

SESAR

Innovation Days

1st December 2011

Yolanda Portillo Perez

Rodney Fewings

Zheng Lei

Cranfield
UNIVERSITY

Flow management
without en route
capacity limitations by
pre-tactical trajectory
compatibility
determination

Purpose of the Research

The research's aim is to reduce the current ATC capacity limitation by pre-tactical trajectories compatibility determination

Presentation structure:

- **Paradigm shift in ATM**
- Capacity versus Predictability
- First Approach:
 - Assumptions
 - Example
 - Conclusions

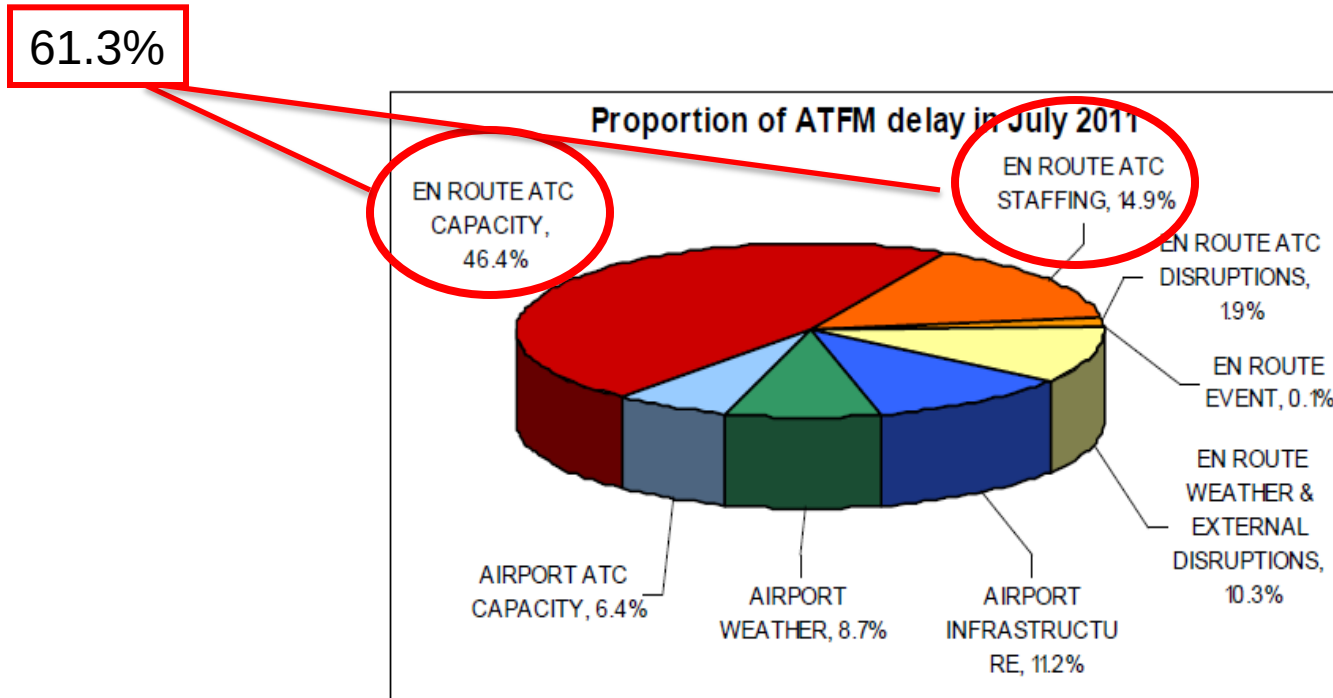
Paradigm shift in ATM

- Current Air Traffic Management (ATM) system shows clear signs of saturation (traffic expected to double by 2030)
- Increased environmental awareness calls for more efficient operations
- ATM based on principles introduced more than 50 years ago



Paradigm shift in ATM

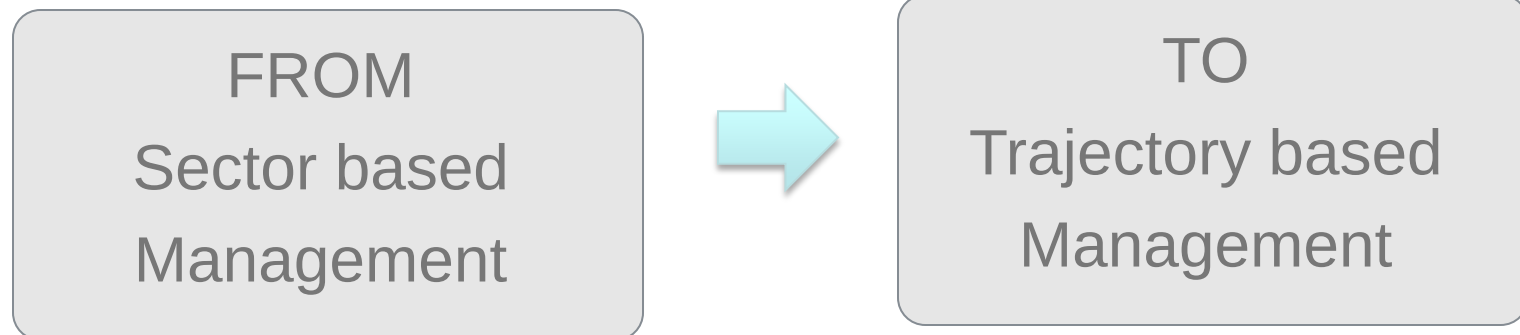
- Tactical actions taken by controllers have been identified as the main bottle neck for today's ATM system



* Network Operations Report July 2011. Eurocontrol

Paradigm shift in ATM

- USA and European initiatives towards a Paradigm Shift in ATM:



Paradigm shift in ATM

FROM
Sector
Management



SESAR Innovation Days

Paradigm shift in ATM

FROM
Sector
Management



Paradigm shift in ATM

FROM
Sector
Management



TO
Trajectory
Management

- Airspace divided into sectors handled by one executive ATCo able to control a limited number of aircraft
- To attend increase of traffic demand the number of available sectors is proportionally increased, but this also has a limit

Paradigm shift in ATM

FROM
Sector
Management



TO
Trajectory
Management

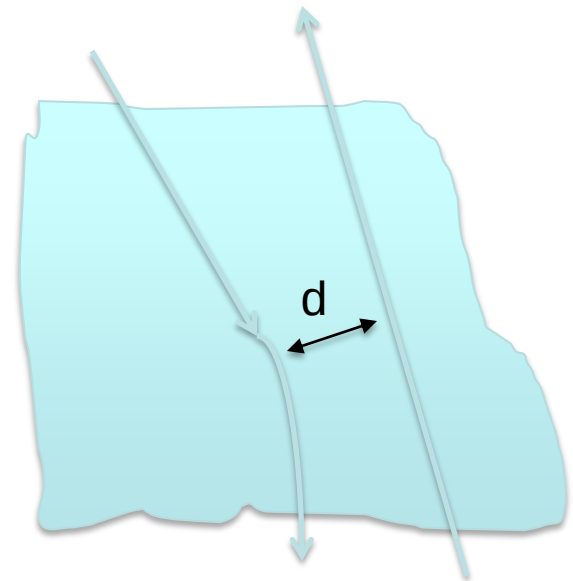
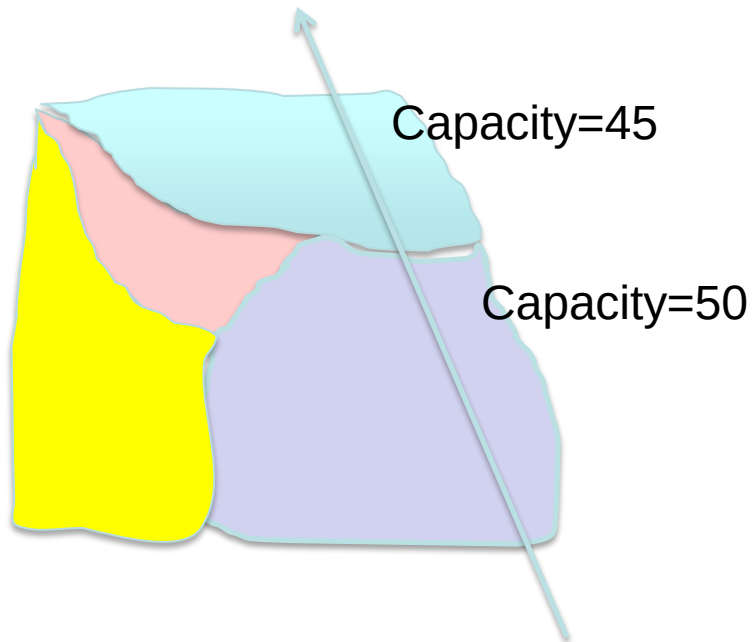
- Future ATM will require decision support tools providing conflict-free trajectories in advance
- ATCO workload reduced by this high degree of automation

Paradigm shift in ATM

FROM
Sector
Management

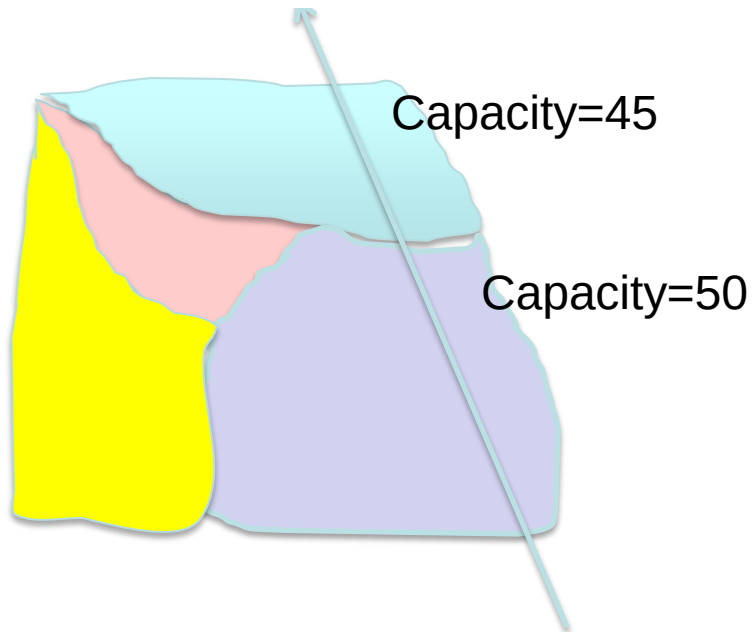


TO
Trajectory
Management



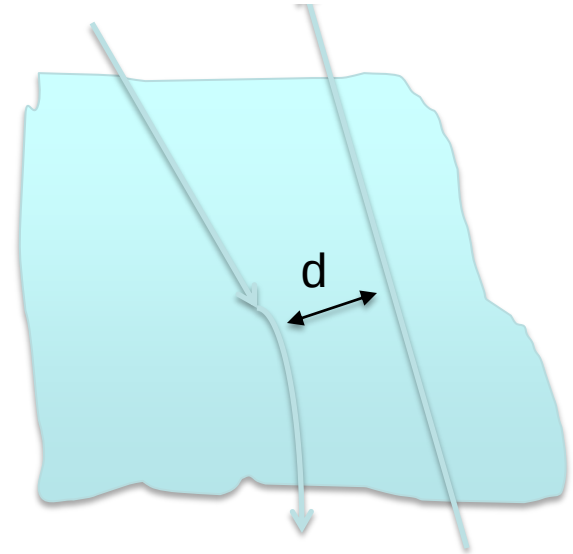
Paradigm shift in ATM

- Strategic: It is not known in advance if the traffic is going to have any conflict
- Tactical: The potential conflicts must be avoided by the ATCO
- The capacity limitation is a human limitation

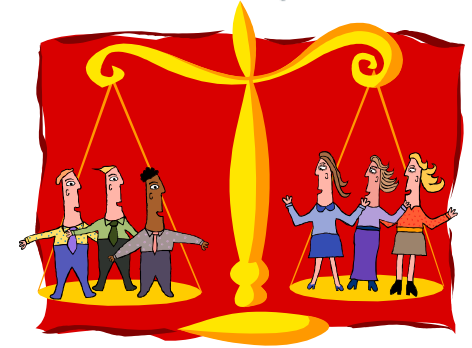


Paradigm shift in ATM

- Strategic: The trajectory is only allowed if there is not any foreseen conflict
- Tactical :The amount of possible conflicts is radically reduced
- The capacity is not limited by the human



Research's Aim



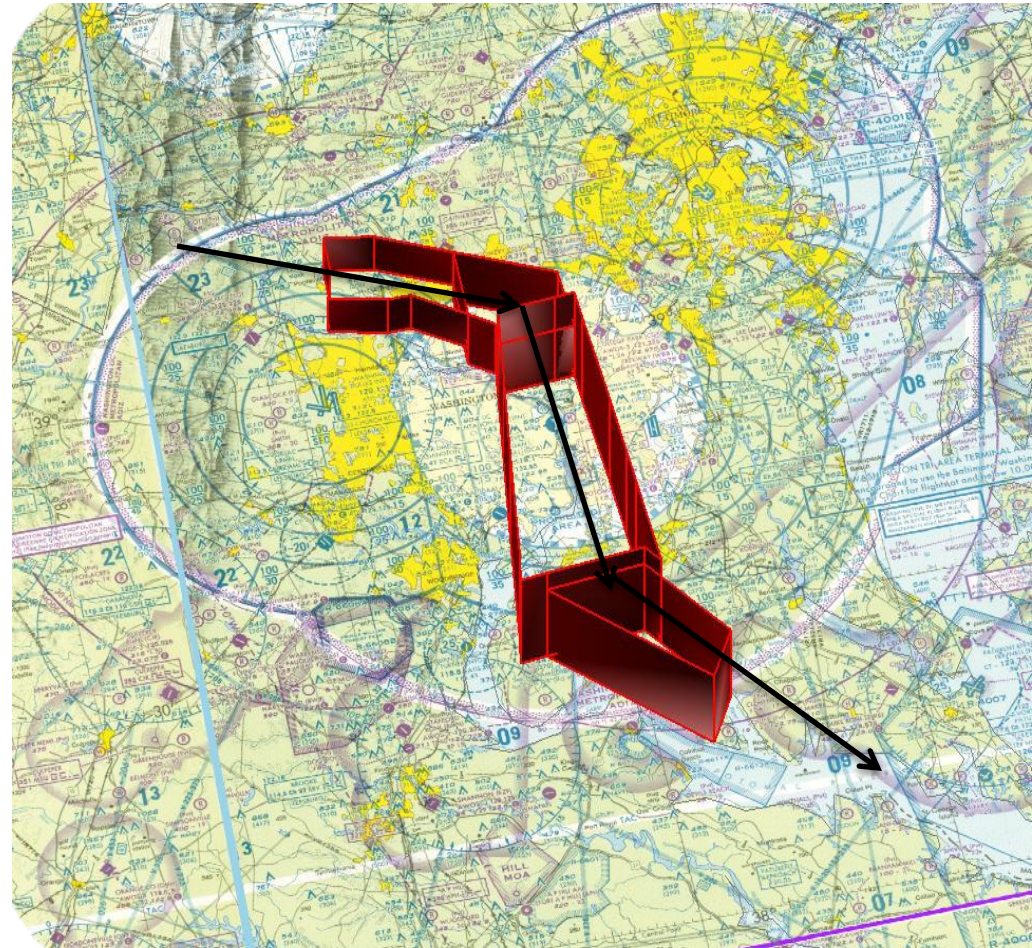
Under which conditions can two trajectories be declared as compatible? Trade off between capacity and predictability

- **Capacity:** demanded number of tactical interventions (en route capacity)
- **Predictability:** degree of compliance between planned and actual a/c positions, affecting total system safety

Capacity

Nowadays

- Max. Number of aircraft per hour : sector capacity
- Trajectory compatibility determination: capacity not exceeded in any of the sectors involved



Capacity

Real data (Maastricht UAC)

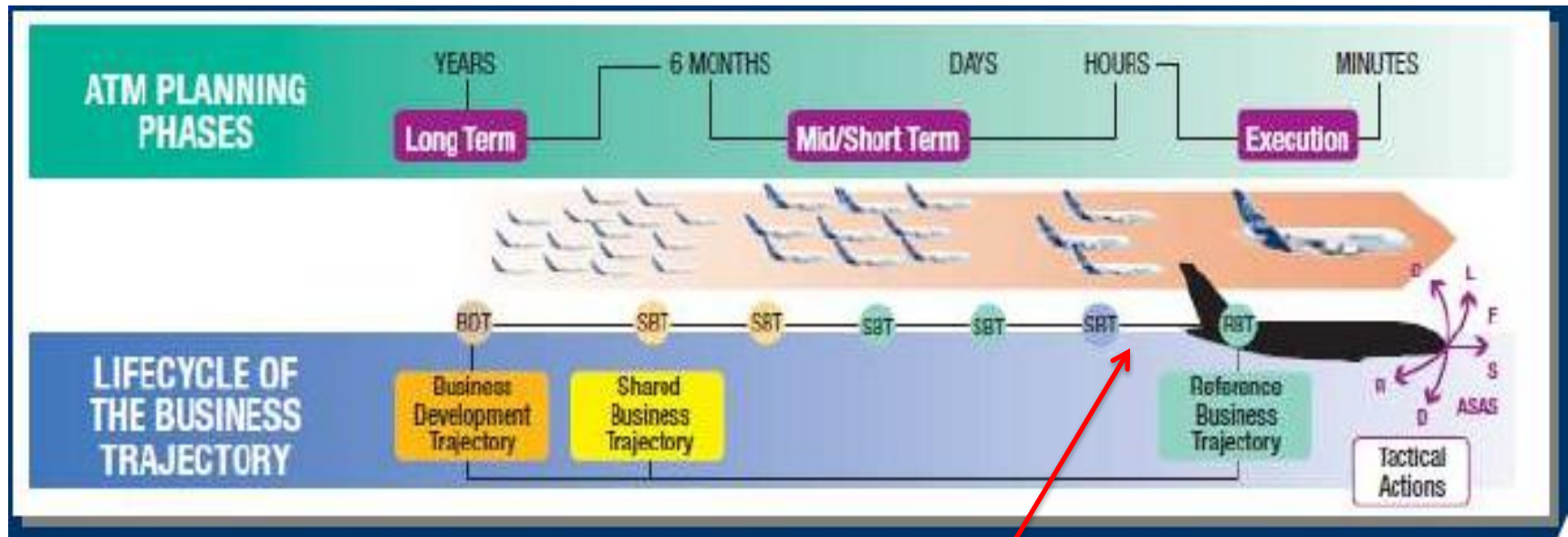
- 600 mov/sector/day
- 50% of conflicted a/c
- 75 potential conflicts/sector/day
 - 5 NM minimum horizontal distance
 - 1000 ft minimum vertical height

Predictability

- Trajectory Based Operations (prediction time)
- Trajectory deviation uncertainties:
 - Lateral
 - Vertical
 - Longitudinal

Trajectory Based Operations

- Business Trajectory, Shared BT, Reference BT

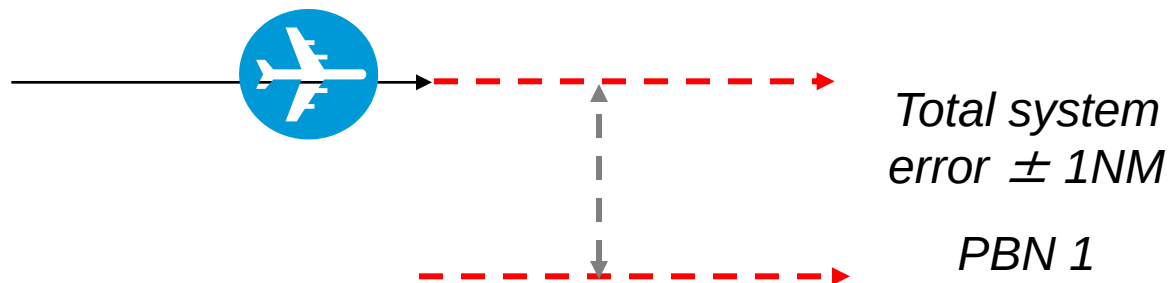


Trajectory compatibility determination

Lateral Uncertainties

PBN concept:

- Aircraft navigation system requirements
- Operation in a particular airspace supported by the appropriate infrastructure

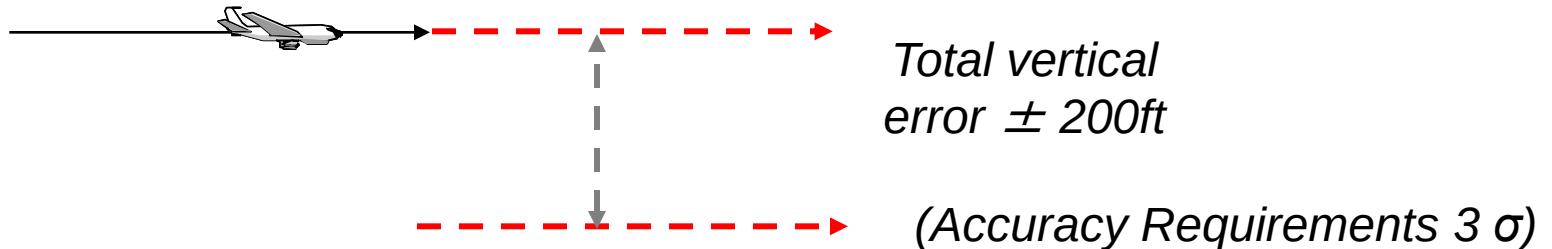


(Accuracy Requirements 95%)

Vertical Uncertainties

Two different cases:

1. Aircraft established at a flight level

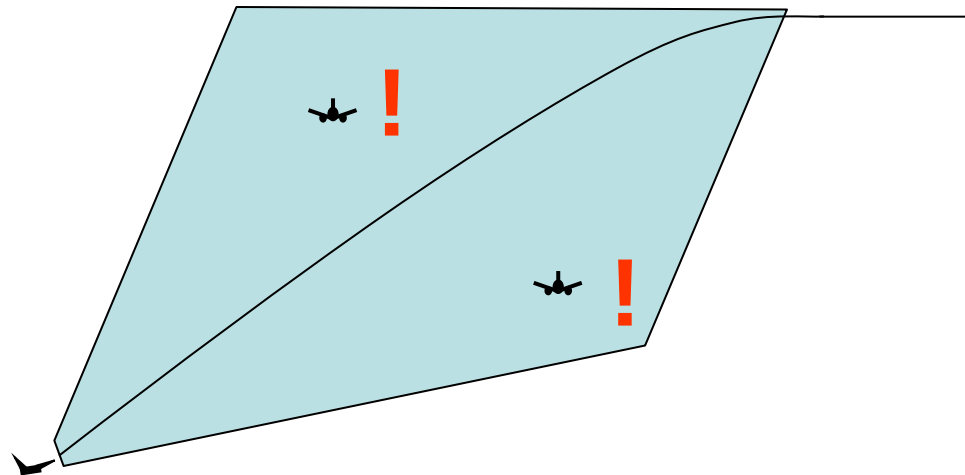


Vertical Uncertainties

Two different cases:

2. Aircraft climbing or descending

- Aircraft vertical profile evolution with T y ρ
- Wind variation with altitude



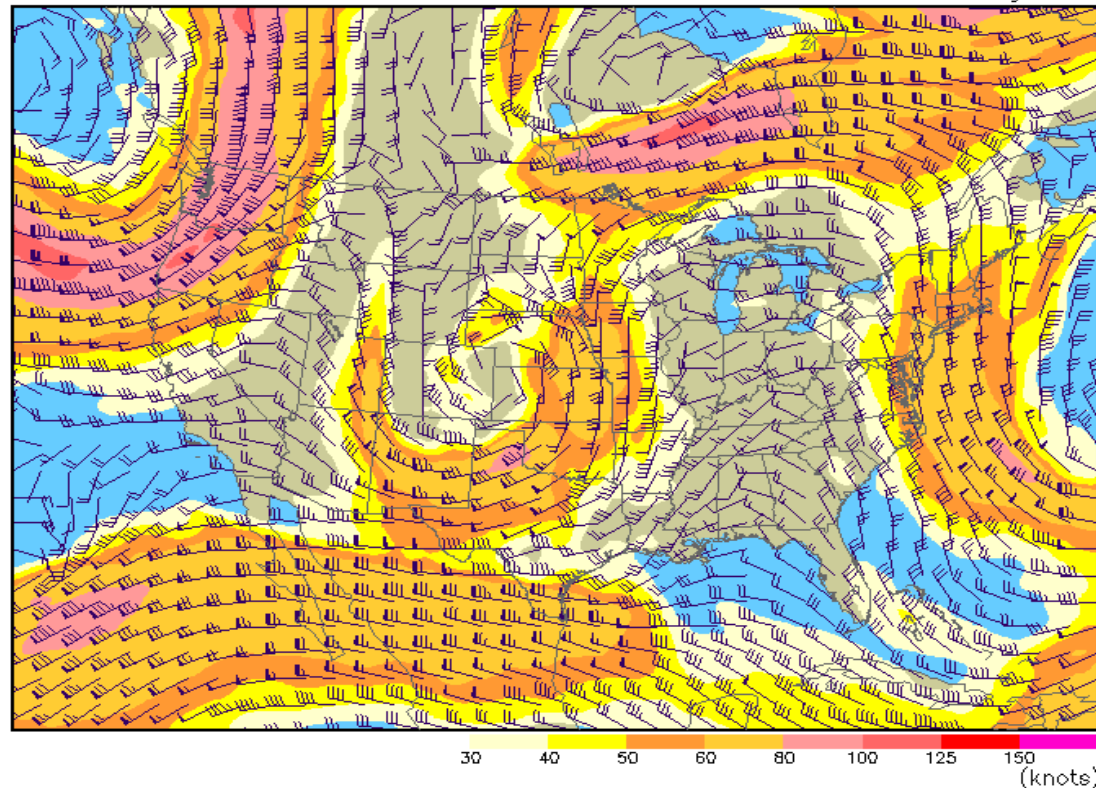
Longitudinal Uncertainties

Wind and ATM

- Wind prediction errors largest source of trajectory prediction errors
- Individual vector errors larger than 10m/s are 3% overall. RMS value for wind error about 6m/s

Wind speed (kts) at 30,000 ft MSL (300 mb)

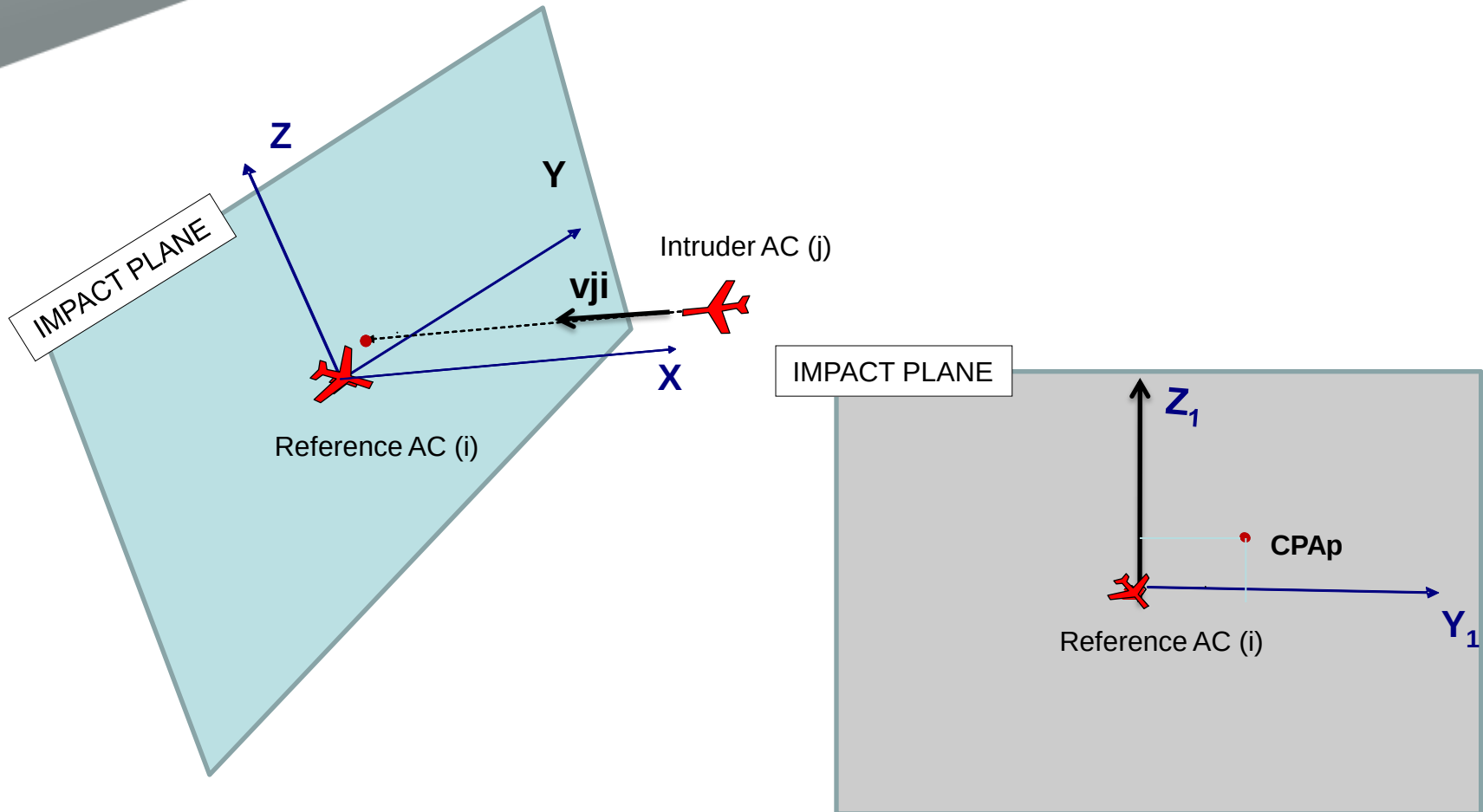
02-hour forecast valid 1400 UTC Thu 12 May 2011



ADDs temp/wind charts supplement, but do not substitute for, the official winds and temperatures aloft forecast contained in the FB product.

First Approach:

Horizontal Movement Uncertainties



First Approach: Assumptions

- En route phase of flight
- Only horizontal components considered (two aircraft established)
- Aircraft position lateral error negligible (PBN may give values as low as 0.1NM, 95% of the time)

First Approach: Expression obtained

$$\sigma = t_{CPA} \cdot a \cdot \sigma_w$$

σ	Standard deviation for CPAy coordinate estimation
t_{CPA}	Time to CPA
a	Geometrical factor (depending on aircraft and wind angles, and speeds ratio)
σ_w	Standard deviation for wind error estimation

Example

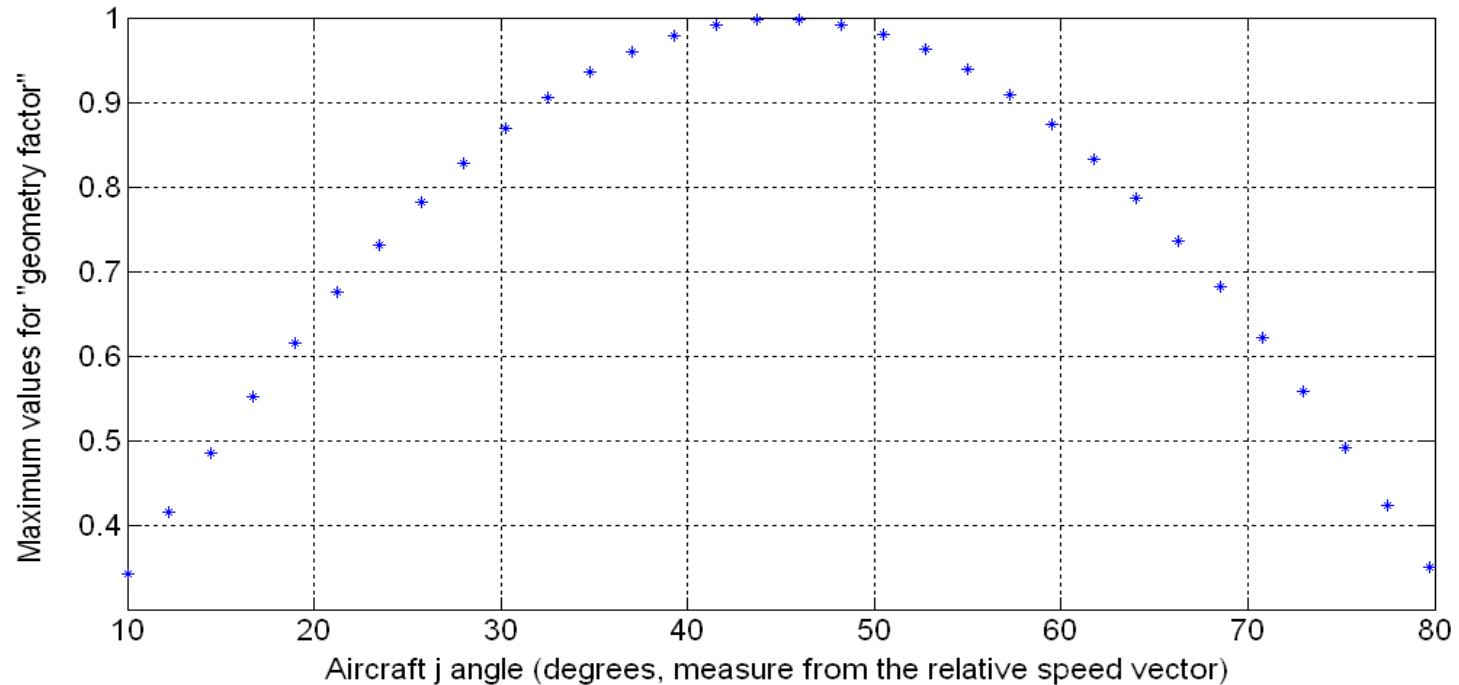
- Geometrical factor a depending on the geometry of the encounter: $\vec{v}_i, \vec{v}_j, \theta_w$
- Speeds ratio and trajectory angles, known through the flight plan (different configurations presented), wind angle unknown (worst case for any configuration chosen for the analysis).

Example

$$\sigma = t_{CPA} \cdot a \cdot \sigma_w$$

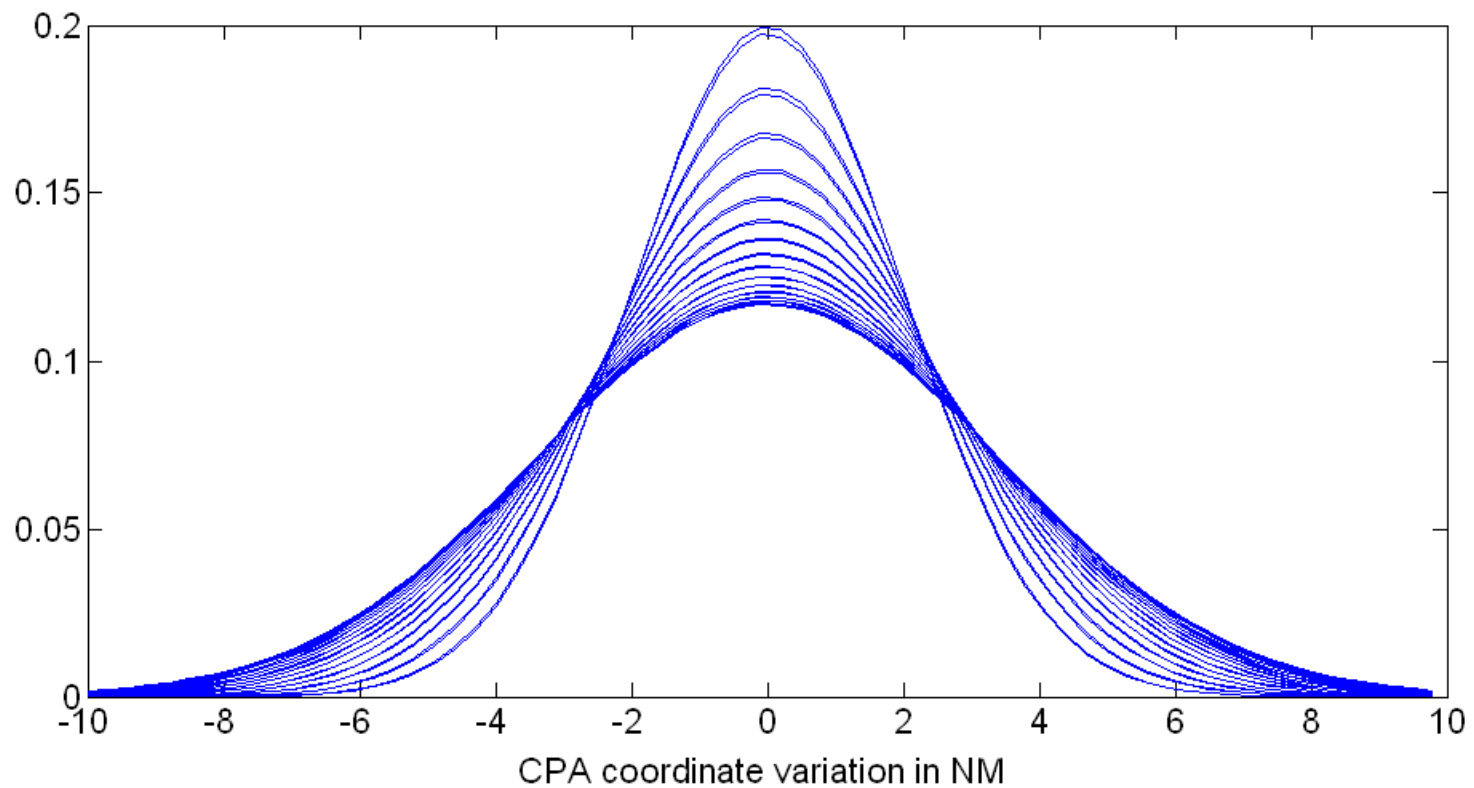
t_{CPA}	1 hour
a	variable with different encounter geometry configurations
σ_w	6 m/s (Gaussian distribution)

Example: Maximum "a"

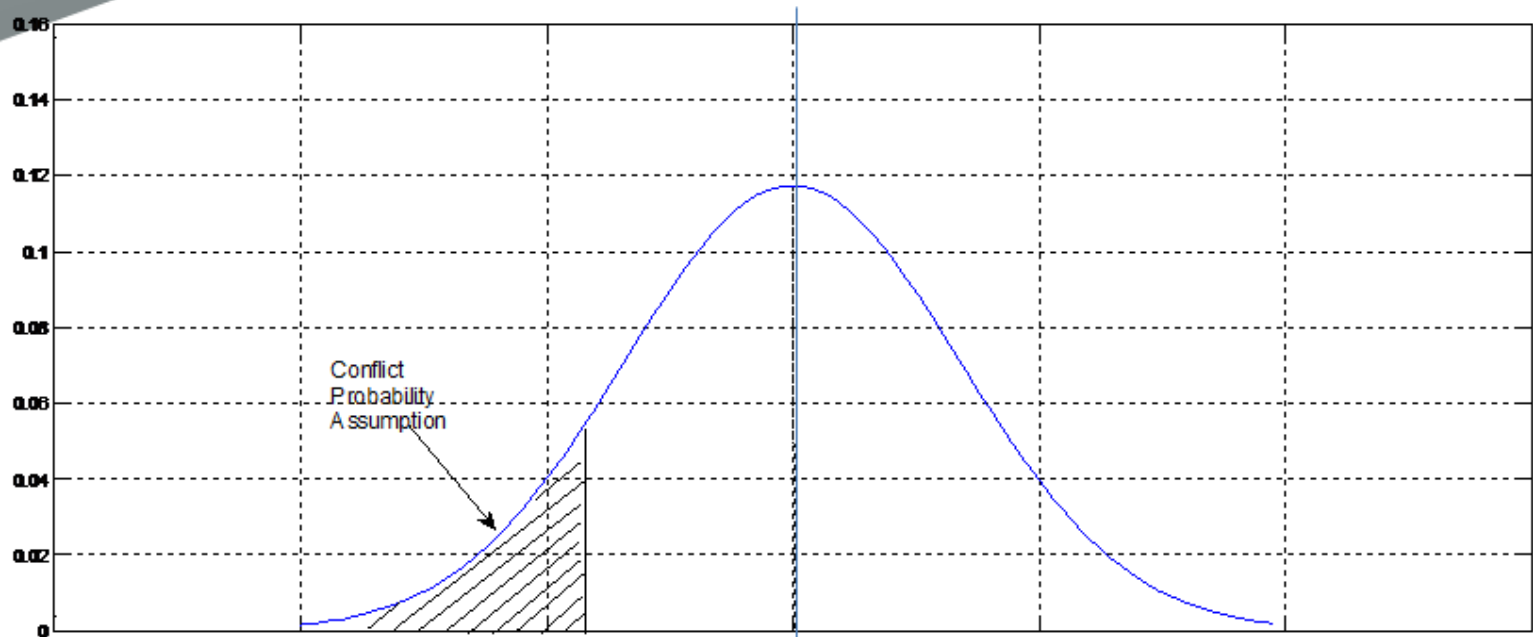


Example

Probability density functions for CPA_y coordinate



Example



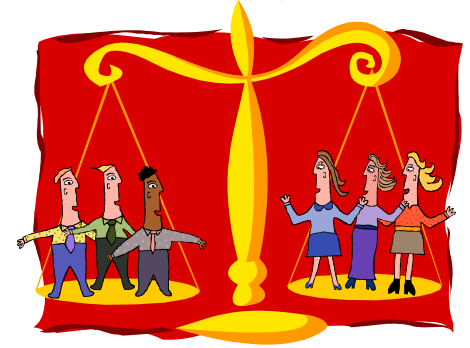
Standard Separation (5NM)

"D" NM

Aircraft i

Aircraft j

Research's Aim



Under which conditions can two trajectories be declared as compatible? Trade off between capacity and predictability

- **Capacity:** demanded number of tactical interventions
- **Predictability:** degree of compliance between planned and actual a/c positions, affecting total system safety

Example

Capacity: demanded
number of tactical interventions

Real data (Maastricht UAC)

- 600 mov/sector/day
- 75 potential confl/sector/day

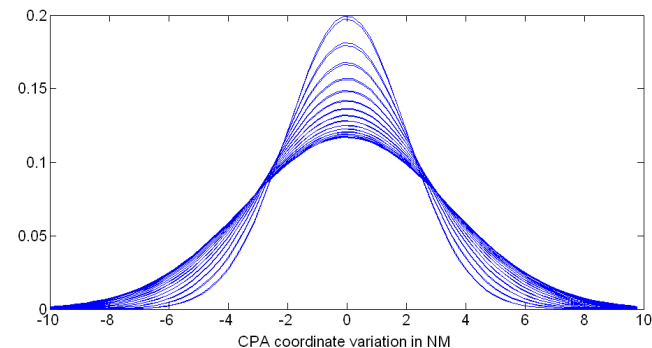
Future

- 1800 mov/sector/day
- 6 potential confl/sector/day

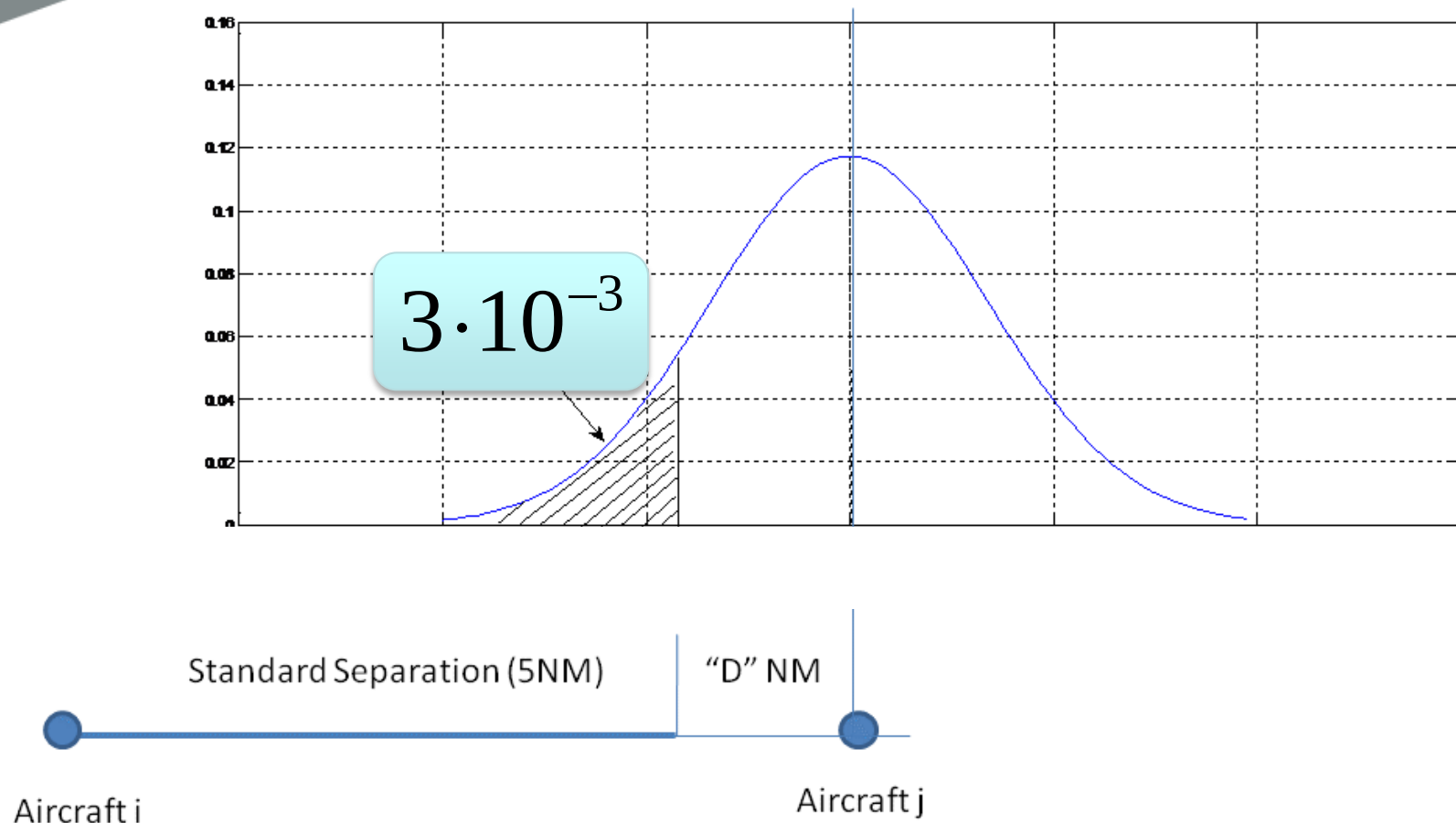
Probability of conflict assumed

$$3 \cdot 10^{-3}$$

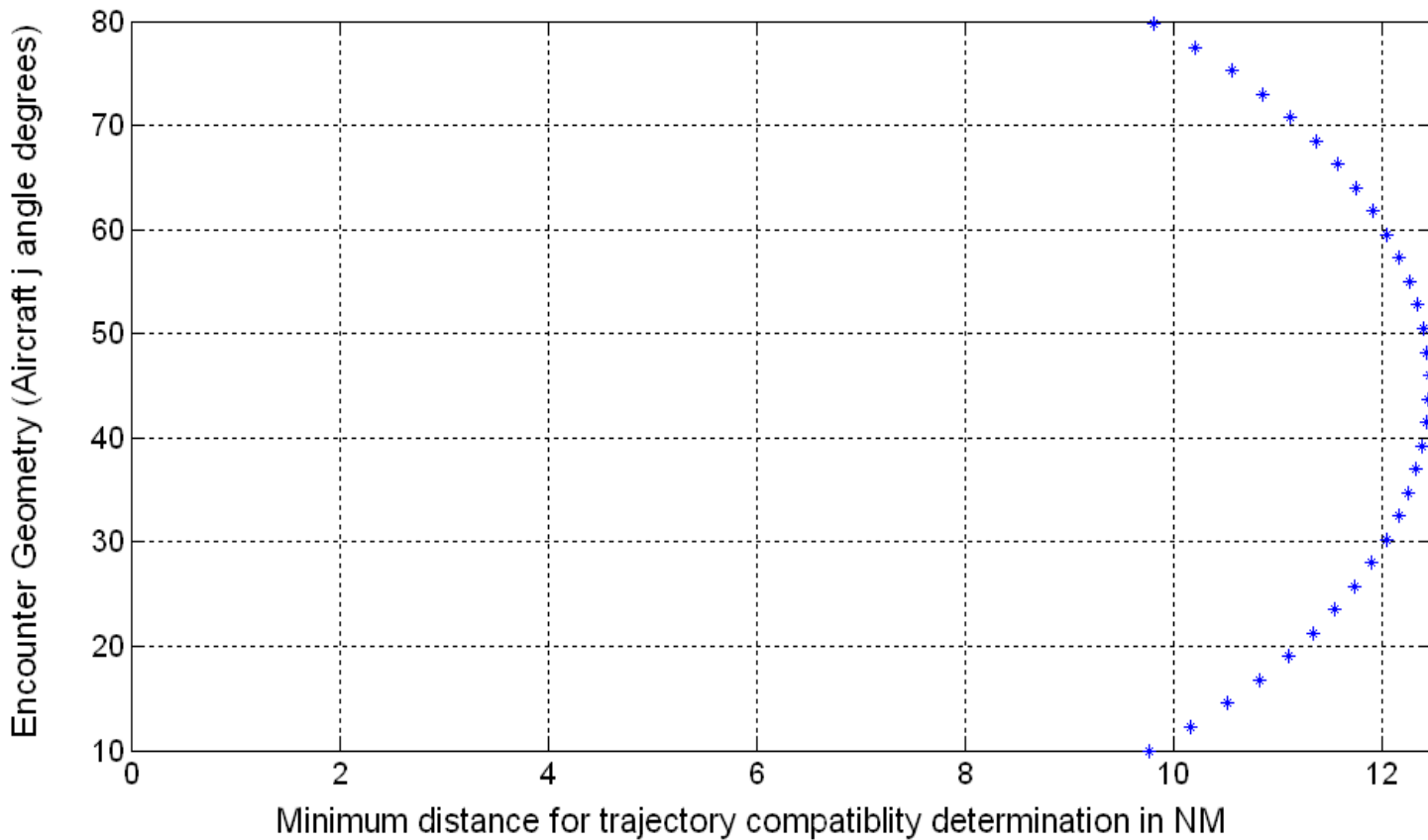
Predictability: degree of compliance
between planned and actual a/c positions,
affecting total system safety



Example



Example



Conclusions

$$\sigma = t_{CPA} \cdot a \cdot \sigma_w$$

t_{CPA}	1 hour
a	variable with different encounter geometry config.
σ_w	6 m/s (Gaussian distribution)

Probability of conflict	$3 \cdot 10^{-3}$
Tactical interventions /sector/day	6
Minimum distance between aircraft to be declared as compatible	12NM

Future Steps

- Vertical movement and other possible uncertainties inclusion (estimated time of departure)
- Algorithm for trajectory compatibility determination
- Evaluation of the impact on Flow Management capacity

SESAR Innovation days

1st December 2011

Yolanda Portillo Perez

Rodney Fewings

Zheng Lei



QUESTIONS ?