

National Aeronautics and
Space Administration



Space Technology Mission Directorate Game Changing Development Program

Erica Montbach | Phillip Abel | FY22 Dust Mitigation Standards Annual Review Presentation | 09.15.22

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Dust Mitigation Best Practices Guide Overview

➤ Technology Product Capability

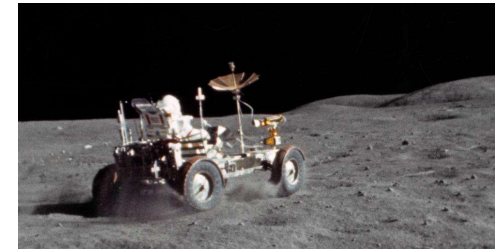
- Develop an accessible, understandable, comprehensive, and refereed guide to avoiding lunar dust problems during surface operations, both for inexperienced mechanisms designers in academia or small companies *and* for seasoned mission veterans.
- Extensive references into the detailed technical literature provide a “how to” lunar dust mitigation reference.

➤ Technical Capabilities

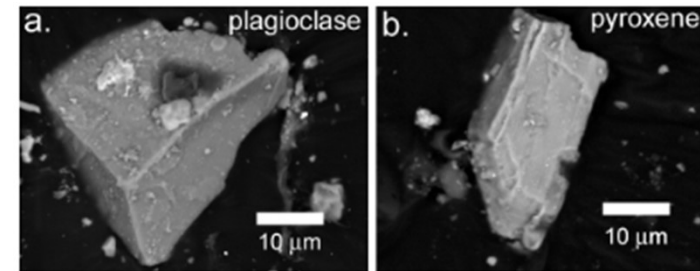
- Interactions and input from potential Guidebook users in industry that are external to NASA during COVID 19, to be incorporated
- Identification and availability of technical expertise across NASA

➤ Exploration & Science Applicability

- Publication and distribution to NASA stakeholders, aerospace industry, and academic partners
 - For use by designers, commercial partners, and service providers
- NASA missions targeted by the guidebook: CLPS, Artemis, Gateway, HLS



Lunar Roving Vehicle (LRV) spraying dust, during Apollo 16 mission, (NASA Photo S72-37002)



Mineral grains common in lunar soils of (a) highland material (b) mare soils, Christoffersen et al., NASA TP-2009-214786

Dust Mitigation Best Practices Guidebook Team

Project Manager: GRC-MT/Erica Montbach

Project Lead Engineer: GRC-LMT/Phillip Abel

GRC

Lead: Phillip Abel

- LMT/Damien Ludwiczak
- LMT/Phillip Abel
- LMA/Pete Bonacuse
- LCF/Jordan Jennifer
- LMT/Samuel (Adam) Howard
- LMT/Fransua Thomas
- LMA/Wayne Jennings
- LMT/Patrick Dunlap
- MB/Michael Anderson
- LTC/Paul Greenberg (ret.)
- LTC/Dave Fischer

KSC

- UBE/Austin Langton
- UBE/James Mantovani
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LARC

- D307/Chris Wohl

JSC

- EC211/Evelyne Orndoff
- EX211/Kristen John
- EC411/Katy Hurlbert

Dust Mitigation Best Practices Guide

Mission Infusion & Partnerships

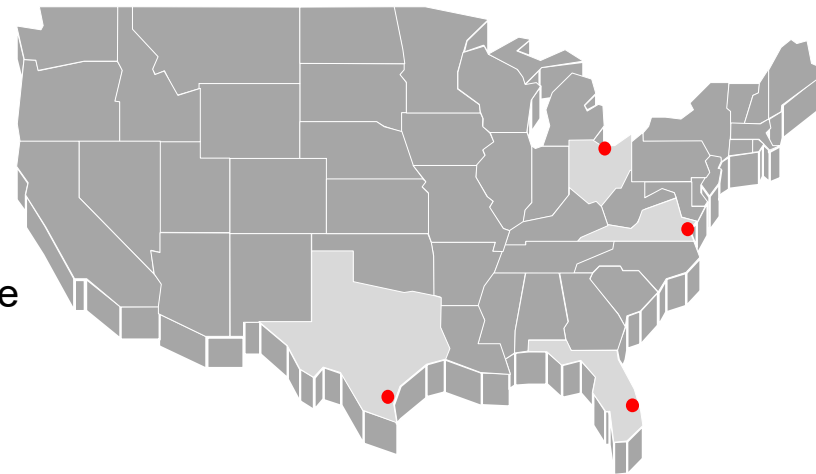


➤ Contributing partners and stakeholders

- Guide will be distributed to NASA stakeholders, academia, and commercial partners
- Planned availability via LSIC Dust Mitigation Focus Group resources
- As appropriate, publicize via technical conference presentations

➤ Infusion / transition plan

- NASA missions targeted by guidebook: CLPS, Gateway, HLS
- Future NASA, commercial, and academic research and development for Lunar surface operations and future Lunar missions will refer to this document to understand and avoid Lunar dust issues
- International collaboration to address knowledge gaps should be pursued
- Potential future updates as mission data is returned from early CLPS experiments and longer-term lunar exploration activities
- New technology developments and their application to lunar dust mitigation can be appended / added, as appropriate & supported



Primary contributors: JSC, GRC, KSC, LaRC

Dust Mitigation Best Practices Guide Technology Goals & Project Objectives



Technology Goals

Goal #1

Generate and publish a lunar dust mitigation guide, both for inexperienced mechanisms designers in academia or small companies, and for seasoned mission veterans. Extensive citations and pointers into the detailed technical literature will provide a “how to” lunar dust mitigation reference, which should become a community “living document” eventually contributed to by many.

Project Objectives

Objective #1

To produce a lunar dust mitigation guide, the planned steps include: assess NASA stakeholders' near-term plans, technology knowledge gaps, and known dust related risks; contact NASA Centers' practitioners and technologies providers to assess beyond-state-of-the-art offerings; assess Commercial Lunar Payload Services providers' dust mitigation knowledge needs; catalog known lunar dust best practices; and assess terrestrial dust mitigation best practices and their relevance to lunar dust concerns. Best practices and recommendations, organized by application (e.g. optics, mechanisms, human health, etc.), will be gathered for use and to highlight where the knowledge gaps need to be addressed.

Accomplishments



➤ Technical Accomplishments FY22:

- Integrated draft document released on Teams/Sharepoint site to contributing authors and project manager for updated format, consistency, and integration check.

- Drafts of technical sections complete.

➤ Remaining work:

- Bibliography and permissions check ongoing
- Final compilation of guidebook sections
- Table of contents
- On track for 30-SEP-22 completion

NASA/TP—2022–000000

Lunar Dust Mitigation A Guide and Reference - 2021

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September 2022

Project Assessment Summary



Project Name	Performance				Comments
	C	S	T	P	
Mid Year	G	G	G	G	<u>Technical</u> – No Issues anticipated <u>Cost</u> – In Budget <u>Schedule</u> – No schedule issues <u>Programmatic</u> - No issues anticipated
Annual	G	G	G	G	<u>Technical</u> – No Issues anticipated <u>Cost</u> – In Budget <u>Schedule</u> – No schedule issues <u>Programmatic</u> - No issues anticipated

Plans Forward and Transition / Infusion Plan



➤ Describe infusion/transition plan

- Publication and distribution of a lunar dust guidebook to NASA stakeholders, aerospace industry, academia, and commercial partners, inexperienced and veterans
- NASA missions targeted by the guidebook: CLPS, Artemis, Gateway, HLS
- Future NASA, commercial, and academic research and development for Lunar surface operations and future Lunar missions will refer to this document to understand and avoid Lunar dust issues

➤ Exploration & Science Applicability

- Dust Mitigation Best Practices Guide will be reference material for future technical development of equipment, materials, and components that will be used in a lunar dust, or similar environment

Education/Public Outreach

EPO Involvement

- Presented at NASA Dust Mitigation Tag, “Dust Adhesion & Mitigation “Sticky Dust,” Don Barker, presented on 3/4/22.
- Completed NASA Technical Memorandum, “A Repeatable Method for Conducting Chamber Studies of Aerosolized Lunar Simulant,” Benjamin Sumlin and Marit Meyer.
- 36th Space Symposium, Colorado Springs, CO March 30 – April 2.
- During a presentation at the Texas A&M engineering project showcase, the T STAR SOAR team won first place presenting their work on the HERMES Lunar G flight equipment.

EPO Calendar Outlook (High Priorities):

30 Day Look-Ahead

Lunar Surface Innovation Consortium (LSIC) – Dust Mitigation monthly meeting	Sept. 22
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60 Day Look-Ahead

Lunar Surface Innovation Consortium (LSIC) – Dust Mitigation monthly meeting	Oct. 15
AIAA SciTech	Jan. 23-27



Hermes Lunar G Flight Opportunity - The T STAR Texas A&M SOAR Team won 1st Place at the university's engineering project showcase.

Summary



➤ Accomplishments

- Integrated draft document released on Teams/Sharepoint site to contributing authors and project manager for updated format, consistency, and integration check.
- Draft of technical sections complete.

➤ Summary TechMat

- When released, the Dust Mitigation Best Practices Guide will be distributed to NASA stakeholders, academia, and commercial partners.
- Planned availability via LSIC Dust Mitigation Focus Group resources.
- As appropriate, publicize via technical conference presentations.
- Intend future updates in 3yrs as mission data is returned from early CLPS experiments and from longer-term lunar exploration activities.
- New technology developments and their application to lunar dust mitigation can be appended / added, as appropriate and supported.

Supplemental Information



REQUIRED

Do NOT include these slides in your Presentation Package that you upload in Teams.

This section only goes in the Presentation Package you upload on your Project Tile in SharePoint.



Flight Demonstration

STMD GCD Dust Liberated from Space Suit Fabric (ClothBot) on Blue Origin

PATH TO FLIGHT DEMONSTRATION

- ClothBot is to provide experimental data as inputs to numerical models and to determine the behavior and fate of lunar dust liberated from space suit fabric (OrthoFabric) during the doffing process in lunar gravity.



NEW INSIGHTS

- Collaboration between lunar-g payloads has encouraged keeping development on track
- Communication between centers has removed procurement roadblocks for certain hardware

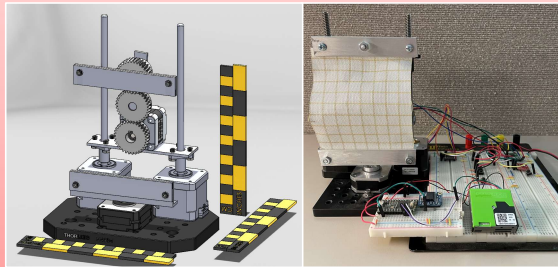


PROJECT/DESCRIPTION APPROACH

- The ClothBot lunar-g demonstration will study how reduced gravity alters the transport properties of lunar dust simulant liberated from space suit fabric during a simulated doffing process
- ClothBot consists of a novel fabric agitation robot, several compact, low-cost COTS dust sensors and samplers, and a laser-illuminated imaging system.
- Data from the demonstration can serve as inputs to numerical models for dust transport in space flight environments such as landers and airlocks.
- The fabric agitation robot can be scaled up for laboratory applications of soft goods testing, such as other fabrics and plastics.

TECHNICAL CHALLENGES TO FLIGHT

- Novel technology without flight history
- Small team balancing several priorities
- Narrow budget for testing required to certify for flight
- If there are issues during testing, there is limited time and resources for troubleshooting or redesign



Upcoming Flight Milestones

- August 2022: ground evaluation of hardware
- Sept 2022: Operational Testing & Structural Analysis
- Oct/Nov 2022: Payload Verification Testing
- December: Prepare flight test coupons
- January 2023: Hardware Delivery to BO
- TBD 2023: Launch – 2 team members attending to load test coupons before launch



PROJECT SUCCESS GOALS FROM FLIGHT

- The success of this project is driven by the quality and duration of lunar gravity achieved by the spacecraft. Achieving high-fidelity lunar-g is necessary for the extrapolated dust transport properties to be relevant to future moon missions.
- Success of our experiment comes from obtaining ≥ 2 minutes of size- and time-resolved data by the integrated dust sensors, video of the dust flow field and large liberation events by the imaging system, and time-integrated "stick where they land" samples from the passive samplers.

Flight Demonstration STMD GCD Hermes LunarG on Blue Origin



PATH TO FLIGHT DEMONSTRATION

- Hermes design is flight-proven hardware certified by the ISS program to conduct experiments with small particles in either atmosphere or vacuum under microgravity or low-gravity conditions
- Hermes leveraged T STAR (previously used provider) to create updated control system and interface to Blue Origin



NEW INSIGHTS

- Syncing up with the other dust mitigation sub-orbital payloads has been helpful
- Having shared PMs and resources helps
- Using heritage hardware helps
- Having flight hardware experience helps



PROJECT/DESCRIPTION APPROACH

- The Hermes LunarG project leverages lunar gravity in a suborbital flight to provide information on regolith dynamics, dust settling, size sorting, and granular mechanics
- Hermes LunarG consists of 4 experiments ("tubes") each containing lunar simulants held in place and to be released to settle upon lunar gravity conditions
- Data from Hermes LunarG can serve as inputs into computational models for several applications, which includes, but is not limited to, dust mobilization, dust transfer, dust mitigation, PSI, and sample containment

TECHNICAL CHALLENGES TO FLIGHT

- Mass constraints are limiting the amount of simulants we can use in each experiment
- Small team each balancing several priorities
- Takes a lot of coordination between different teams and facilities required to certify for flight
- If testing does not go well, there is limited time for trouble-shooting or re-design



Upcoming Flight Milestones

- Sept 2022: Operational Testing & Structural Analysis
- Oct/Nov 2022: Payload Verification Testing
- December: Load flight simulants
- January 2023: Hardware Delivery to BO
- TBD 2023: Launch – 2 team members attending to pull vacuum in tube before launch



PROJECT SUCCESS GOALS FROM FLIGHT

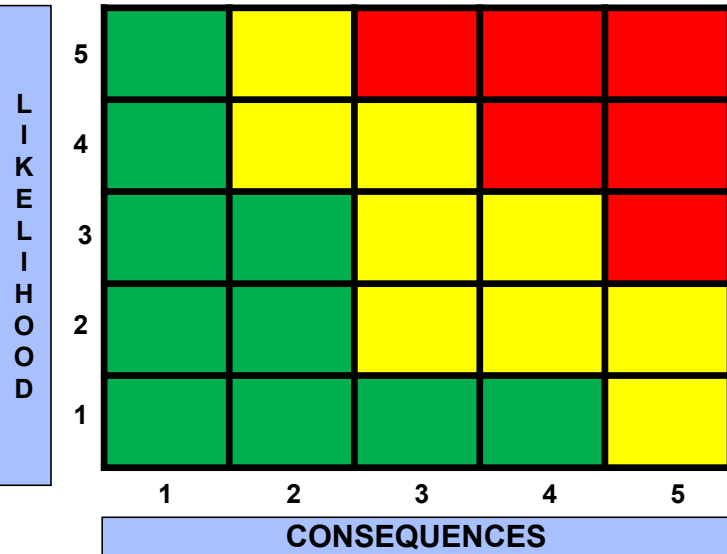
- The success of this project is driven by the spacecraft's ability to reach suborbital flight and its ability to spin on its axis during flight. This spin on its axis is necessary for the regolith to settle in the right direction due to the induced centripetal force, allowing data to be collected correctly.
- Success of our experiment comes from successfully obtaining two minutes of imagery (using Hermes internal cameras) and data sensors (force sensors and load cells) for each of the four tubes with the regolith simulant in motion in the tube.

Project Plan - Milestone Status



Milestone Title (Mirror Project Plan)	Baseline Date	Actual Date	Variance Explanation
<i>Status of milestones due since March 2022</i>			
K1 – Knowledge Gap Assessment	3/31/2022	3/31/2022	Completed
<i>Status of milestones due between September 1, 2022 – March 30, 2023</i>	Baseline Date	Planned Date	
C2 – Guidebook Final	9/30/2022	9/30/2022	On track

Risk Summary



Risk ID	Affinity/ Approach	Description/Status	Trend
CB-01	T, R	Successful tailoring of compliance matrix ahead of flight (no shock testing in proposal)	☐
CB-02	Sc, W	Completing required environmental testing (for BO flight)	☐
CB-03	Sc, M	Aggressive Schedule	☐
CB-04	T, M	Containment of dust-doped orthofabric during launch (pre lunar g)	☐

Criticality

High

Med

Low

L x C Trend

Decreasing (Improving)

Increasing (Worsening)

Unchanged

New Since Last Period

Approach
M - Mitigate
W - Watch
A - Accept
R - Research

Affinity: T-Technical C-Cost Sc-Schedule Sa-Safety

Successful tailoring of compliance matrix

E. Montbach

Risk ID#

CB-01

Trend

New

Criticality

Medium

Current L/C

2x5

Affinity Group

Performance

Planned Closure

TBD

Open Date

12-Jul-2022

Risk Statement:

Given that Clothbot will be on the Blue Origin Lunar-G flight, the GRC SAR has a long list of requirements that must be met ahead of flight. There is a low probability that issues will arise when tailoring the SAR requirements to the project, resulting in failure to meet the flight deadlines.

Context:

BO requirements may be less than GRC requirements. This project's success depends on tailoring the BO requirements to the project.

Status:

7/12/2022 - risk opened

Approach: Research

Mitigation Steps	Dollars to Implement	Trigger/Start Date	Schedule UID	Completion Date	Resulting L/C

(Note: The Schedule UID is the unique id no of the mitigation step in your schedule if appropriate.
Dollars to implement are not extra approved \$ from the Program Office but \$ set aside as part of project budget to mitigate.)

Completing required environmental testing (for BO flight)

E. Montbach

Risk ID#

CB-02

Trend

New

Criticality

Medium

Current L/C

1x5

Affinity Group

Schedule

Planned Closure

TBD

Open Date

12-Jul-2022

Risk Statement:

Given that the Blue Origin Lunar G flight has specific requirements for vibration, shock, EMI and other testing, there is a low probability that the project will be unsuccessful at tailoring the BO requirements to meet the project's budget and technical needs, resulting in failure to meet flight deadlines.

Context:

The project has a limited budget for pre-flight testing. Meeting all requirements may not be possible with current budget - project is seeking waiver for shock.

Status:

7/12/2022 - risk opened

Approach: Watch

Mitigation Steps	Dollars to Implement	Trigger/Start Date	Schedule UID	Completion Date	Resulting L/C

(Note: The Schedule UID is the unique id no of the mitigation step in your schedule if appropriate.
Dollars to implement are not extra approved \$ from the Program Office but \$ set aside as part of project budget to mitigate.)

Aggressive Schedule

E. Montbach

Risk ID#

CB-03

Trend

New

Criticality

Medium

Current L/C

2x4

Affinity Group

Schedule

Planned Closure

TBD

Open Date

1-Aug-2022

Risk Statement:

Given that the project has a deadline set by Blue Origin and several flight qualification tests and GRC board approvals are required prior to flight, there is a small likelihood that delays in the schedule may impact flight readiness

Context:

Prior to flight, thermal cycle, structural analysis, shock and vibe testing must be performed. In addition, a GRC internal ERB and EMB must be completed prior to submitting the data package to BO

Status:

01-AUG-22 - New Risk

Approach: Mitigate

Mitigation Steps	Dollars to Implement	Trigger/Start Date	Schedule UID	Completion Date	Resulting L/C
1: Start SAR requirements right away	TBD (0.1 to 0.3 FTE)	ASAP	N/A	TBD	1x1

(Note: The Schedule UID is the unique id no of the mitigation step in your schedule if appropriate.
Dollars to implement are not extra approved \$ from the Program Office but \$ set aside as part of project budget to mitigate.)

Containment of dust-doped orthofabric during launch (pre lunar g)

B. Sumlin

Risk ID#

CB-04

Trend

New

Criticality

Medium

Current L/C

2x3

Affinity Group

Performance

Planned Closure

TBD

Open Date

23-Aug-2022

Risk Statement:

Given that dust may be liberated from the cloth sample during launch, the PI has devised a mechanism to keep the lunar dust simulant contained, however, this is a novel mechanism that has unknown performance, making the risk of unknown initial conditions high.

Approach: Mitigate

Context:

Difficult to control initial conditions - dust on cloth may not remain in initial state after launch

Status:

13-AUG-22 - New Risk

Mitigation Steps	Dollars to Implement	Trigger/Start Date	Schedule UID	Completion Date	Resulting L/C
1. Research plastic films that do not cause electrostatic or Triboelectric effect	TBD	ASAP	N/A	31-Dec-2022	1x3
2. Test plastic film vs using a second layer of orthofabric					

(Note: The Schedule UID is the unique id no of the mitigation step in your schedule if appropriate.
Dollars to implement are not extra approved \$ from the Program Office but \$ set aside as part of project budget to mitigate.)