

## JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** The Apollo Experience Lessons Learned for Constellation Lunar Dust Management

**Date:** January 17, 2008 **Time:** 12-1:00pm-5:00 pm **Location:** JSC/B4

**DAA 1676 Form #:** [24902](#)

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: [\\139.169.94.174\data\EA\EC\\_SHR\Knowledge-Capture\FY08 Knowledge Capture\20080117\\_S.Wagner\\_LunarDust\1676\\_Review](\\139.169.94.174\data\EA\EC_SHR\Knowledge-Capture\FY08 Knowledge Capture\20080117_S.Wagner_LunarDust\1676_Review)

\*A copy of the video will be provided to NASA Center for Aerospace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

### **Assessment of Export Control Applicability:**

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

\* Mrs. Wagner's presentation is based on her technical report: "*The Apollo Experience Lessons Learned for Constellation Lunar Dust Management*" which was publicly released in September 2006 (DAA 1676 # [10841](#)) and is available on the NTRS ([NASA/TP-2006-213726](#)).

\*\*The document to accompany the video when released is attached and named: [US Spacesuit KC Wagner Lunar Dust 2008-01-17.pdf](#)

**Presenter:** Sandra Wagner

**Synopsis:** In 2008, NASA was embarking on its Exploration Vision, knowing that many technical challenges would be encountered. For lunar exploration missions, one challenge was to learn to manage lunar dust. References to problems associated with lunar dust during the Apollo Program were found on many of pages of the mission reports and technical debriefs. All engineers designing hardware that would come into contact with lunar dust had to mitigate its effects in the design.

**Biography:** Sandra Wagner has been the Constellation Program (CxP) Lead for Lunar Regolith Strategy and Integration. At the Johnson Space Center (JSC), she has worked in Advanced Extravehicular Activity (AEVA), habitability, space station safety, the Orbital Space Plane Project Office, and the Systems Architecture and Integration Office in the Engineering Directorate. Before coming to JSC, she was the project manager for reengineering the wind tunnel and laboratory maintenance delivery system at Langley Research Center and was the program manager for characterization of low-level hazardous waste at the Rocky Flats Nuclear Weapons Plant. Sandra earned a bachelor's degree in physics from the

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# The Apollo Experience Lessons Learned for Constellation Lunar Dust Management

**Sandra Wagner**  
**Lunar Regolith Management  
And Integration**

**January 17, 2008**

# CONSTELLATION

# The Apollo Experience: Lessons Learned for Constellation Lunar Dust Management



Past Legend, Lore, Fiction

To Fact

# Apollo 17: Cross-Country Skiing





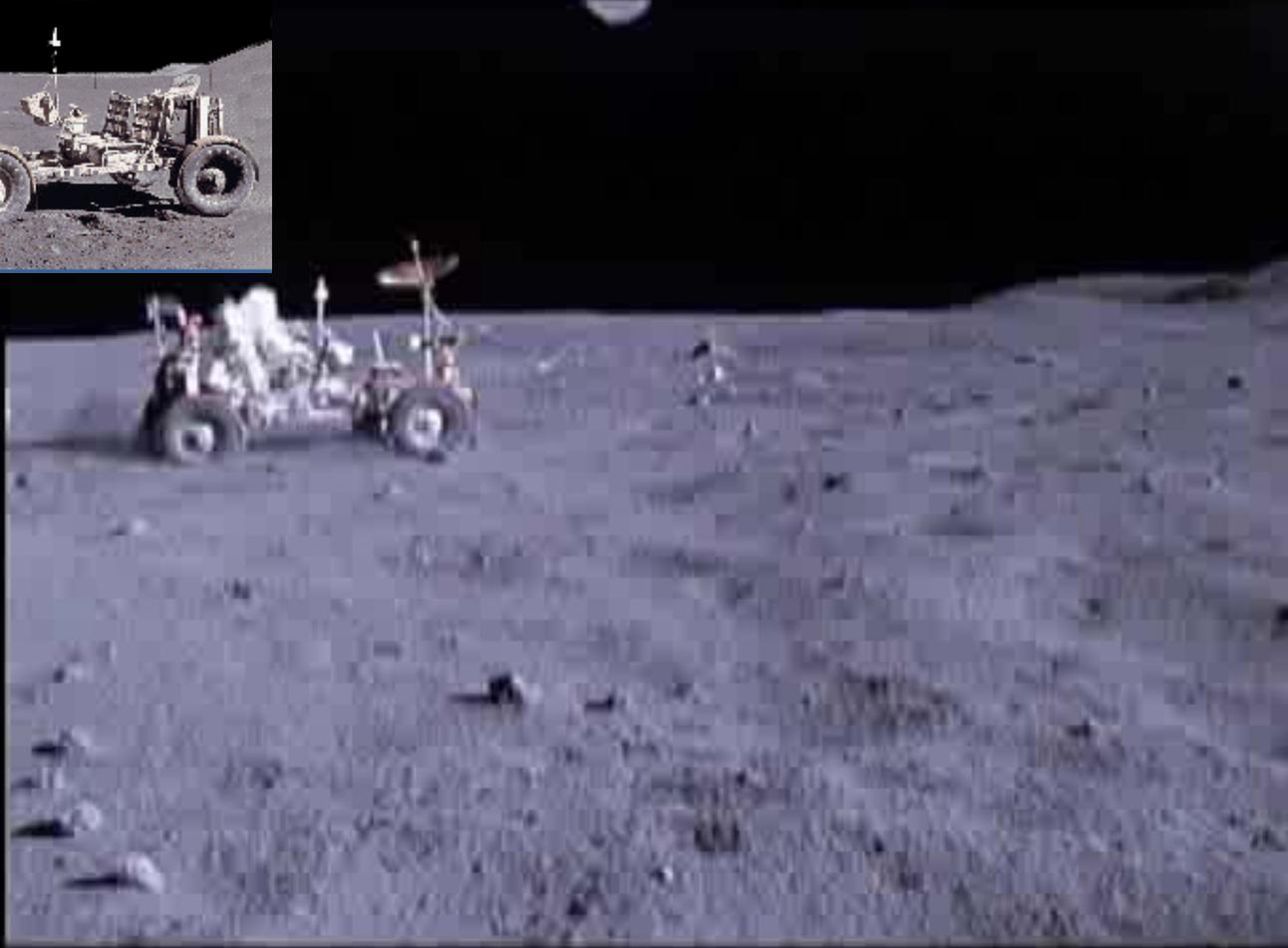
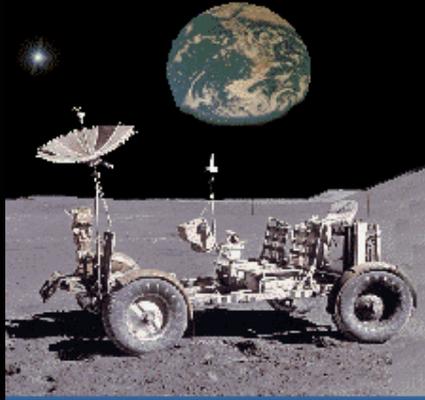
# Kier Dillon Asked?



[http://www.youtube.com/watch?v=s3nryJ\\_J-7c](http://www.youtube.com/watch?v=s3nryJ_J-7c)

Registration for  
2008 race is  
now open!

# Apollo 16: Grand Prix Moon Buggy Races?





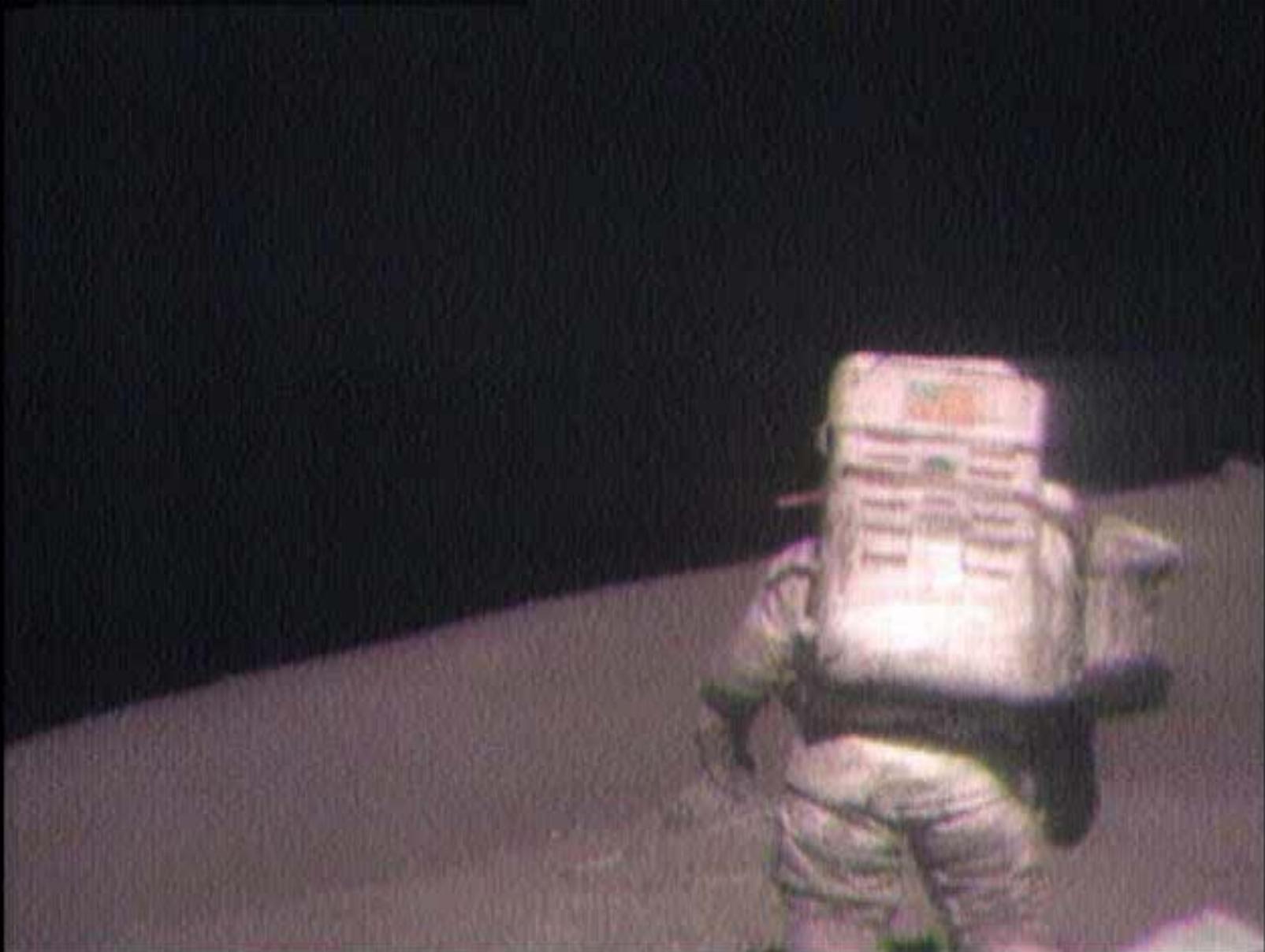
**Astronauts  
will work (and play) on the Moon  
(and in the dust)**

**Again**



Goin' EVA

# Apollo 17: Twinkle Toes





# Thoughts?

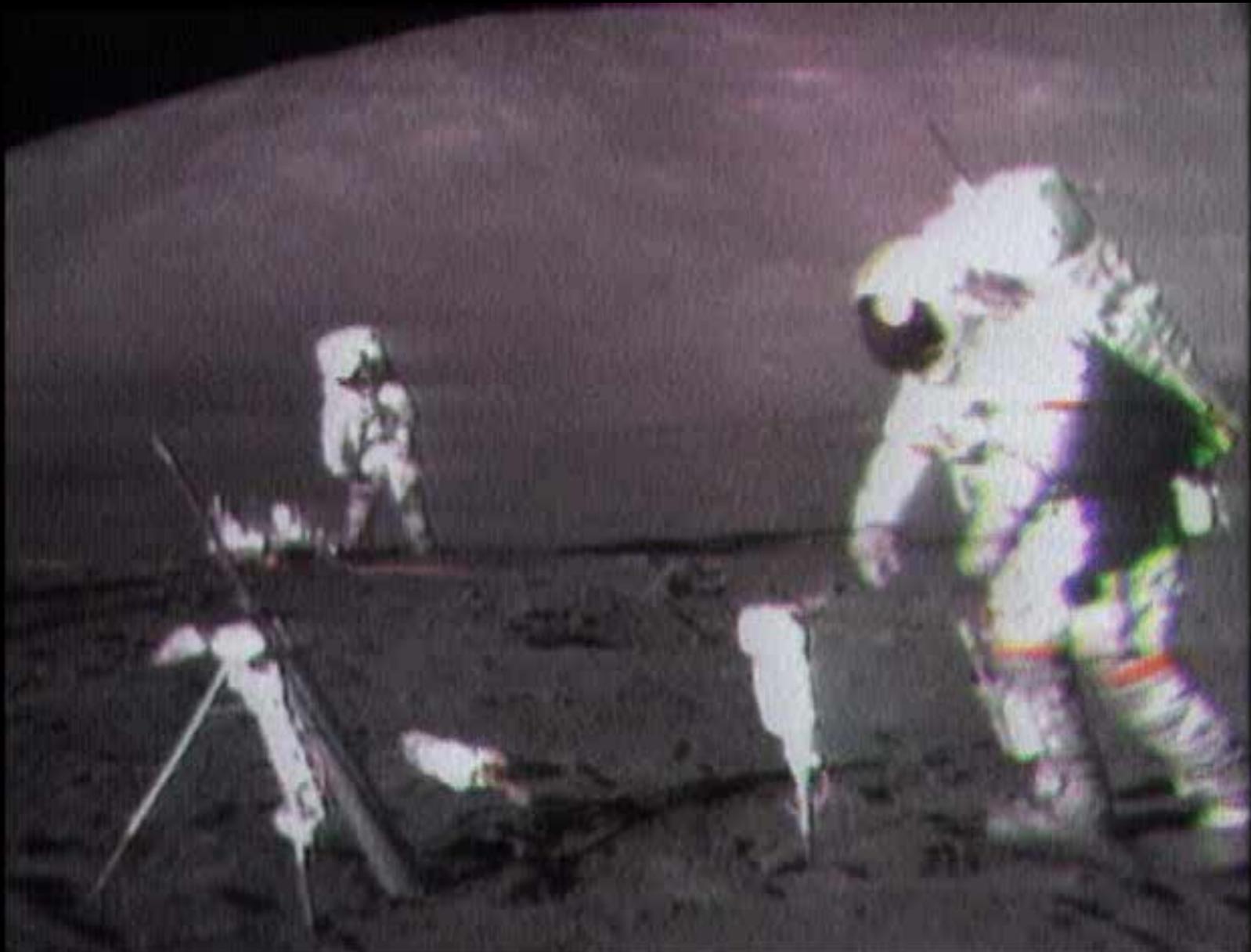


# Experiments

- [One of the color contrast charts] fell over and became covered with dust. I got back up and tried to brush it off, but it was impossible. I just made a shambles of it. The dust clung so badly that we didn't get a color shot of that." -Conrad, Apollo 12
- "A guy really can't lift his feet too high around a central station, because when he does, he kicks dirt all over the [Passive Seismic Experiment] PSE." -Young
- "They said they were having problems with the PSE. " -Young
- "Already! That's because there's dust on them." - Duke, Apollo 16
- "As a general comment for any radiator surfaces that need to be protected, you need to have more than just a cursory design on the protection for those radiators." Schmitt, Apollo 17



# Apollo 17: Central station is a bear



# Thoughts?



# Broken Rover Fenders

- "I think it was station 8 where we lost the rear fender and that was because I fell over it ... Avoid those fenders if you can. Every time a wheel came off the ground and went back in and dug in, it was like we were watching rain. Dirt came over it, covered up the battery cover, and the instrument panel so bad that you couldn't read the POWER DOWN or POWER UP decals." -Young, Apollo 16
- "With the loss of one of the fender extensions, any one of them, the dust is intolerable. Not just the crew gets dusty; but everything mechanical on the Rover is subject to dust." - Cernan, Apollo 17



# Apollo 17: Fender Repair Shop





# Thoughts?



# Trips, Falls and Pushups

- "I was pulling on the lanyard with one hand and trying to take pictures with the other. And of course I fell down there once because I tripped backing up in that soft soil." -Irwin, Apollo 15
  
- "One thing that continually disturbed us the whole time, particularly Pete, was the fact that the TV cable was right in front of the MESA. Our TV cable laid flat on the ground. It didn't curl up or anything like that; ... it rests on top of the dust and your feet go beneath the dust ... It's just too highly traveled an area to have something like that TV cable underfoot."  
- Bean, Apollo 12



# Apollo 15: Slippery Slope





# Thoughts?



# Apollo 16: Hammer Dance

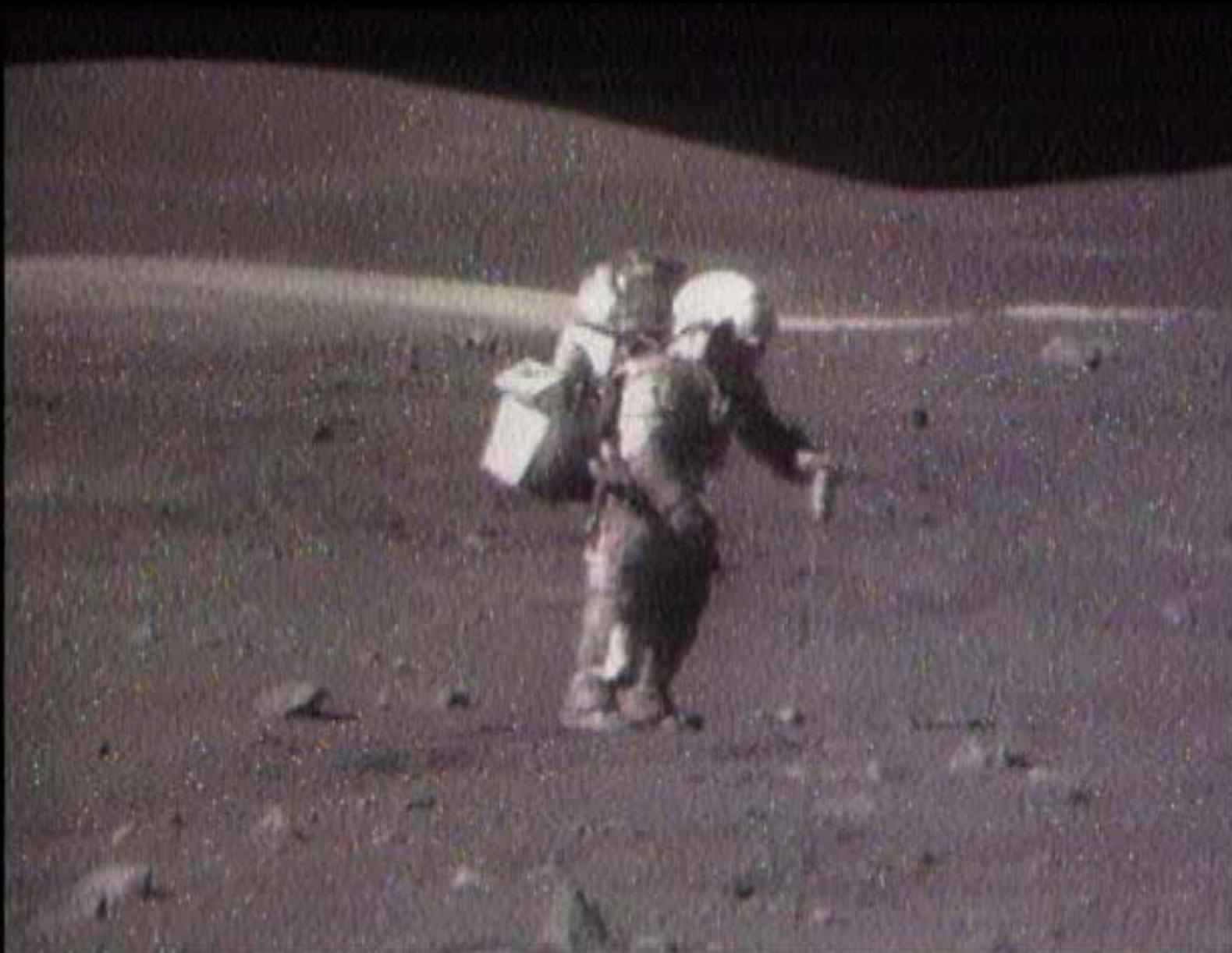




# Thoughts?



# Apollo 16: Easy Does it





# Thoughts?



# EMUs



- "In the area where the lunar boots fitted on the suits, we wore through the outer garment and were beginning to wear through the mylar." -Conrad, Apollo 12
- "I had some difficulty seeing my flags with the visor down." - Irwin
- "I did too. I found it was the dust accumulation." -Scott, Apollo 15
  - "They told us to give a PLSS check, and I couldn't read my RCU numbers because I had make a mistake reaching up with my finger and tried to wipe off the dust. "  
Young, Apollo 16



# Apollo 17: Glove bag





# Thoughts?



# Translation Aids

- “The problem is that the lower end of the strap got completely covered with dust and I got dust all over my hands and my suit arms from handling that strap.” -Conrad, Apollo 12
- “When I removed the first LiOH box on the first EVA to send it up, that one fell off and I had to pick it up out of the dirt. Once it gets in the dirt, forget it.” - Conrad, Apollo 12
- “The connectors got covered with dust - one of mine. One of the primary problems was that LEC [Lunar Equipment Conveyor]. On EVA-1, when I passed you the rock box on the LEC, I just got covered with dirt all down the front. The result was pretty dirty connectors.” - Scott, Apollo 15





# Thoughts?





Goin' IVA

# Pockets, Over Gloves, and Over Boots



- "The place where most of that dirt came from ... was the strap-on pockets we had." -Duke
- "We got smart after EVA-1, and before we got in, we closed the flap. But the first time, I got in with that flap open, and my pocket caught on a hatch sill and when I came in with that right leg, the dust flopped out." - Young
- You had a pocketful - you had a contingency sample right in your pocket. - Duke, Apollo 16
- "In training, we thought that [removing our boots] maybe was an unnecessary time-consuming step and we'd probably sleep with the boots on, but they were so covered with crud that I didn't want it sifting down in my face during sleep. We took them off." - Mitchell, Apollo 14



# Lunar Module Contamination



# Lunar Module Contamination



# Lunar Module Contamination



# Sticky EMU Mechanisms



- "On our final hookup back on the LM ECS system for ascent it was all we could do to get our wrist locks and suit hose locks to work. They obviously were beginning to bog down with dust in them." -Conrad, Apollo 12
- "[PLSS PGA] connected and disconnected all right, except when we got in the dust and dirt. Then sometimes it would stick, but in general, I thought it worked great." -Scott, Apollo 15
- "Donning was hard, I'll tell you, pulling that restraint zipper was really rough. After we got dust in the zipper, closing the zipper and locking it was pretty, pretty bad." -Young, Apollo 16





# Thoughts?





Goin' into Space

# And We Have Lift-off



- "Cabin atmosphere ... was excellent. When we got back inside the first time in 1/6 g, the atmosphere remained that way although we brought in quite a lot of dust. The same with the second time and the cabin jettison depressurization. Once we got into zero-g, there was a lot of dirt, dust, and debris that was floating around the cabin and we chose to remain in our suit loops as much as possible because of the dirt, dust and debris that was floating around." - Bean, Apollo 12
- "Actually [cabin depress] cleaned the floor pretty good. When I opened the door, the dirt would go 'zip' right out." - Young, Apollo 16
- "We found that the brush that we had planned to use to dust off the suits was effective. It did take off the first layer of loose dust." - Shepard, Apollo 14



# And We Have Lift-off



- "Prior to ascent from the lunar surface, the cabin activities included covering all holes in the lunar module floor into which dust had collected could be swept. Although considerable dust appeared in the cabin upon insertion, taping the holes definitely prevented a major dust problem in zero-g." - Mission Report, Apollo 17
- "I think the jettison bags over the legs worked fairly well. I think we kept the majority of the dirt out of the cabin and kept it in the bag." -Scott, Apollo 15
- "I would like to see the Velcro taken off the flight floor, because it sure got dirty." -Young, Apollo 16





# Thoughts?





# Reunion

# Transfer Between Lunar and Command Modules



- "The LM was filthy and it had so much dust and debris floating around in it that I took off my helmet and almost blinded myself." - Conrad, Apollo 12
- "The transfer of equipment between both vehicles was impeded by large amounts of dust and debris in the lunar module. Therefore, the timeline became very tight in meeting the schedule for lunar module jettison." -Mission Report, Apollo 12
- "We tried to vacuum the suits and some of the bags that were dirty like the big rock bags and found it almost totally worthless. You could do a little bit, but the best method was to take a damp towel to wipe things down ... Once we opened one of the DCON bags just a little bit to see what was in there. The dust just floated out and we closed that in a hurry." -Duke, Apollo 16



# Transfer Between Lunar and Command Modules



- "I think having the vacuum cleaner running in the LM had a lot to do with keeping the flow in the other direction, filtering out the air. - Schmitt, Apollo 17
- "I'd recommend that to future crews: get the suits off as soon as you can." -Mitchell, Apollo 14
- "The vacuum cleaner failed after becoming clogged with dust ... The design of the vacuum cleaner is such that lunar dust can clog the impeller. -Mission Report, Apollo 16





# Thoughts?





# Coming Home

# Command Module

- “The dirt is so fine I don’t think the LiOH filters were taking it all out. It would pump it in the ECS system and pump it back out the hoses. This was indicated by Dick’s blue suit hose, which we had tied over the left-hand side and was blowing on panel 8 circuit breaker panel. That whole thing was just one big pile of dust that was collected on the circuit breakers.” -Conrad, Apollo 12
- “A lot of that dust, I believe, kind of got whipped outside when we did our dump depress. The cabin dust kind of swirled around. A lot of that went out through the relief valve at that point, which might have reduced it somewhat.” -Mitchell, Apollo 14



# Command Module

- “The whole thing was a cloud of fine dust. Floating around in there. You could actually see it floated out of the bag through the zipper” - Conrad, Apollo 12
- “Within an hour it was very noticeable that there was a coating of dust on all the instrument panels and all the surfaces. You'd see little rocks float by in front of your nose. I was surprised how rapidly that stuff all had diffused in.” -Mattingly, Apollo 16
- “We were sitting there and there were at least four or five pebbles and rocks that came floating by. That stuff can go through your dump valve and it gets lodged in there so you couldn't close it. That would be a bad thing.” -Young, Apollo 16





# Thoughts?

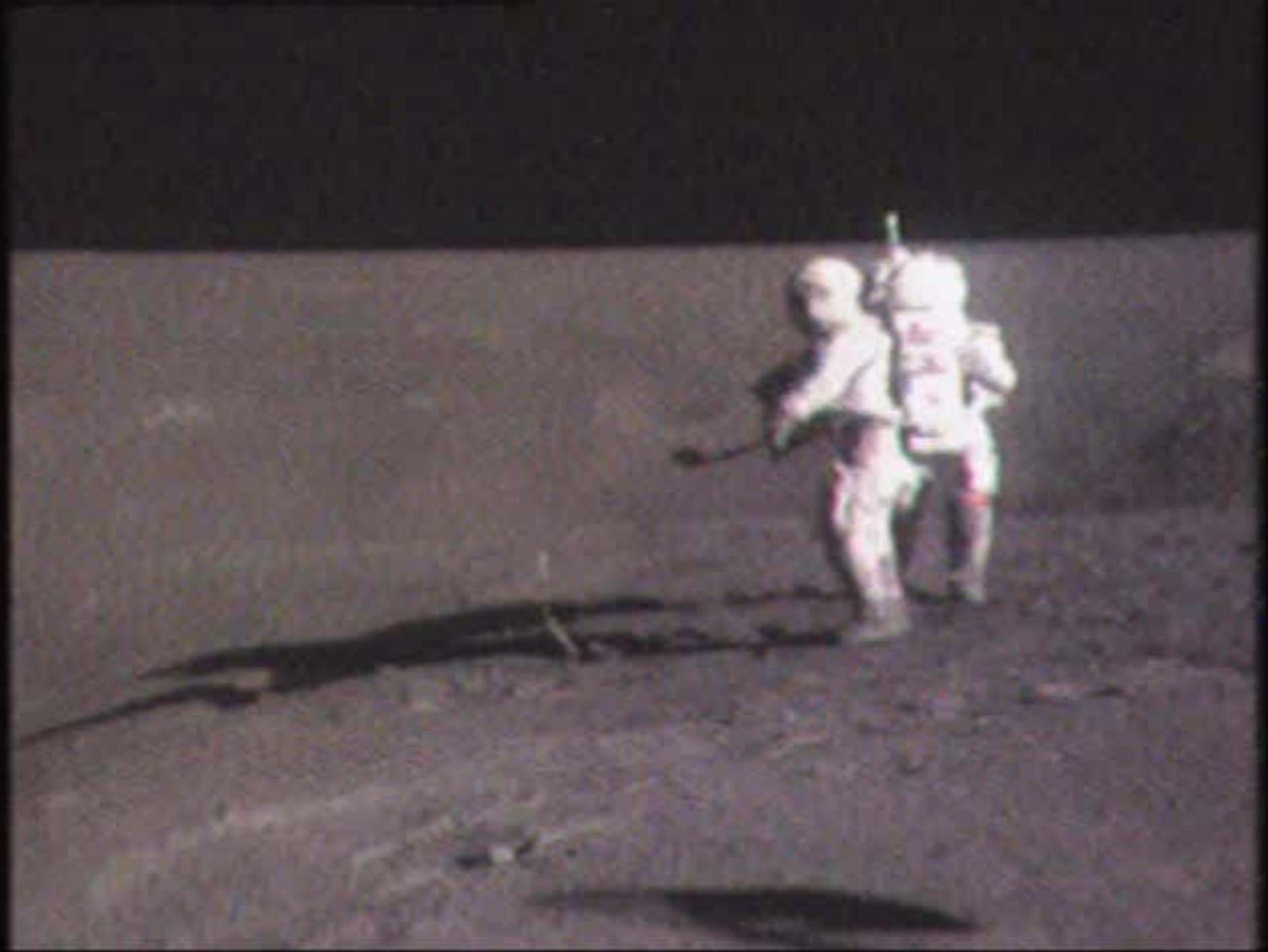




# A Parting Thought

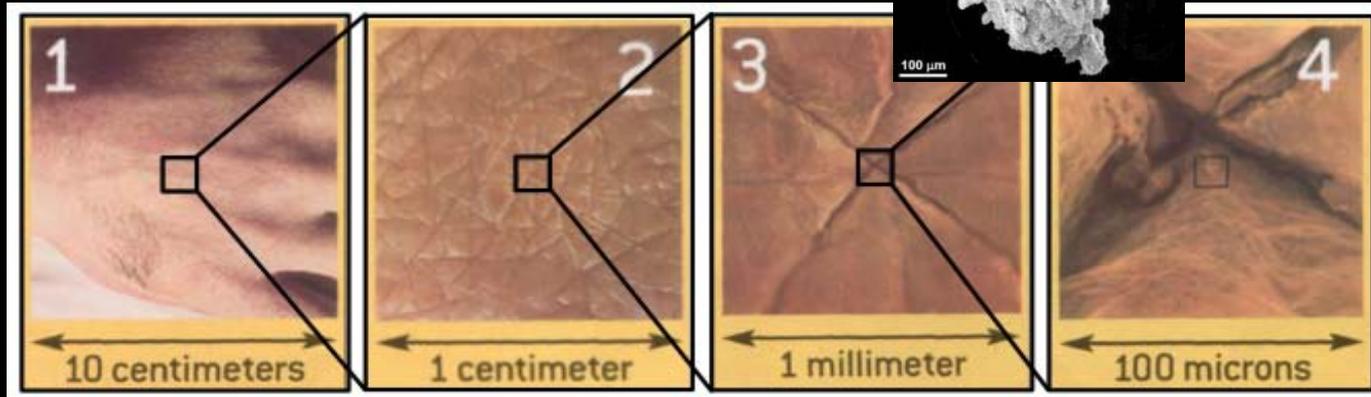
Can we just call it dirt?

# EVA 16: Not a Vial



# How Big is a Nanometer?

◆ Consider a human hand

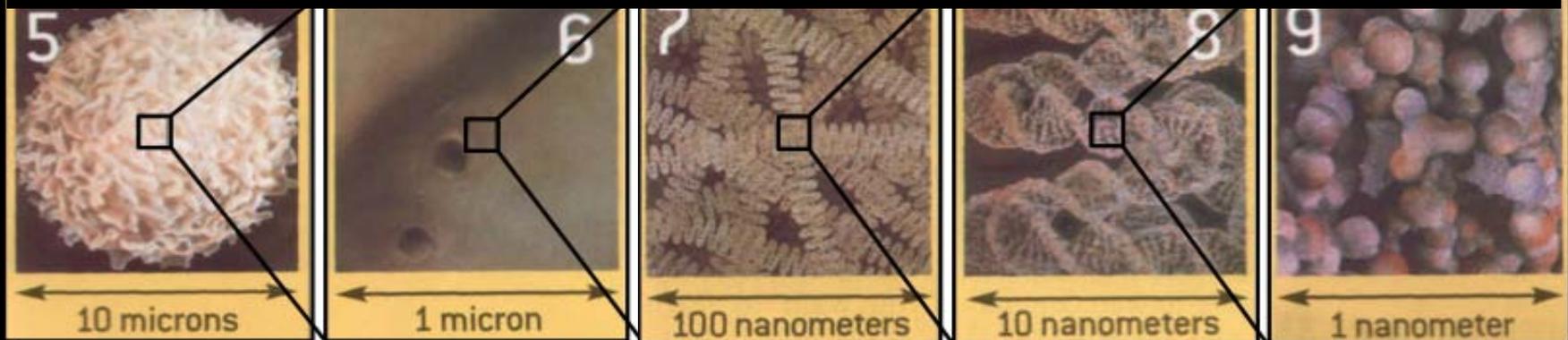


A beautiful agglutinate from returned Apollo regolith ~ 500 microns



The naked eye can see to about 20 microns

New Definition of Lunar Dust



white blood cell

DNA

nanoscale



10 hydrogen atoms lined up

# Let's Call it Dirt



More than "Dust"

- ✓ We could see the dirt that caused our problems during Apollo
- ✓ If we focus on nanoscale dirt, we'll design our systems wrong
- ✓ Regolith clumps together, it's really difficult to break it apart into smaller particles

A Little Perspective

- ✓ Let's keep bulk behavior in mind



# Acknowledgements

## *Our Stars*

Harrison Schmitt

Gene Cernan

John Young

Charlie Duke

Dave Scott

Jim Irwin

Ed Mitchell

Alan Shepard

Pete Conrad

Alan Bean

Neil Armstrong

Buzz Aldrin

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# To the Moon, Mars and Beyond

