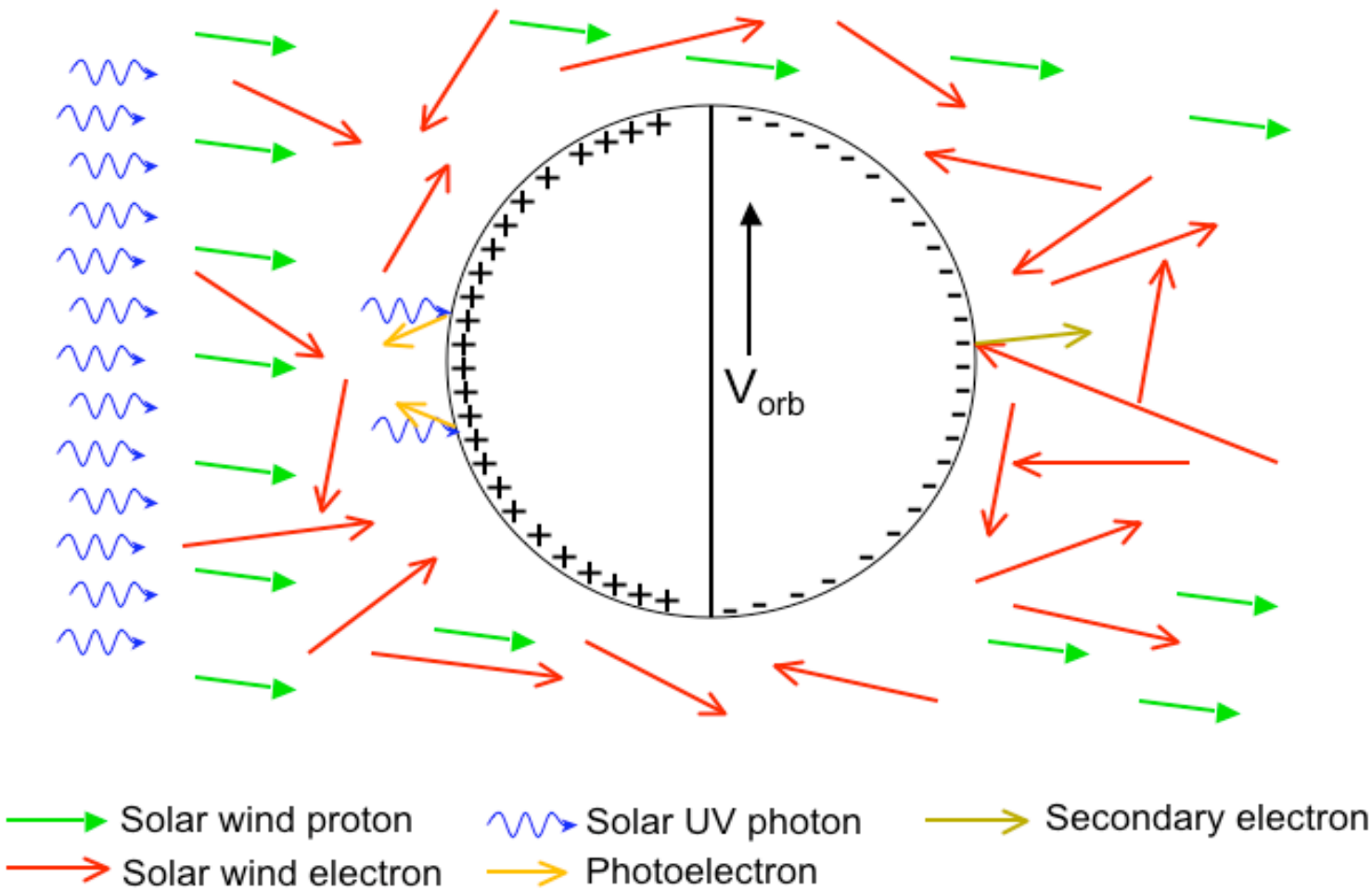
Autonomous Lunar Dust Observer for the Systematic Study of Natural and Anthropogenic Dust Phenomena on Airless Bodies

Dr. C. J. Grund, Ball Aerospace & Technologies Corp.
and
Dr. J. E. Colwell, Lab. for Atmospheric and Space Physics, U Colorado

Presented by: Chris Grund
cgrund@ball.com, 303-939-7217

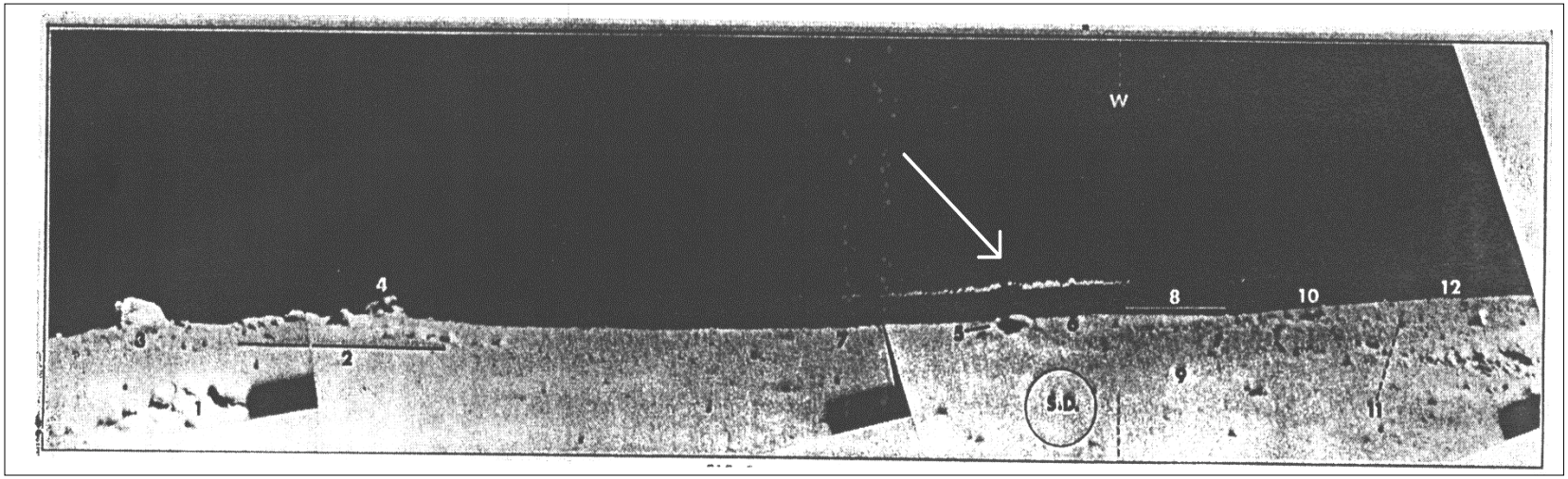
NAC Workshop on Science Associated with the Lunar Exploration Architecture
Tempe, Arizona
3/1/2007

Charging of the Lunar Surface



Lunar Dust “Weather”

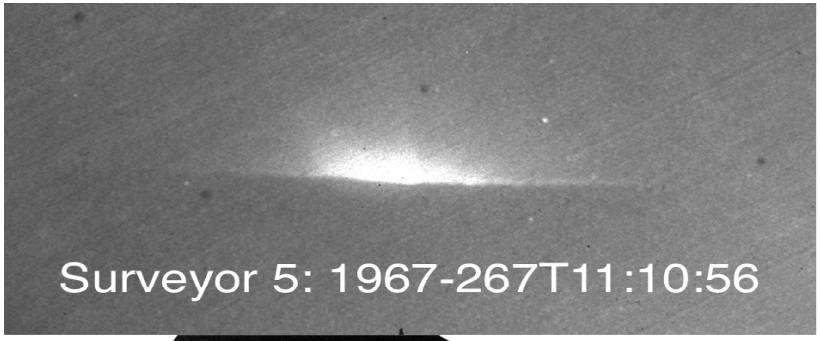
Lunar Horizon Glow - 1

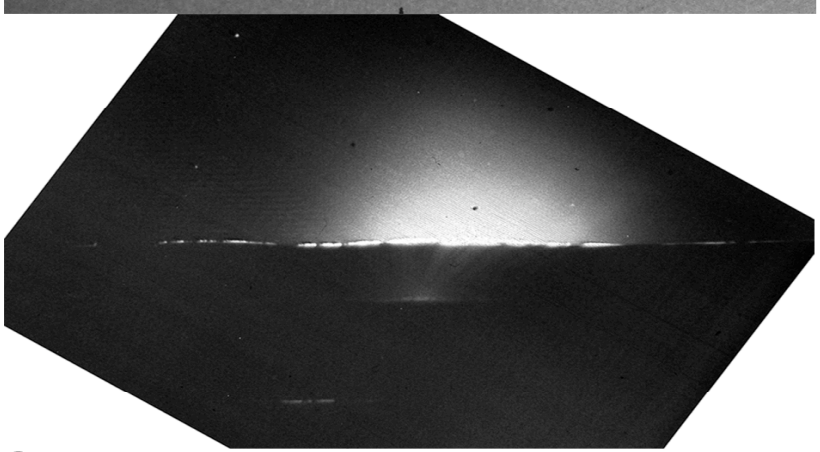


Rennilson and Criswell (1974): Analysis of Surveyor lander images of horizon glow after sunset.

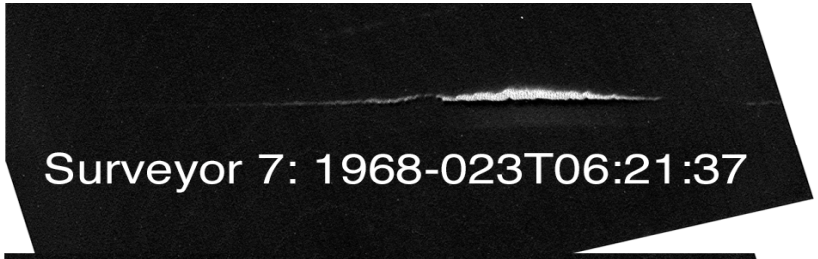
- Image is a composite
- dust cloud has been repositioned
- distance to horizon ~ 150 m suggests h~0.3 m
- angular extent suggests particle radii ~6μm (forward scatter peak)

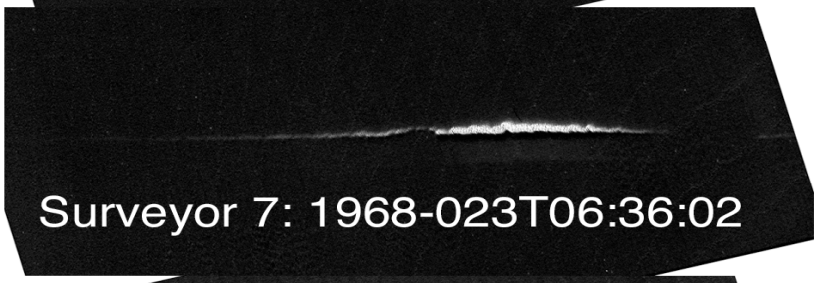
Lunar Horizon Glow - 2

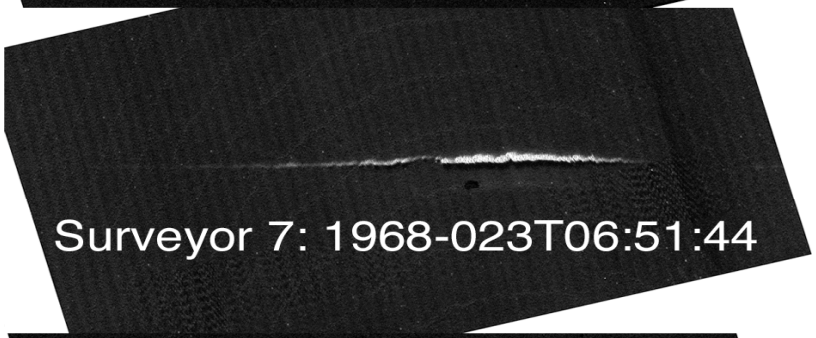


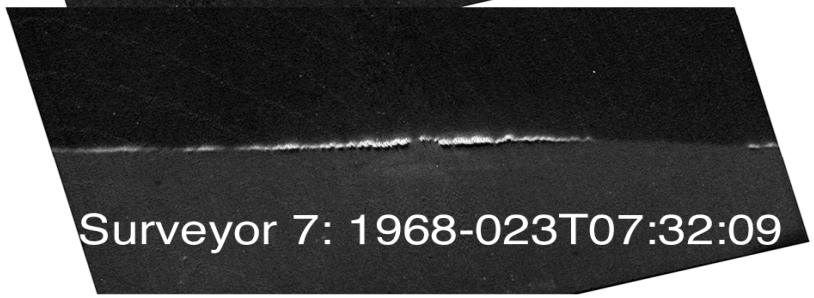


Surveyor 6: 1967-328T14:15:26

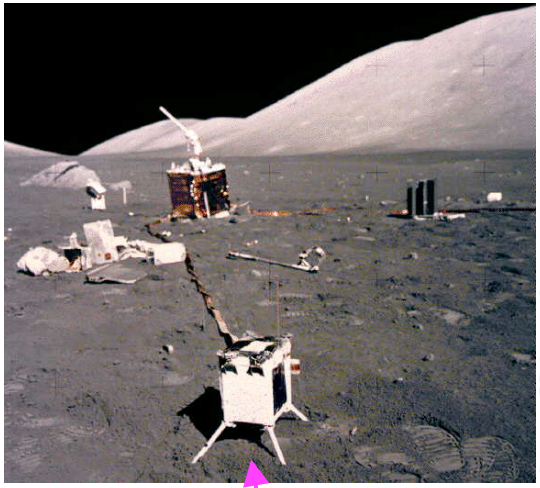




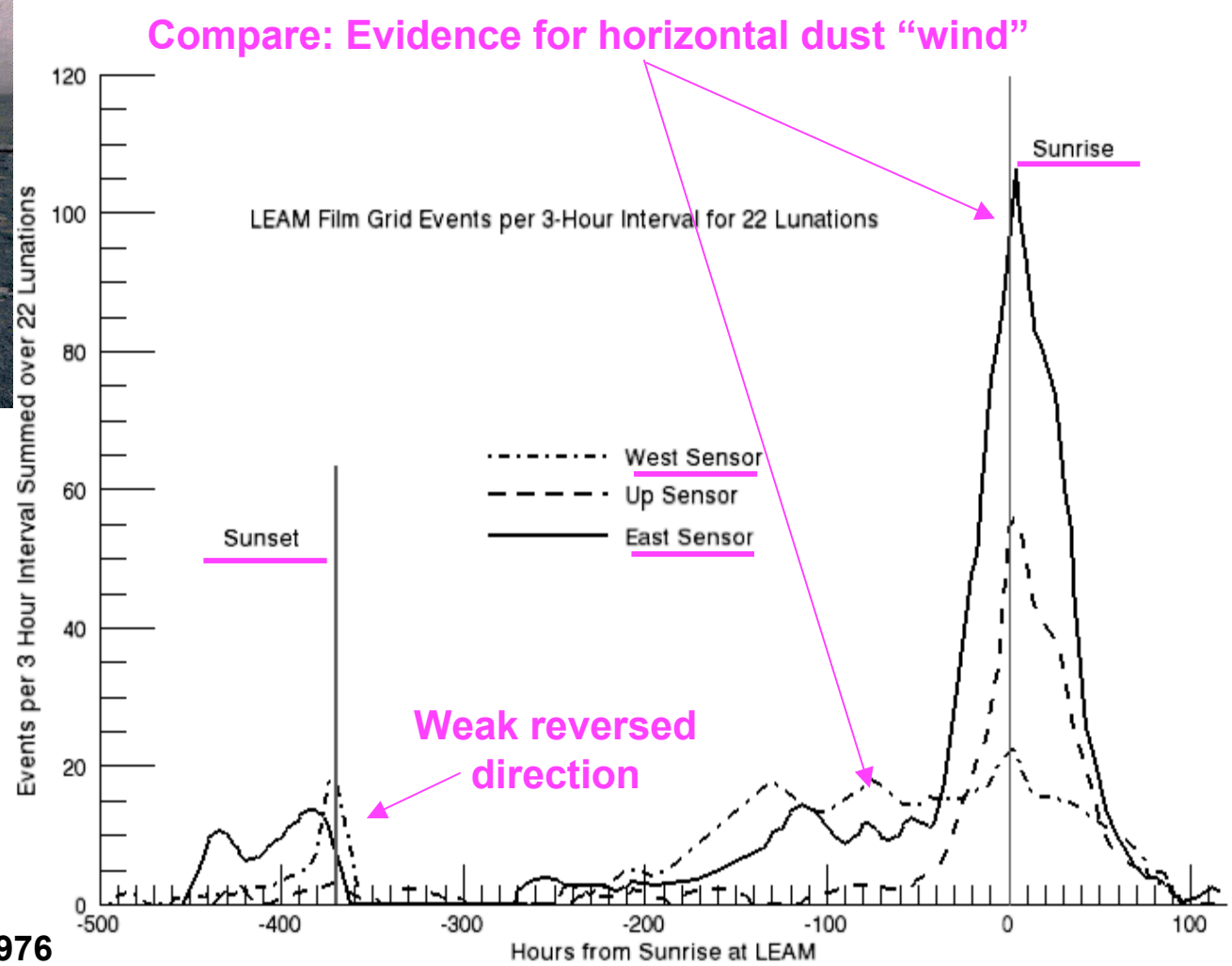




*LEAM Apollo 17: Lunar Dust "Storm"

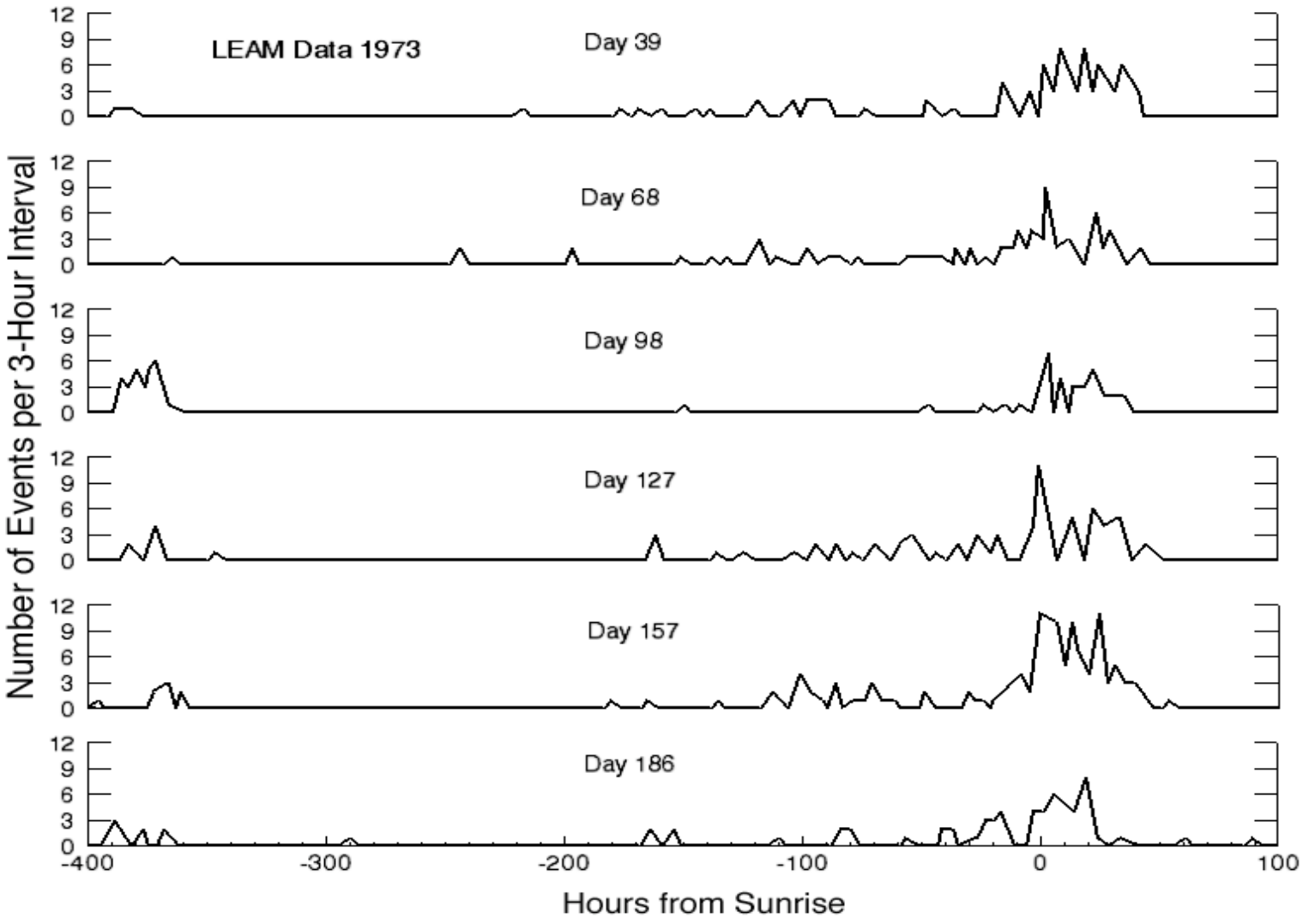


*Lunar Ejecta and Meteoroid Experiment

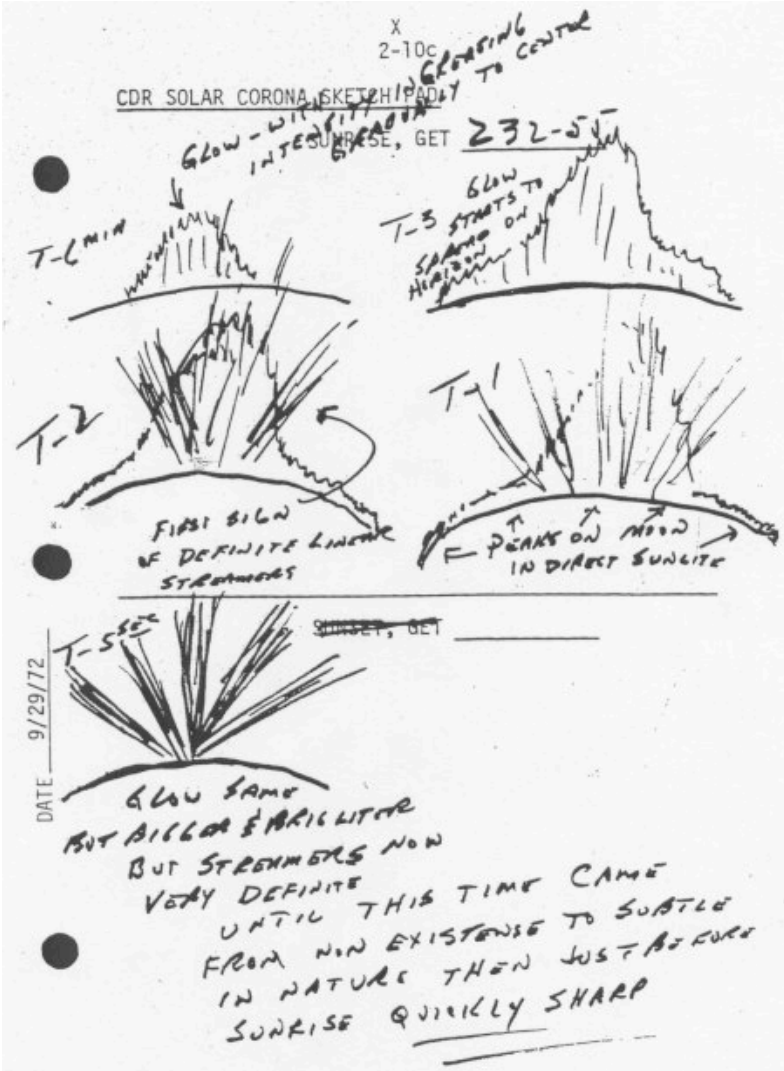


From Berg, et al 1976

LEAM: Systematic Lunar Diurnal Dust Cycles



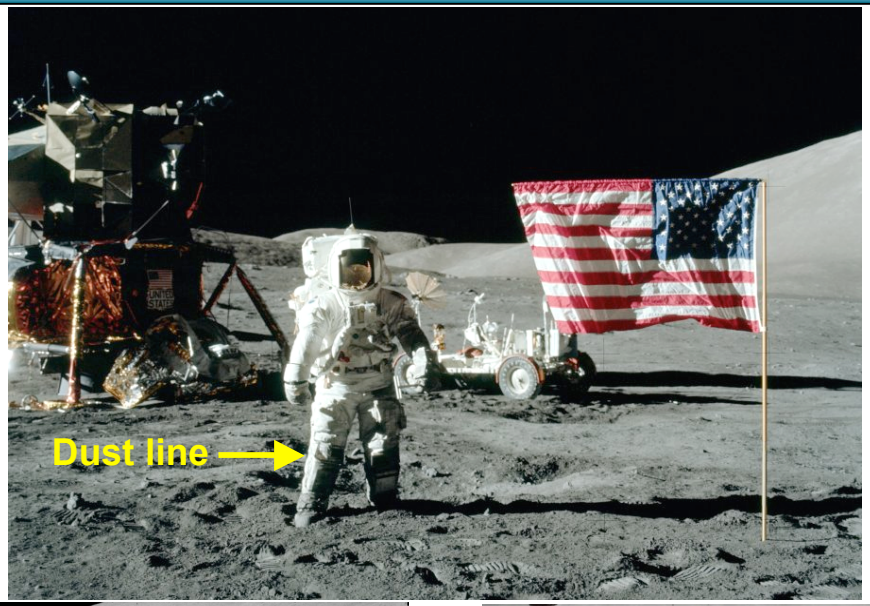
Eye-witness Accounts of Levitated Lunar Dust

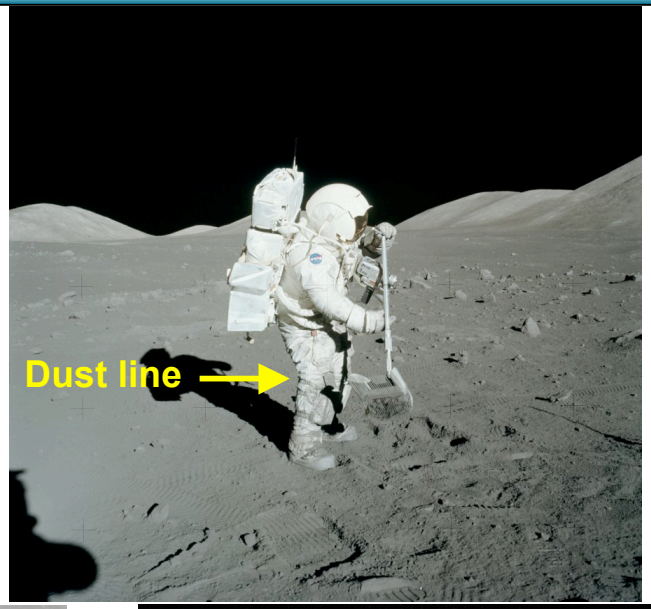


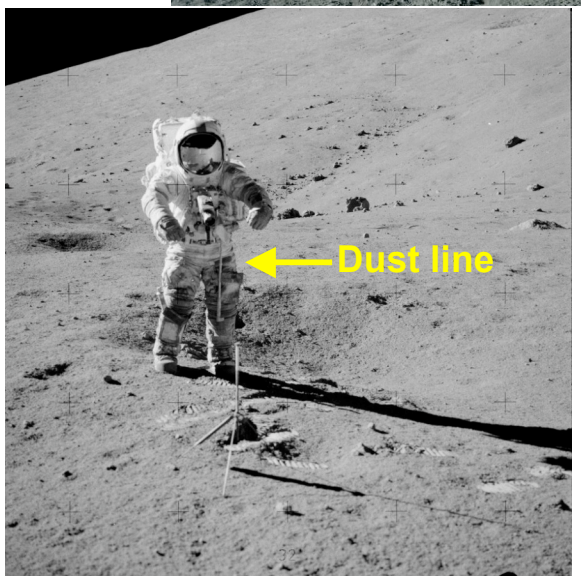
Astronaut sketch of observations from the Apollo 17 command module of streamers extending over 100km in height.

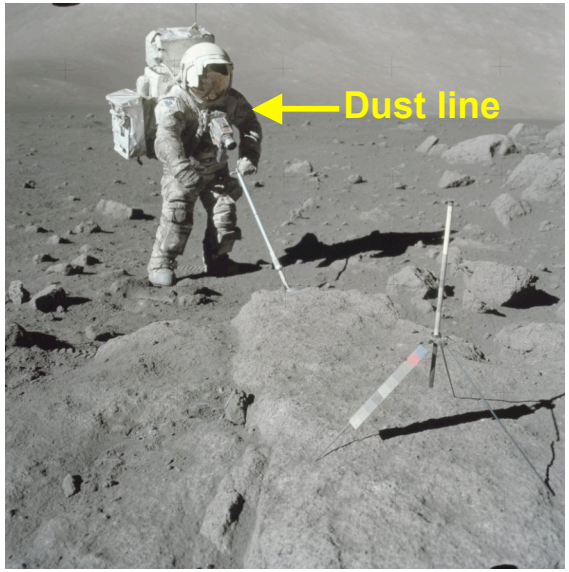
Dust fountains or ion resonance emission? both?

Dust and Human Activities

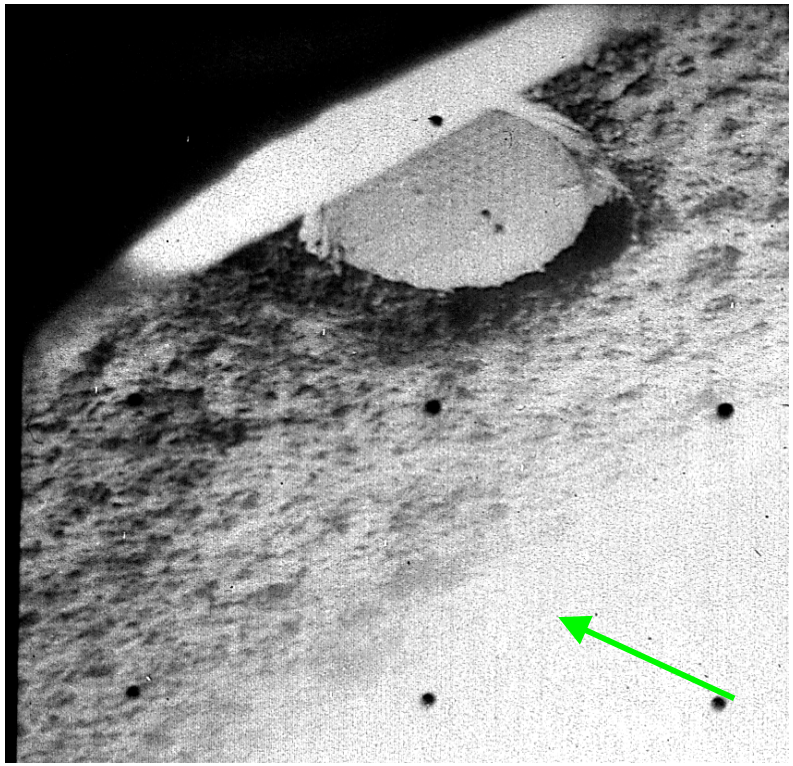




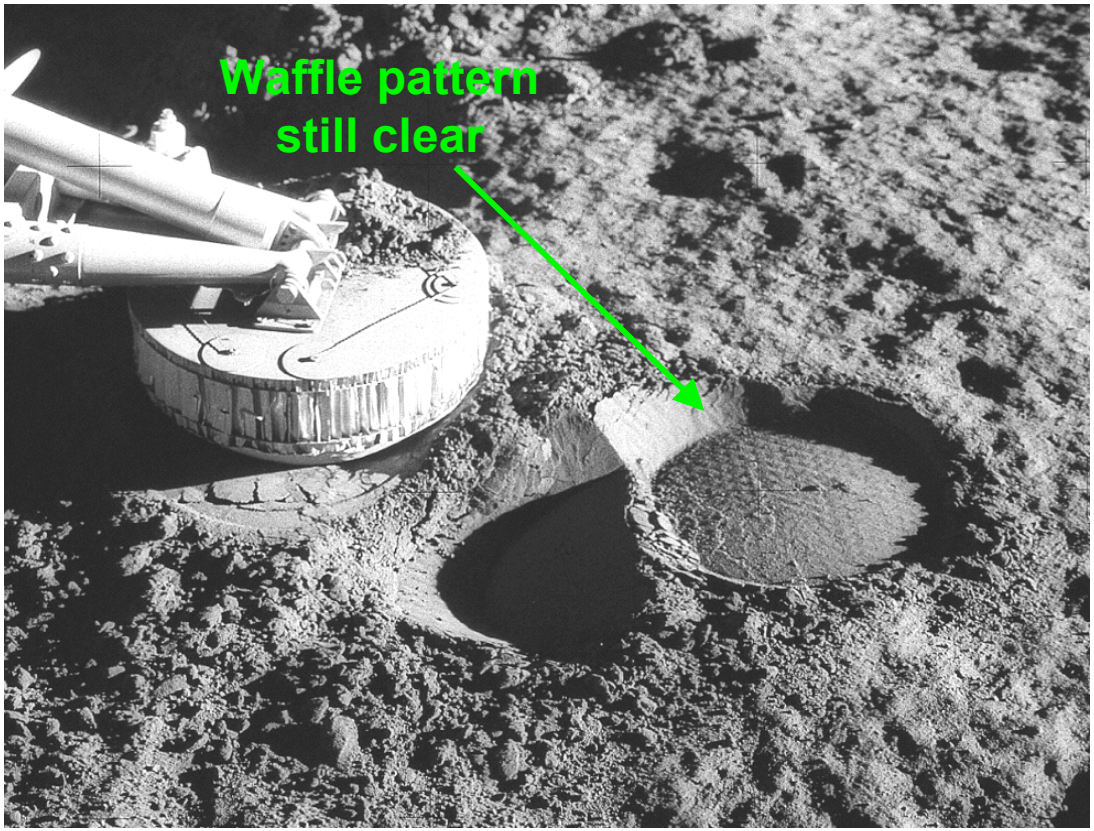




Natural Dust Mass Transport Appears Limited



Surveyor 3 Footprint: 1967
(Self-portrait)

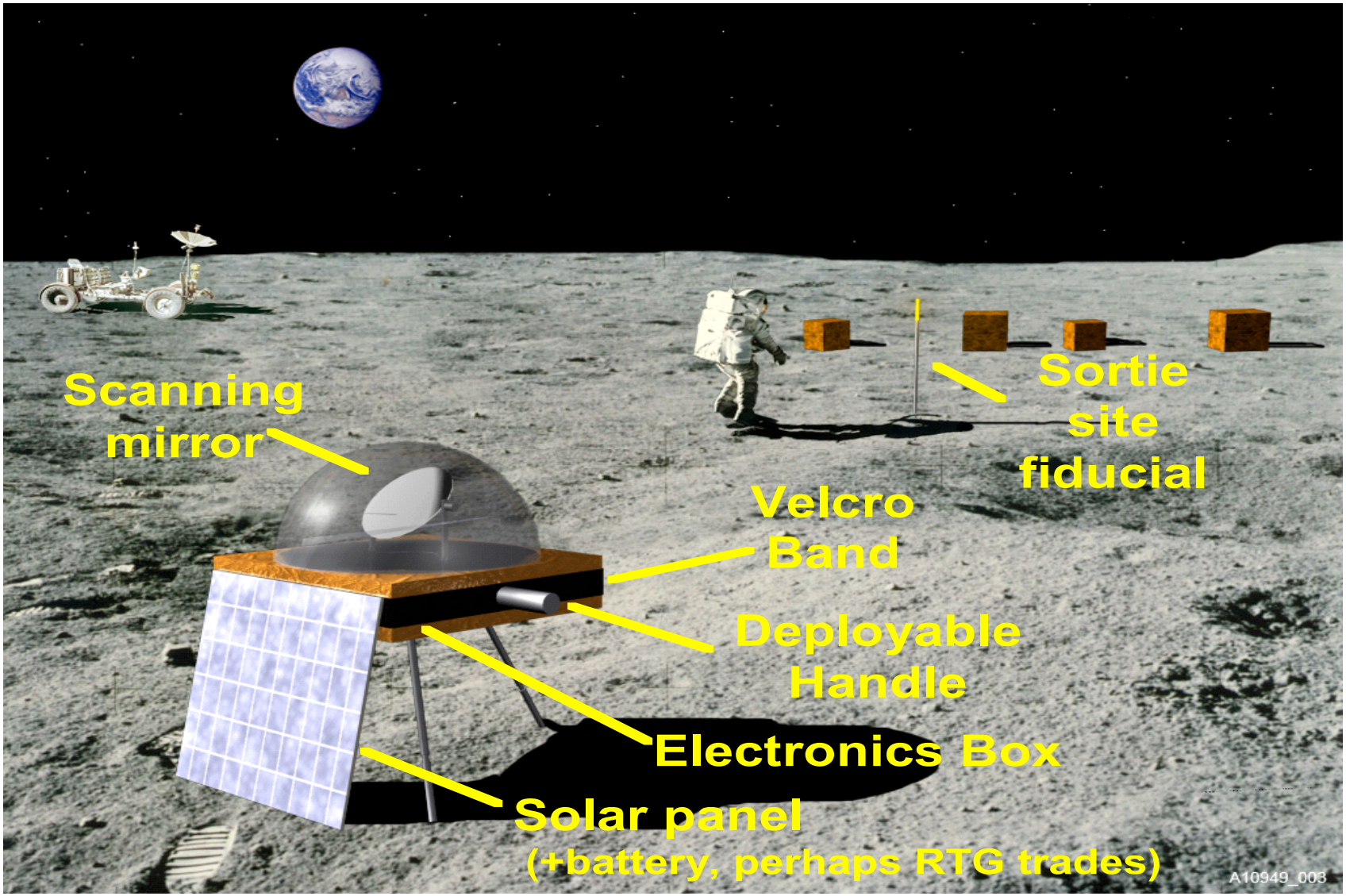


Apollo snapshot 4 years later

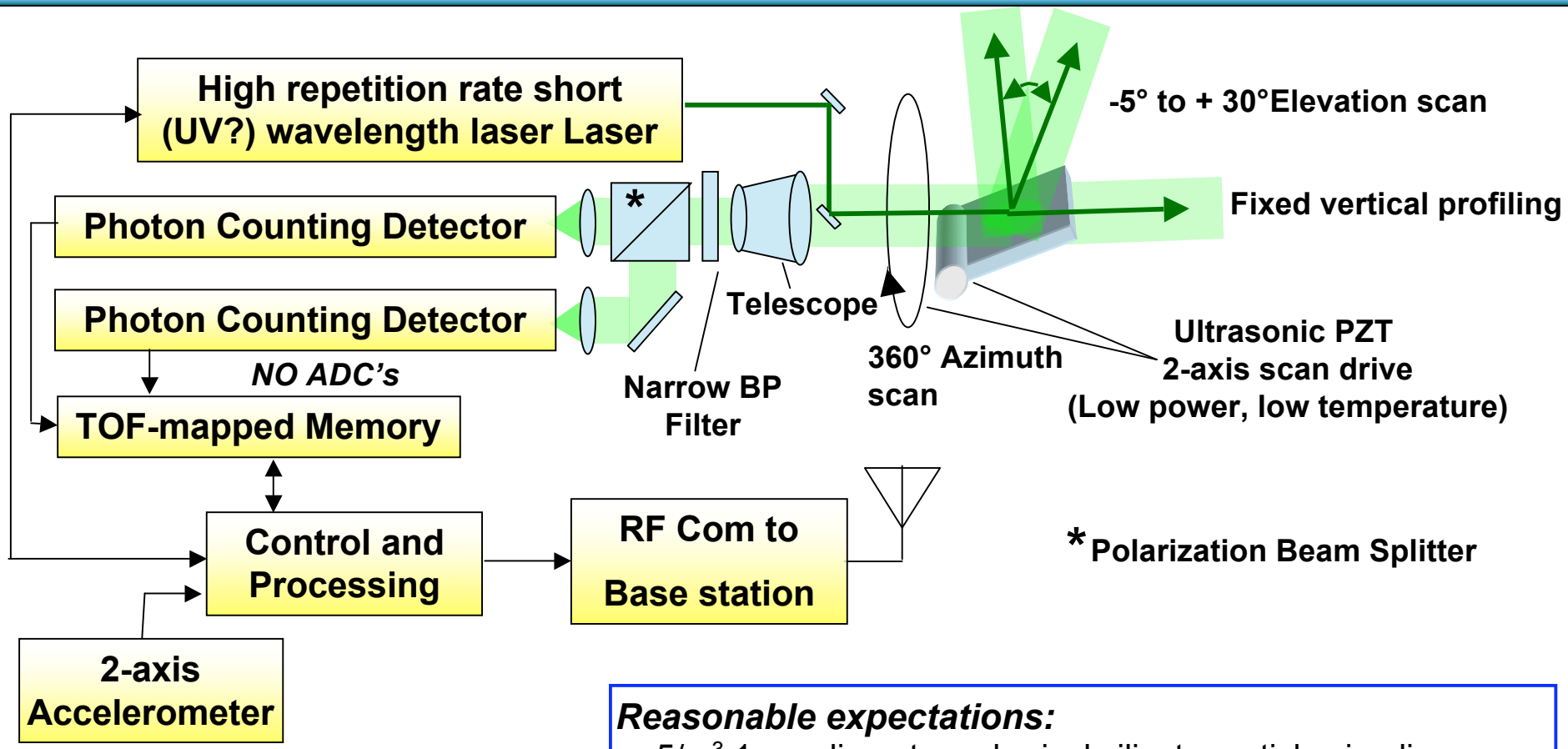
Suggests natural deposition rate is fairly low or Surveyor repels dust due to surface charging processes

Autonomous Lunar Dust Observer (ALDO)

ALDO Concept



ALDO Architecture



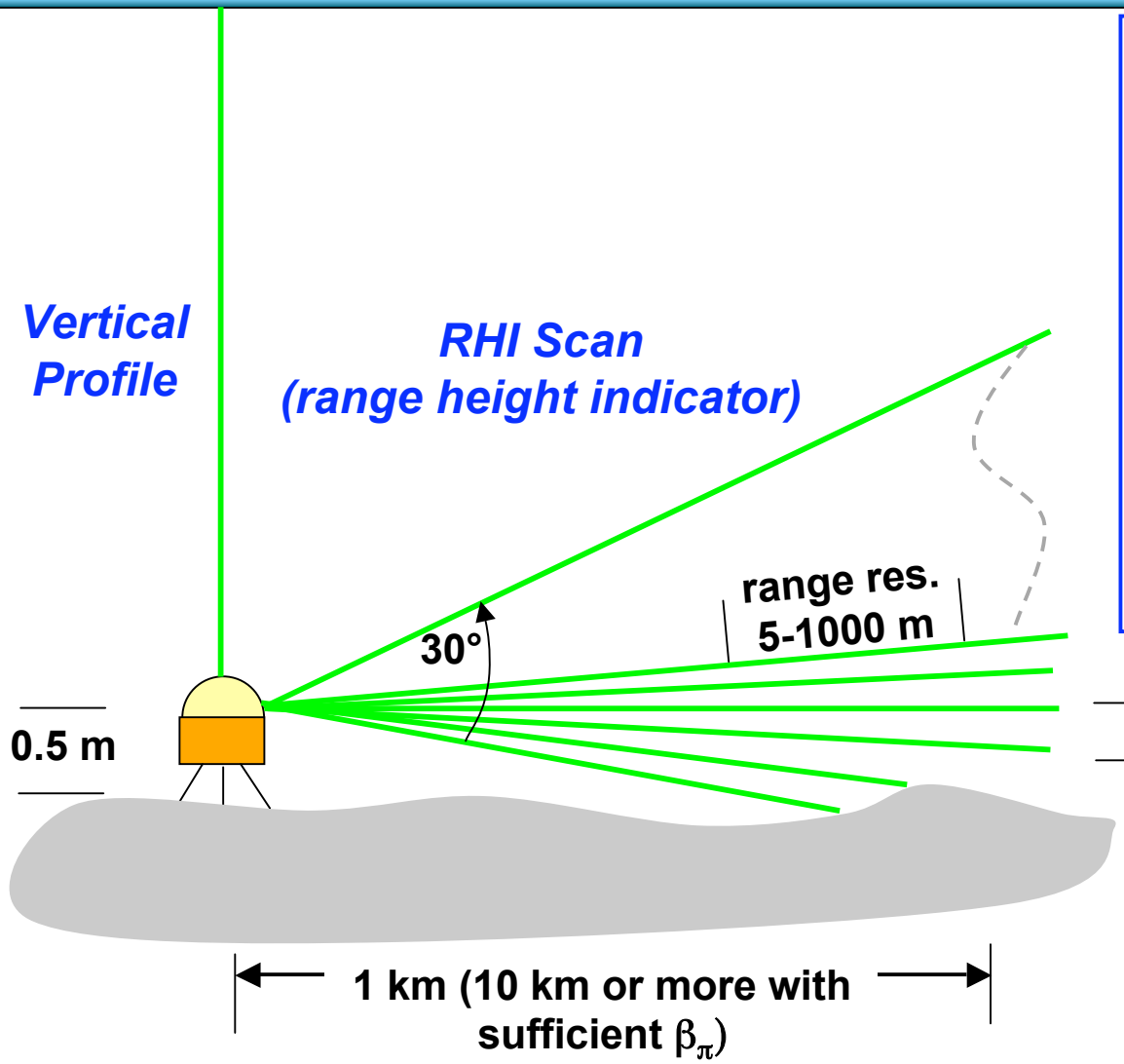
$$P(R) = P_0 * \xi * \frac{A_r}{R^2} * \frac{\Delta R}{2} * \frac{\lambda}{h*c} * \beta_\pi(R)$$

The lidar equation

Reasonable expectations:

- ~5/m^3 1 μm diameter spherical silicate particles implies: β_π ~1*10^{-12} m^{-1}sr^{-1}
- ~2500 photon counts/s from 1 km range (~2% intensity)
- **1 W laser implies ~15 W average system electrical power**

ALDO Scan Modes



Volume Image Scan:

- **repeated RHI's**
- **step each in azimuth**
- **slow, but full 3-D image**

30º elevation X 360° azimuth X $(100\ m)^3$ resolution at 1 km: ~5 min.

PPI (Plan Position Indicator):

- **fixed elevation angle**
- **scan in azimuth**
- **rapid 360° cross sections**

0.1 m vertical res. @ 1 km

High resolution vertical scan

- ***detailed studies of the exospheric boundary layer***

ALDO Modes and Motives

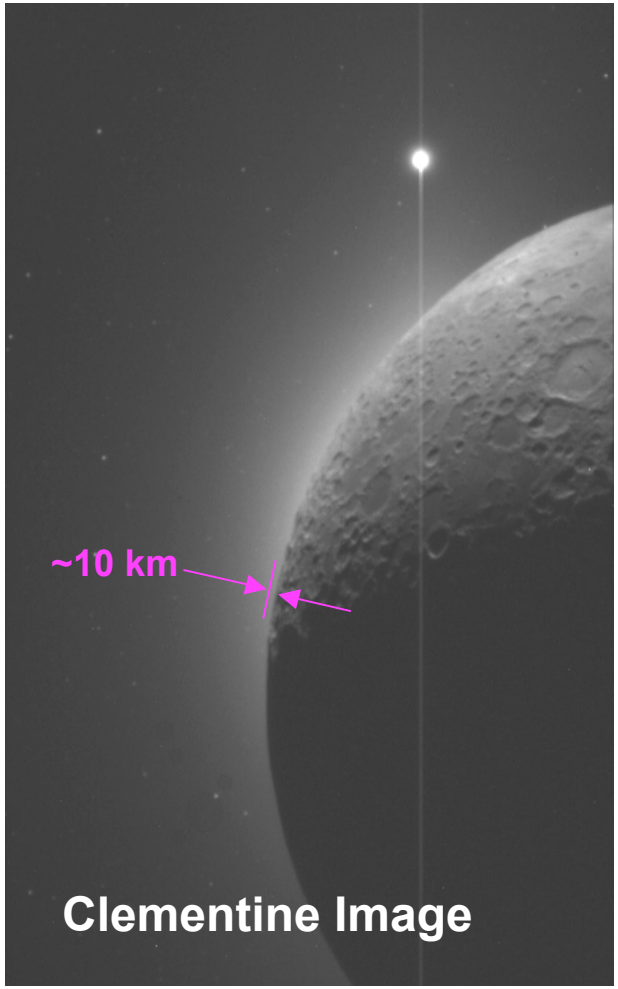
ALDO Operating Modes provide:

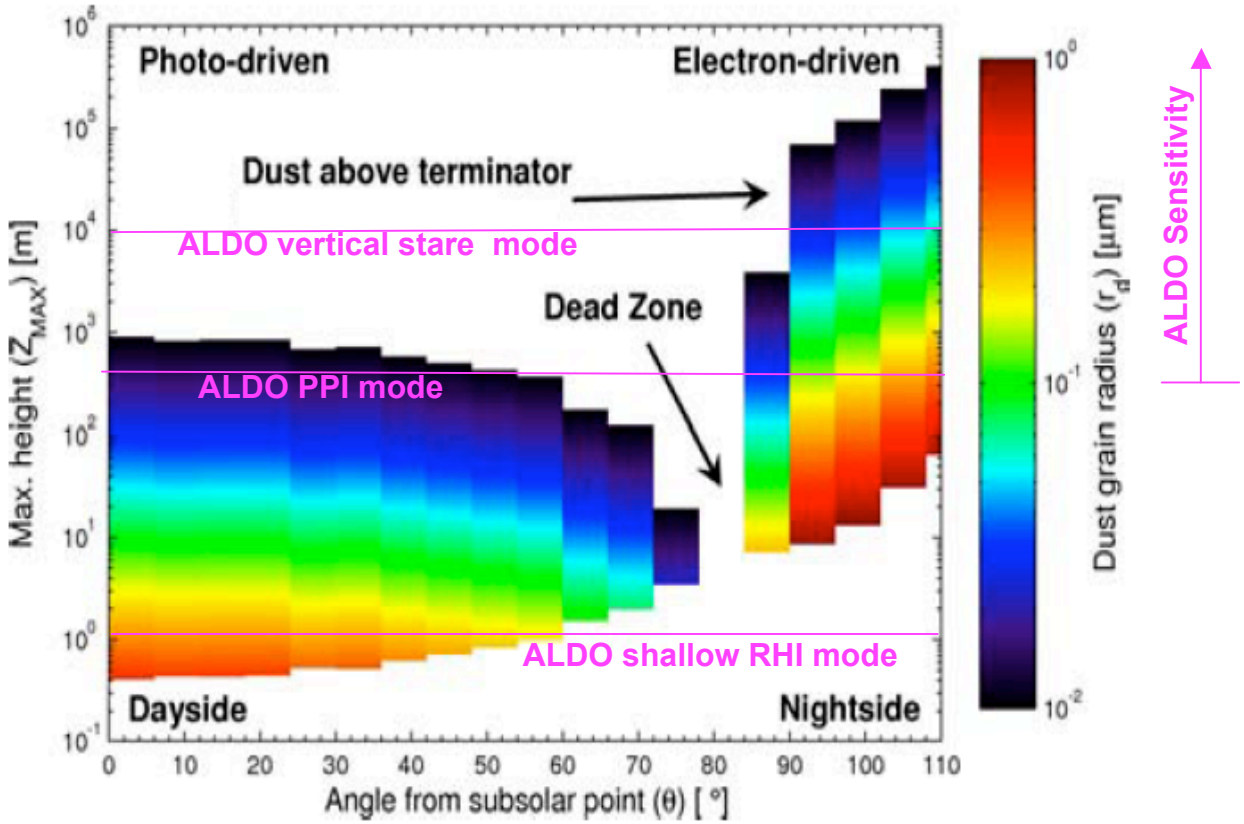
- Autonomous site survey using fiducial markers
- Self-calibration for intensity using fiducial marker signal returns
- Fine scale vertical profiling near surface
- Rapid 360° cross section scans that reveal and track coherent structures
- Panoramic volume images provide large scale dust context
- Long stares high sensitivity vertical profiles (perhaps to 10 km)

Systematic Process Studies:

- Lidar provides large area range-resolved dust observations without affecting plasma
- Micrometeorite impact plumes (rates, decay, transport)
- Natural phenomena – dark vs. sunlit, terminator crossings, fountains, profiles, dust transport and velocities (track coherent structures)
- Anthropogenic effects – what activities/methods kick up the most/least dust
- Decay time from disturbed to natural background state
- Instrument effects on the dust environment
- Solar wind, optical, and tribo- charging phenomena

ALDO Maps Dust Distribution Covering Most Dust Phenomena





From Stubbs, et al, 2005

For "spheres" lidar backscatter peaks: r ~λ
Multi-λ might make particle sizing feasible

Conclusions

Observing natural and anthropogenic dust levitation and transport phenomena supports:

- **Study of the evolution of airless bodies (e.g. moon, NEOs) including formation of regolith, stratigraphy/compaction, water and other resource content, and albedo**
- **Health, safety, and operational efficiencies for extended human activities**
- **Optimal design of instrumentation for long term operation (thermal control, optical effects, power systems, mechanisms)**

Systematic lidar profiling of the dust environment enables study of :

- **Micrometeorite impact plumes (rates, decay, transport, gardening)**
- **Natural background – dark vs. sunlit, terminator crossings, fountains, profiles, transport**
- **Anthropogenic effects – what activities/methods kick up the most/least dust**
- **Decay time from disturbed to natural background**
- **Instrument modifications to the local dust environment**
- **Solar wind, photoelectric, and tribo- charging effects on dust penomenology**

- ***A top level lidar concept employing photon counting has been examined by Ball***
- ***An easily deployed, compact, robust, scanning, dust profiling lidar appears feasible***
- ***Deployable on both robotic and human missions***