Evaluation of the performance of the CCD236 Swept Charge Device in lunar orbit using in-flight data

Mr Lawrence S. Jones, Dr Chiaki Crews, Dr James Endicott , Prof Andrew D. Holland

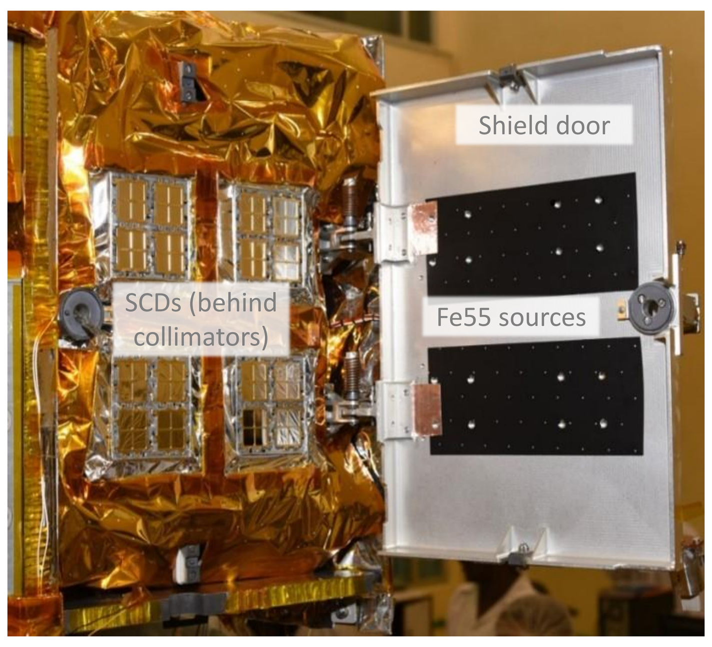
Centre for Electronic Imaging, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK, Email: *lawrence.jones@open.ac.uk*

Introduction and Background

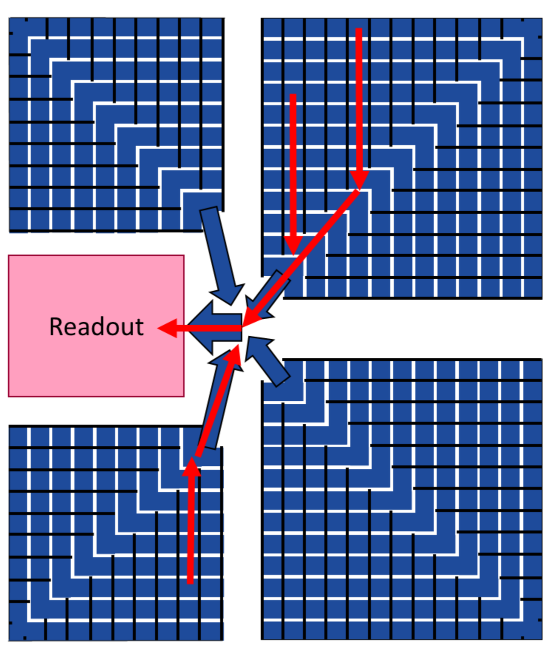
The Chandrayaan Large Area Soft X-ray Spectrometer (CLASS) was launched in 2019 to the Moon aboard Chandrayaan-2 to perform XRF mapping of the lunar surface.

The instrument consists of 16 Teledyne-e2v CCD236 Swept Charge Devices (SCD) and collimators defining a 7° × 7° (FWHM) field of view.

Previous work at the CEI has been used to demonstrate the effect of radiation damage on these sensors. Data that has recently been made available by the instrument operators has permitted the comparison of observed device behaviour with earlier predictions.



CLASS before launch, image credit: ISRO.



CCD236 schematic, with the transfer path of three example charge packets.

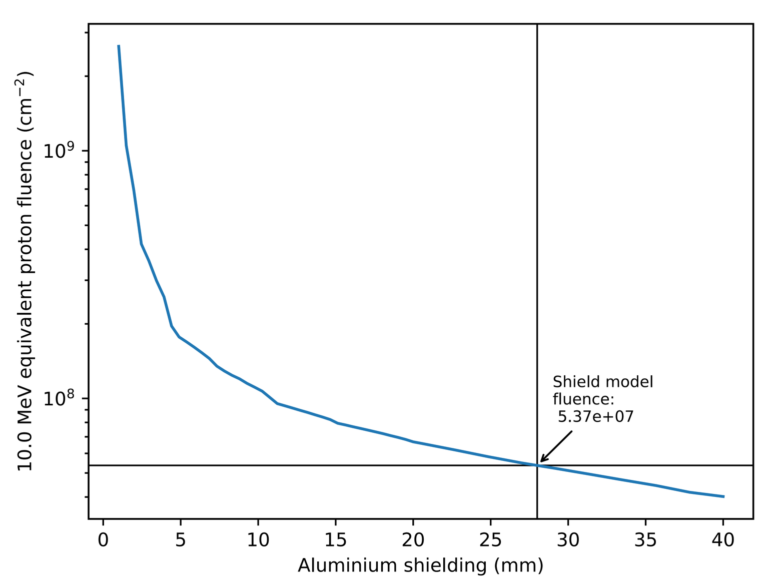
The CCD236 SCDs use an architecture developed from the more traditional CCD. SCDs permit the rapid collection of charge from a large area. When used with continuous readout the devices can be operated at -20 °C, warmer than required for a CCD.

The CCD236 includes channel shaping and modifications to its architecture that are intended to improve radiation hardness compared to earlier devices

The instrument is expected to have experienced radiation damage, with the total non-ionising dose to February 2021 dominated by trapped protons encountered during transit of the Van-Allen belts.

Prior work (Gow et. al. (2015)) established a possible linear relationship between radiation damage and SCD spectral resolution due to radiation induced noise.

SPENVIS has been used to predict the radiation dose experienced by the CLASS SCDS.



Predicted non-ionising dose (as 10 MeV equivalent fluence) for CLASS SCDs, calculated using SPENVIS.

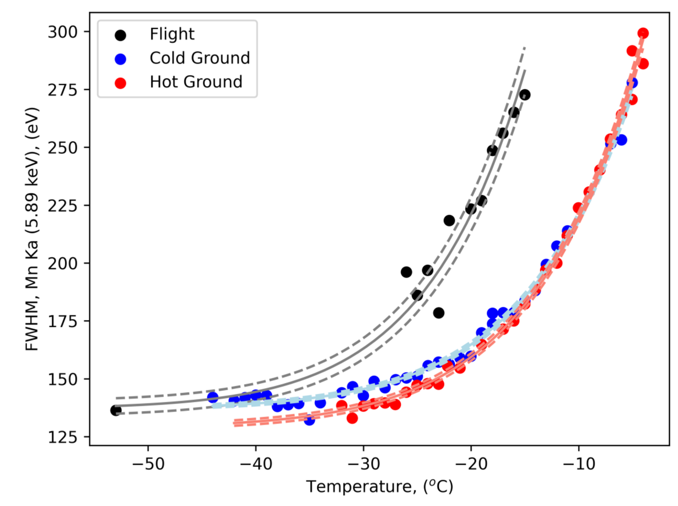
Data Processing

This work aimed to measure SCD performance changes and compare them to previous predictions.

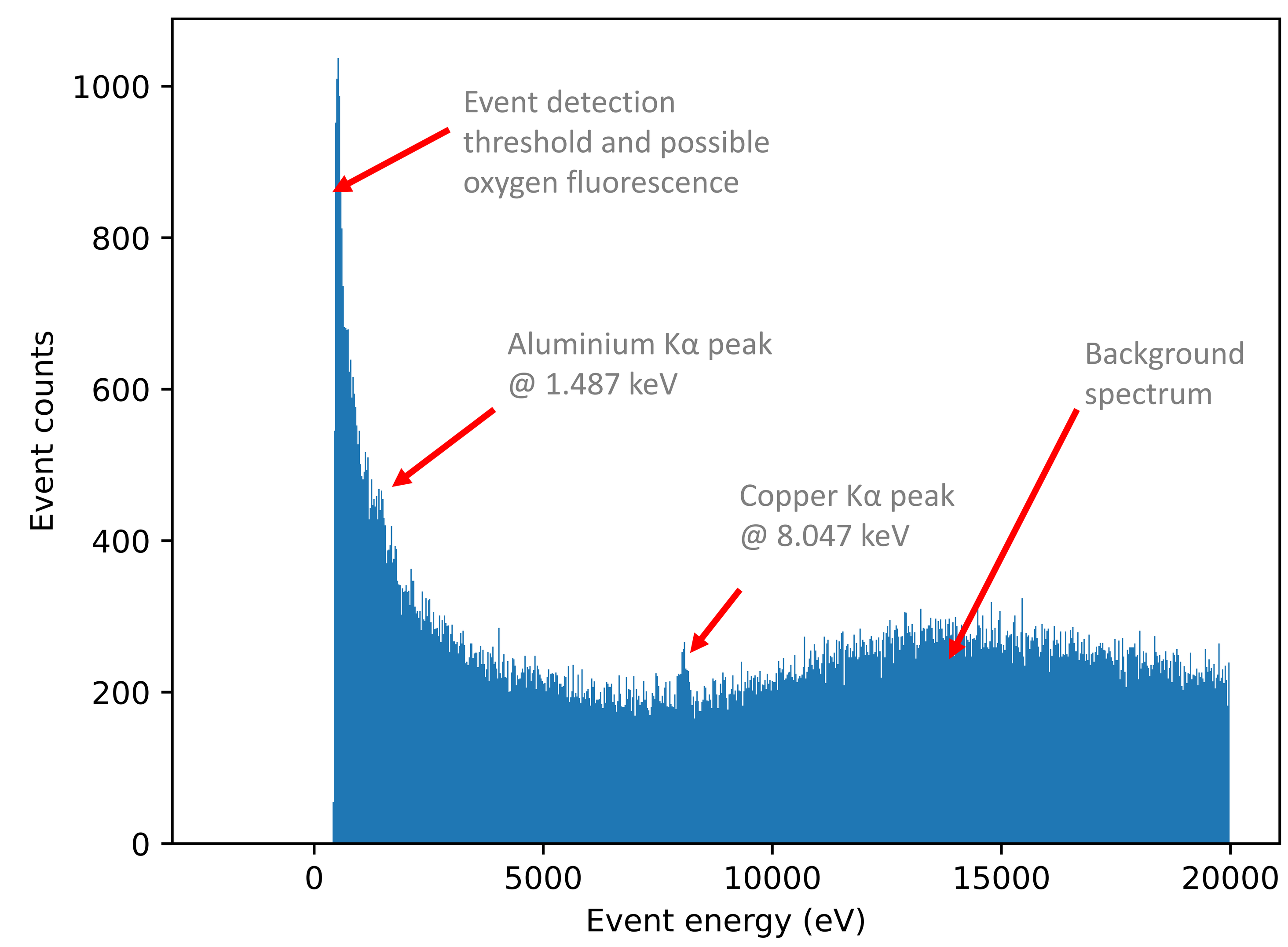
Data from CLASS is reduced before transmission, which has limited analysis options.

Data is downlinked as **level 0** data collected from the instrument. This includes event values, times, and devices of origin, alongside basic housekeeping data for CLASS.

Calibration curves of pre-measured Manganese Kα FWHM for a range of temperatures were made available for initial stages of the flight. These used calibration sources attached to the instrument shield door, which was kept closed during transit.



Calibration measurements provided for SCD6, showing FWHM during hot and cold soak ground tests, and during initial tests of the instrument in orbit.



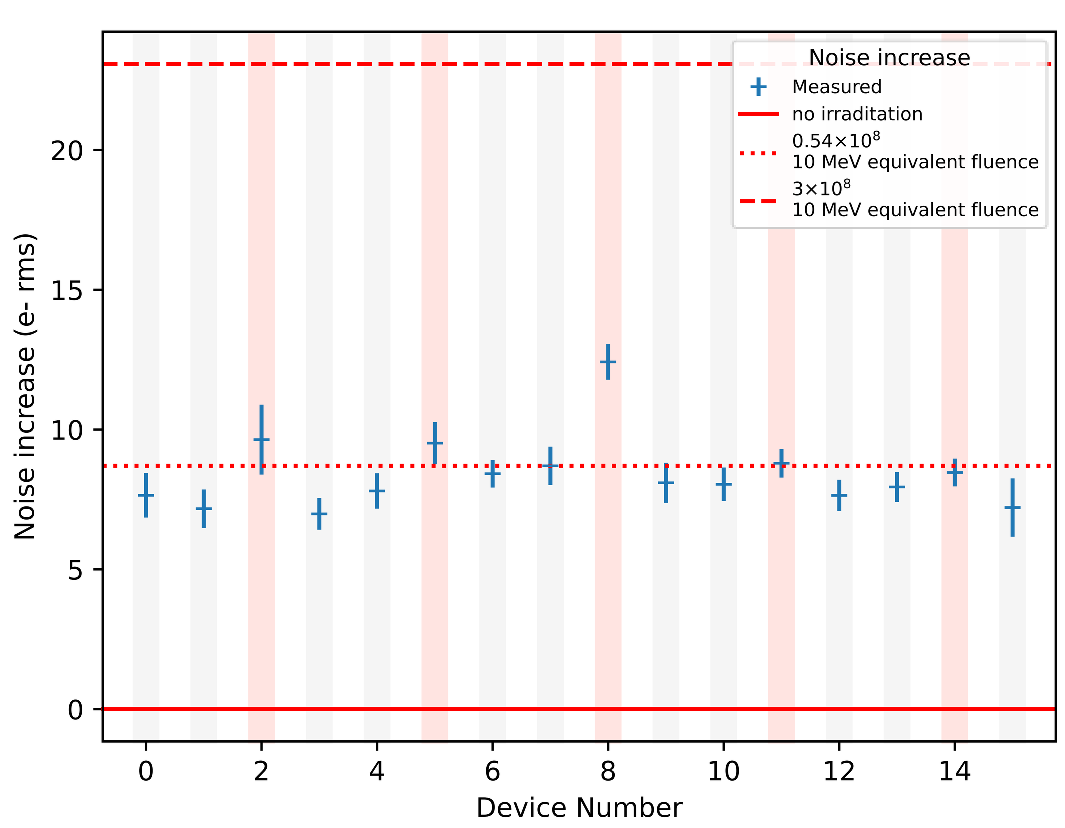
Example X-ray spectrum from SCD6 collected in October 2019, showing key features.

Calibration sources were unavailable once the shield door was opened. Instead instrument noise is estimated from fluorescence peaks in energy spectra generated from science data.

This analysis has used Aluminium Kα and Copper Kα X-rays fluoresced from the instrument collimator, not the lunar surface, which have been visible for most of the period covered.

Results and discussion

Noise after transit to the Moon



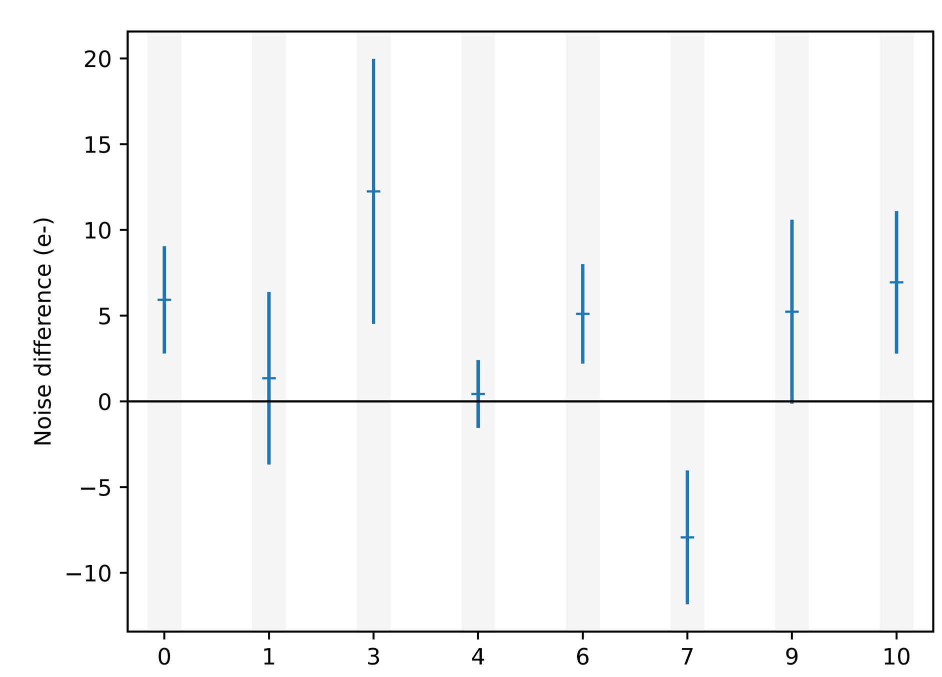
Noise observed after transit to the moon (blue) compared to previous predictions based on Gow et. al. (2015) (red). The 0.54 × 10⁸ 10 MeV equivalent fluence (proton cm⁻²) value has been interpolated from the 0 and 3 × 10⁸ experimental values.

Noise present in post-transit calibration results is close to the predictions made based on the results of Gow et. al. (2015) and the 5.37 × 10^7 cm^{-2} 10 MeV equivalent proton fluence dose estimate produced by SPENVIS.

Devices exhibit similar noise. Outliers correspond with known ADC issues affecting devices highlighted in red.

Difference in noise present in 2019 and 2021 data

Comparisons of the noise exhibited in data collected in 2019 and 2021 show little difference. Discrepancies between devices are thought to be due to issues associated with the XRF data from 2019, when the sun was less active.



Difference in noise, (presented as an equivalent extra source) between 2019 and 2021, devices affected by stray light and electronics issues have been removed.

This would suggest that device performance has not degraded significantly after the first year of operating around the Moon. This matches expectations as very low doses were predicted for the period spent, so far, in lunar orbit.

Device performance has developed roughly as expected. Further analysis with more recent data would help extend findings by monitoring changes in response to recently increased solar activity.

Gow, J. P.D., Smith, P. H., Pool, P., Hall, D. J., Holland, A. D., & Murray, N. J. (2015). Proton irradiation of a swept charge device at cryogenic temperature and the subsequent annealing. *Journal of Instrumentation*, *10*(1).