FUTURE MOON MISSIONS: FLIGHT SYSTEMS FOR THE COLD, DARK, OR UNSEEN 2003-2013. R. Dissly[1], K. L. Miller[1], D. Murrow[1], and J. Van Cleve[1], [1] Ball Aerospace and Technologies Corp., P. O. Box 1062, Boulder CO 80306 (klmiller@ball.com , rdissly@ball.com, dmurrow@ball.com, jvanclev@ball.com).

The Moon Makes a Comeback: The Solar System Exploration Survey ("Decadal" Survey), chartered by the Space Studies Board of the National Research Council, found that a South Pole-Aitken Basin Sample Return (SPA-SR) would be of fundamental importance to all of planetary science, and selected SPA-SR as one of 5 medium (~$650 M) missions for the coming decade. SPA-SR examines the processes involved in Solar System formation in the ~3.7-4.5 Gya epoch, and the impact history of the inner planets.

Engineering and operational interest in the Moon, while not captured in the Decadal Survey mission priorities, includes gravity surveys to improve orbit maintenance, topography and soil surveys for landing and construction, and resource location and extraction experiments. We present our capabilities for lunar and related Solar System missions, then examine science, engineering, and operational questions which can be addressed by systems emerging from various combinations of these capabilities. As examples, we examine

1. Remote sensing of dark and cold regions
2. *In-situ* experiments
3. Sample handling and packaging for return
4. Cryogenic sample return

We emphasize improvements in the state of the art for remote sensing since Clementine and Lunar Prospector in the mid-1990's, and improvements in *in-situ* and sample return operations since the mid-1970's.

Who We Are: Ball Aerospace built instruments for each of the NASA Great Observatories, is a major partner in James Webb Space Telescope, and is successfully expanding into planetary science with projects such as Deep Impact, Kepler, New Horizons (Pluto), the HiRise 20 cm/pixel camera for Mars Reconnaissance Orbiter (MRO), the flight power electronics and mechanism for the Mars Exploration Rover, and concept studies for Mars Sample Return (MSR), VESAT, Inside Jupiter and others. We have flight hardware experience with instruments from gamma rays to 160 µm, and have developed a dozen highly successful spacecraft in the past decade. Ball has also been to the lunar surface; for example, Ball lubricated the bearings for the astronaut-driven lunar rover.

We offer a full range of mission services, including instrument design and production, spacecraft systems and subsystems, and prime contracting. We have a diversity of talents among our more than 1100 engineers, astronomers, and planetary scientists

Capabilities:

Cryogenics. Ball has built flight hardware for each of the 3 methods of maintaining cold temperatures: a 2.5-5 yr lifetime dewar for SIRTF, mechanical cryocoolers for various programs and internal R&D, and radiative cooling for the HgCdTe focal plane on Deep Impact. These methods could be used singly or in combination to cool optics and focal planes for sensitive remote sensing of lunar cold traps or other cold planetary surfaces.

Optics. Optical specialties, with deep roots at Ball, include UV systems and their strict contamination control requirements; for example, we produced the Solar Backscatter UltraViolet (SBUV) terrestrial ozone mapper. Another specialty is IR instruments, for example the Deep Impact IR spectrometer, for which a sample spectrum is shown in Figure 1.

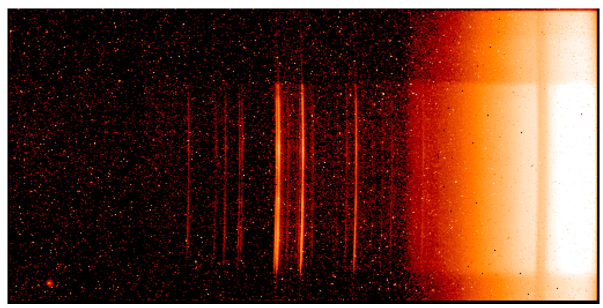

Figure 1: Deep Impact 1-5 um spectrum, showing Kr emission lines, CO2 absorption, and a Blackbody.

Mechanisms. A recent example of our expertise in complex mechanisms is Chandra Science Instrument Module translation stage and focus mechanism.

Focal planes. We have experience integrating and testing detectors and focal planes over much of the EM spectrum, including the 80 megapixel Kepler CCD focal plane

Software. Operations at the lunar poles or Farside, or the distant Solar System, will require a greatly enhanced degree of autonomy and reliability. We developed an autonomous target acquisition system for SIRTF's IR spectrometer, and developed high-level fault protection for Deep Impact.

Attitude control. Ball experience in subarcsecond pointing and attitude control technologies makes us a leader in the field. These capabilities, demonstrated on missions such as QuickBird, are critical to the support of lunar reconnaissance on the spatial scales required for future missions.

Example Measurements and Solutions.

Remote sensing of cold and dark regions. We present examples of our IR instruments that could be used to take the temperature of permanently shadowed regions, visible cameras that the could be used to locate such regions, and cryogenic solutions which take advantage of lunar mission requirements to enable hitherto unavailable sensitivity and long wavelength coverage for lunar and planetary missions.

In-situ experiments. We have developed an *in-situ* test bed for compositional analyses of soil, rock, or ice samples, Thermal Oxidative Pyrolysis and Evolved Gas Analysis (TOPEGA). TOPEGA (Figure 2 and Figure 3) integrates compound-specific detectors,an oven for differential scanning calorimetry and gas chromotography, and an FTIR.

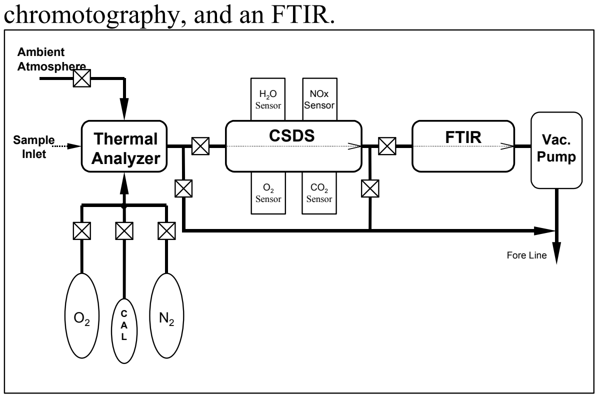

Figure 2: TOPEGA functional block diagram. CSDS = compound-specific detector suite. FTIR = Fourier Transform IR spectrometer.

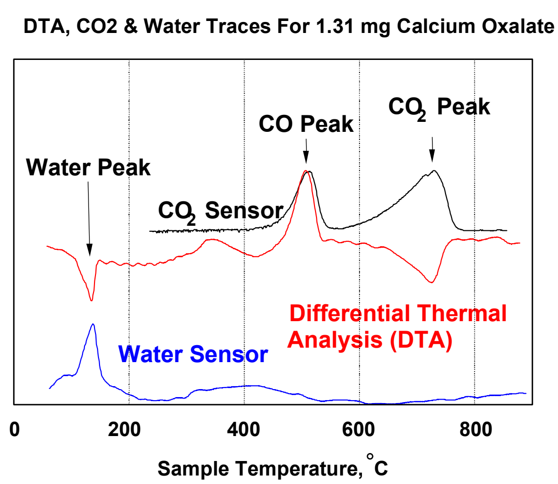

Figure 3: TOPEGA compound specific detection clarifies thermal results.

Sample handling. Cryogenic and mechanical expertise can be combined to handle lunar cold trap materials for *in-situ* measurements which require preservation of volatiles. We present the results of an internal R&D program for hermetic canister sealing in dirty, cryogenic environments, which can be applied to packaging for sample return.

Cryogenic sample return. Mechanisms, cryogenics, and sample handling are combined in an internal R&D concept study for cryogenic sample return, for stratigraphy of lunar polar volatiles. We present preliminary results of this study for sample return temperatures between 130 K and 185 K.