STRATEGIC KNOWLEDGE GAPS I HAVE KNOWN

The NASA lists of Strategic Knowledge Gaps (SKUs) with regard to the Moon are quite extensive: yet there are potential, very important SKUs that are being ignored under the current regime. These include:

- Mercury
- Gold
- Electrostatic Considerations
- Monatomic Hydrogen
- Geographic Accessibility
- Possible low latitude sources of volatiles

Mercury: Probably the most surprising finding of the LCROSS mission was a huge spectrographic peak consistent with large amounts of mercury. However, large concentrations of mercury with in permanently shaded regions (PSRs) was predicted in the 1960s by the University of Chicago geochemist George Reed. If the LCROSS results are to be accepted at face value, soil concentrations on the order of 0.39% were detected. To put this in perspective, at least one EPA study found that acceptable limits of soil concentration of mercury on Earth was 722 ppm—with a safety factor of ten, this reduces to 72 ppm. Thus, it should be noted that 0.39% = 3,900 ppm—over a factor of 5 to 50 above what is considered acceptable by the US EPA. The RPM OVEN experiment can thus be expected to liberate large amounts of mercury. Will such releases of mercury affect experimental results? Perhaps not, but that is a question that needs to be answered. As is proposed, the future RPM mission will have no capability to detect heavy elements such as mercury. An fast acting X-ray fluorescence (XRF) sensor would be able to directly assess mercury concentrations.

Gold: Another surprising finding of the LCROSS mission was anomalously high readings gold (and silver, and possibly platinum). It is difficult to account for the detected concentrations on the basis of contamination by tiny amounts of gold impregnated within the multi-layer foil insulation of the Centaur stage impactor. A plausible theory is that electrostatic dust transport preferentially favors metal dust particles such as gold, that could result in electrostatic placer deposits in permanently shaded regions (PSRs) of the Moon. This is supported by the empirical fact that pristine rocks have higher concentrations of gold than does ordinary regolith. The law of conservation of matter demands that this excess gold went somewhere. Assuming that such heavy elements as gold were not lost to outer space, then it must be concentrated somewhere on the Moon. On Earth, gold is considered a strategic mineral; gold on the Moon, therefore, should also be considered a strategic mineral. Again, gold, as a heavy metal, could be detected with a fast acting XRF sensor.

Geographic Accessibility: All PSRs are not created equal. The most interesting regions are the ultra-cold craters sampled by LCROSS (30 K temperature), and the craters with anomalously high circular polarization ratios (CPR) that are thought to be regions with high concentrations of water ice. However, these tend to be smaller craters within larger PSRs. Thus, RPM-style missions—whereby solar powered rovers make dives into PSRs and then return to lighted territory to recharge their batteries—will have no chance of sampling the most interesting potential mineral deposits on the Moon. Thus, it would be desirable to develop chemical range extenders that would allow rovers to land in the center of the most interesting craters and conduct a prospecting mission without recourse to sunlight.

Monatomic hydrogen: One bizarre result of the LCROSS mission is that the apparent kinetic energy of the debris plume exceeded the kinetic energy of the Centaur impactor. One possible explanation of this anomaly is monatomic hydrogen. The theory is that solar wind protons might impact the soil, and then because of the supercold (30 K) conditions, the protons might become neutralized, but then no further chemistry would happen. Thus, heating of such soil could at worst, cause catastrophic releases of energy, or at best, would dramatically reduce the energy requirements of extracting volatiles from PSRs.

Low latitude volatiles: Over 100 irregular, maar-like pit (IMPs) features have been identified within the lunar maria. One explanation for their formation is explosive outgassing. However, if H2O and CO2 are involved (as suggested by Schultz et al. in *Nature*), then under the prevailing conditions thought to exist, any H2O would tend to condense to liquid form. Interflow zones sandwiched between thick layers of basalt lava flows could potentially provide traps that could preserve liquid water indefinitely.

Further research has shown:

- Patchy distribution of Kaguya's Long Range Sounder (LRS) ground penetrating radar (GPR) indicates that certain regions within the lunar maria are more reflective than others.
- Yet the Chang'e 3 GPR clearly identified interflow zones that were outside of the areas identified by Kaguya's LRS.
- Because of the high dielectric constant of liquid water, that would intensify GPR reflections detected by LRS.
- There is no overlap between regions identified by LRS (potential reservoirs) and the IMPs (areas where outgassing is occurring.
- LCROSS analysis of the detected volatile mix are more consistent with outgassing versus cometary origin.
- Certain lunar meteorites have recently been analyzed that appear to contain dehydrated serpentines; such minerals would be direct evidence of aqueous alteration.
- Geochemical considerations suggest that any liquid water contained within basalt aquifers will tend to be enriched in sodium. Thus, outgassing of briny water within the lunar maria could potentially provide an explanation for anomalous Na detections by LADEE that increased during full moon periods (lunar maria exposed to the full brunt of solar power).