

Stability of intersecting flows of aircraft

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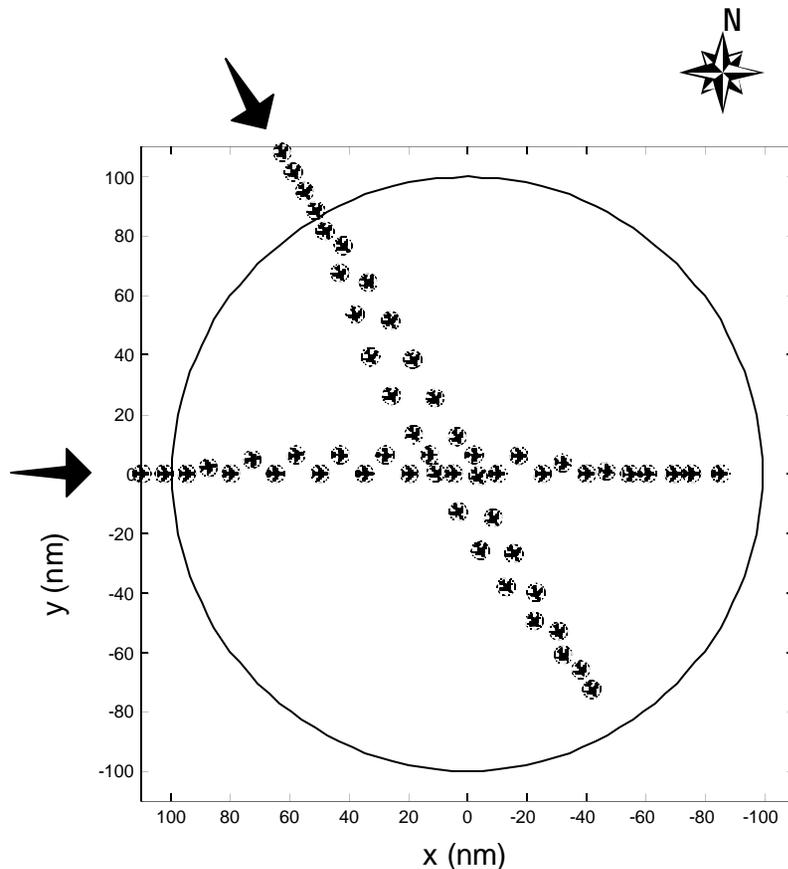
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Research motivation & goals

- Analyses of conflict resolution usually involve pairs or a finite number of aircraft
- Need to address the fear of *domino effect*
 - one conflict resolution triggers a new conflict elsewhere possibly leading to divergence in the system
- Analysis of aircraft *flows*, i.e. *infinite #* of aircraft
 - worst-case standpoint
- Stability & performance
 - simulations for insight on the system dynamics
 - analytical proofs

A “control volume” approach



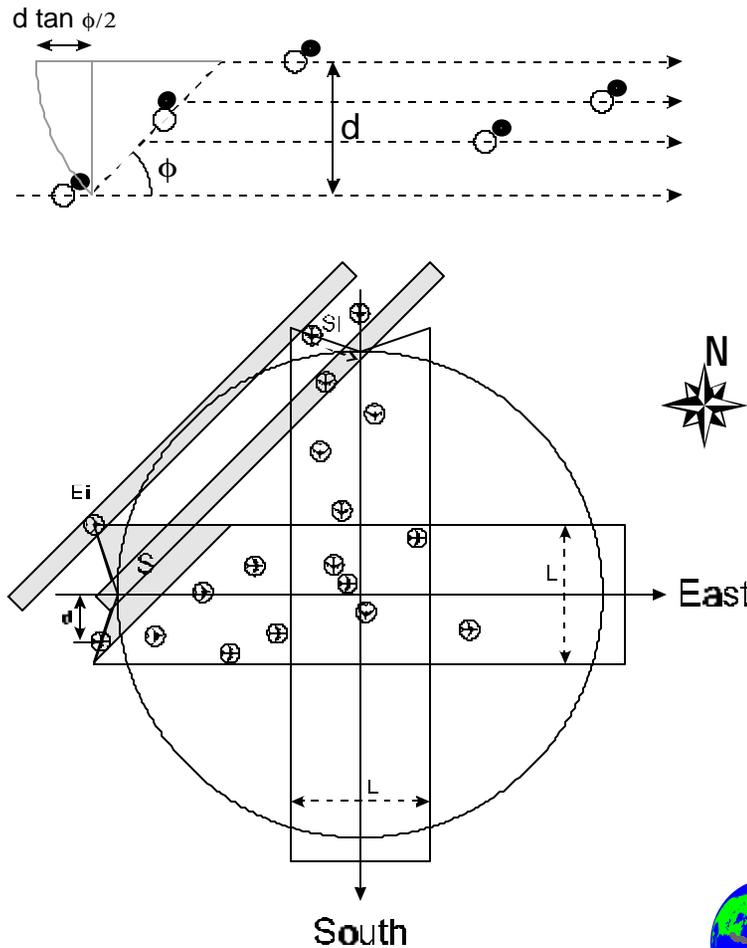
- 2-D
- Structured converging flows
 - pre-determined points of entry
 - regular or random entry
- Aircraft make 1 conflict avoidance maneuver when entering
 - maneuver is *minimal*
 - different maneuvers are considered

Example of an analysis : existence of resolution maneuver

- Using the offset maneuver
- Proof by contradiction
- Upper bound on lateral displacement

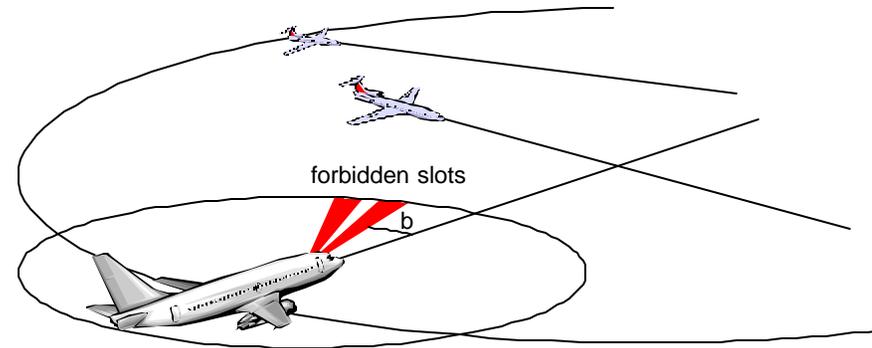
$$L \leq 4\sqrt{2}d_{sep}$$

d_{sep} : min. separation dist.

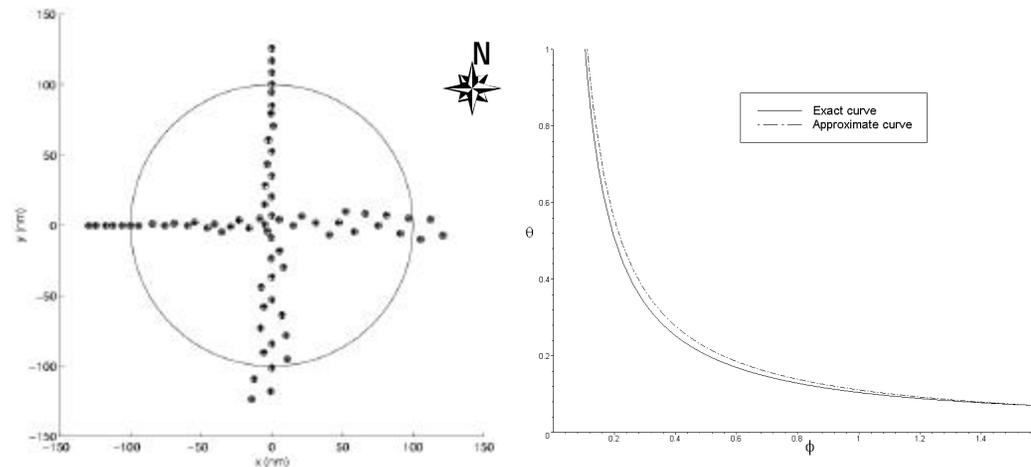


Heading change model

- One pure heading change to solve conflicts

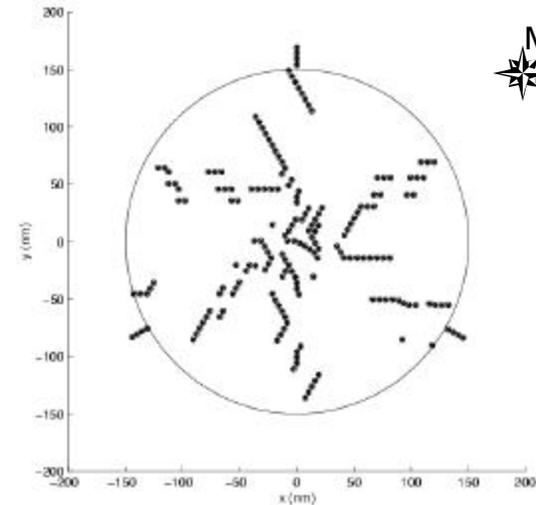


- Analytical upper bound on the deviation for various angles of encounter

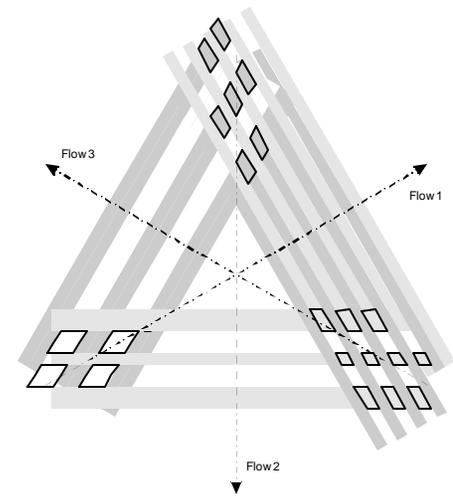
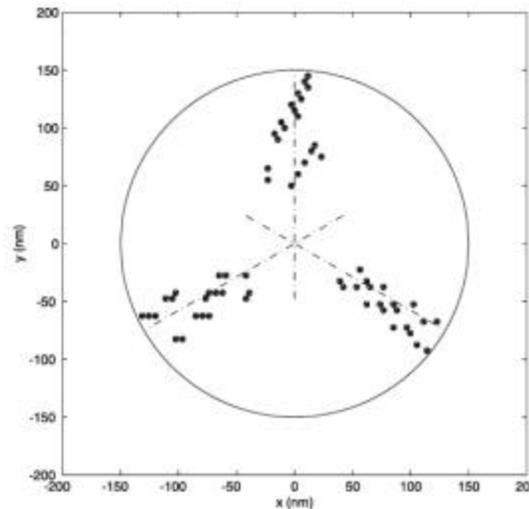


Three flows

- Decentralized resolution
 - diverges



- Centralized resolution
 - stable
 - structure to be further analyzed/optimized

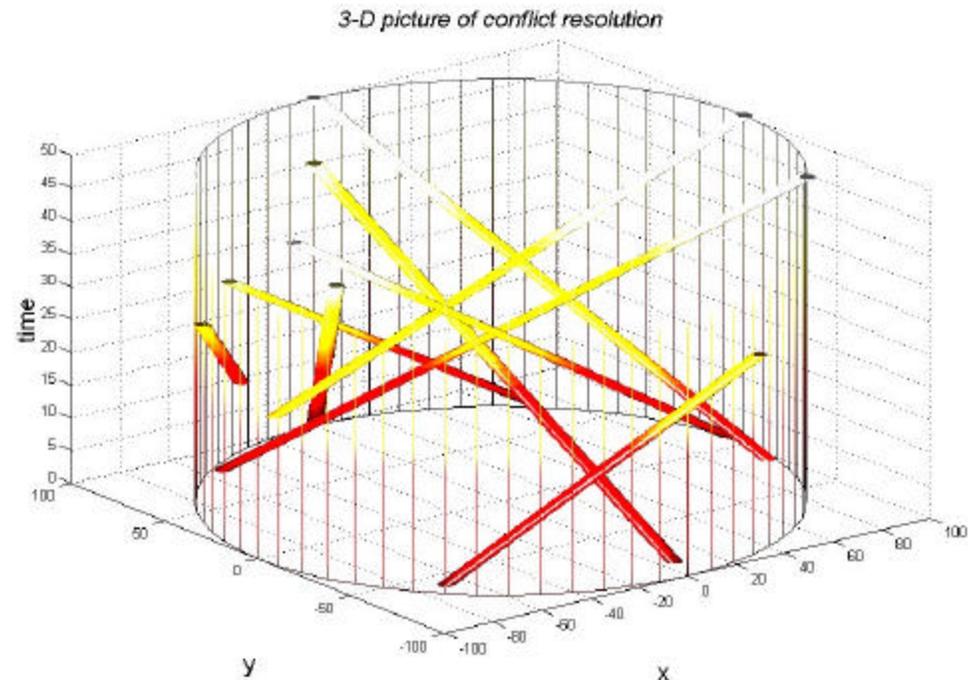
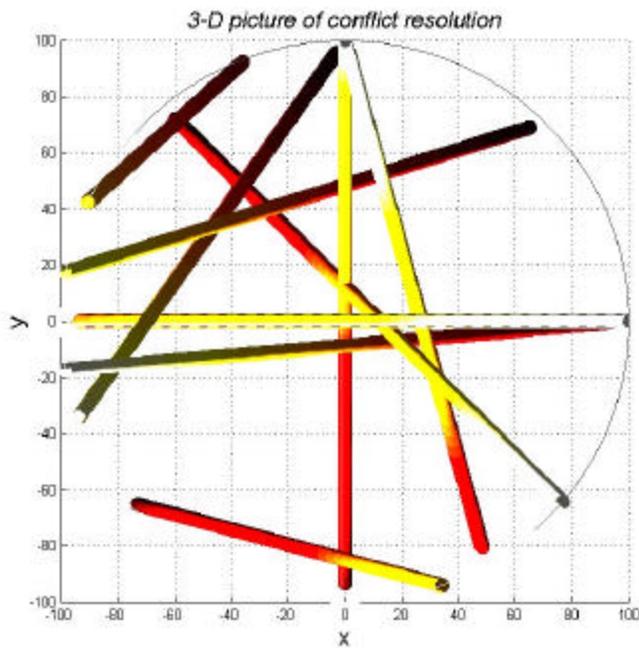


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Analysis and flow management

How geometry and flow management merge ?

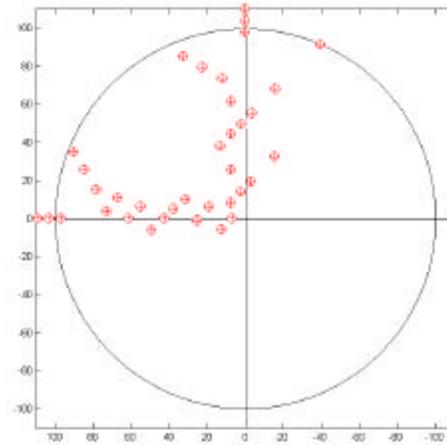


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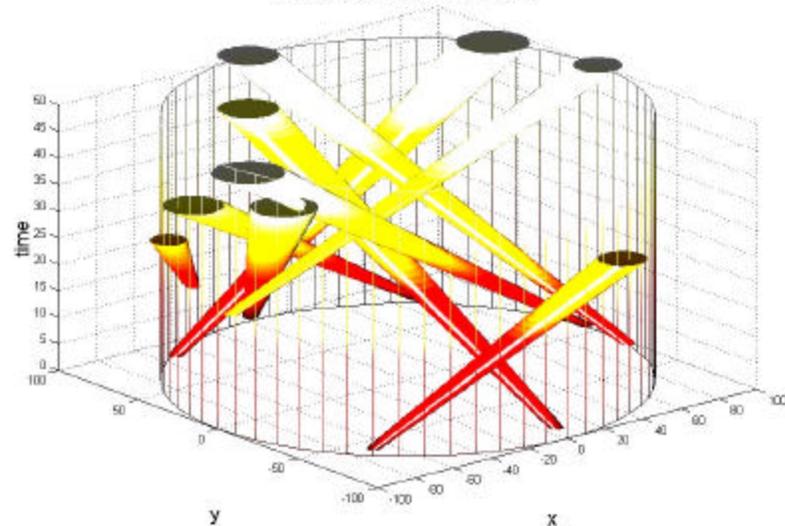


Analysis of robustness

- Maneuver imprecision
 - leads to divergence in some scenarios
- Aircraft position uncertainties
- 3-D geometrical tool may help

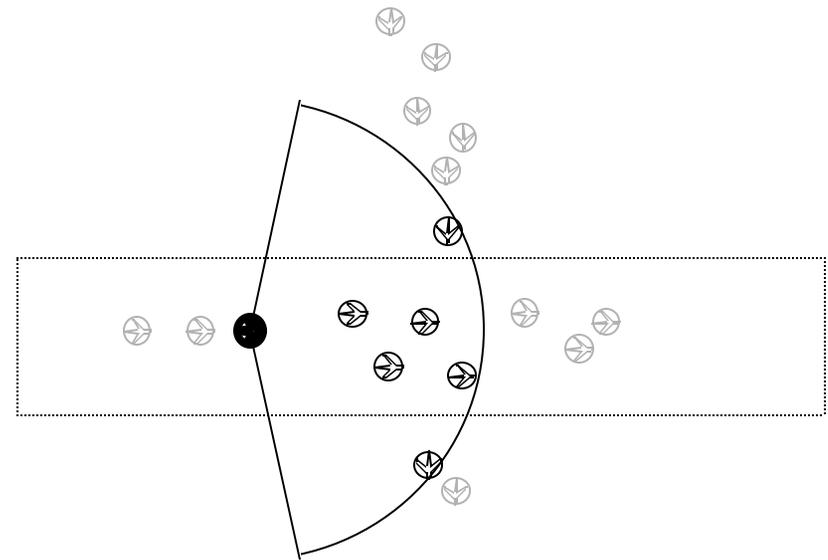


3-D picture of conflict resolution



Towards Free Flight...

- Limited information
- Situation is obtained by onboard device (radar)
 - control volume is attached to each aircraft
 - events happen anytime
- Stability & performance ?



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