Lunar Precursor Robotic Program Mission
Constellation Dust Measurement Needs Assessment

Appendix C

Comments Received

Cell E32 reads “Poor insight into systems. Loss of critical systems.”

Statement: "Particle shape of returned lunar samples has been characterized is well understood." I don't think lunar samples has been characterized is well understood." I don't think particles, I don't think this characteristic is well understood, at least for the <20 um particles, since ARES has just submitted a CDDF partly to apply electron microscopy and image analysis to look these particles. This information is very important for toxicology to determine whether effects similar to silicosis are going to occur in the lungs.

In D129, "Lunar dust would immediately react with the water in the body. Therefore if it were to enter the lungs it would already have satisfied its bonds." This is a fundamental question that LADTAG and ARES are wrestling with right now and I don't believe there is a consensus on how quickly dust is passivated after exposure to water vapor. ARES is working on some quick and dirty assessments of this issue, but it seems like this would be a good candidate for an experiment to perform on a LPRP mission, even if it is just to validate what is found in plasma chambers on the ground.

One note on format. Since a number of comments are repeated in each systems on the y axis and dust characteristics on the x, filling in the impacts of the characteristic on each system. Then the assessment and recommendation could be made at the bottom.

Assuming that these missons are very short, there will not be any food processing. There would only be food stowage, food rehydration and heating, and clean-up (revised title fro affected system). Otherwise, I think your assessment of chemical composition being the only issue is correct.

We should express the knowledge gap as being the understanding of the near surface lunar environment in total, not as separate physical property classifications.

The affected systems column should be expanded to include other relevant surface systems. Power systems are listed, but we should also include ISRU, and be more comprehensive of mobility systems, which includes more than rovers. Alternatively, the rover section could be renamed as “surface mobility systems”, or Human Robotic Surface Systems” to correspond with Chris’s project.

The recommendation WRT reactivity expressed in E129 should be rewritten to address possible reactivity of regolith in situ affecting surface systems that will be exposed over long mission durations, and included for those systems where it is listed a design factor, especially surface systems. I believe it may also apply to comm systems, for elements exposed to the lunar environment.

For D127 should be changed to reflect the lack of characterization of the <20 micron size fraction, and applied anywhere the statement is included.

As stated in D7, the characterization of dust should encompass the range of physical properties listed, including magnetic susceptibility, as a function of particle size, for the < 20 micron fraction, and applied anywhere the statements are included.

Per E7 and elsewhere, the LADTAG is proposing to study the particle size distribution by a variety of techniques, not just SEM. These include optical scattering, and aerodynamic transport. This is a necessary approach, due to the known limitations of the various techniques. Aerodynamic transport diameter (as measured by Greenberg, et al) is measurable directly, and is directly relevant to the assessment of inhalation exposure risk and the subsequent toxicological affects of lunar dust.

I think that your spreadsheet captures the things that I would worry about for thermal control systems - dust on radiators (how does it effect optical properties) and dust in fluid connectors (will it make them leak).

Experimentally, for early missions (including robotics) we should have instrumentation to directly measure not only dust properties but also plasma properties (e.g., using Langmuir probe, etc.). Dusty plasma (a.k.a. complex plasma) is a hot research topic today and I would feel much more comfortable with direct experimental lunar data.

We (and others) are developing fundamental models for dusty plasma which should provide hardware designers with estimates and design rules for material selection, dust mitigation techniques, etc. - but are relying on old Apollo and Russian data for plasma parameters. Again, it would be greatly beneficial to invest now in early measurements of such key parameters.

Electrostatic environmental effects will be most important in the nightside and at the terminator. John Young's quote is interesting, but I suspect that the suites covered in dust is evidence in itself of some triboelectric effect. In the winter time, as we move over a carpet, we get tribocharged, but dont know it until we discharge onto an object. If JohnYoung's suite was tribocharged, he may not have realized it....but the attached dust may be evidence.

GSFC's LEAM Apollo 17 ALSEP dust at the terminator moving at > 500 m/sec....this package detected accelerated "dusty sleet", as we call it here, is a very different nuisance/hazard that dust folks have not been considering. The surface potential at the terminator and nightside, driven by the plasma at and behind the lunar wake, undergoes large negative swings and may be responsible for this accelerated dust....

Hence, the environment: dusty plasma near a charged surface, is pretty important to understand. In sunlight, the environment is photoemission dominated, but at the terminator and night, the environemnt is driven by a low density plasma...which may be a very different animal...

Cell E32 reads "Poor insight into systems. Loss of critical systems."

I think it is important to determine the surface reactivity of the dust not only because it might affect the toxicity of the samples (Cell E129) but because it may also affect the adhesion of dust particles onto sensitive surfaces (radiators, PV arrays, connectors). This hypothetical reactivity could also degrade the polymeric surfaces in seals over time. If we would know that the surface of the dust grains is activated and know to some extent by what mechanism (dangling bonds, crystal dislocations, etc.) then we can probably reproduce that activation in ground tests.

I think it is important to measure the electrostatic charge environment near the surface (not just the charge on dust particles). There have been several models developed describing the rarified plasma environment at the lunar surface (see the work of Arnon Chait at GRC and Bill Farrell at GSFC), and yet there is no evidence of direct local effects in the Apollo record. (I recently spoke to John Young about this and he confirmed that they did not see any electrostatic effects from triobocharging, or when moving between sunlit and shadowed regions.) I think we need surface measurements to quantify the electrostatic environment, to determine if there will be significant electrostatic affects that were not detected by Apollo, but that will affect modern microelectronics or become important in an extended stay.

I'm okay with this for EVA

The "Hardness" characteristic should be changed to "Abrasivity." Hardness is usually defined for solid materials like metals or rocks. My understanding is that there are standard engineering tests that can be used to compare the resistance of materials to being abraded by dust samples.

For particle shape distribution affects on power systems: Secondary factor in solar cell power versus off-pointing due to mono-layer shadowing. 2nd factor in solar array drive assembly tribosurface wear for non-hermetic bearing designs. 2nd factor for heat rejection system performance enhancement and degradation since it would affect layer effective radiating area and contact conductance for a given g/cm2 dust loading. 2nd factor in optical property impacts for solar arrays, radiators, power cabling, power electronics boxes, ect. Impacts the design of dust mitigation and removal systems if used.

For particle size distribution affects on power systems: 2nd factor that influence direction scattering and the impact on solar cell performance both positive (forward scattering current generation enhancement) and negative (back scattering power loss). 2nd factor in solar array drive assembly tribosurface wear for non-hermetic bearing designs. 2nd factor for heat rejection system performance enhancement and degradation since it would affect layer effective radiating area and contact conductance for a given g/cm2 dust loading. 2nd factor in optical property impacts for solar arrays, radiators, power cabling, power electronics boxes, ect. Impacts the design of dust mitigation and removal systems if used.

For electrostatic charge effects on power systems: For solar array and radiator surfaces, will influence the particle arrival rate v. particle size, orientation on the surface and tenacity of staying on the surface. Impacts the design of dust mitigation and removal systems if used.

For magnetic charge effects on power systems: For solar array surfaces, will influence the particle arrival rate v. particle size, orientation on the surface and tenacity of staying on the surface. Impacts the design of dust mitigation and removal systems if used.

For hardness charge effects on power systems: secondary factor in solar array drive assembly tribosurface wear for non-hermetic bearing designs.

For chemical effects on power systems: Optical properties of lunar dust may be needed in developing requirements for solar collection systems, radiators, all radiating surfaces including power cables, MLI, electronics boxes, ect..

The effective optical properties of every engineering system surface will be altered by the arrival of some level of lunar dust from natural (electrostatic, meteoric) and induced (plumes, wheels, EVA feet, ISRU equipment, etc). The arrival rate (particle size, distribution, mass loading, clumping behavior, etc.) must be determined for all engineering surfaces of interest. As a minimum, measurements should be made with surfaces as a function of orientation (vertical and horizontal), height above the surface, distance from particle source (induced particle sources) and conductivity (insulating and conductive) with measured ambient and induce particle production events. Perhaps surface texture should also be evaluated (smooth and rough - beta cloth textile fabric). Some data from Apollo (descent video footage, surface science packages) and assessment of Surveyor-3 surfaces. Recommend LPRP mission.

For particle shape distribution on electrical/electronics: Secondary factor for connector design, function and mate-demate operations.

For particle size distribution on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

For reactivity effects on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

For electrostatics effects on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

For magnetic effects on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

For hardness effects on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

For chemical effects on electrical/electronics: secondary factor for connector design, function and mate-demate operations.

ISRU Feedback

ISRU flowability affects haulers, chutes, bins, excavators recommend LPRP mission. Particle adhesion/cohesion, surface energy is central to flowability recommend LPRP mission. Particle ensemble surface area measurements underpins flowability recommend LPRP mission. Soil mechanics affects excavators, roads, foundations, backfill behavior, recommend LPRP mission. Particle shape distribution affects ISRU. Particle size distribution affects ISRU recommend LPRP to measure sub-20 micron size. Reactivity affects ISRU in corrosion, abrasion and reactor efficiency. Electrostatic charge affects ISRU in dust transport and deposition affects machine life and performance, from abrasion to seals and bearings. LPRP mission recommended to measure dust transport due to dusty plasma. Magnetic charge affects ISRU in some cases. Hardness affects ISRU in abrasion and beneficiation, Chemical composition affects reactor efficiency.

Communications is affected by electrostatic charge. Ionized dust particles, when settled on the surface of aperture type antennas may alter the electromagnetic properties of the antennas. Consequently, this phenomena could adversely impact the performance of such antennas, with the potential for communication systems anomalies. LPRP mission recommended. Assessment and simulation of communication system anomalies should be performed in a controlled environment at the following frequencies: S-band (surface-to-surface and surface-to-space coomunications) and at Ka-Band (surface-to-Earth and surface to orbiter) and with the following antenna types, helix and reflectors, commonly used for space communications. Ground based testing requires validation data/measurements of dust/lunar environment parameters.

Response from ETDP ISRU Project Manager to above comments: I agree that ISRU should be a recognized subsystem with dust characteristics and factors of interest. Some of the characteristics of interest are debatable as to whether they are a "Dust" measurement or something an ISRU experiment in excavation or oxygen production would not do itself. However, the items that I have put a yellow background on I think clearly fall into the Dust Project measurement area {electrostatic, reactivity, magnetic charge]. ISRU might do gross measurements of these characteristics of interest or examine a delta-change in performance, but detailed characterization would need to come out of your area. My approach to ISRU is to first over design something to make sure it works and than back-off, however, this data early on would help tremendously.

Other aspects not necessarily called out are (a) beneficiation as a function of size due to electrical or magnetic fields and (b) Property characterization differences between regolith in the lit regions and regolith in the permanently shadowed crater. Again, ISRU will do gross characterization as a function of making it work, but besides visual or CHAMP/Raman we were not planning on doing any other characterization.