ASEN 6080 HW 2

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1. Estimate the orbit from Homework 2 using a batch, CKF, and EKF. Take measurements with $\sigma_\rho = 1$ m & $\sigma_{\dot\rho} = 1$ mm/s. also create $\bar{P}_0$ using $\sigma_r = 1$ km and $\sigma_v = 1$ m/s.

a. choose a δx_0 within $\bar{P}_0$ to use for all 3 filters.

$$\bar{P}_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1e\text{-}6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1e\text{-}6 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1e\text{-}6 \end{bmatrix}$$

Given $\bar{P}_0$, I'm using

$$\delta x_0 = 0.5 \cdot [1 \;\; 1 \;\; 1 \;\; 1e\text{-}3 \;\; 1e\text{-}3 \;\; 1e\text{-}3]^T$$

b. Process the data using each filter and do the following:

i. compute the error between the estimated & true states for the entire arc, and plot the $\pm 3\sigma$ bounds. what happens during the last set of measurements?

ii. Plot the post-fit measurement residuals. Do these match the noise levels you added?

iii. Report the state RMS errors & post-fit residual RMS values, How do these values change if you ignore the first pass of data when computing RMS values?

iv. For the Batch filter, how many times did you iterate? Show how the RMS values change with each iteration

Batch Filter

i. See PDF for plot.

During the last set of measurements, I don't see anything meaningful happen to the state errors

ii. My post-fit residuals match the provided standard deviations of $\sigma_\rho = 1$ m (1e-3 km) and $\sigma_{\dot\rho} = 1$ mm/s (1e-6 km/s) after the 3rd iteration of the Batch filter!

iii. My state RMS errors after the 3rd iteration were

component: $[2.623\times10^{-5},\ 1.2901\times10^{-5},\ 2.198\times10^{-5},\ 1.3236\times10^{-8},\ 9.3911\times10^{-9},\ 1.1176\times10^{-8}]^T$

full-state: 3.6572×10^{-5}

similarly, my post-fit residuals were as follows:

1st run: 25.7565
2nd run: 1.0052
3rd run: 1.0052

iv. my batch filter converged after the 3rd run as the post-fit residual RMS error settled to ~1.0052.

CKF/LKF

i. See PDF for plot

during the last set of measurements, I don't see anything meaningful happen other than a decrease in uncertainty.

ii. my post-fit residuals match the provided standard deviations of $\sigma_r = 1$ m (1e-3 km) and $\sigma_{\dot{r}} = 1$ mm/s (1e-6 km/s) after the 3rd LKF iteration

iii. my RMS errors after the 3rd LKF iteration were

Component: $[0.0124, 0.0077, 0.0153, 1.2085 \times 10^{-5}, 1.3783 \times 10^{-5}, 1.6003 \times 10^{-5}]^T$

Full-state: 0.0212

ob d ignore the first pass ob data, my RMS errors reduce drastically! in fact, they become the same order as the batch filter.

EKF

i. Ile PDF bor plot

again, during the last set ob measurements d don't see anything meaningful happen other than a reduction in uncertainty.

ii. my post fit residuals match the provided standard deviations ob $\sigma_\rho = 1$ m (1e-3 km) and $\sigma_{\dot\rho} = 1$ mm/s (1e-6 km/s) after only 1 iteration when initialized with 157 EKF measurements.

iii. My state RMS errors were

component: $[7.1202\times10^{-4},\ 1.1939\times10^{-4},\ 5.3141\times10^{-4},\ 6.4186\times10^{-7},\ 2.6282\times10^{-7},\ 7.85\times10^{-7}]$ km

full-state: 8.9648×10^{-4}

ob d ignore the first pass ob data, these values reduce by about an order ob 10!

c. Discuss the comparison between the performance of the different filters.

In terms of full-state RMS errors, the batch filter has the smallest, followed by the EKF and finally the LKF. In terms of post-fit residual RMS, this order is reversed! LKF has the smallest, followed by EKF and then Batch. This makes sense, as the batch filter processes all measurements at once - resulting in less overall error - while the EKF and LKF have uncertainty that propagates from timestep to timestep - getting more certain as more measurements are taken.

In terms of implementation, the EKF converged immediately, while the LKF and batch both needed 3 runs to converge. However, the EKF required a number of LKF runs first, which means that it too needed "3 runs" to converge.

Finally, it seems that the Batch algorithm ran the fastest at ~3 seconds, followed by the EKF and LKF at ~3.5 and ~5.5 seconds respectively.

d. change $\sigma_r = 1000$ km and $\sigma_v = 1$ km/s. How does this change each filter's performance?

changing σ_r and σ_v didn't change the batch filter's performance much at all.

changing σ_r and σ_v increased the number of runs needed for the LKF to converge and increased its final RMS errors, as many of the state errors landed outside of the predicted range. it broke!

changing σ_r and σ_v introduced outliers to the EKF's post-fit residuals and increased its RMS errors, but it still ran in the same amount of time and resulted in plausible state errors.

e. change $\delta x_0 = 100 \delta x_{0,used}$. How does this change each filter's performance? did any stop working?

changing δx_0 didn't affect the Batch filter performance at all!

changing δx_0 further increased my LKF RMS errors and resulted in state errors outside the predicted bounds. it broke!

Since my EKF is initialized with an LKF (which broke), it also broke. However, initializing it with my batch filter made it work again.

In general, it seems that the batch filter is the most resistant to initialization, while the LKF is very sensitive. Likewise, the EKF will behave as long as the filter that initialized it also behaves.

F. What happens to the solution at the original $P_0 + \delta x_0$, but only half the measurements are processed?

If only half the measurements are processed, the batch filter's final state errors vary more, but the LKF and EKF seem relatively unaffected! This makes sense, as the more measurements the batch filter processes the better it is, while the LKF and EKF are "online" estimators, meaning they only need one measurement at a time and their state estimates tend to get better with each measurement.

ASEN 6080 HW 2 Problem 1 Main Script

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By: Ian Faber

Housekeeping

Setup

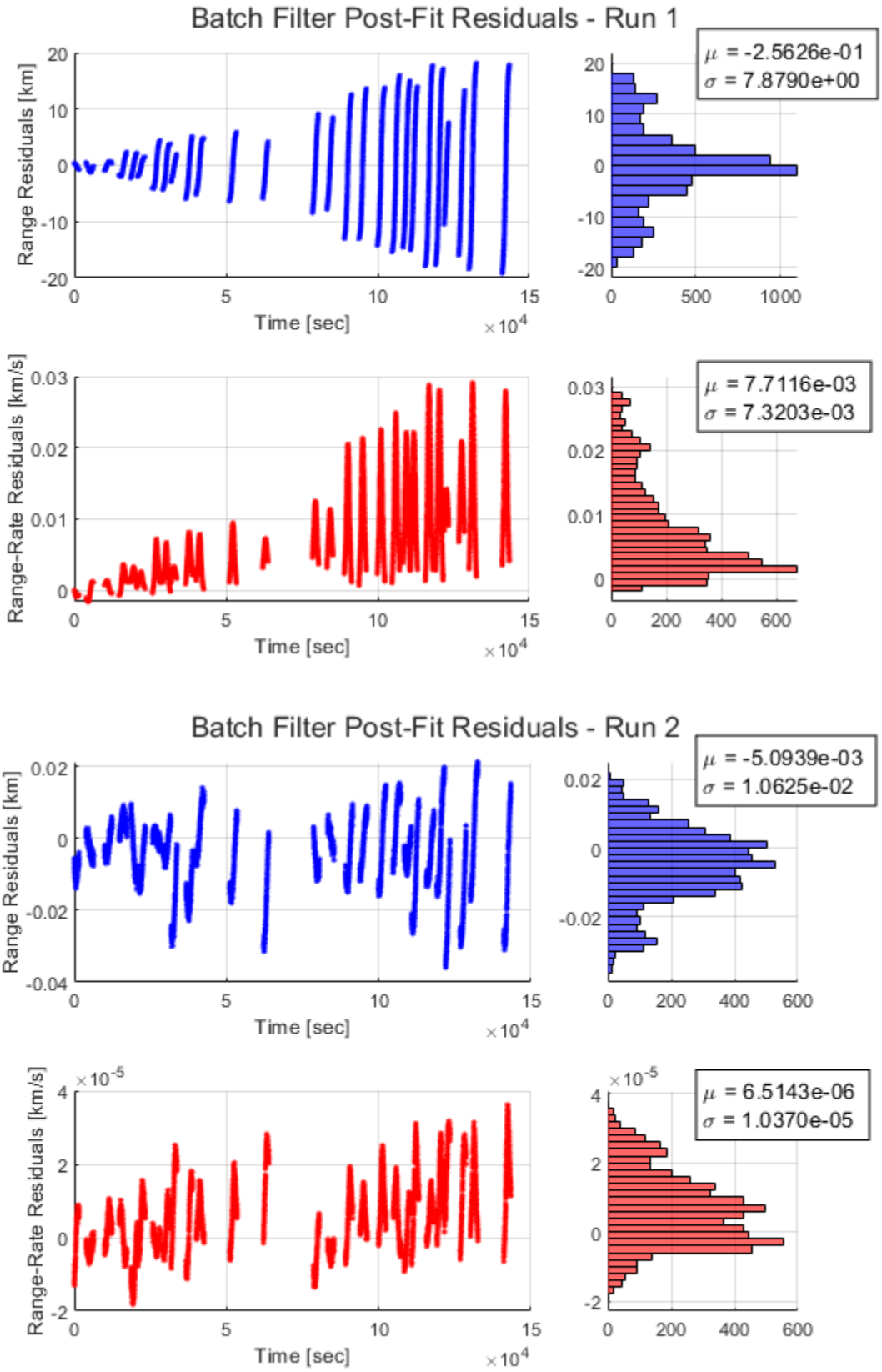
Make Truth Data

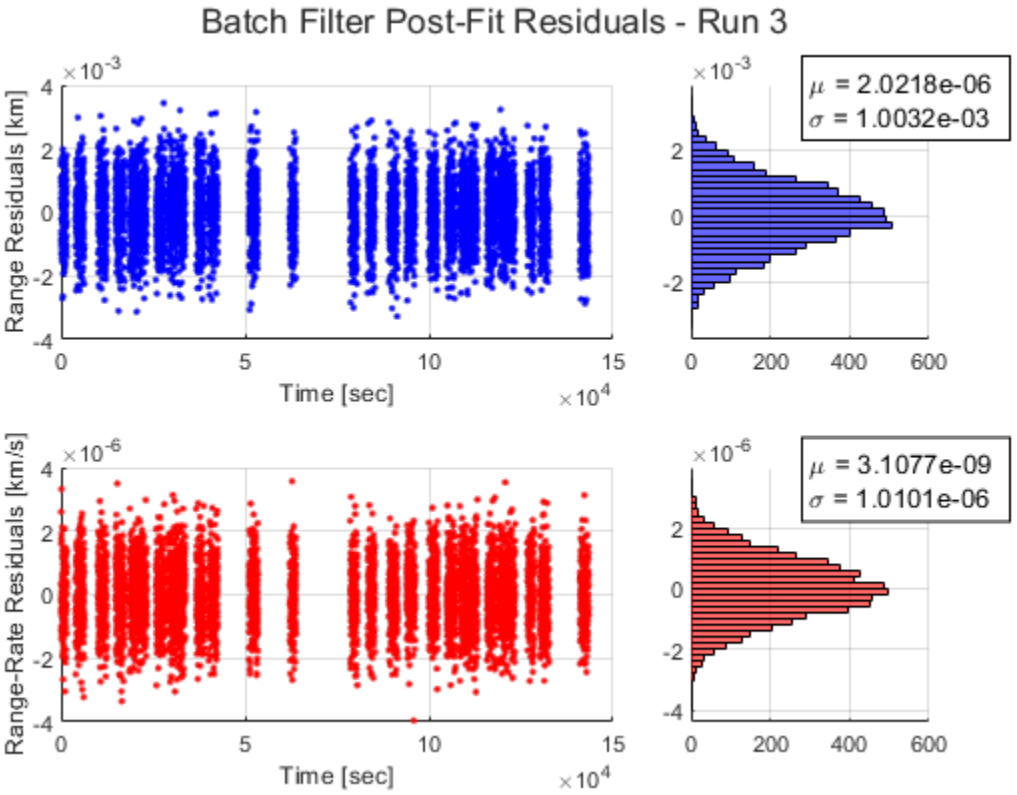
Problem 1a: Filter setup

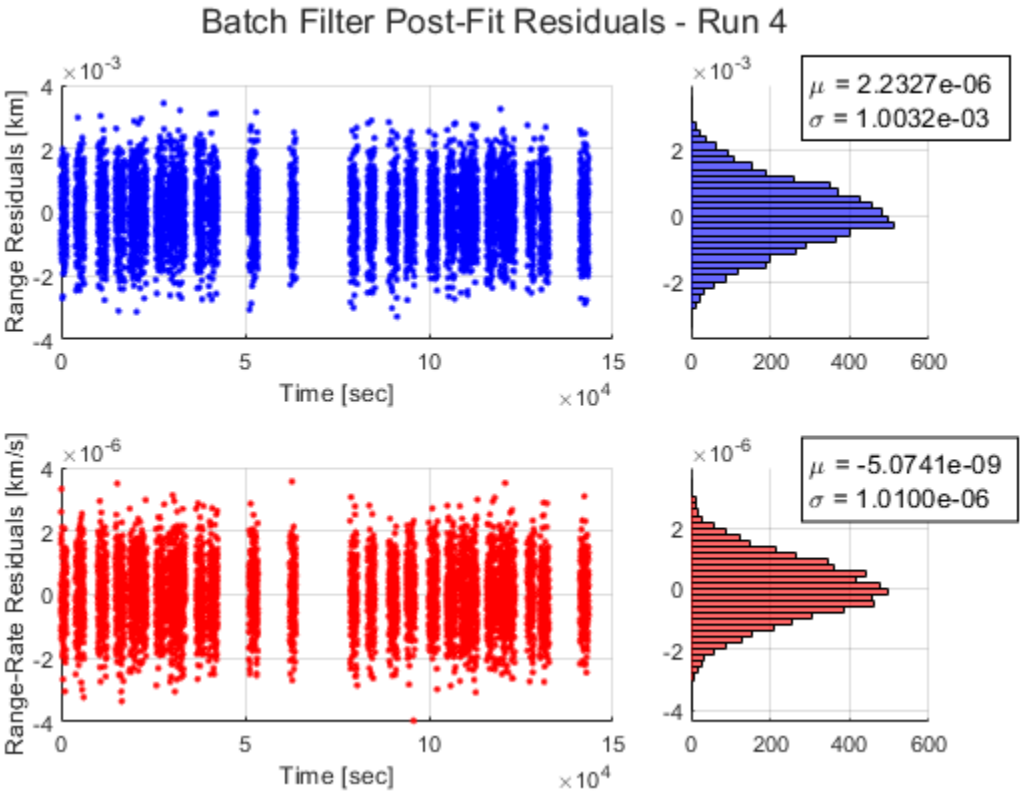
Problem 1b: Batch Filter

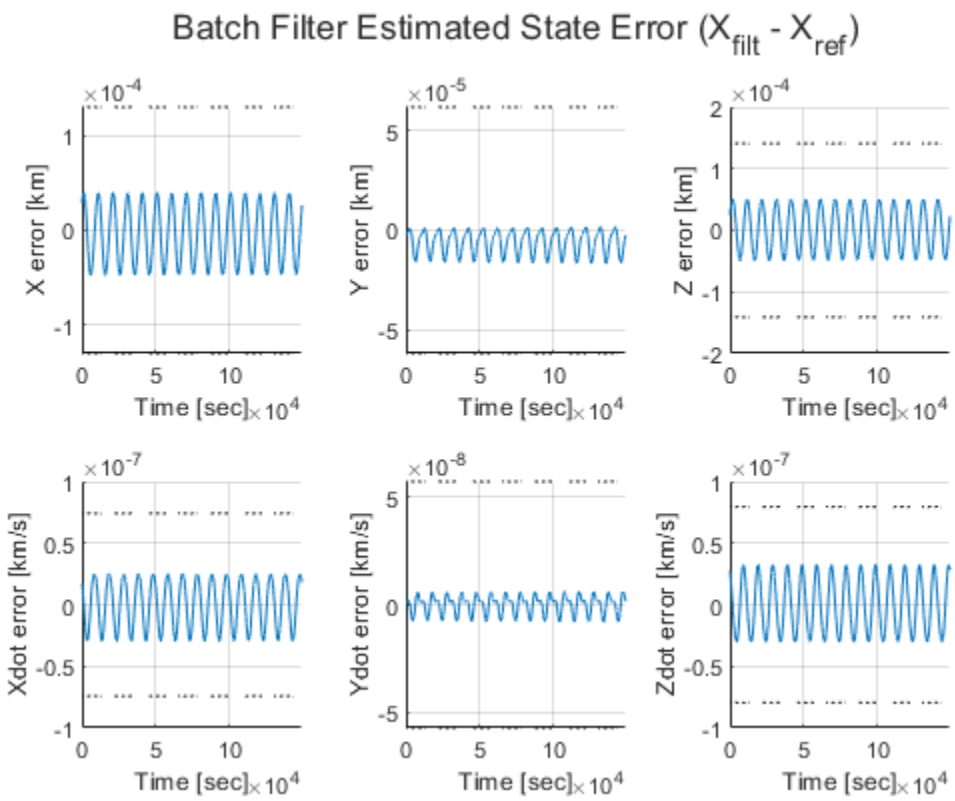
```
1b. Batch Filter


    Running Batch Filter:
Postfit RMS: 25.7449. Iterating Batch with x0_batch = [1.067e-02;
-4.072e-03; 1.021e-02; 1.778e-05; -4.425e-06; 2.383e-05]. Runs so far: 1
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [-2.875e-05; 2.892e-06;
-2.544e-05; -1.682e-08; -1.178e-09; -2.762e-08]. Runs so far: 2
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [-2.879e-05; 2.845e-06;
-2.535e-05; -1.693e-08; -1.208e-09; -2.768e-08]. Runs so far: 3
Final postfit RMS: 1.0065. Converged after 4 runs
```


Batch Filter Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.5626e-01
σ = 7.8790e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.7116e-03
σ = 7.3203e-03
Batch Filter Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -5.0939e-03
σ = 1.0625e-02
×10^-5
Range-Rate Residuals [km/s]
Time [sec]
×10^4
×10^-5
μ = 6.5143e-06
σ = 1.0370e-05


Batch Filter Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 2.0218e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = 3.1077e-09
σ = 1.0101e-06


Batch Filter Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 2.2327e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -5.0741e-09
σ = 1.0100e-06



Problem 1b: CKF/LKF

1b. LKF

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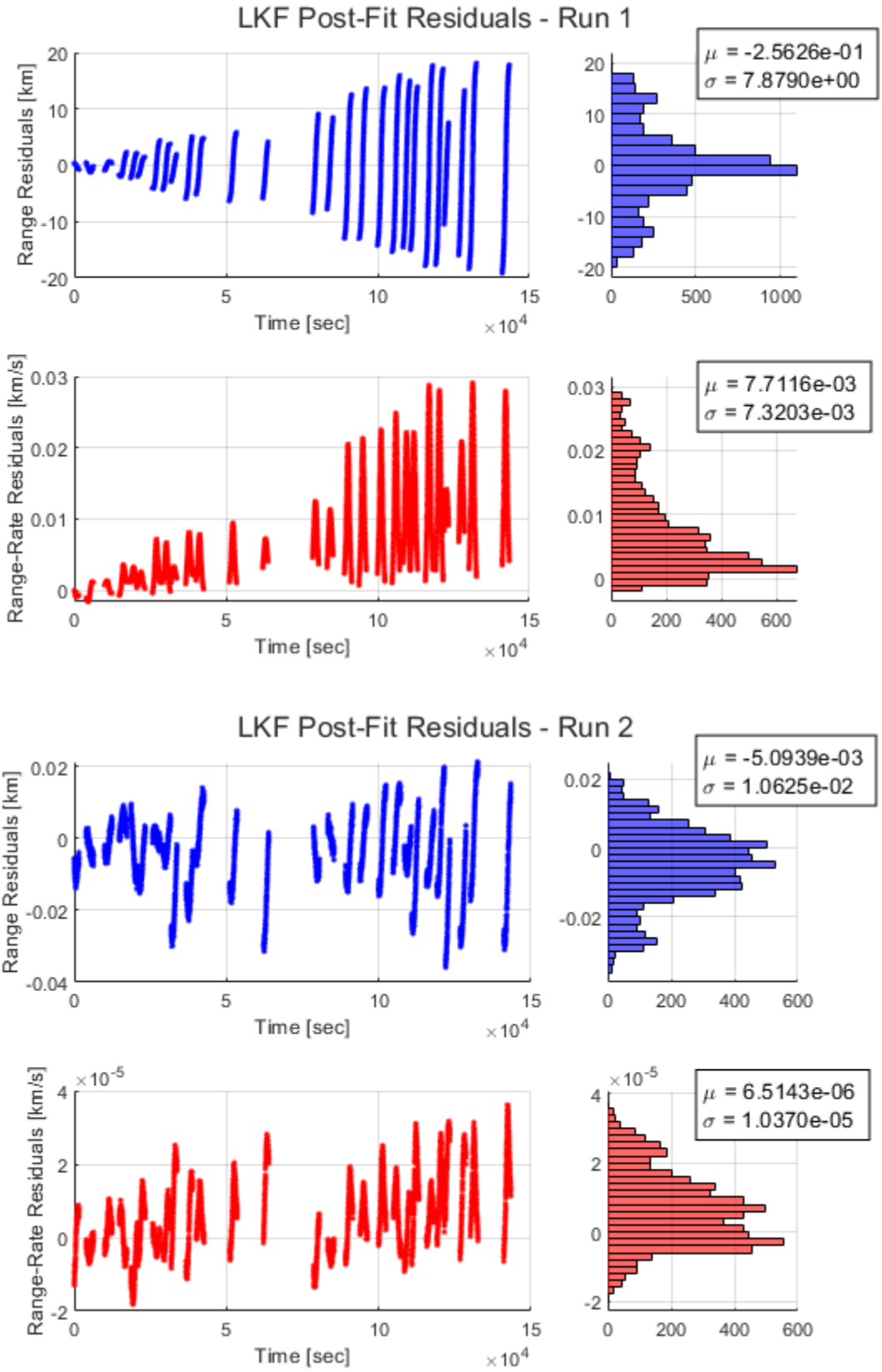
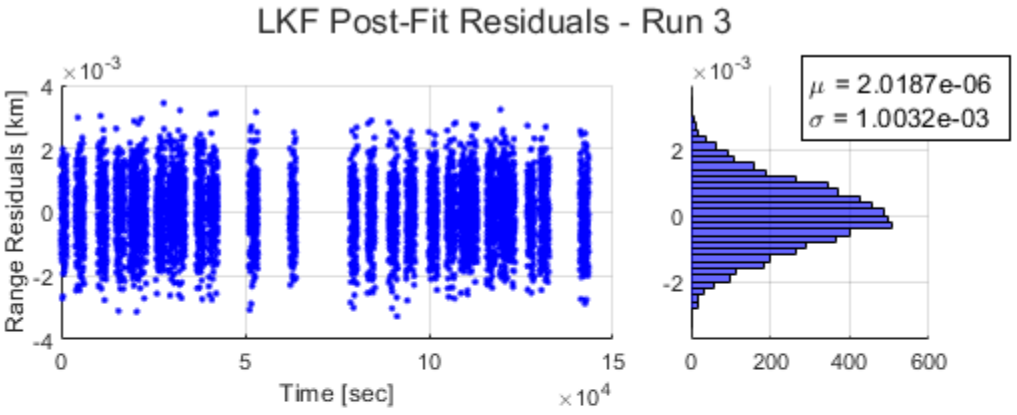
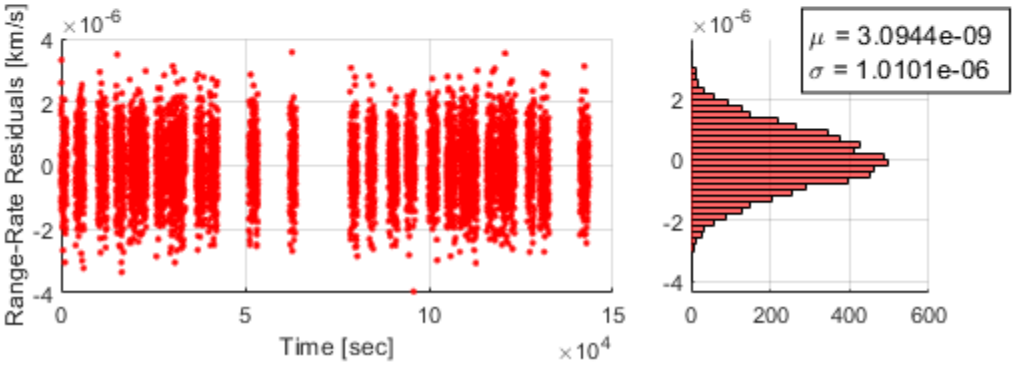
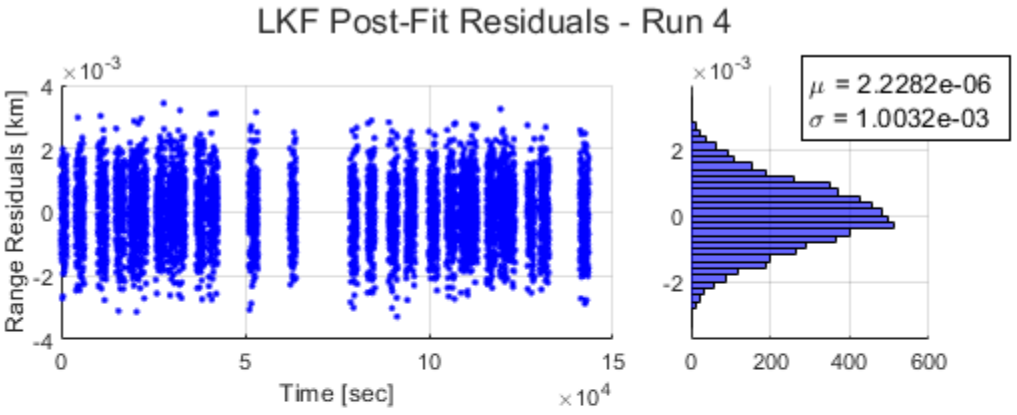
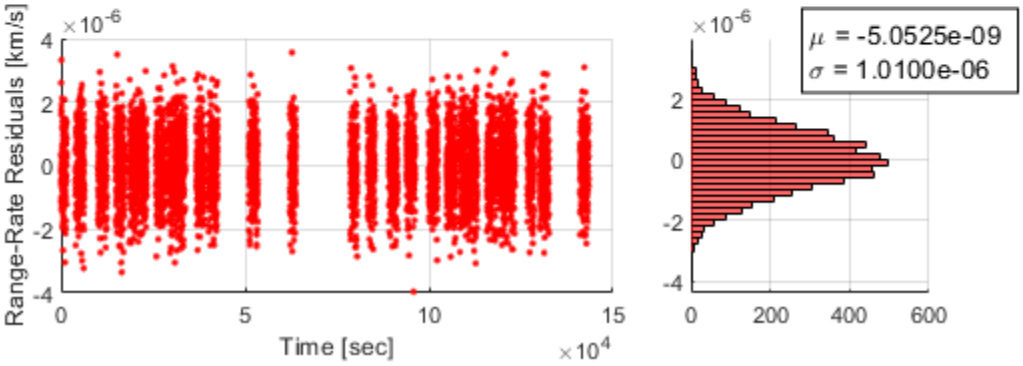
    Running LKF:
Postfit RMS: 25.7373. Iterating LKF with x0_LKF = [4.893e-01; 5.041e-01;
4.898e-01; 4.822e-04; 5.044e-04; 4.762e-04]. Runs so far: 1
Postfit RMS: 1.0029. Iterating LKF with x0_LKF = [1.070e-02; -4.075e-03;
1.023e-02; 1.780e-05; -4.424e-06; 2.385e-05]. Runs so far: 2
Postfit RMS: 1.0029. Iterating LKF with x0_LKF = [3.439e-08; 4.107e-08;
-9.244e-08; 1.191e-10; 2.333e-11; 5.341e-11]. Runs so far: 3
Final postfit RMS: 1.0029. Converged after 4 runs
```

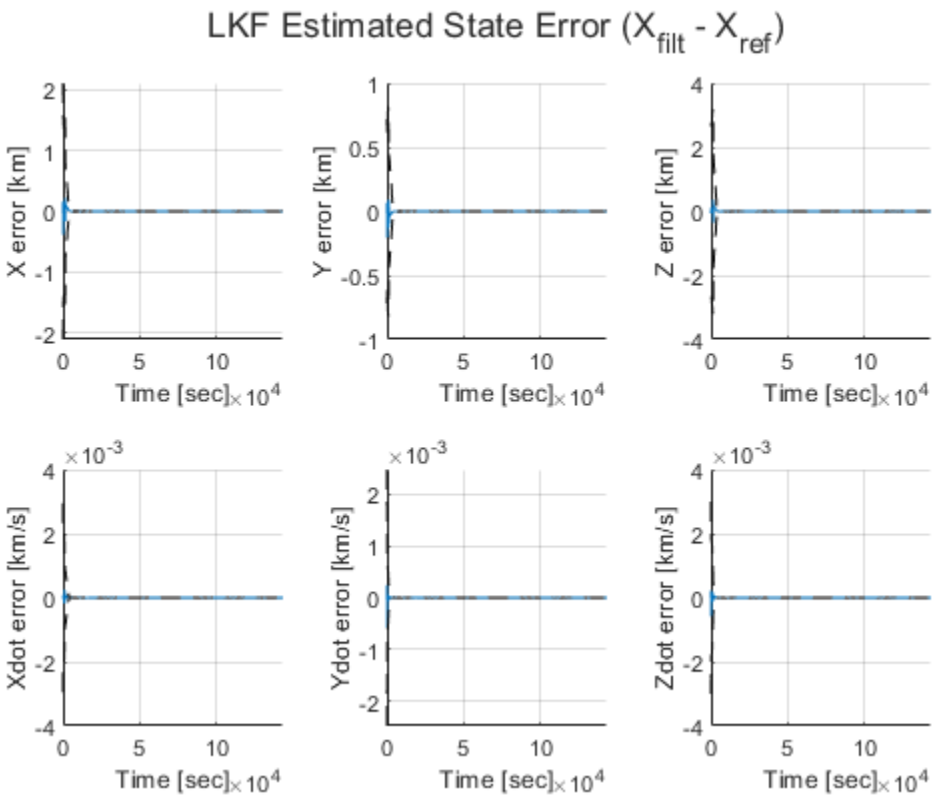

LKF Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.5626e-01
σ = 7.8790e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.7116e-03
σ = 7.3203e-03
LKF Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -5.0939e-03
σ = 1.0625e-02
Range-Rate Residuals [km/s]
×10^-5
Time [sec]
×10^4
×10^-5
μ = 6.5143e-06
σ = 1.0370e-05


LKF Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 2.0187e-06
σ = 1.0032e-03


Range-Rate Residuals [km/s]
Time [sec]
μ = 3.0944e-09
σ = 1.0101e-06


LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 2.2282e-06
σ = 1.0032e-03


Range-Rate Residuals [km/s]
Time [sec]
μ = -5.0525e-09
σ = 1.0100e-06



Problem 1b: EKF

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1b. EKF


    Running EKF:
Postfit RMS: 1.0043
```
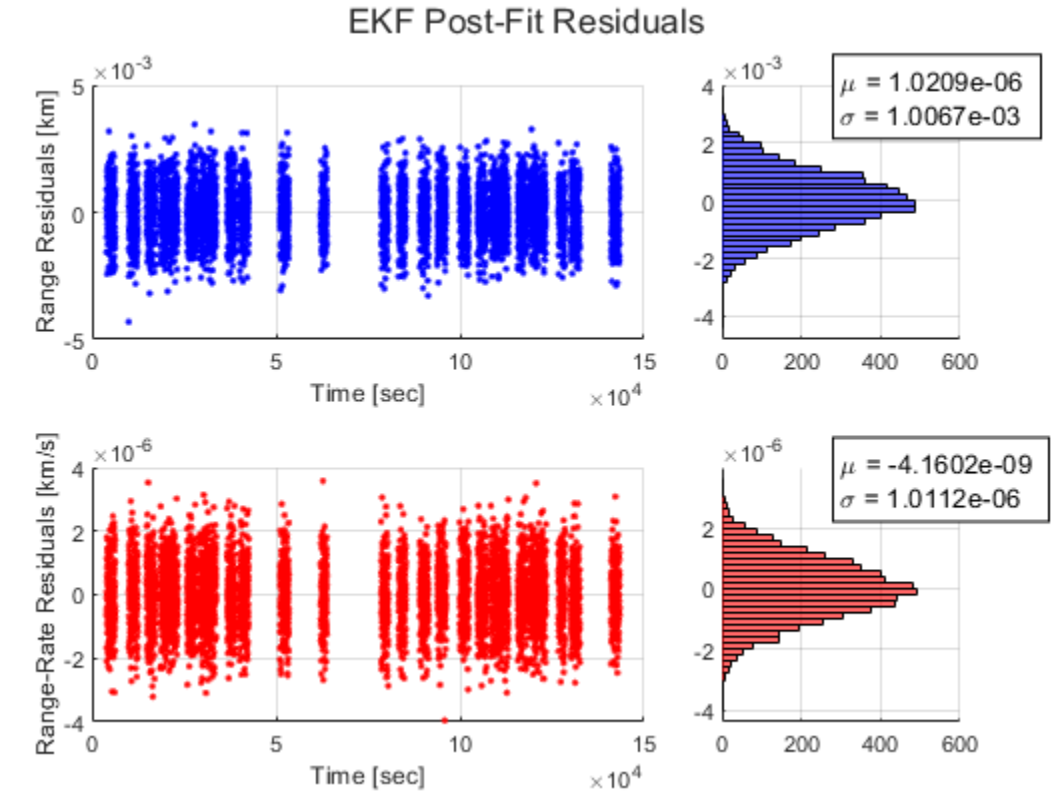
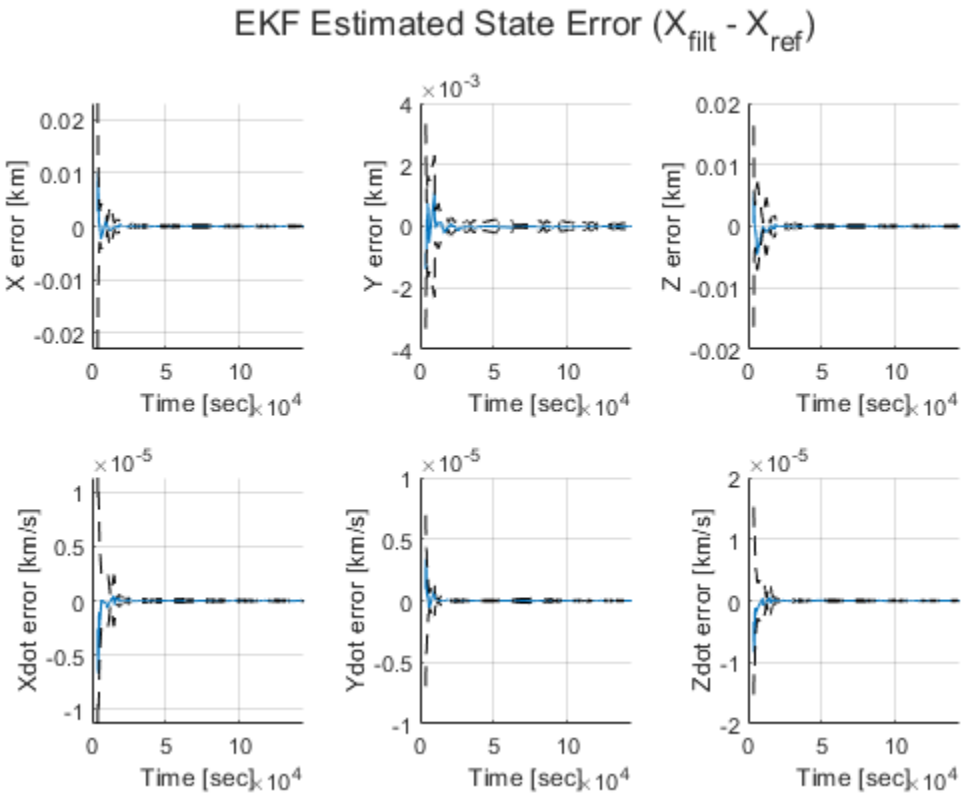
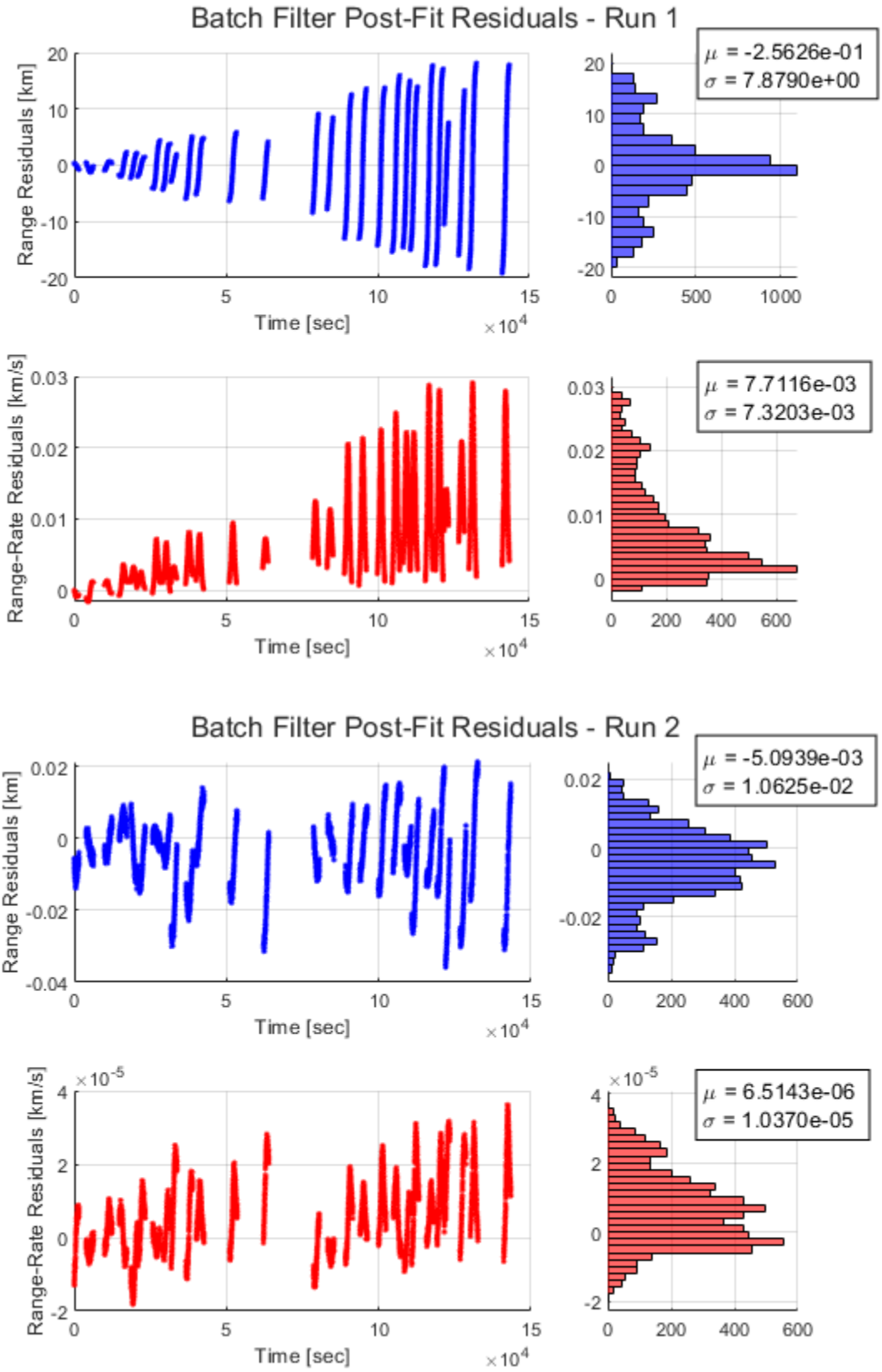
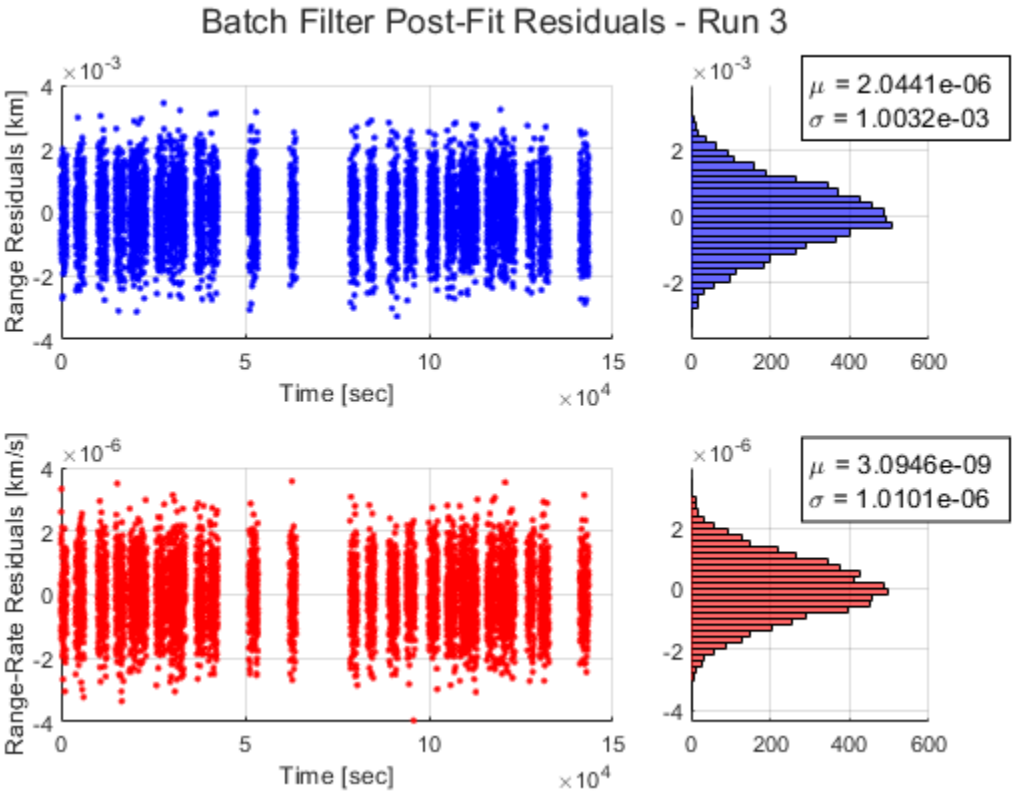


EKF Post-Fit Residuals
Range Residuals [km]
Time [sec]
μ = 1.0209e-06
σ = 1.0067e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -4.1602e-09
σ = 1.0112e-06

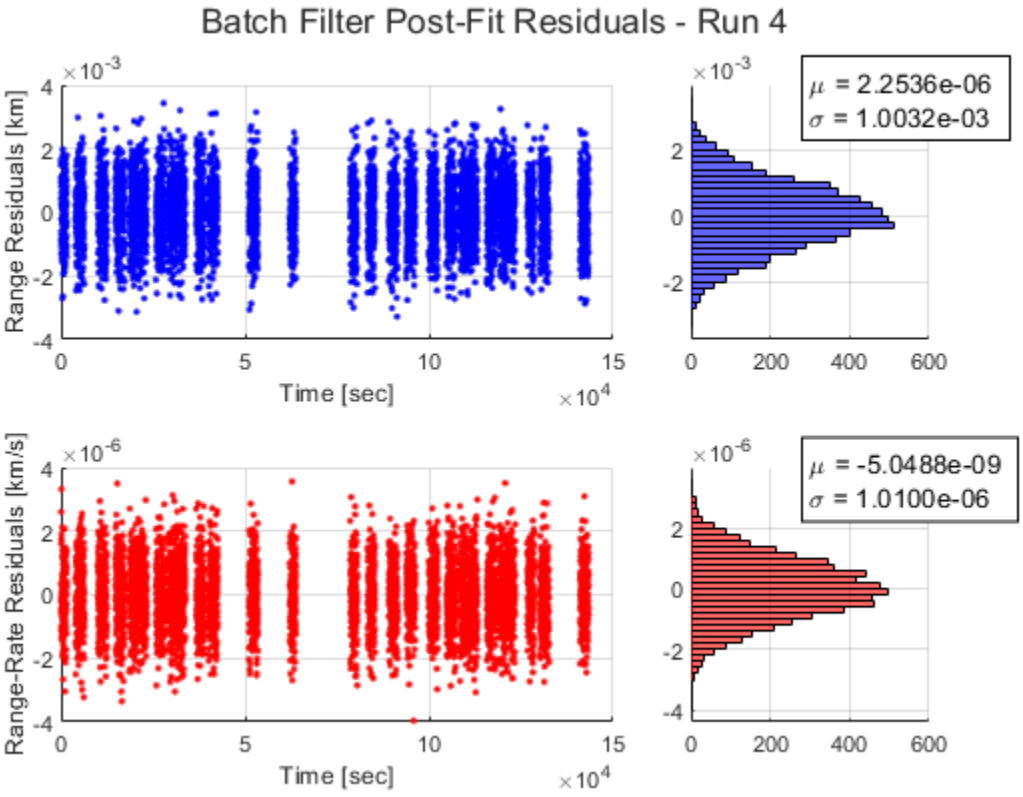

EKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]

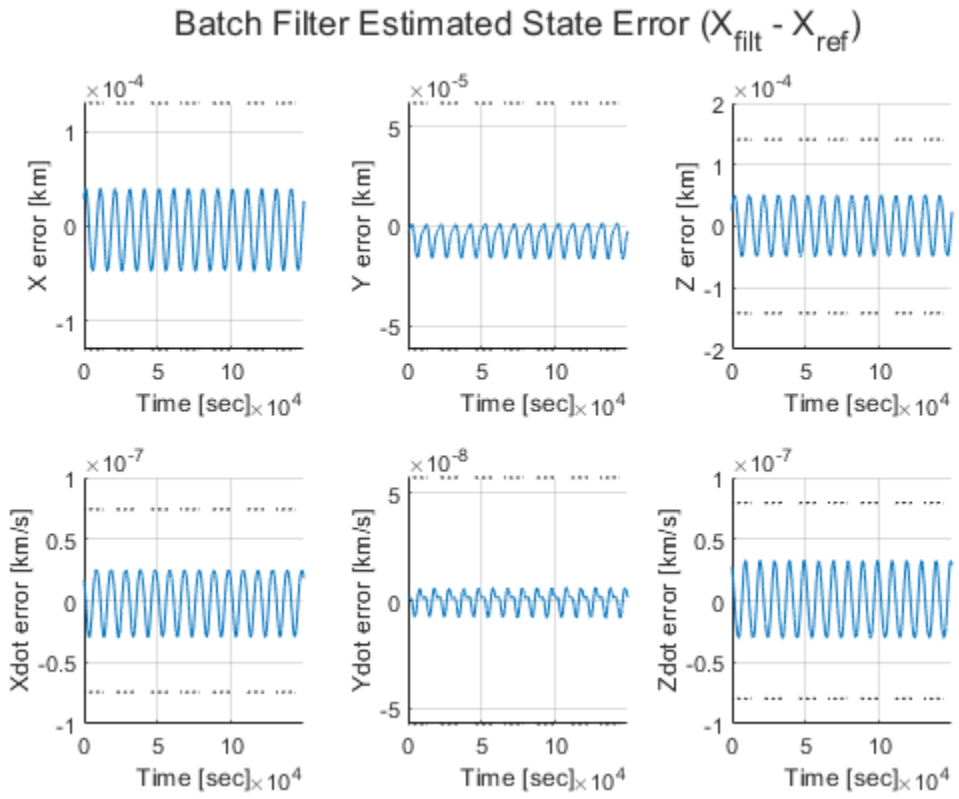
Problem 1d: Increase x0

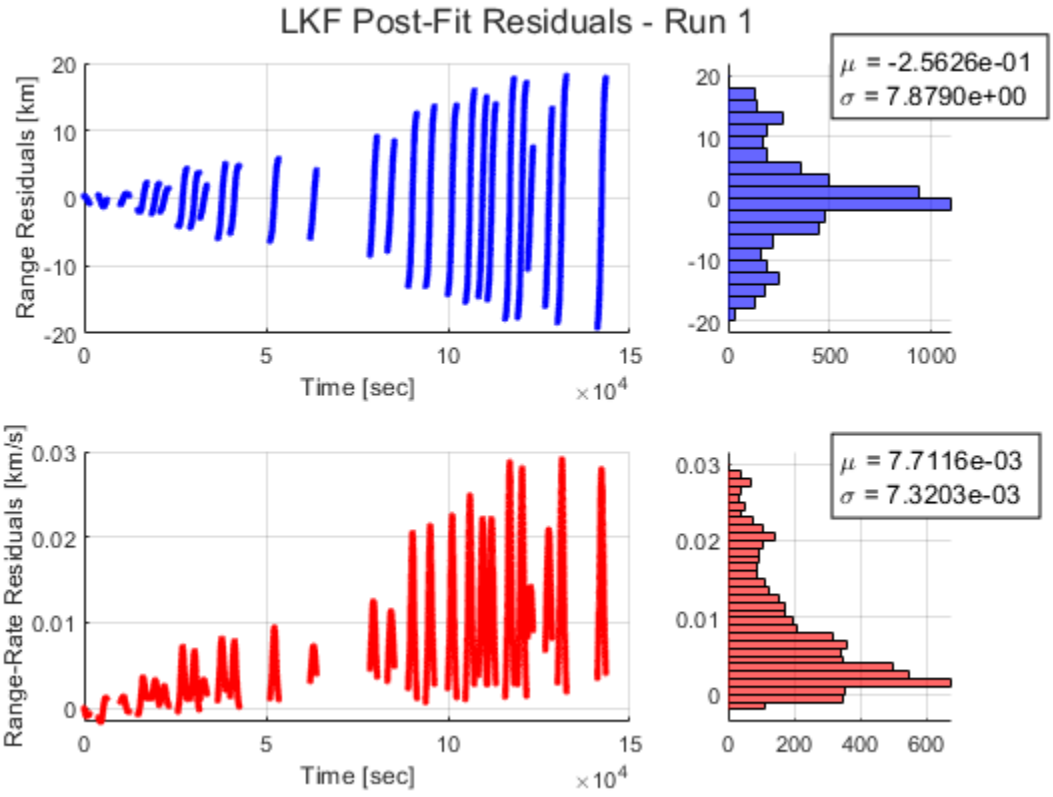
```
1d. Increased x0


    Running Batch Filter:
Postfit RMS: 25.7449. Iterating Batch with x0_batch = [4.951e+01; 4.950e+01;
4.951e+01; 4.952e-02; 4.950e-02; 4.952e-02]. Runs so far: 1
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [4.950e+01; 4.950e+01;
4.950e+01; 4.950e-02; 4.950e-02; 4.950e-02]. Runs so far: 2
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [4.950e+01; 4.950e+01;
4.950e+01; 4.950e-02; 4.950e-02; 4.950e-02]. Runs so far: 3
Final postfit RMS: 1.0065. Converged after 4 runs

    Running LKF:
Postfit RMS: 25.7483. Iterating LKF with x0_LKF = [4.893e-01; 5.041e-01;
4.898e-01; 4.822e-04; 5.044e-04; 4.762e-04]. Runs so far: 1
Postfit RMS: 1.0029. Iterating LKF with x0_LKF = [1.070e-02; -4.075e-03;
1.023e-02; 1.780e-05; -4.424e-06; 2.385e-05]. Runs so far: 2
Postfit RMS: 1.0029. Iterating LKF with x0_LKF = [3.592e-08; 4.190e-08;
-9.354e-08; 1.185e-10; 2.419e-11; 5.383e-11]. Runs so far: 3
Final postfit RMS: 1.0029. Converged after 4 runs

    Running EKF:
Postfit RMS: 1.0043
```

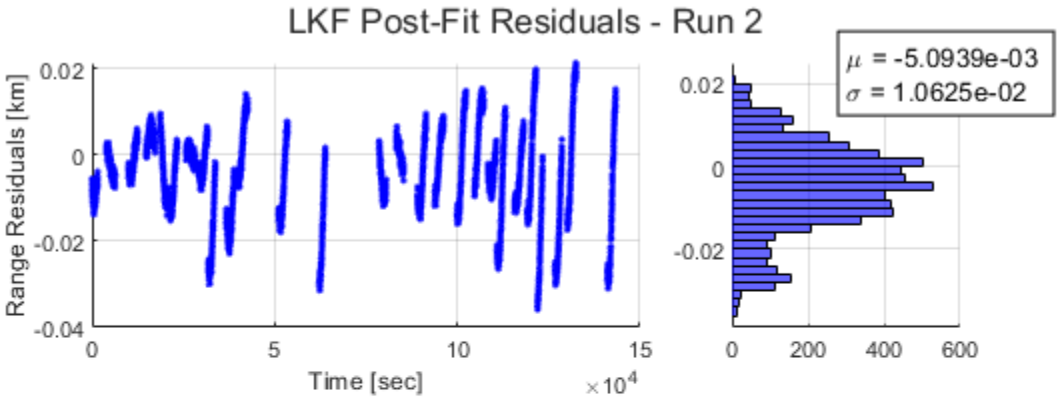

Batch Filter Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.5626e-01
σ = 7.8790e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.7116e-03
σ = 7.3203e-03
Batch Filter Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -5.0939e-03
σ = 1.0625e-02
×10^-5
Range-Rate Residuals [km/s]
Time [sec]
×10^4
×10^-5
μ = 6.5143e-06
σ = 1.0370e-05

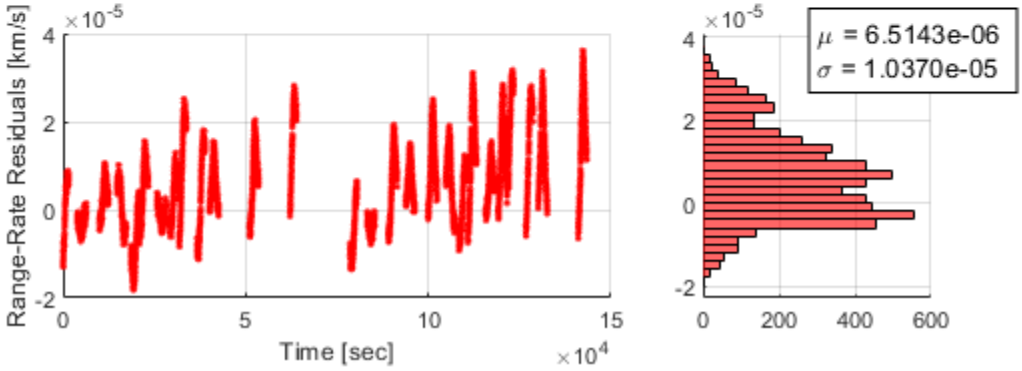

Batch Filter Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 2.0441e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = 3.0946e-09
σ = 1.0101e-06

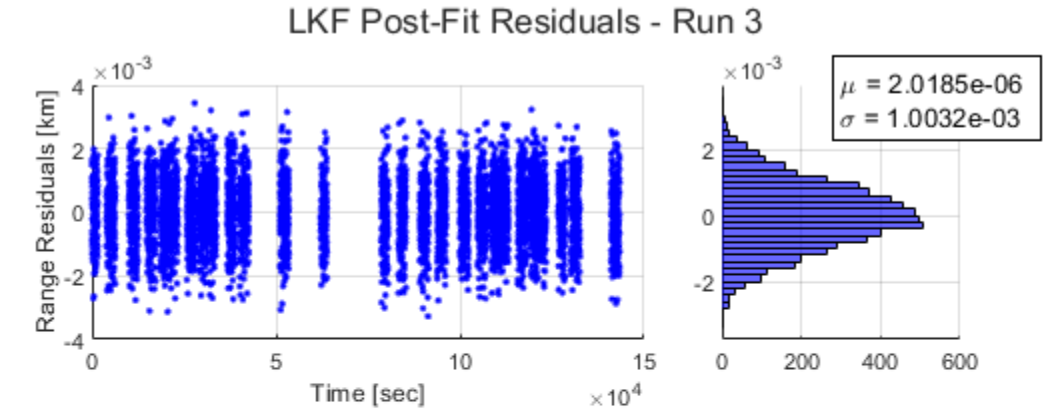

Batch Filter Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 2.2536e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -5.0488e-09
σ = 1.0100e-06

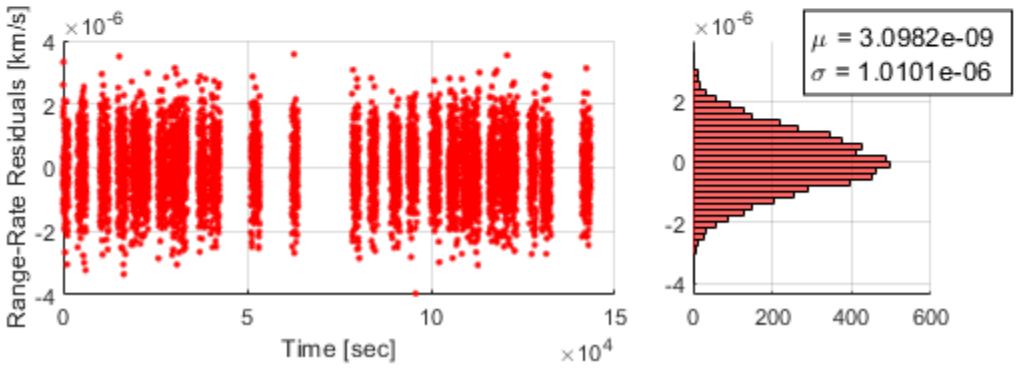

Batch Filter Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]

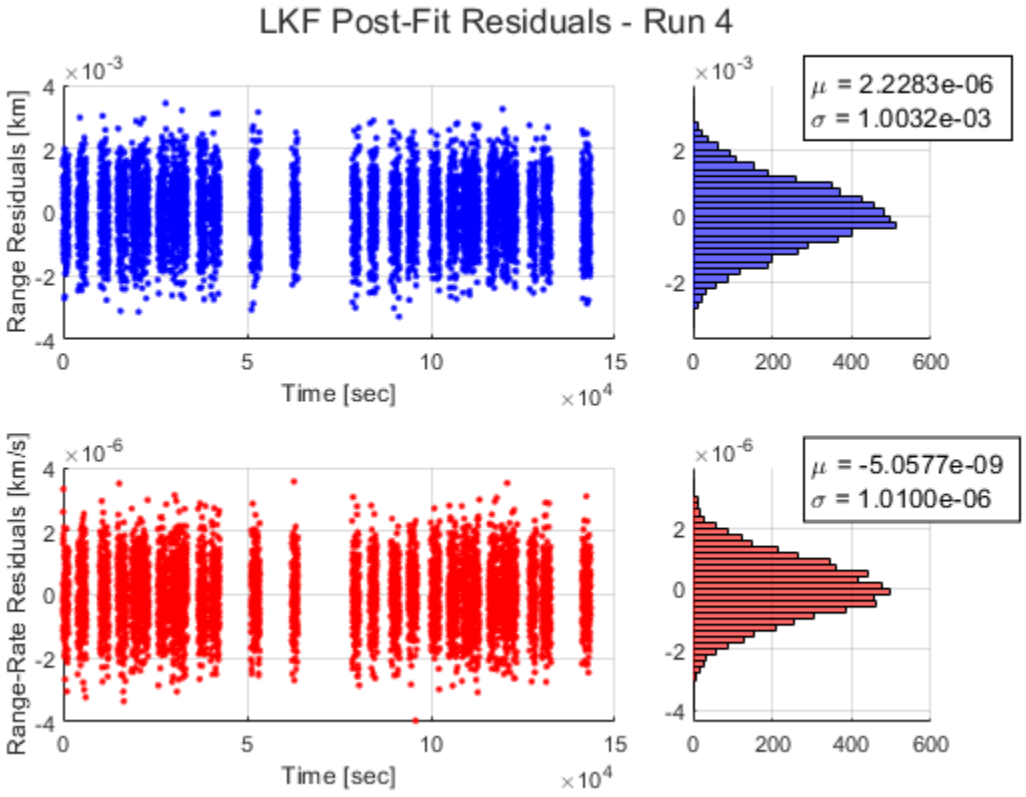

LKF Post-Fit Residuals - Run 1
Range Residuals [km]
Range-Rate Residuals [km/s]
Time [sec]
μ = -2.5626e-01
σ = 7.8790e+00
μ = 7.7116e-03
σ = 7.3203e-03

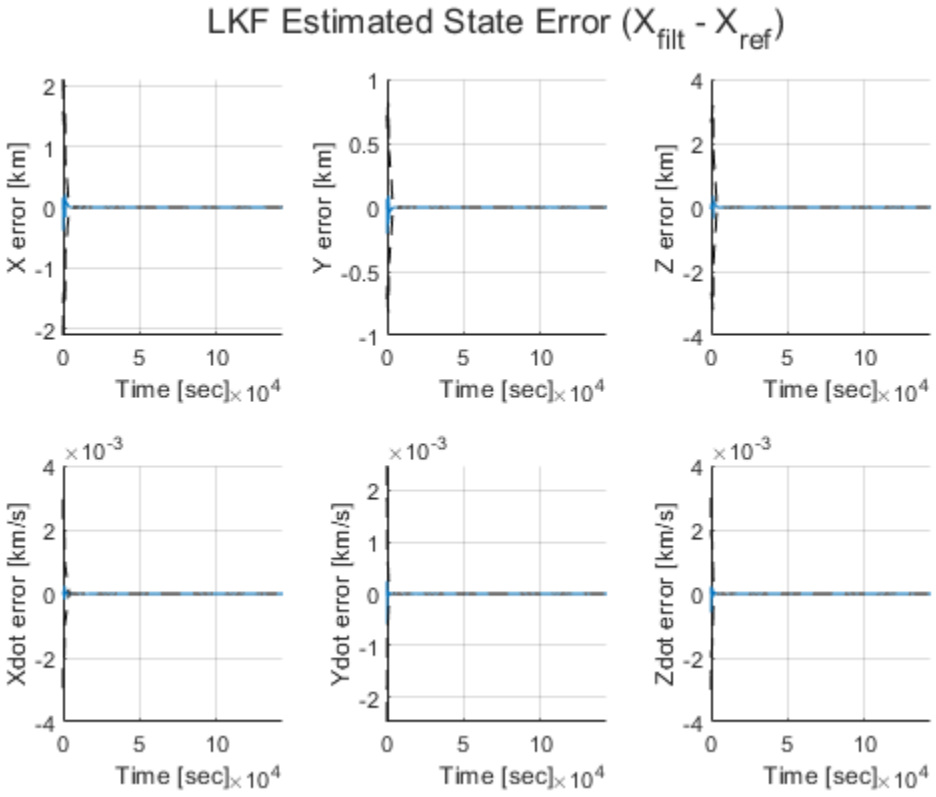

LKF Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
μ = -5.0939e-03
σ = 1.0625e-02

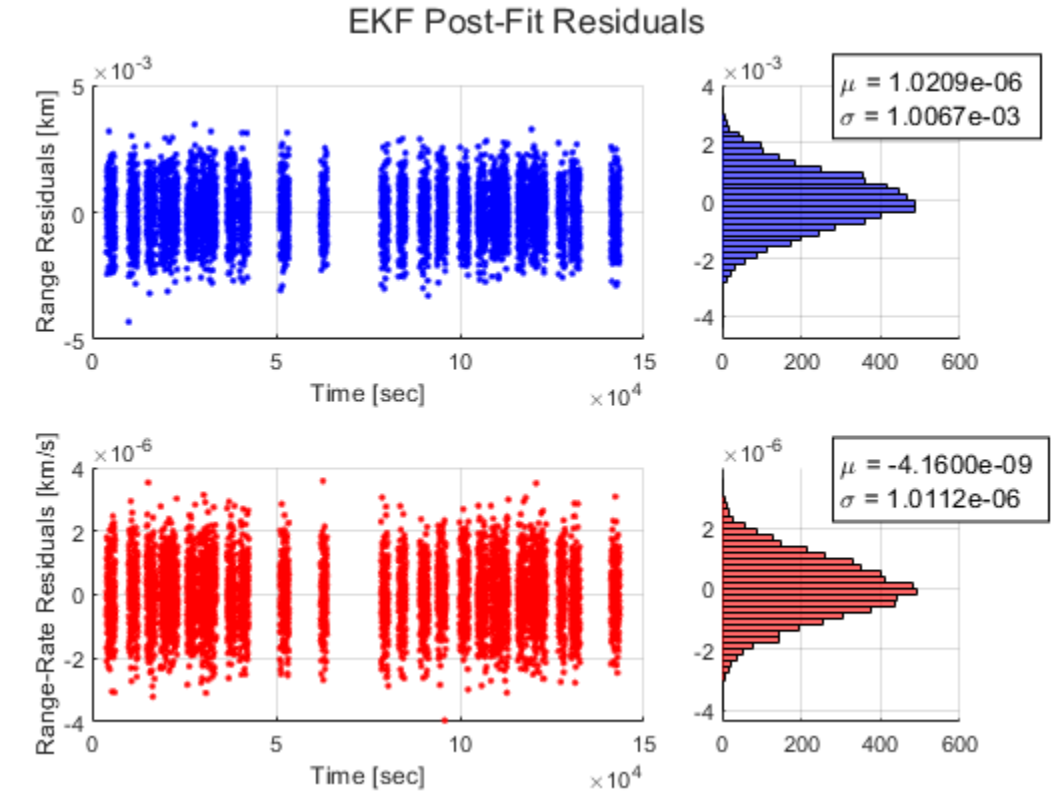

Range-Rate Residuals [km/s]
Time [sec]
μ = 6.5143e-06
σ = 1.0370e-05

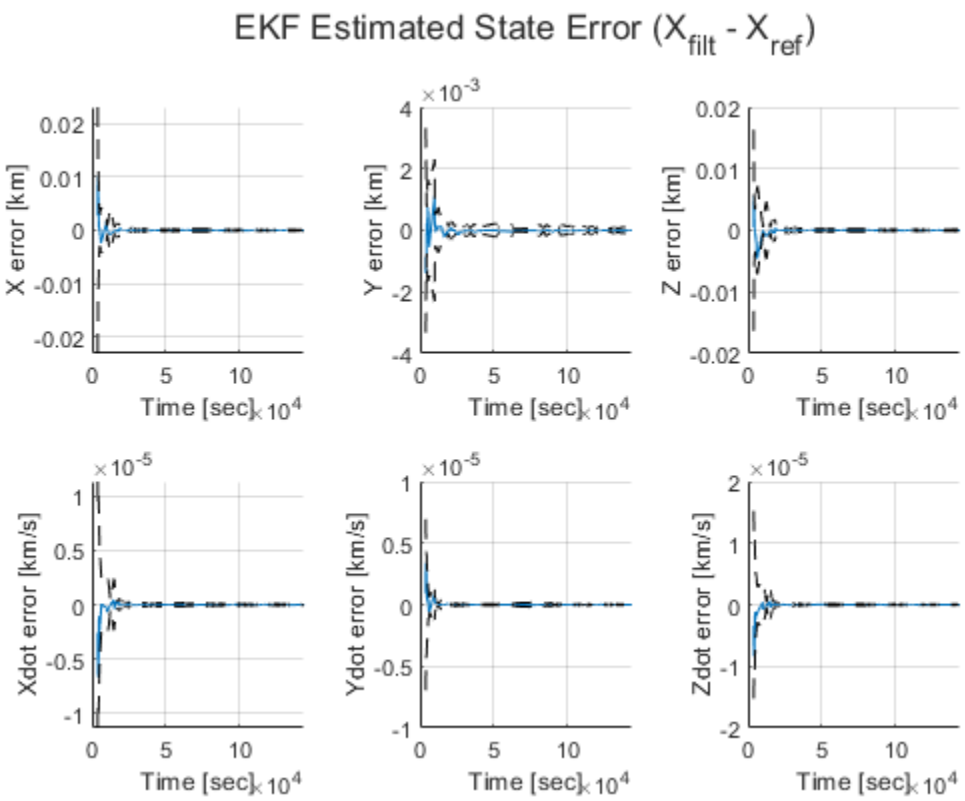

LKF Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 2.0185e-06
σ = 1.0032e-03


Range-Rate Residuals [km/s]
Time [sec]
μ = 3.0982e-09
σ = 1.0101e-06


LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 2.2283e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -5.0577e-09
σ = 1.0100e-06


LKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]


EKF Post-Fit Residuals
Range Residuals [km]
Time [sec]
μ = 1.0209e-06
σ = 1.0067e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -4.1600e-09
σ = 1.0112e-06


EKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]

Problem 1e: Increase P0

```
1e. Increased P0


    Running Batch Filter:
Postfit RMS: 25.7449. Iterating Batch with x0_batch = [4.951e+01; 4.950e+01;
4.951e+01; 4.952e-02; 4.950e-02; 4.952e-02]. Runs so far: 1
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [4.950e+01; 4.950e+01;
4.950e+01; 4.950e-02; 4.950e-02; 4.950e-02]. Runs so far: 2
Postfit RMS: 1.0065. Iterating Batch with x0_batch = [4.950e+01; 4.950e+01;
4.950e+01; 4.950e-02; 4.950e-02; 4.950e-02]. Runs so far: 3
Final postfit RMS: 1.0065. Converged after 4 runs

    Running LKF:
Postfit RMS: 25.7500. Iterating LKF with x0_LKF = [4.884e-01; 5.039e-01;
4.895e-01; 4.822e-04; 5.042e-04; 4.759e-04]. Runs so far: 1
Postfit RMS: 8.8852. Iterating LKF with x0_LKF = [1.143e-02; -3.944e-03;
1.047e-02; 1.781e-05; -4.248e-06; 2.412e-05]. Runs so far: 2
Postfit RMS: 24.2410. Iterating LKF with x0_LKF = [1.288e-04; 7.696e-05;
-3.431e-05; -1.585e-08; 7.017e-08; 4.587e-08]. Runs so far: 3
Postfit RMS: 5.9785. Iterating LKF with x0_LKF = [-7.009e-05; -9.834e-05;
1.114e-04; 3.027e-08; -7.961e-08; -2.710e-08]. Runs so far: 4
Final postfit RMS: 392.4142. Hit maximum number of 5 runs
Warning: Imaginary parts of complex X and/or Y arguments ignored.
Warning: Imaginary parts of complex X and/or Y arguments ignored.
Warning: Imaginary parts of complex X and/or Y arguments ignored.
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Warning: Imaginary parts of complex X and/or Y arguments ignored.
Warning: Imaginary parts of complex X and/or Y arguments ignored.
Warning: Imaginary parts of complex X and/or Y arguments ignored.

    Running EKF:
Postfit RMS: 1.0282
```
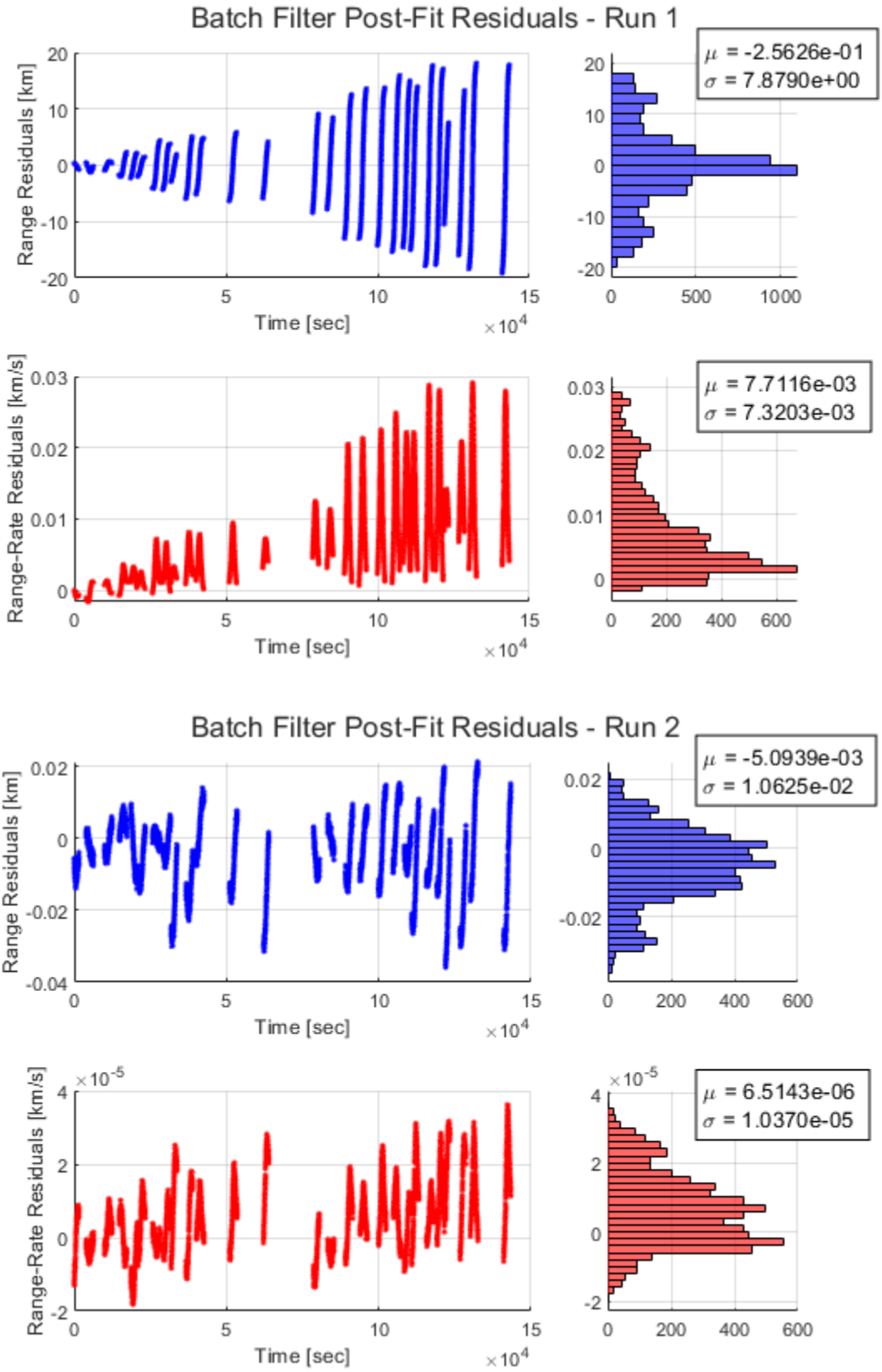
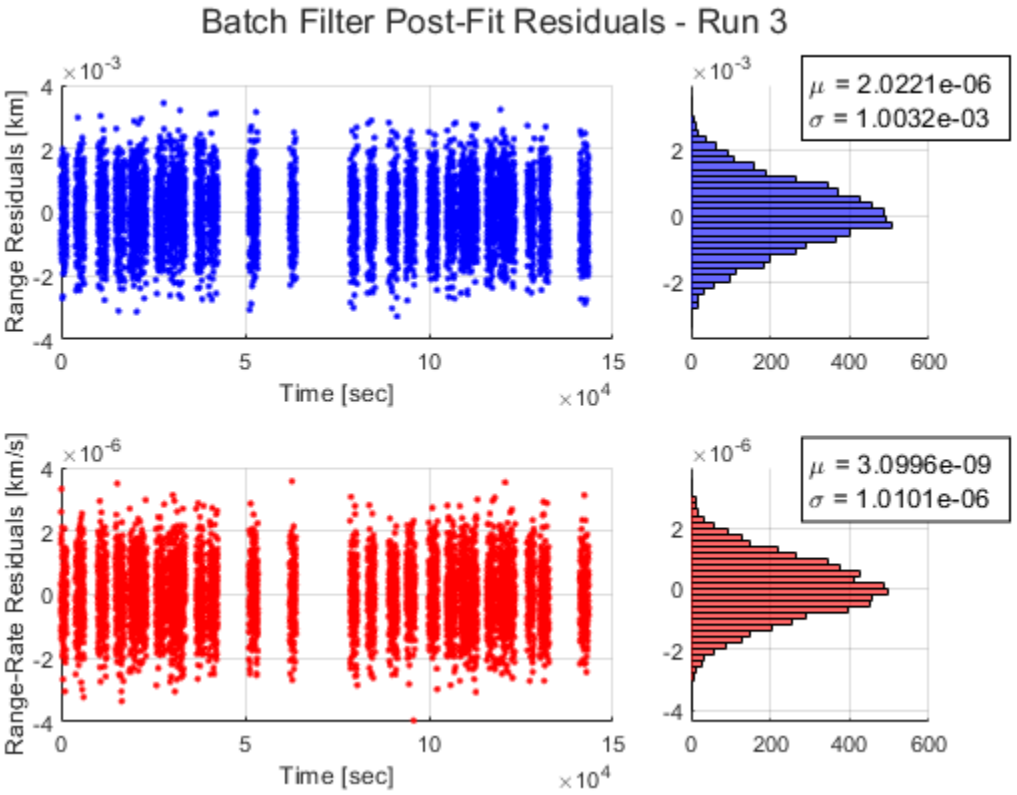
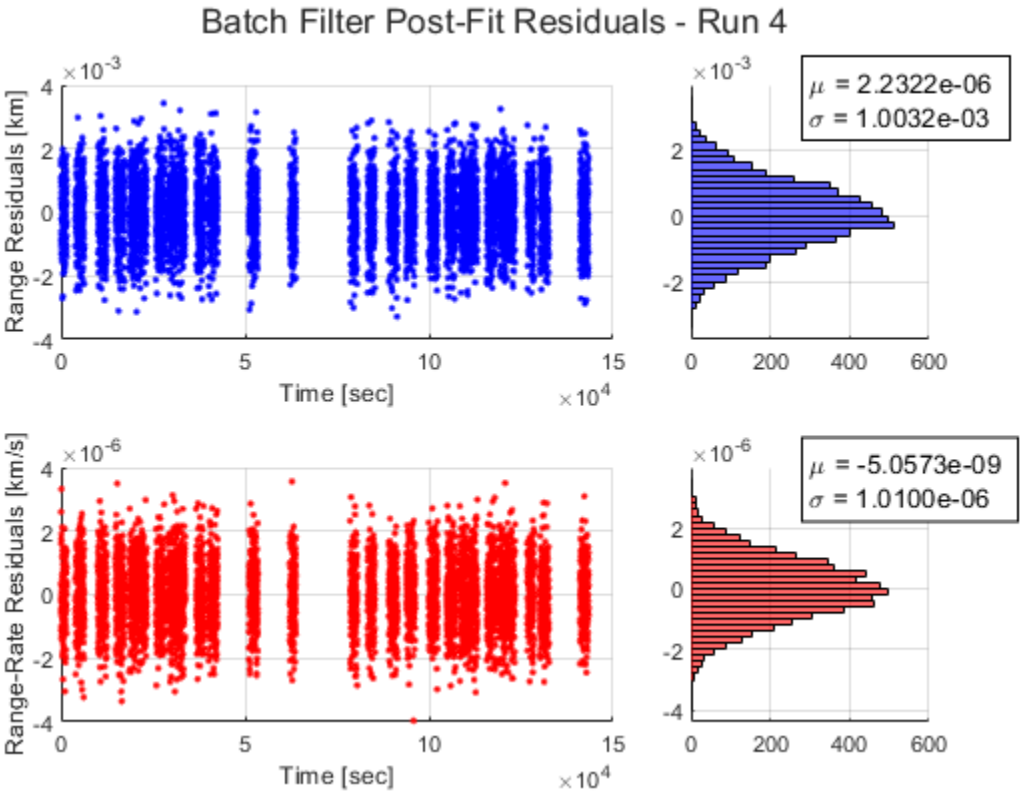
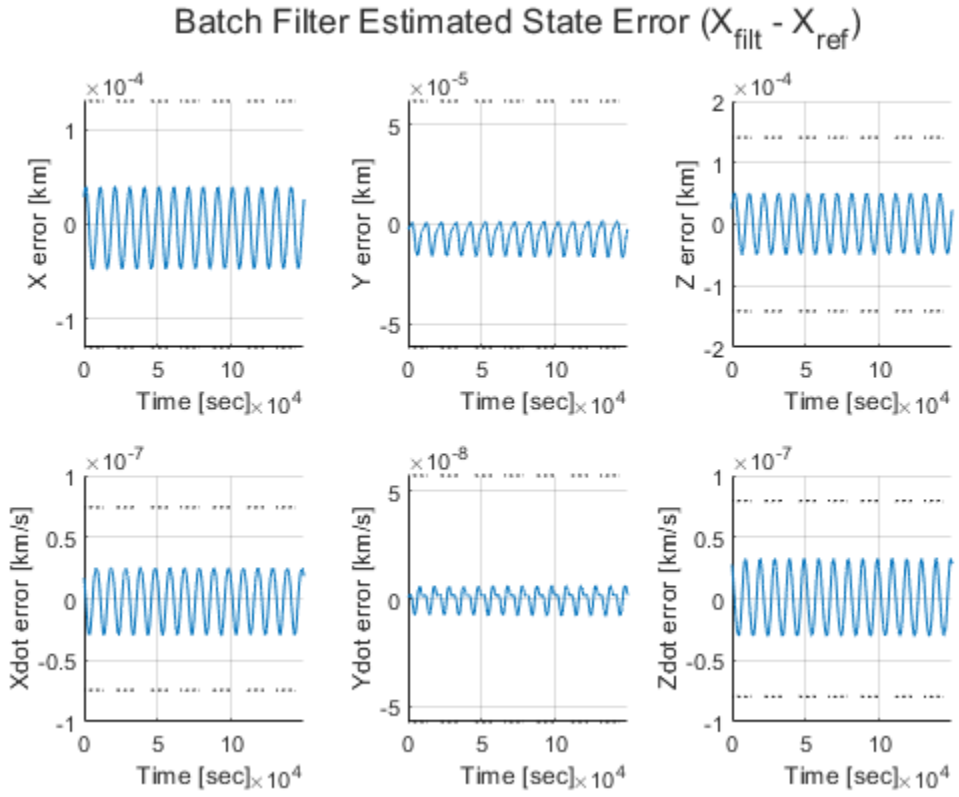
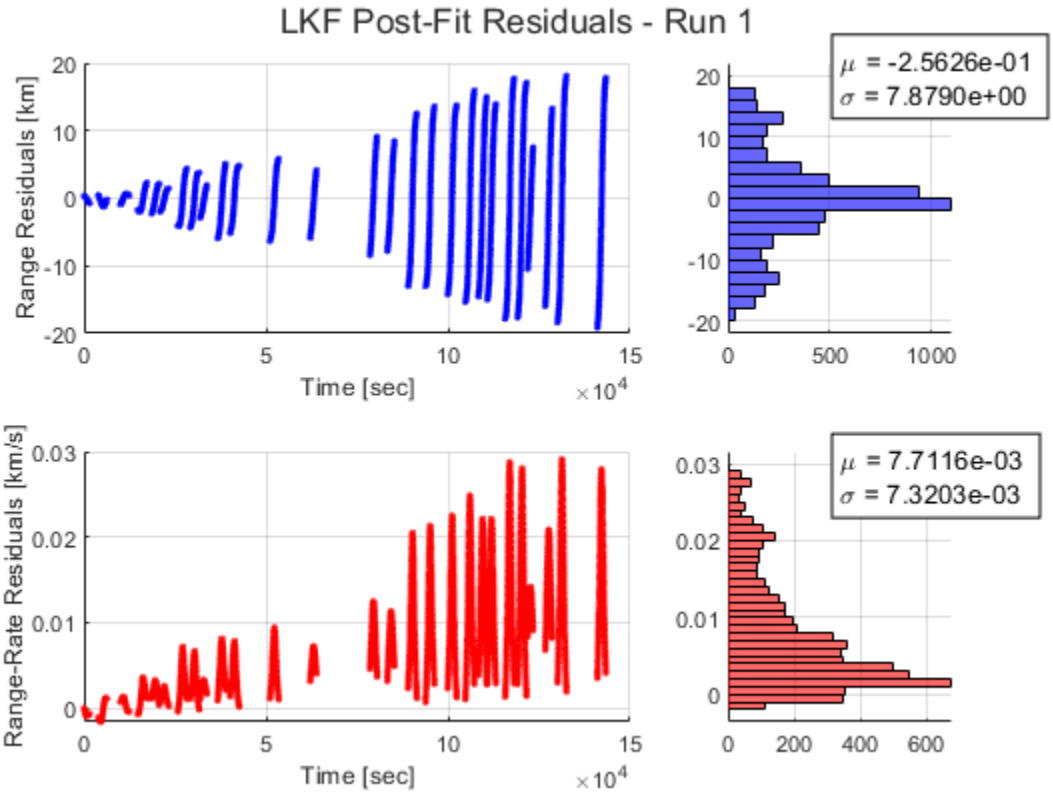
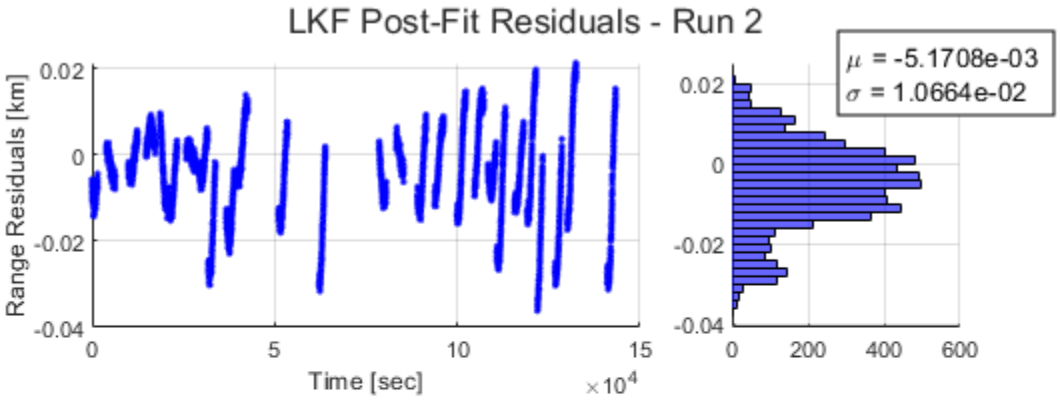


Batch Filter Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.5626e-01
σ = 7.8790e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.7116e-03
σ = 7.3203e-03
Batch Filter Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -5.0939e-03
σ = 1.0625e-02
×10^-5
Range-Rate Residuals [km/s]
Time [sec]
×10^4
×10^-5
μ = 6.5143e-06
σ = 1.0370e-05

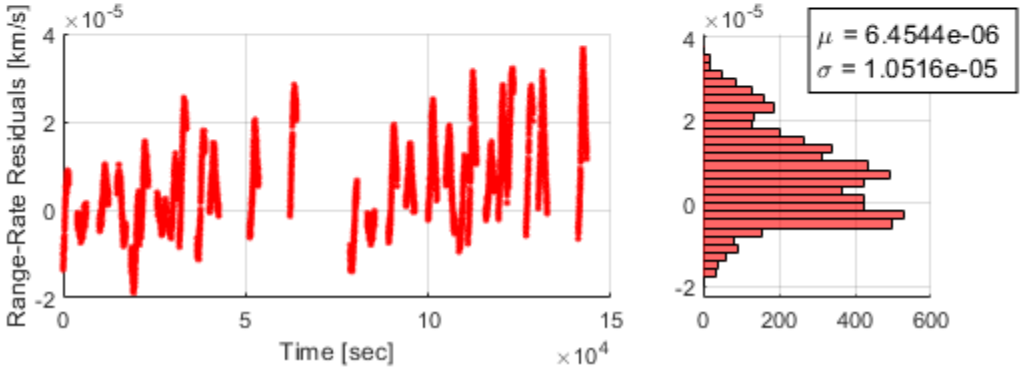

Batch Filter Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 2.0221e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = 3.0996e-09
σ = 1.0101e-06

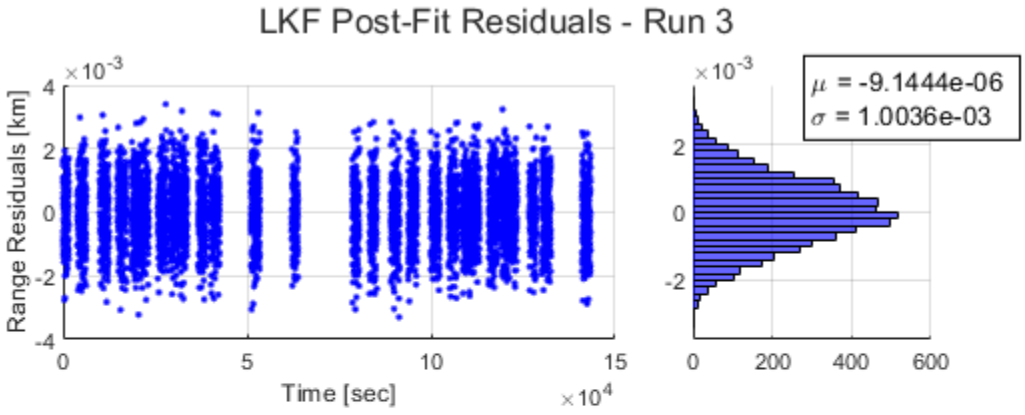

Batch Filter Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 2.2322e-06
σ = 1.0032e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -5.0573e-09
σ = 1.0100e-06

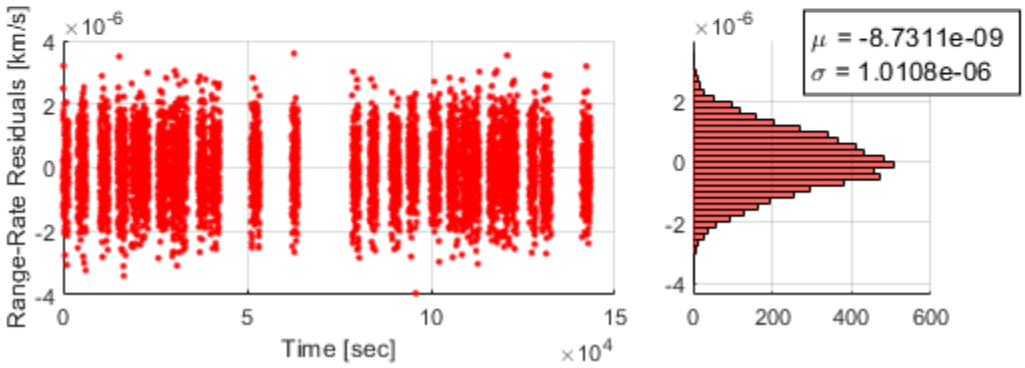

Batch Filter Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]

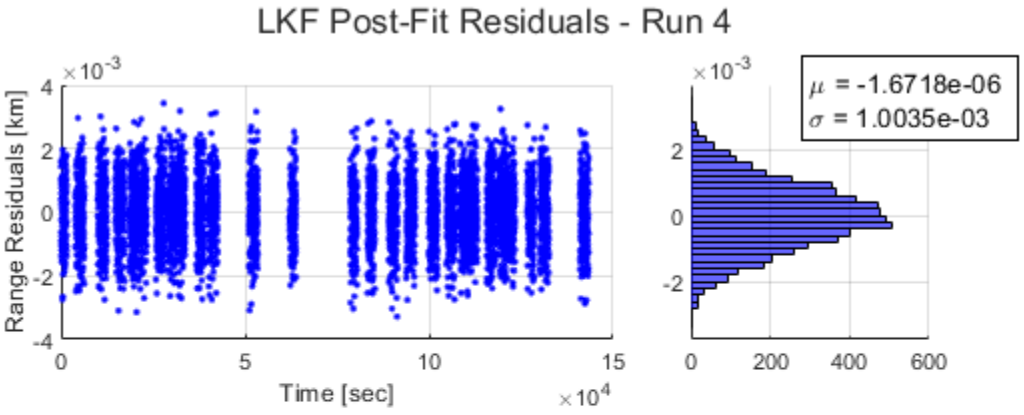

LKF Post-Fit Residuals - Run 1
Range Residuals [km]
Range-Rate Residuals [km/s]
Time [sec]
μ = -2.5626e-01
σ = 7.8790e+00
μ = 7.7116e-03
σ = 7.3203e-03

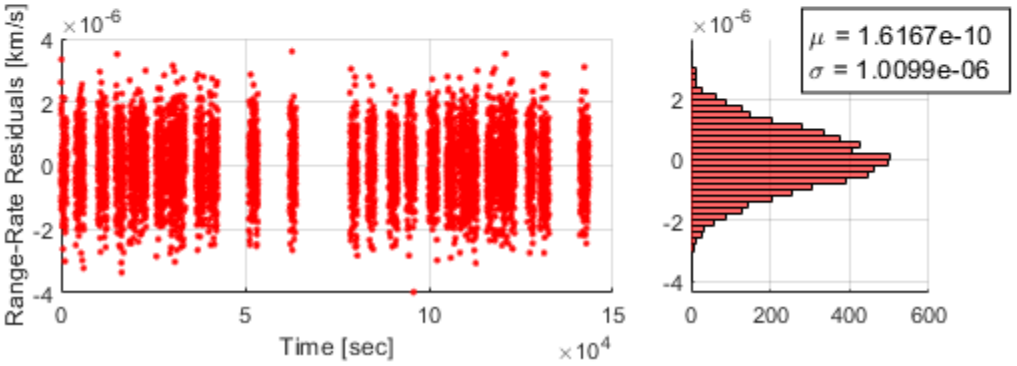

LKF Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
μ = -5.1708e-03
σ = 1.0664e-02

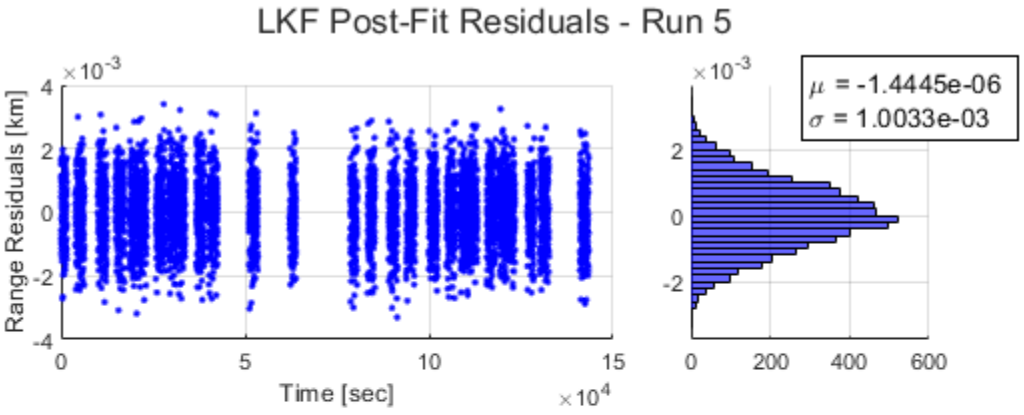

Range-Rate Residuals [km/s]
Time [sec]
μ = 6.4544e-06
σ = 1.0516e-05

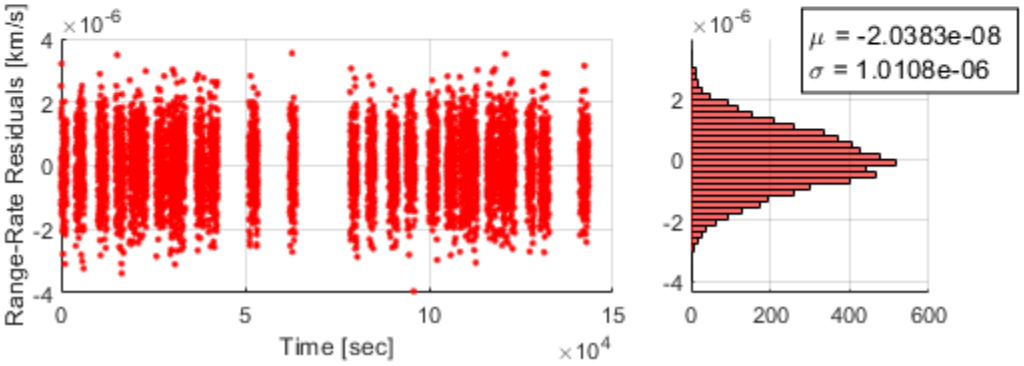

LKF Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = -9.1444e-06
σ = 1.0036e-03

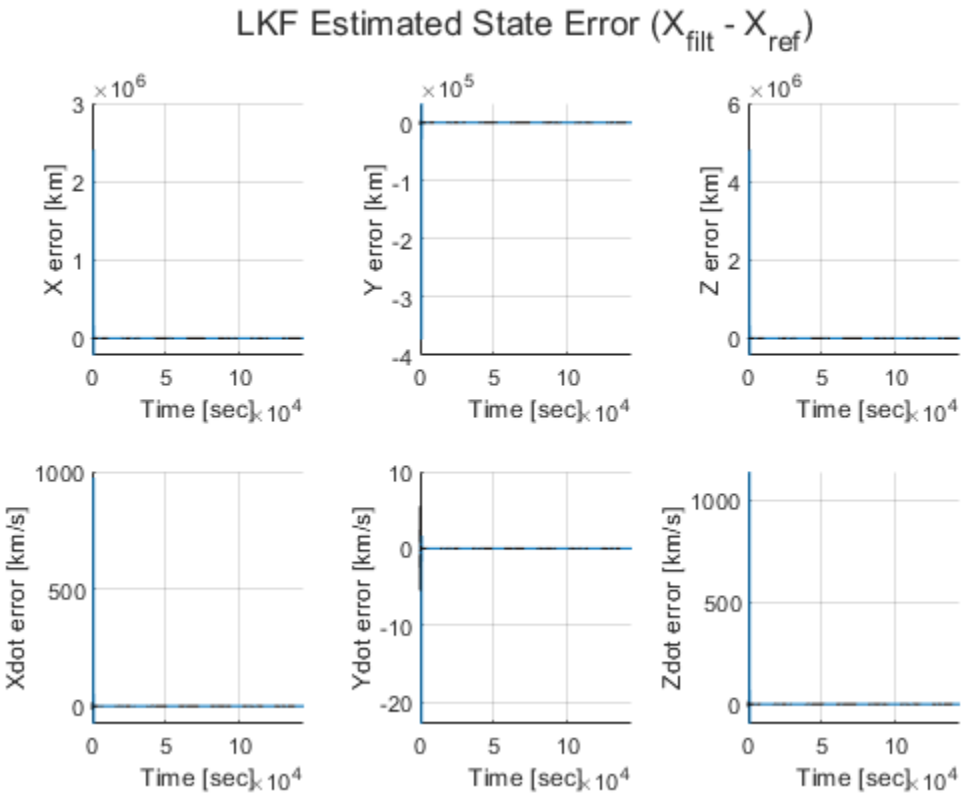

Range-Rate Residuals [km/s]
Time [sec]
μ = -8.7311e-09
σ = 1.0108e-06

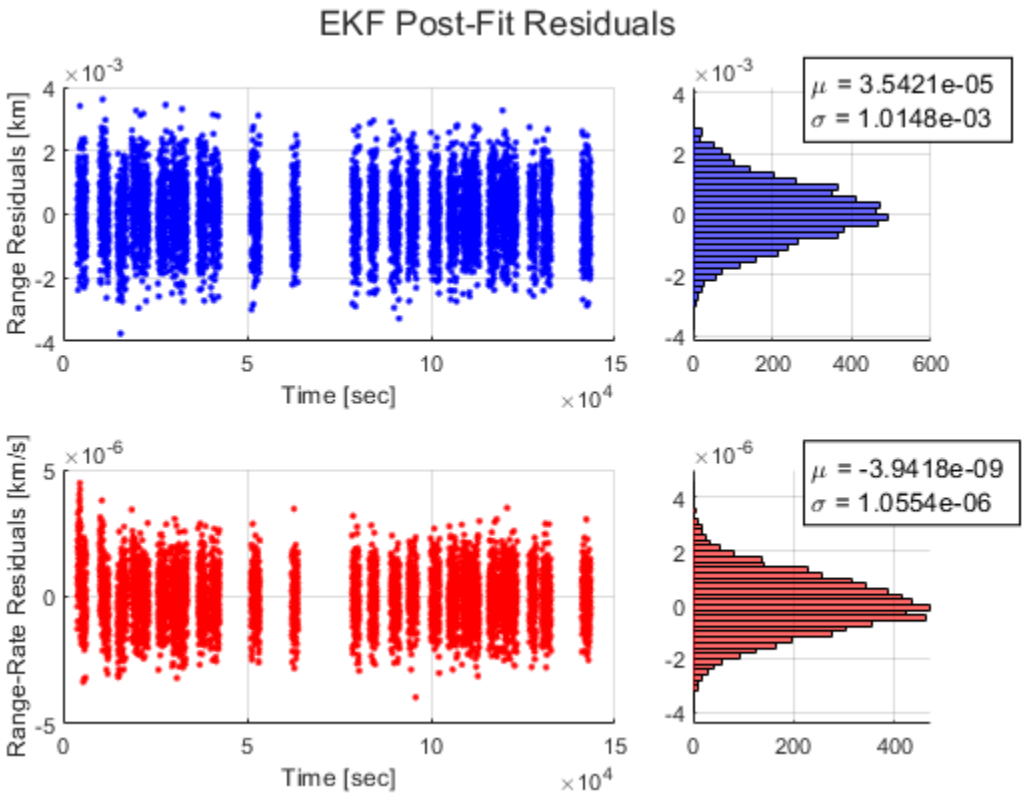

LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = -1.6718e-06
σ = 1.0035e-03

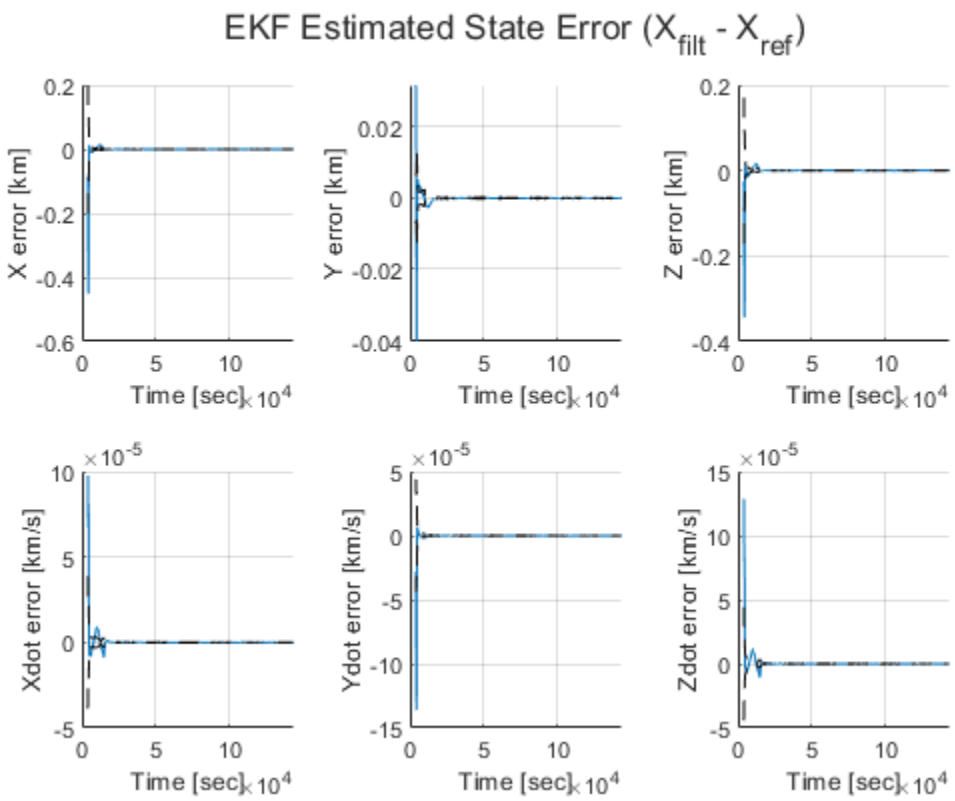

Range-Rate Residuals [km/s]
Time [sec]
μ = 1.6167e-10
σ = 1.0099e-06


LKF Post-Fit Residuals - Run 5
Range Residuals [km]
Time [sec]
μ = -1.4445e-06
σ = 1.0033e-03


Range-Rate Residuals [km/s]
Time [sec]
μ = -2.0383e-08
σ = 1.0108e-06


LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^6
×10^5
×10^4

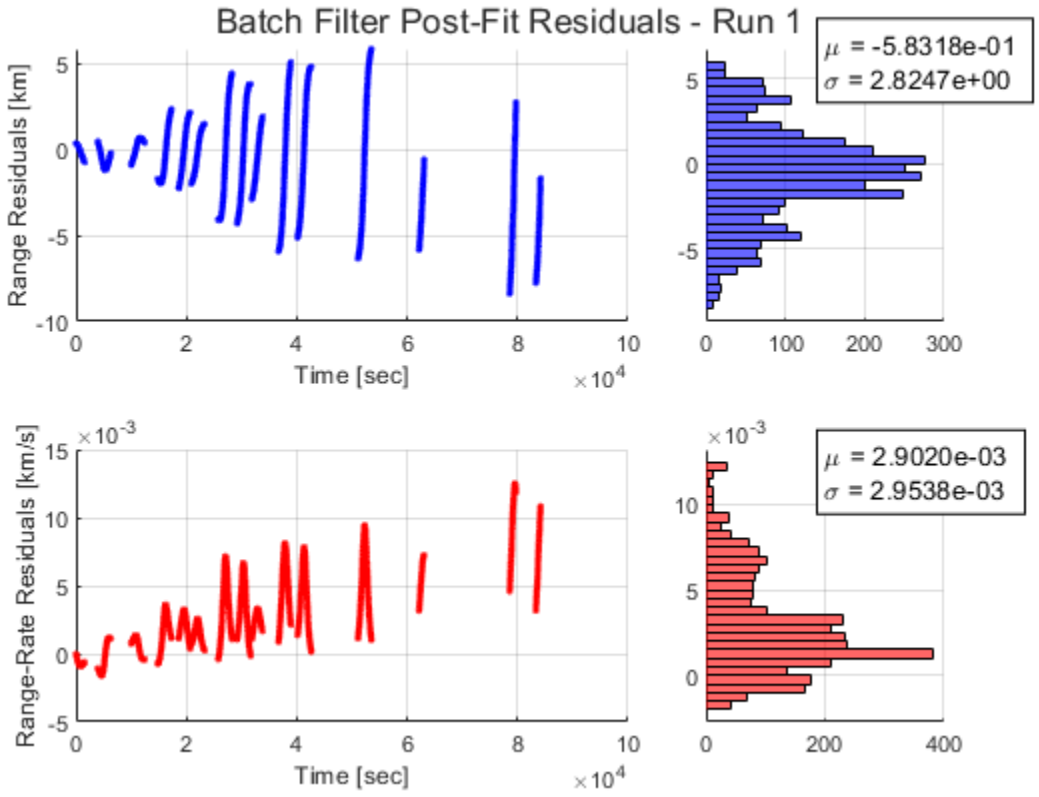

EKF Post-Fit Residuals
Range Residuals [km]
Range-Rate Residuals [km/s]
Time [sec]
μ = 3.5421e-05
σ = 1.0148e-03
μ = -3.9418e-09
σ = 1.0554e-06
×10^-3
×10^-6
×10^4

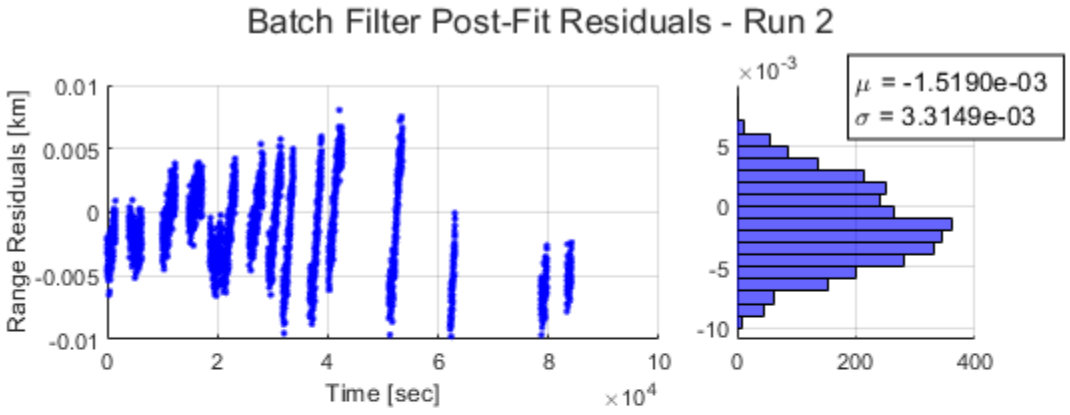


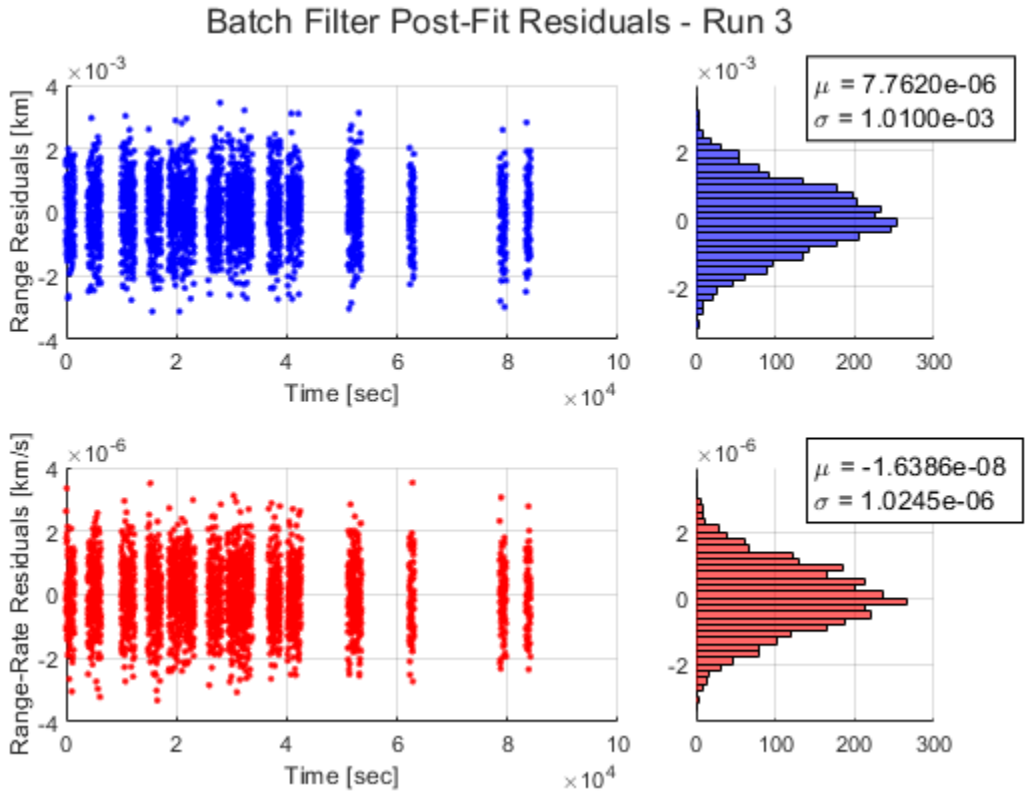
Problem 1f: Process half the measurements

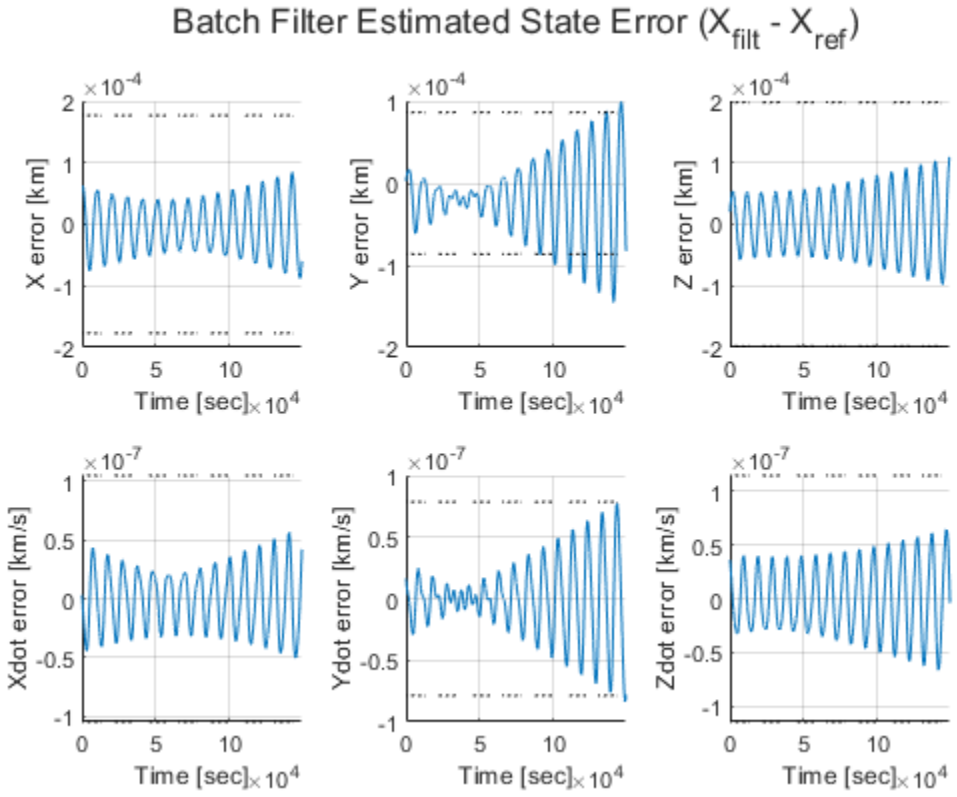
```
Warning: Integer operands are required for colon operator when used as
index.
Warning: Integer operands are required for colon operator when used as
index.
Warning: Integer operands are required for colon operator when used as
index.
Warning: Integer operands are required for colon operator when used as
index.
Warning: Integer operands are required for colon operator when used as
index.

1f. Half measurements


    Running Batch Filter:
Postfit RMS: 4.1014. Iterating Batch with x0_batch = [5.332e-03; -2.111e-03;
7.824e-03; 3.520e-06; -1.241e-06; 4.037e-06]. Runs so far: 1
Postfit RMS: 1.0172. Iterating Batch with x0_batch = [-6.308e-05;
-2.934e-06; -2.034e-05; -3.293e-09; -1.624e-08; -3.591e-08]. Runs so far: 2
Final postfit RMS: 1.0172. Converged after 3 runs

    Running LKF:
Postfit RMS: 4.0959. Iterating LKF with x0_LKF = [4.947e-01; 5.021e-01;
```

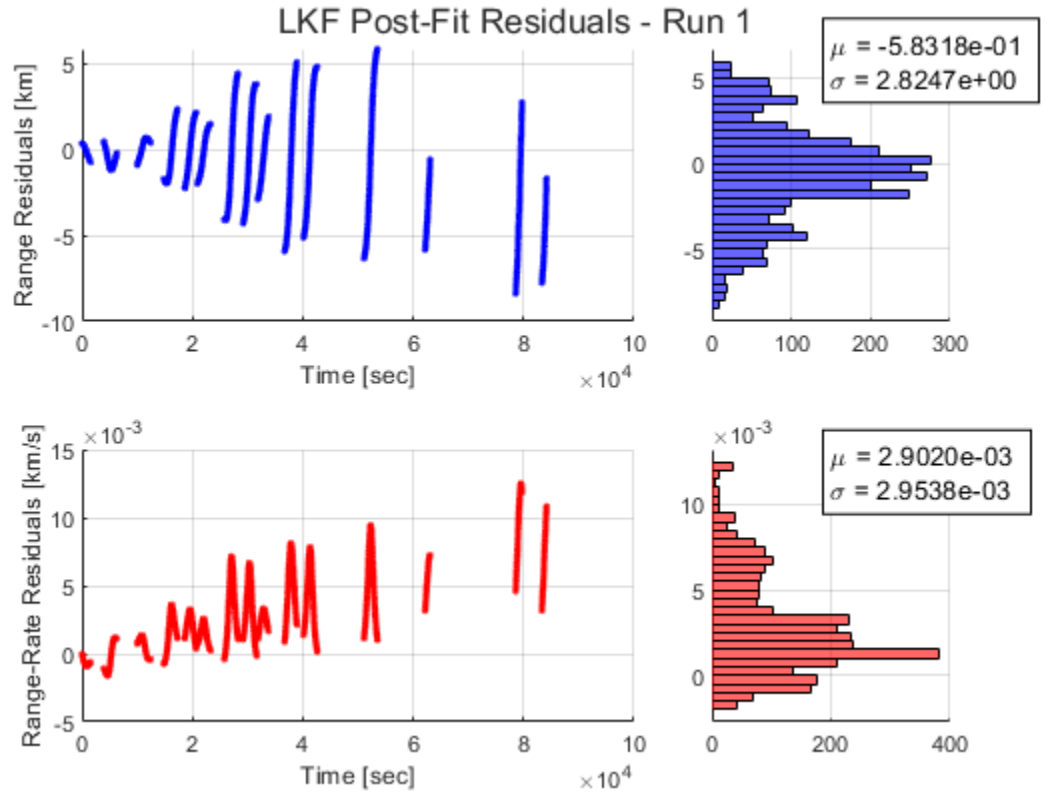
```
4.922e-01; 4.965e-04; 5.012e-04; 4.960e-04]. Runs so far: 1
Postfit RMS: 1.0105. Iterating LKF with x0_LKF = [5.395e-03; -2.108e-03;
7.845e-03; 3.523e-06; -1.225e-06; 4.073e-06]. Runs so far: 2
Postfit RMS: 1.0105. Iterating LKF with x0_LKF = [5.323e-09; -1.762e-09;
-6.386e-09; 7.267e-12; -2.229e-12; 4.500e-12]. Runs so far: 3
Final postfit RMS: 1.0105. Converged after 4 runs

    Running EKF:
Postfit RMS: 1.0137
```

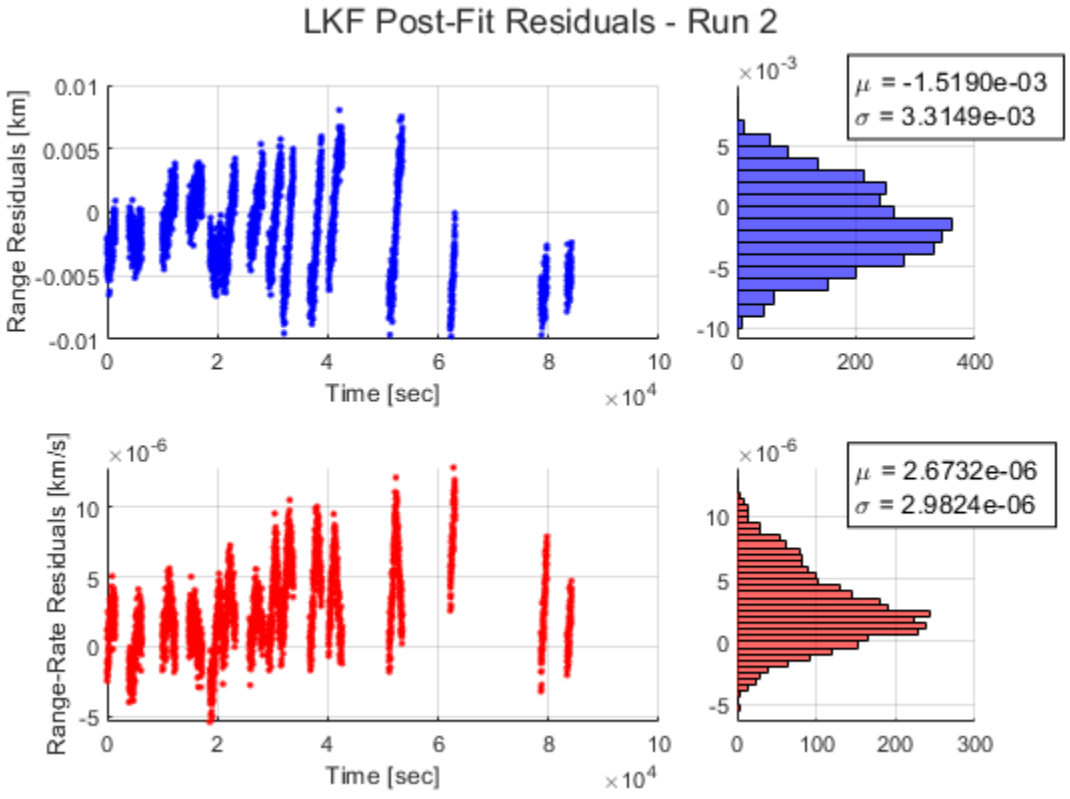


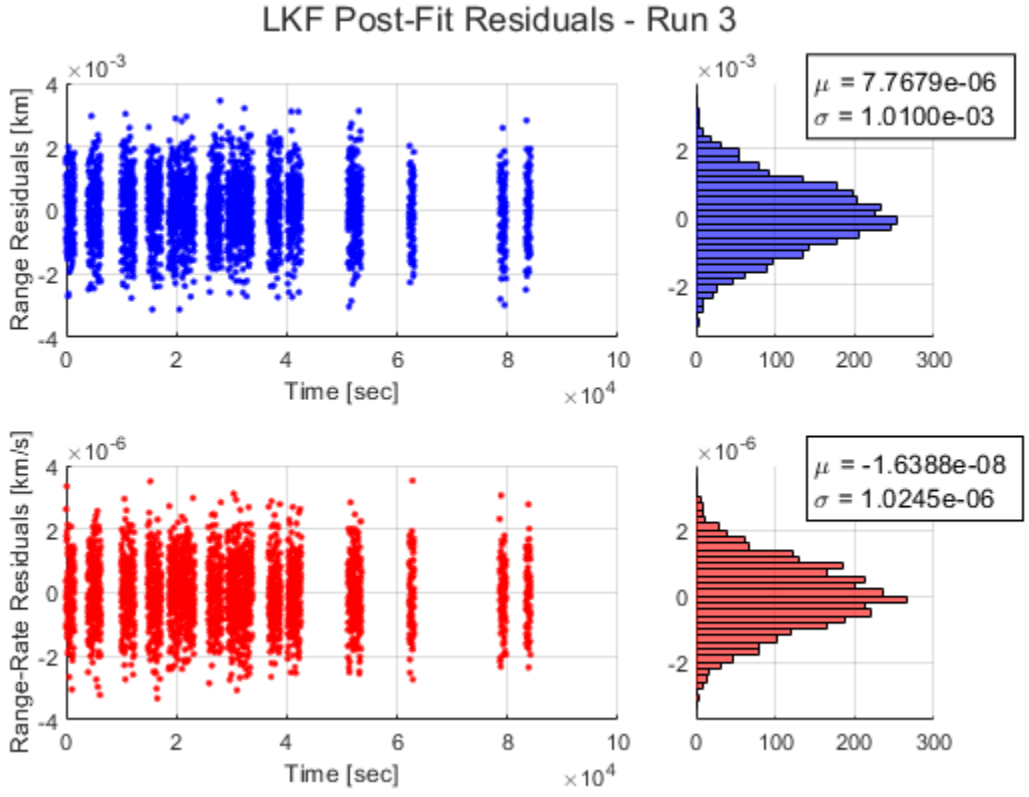

Batch Filter Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
×10^-3
μ = -1.5190e-03
σ = 3.3149e-03
Range-Rate Residuals [km/s]
×10^-6
μ = 2.6732e-06
σ = 2.9824e-06

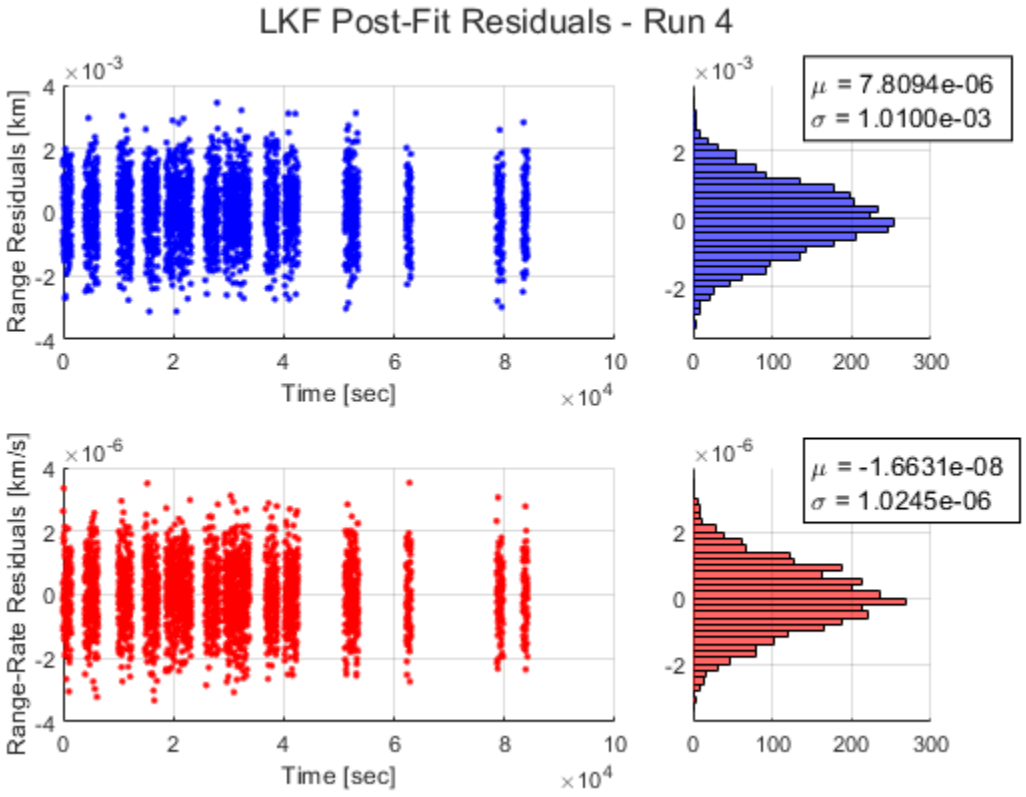

Batch Filter Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
×10^4
×10^-3
μ = 7.7620e-06
σ = 1.0100e-03
Range-Rate Residuals [km/s]
×10^-6
μ = -1.6386e-08
σ = 1.0245e-06

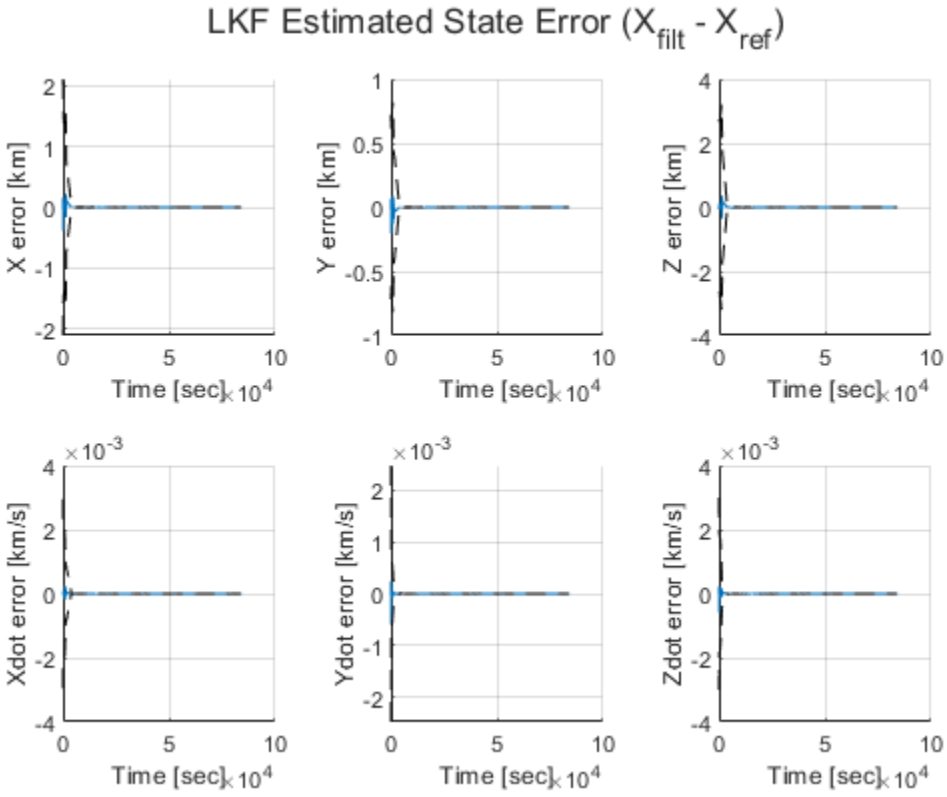

Batch Filter Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-4
×10^-7

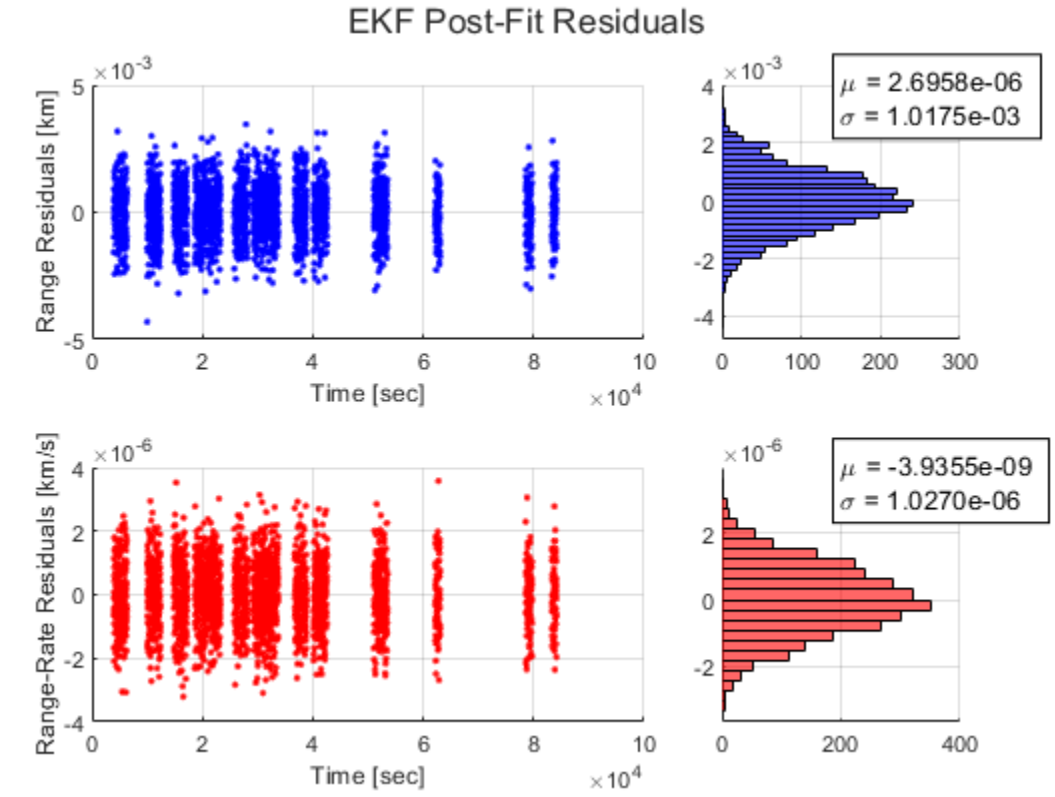

LKF Post-Fit Residuals - Run 1
Range Residuals [km]
Range-Rate Residuals [km/s]
Time [sec]
×10^4
×10^-3
μ = -5.8318e-01
σ = 2.8247e+00
μ = 2.9020e-03
σ = 2.9538e-03

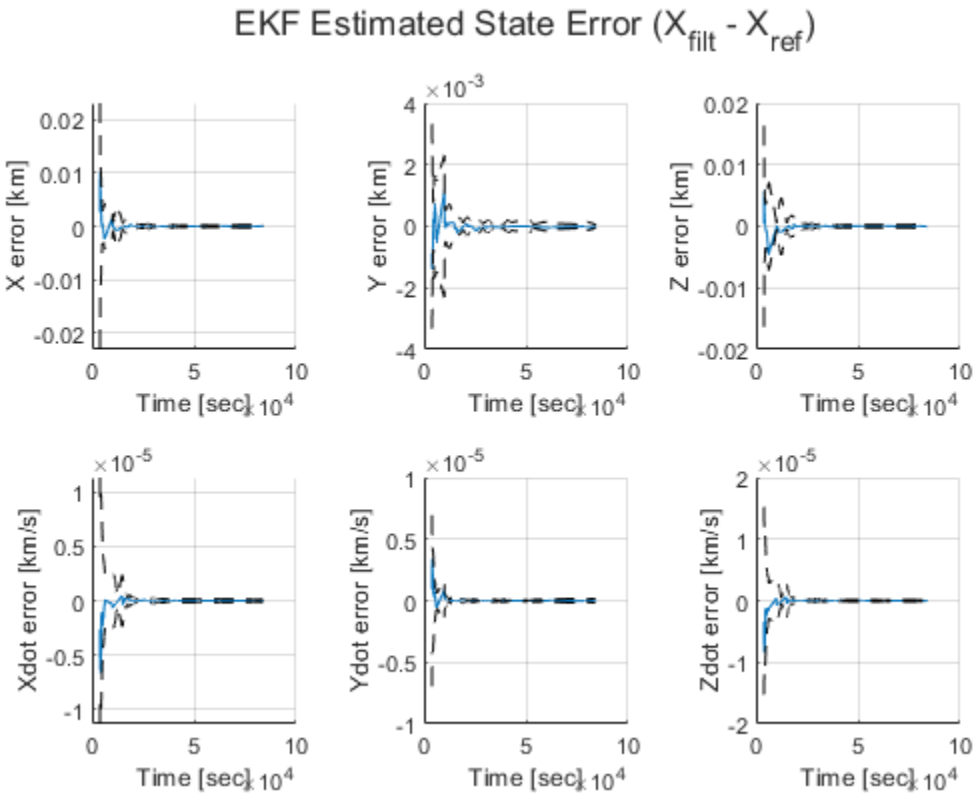

LKF Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
×10^-3
μ = -1.5190e-03
σ = 3.3149e-03
Range-Rate Residuals [km/s]
×10^-6
μ = 2.6732e-06
σ = 2.9824e-06


LKF Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
×10^4
×10^-3
μ = 7.7679e-06
σ = 1.0100e-03
Range-Rate Residuals [km/s]
×10^-6
μ = -1.6388e-08
σ = 1.0245e-06


LKF Post-Fit Residuals - Run 4
Range Residuals [km]
Time [sec]
μ = 7.8094e-06
σ = 1.0100e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -1.6631e-08
σ = 1.0245e-06


LKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]


EKF Post-Fit Residuals
Range Residuals [km]
Time [sec]
μ = 2.6958e-06
σ = 1.0175e-03
Range-Rate Residuals [km/s]
Time [sec]
μ = -3.9355e-09
σ = 1.0270e-06


EKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]

2. Simulate a new truth orbit + measurements w/ J_3

a. Make a new set of truth data including J_3 and plot the difference of this new data and that from HW1.

All PDF for plot

b. Process the data above using just J_2 dynamics in the filters. How does this change filter performance?

When J_3 isn't included in the filter dynamics, every filter breaks. Their RMS errors are large, and their state errors fall outside of their predicted bounds. In particular,

The batch filter errors exhibit strange trends

The LKF error oscillates wildly, as do the EKF's

Finally, none of the post-fit residuals are zero-mean Gaussian, implying unmodeled dynamics (like J_2!)

ASEN 6080 HW 2 Problem 2 Main Script

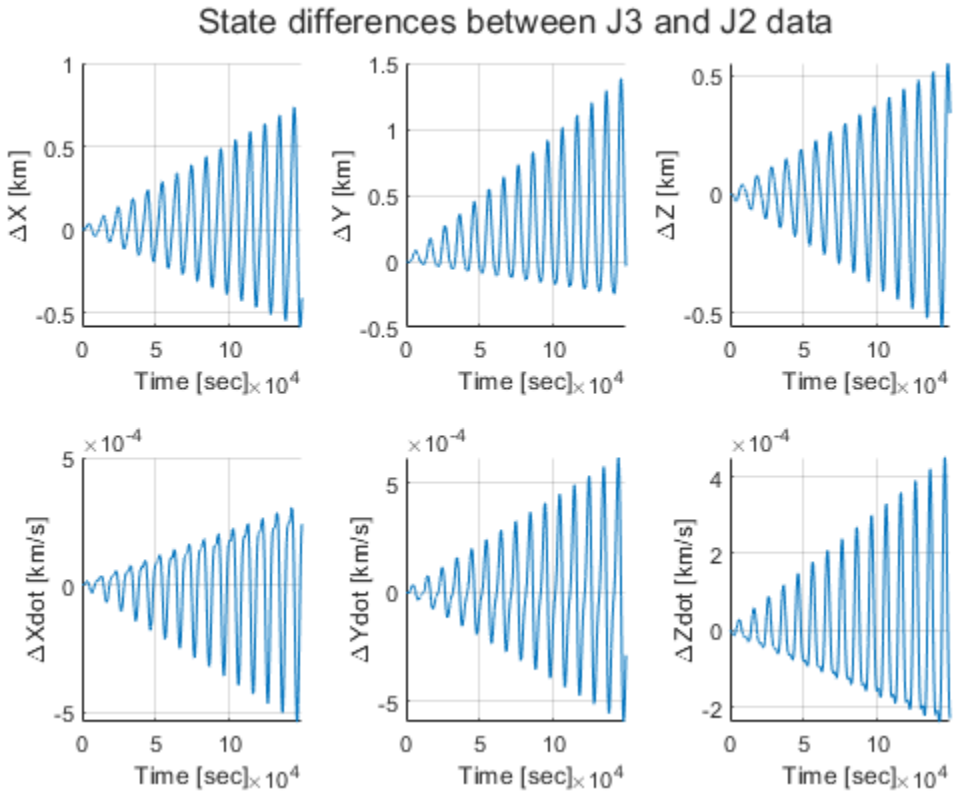
Table of Contents

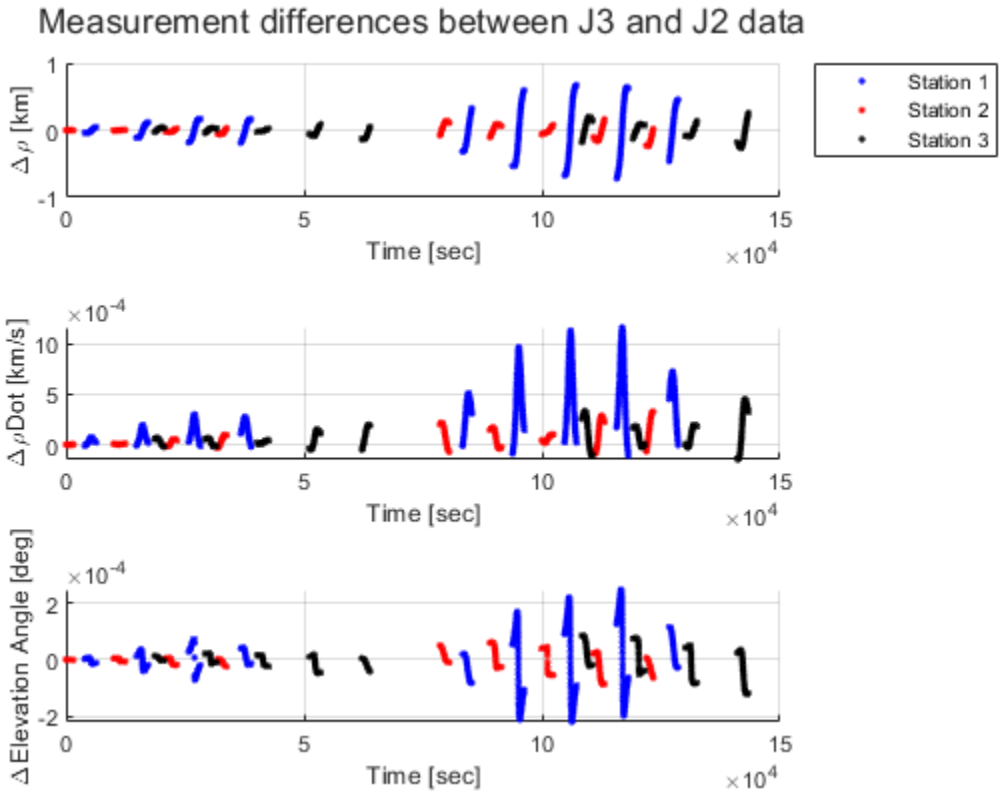
By: Ian Faber

Housekeeping

Setup

Problem 2a: Make Truth Data with J3

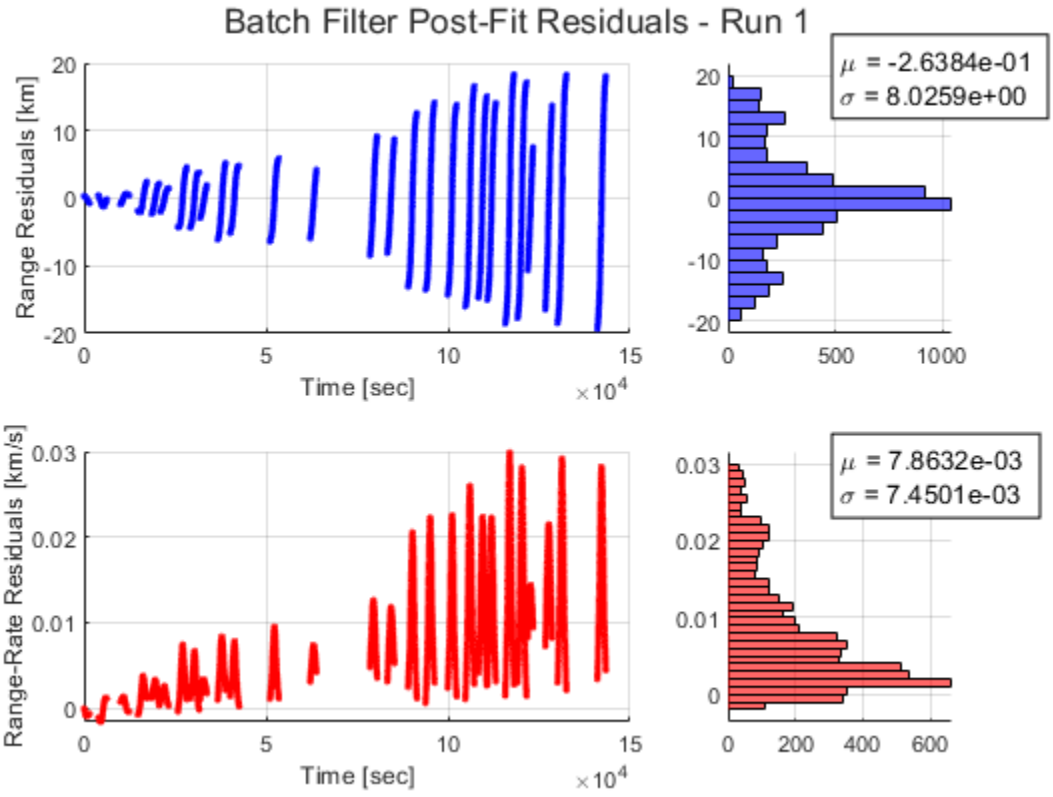


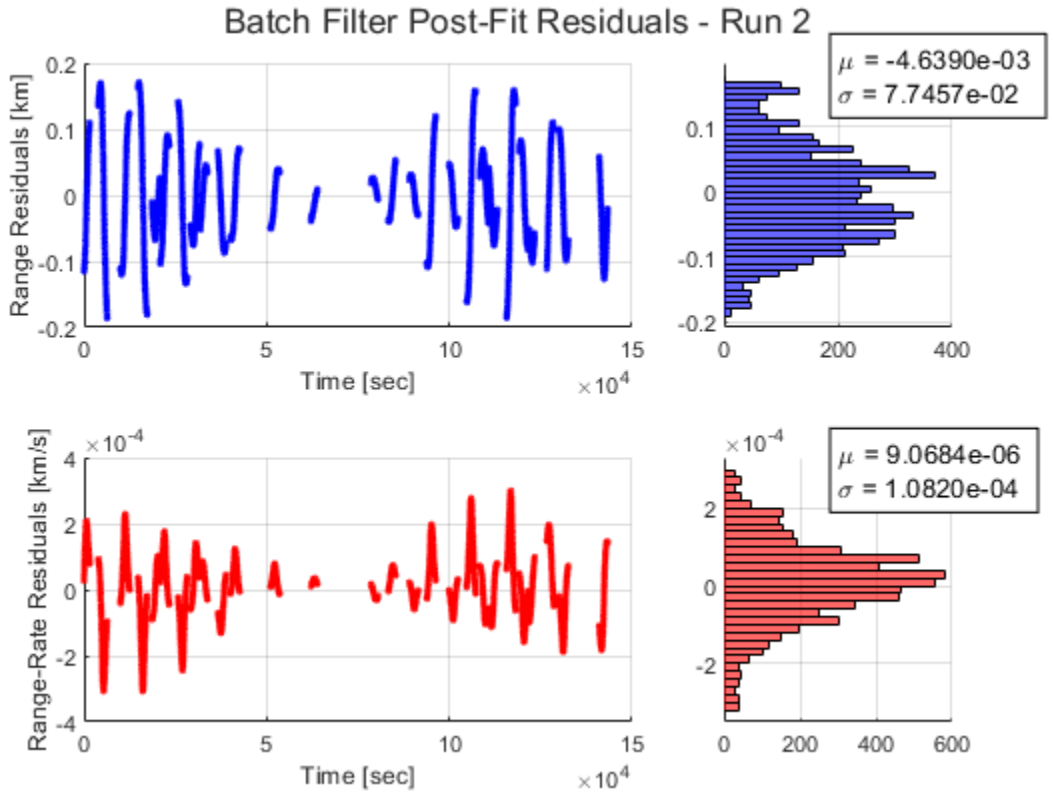


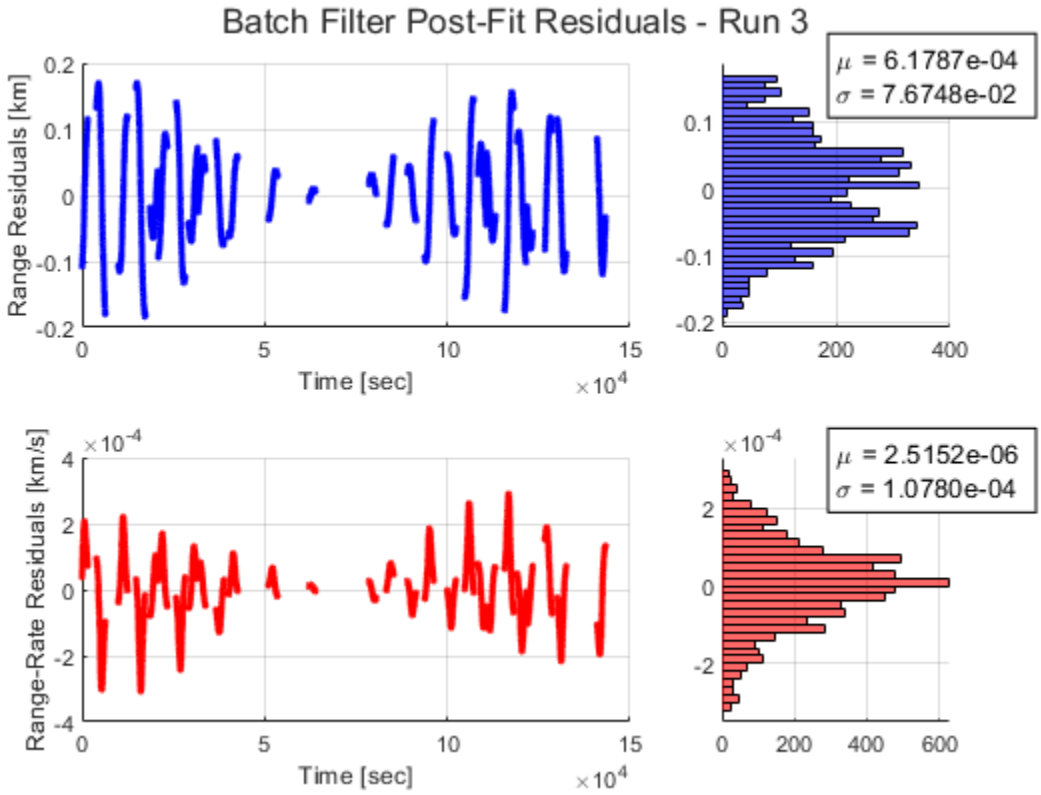
Problem 2b: Filter setup

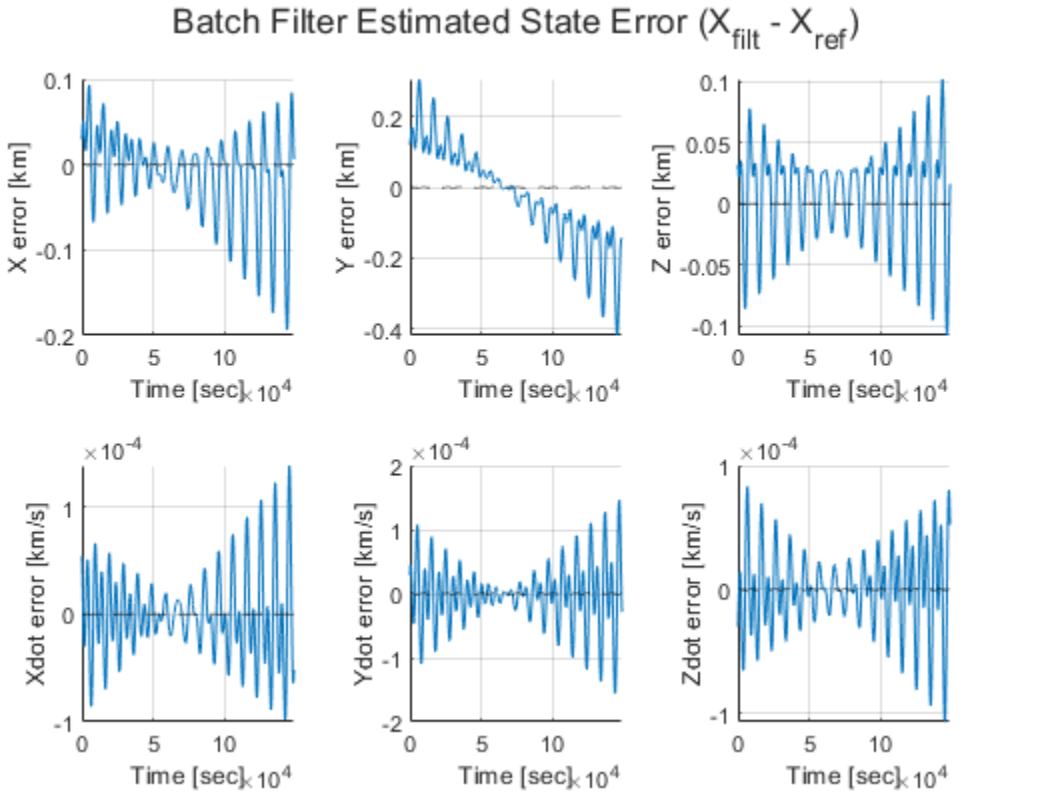
Problem 2b: Run filters on new data

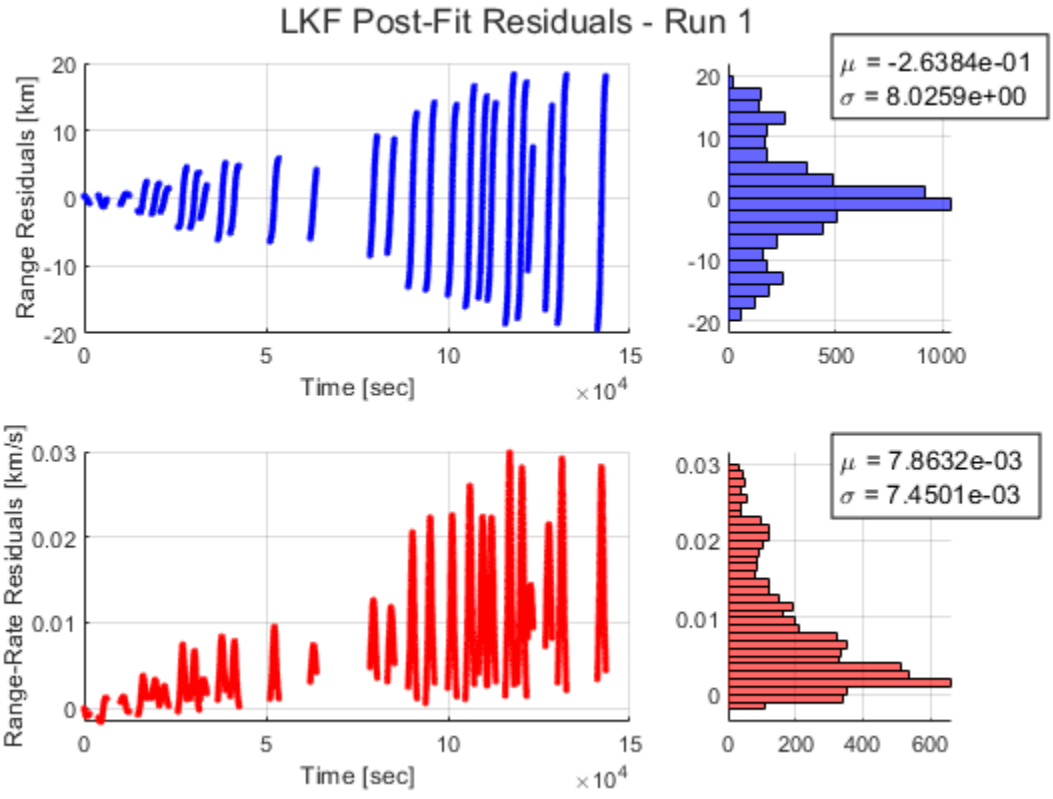
```
    Running Batch Filter:
Postfit RMS: 97.8506. Iterating Batch with x0_batch = [-1.860e-02;
-1.256e-01; -2.042e-02; -3.525e-05; -3.391e-05; 5.462e-05]. Runs so far: 1
Postfit RMS: 93.5787. Iterating Batch with x0_batch = [-2.901e-02;
-1.212e-01; -3.210e-02; -5.429e-05; -2.915e-05; 2.986e-05]. Runs so far: 2
Final postfit RMS: 93.5787. Converged after 3 runs

    Running LKF:
Postfit RMS: 97.7726. Iterating LKF with x0_LKF = [5.186e-01; 6.256e-01;
5.204e-01; 5.352e-04; 5.339e-04; 4.454e-04]. Runs so far: 1
Postfit RMS: 93.5017. Iterating LKF with x0_LKF = [1.041e-02; -4.457e-03;
1.168e-02; 1.905e-05; -4.761e-06; 2.476e-05]. Runs so far: 2
Final postfit RMS: 93.5017. Converged after 3 runs

    Running EKF:
Postfit RMS: 93.5599
```

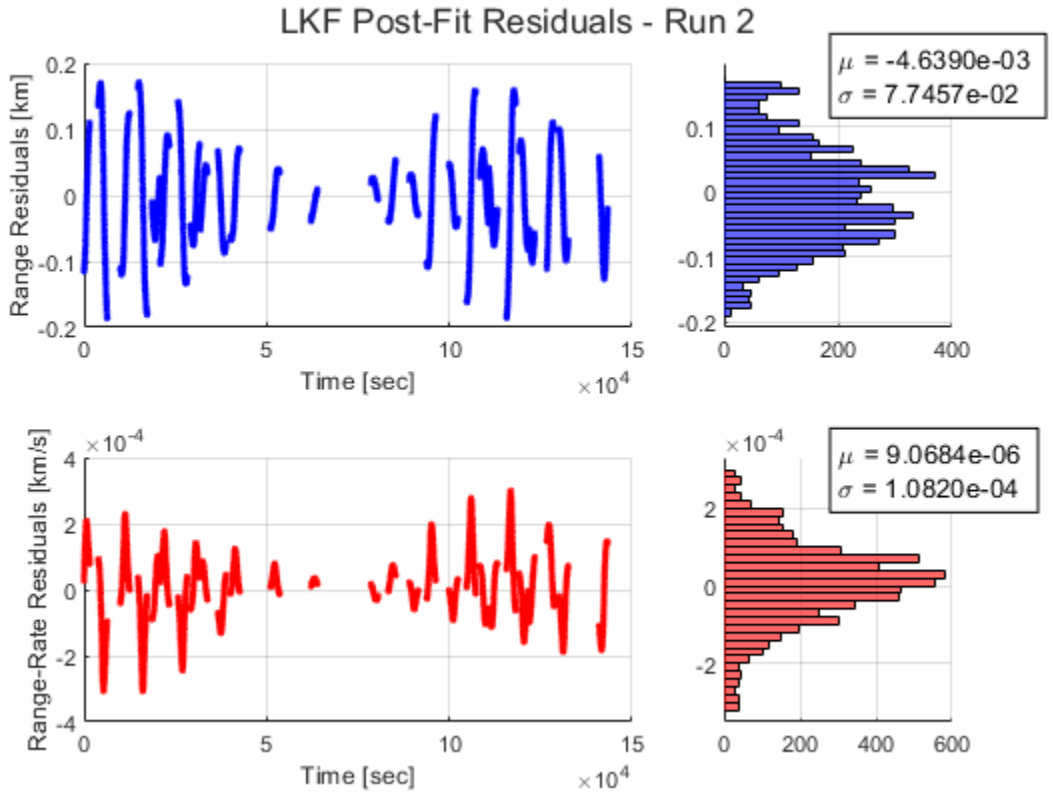

Batch Filter Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.6384e-01
σ = 8.0259e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.8632e-03
σ = 7.4501e-03

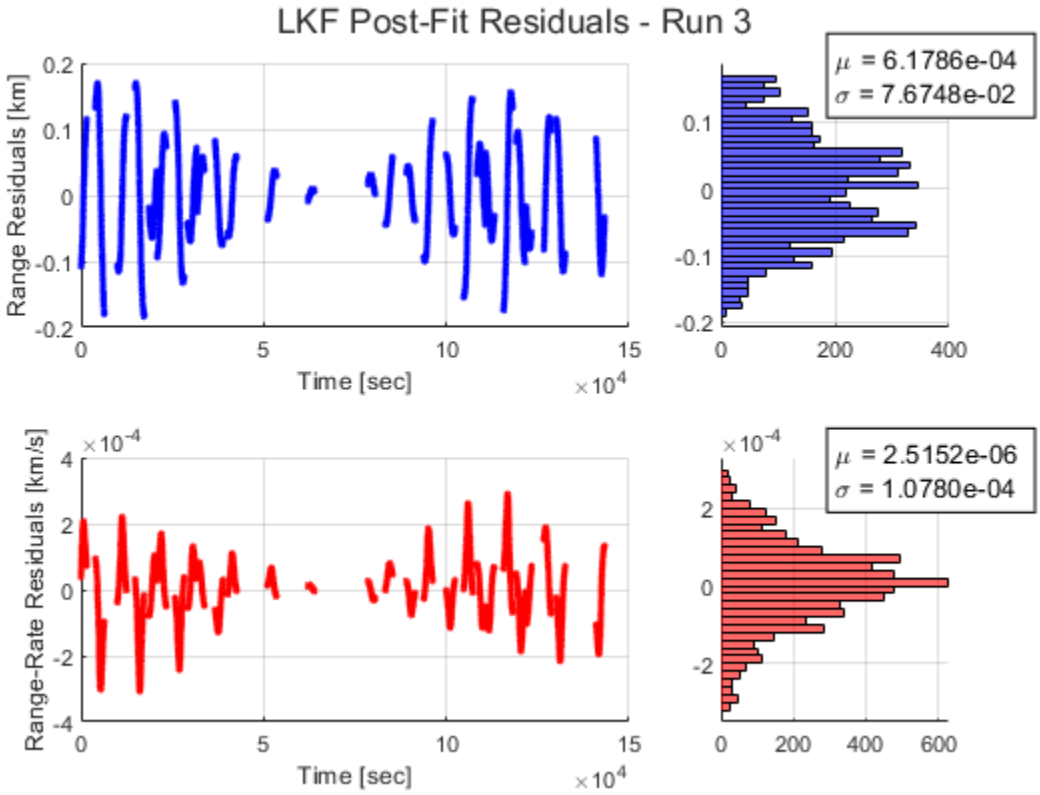

Batch Filter Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -4.6390e-03
σ = 7.7457e-02
Range-Rate Residuals [km/s]
×10^-4
Time [sec]
×10^4
μ = 9.0684e-06
σ = 1.0820e-04

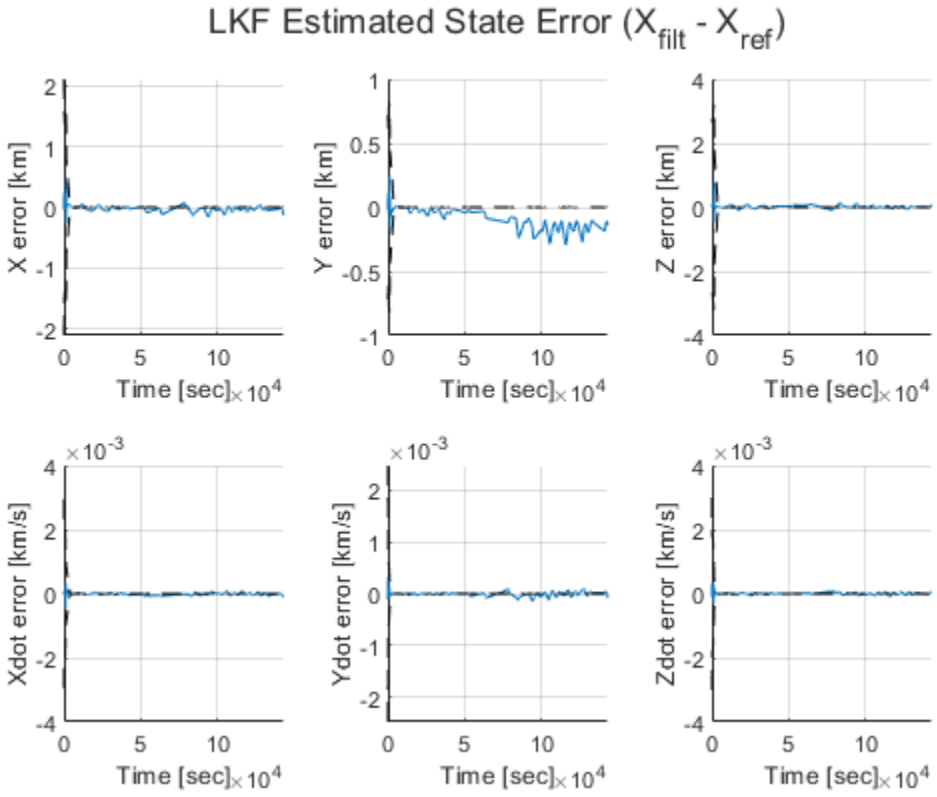

Batch Filter Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
×10^4
μ = 6.1787e-04
σ = 7.6748e-02
Range-Rate Residuals [km/s]
×10^-4
Time [sec]
×10^4
μ = 2.5152e-06
σ = 1.0780e-04

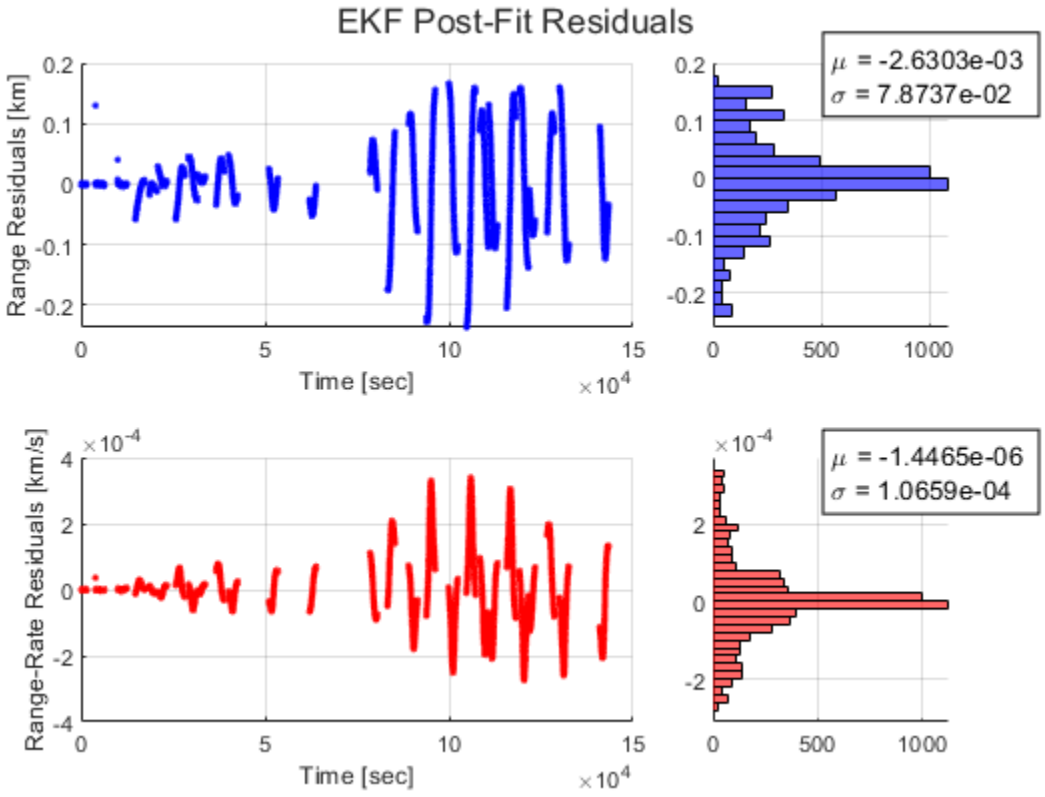

Batch Filter Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-4

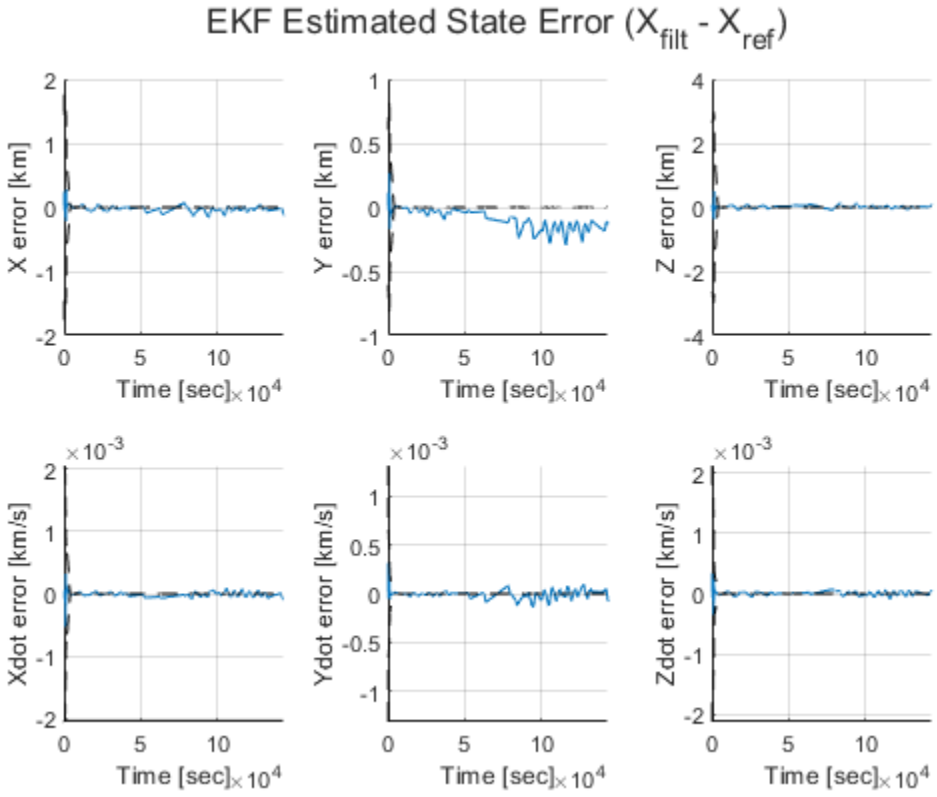

LKF Post-Fit Residuals - Run 1
Range Residuals [km]
Time [sec]
×10^4
μ = -2.6384e-01
σ = 8.0259e+00
Range-Rate Residuals [km/s]
Time [sec]
×10^4
μ = 7.8632e-03
σ = 7.4501e-03


LKF Post-Fit Residuals - Run 2
Range Residuals [km]
Time [sec]
×10^4
μ = -4.6390e-03
σ = 7.7457e-02
Range-Rate Residuals [km/s]
×10^-4
Time [sec]
×10^4
μ = 9.0684e-06
σ = 1.0820e-04


LKF Post-Fit Residuals - Run 3
Range Residuals [km]
Time [sec]
μ = 6.1786e-04
σ = 7.6748e-02
Range-Rate Residuals [km/s]
Time [sec]
μ = 2.5152e-06
σ = 1.0780e-04


LKF Estimated State Error (X_{filt} - X_{ref})
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]


EKF Post-Fit Residuals
Range Residuals [km]
Time [sec]
×10^4
μ = -2.6303e-03
σ = 7.8737e-02
Range-Rate Residuals [km/s]
×10^-4
Time [sec]
×10^4
μ = -1.4465e-06
σ = 1.0659e-04


EKF Estimated State Error (X_filt - X_ref)
X error [km]
Y error [km]
Z error [km]
Xdot error [km/s]
Ydot error [km/s]
Zdot error [km/s]
Time [sec]
×10^4
×10^-3