Apollo 16 Landing Site as a Calibration/Validation Target for Chang'E 1 Lunar Orbiter

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Aristarchus Region as a Location for Future Surface Exploration

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Part One: Calibration and validation for Chang'E 1 data: an example from Apollo 16 landing site.

Part Two: Aristarchus region: an ideal location for future manned/unmanned exploration.
Introduction

1. Two ongoing lunar missions: KAGUYA (Japan) and Chang'E 1 (China). Another two planned in 2008: Chandrayaan (India) and Lunar Reconnaissance Orbiter (US).

Huge amount of data will be available. Calibration and validation should be done before data release, e.g.,

- In-flight calibration to monitor the instruments.
- Peer review before the data are archived in Planetary Data System (PDS).

Here Apollo16 landing site is given as an example for the calibration and validation of Chang'E 1 data.
Introduction

2. Rover missions are planned in Chang'E phase II around 2012 and sample return missions are proposed for Chang'E phase III around 2020. Aristarchus region is an ideal location for the surface exploration.
Part One: Chang'E 1 Payload & Science Objectives

1) CCD Stereo Camera and Laser Altimeter  
   Map the lunar surface in three dimensions

2) Interferometer Spectrometer  
   Map the minerals on the lunar surface

3) Gamma/X Ray  Spectrometers  
   Map elemental abundances of the lunar surface

4) Microwave Radiometer  
   Survey the thicknesses of the lunar regolith to estimate $^3\text{He}$ content in the regolith

5) Electron, proton, heavy ion, and solar wind detectors  
   Monitor the Earth-Moon environment
Part One: CCD Stereo Camera

CCD Stereo Camera
Spatial Resolution: 120m/pixel
Wavelength Range: 0.5-0.75 μm
Field of View: Forward: 16.7° Backward: 16.7°
Part One: CCD Stereo Camera Data

The image taken by CCD Stereo Camera. This is a mosaic of 19 raw images 57° -83° E, 54° -70° S

Nearside of the Moon
Clementine 750 nm Image
### Part One: Laser Altimeter

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength:</td>
<td>1064 nm</td>
</tr>
<tr>
<td>Pulse Power:</td>
<td>150mJ</td>
</tr>
<tr>
<td>Pulse Frequency:</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Pulse Width:</td>
<td>&lt; 7nm</td>
</tr>
<tr>
<td>Pulse Divergence:</td>
<td>500 microrad</td>
</tr>
<tr>
<td>Vertical Resolution:</td>
<td>5 m</td>
</tr>
<tr>
<td>Range:</td>
<td>175-225 km</td>
</tr>
<tr>
<td>Field of View:</td>
<td>1500 microrad</td>
</tr>
<tr>
<td>Footprint:</td>
<td>100 m</td>
</tr>
</tbody>
</table>
Part One: Laser Altimeter Data

Distance (meter)

Count
Part One: Interferometer Spectrometer

Interferometer Spectrometer

Wavelength Range: 0.48-0.96 μm
Band Number: 32
Spatial Resolution: 200 m/pixel
Swath: 25.6 km
Part One: Interferometer Spectrometer Data

Band 4: 500-509 nm
Band 17: 635-651 nm
Band 30: 878-904 nm

Fig. 1 Interference Diagram for the Line 1 in the right image: 128 samples
Fig. 2 Interference Curve at the sample 65
Fig. 3 Spectrum at the sample 65

Time: 04:54:27-04:56:10 Nov. 27th
Location: 21°W, 50°N-55°N
Range: 25.6 km x 150 km
Part One: Gamma Ray Spectrometer

Gamma-Ray Spectrometer

Detector: CsI(Tl)
Energy Range: 0.3-9 MeV
Energy Resolution: 8% FWHM @ 662 keV
Spatial Resolution: 170 km x 170 km
Part One: Gamma-Ray Spectrometer Data

Real Time Data

Accumulated Photon Counts for 44 hours and 44 minutes
Frame Number: 53780
Counting Rate: 3 second/spectrum
Channel Number: 512
X axis: Channel Number
Y axis: Photon Counts
Part One: X-Ray Spectrometer

X-ray Spectrometer
Energy Range: 0.5-60 keV
Energy Resolution: 160 eV @ 5.9 keV for 0.5-10 keV
9% @ 59 keV for 10-60 keV
Spatial Resolution: 10 km
Part One: X-Ray Spectrometer Data

Upper-left: 0.5-10 keV detector
Upper-right: 10-60 keV detector
X axis: channel number
Y axis: counts
Accumulated Time: 44 hours 49 minutes
### Part One: Microwave Radiometer

<table>
<thead>
<tr>
<th>Frequencies</th>
<th>3, 7.8, 19.35, 37 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidths</td>
<td>100, 200, 500, 500 MHz</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>56km for 3 GHz, 30 km for others</td>
</tr>
<tr>
<td>Temperature Resolution</td>
<td>0.5 K</td>
</tr>
</tbody>
</table>
Part One: Microwave Radiometer Data

![Graph of Microwave Radiometer Data](image)

- **3.7GHz**
- **7.8GHz**
- **19.35GHz**
- **37GHz**

Time:

- 2007-11-30T03:57:02.007Z
- 2007-11-30T04:56:57.998Z
- 2007-11-30T05:59:52.788Z
Part One: Calibration and Validation for Chang'E 1 Instruments

Datasets that can be used for calibration/validation:

- Remote sensing data from former lunar missions: Lunar Orbiter, Apollo missions, Clementine, Lunar Prospector and Smart 1.
- Data from ongoing missions for cross-calibration, such as KAGUYA and Chang'E 1.
- Earth-based telescopic observations.
- Ground-truth: Apollo and Luna samples, lunar meteorites.

Several datasets for Apollo 16 site are collected for Chang'E1 calibration/validation.
Part One: Apollo 16 site

Apollo 16 Landing Site (9°S, 15.5°E)
1. Central nearside lunar highlands
2. Smooth Cayley Plains lies among hilly areas

Lunar Orbiter Image -IV89H3
Part One: Apollo 16 Site

1. Apollo 16 lies between two bright small craters
2. Cayley Plains are covered by dark, uniform material

Clementine false color image
Red = 1000 nm
Green = 750 nm
Blue = 415 nm
1. The Cayley Plains are very mature and uniform
2. Two small fresh craters are near the landing site.

Clementine ratio image
Red    = 750/415 nm
Green  = 750/950 nm
Blue   = 415/750 nm
Part One: Apollo 16 Site-FeO Map

FeO map derived from Clementine UVVIS data. This map is overlaid on the Clementine 750 nm basemap.

Cayley Plains have a low uniform FeO concentration, about 6-8 WT%.

FeO map derived from Lunar Prospector Gamma-Ray Spectrometer. This map is overlaid on the Clementine 750 nm basemap.
Part One: Apollo 16 Site-Thorium Map

Low thorium concentrations:
~3 ppm in Cayley Plains

Lunar Prospector Gamma-Ray Thorium Map overlaid on Clementine 750 nm basemap
Sampled to the same resolution.
1. Apollo 16 site, especially the Cayley Plains, is relatively uniform in terms of composition and maturity.

2. This site is low in FeO (< 8 WT.%) and relatively low in thorium (about 3 ppm). The Apollo 16 landing site is considered the only true highland landing site of the Apollo program. However, the thorium concentrations argue against that it is a “typical highland (Th < 2 ppm).
The spectra of Apollo 16 62231 soil provide the ground-truth for the calibrations of UV-VIS-NIR data.

UV-VIS-NIR spectra of Apollo 16 62231 soil
Chang'E1 mission will provide information for Chang'E2 rover which is scheduled for launch around 2012.

Five potential landing sites were proposed for Chang'E2 rover.

Here we propose Aristarchus region as a lunar outpost for its high science value.

Nearsiden of the Moon. Blue shows potential sites for Chang'E2 Rover
Part Two: Rationale for selecting Outpost

- Science: mare-highland boundary
- Space transportation and communication: polar, equatorial, mid-latitudes on the nearside
- Safety: large flat areas
Part Two: Aristarchus Region

Clementine False Color Image of Aristarchus Region

1. Aristarchus
2. Lichtenberg
3. Gruithuisen Domes
Part Two: Aristarchus Crater and Plateau

Aristarchus Plateau is mantled by pyroclastic deposits which may be the resources for O, Fe and Ti.
Part Two: Aristarchus Crater and Plateau

Lunar Prospector Gamma Ray Spectrometer Thorium Map overlaid on Clementine color image, normalized to the same resolution as FeO map.

FeO map derived from Clementine UVVIS
Part Two: Aristarchus Crater and Plateau

Material excavated by Aristarchus Crater might be mixed with mare basalts.

In Thorium-FeO correlation plot, Aristarchus Crater lies on the red correlation line. If we assume an end-member containing 10% FeO, Thorium in this end-member is 28 ppm, maybe monzongabbro or granite/felsite -- Rare
Bright ejecta and ray system indicate a young age of the crater. The south and east parts of ejecta are flooded by the even younger mare basalt. It has an estimated age of 1.68 Ga, among the youngest mare basalts.
Gruithuisen Domes are red spots featured by high albedo and strong absorption in visible bands, which is not found in lunar sample. The domes are thought to be constructed by silicic non-mare volcanism—Only indicated here.
The silicic materials are rare in lunar sample and appear as small fragments of granite/felsite which are extremely rich in Th, between 10 and 66 ppm.

However, remote sensing data show that Th concentrations of Gruithuisen Domes are only between 7 and 9 ppm.

Small features may have high Th concentrations
Conclusions: Part I

1. Calibration and validation of Chang'E 1 data provide accurate information for Chang'E rover missions.

2. A variety of datasets for Apollo 16 sites can be used in the calibration of Chang'E 1 data.

3. Since Apollo 16 site is relatively uniform, it is an ideal site for calibration and validation.
We believe that Aristarchus Region is a good lunar outpost for the following reasons:

1. Aristarchus Crater exposed most evolved rock types, maybe monzogabbro or granite/felsite.
2. Pyroclastic deposit on Aristarchus Plateau and mare basalts around the Plateau may be potential resource for O, Fe and Ti.
3. Dating the young (one of the youngest) mare basalts near Lichtenberg Crater is important for understanding lunar thermal history.
4. Volcanic domes consist of spectrally and chemically unknown material.
5. There are relatively large, flat maria in this region.

Conclusions: Part II
Future Work

1. Calibration and validation for the Chang'E1 Interferometer Spectrometer data using telescopic data and spectral data of lunar samples.

2. Possible heat flow measurement by the Microwave Radiometer. Heat flow is related to the concentrations of heat-producing elements in the underlying lunar crust and mantle. Only two in situ measurements were conducted: Apollo 15 and 17 sites. Earth-based observations of lunar microwave radiation only gave average heat flow. Microwave Radiometer has four frequencies to measure the temperatures at the depths of 1, 10, 20 and 30 m with spatial resolutions from 30 km to 50 km. It may give regional heat flows for the whole Moon.

3. Improvement on the spatial resolution of Th map in Aristarchus crater and Gruithuisen Domes.