CubeSat Camera – ‘CCAM’: A Low Cost Imaging System for CubeSat Platforms

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What is CCAM?

- UKATC and RAL Space collaboration - UKRI
- Modular
- Low cost
- Optics module and detector module
- 1.5U
- 5m GSD at 400km Earth orbital height = (2.58 arcsec)
- 2K x 2K detector
- 2° field of view
- 1-2 year lifetime in Low Earth Orbit
CCAM Design Drivers

- Off-the-shelf components
- Compatibility with a 3 U CubeSat bus
- RGGB Bayer pattern off-the-shelf CMOS detector and FPGA FPU design
- Single aperture OT system mounted in the long axis of a 3U CubeSat
- Image quality – NIIRS (National Image Interpretability Rating Scale) of level 2 [1]
CCAM Uses

- CCAM is ‘off the shelf’ – Quicker and cheaper to launch
- Typical EO applications
- Interplanetary observations: geological activity, meteoroid environments, weather systems or landscape mapping

Shandong Peninsula in Eastern China taken by Landsat 8 [2]

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CCAM Detector Module

- 2048 x 2048 CMOS sensor
- FPGA for module control
- Memory included for buffering between FPU and OBC

- Uses regulated 3V3 and unregulated 6V lines from CubeSat
- All other voltages generated internally by low noise regulators
- No more than 2A will be drawn from a single line
- Overall power consumption around 6W

- 2/3fps frame rate
- Blur minimised through 500µs exposures
- A selection of power modes allow easy enabling/disabling of components for maximum performance or power saving
- Utilises passive thermal control
CCAM Optics Module - Design

Secondary mirror
Baffling
Field corrector
Primary mirror

Focal plane
NIR filter

50 mm
CCAM Optics Module - Performance

- Diffraction limited RMS spot size across visible and NIR wavelength range
- Pixel size for the CMOS sensor is 5.5μm
- RMS wavefront error is diffraction limited across full field of view

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CCAM Optomechanics

- 3-point kinematic mount connecting modules – preserving optical alignment
- Can mount to numerous cubesat structures
- Passive thermal compensation features: $-20^\circ C < T < +60^\circ C$
- Vibration dampeners to mitigate various launch load vibration effects
SNR Challenge

• SNR limited by:
  • Cubesat volume i.e. aperture size
  • CMOS sensor well capacity of $13500e^-$
    - limits dynamic range
  • Maximum possible exposure time
    $\sim500\mu s$ to avoid blur
  • Shot and readout noise
  • Dark current

• NIIRS level 2 achievable
SNR Challenge

- Possible solutions:
  - Image stacking
  - Longer exposure time
  - Or using deployable apertures – UKATC deployable cubesat:

Folded state

Deployed state

Current testing of UKATC deployable cubesat

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• Modular, low-cost imager for cubesat platforms
• Resilient to space and launch environments
• 3U or larger cubesats
• FPGA and CMOS sensor
• Diffraction limited reflective optics
• High resolution
• NIIRS level 2
Any Questions
References

[1] https://fas.org/irp/imint/niirs.htm - accessed 22/05/18


[3] https://fas.org/irp/imint/niirs_c/append.htm - accessed 24/05/18
Further details

- NIIRS level 2:
  - Identify large (i.e., greater than 160 acre) centre-pivot irrigated fields during the growing season.
  - Detect large buildings (e.g., hospitals, factories).
  - Identify road patterns, like clover leafs, on major highway systems.
  - Detect ice-breaker tracks.
  - Detect the wake from a large (e.g., greater than 300’) ship.