iFly

WP7 Accident risk and flight efficiency of A3 operation

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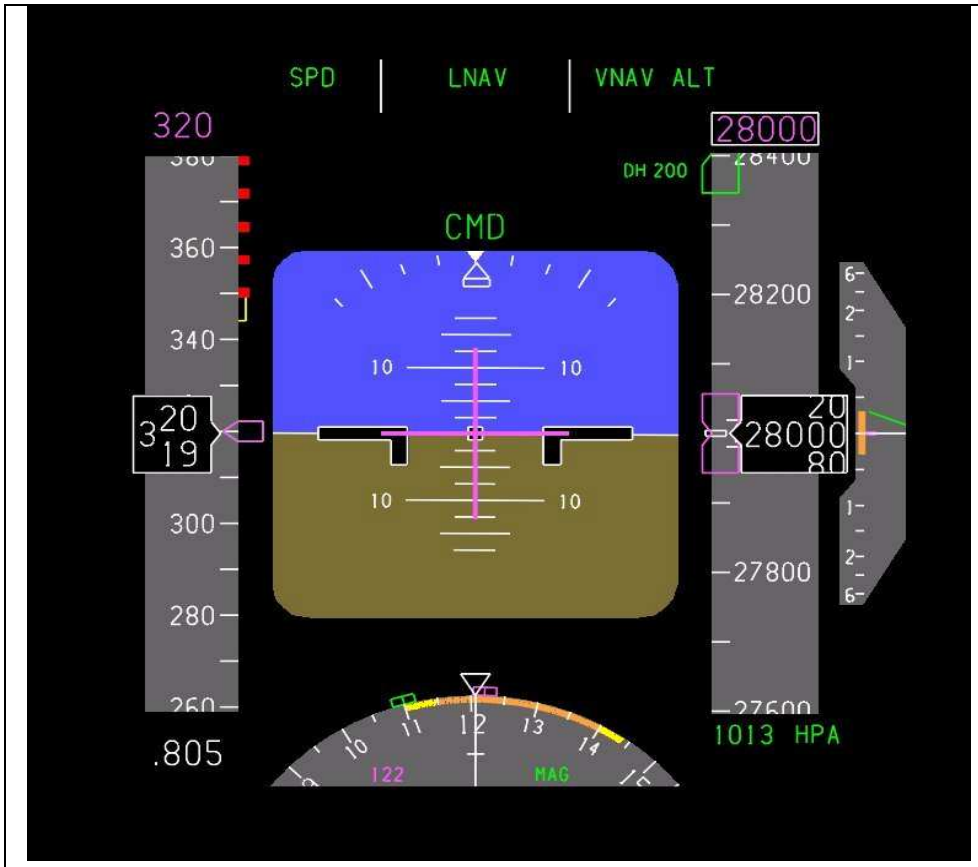
a. Stochastic Modelling and MC simulation
   - Autonomous Mediterranean Free Flight (AMFF)
     [ATC Quarterly, March 2009, pp. 63-93]
   - Extensions needed for A3 operation

b. D7.1b Hazard identification and initial analysis

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)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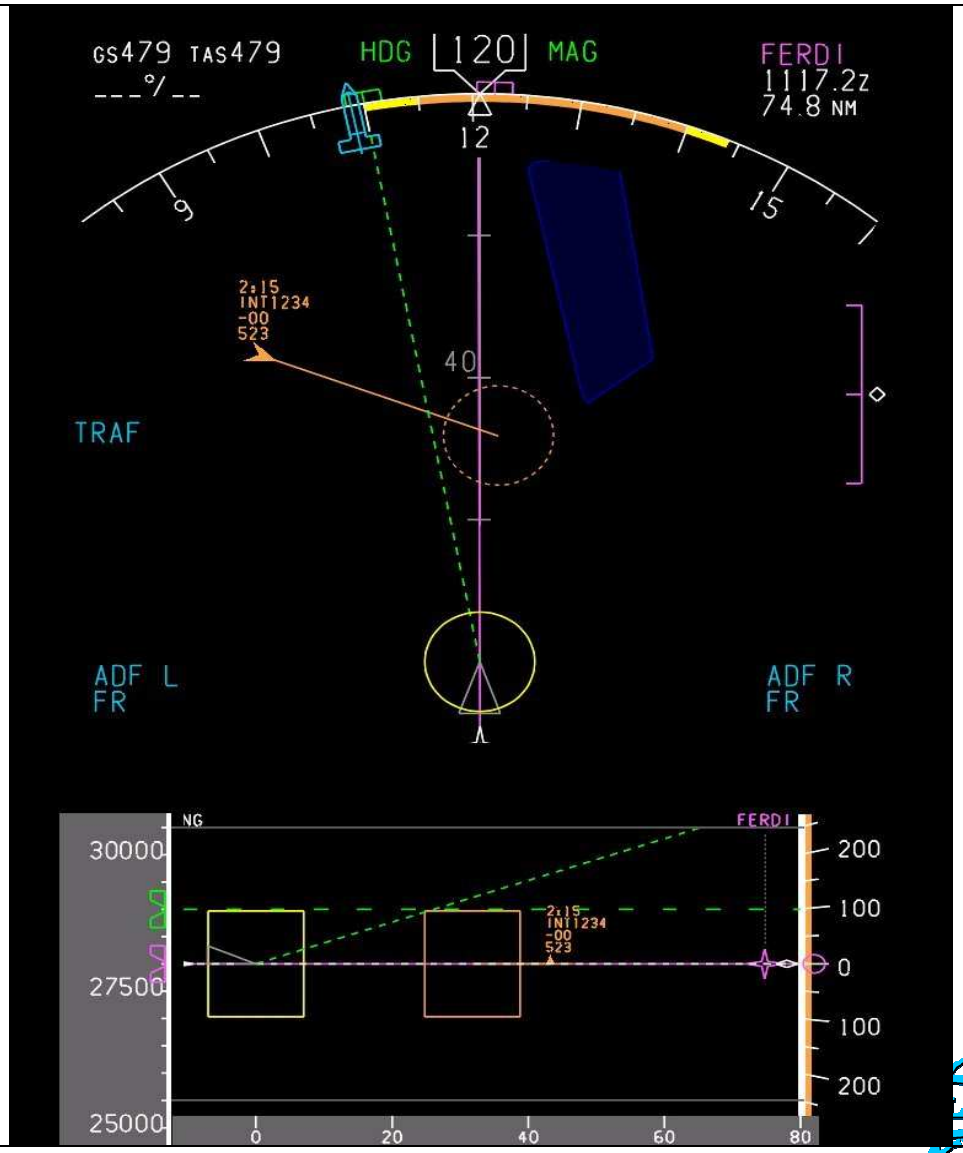
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Evaluations performed by MFF project

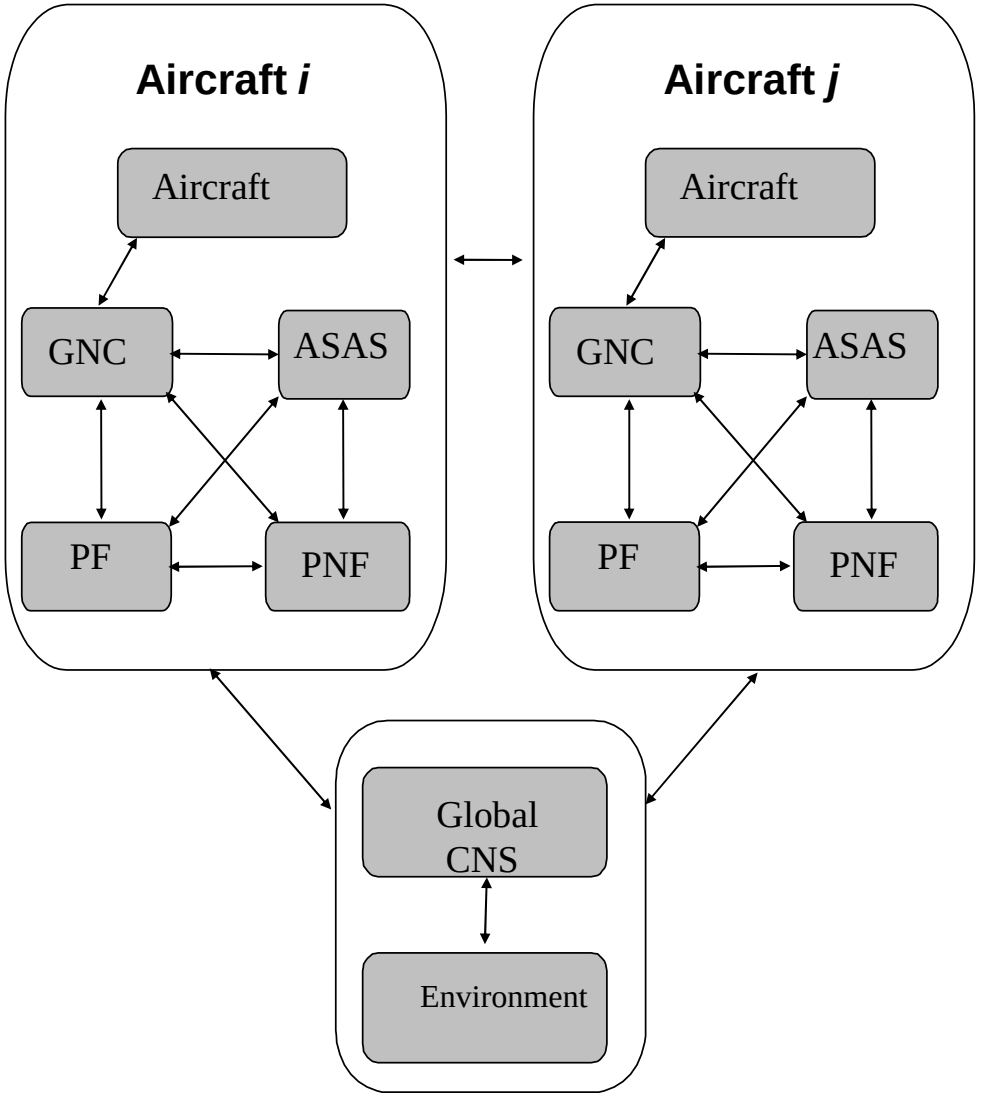
- Real-time pilot-in-the-loop simulations
- Eurocae/RTCA ED78a safety assessment

Can AMFF accommodate high traffic demand ?

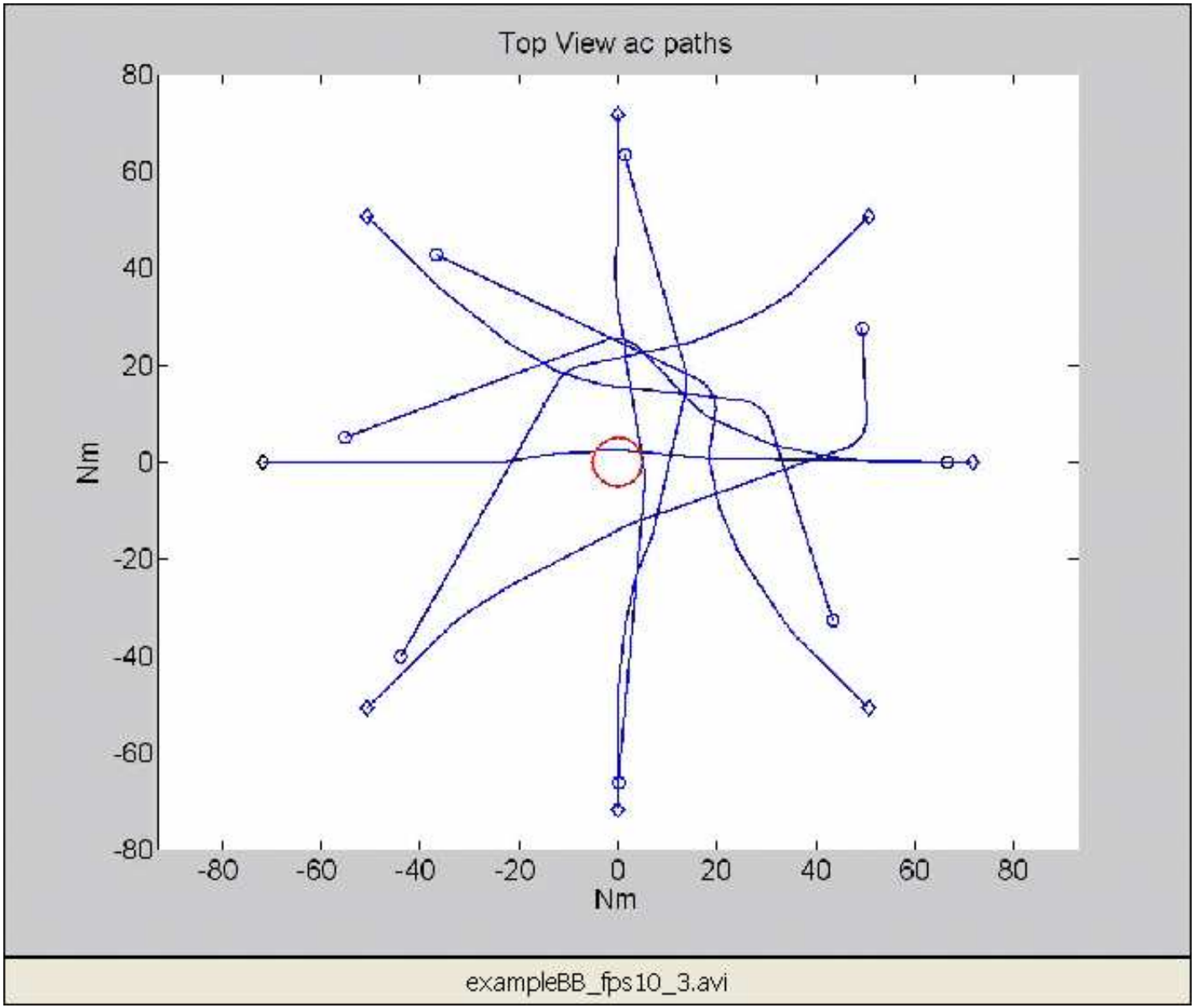
Stochastic modelling and MC simulation

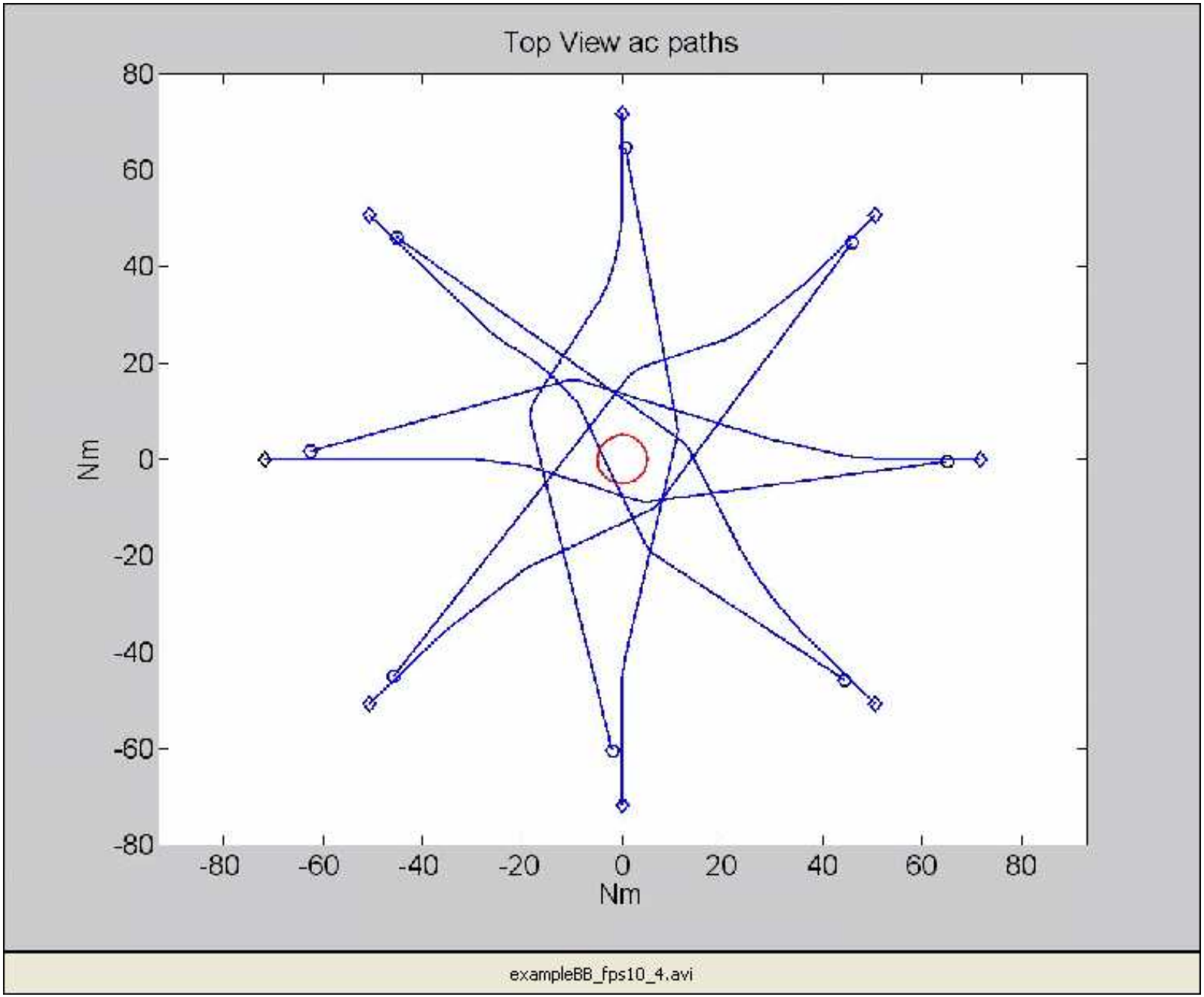
- Hazard identification
- Defining the relevant Agents
- Developing Petri net for each Agent
- Connecting Agent Petri nets
- Parametrization, Verification & Calibration
- Monte Carlo simulation
- Speeding up MC simulation
- Validation

Multi Agent model



Eight aircraft encounter

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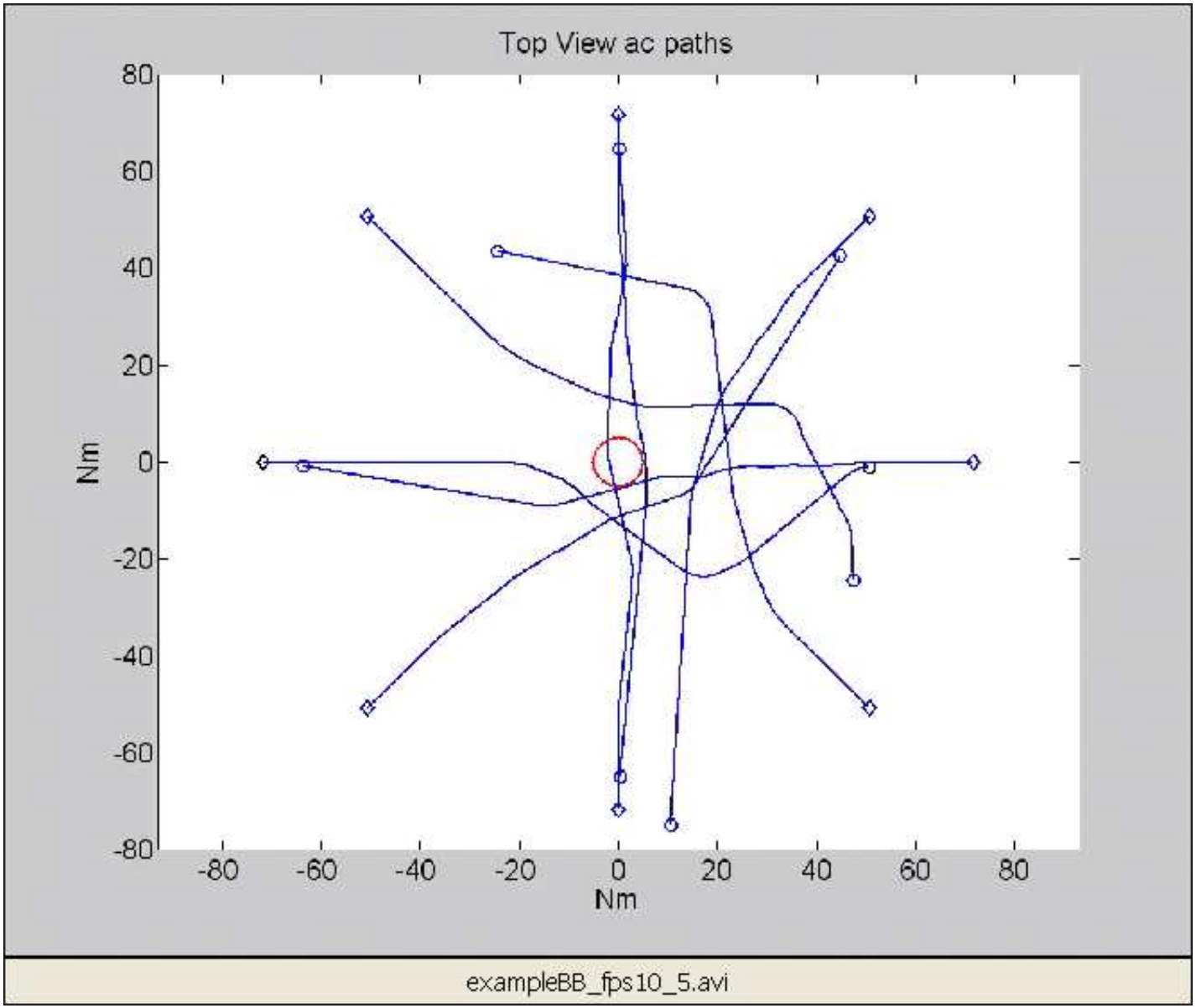
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MC simulation speed up

- 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)

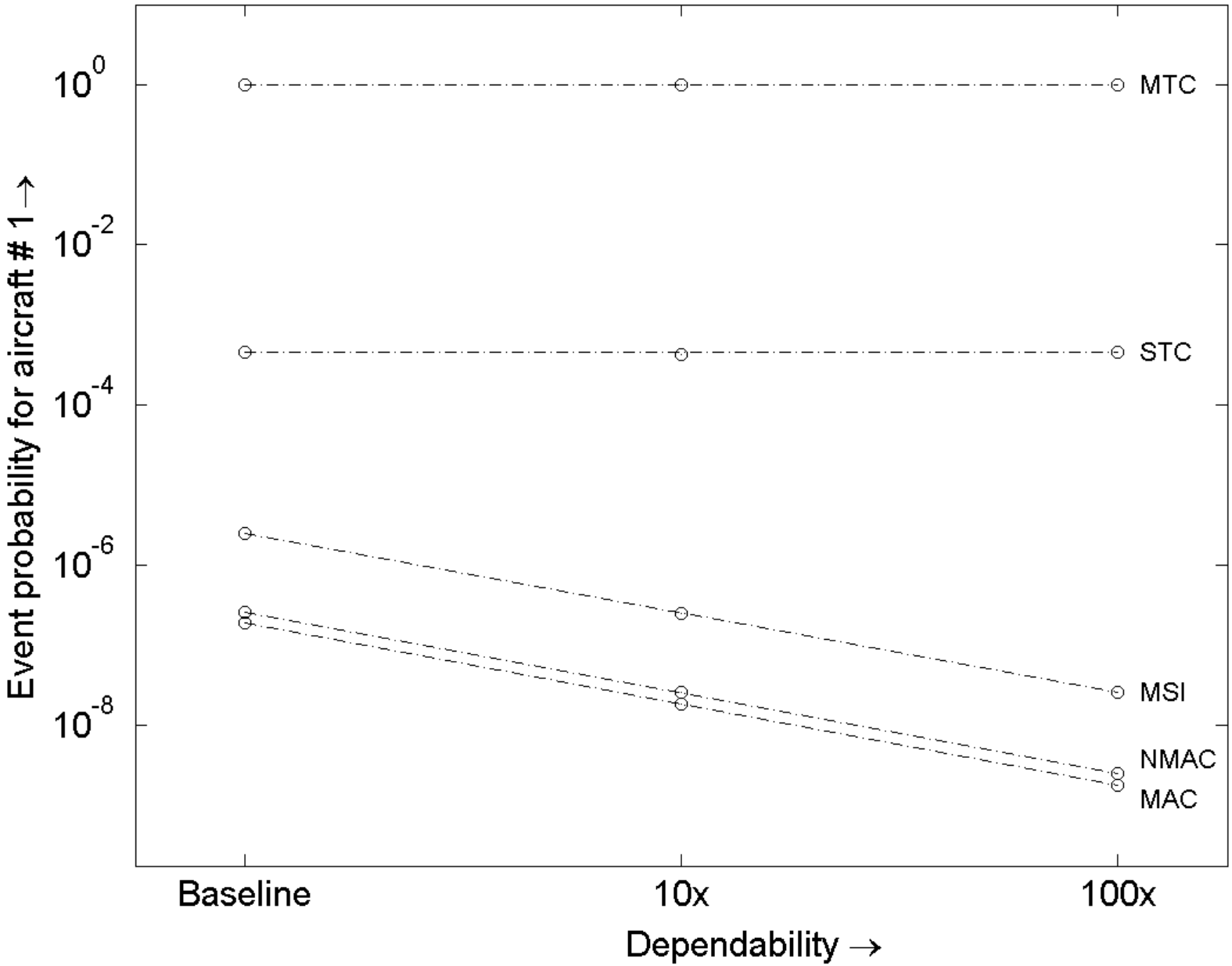
Conflict levels in air traffic

MTC = Medium Term Conflict
STC = Short Term Conflict
MSI = Minimum Separation Infringement
NMAC = Near Mid-Air Collision
MAC = Mid-Air Collision

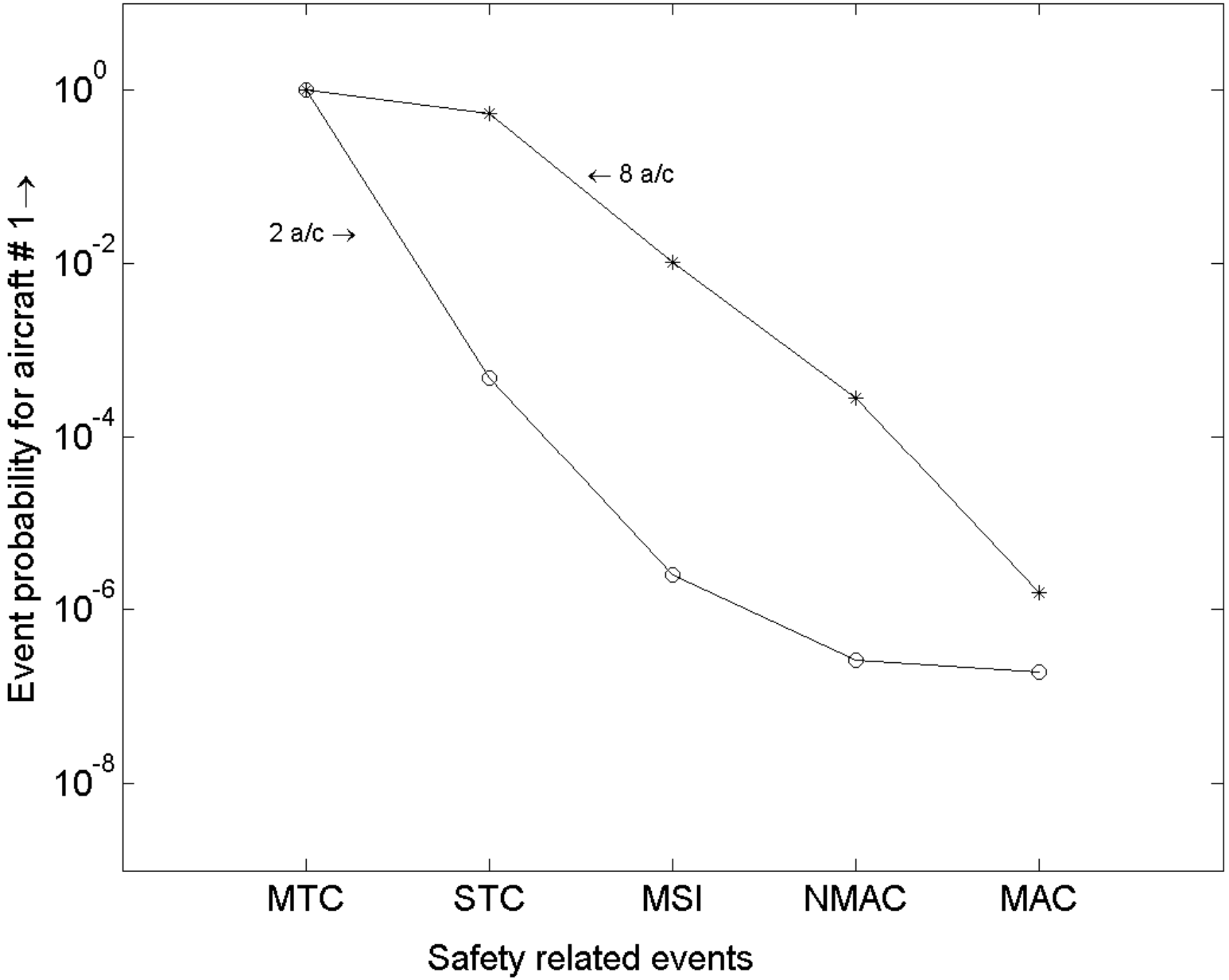
Scenarios

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

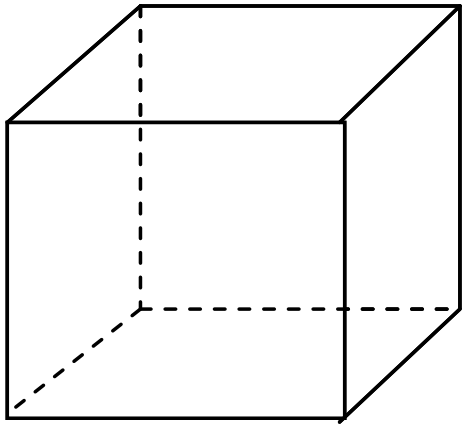
Two-aircraft head-on encounter



Two-aircraft vs. eight-aircraft encounter.



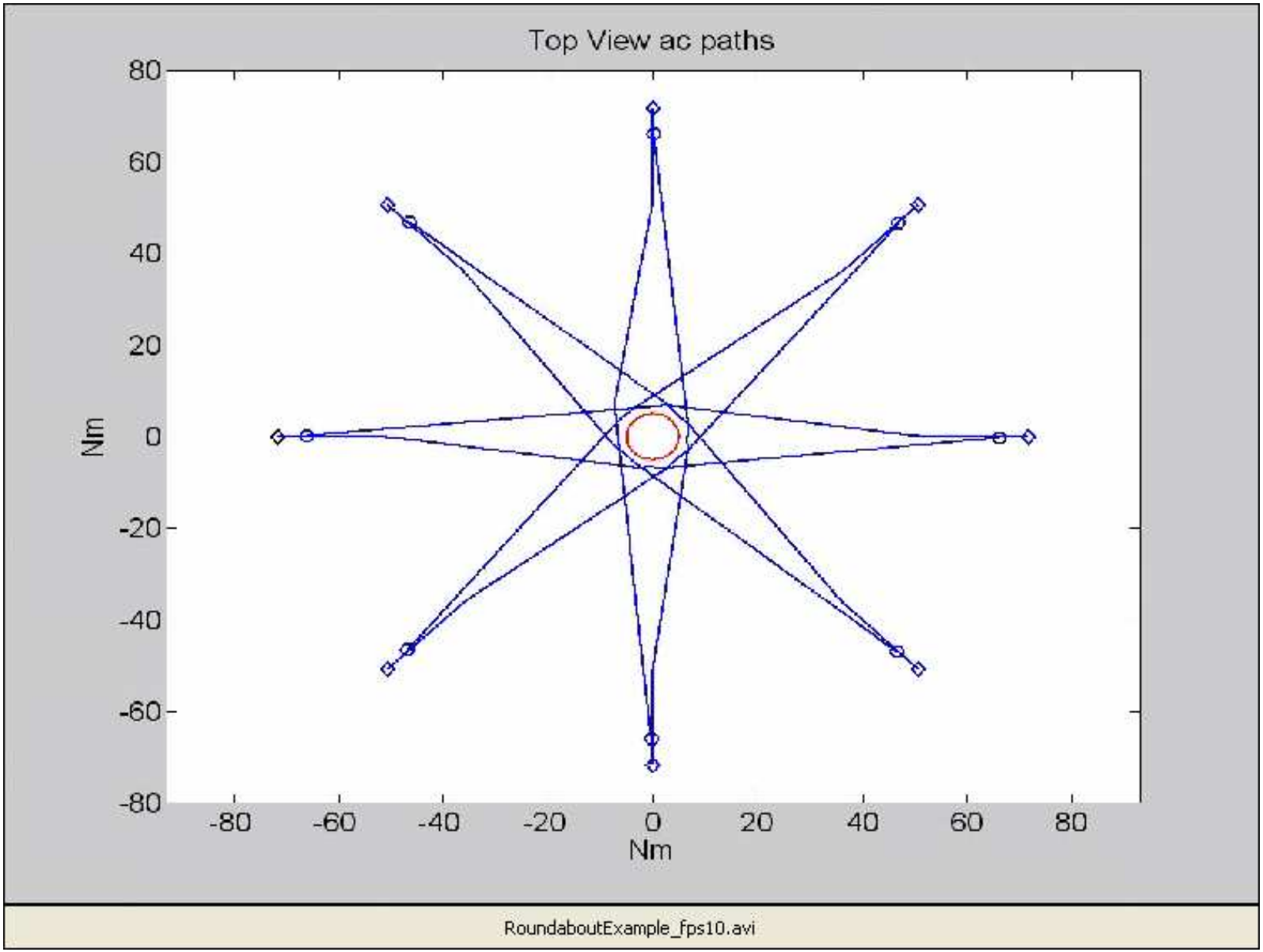
Random traffic, high density



- **Eight aircraft per packed container**
  - 3 times as dense above Frankfurt on 23rd July ’99

What does this mean for iFly?

- AMFF type of approach falls short in safely accommodating high en route traffic demand
- This need not apply to more advanced airborne self separation
- Assessing D1.3 proposed A3 ConOps based operation:
  - Extend stochastic model from AMFF to A3
  - Include ACAS in stochastic model
  - Improve MC simulation speed-up by factor 100
  - Assess bias and uncertainty of assessed risk level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RoundaboutExample_fps10.avi

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Extend model for AMFF to model for A3

- Re-using AMFF stochastic model as much as is possible
- Agents that are new: SWIM, ACAS
- AMFF agents that change dramatic: ASAS
- AMFF agents that change significant: GNC, PF, PNF
- AMFF agents that are copied: Aircraft
- Significant update of interaction between agents
- Software update based on A3 stochastic model

Improve MC speed-up by additional factor 100

- Markov Chain Monte Carlo (D7.2b)
- Rare events in large stochastic hybrid systems (D7.2e)
- Initial sampling based on Complexity
  - High expectations, but practical progress is though
  - Two more partners have started to work on this
- Periodic Boundary Conditions
  - Conditions on minimal sizes of random traffic packed containers
- Bias and uncertainty
  - Combine MC simulation with multi-dimensional regression analysis
- Enhancing computational and memory power of computers

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D7.1b Hazard identification and initial analysis

- Build working understanding of A3 ConOps
- Hazard identification brainstorm workshop
- Complementary hazards from AMFF hazard brainstorm
- Cluster hazards according to combinations of intent related conditions
- Rough assessment of frequency and consequences of identified combinations of intent related conditions
- Main combinations may happen up to once per 10 flights

Main intent related (non-nominal) conditions

Rank	Class	Description
3	(A1 ∩ P1 ∩ Q2)	Own a/c intent is not conflict free and nobody is aware
4	(B1 ∩ P2 ∩ Q2 ∩ R1)	Another a/c intent is not conflict free and nobody is aware
7	(B1 ∩ P2 ∩ Q2)	Another a/c intent intentionally not conflict free; others are not aware
8	(A1 ∩ Q2)	Own a/c intent intentionally is not conflict free; others are not aware
17	A4	Intent of ownship aircraft not broadcasted
18	B4	Intent of one other aircraft not received
19	(B4' ∩ P4 ∩ Q4)	New intents of multiple a/c not received and crew does not know
29	P2	Own crew has SA difference for another a/c
30	R2	Ownship state/intent is not properly perceived by encountering crew.
42	(A4 ∩ B4' ∩ P4 ∩ Q4)	Intent exchange does not work well and nobody is aware

D7.1b findings are of use for WP4, WP7, WP8 and WP9

- WP4 aims to address (part of) the eight main intent related conditions
- WP7 aims to improve insight into the risks of these intent related conditions
- WP8 aims to study potential SWIM and FOC mitigating options
- WP9 aims to study potential airborne and FOC mitigating options

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WP7 completed deliverables

- D7.1a final report at website (NLR)
- D7.1b draft final report (NLR)
- D7.2a final report at web site (NLR/TWEN/DSNA)
- D7.2b: MCMC draft final report at website (UCAM)
- D7.2e: Large SHS rare events draft final report at website (NLR+TWEN)
- Scientific papers:
  - AIAA-ATIO 2007 (NLR),
  - ATM Safety Seminar 2007 (NLR),
  - IEEE CDC 2007 (NLR&TWEN),
  - Eurocontrol INO workshop 2008 (NLR)
  - Chapter in Wiley volume 2009 (NLR&TWEN)
  - ATC-Quarterly 2009 (NLR)

Tasks 7.3 & 7.4 Performing Monte Carlo simulation and Reporting

- From T0+32 through T0+44
- Perform Monte Carlo simulations
  - Verification
  - Incorporate novel speed-up approaches
  - Point estimation
  - Bias and uncertainty assessment
- Reporting
  - A3 ConOps safety/efficiency report
  - Intermediate report at T0+38 (Internal)
  - Final report at T0+44 (Public)

Thank You !