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Research & Consultancy

Modelling and Analysis of Safety Risk in Air Traffic Design

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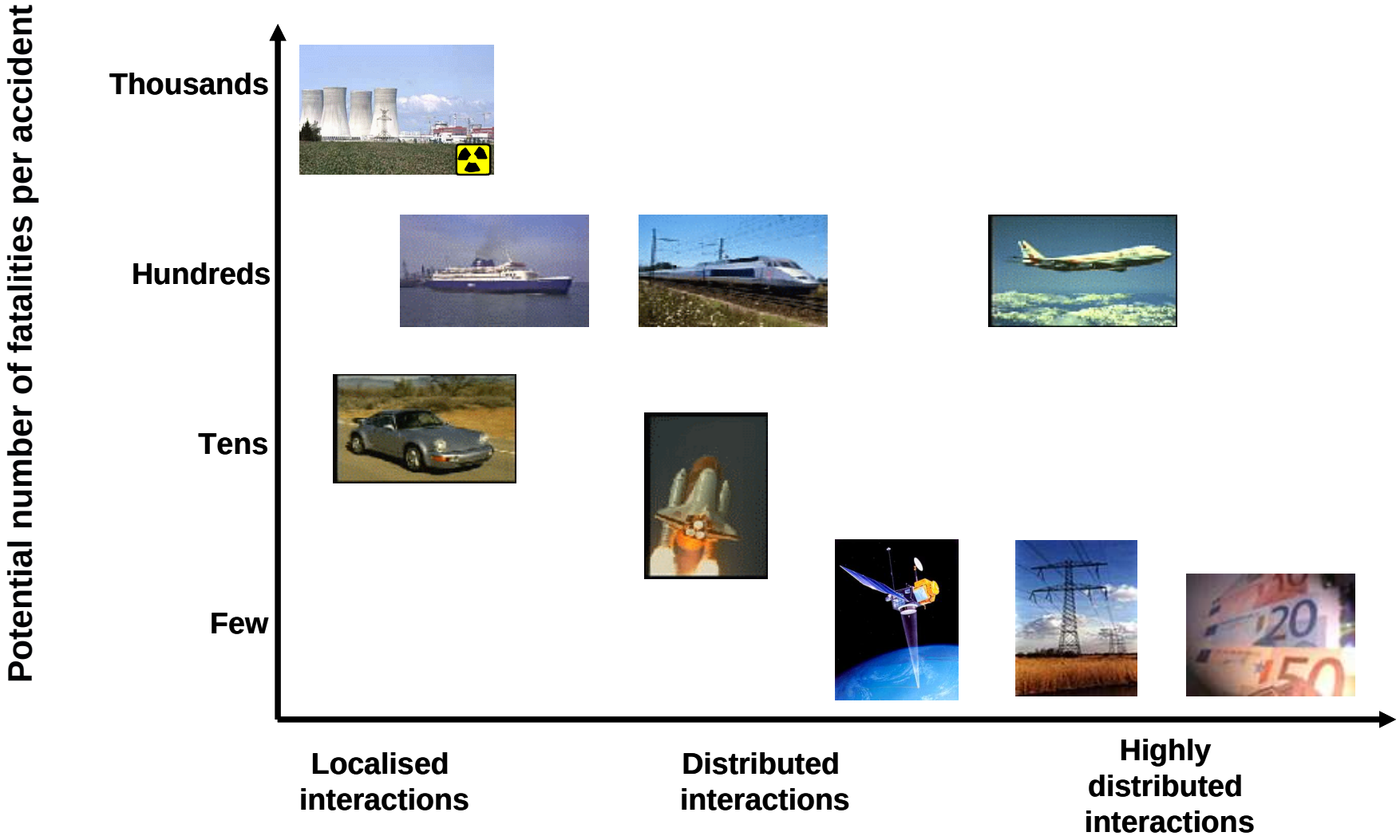
Potential number of fatalities per accident
Thousands
Hundreds
Tens
Few
Localised interactions
Distributed interactions
Highly distributed interactions

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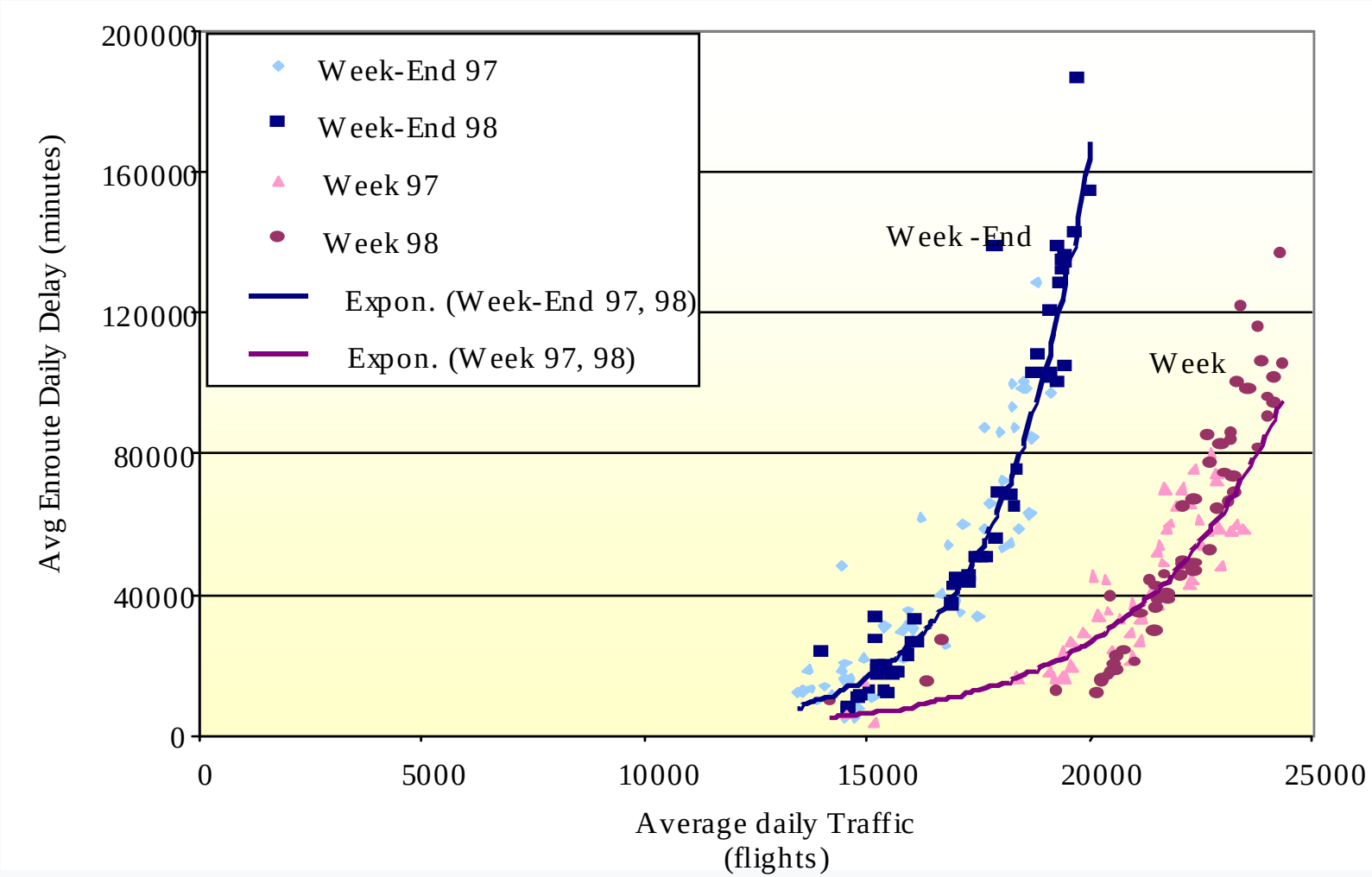
Motivation

Rare Event Simulation

Example scenarios

iFLY project

The capacity 'wall'



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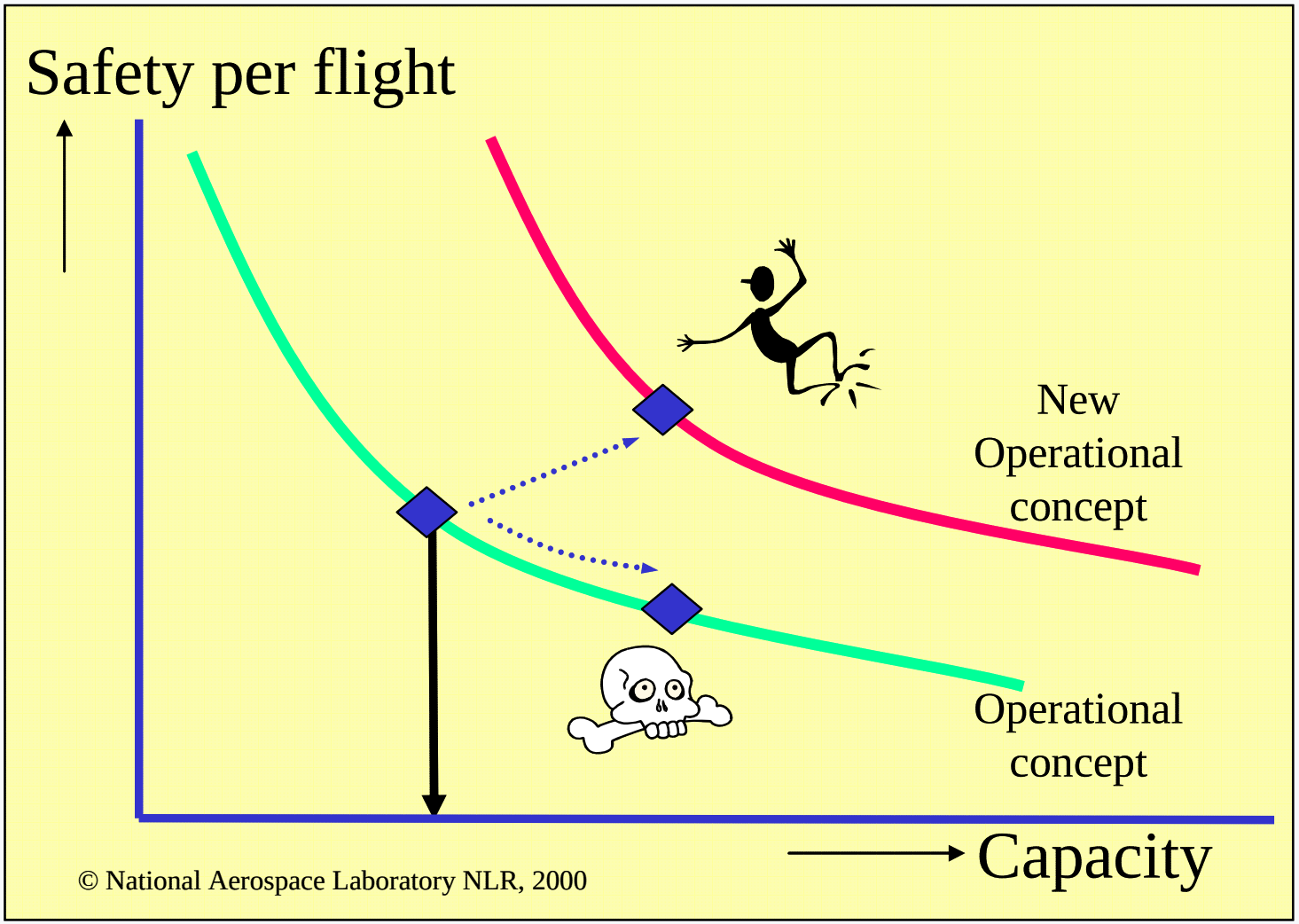
Source: PRC 1 report

The capacity "wall" is a safety "wall"



Safety feedback based design

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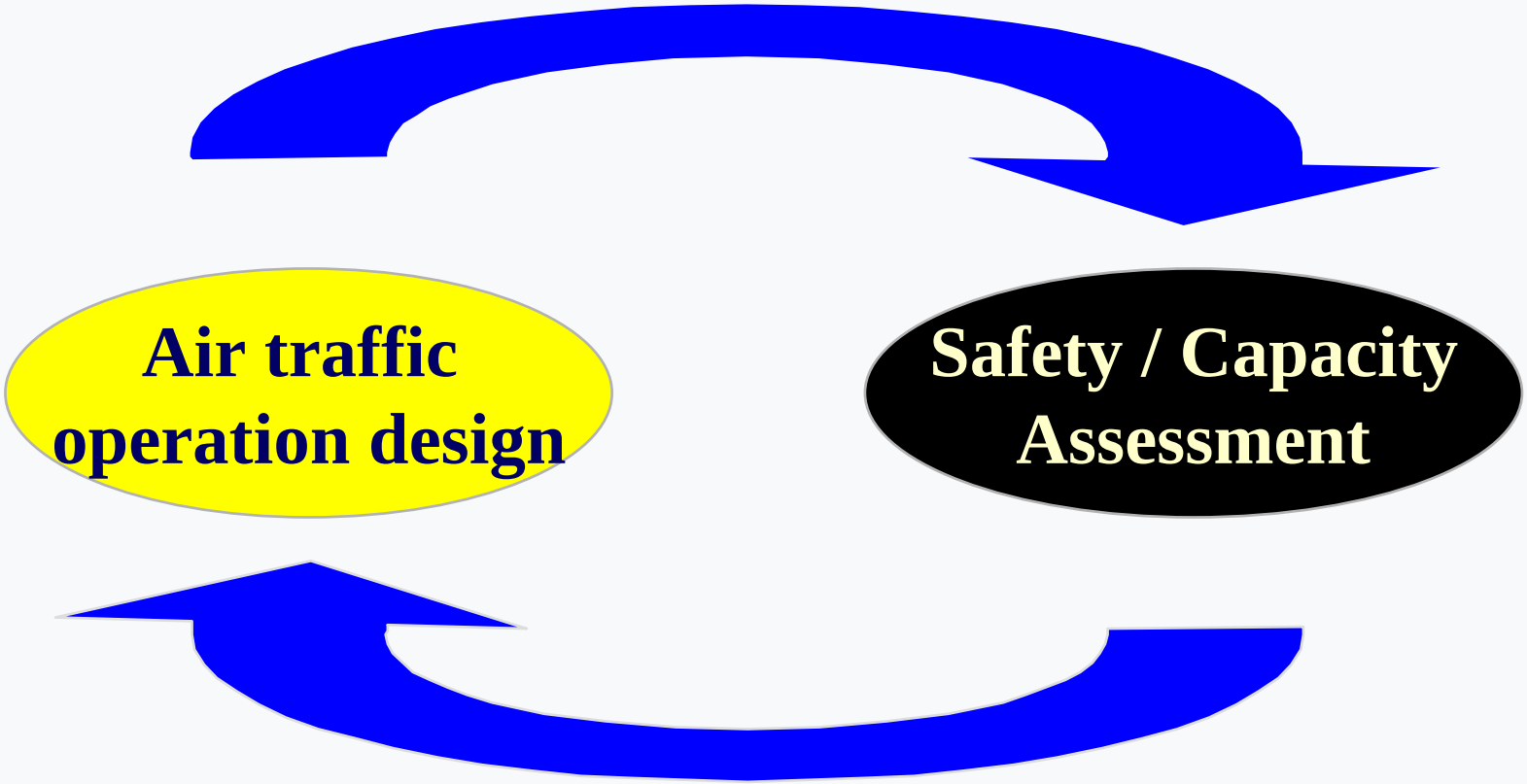

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Risk Factorization

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$$D_1 \supset D_2 \supset \ldots \supset D_m = D$$

$$P\{\tau < T\} = \prod_{k=1}^{m} P\{\tau_k < T \,|\, \tau_{k-1} < T\}$$

τ = first hitting time of D

τ_k = first hitting time of D_k, $k = 1,2,..m$

τ_0 = 0, initial state $\notin D_1$

Interacting Particle System (IPS)

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- Simulate Np particles (all starting outside D1)
- Freeze each particle that reaches the next urgent level within time T
- Make Np copies of frozen particles
- Repeat this until the most urgent level has been reached
- Count the simulated fraction Yk that reaches level k
- Estimated collision risk = Y1 x Y2 x Y3 x … x Ym

Proof of Convergence for Strong Markov process

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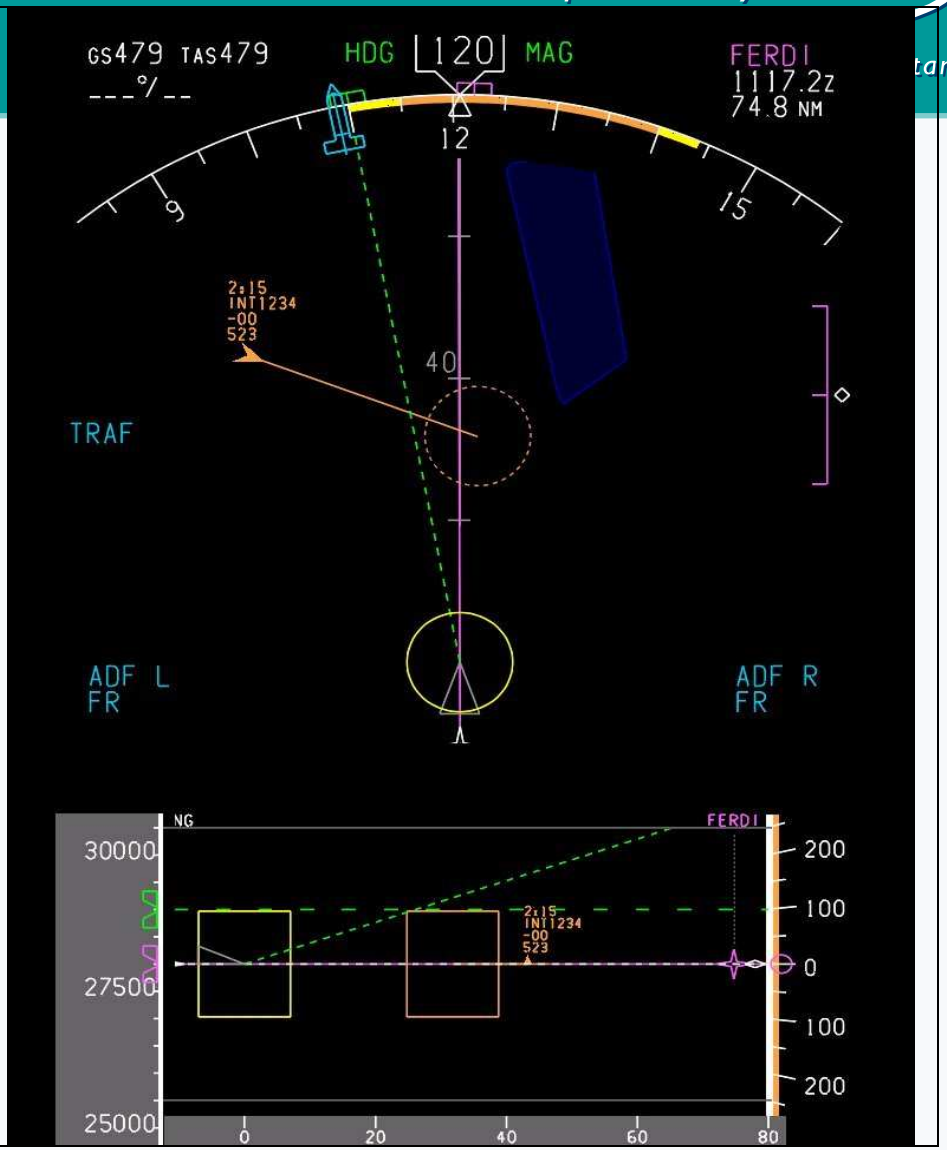
SPD
LNAV
VNAV ALT
320
360
340
320
319
300
280
260
.805
28000
DH 200
28200
28000
20
80
27800
27600
1013 HPA
CMD
10
10
10
10
122
MAG


GS479 TAS479
---°/--
HDG
120
MAG
FERDI
1117.2Z
74.8 NM
12
9
15
2:15
INT1234
-00
523
40
TRAF
ADF L
FR
ADF R
FR
NG
FERDI
30000
27500
25000
200
100
0
100
200
0
20
40
60
80

Agents in Example model

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- Aircraft
- Pilot-Flying
- Pilot-Not-Flying
- ASAS
- Airborne GNC (Guidance, Navigation and Control)
- Global CNS (Communication, Navigation and Surveillance)

Safety related event levels

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Event	MTC	STC	MSI	NMAC	MAC
Prediction time (minutes)	8	2.5	0	0	0
Horizontal distance (Nm)	4.5	4.5	4.5	1.25	0.054
Vertical distance (ft)	900	900	900	500	131

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

Monte Carlo simulated scenarios

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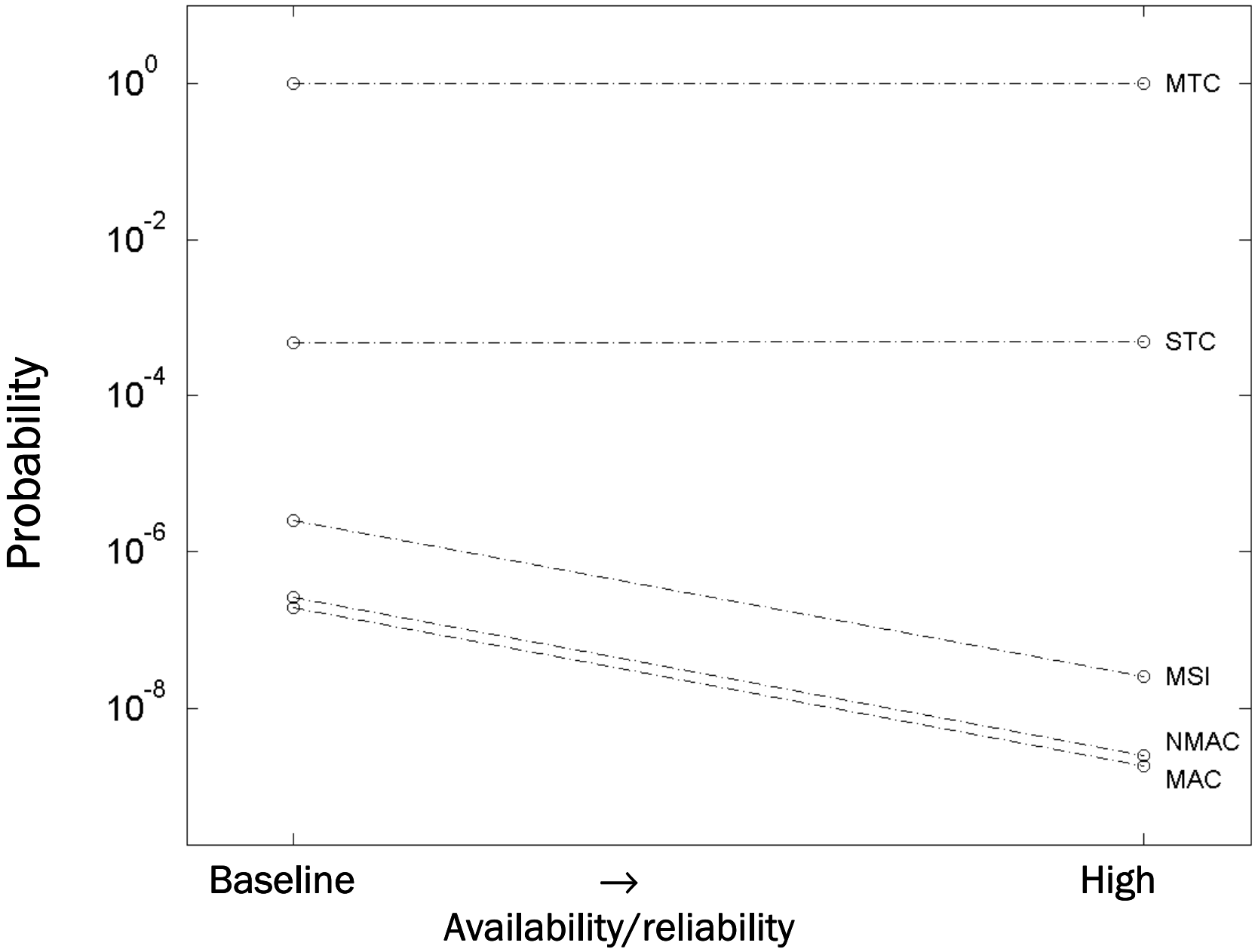
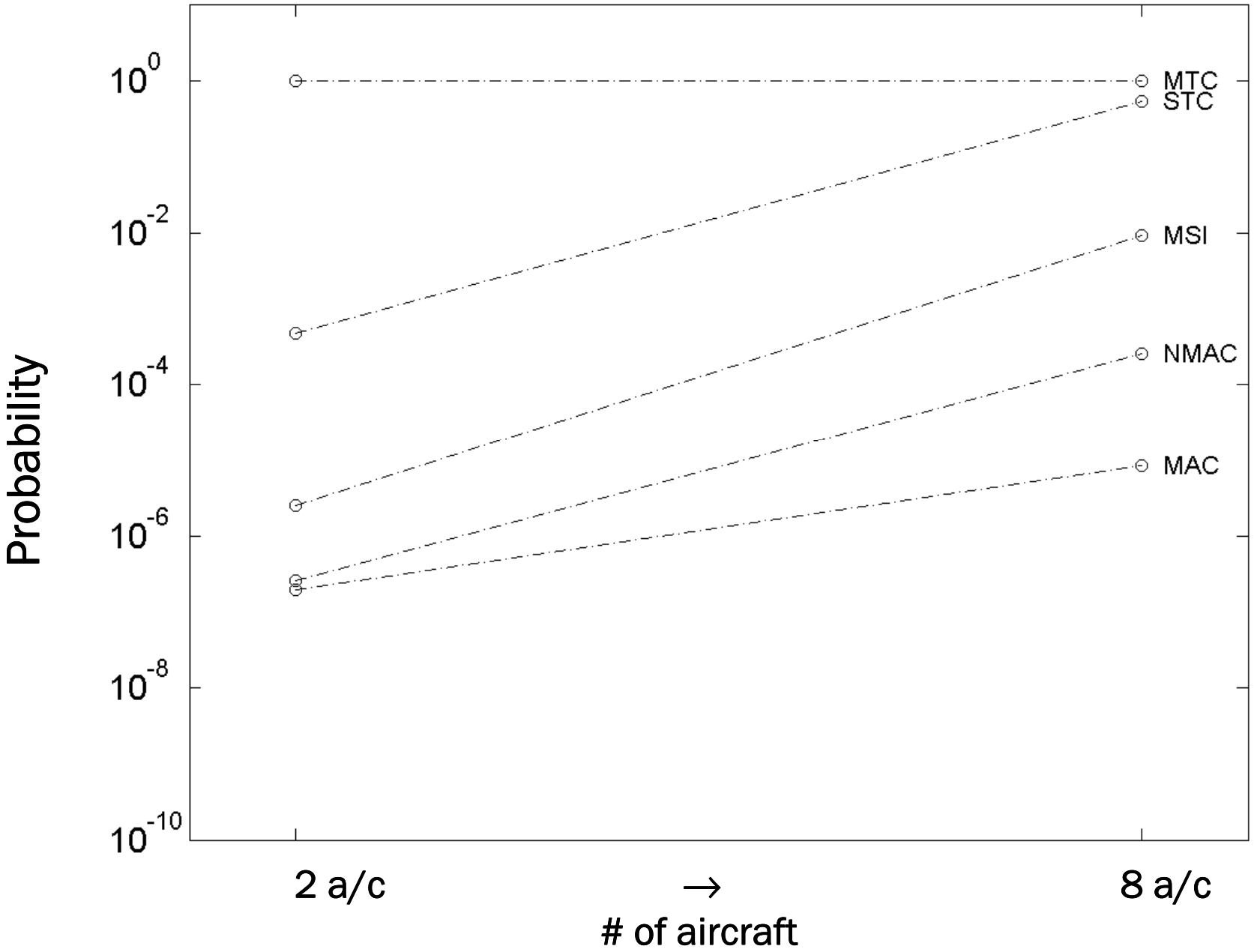
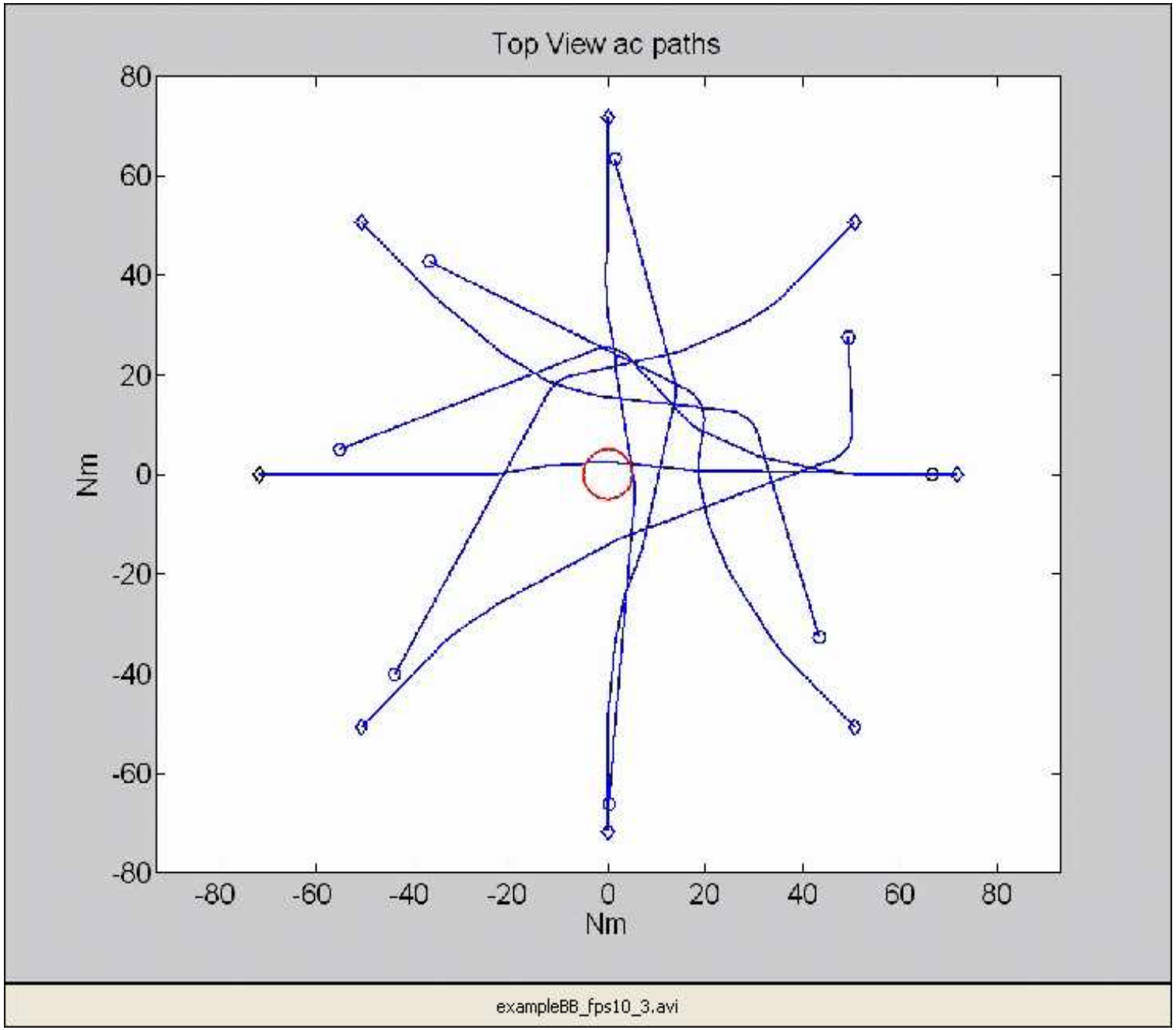
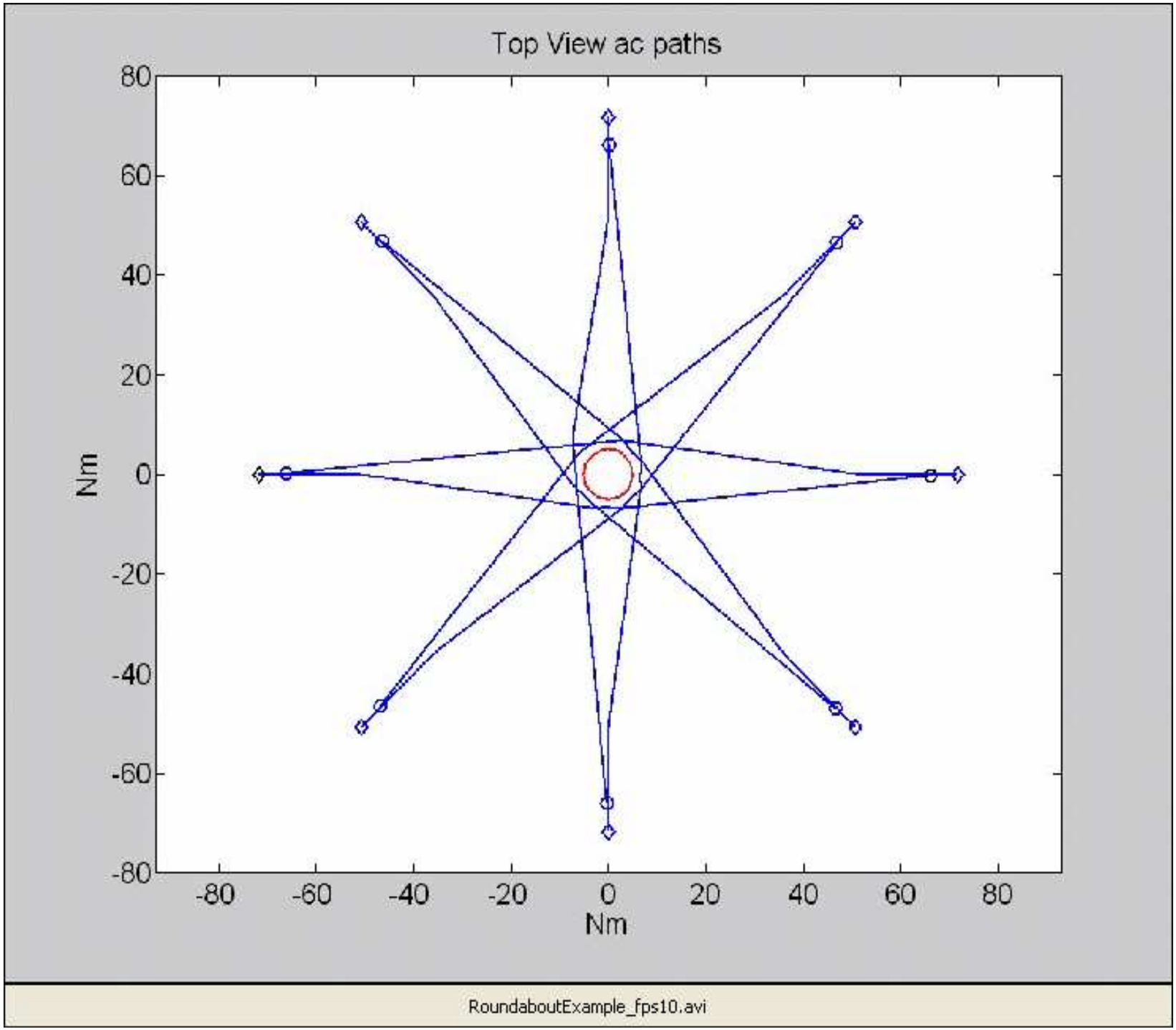
Two aircraft head on encounter

Eight aircraft encounter


Probability
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
MTC
STC
MSI
NMAC
MAC
Baseline
→
High
Availability/reliability


Probability
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
MTC
STC
MSI
NMAC
MAC
2 a/c
→
8 a/c
# of aircraft


Top View ac paths
80
60
40
20
0
-20
-40
-60
-80
Nm
-80
-60
-40
-20
0
20
40
60
80
Nm
exampleBB_fps10_3.avi


Top View ac paths
80
60
40
20
0
-20
-40
-60
-80
Nm
-80
-60
-40
-20
0
20
40
60
80
Nm
RoundaboutExample_fps10.avi

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iFLY project

iFLY project

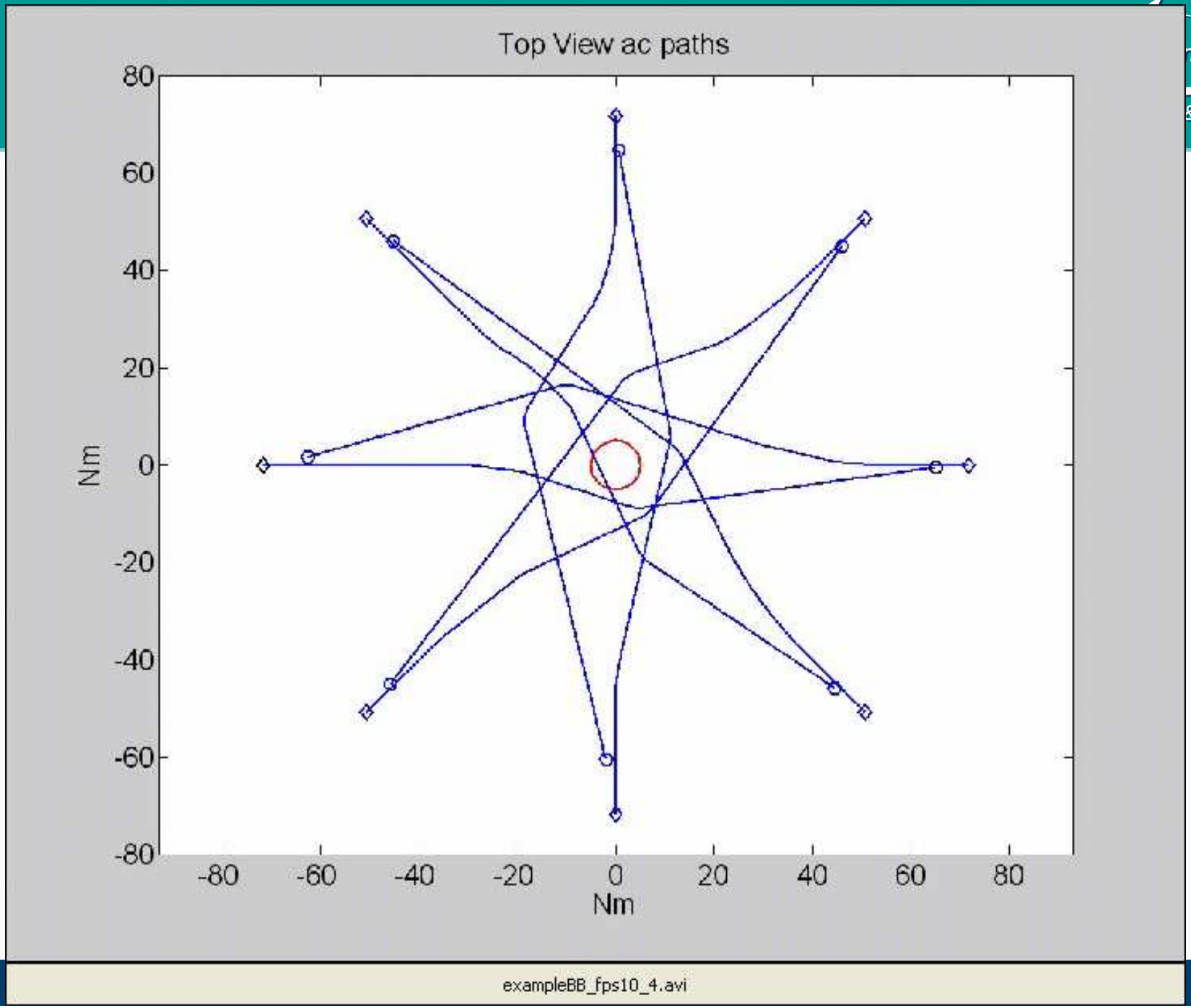
- 18 Partners from universities + industry
- Period: May 2007- August 2010
- NLR is coordinator

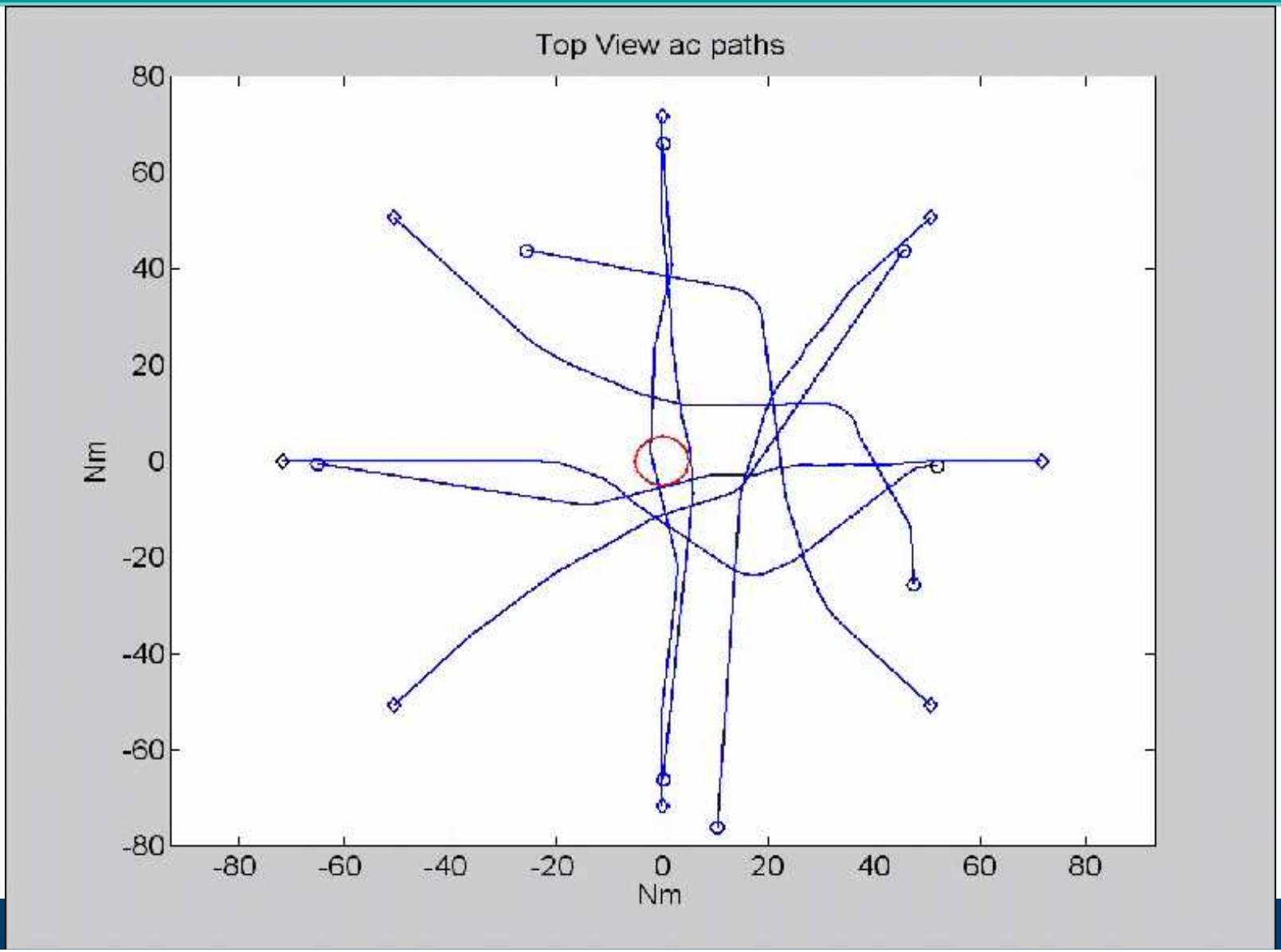
Key research questions:

- At which en-route traffic demands is self separation sufficiently safe ?
- Which complementary support services from ground ATM are needed in order to accommodate higher traffic demands ?

Thank you

Your questions are welcome


Top View ac paths
80
60
40
20
0
-20
-40
-60
-80
Nm
-80
-60
-40
-20
0
20
40
60
80
Nm
exampleBB_fps10_4.avi


Top View ac paths
Nm
Nm
80
60
40
20
0
-20
-40
-60
-80
-80
-60
-40
-20
0
20
40
60
80

Scenario 3
Random traffic, high density

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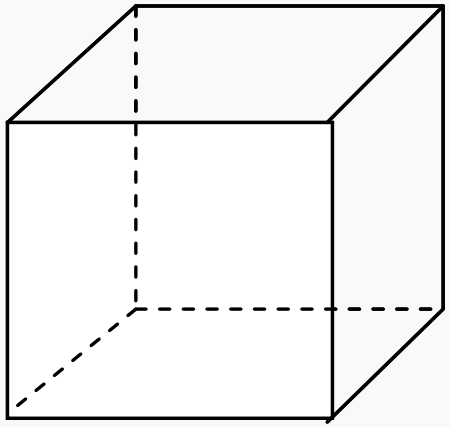

Eight aircraft per packed container

- 3 times as dense above Frankfurt on 23rd July ’99
- factor 4 lower dense

High density random traffic

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