National Aeronautics and
Space Administration

Stereo Cameras for Lunar Plume-Surface Studies (SCALPSS) Payload Overview

Lunar Surface Science Workshop

January 27th, 2026

Virtual

Presenting: Paul Danehy[1]

[1]*NASA's Langley Research Center, Hampton, VA*

SCALPSS Team

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- **Principal Investigators:** Michelle Munk (retired) and Wesley Chambers
- **Project Technologist:** Paul Danehy
- **CLPS 2 Project Scientist:** Susan Lederer
- **CLPS 19D Project Scientist**: Maria Banks
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- **Engineering Team:** Raymond Lueg, Cornell Wilson, Matthew Rodgers, Sarah Foyer, Miko Coleman, Alexander Scammell, Kimberly Martin, Adam Ben Shabat, Nicholas Vitullo, J. Richard Rawls (retired)

- **Funding**: NASA Space Technology Mission Directorate, Game Changing Development.   (Also NASA Science Mission Directorate for SCALPSS 1.0)

Outline

- Background: Plume Surface Interaction
- Stereo photogrammetry
- SCALPSS System Designs
  - IM-1 Nova-C and FF BGM1 layouts
  - Design methodology
  - Environmental Testing
- SCALPSS 1.0 Payload on IM-1 Nova-C Mission

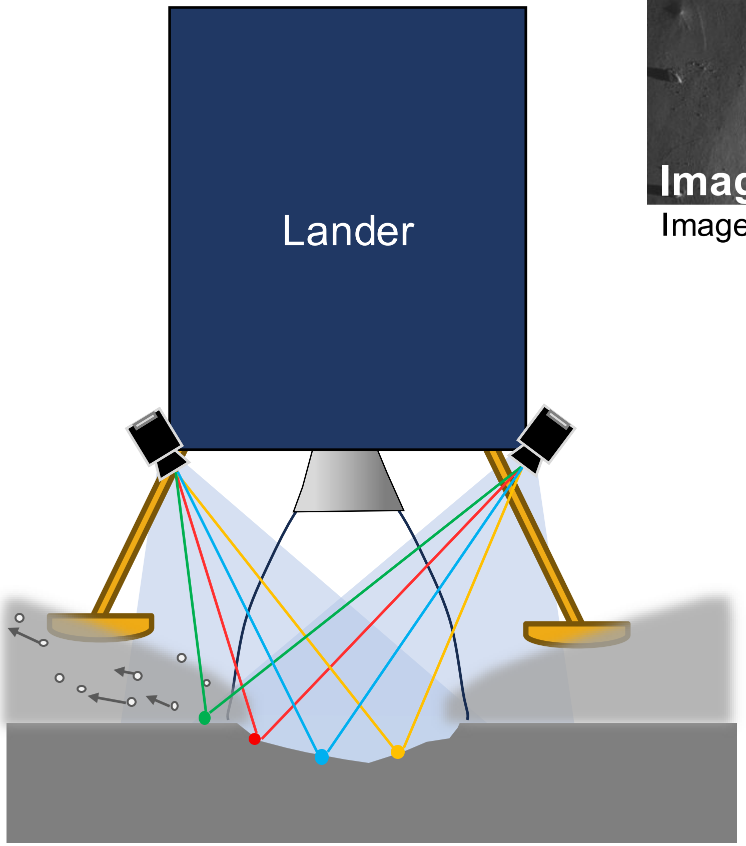
Background: Plume-Surface Interaction

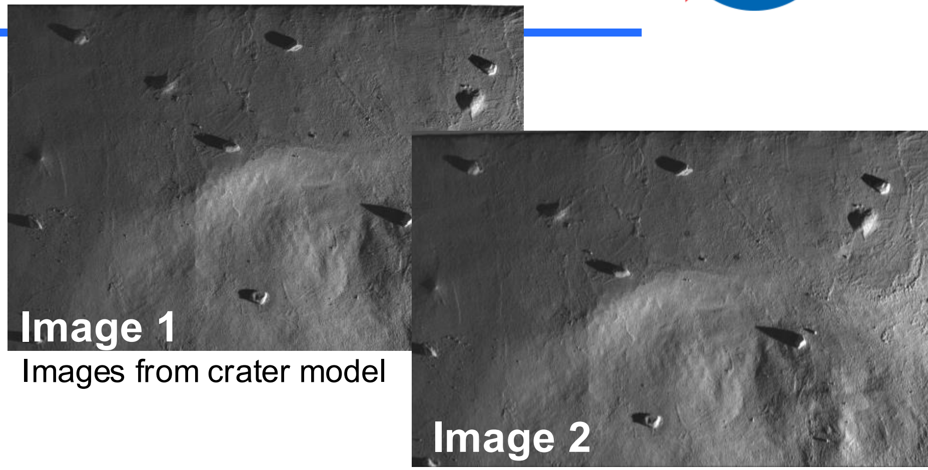
- Flow of a rocket plume onto a planetary or lunar surface causes:
  - Particle ejection
  - Regolith erosion
- These phenomena can pose hazards and risks to mission and crew infrastructure.
- Evident in Apollo and subsequent lunar and Martian landings.
- Difficult to simulate on Earth and limited in-situ data. Difficult to predict.
- NASA Stereo CAmeras for Lunar Plume Surface Studies (SCALPSS) missions would measure craters.

Apollo 15 Lands at Hadley Rille, Moon
August 1971

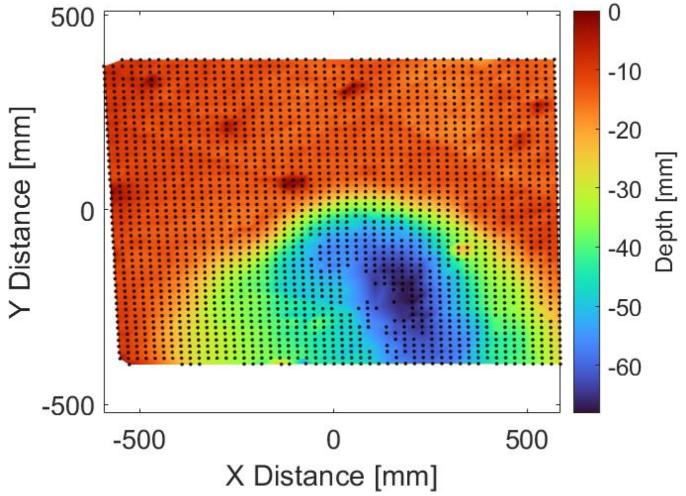
Stereo Photogrammetry

- Cameras collect images of the lunar surface during the final descent and landing of the spacecraft.
- Images are stored on the DSU and then transferred to the lander for downlink to Earth.
- **Stereo photogrammetry** is used to reconstruct the 3D shape of the surface from the images.
    - Goal: to determine how much lunar regolith has been eroded by the landing vehicle's engine plume(s).
    - First dedicated, quantitative in-situ PSI instrument.



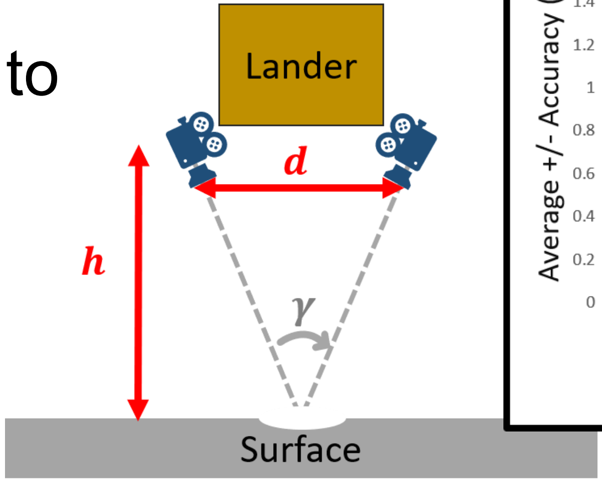


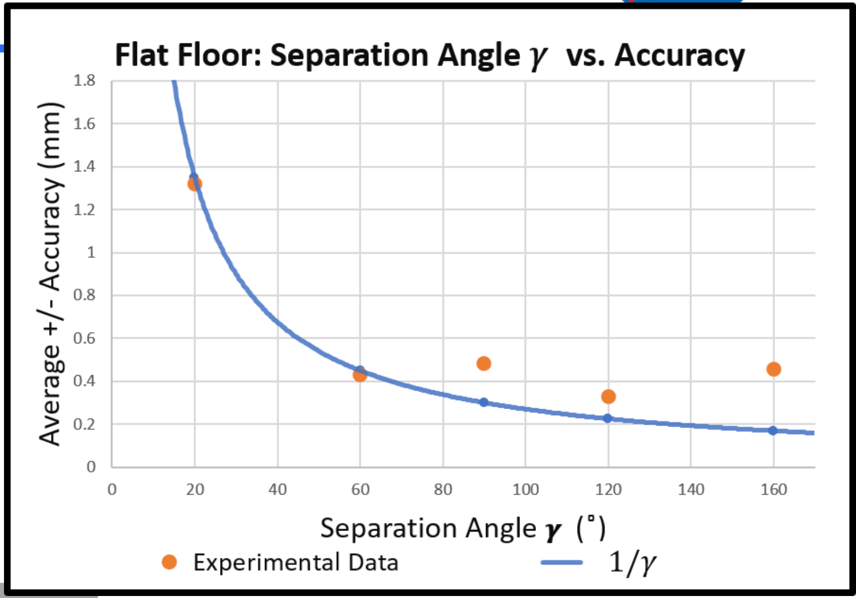
Images from crater model



Stereo Photogrammetry: Accuracy

- Testing for SCALPSS 1.0 provided data relating camera separation and altitude to photogrammetry accuracy.
- This data was used to develop an accuracy prediction equation for SCALPSS 1.1:

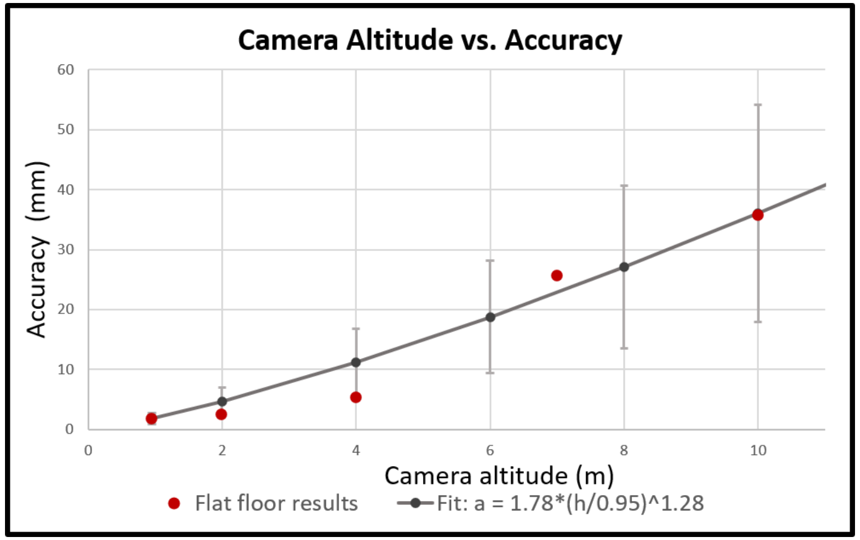




Based on data acquired at NASA Marshall:

$$\boldsymbol{Accuracy\ (mm)} = \begin{cases} \mathbf{1.78\ mm} * \left(\dfrac{\boldsymbol{h}}{\mathbf{0.95}\boldsymbol{m}}\right)^{\mathbf{1.28}} * \left(\dfrac{\mathbf{3.37}\boldsymbol{mm}}{\boldsymbol{f}}\right) * \left(\dfrac{\mathbf{1.9}\boldsymbol{m}}{\boldsymbol{d}}\right), & \text{for } h \geq 0.95 \text{ m} \\ \mathbf{1.78\ mm} & \text{for } h < 0.95\text{m} \end{cases}$$

h = camera altitude(m), f = lens focal length(mm), d = camera separation distance(m)

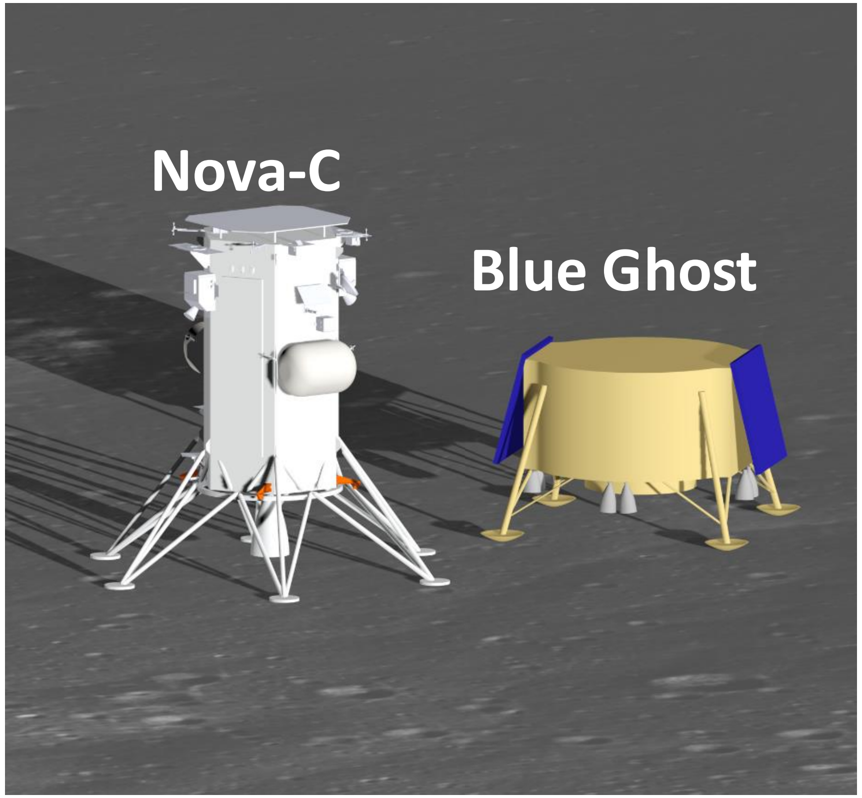


- Have since improved by a factor of 2.

Background: SCALPSS Payloads

SCALPSS 1.0

- Intuitive Machines' Nova-C lander
- 4-camera system
- Target fully eroded craters
- 1 plume-surface interaction
- 1.5 m primary cratering region
- 1 lens type used

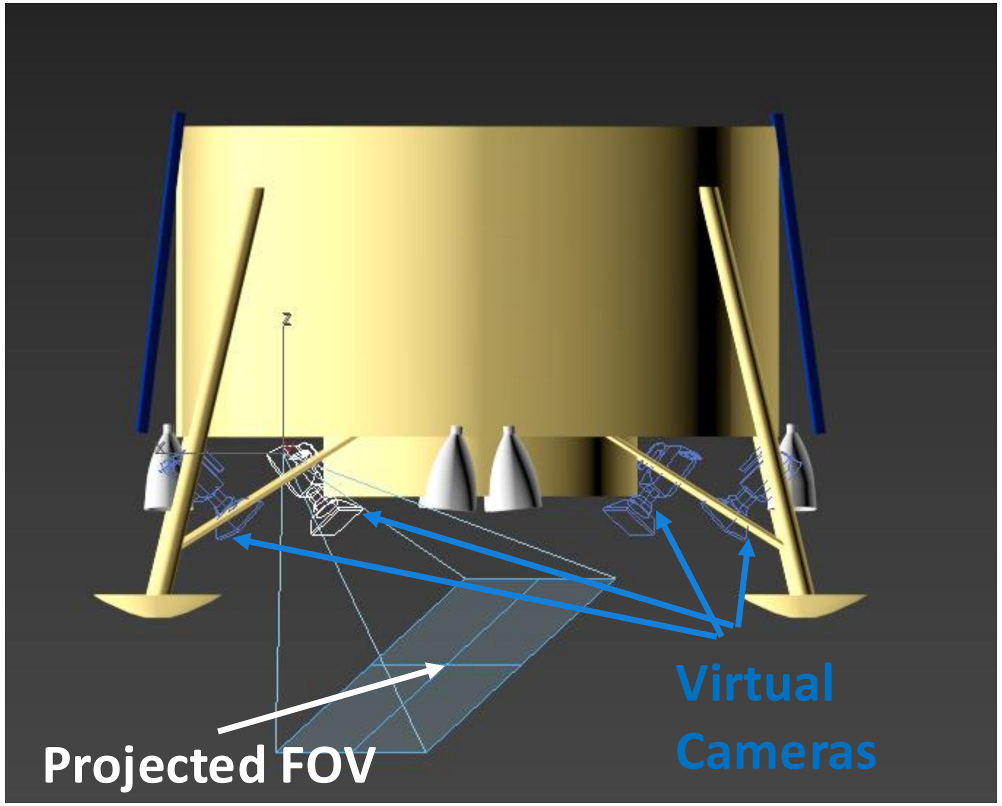


SCALPSS 1.1

- Firefly Aerospace's Blue Ghost lander
- 6-camera system
- Target pre-disturbed regolith (2) and full eroded craters (4)
- 8 plume surface interactions
- 3 m primary cratering region
- 3 lens types used

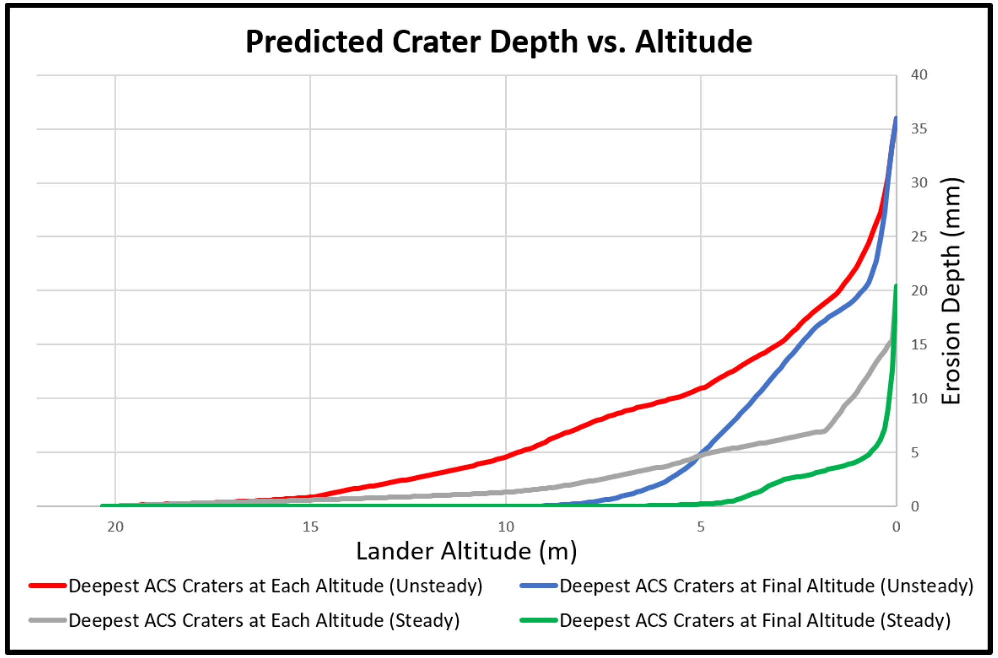
The Virtual Diagnostics Interface (ViDI)

- Simulation environment for SCALPSS.
- Enables camera placement on lander design, camera view simulation and rapid implementation of design changes.
  - Simulate solar radiation (IM-1).
  - Simulate vibration environment.
  - Simulate motional blur during landing.
  - Helps with post-processing data after mission.

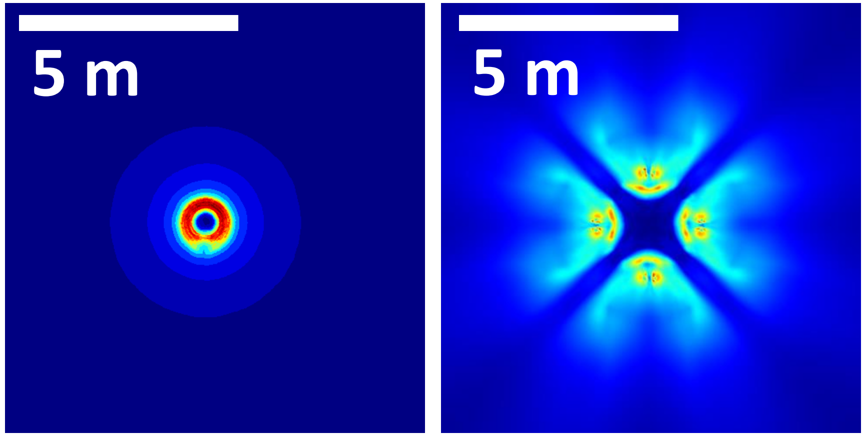


Prediction of Plume-Surface Interaction

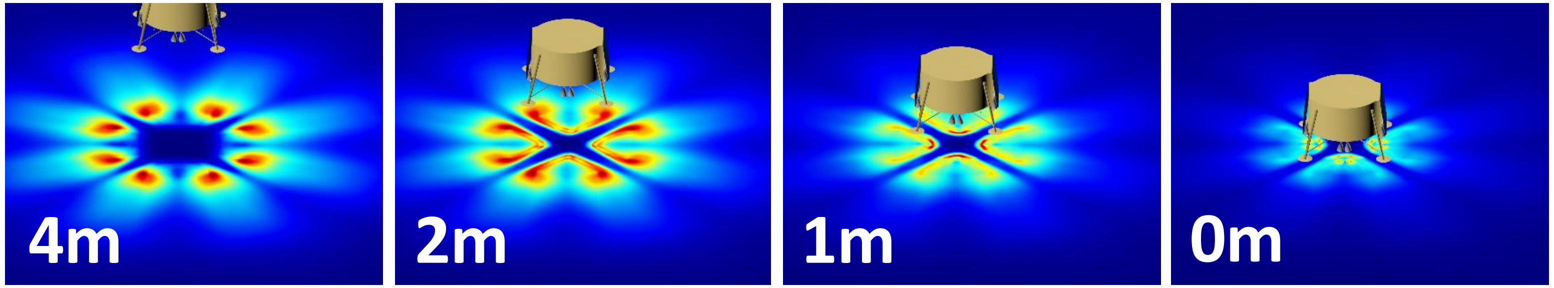
- CFD solutions developed at Marshall Space Flight Center predict regolith erosion vs. altitude. [West Group, MSFC]



Erosion patterns at 0 m lander altitude:



Nova-C **Blue Ghost**

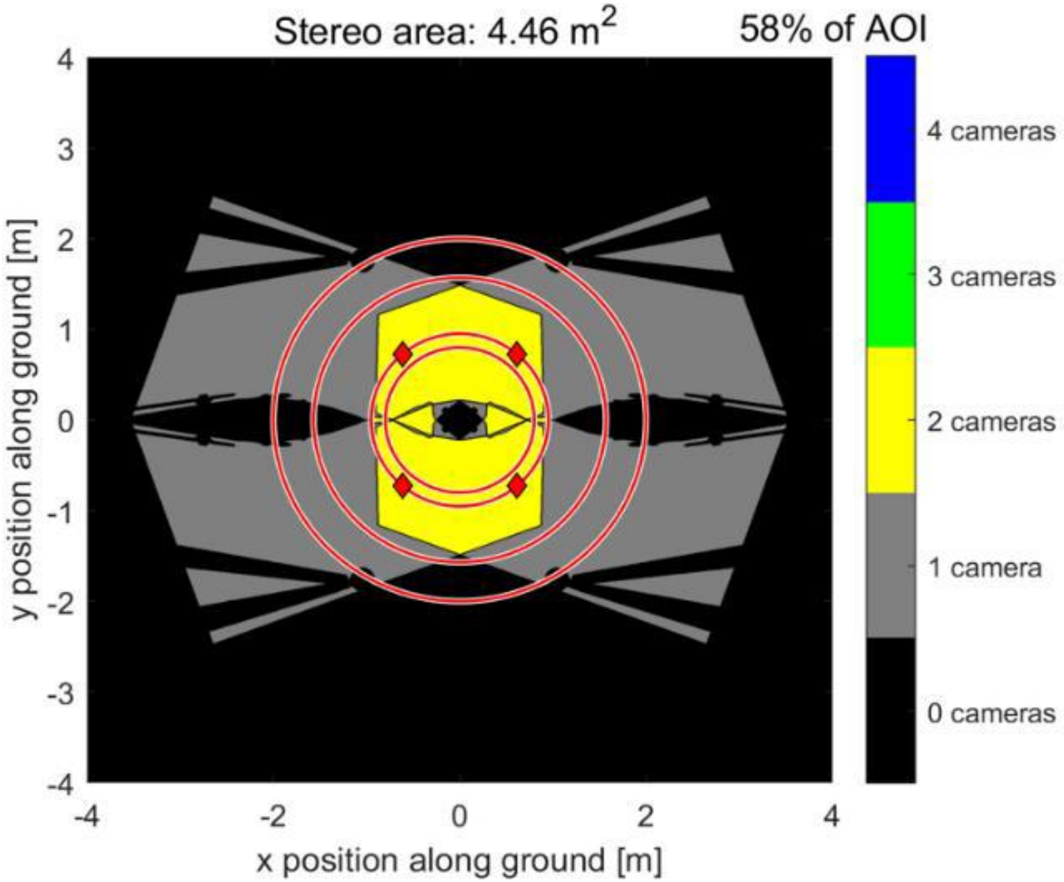


O. K. Tyrrell, R. J. Thompson, P. M. Danehy, C. J. Dupuis, M. M. Munk, C. P. Nguyen, R. W. Maddock et al. "Design of a lunar plume-surface interaction measurement system." In *AIAA SciTech 2022 Forum*, AIAA 2022-1693, January 2022.

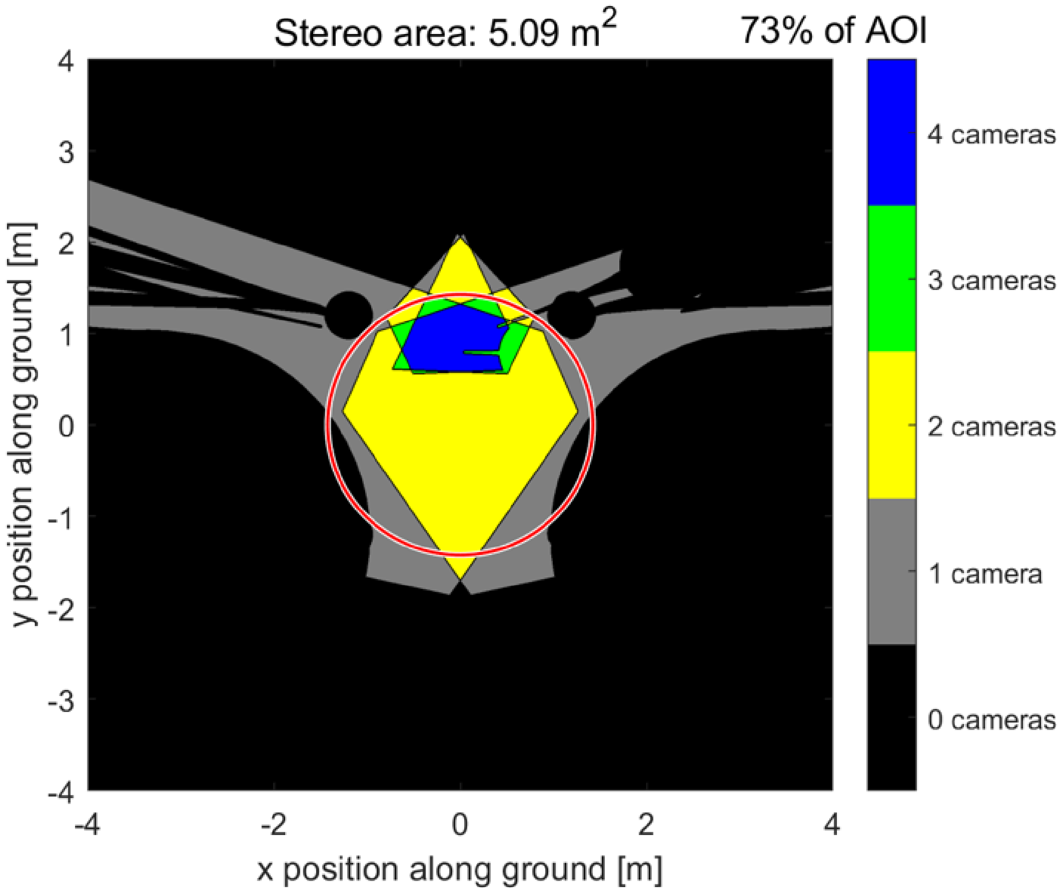
Comparison of SCALPSS 1.0, 1.1 FOVs

SFL Cameras at 0m Lander Altitude

SCALPSS 1.0: Intuitive Machines



SCALPSS 1.1: Firefly Blue Ghost Mission 1



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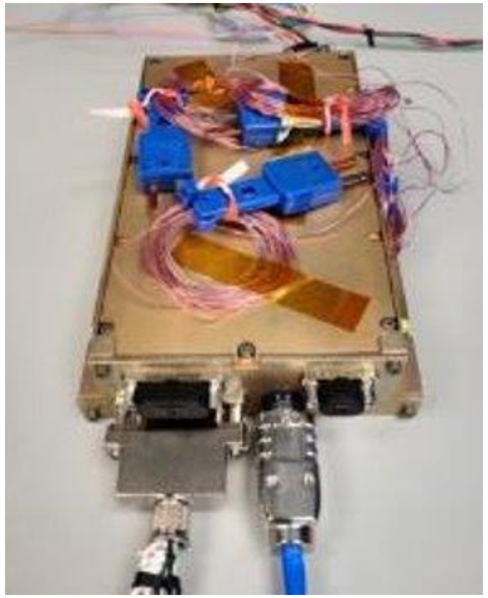
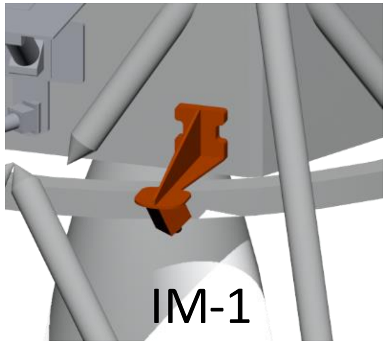
Stereo Cameras for Lunar Plume-Surface Studies

- Payload developed for the Commercial Lunar Payload Services (CLPS) program
- Heritage hardware from Mars 2020 EDLCam (NASA JPL)

1. Four camera for IM-1 Nova-C; Six cameras for FF-BGM1
   - SFL – short focal length
   - LFL – long focal length
2. USB Hub
3. Data Storage Unit (DSU)

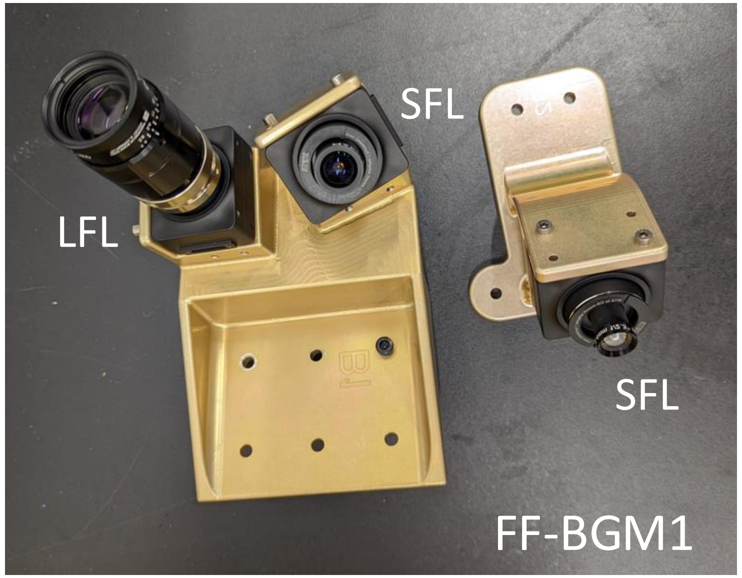
Data Storage Unit (DSU)





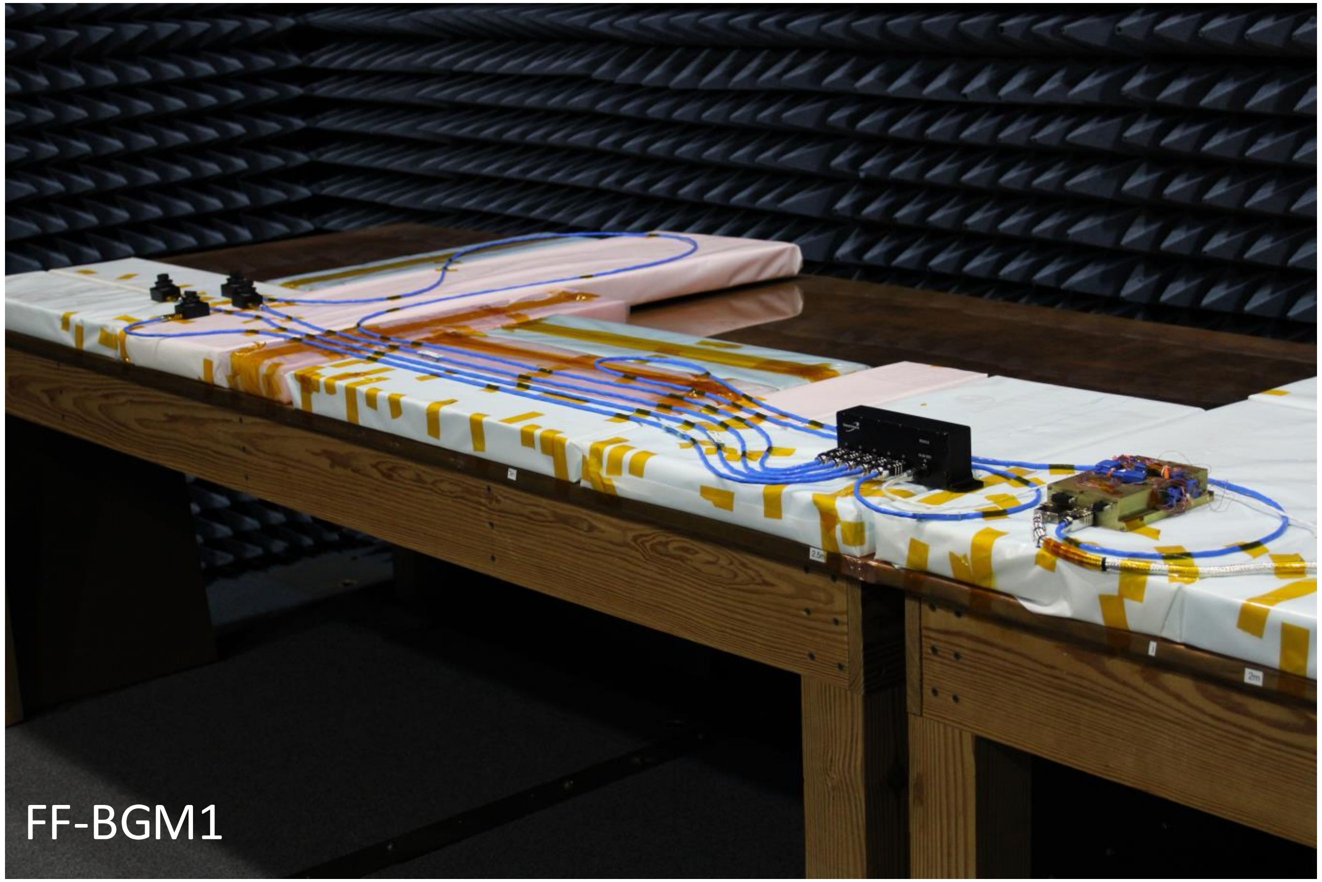
USB Hub

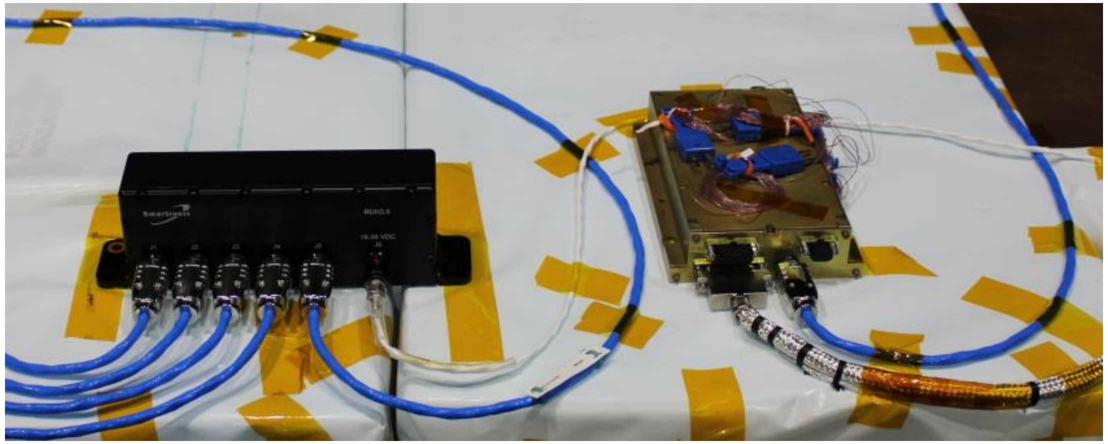
Cameras + Brackets

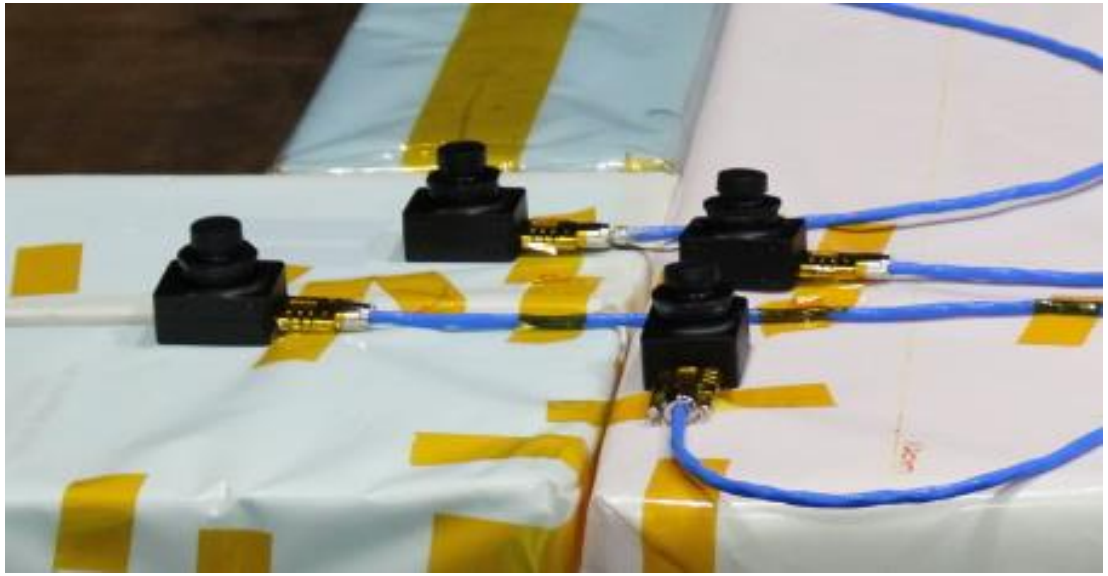


Environmental Testing (1/3)

Electromagnetic Interference/Compatibility
(data analysis by Raymond Lueg)

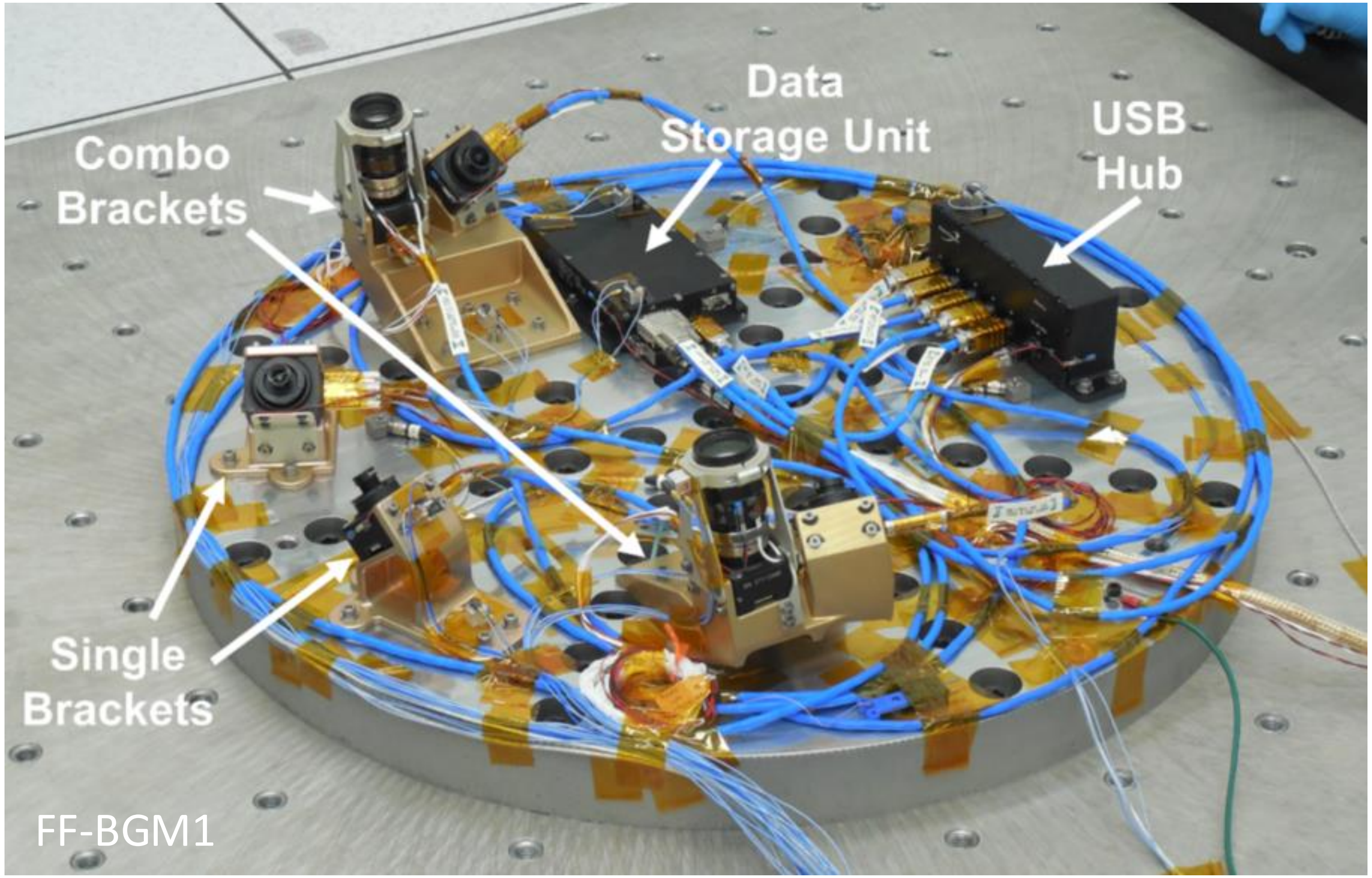


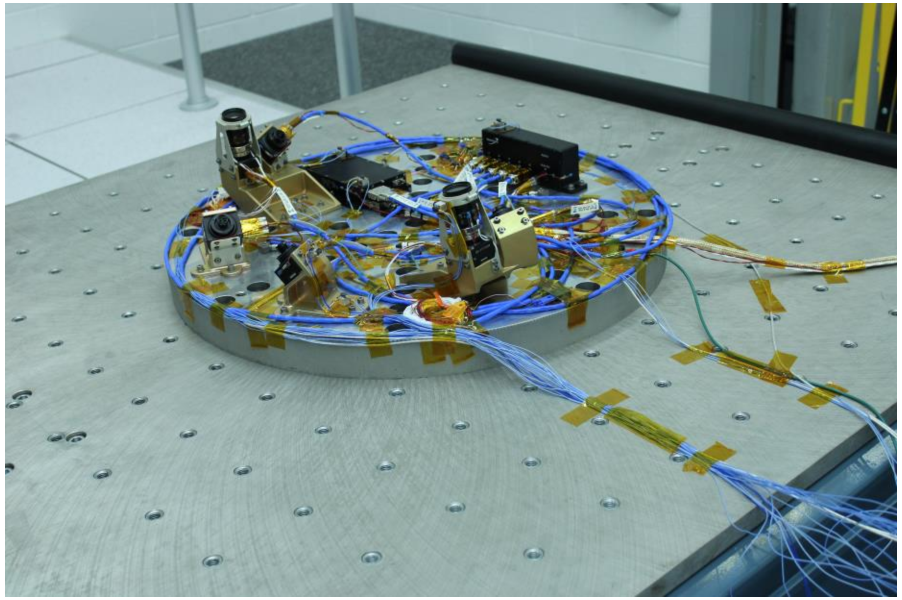




Environmental Testing (2/3)

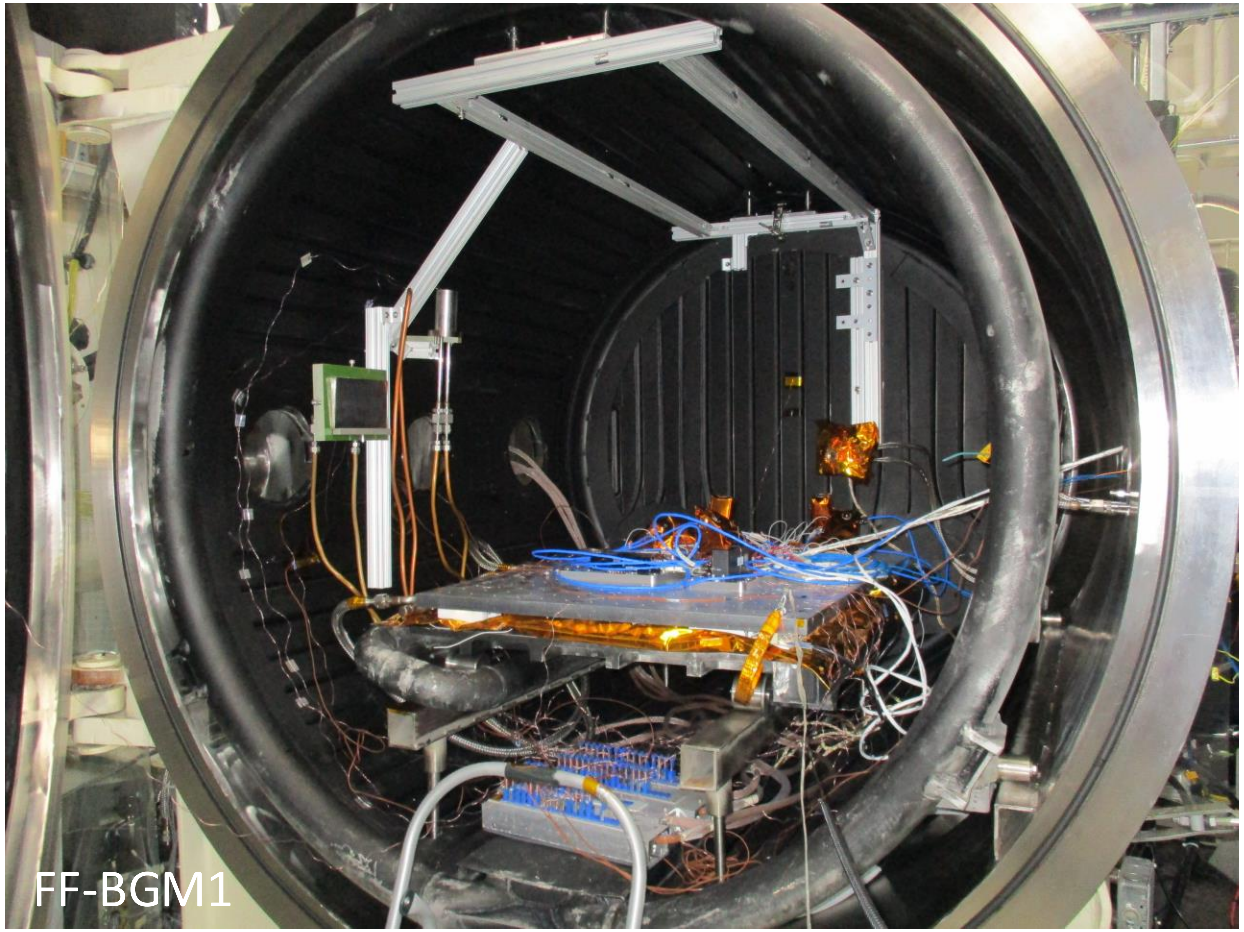
Vibration (structural analysis by Adam Ben Shabat)

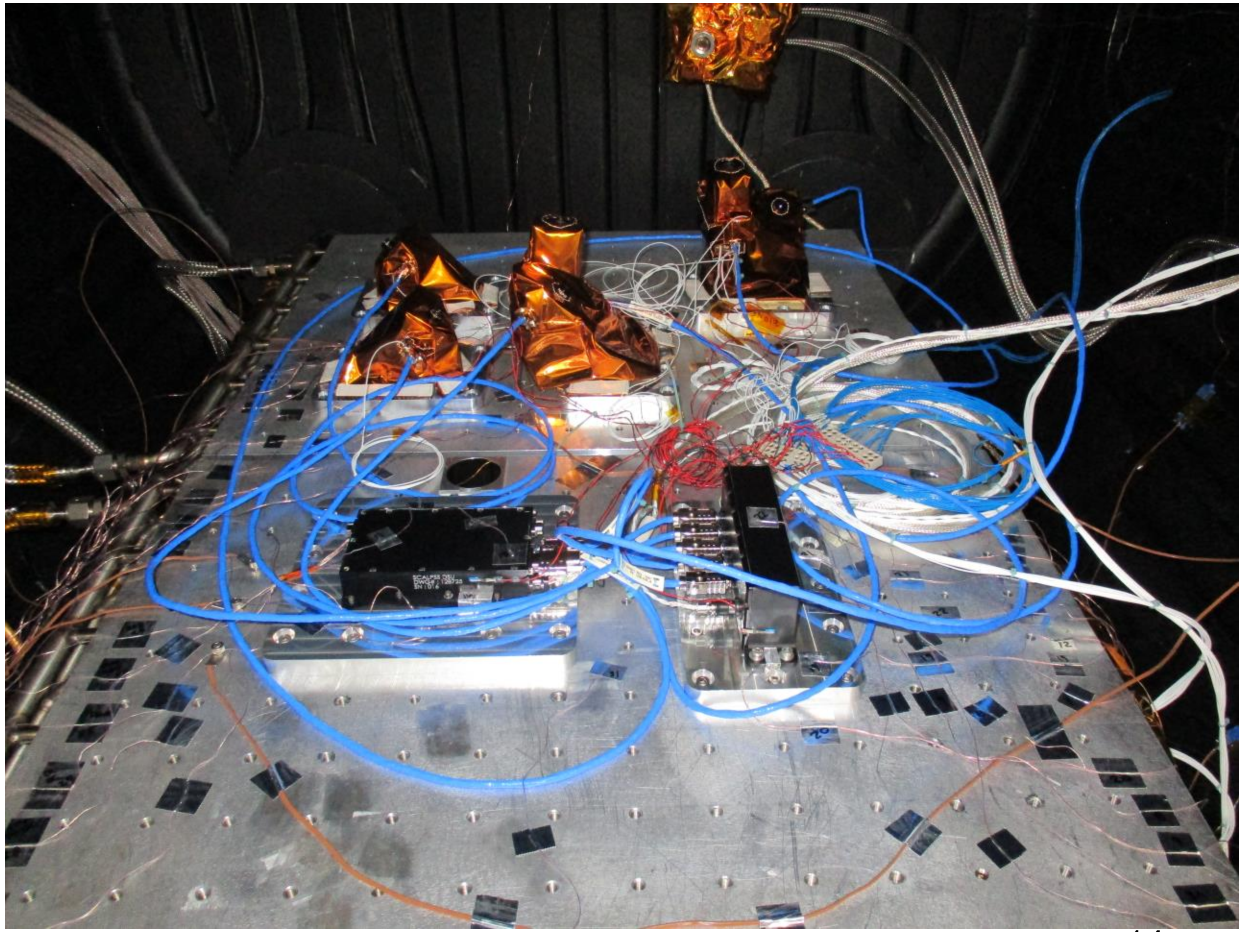




Environmental Testing (3/3)

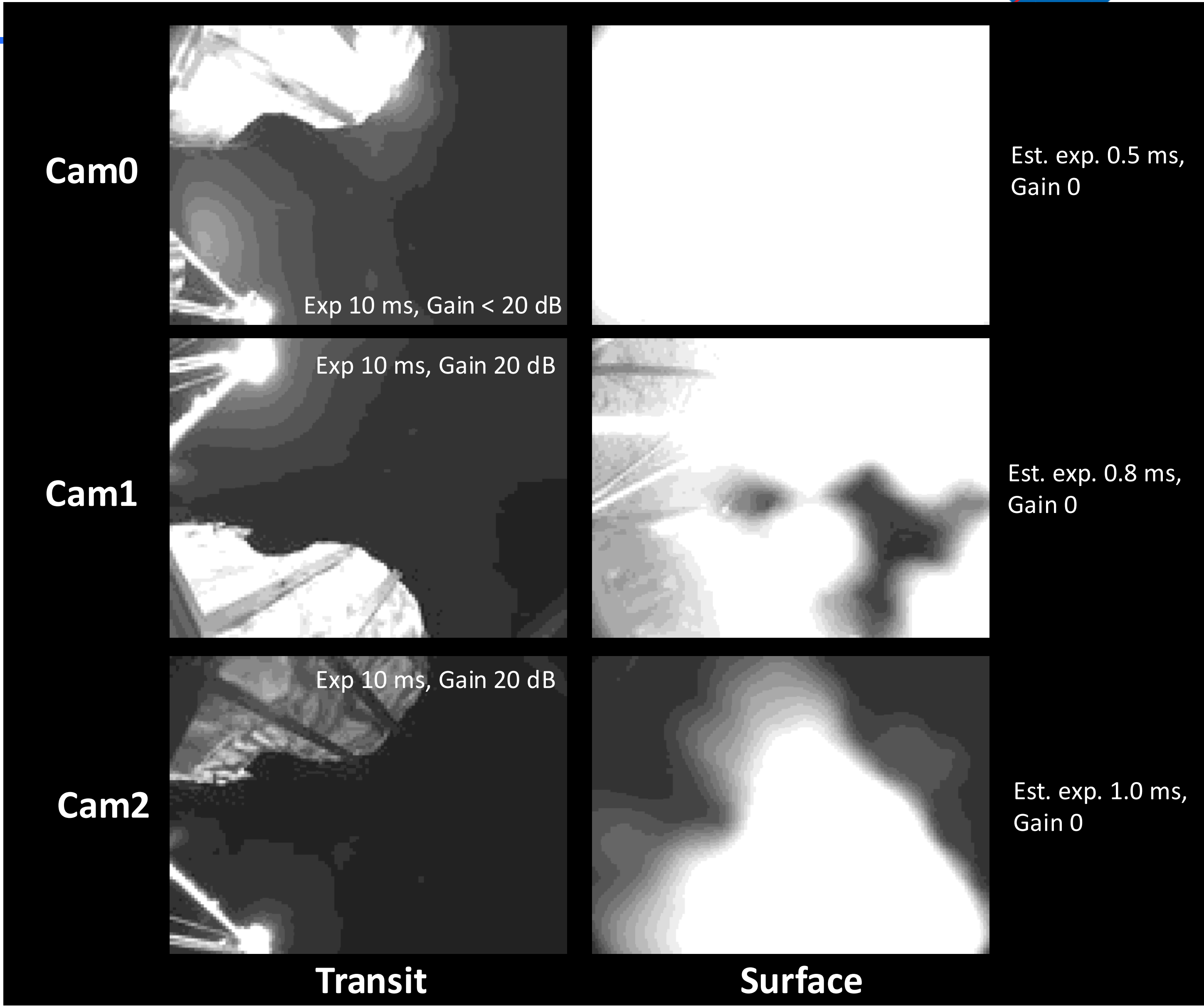
Thermal Vacuum (thermal analysis by Alex Scammell)





Successes from IM-1 Nova C

- Cameras were operated manually post-landing.
- 5 days after landing, IM downlinked six thumbnail images from the lander.
- Cams 0, 1, and 2 each collected two thumbnails. Cam3 did not operate (too high temperature).
  - Images were overexposed and partially obscured by dust.
- **Cameras and Electronics survived launch, transit, and landing.** Three out of four provided thumbnails and full resolution images from the lunar surface.



References

1. R. J. Thompson, P. M. Danehy, M. M. Munk, M. Mehta, M. S. Manginelli, C. Nguyen and O. H. Thomas. “Stereo Camera Simulation for Lunar Surface Photogrammetry”. *AIAA SciTech 2021 Forum*. AIAA 2021-0358. January 2021.
2. O. K. Tyrrell, R. J. Thompson, P. M. Danehy, C. J. Dupuis, M. M. Munk, C. P. Nguyen, R. W. Maddock et al. "Design of a lunar plume-surface interaction measurement system." *AIAA SciTech 2022 Forum*, AIAA 2022-1693, January 2022.
3. O. K. Tyrrell, J.M. Weisberger, T.W. Fahringer, P.M. Danehy, and W.D. Hutchins, 2023. Investigating Photogrammetric Accuracy of a Lunar-lander-induced Crater Measurement System. *AIAA SciTech 2023 Forum,* AIAA 2023-2475, January 2023.
4. R. Maddock, M. Munk, P.M. Danehy, O.K. Tyrrell, J.M. Weisberger, T.W. Fahringer, R. Lueg, C. Wilson, A. Scammell, K. Martin, and A. Ben Shabat, Firefly Blue Ghost Mission 1: SCALPSS 1.1 Payload and Mission Overview. AIAA SciTech 2026 Forum AIAA 2026-1308, January 2026.

Future SCALPSS opportunities

Completed

SCALPSS 1.0

- Intuitive Machines 1.
- 4-camera system with 1 lens type.
- Primary measurement goal: post-landing erosion profile.
- Mission Completed March 2024.

SCALPSS 1.1

- Firefly Aerospace Blue Ghost Mission 1.
- 6-camera system with 3 lens types.
- Primary measurement goals: Pre-landing and post-landing erosion profiles.
- Mission Completed March 2025.

SCALPSS 1.X

- Blue Origin MK1 Pathfinder.
- 4-camera system with 1 lens types.
- Primary measurement goals: Pre-landing and post-landing erosion profiles.
- Payload delivered to vendor, awaiting mission.

SCALPSS 2.0

- Firefly Aerospace Blue Ghost Mission 4
- 6-camera system, active (laser) and passive illumination components.
- Primary measurement goals: Pre-landing and post-landing erosion profiles, ejecta sheet shape, particle dynamics.
- Custom avionics "Mini-Suite Lite" (MSE).
- Payload configuration design underway.

SCALPSS 2.1*

- CLPS CT-4 (Lander Selection TBD)
- 6+ camera system, active (laser) and passive illumination components.
- Primary measurement goals: Pre-landing and post-landing erosion profiles, ejecta sheet shape, particle dynamics.
- Custom avionics "Mini-Suite Lite" (MSE).

SCALPSS GT

- Human Landing System Plume-Surface Interaction Ground Test (HLS-PSI-GT) at NASA LaRC
- 4-camera and 2-laser system.
- Primary erosion measurement system for test campaign.
- Testing currently underway.