SGSLR Receiver
Detector Pulse Width Calibration Technique

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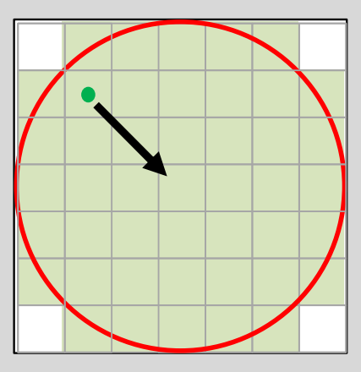
Abstract

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. This detector provides high precision event measurements along with spatial information essential to closed loop tracking and system automation. Additionally, the system time tags the leading and trailing edges of return pulses, which provides the capability to determine a pulse width measurement. During testing of the prototype the pulse width information was utilized to develop techniques to distinguish between single and multi-photoelectron returns and to determine a calibration factor that compensates for pulse width (and inferred pulse intensity) dependent range differences. The new calibration factor enabled the system to meet stability acceptance criteria over a wide range of pulse intensities. This poster will describe the techniques, show the effects of utilizing the techniques, and display results from the recent SGSLR prototype Receiver subsystem detector testing on a ground calibration target in which the techniques were applied.

Sigma Space Receiver (SSRx) Detector Overview

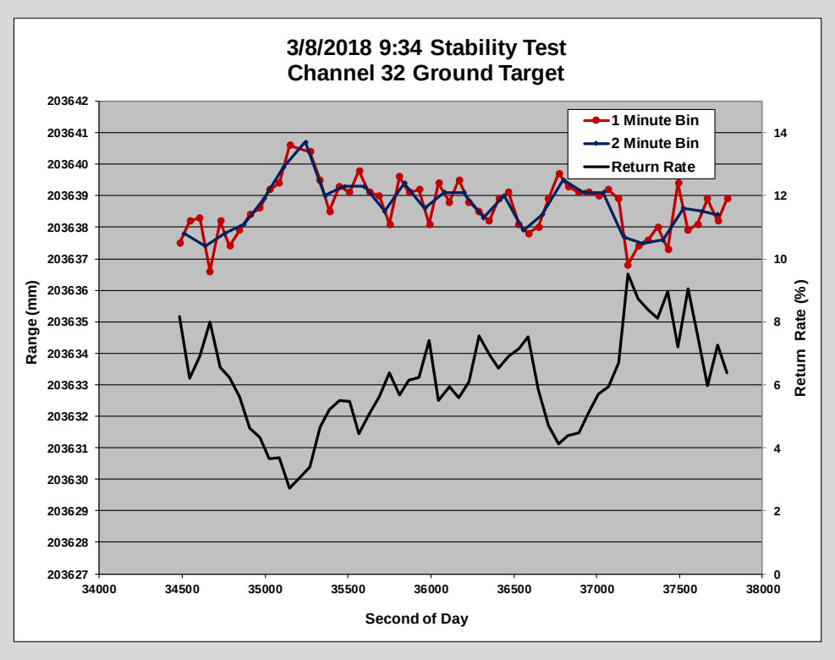
The Sigma Space Receiver Subsystem (SSRx), developed by Hexagon US Federal, consists of an array of SensL detectors and a proprietary event timer chip. The pixelated detector will enable the system to detect the spatial location of returns. The spatial information may be translated into azimuth and elevation 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.

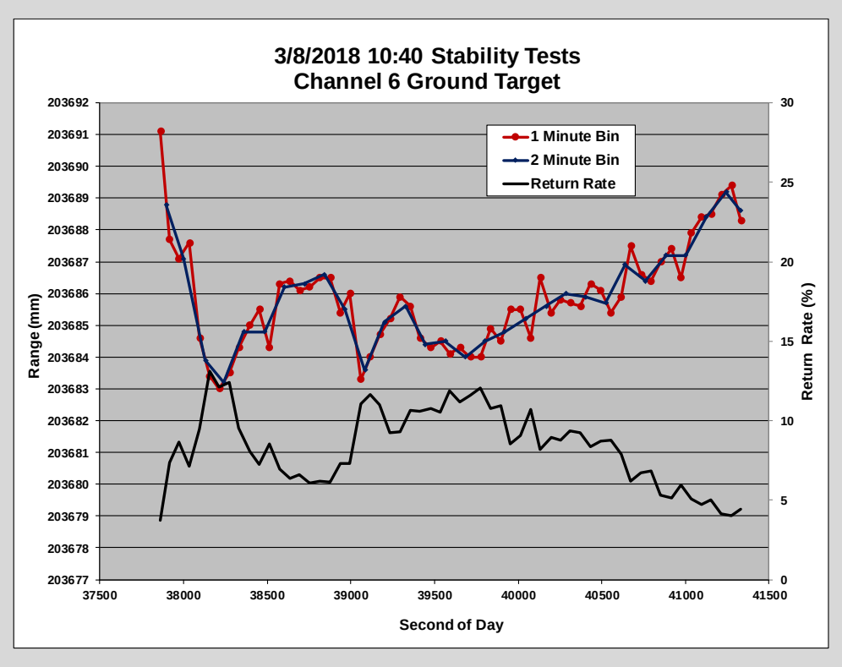
The operational SSRx Detector will be a 7 X 7 pixelated array with the four corners being unused. The demonstration unit that will be discussed in the poster consists of a 5 X 5 pixelated array.

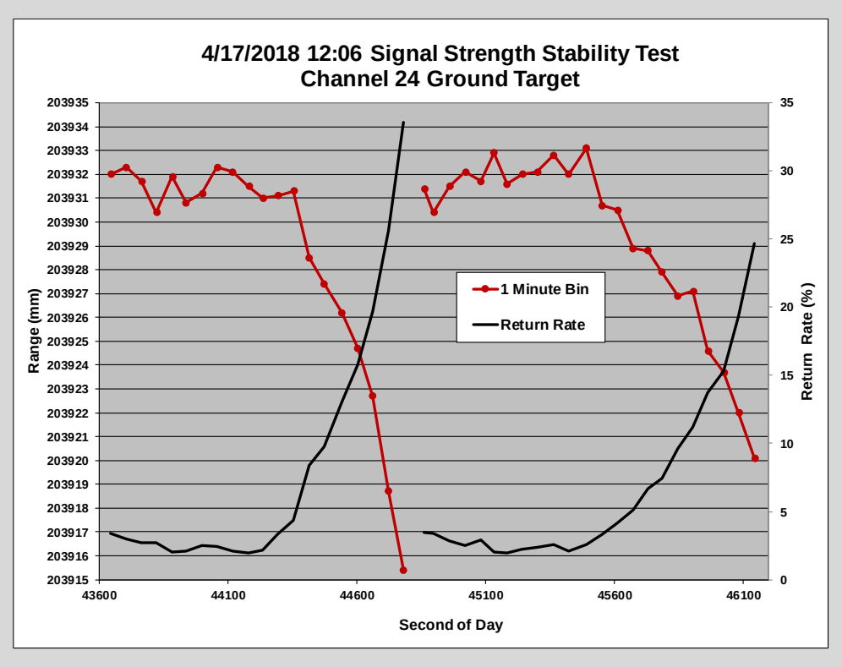


Initial SSRx Subsystem Testing

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.

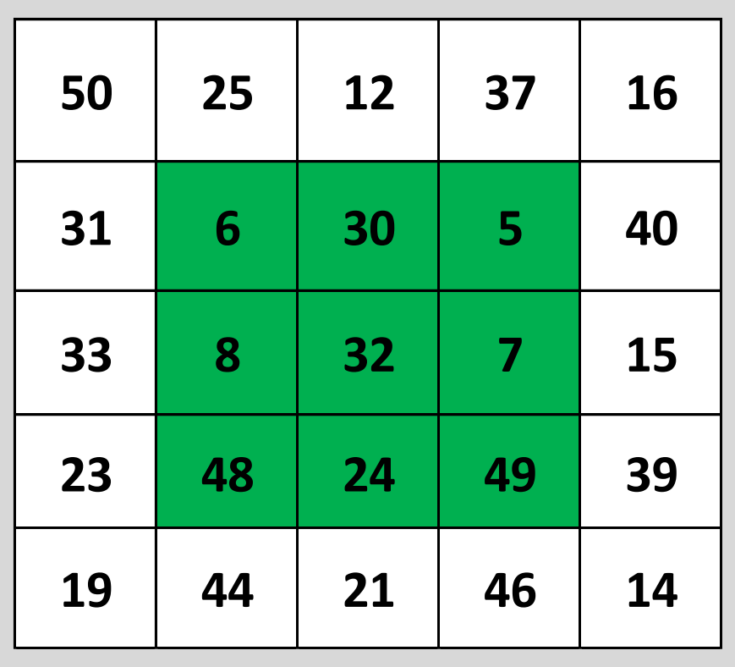






The range dependence on return rate was assumed to be due to the increased multi-photoelectron returns at the greater return rates (applied signal strength). The Hexagon US Federal team determined they could configure the detector chips so that that both the leading edge and trail edge of the return 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. The center nine channels of the pixelated were modified to the new configuration.

The channel numbering scheme of pixelated detector (below). Center nine are configured for pulse width calculation.



50	25	12	37	16
31	6	30	5	40
33	8	32	7	15
23	48	24	49	39
19	44	21	46	14

Pulse Width Calibration Technique

Using the pulse width measurement a calibration curve was developed using the following steps on a high return rate data set.

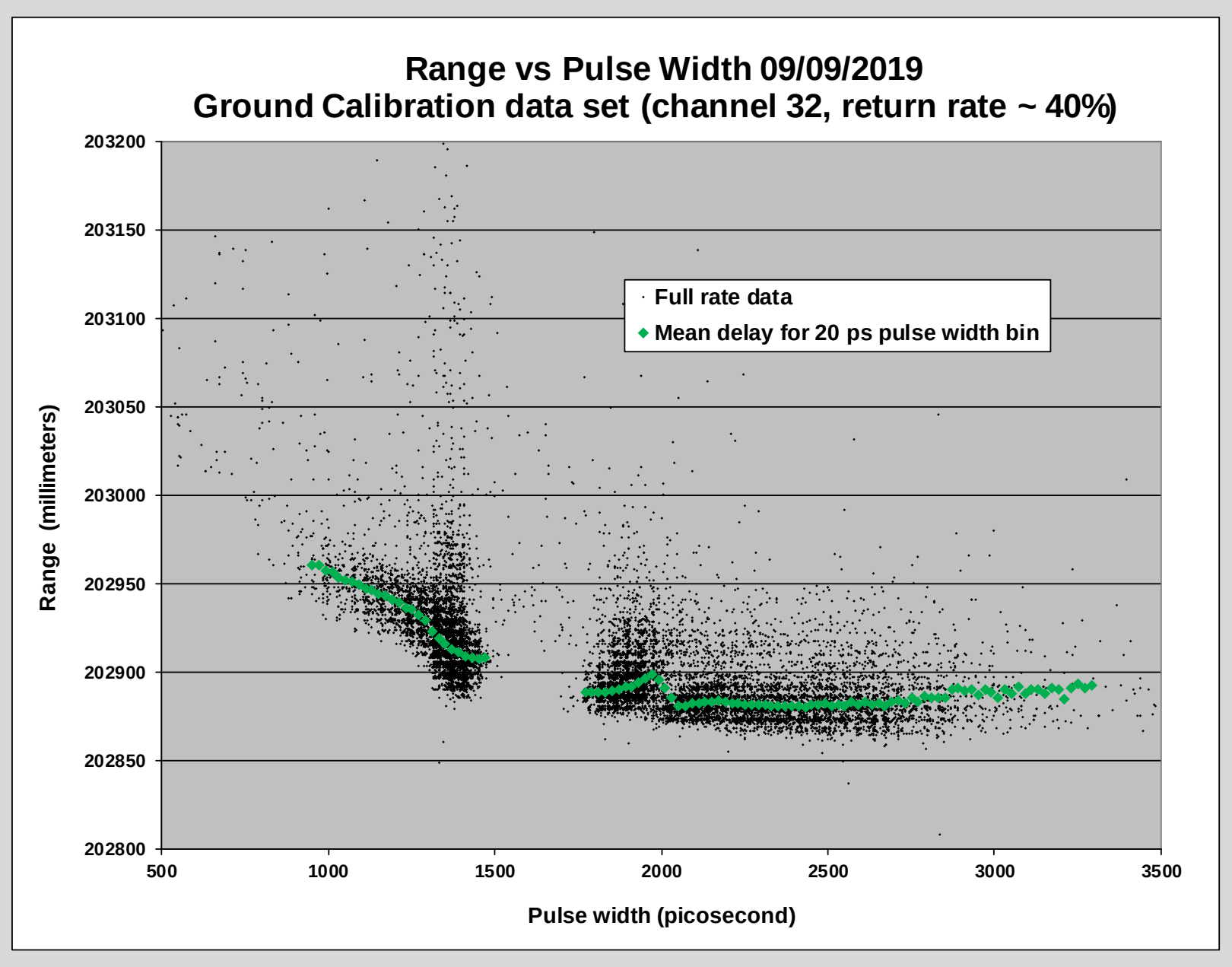
1. Bin range measurements by pulse width.
   (20 picosecond pulse width bins were used in the example)
2. Perform a iterative three sigma multiplier filter on the ranges in each bin and determine the mean range in each bin of the accepted observations.
3. Determine the mean range of the single photoelectron data.
   (the first grouping of data in plot on the top left of next column)
4. Determine the calibration value for each bin by subtracting the single photoelectron mean from the mean range in each bin.

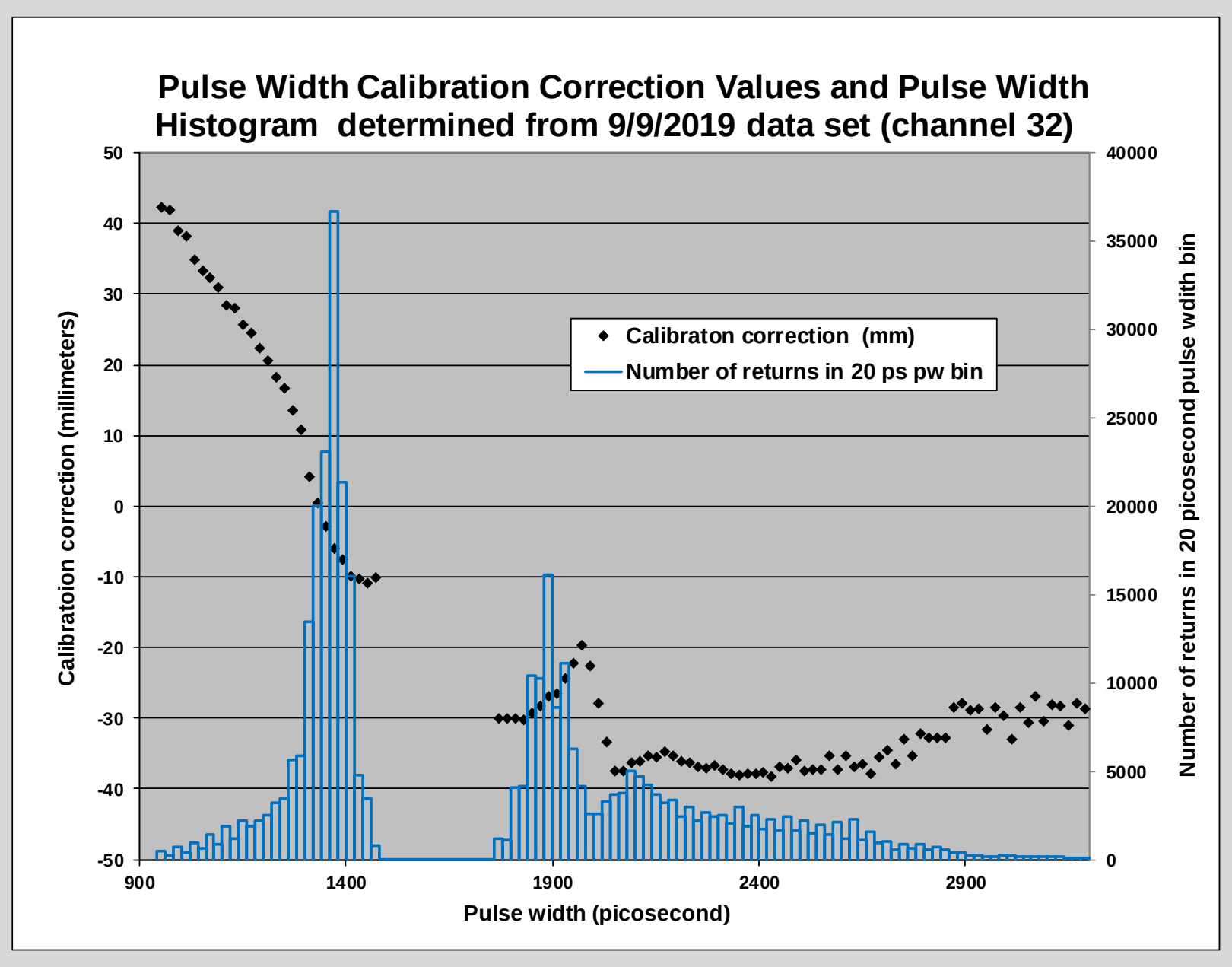
The calibration is applied by subtracting the calibration value from each range based on the pulse width of that observation. The calibration translates the range to the single photoelectron mean values.

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.*

Pulse Width Calibration Technique (continued)

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.

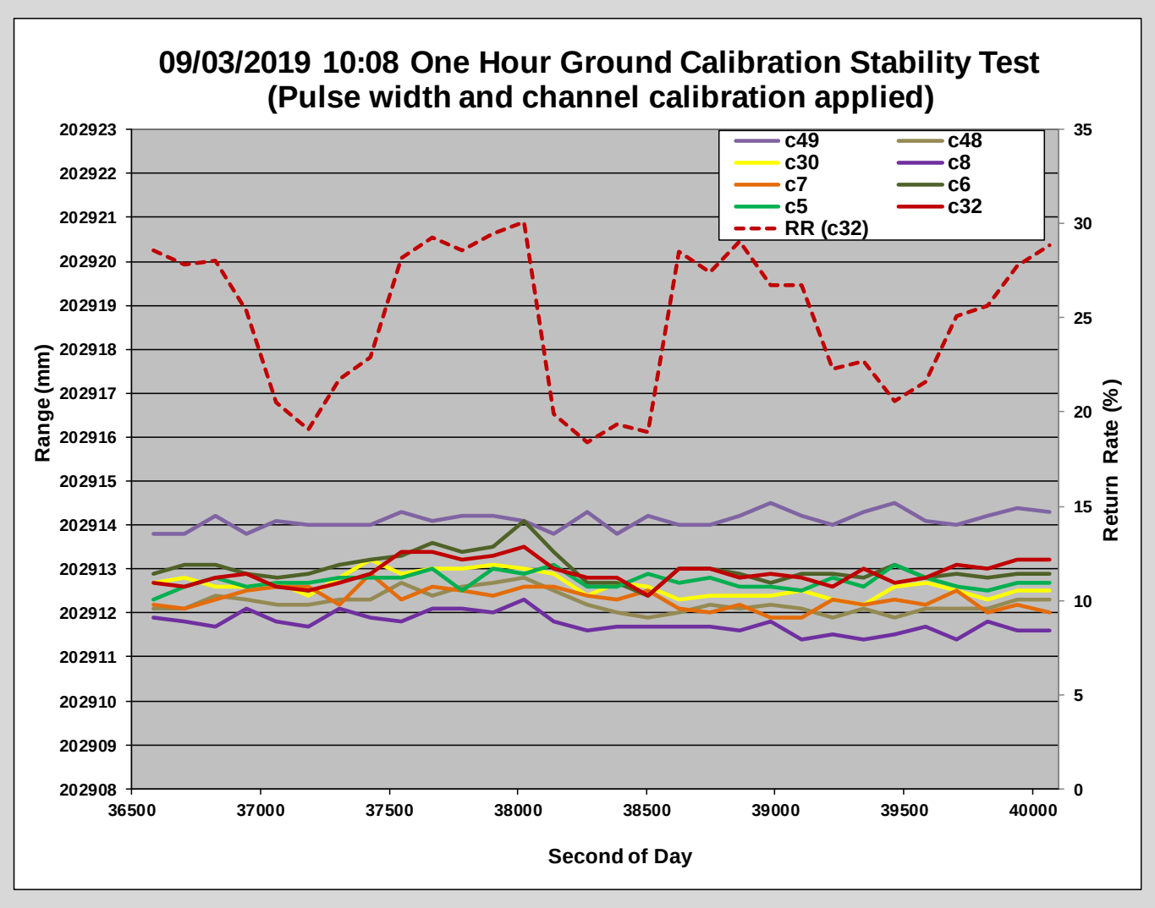




Channel Calibration

The delays between the channels are also calibrated. The is achieved by processing a data set with returns in all channels then determining the offset between channels. The table (below left) displays the results of a channel calibration. In this calibration the center channel, number 32, is chosen as the reference channel. The plot (below right) displays a stability test taken approximately two months later processed with the channel and pulse width calibration applied.

Channel	Range (mm)	Channel Calibration Value (mm)
32	202906.25	0.0
5	202799.74	-106.5
6	202750.72	-155.5
7	202649.36	-256.9
8	202584.99	-321.3
24	202927.00	20.8
30	202606.49	-299.8
48	202829.89	-76.4
49	202833.41	-72.8

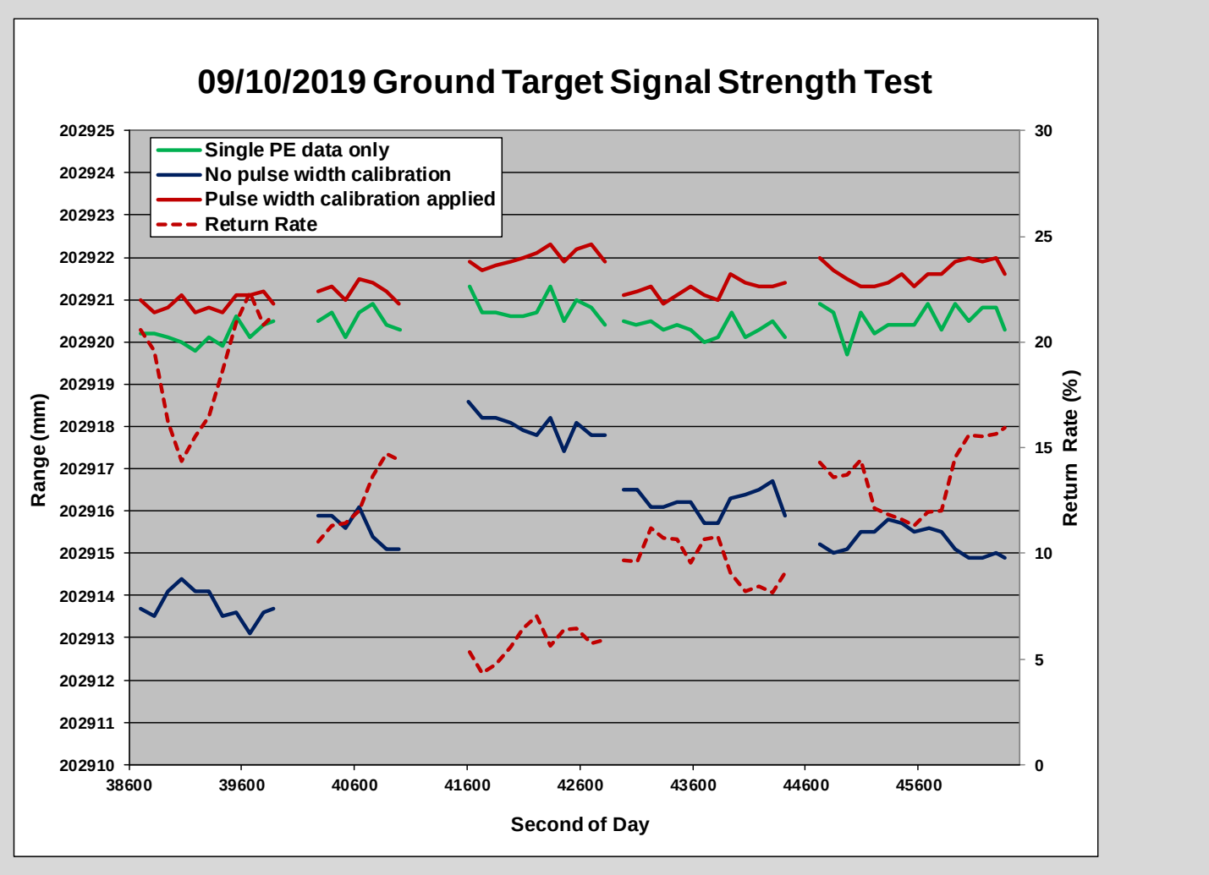


Effects of Applying the Pulse Width Calibration Technique

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

The table (below right) displays the results of some recent SSRx Demonstration unit testing with and with out the pulse width calibration applied.

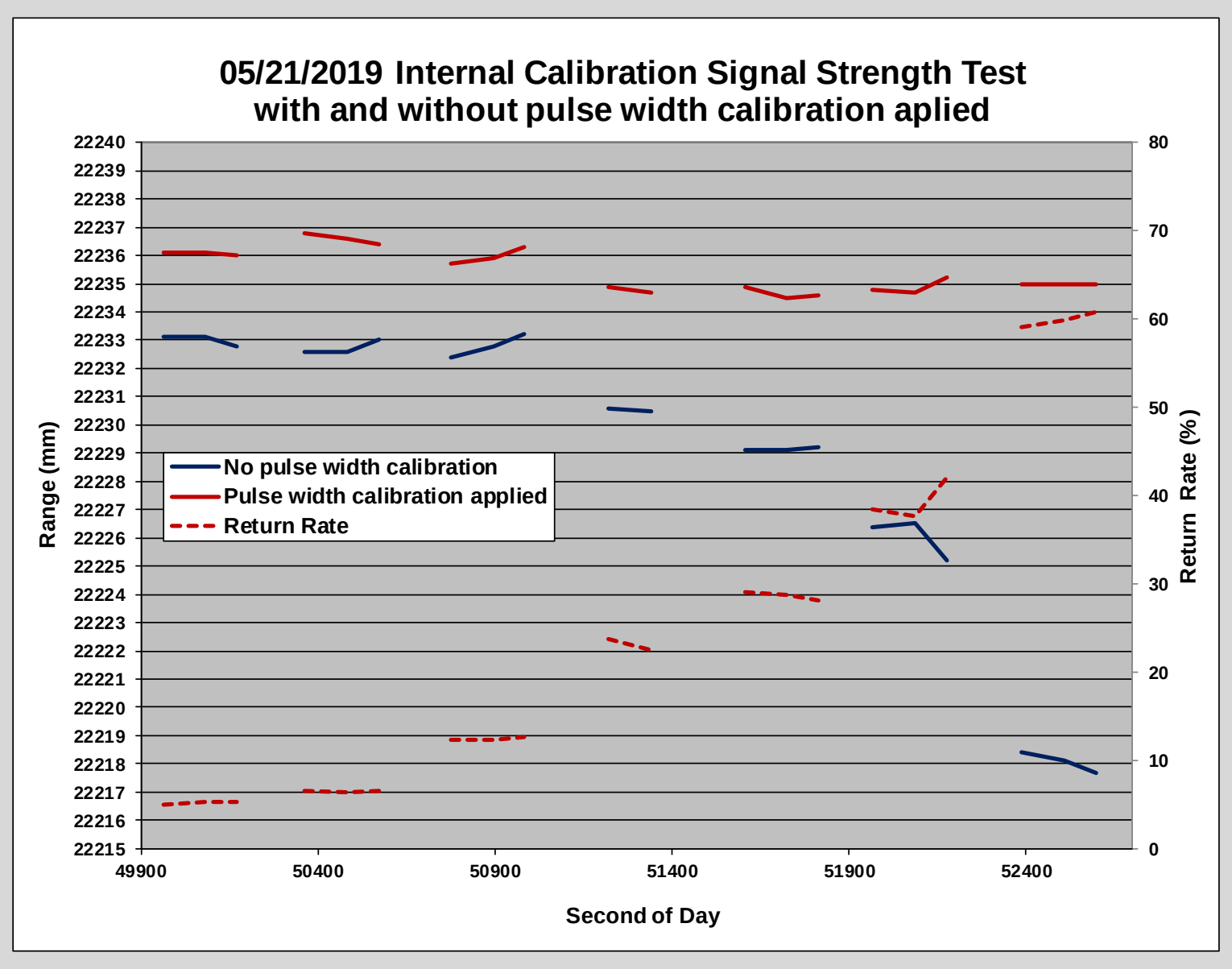


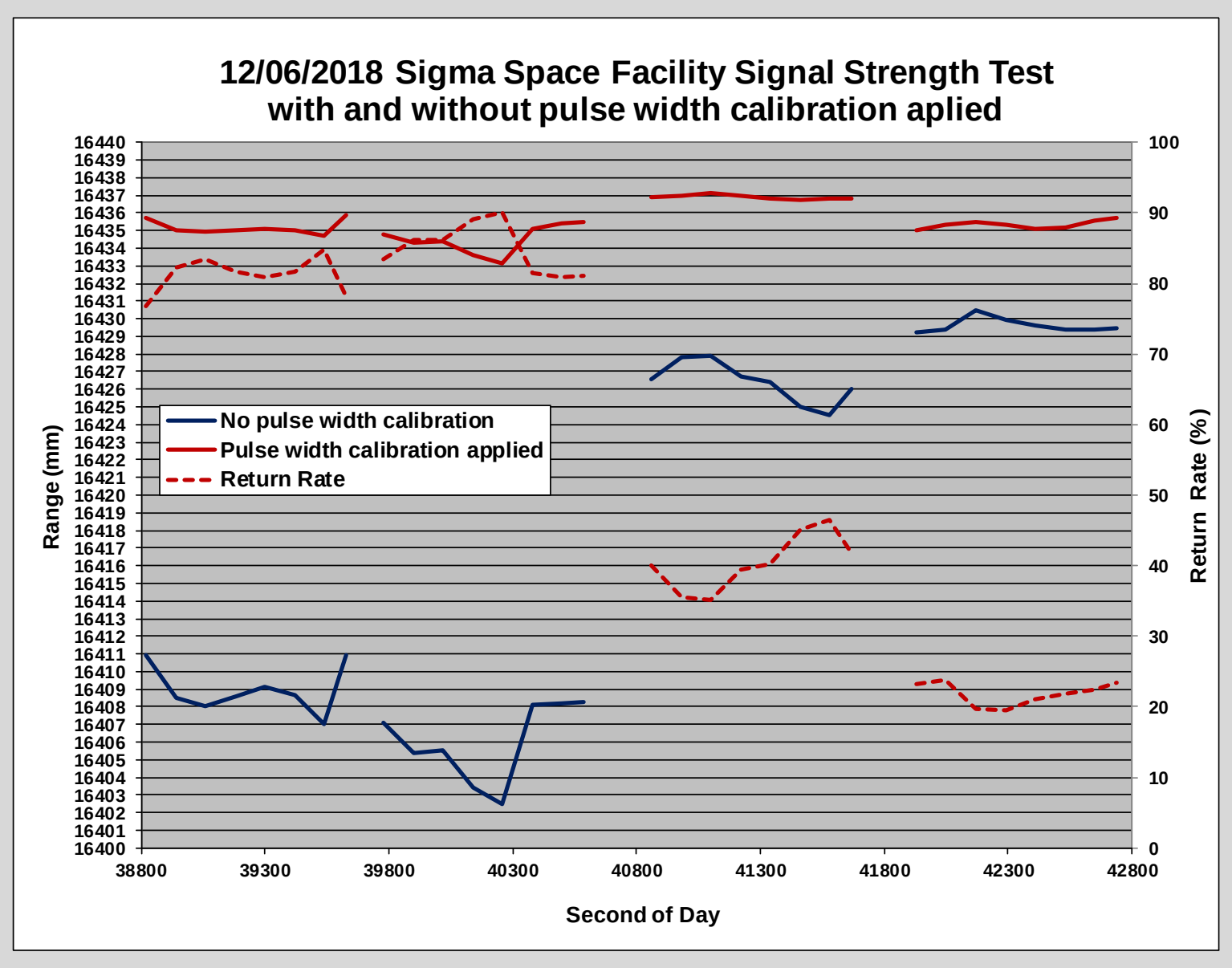
Test	Standard Deviation of NPs (mm)	Standard Devaition of NPs (mm) with pulse calibrtion applied
9/10/19 Stability	1.35	0.55
9/11/19 Stability	0.56	0.27
9/13/19 Stability	0.49	0.48
8/19/19 one minute calibration sims	1.41	0.74
9/10/19 Signal Strength	1.48	0.43

Notice without the pulse width calibration applied the delay shifts approximately 5 millimeters. With the pulse width calibration applied the delay remains stable and agrees well with the single photoelectron data. The standard deviation of the normal points of the demonstration unit test improves significantly with the pulse width calibration applied.

Results of Applying the Pulse Width Calibration to High Return Rate Data

The pulse width calibration generated from the 9/9/19 data set 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 only varies a few millimeters while the uncorrected data varies tens of millimeters. The time between the test data and pulse calibration is four and nine months for the two tests.