Detect & Avoid
UAV Integration in the Lower Airspace Traffic

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ICRAT
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Context & Objective

- Demand for civilian UAV operations increases (fire detection, river bed surveillance, parcel delivery...)
- Most UAVs operate at low altitudes, interfering with traffic in TMAs

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- Delegated to both aircraft and UAV (TCAS-like)
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Our solution

- A geometrical *detect & avoid* algorithm
- Validated by intensive simulation

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1 Model

2 Experimental Setup

3 Results

4 Conclusion & Further Work

Geometrical algorithm

Based on [van den Berg *et al.*, 2011]

n-body collision avoidance algorithm for robotics

... with a few substantial differences

- only the UAV handles the avoidance maneuver
- only heading changes are considered
- speed ratio between aircraft and UAV might be high:

Aircraft	from 200 kn up to 450 kn
UAV	from 80 kn to 160 kn

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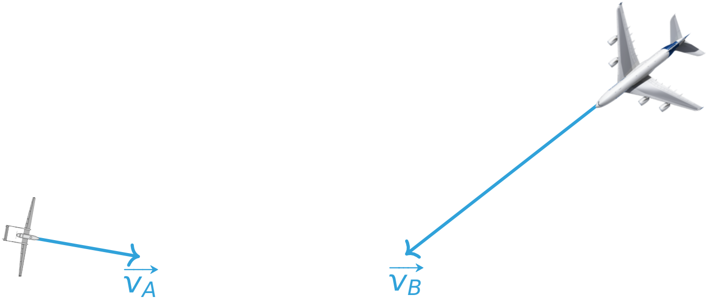

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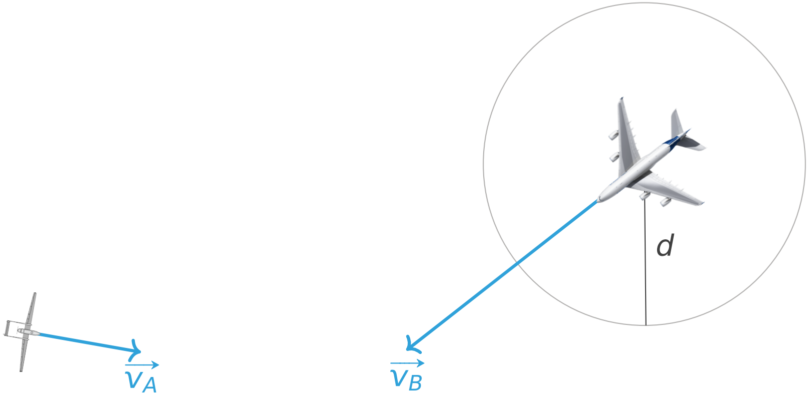

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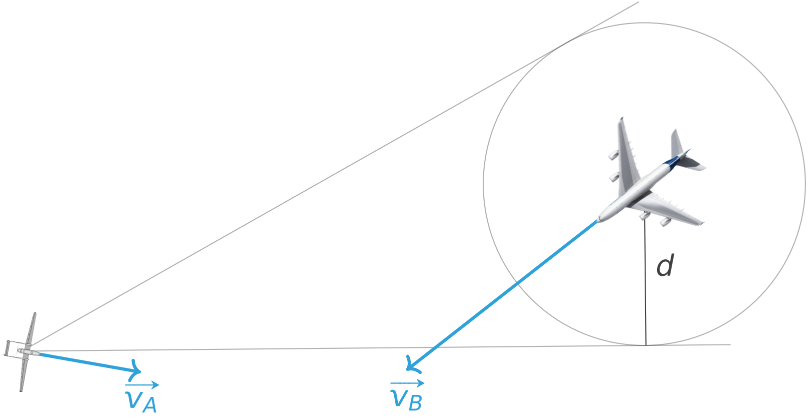

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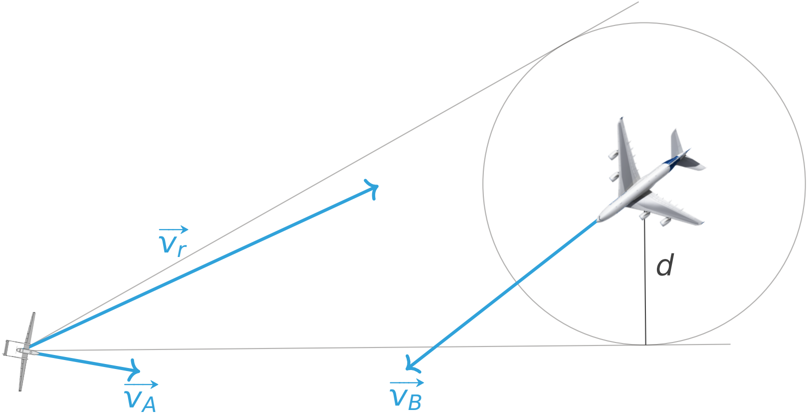

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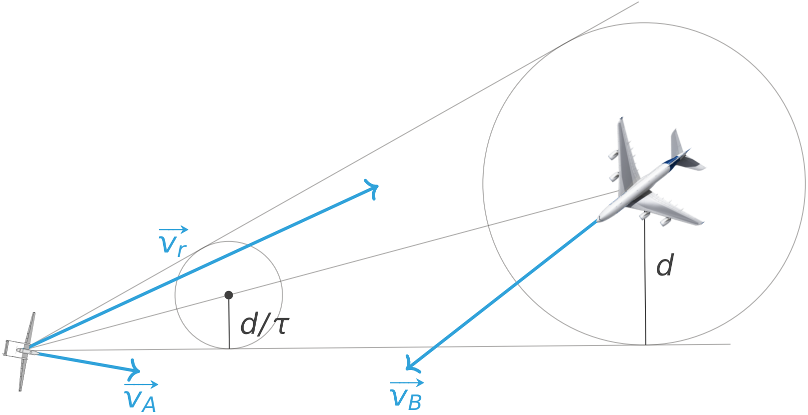
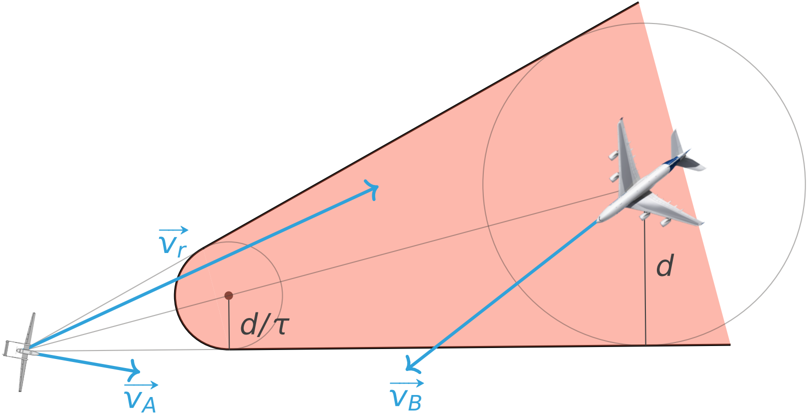


τ is the anticipation time

Conflict detection



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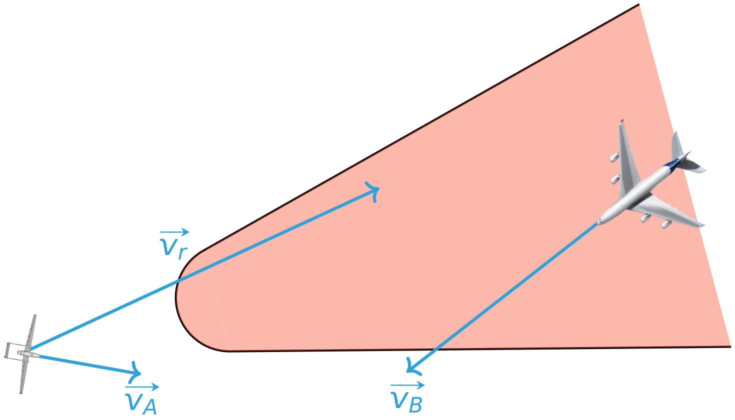
Resolution principle



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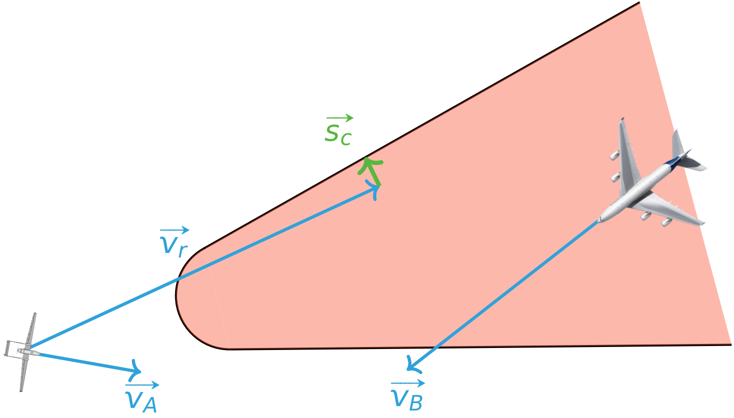

$\overrightarrow{s_C}$ is the “escape vector”

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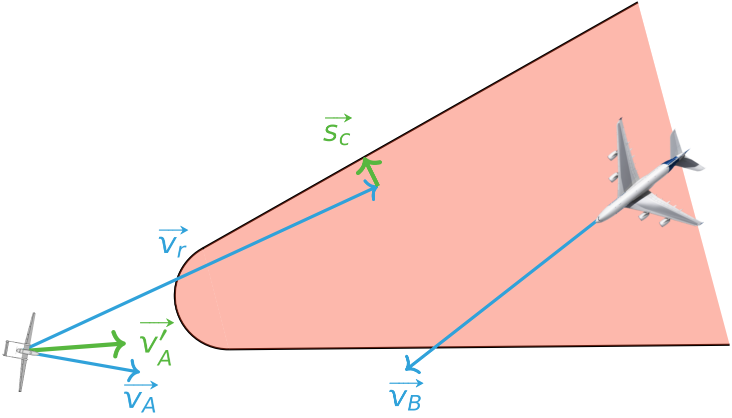

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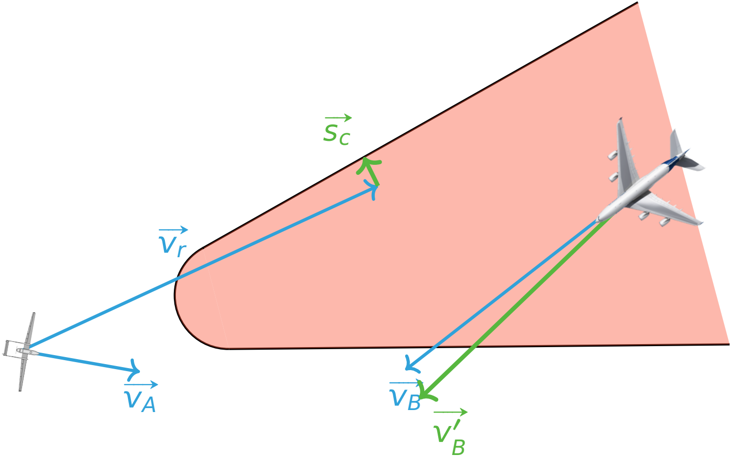

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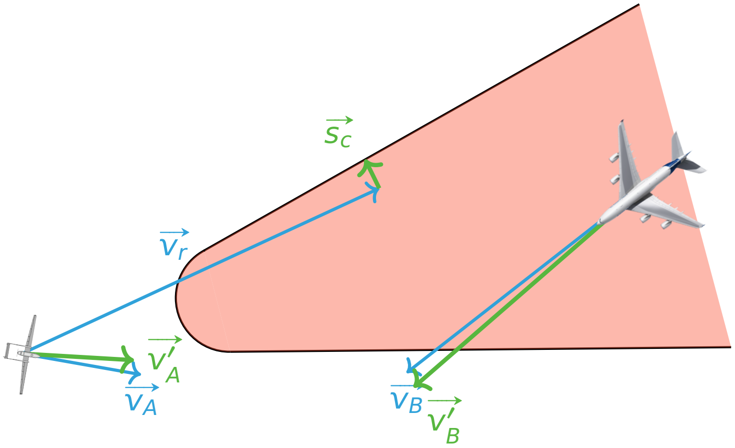

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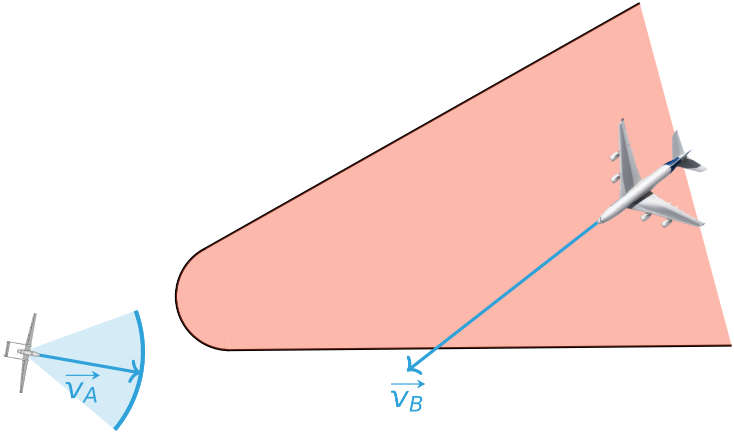

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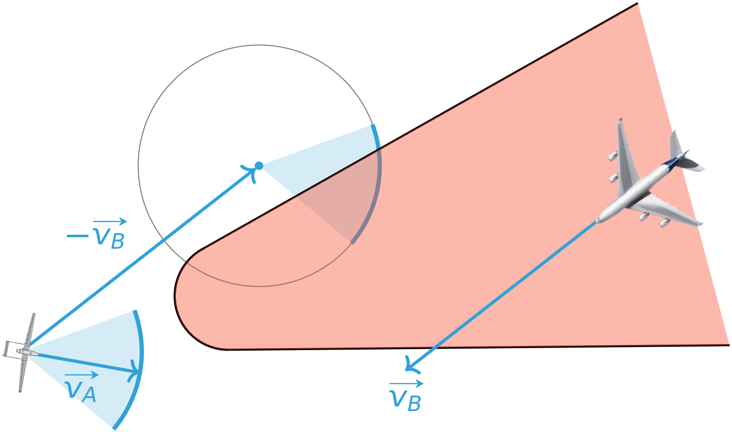

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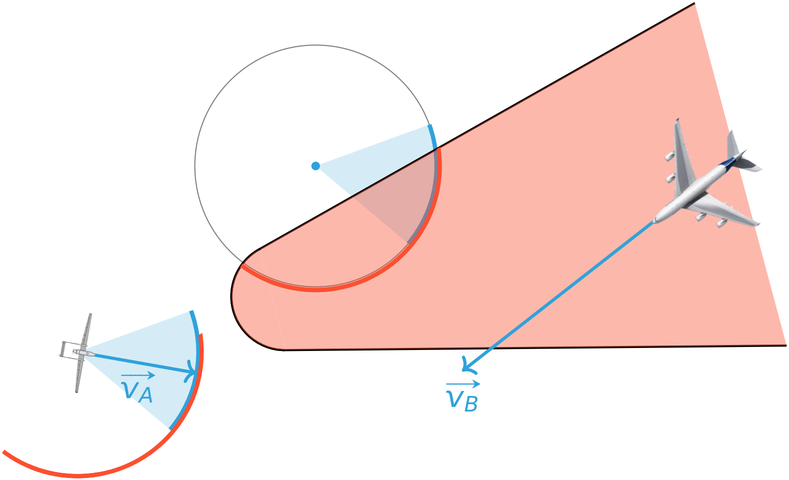

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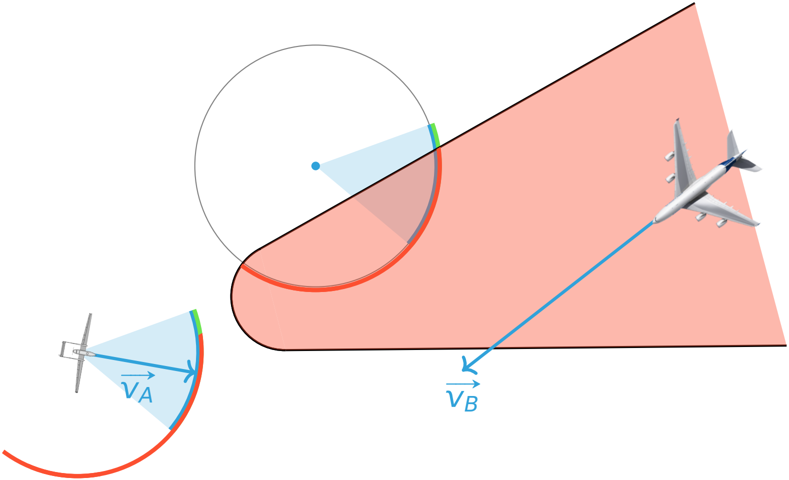

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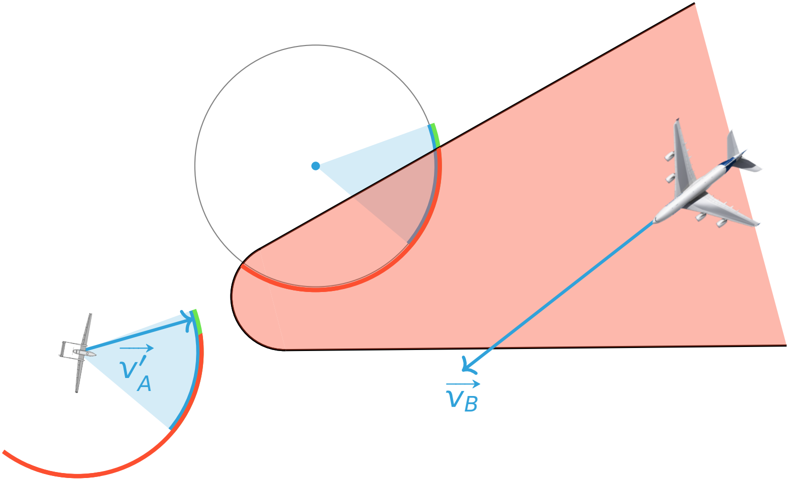
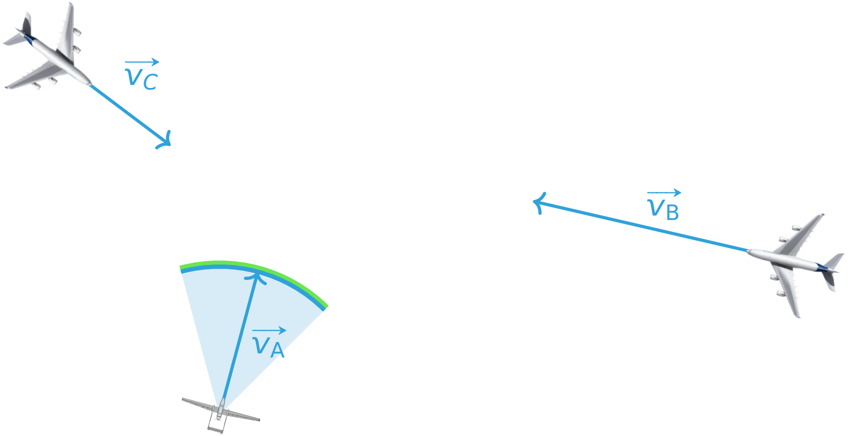


Multiple constraints



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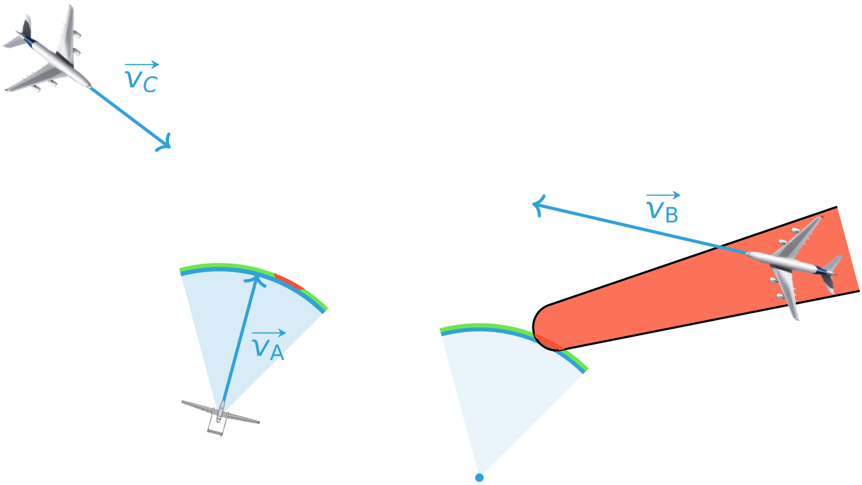

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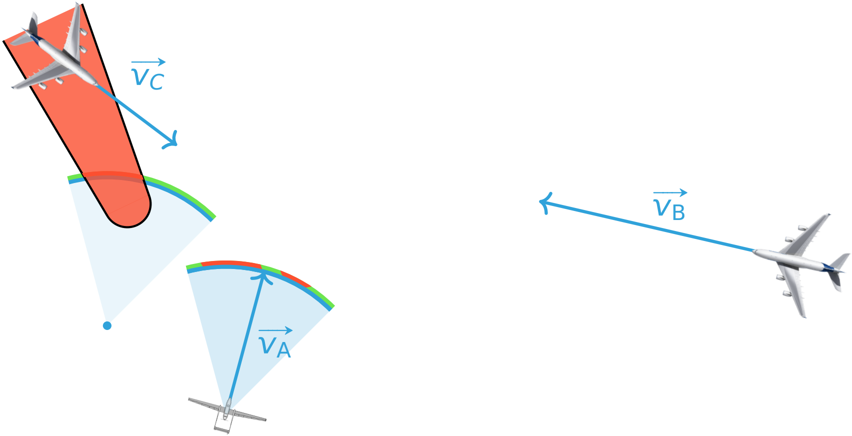

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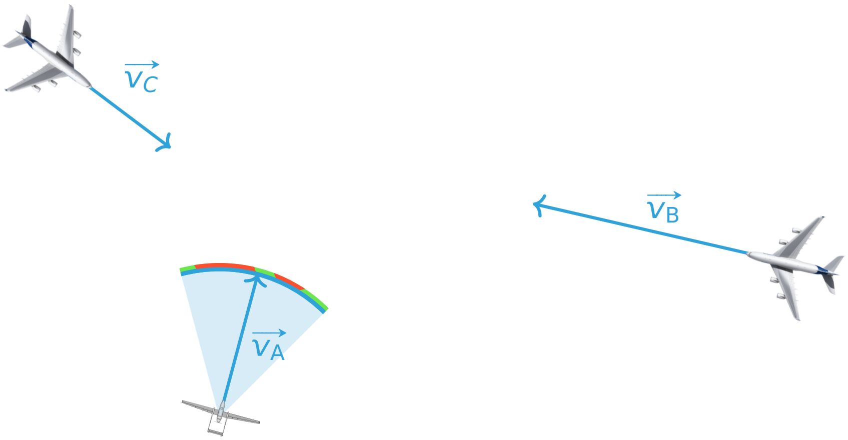

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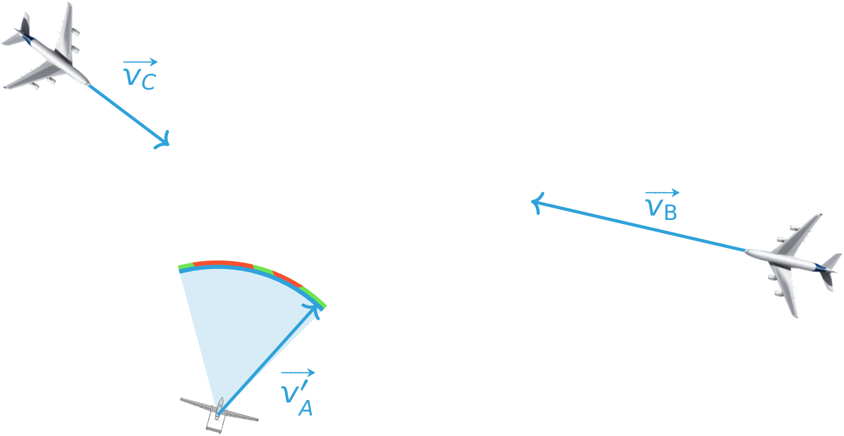
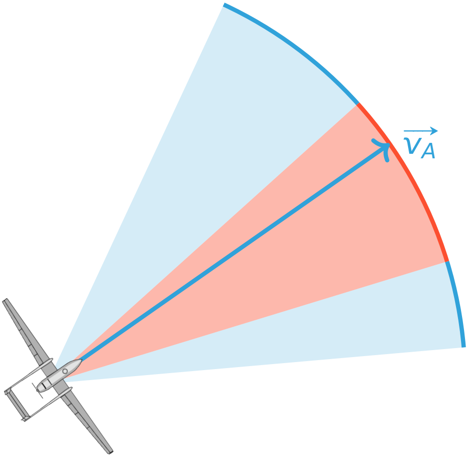


Resolution strategies

Closest



- Try to stay as close as possible to planned trajectory

Resolution strategies

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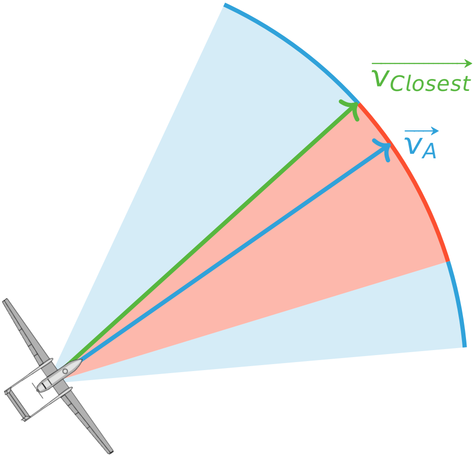
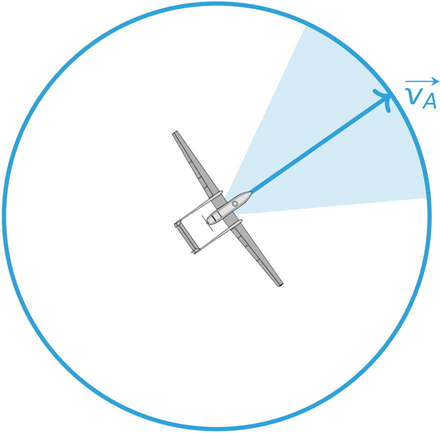


- Try to stay as close as possible to planned trajectory
- Saturates the constraint

Resolution strategies

Safest



- Try to keep the most room for maneuver

Resolution strategies

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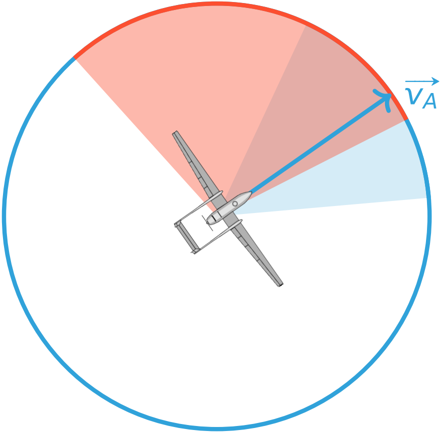

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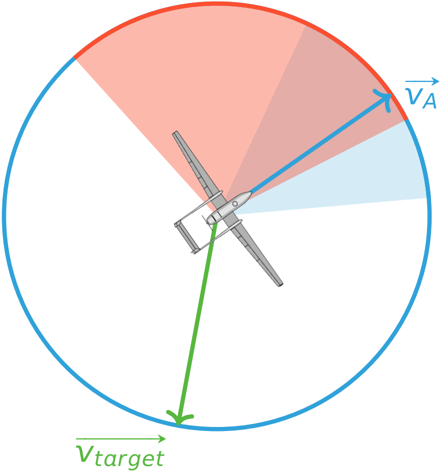

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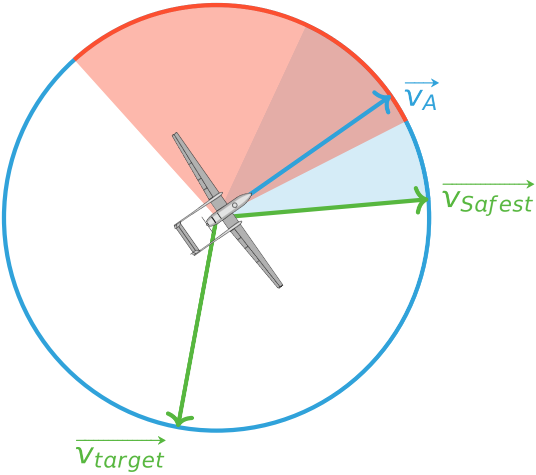

- Try to keep the most room for maneuver
- Longer-term view

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Experimental Setup

Traffic

- Terminal Maneuvering Areas in Bordeaux FIR, France
- 475 recorded trajectories

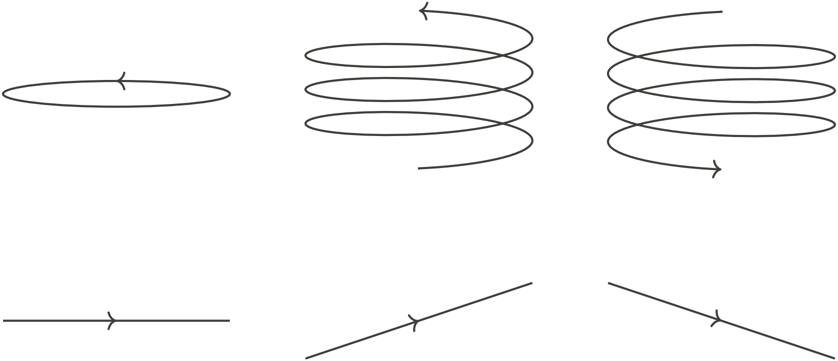
Simulations

- Scenarios are built so that if no maneuver is issued, there is a collision
- Target separation distance: $d = 3\,\mathrm{NM}$
- Many sets of parameters for more than 200 000 simulations

UAV

Experimental Setup

- Speed: 80 kn & 160 kn
- Turn rate: 3 °/s to 7 °/s
- Six different missions



- Anticipation time: $\tau = 5\,\mathrm{min}$
- Resolution every 10 s

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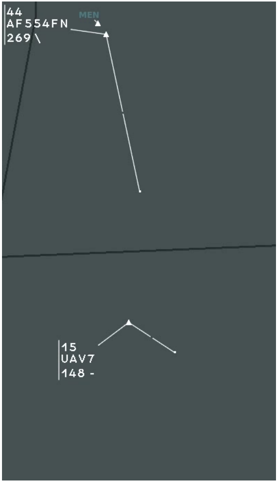
Resolution Example

Scenario



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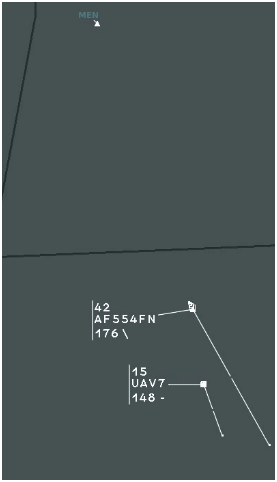

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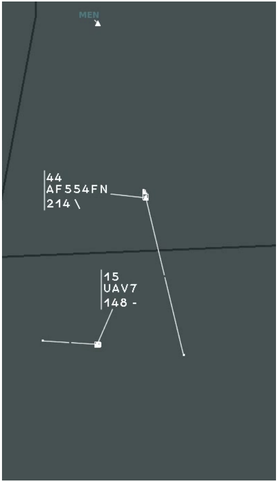
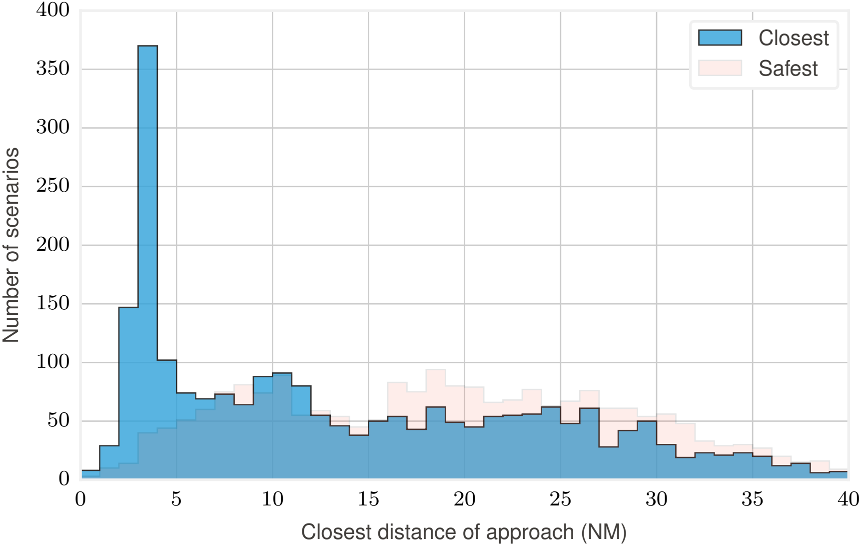


Comparison of strategies



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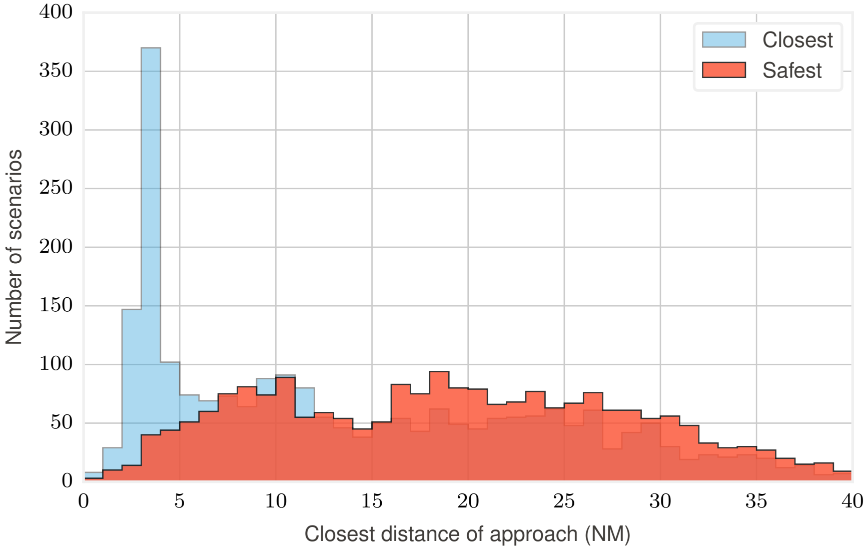
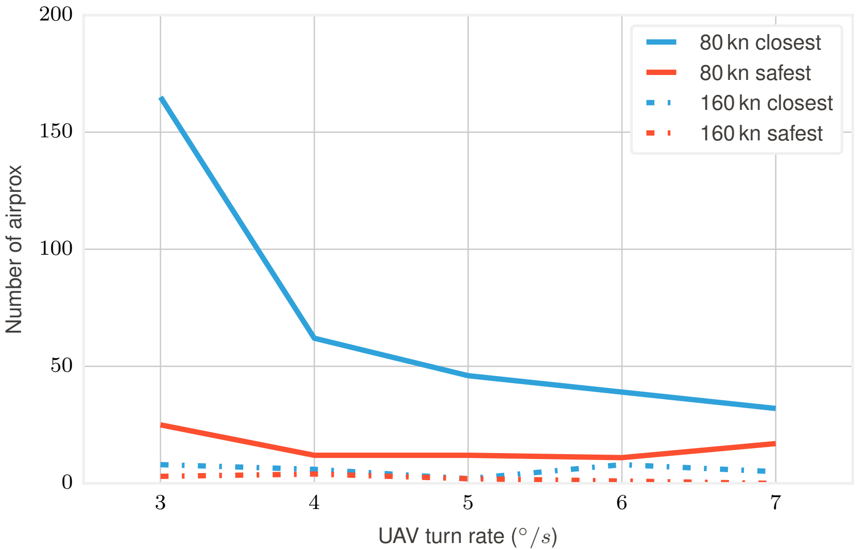


Influence of UAV maneuverability



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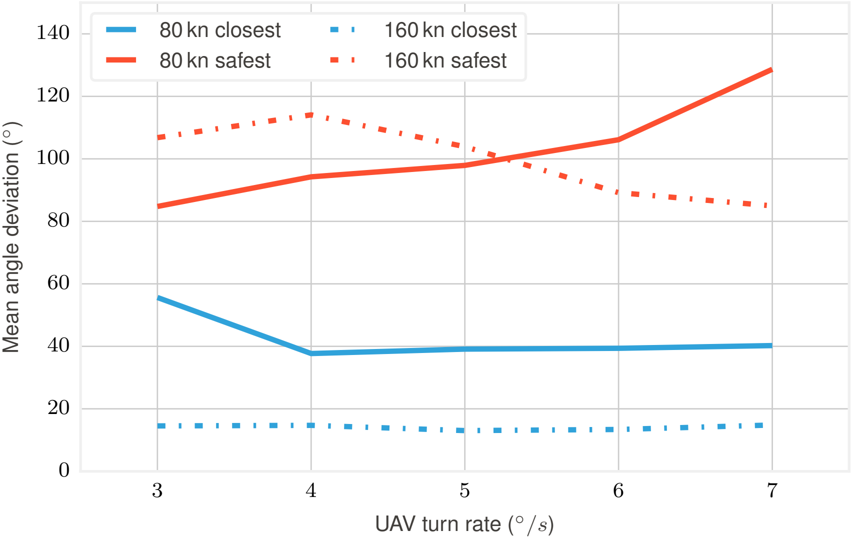

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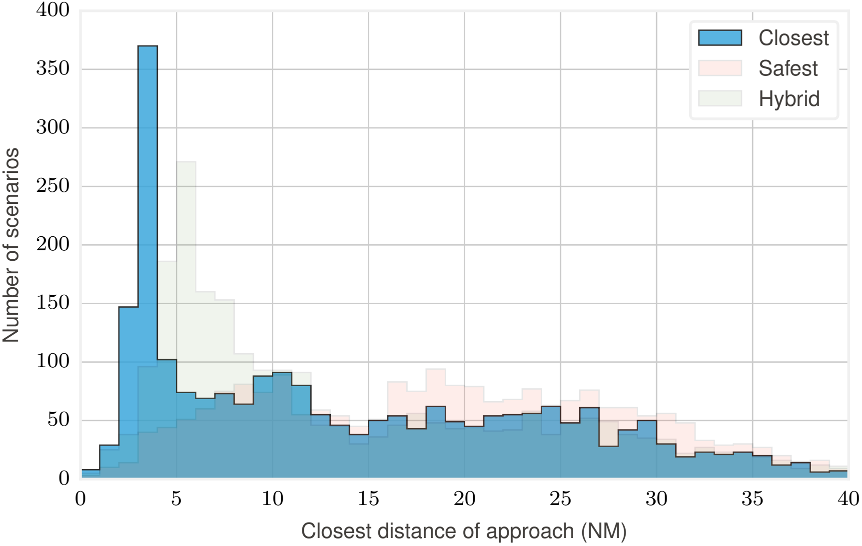
Conclusion

- Detect & Avoid geometrical algorithm
  - Intended to UAVs avoiding surrounding aircraft
  - Heading change maneuvers at constant speed
- Validated through intensive fast time simulation against recorded traffic in TMAs
- Two different strategies
  - Trying to stay as close as possible to mission trajectory
  - Providing a better safety level
- Maneuverability (speed and then turning capacity) is the key for an efficient collision avoidance
- Still a few conflicts remain (mainly with the least maneuverable configurations) that need analysis

Further Work
Strategies Hybridization



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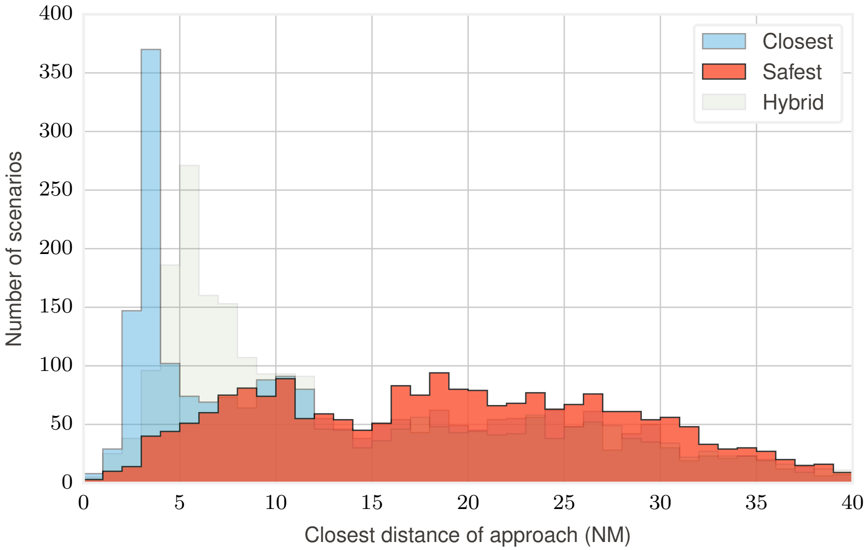

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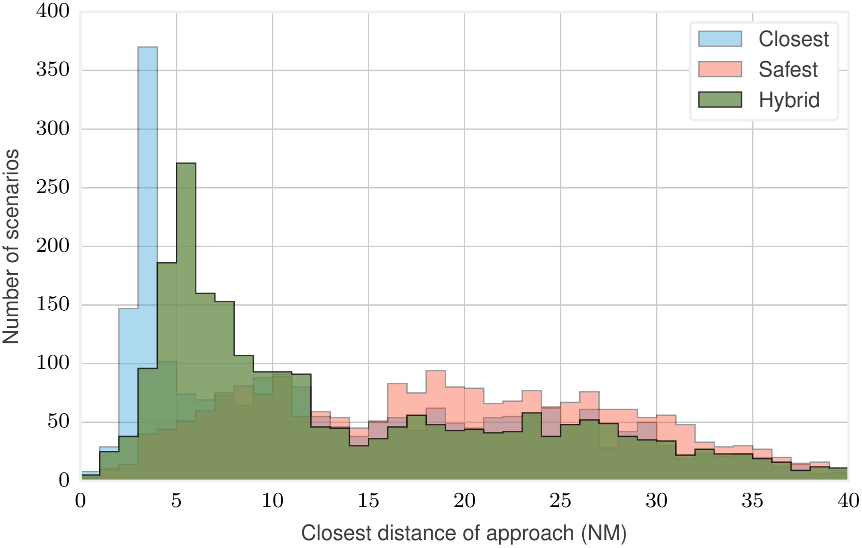

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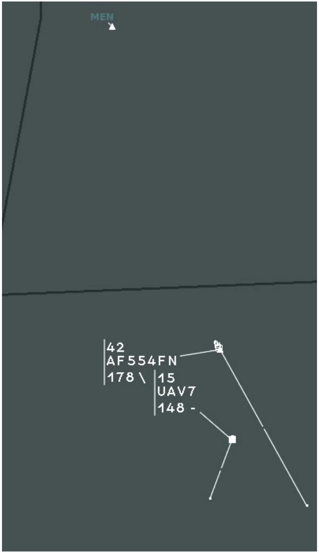
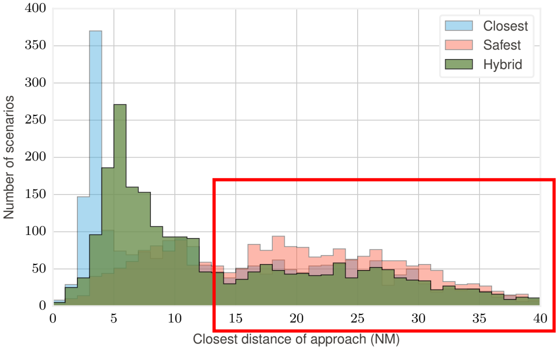


Further Work

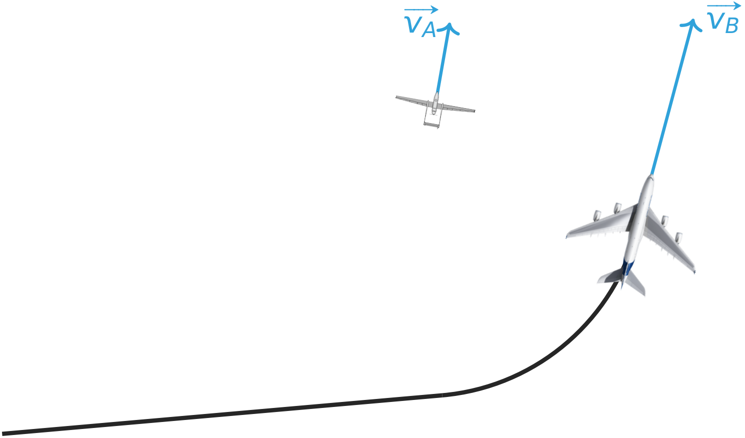
Back to mission



- Maneuvers might lead the UAV far from its mission
- Need to compute a route back to mission
- How to detect end of conflict?

Further Work

Aircraft Trajectory Prediction



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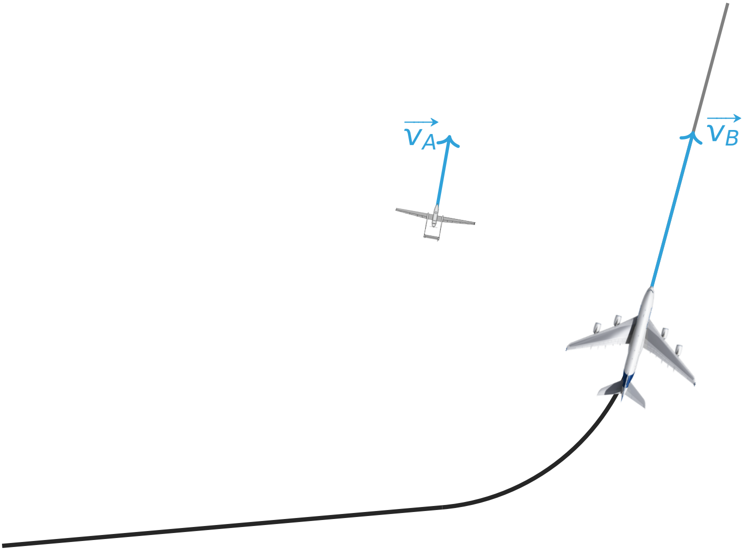

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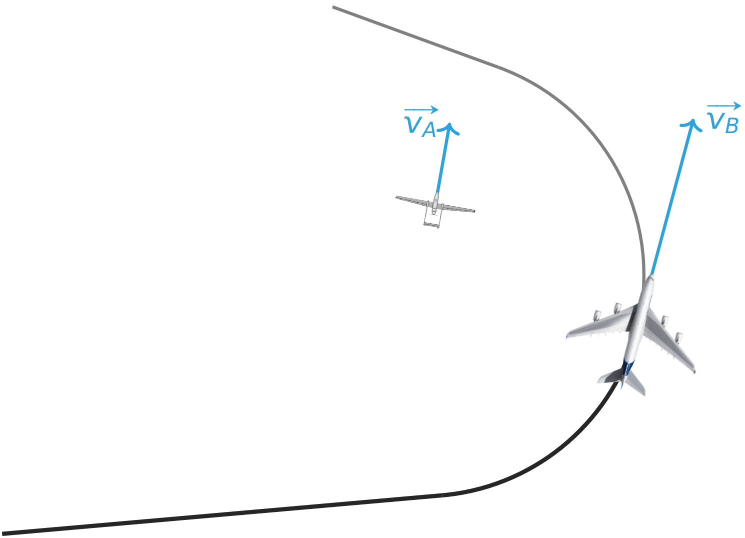

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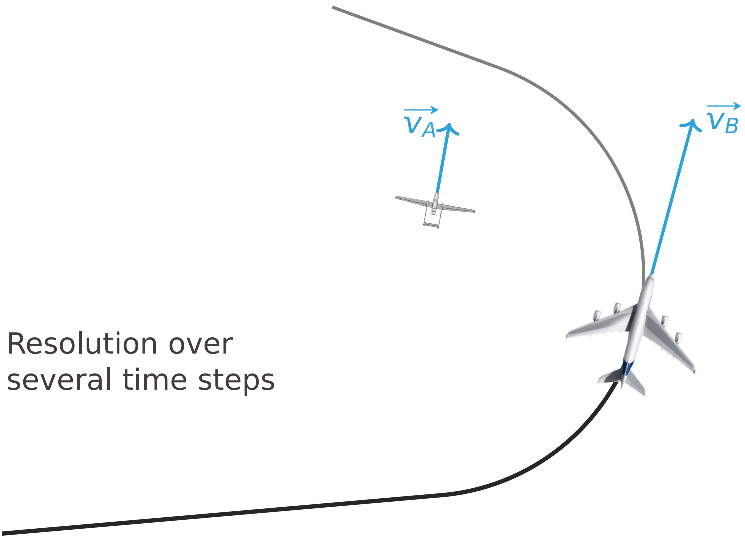
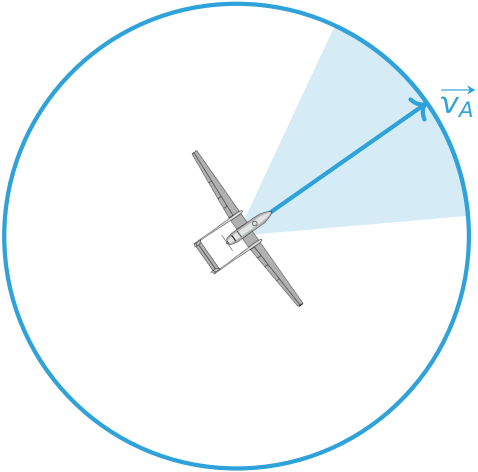


Resolution over several time steps

Further Work

Enhanced strategy to escape “traps”



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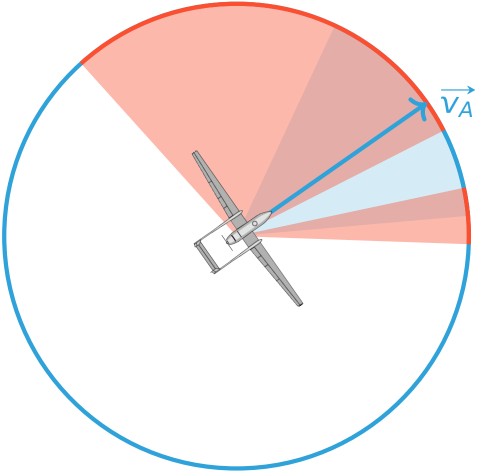

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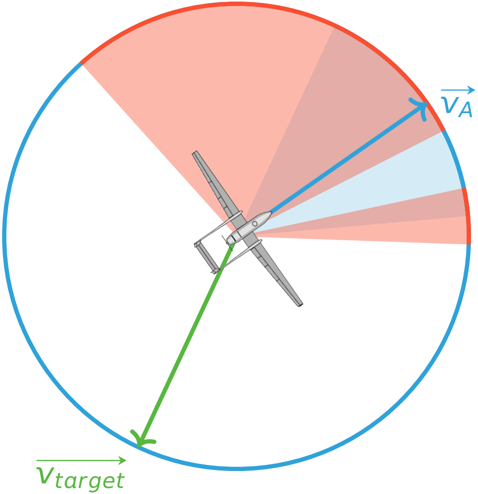

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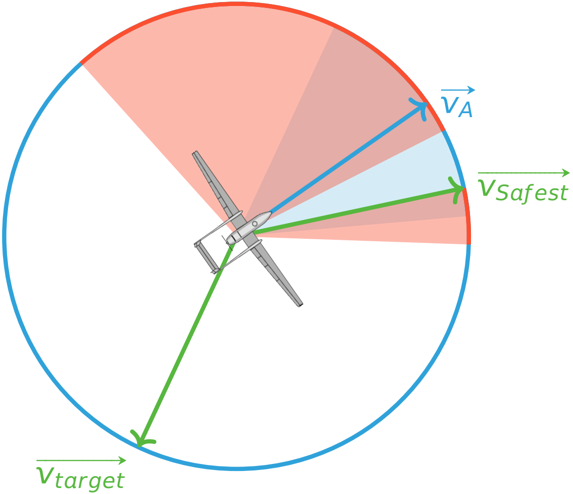

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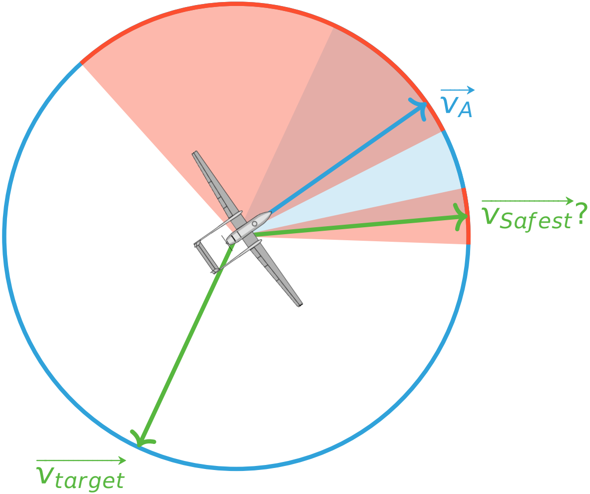

Time for questions

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