Jonathan Pfefferle

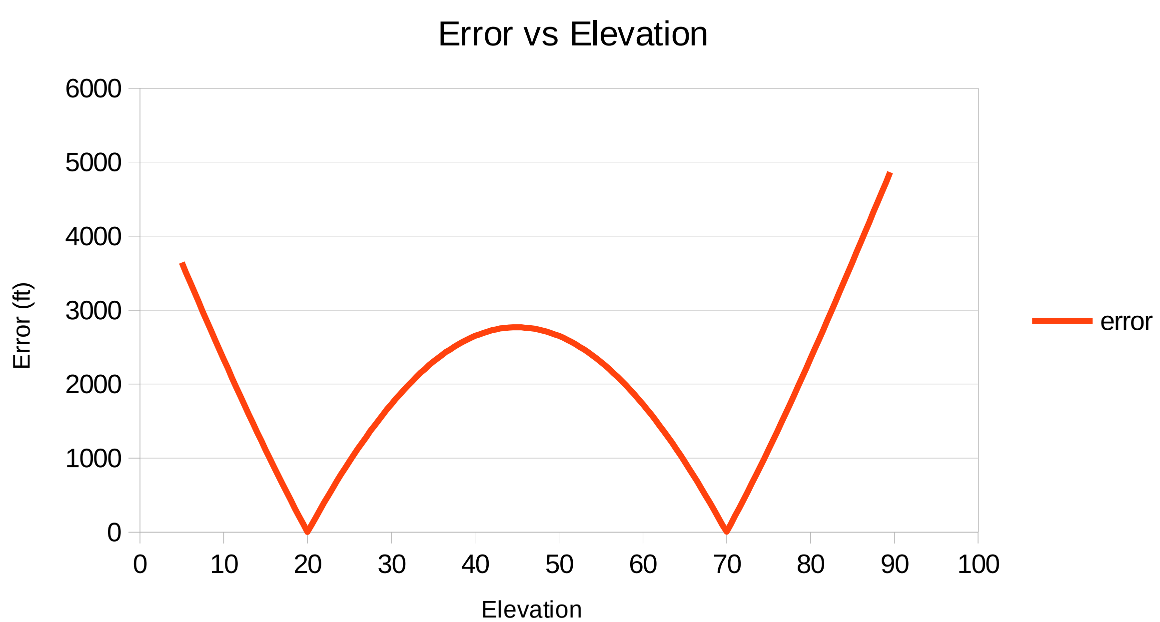
Artillery section

A deterministic solution is mathematically perfect. There is no randomness involved to model errors. Therefore, one run is sufficient to determine its performance. This part is "clean" because the environment introduces no errors. Part E introduces nonrandom wind.

Use firing position (0,0), initial velocity 500 fps, and range to target 5000 feet.

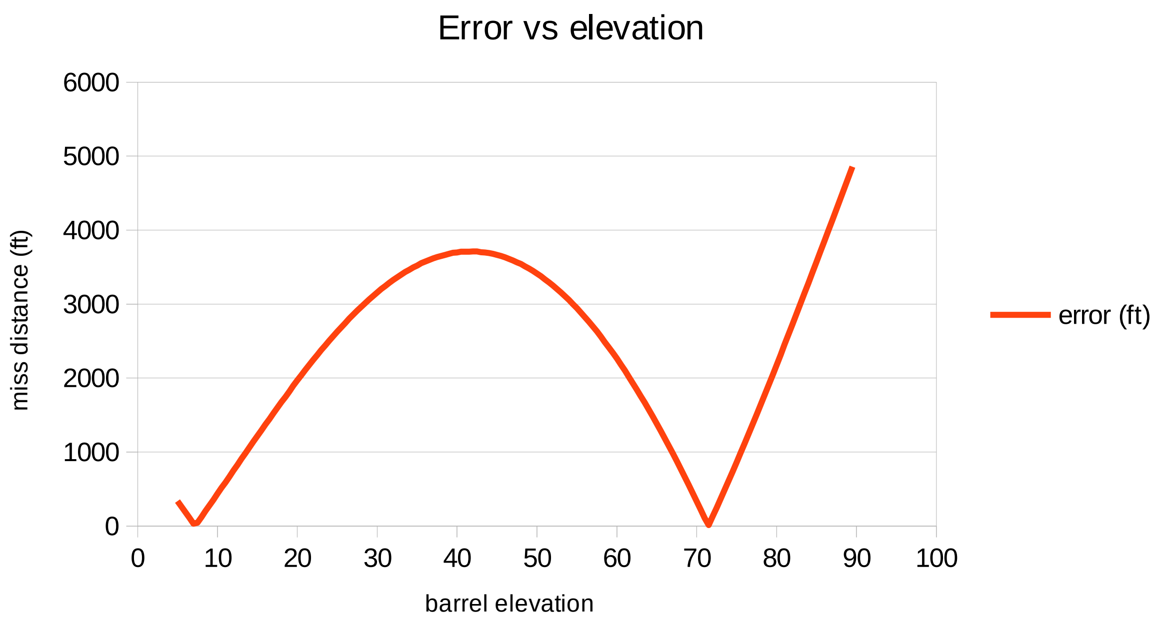
This part is small enough to do by hand, but it is important for the later parts to build a simple control system in your simulation. You know the (distance) range to the target. Loop over a (mathematical) range of elevations until the projectile hits it (give or take). Alternatively, output all the results to Excel and plot them to determine the points of interest by eye.

Part I A 1. Calculate the elevation to hit a target at the same altitude.
Ideal angles for hitting the target are 20 degrees (error of 0.853 feet) and 70 degrees (error of 6.506 feet.)



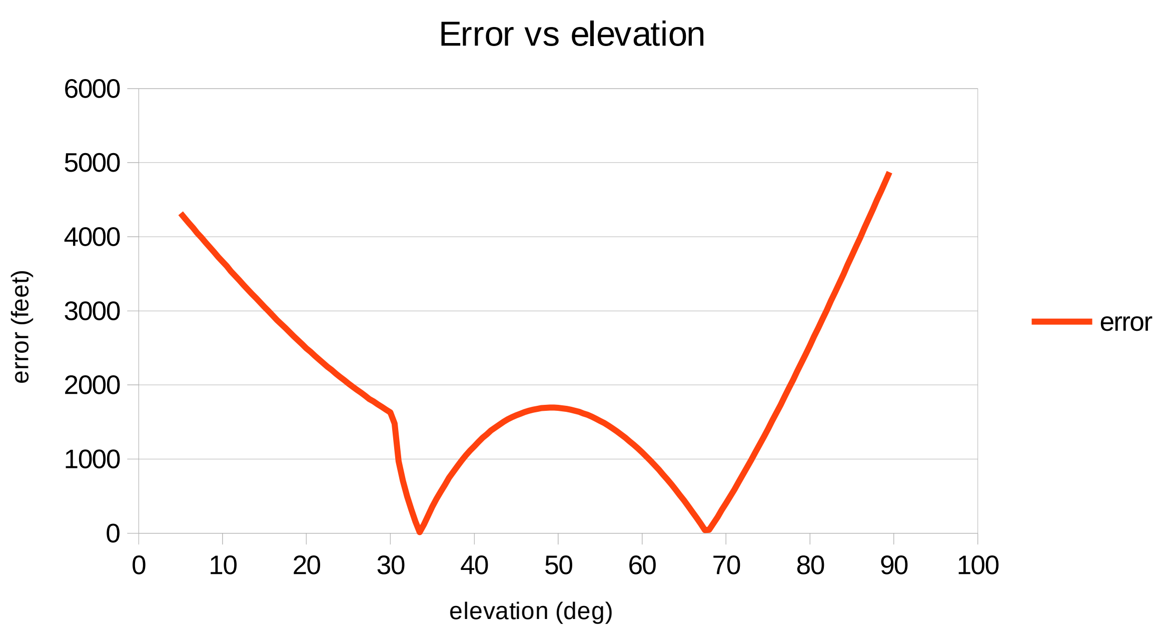
Part I A 2. Calculate the elevation to hit a target at lower altitude –1000

Ideal angels for hitting the target are 7 degrees (error of 32.307 feet) and 71.5 degrees (error of 11.971 feet)



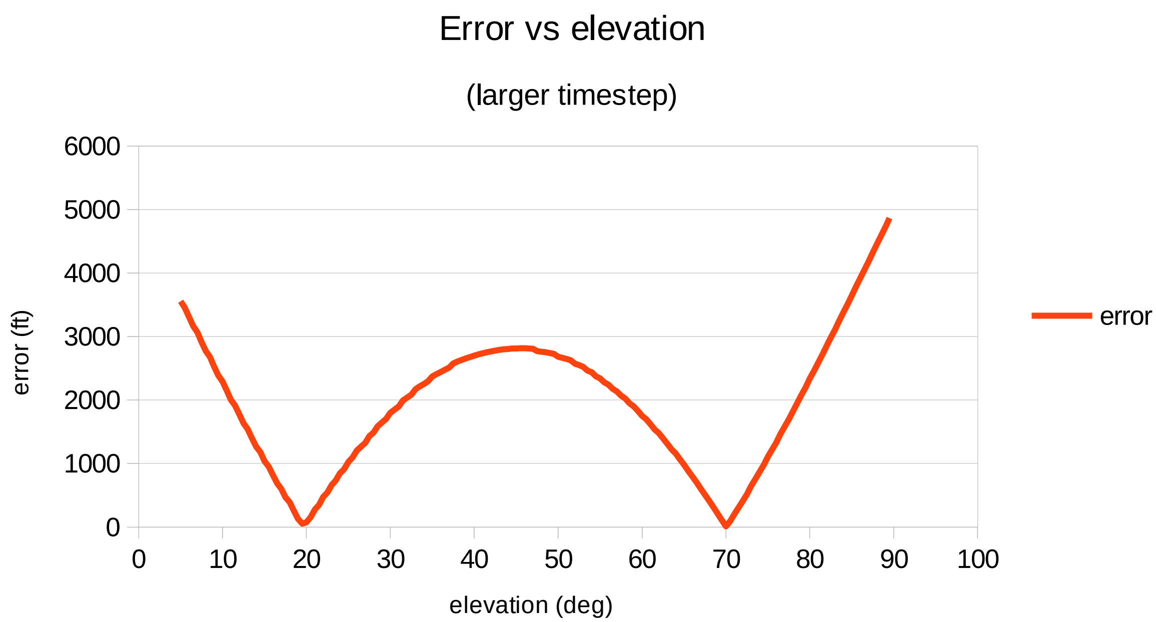
Part I A 3. Calculate the elevation to hit a target at higher altitude +1000.

The ideal angles for hitting the target are 33.5 degrees (error of 13.363 feet) and 67.5 degrees (error of 41.864 feet.)



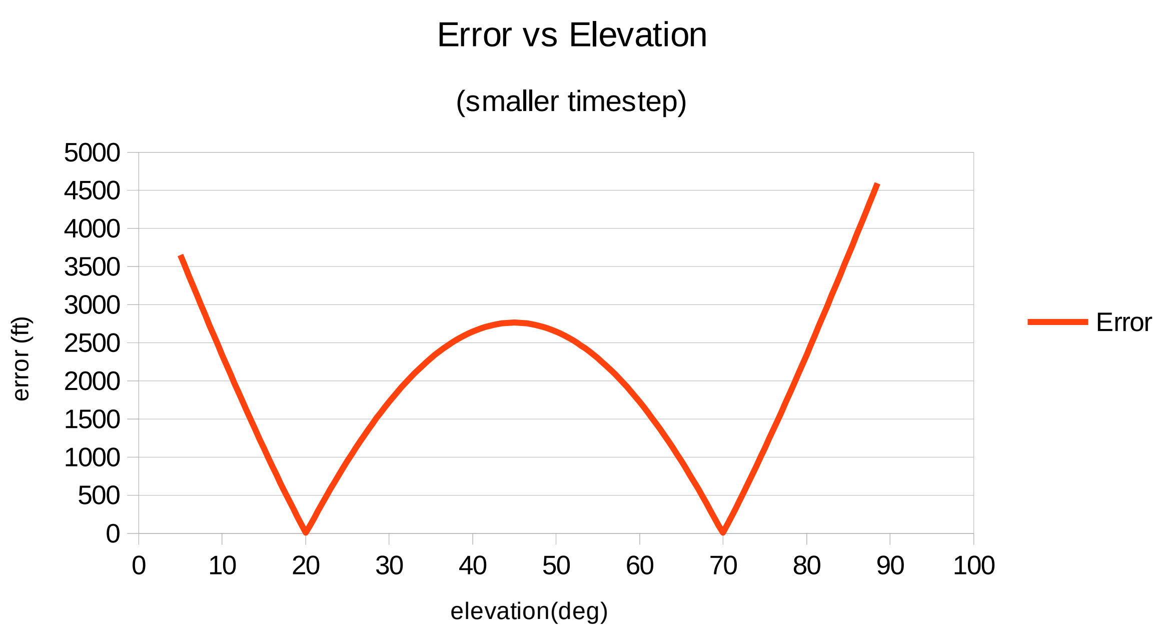
Part IA 4. Rerun 1 with time step 0.1 and compare the difference as the error attributed to the time step

The graph has a noticeably more jagged curve to it, likely due to shells ghosting through the ground in between physics updates.



Part I A 5. Rerun 4 with time step 0.001.

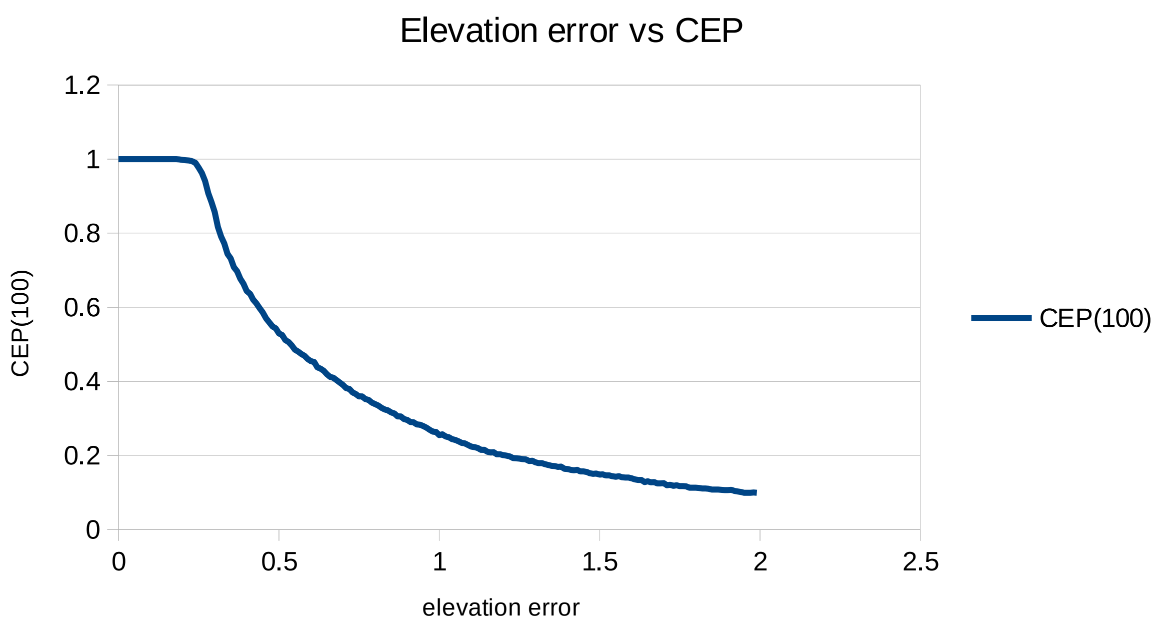
The graph does not look noticeably different. There's probably no point to running a simulation this granular, we are after all playing with explosives.



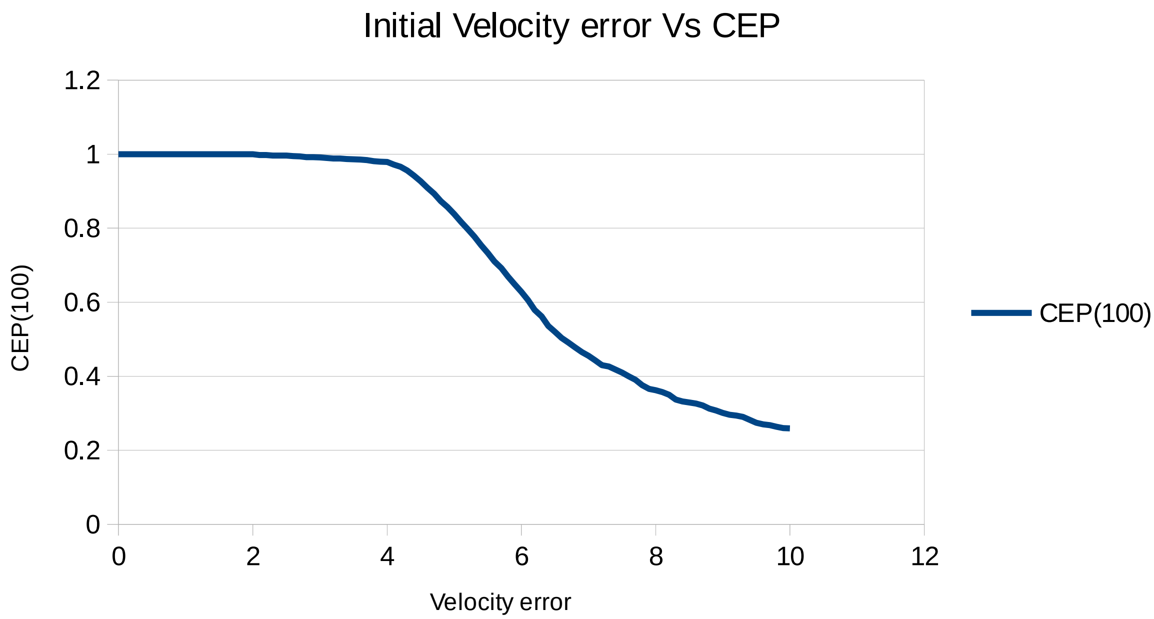
The Monte Carlo experiments use randomization to perturb elements of the model as the simulation executes it. This part perturbs the launch conditions of the artillery piece, but the flyout conditions of the munition are perfect.

For 1 through 5, fire 1000 shots each. Return the value that produces a result that satisfies CEP 100. For 1, 2, and 6, the target is 5000 feet away. Initial velocity is 500 fps for all

Part I B 1. Calculate the maximum variation in elevation.
The maximum elevation variance while maintaining CEP(100) >- 5 is .54 degrees.



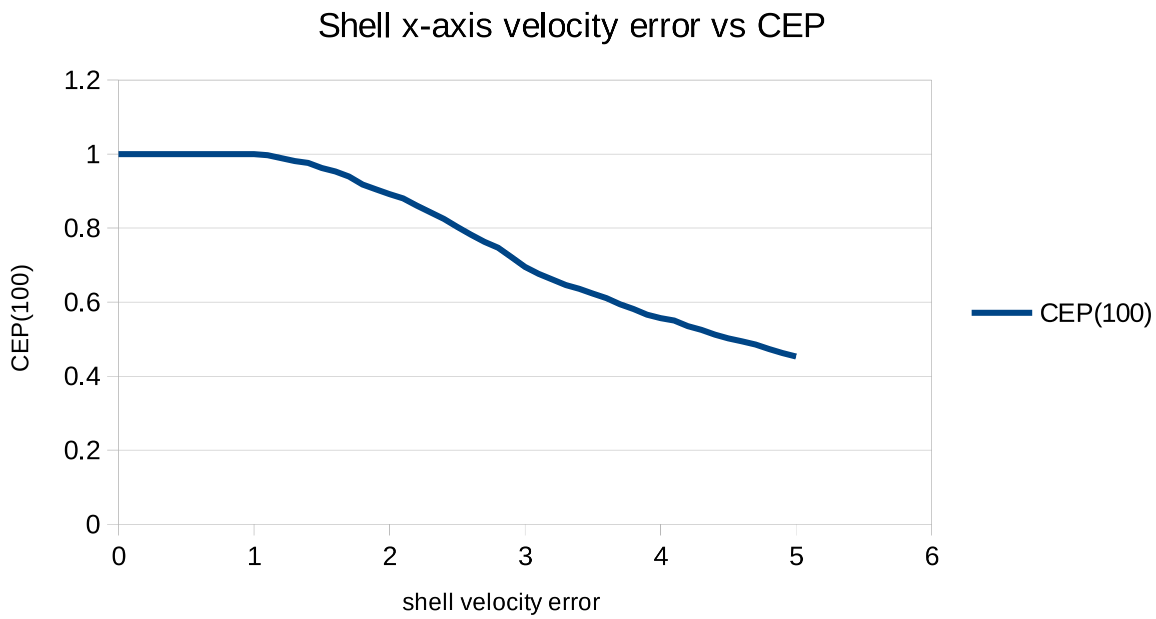
Part I B2. Calculate the maximum variation in initial velocity.
The maximum initial velocity error allowable without dropping CEP(100) below .5 is 6.7 feet per second.



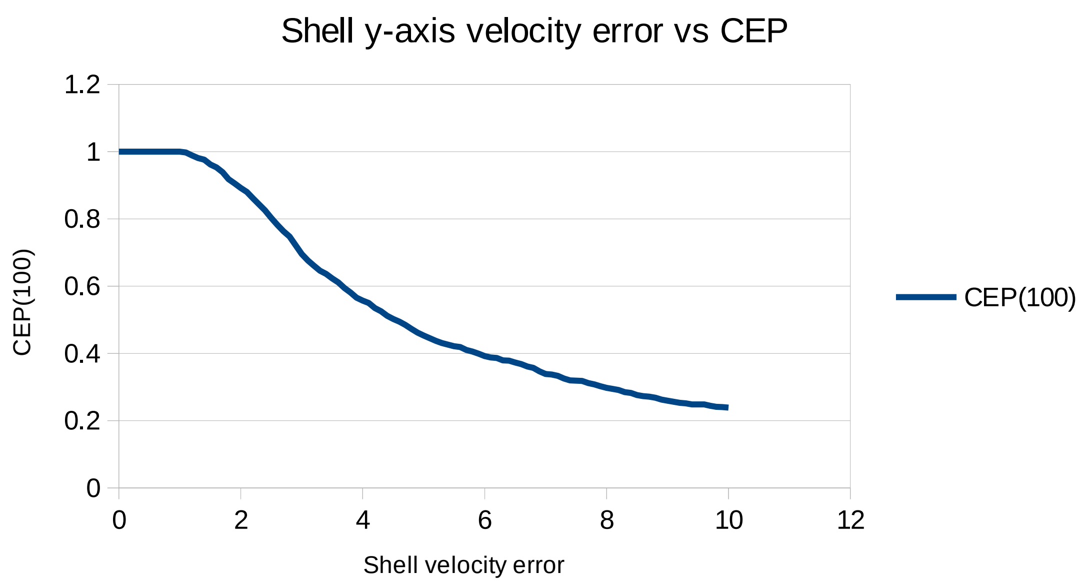
(B3 -B6 skipped because I am an undergrad.)

This part perturbs the flyout conditions, but the launch conditions are perfect. Assume the same initial conditions as in Part I.B.

Part I C1. Calculate the maximum variation in velocity x.
The maximum x-axis shell velocity error allowed while maintaining acceptable accuracy is 4.6 feet per second.



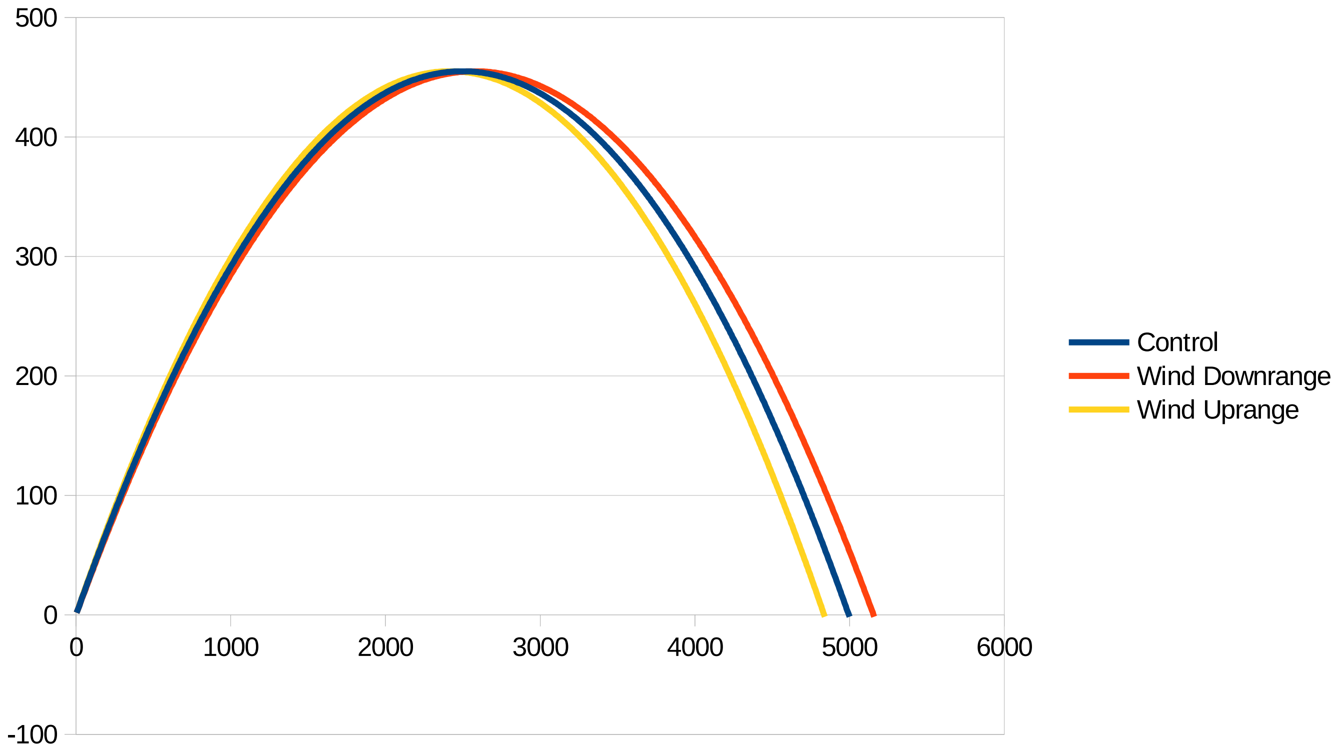
Part I C2. Calculate the maximum variation in velocity y
The maximum y-axis shell velocity error allowed while maintaining acceptable accuracy is 4.6 feet per second.



Monte Carlo I and II are typically not combined for analysis because it is practically impossible to determine which inputs contribute to which outputs (known as confounding variables). However, in the real world, all factors usually combine in insidious ways. This test provides some insight into more realistic performance where both the launch and flyout conditions have random errors.

Part I D1. Fire 1,000 shots at 45 degrees of elevation. The elevation variation is 2, initial velocity variation 2, velocity x variation 2, and velocity y variation 2. Report the average error compared to the deterministic solution; i.e., with no variations.
The result of this simulation was an average error of 188.721 feet, with a standard deviation of 145.902 feet.

The deterministic firing solution in Part A had no errors in the artillery piece or munition. Assume this is still the case, but there is now a 15 mph wind in the “dirty” firing environment. Downrange means away from the launcher, uprange toward it. Compare against the clean deterministic solution. For 1–6, show a graph of the expected versus actual flight paths. If it is not too cluttered, all seven can appear on the same graph.



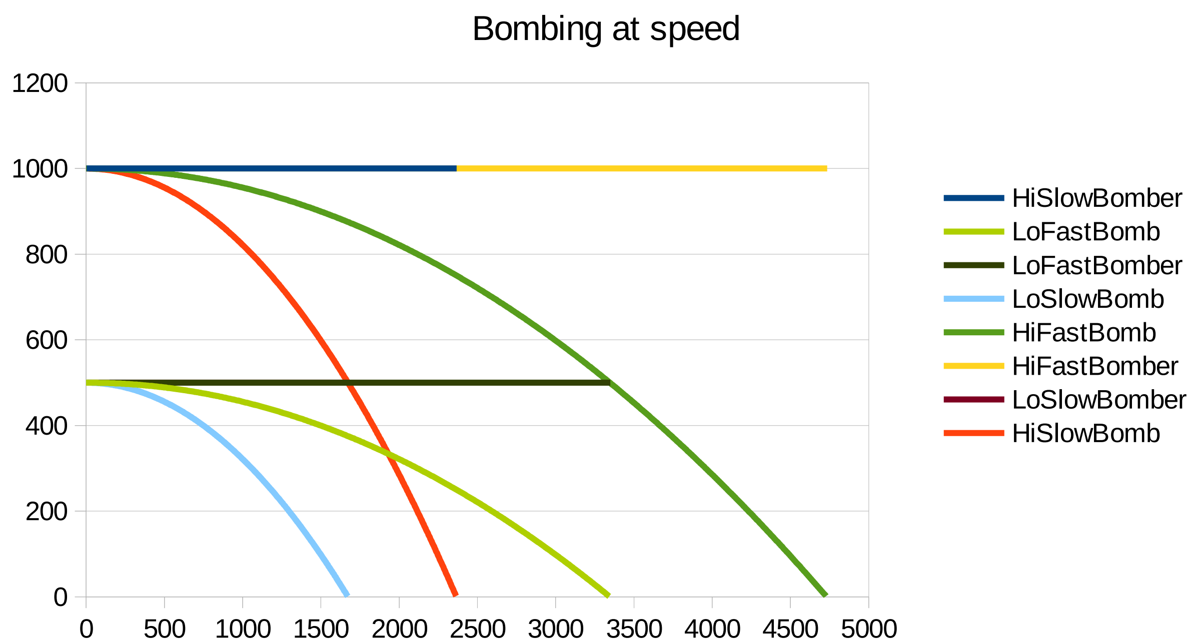
Part I E1. Calculate the targeting error when the wind is downrange.
The targeting error was 159.6 feet long.
Part I E2. Calculate the targeting error when the wind is uprange.
The targeting error was 159.6 feet short.

Parts 3-7 were not done.

Bomber Section

A. Deterministic Solutions As with the artillery, a deterministic solution is mathematically perfect. It sets the baseline performance that the Monte Carlo solutions try to achieve.

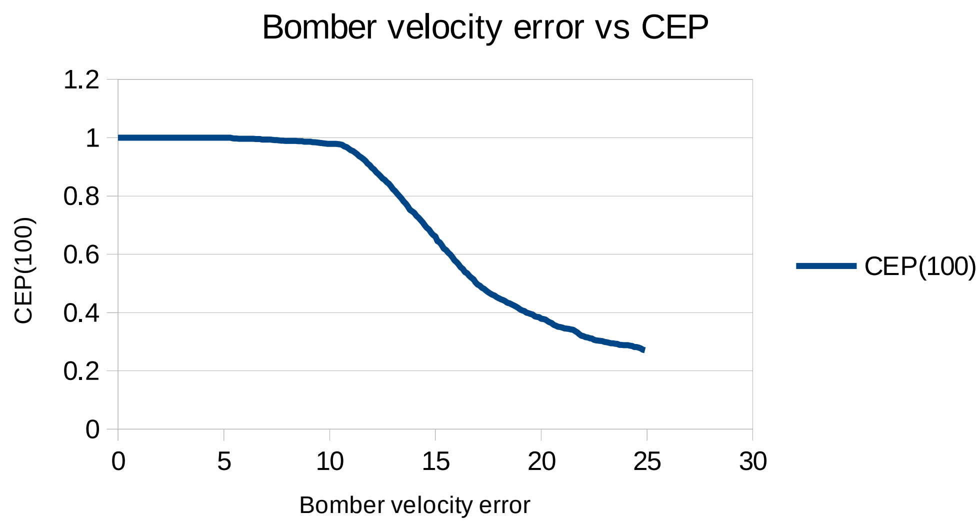
Part II A1. Plot the four combinations of release altitude 500 and 1000 feet and speed 300 and 600 on one graph. What are your general observations?
Flying higher or faster extends the lateral distance the bomb falls, with speed seeming to be the more significant factor here.



B. Monte Carlo I Solutions: Variable Release Conditions This part perturbs the bomber to model variations in the release conditions, but the descent conditions for the bomb are perfect. Assume the release altitude is 1000 feet at 500 feet per second. The target is 3945 feet away. Measure against CEP 100.

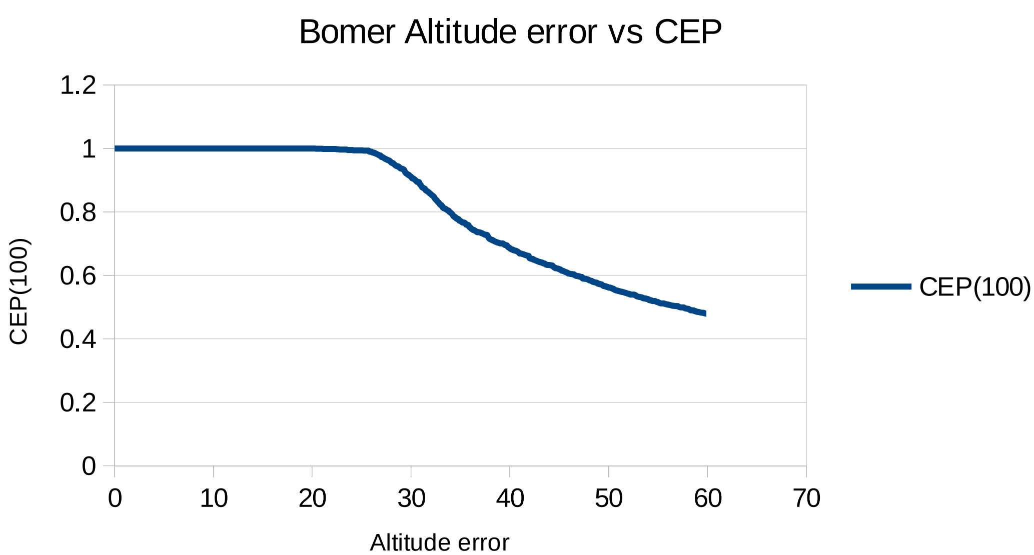
Part II B1. Calculate the maximum variation in velocity.

The maximum variance in bomber velocity while maintaining accuracy is 17 feet per second.



Part II B2. Calculate the maximum variation in altitude.

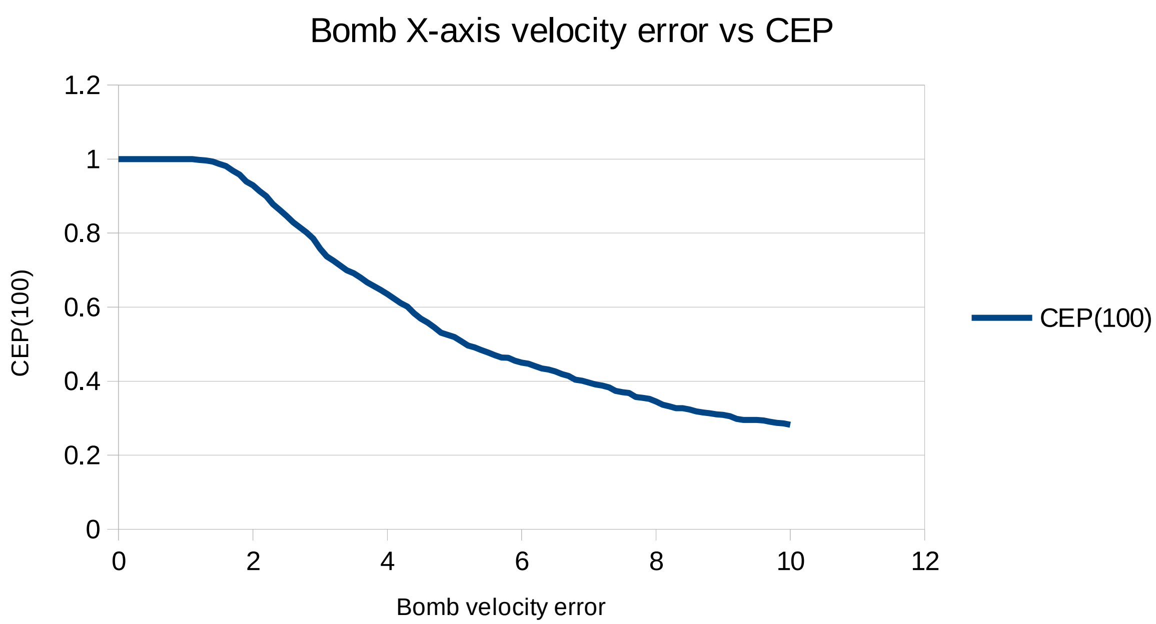
The maximum altitude error without compromising accuracy is 57.3 feet.



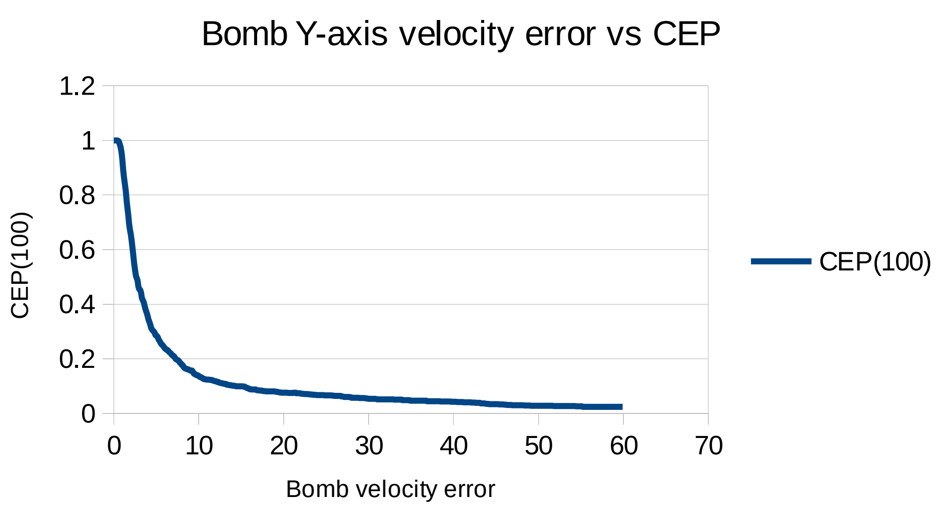
Part II B3 not done.

C. Monte Carlo II Solutions: Variable Descent Conditions This part perturbs the bomb to model variations in the descent conditions, but the release conditions are perfect. Assume the same initial conditions as in Part II.B.

Part II C1. Calculate the maximum variation in velocity x.
The maximum allowable variation in velocity x is 5.1 feet per second.



Part II C2. Calculate the maximum variation in velocity y.
The maximum allowable variation in velocity y is 2.3 feet per second.



Part C3 was not done.

As in Part I.D, this part models a lot of factors simultaneously. It gives a good overview of the performance landscape, but it does not offer much help in the inverse direction to determine what contributed to it.

Part II D1. Drop 1,000 bombs from 1,200 feet at 450 miles per hour. The altitude variation is 5, speed variation 5, velocity x variation 5, and velocity y variation 5. Report the average error compared to the deterministic solution.

The average error was 223.563 feet, with a standard deviation of 173.375 feet.