

Recent experiments on thruster plume induced contamination

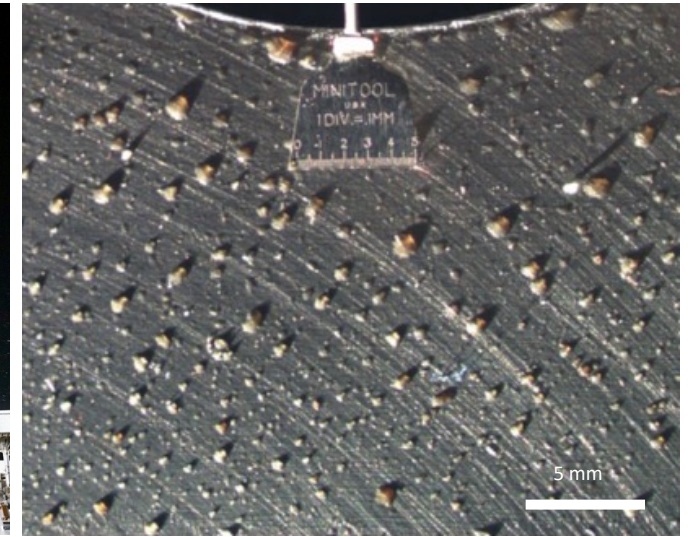
Martin Grabe (DLR)

CCMPP - September 12, 2023



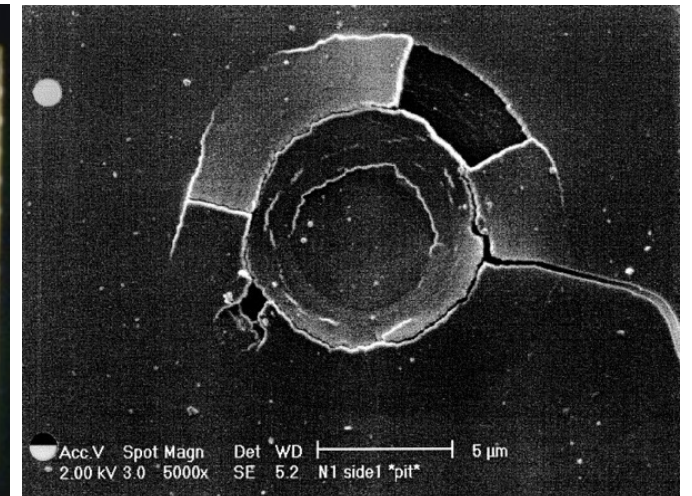
Thruster Plume Induced Contamination (PIC)

- Reaction control thrusters eject **gas** (expected!), but potentially also **liquid** and **solid** matter
- **“Contamination”**: plume effluents impair function of a surface or purity of a natural environment.



Manifestations of PIC

- Alteration of surface properties (through deposition, erosion or etching)
- Degradation of instrument performance
- Sample invalidation

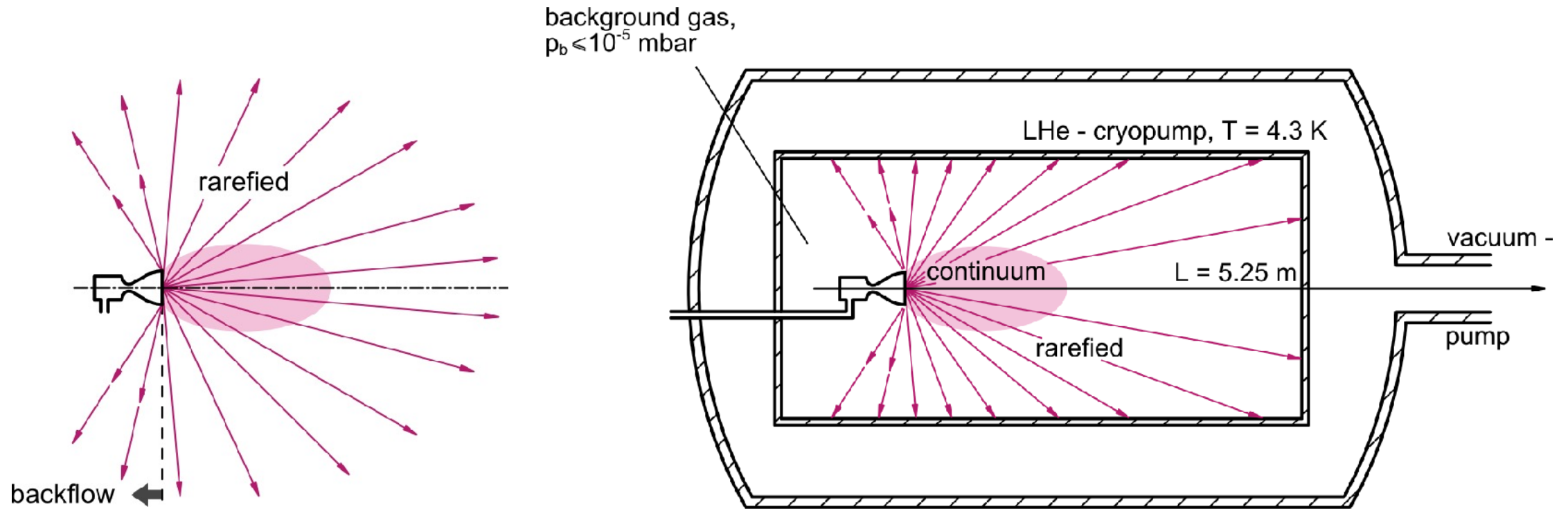


- taken from Naumov et al., ISMSE 2003 (bottom left)
- taken from Soares and Mikataian, SPIE 2002 (bottom right)

Image credits:
- NASA (top left)
- DLR Göttingen (top right)

Thruster Plume Induced Contamination

Challenges in ground-based testing



- high-vacuum required for free plume expansion ($p_b < 10^{-5}$ mbar)
- Thruster mass flow rate: few gram per second!
- Must prevent molecular backscatter



DLR High-Vacuum Plume Test Facility “STG-CT”



Image: DLR

- **Test section:** 5.2 m × \varnothing 1.6 m
(Vacuum vessel: 7.6 m × \varnothing 3.3 m)
- **LHe-cooled** cooper walls ($T_{\text{wall}} = 4.2\text{K}$)
- Background pressure **during** thruster operation: $p_b < 10^{-5}$ mbar

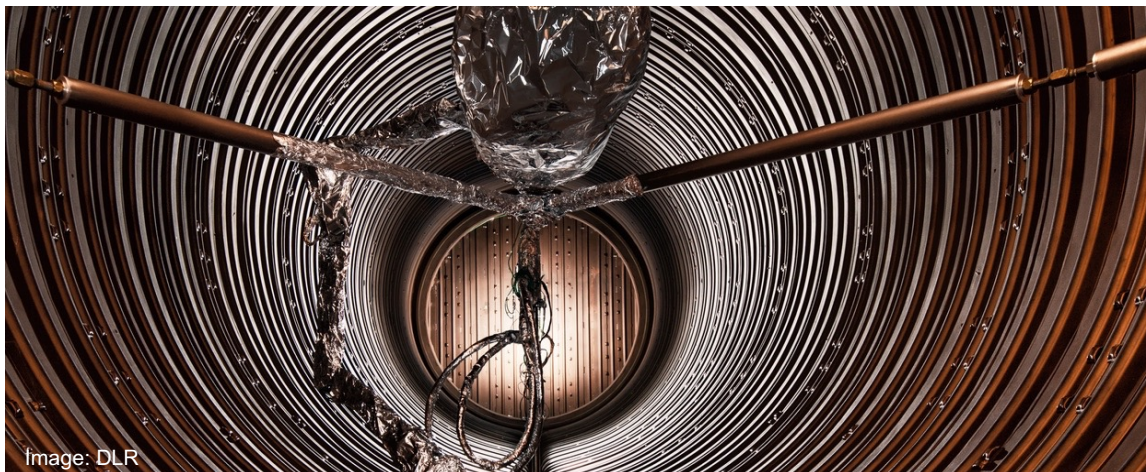


Image: DLR



Image: J. Vetter / DLR

DLR High-Vacuum Plume Test Facility “STG-CT”

Typical instrumentation



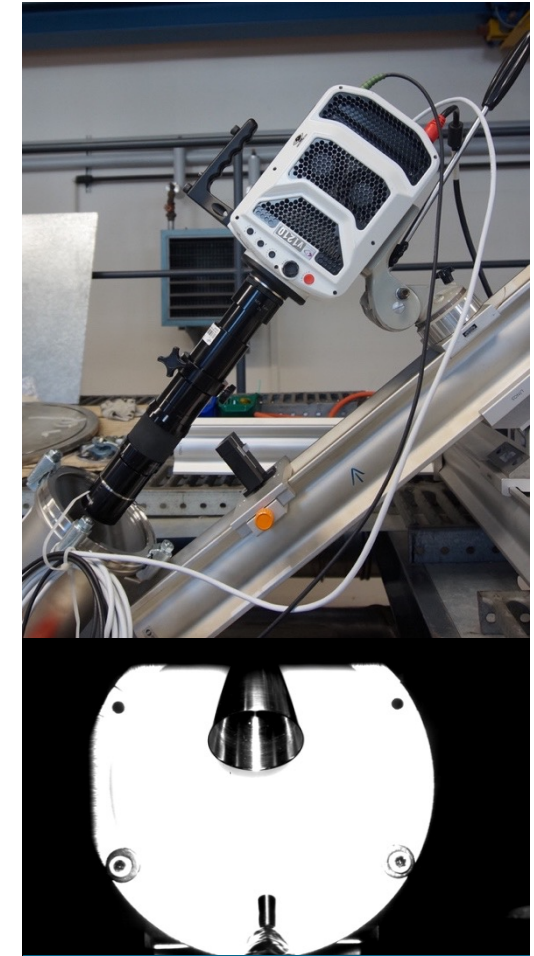
Mass spectrometer



QCMs



Material witness samples



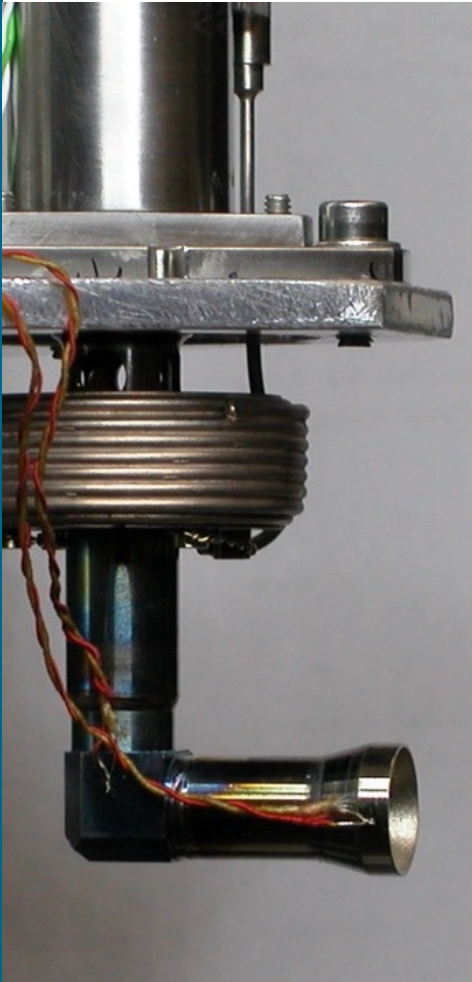
High-speed camera



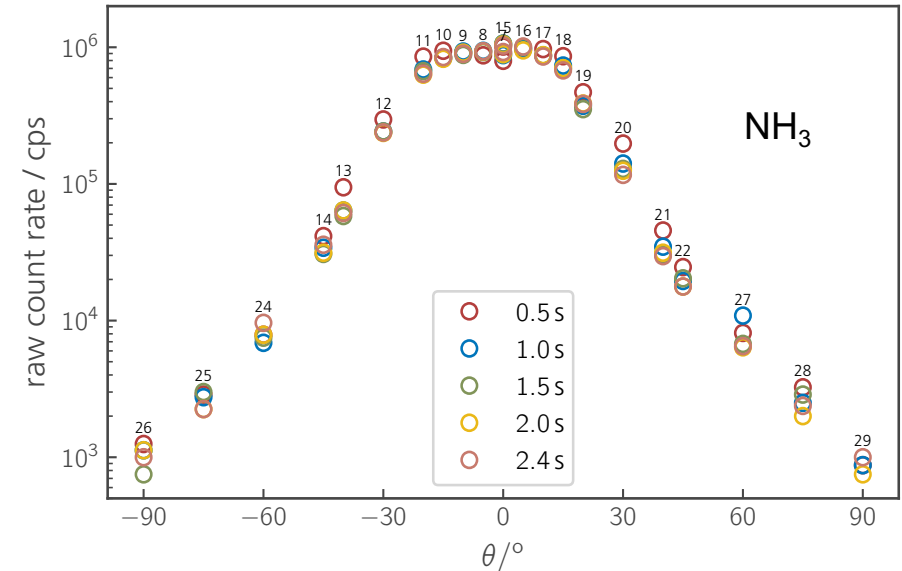
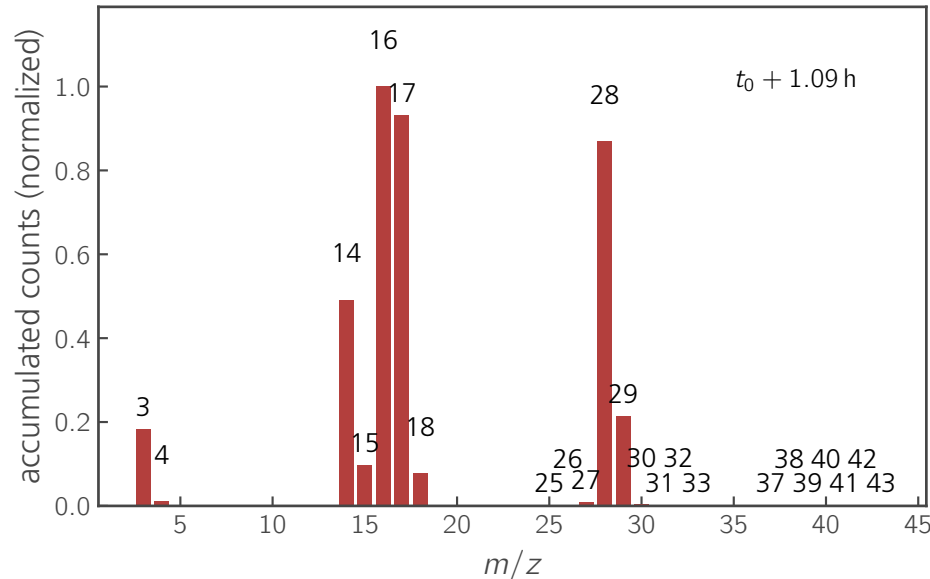
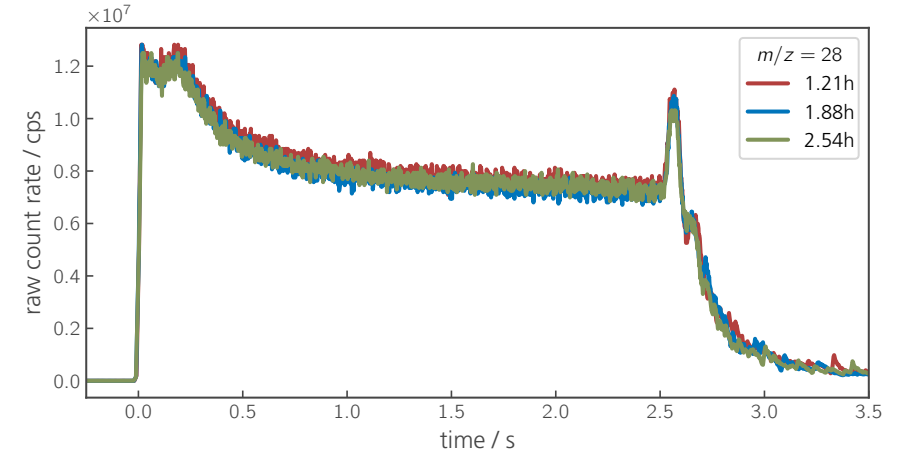
MONOPROPELLANT THRUSTERS

ESA "PhobosSR"

1N - Hydrazine



- European thruster
- Experiments:
 - Pitot pressure measurements
 - In-situ **mass spectrometry**
 - Regolith sample contamination (Analysis: The Open University, UK)

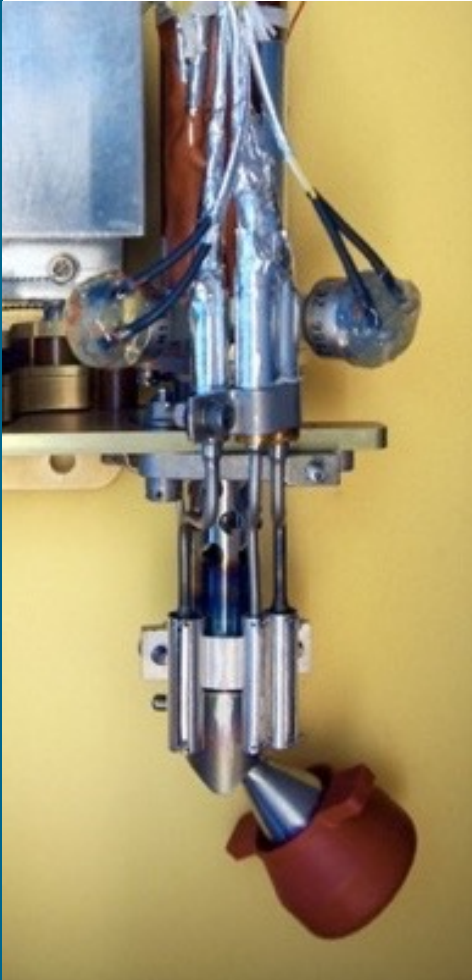


JPL / NASA "EPIC"

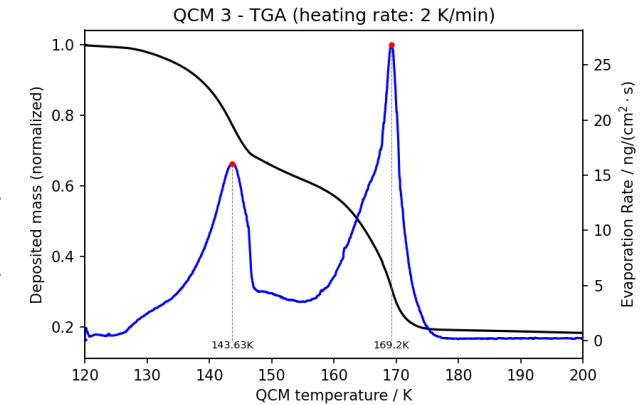
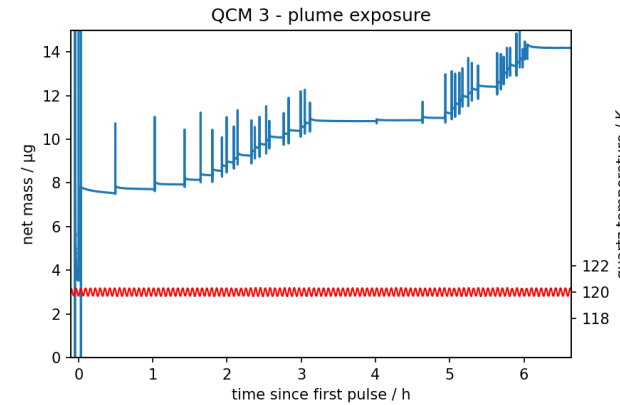
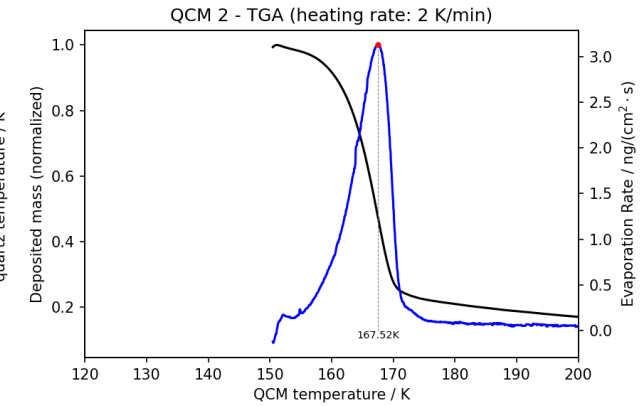
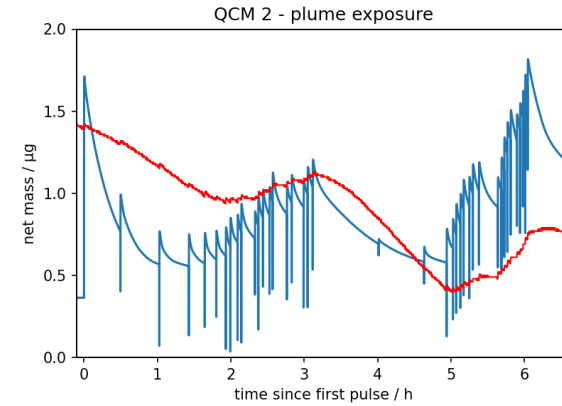
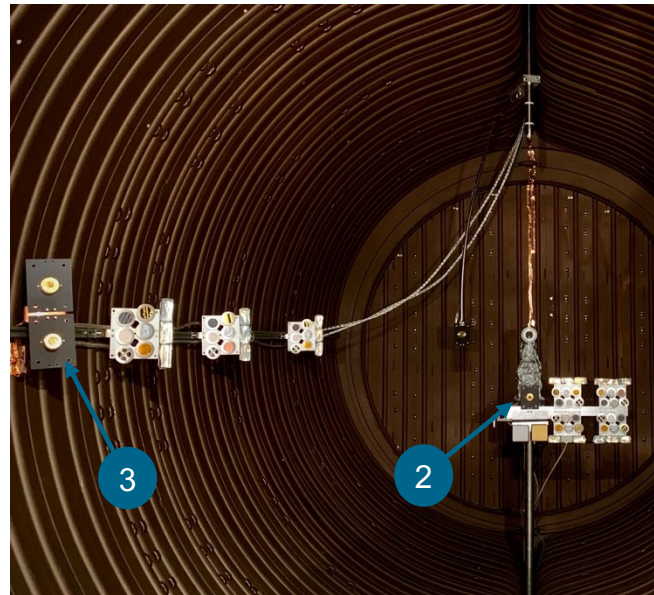
5N - Hydrazine



Jet Propulsion Laboratory
California Institute of Technology



- U.S. thruster
- Experiments:
 - **Contaminant flux**
 - Non-gaseous effluents
 - Plume composition
 - Permanent contamination



JPL / NASA "EPIC"

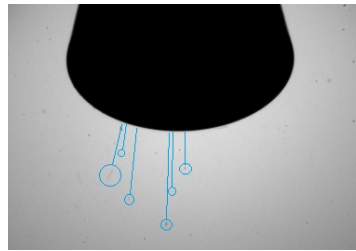
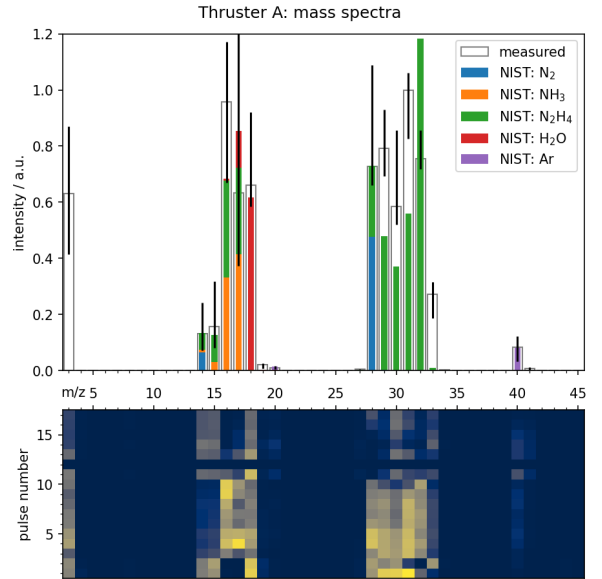
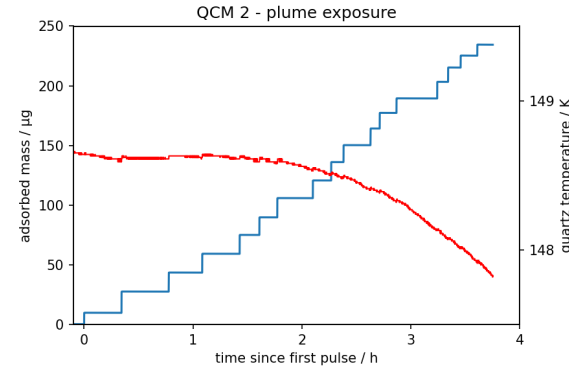
18N - Hydrazine



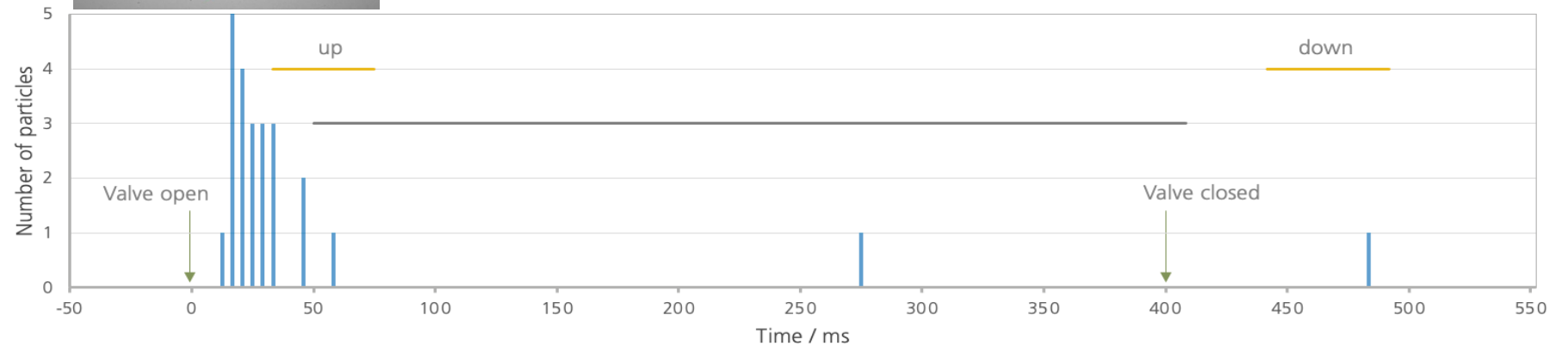
Jet Propulsion Laboratory
California Institute of Technology



- U.S. thruster (qualification unit)
- Experiments:
 - Contaminant flux
 - Non-gaseous effluents
 - Plume composition
 - Permanent contamination



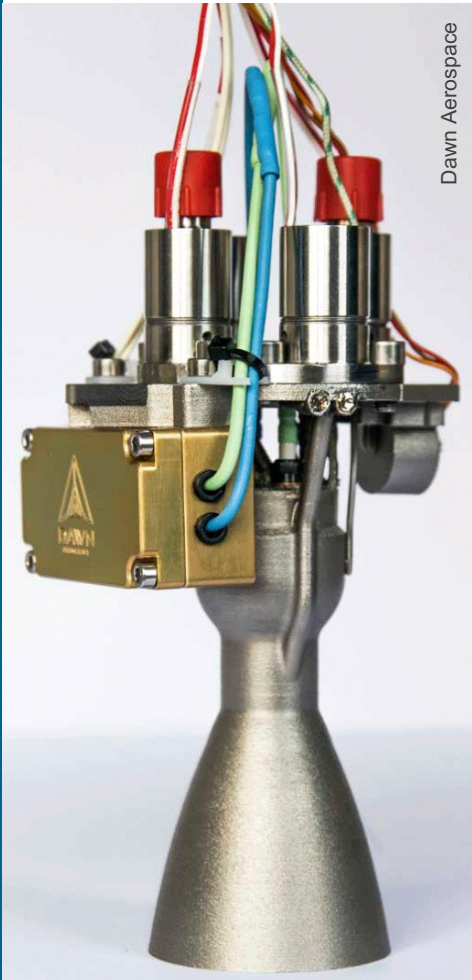
Particle Event Movement of Nozzle Spray inside Nozzle



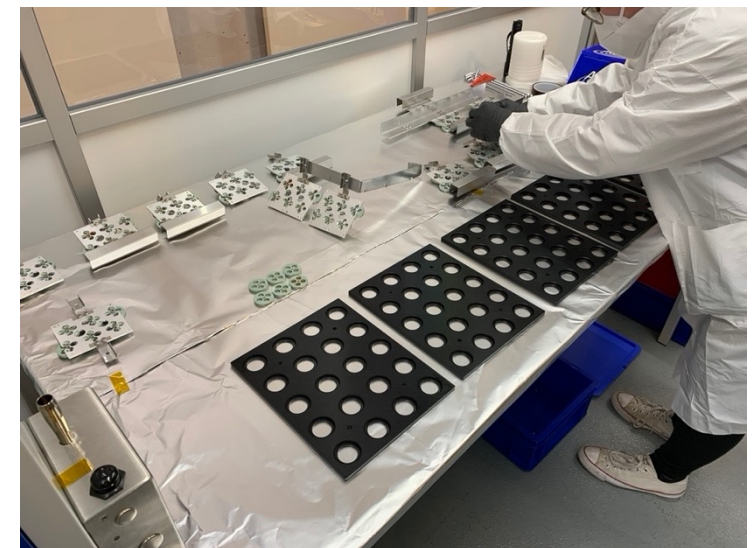
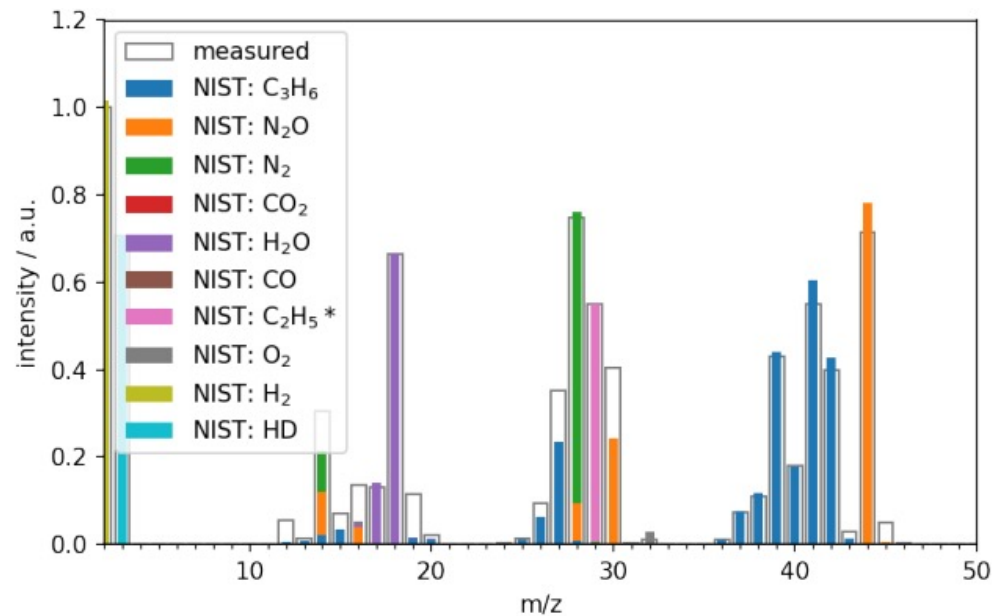
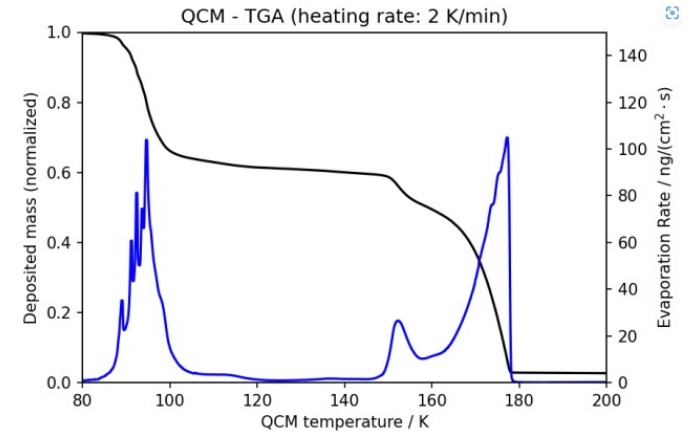
BIPROPELLANT THRUSTERS

ESA “Green Propellant Plume Contamination”

20N - Propene / N₂O



- European / NZ thruster
 - 3D-printed
- Experiments:
 - Contaminant flux
 - Non-gaseous effluents
 - Plume composition
 - Permanent contamination



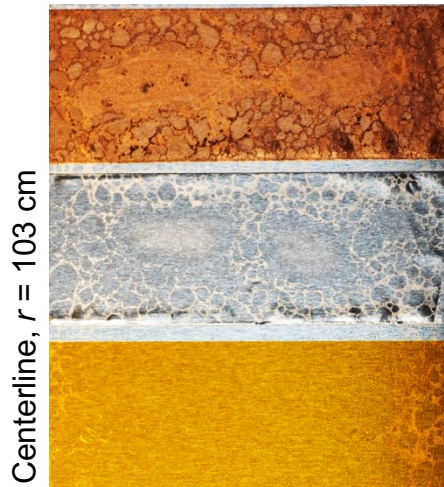
ESA "PhobosSR"

20N - Hydrazine / MON3

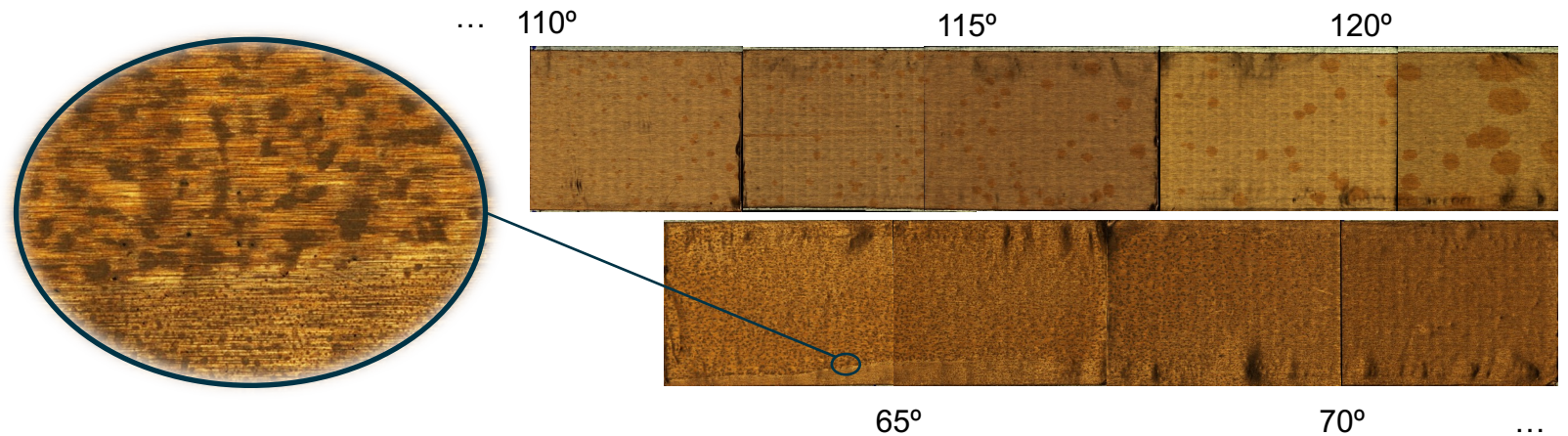
- European thruster
- Experiments:
 - Pressure and heat flux
 - In-situ mass spectrometry
 - Shadowgraphy
 - **Witness materials**



$r = 78 \text{ cm}$



Centerline, $r = 103 \text{ cm}$



... 110°

115°

120°

65°

70°

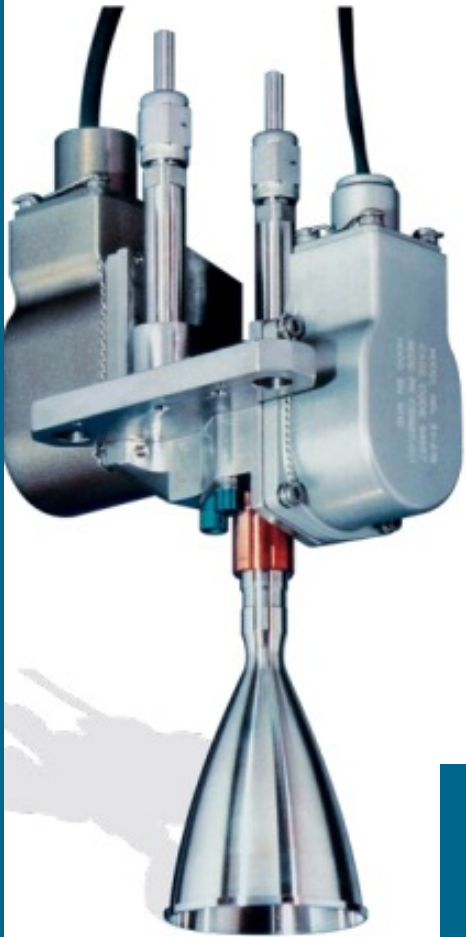
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Outlook: ESA “Bi-Prop Contam” + JPL / NASA “EPIC2”

10N - MMH / MON3



EUROPA
CLIPPER



- European thruster(s)
- Experiments:
 - Pressure and heat flux
 - In-situ mass spectrometry
 - Shadowgraphy
 - Deposition and evaporation rates
 - Witness materials
 - FORP resistivity
 - Plume gas sampling
- Numerical modeling



Expect updates at the next workshop!

Thank you!



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33rd International Symposium on
Rarefied Gas Dynamics

15-19 July 2024 in Göttingen, Germany

