



Risk Mitigation Simulations with Constrained MC

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Risk is the potential that a chosen action or activity (including the choice of inaction) will lead to a loss (an undesirable outcome).

Risk with intervention

Risk with no intervention *

How to model flight paths



Risk Mitigation Simulations with Constrained MC

Idea is that we don't know the flight path of the intruder aircraft.

Leads to a random walk. But aircraft have maneuvering constraints.

A constrained Monte Carlo Method is employed to determine a probability of an interaction of a stationary or randomly traveling aircraft with an intruder aircraft in a three dimensional space.

The constraint maneuverability of aircraft is taken as 20% of positional heading.



Risk Mitigation Simulation

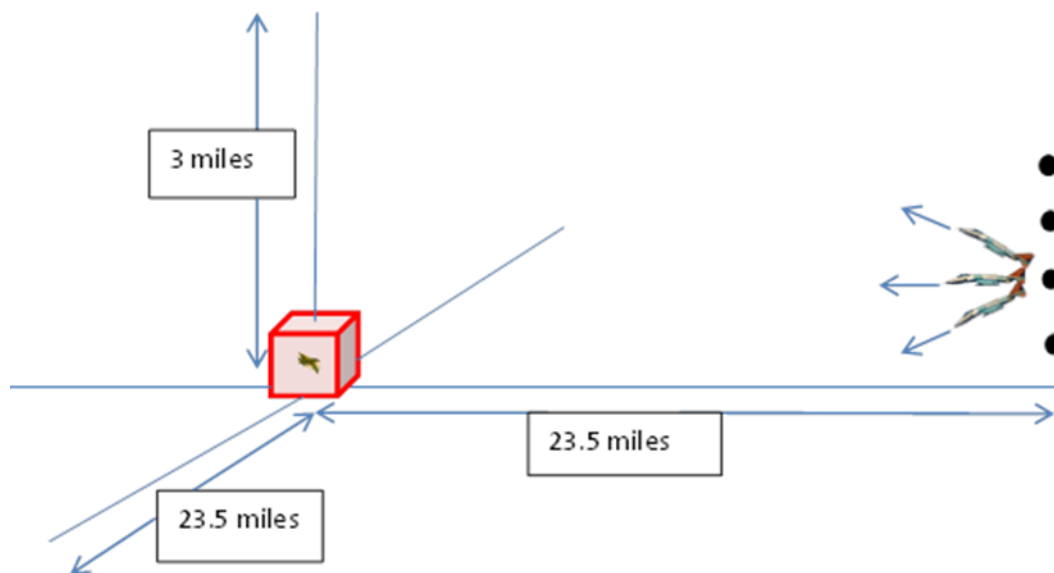
- Goals
- Develop working random walk code
- Develop 3-D Constrained Monte Carlo Code
- Develop MPI code
- Test code for consistency
- Run simulations with all parameters of aircraft entry.
- Develop a interpolation method for calculating probabilities for real time avoidance.
- *(Develop an indication of probability of intruder aircraft collision. Color coded bar.)*





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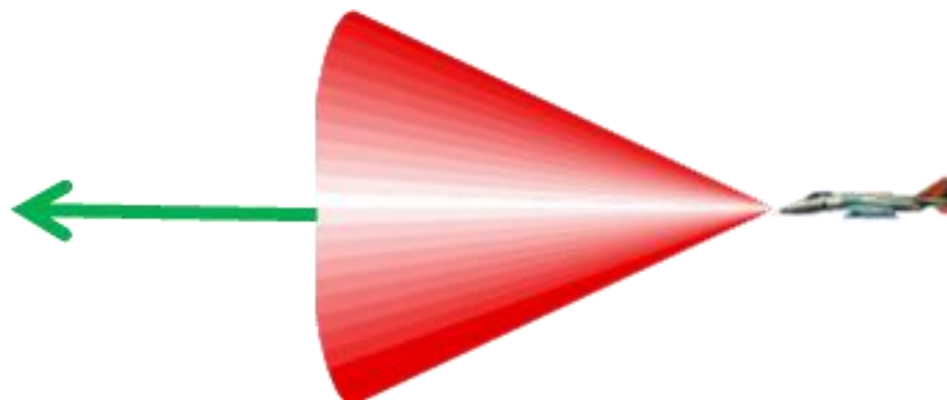
Geometry and entry into the airspace





Aircraft Maneuverability

- Aircraft maneuvering
- Green arrow is projected path
- Red cone is the probable path.
- Time step sets the path length.

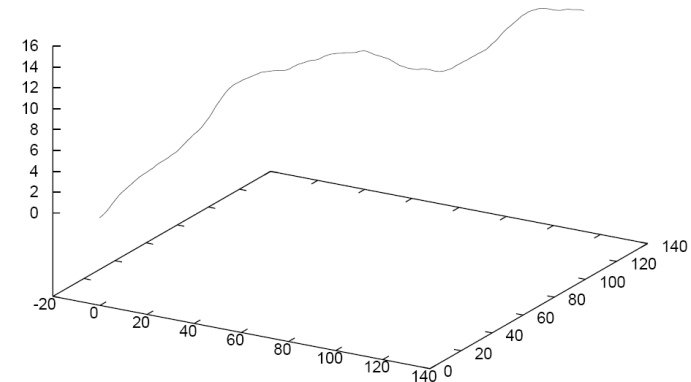




Risk Mitigation Simulation

- Code – Pseudo random walk has been written in MPI.
- – Probability determined by number of collisions / number of paths simulated.

$$P(r, \theta, \varphi) = \frac{\alpha}{\alpha + \beta}$$



One quadrant of 23.5 X 23.5 x 3 mile
Airspace. Units are in 1,000 ft.





Risk Mitigation Simulation

- Testing included:
- Velocity/time step minimum number of distance steps 1100 at 500 ft. per time unit.
- Conservation of planes.
- Size of UAS NMAC.
- Correlations between variables.

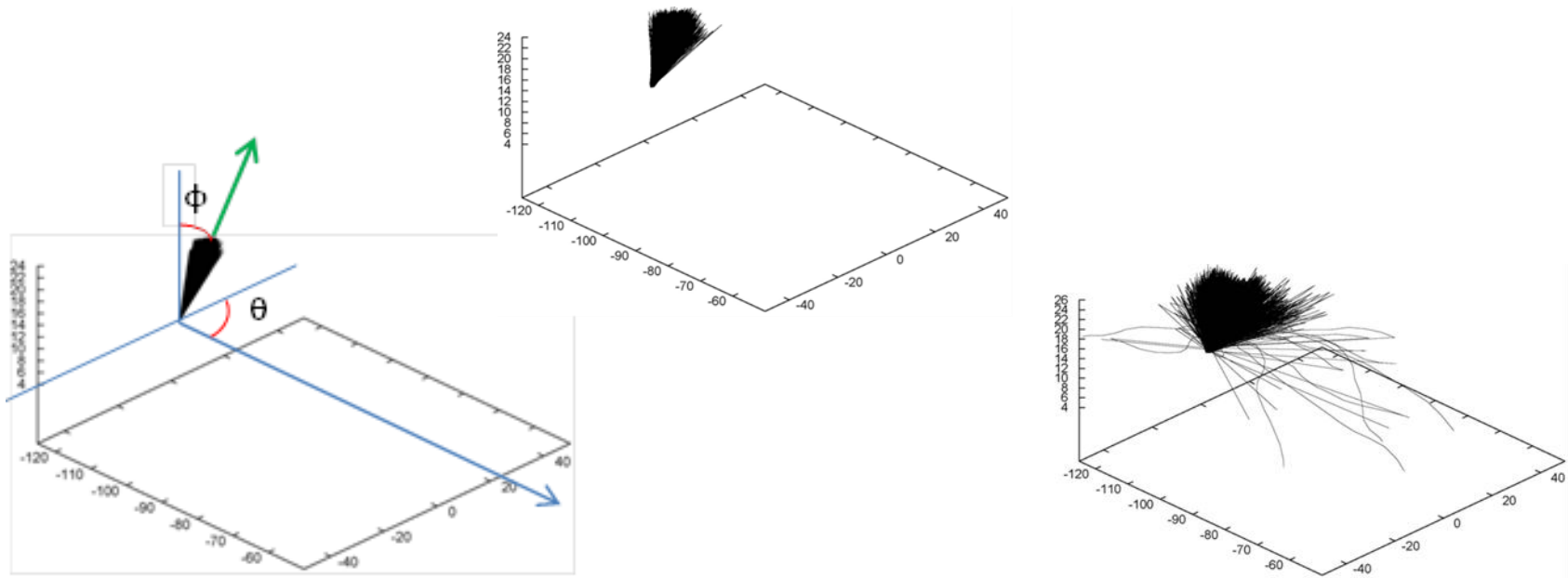




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Aircraft Maneuvering Cone

Dependence on Maneuvering angle, 5, 10, 20 degrees

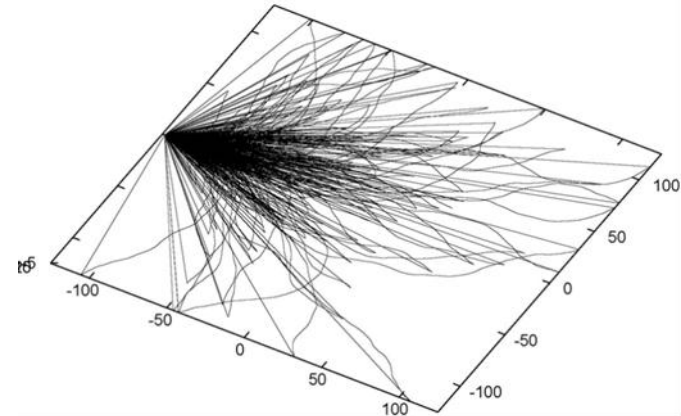
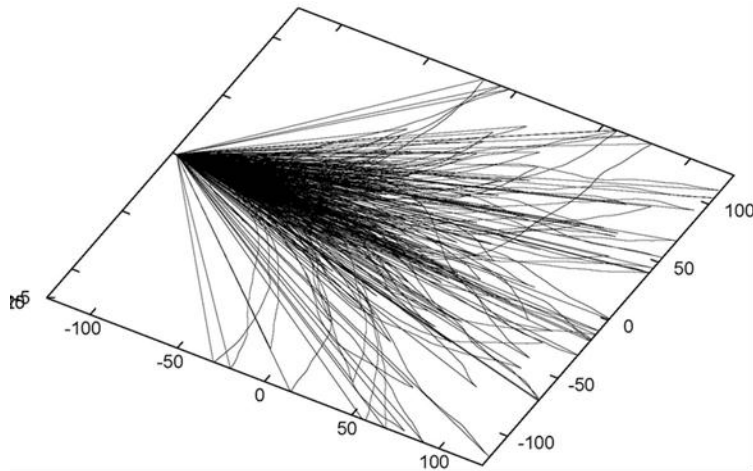




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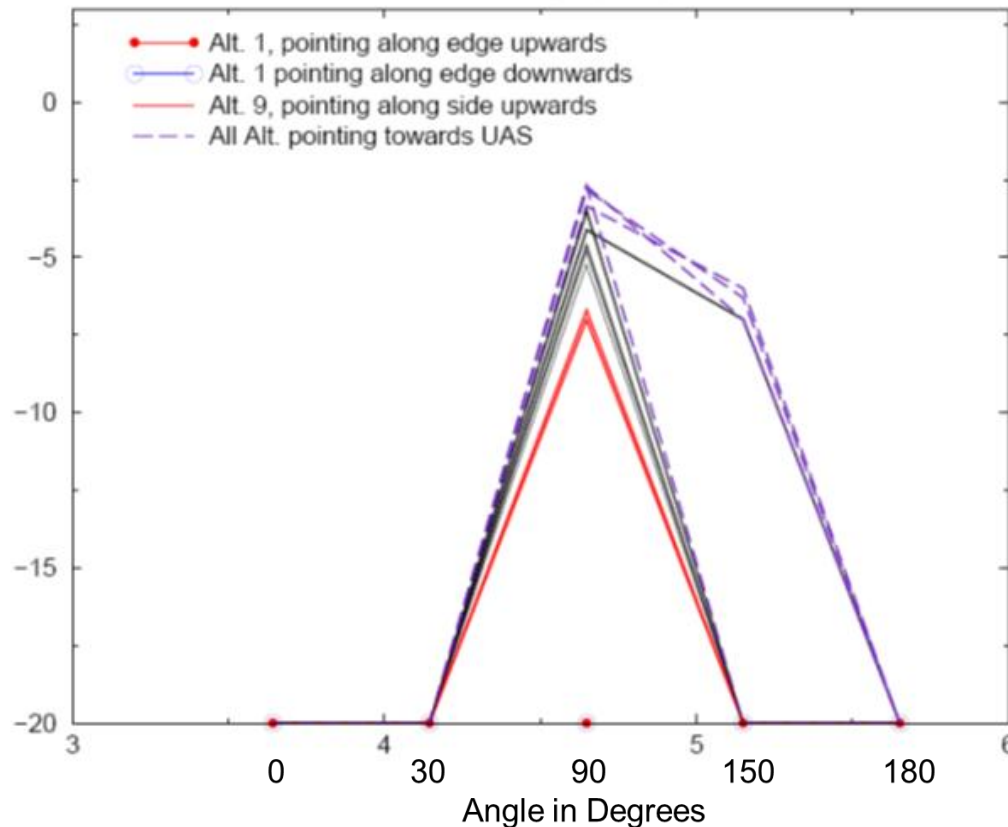
Aircraft Speed

Dependence on aircraft speed, 160 mph and 60 mph



Probability of Collision vs 5 Theta Angles- Large Target

Phi varies from 0, 30, 150, 180

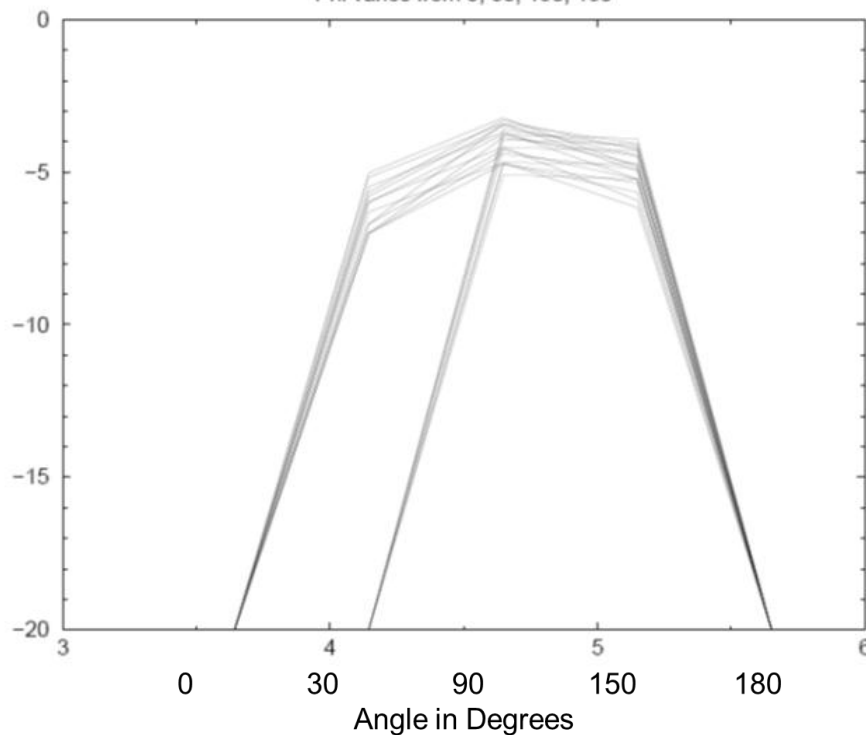


Log of the probability versus theta with 10 million paths. At extreme angles the probability drops to zero. In the middle, where intruder is pointed towards UAS the probability is the highest. The intruder aircraft speed is 260 mph.



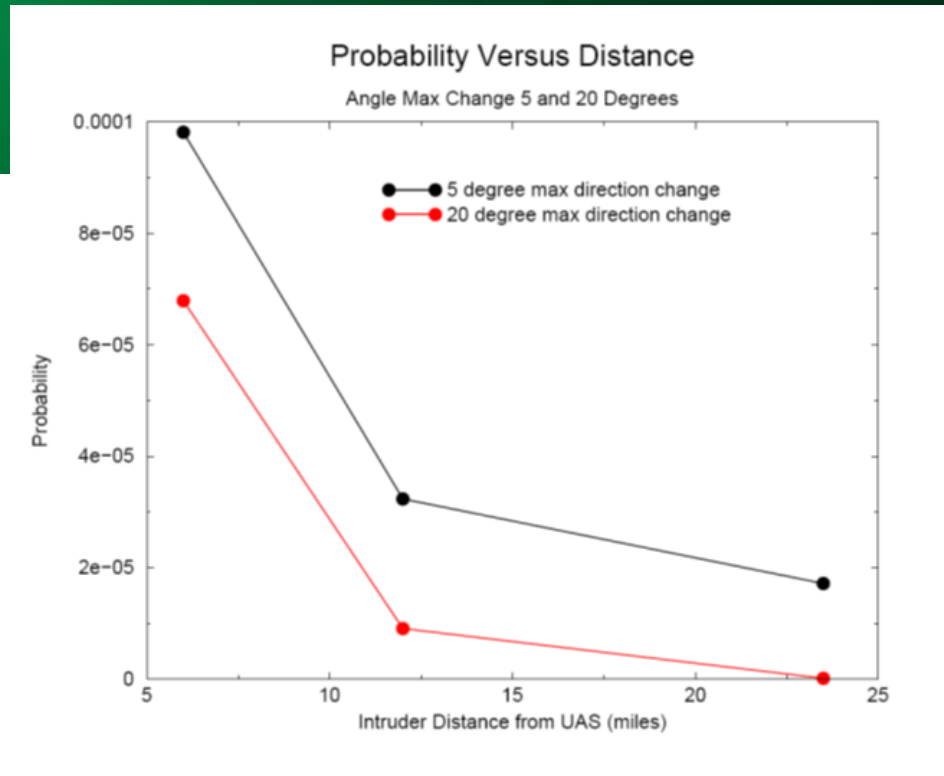
Probability of Collision vs 5 Theta Angles- Large Target

Phi varies from 0, 30, 150, 180



Same previous figure except the intruder aircraft speed was changed to 60 mph. There is an increased probability at most angles indicating that direction change at lower speeds influences the probability of collision.





Probability of intruder interaction as a function of distance. Two maximum directional cone angles are shown. The smaller angle (black) shown that for pointing directly at the UAS the intruder has a higher probability. The larger 20 degree angle shows a lower probability.



Real time calculation

- Tabulated data
- Based on 128 billion intruder flight paths.
- Based on three parameter, r , θ , ϕ
- Logarithmic interpolation of real-time data.





Risk Mitigation Simulation

- Conclusions
- We have a exploratory FORTRAN code to simulation aircraft interactions.
- Risks do not include human interactions or mechanical error or malfunctions.
- Interestingly in does include inaction!





Risk Mitigation

- Future Work
- Continued Data Calc. to improve statistics.
- Develop interaction indicator based on heading and distance of intruder. This can be a color bar or % based on possibility of interaction at any distance and header
- Refine analytic solution to numerical data for real time calculations.

