Comparison of pair-wise priority-based resolution schemes through fast-time simulation

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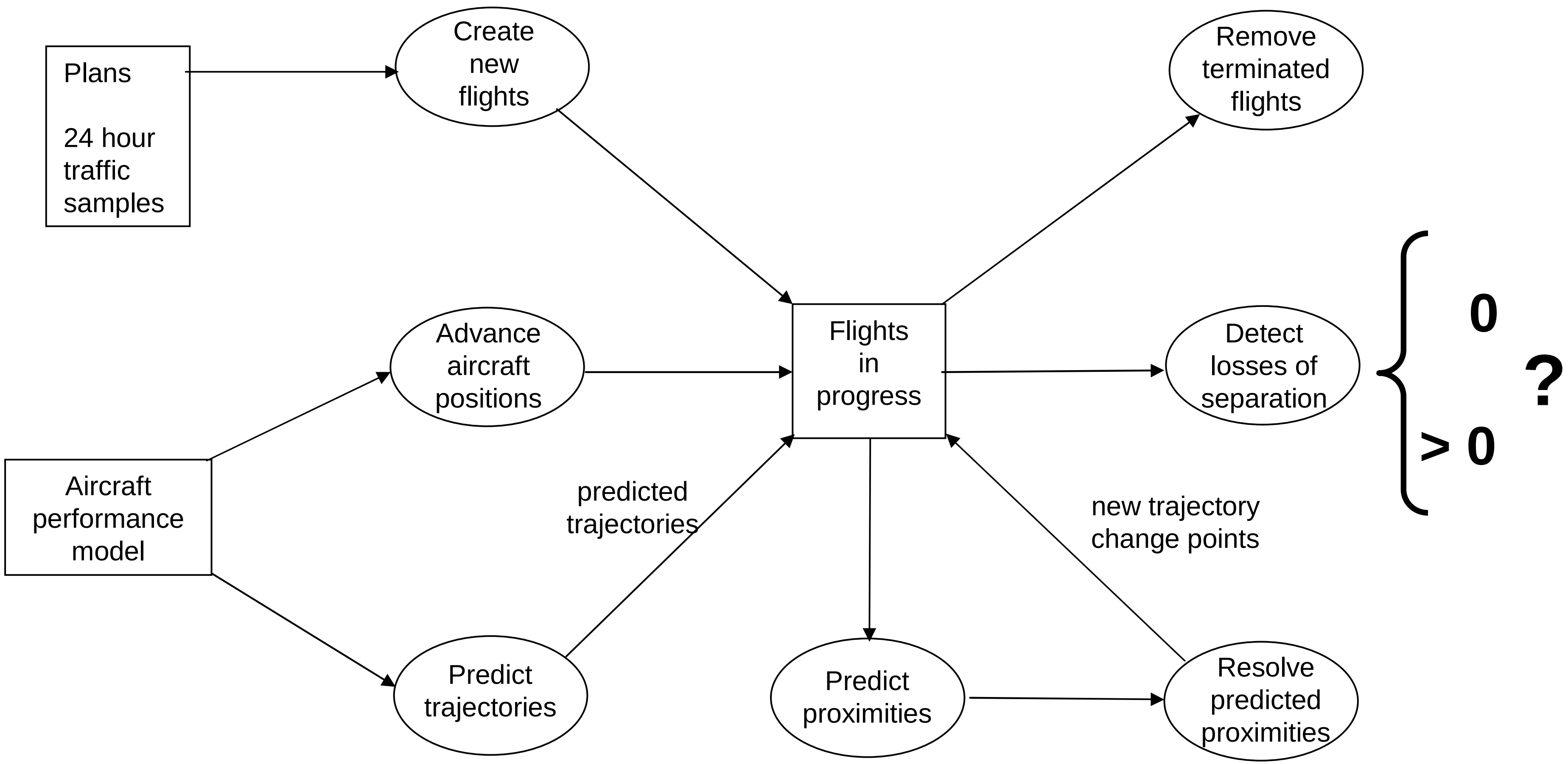
Overview

- Assembling a fast-time air traffic simulator with separation provision
- What can this kind of simulator be used for?
- Current limitations in modelling
- EC iFly project and airborne self-separation concept
- Simulation results
- Improving the resolution strategy
- Comparison of strict application of priority rule and priority reversal
- Conclusions

Assembling a fast-time air traffic simulator with separation provision



Resolution scheme

- Which aircraft (one or more) should manoeuvre to prevent loss of separation?

  Choose one aircraft from each predicted proximity, using a priority rule.

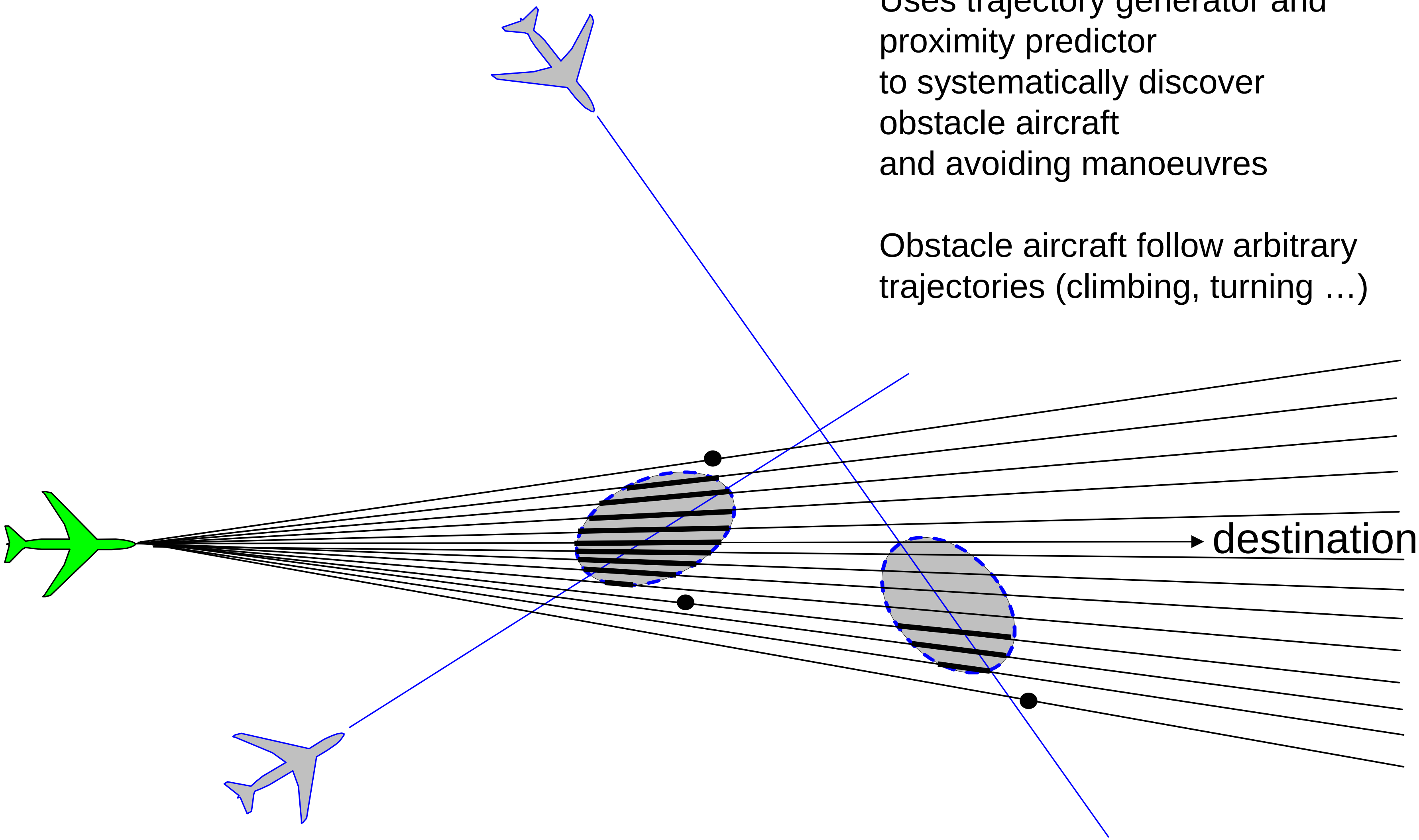
- Which new trajectory or trajectories will avoid loss of separation?

  Resolution algorithm searches for new proximity-free trajectories for the aircraft chosen by the priority rule.

- If two or more aircraft must modify their trajectories, how can one ensure that their new trajectories are **compatible** so that new potential losses of separation are not created?

  Resolution is centralised and new trajectories are found sequentially

Resolution algorithm

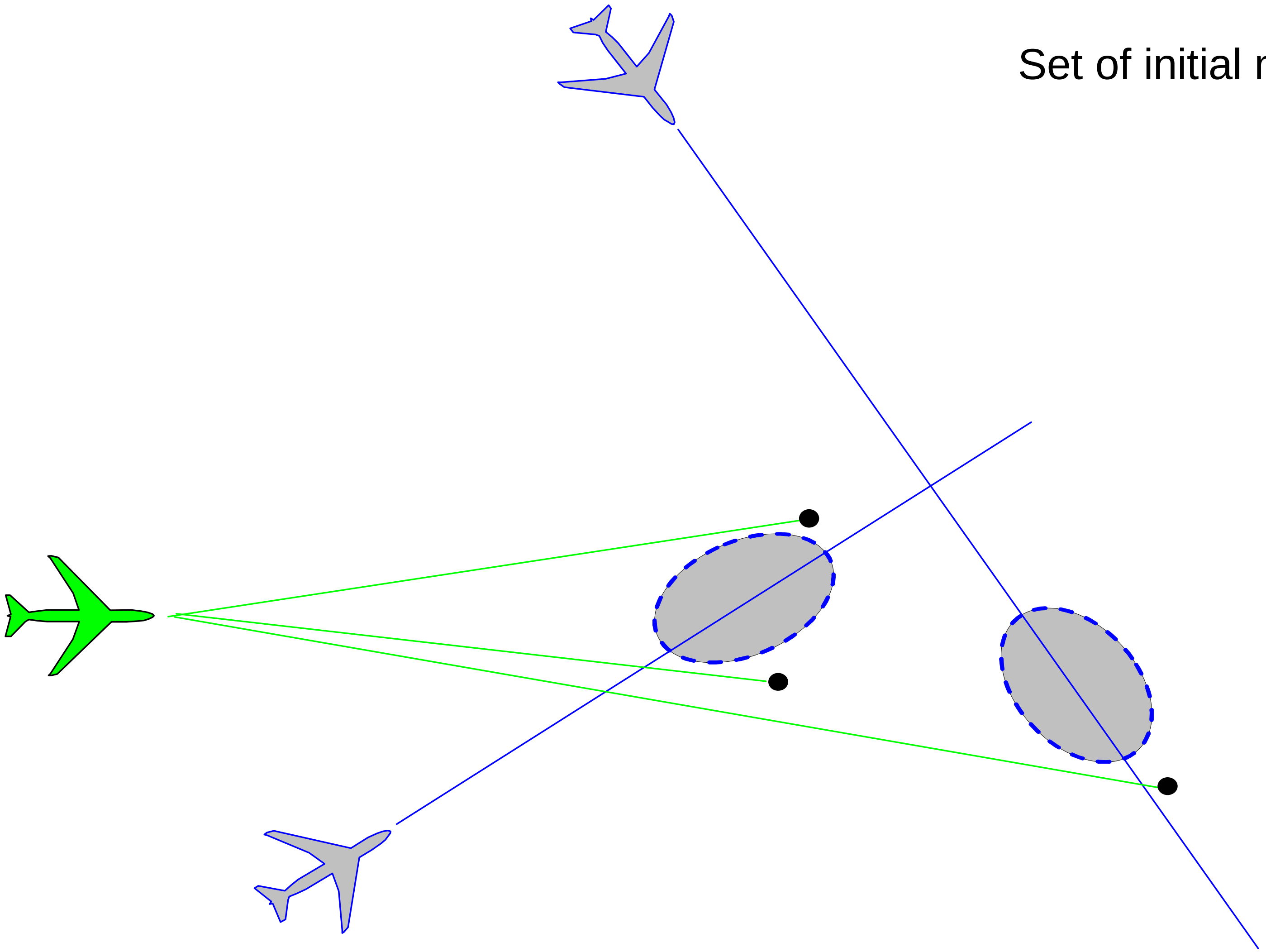


Uses trajectory generator and proximity predictor
to systematically discover obstacle aircraft
and avoiding manoeuvres

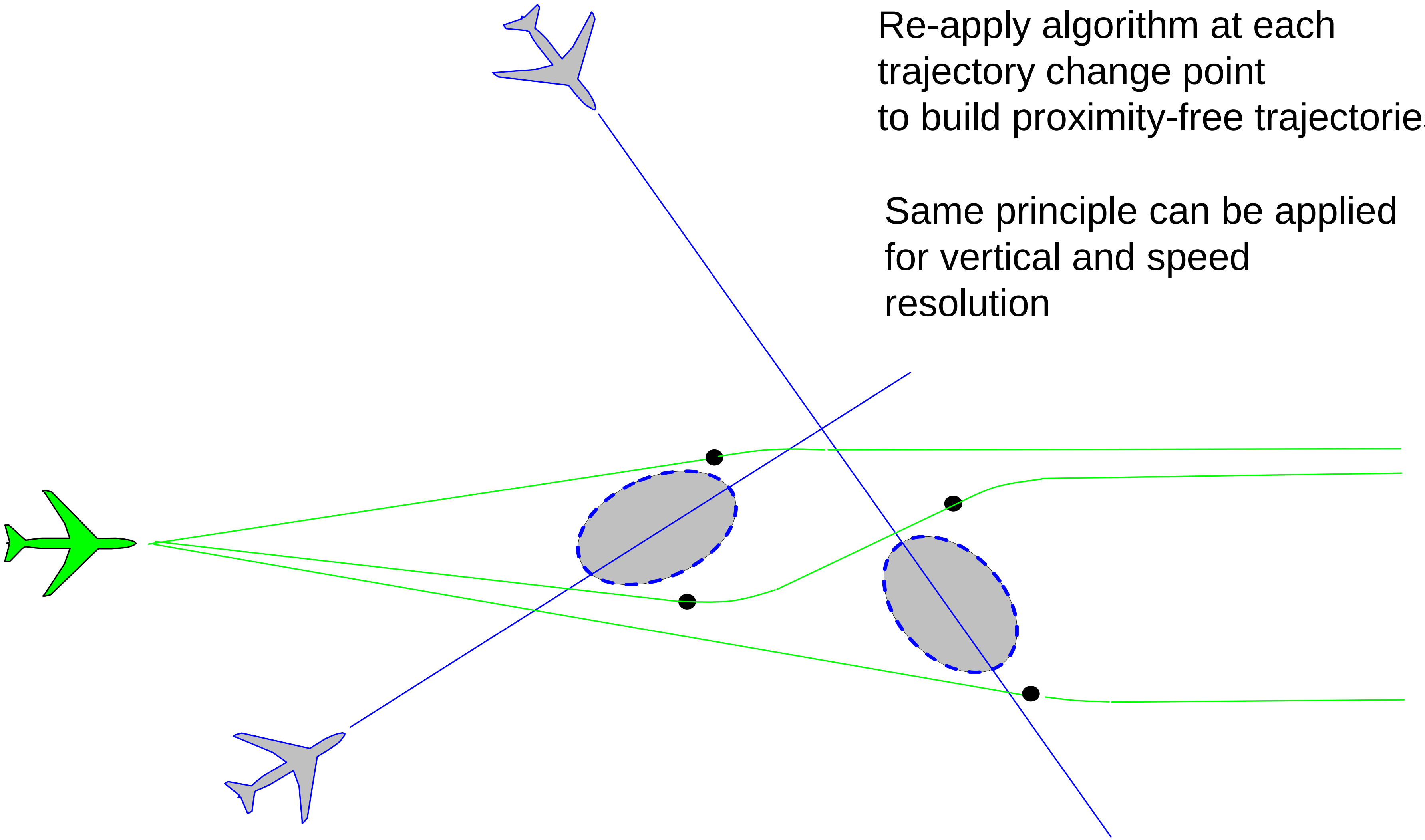
Obstacle aircraft follow arbitrary trajectories (climbing, turning …)

Resolution algorithm

Set of initial manoeuvres



Resolution algorithm



Re-apply algorithm at each trajectory change point to build proximity-free trajectories

Same principle can be applied for vertical and speed resolution

What can this kind of simulator be used for?

- Investigating the feasibility of operational concepts
- For a given concept, investigate conditions (parameters) under which the resolution scheme cannot separate aircraft
- Develop (lower bounds on) **performance requirements** – how well do system components have to work to avoid failure of the resolution scheme?

- In the context of **trajectory management** (SESAR), what **trajectory accuracy** is needed to enable separation of a required traffic level (e.g. SESAR long-term capacity goal)?

Current limitations in modelling

- No uncertainty – all aircraft fly as if equipped with a perfect 4D flight management system, i.e., they follow predicted trajectories exactly.

- No reserved areas

- Instantaneous communication
- Instantaneous computation

- TBD

iFly project

- "Safety, Complexity and Responsibility based design and validation of highly automated ATM"
- 4+ Year innovative ATM project (2007-2011) within EC DG-TREN, 18 partners
- Design and assess the safety of an airborne self-separation concept (A3)

  Up to what traffic level could such a system be operated safely?
- How could the concept be enhanced (e.g. ground support) to allow greater capacity?

iFly airborne self-separation concept (A3)

Communication enablers: air-air broadcast (ADS-B) & SWIM

3 levels of trajectory replanning:

- **Long-term** replanning makes use of SWIM data to avoid bad weather, congested regions, reserved areas etc.
- **Medium-term** replanning (up to 15 to 20 minutes before predicted proximity) uses intent (trajectory) data to separate aircraft.

  This data may be available via SWIM or air-air broadcast (ADS-B).

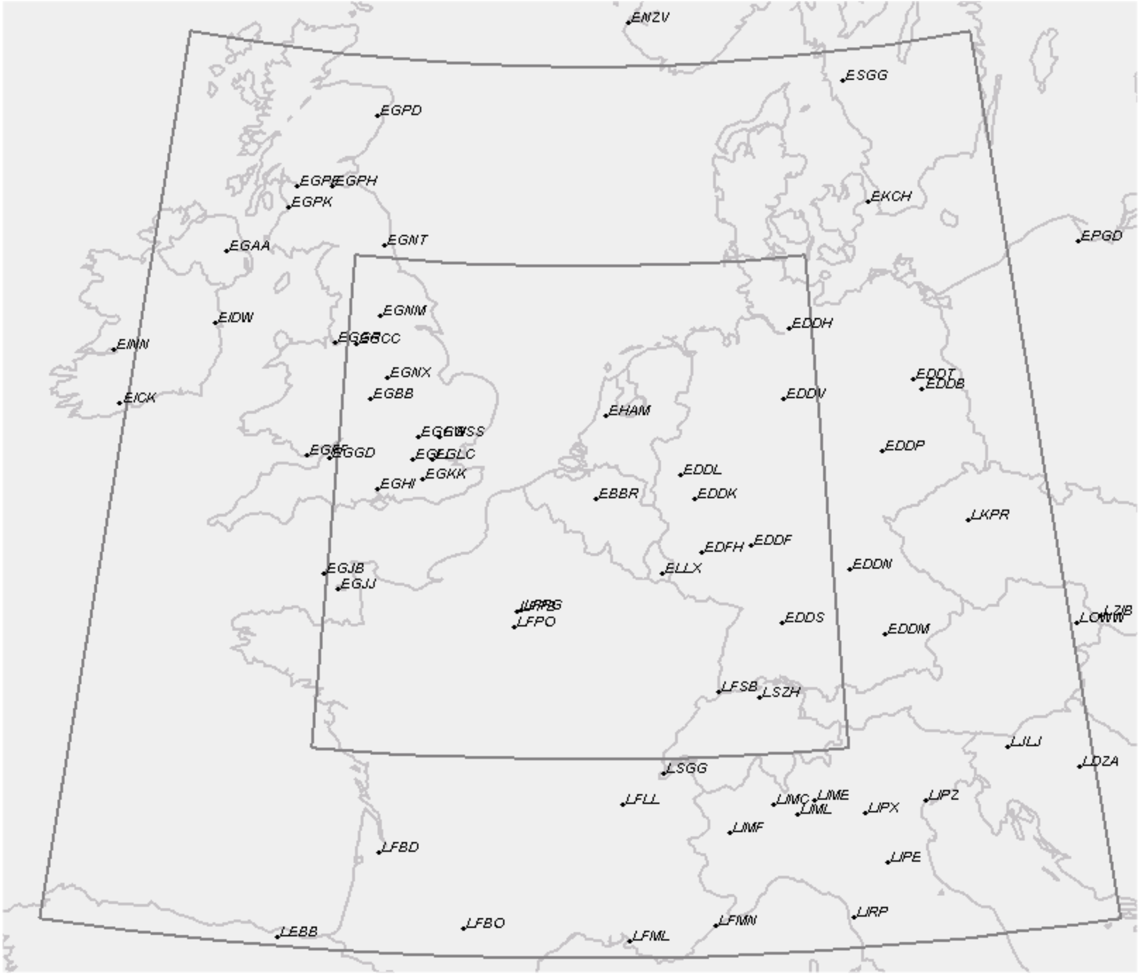
  Priority rules designate ONE aircraft in a predicted proximity which must find and follow a new proximity-free trajectory.
- **Short-term** replanning (up to 3 to 5 minutes before predicted proximity) uses state data (position and velocity) and up to one intent point, available via air-air broadcast.

  ‘Co-operative’ resolution manoeuvres.

Simulator configuration

- 24 hour traffic sample developed for Episode 3 (Initial SESAR validation), 3x 2006 traffic
- Traffic can be decreased or increased by omitting or cloning plans
- Trajectories predicted for 20 minutes
- All trajectory information available to all aircraft - perfect SWIM

Volume of interest + trajectory prediction area



Volume of interest
> FL 245

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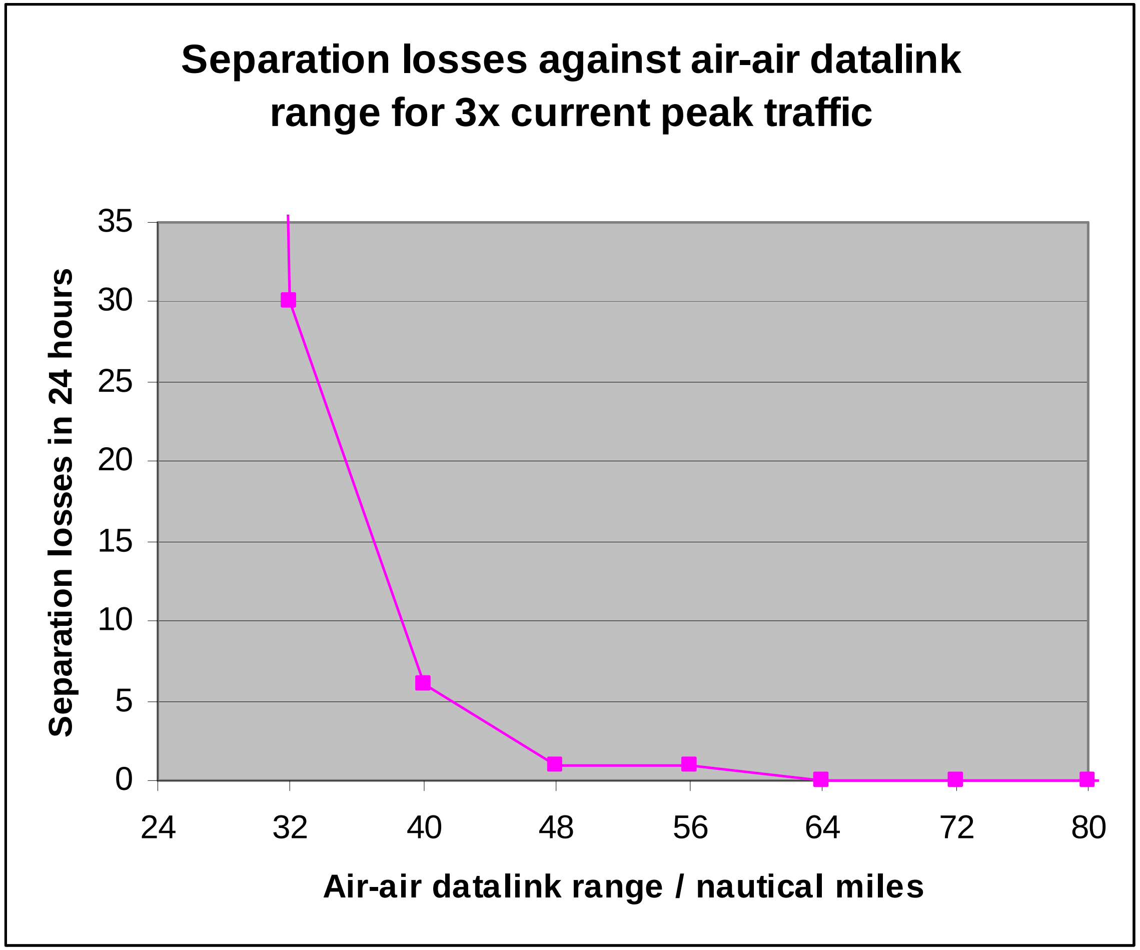
Simulations without proximity resolution

Traffic level / 2006 traffic	Number of flights entering the measured volume	Total flight time in measured volume / hours	Separation losses in the measured volume	Separation losses per flight hour
1	12247	5997	2759	0.46
2	24509	11973	10912	0.91
3	36775	17905	24484	1.36
4	49018	23900	45165	1.88

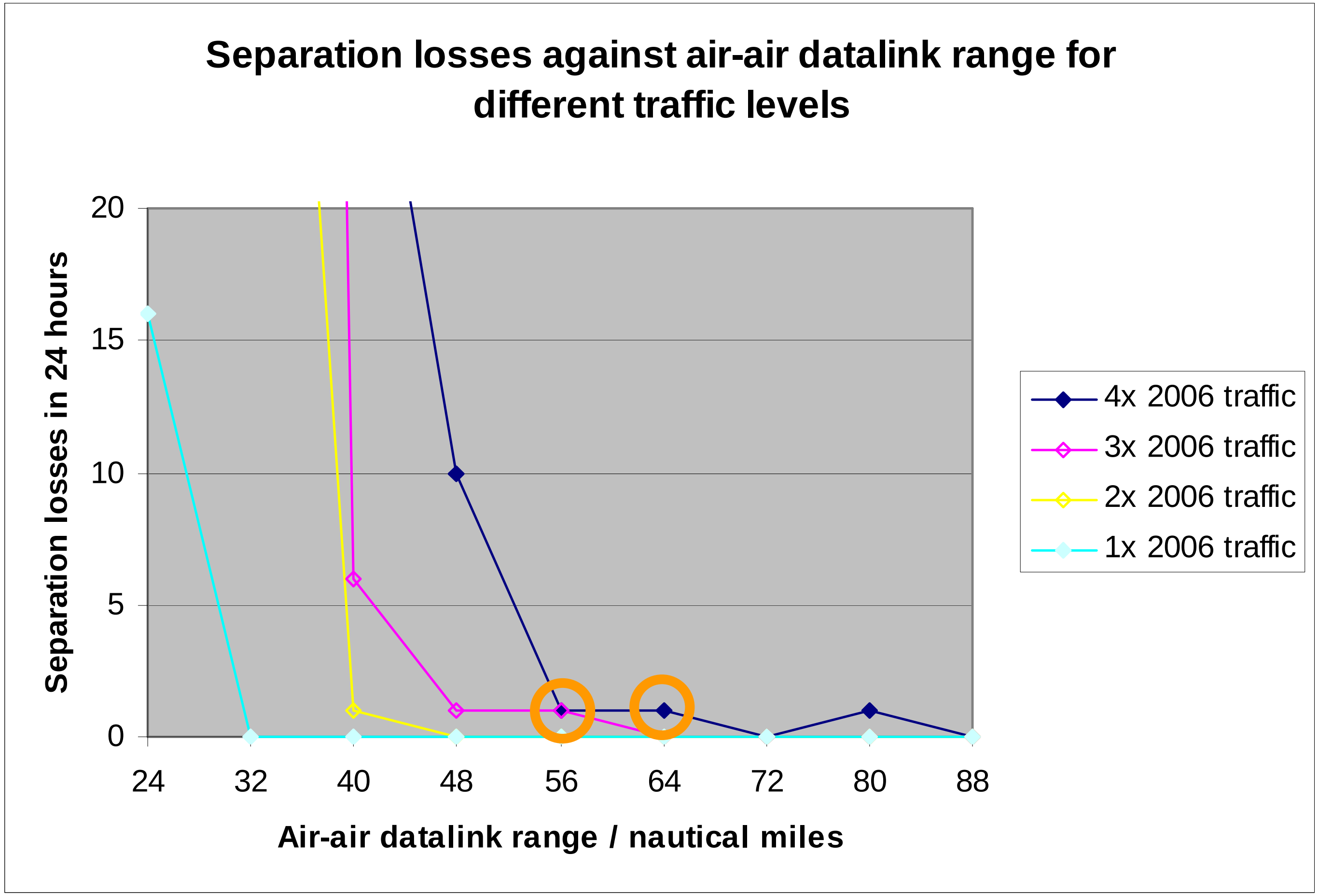
Initial simulation with proximity resolution

- 3 x 2006 traffic
- No losses of separation
- How is this possible?
- What air-air datalink range is needed?

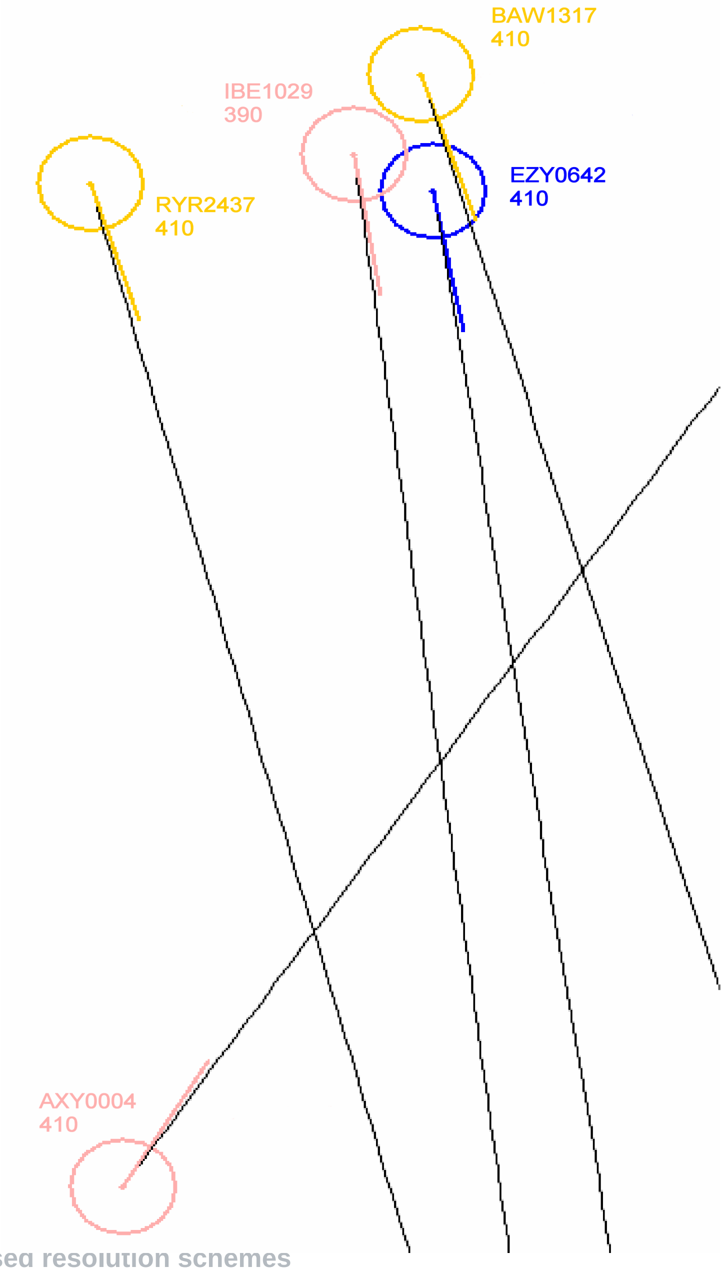
3 x 2006 traffic, varying air-air datalink (ADS-B) range



Various traffic levels, varying air-air datalink (ADS-B) range

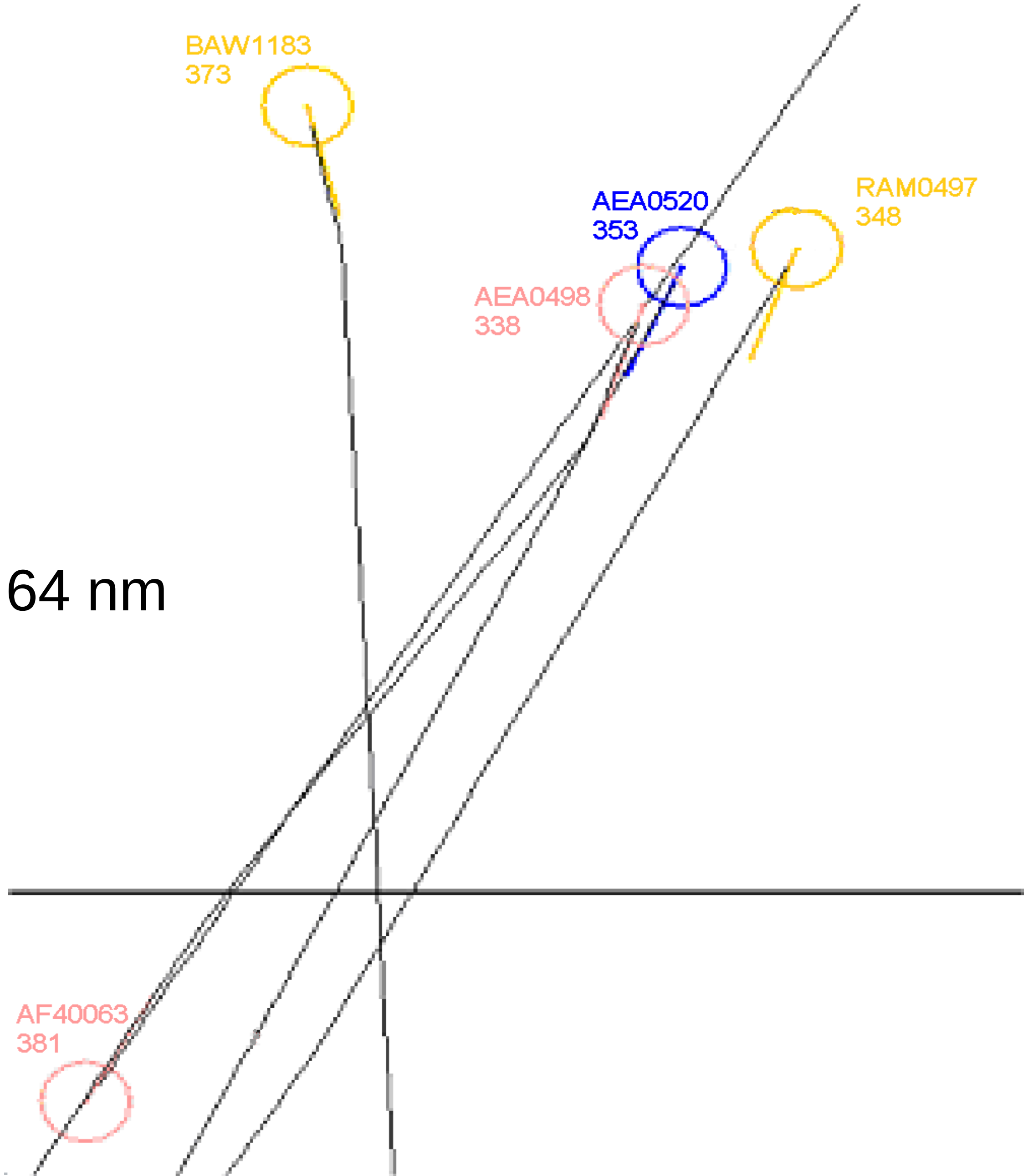


Some
examples …



3x traffic,
air-air range 56 nm

4x traffic,
air-air range 64 nm



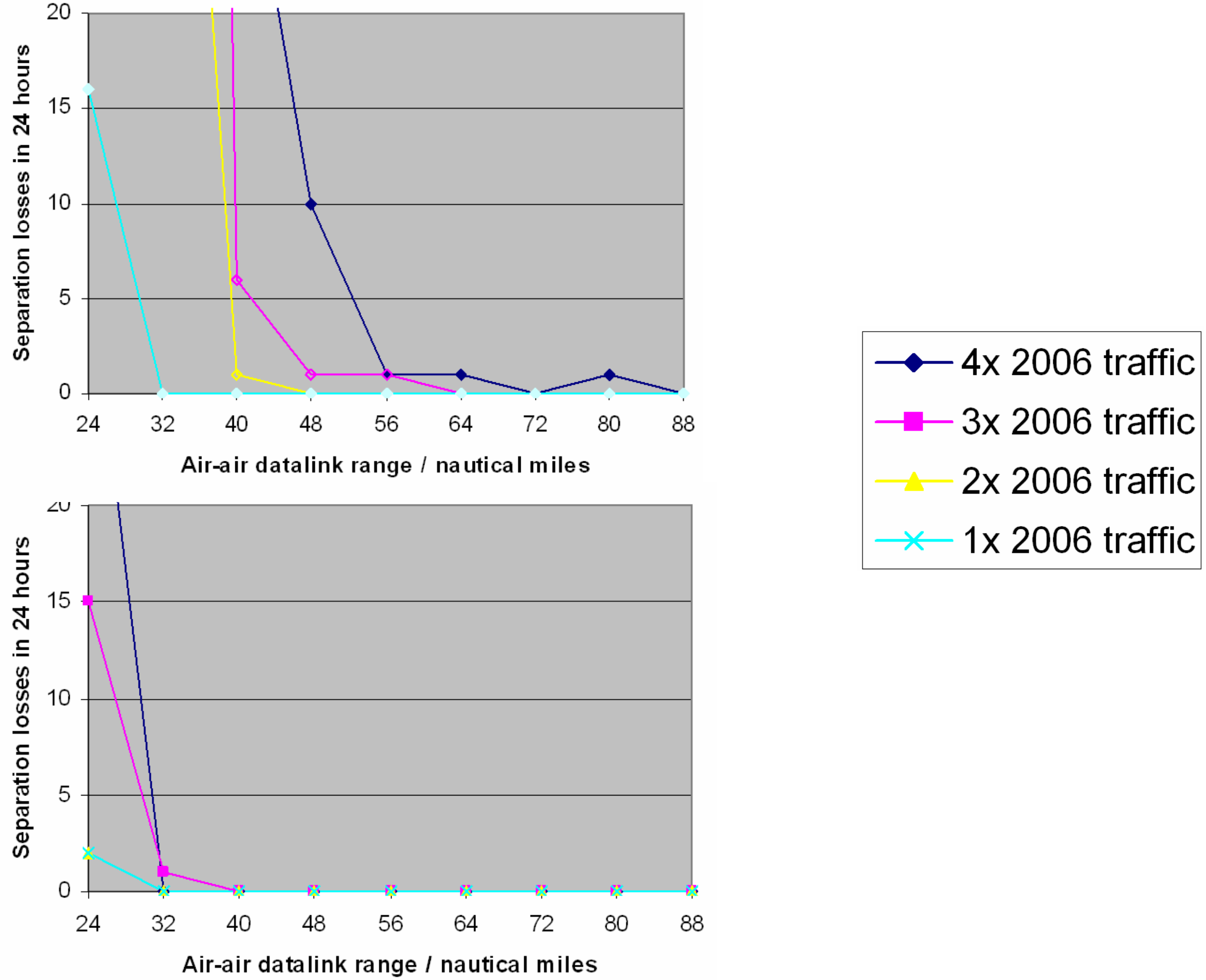
How to improve the resolution strategy?

- Provide another resolution method in case the first one fails.
- Always try to preserve ‘manoeuvrability’ around an aircraft i.e. prevent aircraft from being boxed in.
- Allow priority reversal if the aircraft designated by the priority rule cannot find a resolution.
- …

Comparison of strict application of priority rule and priority reversal

Without priority reversal:

With priority reversal:



Conclusions

- Under highly idealised conditions, 24 hour en-route simulations have been conducted without separation loss in the European core area using 3x and 4x current traffic.
- By limiting air-air datalink range, situations have been illustrated in which an aircraft designated by a priority rule is ‘boxed-in’ and cannot find a conflict-free trajectory.
- A resolution strategy which allows the reversal of priorities in such cases is less likely to fail, since this would require both aircraft involved in a predicted conflict to be ‘boxed-in’.

The end

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