Ball Aerospace & Technologies Corp.

University of Notre Dame

The University of Arizona

University of Michigan

IPGP Institut de Physique du Globe de Paris

L-GIP

A LUNAR GEOPHYSICAL INSTRUMENT PACKAGE (L-GIP)

AS A CANDIDATE FOR THE INTERNATIONAL LUNAR NETWORK (ILN)

Part II - Science and Instrumentation

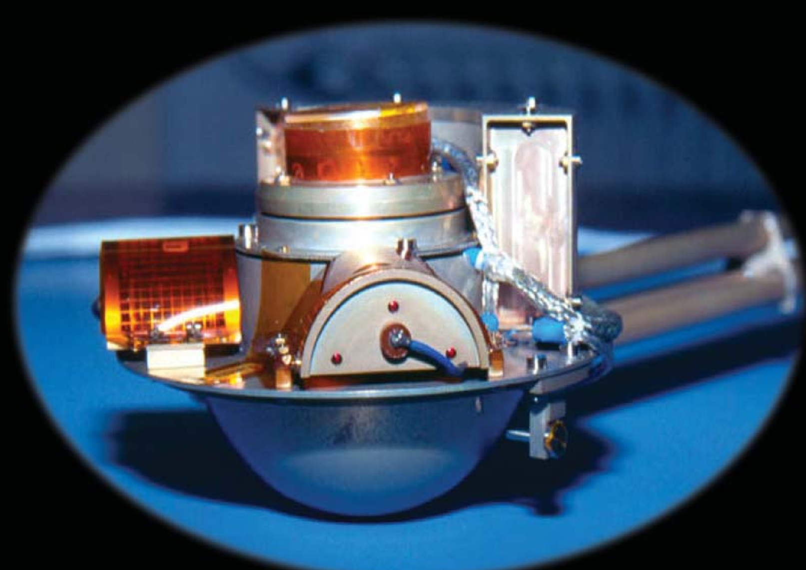
J. D. Weinberg[1], C. R. Neal[2], P. Lognonné[3], L. Hood[4], S. Huang[5]

A NASA Planetary Instrument Definition and Development Program (PIDDP)

1. Ball Aerospace & Technologies Corp. Civil and Operational Space jweinber@ball.com
2. University of Notre Dame Dept. of Civil Engineering & Geological Science neal.1@nd.edu
3. Institut de Physique du Globe de Paris Equipe Etudes Spatiales et Planétologie lognonne@ipgp.jussieu.fr
4. The University of Arizona Lunar and Planetary Laboratory lon@lpl.arizona.edu
5. The University of Michigan Department of Geological Sciences shaopeng@umich.edu

APOLLO LUNAR SURFACE EXPERIMENT PACKAGES (ALSEP)

- Astronaut deployed instrument packages included:
  - Passive Seismic Experiment (PSE)
  - Heat Flow Experiment (HFE)
  - Lunar Surface Magnetometer (LSM)
- Provided critical lunar geophysical information
- Measurements were spatially limited
- Non-optimal measurement locations
- Incomplete data sets
- Fundamental geophysical questions still remain
  - How did the Moon form and evolve?
  - What Lunar hazards exist for human exploration?



MAGNETOMETER

- Based upon the Rosetta ROMAP instrument
- Investigate the feasibility of encompassing the magnetometer under the same conductive sheath as the seismometer; or look at whether the magnetometer may need remote deployment as compared to the other instruments
- Investigate the possibilities of including a solar wind detector to help determine the origin of high albedo markings; examine mass, power and packaging considerations

Measurements made at sites which have known strong magnetic anomalies in conjunction with unusual albedo markings (such as Reiner Gamma and the Descartes Mountains) will help to understand both their origins and correlation

OBJECTIVES

- Develop the next-generation integrated instrument package for use in a network of in-situ lunar geophysical probes
- Equip the package to be able to make complementary measurements to address fundamental science questions about the moon
- Design the package to have the sensitivity, longevity and robustness to make measurements which provide substantial improvements over the Apollo Lunar Science Experiment Packages (ALSEP)

APPROACH

- Use mature and heritage instruments and electronics to minimize development and increase reliability
- Design the probe packaging to be flexible to accommodate a variety of different instruments within a standard architecture
- Collaborate with international partners to leverage global resources and establish a standard probe which may be used with any domestic or international robotic or crewed lunar lander

LGIP PROBE

- Design a probe that can provide long life and power (at least 6-7 years, multi-Watts)
- Develop a probe that can withstand the diverse and harsh environments of the lunar surface
- Develop a generic yet highly flexible probe that can be easily adapted for use with a variety of mission scenarios anywhere on the lunar surface

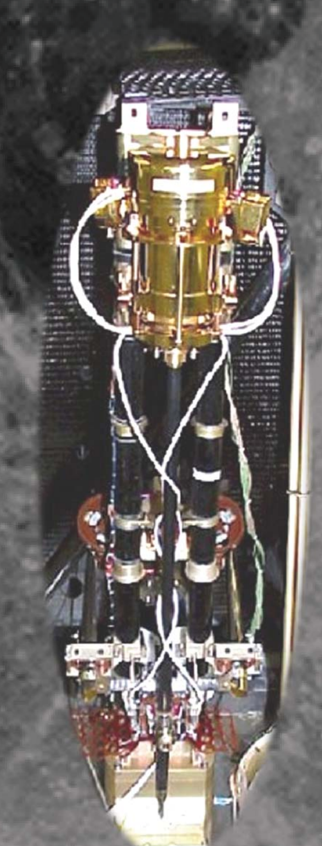
LONG TERM MEASUREMENTS (6-7 YRS) ARE NEEDED

- Seismometry
  - Tidal influence on certain moonquakes necessitate seismic measurements for a period of at least one lunar tidal cycle (6 yr) to characterize the effect
  - A large statistical data set of measured shallow moonquakes (more than the 5 yr Apollo set) is needed to correlate source locations with tectonic features and to determine causal mechanisms
- Heat Flow
  - Potential variations in heat flow could take 5-7 years to re-equilibrate to steady state levels, thus long term measurements are necessary to examine these phenomenon and to determine a steady state condition
- Magnetometry
  - While sounding study integration time for each plasma environment is relatively short (~1 week), obtaining a sampling from numerous instances over long periods of time allows for more accurate readings and helps contextualize the accompanying seismic and heat flow measurements

Globally distributed heat flow measurements will provide a better estimate of mantle radioactivity, reveal the presence of any heat flow variations and provide contextual data to aid in seismic modelling

Data obtained from a diversity of lunar terranes will vastly increase knowledge of the lunar thermal structure

Specific sites of interest include the center of a mare basin, near-side and far-side highlands, near the center of the near-side PKT unit and from the floor of the Aitken basin



HEAT FLOW PROBE (WITH MOLE)

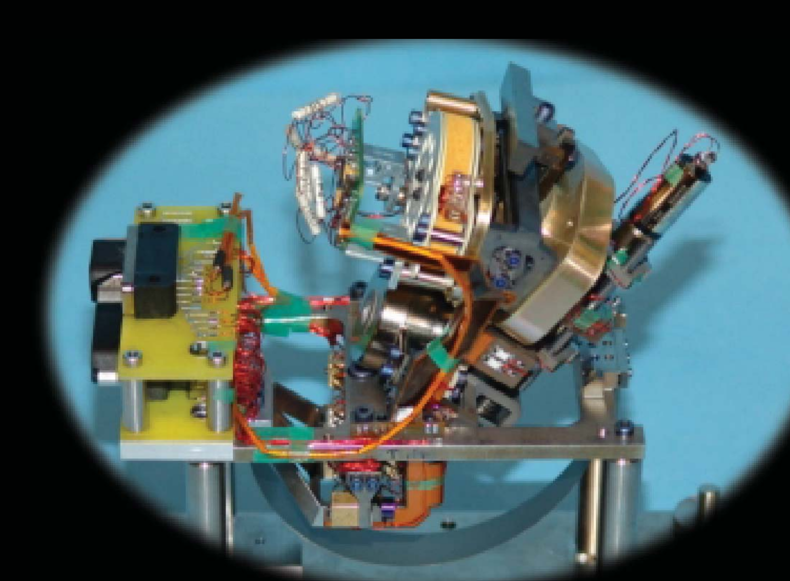
- Incorporate facets of the Lunar-A probe design into the Rosetta / ExoMars MUPUS-TP instrument to improve performance
- Investigate probe deployment and regolith penetration options such as self burrowing, spring or mortar assemblies, etc.
- Trade one or two probes per package science return with mass, power and complexity
- Investigate probe length in relation to regolith coupling and packaging concerns

Shallow moonquake characterization requires a cluster (three or more) of seismometers near each suspected source location or area of interest (such as a lunar habitat site)

Deep moonquake detection requires one seismometer near the source and one or more near the antipode to characterize core and deep mantle properties; this includes lunar near-side and far-side placement

LUNAR GEOPHYSICAL INSTRUMENT PACKAGE (LGIP)

- Following ALSEP, lunar geophysical probes should be equipped with a seismometer, heat flow probe and magnetometer to provide synergistic data to help answer fundamental lunar geophysical science questions
- Multiple long-lived (>6 yr), globally distributed probes are needed to achieve a comprehensive set of data necessary to answer key remaining science questions
- Geophysical probes should be small and light-weight to allow easy transport and deployment within the framework of both robotic and human lunar exploration missions



SEISMOMETER

- Based upon the Netlander Very Broad Band Seismometer (VBB-SEIS) instrument
- Decrease instrument noise to at least a factor of 10 below ALSEP by improving the differential capacitive sensor
- Remove the vacuum containment sphere and replace it with a conducting sheath or some other system to cope with the wide lunar temperature variations
- Trade 2, 3 & 4 axis design performances with mass and power constraints

Global seismic measurements are needed to characterize global lunar structure, including mantle variations, detection of plastic zones and determination of deep moonquake source locations