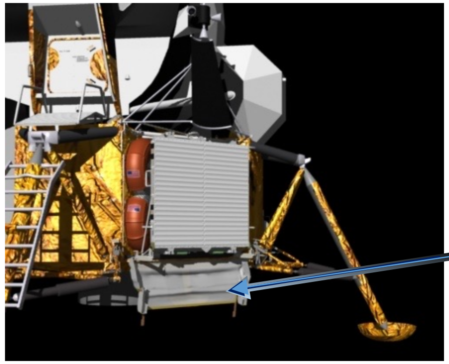
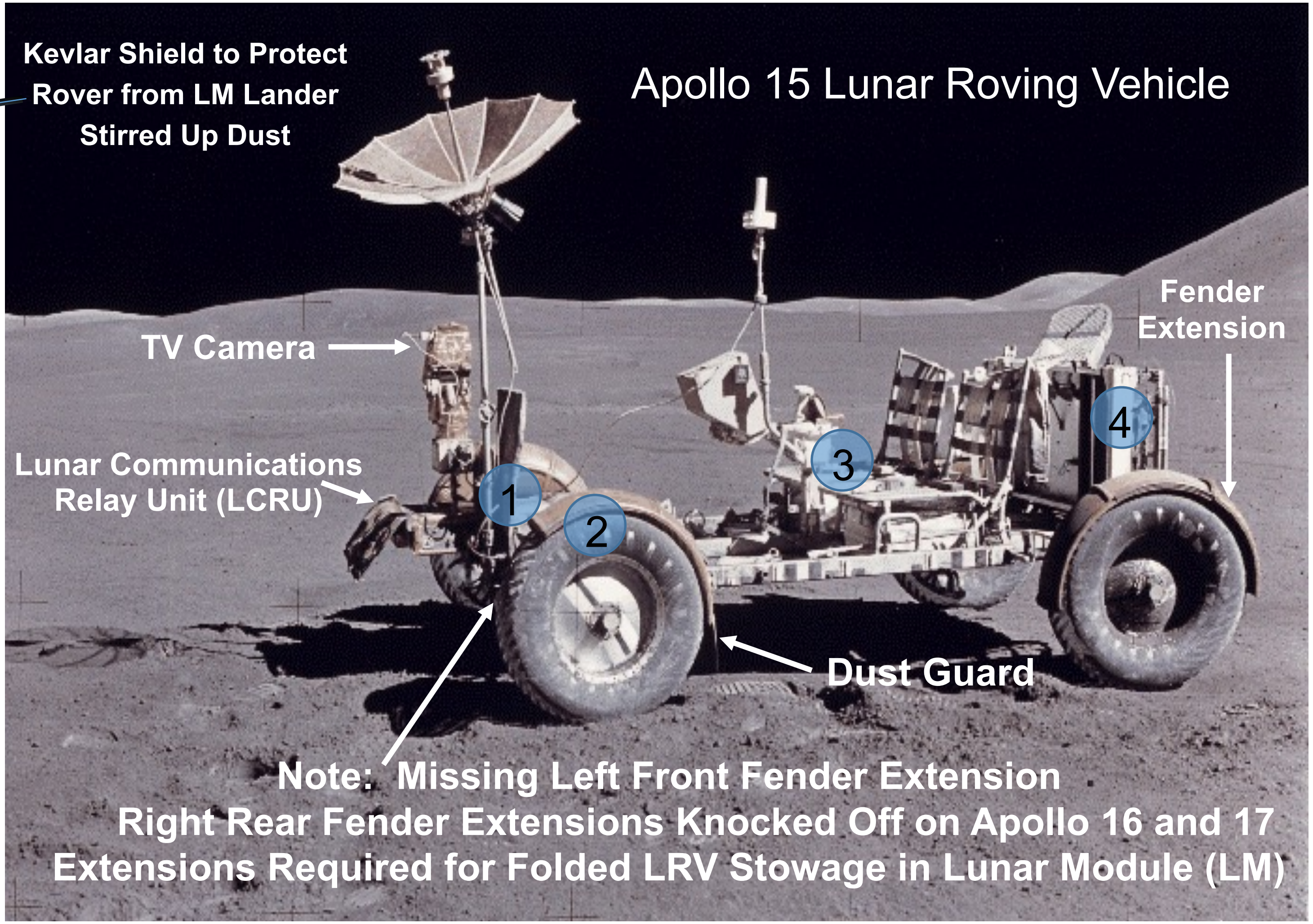


Dust, Dust, Everywhere - What Are We Going To Do?

(Earth Dust Removal Testing Is NOT Adequate)



Ron Creel - Retired Space & Thermal Systems Engineer
Member of the Apollo Lunar Roving Vehicle (LRV) Team

LRV Dust Mitigation Design Features

1 - Forward Chassis - Insulated Dust Covers Over Thermal Radiators

2 - Mobility Subsystems - Full Fenders and Dust Guards, Sealed Traction Drives, Suspension Torsion Bar End Gaskets, and Fluid Damper Shields

3 - Crew Station - Hand Controller Boot Seal

4 - Aft Pallet - Hinged Door for Tool Access

-1

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Misleading 1971 Pre-Apollo 15 Dust Removal Testing at MSC (Now JSC)- Using Apollo 12 Lunar Soil

Bad Earth Testing Results/Conclusions

LUNAR DUST DEPOSITION EFFECTS ON THE SOLAR ABSORPTANCE OF THERMAL CONTROL MATERIALS

AIAA Paper No. 71-459

by
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and
ROBERT S. HARRIS JR.
NASA Manned Spacecraft Center
Houston, Texas

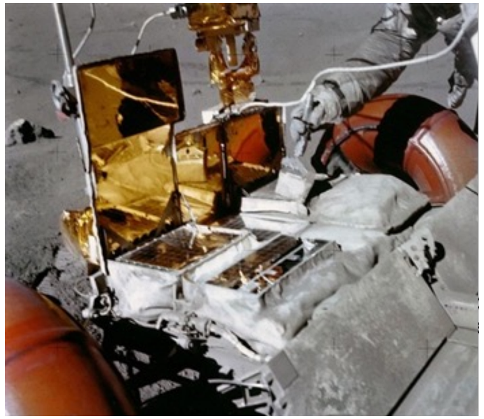
Test conclusions are summarized as follows:

1. Brushing dust from the sample surface is an effective method of removing dust.
2. The nylon-bristle brush is far superior to the brass-bristle brush for removing the lunar dust from the sample surface.
3. There is apparently no significant difference between the effect of lunar dust which was stored in a vacuum and that which was stored in nitrogen when both types of dust are applied in a vacuum environment.
4. There is a wide variation in adhesion of lunar dust to various materials.

As a result of these lunar-dust-deposition tests in a vacuum environment, the following additional comments are made:

1. The nylon-bristle brush is quite efficient and should be considered for use in removing lunar dust from thermal control materials.
2. In future ground tests of this type, lunar dust which is stored in a nitrogen environment at atmospheric pressure can be used in vacuum tests without significant loss in efficiency.
3. Of the possible thermal control materials for use in lunar surface operations, quartz second-surface mirrors, which are highly efficient thermally, can apparently be cleaned easily

NOT True on the Moon with 10^{-12} Torr Pressure



Astronaut Brushing Dust from LRV Thermal Radiators

Lunar Dust Brush

Recommendations for Future Tests

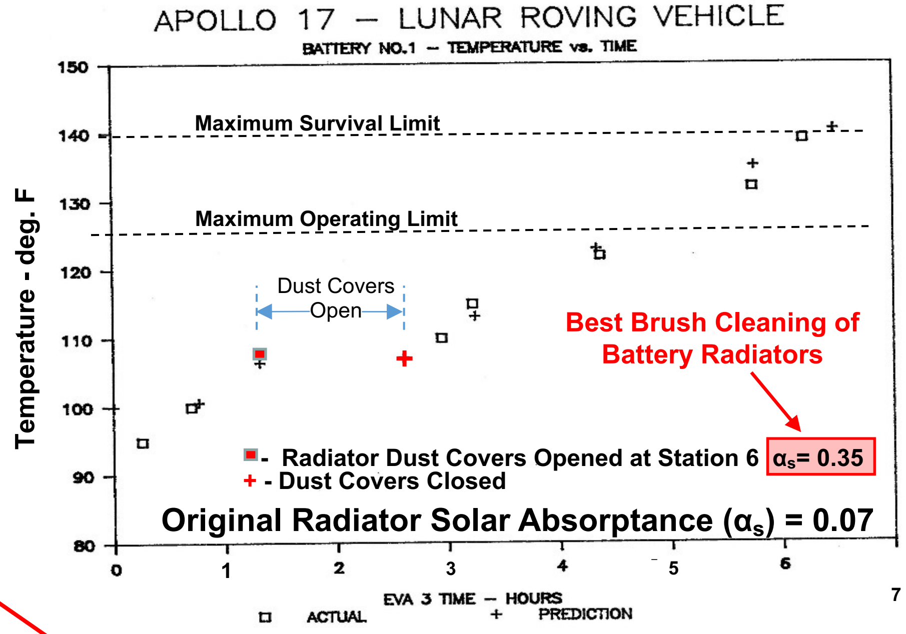
A literature study yielded the following two categories which are worthy of future studies:
1. Effect of static charge on adhesion of lunar dust
2. Effect of ultrahigh vacuum levels on adhesion of lunar dust

Effect of Ultrahigh Vacuum

There are indications (ref. 4) that particles of a silicate material in an ultrahigh-vacuum environment (6.3×10^{-10} to 1.3×10^{-9} torr), with a particle size distribution nearly equivalent to that of lunar soil, exhibit adhesion to a substrate to a greater degree than at somewh-- higher pressure levels (10^{-6} torr). Therefore, it is appropriate to perform additional tests with lunar soil at ultrahigh-vacuum levels to compare with those tests previously performed at vacuum levels in the 10^{-6} torr range.

Much Lower Pressure Testing Recommended

Lunar Roving Vehicle Thermal Control Radiators Were Designed With the Expectation that Lunar Dust Could Be Successfully Removed On the Moon - Did NOT Happen in Apollo 15, 16, and 17



Dr. Jim Gaier (GRC) Has Verified Lower Pressure Effects and Agrees That the Best Vacuum Test Chamber Is On the Moon, and 10^{-6} Torr in NASA Standard 1008 is NOT Low Enough

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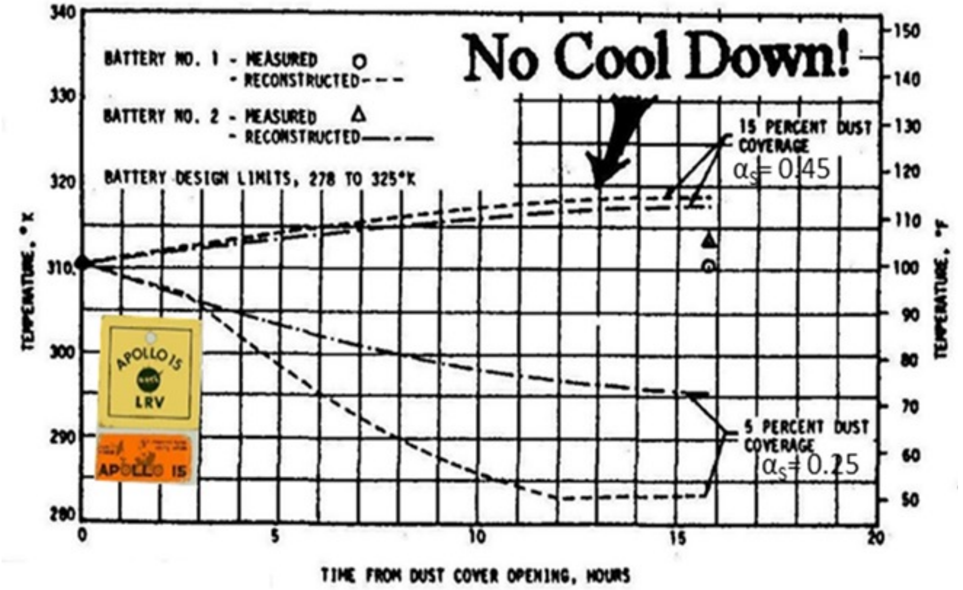
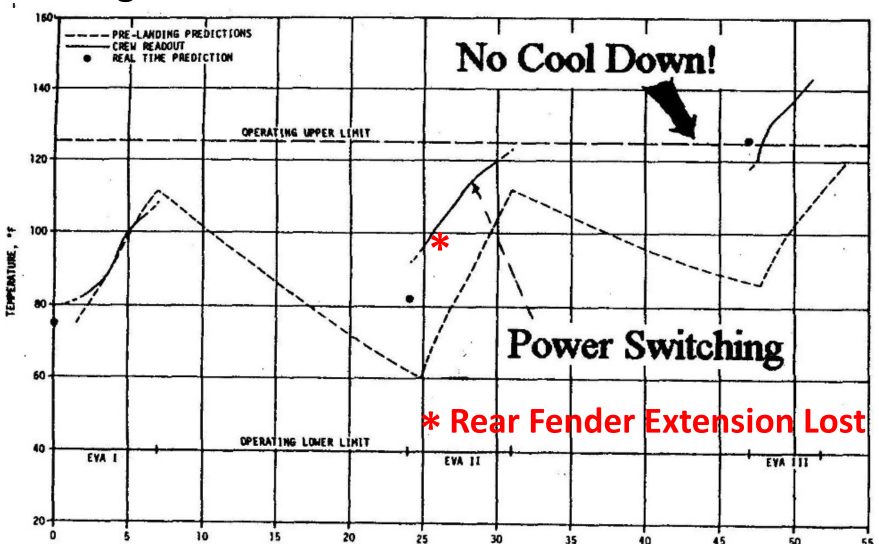
Radiator Dust Removal Regrettably Did NOT Work on the Moon With A Much Lower Environmental Pressure of 10^{-12} Torr - Resulting in Needed Operational "Housekeeping" Adjustments and Science Time Loss

Apollo 15 - Started to See Adverse Effects of Lunar Dust on Thermal Radiators After EVA 2



Apollo 16 - LRV Provided LCRU Power and Right Rear Fender Extension Lost in EVA 2



Battery No. 2 (Right) Temperature vs Time - Hours

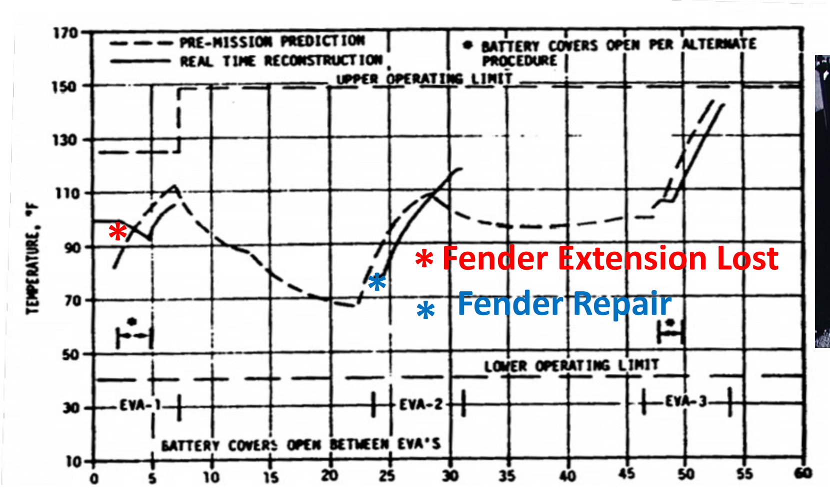
Crew Reported at the End of Both EVA 1 and EVA 2 That "LRV Battery Mirrors Remained Dust Covered After Having Been Brushed As Well As Possible"

Battery No. 2 Was Switched Off in EVA 2 To Maintain Temperature Below Upper Operating Limits

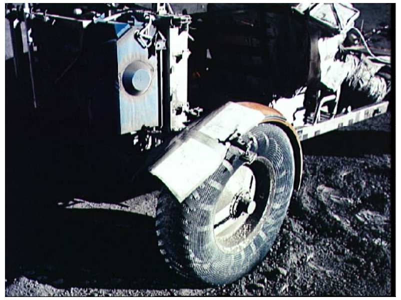
Both Batteries Exceeded Upper Operating Temperature Limits During EVA 3

Apollo 17 - Better Battery Cooldowns Due To Recommended Additional Dust Cover Housekeeping Cleaning Before Opening Covers - Even After Another Loss of the Right Rear Fender Extension in EVA 1

> *"I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust."*
>
> Gene Cernan, Apollo 17 Technical Debrief



Battery No. 1 (Left) Temperature vs Time - Hours



Apollo 17 Right Rear Fender Repair

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Sources - Crew Interviews and NASA Saturn V Flight Evaluation Working Group Reports

We Must Do Everything Possible To Keep Lunar Dust Out of Habitats and Lungs

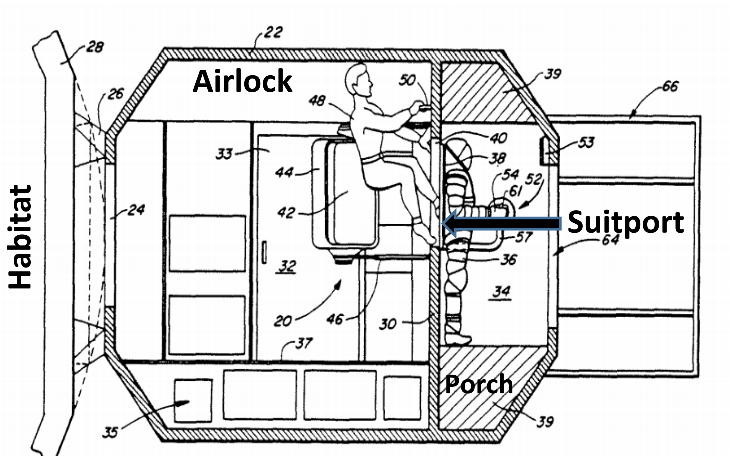
Having Crews and Their Suits Not Be Directly Exposed to Dust in the First Place is the Best Way to Survive Adverse and Hazardous Lunar Dust Effects - As is Done on Earth with Protective "Overgarments":

Example Suit Cover and Hang Up Area

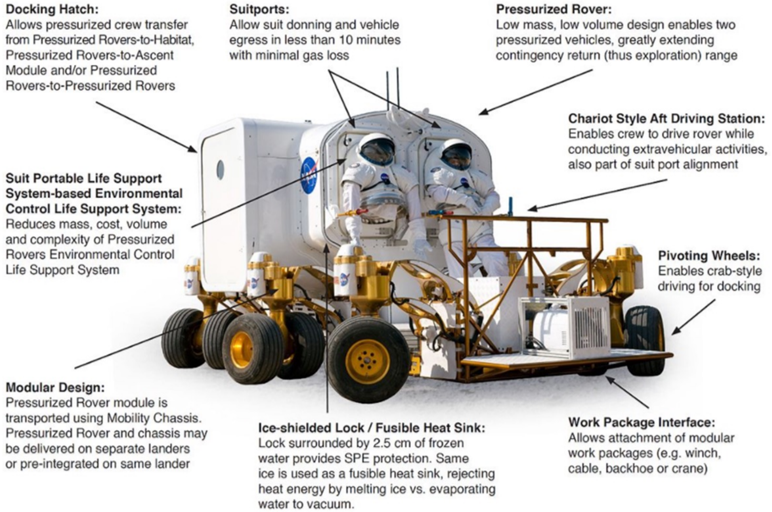
2007 - Space Suit Cover Don/Doff Testing (< 10 Min.)

Suit Cover Donning and Doffing

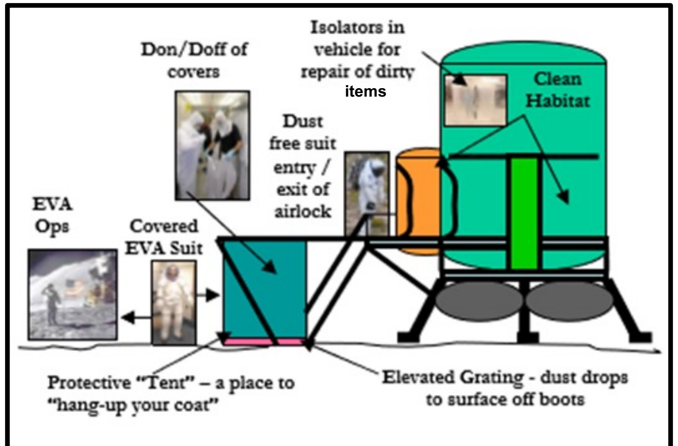
NASA Has Designed and Tested "Isolation Technologies" That Can Help Ensure Good Astronaut Health and Increase Artemis "Science" Time by Leaving the Dust OUTSIDE of the Lunar Habitat and Explorer Lungs with: Lightweight, Flexible, Reusable or Disposable Below Helmet Suit Covers for Protection of Astronaut Suits and Suit Joints - with Airlocks and Suitports for Future Artemis EVAs, Rovers, and Lunar Bases



1989 NASA Ames Patent



2008 - JSC "Chariot" Rover with Suit Ports and Airlock



Operational Scenario for flexible space suit covers on the lunar surface

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We Are At a Dust "Crossroads" for Artemis Crews - Let's Not Repeat Bad Apollo Dust Lessons

Implement Suit Covers, Airlocks, and Suitports to Ensure Good Astronaut Health and Maximize "Science" Time, While Minimizing "Housekeeping" Time (Multi-step Process That May Also Include Masks with Filters for Use Inside Habitat)

1

Isolation

Take Action

Technologies

3

Earth Based Moon Dust Environment Simulation and Testing is Extremely Difficult and Not Reliable

Limited Low Pressure and Low Gravity Testing Capability

Earth — Dust Removal Equipment Testing — Moon

Costly Environment Testing and Wasted "Science" Time

2

Endanger Early Exploration Crews by Waiting for Moon Dust Environment Testing

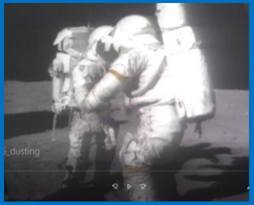
Repeat Toxic Hazard

Stay the Course

Wasted "Science" Time

4

Example - 2 Minute Apollo 16 Video of Frustrating Suit "Housekeeping" with Lunar Dust Still Brought Into the Lunar Habitat and Lungs:



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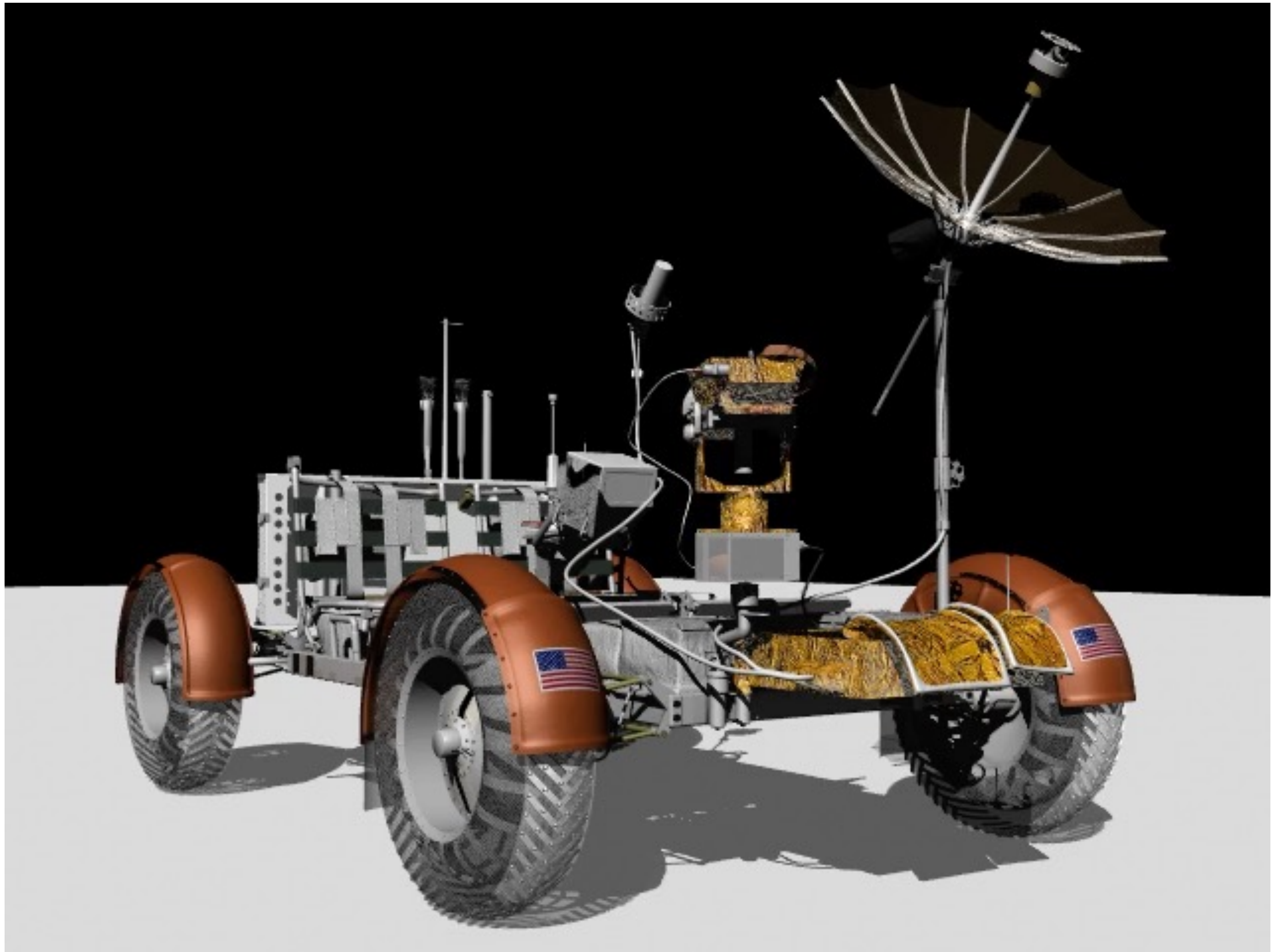
Questions?



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