Linearity Studies of CMOS Image Sensors
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Introduction
The Brandeis high energy physics group provides an alignment system for the endcaps of the muon detectors at ATLAS. An essential instrument we use in the alignment system is the Brandeis CCD Angle Monitor (BCAM), which is designed to monitor the geometry of large structures. This work focuses on studying two CMOS image sensors, the Omnivision OV5647 and the Sony IMX219, for potential use in BCAMs. This will require that the CMOS sensors take clear, uniform images. It also requires that the CMOS image sensor is spatially linear, and that the standard deviation of images taken across the field of view is less than 0.5μm.

Background and Motivation
ATLAS is one of four experiments at the Large Hadron Collider (LHC) at CERN built to test the predictions of the Standard Model. Brandeis provides an alignment system for the muon detectors which uses BCAMs to monitor the geometry of the endcaps. BCAMs consist of at least one camera and two laser diodes which are used to monitor other BCAMs in its field of view. Thus, a BCAM can detect the movement of other BCAMs and can resolve the relative change in location of a point source to an accuracy of 5 microradians. They can also resolve the absolute location of a point source to an accuracy of 50 microradians (1). As the name states, BCAMs utilize a CCD image sensor, specifically the Sony ICX424. However, these CCDs are no longer being manufactured so our group is looking for another type of image sensor so that the alignment system may continue to work for years to come.

Methods
We measured the linearity of an image sensor by moving a laser across its field of view with a micrometer stage and plotting the image position vs stage position. The residuals from a straight line fit for the image position is the non-linearity of the camera with respect to translation of the source (1). For this experiment we used a motorized stage that is precise to 1μm and linear to better than 100ppm (1).

Linearity Tests: Sony IMX219 CMOS
The Sony IMX219 is a back lit CMOS image sensor with 1.12μm pixels. For the IMX219 CMOS, we did not see any well-defined shape in the residuals. Standard deviation: 0.20μm

Conclusions
Both the Omnivision OV5647 and the Sony IMX219 CMOS sensors have good linearity. The standard deviation of the residuals for the Omnivision OV5647 was 0.17μm and for the Sony IMX219 was 0.20μm. These are both below the limit of 0.5μm necessary. Both CMOS sensors also out perform the Sony ICX424 CCD in terms of linearity. For while we saw a 1-pixel variation with the CCD, we did not see this either CMOS sensor, due to their smaller pixel size. Thus far both the Omnivision OV5647 and Sony IMX219 CMOS sensors appear to be suitable for future use in BCAMs.

Future work to be done will focus on how binning the images to smaller resolutions will affect the linearity of the sensors. This is necessary because reading out the images at full resolution is time intensive.

References
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Acknowledgments
This material is based upon work supported by the US ATLAS Summer Undergraduate Program for Exceptional Researchers 2019 grant.

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