What en-route traffic demand can safely be accommodated by Advanced Airborne Self Separation?

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Key differences between A3 and AMFF

- Aircraft plan conflict free 4D trajectories (4D intents)
- Aircraft broadcasts these 4D intents to other aircraft
- Conflict detection and resolution take all aircraft into account
- Tactical Separation Minima is down from 5Nm to 3 Nm

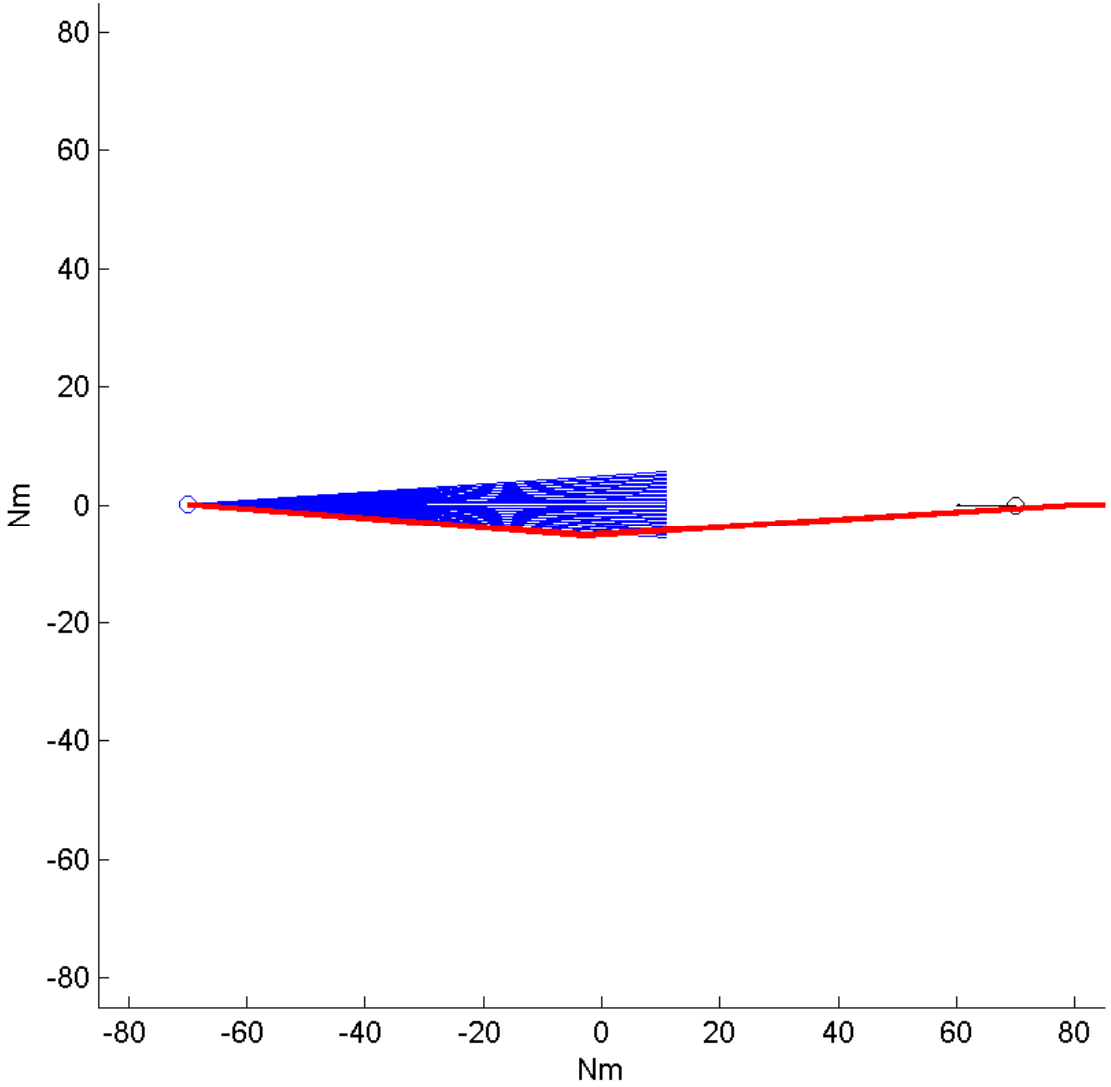
What en-route traffic demand can safely be accommodated?

- CD&R approach
- A3 ConOps modelling
- Monte Carlo simulations
- Conclusions

Medium Term CD&R approach

- Each a/c broadcasts its current 4D plan and its destination; SWIM transfers this over-the-horizon.
- 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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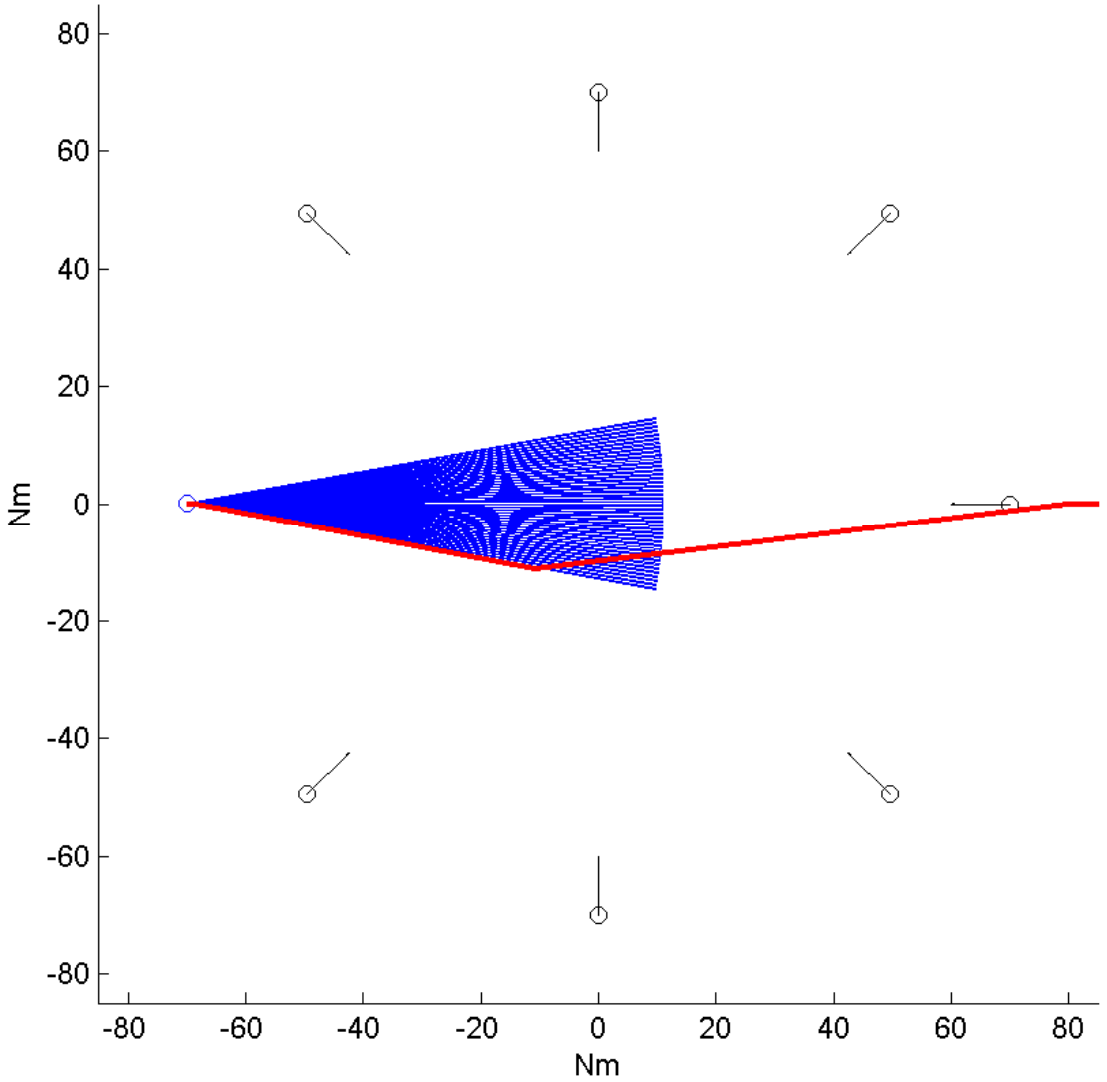

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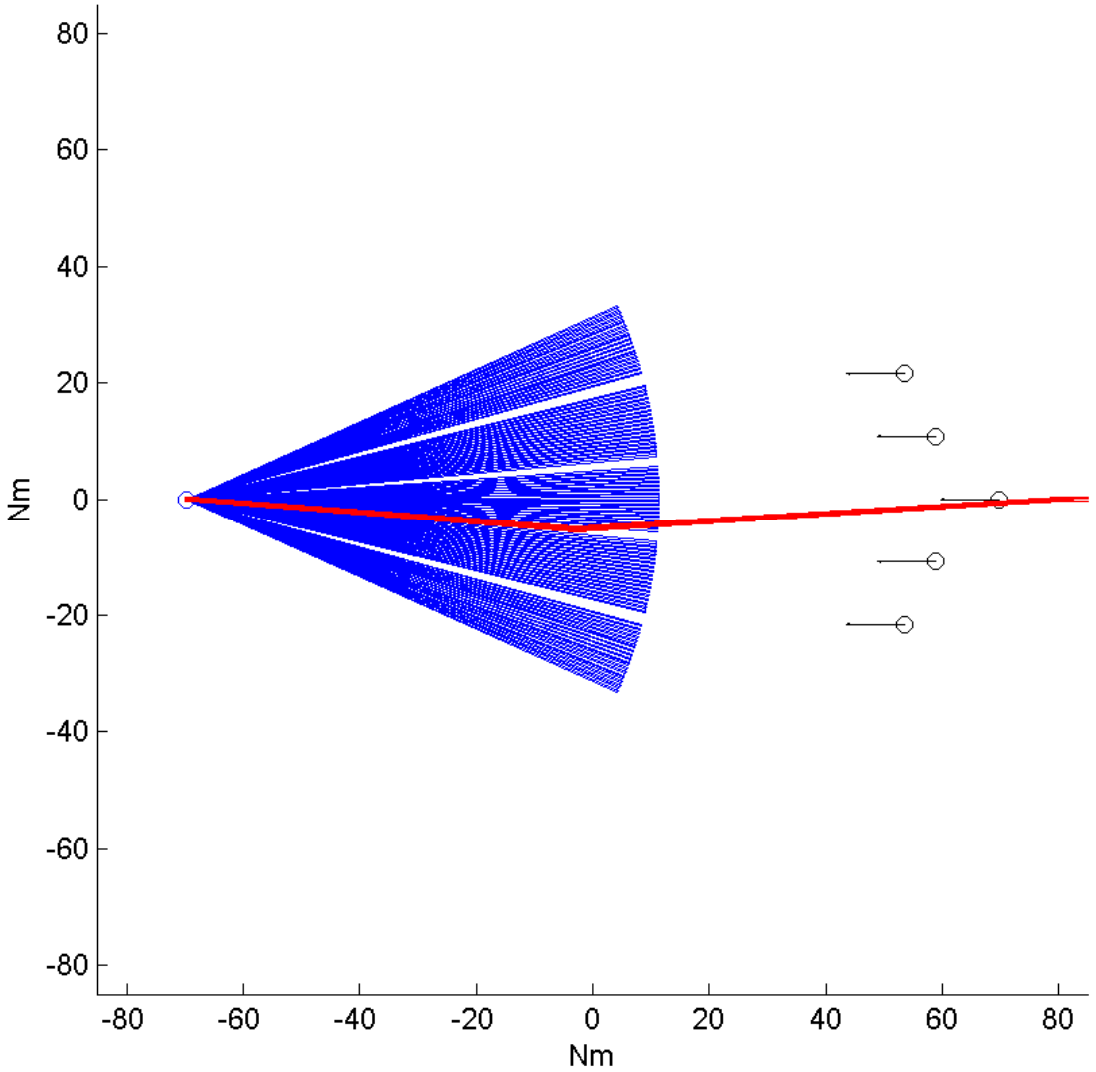
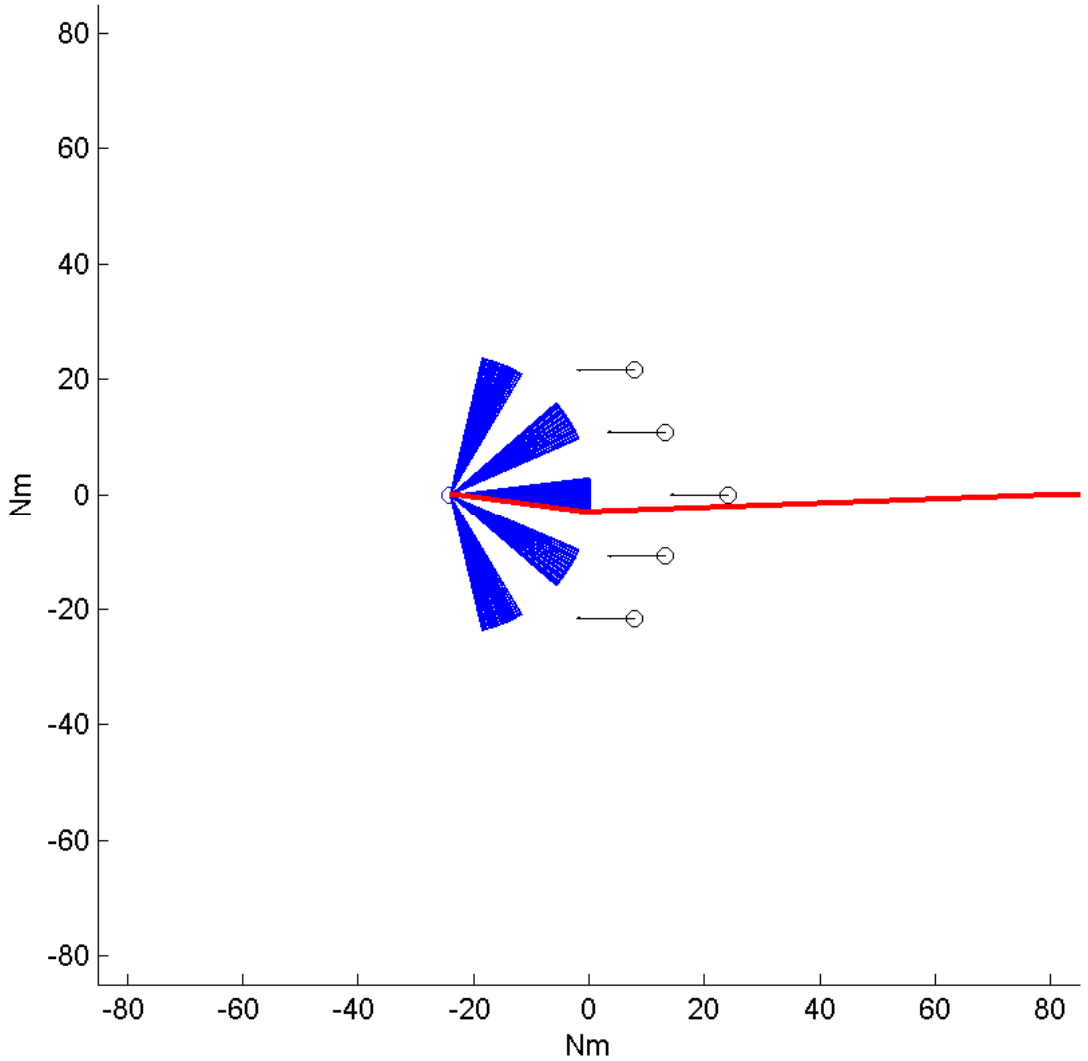


Short Term CD&R approach

- 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

Velocity Obstacles = Collision Cones
Short Term (3 min & 3 Nm)



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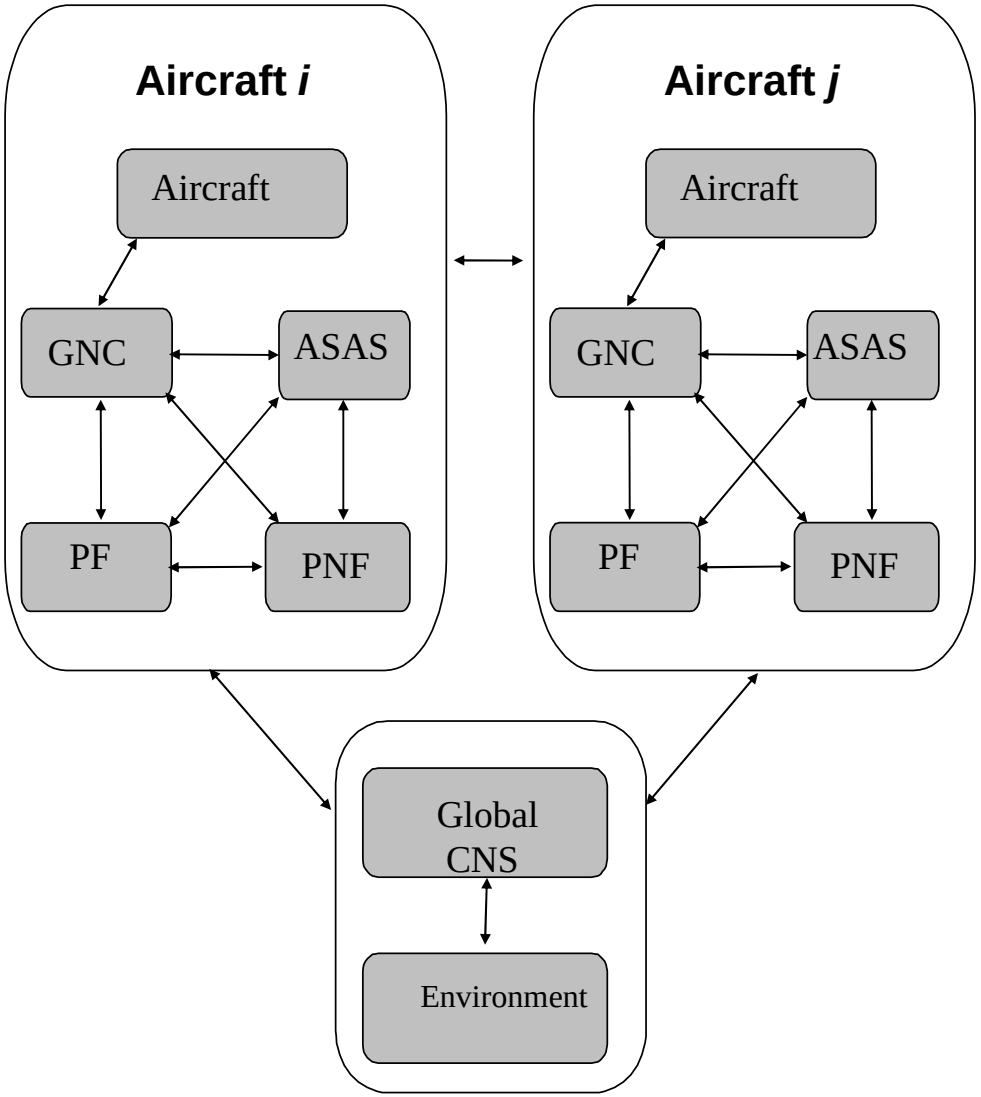
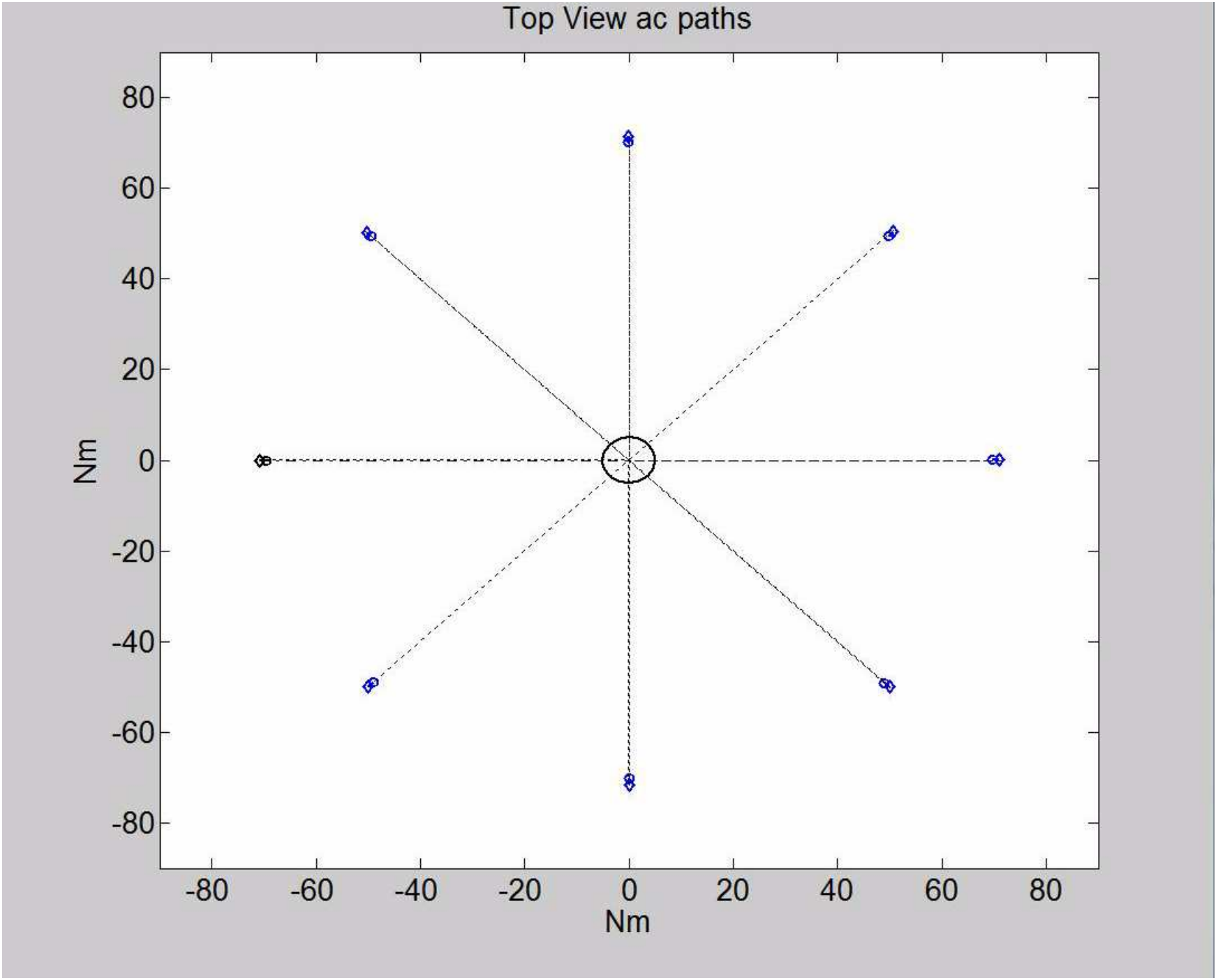
Stochastic modelling and MC simulation

- Hazard identification
- Defining the relevant Agents
- Developing Petri net for each Agent
- Connecting Agent Petri nets
- Parametrization, Verification & Calibration
- Monte Carlo simulation
- Speeding up MC simulation
- Validation

Multi Agent model




Top View ac paths
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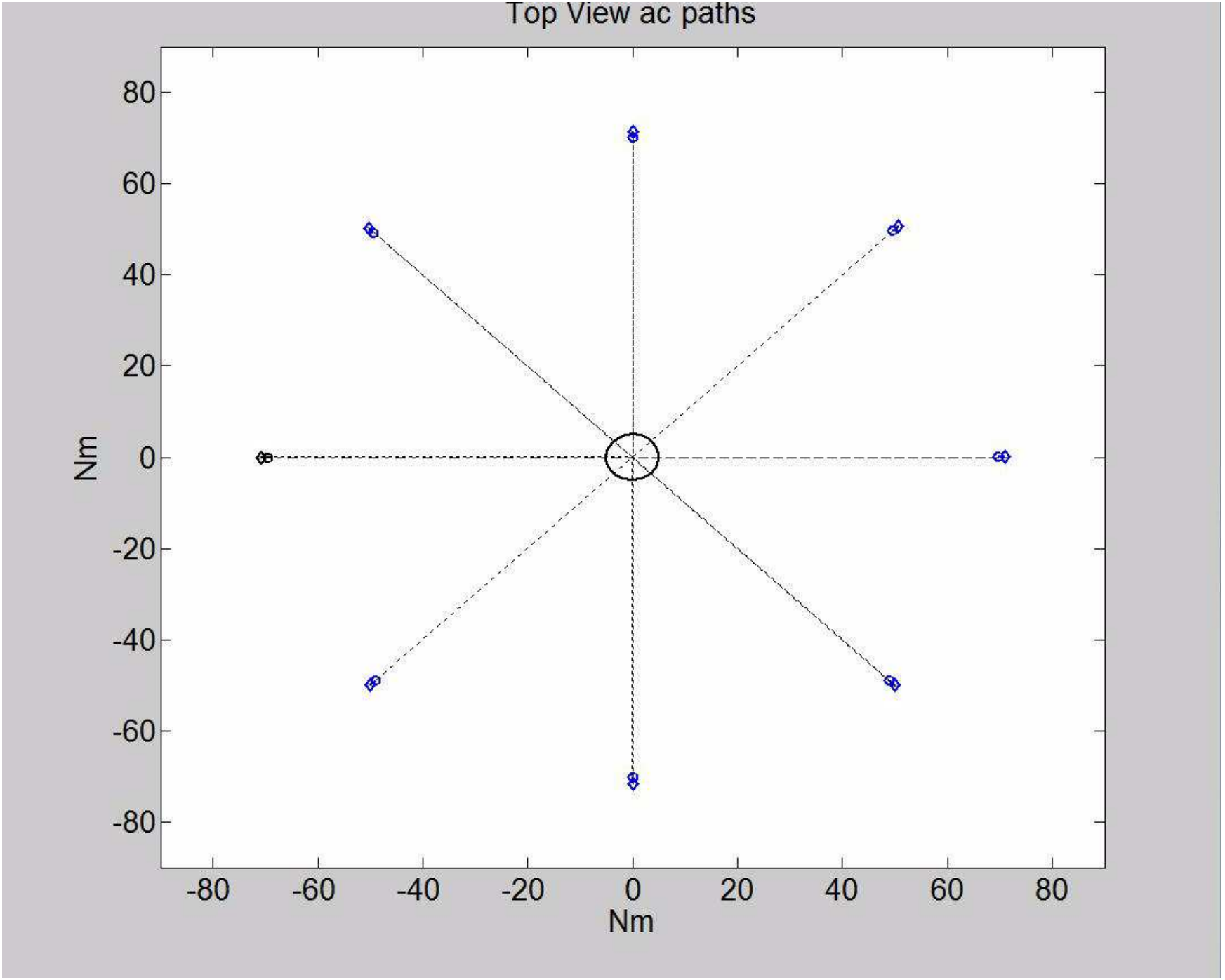
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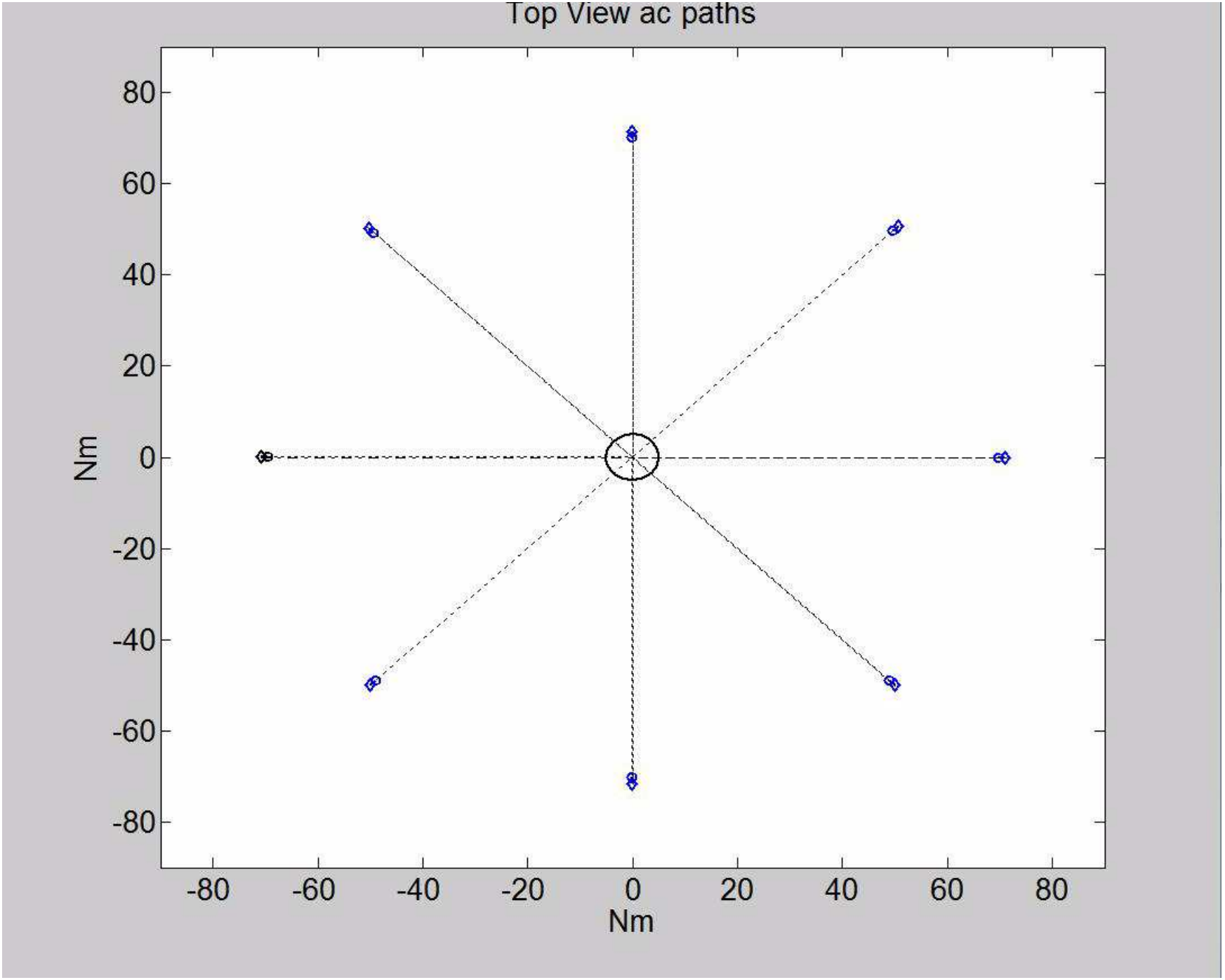
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80
Nm

MC simulation speed up

- **Simulate from one conflict level to conflict level**
- **A fraction of simulations reaches next level**
- **Multiply fractions of these simulations**
- **Conditions for convergence (Cerou et al., 2002)**

Conflict levels in air traffic

MSI = Minimum Separation Infringement
LOS = Loss of Separation (2/3 of MSI)
NMAC = Near Mid-Air Collision
MAC = Mid-Air Collision

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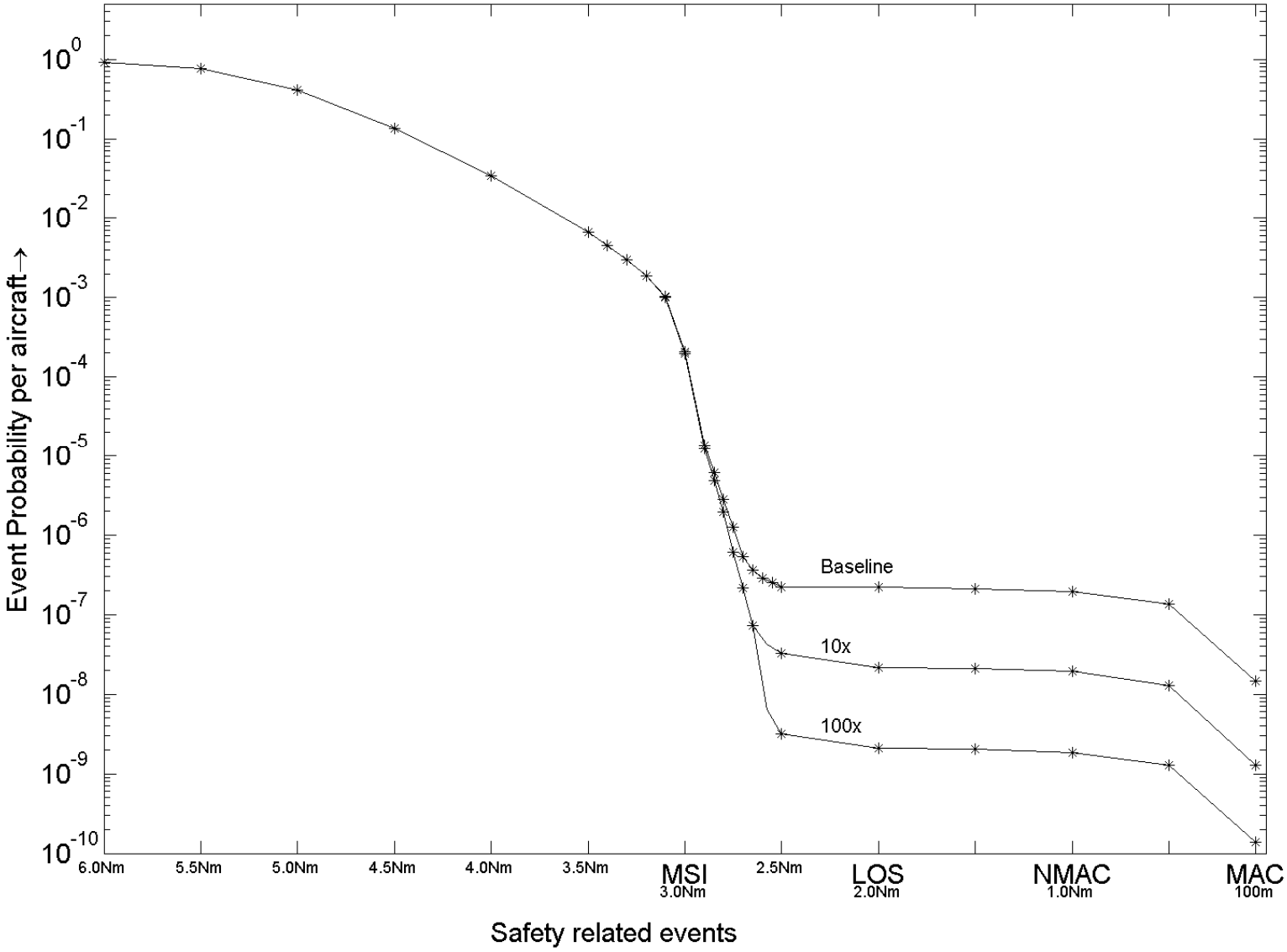
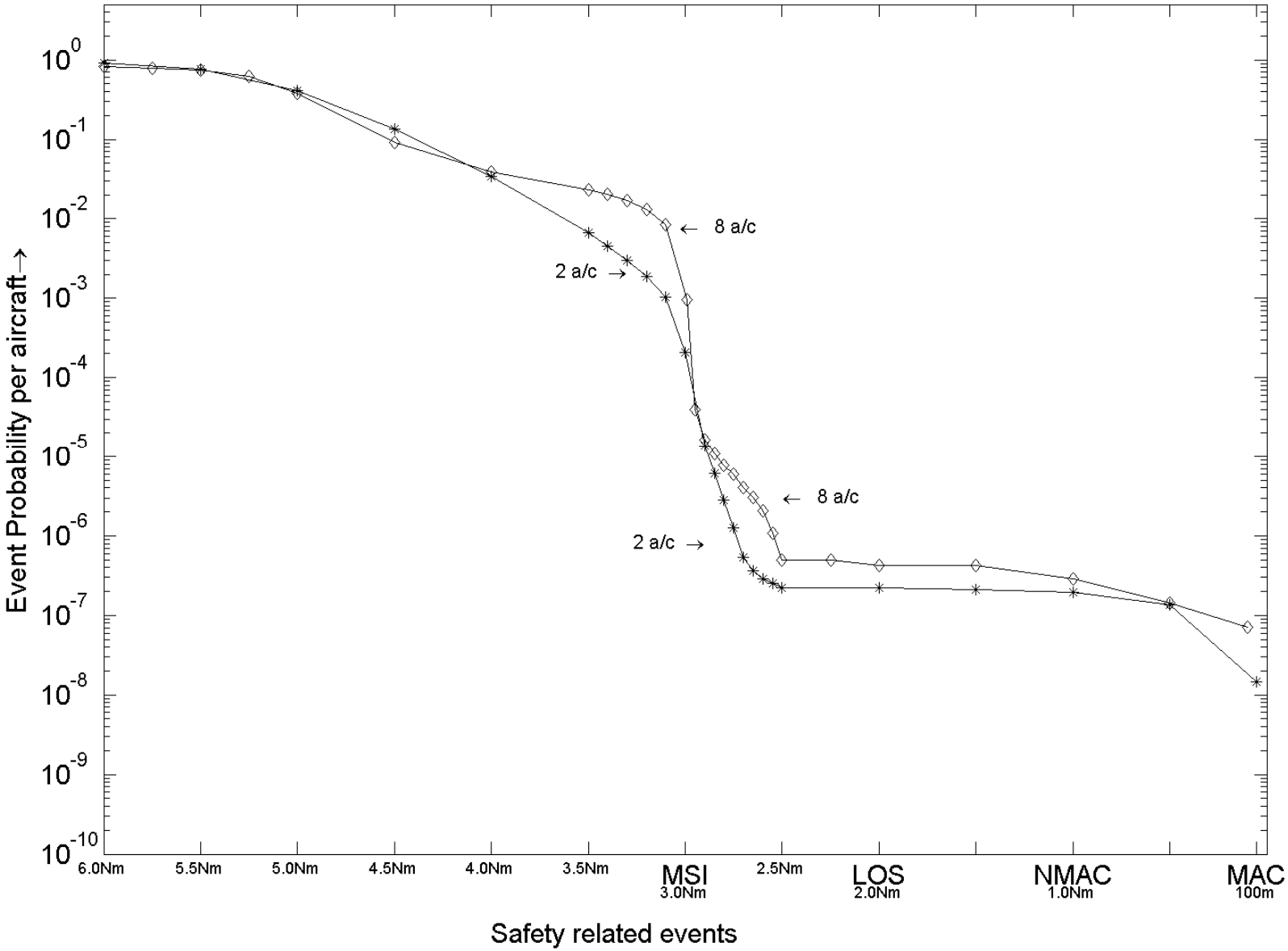
Monte Carlo Simulation Scenarios

- Two aircraft encounter under A3 ConOps
- Eight aircraft encounter under A3 ConOps
- Random traffic high density under A3 ConOps

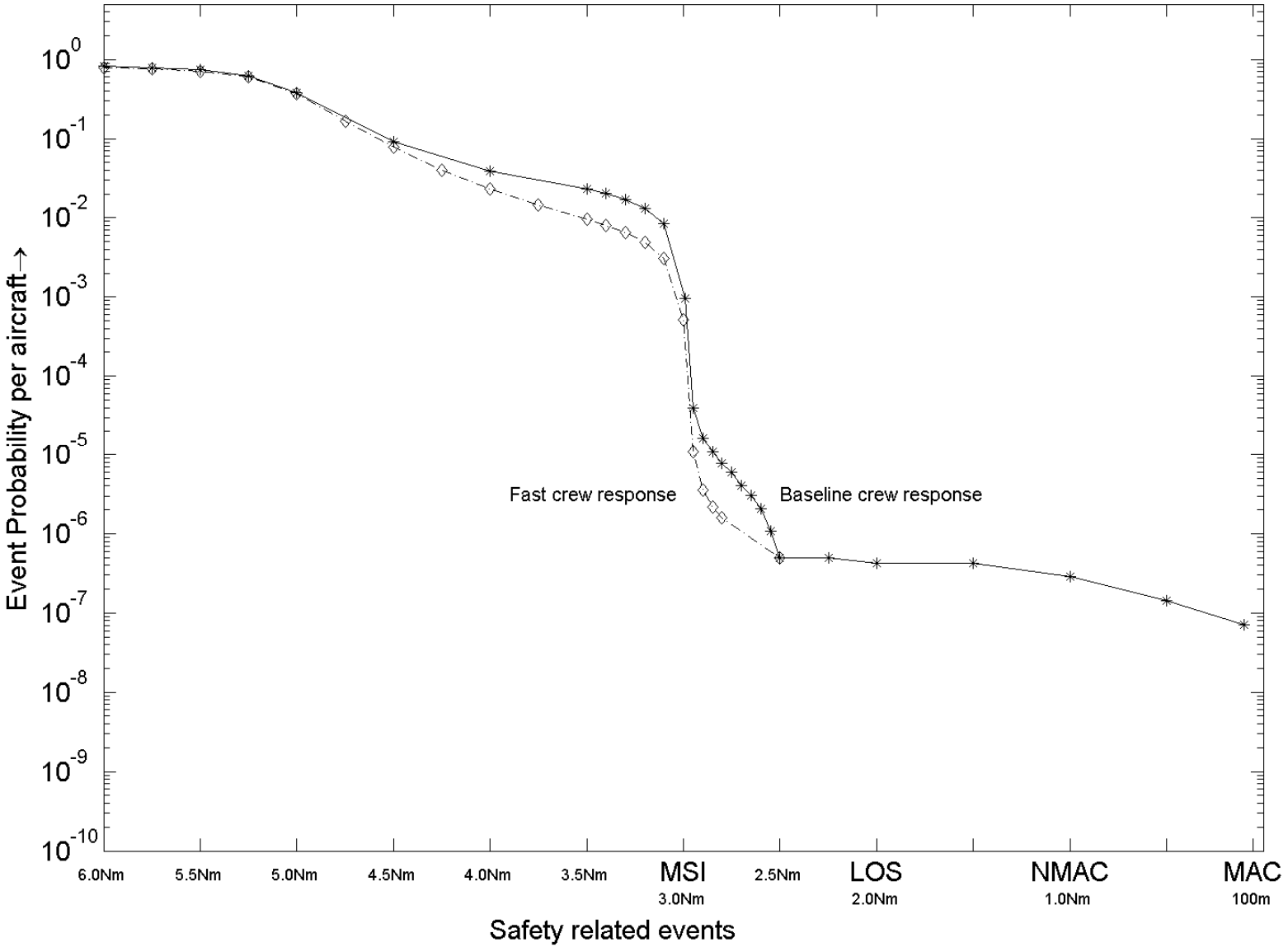
2 a/c, varying ASAS dependability



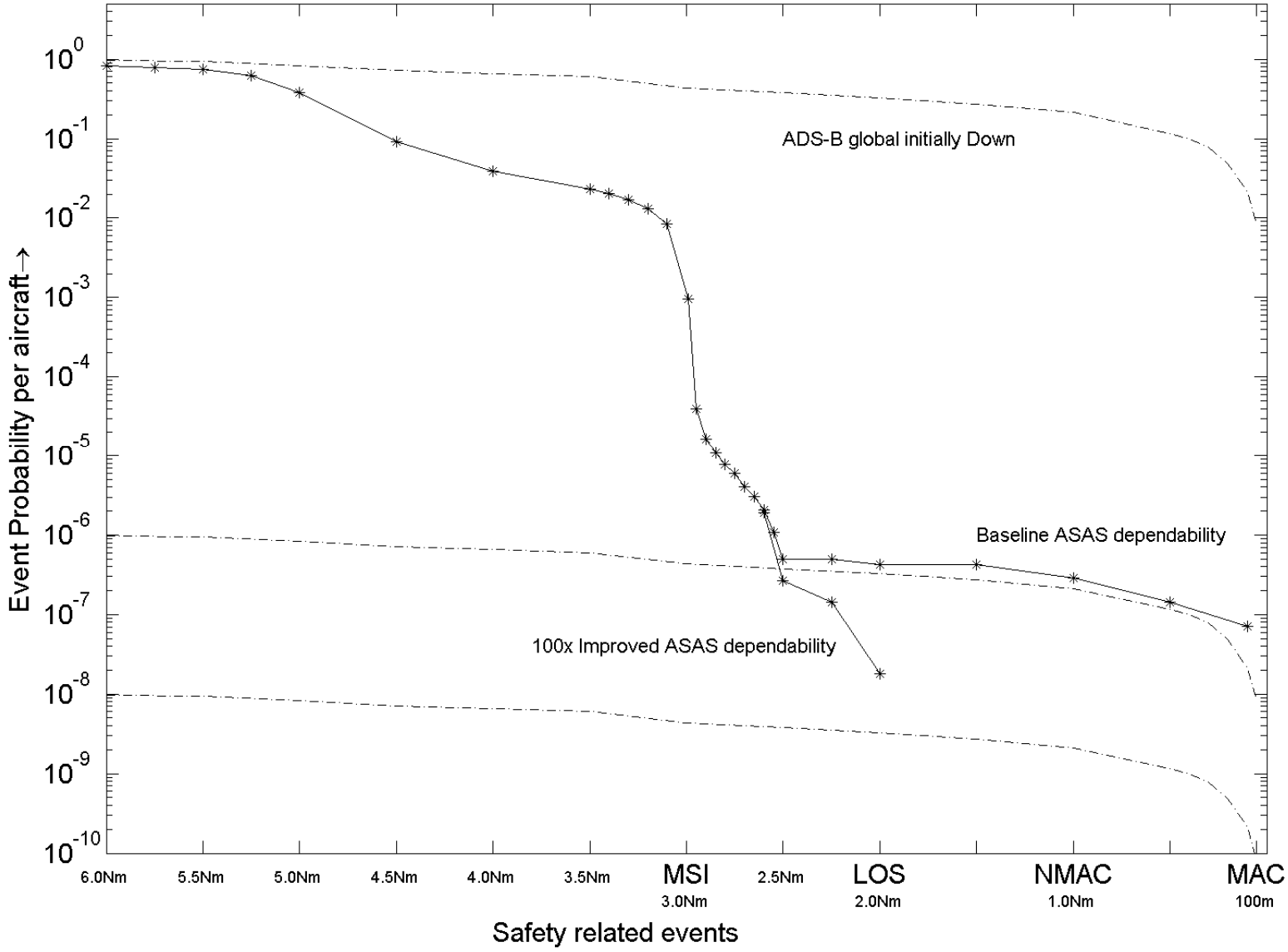
8 a/c versus 2 a/c



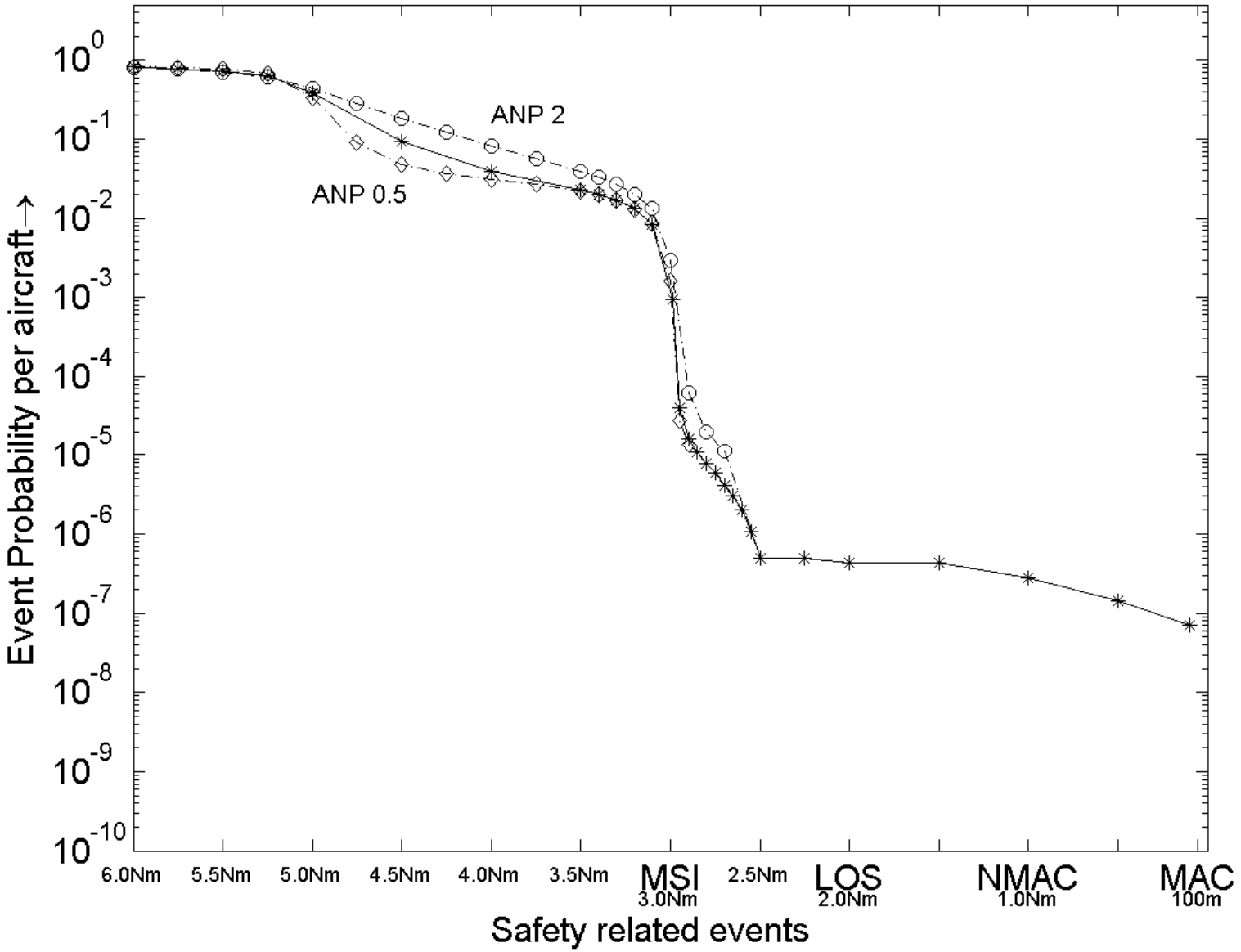
8 a/c, crew response



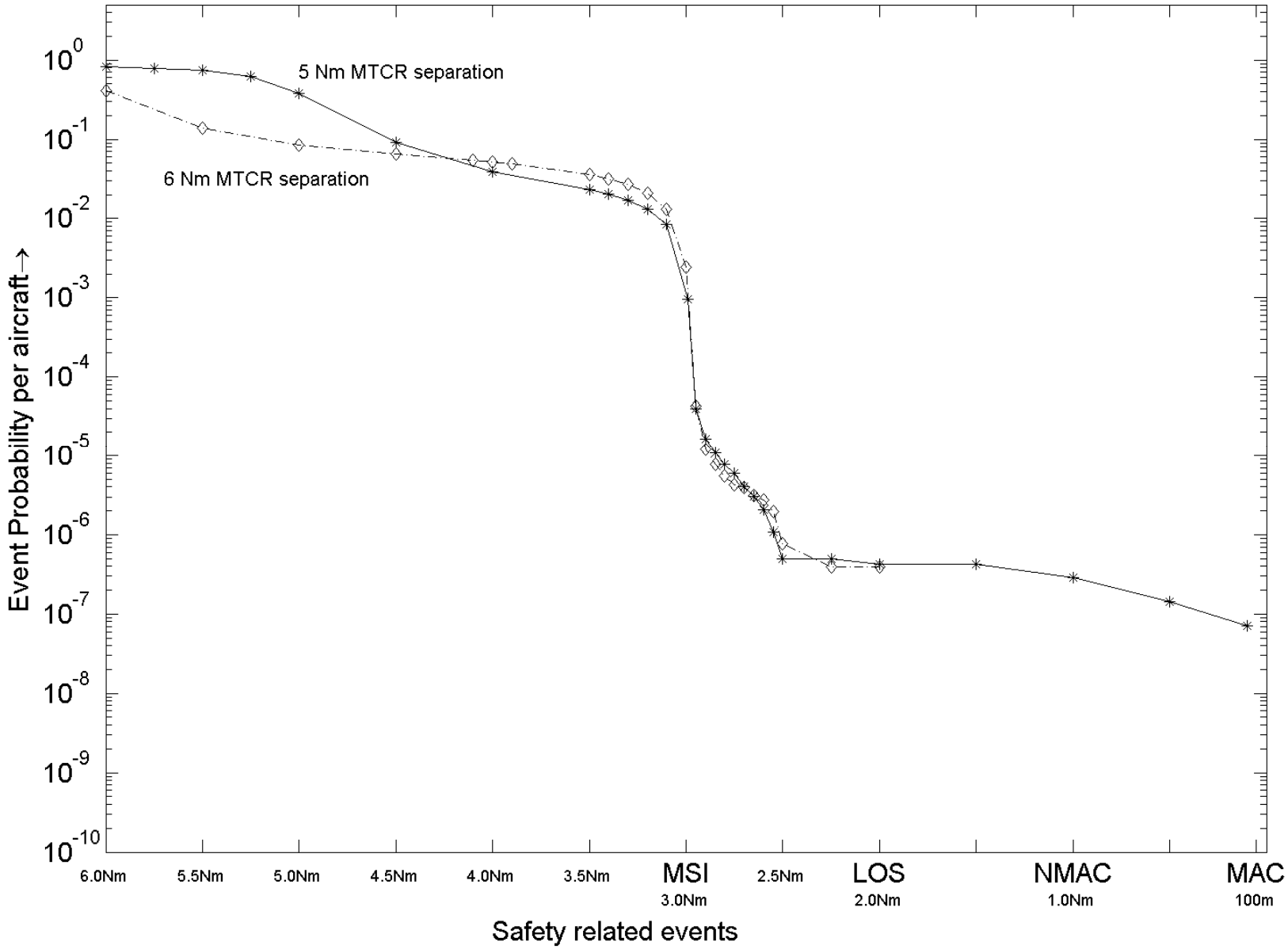
8 a/c. ASAS dependability



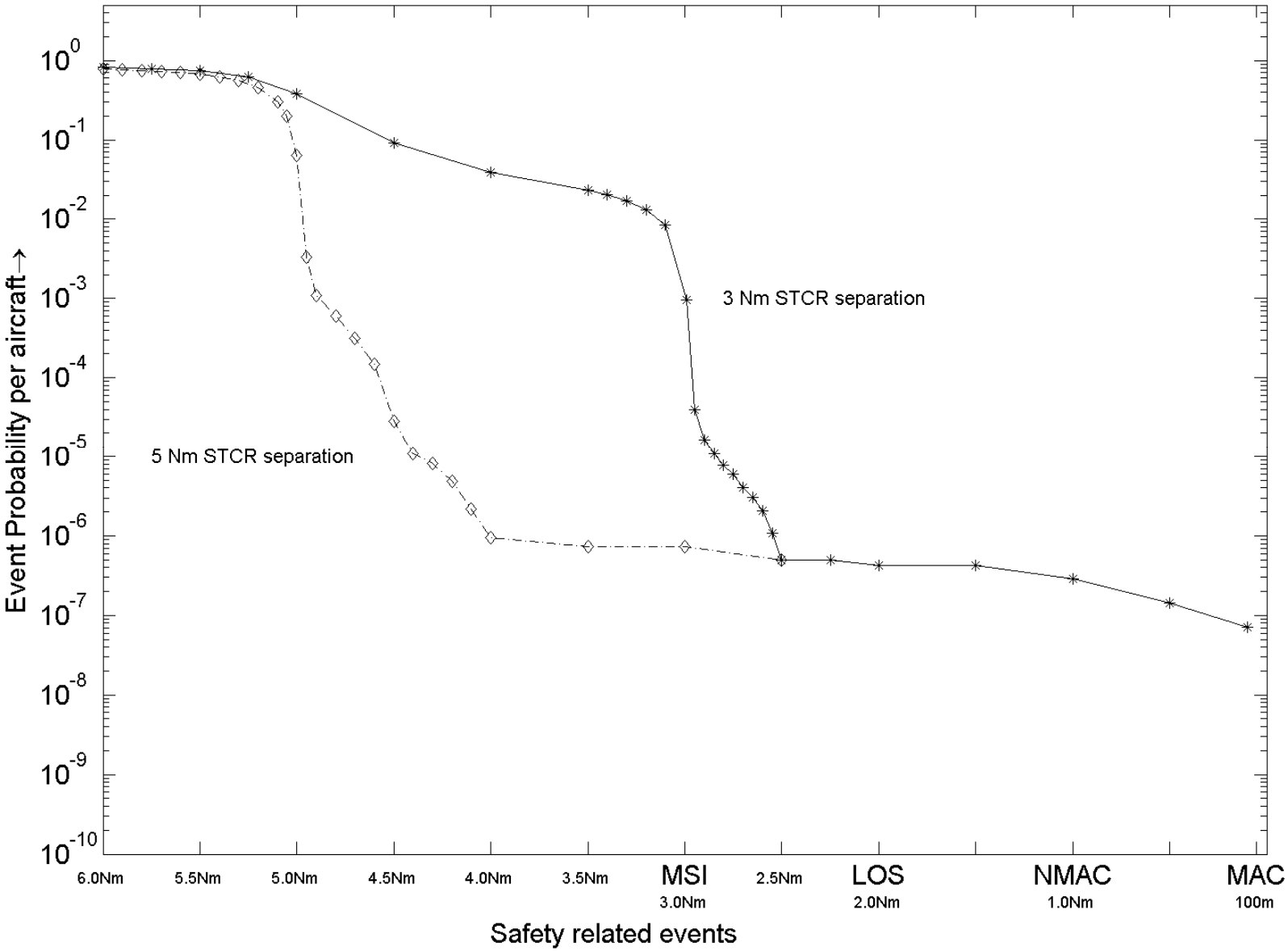
8 a/c, varying ANP



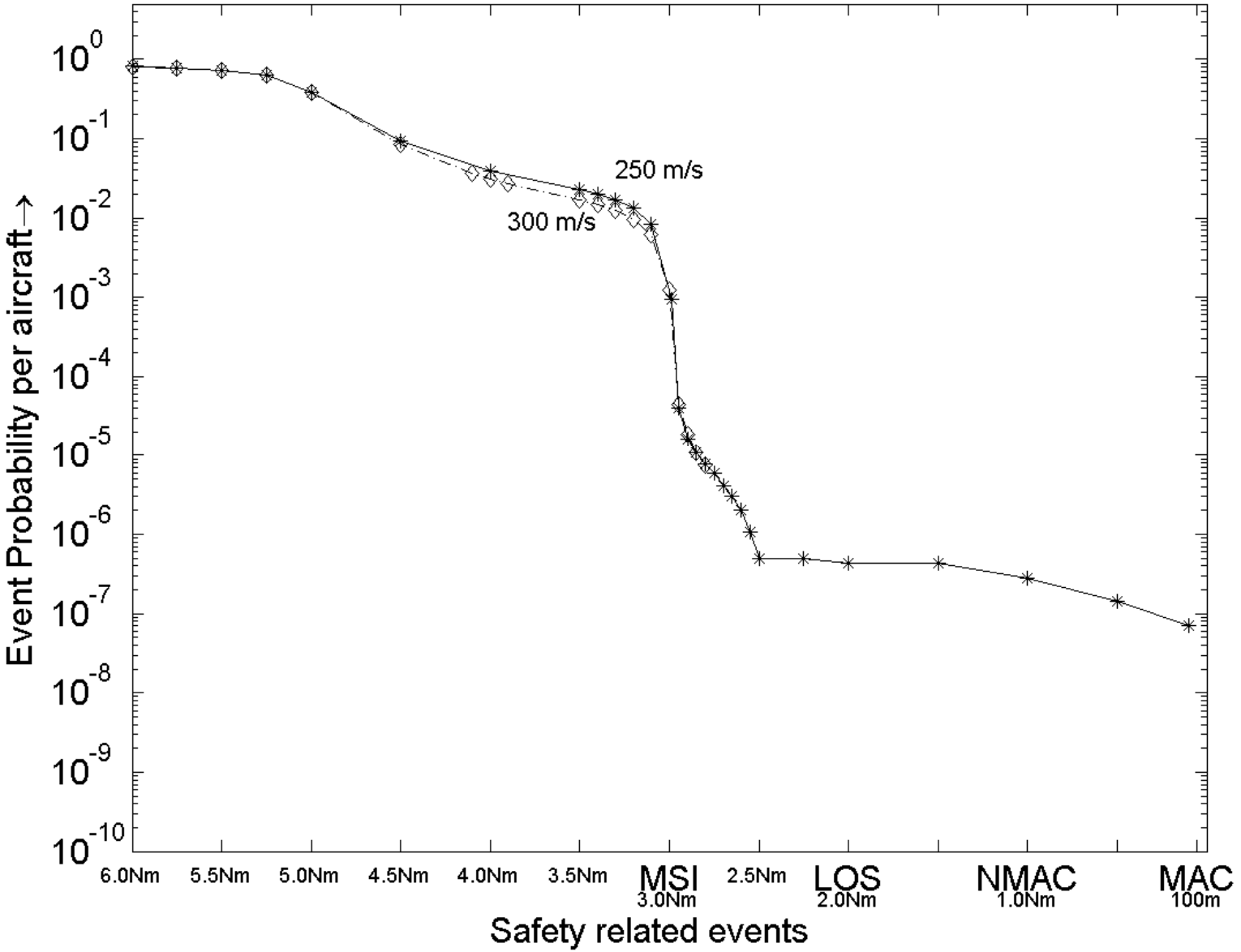
8 a/c, varying MTCR separation



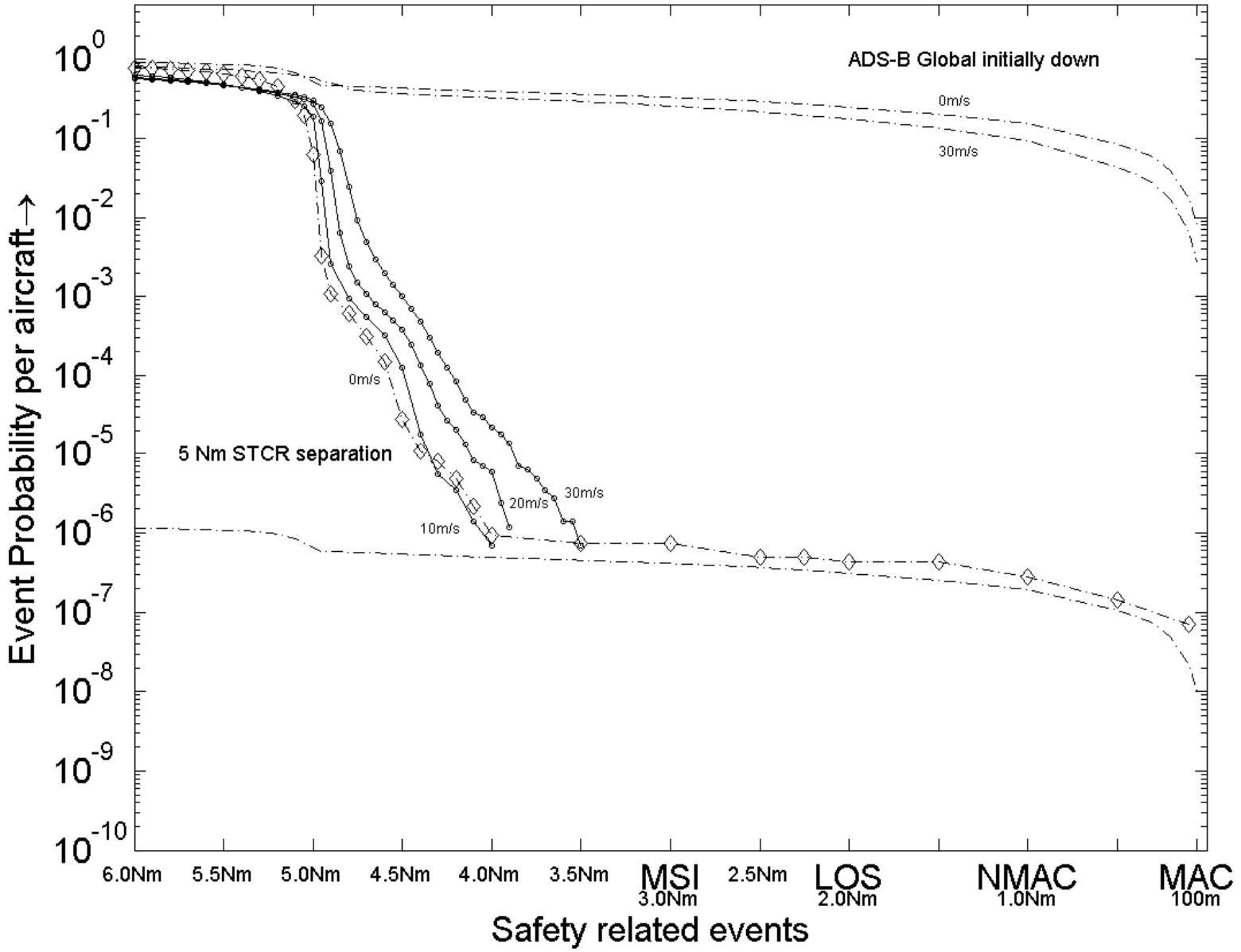
8 a/c, STCR separation back to 5 Nm



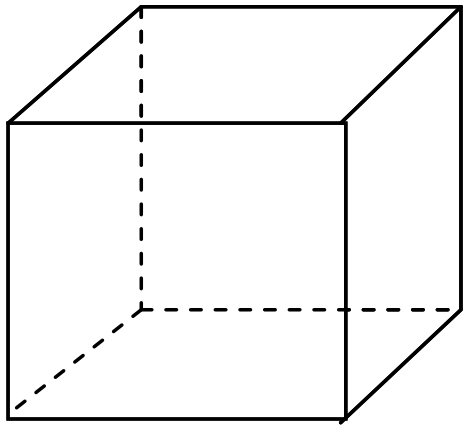
8 a/c, varying speed



8 a/c, systematic wind errors

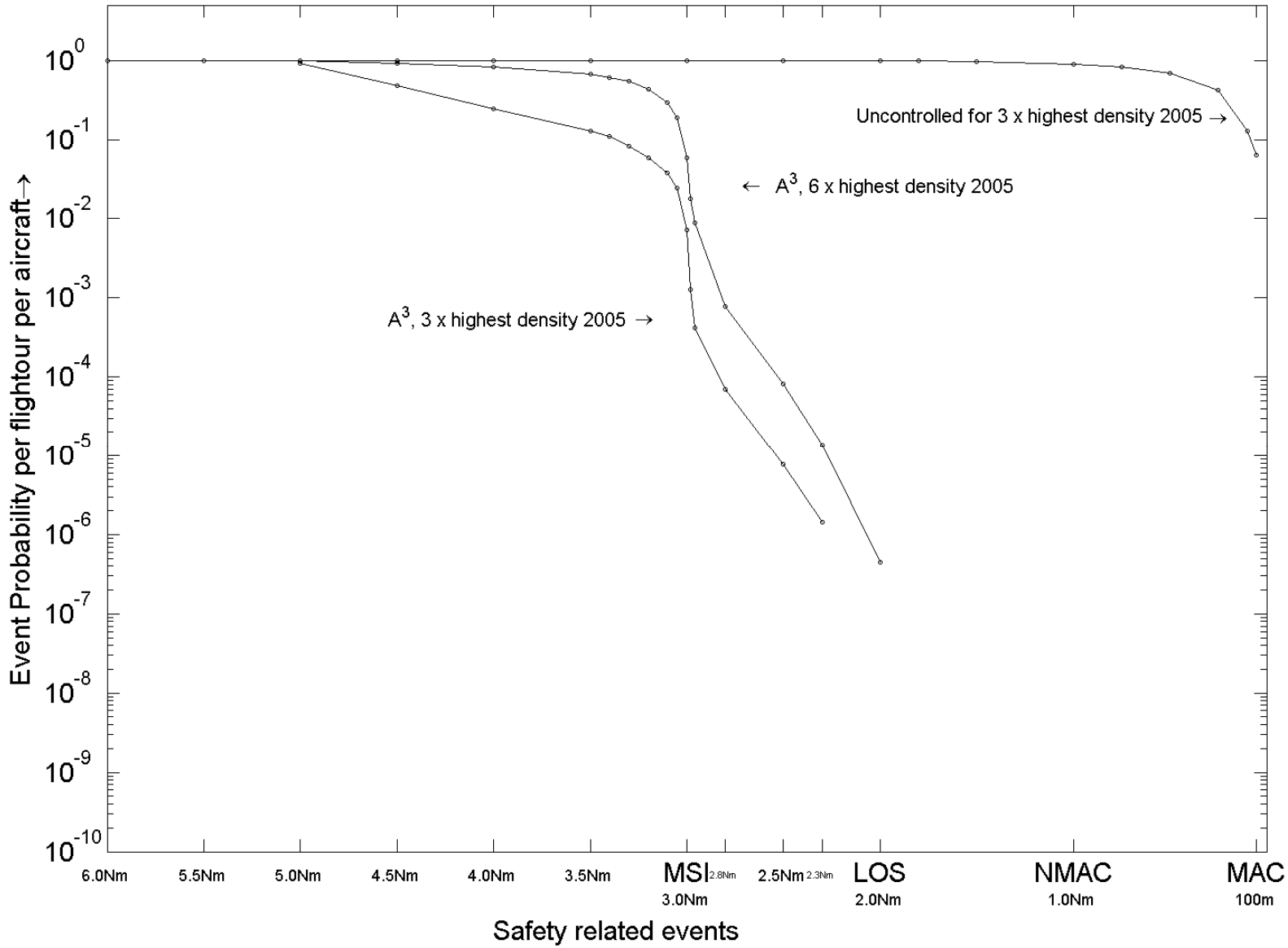


Random Traffic Scenarios

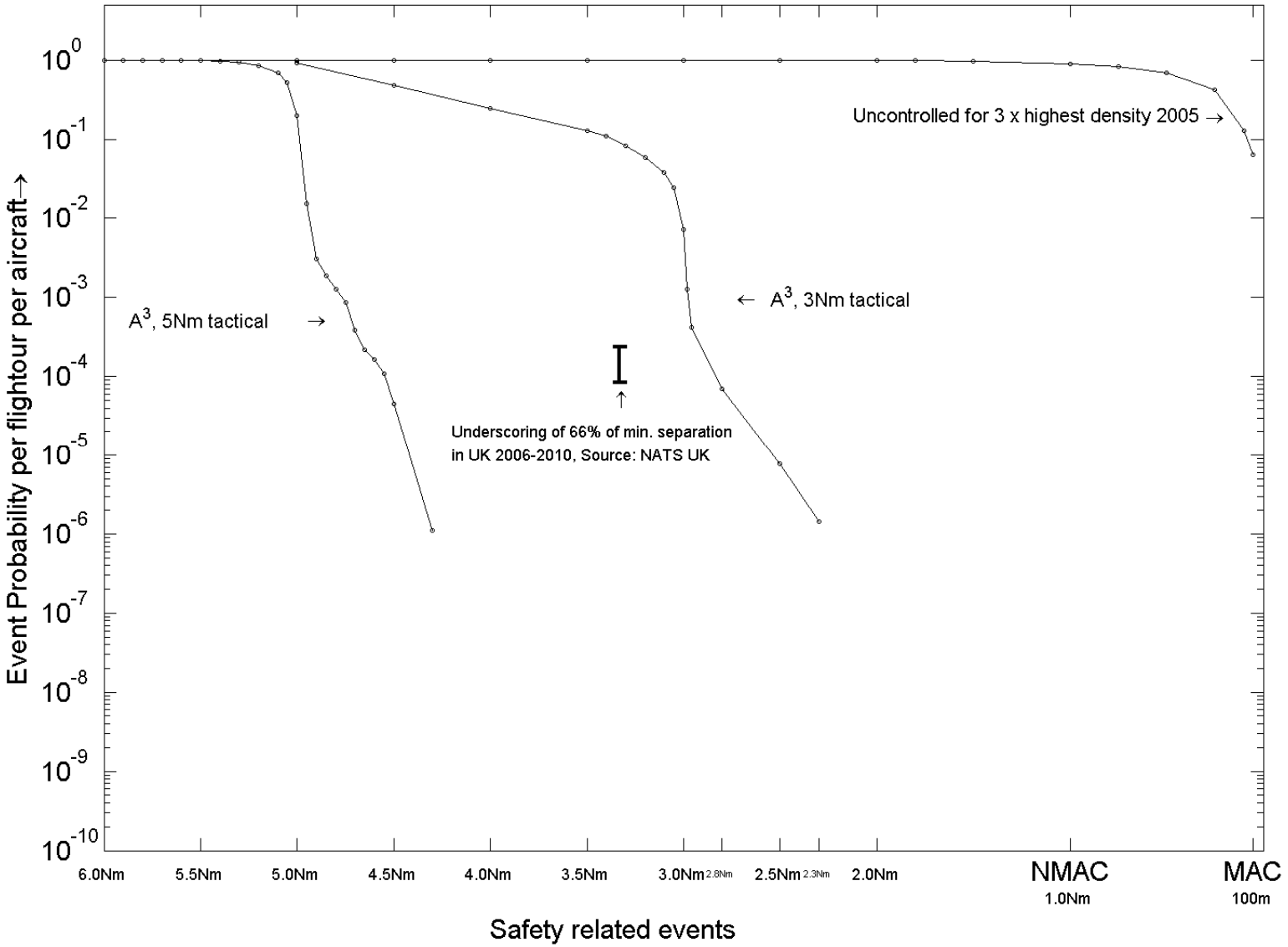


- Periodic Boundary Condition
- Eight a/c per packed box/ no climbing or descending a/c
- Vary container size in order to simulate:
  - 3x as dense as high density area in 2005
  - 6x as dense as high density area in 2005

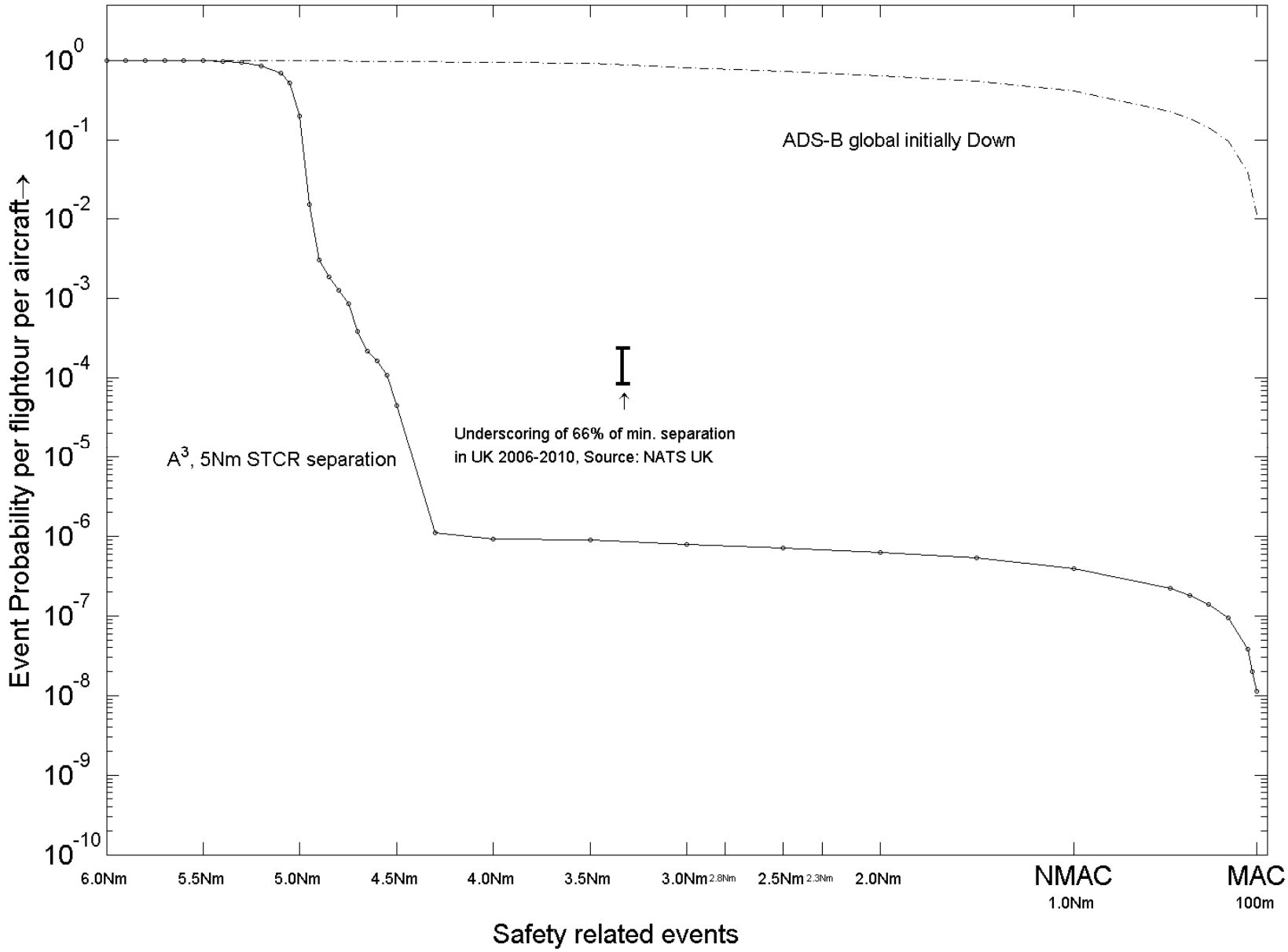
Random traffic: 3x and 6x 2005



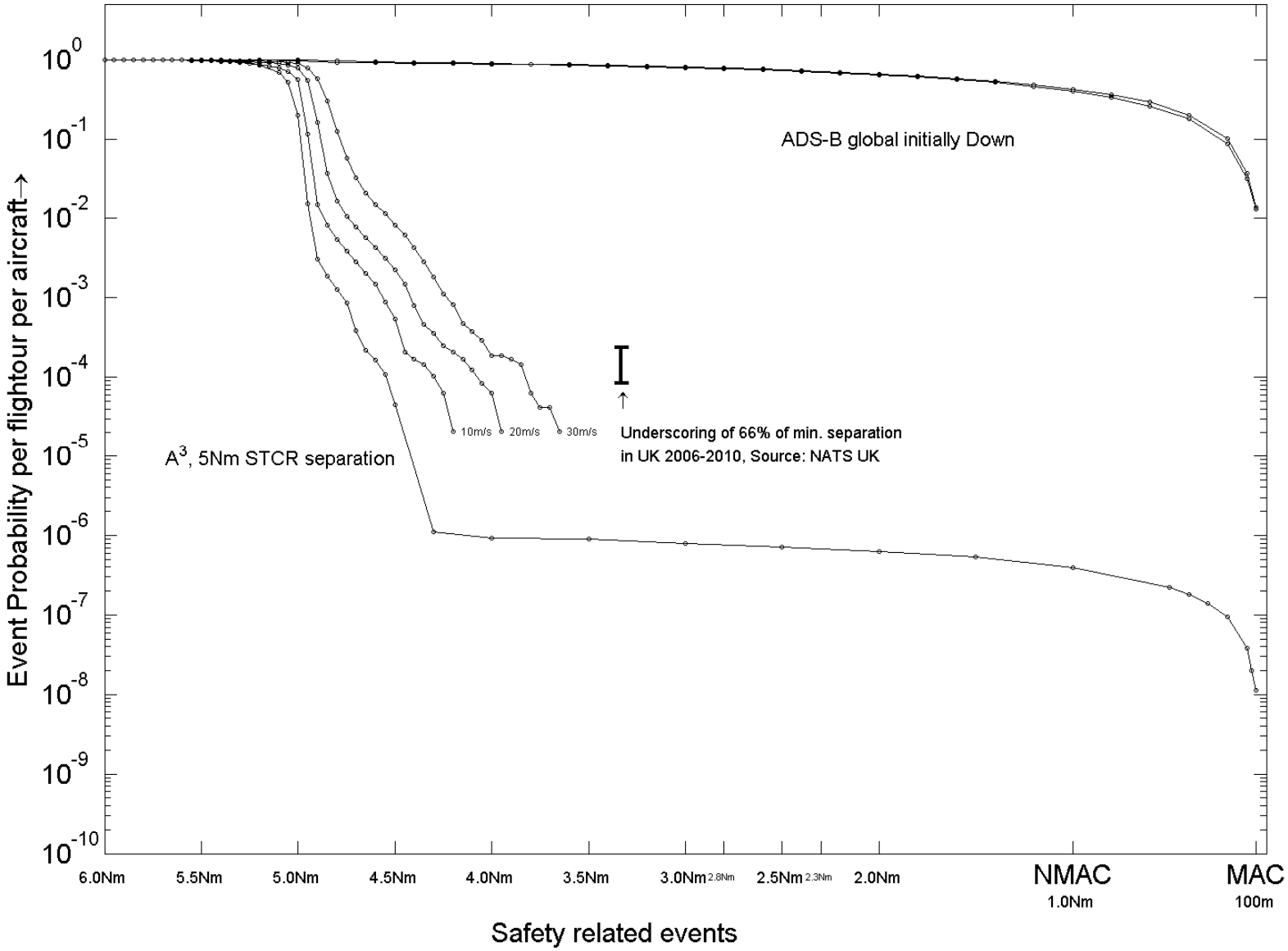
Tactical Separation: 5Nm and 3Nm



3x high 2005 random traffic



3x high 2005 traffic + systematic wind error



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Conclusions

- A3 ConOps with Velocity Obstacles based CD&R algorithms has very good rare event behaviour under very high en-route traffic demand
- NMAC and MAC events have not been observed during the rare event Monte Carlo simulations
- To safely accommodate 3x more traffic than high 2005, Tactical Separation distance can stay at 5 Nm
- Various other aspects studied in separate Work Packages:
  - CD&R algorithms more advanced than Velocity Obstacles
  - Shared Situation Awareness
  - Cost Benefit

Reporting of the safety results

Completion of iFly safety analysis and corresponding reports:

- D7.2g Final report on Monte Carlo speed-up
  - To explain techniques used to accelerate the Rare Event Monte Carlo simulations
- D7.4 Final report on A3 ConOps safety evaluation
  - Including initial sensitivity analysis
- These reports have been submitted to EC, and will appear on the iFly web site: http://iFly.nlr.nl

Questions / Discussion

iFly

What are the potential benefits for SESAR and NEXTGEN ?

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Airborne Self Separation Findings

- Pilots like it, if they know that ASAS supporting systems are dependable
- Dependability requirements have been identified using RTCA DO-246 (=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
- The proper working of advanced Conflict Detection and Resolution algorithms has been demonstrated
- The potential problems regarding shared SA have been identified, and a start has been made in recovering from these latent conditions

Main Differences and Similarities between A3 ConOps and SESAR2020

- 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 yet
  - Transition paths have not been explored yet

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

Advanced ATM Design Space perspective

- iFly does not claim that A3 ConOps is THE future solution.
- iFly findings enlarge the feasible advanced ATM Design Space;
  - A3 ConOps forms an extreme corner of this design space.
- High level assessment of this extreme corner has shown it 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 to A3 ConOps 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 A3 ConOps design elements and SESAR 2020 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 the transition paths identified sofar for SESAR 2020

- Evaluate most promising transition paths at the high level key performance indicators, such as safety/capacity and economy,

Questions / Discussion