



# Indian Institute of Technology Madras

Department of Aerospace Engineering

AS5570

## Principles of Guidance of Autonomous Vehicles

*Extension to 'All Aspect Approach to A Stationary Target'*

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# 1 Motivation

In the 2pPPN guidance, the orientation phase can be attained with different trajectories. We computed the cost requirement as  $\int a_p^2 dt$ . The minimum lateral acceleration requirement gives the best trajectory. Also, we have analyzed the phase after the orientation phase for  $N > 2$  values and concluded an optimum N for that phase.

## 2 Procedure

- The pursuer has to reach the target with finite bounded lateral acceleration.
- The pursuer takes the orientation phase to reach the  $N = 2$  line in the  $\alpha_P - \theta$  plane. Then, it follows the  $N = 2$  line to reach the target.
- The initial conditions in our case are -  $(\alpha_{P_0}, \theta_0) = (\pi/4, 0)$ . The desired approach angle is  $-150^\circ$ . The orientation gain is found by -

$$N = \frac{\alpha_P - \alpha_{P_0}}{\theta - \theta_0} \quad (1)$$

We have considered the gains from  $(-2, 1)$  during this phase.

- The lateral acceleration is found as -

$$a_p = \frac{NV_p V_\theta}{R} \quad (2)$$

Here  $a_{p(ori)}$  is when  $N=N_{ori}$  and  $a_{p(end-phase)}$  is when  $N = 2$ .

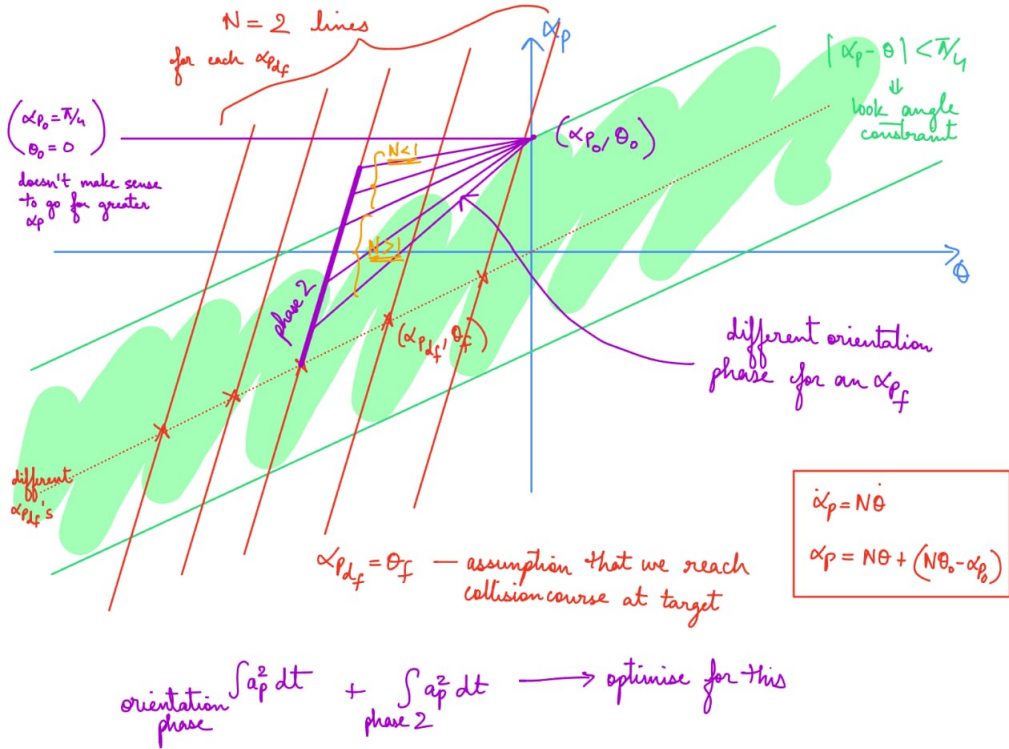


Figure 1:  $\alpha_P - \theta$  plane

### 3 Interpretation

The initial conditions in our case are -  $(\alpha_{P_0}, \theta_0) = (\pi/4, 0)$ . The desired approach angle is  $-150^\circ$ . The final phase gain or  $N_f$  is 2 for the plots shown.

#### 3.1 Gain = -2

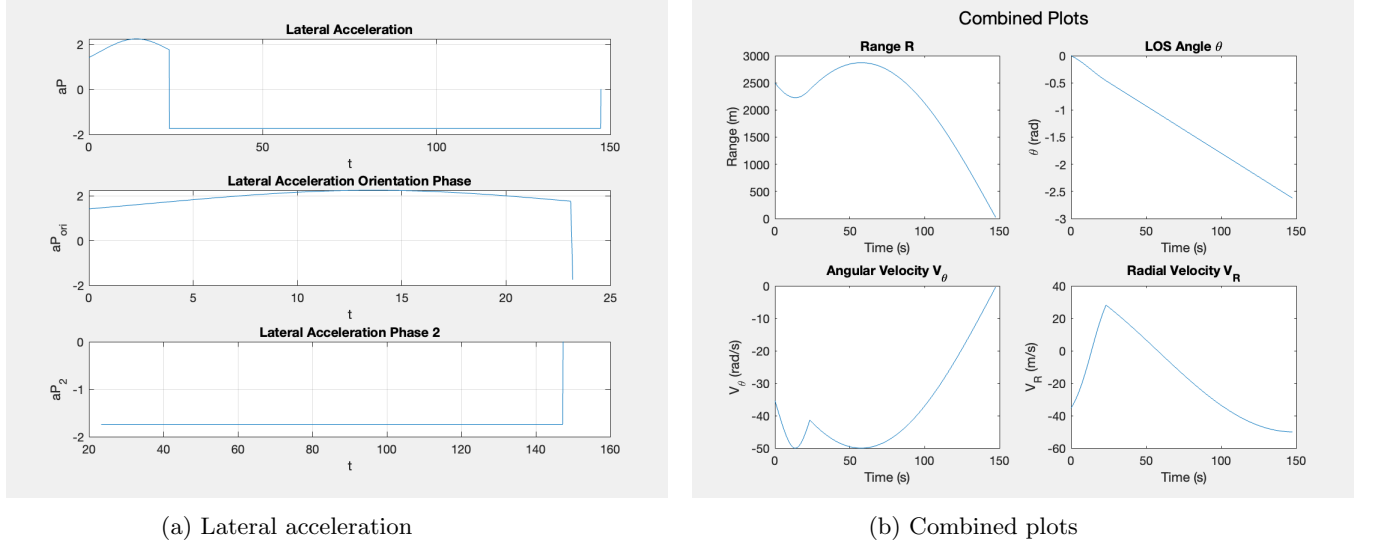


Figure 2: Comparison of plots

#### 3.2 Gain = -1

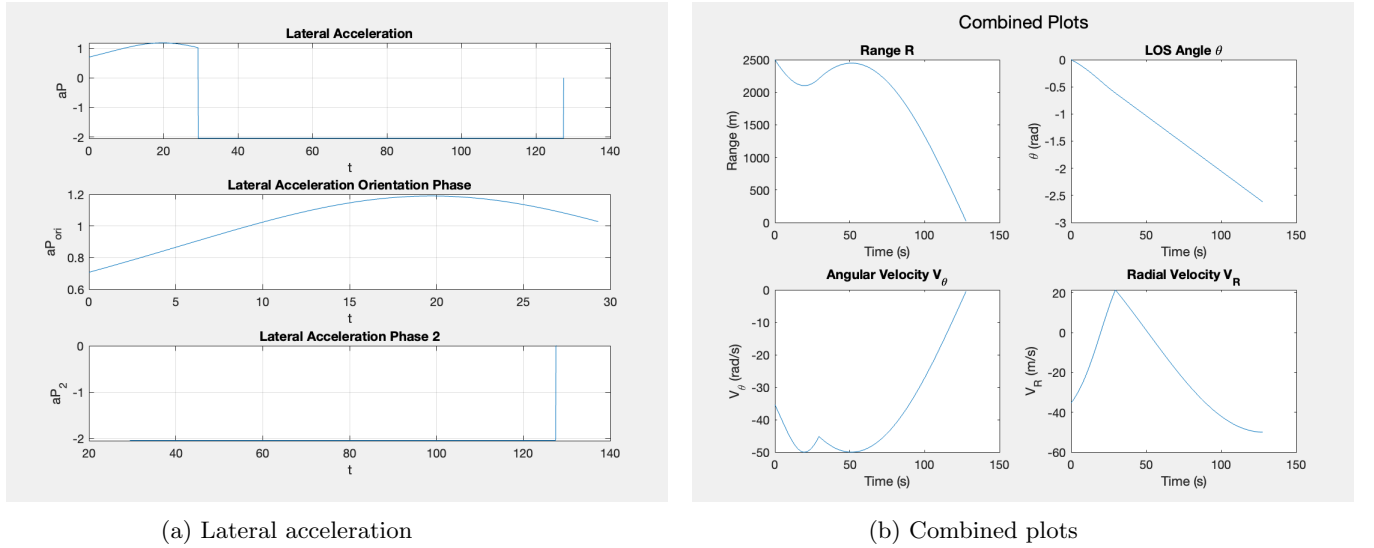
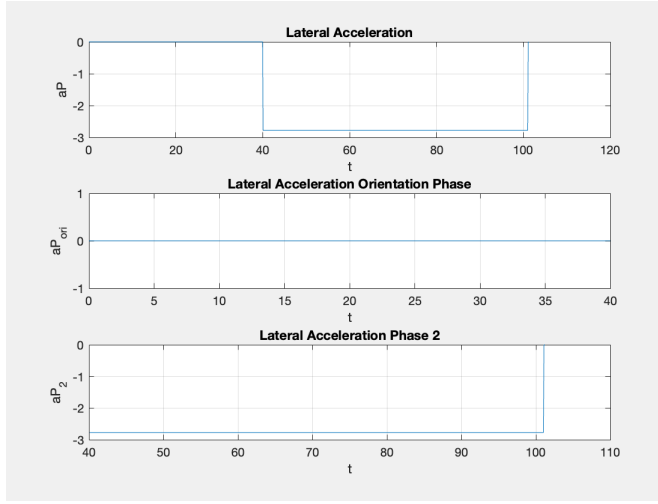
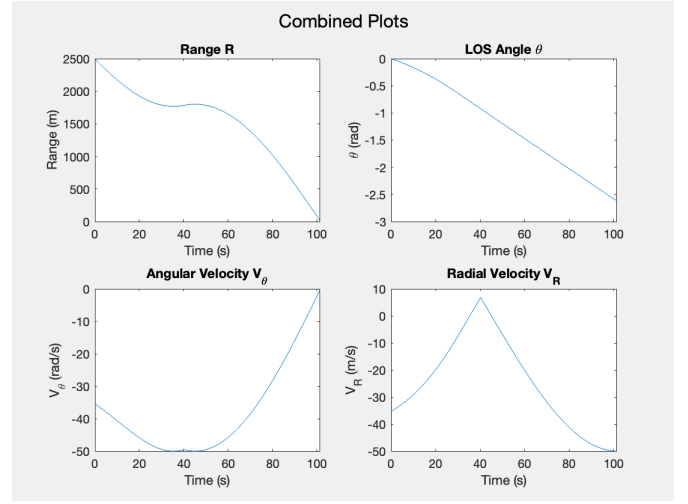


Figure 3: Comparison of plots

### 3.3 Gain = 0



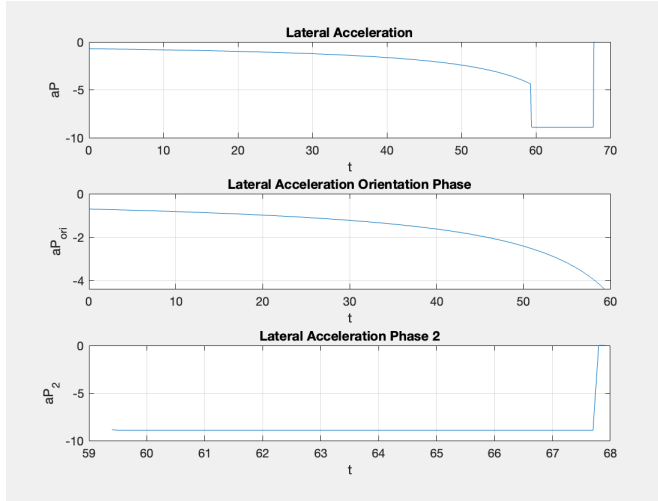
(a) Lateral acceleration



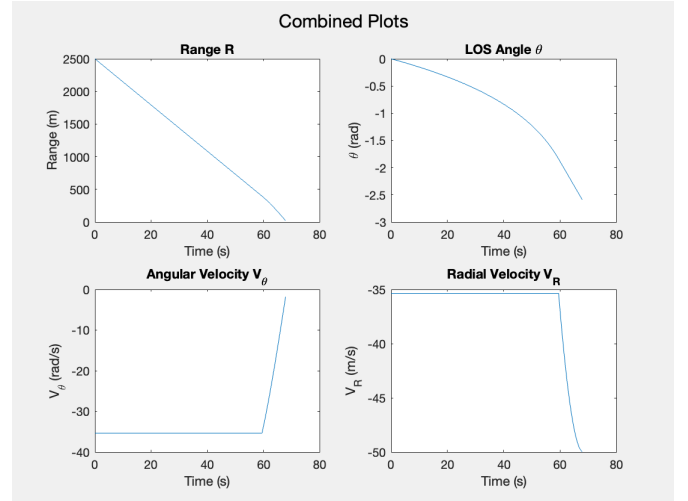
(b) Combined plots

Figure 4: Comparison of plots

### 3.4 Gain = 1



(a) Lateral acceleration



(b) Combined plots

Figure 5: Comparison of plots

### 3.5 Cost and Time to reach

We can observe from the plots that time to reach decreases with increase in  $N_{ori}$ . The cost variation and trajectories for different  $N_{ori}$  is also shown.

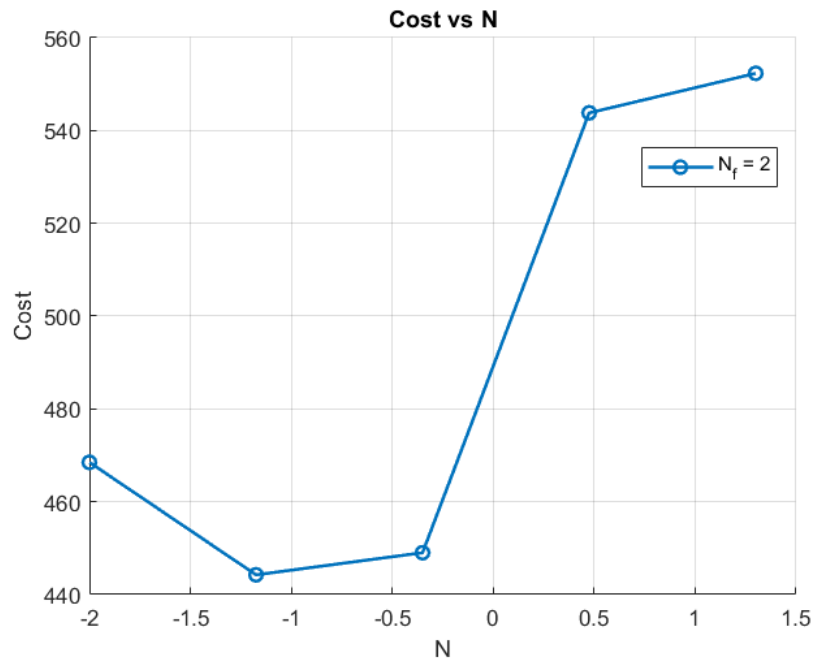


Figure 6: Cost v/s  $N_{ori}$

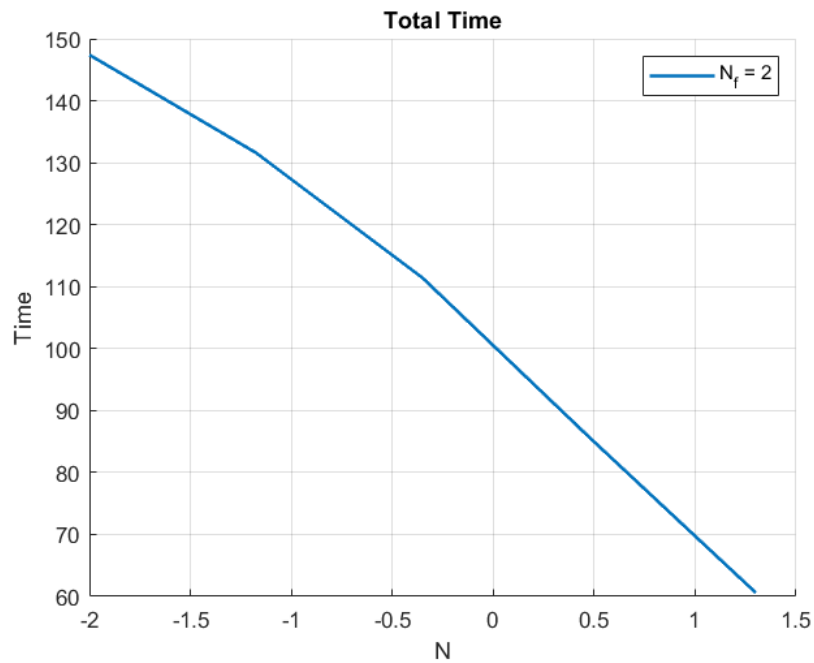


Figure 7: Time to reach v/s  $N_{ori}$

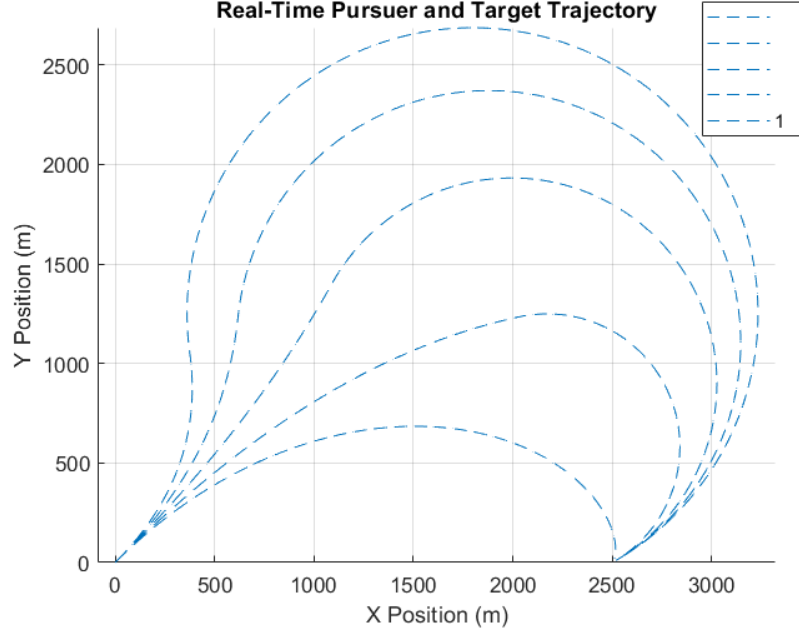


Figure 8: Trajectories

## 4 Optimising Cost

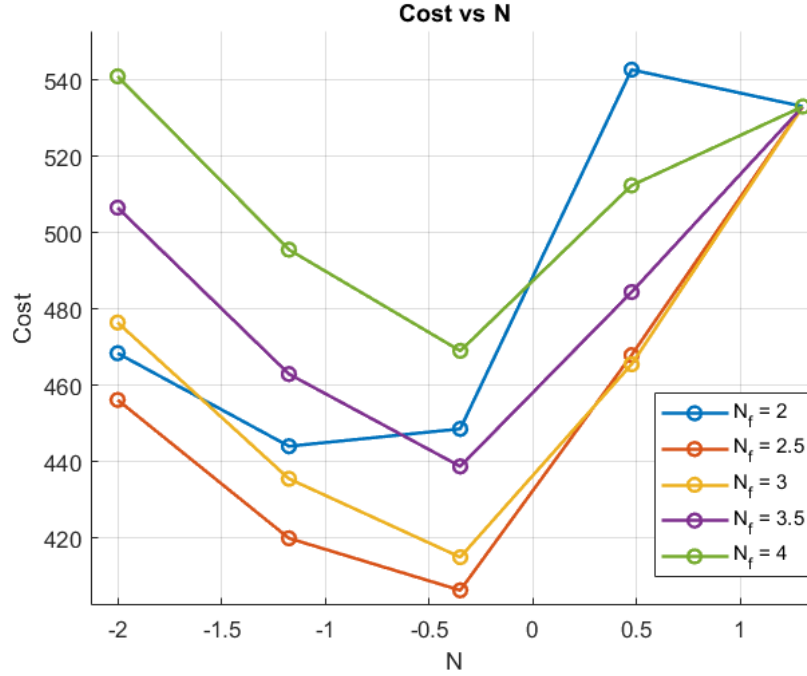


Figure 9: Cost Comparison

As we can see cost has an overall minima compared to the rest at  $N_f = 2$ , and then increases after. Hence, **optimum  $N_f$  is 2.5** and **optimum  $N_{ori}$  for it is -0.35** for  $\alpha_{P_{df}} = -150^\circ$

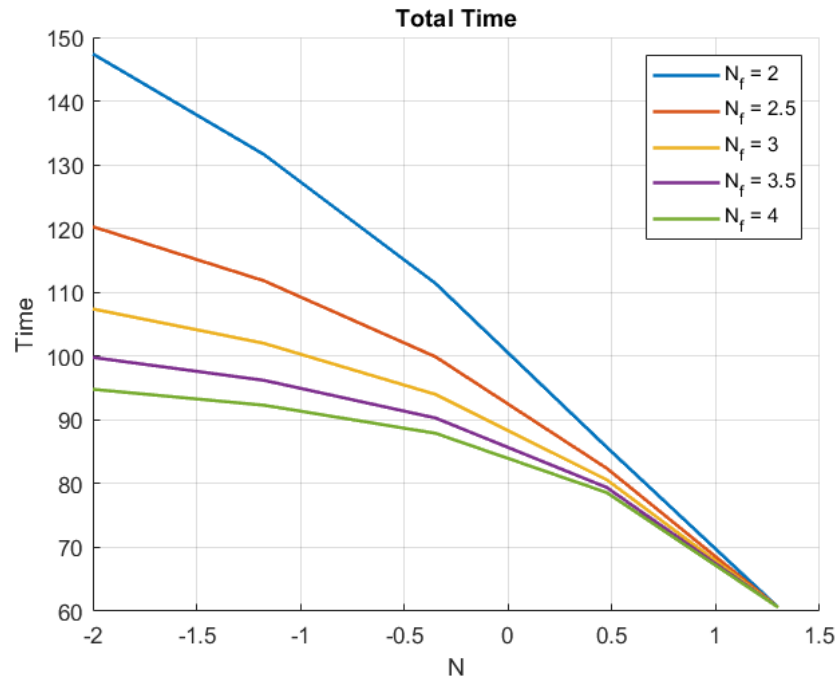


Figure 10: Time to Reach

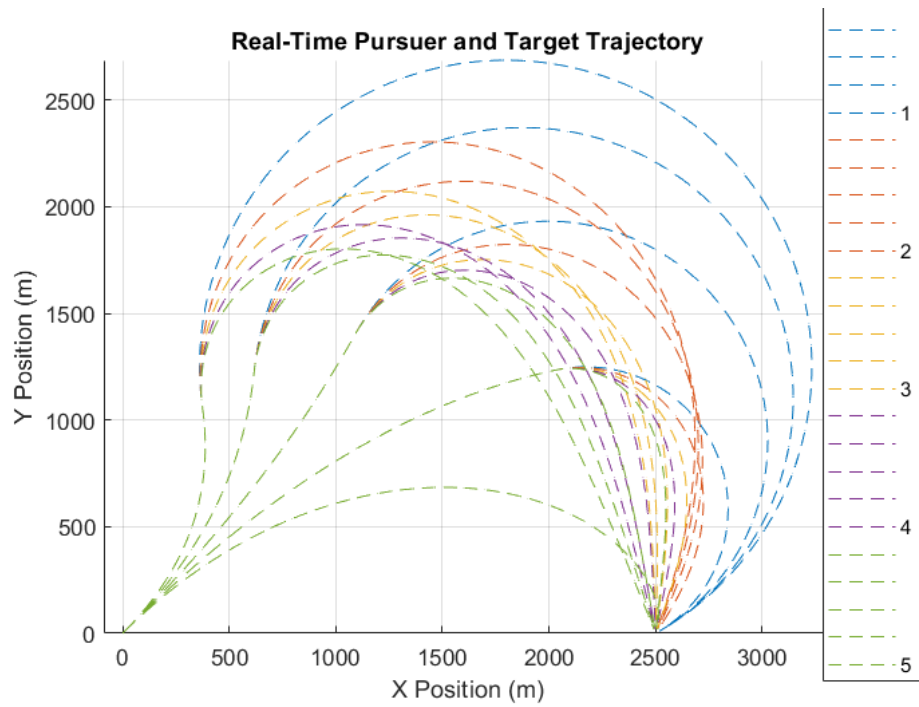


Figure 11: Trajectory Comparison

## 4.1 Variation of Cost with change in Desired Approach Angle

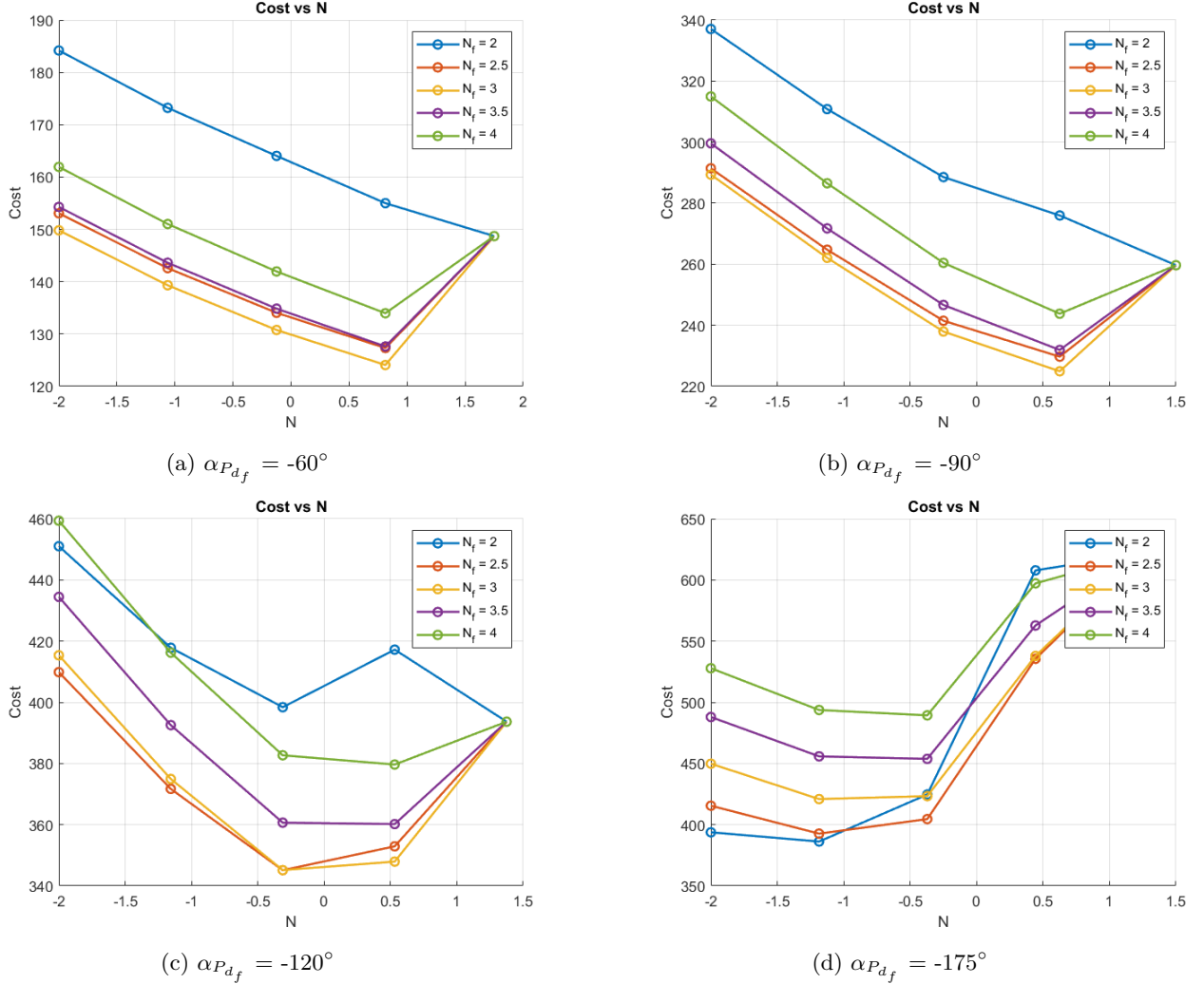


Figure 12: Comparison for different  $\alpha_{P_{df}}$

We can clearly see a shift in the optima value with change in  $\alpha_{P_{df}}$

## 5 Conclusion

- The minima of the cost function was observed at  $N_{ori} = -0.35$  for different  $N_f$ . Hence, it is the optimum orientation phase for our given conditions.
- As the  $N_{ori}$  increases from 0, the cost increases, and the time to reach the target decreases. Hence, it is a **tradeoff between lateral acceleration requirement and time to reach here**.
- Based on the Cost vs N plot, we can conclude that **optimum  $N_f$  is 2.5**. We could use a finer array of N values around optimum  $N_f$  to check for a better optimal final phase N.
- The range of angles which can be attained using PPN is  $[-45^\circ, 0^\circ)$ , but we want to optimise  $a_P$  over both phases. So, we ran the simulations for different final approach angles like  $[-60^\circ, -90^\circ, -120^\circ, -175^\circ]$ . As we increase the angle from  $-45^\circ$  to  $-180^\circ$ , the optimal orientation gain decreases. Also, the optimum



gain for the final phase decreases ( $3 - > 2.5 - > 2$ ). But for all approach angles, the time to reach decreases as  $N_{ori}$  increases.

- There is some anomalous behavior for  $N_f = 2$ , for a certain  $\alpha_{P_{df}}$  it does not follow a similar trend compared to the other higher N values. We can associate this behaviour to it being the minimum bound for finite missile latex.