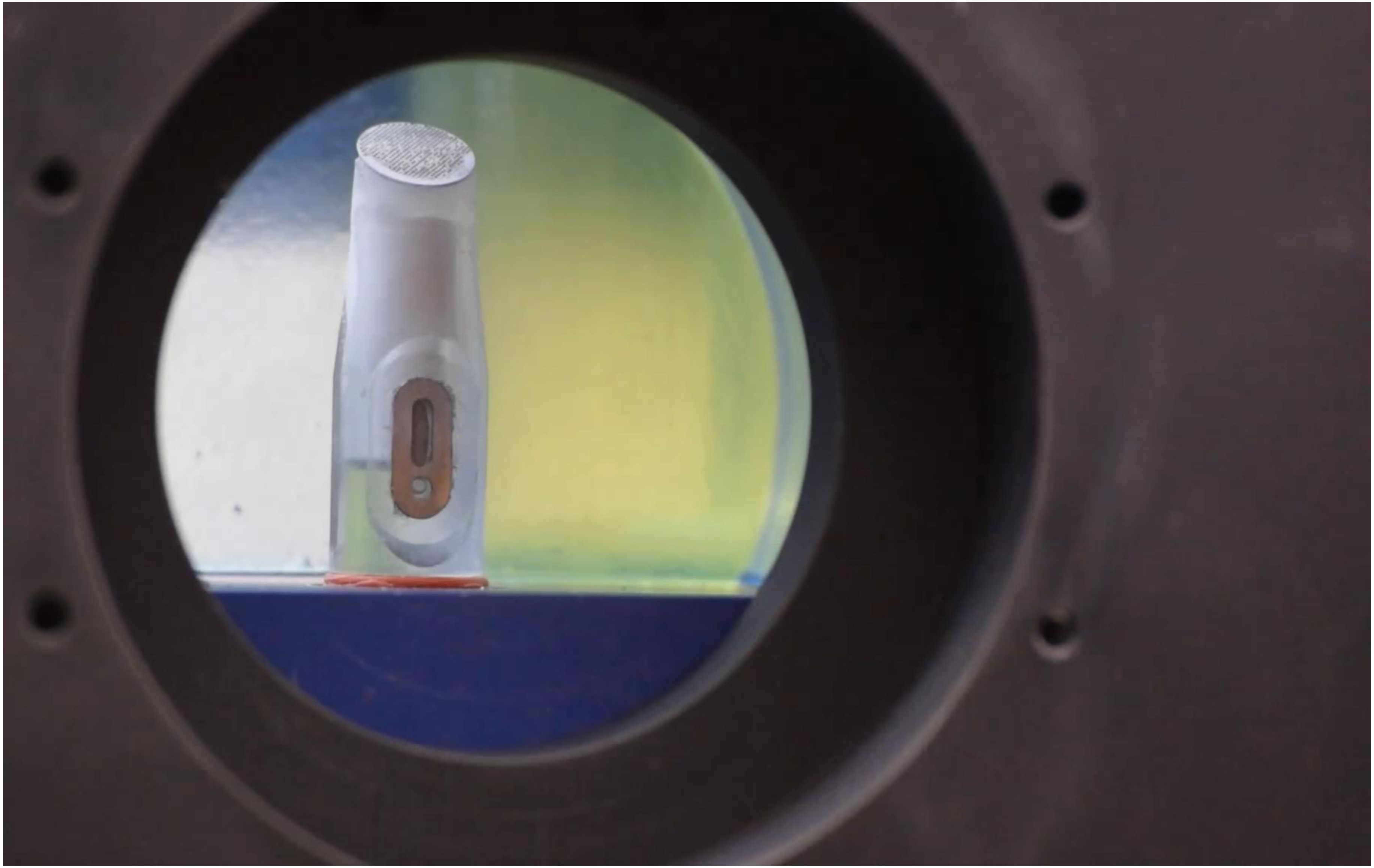


Window Sensitivity Results



Sample Delivery

Sample Analysis



Conclusion

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

Dragonfly's LDMS sample cup design combines two different functions

Collection
Deflector Cup Architecture

- ✓ Material Agnostic
- ✓ Gravity Agnostic
- ✓ Self-Metering
- ✓ Clean

Presentation
Laser-Window + Repositionable Seal

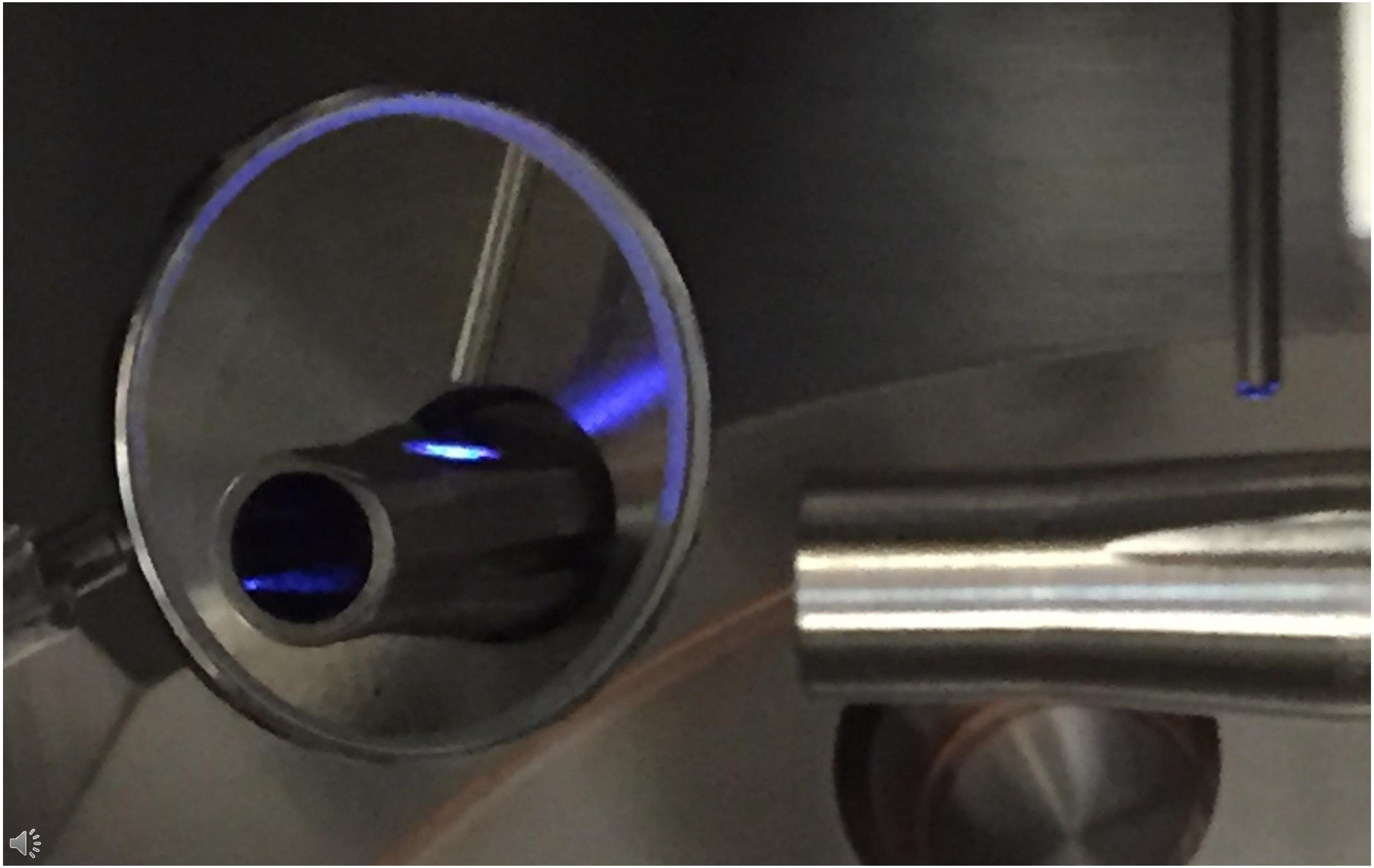
- ✓ Demonstrated LDMS Compatibility

While developed for Dragonfly…

Sample collection and presentation methods demonstrated to be robust and viable architecture solutions for many sampling applications

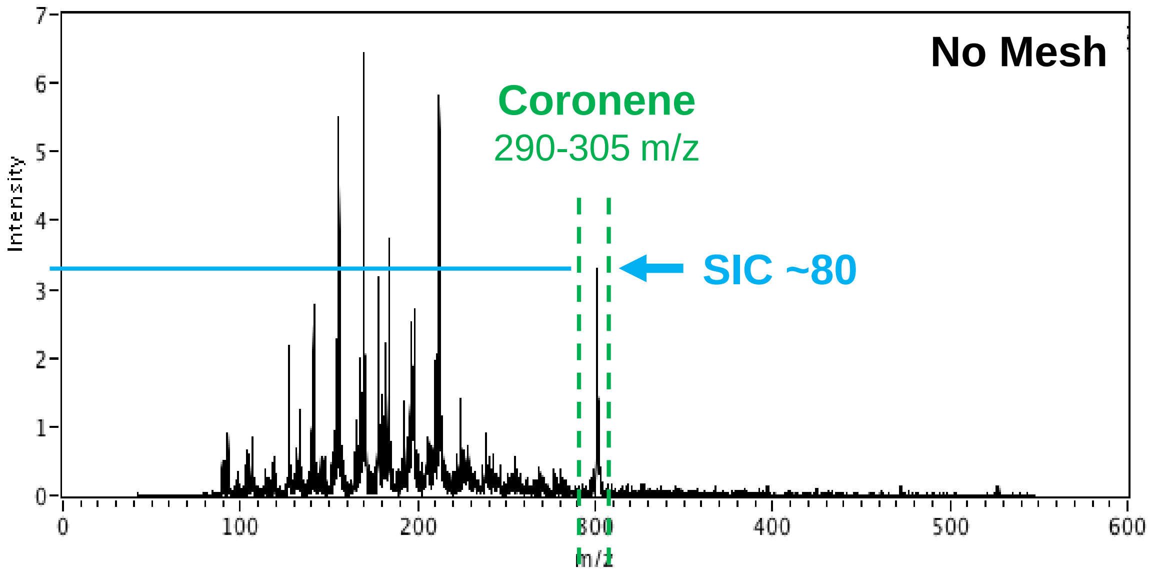
Questions?

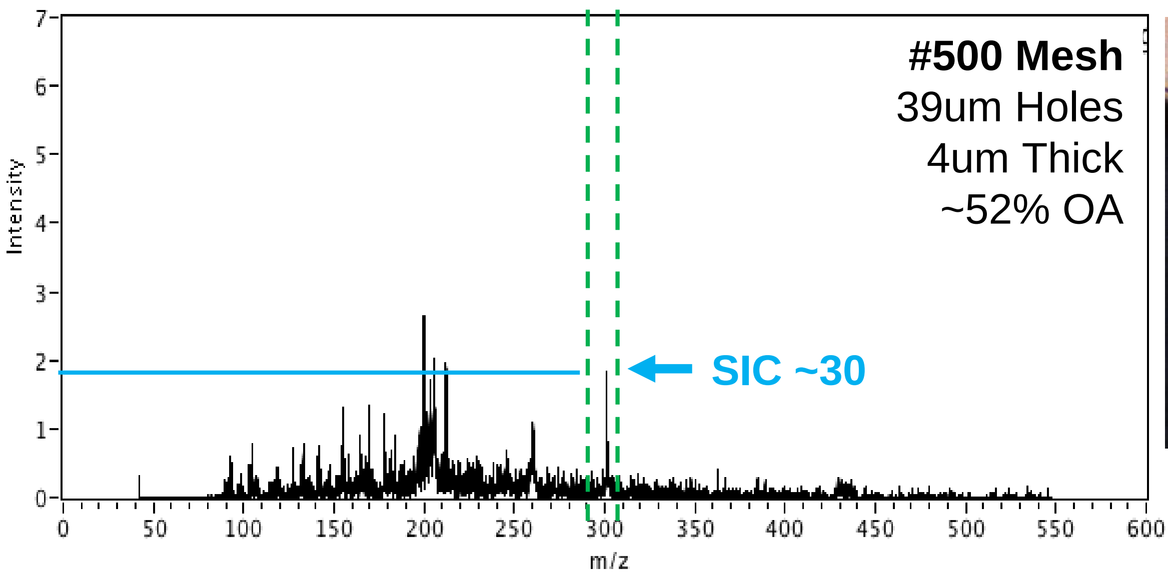
HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation



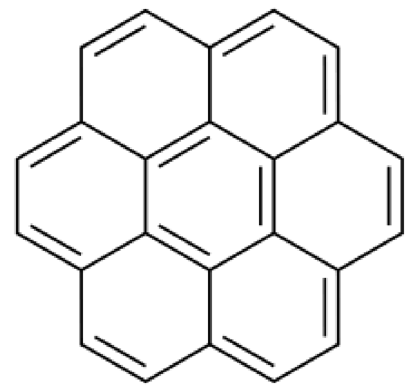
Appendix

1ppmw Coronene Sensitivity

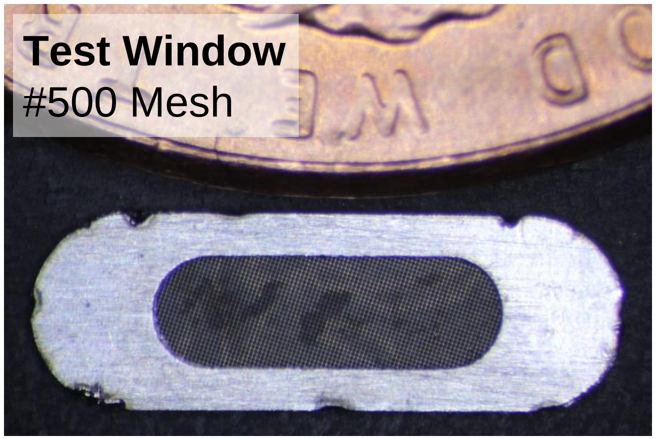




Coronene



300 Da

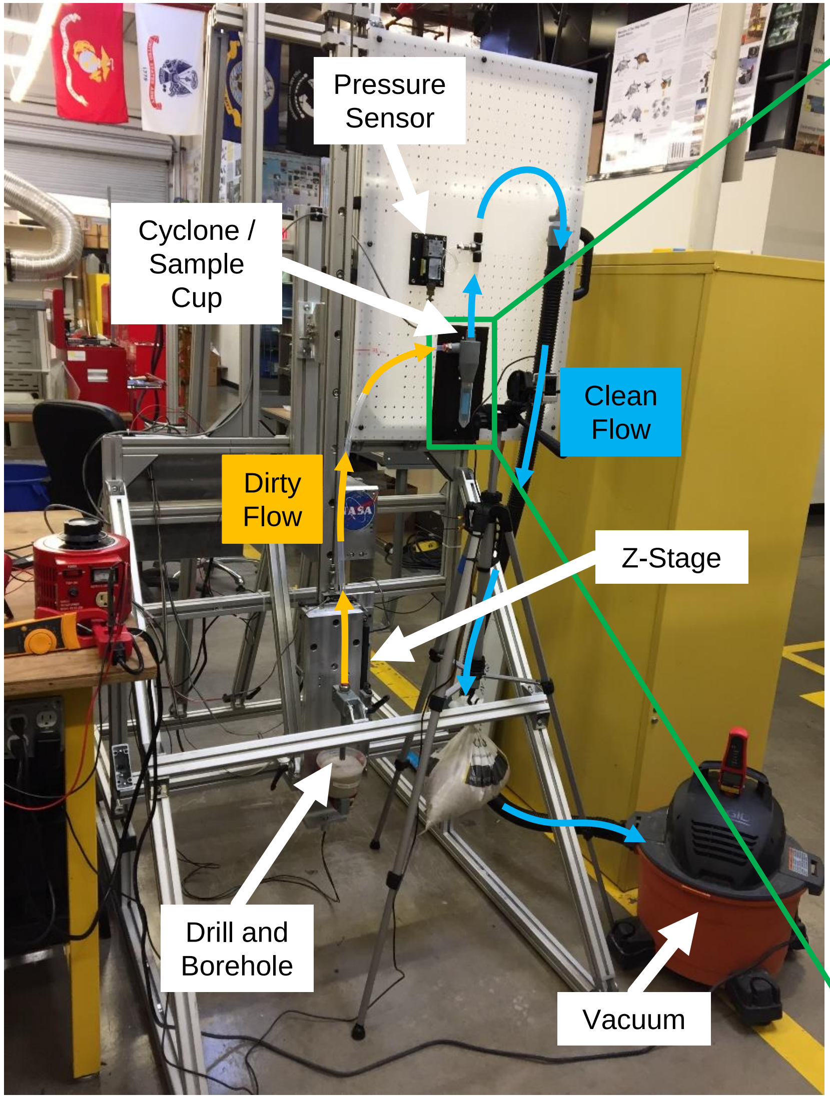


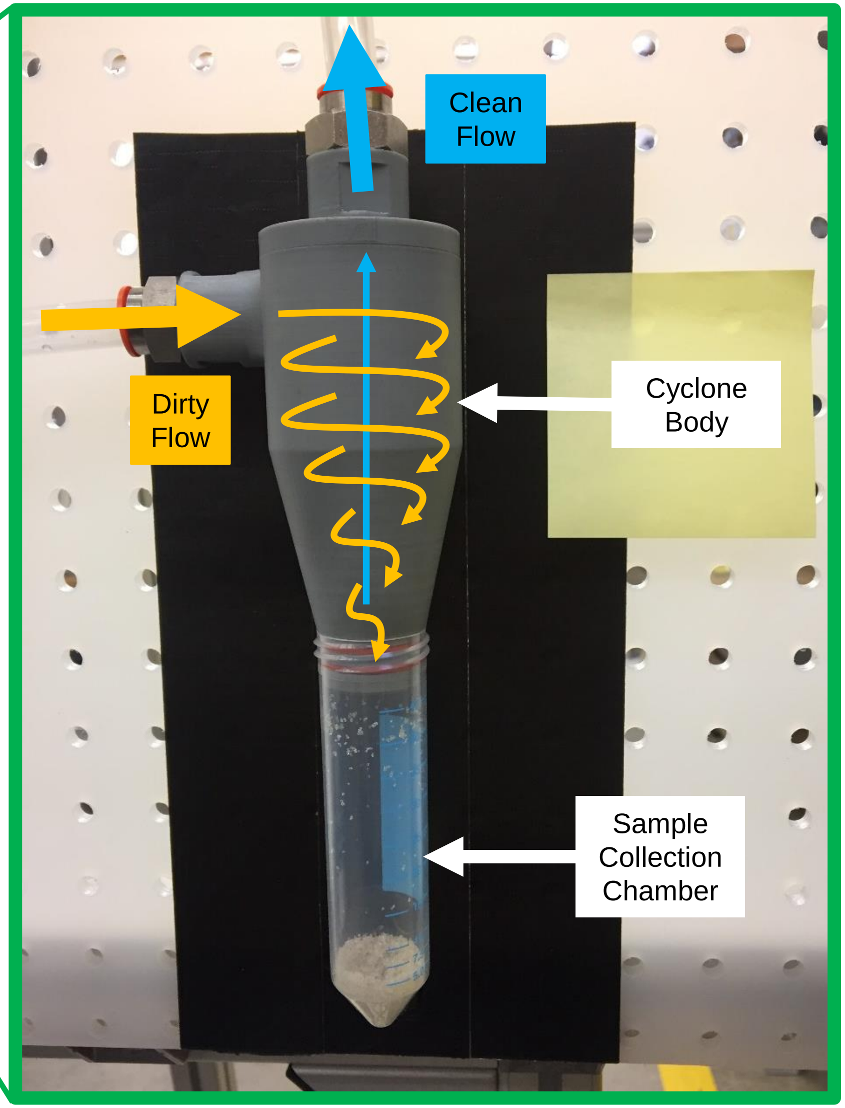
N = 20 spectral average
1-pt smoothing

Side-by-Side Comparison

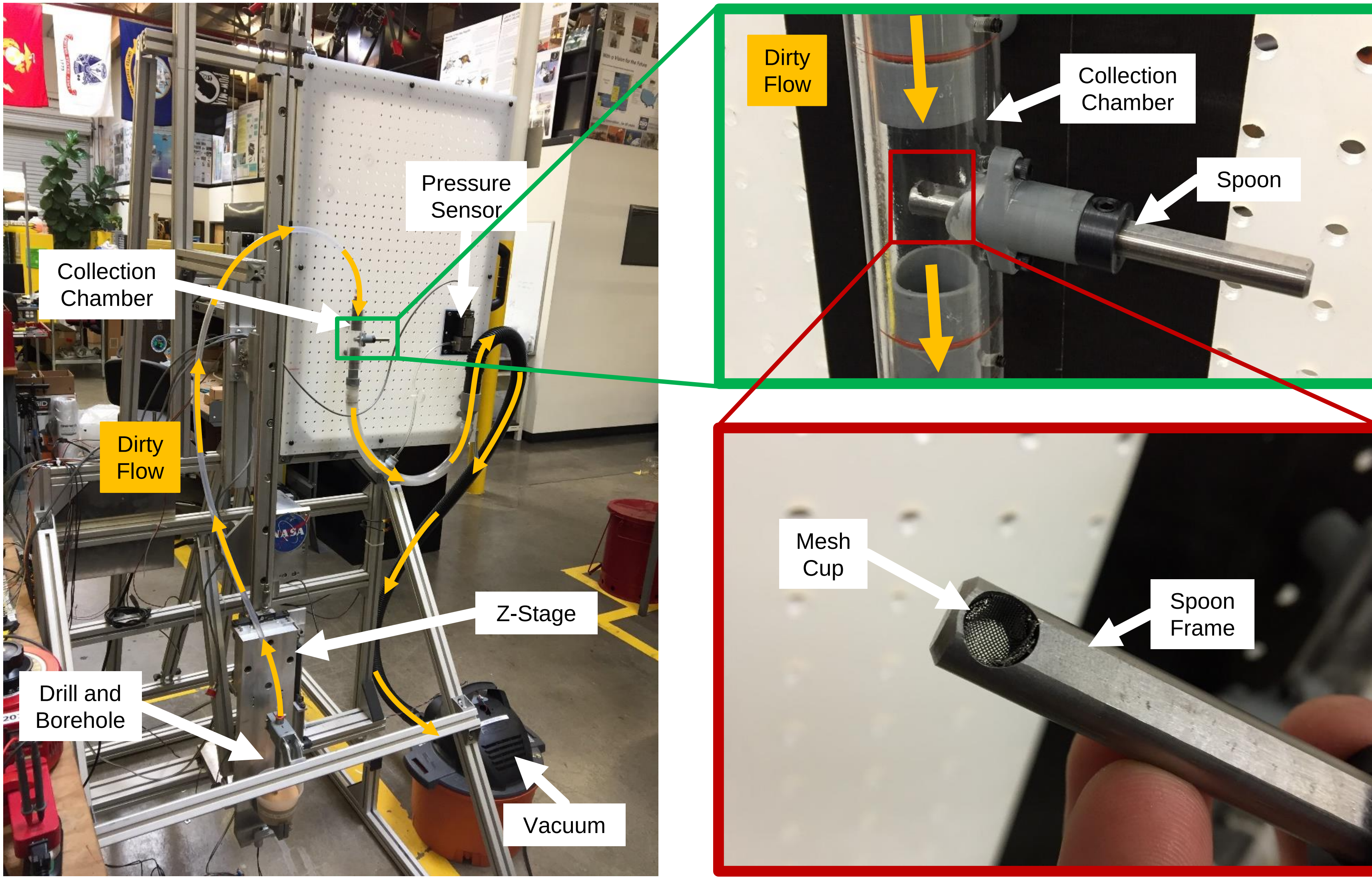
<table>
<tr><th></th><th>Cyclone</th><th>Tea-Strainer</th><th>Deflector Cup</th></tr>
<tr><td>Operational Mechanism</td><td>• Solids in vortex flow hit walls and slow down</td><td>• Mesh catches solids suspended in flow</td><td>• Solids deflected out of flow and into sample cup</td></tr>
<tr><td rowspan="2">Cross-Contamination</td><td>• Uncollected sample builds up in cyclone</td><td colspan="2">• Uncollected sample passes through system</td></tr>
<tr><td>• Too large for single-use sample cups</td><td colspan="2">• Scalable for single-use sample cups</td></tr>
<tr><td>Self-Metering</td><td>• No (bulk collection)</td><td>• Yes (clogged filter)</td><td>• Yes (full sample cup)</td></tr>
<tr><td rowspan="3">Sample Bias</td><td>• Larger particles</td><td colspan="2">• Depends on mesh</td></tr>
<tr><td>• Dry sample</td><td>• Sticky sample</td><td>• No preference</td></tr>
<tr><td>• All particles</td><td colspan="2">• First particles</td></tr>
<tr><td>Collection Efficiency</td><td>• Efficient (>90%)</td><td colspan="2">• Inefficient (<5%)</td></tr>
<tr><td rowspan="2">System Impact</td><td>• Clean blower</td><td colspan="2">• Dirty blower</td></tr>
<tr><td>• “Unlimited” collection</td><td colspan="2">• Small sample quantities only</td></tr>
</table>

Cyclone Testing





Tea-Strainer Testing



Deflector Cup Testing