GEOMETRIC CALIBRATION OF THE CLEMENTINE UVVIS CAMERA

E. J. Speyerer, R. V. Wagner, M. S. Robinson, V. Silva
Arizona State University
Clementine Mission

- Launched: 25 January 1994
- Lunar orbit: 73 Days
- Altitude: ~425 km periselene
- Six Cameras:
  - Ultraviolet/Visible (UVVIS)
  - Near-Infrared (NIR)
  - Long-Wave Infrared (LWIR)
  - High-Resolution (HIRES)
  - Two Star Trackers (ST)
# Clementine UVVIS Camera

## Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UVVIS</th>
</tr>
</thead>
</table>
| Spectral filters                | a: 415 ± 20 nm  
b: 750 ± 5 nm  
c: 900 ± 10 nm  
d: 950 ± 15 nm  
e: 1000 ± 15 nm  
f: 400 – 1000 nm|
| Focal length                    | 90.15 mm                           |
| Pixel size                      | 0.023 mm                           |
| Ground sampling distance*       | 115 m                              |
| Field of view                   | 5.6° x 4.2°                        |
Objective

- The Clementine UVVIS camera captured nearly 600k images of the Moon
- Improve the mapping precision by deriving the interior and exterior orientation parameters for the entire UVVIS dataset
Previous UVVIS Control Networks

- **Clementine Lunar Control Network** *(Edwards, et al., 1996)*
  - 44,750 images (750 nm band)
  - No shape model

- **Unified Lunar Control Network 2005** *(Archinal et al., 2006)*
  - Combined the Clementine control network with a previous network derived from Apollo, Mariner 10, Galileo, and Earth-based observations
  - Solved for the radii of the control points

- Derived UVVIS/NIR products have since been **warped** to the ULCN 2005
Since Clementine...

LRO has provided:

- Accurate lunar topography (WAC/LOLA)
- Precise knowledge of the location of lunar features
  - LRO ephemeris derived using GRAIL gravity models
  - Geometric calibration of LROC NAC/WAC images
ULCN2005 vs. LRO Coordinates

Frequency

Planimetric offset in km (ULCN 2005 vs. LOLA)
Updating the UVVIS Geometry

- **Interior Orientation (IO) Parameters**
  - Focal Length
  - Optical Distortion (if any)
  - Wavelength dependent parameters (if any)

- **Exterior Orientation (EO) Parameters**
  - Mounting angles relative to spacecraft
  - Pointing of instrument (per image)
Updating the Clementine UVVIS Geometry

Find Image Pairs
Locate WAC images with similar lighting

Pre-Process Images
Calibrate and apply a photometric correction

Match Features
Register the image pairs with automated feature matching

lua2293f.102
M123397685C
Updating the Clementine UVVIS Geometry

Find Image Pairs
Locate WAC images with similar lighting

Pre-Process Images
Calibrate and apply a photometric correction

Match Features
Register the image pairs with automated feature matching

lua2293f.102  M123397685C
Updating the Clementine UVVIS Geometry

**Find Image Pairs**
Locate WAC images with similar lighting

**Pre-Process Images**
Calibrate and apply a photometric correction

**Match Features**
Register the image pairs with automated feature matching

- Apply feature based matching (`findfeatures`) to locate common features in the image pairs
- Conduct sub-pixel registration of each matched feature (`pointreg`)
- Retrieve focal plane coordinates for each successful match (`fplanemap`)

Red = WAC Image
Cyan = UVVIS Image
 Updating the Clementine UVVIS Geometry

- Boresight Adjustment
  - $x_{obs}, y_{obs}$
- Optical Distortion Adjustment
  - $k_2, P_1, P_2$
- Exterior Orientation Adjustment
  - $(\text{Lat}, \text{Lon}, R)_{wac}$
  - $\delta \varphi, \delta \omega, \delta \kappa$
- Focal Length Adjustment
  - $f_l$
- Error Analysis
- Model Optimization
-derived the IO for each Clementine UVVIS band:
- Effective focal length, \( f_l \)
- Radial distortion coefficient, \( k_2 \)
- Tangential distortion coeff., \( P_1 \) & \( P_2 \)

\[
\begin{align*}
    x_d &= x_u \left(1 + k_2 r^2 \right) + P_2 \left( r^2 + 2x_u^2 \right) + 2P_1 x_u y_u \\
    y_d &= y_u \left(1 + k_2 r^2 \right) + P_1 \left( r^2 + 2y_u^2 \right) + 2P_2 x_u y_u
\end{align*}
\]

Radial dist.  Tangential distortion

Distortion map of 750 nm band
- \( f_l = 89.97 \) mm
- \( k_2 = +4.16e-5 \)
- \( P_1 = -2.47e-5 \)
- \( P_2 = +3.99e-5 \)
Exterior Orientation (EO) Correction

- Horizontal offsets between mapped UVVIS and WAC images can be corrected with:

  - SPK adjustment
  - CK adjustment
  and/or

![Graph showing the relationship between image offset and altitude](image-url)
This Work

Original Spice -> Registered to LRO

Planimetric displacement, km
Comparing CK adjustments

ULCN 2005

This Work

Displacement from CK adjustment, km

Count

ULCN 2005

This Work

Displacement from CK adjustment, km

Count
Current Status

- Solved the interior orientation parameters for each band
  - New IK with radial and decentering distortion
- Built an automated image registration pipeline to update the camera orientation (CK) for each UVVIS image
- Producing updated CKs with the original Clementine SPKs

Future work:
- Generate updated CKs with updated SPKs (E. Mazarico)
- Publish new kernels and ISIS camera model
- Create registered multispectral maps, OMAT, and mineral maps
Questions