# Violent Fluidization and Erosion in Plume Surface Interactions

**November 21, 2021**


**Matt Gorman**

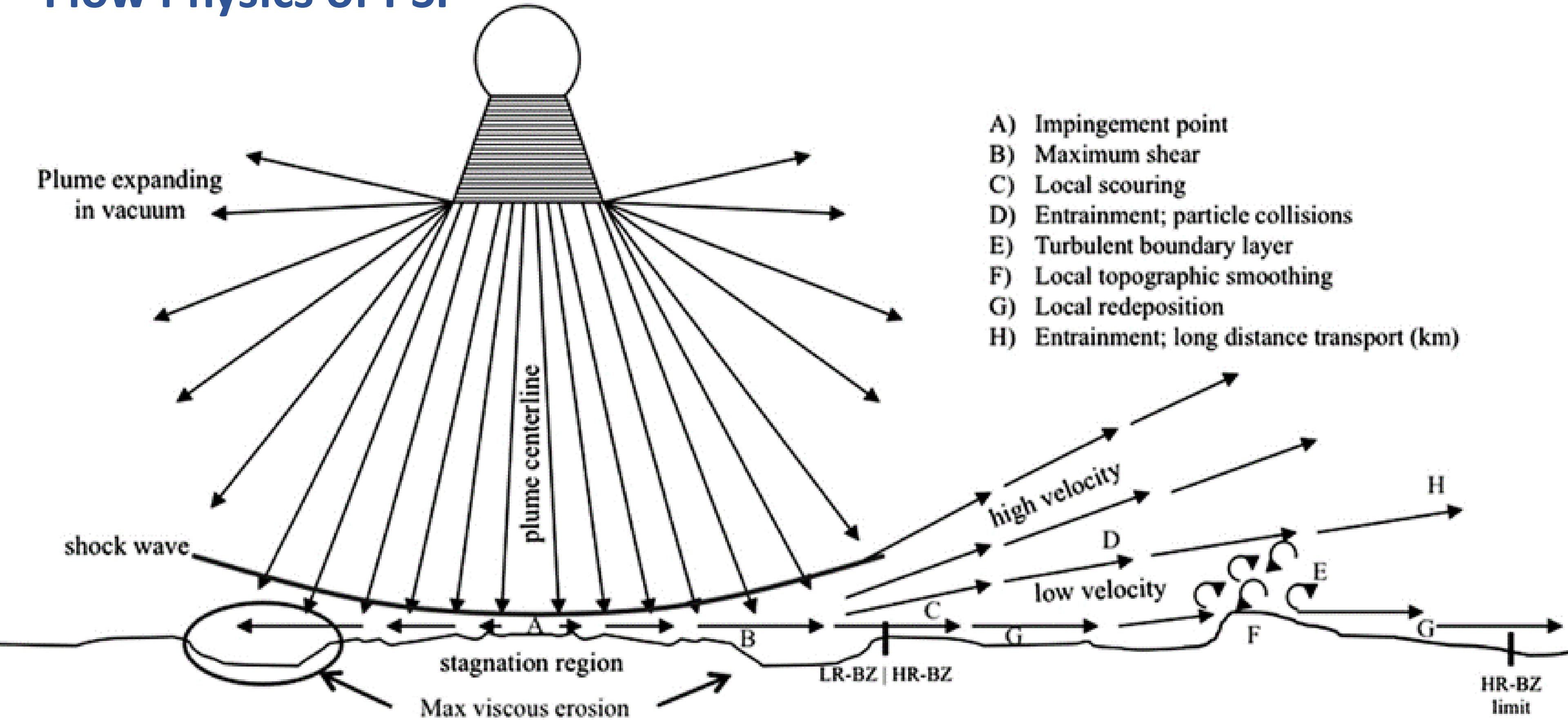
Juan Sebastian Rubio
Miguel X. Diaz-Lopez
Dr. Rui Ni

# Impinging Plumes Induce Crater and Ejecta


*Lane and Metzger (UCF) 2015 – Acta Geophysica*


*https://nasa.gov/*

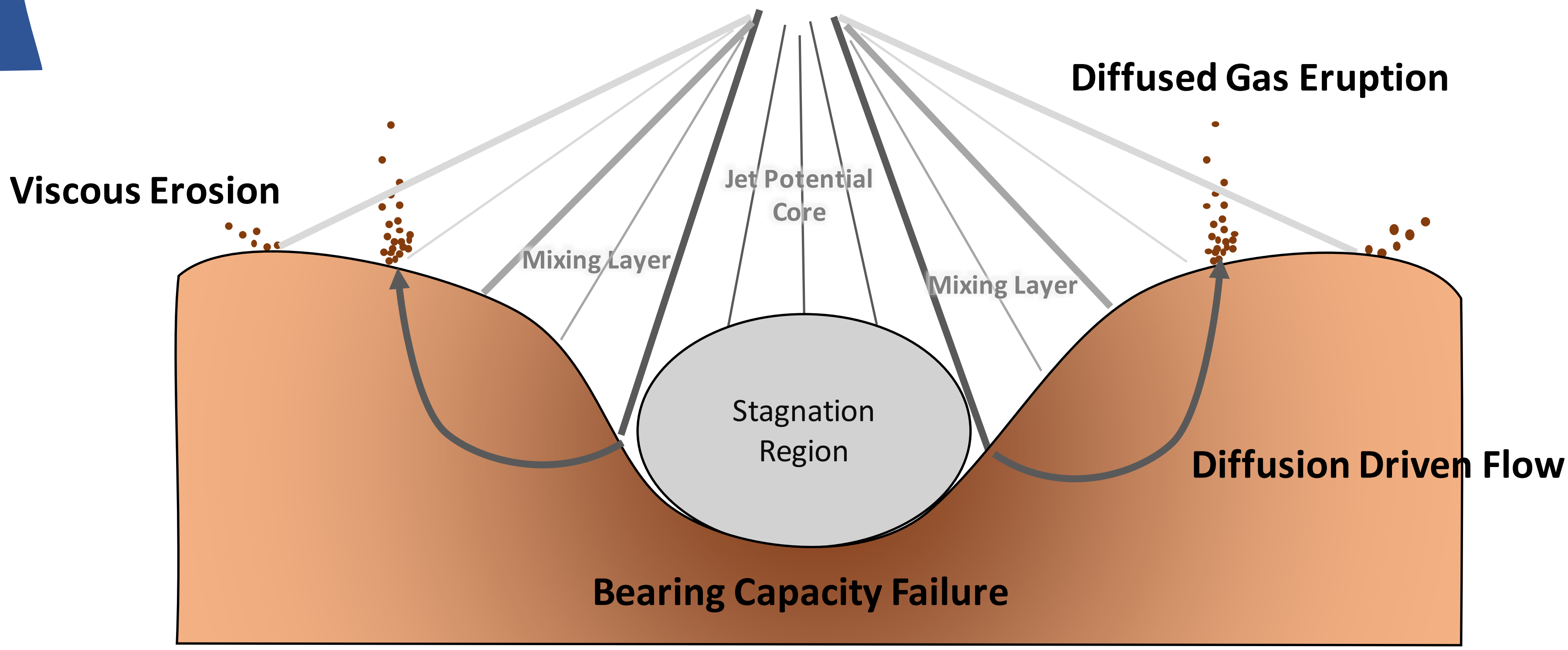
# Flow Physics of PSI




1. Under-expanded supersonic jet
2. Surface impingement
3. Granular media

*Metzger, P., et al. 2009 - 47th AIAA Aerospace Sciences Meeting including The New Horizons Forum and Aerospace Exposition*

# Cratering Mechanisms Identified during Apollo and Viking Programs




*Metzger and Immer (KSC) 2009, Journ. Aero Eng.*

*Guerriero and Mazzoli 2021, Geosciences*

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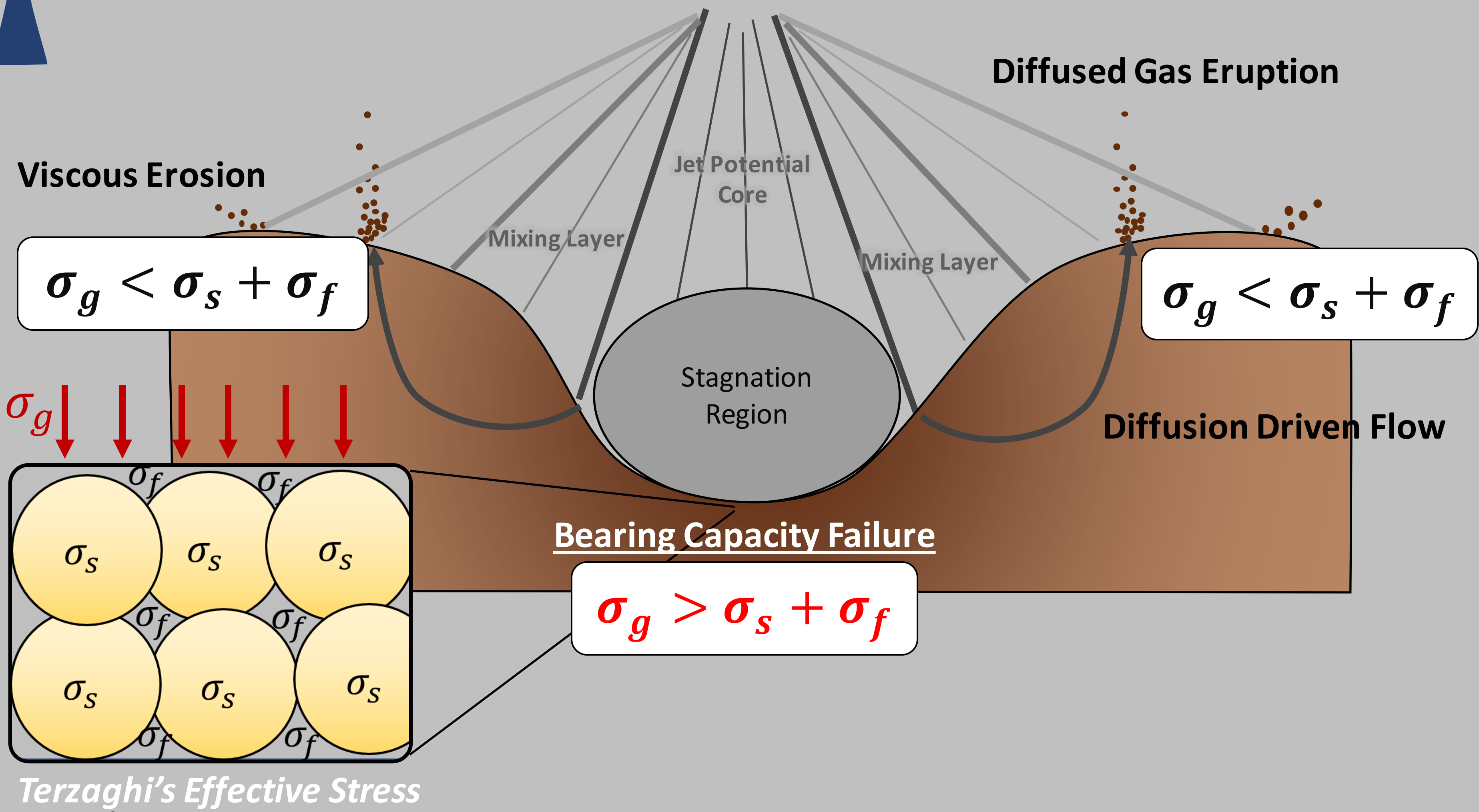


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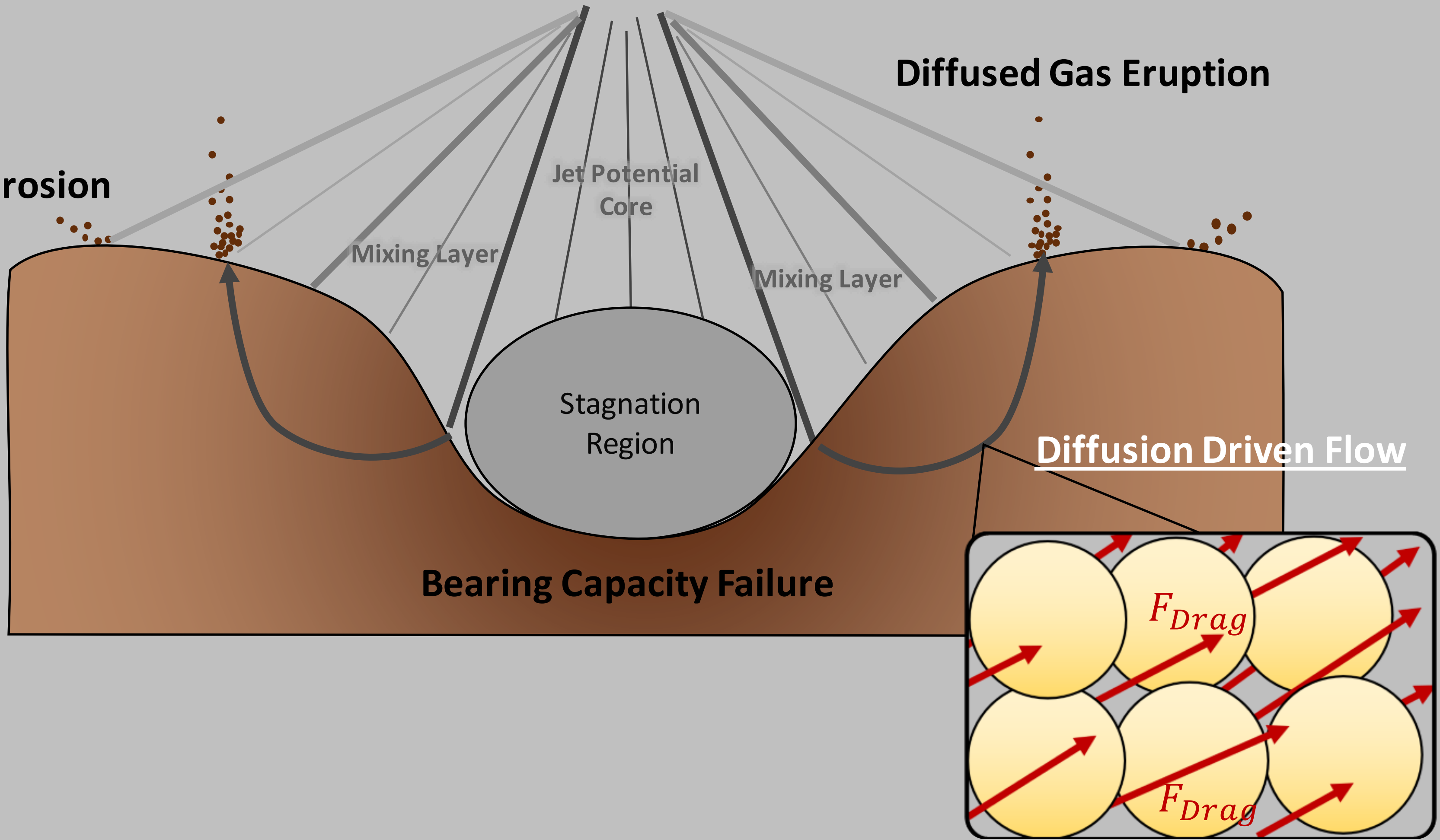


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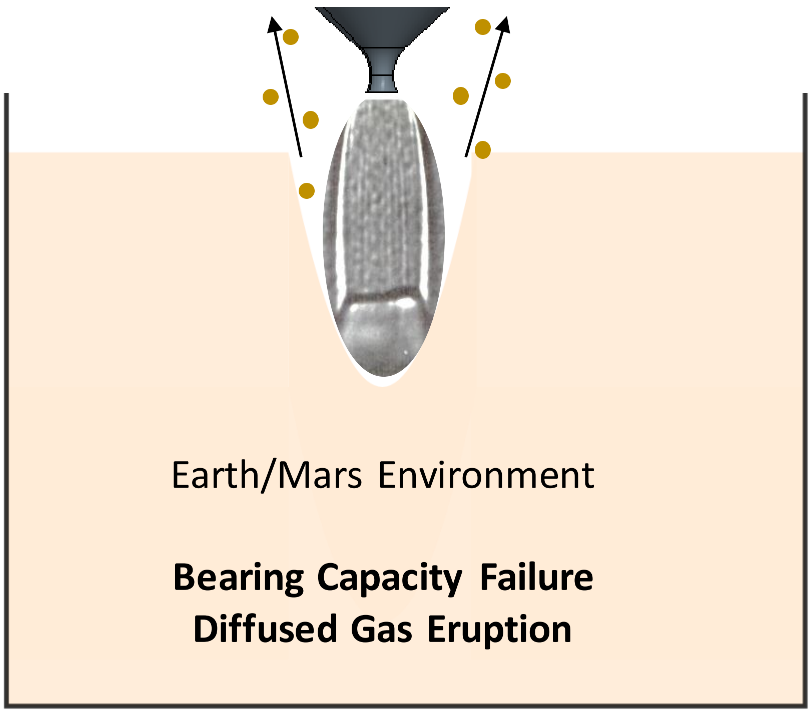
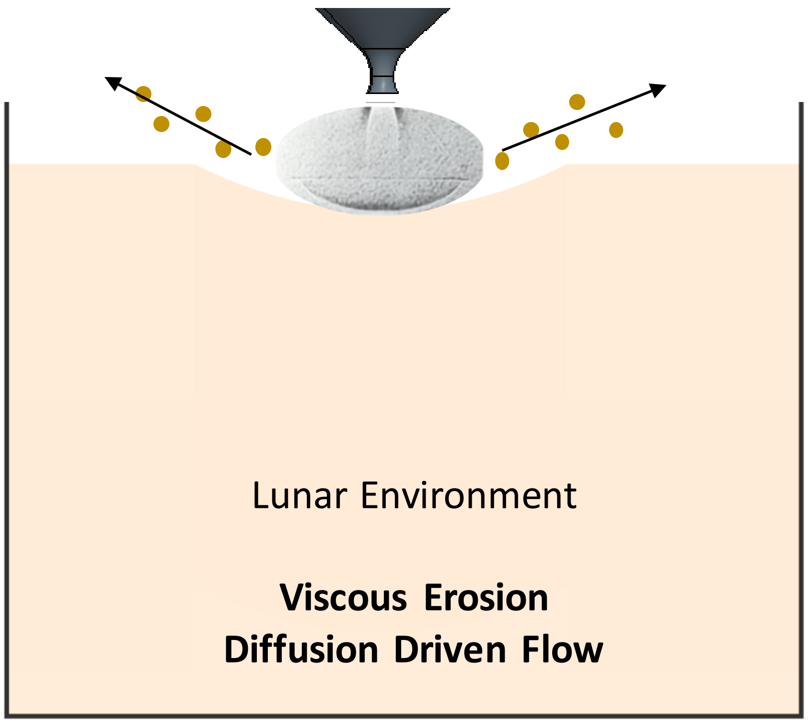
*Guerriero and Mazzoli 2021, Geosciences*

# Role of Ambient Pressure on Cratering and Ejecta dynamics




***Shadowgraphs of a Mach 5 jet exhausting onto a flat plate***

*Land and Clark (LRC) 1965, NASA*

# PFGT1: Physics Focused Ground Test 1

**PFGT1 Objective:**

**Study Erosion and Ejecta Dynamics due to Plume-Surface Interactions**

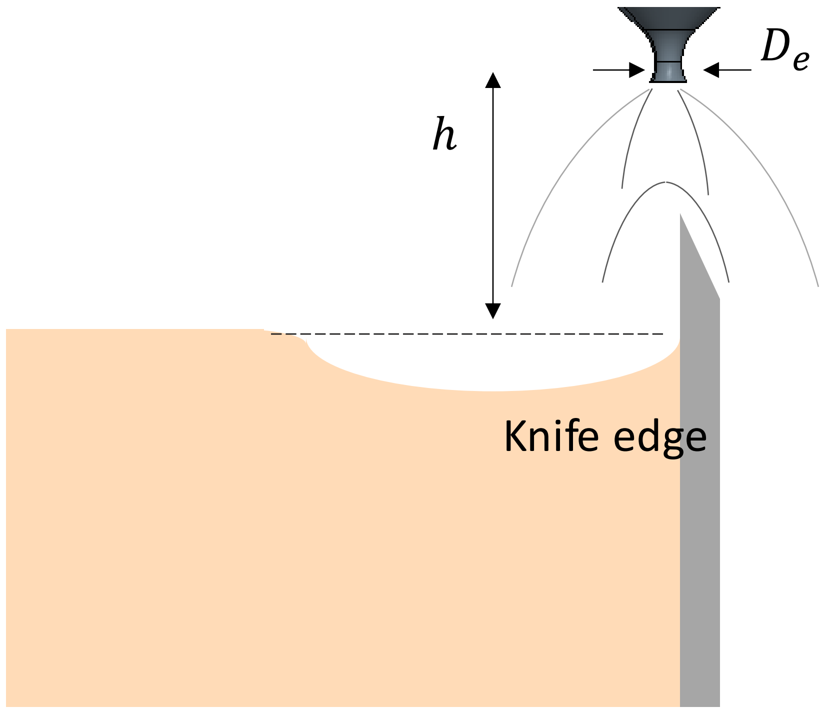
| Parameter | Range |
|---|---|
| $p_{vac}$ | 0.02 torr to 4.5 torr |
| $h/D_e$ | 3.0 to 10.0 |
| $\dot{m}_j$ | 0.32 g/s to 8.6 g/s |
| $T_{0,j}$ | 500 K (fixed) |
| Ma | 5 (fixed) |

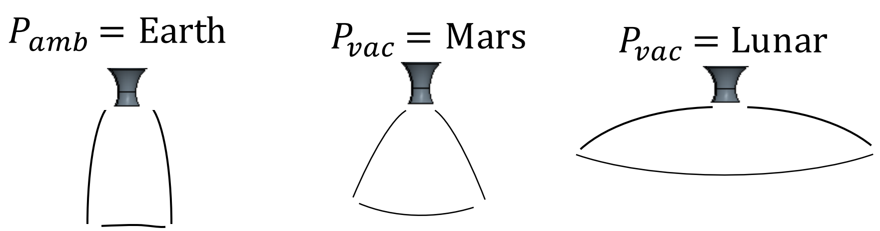
$h/D$: Nozzle Height

$p_{vac}$: Vacuum Pressure

$\dot{m}_j$: Mass Flow Rate

**Side View**

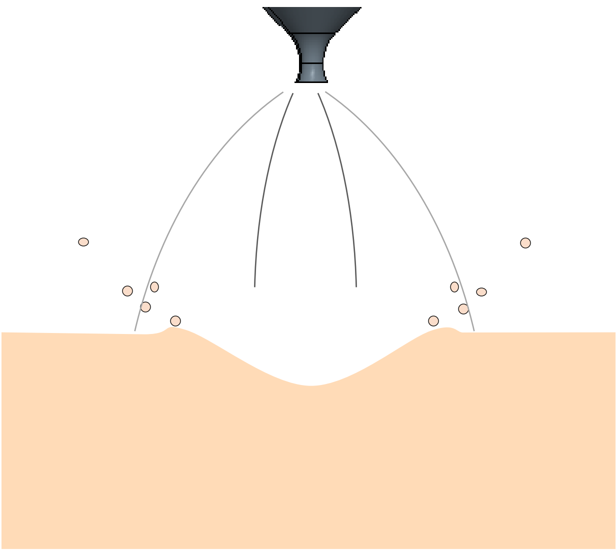


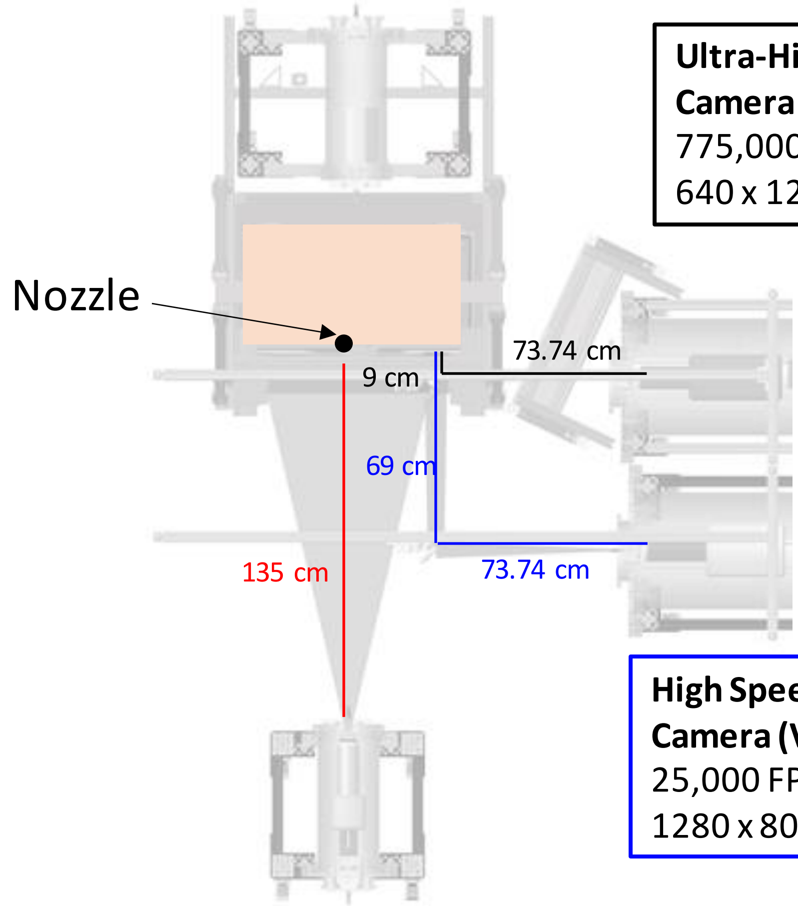
# PFGT1: Diagnostics

**PFGT1 Test Conditions:**
Lunar and Martian pressures
Mach 5 jet flow

**Front View**



**Top View**

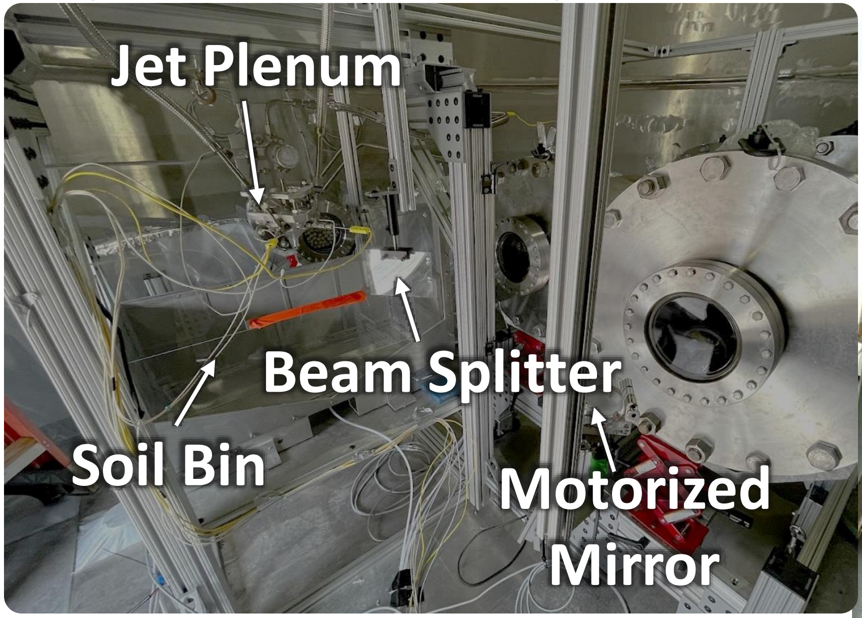


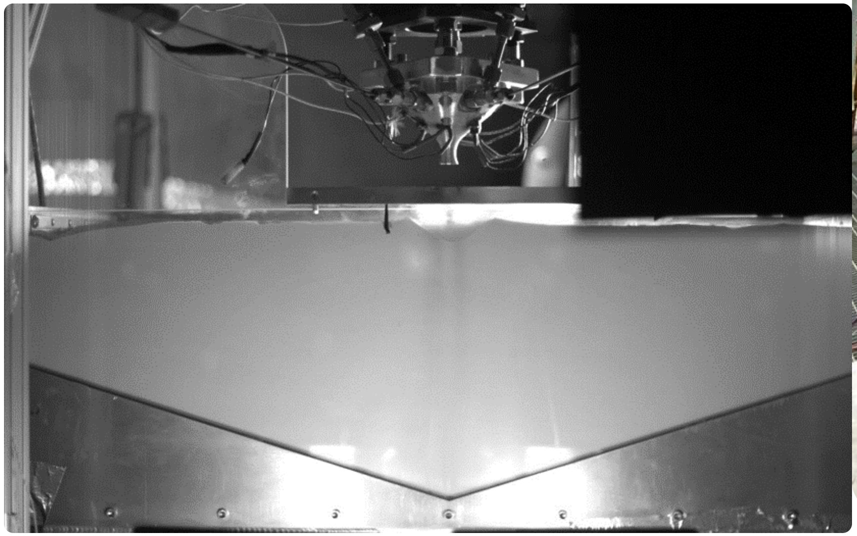

**Ultra-High Speed Ejecta Camera (TMX)**
775,000 FPS
640 x 128 pix Resolution

**High Speed Ejecta Camera (V2511)**
25,000 FPS
1280 x 800 pix Resolution

**Crater Camera (VEO)**
5,000 FPS
1280 x 800 pix Resolution

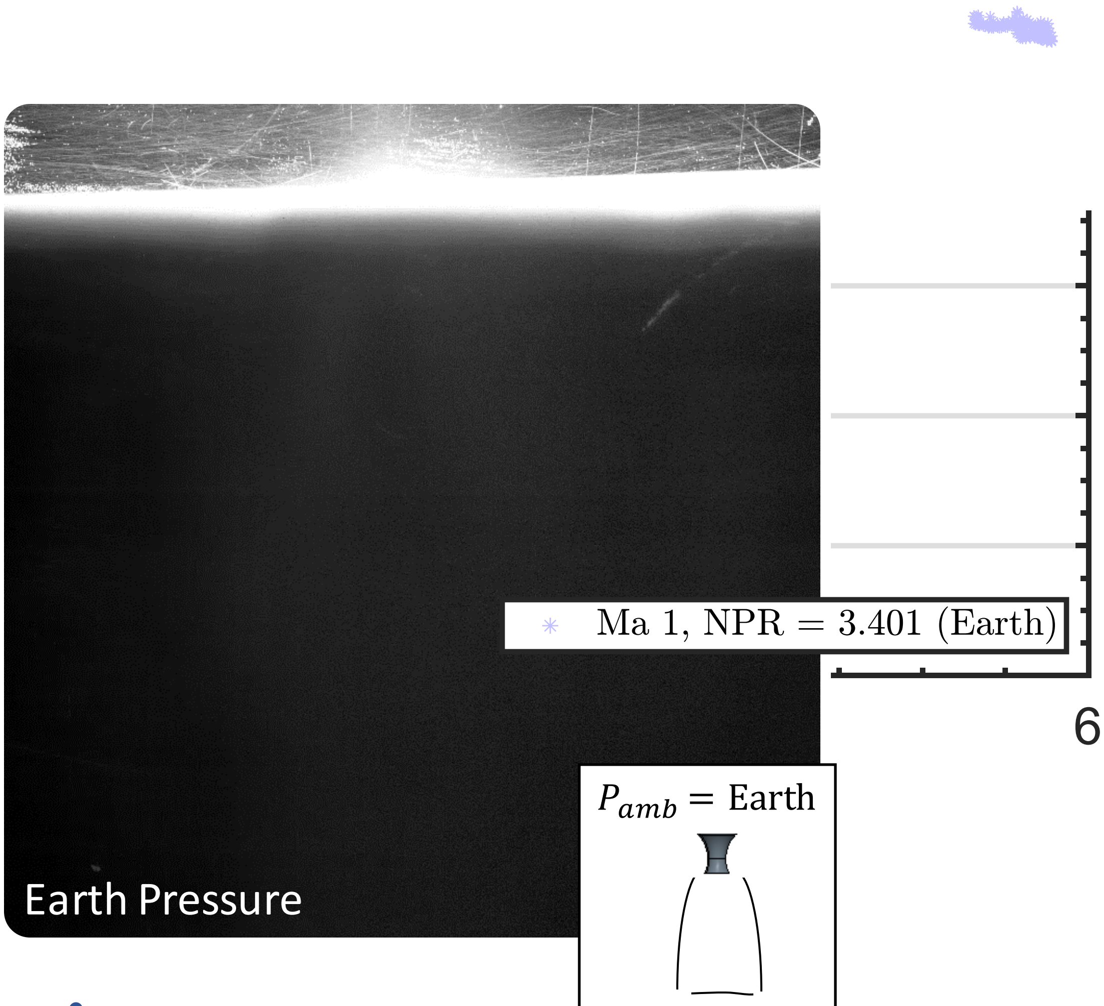
# PFGT1: Experimental Facility



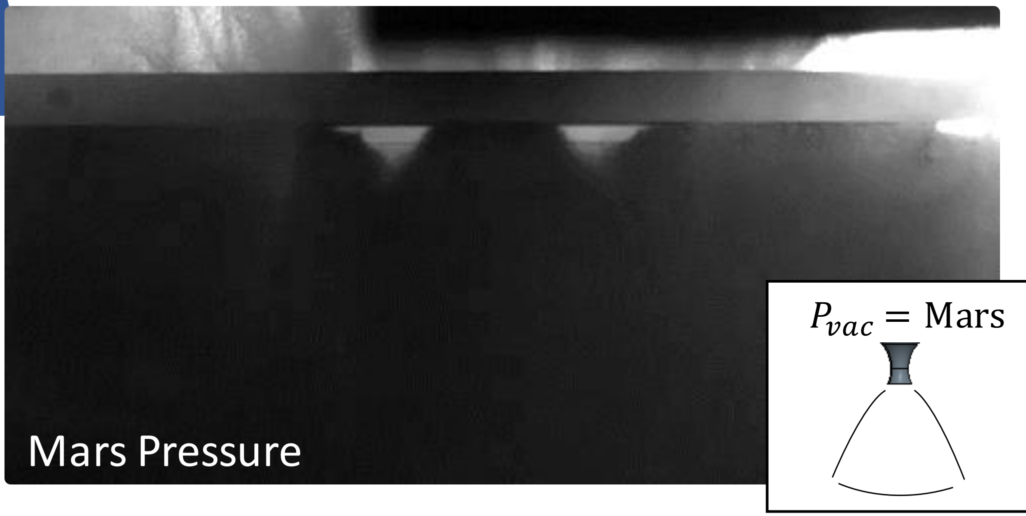



# Results

# Earth Pressure Test

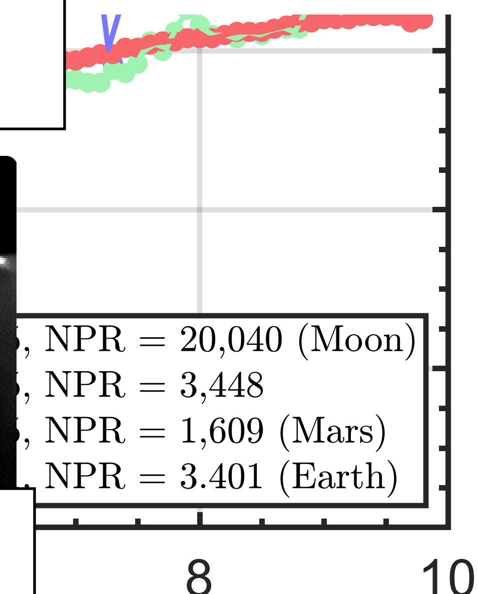


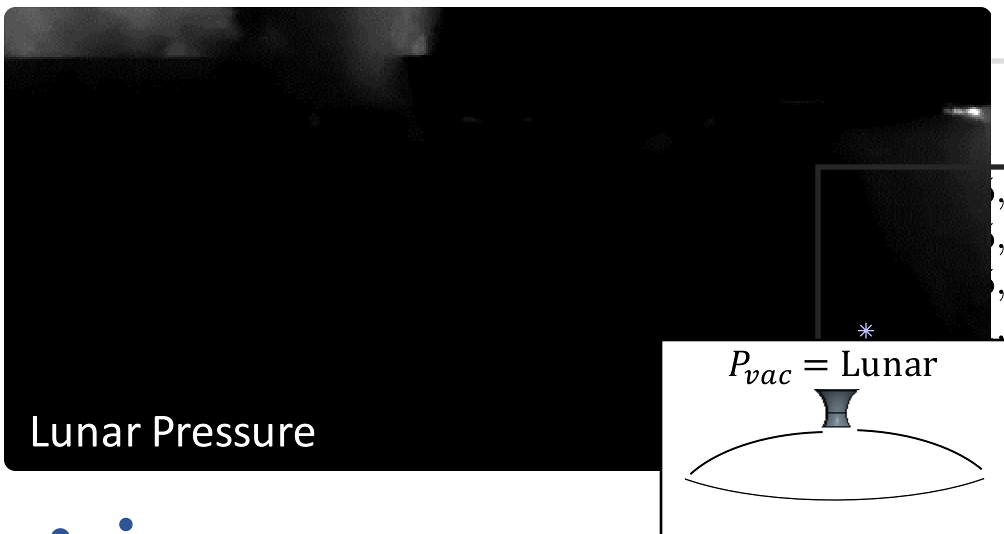
# Low Pressure Tests



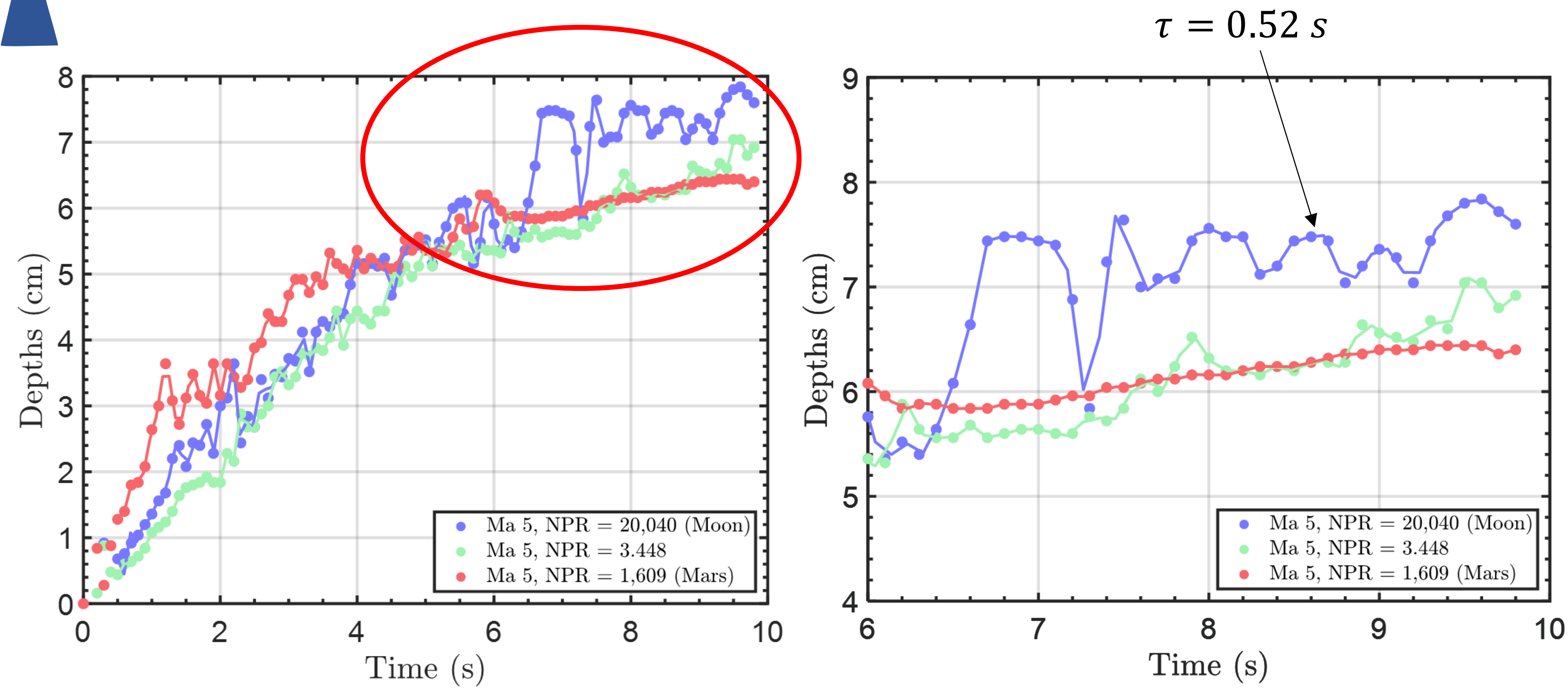

Depths evolve more slowly at lower pressures.

Less collimated plume yields more viscous erosion, less penetration



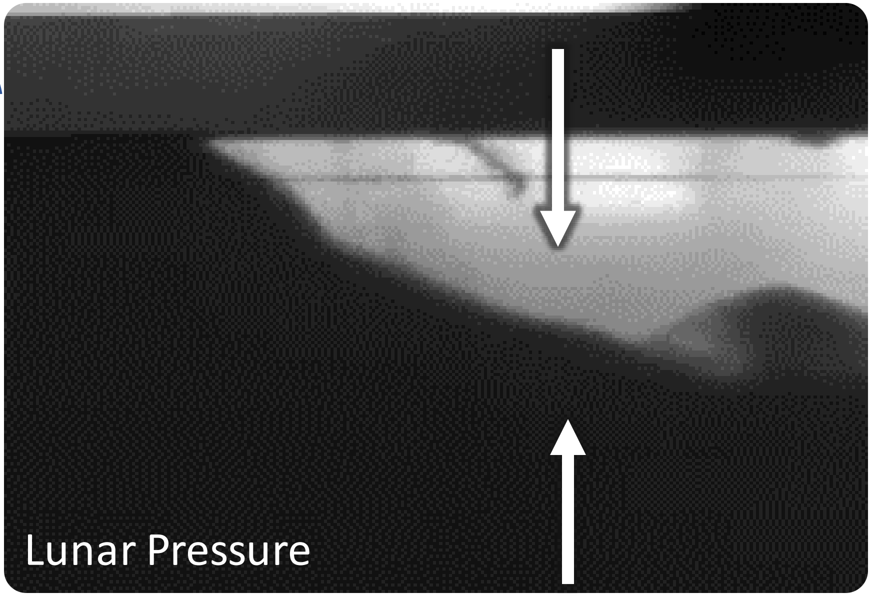



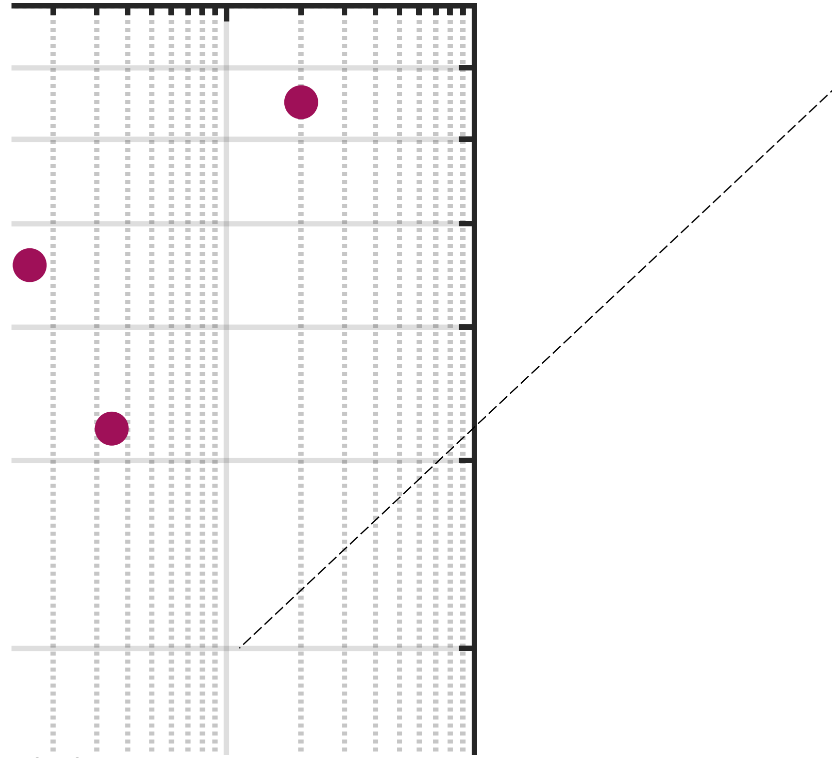
# Low Pressure Tests - Oscillation




Oscillations observed at low pressures - Competition between pore pressure and impinging jet pressure.

# Crater Interface Oscillations



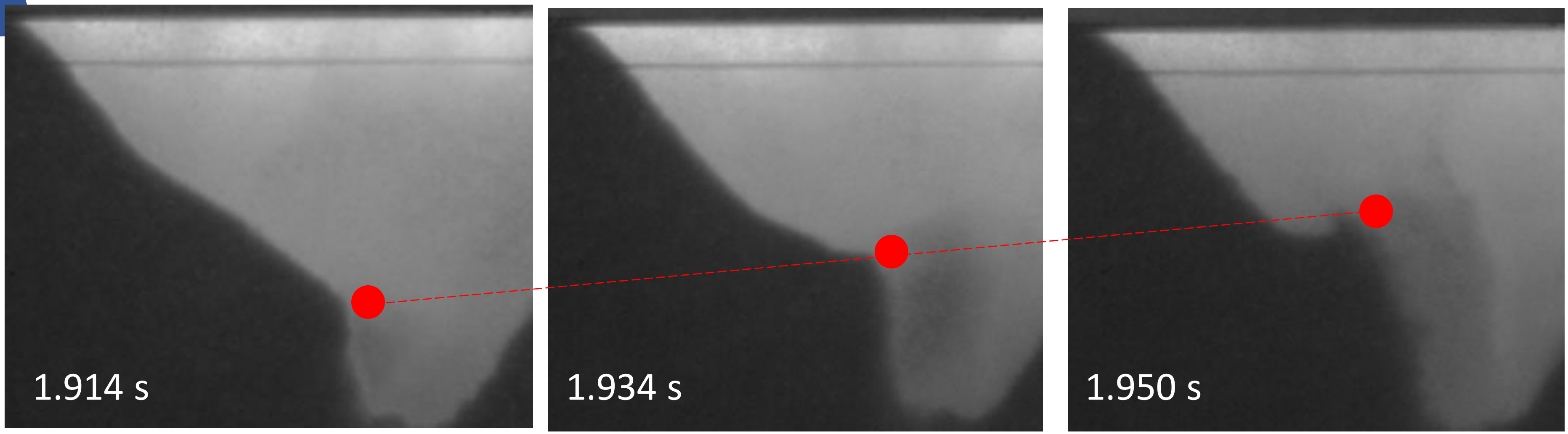




Fluidization: Impinging gas permeates regolith.

Periods of observed oscillations increase with Nozzle Pressure Ratio ($NPR$).

$$NPR = \frac{\mathrm{P_{nozzle}}}{\mathrm{P_{ambient}}}$$

# Crater Interface "Roll-up" – Higher ambient pressure cases




Crater Interface "Roll-up" observed at higher ambient pressures.
Frequencies are consistent with bed oscillation frequency.

Analogous to Kelvin Helmholtz Instability.

Only observed when ambient pressure is high enough that viscous shear is appreciable.

# Conclusions

Successfully completed PFGT1 Experimental Campaign

- Investigated cratering and ejecta dynamics in new flow regimes.
- Obtained valuable dataset for NASA for future missions to the Moon and Mars.

Initial Observations

- Crater Dynamics depend on the ambient pressure.
- Characterized oscillatory behavior at low pressures - competition between pore pressure and impinging jet pressure leads to oscillations at lower ambient pressures.

Future Steps – Data Processing

- Time Dependence of Oscillation behaviors.
- Analyze remaining tests - different soil simulants and nozzle heights.