Small Satellite Payload Calibration

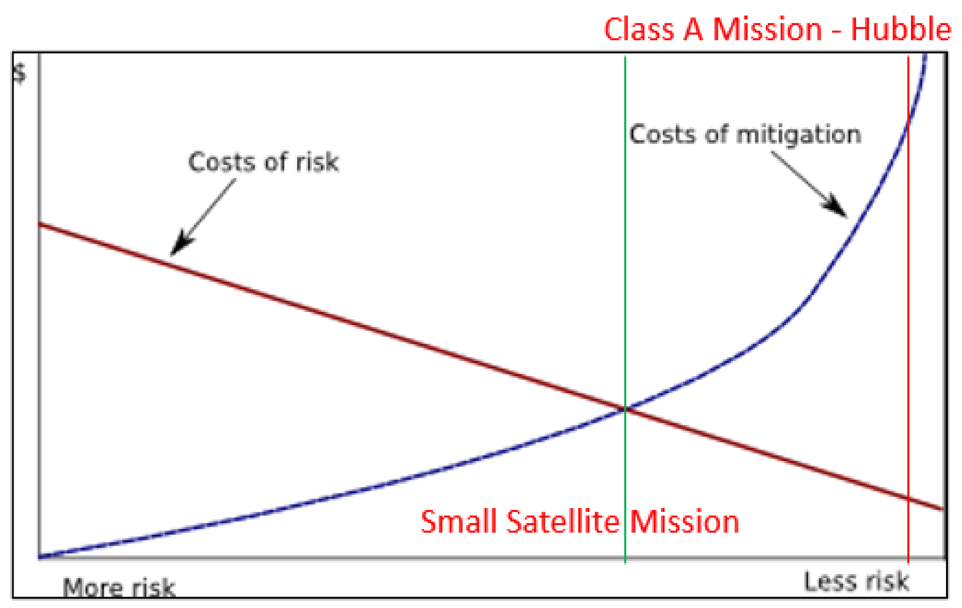
Collaborators: Deron Scott, Cole Miller, Eli Salay, Shane Canfield, Scott Hansen, Matt Berghout, Jan Kunzler, Duane Miles

Space Dynamics Laboratory
Utah State University

This project focused on developing an efficient and cost-effective method for calibrating optical payloads that streamlines setup, measurement, and analysis time while staying within a SmallSat budget. To develop and test the concept, the team identified key calibration parameters and performed a demonstration on a surrogate payload using spatial, spectral, and radiometric calibration methods. Calibration results were derived from the demonstration and are detailed below.

A Small Satellite Calibration on a Budget

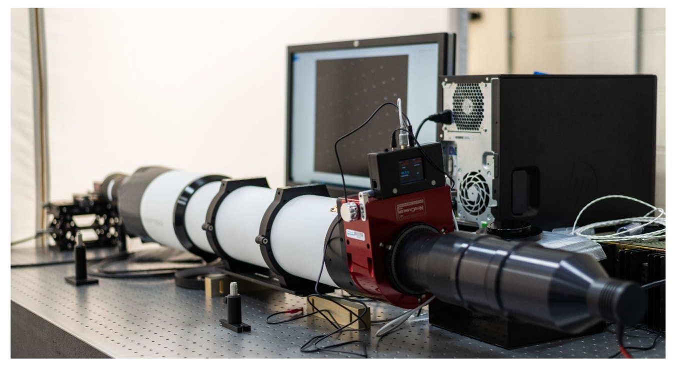
SmallSat missions have cost, time, and scale limitations. Calibration methods can be optimized to enable mission success at a low cost by providing customers the best "bang for their buck."



Objective 1: Identify key payload calibration parameters that offer the best chance of mission success.
Objective 2: Develop a working calibration method to provide spatial, spectral, and radiometric calibration.
Objective 3: Demonstrate that the calibration method improves performance for a surrogate payload at a low cost.

B Calibration Methods

Spatial Calibration
- Determine best focus over field of view (FOV)
- Determine unit under test (UUT) current focus relative to test system focus (truth)
- Adjust UUT focus to match system focus
- Re-test to verify that UUT is in focus

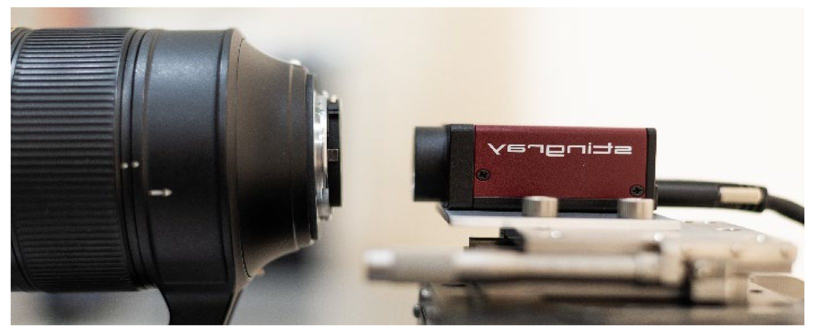

Target and Collimator

Spectral Calibration
- Characterize payload response as a function of incident wavelength
- Payload views scene with known spectral channels
- Response is normalized to the integrated spectral radiance and to the maximum response

Radiometric Calibration
Determine peak radiative responsivity (PRR), non-uniformity correction (NUC), and system noise response
- PRR: Conversion from measured response (corrected counts) to engineering units (W/m^2-sr)
- NUC: Pixel-by-pixel correction to adjust response to be homogeneous for uniform source
- System noise: UUT response to lowest signal level

C Small Satellite Surrogate Payload

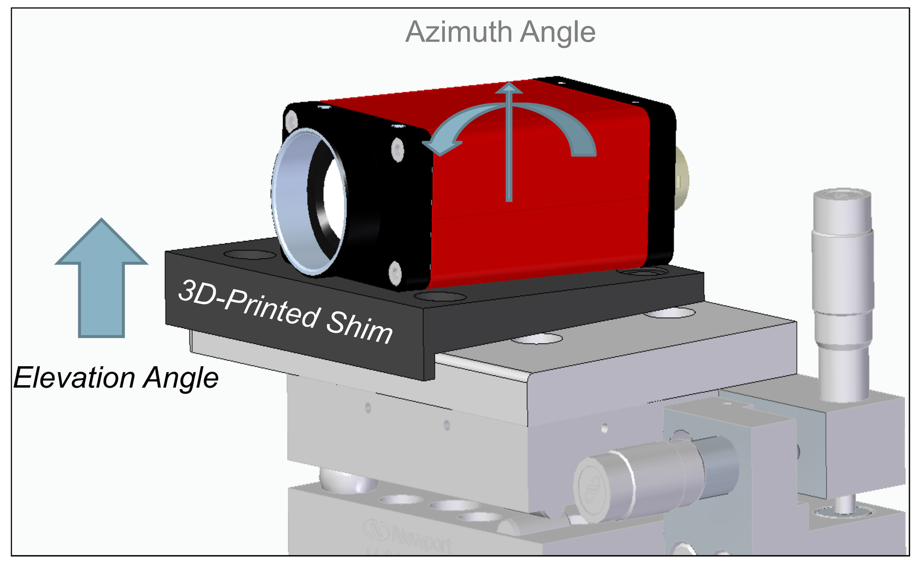
Unit Under Test
- Camera: 1380 p x 1038 p visible focal plane array (FPA)
- Telescope: Stellarvue SVX152T


Surrogate Payload

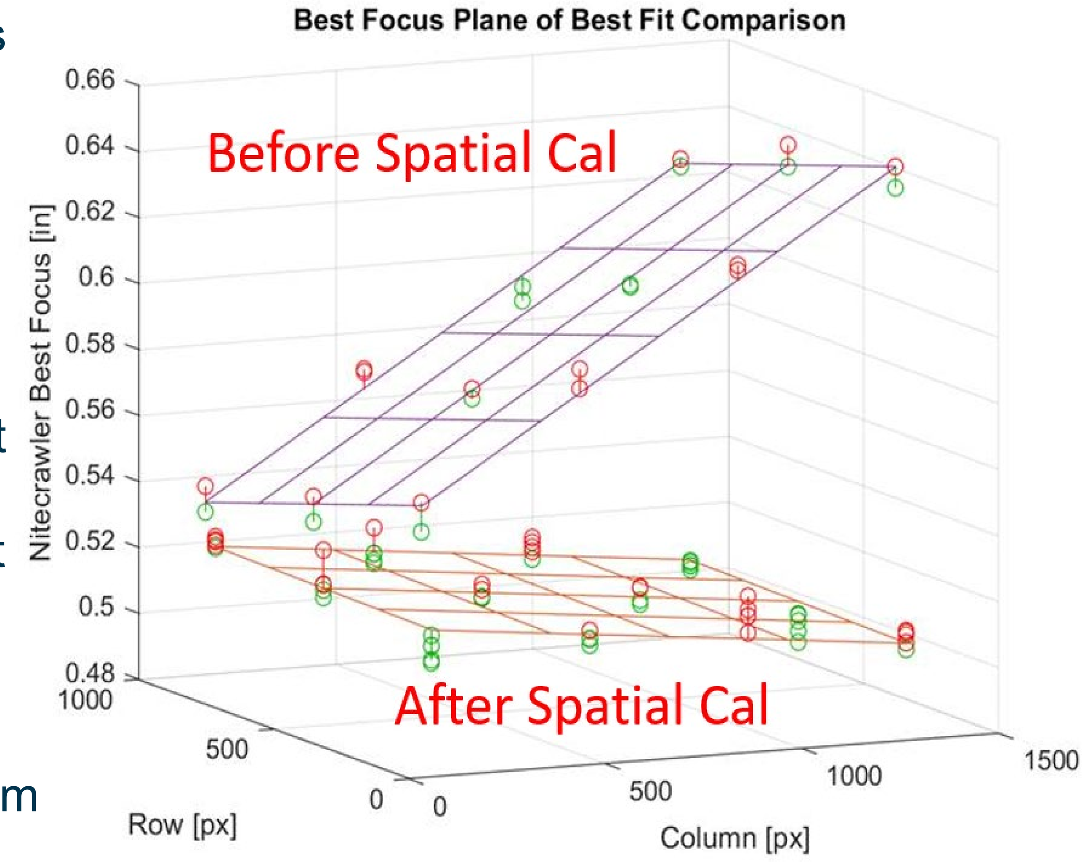
D Small Satellite Calibration Demonstration

To perform the demonstration, the team simulated a real-world scenario by intentionally placing the surrogate payload out of focus.

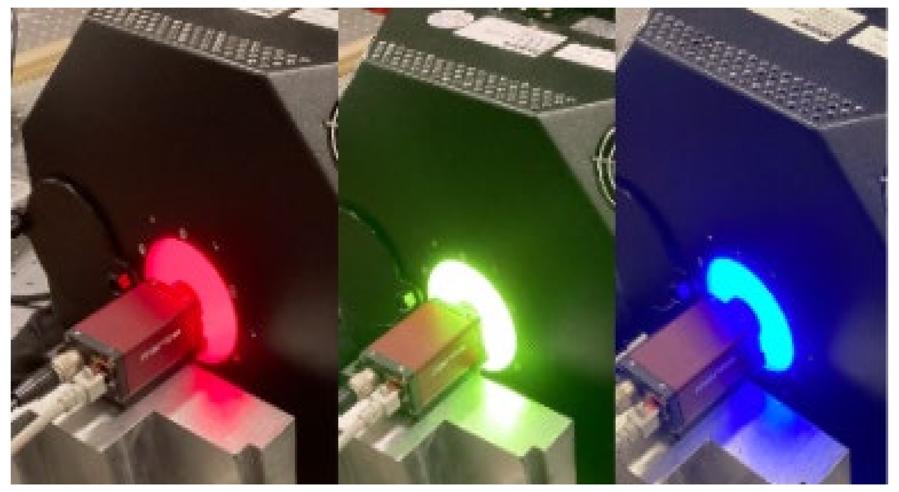
Spatial Calibration
Key Parameters
- Camera spatial adjustment
- Point response function (PRF)
- Distortion can be calculated
- Surrogate payload looks into multi-point source

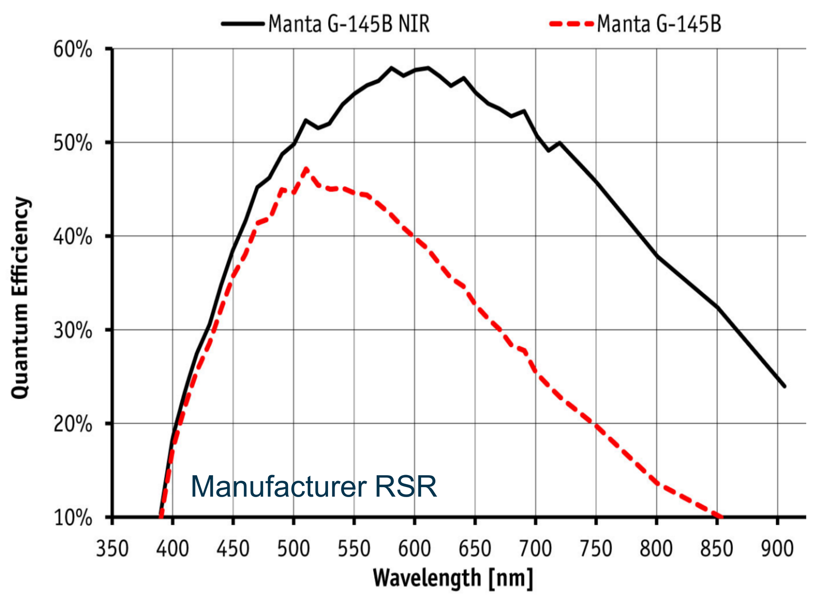


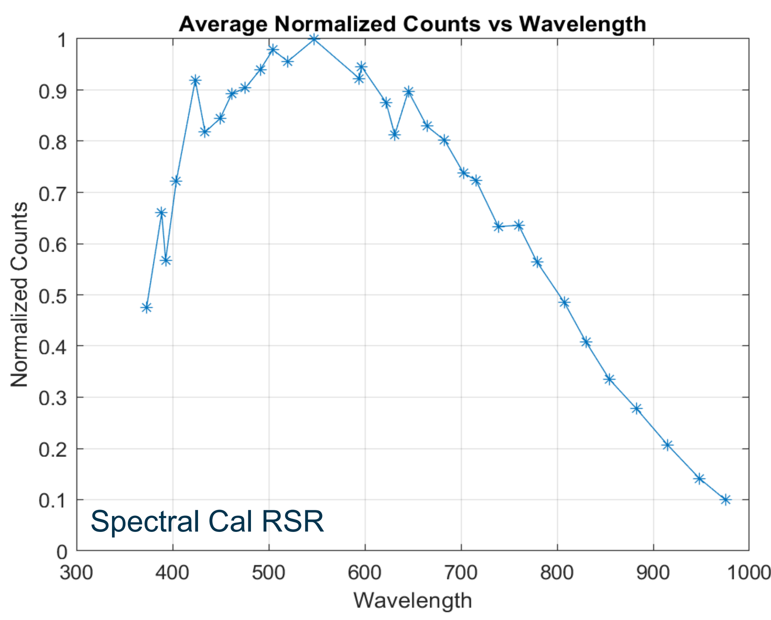
Initial measurements showed that the payload was ~720 um out of focus. After a hardware correction was performed to move the payload into best focus, the payload was only ~25 um out of focus.



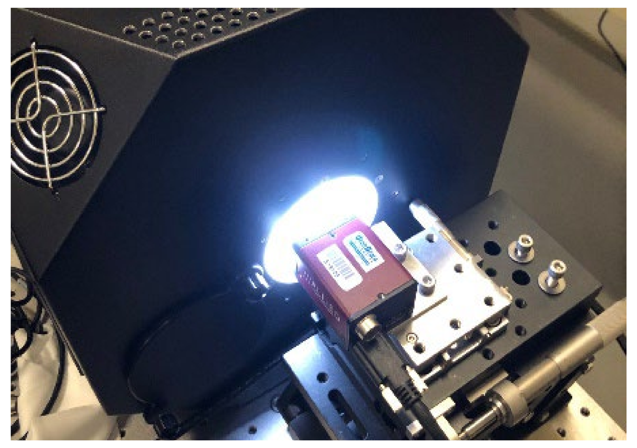
Spectral Calibration
- Camera was most sensitive to ~546 nm (green)
- All other responses were normalized to this value to produce relative spectral response (RSR)
- Change in response from various spectral radiance values suggests non-linear response at those wavelengths

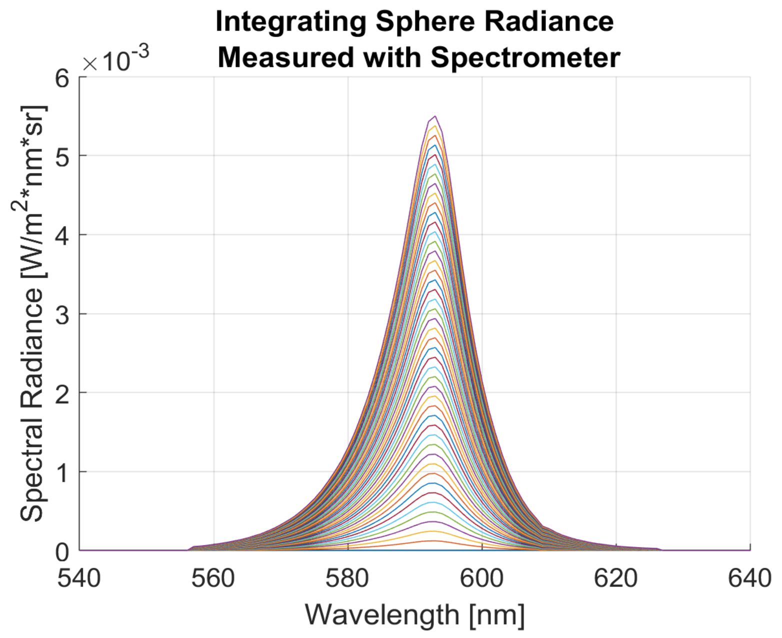

Surrogate Payload Exposed to Various LED Wavelengths for RSR

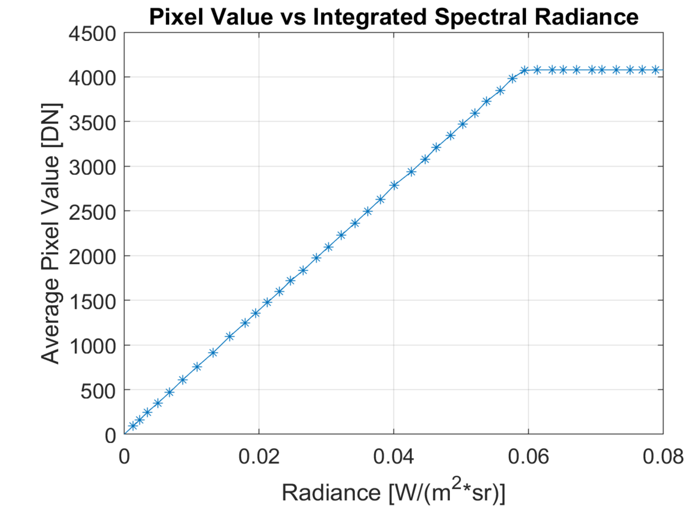




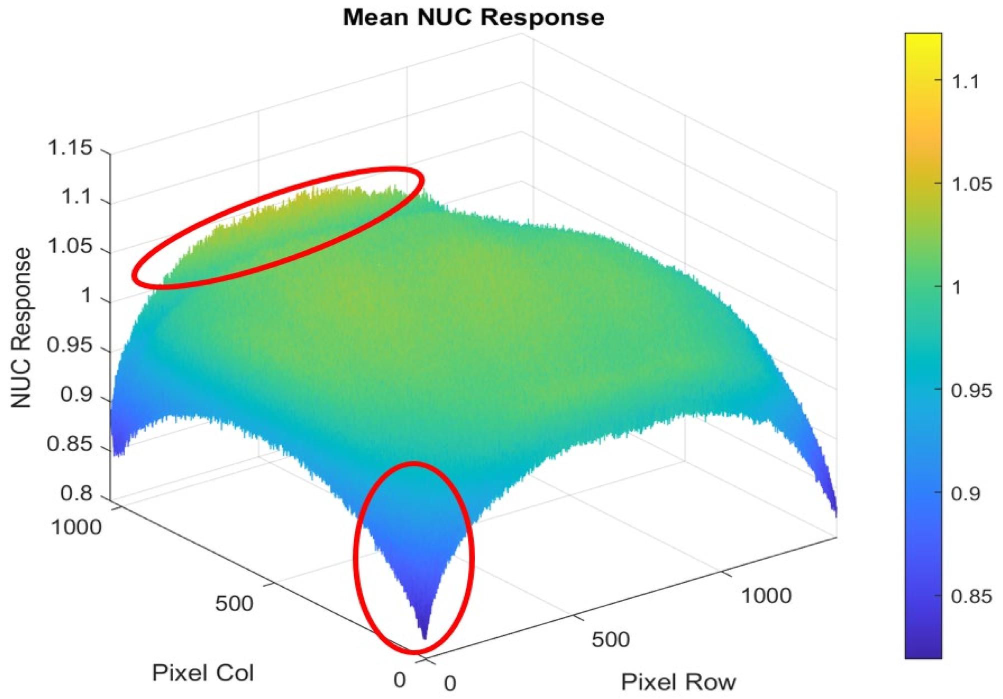
Radiometric Calibration
Key Parameters
- Peak radiative responsivity
- Non-uniformity correction
- Rudimentary linearity correction can be derived from peak radiative response


Integrating Sphere and Payload





Non-Uniformity Correction
- Regions with response in pixels >1 are due to pixel noise
- Regions with response <1 are due to vignetting in corners of detector
- Determined pixel-by-pixel correction
- Adjusted response to be homogeneous for uniform source
- Multiple images were collected at different illumination levels
- Surface plot shows average variation in pixel-to-pixel response



E Summary

Calibration Results
- Improved camera spatial focus to within ~25 um of best focus
- Verified manufacturer RSR and identified variations
- Calculated distortion, PRR, NUC, and linearity correction

The calibration regiment developed during this effort provides the following benefits to a SmallSat mission:
- **Quick**: Fewer tests and more automation lead to faster results.
- **Flexible**: Calibration can be performed on a variety of payloads.
- **Mobile**: Less hardware allows for calibration to be performed on site or at customer locations.
- **Reliable**: Less test hardware introduces fewer uncertainty contributions.
- **Cost Effective**: This method can meet the technical demands of a mission and maintain an acceptable level of risk on a SmallSat budget.

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