SGSLR Receiver Detector Testing and the Pulse Width Calibration Technique

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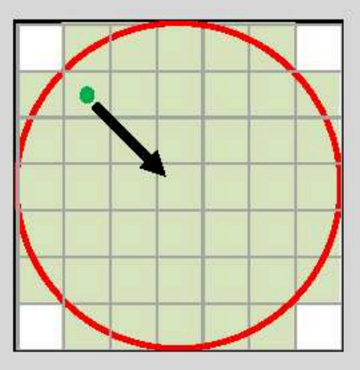
Abstract

The NASA Space Geodesy Satellite Laser Ranging (SGSLR) Receiver subsystem detector combines a proprietary Hexagon US Federal (Sigma Space) event timer chip and an array of SensL detectors. The receiver provides high precision event measurements along with spatial information essential to closed loop tracking and system automation. During the initial characterization testing of the prototype receiver a range dependence on the signal return rate (and inferred pulse intensity) was observed. Using the pulse width determined from the return leading and trailing time tags provided by the receiver, a technique was developed to compensate for range dependence on pulse intensity (2019 Technical Workshop, SGSLR Receiver Detector Pulse Width Calibration Technique, C. Clarke, et al). This poster will provide an update to the referenced poster. It will also describe the technique, compare test results before and after the correction, describe the method to differentiate between single and multi-photoelectron returns, and summarize the results of recent calibration stability testing and multi-cube configuration testing.

Sigma Space Receiver (SSRx) Detector Overview

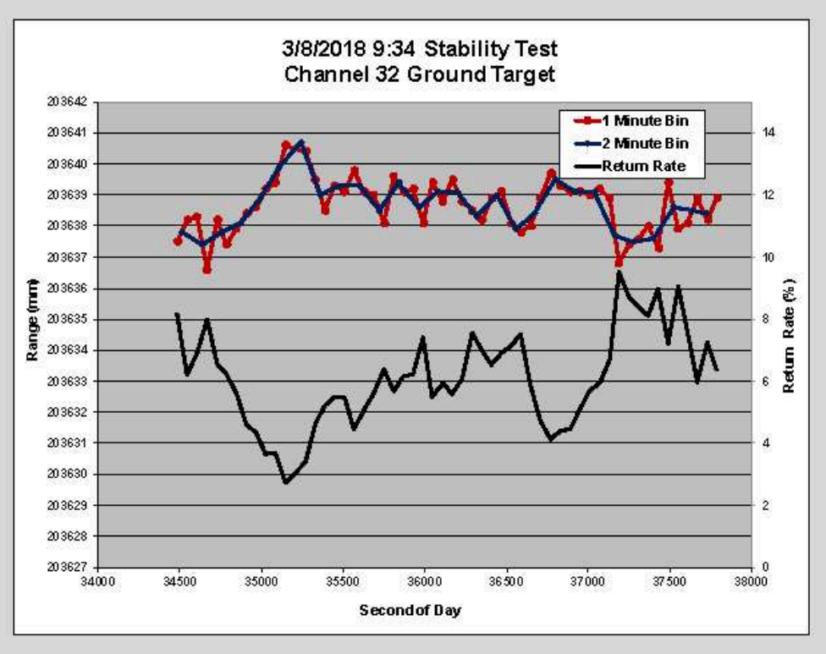
The Sigma Space Receiver Subsystem (SSRx), developed by Hexagon US Federal, consists of an array of SensL detectors and a proprietary event timer chip. The pixelated detector will enable the system to detect the spatial location of returns. The spatial information may be translated into azimuth and elevation biases that can be utilized to steer the return into the center of the field of the view. Applying angle corrections will increase signal strength and are essential to the automation of the system. The increased signal strength and precise timing chip are essential to meeting the ITRF requirements.

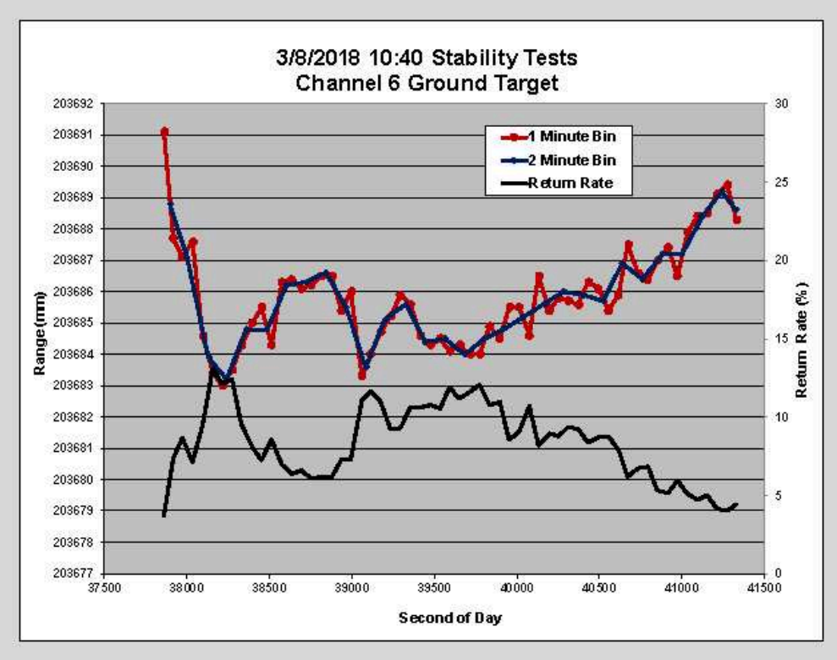
The operational SSRx Detector will be a 7 X 7 pixelated array with the four corners being unused. The demonstration unit that will be discussed in the poster consists of a 5 X 5 pixelated array.

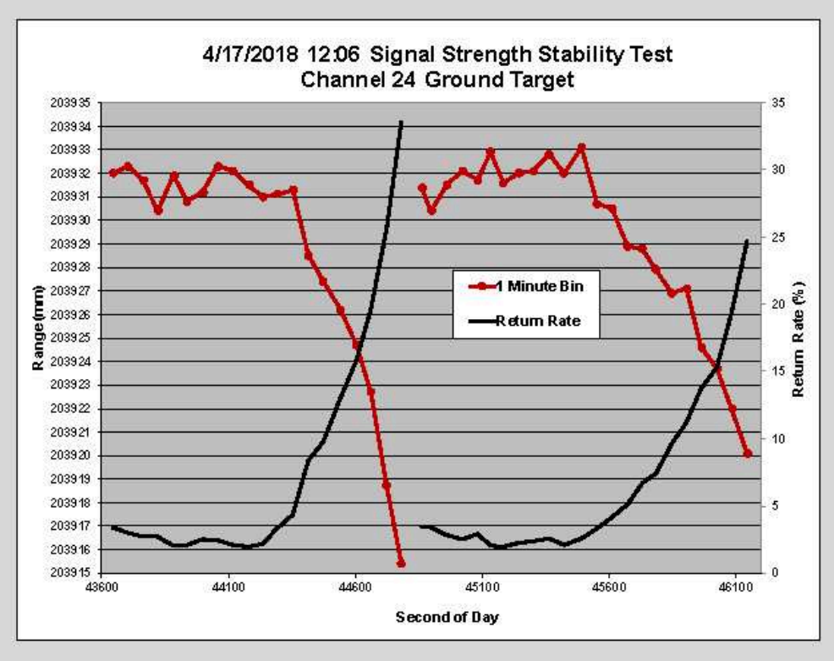


Initial SSRx Subsystem Testing

During the initial testing of the SSRx Subsystem a range dependence on return rate (implied signal strength) was observed in stability tests. The dependence was further verified in a test where the signal strength was deliberately varied. The two stability ground calibration stability tests (left two plots) and signal strength test (right plot) are examples of the this range dependence.The range dependence on return rate was assumed to be due to the increased multi-photoelectron returns at the greater return rates (applied signal strength).







Pulse Width Calibration Technique

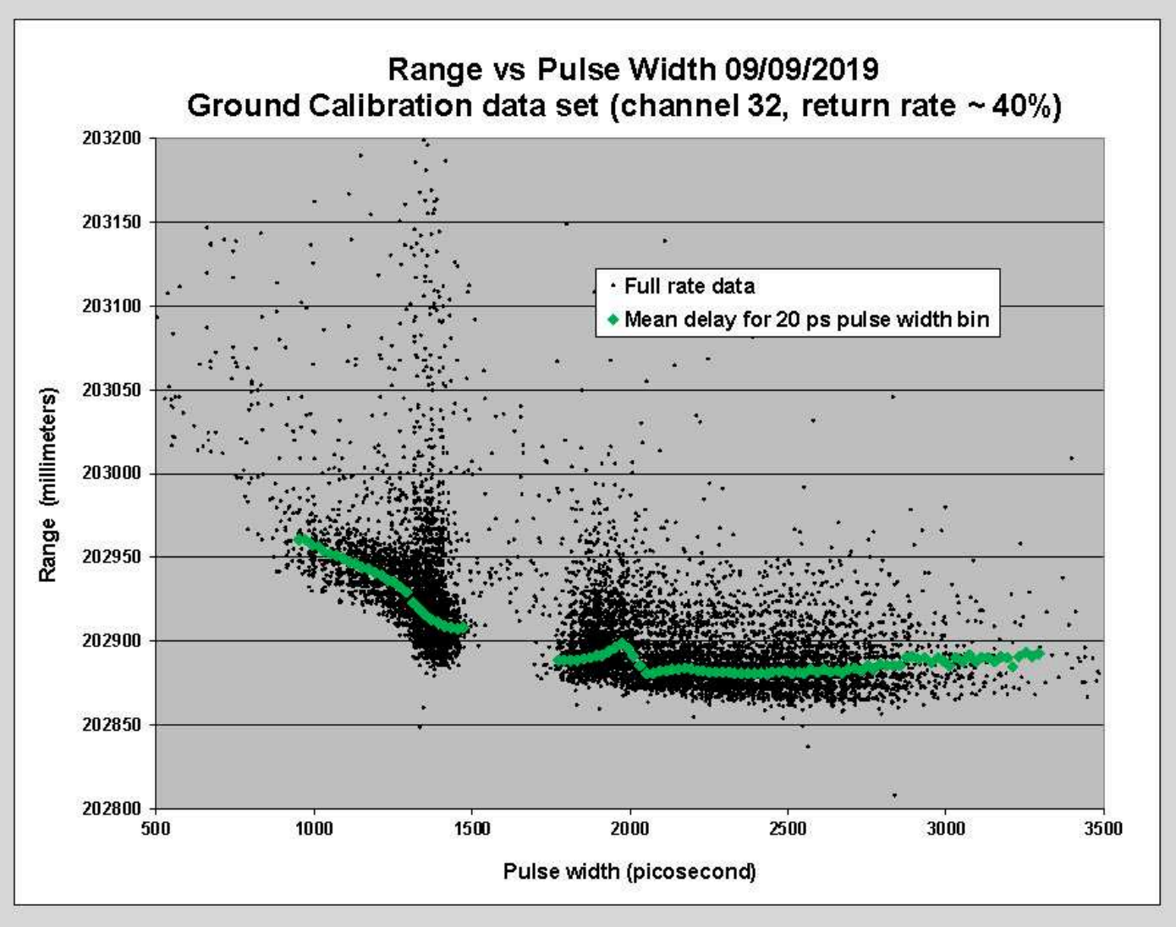
The Hexagon US Federal team determined they could configure the detector chips so that that both the leading edge and trailing edge of the return pulse could be detected and pulse width could be calculated. The pulse width (and inferred pulse intensity) could be used to differentiate between single and multi-photoelectron returns and the range dependence could be calibrated. Using the pulse width measurement a calibration curve was developed using the following steps on a high return rate data set.

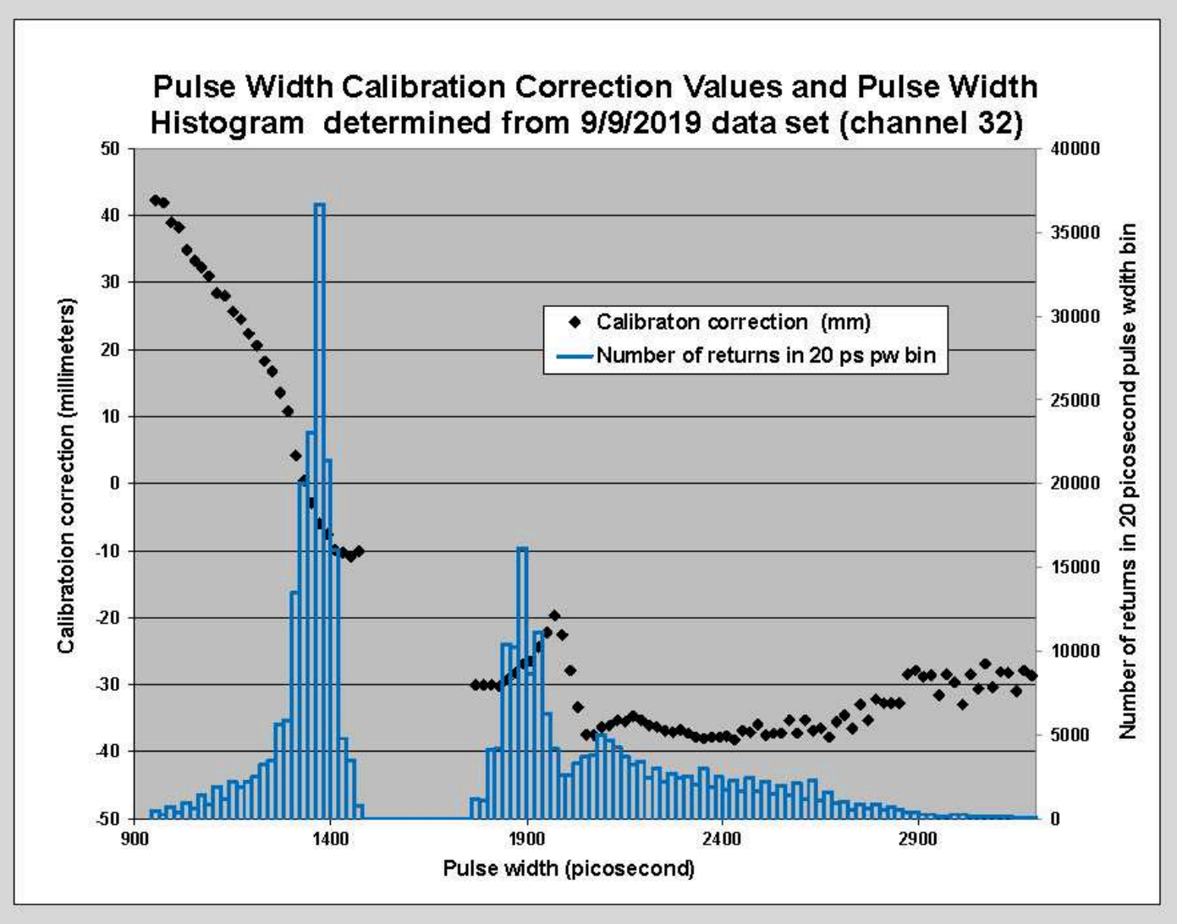
1. Bin range measurements by pulse width and perform an iterative three sigma multiplier filter on the ranges in each bin and determine the mean range in each bin of the accepted observations. (20 picosecond pulse width bins were used in the example)

2. Determine the mean range of the single photoelectron data.
   (the first grouping of data in plot on the top left of next column)

3. Determine the calibration value for each bin by subtracting the single photoelectron mean from the mean range in each bin.

The calibration is applied by subtracting the calibration value from each range based on the pulse width of that observation. The calibration translates the range to the single photoelectron mean values. The plots display the full rate data (below left) with mean range of each bin and a histogram (below right) of pulse width values with corresponding range correction values.



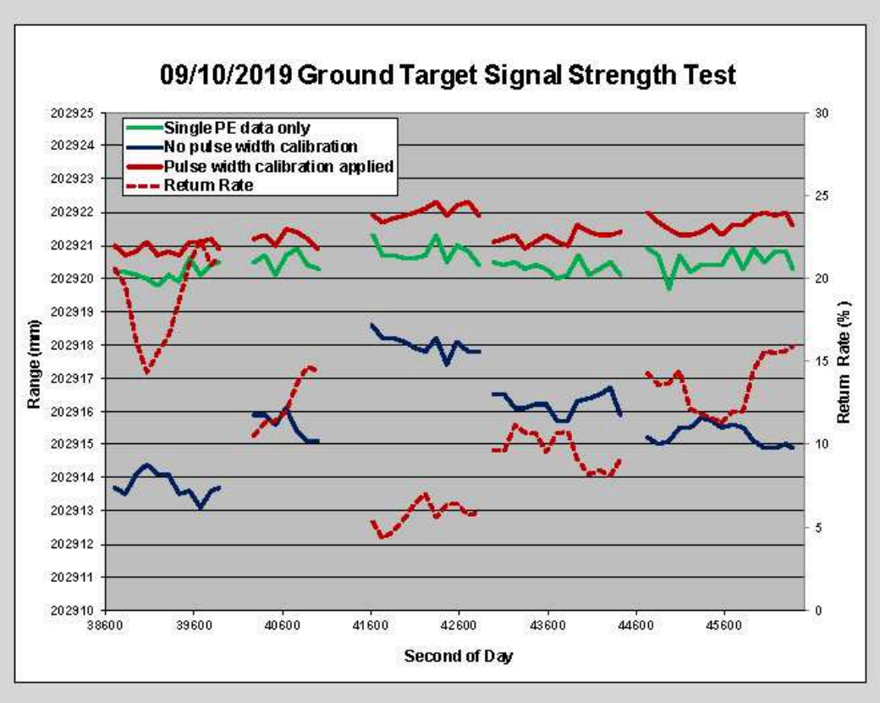


NOTE: *During SSRx Demonstration unit testing, the three sigma filter was performed on a larger range of pulse widths. Also, the reference or zero calibration value was chosen at the largest single photoelectron pulse width bin.*

Effects of Applying the Pulse Width Calibration Technique

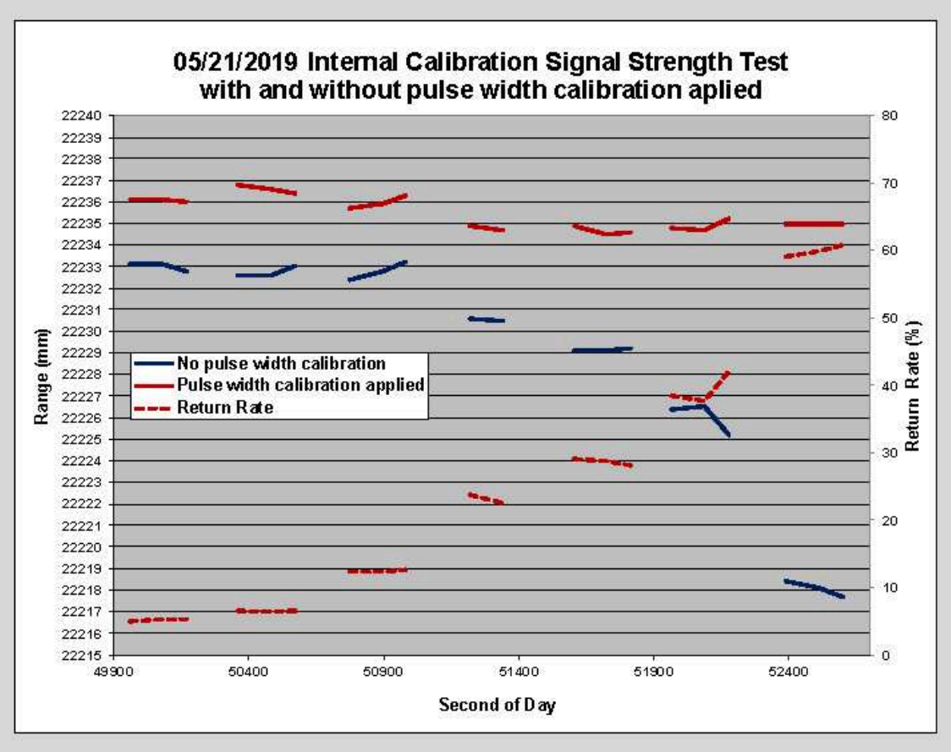
The following section displays the effects of applying the pulse calibration technique. The plot (below left) displays a signal strength test where the return rate is varied from approximately 5% to 20%. The data was processed three ways;

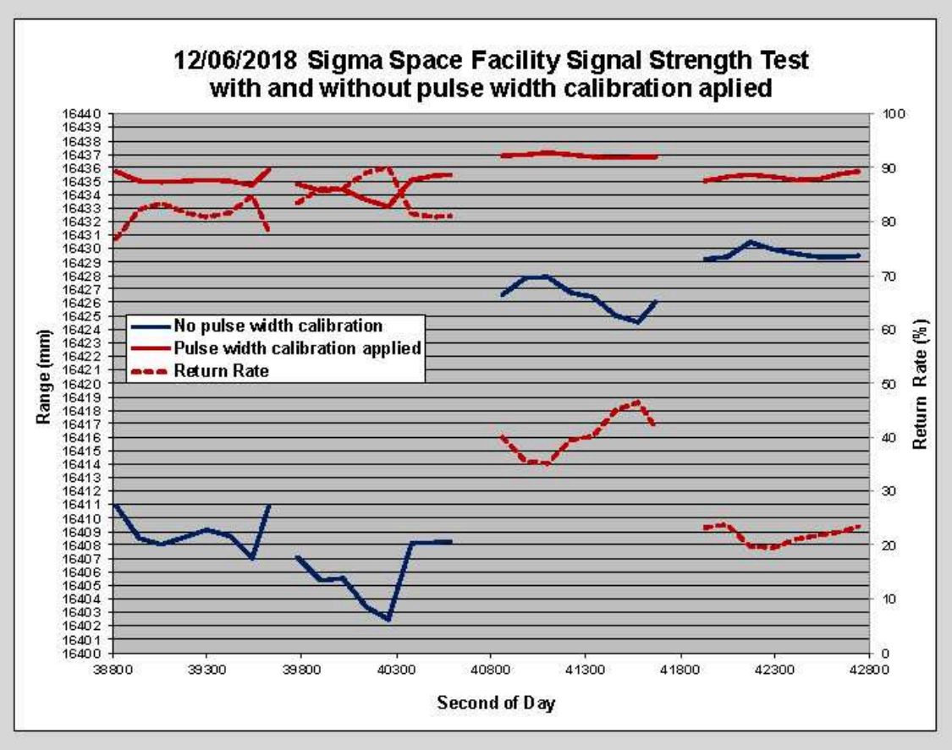
1) Without the pulse width calibration applied
2) With the pulse width calibration applied
3) Using only single photoelectron data



Notice without the pulse width calibration applied (blue line) the delay shifts approximately 5 millimeters. With the pulse width calibration applied (red line) the delay remains stable and agrees well with the single photoelectron data (green line).

The pulse width calibration was applied to two data sets with very high variations in return rates. The data sets where taken 12/6/2018 at the Hexagon US Federal Sigma Space facility (below left) and off an internal calibration target on the 5/21/2019 (below right). The return rates for these data sets vary from about 5% to 90%. The data sets were processed with and without the pulse width calibration applied.





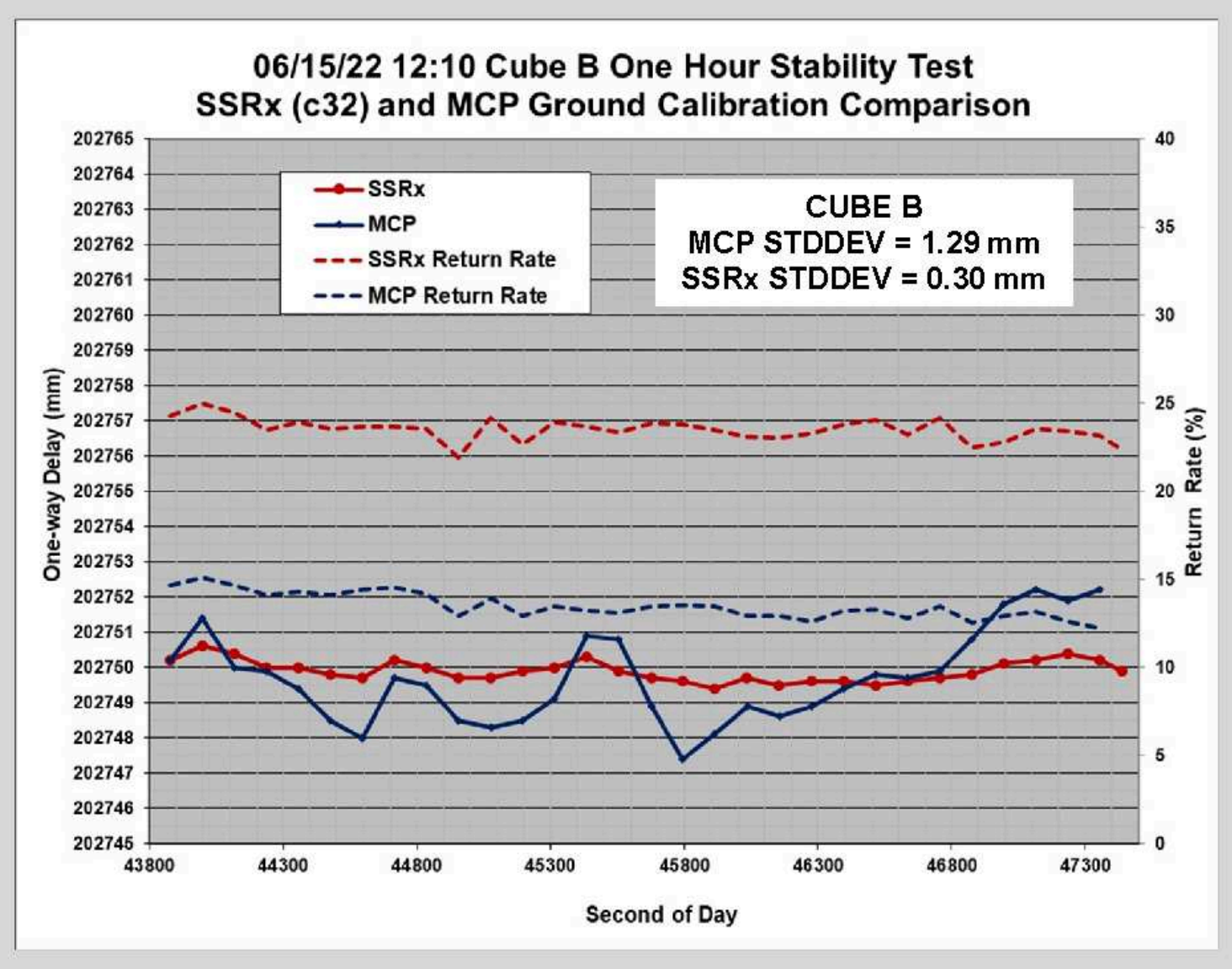
Notice the corrected data (red line) only varies a few millimeters while the uncorrected data (blue line) varies tens of millimeters.

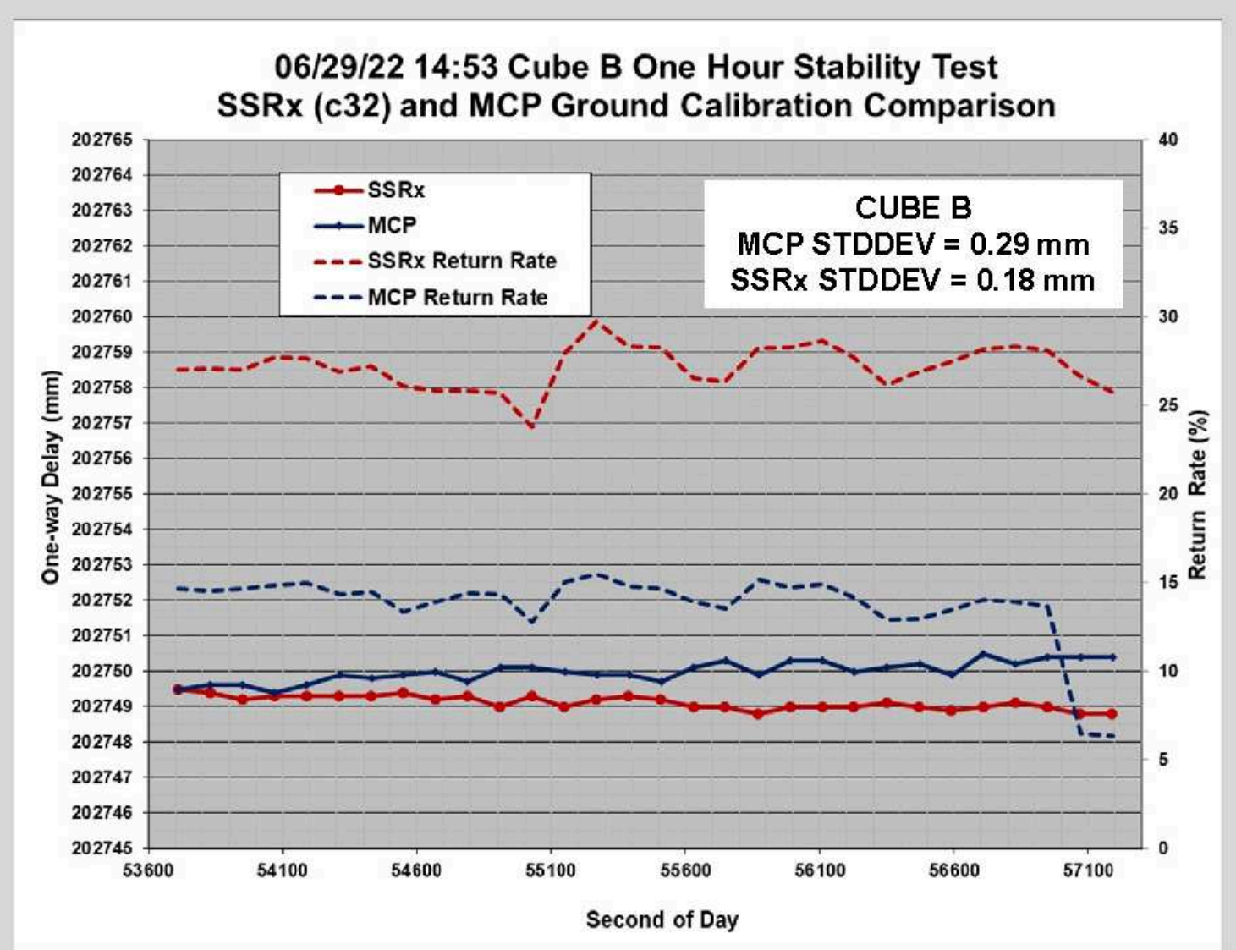
Results of Recent Ground Calibration Stability Tests and Multi-Cube Configuration Tests

In previous tests all testing was performed using a single cube. In order baseline the system and determine if pulse calibration technique was valid for returns from multi-cube configurations (some satellite retroreflector designs give return signals from multiple cubes) testing continued.

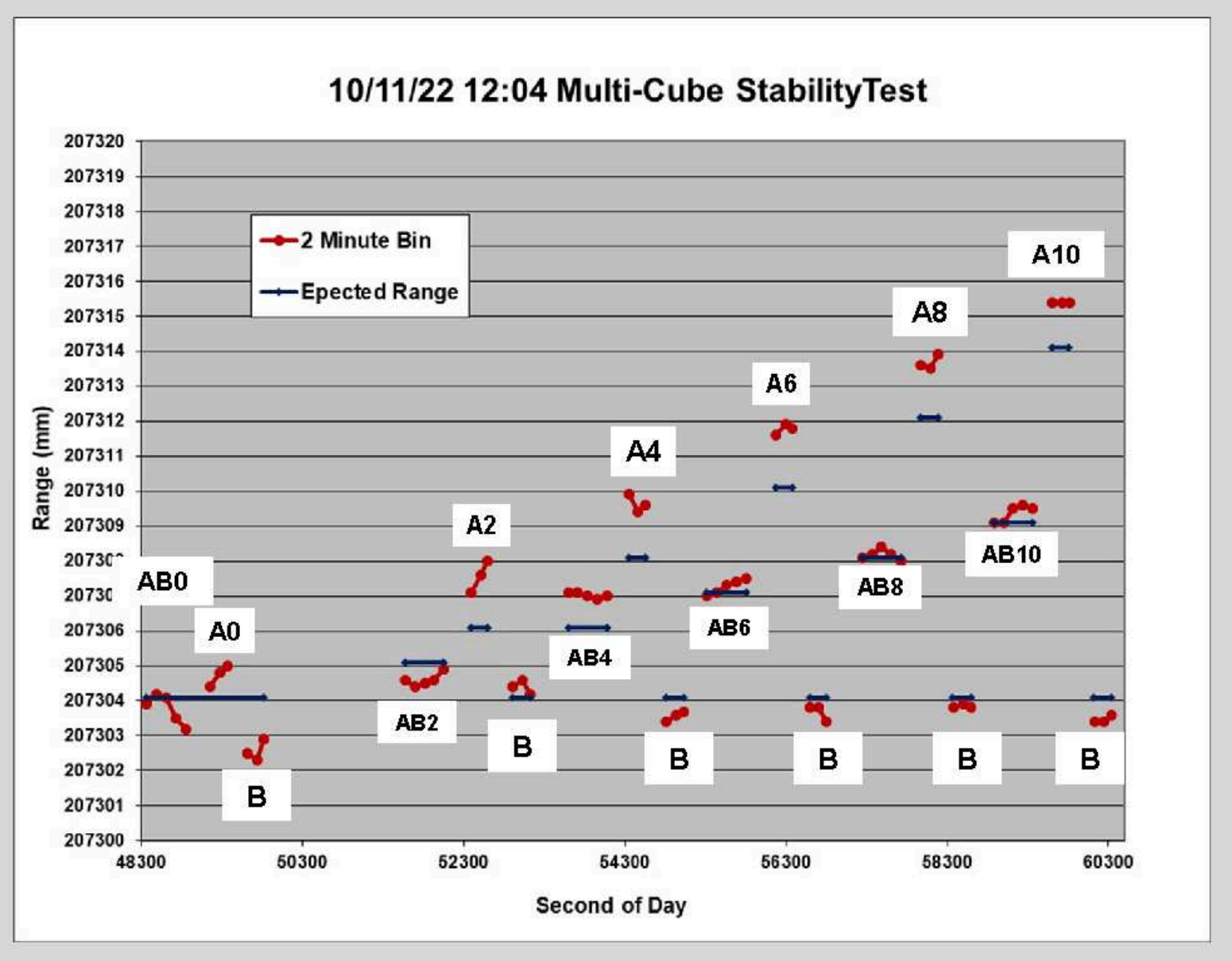
Many one hour stability tests were performed in tandem with a SLR heritage microchannel-plate photomultiplier tube (MCP-PMT) detector. Additionally, multi-cube tests were performed using a multi-cube apparatus at the ground target pier. The apparatus had two fixed cubes (B and C) and a movable Cube A on a one translational stage. The configuration allowed the faces of Cube A and B to be adjusted to be coplanar. During testing Cube A was moved in steps. At each step, data sets taken with just Cube A exposed, just Cube B exposed, and with both Cube A and B exposed.

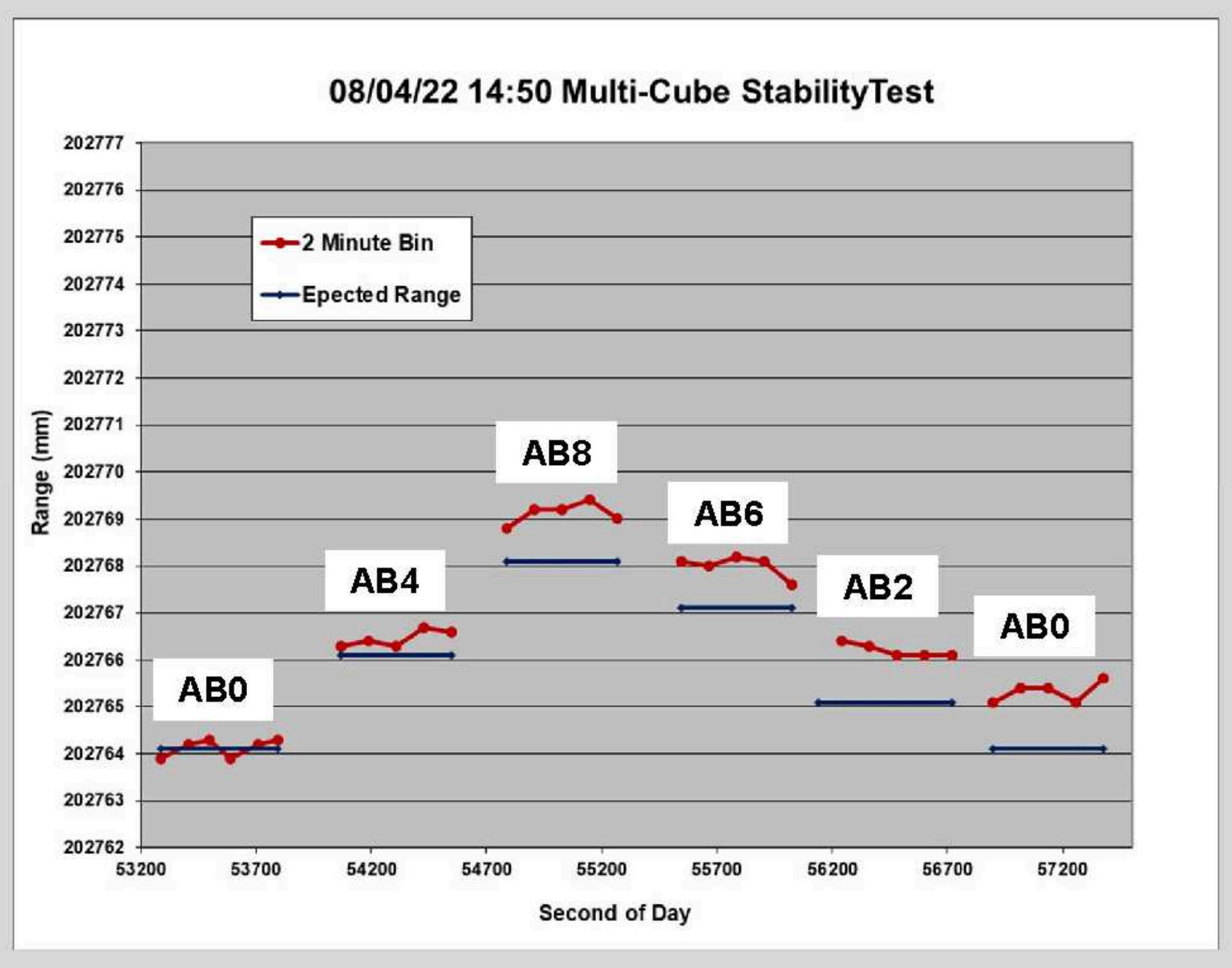
Plots below are examples of two one hour stability tests. The data processed in two minutes. The test standard deviation is calculated using the range from each two minutes bin. The standard deviation was 0.3 mm for the 6/15/22 test and 0.18 mm for the 6/29/22 test.





Plots below are examples of Multi-cube step tests. The data processed in two minutes. The date sets are label A*x* (only A exposed, *x* mm from B), B (only B exposed), Abx (A and B exposed separated by *x* mm). The expected range is based on position of the cube or in the case of AB mean position of the A and B cubes. Notice the range follows the expected range indicating pulse width calibration technique is valid for multi-cube returns.





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