



CANSO GLOBAL SAFETY CONFERENCE 2025

24 – 28 MARCH 2025 • CHRISTCHURCH, NEW ZEALAND

HOSTED BY **AIRWAYS**



QUANTIFYING AIRSPACE RISK – OCCURRENCES, AIRSPACE RISK, AND SAFETY CHANGE



PRESENTER



Dr. Steven Barry

Risk Intelligence Lead
Airservices Australia

INTRODUCTION

Who, why, what



Left to Right: Risk Intelligence team

- Dr Giovanni Guccione
- Dr Gino Lu
- Dr Shea Houlihan
- Dr Steve Barry
- Dr Lara Connolley
- Dr Kshama Kurian

WHO

Myself

- Dr Steven Barry
- Airservices Australia
 - Risk Intelligence Lead
- Rapporteur - Mathematics Subgroup
 - ICAO Separation Airspace Safety Panel (SASP)



My team quantifies risk for

- Occurrences
- Airspace monitoring
- Airspace changes
- RVSM airspace – ICAO regional monitoring agency

My Colleagues

- Benoit Figuet
 - Zurich university of applied sciences (ZHAW)
 - SkAI Data Services
 - Advisor to ICAO SASP
- ICAO - Separation Airspace Safety Panel



WHY

CANSO paper to AN-14

Nov 2024



International Civil Aviation Organization

AN-Conf/14-WP/88¹
28/6/24

WORKING PAPER

FOURTEENTH AIR NAVIGATION CONFERENCE

Montréal, Canada, 26 August to 6 September 2024

- Agenda Item 2:** Timely and safe use of new technologies
2.3: 2026-2028 Edition of the Global Aviation Safety Plan (GASP)

MOVING BEYOND COMPLIANCE MEASUREMENT

(Presented by Civil Air Navigation Services Organisation (CANSO) and
International Federation of Air Traffic Controllers' Associations (IFATCA))

CANSO AN-24 PAPER

Existing reporting

- A loss of separation event has traditionally been used as a proxy to measure the ANSP's exposure to this accident risk.
- Each loss of separation event is scored as to its "severity" class

Existing limitations

- the measurement of IFR-IFR losses of separation will not provide a complete understanding of safety risks in a system.



CANSO AN-24 PAPER

Proposed reporting

- [...] measurement that expresses the potential risk of collision [...] that will detect how often aircraft have converging trajectories
- [...] whether a pair of aircraft [...] would be predicted to [...] come into very close proximity to one another without a subsequent change of trajectories

Proposed reporting

- For each detected interaction, such a time to conflict methodology, calculates a score that represents the significance of the interaction based on the aircraft geometries

Recommendations

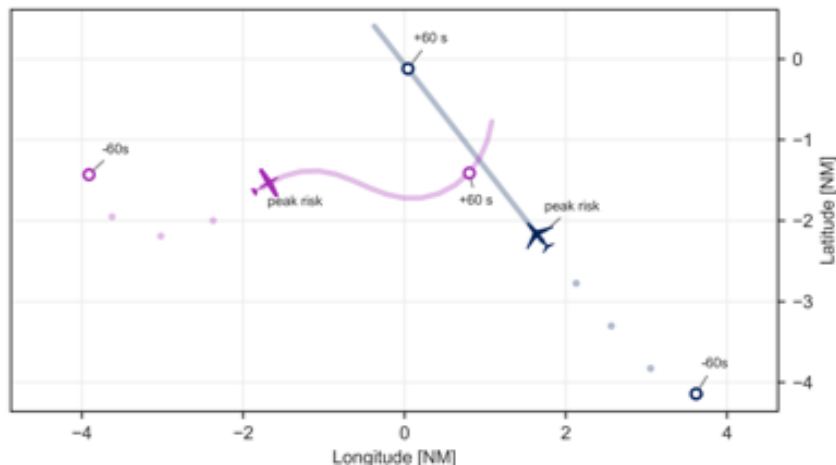
- [...] ANSPs develop methodologies and safety performance indicators to assess and monitor risk beyond existing or conventional compliance measures



WHY

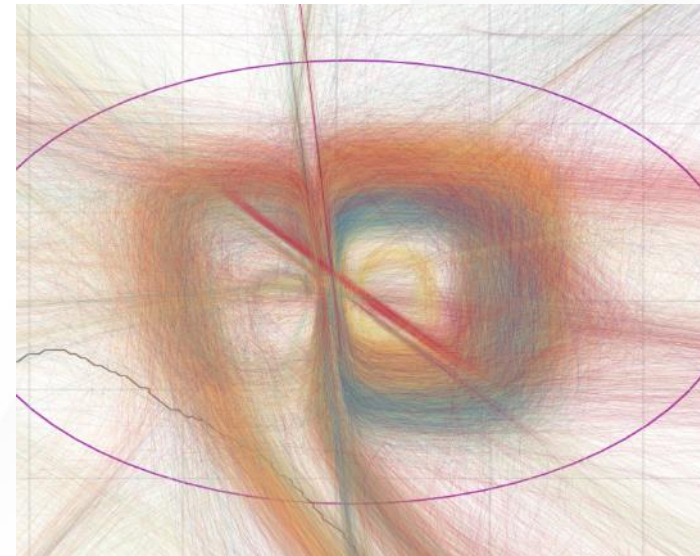
Quantifying risk for occurrences and conflicts

- Which occurrences and conflicts are riskier?
- Allow subject matter experts more exact information



Quantifying risk for airspace

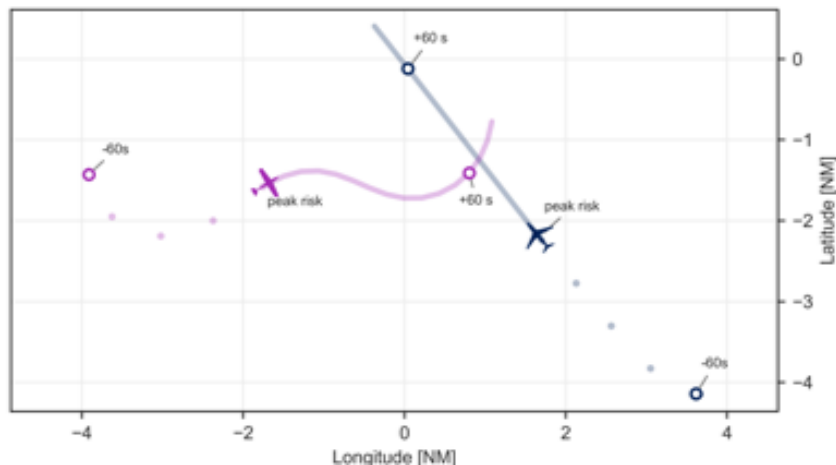
- Which airspaces have the most risk
- Why and where are they risky?



WHAT I WILL SHOW

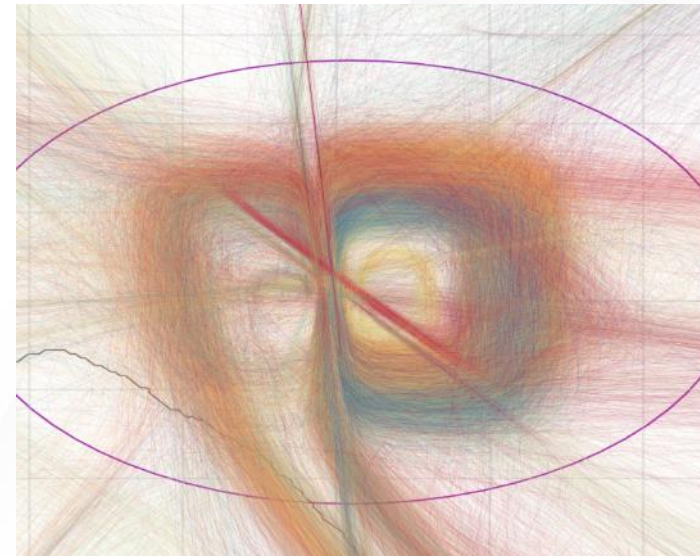
Quantifying risk for occurrences and conflicts

- Examples of how we quantify risk for any conflict
- Overview of the method



Quantifying risk for airspace

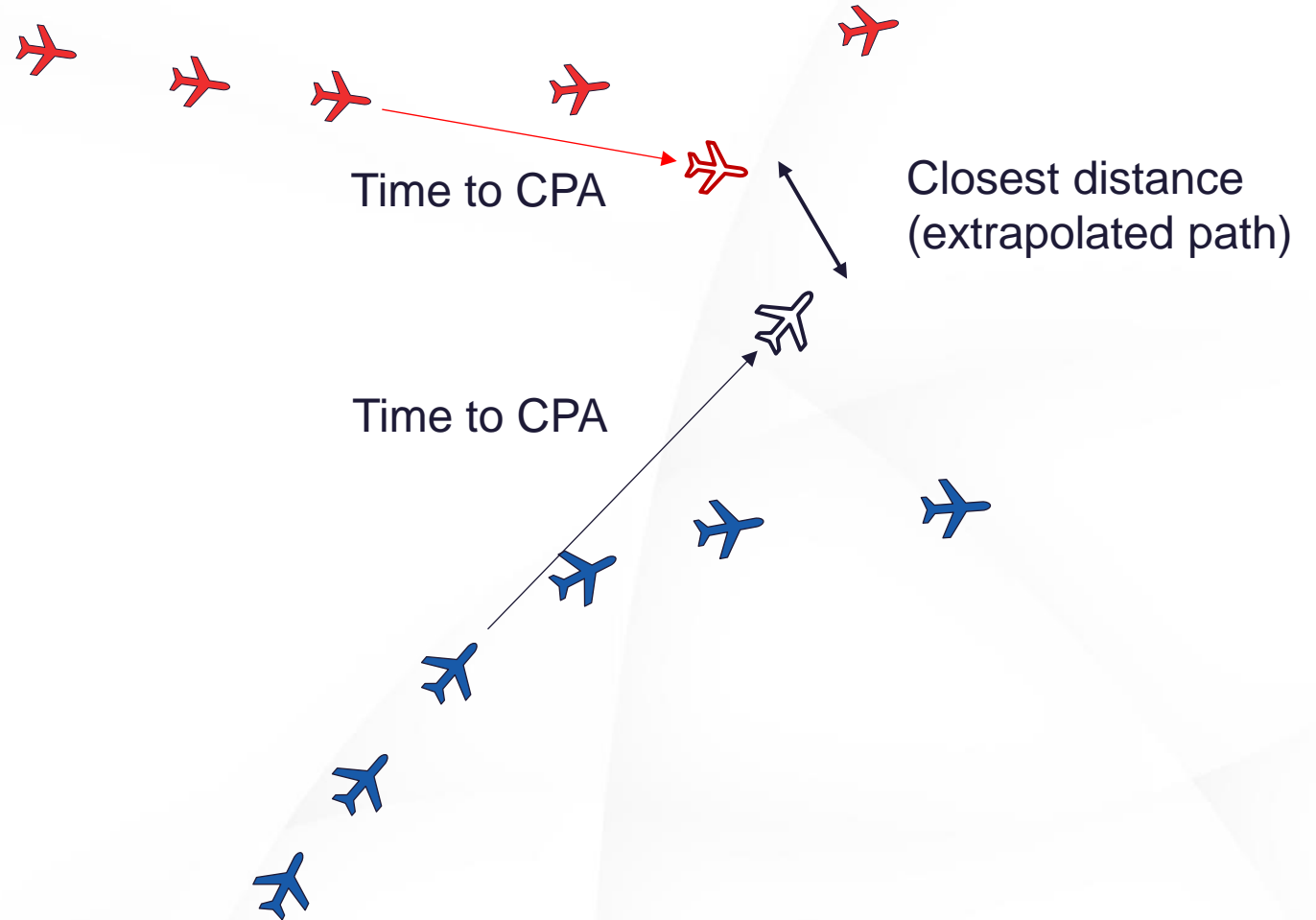
- Examples for two Class D aerodromes
- Overview of methods



OCCURRENCE RISK

Key concepts

- Two aircraft were on a course for a conflict
- ATC saw the conflict and intervened – vectoring both aircraft
- How do we measure the risk?
- Find closest distance of extrapolated paths
- Closest point of approach (CPA)
- Find time to CPA



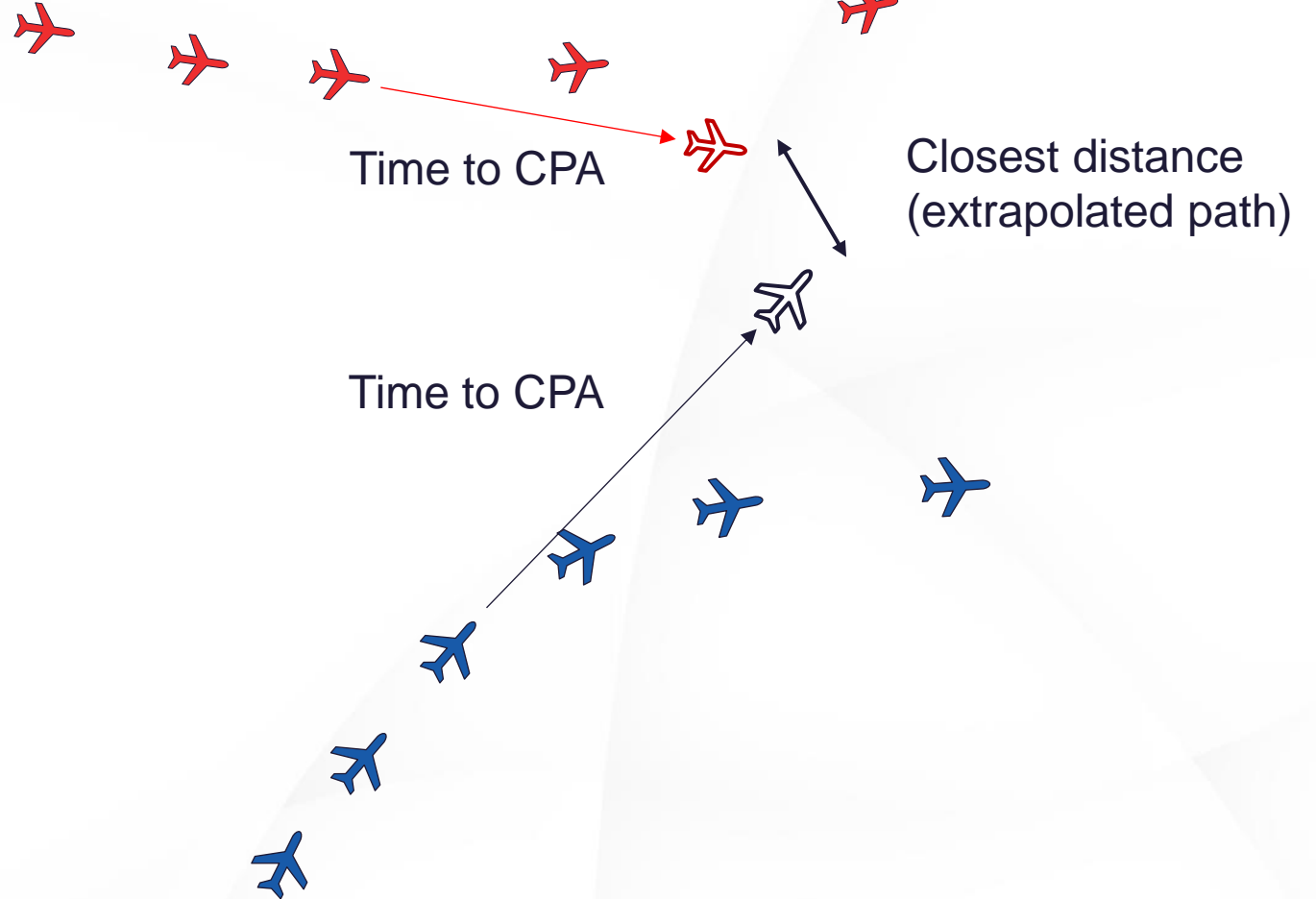
OCCURRENCE RISK

Key concepts

- MITRE model (Parker 2019)
 - T_c time to CPA
 - X_c lateral separation at CPA
 - Z_c vertical separation at CPA

$$\text{score} = \left(\frac{T_c}{a}\right)^2 + \sqrt{\left(\frac{X_c}{b}\right)^{2.5} + \left(\frac{Z_c}{c}\right)^{2.5}}$$

- $a = 30\text{s}$, $b = 0.25 \text{ NM}$, $c = 250 \text{ ft}$
- Lower score – higher the risk

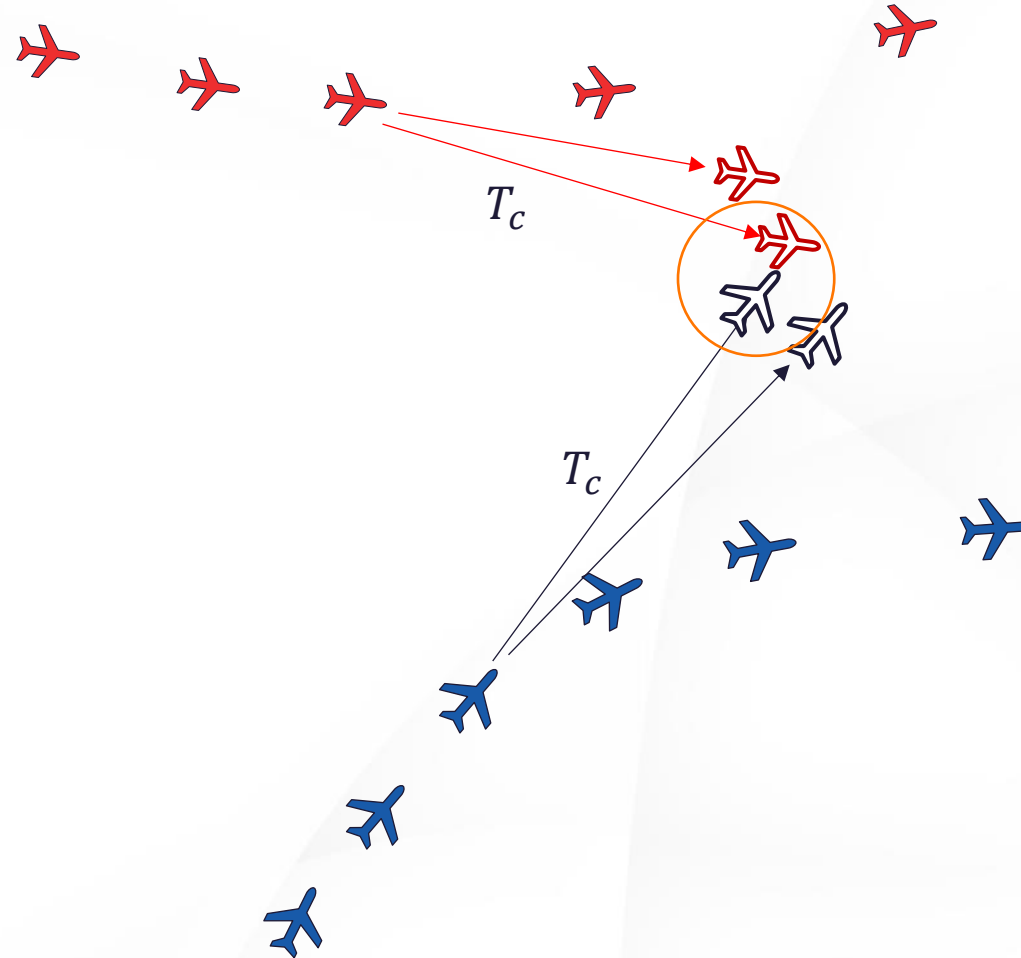


MITRE	Airborne Risk Identification and Assessment
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OCCURRENCE RISK

Airservices model

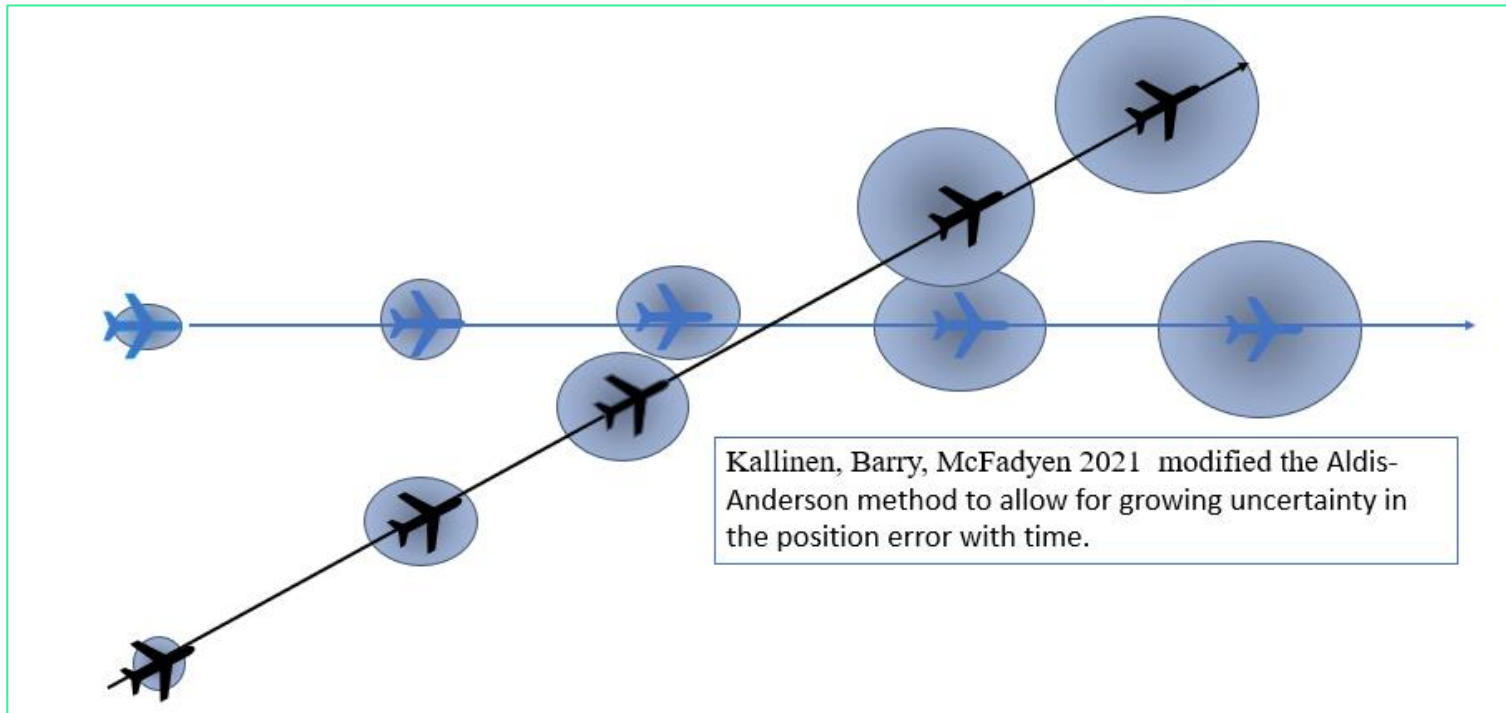
- Consider one of the path times
- Vary speeds and angles according to known variations
- Find probability of horizontal overlap
- Look at extrapolated altitudes – find vertical overlap
- Model probability of intervention in time T_c



HORIZONTAL OVERLAP

Several methods were tried – position distributions

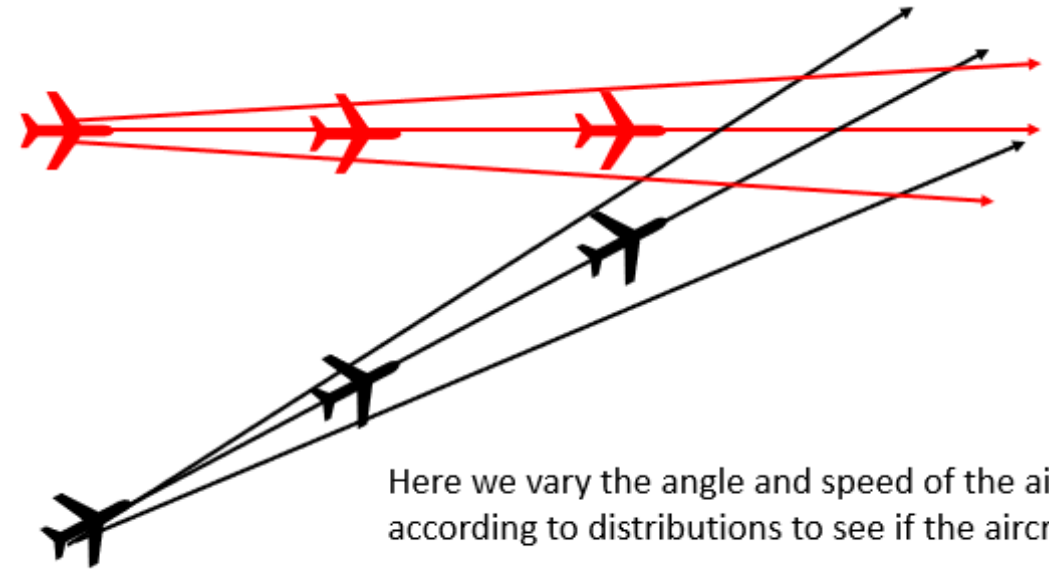
- Overlapping distributions based on SASP models



HORIZONTAL OVERLAP

Several methods were tried – varying speed, angle

- Evolved a model based on variations of angle and speed
- Allows for small and large variations in angle
- Essential provides a mechanism for position variation

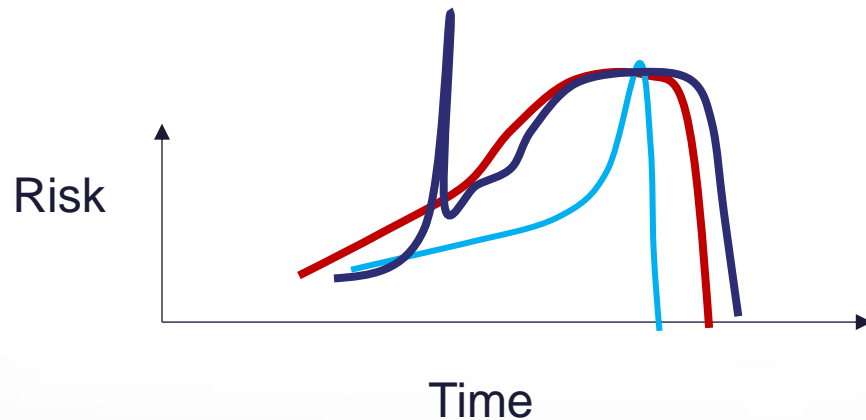


Here we vary the angle and speed of the aircraft according to distributions to see if the aircraft collide.

OCCURRENCE RISK

Airservices model

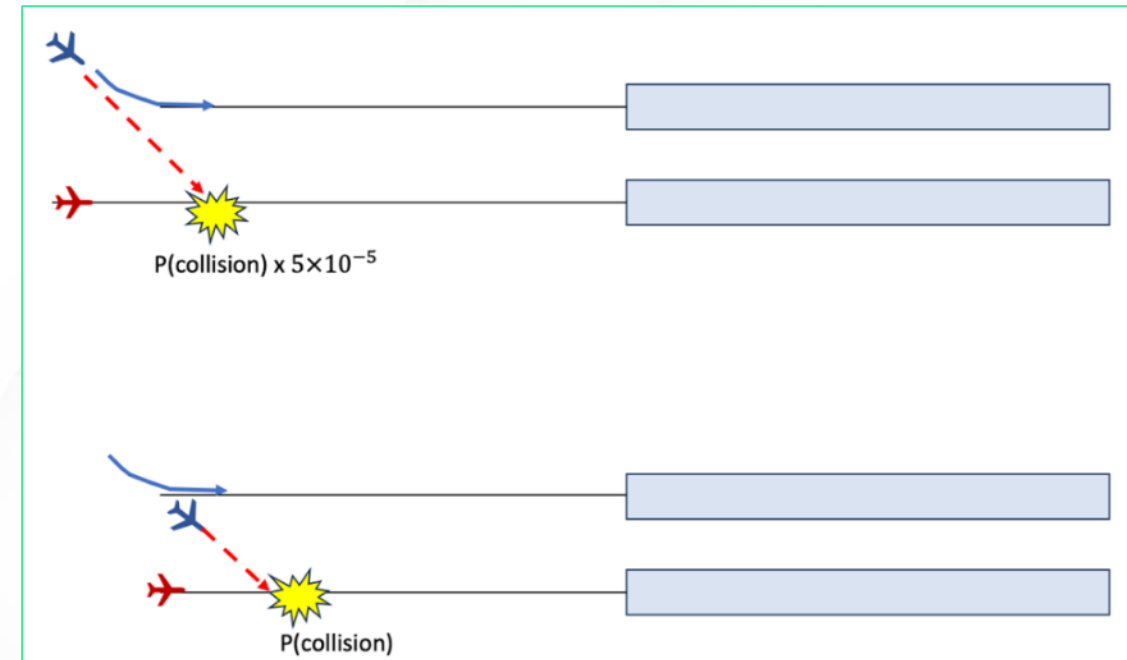
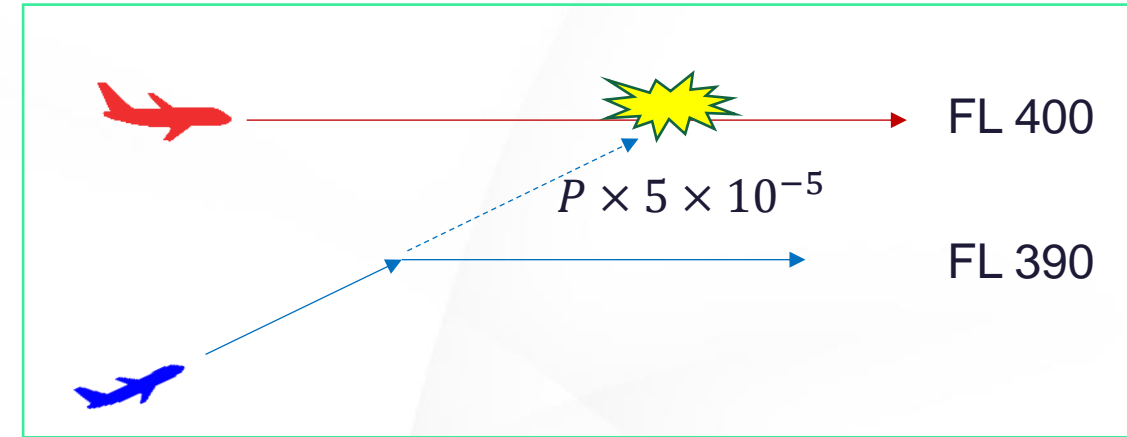
- Long time to CPA → smaller risk
- Further apart at CPA → smaller risk
- Get risk at each time step
- Risk will grow then drop off quickly
- Do integration over the time (via modification of reliability theory)
- Accounts for small peaks and long periods of risk



OCCURRENCE RISK – KEY FACTOR

Would aircraft have continued the path?

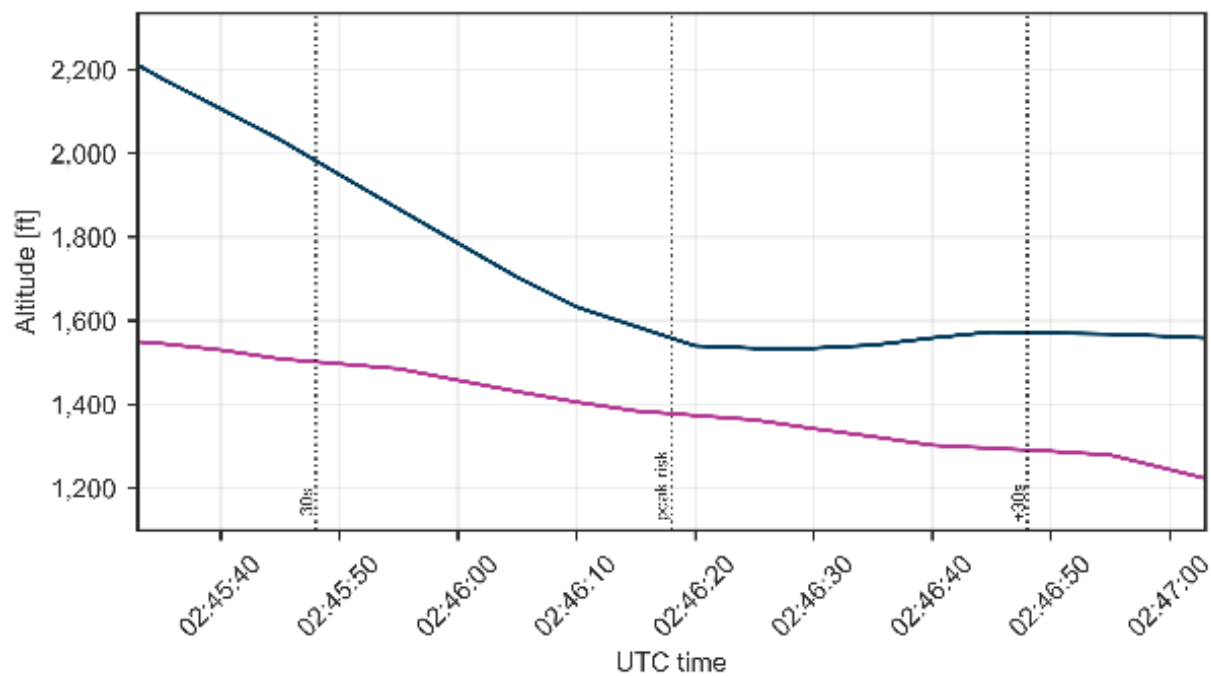
- Aircraft did not collide
- Model is estimating risk if
 - successful barrier had not succeeded
 - subsequent barriers fail
- If before a known path change risk is multiplied by error rate 5×10^{-5}
- If after the expected path, then the risk is not multiplied
- 5×10^{-5} SASP error rate for controlled IFR traffic – based on multiple data sources



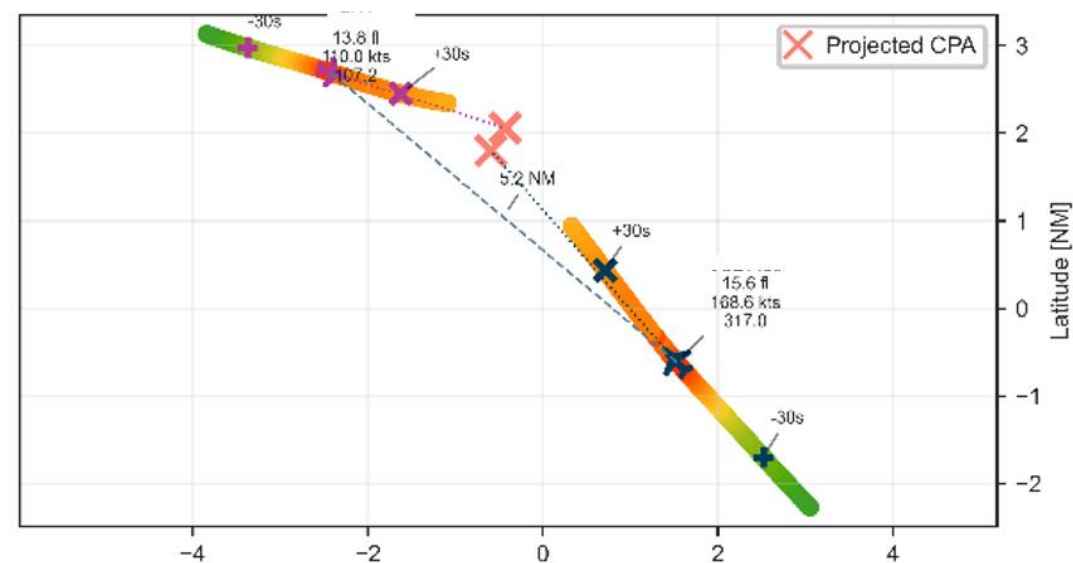
EXAMPLE 1

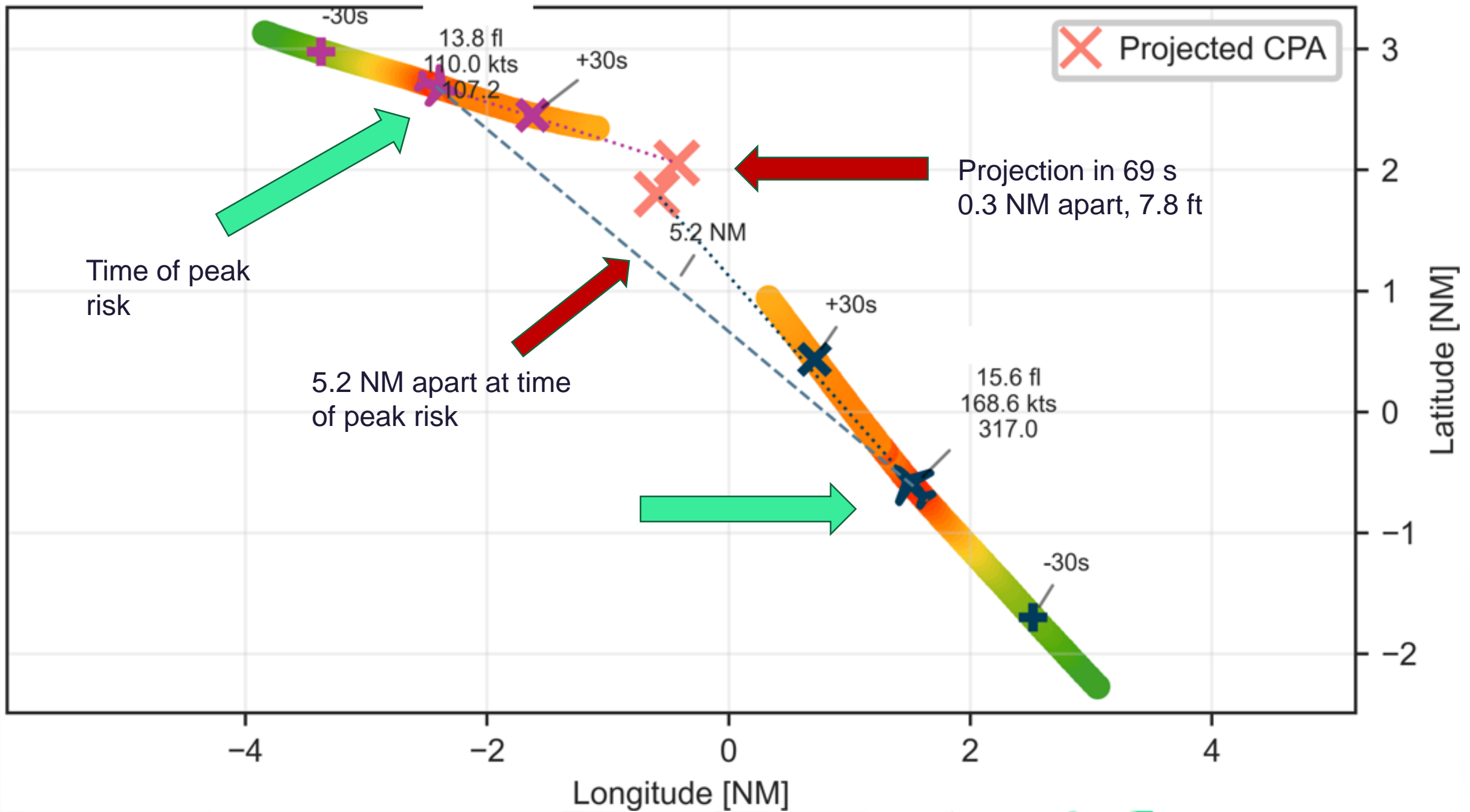
ACAS RA

Altitude vs time around the time of peak risk

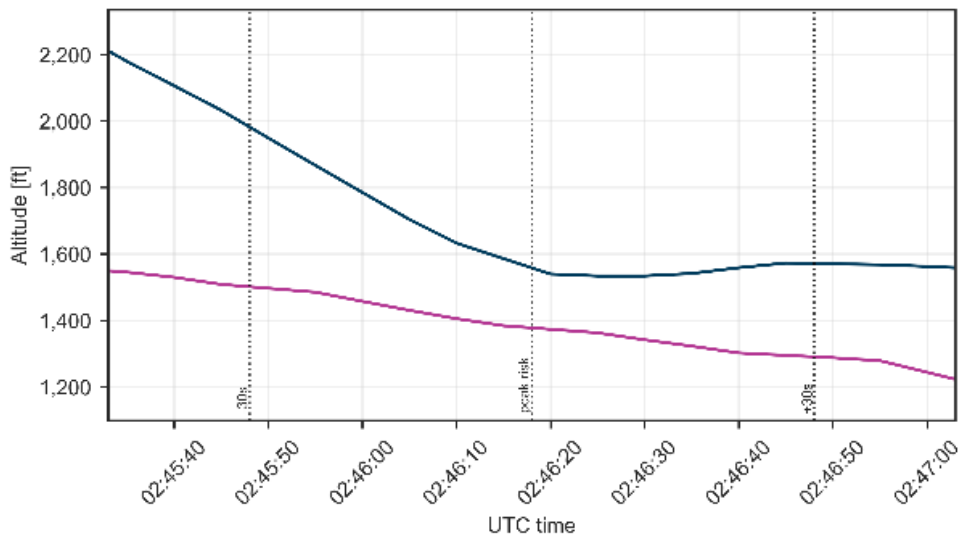


Trajectory at peak risk

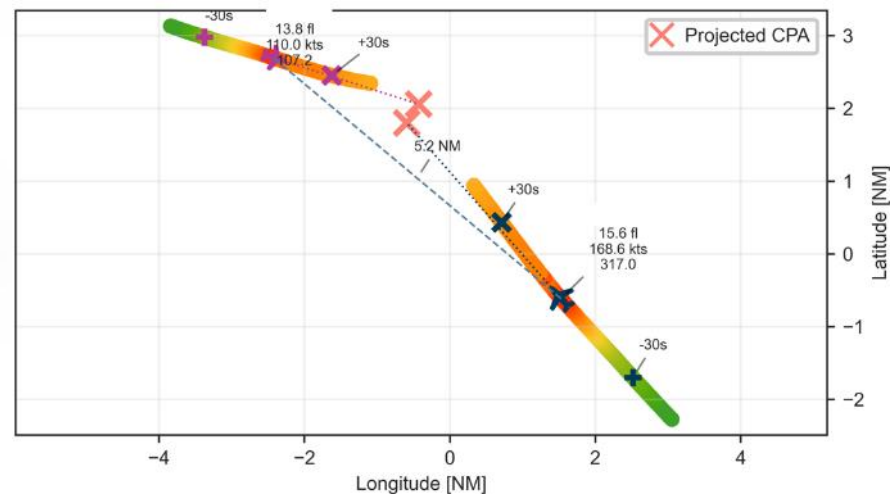




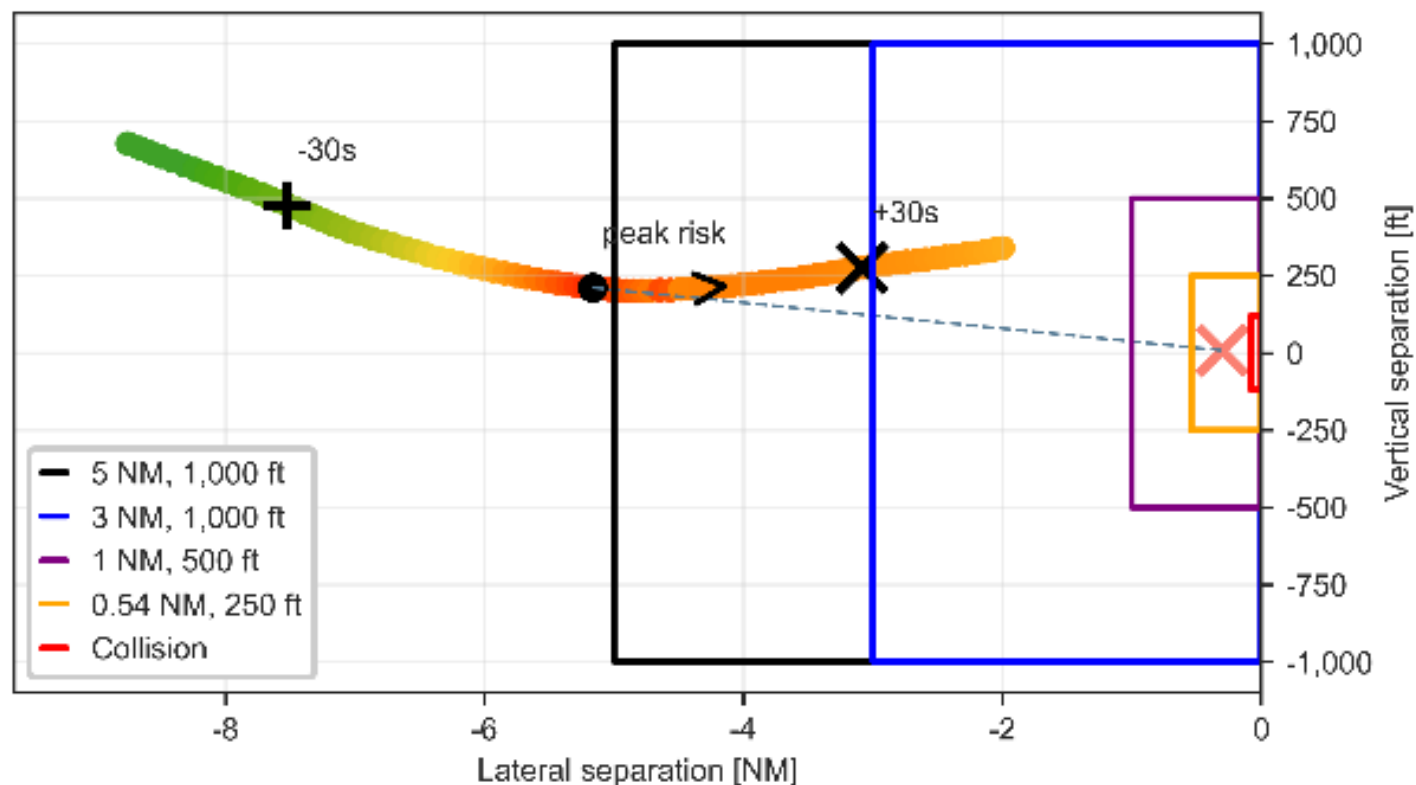
Altitude vs time around the time of peak risk



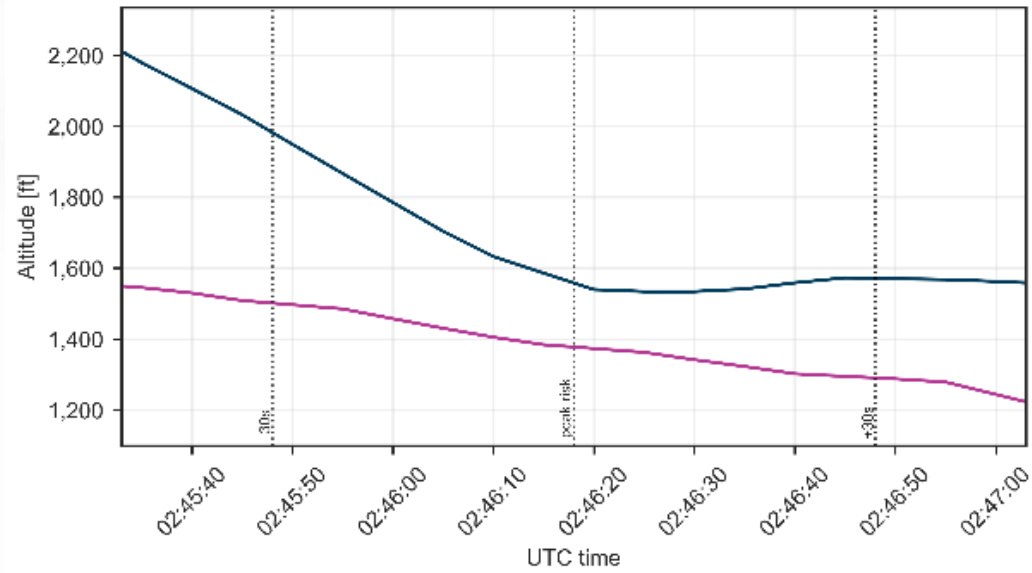
- Combine horizontal and vertical separations
- 68 seconds to being 0.3 NM and 7 ft
- Closing 268 knots
- Risk apparent for ~20 seconds
- 97% chance of intervention in 68 s
- $CR = 5 \times 10^{-8}$



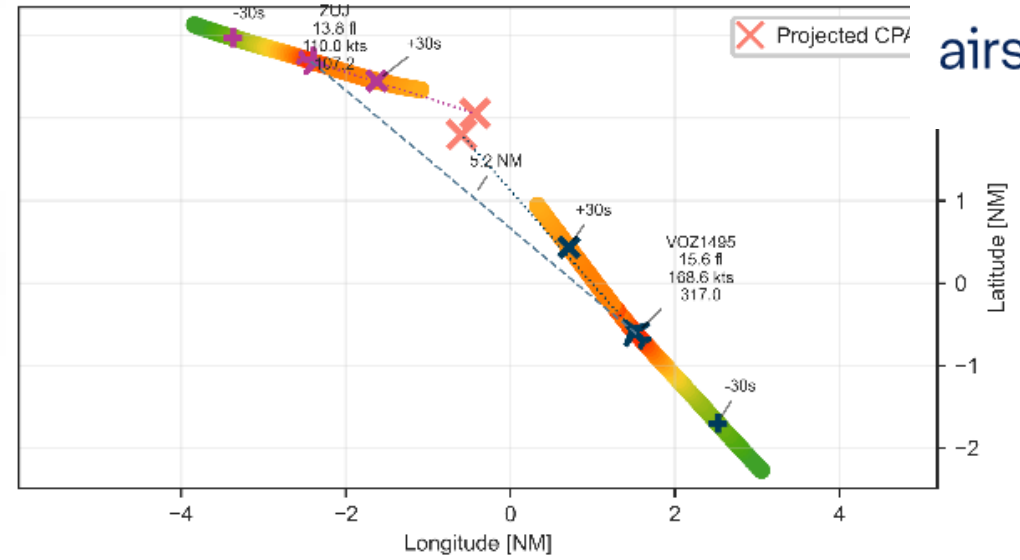
Vertical and lateral separation around the time of peak risk



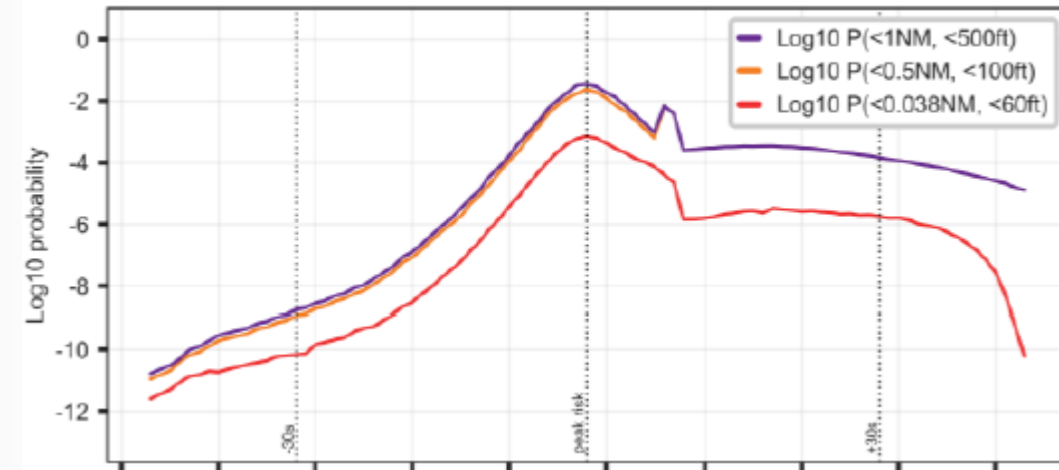
Altitude vs time around the time of peak risk



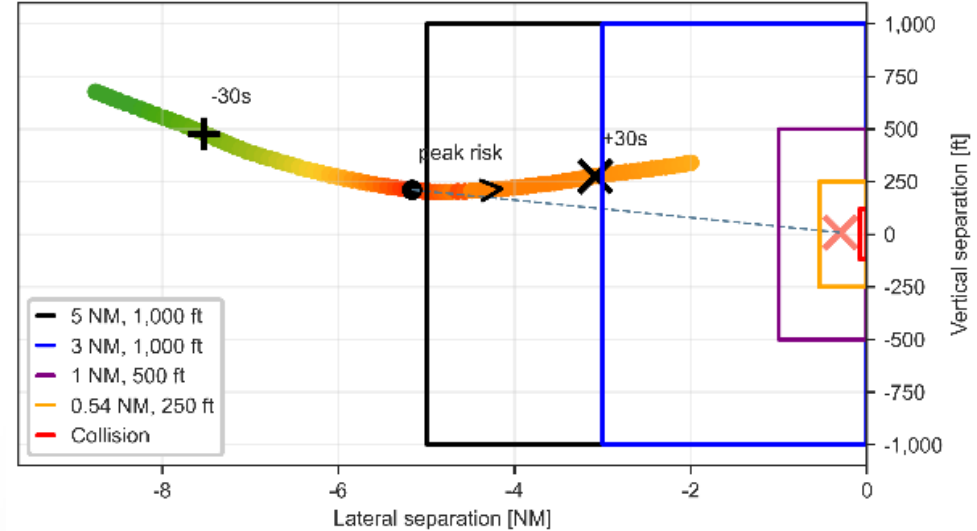
Trajectory at peak risk



Risk probabilities around the time of peak risk



Vertical and lateral separation around the time of peak risk

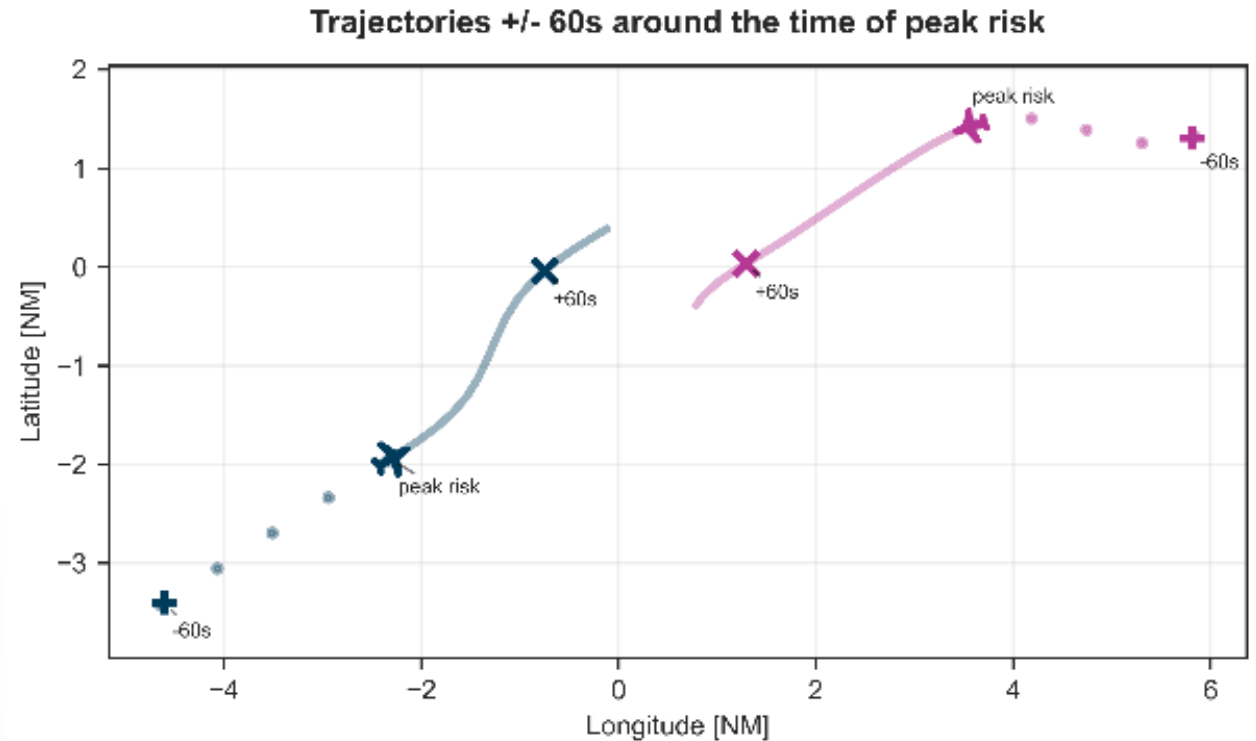
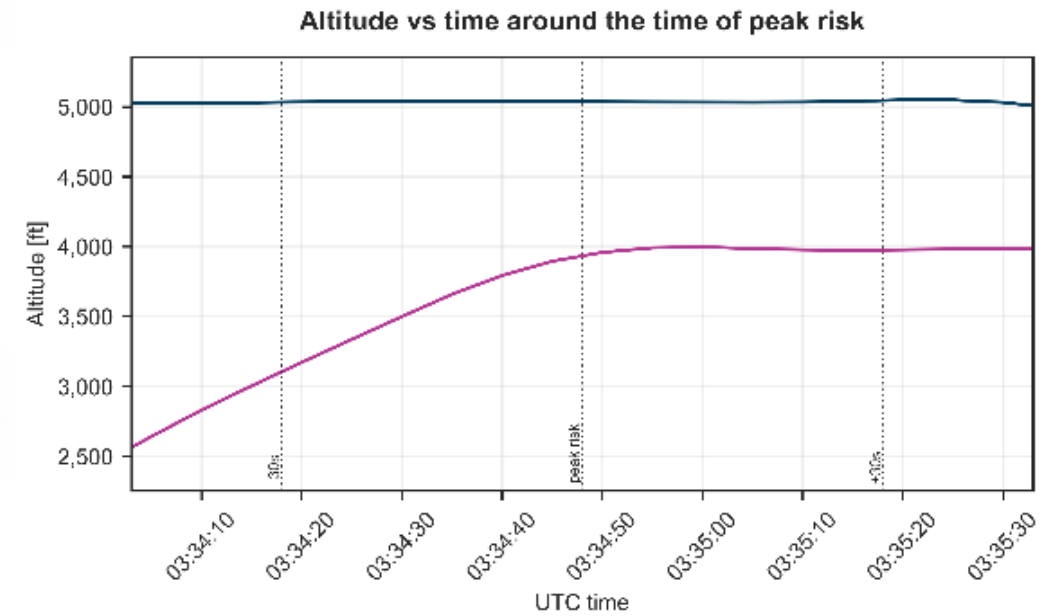
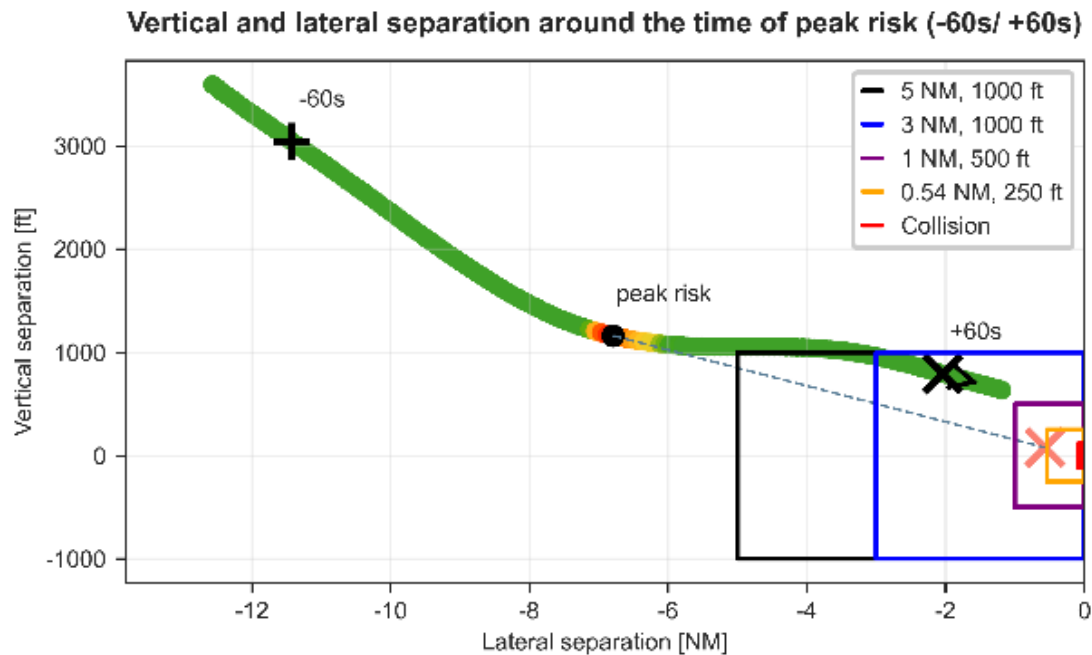


- Risk growing over time and then rapidly dropping

EXAMPLE 2

Loss of Separation

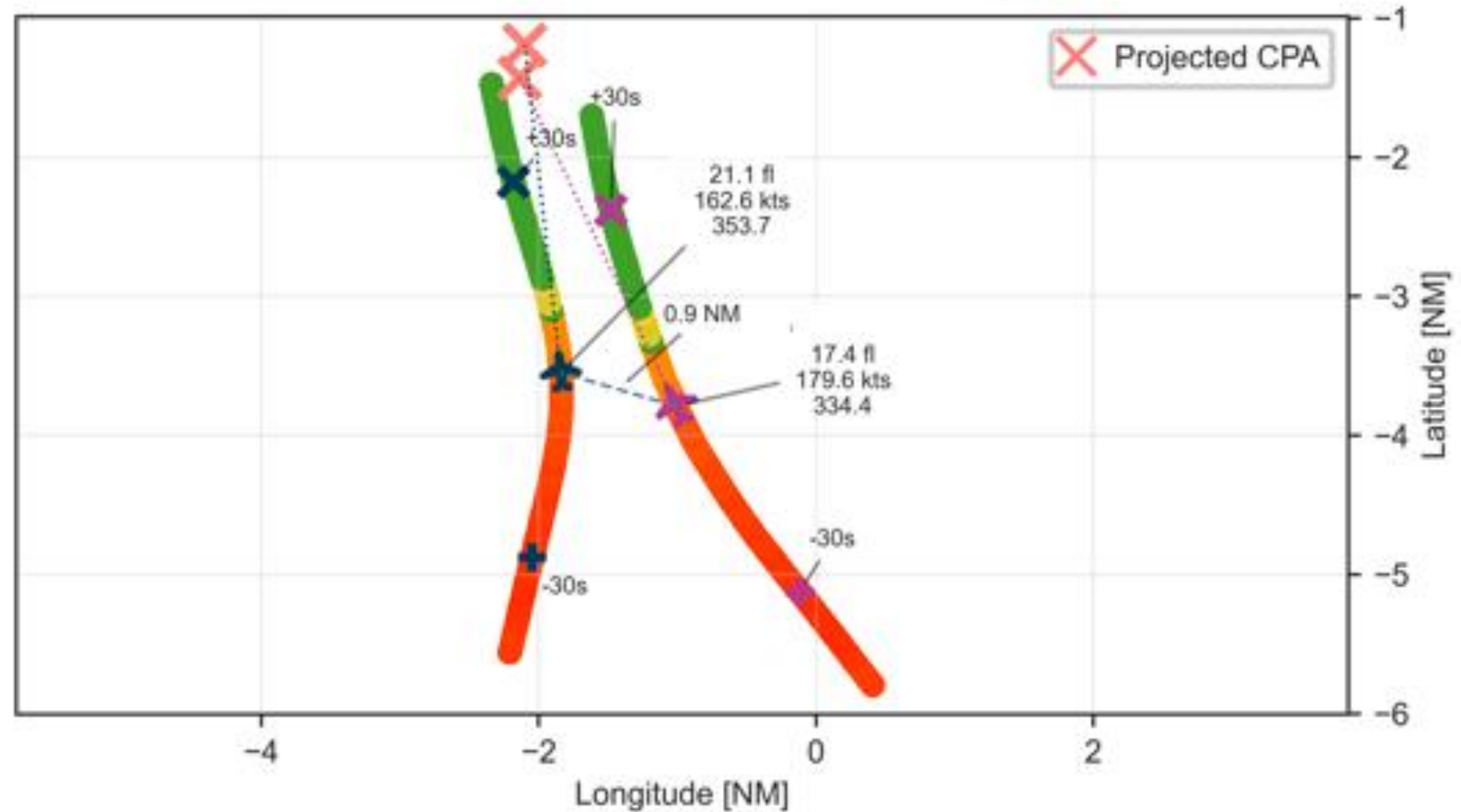
- 81 seconds to 0.57 NM and 78 ft
- Risk 5×10^{-10} - quite low



EXAMPLE 3

ACAS – parallel approach

- Aircraft expected to turn
- Need to account for 5×10^{-5} chance of going to wrong runway

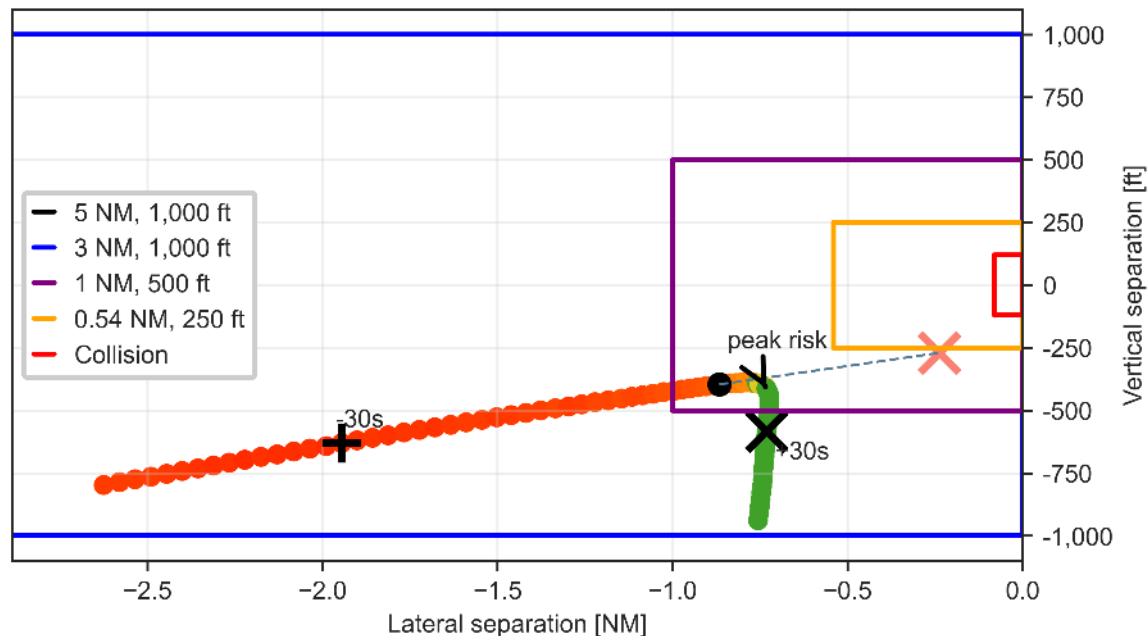


EXAMPLE 3

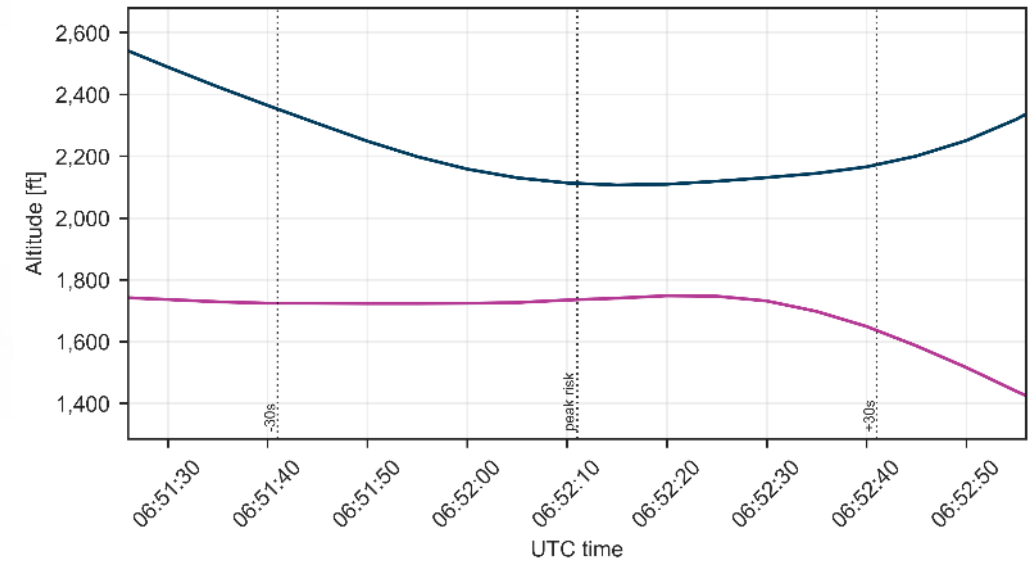
ACAS – parallel approach

- 52 seconds to 0.2 NM and 270 ft
- Naïve risk 4×10^{-9} if
 - aircraft did not turn, and ACAS ignored
- Actual risk $\times 5 \times 10^{-5}$ - failure of aircraft to turn

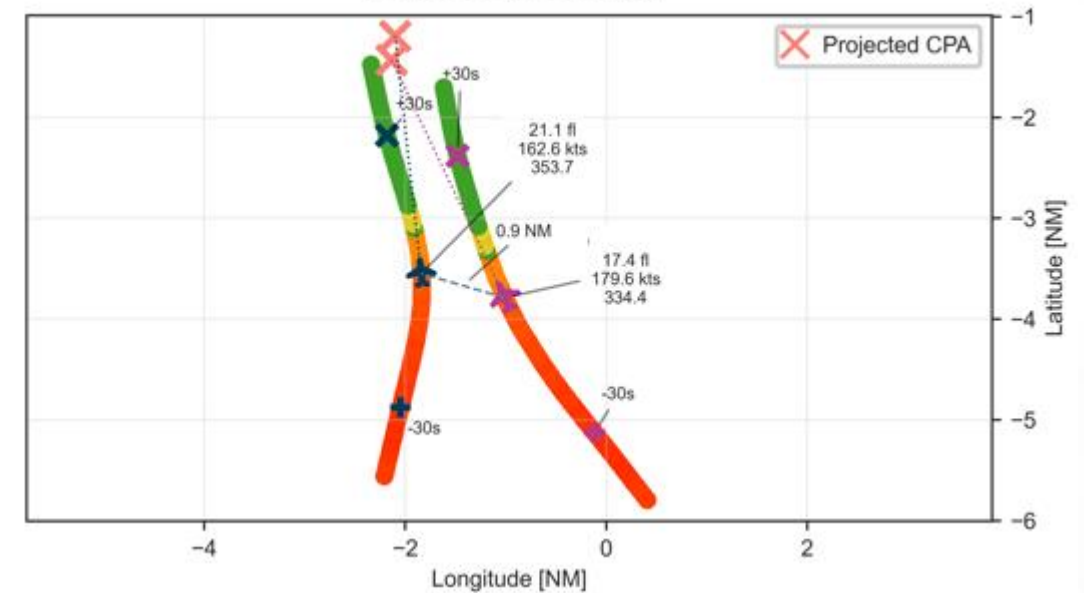
Vertical and lateral separation around the time of peak risk



Altitude vs time around the time of peak risk

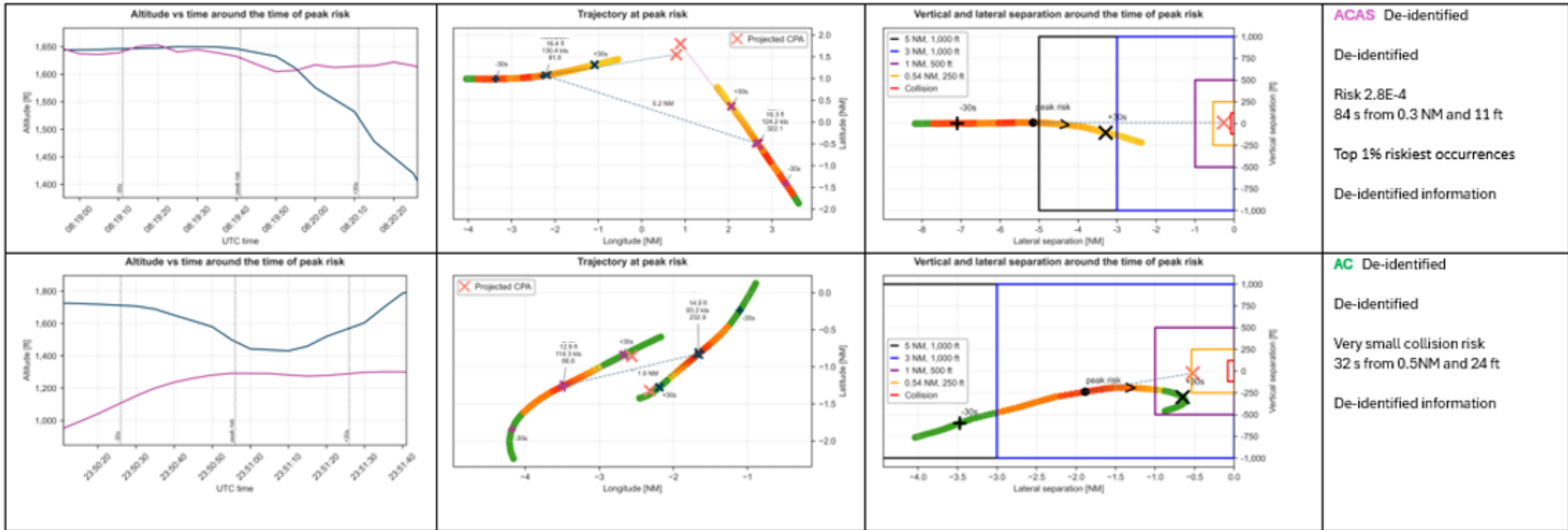


Trajectory at peak risk



USE CASE

- Create easy summary of monthly occurrence – ordered by risk
- Some LOS are less risky than other occurrences.
- These examples have identifying information removed (location, aircraft, description)



OCCURRENCE AND CONFLICT RISK

Summary

- Gets a quantified risk estimate
- Also get risk of NMAC or risk of proximity event
- We account for aircraft size
- We can account for different airspace – $P(\text{intervention in time } T_c)$ –
 - scale 15 s (terminal),
 - 20s en-route,
 - 2 minutes – oceanic
- We also get ‘significance factor’
 - Collision risk \times People on Board \times 1,000,000
- Produce semi-automated pdf report for each occurrence or conflict

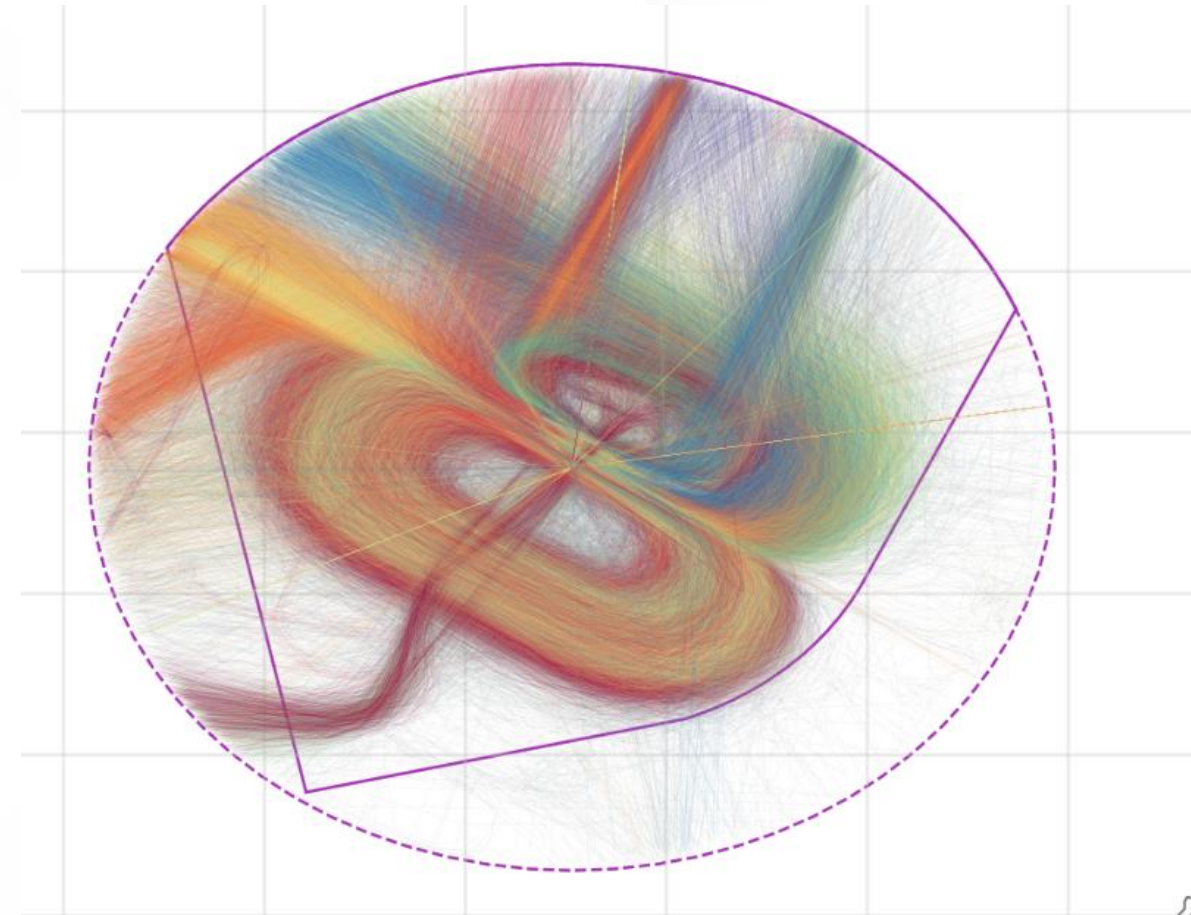
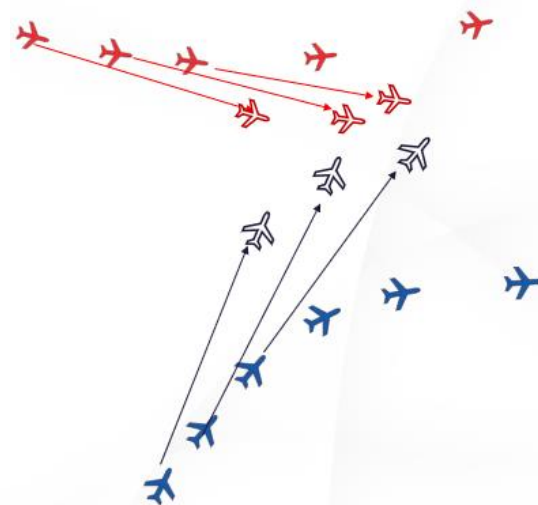
Types of risk

- Model what if ...
 - ACAS had failed
 - Controller had not intervened
 - Communications had failed
 - ...
- Model extrapolates paths as if
 - Successful barrier failed
 - Subsequent barrier fail
- For some occurrences we multiply risk by operational error rate – aircraft intending to turn
 - 5×10^{-5} Class C – IFR
 - 10^{-3} VFR

RISK FOR AN AIRSPACE

Example – two class D towers

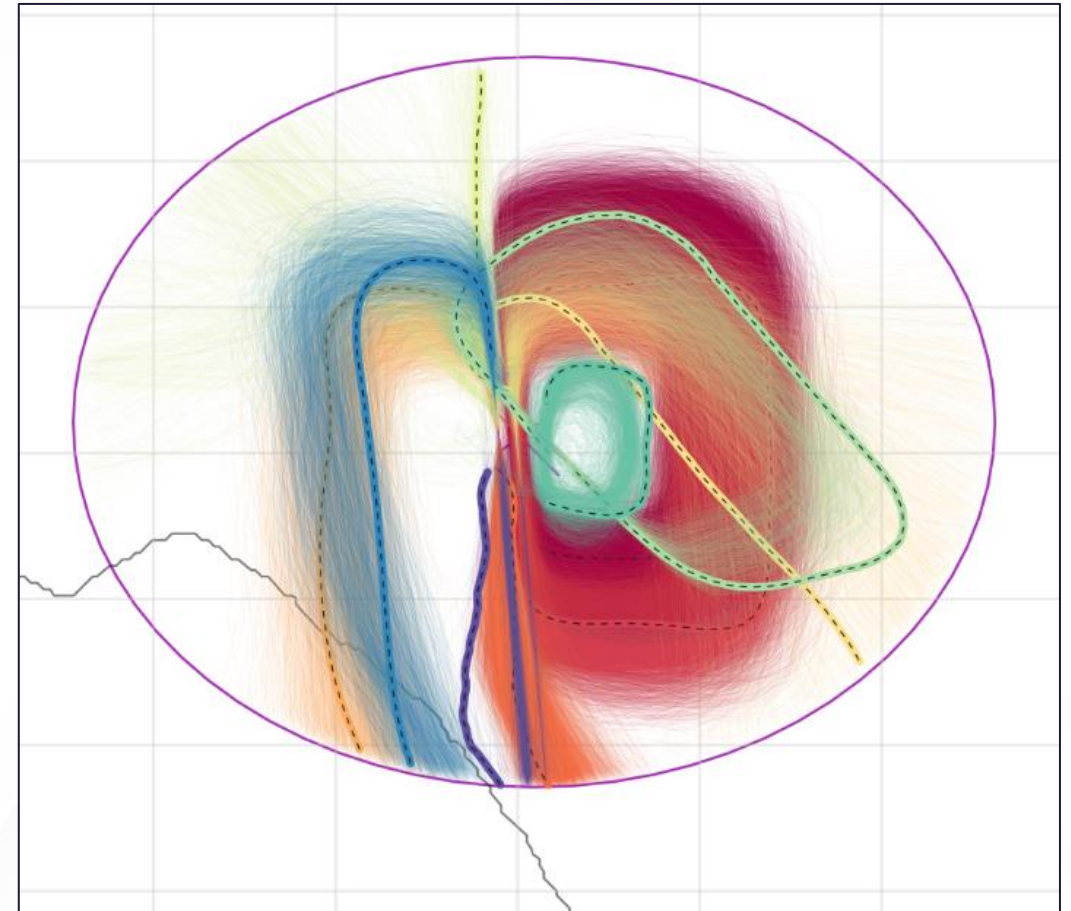
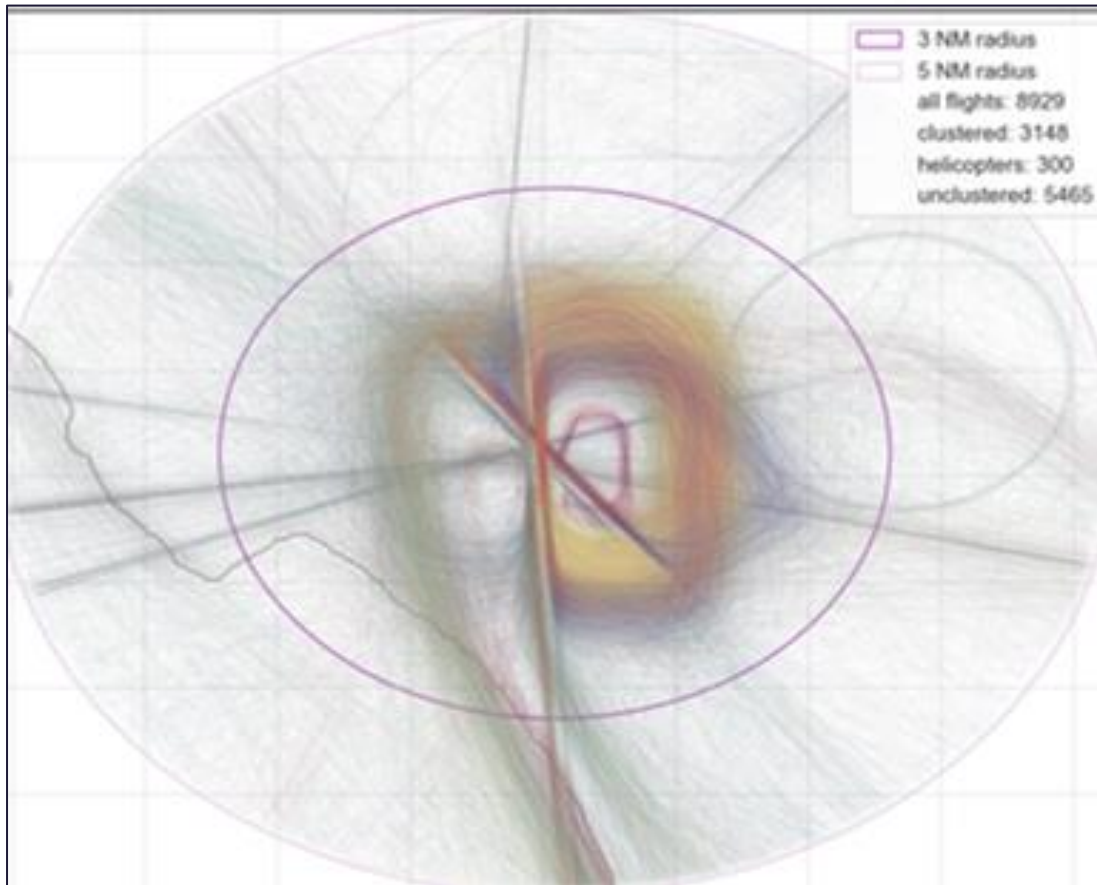
- Trajectory based approach
- What are key patterns (clusters)
- Risk within and between clusters
- Gridding the risk
- Pair wise risk

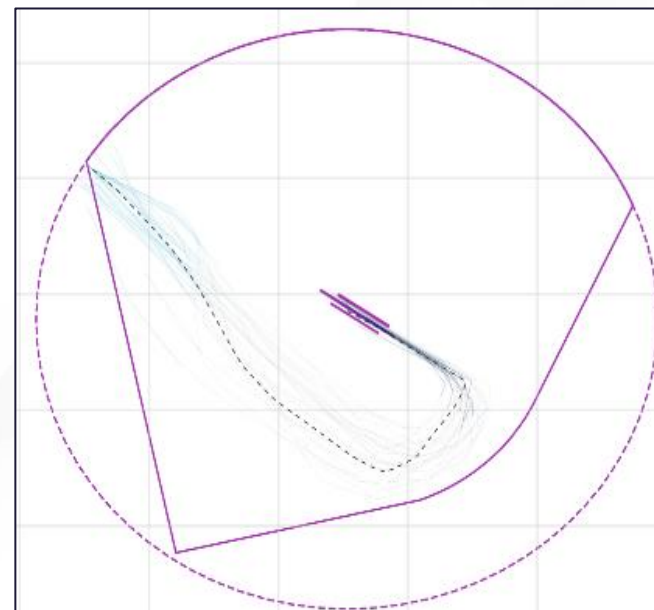
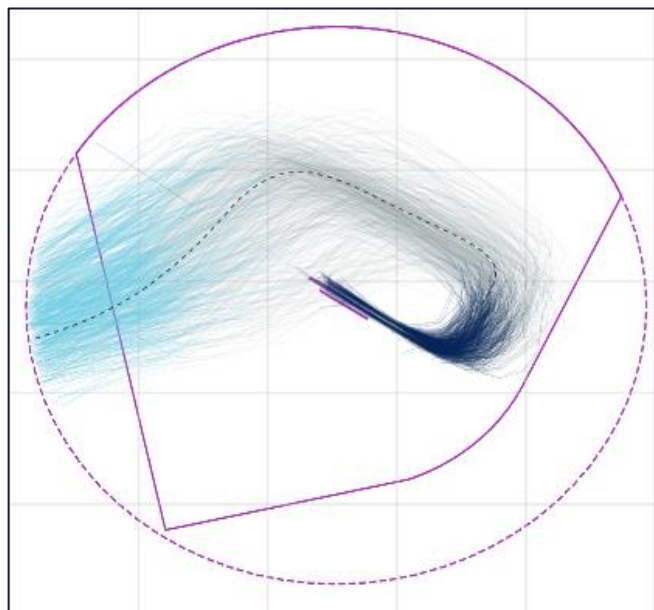
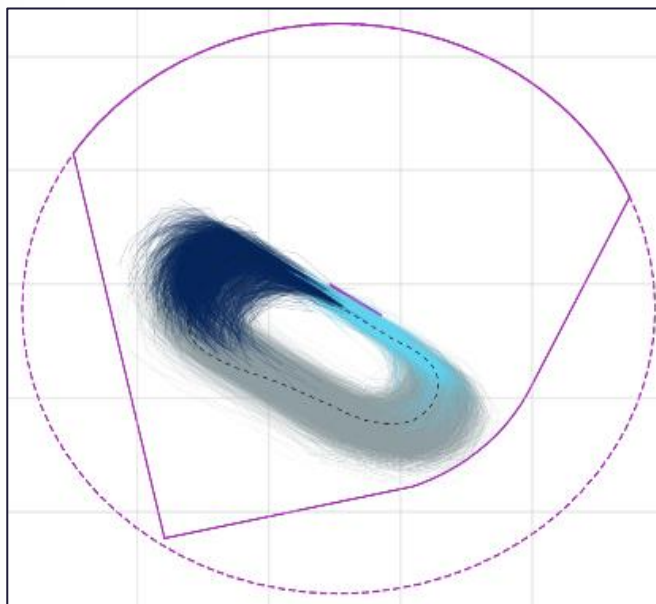
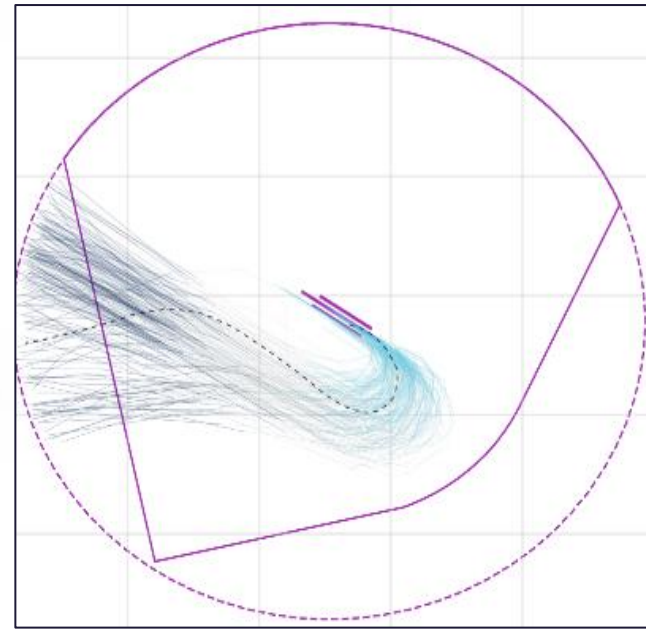
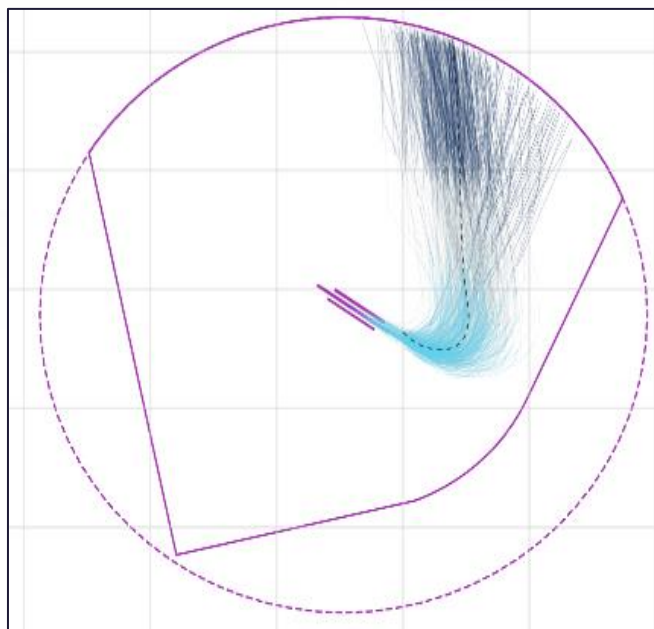
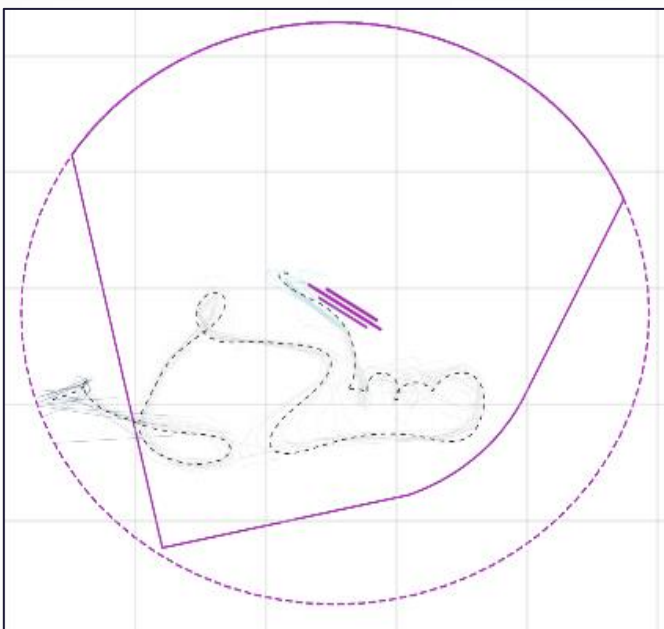


3 NM around an aerodrome

RISK FOR AIRSPACE

Finding patterns

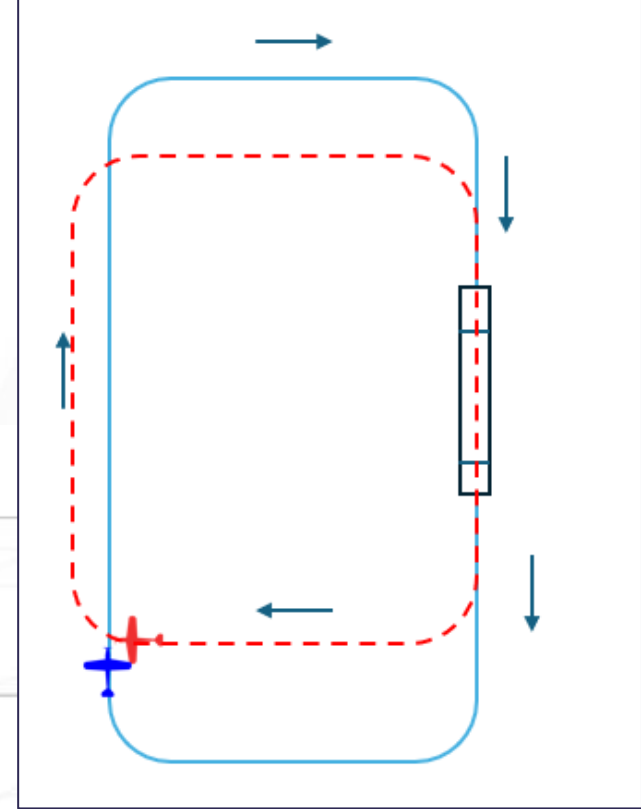
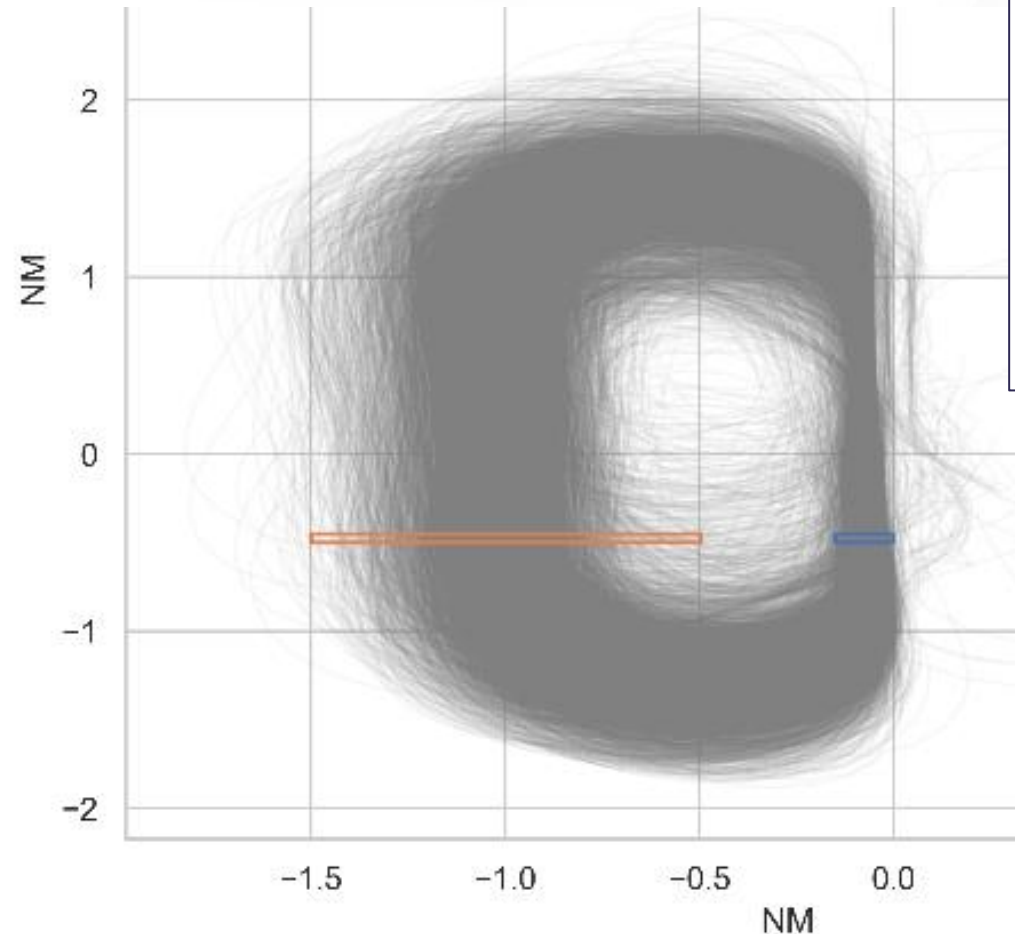




RISK WITHIN A CLUSTER

Circuit risk

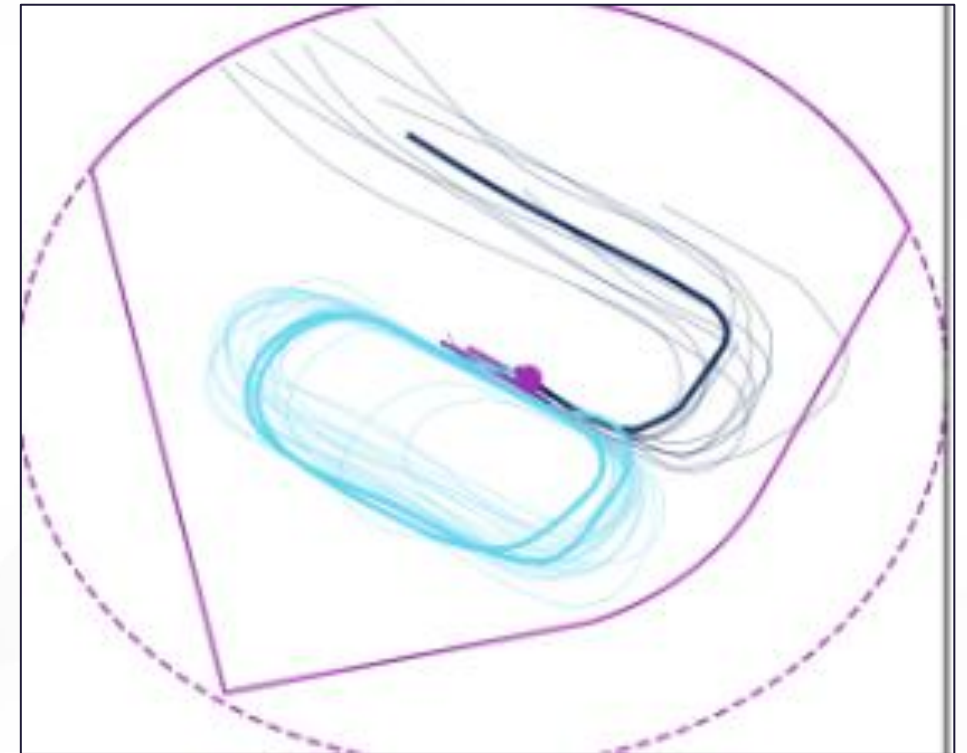
- Risk of one aircraft doing a short circuit and cutting off aircraft that takes a longer path
- Natural variation drives the risk
- We compared two aerodromes, showing one had risk 20% higher.
- Able to recommend a given time between circuits to reduce the risk



RISK BETWEEN CLUSTERS

Circuit and approach

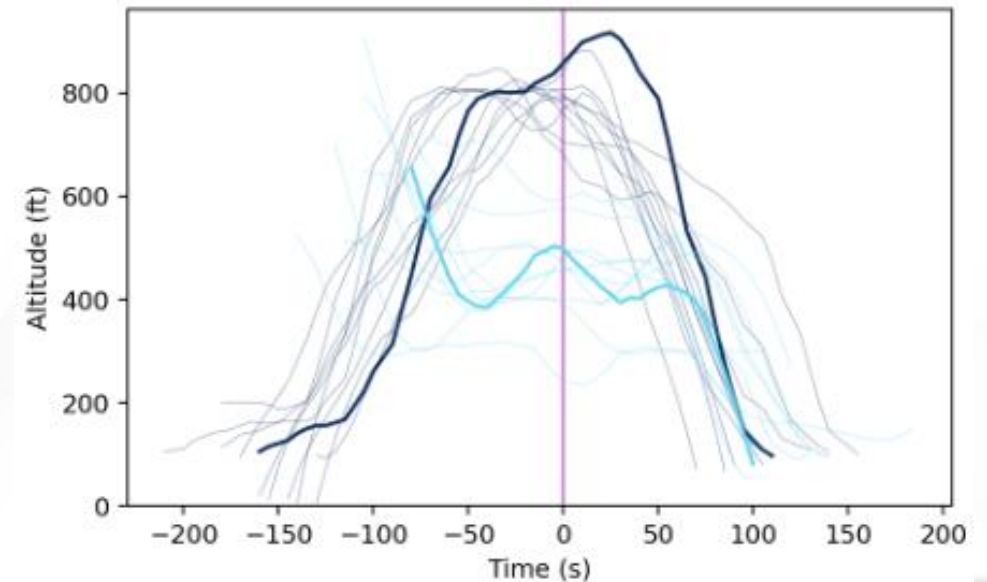
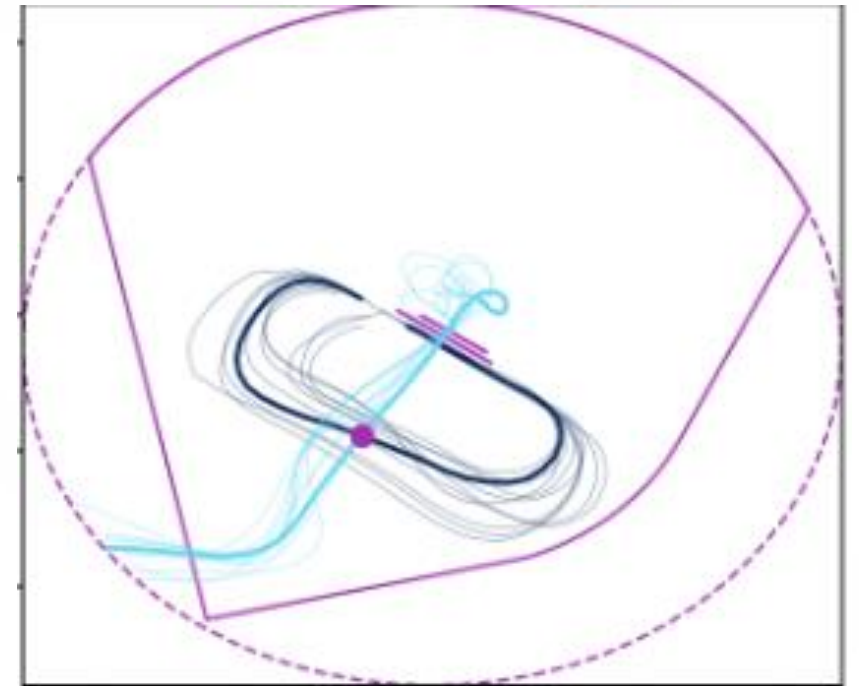
- What if approach goes to wrong runway?
 - Include known rate of this error
- This type of error does occur
- Quantify risk based on known arrival time separations
- Is risk acceptable?



RISK BETWEEN CLUSTERS

Circuit and helicopter

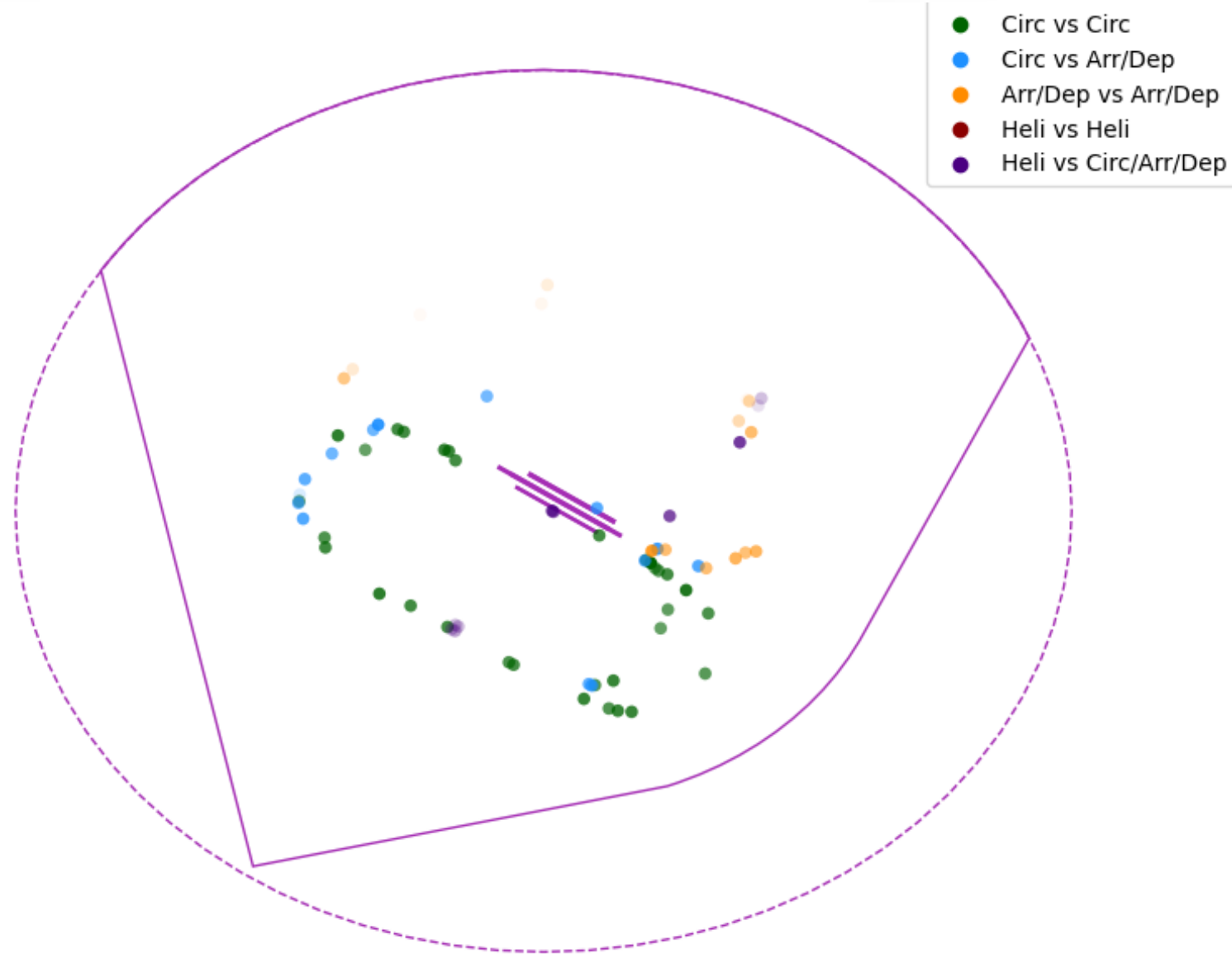
- What if circuit is a bit low and helicopter a bit high?
- This type of error does occur
- Risk easily quantified



RISK HOTSPOTS

Circuit and helicopter

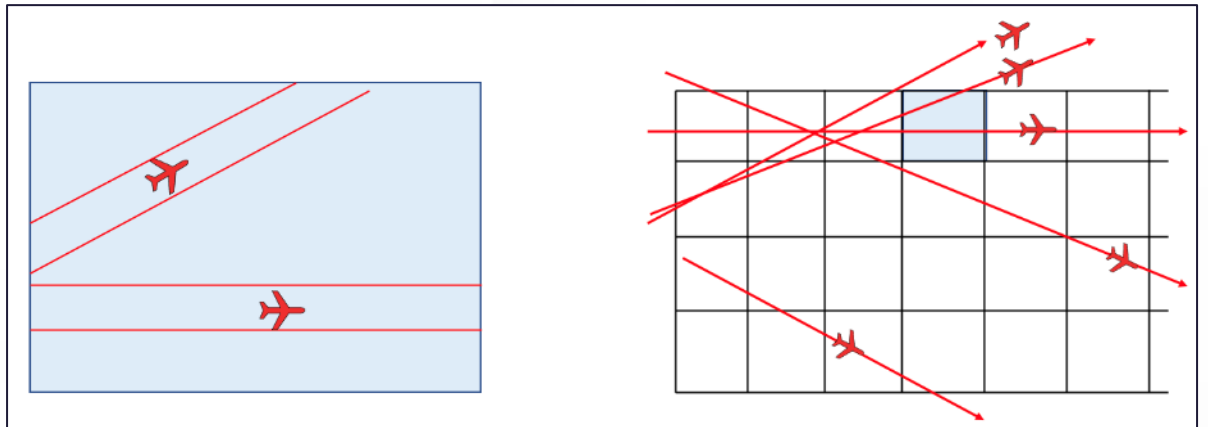
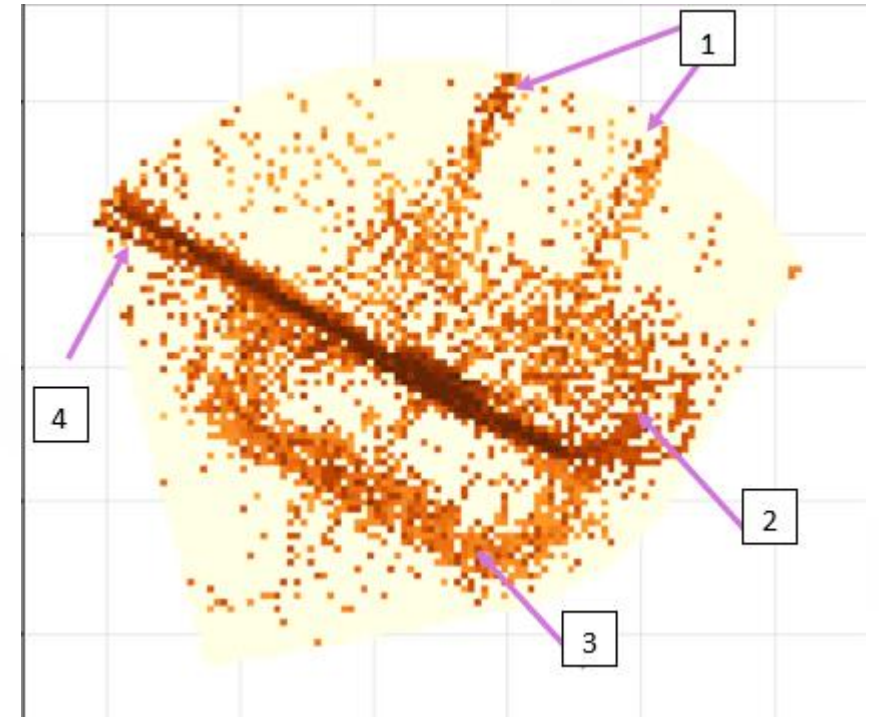
- Look at where cluster overlap
- Quantify risk hotspots



RISK BY GRIDS

Discretise airspace

- Split airspace into grids
- Look at time and altitude in grids
- Time between aircraft entering grid
- Altitudes of aircraft
- Probability of being in grid at same time and at same altitude
- Can then identify hot spots and groups.
- Some areas over runways can be ignored



AIRSPACE RISK

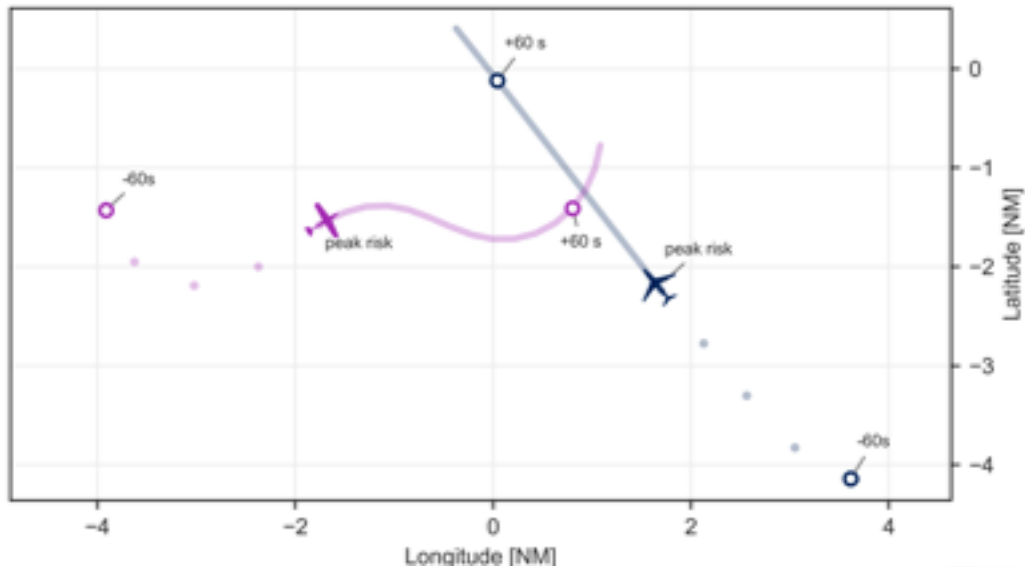
Benefits

- Able to quantify risk for all trajectories – not just occurrences
- Gets risk as collisions per movement
- Gets risk hotspots
- Gets key procedures causing risk
- Able to compare airspaces
 - We found Aerodrome 1 had three times the risk as Aerodrome 2 and in different places
 - We can focus effort (and money) on key aerodromes or sectors
 - Focus effort on what was different between the two aerodromes
 - Look at quantified changes in risk over time

SUMMARY

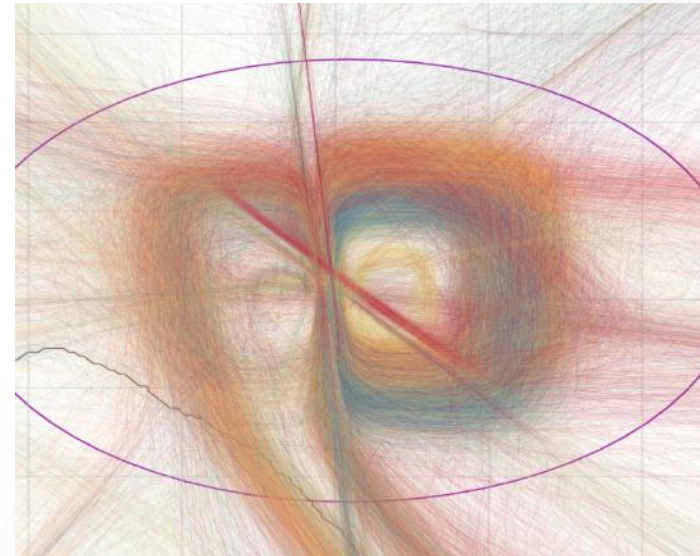
Occurrence and conflict

- ICAO methods can quantify risk of collision for occurrence and conflicts



Airspace risk

- Able to quantify risk and find hot spots and key groups causing risk based on all trajectories



NEXT STEPS

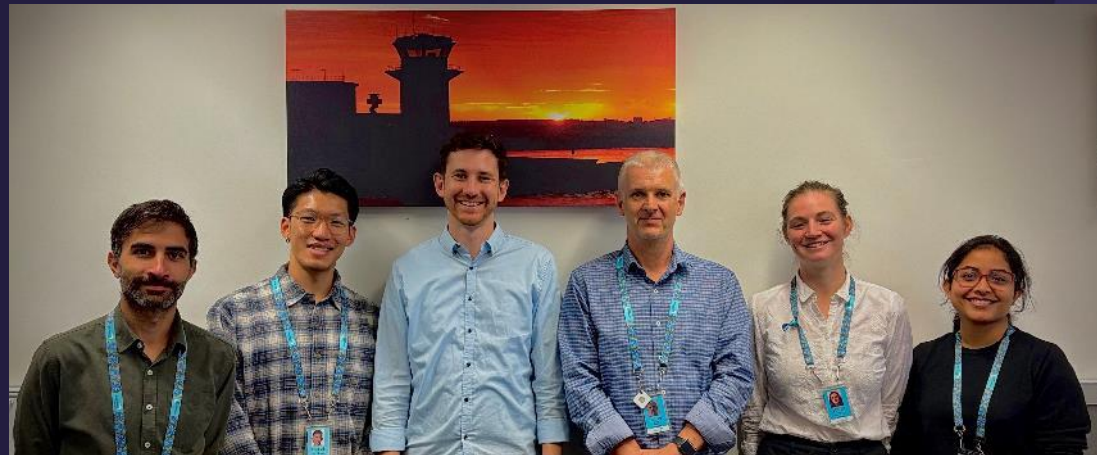
Airservices

- Refine and extend methods
- Doing airspace risk for
 - Regional airports
 - Major airports
 - Sector groups

CANSO

- Feedback and suggestions
- Cooperation and collaboration?
- This is not a 'software tool' - it is a programming system (Python) for analysts to build and use
- Requires trajectory data in simple formats

THANK YOU



Additional material

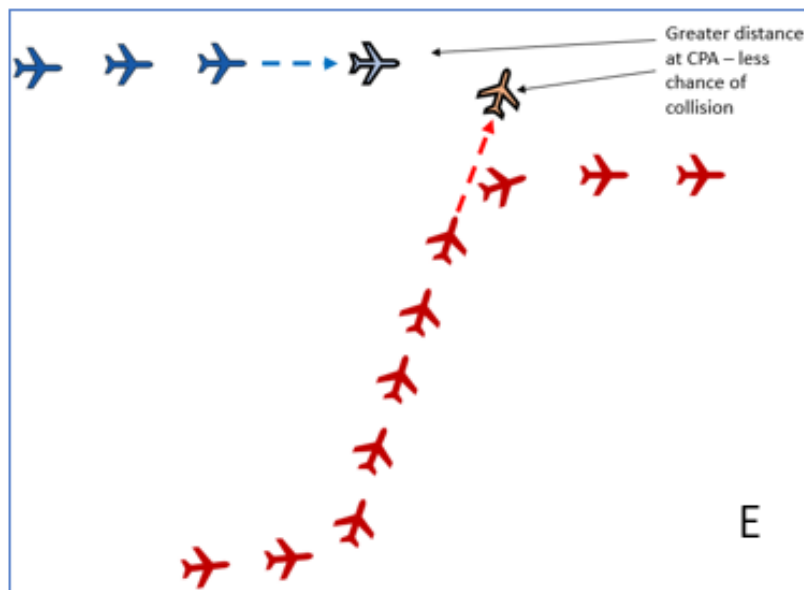
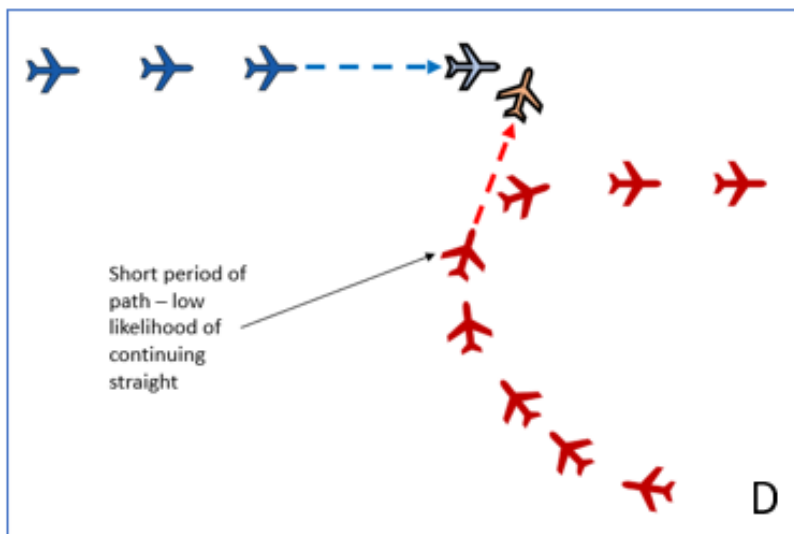
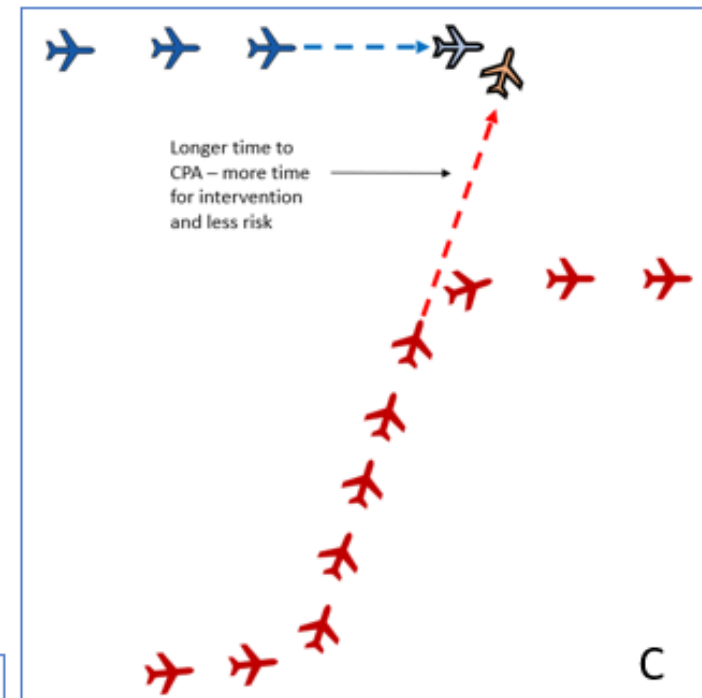
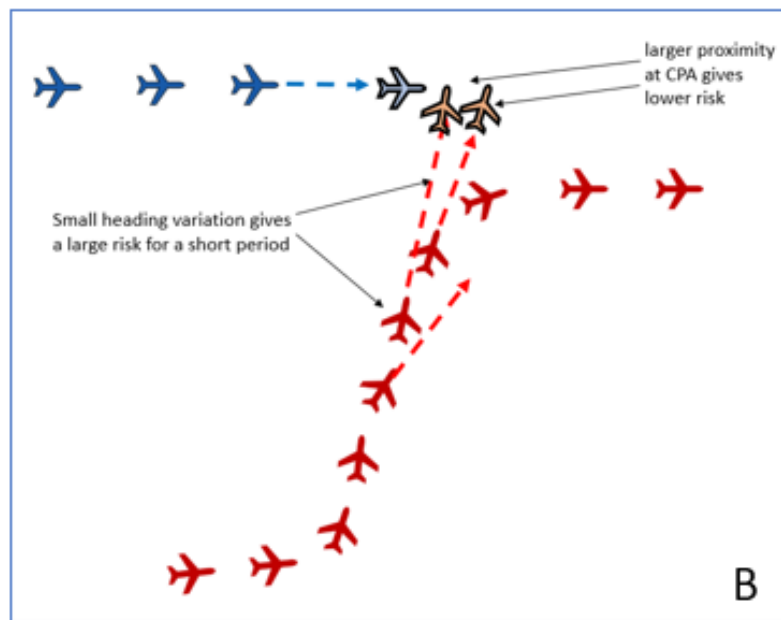
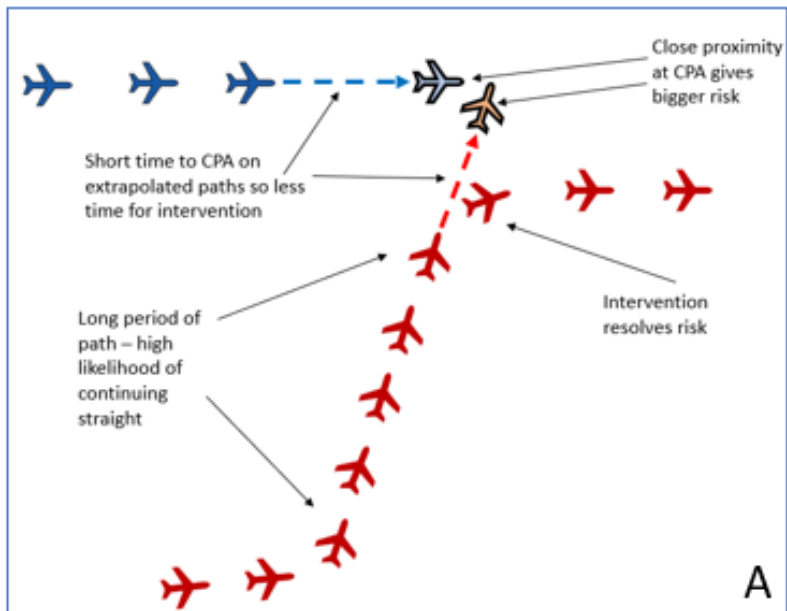
To answer questions if they arise

OCCURRENCE

Output

- Produce data each second of actual and projected separations

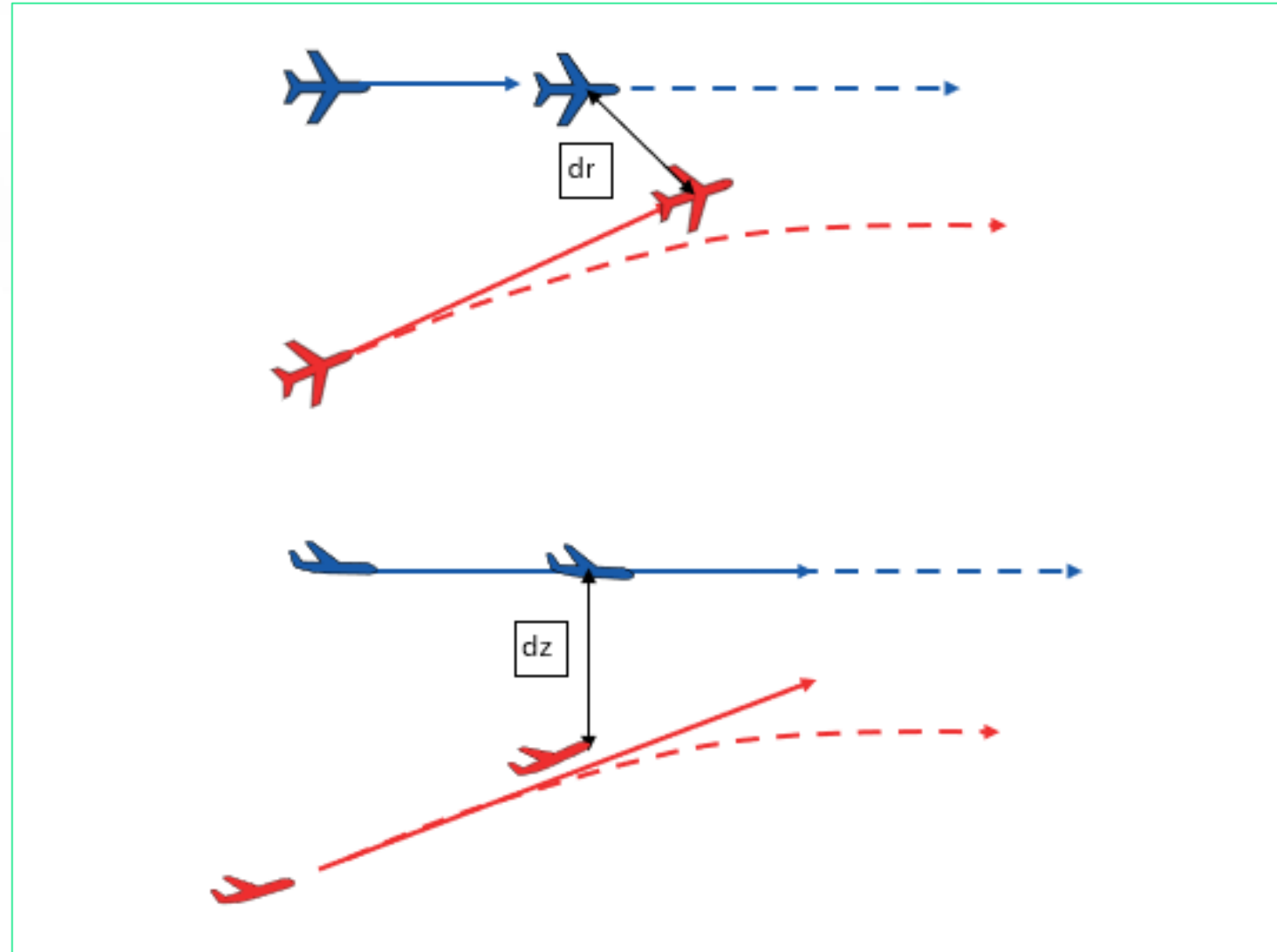
Time (UTC)	Actual				Projected				Note
	Relative speed (kn)	Relative angle (°)	Lateral sep. (NM)	Vertical sep. (ft)	Lateral sep. at CPA (NM)	Vertical sep. at CPA (ft)	Time to CPA (s)	Collision prob.	
02:45:48	280 kn	149.1°	7.52 NM	478.4 ft	0.2 NM	700.7 ft	95 s	6.8e-11	
02:45:53	279 kn	148.6°	7.18 NM	418.0 ft	0.2 NM	660.6 ft	92 s	2.4e-10	
02:45:58	277 kn	148.6°	6.79 NM	361.1 ft	0.3 NM	588.5 ft	87 s	1.3e-09	
02:46:03	275 kn	148.8°	6.36 NM	309.4 ft	0.3 NM	482.4 ft	82 s	1.8e-08	
02:46:08	272 kn	148.6°	5.93 NM	265.4 ft	0.3 NM	342.8 ft	78 s	7e-07	
02:46:13	271 kn	148.7°	5.52 NM	231.9 ft	0.3 NM	170.7 ft	73 s	4.8e-05	
02:46:18	269 kn	149.0°	5.16 NM	210.7 ft	0.3 NM	7.8 ft	69 s	0.00071	Peak risk
02:46:23	263 kn	147.1°	4.85 NM	202.4 ft	0.2 NM	175.2 ft	66 s	0.00014	
02:46:28	258 kn	145.7°	4.49 NM	205.9 ft	0.1 NM	405.8 ft	62 s	1.4e-06	
02:46:33	254 kn	144.8°	4.09 NM	218.4 ft	0.1 NM	394.9 ft	58 s	2.3e-06	
02:46:38	251 kn	143.7°	3.71 NM	236.2 ft	0.1 NM	394.5 ft	53 s	3e-06	
02:46:43	248 kn	142.8°	3.38 NM	256.1 ft	0.2 NM	407.5 ft	49 s	2.4e-06	
02:47:03	239 kn	135.7°	2.00 NM	339.9 ft	0.3 NM	528.5 ft	29 s	6e-11	
02:47:08	234 kn	132.1°	1.69 NM	373.2 ft	0.3 NM	586.4 ft	25 s	5.6e-11	
02:47:13	231 kn	130.9°	1.42 NM	419.3 ft	0.2 NM	635.2 ft	20 s	4.9e-10	
02:47:18	227 kn	127.1°	1.10 NM	478.7 ft	0.2 NM	671.5 ft	15 s	4.7e-08	
02:47:23	218 kn	118.0°	0.77 NM	549.6 ft	0.2 NM	696.4 ft	10 s	1.6e-08	
02:47:28	214 kn	116.7°	0.46 NM	628.2 ft	0.2 NM	701.4 ft	5 s	4.2e-12	
02:47:30	215 kn	118.6°	0.34 NM	660.3 ft	0.2 NM	696.8 ft	2 s	7.5e-09	Closest point



OCCURRENCE

Model

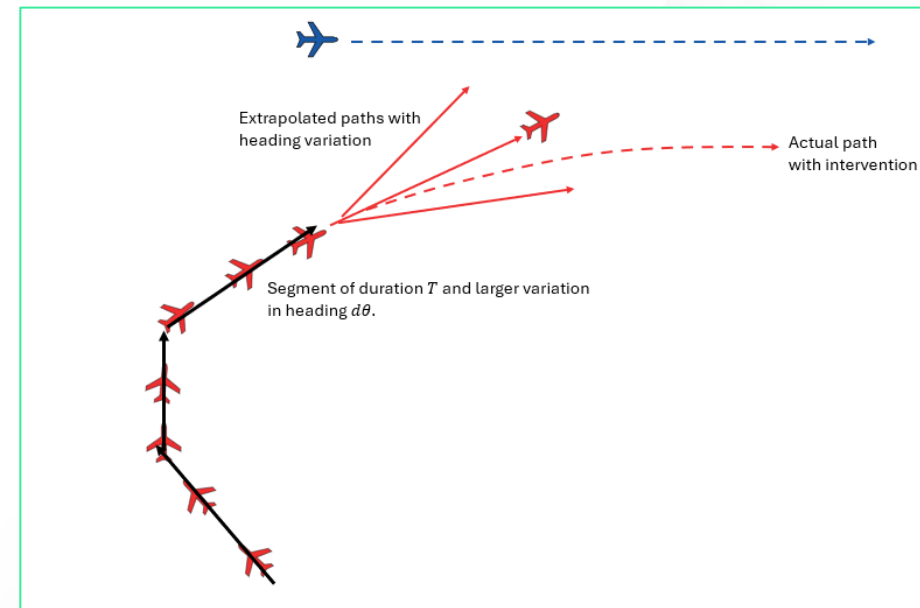
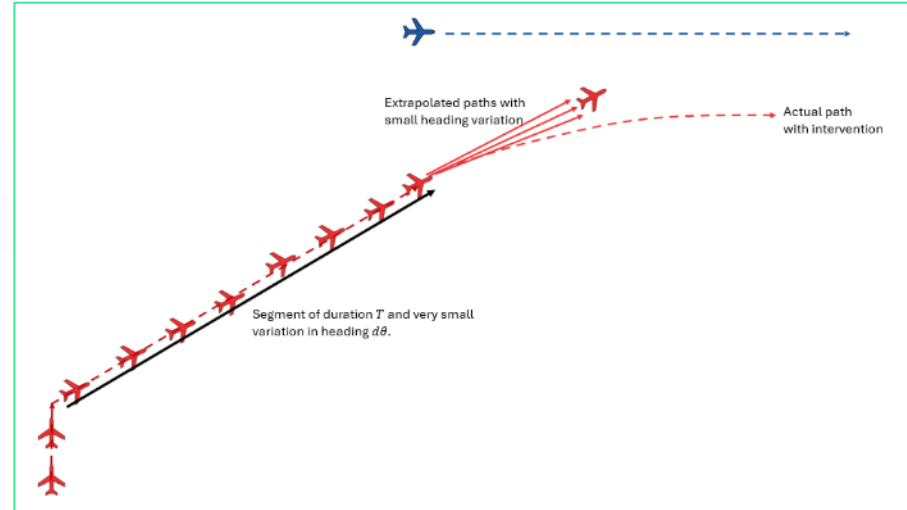
- We extrapolate in 3-d



OCCURRENCE

Model extension

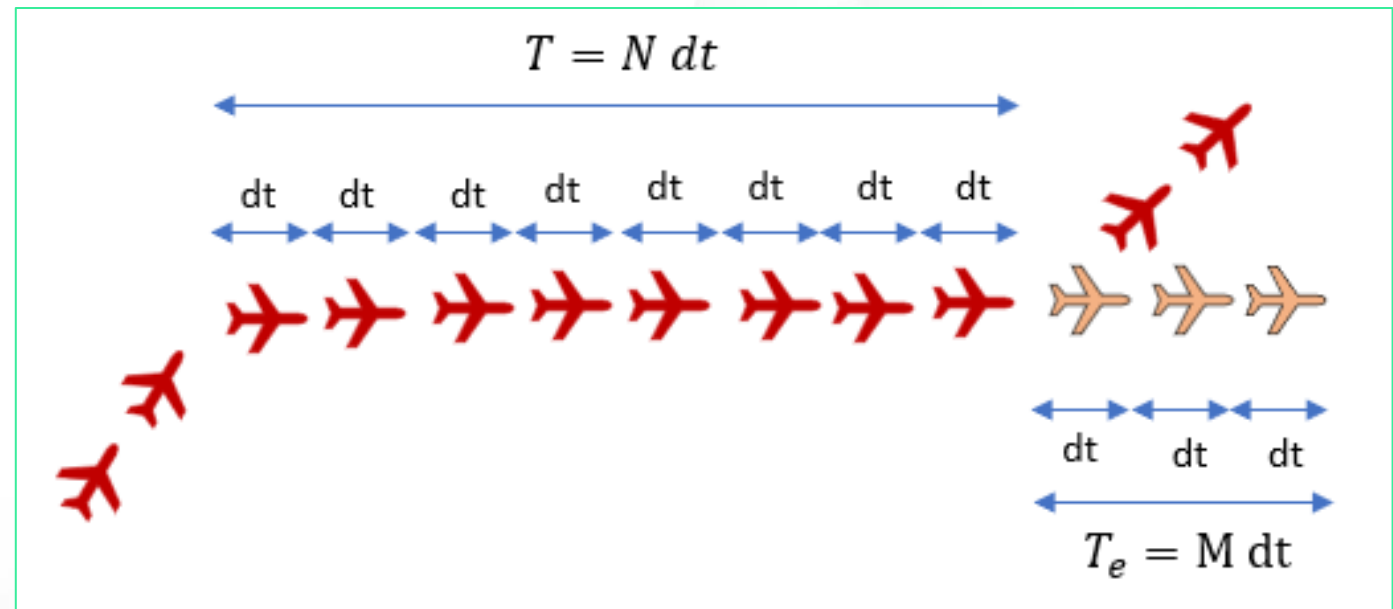
- Look for angle variation over history to see likely changes in angle



OCCURRENCE

Model

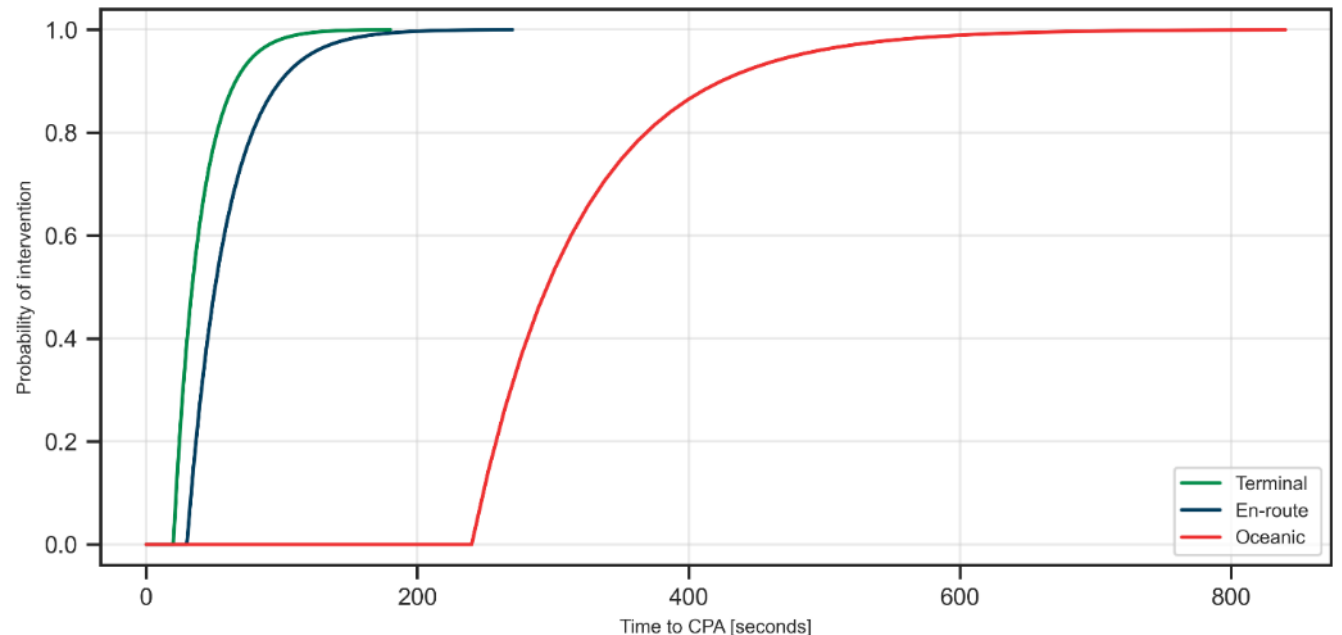
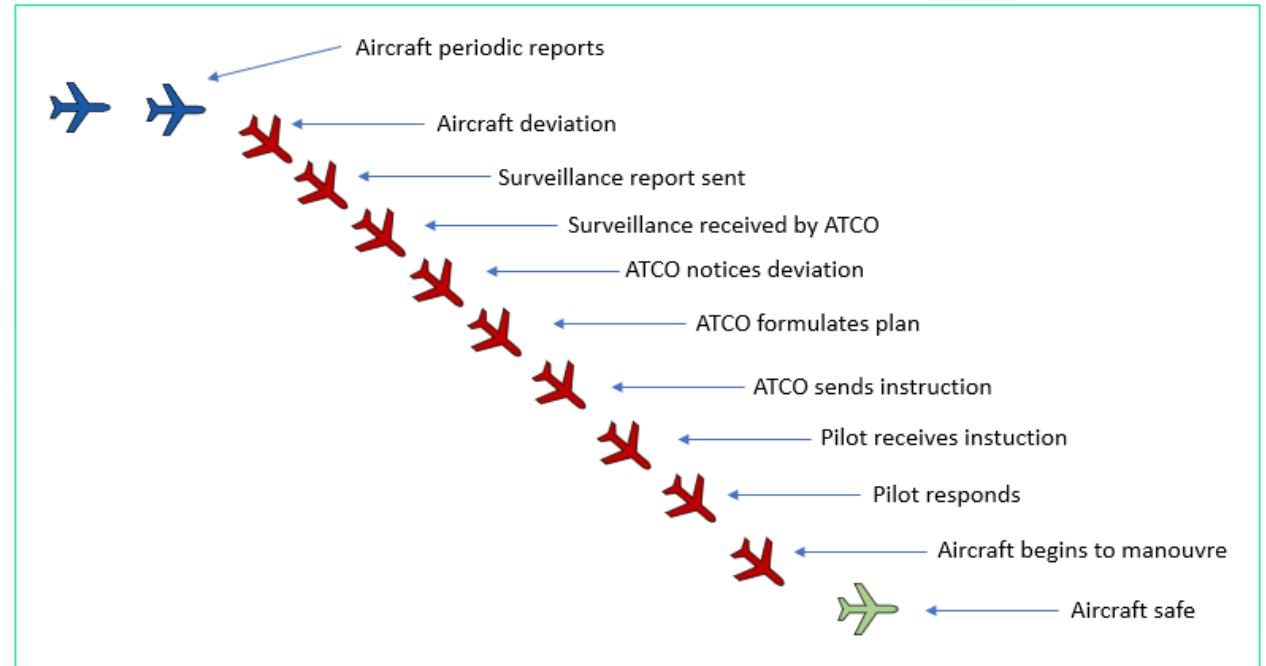
- If aircraft on straight path of time T more likely to continue straight path to CPA T_c
- This can be estimated by reliability theory
- $\exp \frac{-T_c}{T}$



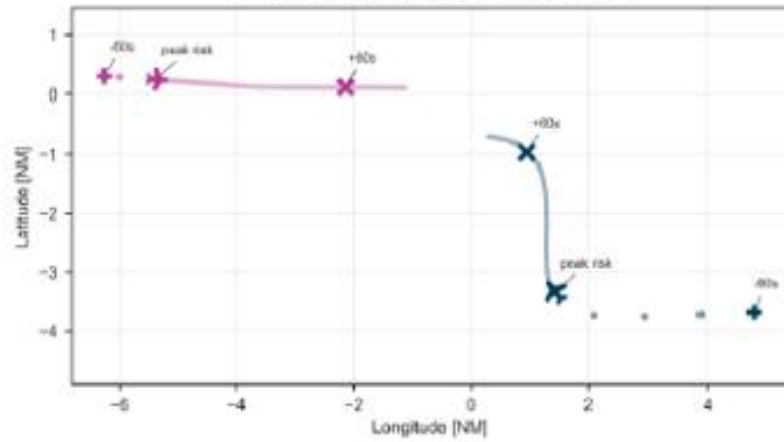
OCCURRENCE

Intervention times

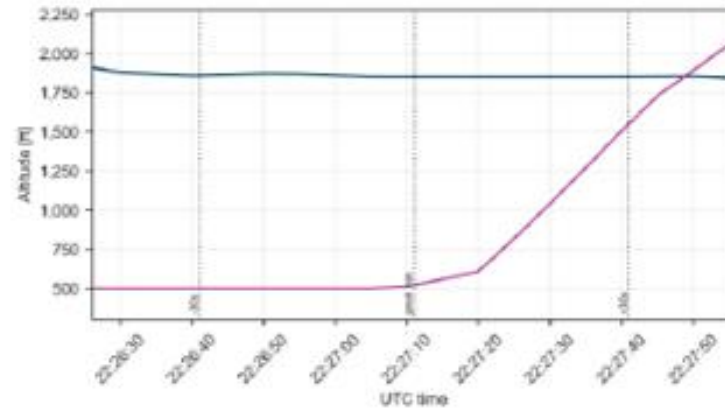
- In terminal areas intervention can be fast ~ 10 seconds
- In oceanic it can be slow ~ 4-10 minutes
- We model intervention with decaying exponential



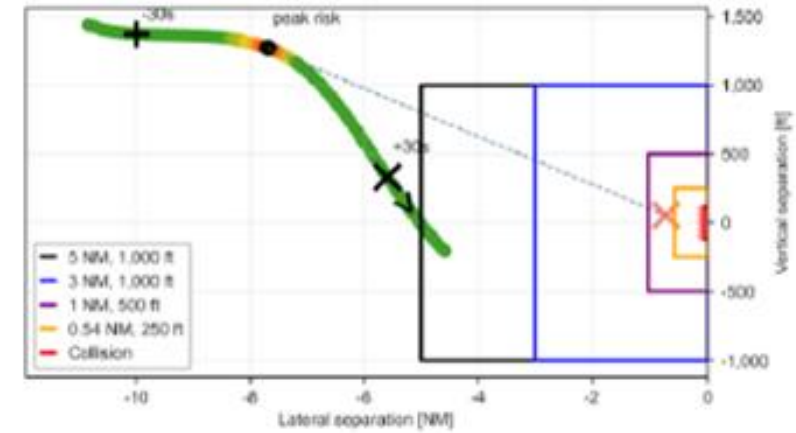
Trajectories around the time of peak risk



Altitude vs time around the time of peak risk



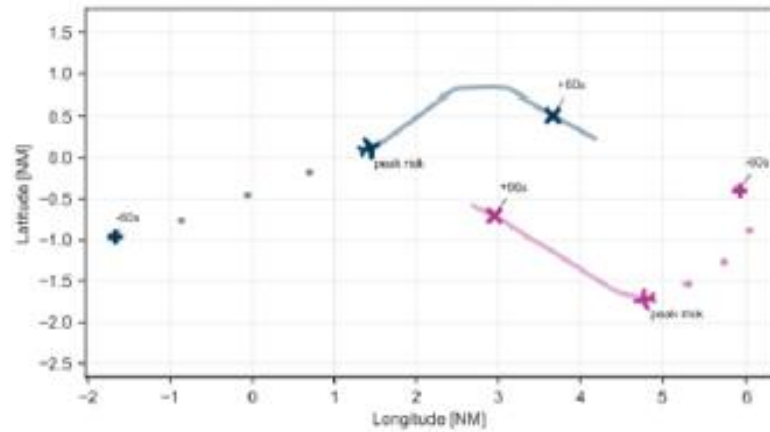
Vertical and lateral separation around the time of peak risk



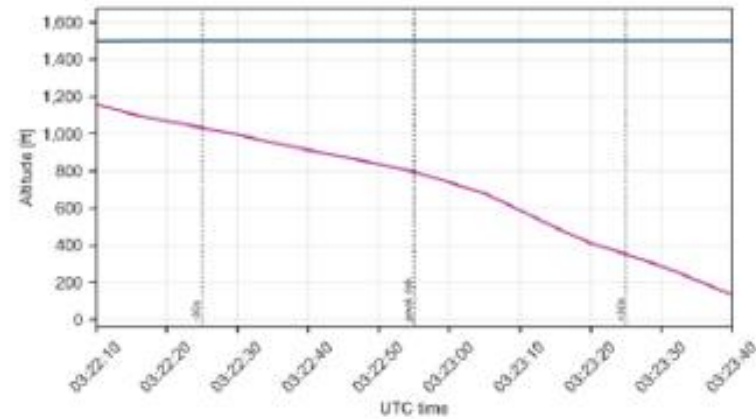
4.5 NM, 200 ft; 274 knots,
127 degrees

99s to 0.7 NM, 55 ft;
Peak risk: $2.2E-5$
Overall risk: $1E-13$

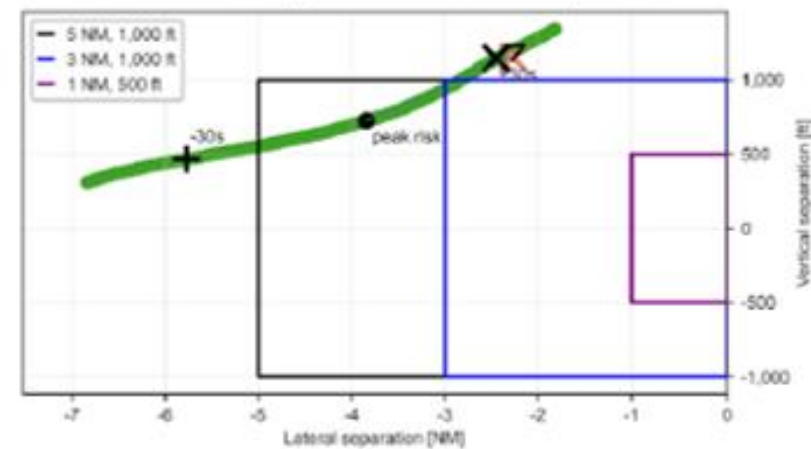
Trajectories around the time of peak risk



Altitude vs time around the time of peak risk



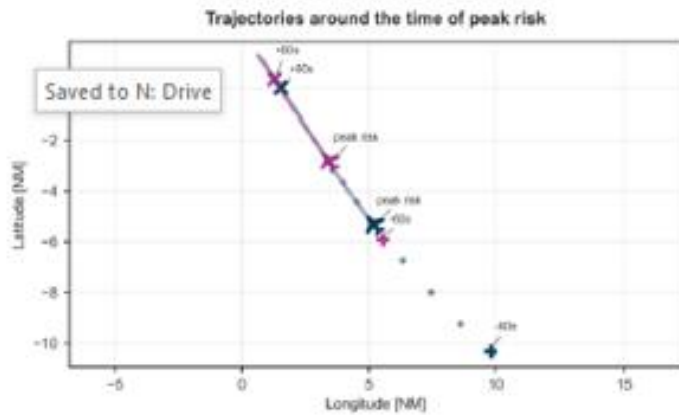
Vertical and lateral separation around the time of peak risk



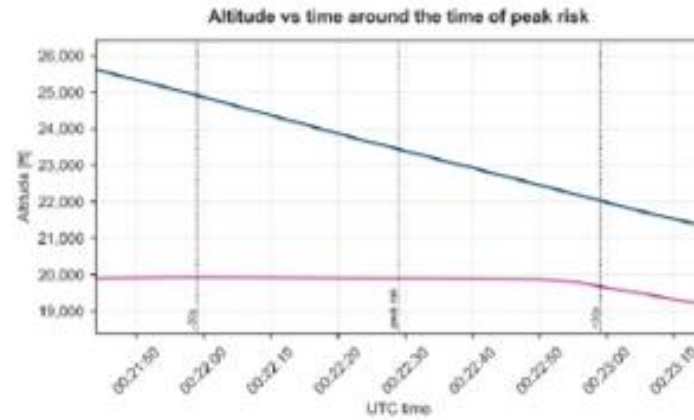
3.8 NM, 725 ft; 261 knots
139 degrees

39s to 2.3 NM, 1,155 ft;
Peak risk $5.2E-15$
Overall risk: $< 1E-20$

A LOS with low risk as
extrapolation always well
separated.

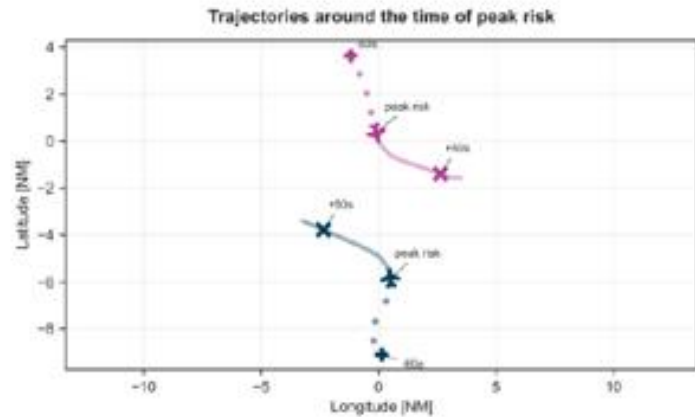
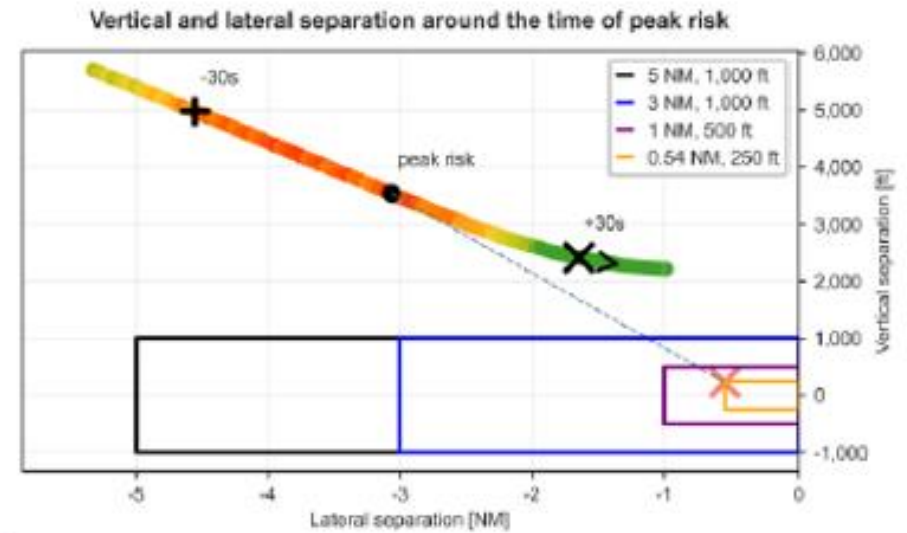


1 NM, 2000 ft; 175 knots,
3 degrees

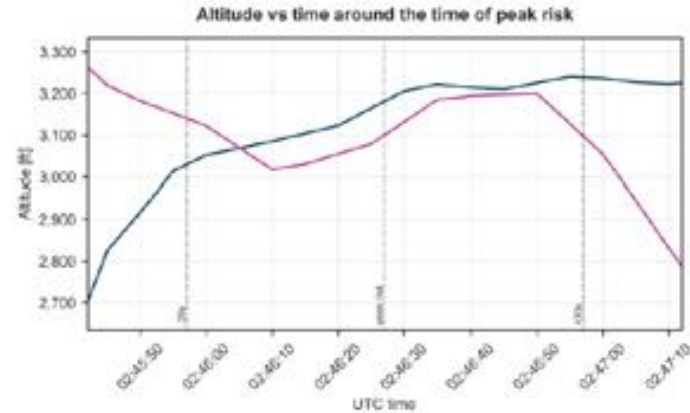


69s to 0.5 NM, 229 ft;
Peak risk: $3E-4$
Overall risk: $4E-8$

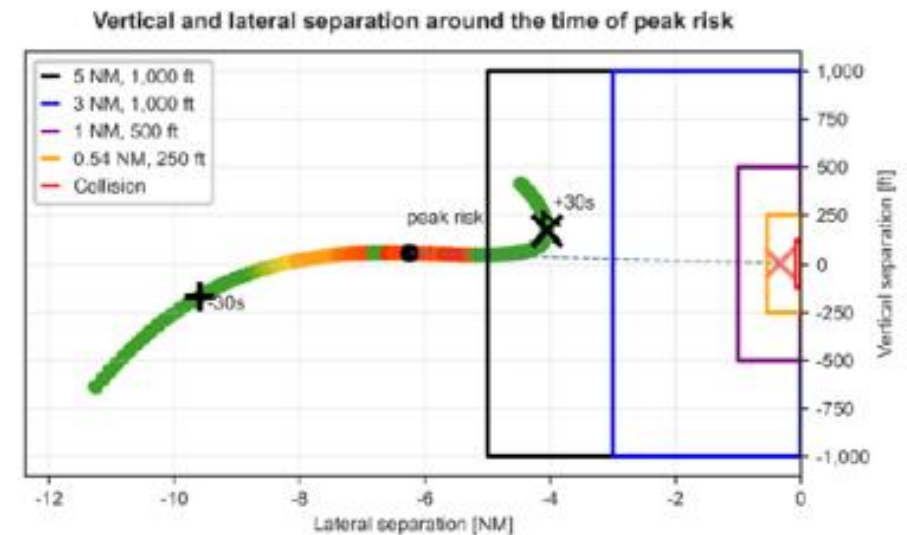
Similar risk although less peak
risk.



4 NM, 59 ft; 416 knots
171 degrees



54s to 0.33 NM, 7ft;
Peak risk $2E-3$
Overall risk: $3E-8$





THANK YOU