Multi-Spectral Vision Processing
For the ExoMars 2018 Mission

Dave Barnes, Martin Wilding, Matt Gunn, Stephen Pugh, Laurence Tyler – Aberystwyth University, UK
Andrew Coates, Andrew Griffiths, Claire Cousins – UCL, UK
Nicole Schmitz – DLR, Gemany
Arnold Bauer, Gerhard Paar – Joanneum Research, Austria

UK Work Funded by UK Space Agency with contributions from EU FP7 PRoVisG and PRoViScout projects
ESA ExoMars Rover: Phase-B2X Design Launch 2018

(Credit ESA & EADS Astrium)
Why Do We Need A Calibration Target?

• The PanCam Calibration Target (PCT) is an essential component for the science operations of the PanCam instrument.

• Its purpose is to allow both radiometric and geometric calibration of the PanCam instrument whilst operating on the surface of Mars.

• Science target spectra can be generated (e.g. for rock mineralogy), if the returned WAC images are radiometrically corrected. A key element within this process involves measuring the reflectance of the individual grey and coloured calibration targets on Mars, and comparing these values with pre-flight laboratory measured data.

• The radiometrically corrected filtered images for those wavelengths within the human visible light region can be used to create ‘true-colour’ image products of the Martian surface; i.e. if a human stood on the Martian surface, then they would perceive the same colours as those exhibited by the generated PanCam image.
Past and Current Mars Calibration Targets

- NASA VL2 1976
- NASA Pathfinder 1997
- ESA Beagle 2 2003
- NASA Phoenix Lander 2008
PanCam Calibration Target (PCT) CAD Model

Width = 50 mm
Depth = 50 mm
Height = 16 mm
4 x M3 Bolts

Stained glass calibration targets
Good for Planetary Protection
Will not ‘bleach’ under UV irradiation
All Greys and RGBY targets are made from stained, radiation hard (Soda-Lime-Silica + Cerium) glass wafers
Early Prototype Model and Early Fabricated Glass Targets

Early PCT prototype with Macbeth colour checker targets. Note top retaining plate inverted.

Early version of top retaining plate with test glass target wafers. Target homogeneity under investigation.
Calibration Target Radiometric Characterisation

AU Integrating Sphere, Spectrometers, Uniform L.S., NIST Certified Calibration Standards etc.

AU BRDF Gonioreflectometer
Prototype Glass Target Relative Reflectance Data
(untreated sawn top surface used with ‘tin-foil’ against bottom surface!)

Stained Glass
Reflective Al coating
Top surface
Glass layer
Bottom reflective surface

Early results very encouraging
Scope for improvement

BS(surface)S(cattering)RDF model required
Current PCT Mass Budget  = 20 g + 20% contingency

Current PCT Mass Estimates:

<table>
<thead>
<tr>
<th>PCT Component</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shadow post × 3 (Al)</td>
<td>0.651</td>
</tr>
<tr>
<td>Retaining plate (Ti)</td>
<td>5.6</td>
</tr>
<tr>
<td>Calibration targets (glass)</td>
<td>5.958</td>
</tr>
<tr>
<td>Base plate (Ti)</td>
<td>11.797</td>
</tr>
<tr>
<td>Mounting pads (Al)</td>
<td>0.894</td>
</tr>
<tr>
<td>PCT TOTAL MASS (g)</td>
<td>24.9</td>
</tr>
</tbody>
</table>

Current design NOT mass optimised
PCT and 3 × Fiducial Markers mounted on rover deck – Preferred Option
PanCam Simulated Camera Views of the PCT

Left WAC  
HRC  
Right WAC

PCT Square Pixel Sample Areas Checked
AU PanCam Emulator (AUPE)

Right WAC

Left WAC

HRC

Lightweight optical bench

Filter wheel

Pan/tilt unit

Mount

Filter wheel detail showing servo

Monochromatic COTS Cameras
## AUPE Filters

### LEFT FILTER WHEEL

<table>
<thead>
<tr>
<th>Filter</th>
<th>Centre nm</th>
<th>Width</th>
<th>Camera sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Blue</td>
<td>460</td>
<td>~100</td>
<td>~0.85</td>
</tr>
<tr>
<td>2) Green</td>
<td>550</td>
<td>~100</td>
<td>~0.94</td>
</tr>
<tr>
<td>3) Red</td>
<td>660</td>
<td>~100</td>
<td>~0.62</td>
</tr>
<tr>
<td>4) Geol1</td>
<td>440</td>
<td>10</td>
<td>0.76</td>
</tr>
<tr>
<td>5) Geol2</td>
<td>470</td>
<td>10</td>
<td>0.89</td>
</tr>
<tr>
<td>6) Geol3</td>
<td>510</td>
<td>10</td>
<td>1.00</td>
</tr>
<tr>
<td>7) Geol4</td>
<td>560</td>
<td>10</td>
<td>0.92</td>
</tr>
<tr>
<td>8) Geol5</td>
<td>600</td>
<td>10</td>
<td>0.79</td>
</tr>
<tr>
<td>9) Geol6</td>
<td>660</td>
<td>10</td>
<td>0.62</td>
</tr>
</tbody>
</table>

### RIGHT FILTER WHEEL

<table>
<thead>
<tr>
<th>Filter</th>
<th>Centre nm</th>
<th>Width</th>
<th>Camera sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Blue</td>
<td>460</td>
<td>~100</td>
<td>~0.85</td>
</tr>
<tr>
<td>2) Green</td>
<td>550</td>
<td>~100</td>
<td>~0.94</td>
</tr>
<tr>
<td>3) Red</td>
<td>660</td>
<td>~100</td>
<td>~0.62</td>
</tr>
<tr>
<td>4) Geol7</td>
<td>720</td>
<td>10</td>
<td>0.49</td>
</tr>
<tr>
<td>5) Geol8</td>
<td>760</td>
<td>10</td>
<td>0.38</td>
</tr>
<tr>
<td>6) Geol9</td>
<td>830</td>
<td>10</td>
<td>0.26</td>
</tr>
<tr>
<td>7) Geol10</td>
<td>880</td>
<td>10</td>
<td>0.16</td>
</tr>
<tr>
<td>8) Geol11</td>
<td>950</td>
<td>10</td>
<td>0.08</td>
</tr>
<tr>
<td>9) Geol12</td>
<td>1000</td>
<td>10</td>
<td>0.04</td>
</tr>
</tbody>
</table>

PanCam will fly 11 × filters on each WAC
AUPE and PCT Field Trial Equipment
Bridget the rover traversing northwards at Clarach Bay (July 2010)
Bridget traversing southwards spots an interesting target
AUPE and PCT Field Trials – Clarach Bay, UK

Bridget on her way back to the ‘mission control centre’
AUPE and PCT Field Trials

Field Trials with the AU Idris Rover at Clarach and Ynyslas
Baseline Radiometric Image Processing Pipeline Developed

- raw image data
- compress
- ESA PSA PDS format
- flats/darks (temp,exp)
- uncompress
- flat/dark correction
- camera response correction
- PCT BRDF data
- relative reflectance
- CIE XYZ
- CIE XYZ to sRGB etc
- PanCam image
- R* data
- CIE XYZ data
- reflectance ROI select
- PanCam spectrum
- ESA PSA PDS format

Surface Operations

SOC Operations

Mathcad
Java
LabVIEW

camera radiometric correction
pixel → spectral radiance
\( W \cdot sr^{-1} \cdot m^{-2} \cdot nm^{-1} \)
Generating Rock Spectra AMASE 2009, BOCK01 Site using PCT test target

(Artic Mars Analogue Svalbard Expedition – AMASE)
Baseline Radiometric Image Processing Pipeline Developed

- Raw image data
- Compress
- ESA PSA PDS format
- Flats/darks (temp, exp)
- Uncompress
- Flat/dark correction
- Camera response correction
- Camera radiometric correction
  - Pixel $\rightarrow$ spectral radiance ($W \cdot sr^{-1} \cdot m^{-2} \cdot nm^{-1}$)
- Relative reflectance
- CIE XYZ data
- ROI select
- Reflectance
- PanCam spectrum
- PanCam image
- ESA PSA PDS format
- CIE XYZ to sRGB etc

Surface Operations

SOC Operations
AMASE 2009, Bock01

Colour images generated from ‘raw’ uncorrected broadband (100 nm) RGB Filters

Left WAC

Right WAC
Svalbard, Bock01, 2009

Image True Colour Correction

Narrow-band (10 nm) filtered input images

Output colour corrected image in sRGB format
Clarach Bay, March 2010

Colour images generated from ‘raw’ uncorrected broadband (100 nm) RGB Filters

Left WAC

Right WAC
Clarach Bay 2010

Image True Colour Correction

Narrow-band (10 nm) filtered input images

Output colour corrected image in sRGB format
Conclusion

- The PanCam Calibration Target (PCT) has been designed
- Early stained glass wafers manufactured
- Preliminary radiometric characterisation looks very encouraging
- Baseline radiometric and colourimetric image processing pipeline developed in Mathcad and ported to Java and LabVIEW
- Early PCT field trials conducted at Clarach Bay and Ynyslas (UK) and for AMASE
- STM PCT being fabricated for ΔPDR later this year
- Plan to perform preliminary thermal cycle and vibration tests prior to ΔPDR
- Radiometric and colourimetric image processing pipeline will continue to be developed