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

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Charging of the Lunar Surface

- Solar wind proton
- Solar wind electron
- Solar UV photon
- Secondary electron
- Photoelectron
Lunar Dust “Weather”

- 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 5: 1967-267T11:10:56

Surveyor 6: 1967-328T14:15:26

Surveyor 6: 1967-328T14:36:41

Surveyor 7: 1968-023T06:21:37

Surveyor 7: 1968-023T06:36:02

Surveyor 7: 1968-023T06:51:44

Surveyor 7: 1968-023T07:32:09
*LEAM Apollo 17: Lunar Dust “Storm”

* Lunar Ejecta and Meteoroid Experiment

Compare: Evidence for horizontal dust “wind”

LEAM Film Grid Events per 3-Hour Interval for 22 Lunations

From Berg, et al 1976
LEAM: Systematic Lunar Diurnal Dust Cycles

LEAM Data 1973

Day 39

Day 68

Day 98

Day 127

Day 157

Day 186

Number of Events per 3-Hour Interval

Hours from Sunrise
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 Architecture

High repetition rate short (UV?) wavelength laser Laser

Photons Counting Detector

Photon Counting Detector

TOF-mapped Memory

Control and Processing

RF Com to Base station

Telescope

Narrow BP Filter

360° Azimuth scan

-5° to + 30° Elevation scan

Fixed vertical profiling

Ultrasonic PZT

2-axis scan drive (Low power, low temperature)

* Polarization Beam Splitter

Reasonable expectations:

• ~5/m^3 1 µm diameter spherical silicate particles implies:
  \[ \beta_\pi \sim 1 \times 10^{-12} \text{ m}^{-1} \text{sr}^{-1} \]

• ~2500 photon counts/s from 1 km range (~2% intensity)

• 1 W laser implies ~15 W average system electrical power

The lidar equation

\[ P(R) = P_0 \* \frac{\xi \* A_r \* A \* \frac{\Delta R}{2}}{\frac{R^2}{h \* c}} \* \beta_\pi (R) \]
ALDO Scan Modes

**Vertical Profile**

**RHI Scan (range height indicator)**

- Range resolution: 5-1000 m
- 30° elevation
- 360° azimuth
- 0.1 m vertical resolution at 1 km: ~5 min.

**Volume Image Scan:**
- Repeated RHI’s
- Step each in azimuth
- Slow, but full 3-D image
- 30° 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

**High resolution vertical scan**
- Detailed studies of the exospheric boundary layer

1 km (10 km or more with sufficient $\beta_n$)
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: $r \sim \lambda$
Multi-$\lambda$ 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