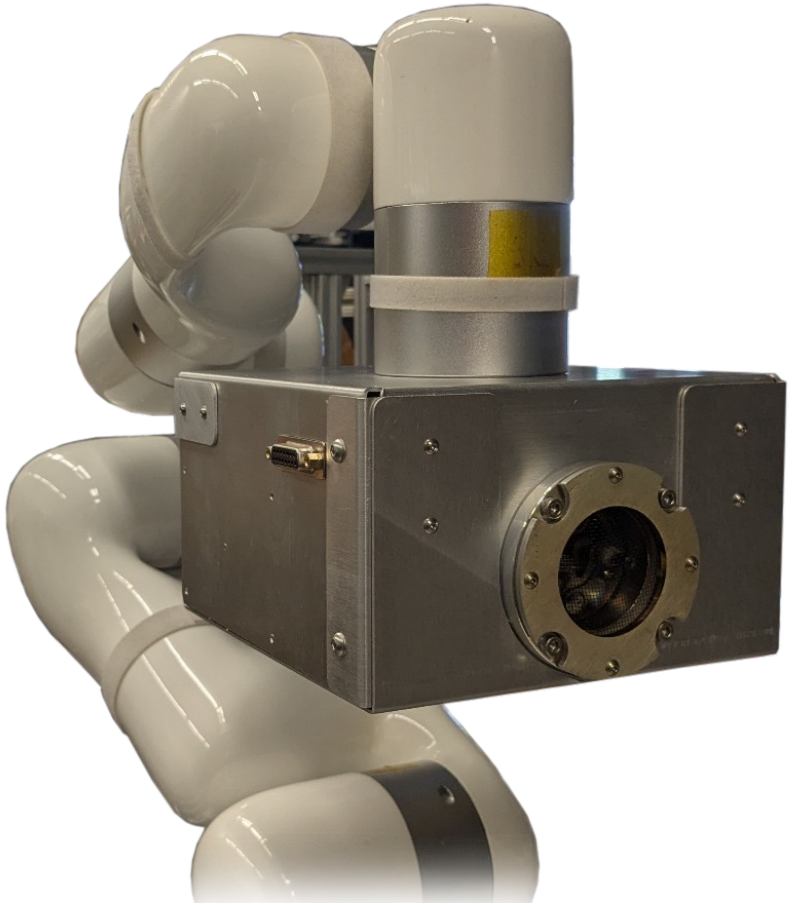
ORBITAL MINING CORPORATION



Lunar Surface Cleaning Robotic Unit with Electron Beam (SCRUB)

Dr David M Asner

Chief Science Officer

Orbital Mining Corporation

In partnership with:

SPACE DUST Research & Technologies

Apollo era: Lunar Dust Problem

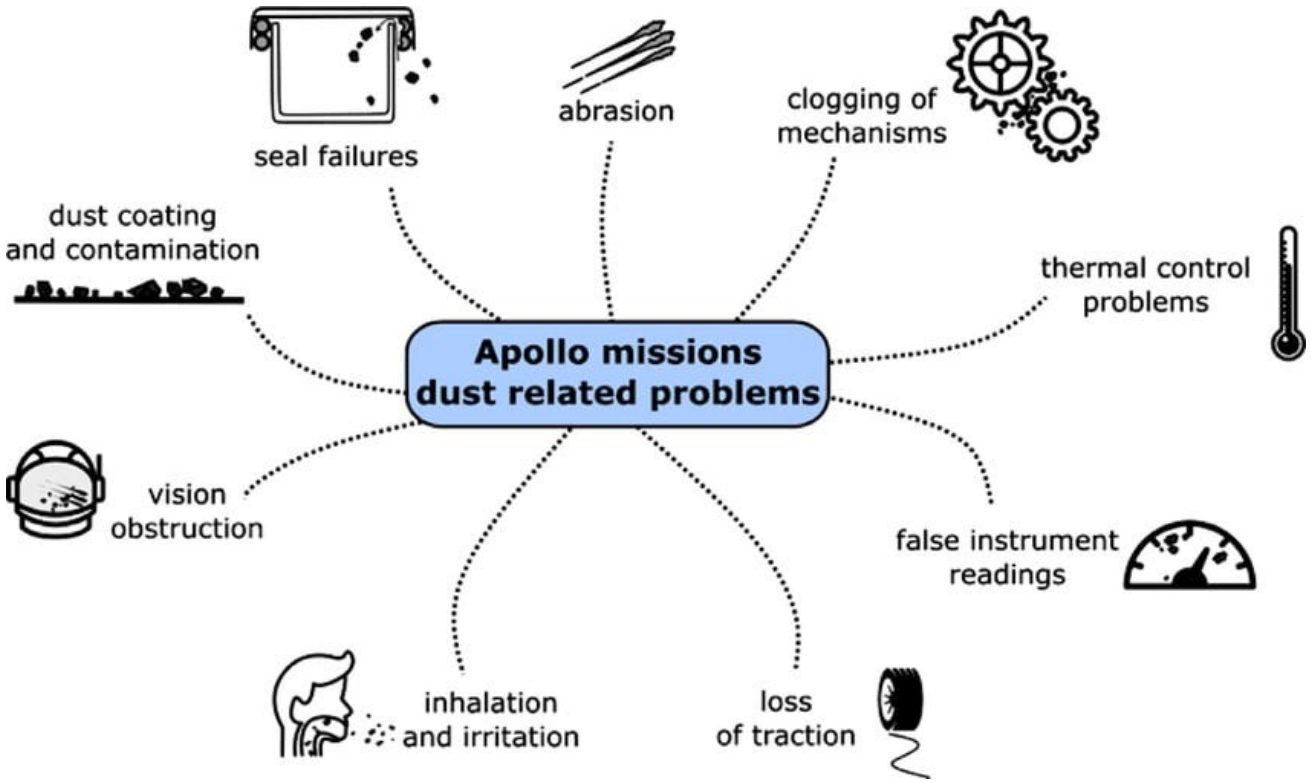


Image credit: Implicit lunar dust mitigation technology: Compliant mechanisms, 2022
Gaier, J.R., *The Effects of Lunar Dust on EVA Systems During the Apollo Missions*, NASA/TM-2005-213610, NASA Glenn Research Center, Cleveland, OH, 2005.

Lunar SCRUB: Dust Mitigation tool

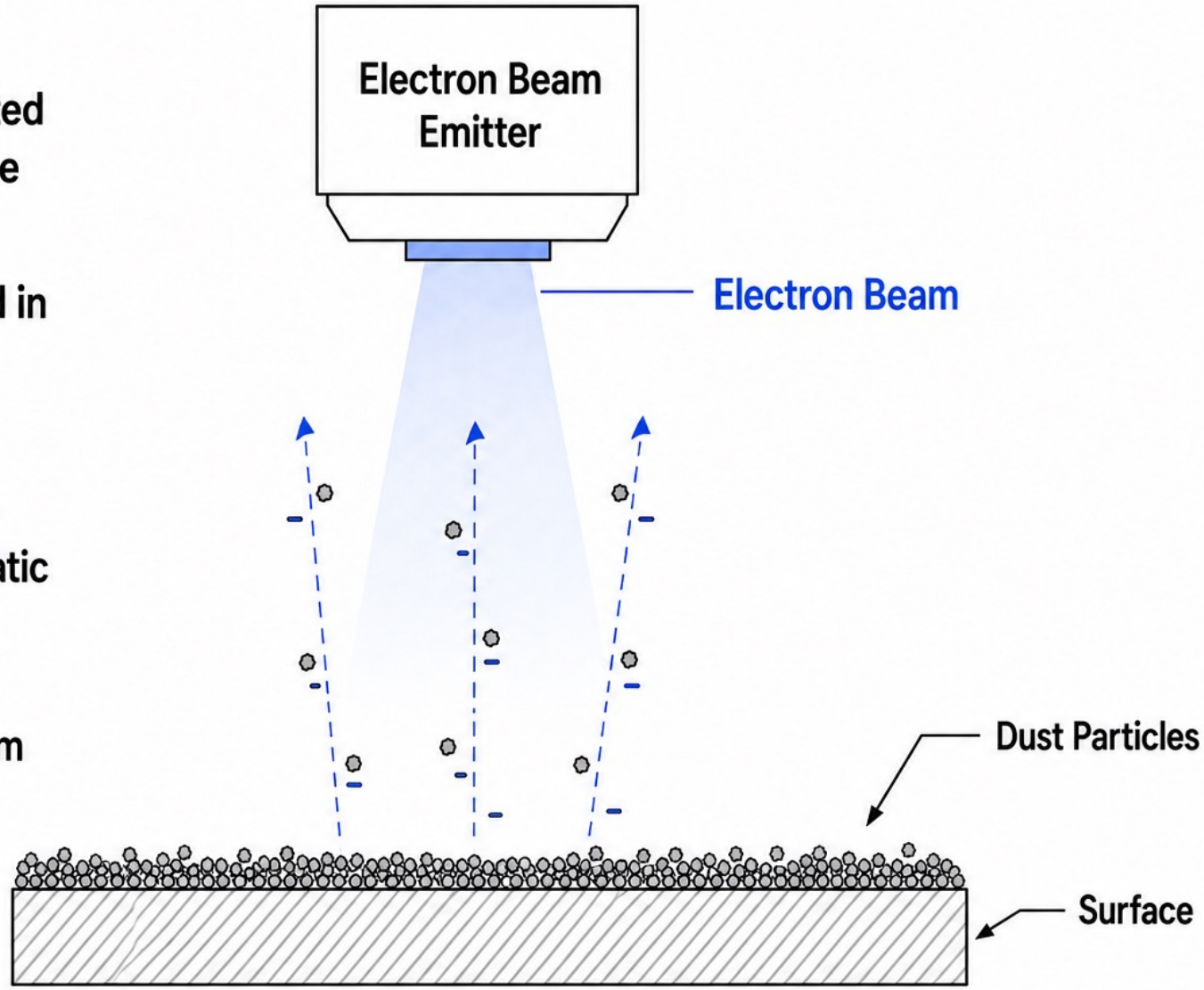
Background

- Evaluated electron beam removal of lunar regolith simulants across varied surfaces and geometries in vacuum [*via electrostatic lofting]*
- Operated in different environmental (temperature) conditions to characterize robustness
- Completed as part of **NASA Phase I SBIR**
- Measured efficacy of dust removal from solar array components or similar testing substrates
- Several companies provided components for testing

Image credit: NASA

Electron Beam Dust Lofting Concept

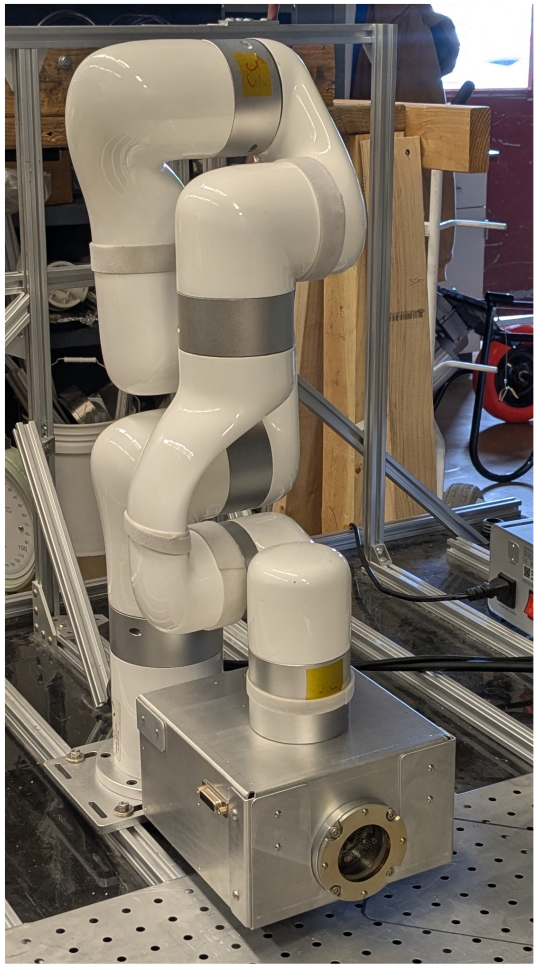
1. Electron beam emitted toward dusty surface
2. Charge accumulated in microcavities
3. Accumulated charge overcomes electrostatic attraction to surface
4. Particles loft away from surface and are not physically contacted



Lunar SCRUB: Dust Mitigation tool

Goals:

- **Active dust mitigation tool** designed for tailored cleaning of complex geometries, connectors, seals, and mission-critical hardware
  - solar panels, batteries, sensors
  - thermal control surfaces (radiators), mechanical interfaces
- On VSATs, LTVs, rovers, habitats…
- Three implementation concepts
  - **SCRUB-Fixed** (low-power, fixed-mounted)
  - **SCRUB-Mobile** (robotic-arm-compatible / handheld)
  - **SCRUB-Intelligent** (AI-supported optimization of real-time cleaning strategy)



Lunar SCRUB: Dust Mitigation tool

Testing Summary

- Jan – Mar 2026, OMC completed **51 vacuum tests**
- Implemented mobility to simulate robotic arm use
- Operated in different environmental conditions to characterize robustness
- **Primary focus:** measure efficacy of lunar regolith simulant removal
  - Angle-scan measurement program
  - Mobility Tests
  - Repeatability Tests
  - Environmental Tests

BEFORE

AFTER

Lunar SCRUB works!

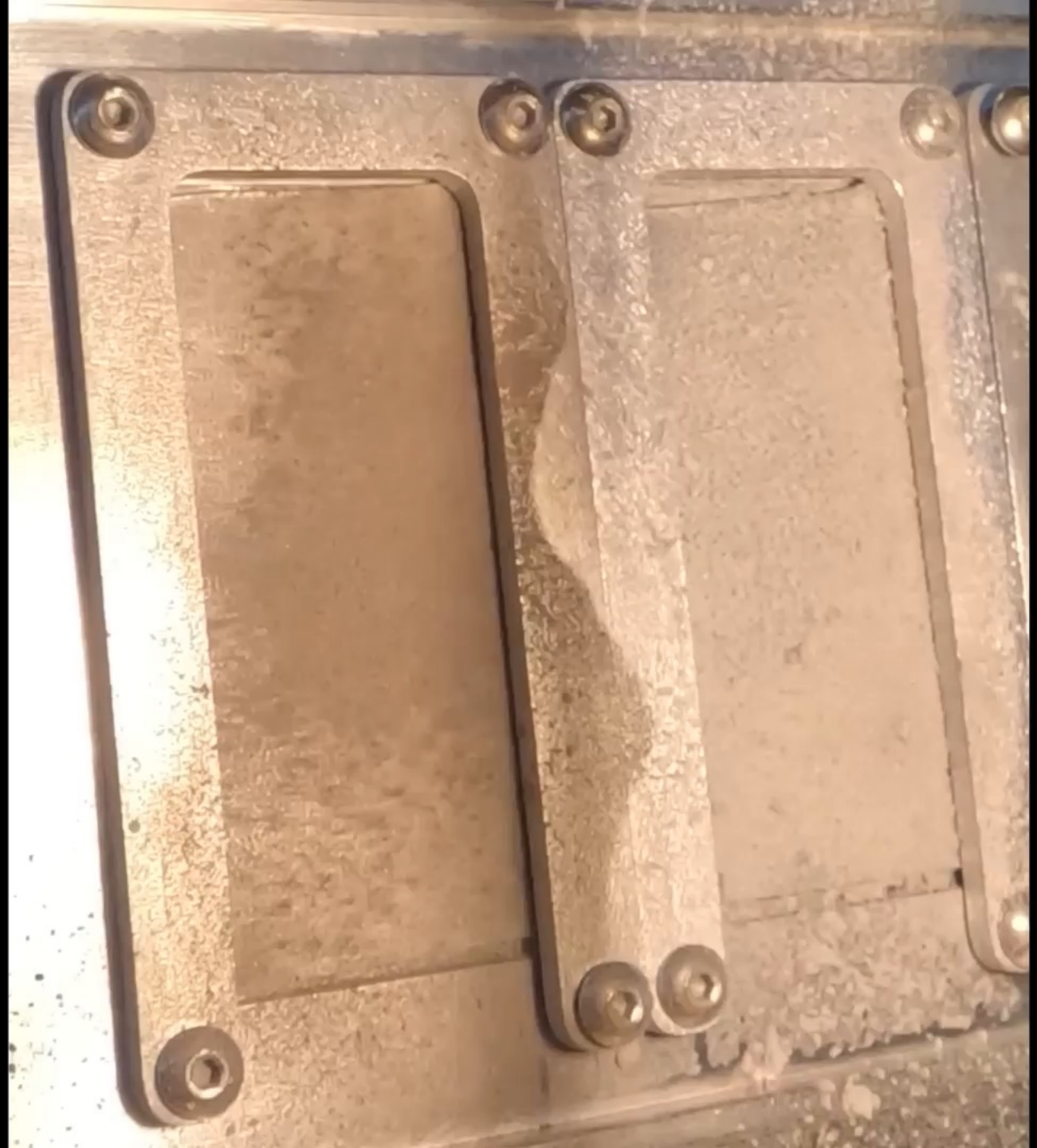
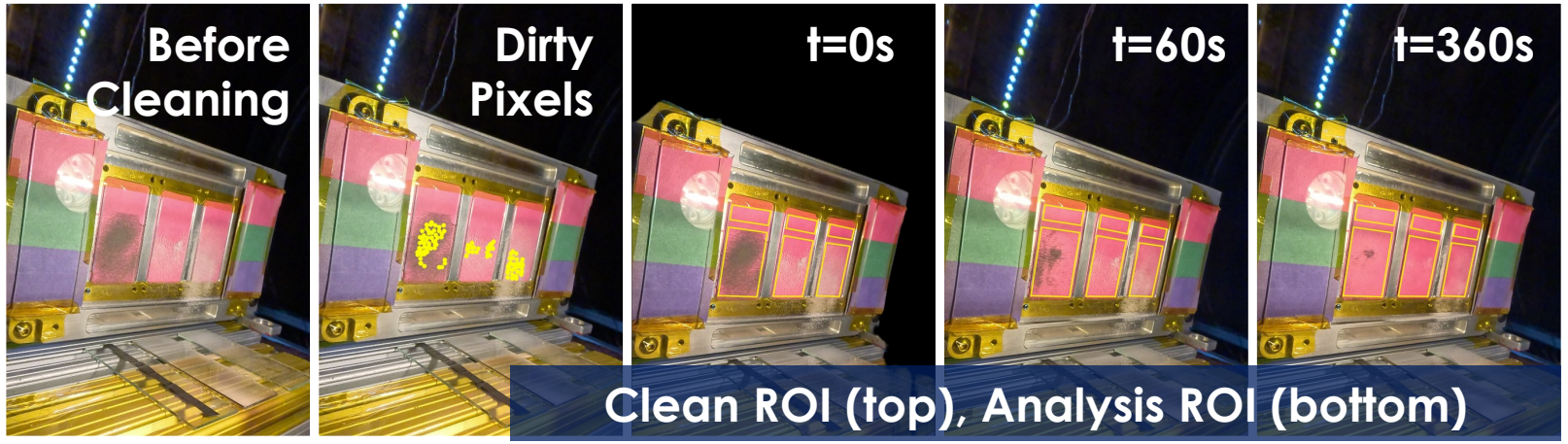
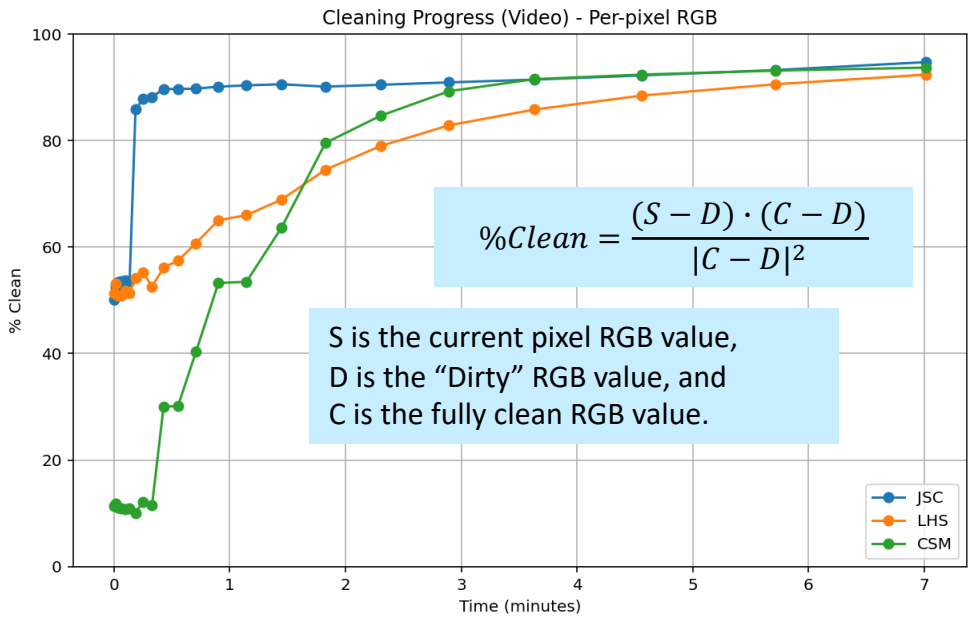


Image Analysis

Image Analysis

- Dust removal efficacy determined on **pixel-by-pixel** analysis of color (not gray-scale) images
- Images are sampled non-uniformly in time from GoPro camera videos
- Development of image analysis framework using Python image processing libraries is complete
- Test shown. nearly vertical sample **(75^0)** with horizontal SCRUB achieved **90% clean** with three regolith simulants





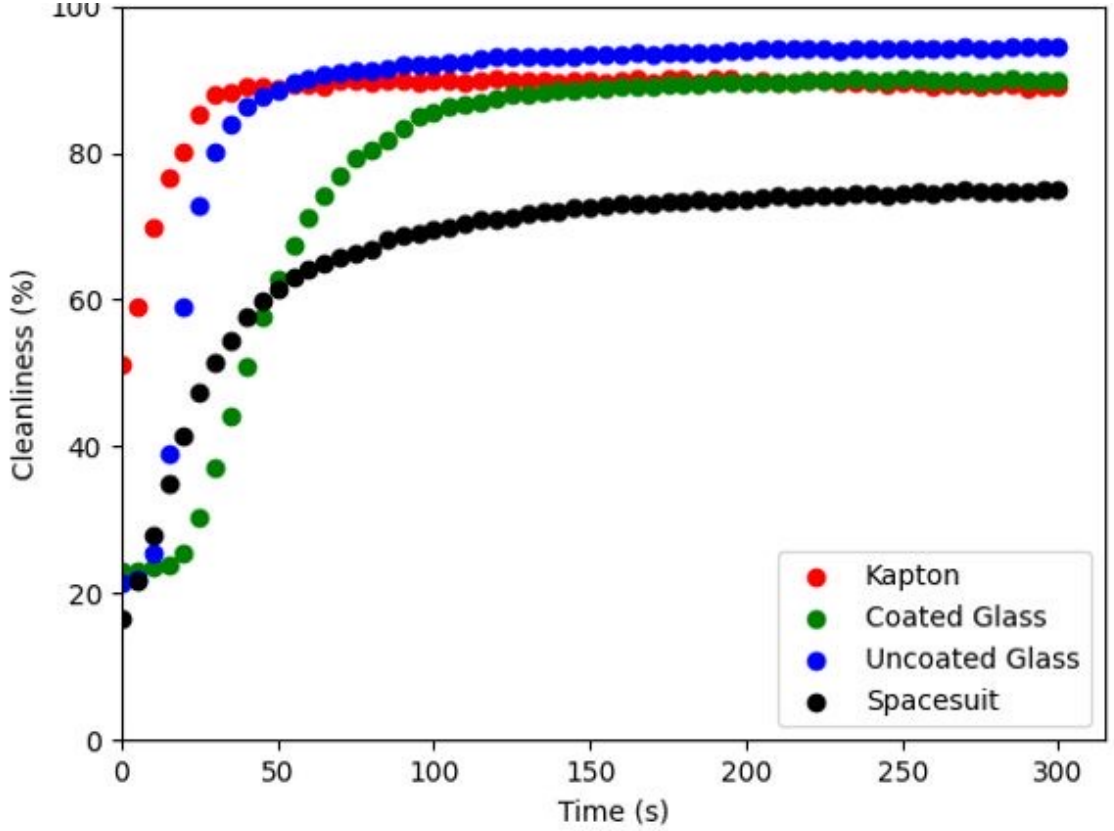
OMC and SDRT Cleaning Tests

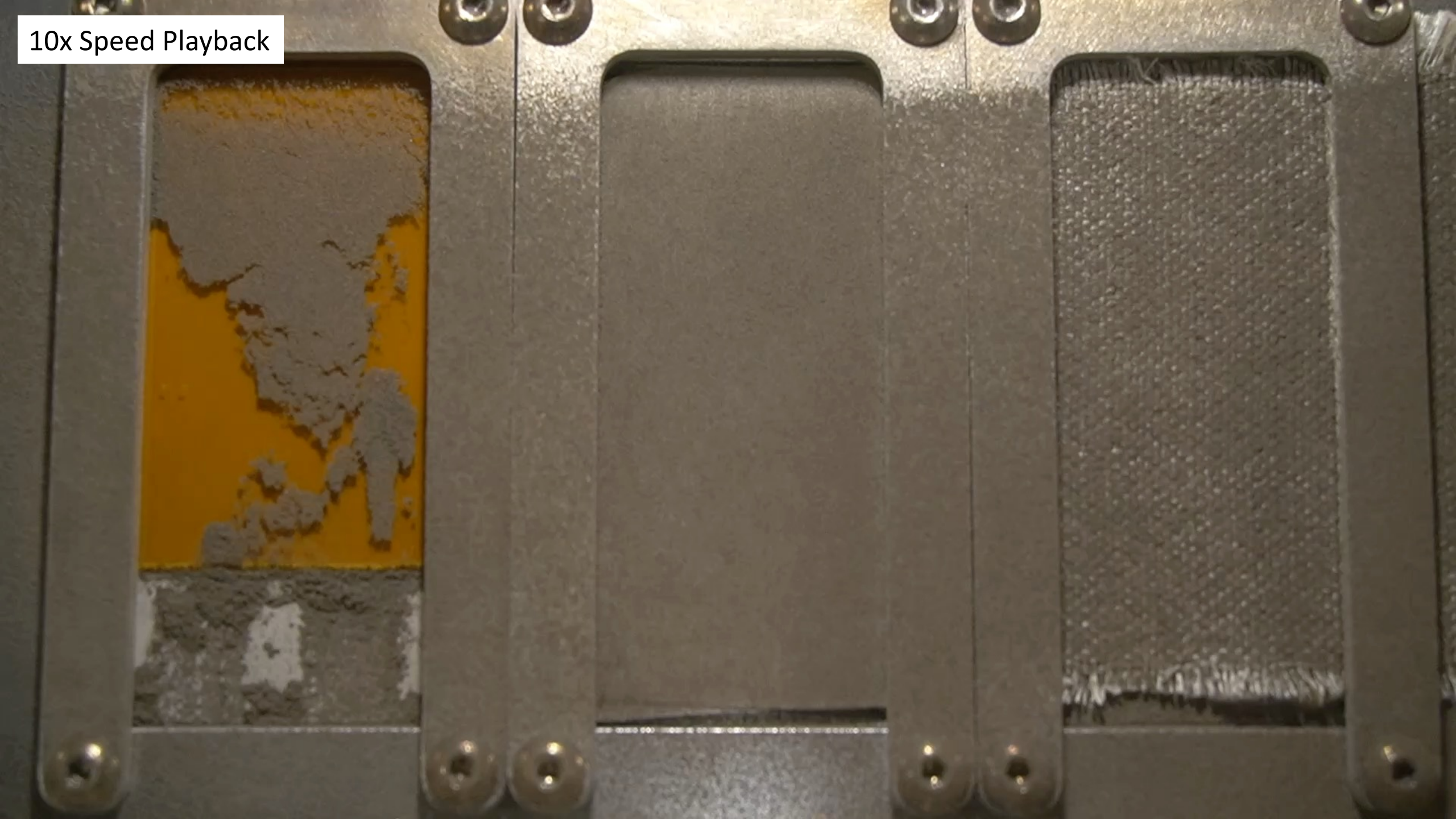
- Tests were conducted with **JSC-1** lunar regolith simulant
- Test materials: Deposited on Kapton, coated glass, uncoated glass, and a spacesuit material.

Results

Material	Time	Efficacy
Kapton	**30s**	**~ 90%**
Coated Glass	**125s**	**~ 90%**
Uncoated Glass	**50s**	**~ 95%**
Spacesuit Fabric	**120s**	**~ 70%**

Summary of SDRT cleaning tests




10x Speed Playback

Lunar SCRUB: Dust Mitigation tool

Accomplishments

- Evaluated **electron beam removal** of lunar regolith simulants across varied surfaces & geometries in vacuum
- Completed **50+ tests in vacuum** (commissioning, angle, repeatability, environmental)
- Achieved cleaning **efficiency above 90%** with three lunar regolith simulants.
- Survived exposure to **extreme temperatures** (-40C,+100C). Operated (-40C,+70C)

Next Steps

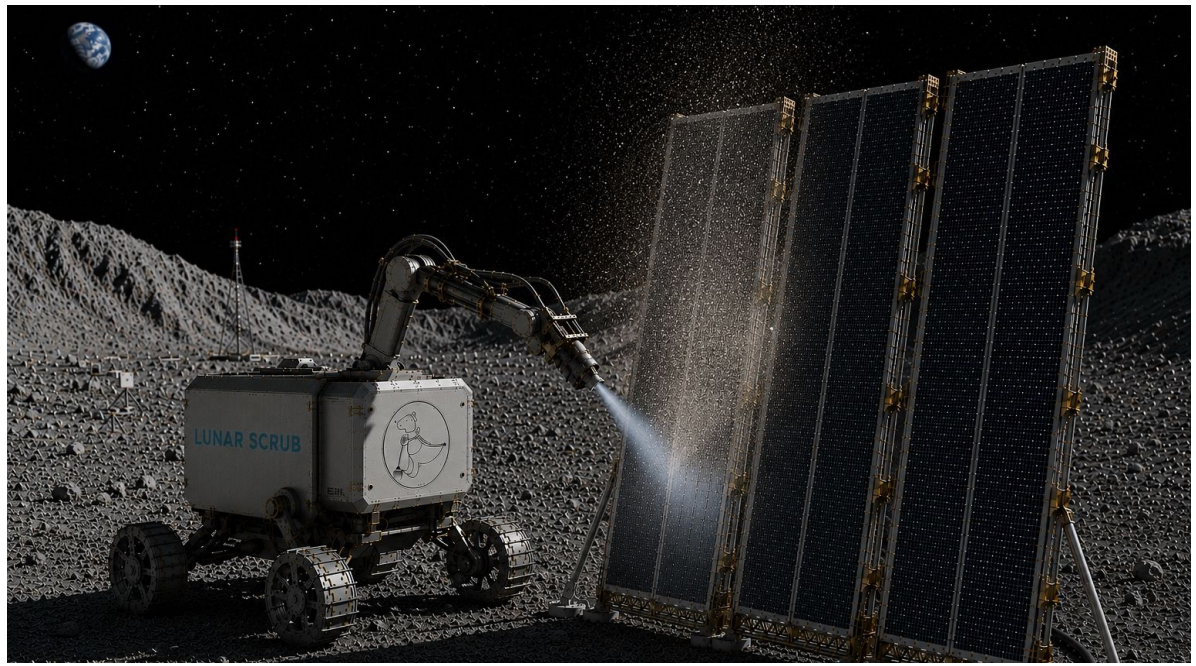
- Market Research & Product Development
- Commercialization
- Target lunar deployment by **2029**

SCRUB-Fixed

SCRUB-Mobile

SCRUB-Intelligent

SBIR Phase II plan



- Advance Lunar SCRUB from TRL 4 to TRL 6+ via an integrated, lunar-relevant prototype demonstrated in vacuum.
- Mature electron-beam source technology, integrating lightweight power electronics and advanced (pulsed) operating modes.
- Demonstrate repeatable, non-contact dust removal on representative lunar hardware (solar arrays, radiators, mechanical interfaces, EVA-relevant materials).
- Validate system performance and survivability under relevant vacuum and thermal conditions using lunar regolith simulants in dirty TVAC chambers.
- Implement robotic-arm-enabled cleaning in vacuum and define the integration path with an Intuitive Machines robotic arm for future CLPS infusion.
- Show real-time functional recovery of operating solar and thermal-control hardware and deliver an infusion roadmap for CLPS and Artemis-relevant missions.

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Thank you!

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In partnership with:

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