Safety of advanced airborne self separation under very high en-route traffic demand

Henk Blom

National Aerospace Laboratory NLR
Delft University of Technology
e-mail: blom@nlr.nl

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- Advanced Airborne Self Separation
- Agent Based Stochastic Modelling
- Rare event simulation results
- Discussion of results

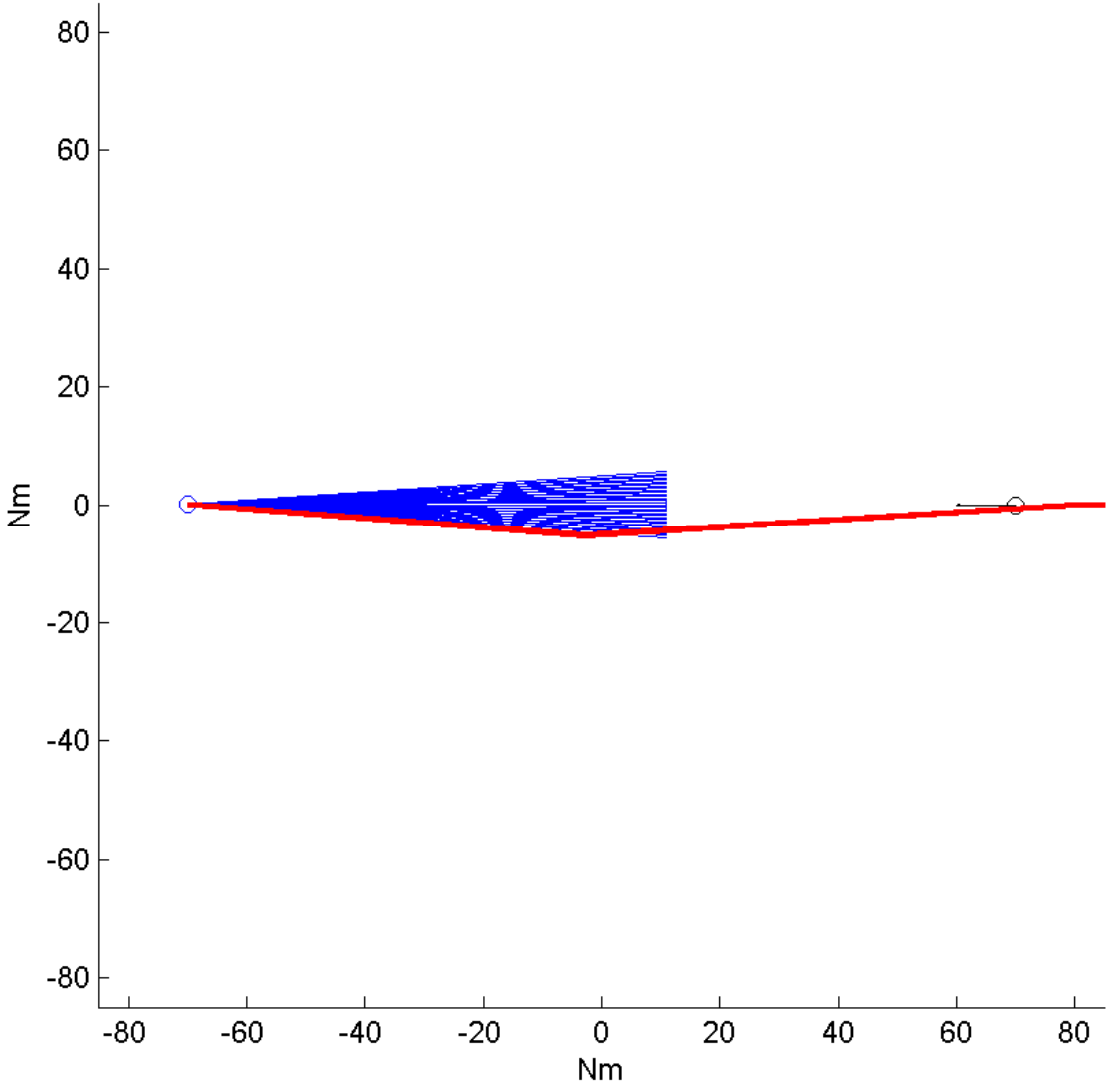
Advanced Airborne Self Separation ConOps considered

- Aircraft plan conflict-free 4D trajectories
  - Reference Business Trajectory (RBT)
- Each a/c broadcasts its current RBT and its destination to other aircraft
- SWIM transfers this over-the-horizon.
- Conflict detection and resolution take all aircraft into account
  - Medium Term (5-15 mins)
  - Short Term (3-5 mins)
- Tactical Separation Minima is down from 5Nm to 3 Nm
  - Stemming from RESET project

Medium Term CD&R approach

- Each aircraft detects conflicts (5NM/1000ft) 10 min. ahead
- a/c nearest to destination has priority over other a/c.
- a/c with lowest priority has to make its 4D plan conflict free (15 min ahead) with all other plans.
- Undershooting of 5Nm/1000ft is allowed if there is no feasible conflict free plan and it does not create a short term conflict (this way everyone keeps on moving)
- Then such aircraft broadcasts its non-conflict-free 4D plan together with a message of being “Handicapped” (which is priority increasing)

Velocity Obstacles = Collision Cones
Medium Term (10 min & 5 Nm)



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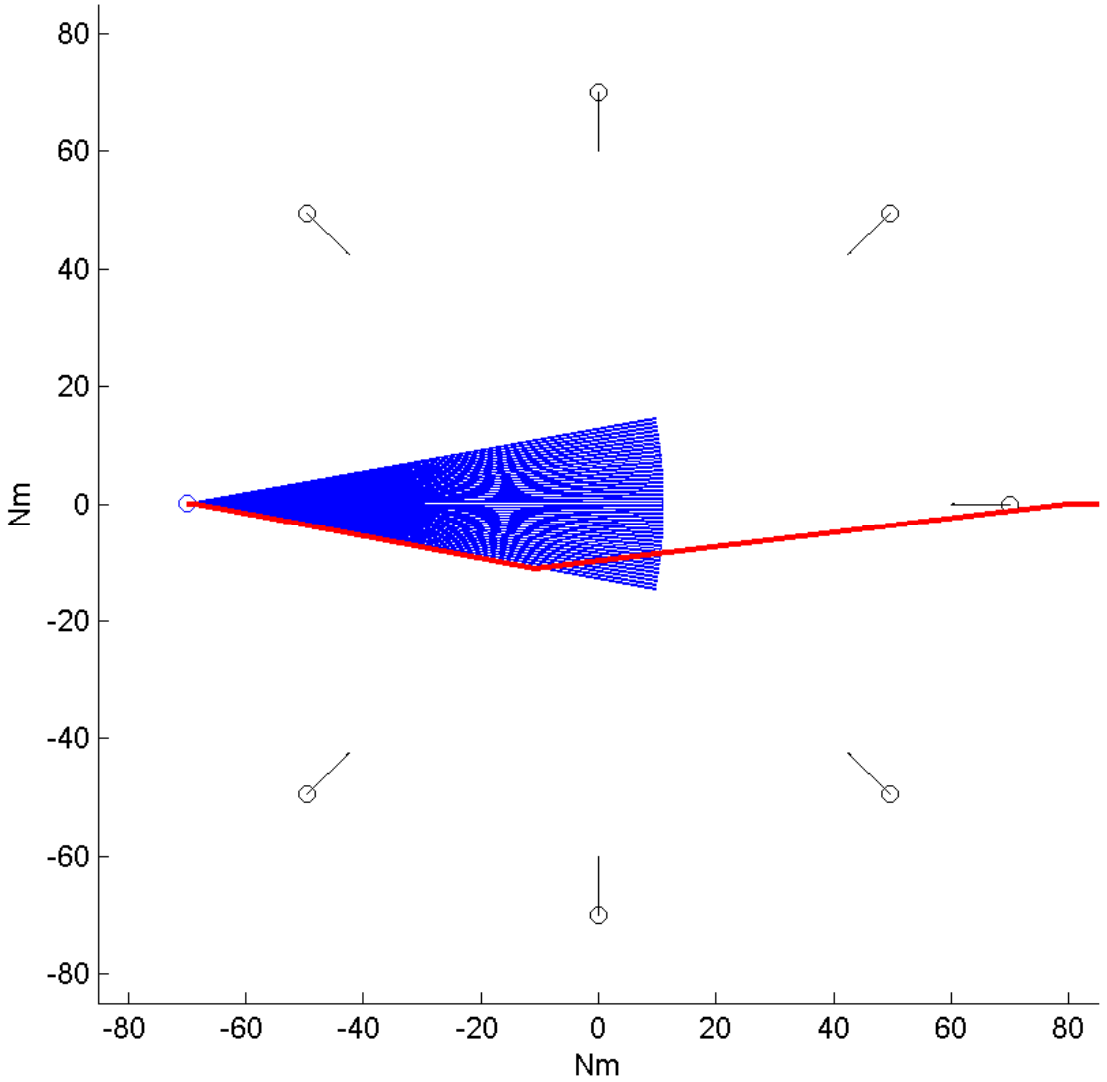

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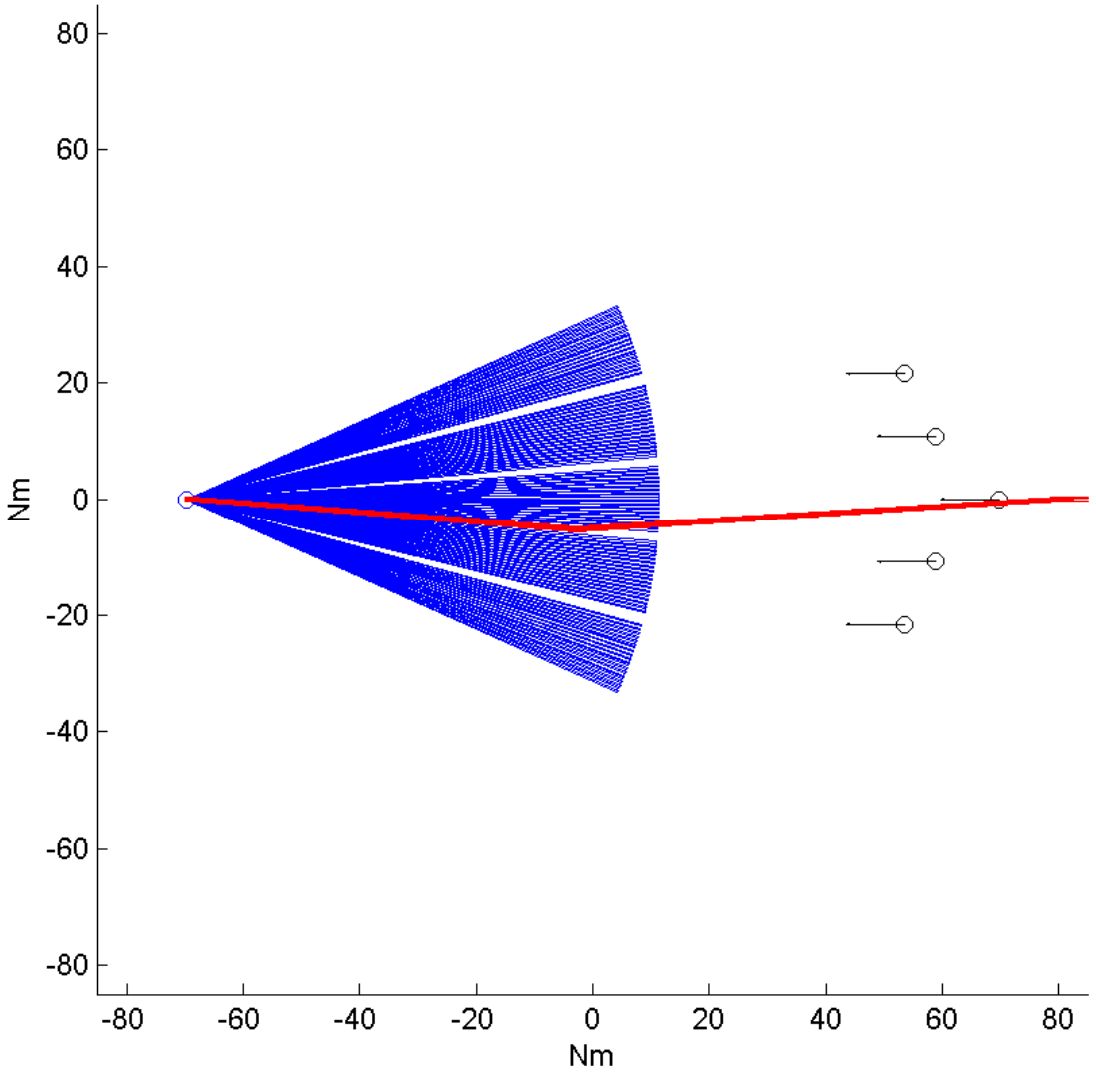

Short Term CD&R approach

- a/c which detects conflict is obliged to resolve the conflict without awaiting any of the other aircraft
- Course change is identified using Velocity Obstacles (3 min. ahead)
- Conflict free means 3Nm/900ft minimal predicted miss distance
- Undershooting of these values is allowed if there is no feasible alternative (this way everyone keeps on moving)
- a/c broadcasts its new course or rate of climb/descend

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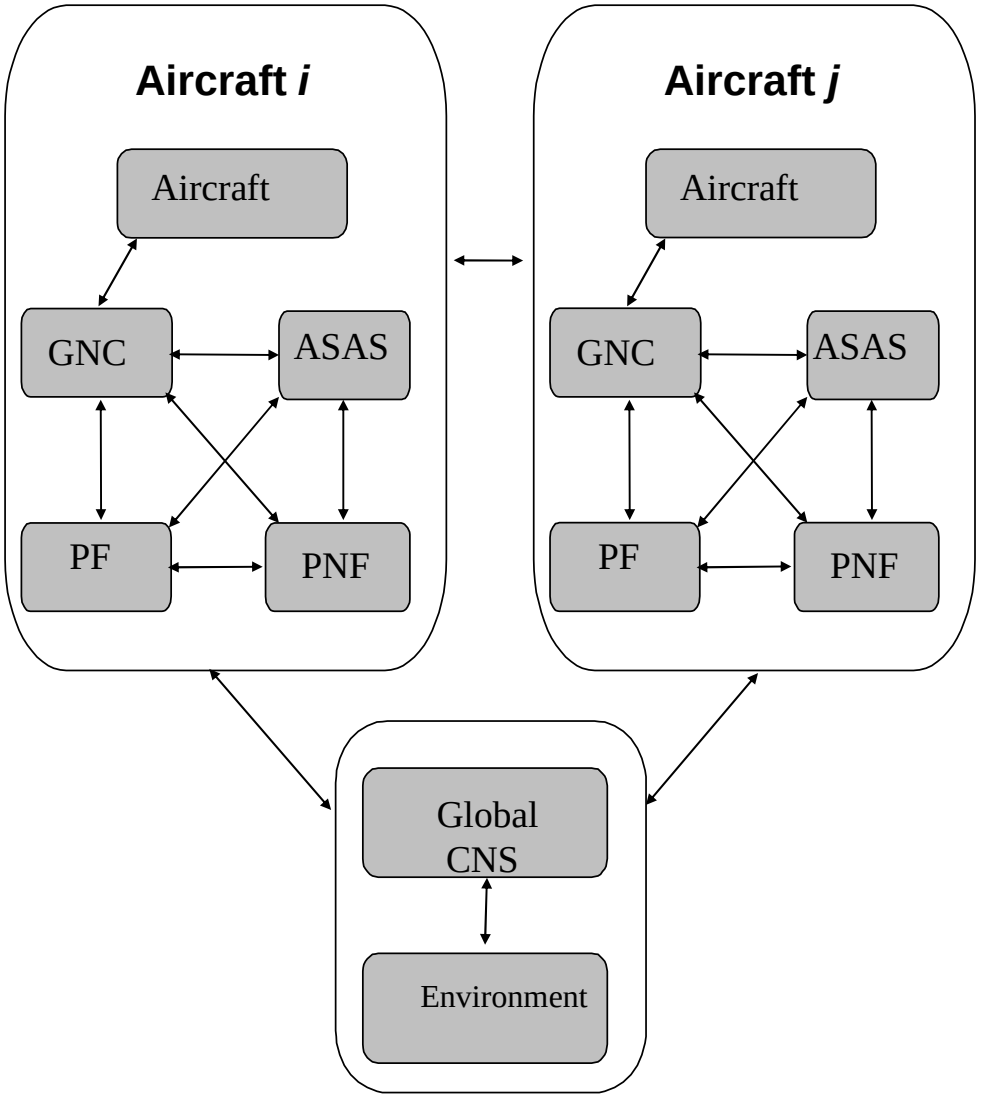
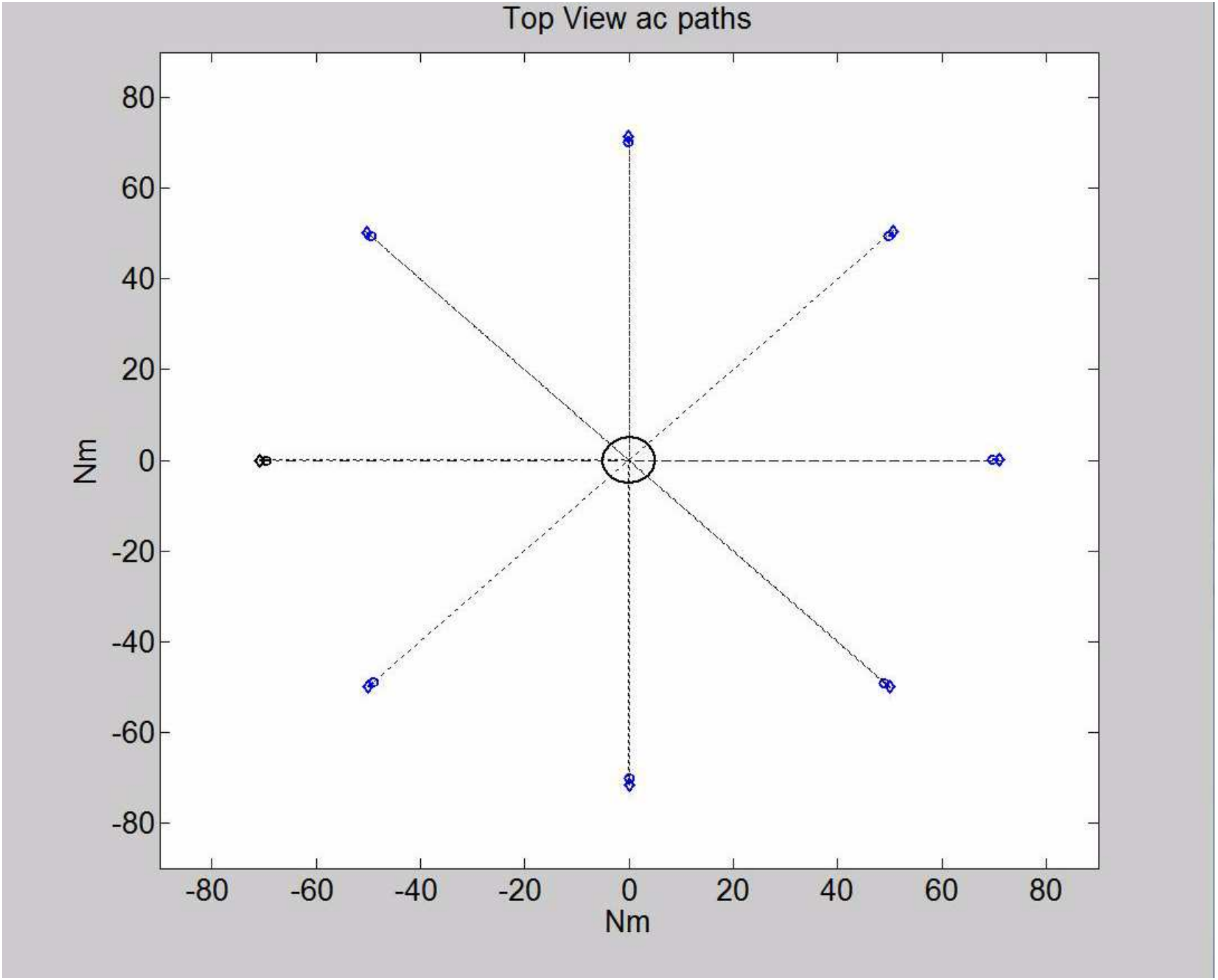
Multiple Agents in Advanced Airborne Self Separation




Top View ac paths
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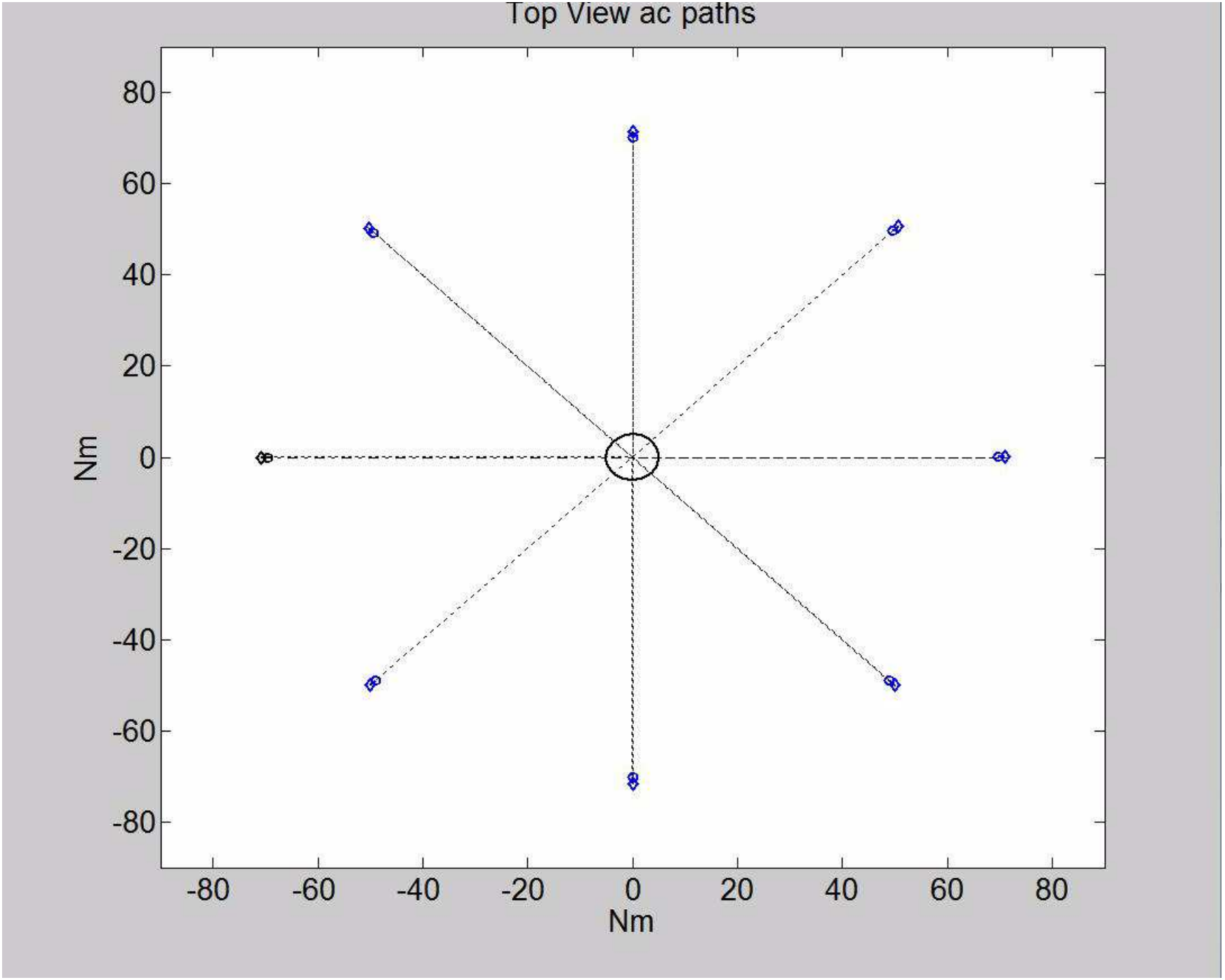
Nm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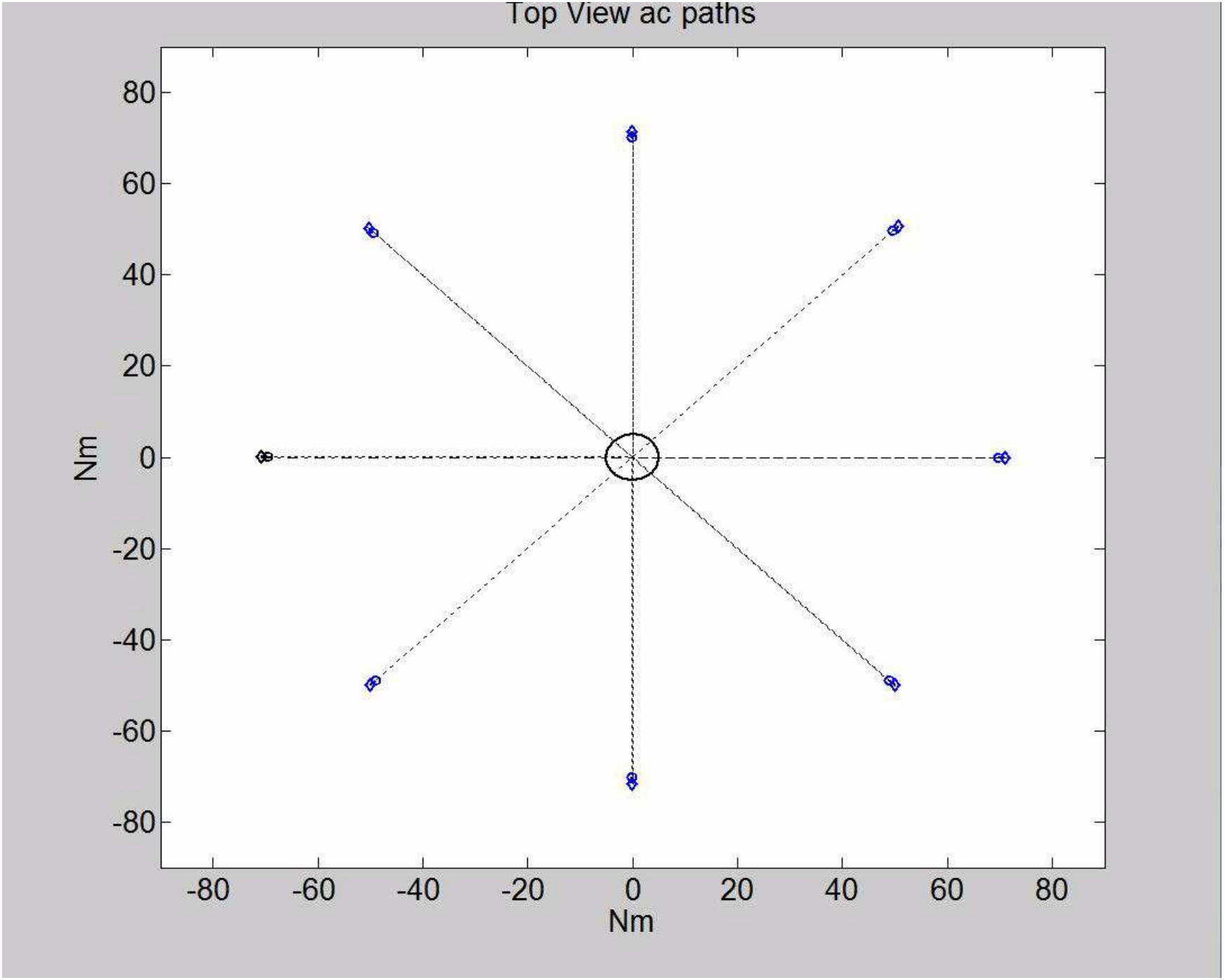
Top View ac paths
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80

Rare event Monte Carlo Simulation

- Start with N initial traffic scenarios
- Simulate from one conflict level to next conflict level
- Fraction of N scenarios reaches next conflict level
- Multiply fractions of these simulations
- Conditions for convergence [Cerou et al., 2002]
- Systematic way to adhere to these conditions in a stochastic Multi Agent model [Everdij & Blom, 2006]

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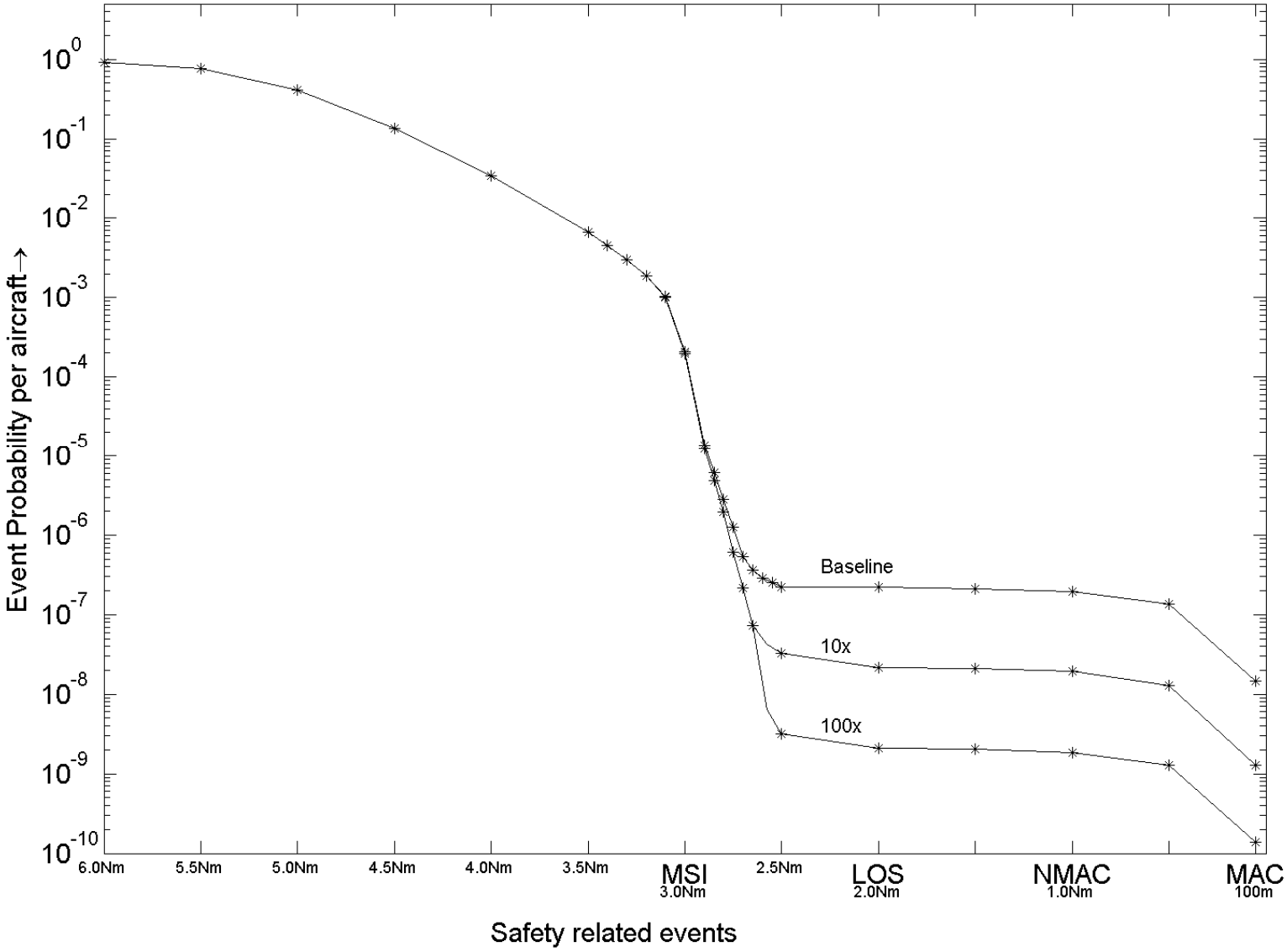
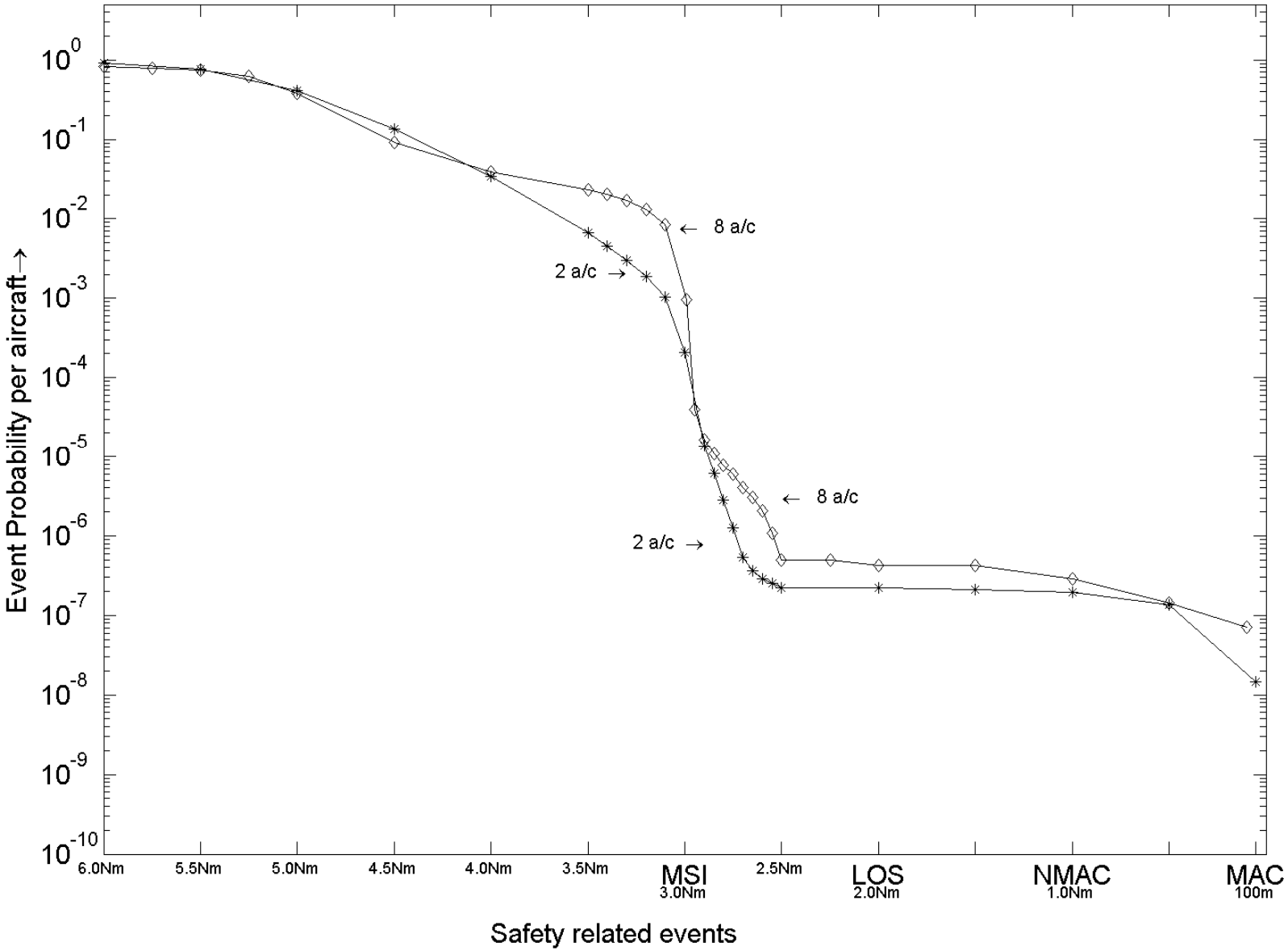
Traffic Scenarios

- Two aircraft encounter
- Eight aircraft encounter
- Random traffic high density

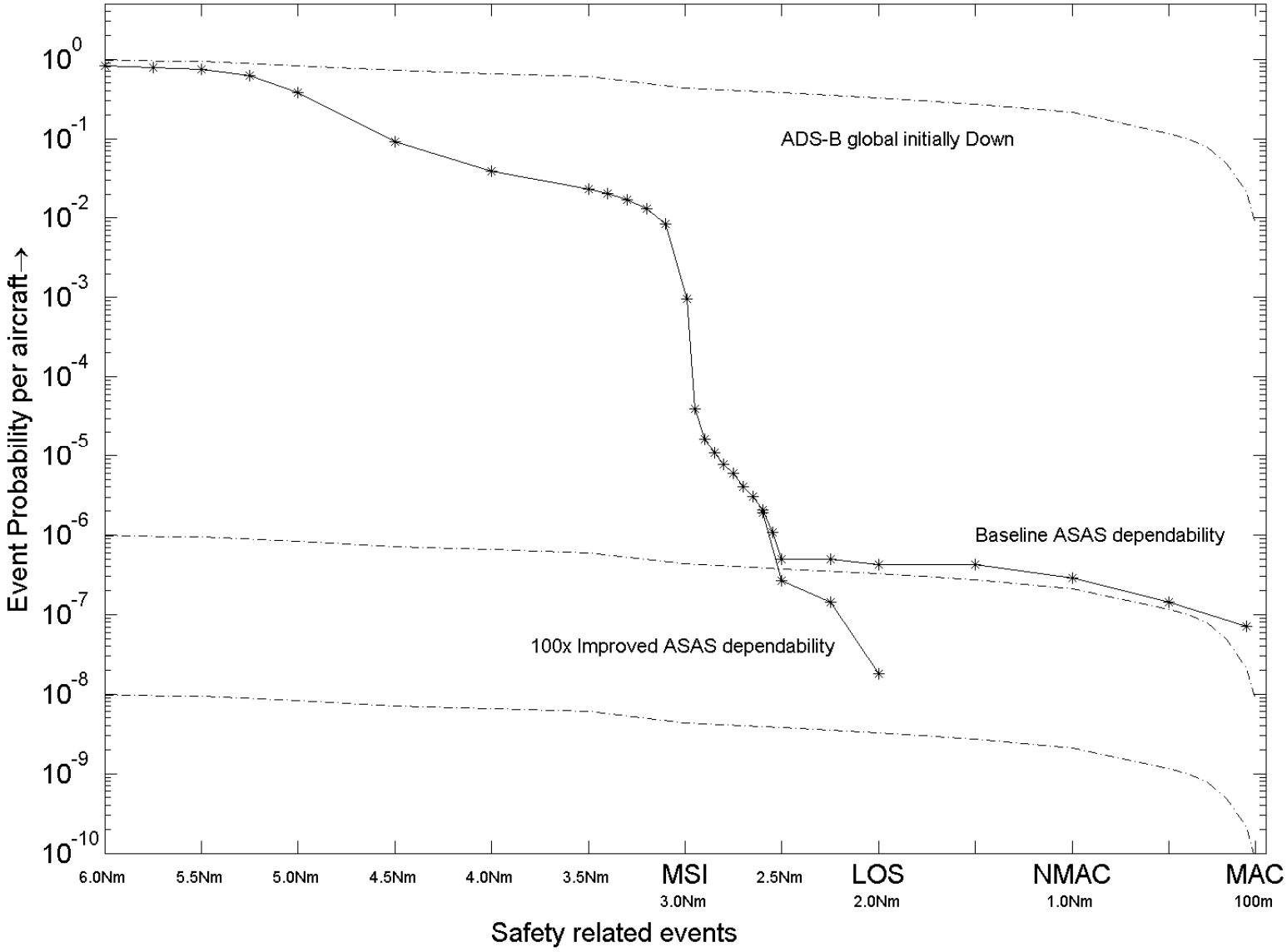
2 a/c, varying ASAS dependability



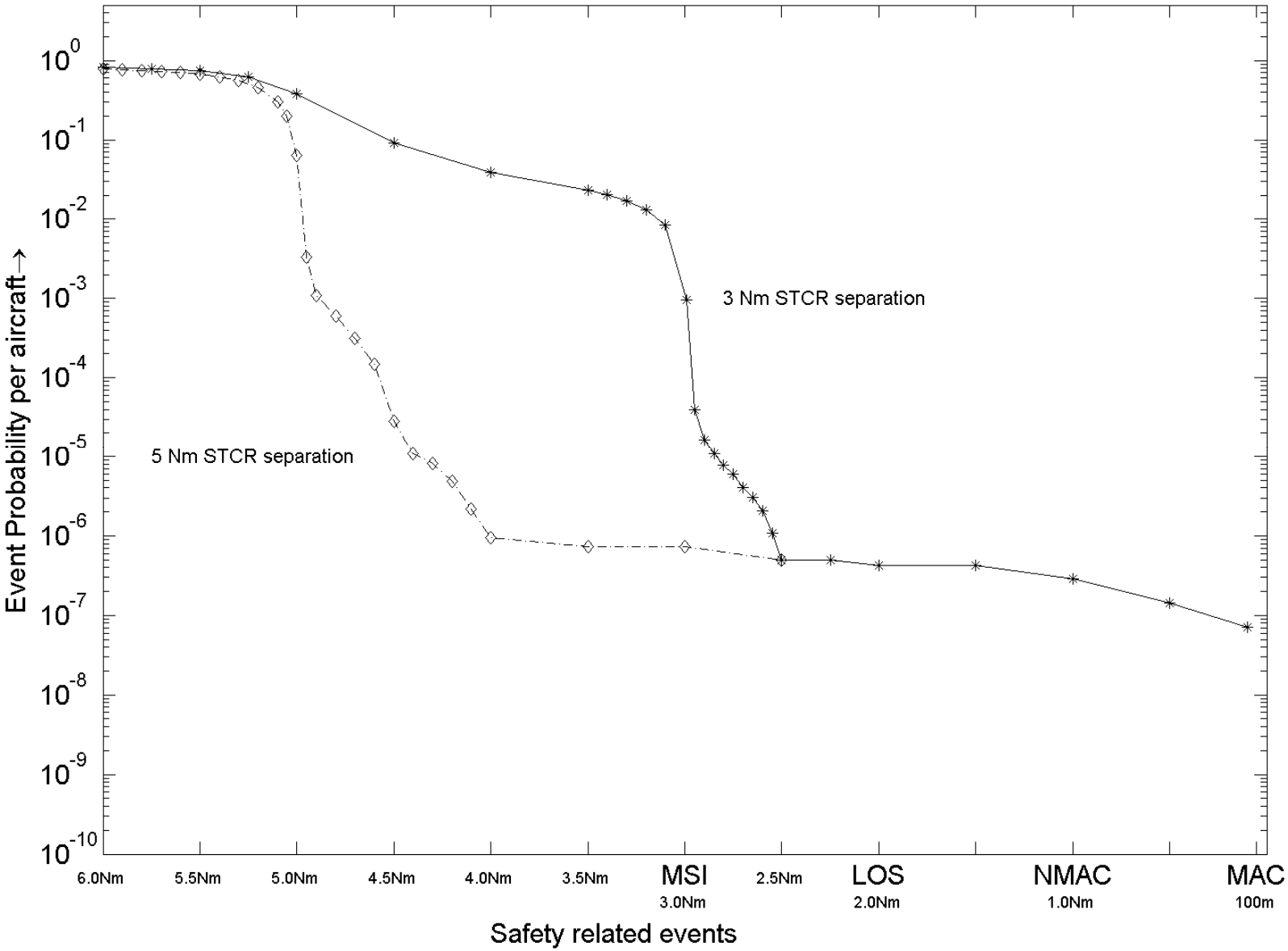
8 a/c versus 2 a/c



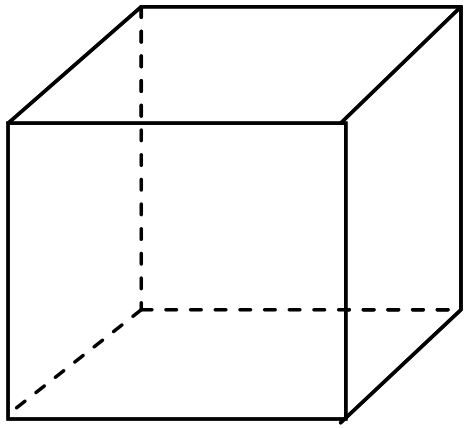
8 a/c, varying ASAS dependability



8 a/c, STCR separation back to 5 Nm

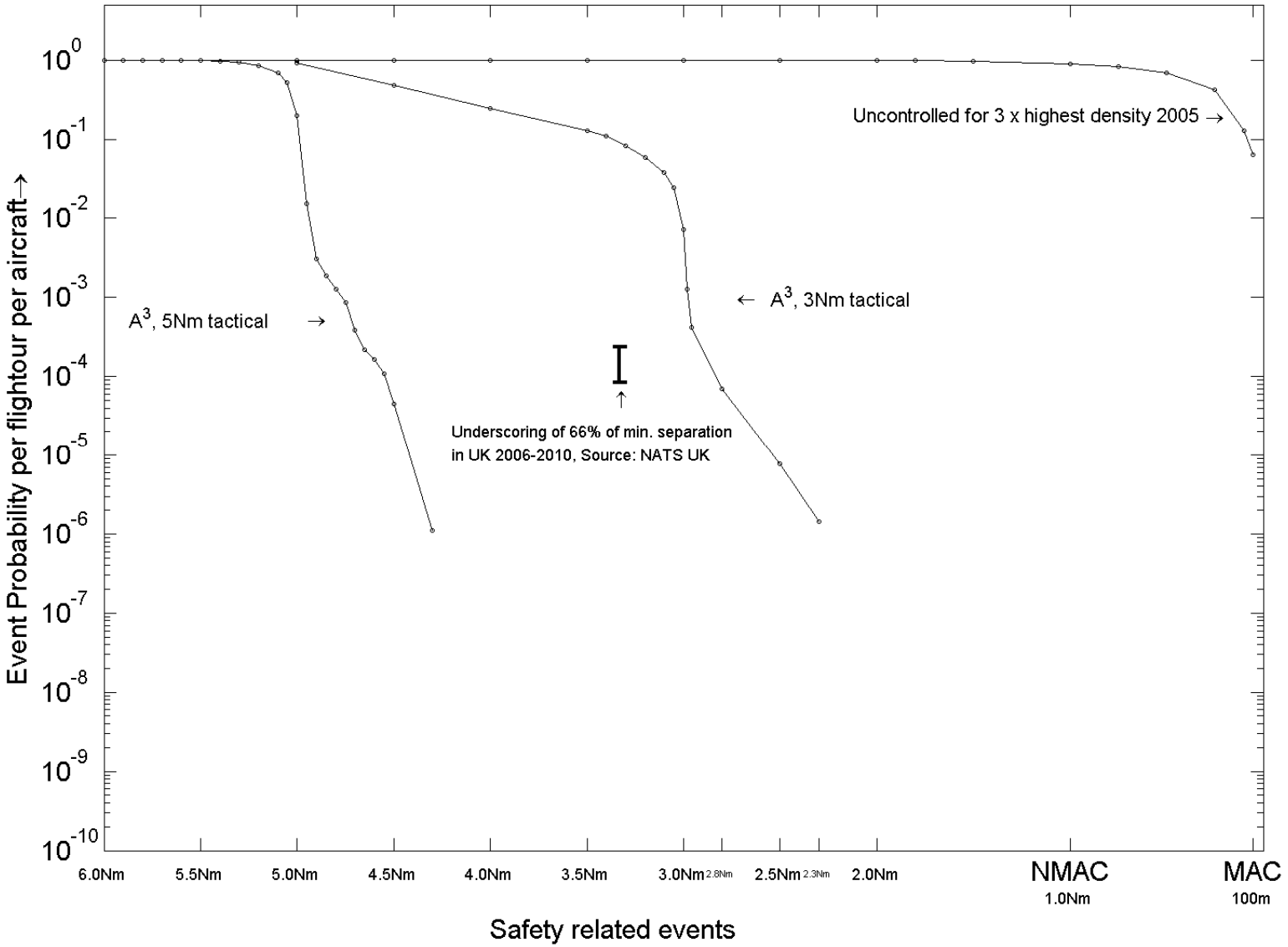


Random Traffic Scenarios

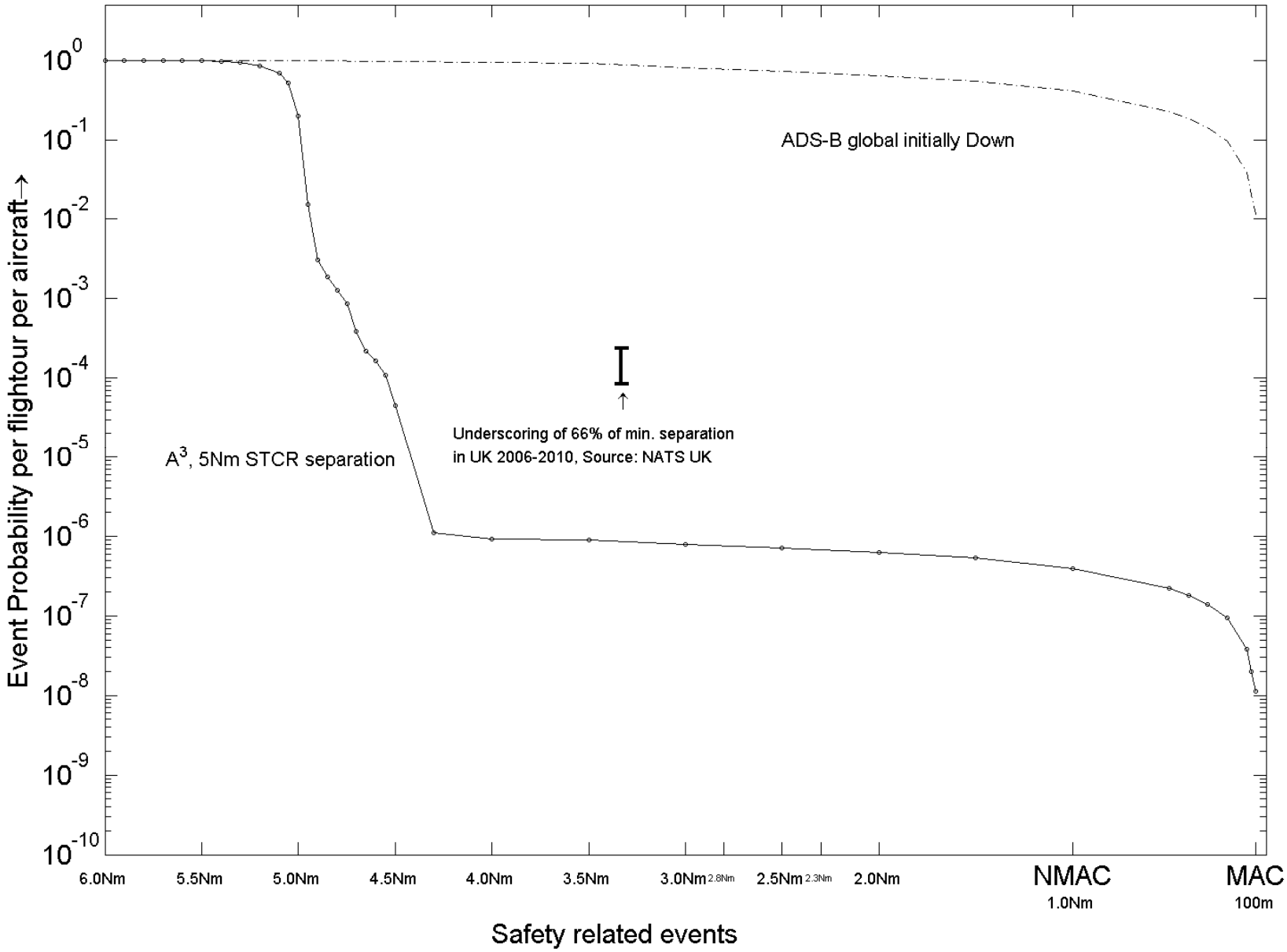


- Periodic Boundary Condition
- Eight a/c per packed box/ no climbing or descending a/c
- Vary container size in order to simulate:
  - 3x as dense as high density area in 2005
  - 6x as dense as high density area in 2005

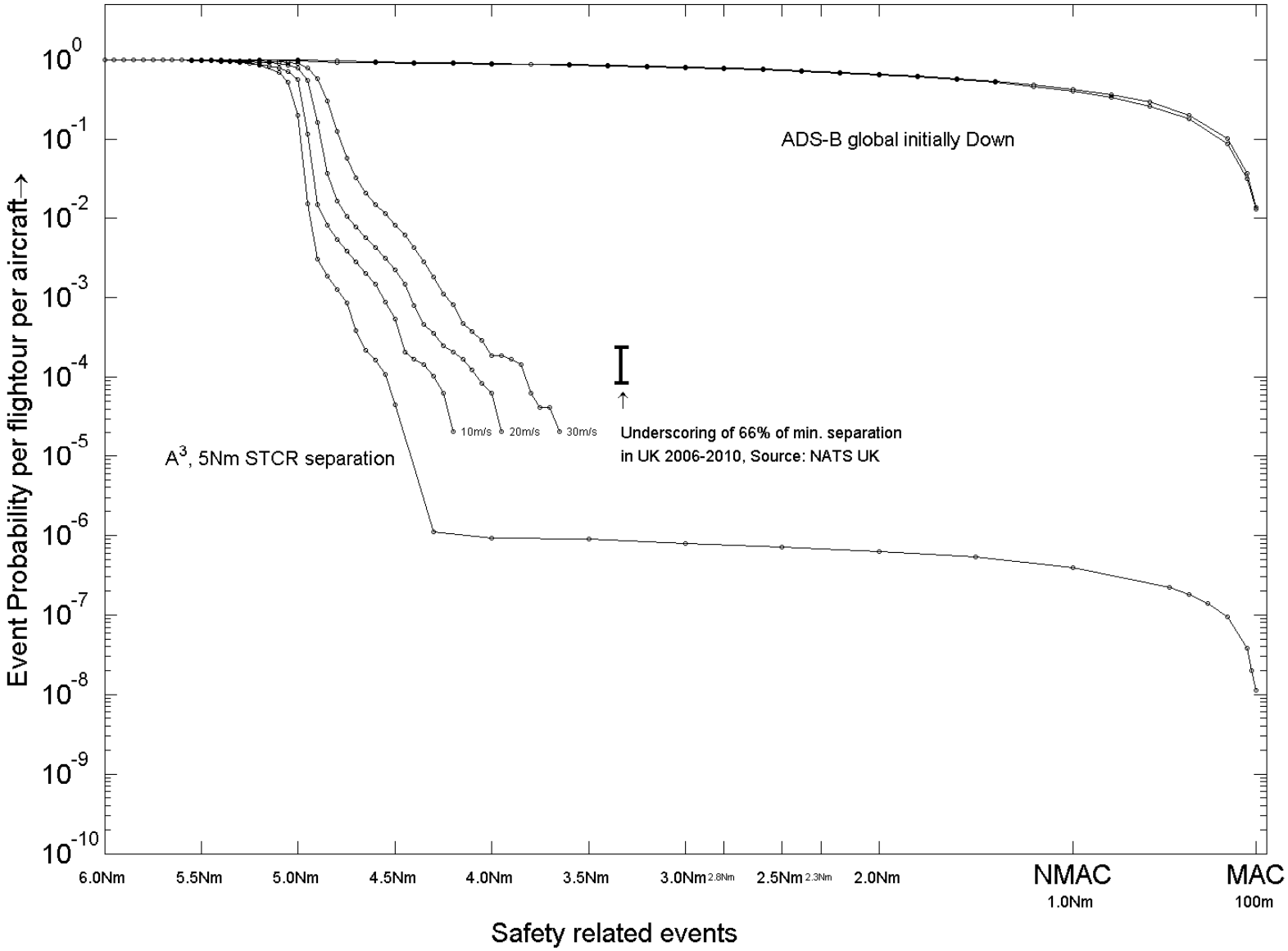
Tactical Separation: 5Nm and 3Nm



3x high 2005 random traffic



3x high 2005 traffic + systematic wind error



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Airborne Self Separation Findings

- MFF project showed: Pilots like it, if they know that ASAS supporting systems are dependable
- Dependability requirements have been identified using RTCA DO-264 (=EurocaeED78a) and rare event MC simulations
- It can safely accommodate very high en route traffic demands at current separation minima
- It has a very healthy economic perspective [iFly report D6.4]
- The potential problems regarding shared SA have been identified, and a start has been made in recovering from these latent conditions [iFly report D4.2]

Similarities and Differences between Advanced Airborne Self Separation and SESAR2020

- Similarities
  - Reference Business Trajectory based
  - ADS-B In & Out
  - SWIM
  - CDM
  - ASAS, though with more advanced functionality

- Differences
  - Flight crews become responsible for medium and short term conflict detection and resolution
  - Handling of mixed aircraft equipage has not been explored
  - Interfacing with Terminal Areas has not been explored
  - Transition paths have not been explored

Advanced ATM Design Space perspective

- Findings enlarge the feasible advanced ATM Design Space
  - The extreme corner can safely accommodate very high en-route traffic demand.

- The key challenge is how to manage transitions from conventional ATM to a much better point in the design space.
  - Applies as well as SESAR 2020 and NEXTGEN 2025.

- Then it might be of significant value for SESAR and NEXTGEN to know that under adequate ASAS support, flight crew are very well able to safely perform functionalities current done by ground controllers.

Follow-up research

- Identify combinations of SESAR 2020 and Advanced Airborne Self Separation design elements, with focus on:
  - Mixed equipage of aircraft fleet
  - Mixed equipage of ground centres
  - Sharing SA and responsibilities between ATC and Flight crews
- Explore potential transition paths from conventional ATM to these combinations, and compare these against transition paths identified by SESAR 2020
- Evaluate most promising transition paths at the high level key performance indicators, such as safety/capacity and economy,

Questions / Discussion