



# Simulated collision risk of uncoordinated airborne self separation

by

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# Simulated collision risk of uncoordinated airborne self separation



- Motivation
- AMFF (Autonomous Mediterranean Free Flight)
- MC simulation modelling
- MC simulation results
- Conclusions





# Motivation



- Free Flight has been “invented” as a potential solution for high density airspace
- During recent years ATM community research trend is to direct self separation research to situations of less dense airspace (e.g. MFF, ASSTAR)
- Key question: up to which en-route traffic density is safe free flight feasible?





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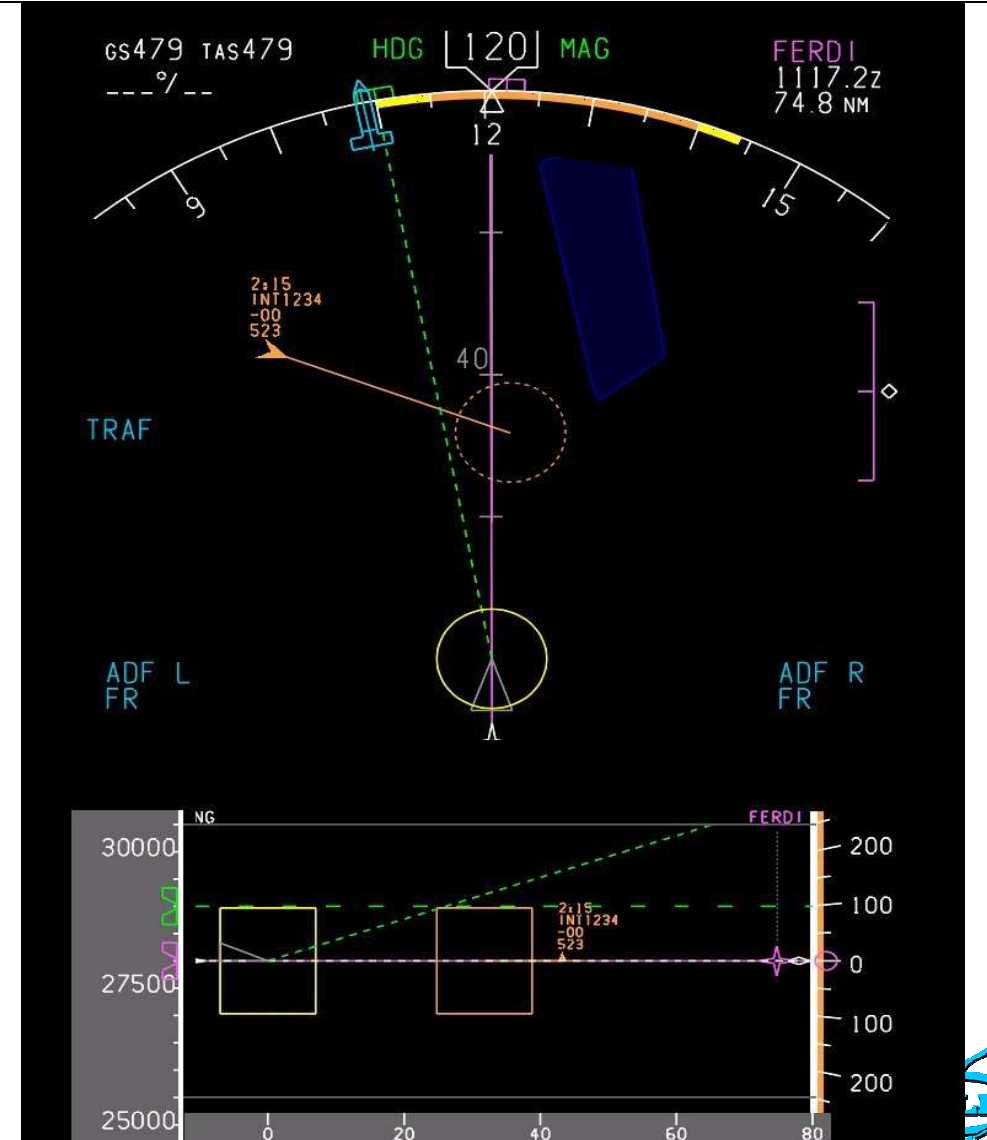
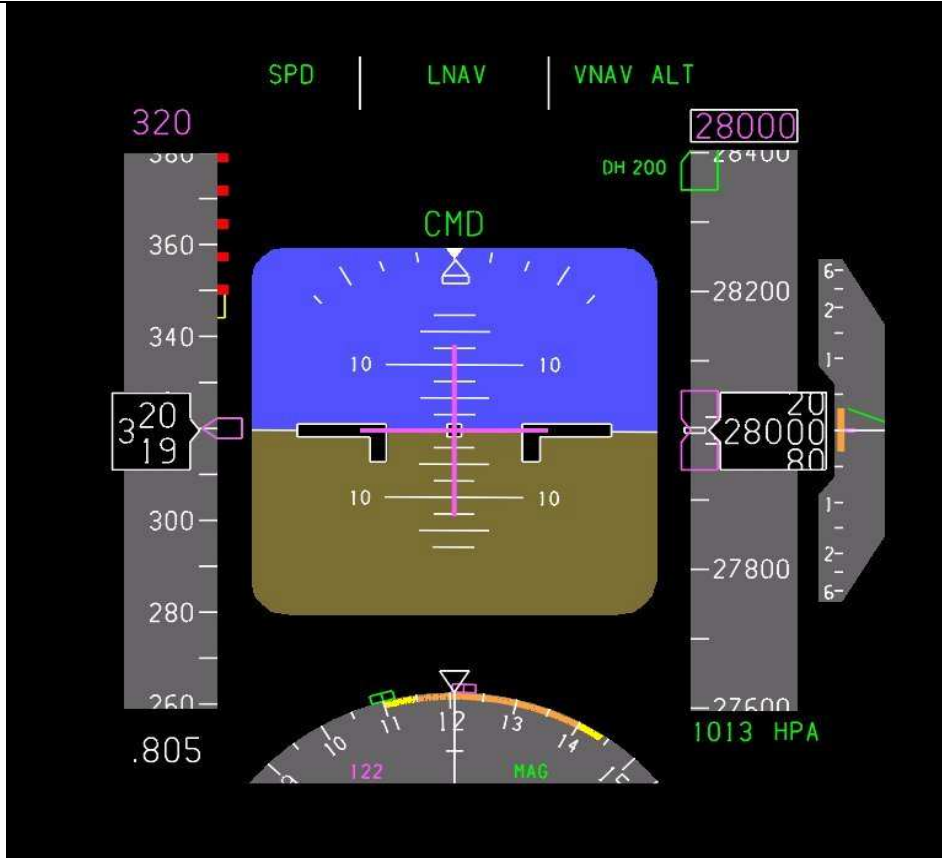


# Autonomous Mediterranean Free Flight (AMFF)



- Future concept developed for traffic over Mediterranean area
- Aircrew gets freedom to select path and speed
- In return aircrew is responsible for self-separation
- Each a/c equipped with ASAS (Airborne Separation Assistance System)
- Conflicts are solved one by one (pilot preference)







## Evaluations performed by MFF project

- Real-time pilot-in-the-loop simulations
- Eurocae/RTCA ED78a safety assessment

**Can AMFF accommodate high traffic demand ?**





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# Systemic modelling and simulation using TOPAZ methodology

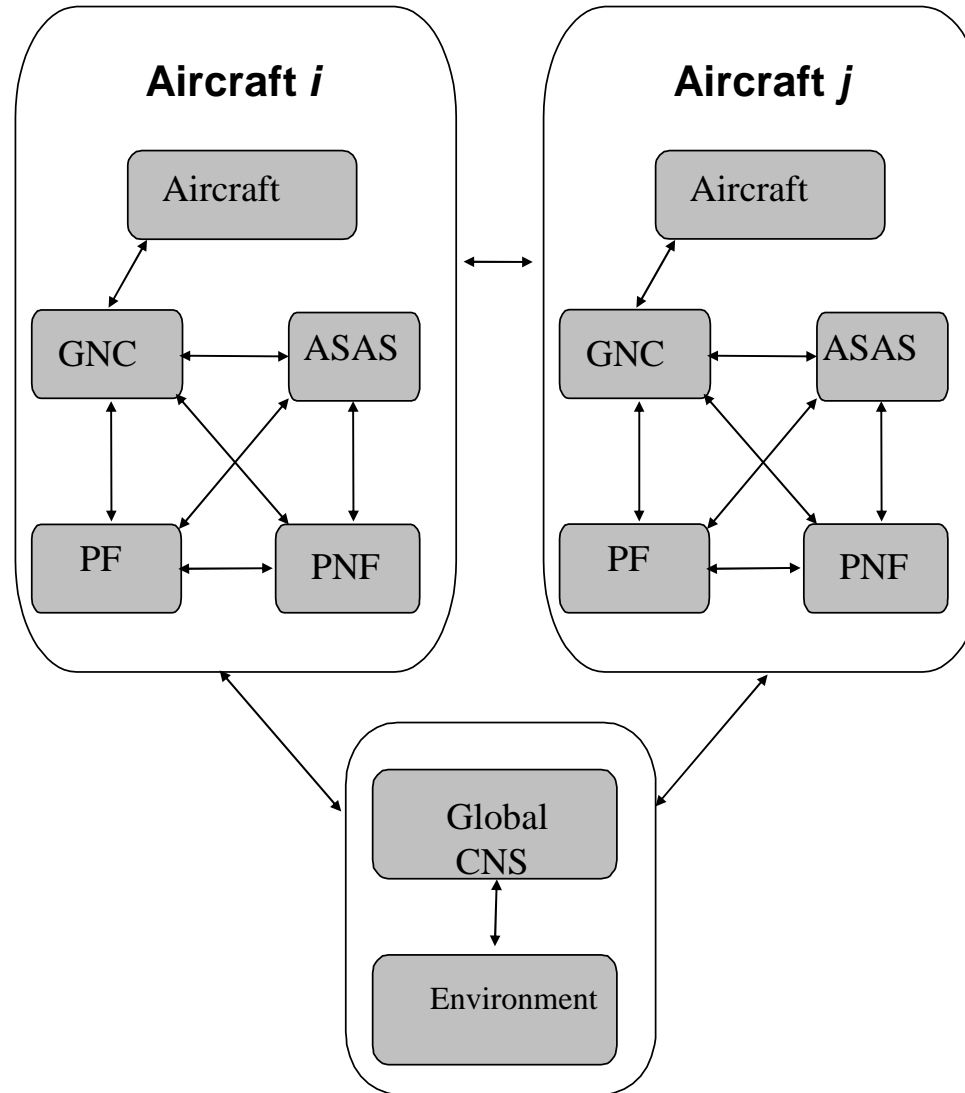


- Hazard identification
- Defining the relevant Agents
- Developing Petri net for each Agent
- Connecting Agent Petri nets
- Parametrization, Verification & Calibration
- Monte Carlo simulation
- Speeding up MC simulation
- Validation



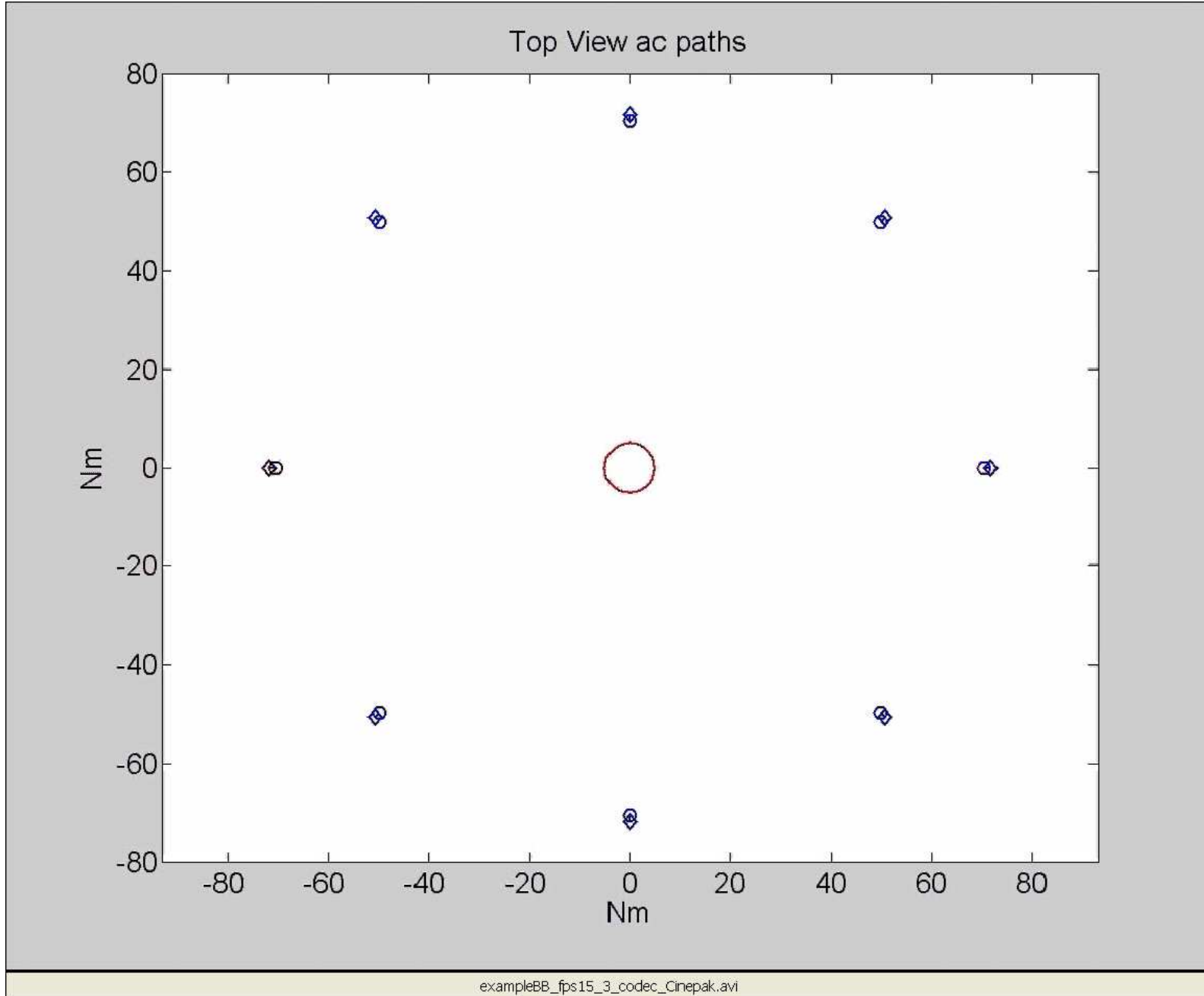


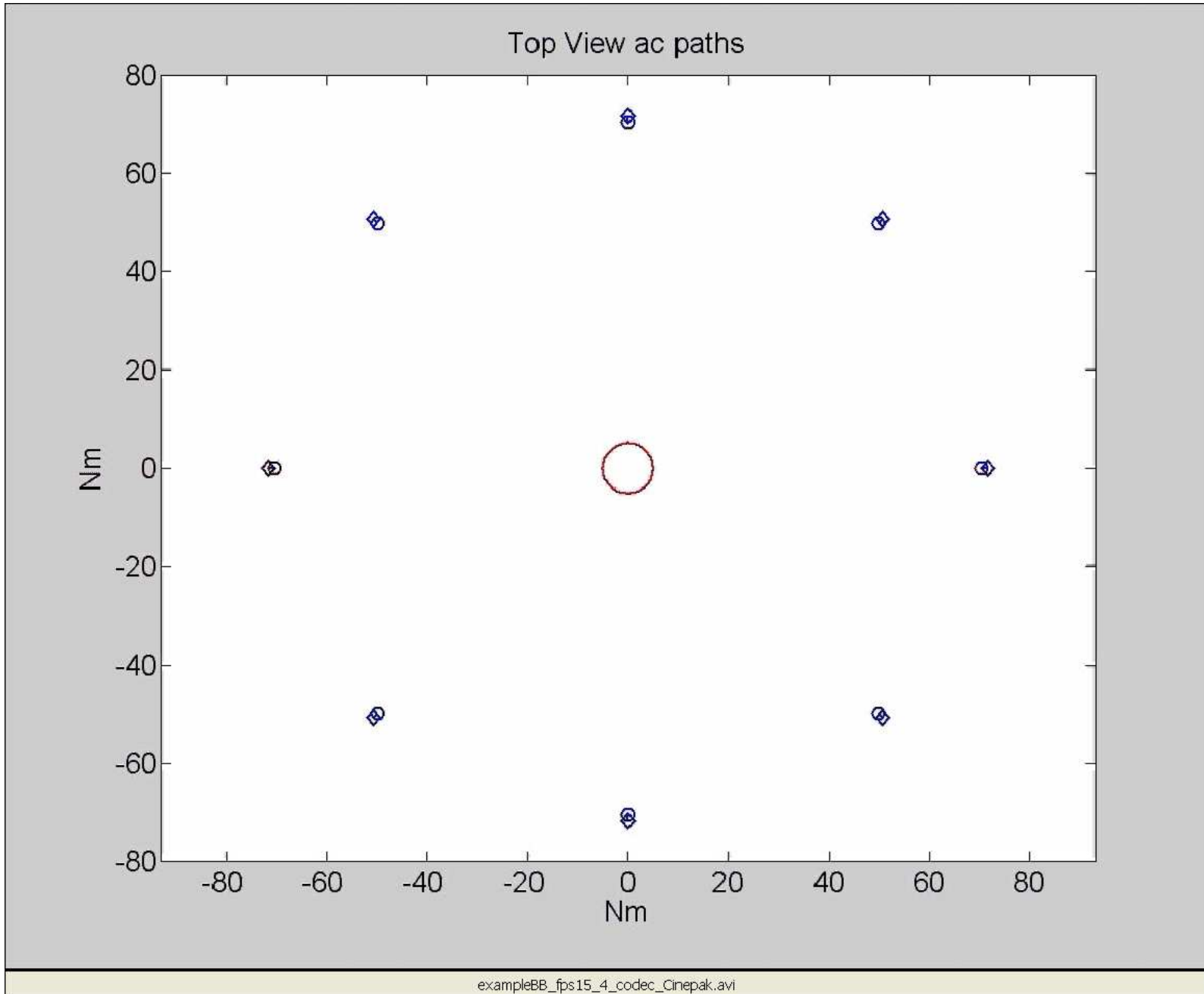
# Multi Agent model

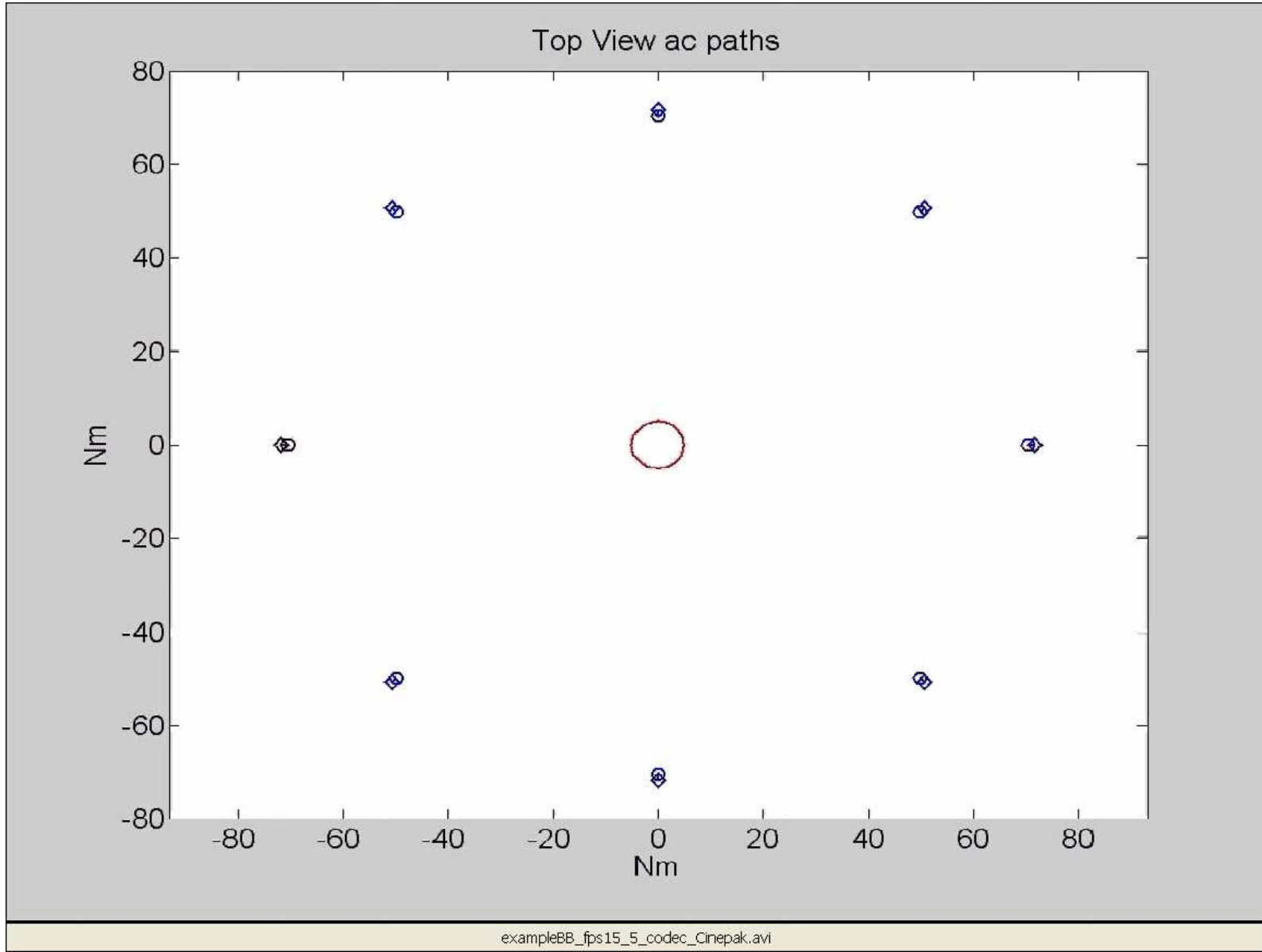




# Eight aircraft encounter









# 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

MTC = Medium Term Conflict

STC = Short Term Conflict

MSI = Minimum Separation Infringement

NMAC = Near Mid-Air Collision

MAC = Mid-Air Collision





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# Scenarios

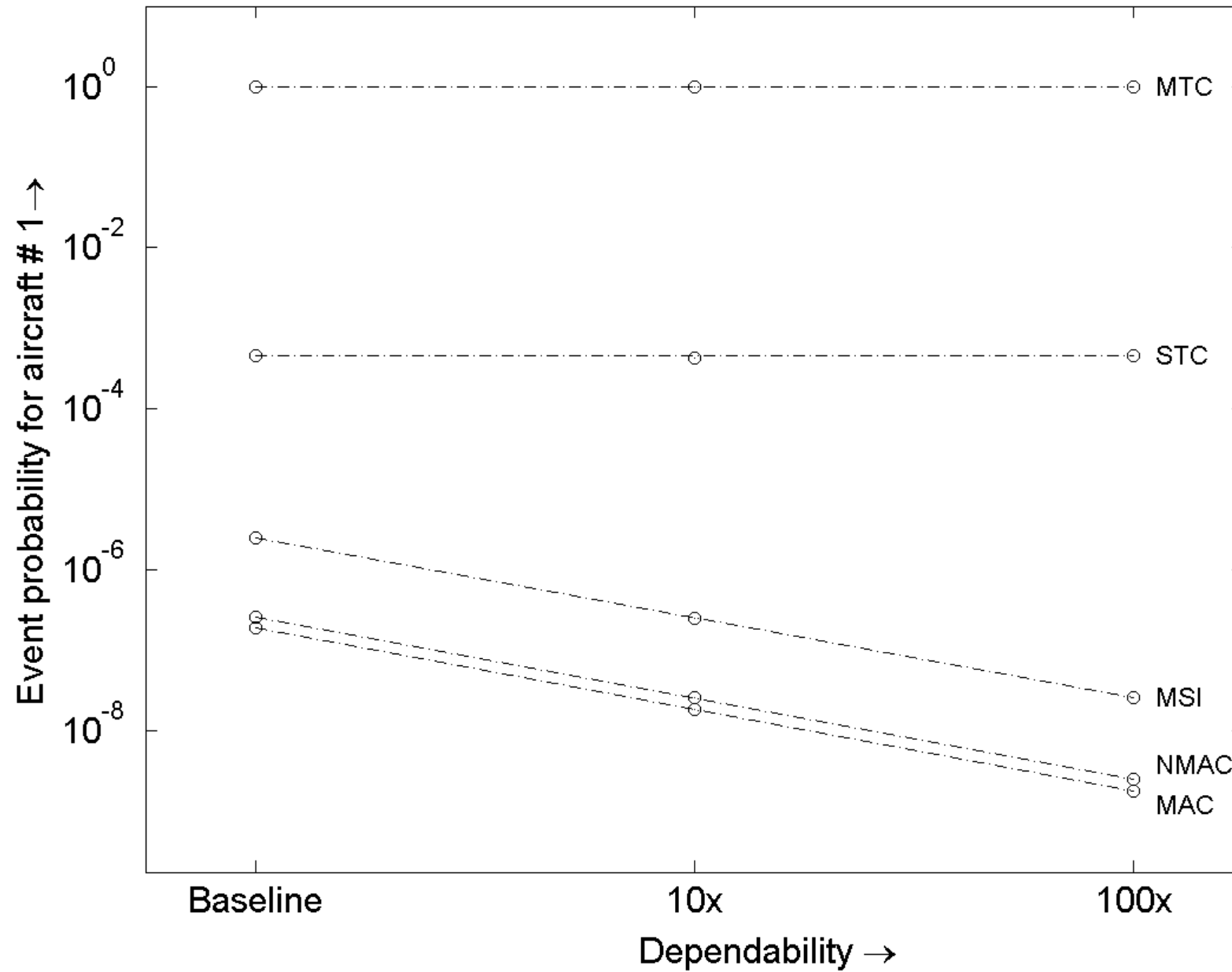
- Two aircraft encounter
- Eight aircraft encounter
- Random traffic high density





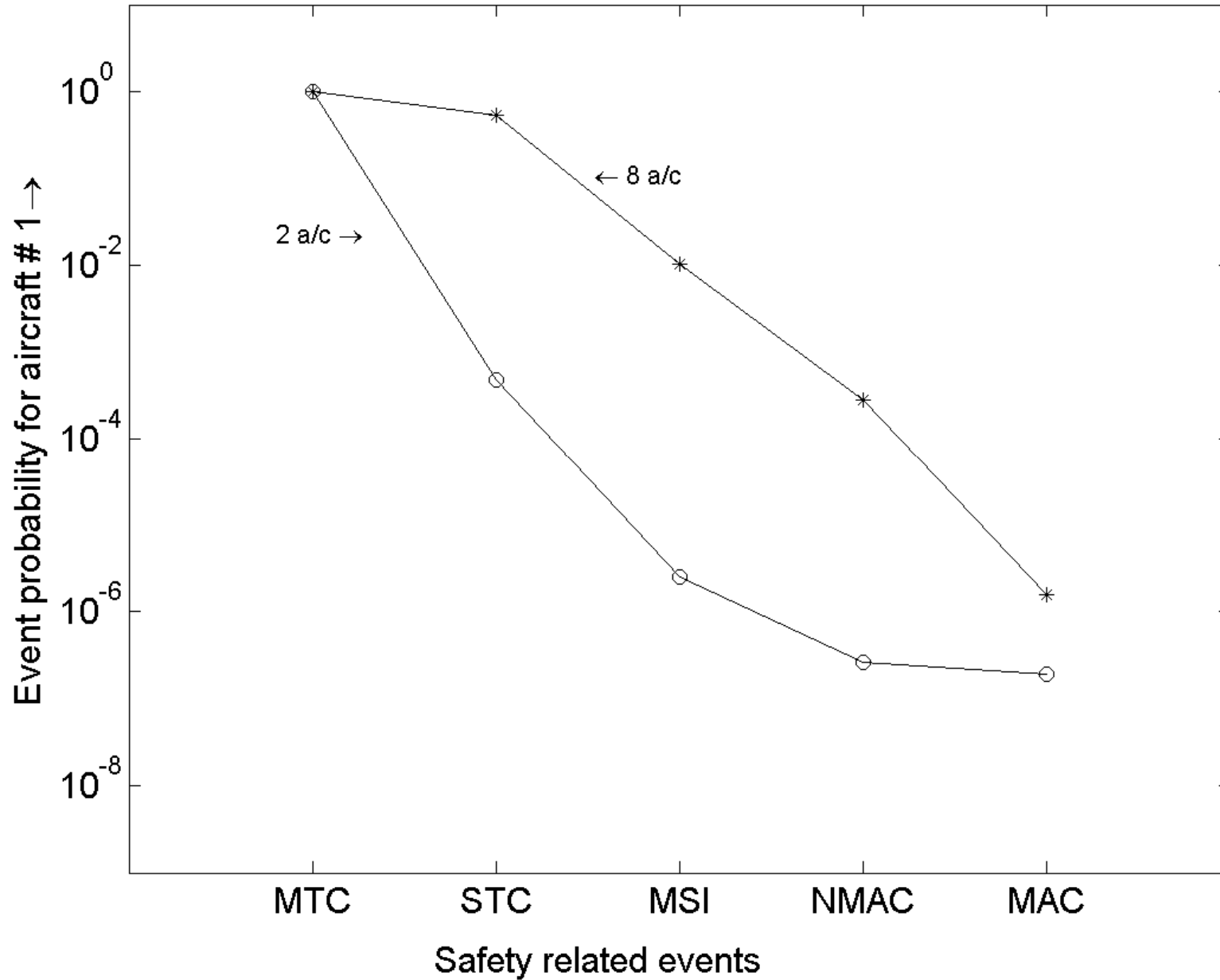


# Two-aircraft head-on encounter



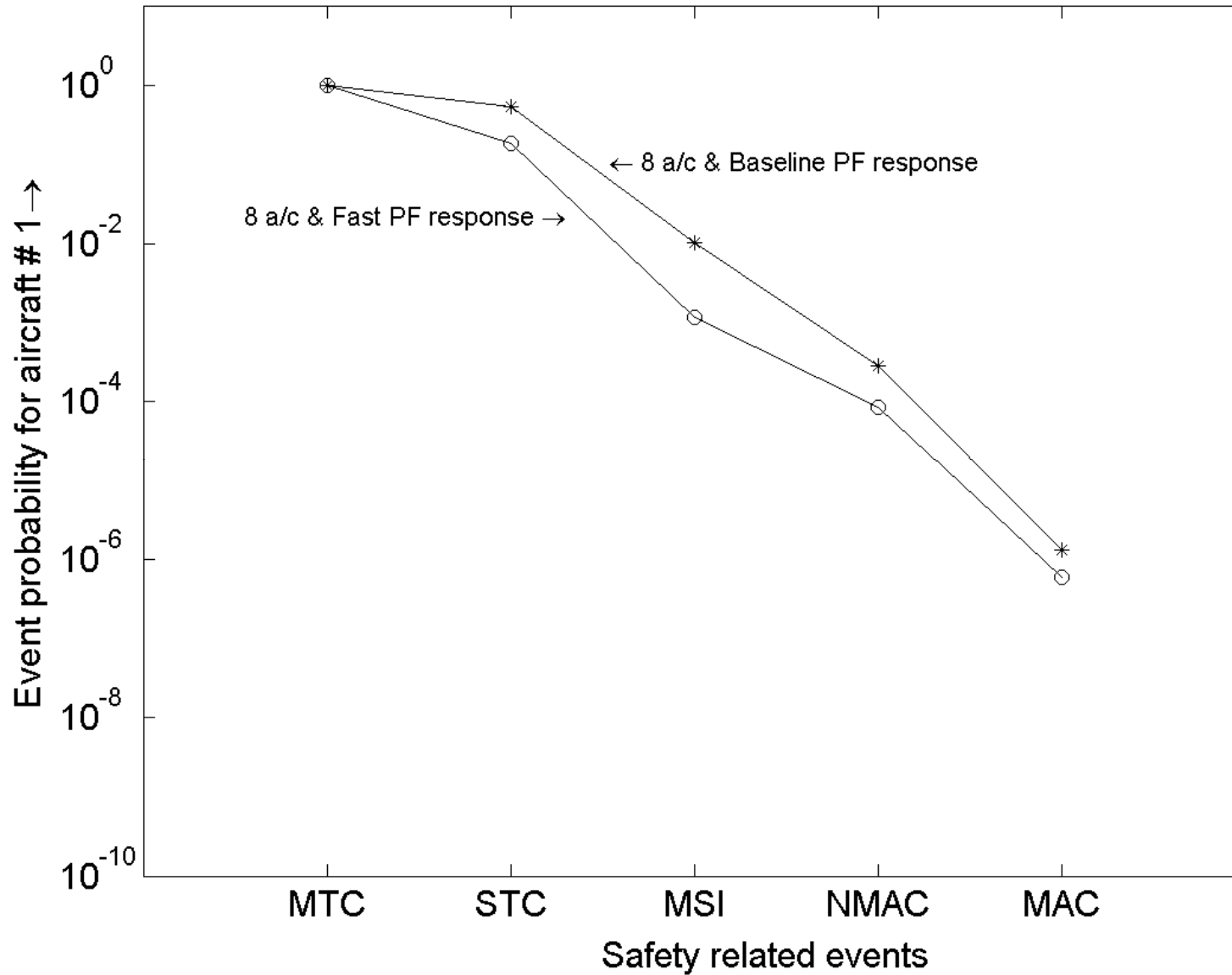


# Two-aircraft vs. eight-aircraft encounter.



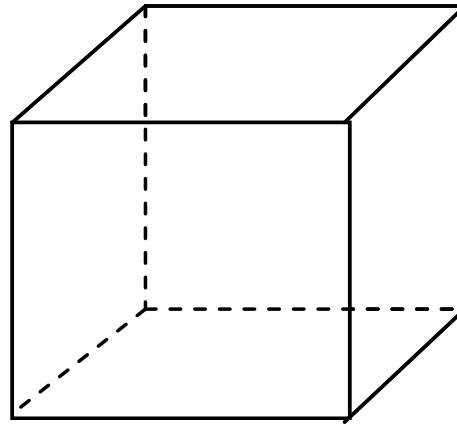


# Eight-aircraft encounter: Baseline PF response vs. Fast PF response





## Random traffic, high density

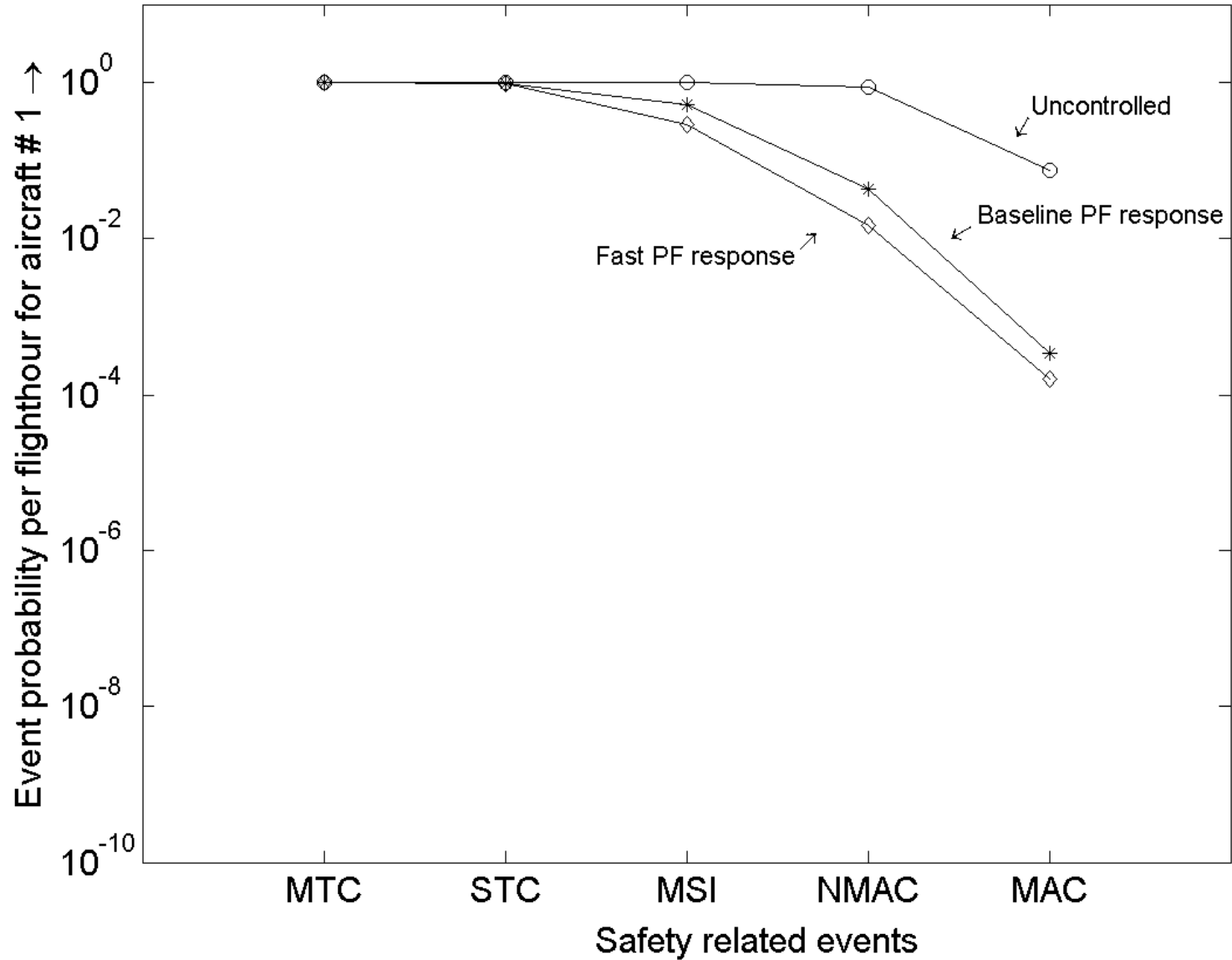


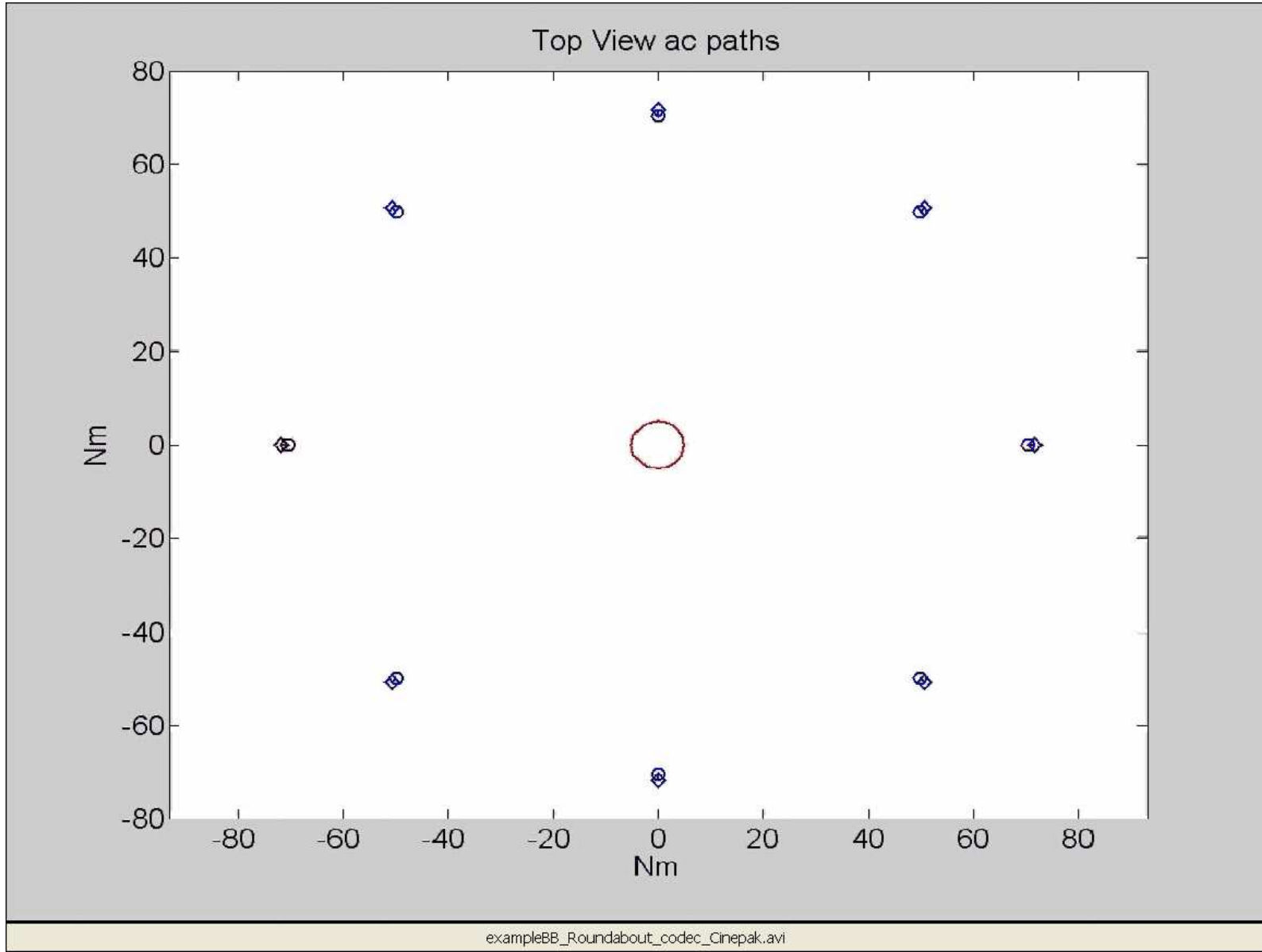
- **Eight aircraft per packed container**
  - 3 times as dense above Frankfurt on 23<sup>rd</sup> July '99





# Random high traffic: Uncontrolled vs. AMFF controlled







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# Conclusions

- Uncoordinated conflict resolution falls short in safely accommodating high en route traffic demand
- Advanced airborne self separation might do much better
- Follow-up work on risk assessment:
  - Evaluate advanced airborne self separation concept
  - Include ACAS in simulation model
  - Further improve simulation speed-up
  - Validation of assessed risk level







**To be continued**

**<http://iFly.nlr.nl>**

