Third Order Maneuvering Track Filter Design and Simulations

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Definition Of A Third Order Track Filter

- An algorithm that combines previous and current data pertaining to the target position(range), velocity and acceleration to estimate the current and future target position (range), velocity and acceleration.
- Filters can be evaluated by several parameters such as:
  - The accuracy of the estimate given a particular target motion and measurement accuracy
  - The responsiveness of the estimate to changes in target dynamics
  - The ability of the algorithm to characterize its own accuracy
  - The computational complexity of the algorithm
  - The robustness of the algorithm

Track Filter Algorithm System Diagram

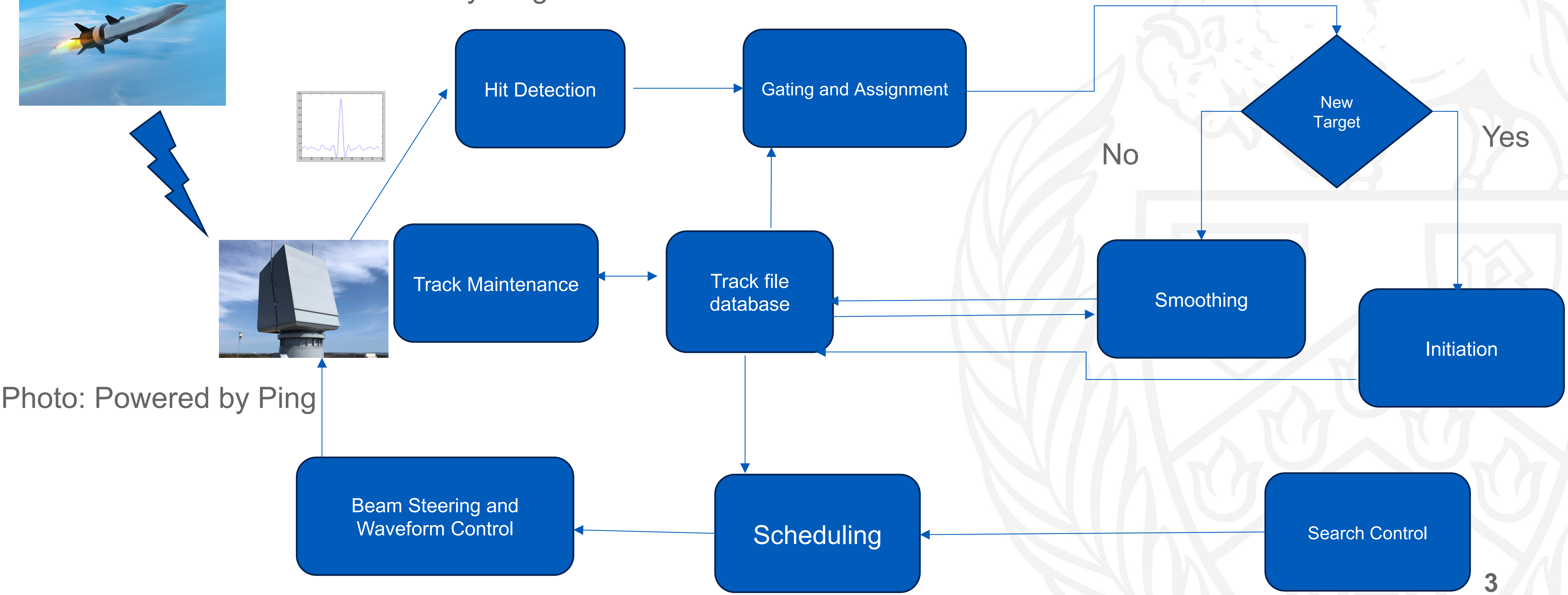

Photo: Powered by Ping

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Kalman Filter and Separate Filter

- For both filters, the state update equation is

$$Rs = (1-\alpha)\, Rp + \alpha\, Rm$$

Given the same value of α, the same results are achieved regardless of the model chosen

- The more standard Kalman filter approach of choosing process noise can result in the same results
  - The optimum process noise is non-trivial to compute in real time
  - The standard approach of using a constant process noise does not result in optimal noise
  - No bias estimate is easily available
- For the reason above, Optimal Reduced State Estimator (ORSE) is extensively use

Higher Order Filter

- To improve the system performance, the filter order should be increased
- The system mode is expressed in matrix form

  - For a second order track filter, the long form system model is defined as follows:

    The state equation, $x_{k+1} = Fx_k + G\lambda_k$

    $R_{k+1} = R_k + T V_k + 0.5T^2\lambda_{k;}$ the range(position)

    $V_{k+1} = V_k + T \lambda_{k\,;}$ the velocity

and the measurement model in matrix form is expressed as

- $Rm = Hx + n_k$
- where H = [1 0] and $n = N(0, sRm^2)$, Measurement Noise Long Form: $R_m = R_k + n_k$

ORSE Equations For Prediction In Matrix Form

- The equation to predict a state estimate forward in time can be written
  $$x_P = F\ xS$$
- Note that the unknown acceleration component is not added.
  The covariance of the predicted state can be written
  - $M_P = F\ MSF^T$
  - $D_P = F\ D_S + G$
  - $S_P = M_P + D_P \Lambda D_P^T$
- Note new terminology (from ORSE papers)
  - M: Covariance of track state
  - D: Bias scaling matrix
  - S: RSS of covariance and bias
  - L: Maximum maneuver (squared), in each dimension

ORSE Equations For Prediction In Matrix Form Cont'd

- λ is the maximum uncertainty in the model
- D describes how a maneuver creates a bias ($D\lambda$)
- M is the random, unbiased variance in the track state
- When reporting the total covariance, it is usually intended to represent a (1- σ) representation of the data
- $Cov = M + D \Lambda D'$
- In this case, Λ represents the 'variance' of the maneuver –not technically correct

Gain and ORSE Smoothing Equations In Matrix Form

- The gain equation can be written

  $K = Sp\ H^T(\sigma R_m 2 + H\ Sp\ H^T)^{-1}$

- This is the gain to minimize the smoothed covariance
- Compare this to

  $\alpha = Pp / (Pp + Pm)$

- The components of the gain of a second order filter are often labeled

  $K = \begin{bmatrix} \alpha \\ \beta / T \end{bmatrix}$

Gain And ORSE Smoothing Equations In Matrix Form Cont'd

- The equation to smooth a state prediction with a measurement can be written
  $x_s = x_p + K(Rm - Hx_p)$;
  Compare this to $Rs = Rp + \alpha(Rm - Rp)$
- The covariance of the smoothed state can be written
  $M_s = (I-KH)\, M_p (I-KH)^T + KPm\, K^T$
  $D_s = (I-KH)\, D_p$
  $S_s = M_S + D_S \Lambda D_S T$

Track Initialization and Reinitialization

- At first measurements
- $X_1 = \begin{bmatrix} R_{m1} \\ 0 \end{bmatrix}$,
- $M_{1|1} = \begin{vmatrix} \sigma^2{}_n & 0 \\ 0 & \infty \end{vmatrix}$ and $D_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$,
- Infinite value is difficult to enter into software
  - Never look at value until reinitialized at second measurement
  - Use reasonable large value,
- At second update, two measurements are available

Track Initialization and Reinitialization Cont'd

- At second update, two measurements are available

- $X_2 = \begin{bmatrix} R_{m2} \\ (Rm_2 - R_{m1})/\Delta T \end{bmatrix}$,

- $M_{2|2} = \begin{bmatrix} \sigma^2{}_n & \sigma^2{}_{n/\Delta T} \\ \sigma^2{}_{n/\Delta T} & \sigma^2{}_{n/\Delta T^2} \end{bmatrix}$ and $D_2 = \begin{bmatrix} 0 \\ \Delta T/2 \end{bmatrix}$,

Third order Filter System Modeling

- The system model is expressed in matric form as

$$x_{k+1=} F\ xk + G\lambda_k$$

Where $G = \begin{bmatrix} \frac{1}{6}T^3 \\ \frac{1}{2}T^2 \\ 1 \end{bmatrix}$

λ= maneuver (acceleration, now)

$F = \begin{matrix} 1 & T & 0.5T^2 \\ 0 & 1 & T \\ 0 & 0 & 1 \end{matrix}$ is the transition matrix

Third order Filter System Modeling Cont'd

- The measurement model is expressed in matrix form

$$Rm = Hx + nk$$

where

$H = [\,1\ 0\ 0\,]$

$n = N(0, \sigma_{Rm}^{2})$ is the measurement noise

Third order Filter System Modeling Cont’d

- The third order track filtering consists of :
  - A third order track initialization module: initializes track detection, track time, next track, track state and track update
  - A third order track reinitialization module: Update the track state and detection
  - A third order target module: define target state parameters, time and update time
  - A third order prediction module: Predict track state and time
  - A third order detection module: defines detected track parameters with added detection noise
  - A third order filter module: defines track state and detection filter
  - A Driver module: runs the models and plotting
  - A plotting module: plots track simulations parameters

Known Motion Compensation

- Knowing additional information can help in improving system performance
- Ballistic targets have predictable acceleration due to gravity
  - In the prediction model, known acceleration can be added into the model
  - Approximately known forces, such as forces due to drag, can be added into the model, and the errors can also be taken into consideration
- Target tracking in a relative coordinate frame will have motion components due to sensor platform motion, and these can be compensated

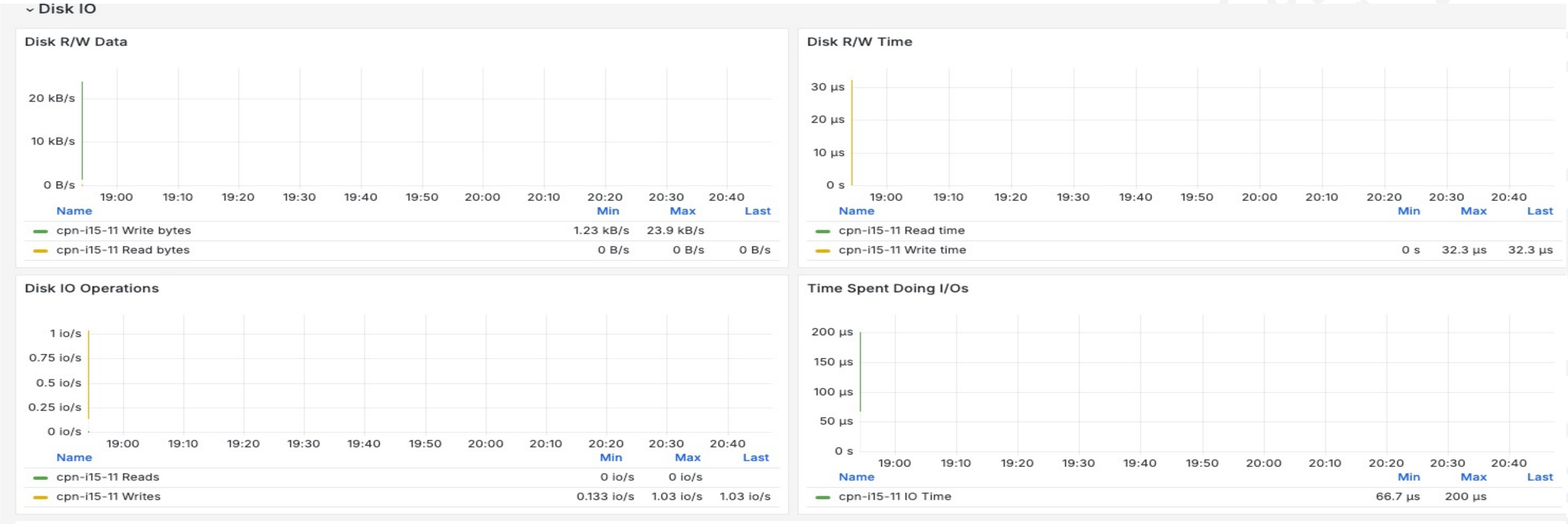
Code Repository

- /user/jeandedi/Desktop/FinalProjectCodes

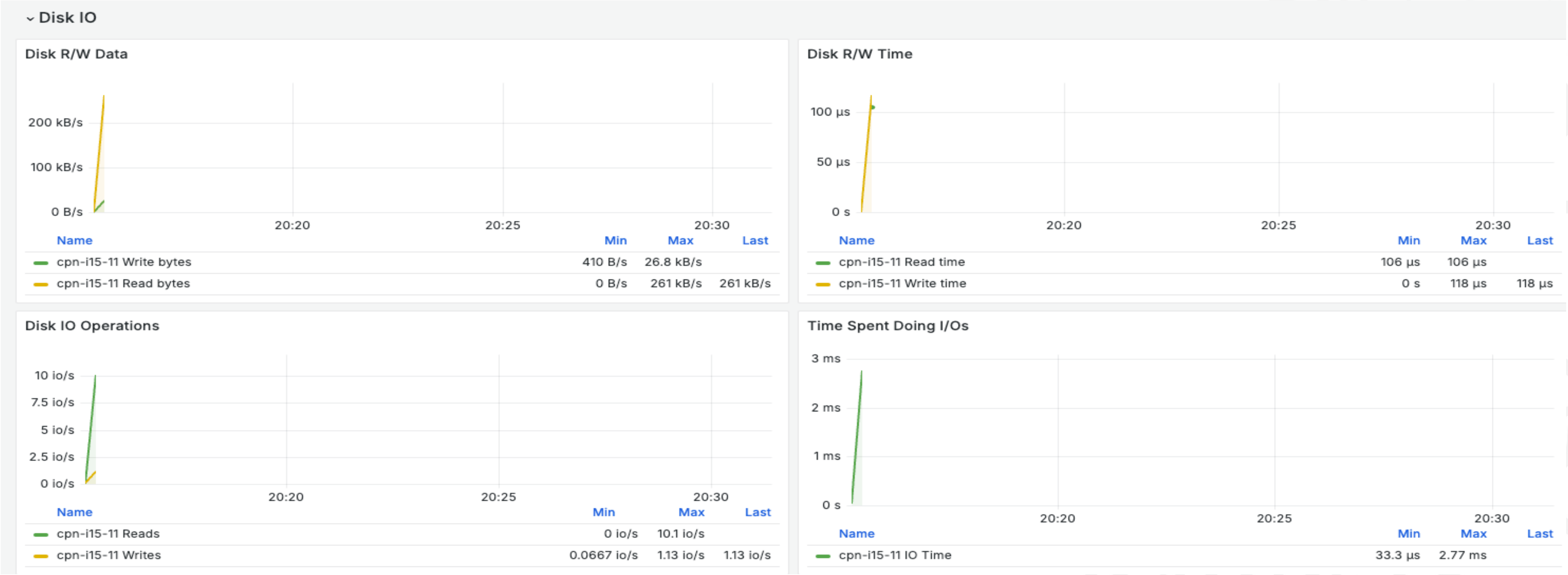
Job Submission Script

```
#!/bin/bash -l
#SBATCH –ntasks=2
#SBATCH –cpus-per-task=2
#SBATCH –time=00:10:00
#SBATCH –nodes=16
#SBATCH –mem=10000
#SBATCH –job-name=TrackFilter
#SBATCH –output=TrackFilter.out
#SBATCH –ntasks-per-node=32
#SBATCH –partition=general-compute
#SBATCH –qos=general-compute
#SBATCH –cluster=ub-hpc
#SBATCH –account=cse633
#SBATCH –mail-type=ALL
#SBATCH –mail-user=jeandedi@buffalo.edu
srun ./driver.exe
module load gcc
module load openmpi
module load gcc/11.2.0 openmpi/4.1.1
export OMP_NUM_THREADS=$SLURM_CPUS_PER_TASK
```

Nodes = 4, Total CPUs =128



Nodes = 2, Total CPUs =64



Slurm Job Runs Settings and Performance

```
jeandedi@login1:~$ sacct  --jobs=15758151 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
AlBe2H8_1+                 1         16   10:53:36  masashik               00:40:51      cpn-h22-06
     batch        1        1         16   10:53:36            00:00:02   00:40:51      cpn-h22-06
    extern        1        1         16   10:53:36            00:00:00   00:40:51      cpn-h22-06
  vasp_std       16        1         16   10:52:32            00:40:34   00:40:47      cpn-h22-06
jeandedi@login1:~$ sacct  --jobs=15758150 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
AlBe2H8_1+                 1         16   11:39:44  masashik               00:43:44      cpn-h22-10
     batch        1        1         16   11:39:44            00:00:02   00:43:44      cpn-h22-10
    extern        1        1         16   11:39:44            00:00:00   00:43:44      cpn-h22-10
  vasp_std       16        1         16   11:38:40            00:43:26   00:43:40      cpn-h22-10
jeandedi@login1:~$ sacct  --jobs=15757187 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
download.+                 1          8   00:00:08  kendrasc               00:00:01      cpn-h22-15
     batch        1        1          8   00:00:08            00:00:00   00:00:01      cpn-h22-15
    extern        1        1          8   00:00:08            00:00:00   00:00:01      cpn-h22-15
jeandedi@login1:~$ sacct  --jobs=15768205 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         64   00:03:12  jeandedi               00:00:03      cpn-i15-11
     batch        1        1         64   00:03:12            00:00:01   00:00:03      cpn-i15-11
    extern        1        1         64   00:03:12            00:00:00   00:00:03      cpn-i15-11
driver.exe        2        1         64   00:00:00            00:00:00   00:00:00      cpn-i15-11
jeandedi@login1:~$ sacct  --jobs=15768207 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         64   00:02:08  jeandedi               00:00:02      cpn-i15-11
     batch        1        1         64   00:02:08            00:00:01   00:00:02      cpn-i15-11
    extern        1        1         64   00:02:08            00:00:00   00:00:02      cpn-i15-11
driver.exe        2        1         64   00:00:00            00:00:00   00:00:00      cpn-i15-11
jeandedi@login1:~$ sacct  --jobs=15770779 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1          4   00:00:20  jeandedi               00:00:05      cpn-h22-15
     batch        1        1          4   00:00:20            00:00:02   00:00:05      cpn-h22-15
    extern        1        1          4   00:00:20            00:00:00   00:00:05      cpn-h22-15
driver.exe        2        1          4   00:00:00            00:00:00   00:00:00      cpn-h22-15
jeandedi@login1:~$ sacct  --jobs=15770776 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         32   00:02:08  jeandedi               00:00:04      cpn-h22-33
     batch        1        1         32   00:02:08            00:00:01   00:00:04      cpn-h22-33
    extern        1        1         32   00:02:08            00:00:00   00:00:04      cpn-h22-33
driver.exe       16        1         32   00:00:32            00:00:00   00:00:01      cpn-h22-33
jeandedi@login1:~$ sacct  --jobs=15768949 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         32   00:01:36  jeandedi               00:00:03      cpn-i15-11
     batch        1        1         32   00:01:36            00:00:01   00:00:03      cpn-i15-11
    extern        1        1         32   00:01:36            00:00:00   00:00:03      cpn-i15-11
driver.exe       16        1         32   00:00:32            00:00:00   00:00:01      cpn-i15-11
```

```
jeandedi@login1:~/Desktop/FinalProjectCodes$ sacct  --jobs=15793688 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         32   00:03:12  jeandedi               00:00:06      cpn-i15-17
     batch        1        1         32   00:03:12            00:00:01   00:00:06      cpn-i15-17
    extern        1        1         32   00:03:12            00:00:00   00:00:06      cpn-i15-17
driver.exe        4        1         32   00:00:00            00:00:00   00:00:00      cpn-i15-17
jeandedi@login1:~/Desktop/FinalProjectCodes$ sacct  --jobs=15793553 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         16   00:01:20  jeandedi               00:00:05      cpn-i15-21
     batch        1        1         16   00:01:20            00:00:01   00:00:05      cpn-i15-21
    extern        1        1         16   00:01:20            00:00:00   00:00:05      cpn-i15-21
driver.exe        2        1         16   00:00:00            00:00:00   00:00:00      cpn-i15-21
jeandedi@login1:~/Desktop/FinalProjectCodes$ sbatch trackFilter.sh
Submitted batch job 15793843 on cluster ub-hpc
jeandedi@login1:~/Desktop/FinalProjectCodes$ sacct  --jobs=15793843 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         16   00:01:52  jeandedi               00:00:07      cpn-h22-15
     batch        1        1         16   00:01:52            00:00:02   00:00:07      cpn-h22-15
    extern        1        1         16   00:01:52            00:00:00   00:00:07      cpn-h22-15
driver.exe        4        1         16   00:00:16            00:00:00   00:00:01      cpn-h22-15
jeandedi@login1:~/Desktop/FinalProjectCodes$ sbatch trackFilter.sh
Submitted batch job 15793844 on cluster ub-hpc
jeandedi@login1:~/Desktop/FinalProjectCodes$ sacct  --jobs=15793844 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime       User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         64   00:00:00  jeandedi               00:00:00   None assigned
jeandedi@login1:~/Desktop/FinalProjectCodes$
```

Slurm Job Runs Settings and Performance

```
jeandedi@login1:~$ sacct  --jobs=15768204 --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node,time
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList  Timelimit
---------- ---------- ---------- -------- -------- --------- ---------- ---------- --------------- ----------
TrackFilt+         32   00:01:36        1           jeandedi              00:00:03      cpn-i15-11   00:10:00
     batch         32   00:01:36        1        1             00:00:01   00:00:03      cpn-i15-11
    extern         32   00:01:36        1        1             00:00:00   00:00:03      cpn-i15-11
driver.exe         32   00:00:32        1        4             00:00:00   00:00:01      cpn-i15-11
jeandedi@login1:~$ sacct  --jobs=15768204 --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+         32   00:01:36        1           jeandedi              00:00:03      cpn-i15-11
     batch         32   00:01:36        1        1             00:00:01   00:00:03      cpn-i15-11
    extern         32   00:01:36        1        1             00:00:00   00:00:03      cpn-i15-11
driver.exe         32   00:00:32        1        4             00:00:00   00:00:01      cpn-i15-11
jeandedi@login1:~$ sacct  --jobs=15767188  --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+         64   00:02:08        2           jeandedi              00:00:02 cpn-i15-[11,13]
     batch         32   00:01:04        1        1             00:00:01   00:00:02      cpn-i15-11
    extern         64   00:02:08        2        2             00:00:00   00:00:02 cpn-i15-[11,13]
driver.exe         64   00:00:00        2        4             00:00:00   00:00:00 cpn-i15-[11,13]
jeandedi@login1:~$ sacct  --jobs=15768204  --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+         32   00:01:36        1           jeandedi              00:00:03      cpn-i15-11
     batch         32   00:01:36        1        1             00:00:01   00:00:03      cpn-i15-11
    extern         32   00:01:36        1        1             00:00:00   00:00:03      cpn-i15-11
driver.exe         32   00:00:32        1        4             00:00:00   00:00:01      cpn-i15-11
jeandedi@login1:~$ sacct  --jobs=15768451 --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+         32   00:01:36        2           jeandedi              00:00:03 cpn-i15-[05,07]
     batch         16   00:00:48        1        1             00:00:01   00:00:03      cpn-i15-05
    extern         32   00:01:36        2        2             00:00:00   00:00:03 cpn-i15-[05,07]
driver.exe         32   00:00:00        2       16             00:00:00   00:00:00 cpn-i15-[05,07]
jeandedi@login1:~$ sacct  --jobs=15767182  --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+        128   00:12:48        4           jeandedi              00:00:06 cpn-q07-24,cpn+
     batch         32   00:03:12        1        1             00:00:03   00:00:06      cpn-q07-24
    extern        128   00:12:48        4        4             00:00:00   00:00:06 cpn-q07-24,cpn+
driver.exe        128   00:00:00        4       16             00:00:00   00:00:00 cpn-q07-24,cpn+
jeandedi@login1:~$ sacct  --jobs=15767169  --format=jobname,ncpus,cputime,nnodes,ntasks,user,avecpu,elapsed,node
   JobName      NCPUS    CPUTime   NNodes   NTasks      User     AveCPU    Elapsed        NodeList
---------- ---------- ---------- -------- -------- --------- ---------- ---------- ---------------
TrackFilt+         48   00:03:12        4           jeandedi              00:00:04 cpn-i14-35,cpn+
     batch         12   00:00:48        1        1             00:00:01   00:00:04      cpn-i14-35
    extern         48   00:03:12        4        4             00:00:00   00:00:04 cpn-i14-35,cpn+
driver.exe         48   00:00:00        4        6             00:00:00   00:00:00 cpn-i14-35,cpn+
```

```
jeandedi@login1:~$ sacct  --jobs=15768205 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed
---------- -------- -------- ---------- ---------- --------- ---------- ----------
TrackFilt+                 1         64   00:03:12  jeandedi              00:00:03
     batch        1        1         64   00:03:12             00:00:01   00:00:03
    extern        1        1         64   00:03:12             00:00:00   00:00:03
driver.exe        2        1         64   00:00:00             00:00:00   00:00:00
jeandedi@login1:~$ sacct  --jobs=15752043 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2         16   00:01:20  jeandedi              00:00:05 cpn-i14-[33,35]
     batch        1        1          8   00:00:40             00:00:03   00:00:05      cpn-i14-33
    extern        2        2         16   00:01:20             00:00:00   00:00:05 cpn-i14-[33,35]
driver.exe        4        2         16   00:00:00             00:00:00   00:00:00 cpn-i14-[33,35]
jeandedi@login1:~$ sacct  --jobs=15752044 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1          4   00:00:20  jeandedi              00:00:05      cpn-i14-33
     batch        1        1          4   00:00:20             00:00:03   00:00:05      cpn-i14-33
    extern        1        1          4   00:00:20             00:00:00   00:00:05      cpn-i14-33
driver.exe        1        1          4   00:00:00             00:00:00   00:00:00      cpn-i14-33
jeandedi@login1:~$ sacct  --jobs=15752046 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2         16   00:01:20  jeandedi              00:00:05 cpn-i14-[33,35]
     batch        1        1          8   00:00:40             00:00:03   00:00:05      cpn-i14-33
    extern        2        2         16   00:01:20             00:00:00   00:00:05 cpn-i14-[33,35]
driver.exe        2        2         16   00:00:00             00:00:00   00:00:00 cpn-i14-[33,35]
jeandedi@login1:~$ sacct  --jobs=15752047 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2          8   00:00:40  jeandedi              00:00:05 cpn-i14-[33,35]
     batch        1        1          4   00:00:20             00:00:03   00:00:05      cpn-i14-33
    extern        2        2          8   00:00:40             00:00:00   00:00:05 cpn-i14-[33,35]
driver.exe        2        2          8   00:00:00             00:00:00   00:00:00 cpn-i14-[33,35]
jeandedi@login1:~$ sacct  --jobs=15752049 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2         24   00:02:24  jeandedi              00:00:06 cpn-i14-[33,35]
     batch        1        1         12   00:01:12             00:00:03   00:00:06      cpn-i14-33
    extern        2        2         24   00:02:24             00:00:00   00:00:06 cpn-i14-[33,35]
driver.exe        2        2         24   00:00:24             00:00:00   00:00:01 cpn-i14-[33,35]
jeandedi@login1:~$ sacct  --jobs=15752049 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2         24   00:02:24  jeandedi              00:00:06 cpn-i14-[33,35]
     batch        1        1         12   00:01:12             00:00:03   00:00:06      cpn-i14-33
    extern        2        2         24   00:02:24             00:00:00   00:00:06 cpn-i14-[33,35]
driver.exe        2        2         24   00:00:24             00:00:00   00:00:01 cpn-i14-[33,35]
jeandedi@login1:~$ sacct  --jobs=15752052 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 2        128   00:08:32  jeandedi              00:00:04 cpn-i15-[07,23]
     batch        1        1         64   00:04:16             00:00:03   00:00:04      cpn-i15-07
    extern        2        2        128   00:08:32             00:00:00   00:00:04 cpn-i15-[07,23]
driver.exe        2        2        128   00:00:00             00:00:00   00:00:00 cpn-i15-[07,23]
jeandedi@login1:~$ sacct  --jobs=15752060 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         64   00:05:20  jeandedi              00:00:05      cpn-i15-30
     batch        1        1         64   00:05:20             00:00:03   00:00:05      cpn-i15-30
    extern        1        1         64   00:05:20             00:00:00   00:00:05      cpn-i15-30
driver.exe        8        1         64   00:00:00             00:00:00   00:00:00      cpn-i15-30
jeandedi@login1:~$ sacct  --jobs=15752061 --format=jobname,ntasks,nnodes,ncpus,cputime,user,avecpu,elapsed,nodeList
   JobName   NTasks   NNodes      NCPUS    CPUTime      User     AveCPU    Elapsed        NodeList
---------- -------- -------- ---------- ---------- --------- ---------- ---------- ---------------
TrackFilt+                 1         64   00:05:20  jeandedi              00:00:05      cpn-i16-09
     batch        1        1         64   00:05:20             00:00:03   00:00:05      cpn-i16-09
    extern        1        1         64   00:05:20             00:00:00   00:00:05      cpn-i16-09
driver.exe       32        1         64   00:00:00             00:00:00   00:00:00      cpn-i16-09
```

Occurring Libraries Issues

```
jeandedi@login1:~$ module load gcc
jeandedi@login1:~$ module load openmpi
jeandedi@login1:~$ cd Desktop/
jeandedi@login1:~/Desktop$ cd FinalProjectCodes/
jeandedi@login1:~/Desktop/FinalProjectCodes$ ls -al
total 104
drwxr-xr-x 2 jeandedi jeandedi  4096 May 11 23:13 .
drwxr-xr-x 2 jeandedi jeandedi  4096 May  9 18:32 ..
-rwxrwxrwx 1 jeandedi jeandedi 14970 May 11 16:29 driver.cpp
-rwxrwxr-x 1 jeandedi jeandedi 88152 May 11 18:53 driver.exe
-rwxrwxrwx 1 jeandedi jeandedi   722 May 12 11:34 TrackFilter.out
-rwxrwxrwx 1 jeandedi jeandedi   578 May 12 00:40 trackFilter.sh
jeandedi@login1:~/Desktop/FinalProjectCodes$ g++ driver.cpp -o driver.exe -fopenmp -L/opt/openmpi/lib -lmpi -ldl -lm -Wl,--export-dynamic -lrt -lnsl -lutil -lm -ldl
jeandedi@login1:~/Desktop/FinalProjectCodes$ vi TrackFilter.out
jeandedi@login1:~/Desktop/FinalProjectCodes$ vi TrackFilter.out
```

```
/user/jeandedi/Desktop/FinalProjectCodes/./driver.exe: error while loading shared libraries: libmpi.so.40: cannot open shared object file: No such file or directory
/user/jeandedi/Desktop/FinalProjectCodes/./driver.exe: error while loading shared libraries: libmpi.so.40: cannot open shared object file: No such file or directory
srun: error: cpn-i15-11: task 0: Exited with exit code 127
srun: launch/slurm: _step_signal: Terminating StepId=15768151.0
srun: error: cpn-i15-37: task 1: Exited with exit code 127
The following modules were not unloaded:
  (Use "module --force purge" to unload all):

  1) ccrenv   2) gentoo/2023.01   3) ccrsoft/2023.01

Lmod is automatically replacing "gcc/11.2.0" with "intel/2022.00".
```

Conclusion

- A third order track filter for position, velocity and acceleration of a maneuvering target was implemented using C++; However, I could not plot the results due to C++ plotting limitations.
- The C++ Third Order Track Filter debugged using a GCC and openmpi compilers libraries
- An MPI adaption of the C++ Third Order Track Filter was implemented
- The C++ Third Order Track Filter was submitted to slurm using a batch script to test run timing performance using a variety of CCR cluster nodes, cpu per task and other ub–hpc setup resources configurations.
- Due to some Lockheed Martin PI reference materials, the associated MATLAB filter algorithm design with not be shared but can be demonstrated via a video reference to only U.S citizens, and cannot be shared in a personal email.
- Note that the variance estimation & smoothing algorithm was not implemented and simulated using C++ as well at this time
- Also, the gain calculations algorithm was not implemented and simulated using a C++ code as well at this time
- In the future, I would like to investigate more and simulate the optimal gain, variance estimation & smoothing algorithm to have a more robust tracking system

References

- Lockheed Martin RMS Employee Top Gun Track and Advanced Track Filtering Internal Courses: Unable to disclose the referenced resources due to unpublished Lockheed Martin Proprietary Information Contained
- Tracking Multiple Moving Objects Using Unscented Kalman Filtering Techniques by Xi Chen, Xiao Wang and Jianhua Xuan Bradley
- UB CCR Documentations and high- performance computing resources
- Extensive Google Research while debugging the C++ code and other associated issues.