ARTEMIS GENERATION SCIENCE SERIES

LUNAR DUST PROJECT

Requirements, Constraints & Deliverables

LAB PROTOCOL

HEPA Filtration Study

RESEARCH PAPER

Physiology & Remediation

LEVEL

Freshman Undergraduate

What Problem are we trying to Solve

End of an EVA on Lunar Surface

- You are done with an EVA and entering the Airlock Chamber.
- Your Suit is covered in Lunar Regolith Dust
- You need to safely remove this dust prior to removing your suit.

Airlock – Pressurize- Lunar Dust removal- Safely remove suit.

Why is Lunar Dust so Harmful

Lunar Dust has sharp microscopic silica, metals, and electrostatic charge that can be extremely harmful to:

- Lungs if inhaled
- Eyes
- Skin
- Immune
- Musculoskeletal
- Neurologic

Project Overview

Two integrated deliverables — one lab, one research paper ***Students doing this project must have access to a laminar flow fume hood.***

LAB 01

HEPA Filtration Study

Build a test chamber, aerosolize lunar simulant, and measure particle capture efficiency of 6+ filter types

LAB 02

Research Paper

10-page college-level paper covering ≥4 physiological systems affected by lunar regolith exposure + remediation strategies

3 Lab Sessions	**10+** Paper Pages	**4+** Body Systems	**8+** Sources
90 min each	body content	required	peer-reviewed

BACKGROUND & MOTIVATION

Why Lunar Dust?

Apollo astronauts reported respiratory symptoms within hours of dust exposure inside the lunar module

Lab studies show lunar simulant kills up to 90% of human lung cells and mouse brain cells

Artemis missions will last 30+ days — far longer than any Apollo surface stay

No permissible exposure limit (PEL) for lunar dust has been officially established by NASA — this is an open research question

~20µm

Particle size that penetrates deep into lung tissue

90%

Cell death rate in simulant exposure lab studies

~50%

SiO_2 composition — similar to silica occupational hazards

Lab Protocol Requirements

HEPA FILTRATION STUDY

Deliverables

- Test chamber built from PVC
- Minimum 6 filter types tested
- Tier 2 OR Tier 3 measurement
- 3 replicate trials for top 2 filters
- Bar chart of efficiency by filter
- Cost-vs-efficiency scatter plot
- Completed student data sheet
- Group lab report or presentation

Constraints

- N95 respirator required at all times
- All aerosolization in fume hood
- Method A or B only (no nebulizers)
- Fixed flow rate across ALL trials
- Identical procedure per filter test
- Simulant: LHS-1, LMS-1, or volcanic basalt
- Electronic sensors: Plantower PMS5003 only
- Gravimetric: MCE membrane 0.8µm discs

Timeline

- Session 1 — Build & calibrate
- Session 2 — Data collection
- Session 3 — Analysis & reporting
- Each session: 90 minutes
- Analysis requires spreadsheet software
- Data recorded in pen, no erasing
- Extension activities for early finishers

LAB DETAIL

Simulant Choice & Particle Measurement

Simulant Options

Exolith LHS-1 / LMS-1
Preferred — mineralogically accurate

JSC-1AF fine grade
Acceptable — 27µm avg particle size

Volcanic basalt powder
Budget — <75µm sieved fraction

Ground obsidian
Geometry proxy for adhesion studies

Measurement Tiers

Tier 2 — Optical Sensor

Est. cost: $30–$80

- Plantower PMS5003 + Arduino Uno
- Outputs PM1, PM2.5, PM10 every second
- Place upstream & downstream simultaneously
- Log via Serial Monitor (9600 baud)
- Efficiency = (C_up − C_down) / C_up × 100

Tier 3 — Gravimetric

Est. cost: $5–$20

- MCE membrane discs, 0.8µm, 47mm
- Tare each disc to 0.0001g before run
- 10-minute timed collection per trial
- Equilibrate 30 min before post-weighing

SAFETY: N95 respirator + goggles + nitrile gloves required at all times when simulant is open or aerosolized

Filter Types Under Test

Independent variable — one trial per filter, 3 replicates for top performers

A

True HEPA H13

99.95% @ 0.3µm

Cost: $15–25*

Commercial standard; NASA minimum

B

MERV-13 HVAC

~90% @ 1µm

Cost: $10–15*

High-efficiency HVAC filter

C

MERV-8 HVAC

~70% @ 3µm

Cost: $5–8*

Standard HVAC filter

D

Surgical Mask

~95% BFE

Cost: < $0.25

3-ply procedure mask material

Efficiency Formula

$$\frac{(C_{up} - C_{down})}{C_{up}} \times 100$$

Where C = concentration (µg/m³)
or M = membrane mass (mg)

Analysis Goals:

- Efficiency bar chart (all filters)
- Cost vs. efficiency scatter plot
- Time-series for best filter (Tier 2)

RESEARCH PAPER

Research Paper Requirements

Required Structure

Title Page	Name, course, date, word count
Abstract	150–250 words, self-contained
Intro	Artemis context, paper roadmap
Regolith Properties	Physical/chemical, Apollo comparison
Body Systems (×4 min.)	1.5 pages each, all 7 sub-elements
Remediation	Engineering + pharmaceutical + behavioral
Discussion	Original argument — integrate findings
Conclusion + References	Min. 8 sources, APA 7th ed.

Format Rules

Length	10+ pages of body content
Font	Times New Roman or Arial, 12pt
Spacing	Double-spaced throughout
Margins	1 inch all sides
Person	Third person only
Citations	APA 7th edition in-text + reference list
Sources	8+ total, 5+ peer-reviewed, 2010–present
Systems	Min. 4 body systems, 1.5 pp. each

Required Physiological Body Systems

Minimum 4 required — each must include mechanism, clinical outcome, and a cited source

Respiratory

REQ'D

Primary exposure route. Covers: ROS generation, NLRP3 inflammasome, frustrated phagocytosis, alveolar fibrosis, PM2.5 vs PM10 deposition.

Immune

REQ'D

Mast cell IgE-mediated allergy, spaceflight immune suppression, Th2 shift, anaphylaxis risk. Apollo 16 sample study.

Cardiovascular

Translocation of ultrafine particles into bloodstream, endothelial dysfunction, coagulation cascade, thrombosis risk.

Integumentary

Corneal abrasion, silanol radical chemistry on skin, mucosal barrier disruption, UV flux amplification with contaminated visors.

Neurological

Olfactory nerve pathway bypasses blood-brain barrier. Microglial activation, 90% brain cell death in simulant studies, cognitive risk.

Musculoskeletal

Systemic IL-1β/TNF-α suppress osteoblasts, accelerate bone loss. Synergizes with microgravity-induced osteopenia.

★ **Each system section must cover: (1) normal function (2) exposure route (3) cellular mechanism (4) tissue/organ consequence (5) clinical symptoms (6) cited source (7) protective challenge**

RESEARCH PAPER — SECTION 4

Remediation Strategies

Each remedy must be explicitly connected to a physiological mechanism — not just listed

Engineering Controls

- HEPA H13/H14 filtration
- Electrostatic dust shields (EDS)
- Airlock & suitport design
- Anti-adhesion coatings (WFM, CNT fiber)
- UV-C decontamination chambers

Pharmaceutical

- Antioxidants: NAC, Vitamin C/E, Melatonin
- NLRP3 inflammasome inhibitors
- Corticosteroid inhalers
- Biologic TNF-α / IL-6 inhibitors
- Prophylactic nasal saline lavage

Behavioral / Operational

- EVA time & frequency limits
- Buddy-system suit inspection
- Real-time PM2.5/PM10 monitoring
- Anti-inflammatory diet (omega-3)
- Post-EVA ocular flush protocol

Key constraint: every remedy must name the specific cellular or physiological mechanism it targets — generic lists receive minimal credit

Project Constraints

Non-negotiable requirements for both deliverables

LAB Constraints

N95 respirator + goggles + nitrile gloves
Required 100% of the time when simulant is open or aerosolized

Sealed aerosolization only
No open-room dust release — fume hood or sealed chamber required

Approved simulants only
LHS-1, LMS-1, JSC-1AF, or volcanic basalt — no substitutions

Fixed flow rate
Must be identical across ALL filter trials — any change invalidates comparison

Aerosolization: Method A or B only
Fluidized bed or impulse syringe — no nebulizers or ultrasonic methods

Measurement: Tier 2 or 3 only
PMS5003 optical sensor or gravimetric membranes — no other devices

3 replicates minimum
Required for the top 2 performing filters only

Data recorded in pen
No erasing — single line through errors, initialed

PAPER Constraints

10+ pages of body content
Title page and references do NOT count toward the 10-page minimum

Minimum 4 body systems
Respiratory and Immune are required — 2 additional of your choice

All 7 sub-elements per system
Missing any sub-element (e.g., cellular mechanism) reduces score per rubric

Third person writing only
No 'I' or 'we' in any section except the Discussion

8+ sources, 5+ peer-reviewed
Wikipedia and general science sites do not qualify

APA 7th edition format
In-text citations AND full reference list — checked against rubric

Remedies linked to mechanisms
Each remedy must name the specific mechanism it targets

2010–present sources only
Apollo primary reports and foundational silica papers are excepted

ASSESSMENT

Grading Rubric (For teacher use)

Lab Protocol

Chamber & setup	10 pts
Data collection — control + 6 filters	20 pts
Replicate trials (×3 for top 2)	15 pts
Efficiency calculations (correct formula)	20 pts
Bar chart + scatter plot	15 pts
Discussion questions (7)	15 pts
Safety compliance + data sheet	5 pts
LAB TOTAL	**100 pts**

Research Paper

Regolith properties accuracy	25 pts
Physiological systems (depth/system)	25 pts
Number of systems (min. 4)	20 pts
Remediation — mechanisms linked	20 pts
Discussion / critical thinking	15 pts
Source quality and quantity	10 pts
Writing quality and format	10 pts
PAPER TOTAL	**130 pts**

Timeline & Milestones

1

Week 1

Pre-Lab Prep

• Read both assignment documents fully • Choose your 4+ body systems for paper

2

Week 2

Lab Session 1 + Paper Draft Start

• Build & calibrate test chamber • Verify particle signal in control trial

3

Week 3

Lab Sessions 2 & 3

• All filter data collected • Efficiency calculations complete

4

Week 4

Paper Completion

• Complete remaining body system sections • Write Remediation section

5

Due Date

Final Submission

• Lab: data sheet + lab report • Paper: 10+ pp., abstract, 8+ sources, APA

RESEARCH PAPER — CITATIONS

Source Requirements & Starter References

8+
Total sources required

5+
Peer-reviewed journal articles

APA
7th edition citation format

Provided Starter Sources (find 4+ more independently):

1	**Overview of Lunar Dust Toxicity Risk**	*npj Microgravity, 2022*
2	**Hazards of Lunar Dust — Immunogenicity / Allergenicity**	*Frontiers in Immunology, 2025*
3	**Lunar Dust Toxicity: Final Report**	*NASA/TP-2014-217378, 2014*
4	**Dust Mitigation Gap Assessment Report**	*ISECG, 2016*
5	**Cytotoxic Potential of Simulated Lunar Dust on Brain & Lung Cells**	*GeoHealth, 2018*
6	**Risk of Adverse Health Effects from Lunar Dust Exposure**	*NASA HRP Evidence Report, 2021*
7	**Free Radical Chemistry of JSC-1A Lunar Simulant**	*Astrobiology, 2015*

⚠ Safety Requirements

N95 Respirator	Standard: NIOSH-approved N95 or better When: Any time simulant container is open or aerosolized
Safety Goggles	Standard: ANSI Z87.1, indirect vent When: All lab sessions when simulant is present
Nitrile Gloves	Standard: Any thickness nitrile When: All simulant handling, filter removal, membrane weighing
Lab Coat / Long Sleeves	Standard: Cover all skin When: All sessions — avoid cotton that traps dust

EMERGENCY PROCEDURES

- Eye contact: Flush 15 min with running water — do NOT rub — seek medical attention
- Inhalation: Move to fresh air immediately — notify instructor — seek medical care if coughing persists
- Skin contact: Wash with soap and water — simulant is abrasive but not acutely toxic on skin

Key Takeaways

What success looks like for this project

Lab: Rigorous comparison

You are engineers testing real solutions to a real NASA problem. Control every variable, replicate critical trials, and let the data guide your conclusions.

Paper: Mechanisms, not symptoms

The difference between a B and an A paper is explaining WHY damage happens at the cellular level — not just what symptoms an astronaut experiences.

Connect the deliverables

Your HEPA filter testing directly answers the engineering control question in your remediation section. Reference your own lab findings in your paper's Discussion.

Think like a space medicine researcher

We have almost no long-term human data on lunar dust exposure. Your Discussion should identify what future research is most urgently needed — and why.