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

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29th-30th May 2018

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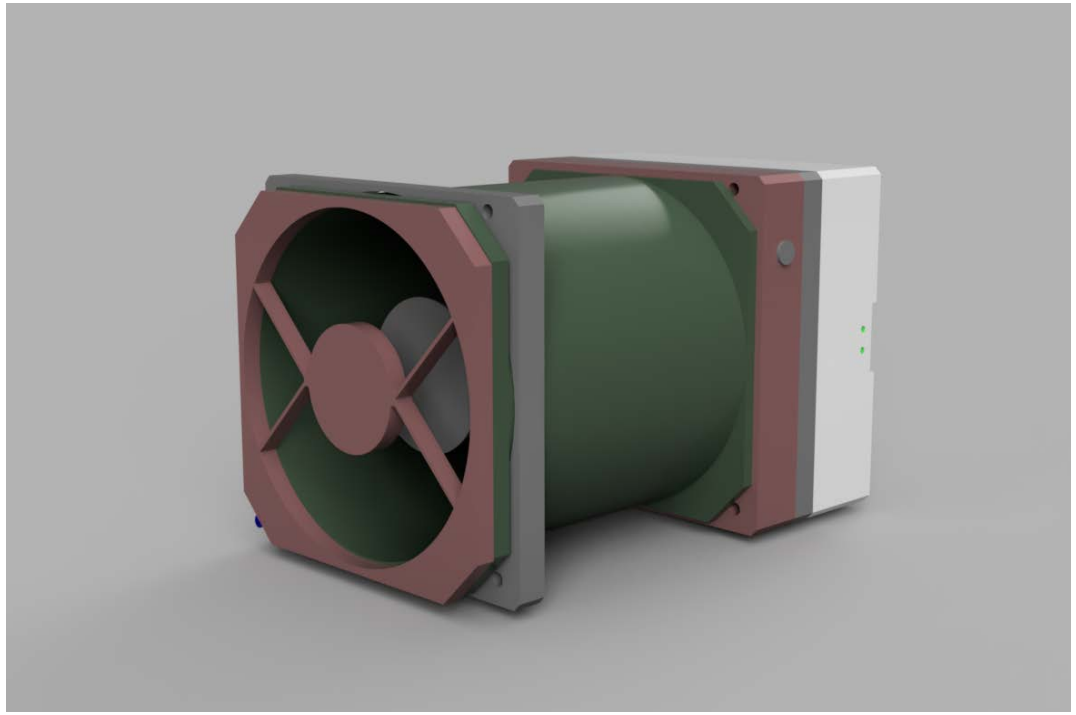
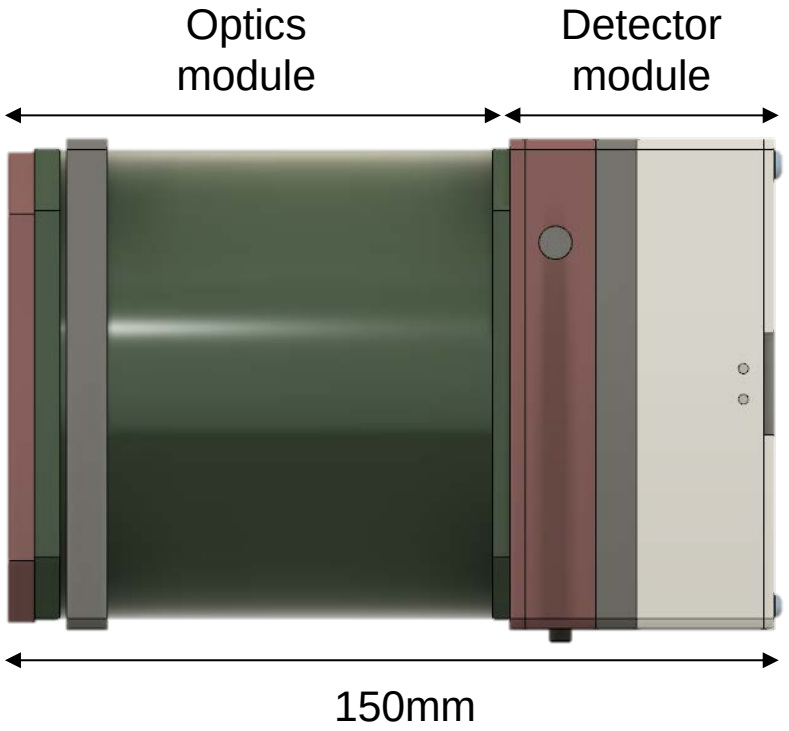


CCAM module

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
- 2º field of view
- 1-2 year lifetime in Low Earth Orbit



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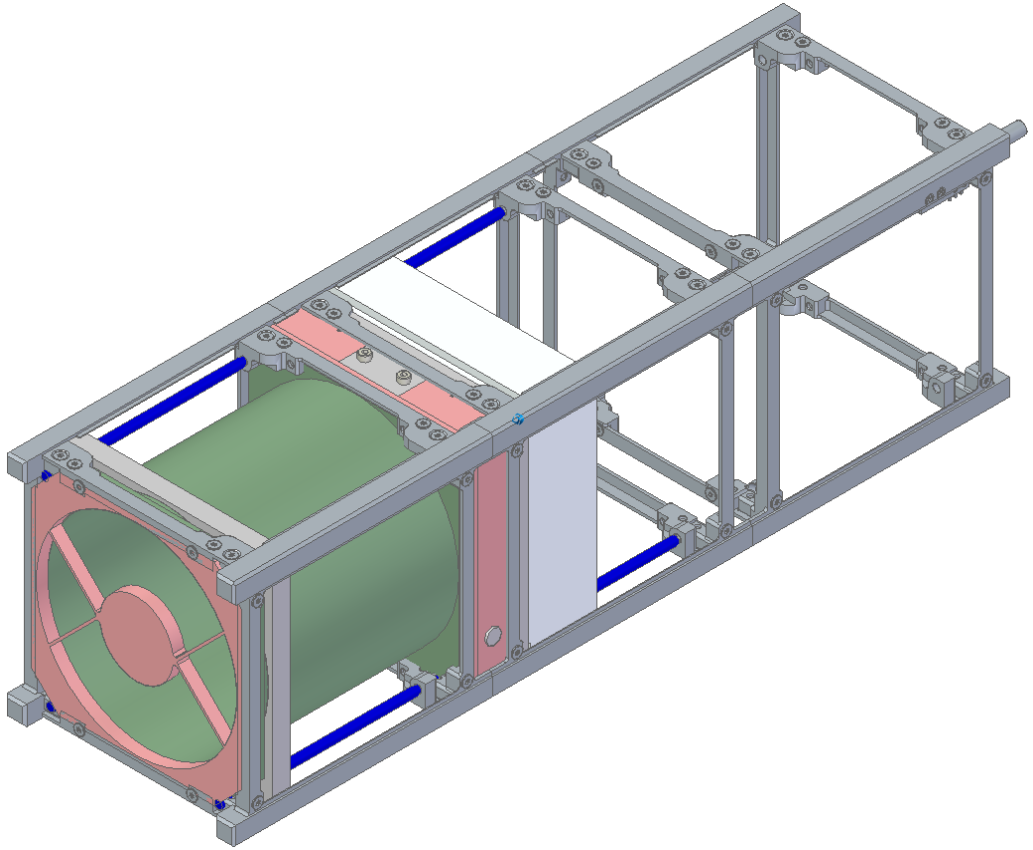
CCAM Design Drivers

- 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 integrated into 3U cubesat structure

CCAM Uses

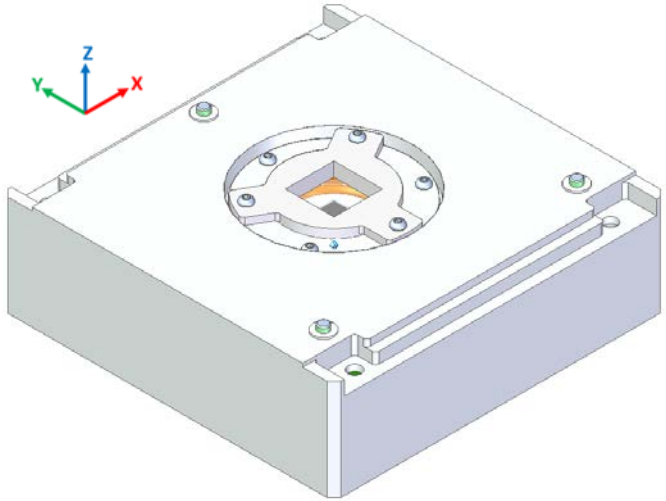
- CCAM is ‘off the shelf’ – Quicker and cheaper to launch
- Typical EO applications
- Interplanetary observations: geological activity, meteoroid environments, weather systems or landscape mapping

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

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



CCAM detector module

- 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

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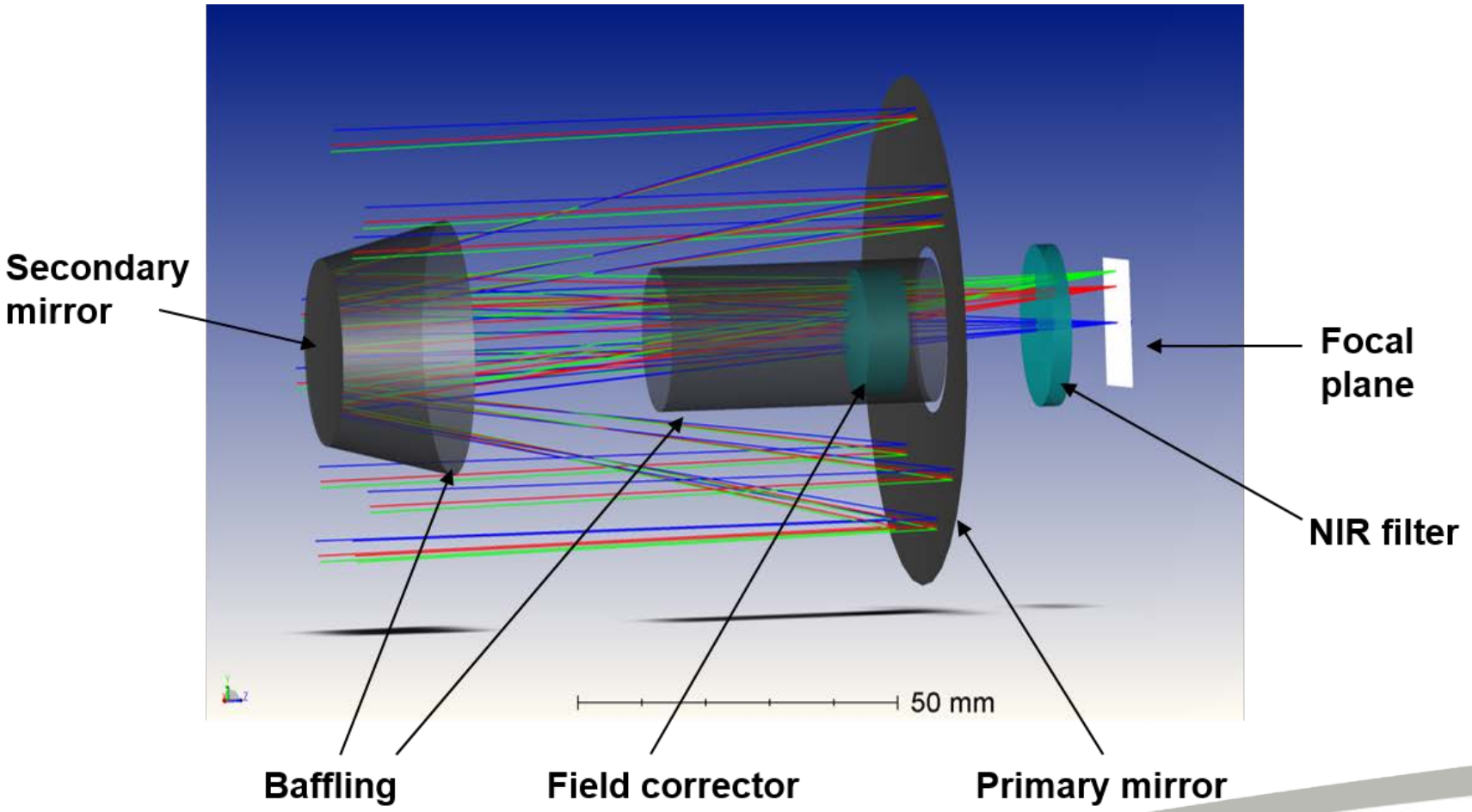
CCAM Optics Module - Design



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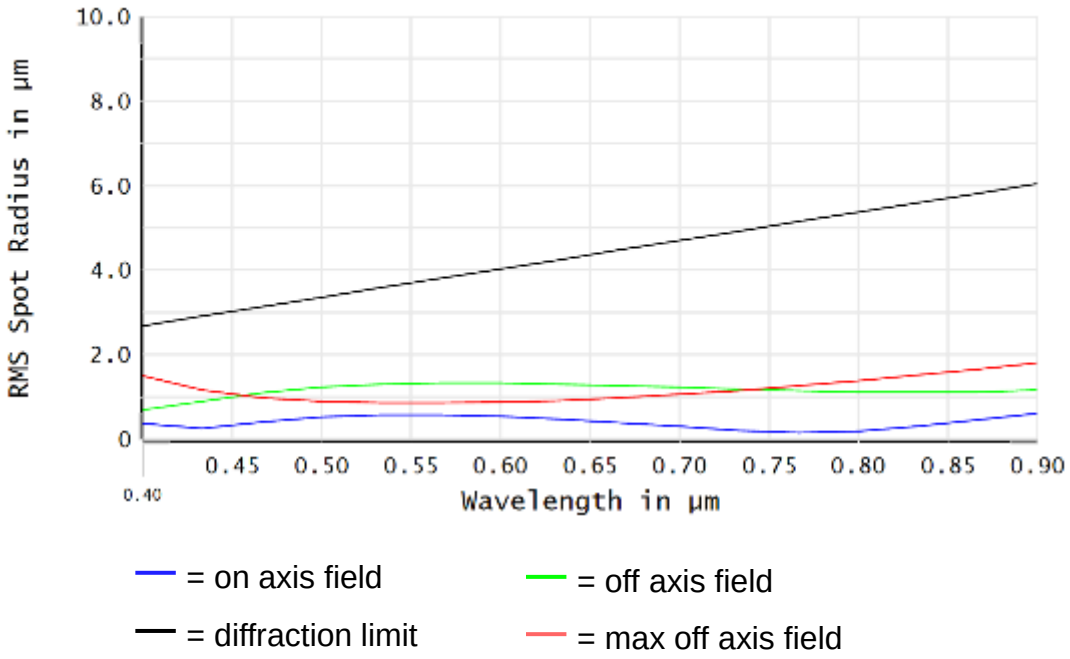
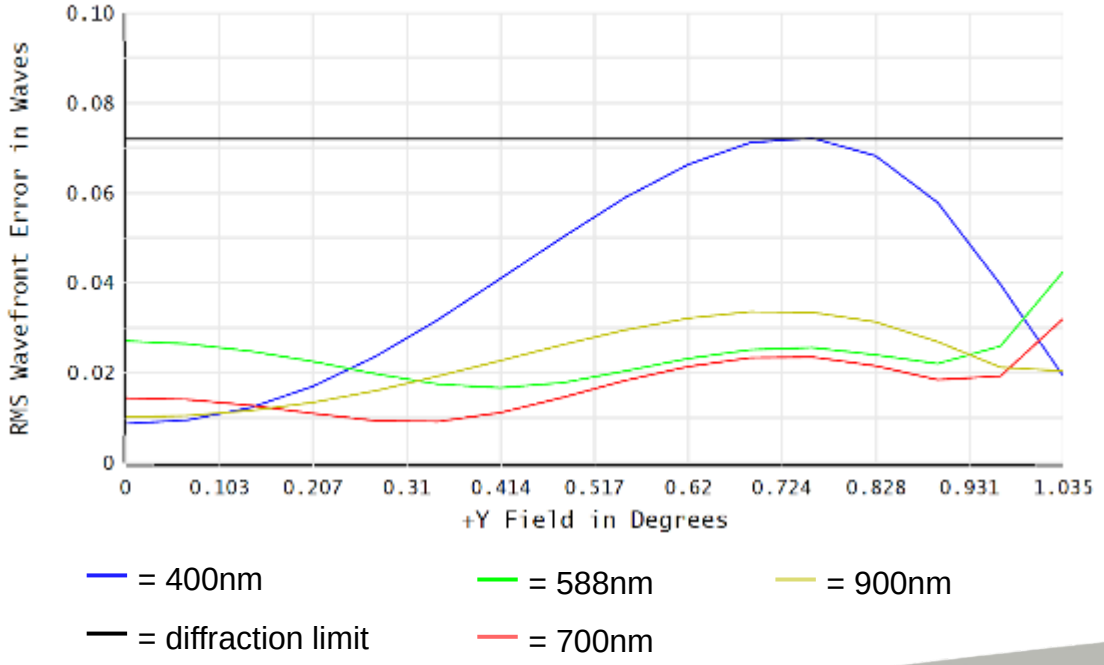
CCAM Optics Module - Performance

- 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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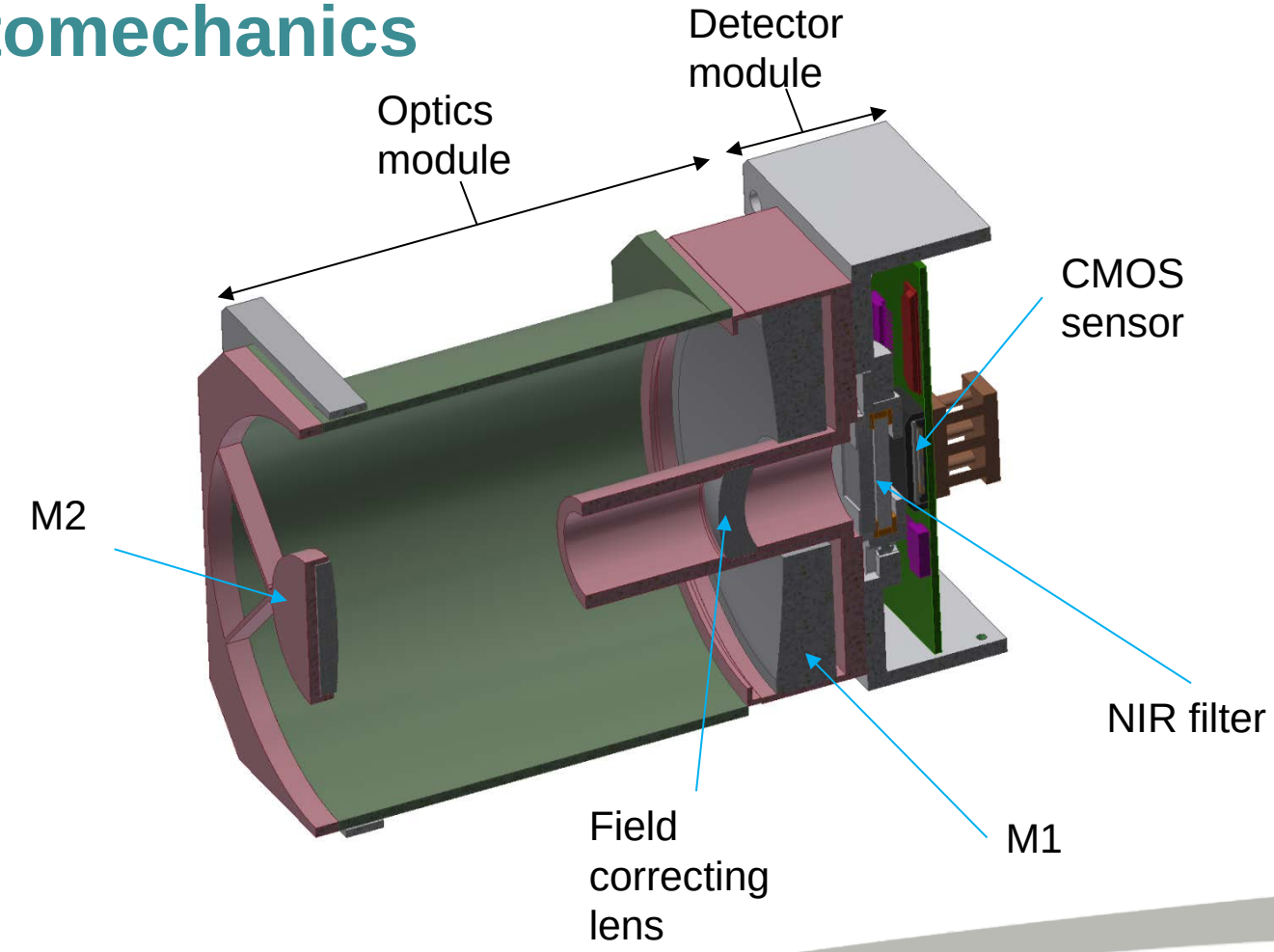
CCAM Optomechanics

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



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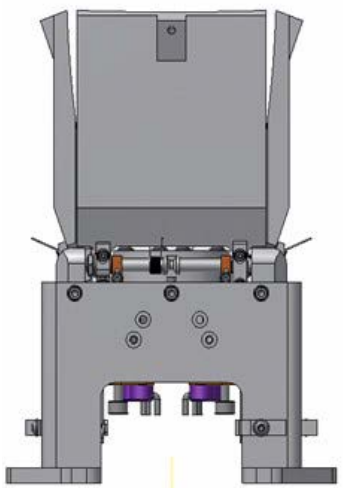
SNR Challenge

- SNR limited by:
  - Cubesat volume i.e. aperture size
  - CMOS sensor well capacity of 13500e^- - limits dynamic range
  - Maximum possible exposure time ~500μs to avoid blur
  - Shot and readout noise
  - Dark current
- NIIRS level 2 achievable

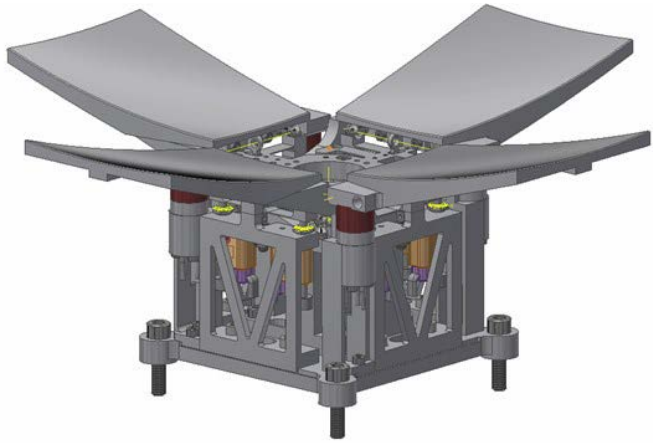
NIIRS level 2 reference image [3]

SNR Challenge

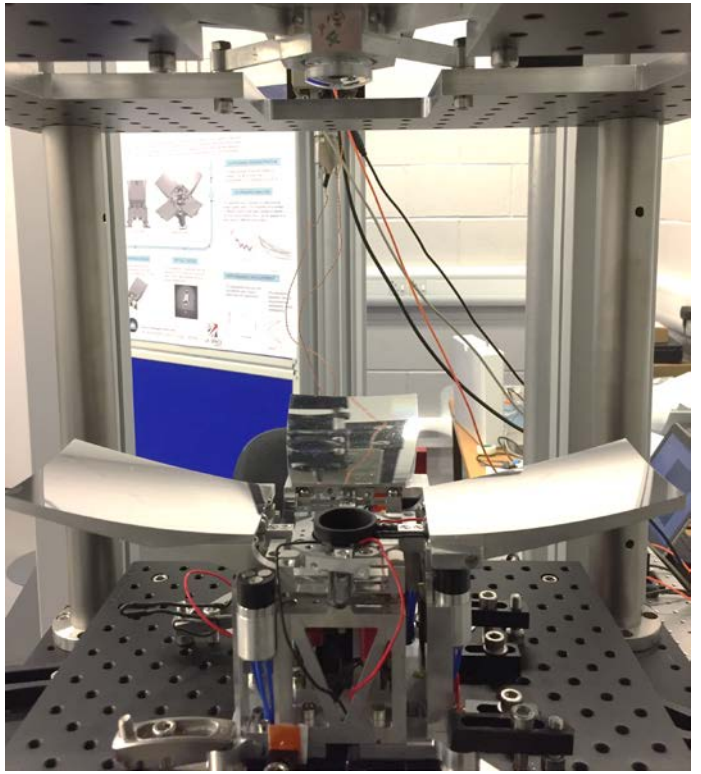
- Possible solutions:
  - Image stacking
  - Longer exposure time
  - Or using deployable apertures – UKATC deployable cubesat:



Folded state



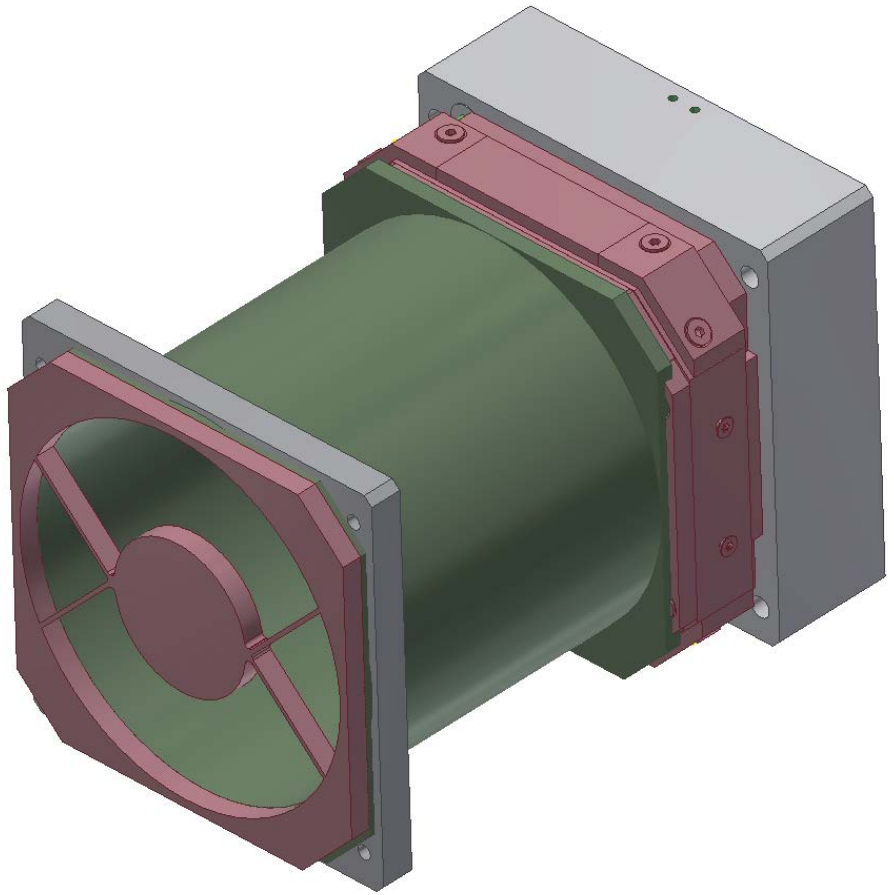
Deployed state



Current testing of UKATC deployable cubesat

Summary

- 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



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Any Questions

References

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

[2] https://earthobservatory.nasa.gov/IOTD/view.php?id=91195&src=ve - accessed 23/05/18

[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.