

In Search of Positive Emergent Behaviour in Trajectory Based Operations

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In Search of Positive Emergent Behaviour in Trajectory Based Operations

Motivation

Airborne Self Separation TBO

Agent Based Stochastic Modelling

Monte Carlo simulation results

Conclusions & Follow up

Conventional ATM: Optimization between planning and tactical control through decades of evolutionary development

SESAR2020+: 4D trajectory plans (RBT's)

What happens under various uncertainties?

- Meteo
- Data
- Human
- Technical systems

How to optimize collaboration between RBT and tactical layer ?

1. How good is the tactical layer in managing uncertainties that are not timely resolved by the 4D planning layer?
2. What distances should be used between the centrelines of 4D trajectory plans in order to safely manage the various uncertainties?
3. At which traffic demands are phase transitions starting to happen and what are the consequences?

In this presentation:

- Answering these questions for Airborne Self Separation TBO
- Follow up research in the EMERGIA WP-E project

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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 each RBT 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 goes down from 5Nm to 3 Nm

- Stemming from RESET project

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.

However, undershooting of 5Nm/1000ft is better than doing nothing if there is no feasible conflict free plan. It should not create a short term conflict.

Then, the aircraft broadcasts its non-conflict-free 4D plan together with a message of being “Handicapped” (which is priority increasing).

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.

However, undershooting of these values is better than doing nothing if there is no feasible alternative.

Then, the a/c broadcasts its new course or rate of climb/descend.

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Agent Based Stochastic Modelling and Simulation

Hazard identification

Defining the relevant Agents

Developing Petri net for each Agent

Connecting Agent Petri nets

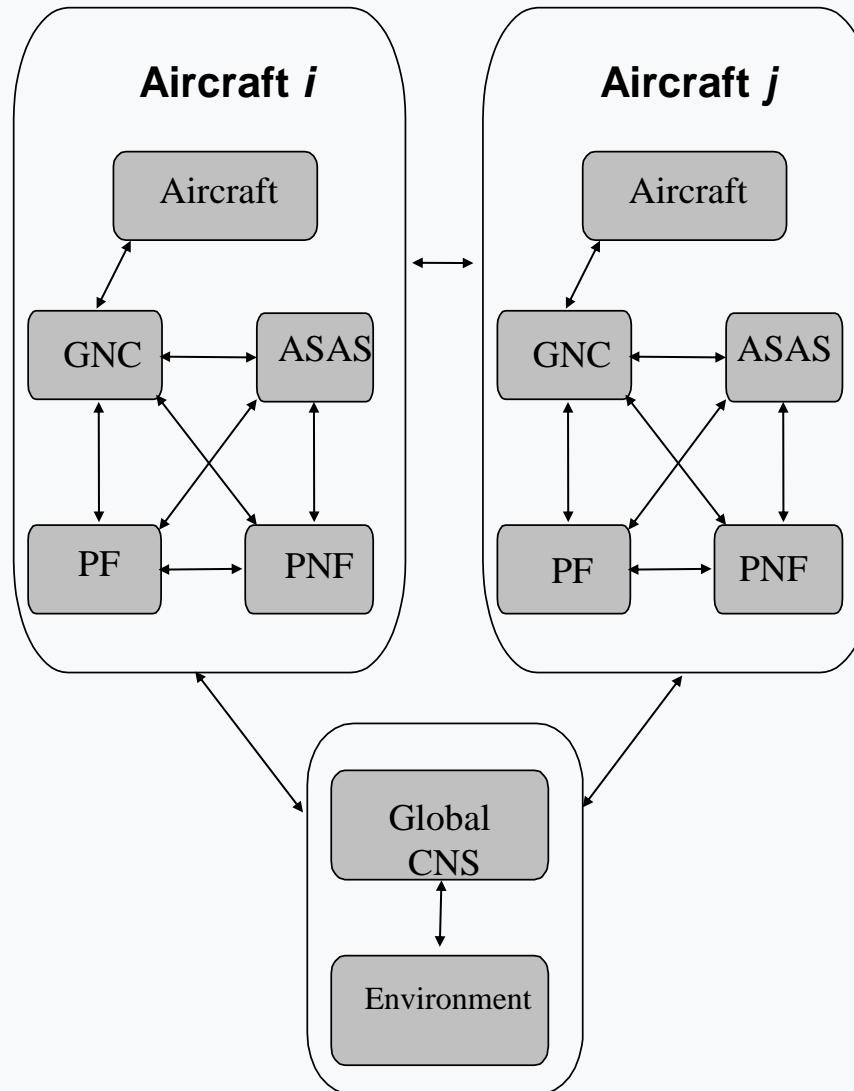
Parametrization, Verification & Calibration

Monte Carlo simulation

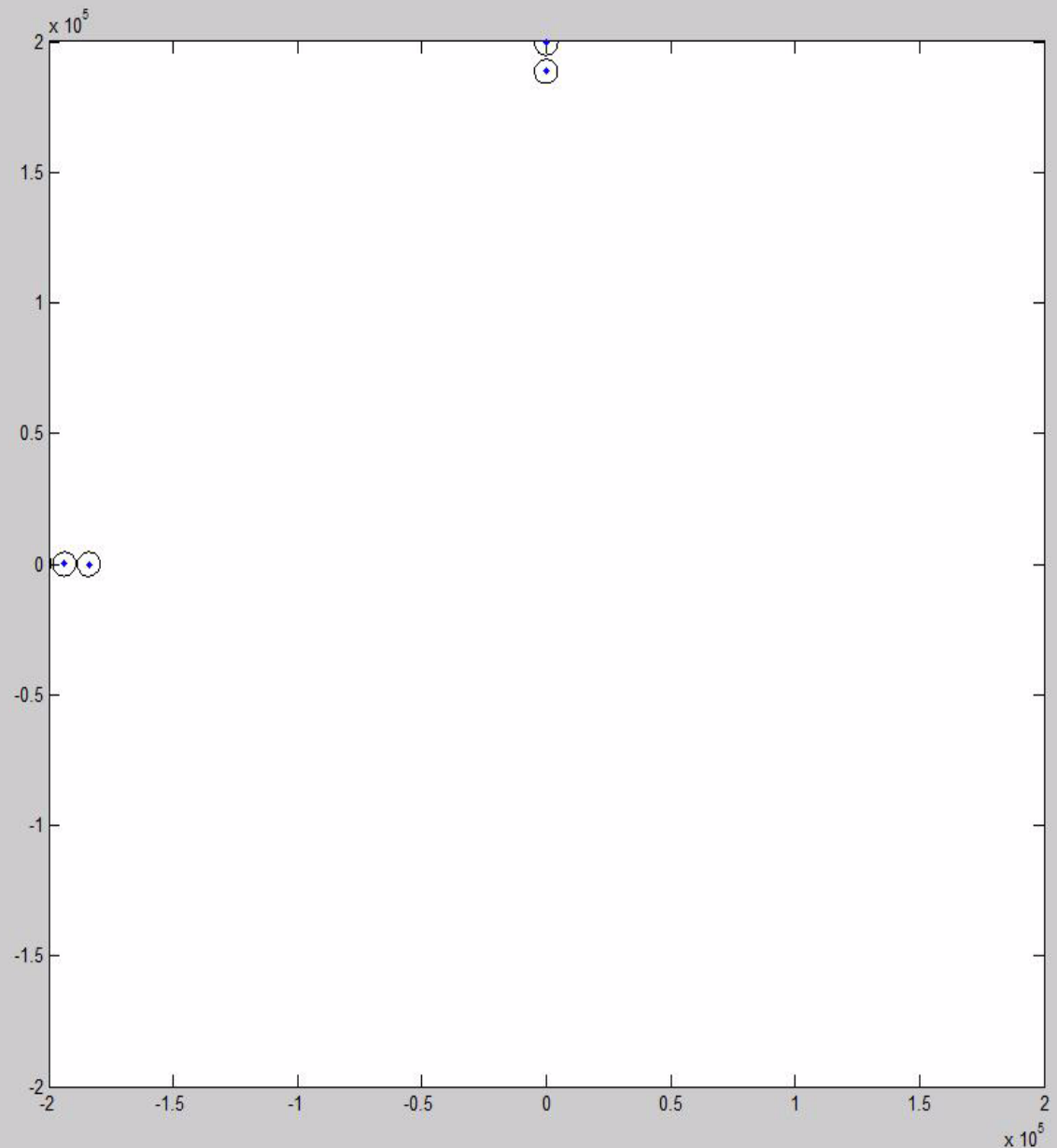
Rare Event Monte Carlo simulation

Validation

Agent Based Stochastic Model of Airborne Self Separation TBO



Two crossing traffic flows



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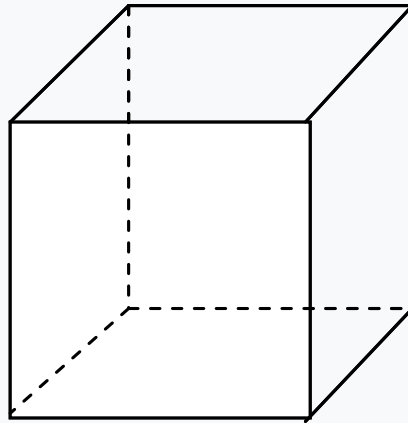
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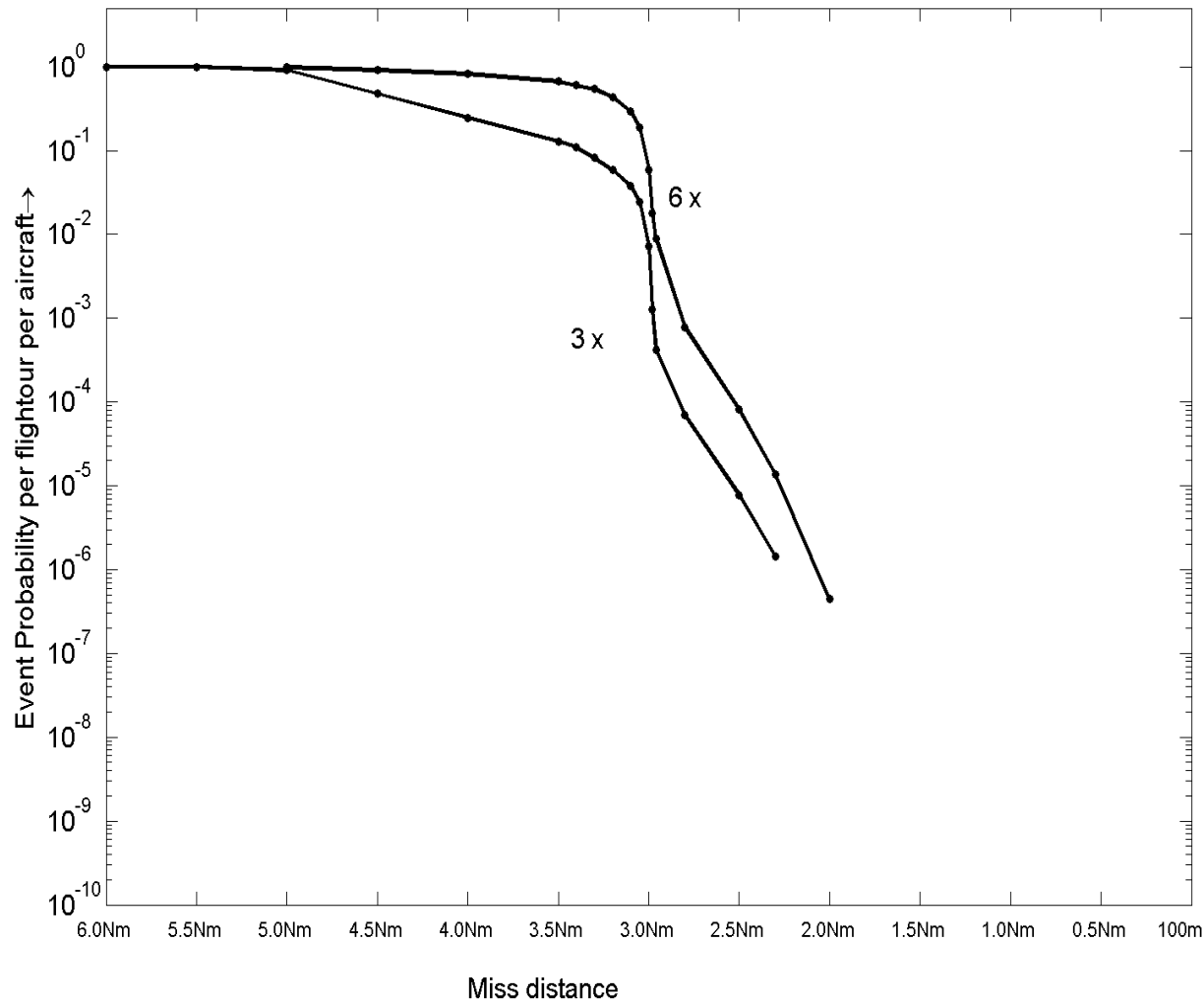
Periodic Boundary Condition

Eight a/c per packed box/ no climbing or descending a/c

Vary container size in order to simulate:

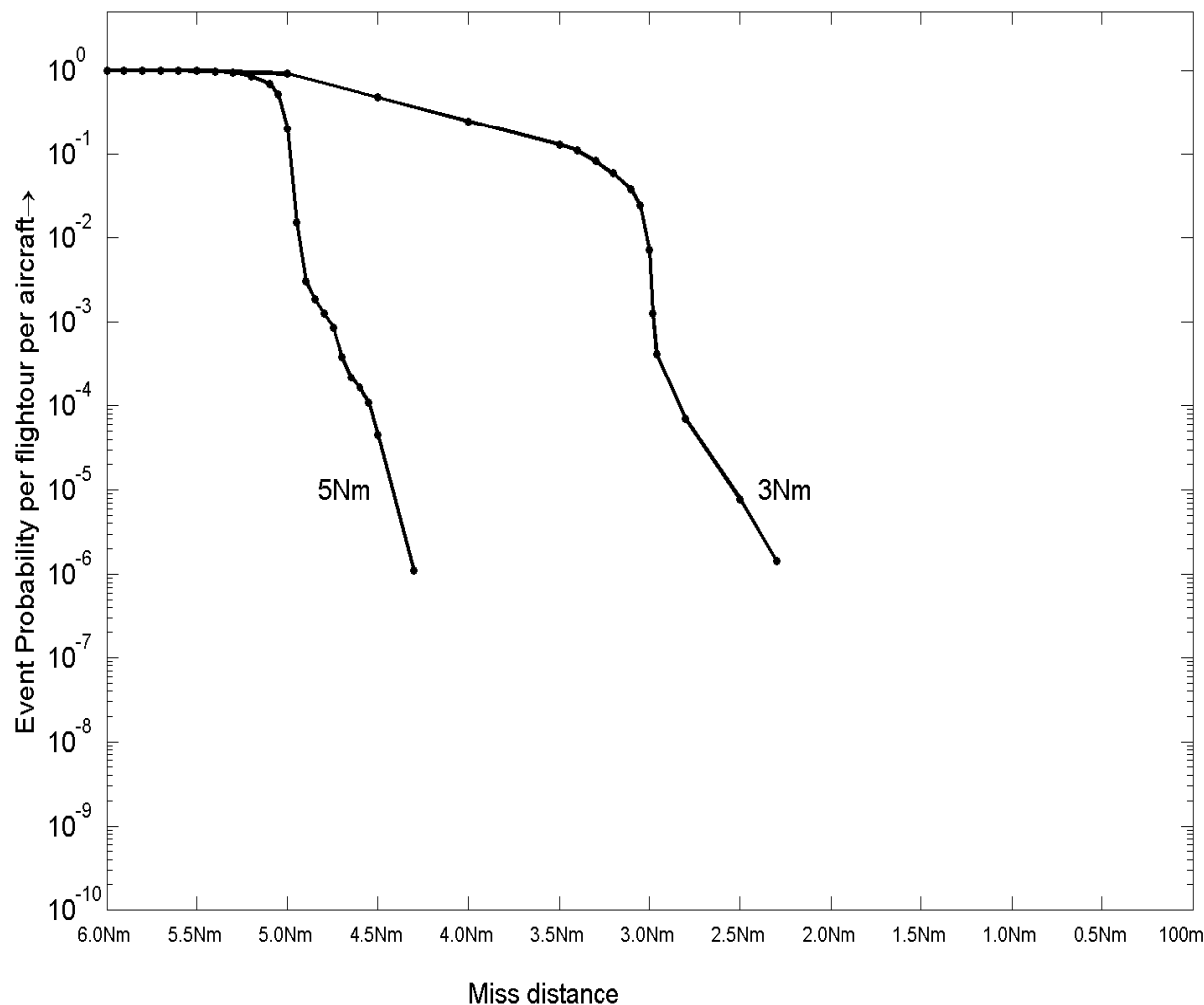
- 3x as dense as high density area in 2005
- 6x as dense as high density area in 2005

Traffic demand 3x and 6x

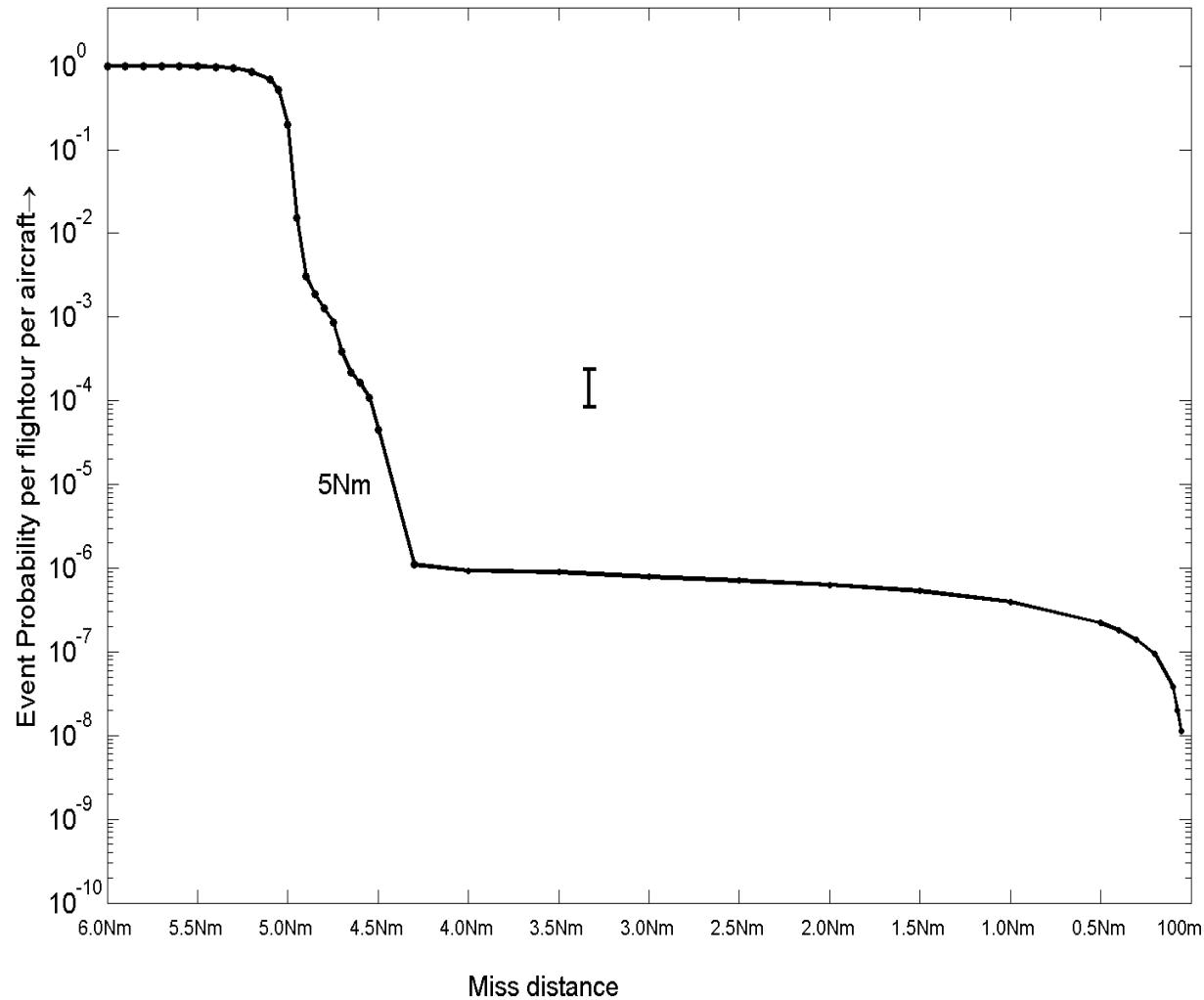




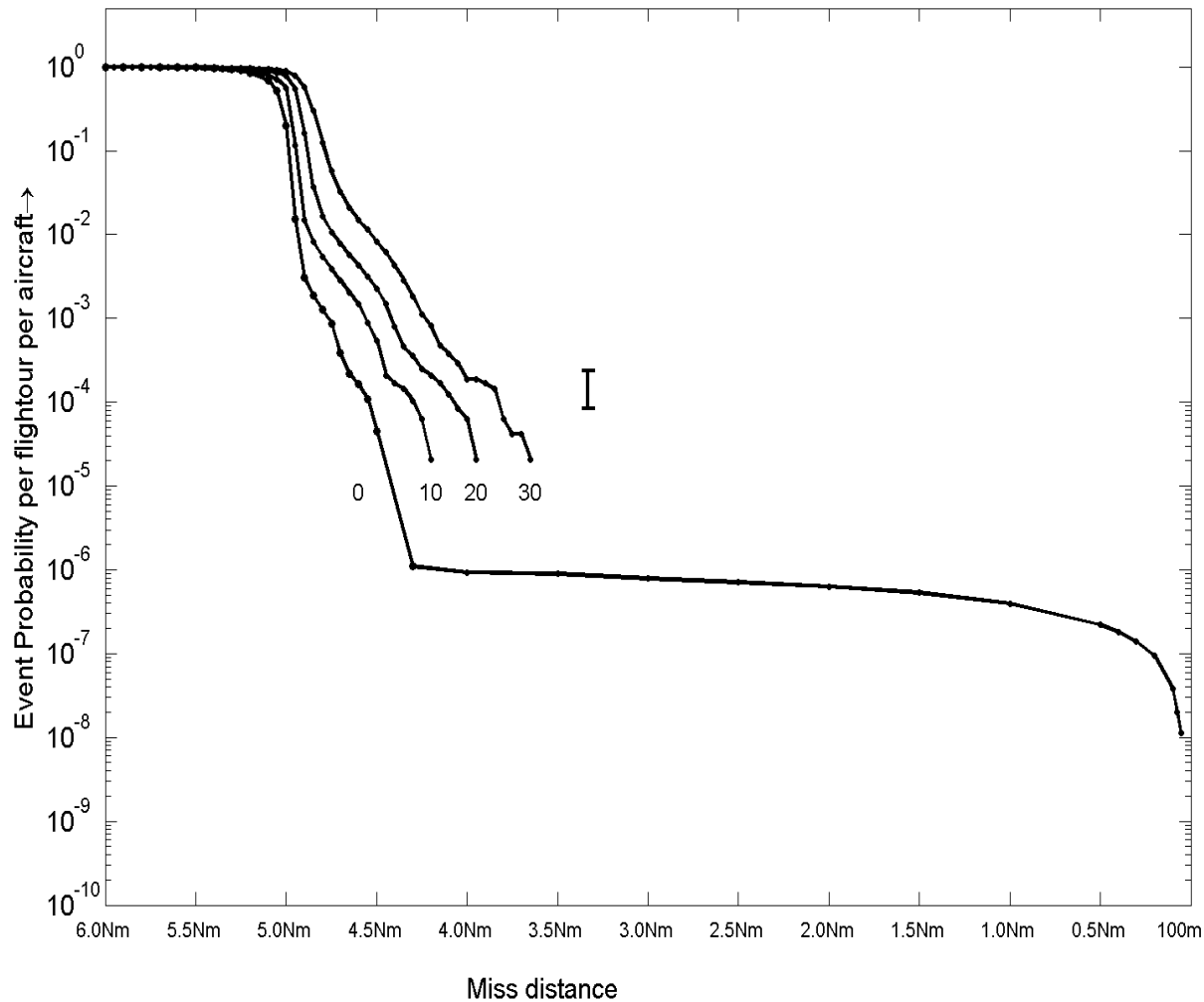
Tactical Separation: 5Nm and 3Nm



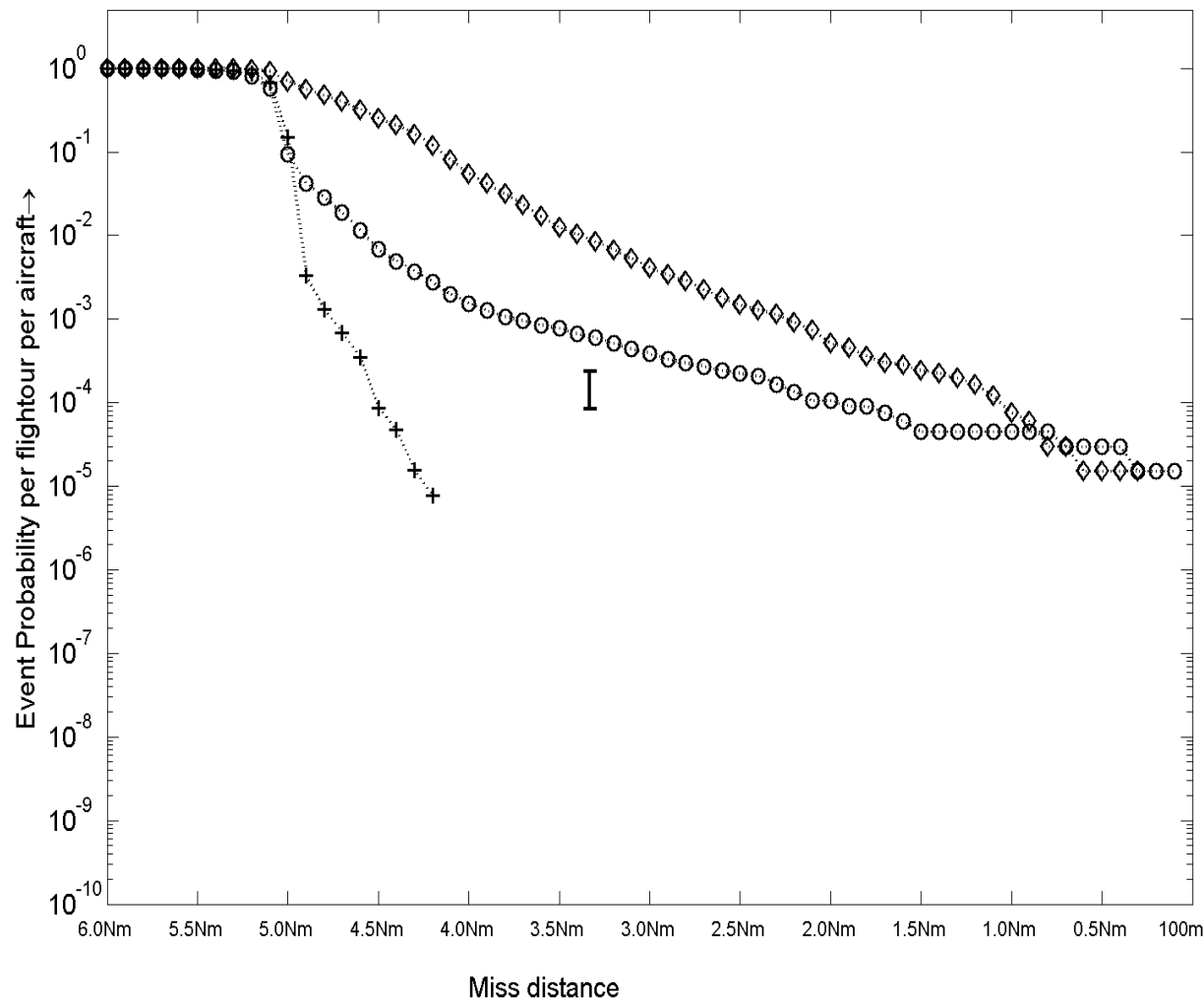
3x high 2005 random traffic



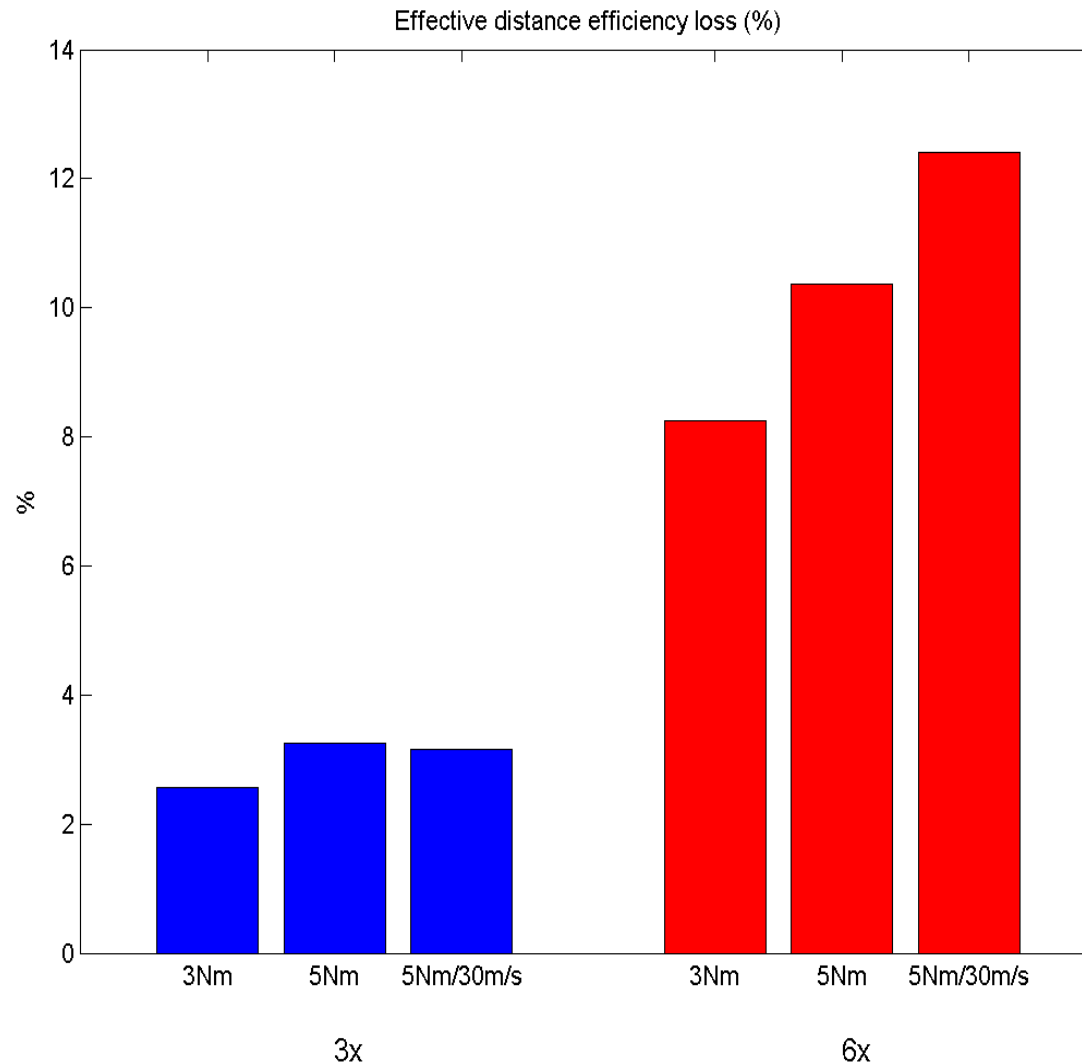
3x high 2005 traffic + systematic wind error



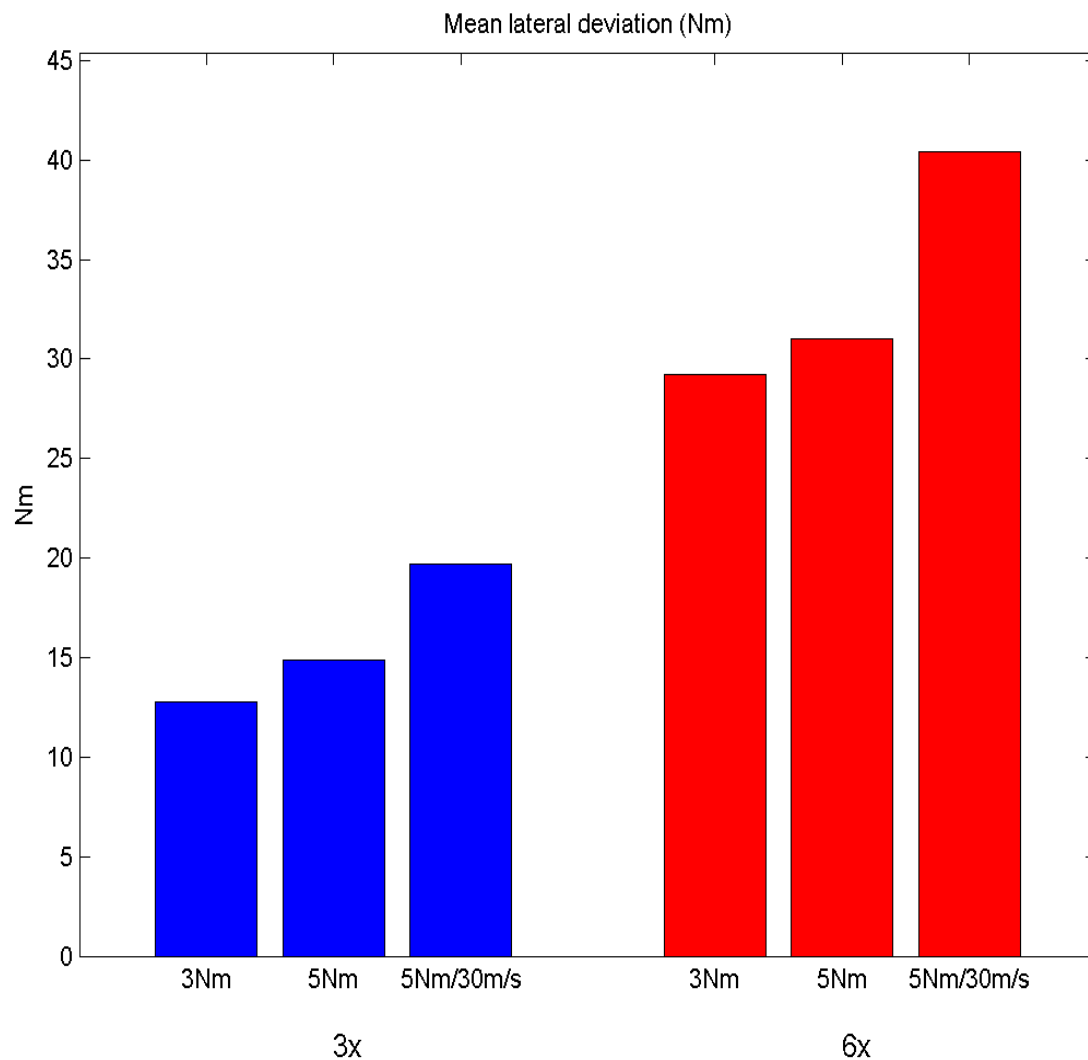
What happens when RBT's are not broadcasted?



Mean loss in effective distance travelled



Mean absolute value of lateral deviation



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Positive Emergent Behaviours identified

1. A proper tactical conflict detection and resolution layer makes it possible for the pilot to resolve tactical situations under which its 4D trajectory plan has lost the conflict-free quality.
2. There appears to be no need to keep centerlines of conflict-free 4D plans further away from each other than the tactical separation minimum.
3. In addition to safely accommodating 3x busy en-route 2005 traffic demand, above this level no phase transitions: flight efficiency deteriorates in a gradual way.

Follow-up research question:

Can these powerful positive emergent behaviours also come alive in the SESAR2020+ concept?

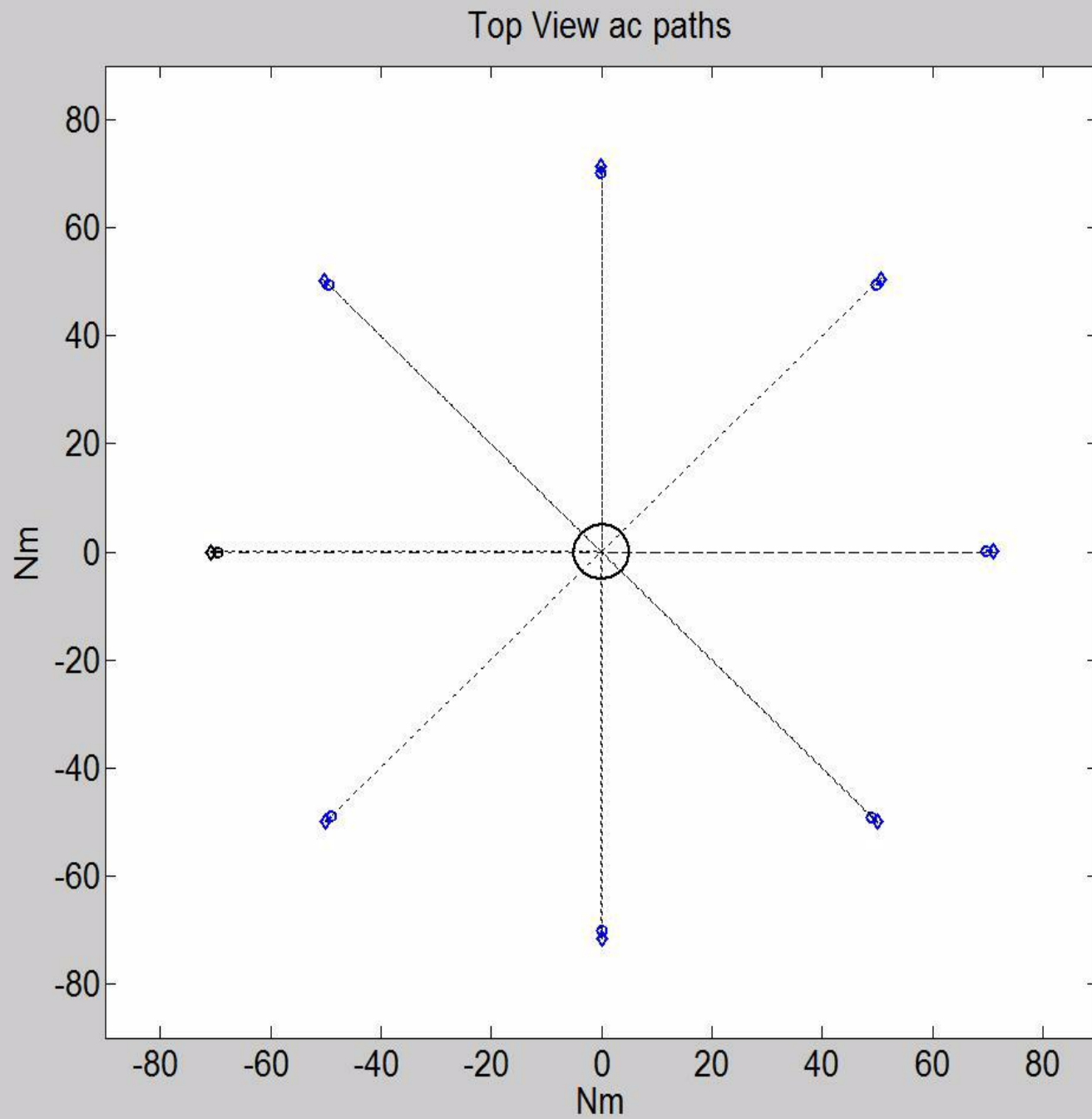
EMERGIA follow up: In search of positive SESAR2020+ emergent behaviour

- Develop an agent based stochastic model of SESAR2020+ TBO; use this to learn its emergent behaviour through Monte Carlo simulation
- Identify differences with airborne self separation TBO; any differences in positive emergent behaviour are used by future concept developers to improve the SESAR2020+ concept.
- Develop an agent based stochastic model of the improved SESAR2020+ concept, and use this to learn its emergent behaviour
- Compare emergent behaviours of improved SESAR2020+ and of airborne self separation TBO

Questions ?

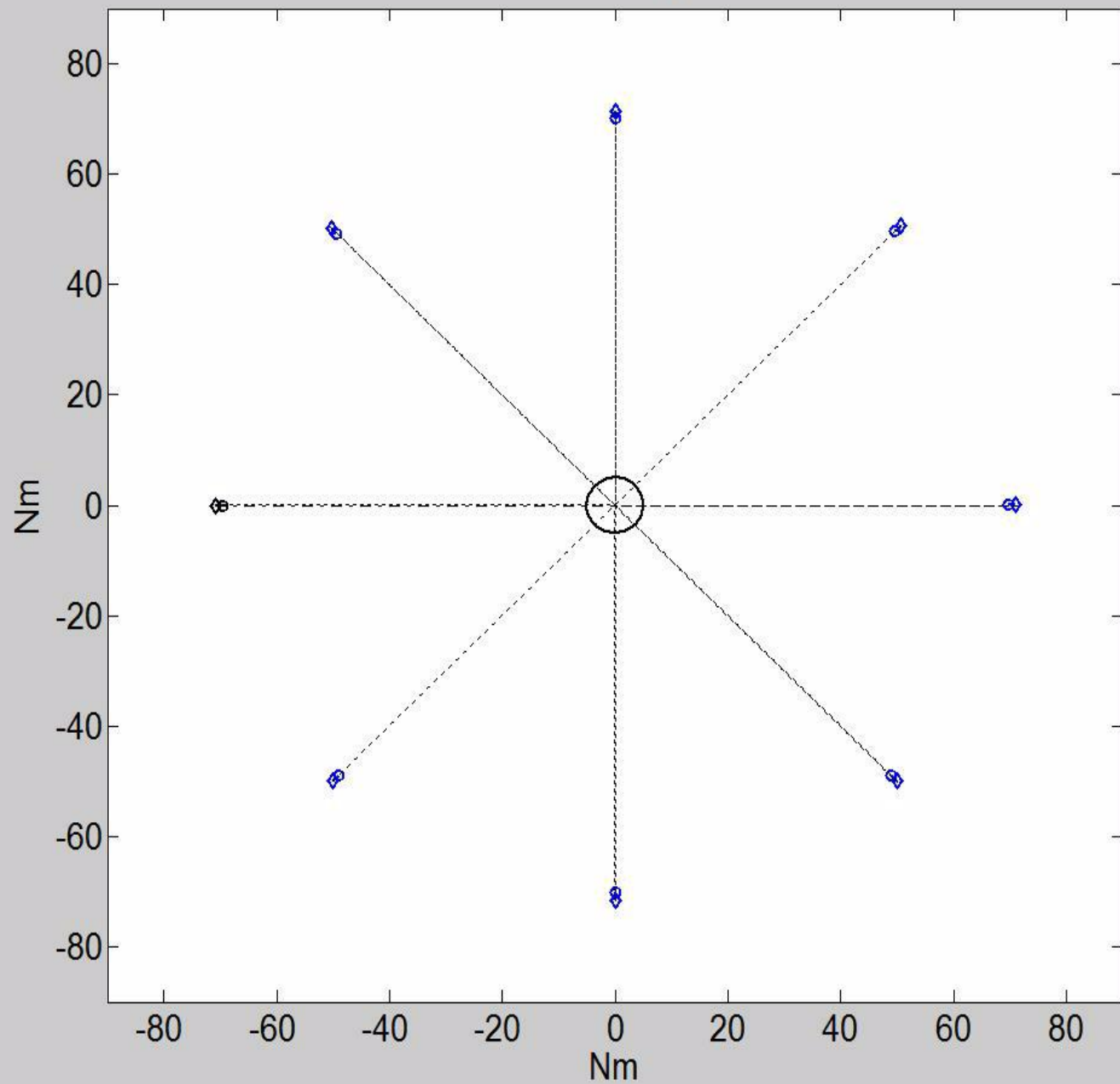


Run #1



Run #2

Top View ac paths



Run #3

Top View ac paths

