EUROCONTROL

Safely Optimised Runway Throughput

Arrival Management Streaming for Optimised use of Systemised Airspace

Opportunities for Arrival Management to Reduce Airborne Holding Times

Pairwise Separation including Runway Occupancy (ROT) elements and impact on Minimum Radar Separation (MRS)

15th June 2023 10:00-16:00

NATS, Whiteley, Southampton, UK

EUROPEAN PARTNERSHIP

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Co-funded by the European Union

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NATS

SORT Safely Optimised Runway Throughput

ITARO INTEGRATED TMA • AIRPORT • RUNWAY OPERATIONS

EAD

Welcome and Introduction

Siân Andrews – PJ.01-W2-08B1 Solution Lead & NATS VLD3 lead

PJ.01-W2 EAD: Enhanced Arrivals and Departures

PJ.37-W3 ITARO: Integrated TMA, Airport and Runway Operations

VLD3 SORT: Safely Optimised Runway Throughput

Agenda

- Coffee and Welcome 10:00 – 10:30
- 08B1 Arrival streaming concept overview 10:30 – 11:00
- 08B1 Arrival streaming exercise descriptions and results 11:00 – 11:30
- 08B5 Reduced arrival airborne holding times overview and results 11:30 – 12:30
- LUNCH 12:30 – 13:30
- VLD3 TBS Pairwise overview and results 13:30 – 14:30
- Coffee break 14:30-14:45
- VLD3 TBS Pairwise sim replay 14:45 – 15:15
- Next steps and Questions (08B1, 08B5, VLD3) 15:15 – 16:00

Arrival Management Streaming for Optimised Use of Systemised Airspace

PJ01 EAD

- PJ.01-W2-08A1
- PJ.01-W2-08A2
- PJ.01-W2-08B1
- PJ.01-W2-08B2
- PJ.01-W2-08B4
- PJ.01-W2-08B6
- PJ.01-W2-06

PJ37 ITARO

- PJ.37-W3-03

PJ.01-W2-08B1 Arrival Management Streaming for Optimised Use of Systemised Airspace

Includes Activity **08B5**: Opportunities for reduction of airborne holding times through arrival management

Optimised wake separation for arrivals with reduced MRS and enhanced ROT

VLD3 SORT

- WP2
- WP3
- WP4
- WP5

PJ.02-01-01 Optimised Runway Delivery (ORD) on Final Approach

PJ.02-01-04 Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics

PJ.02-03 Minimum-Pair separations based on Required Surveillance Performance (RSP)

PJ.02-08-03 Reduced separation based on local Runway Occupancy Time (ROT) characterisation

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Safely Optimised Runway Throughput

Welcome

Brendan Kelly – NATS Queue Management Benefits Owner

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PJ.37-W3-03/PJ.01-W2-08B1
Arrival Streaming Concept overview

James Daley – NATS 08B1 Technical Lead

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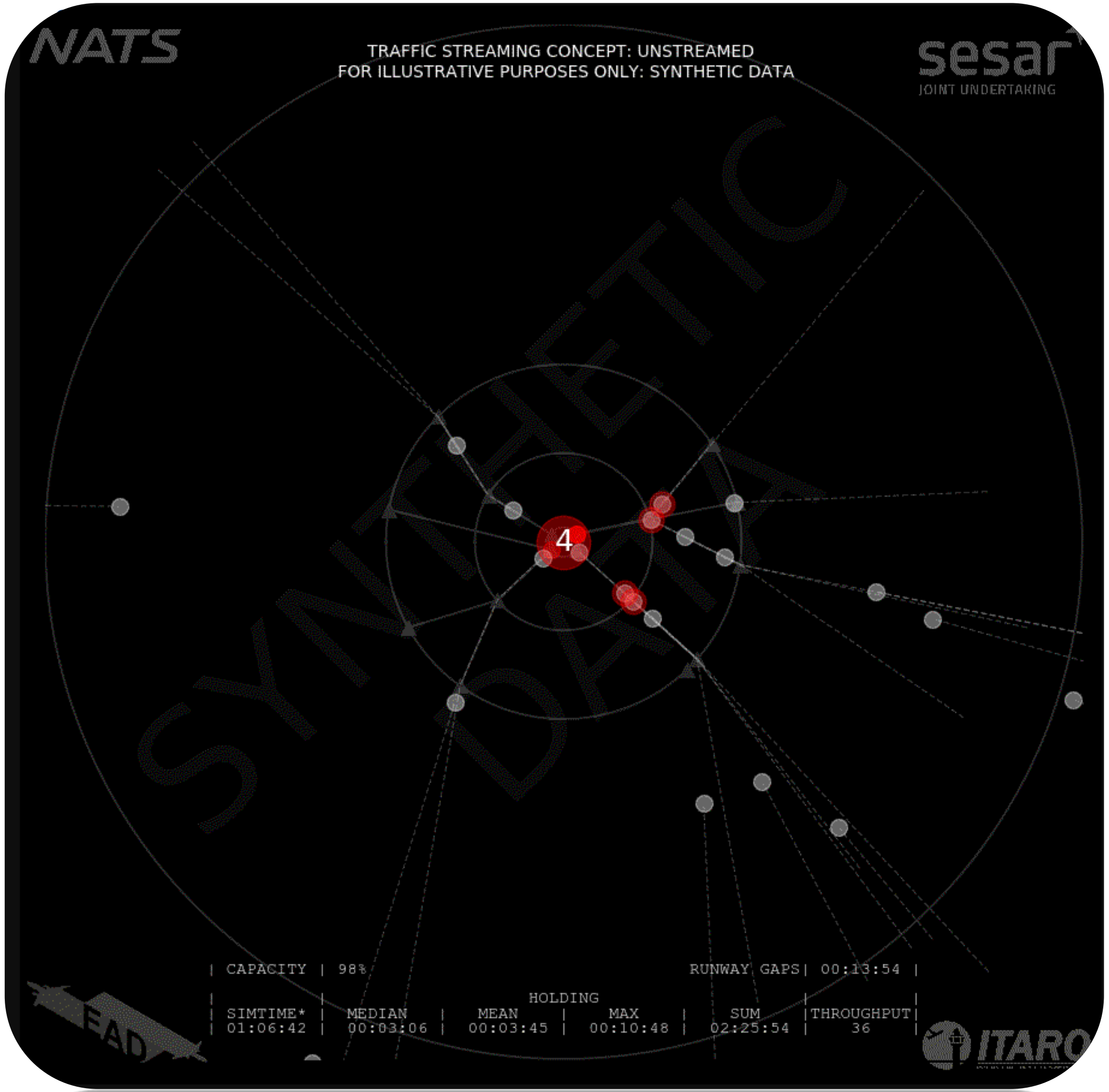
NATS Strategic goals

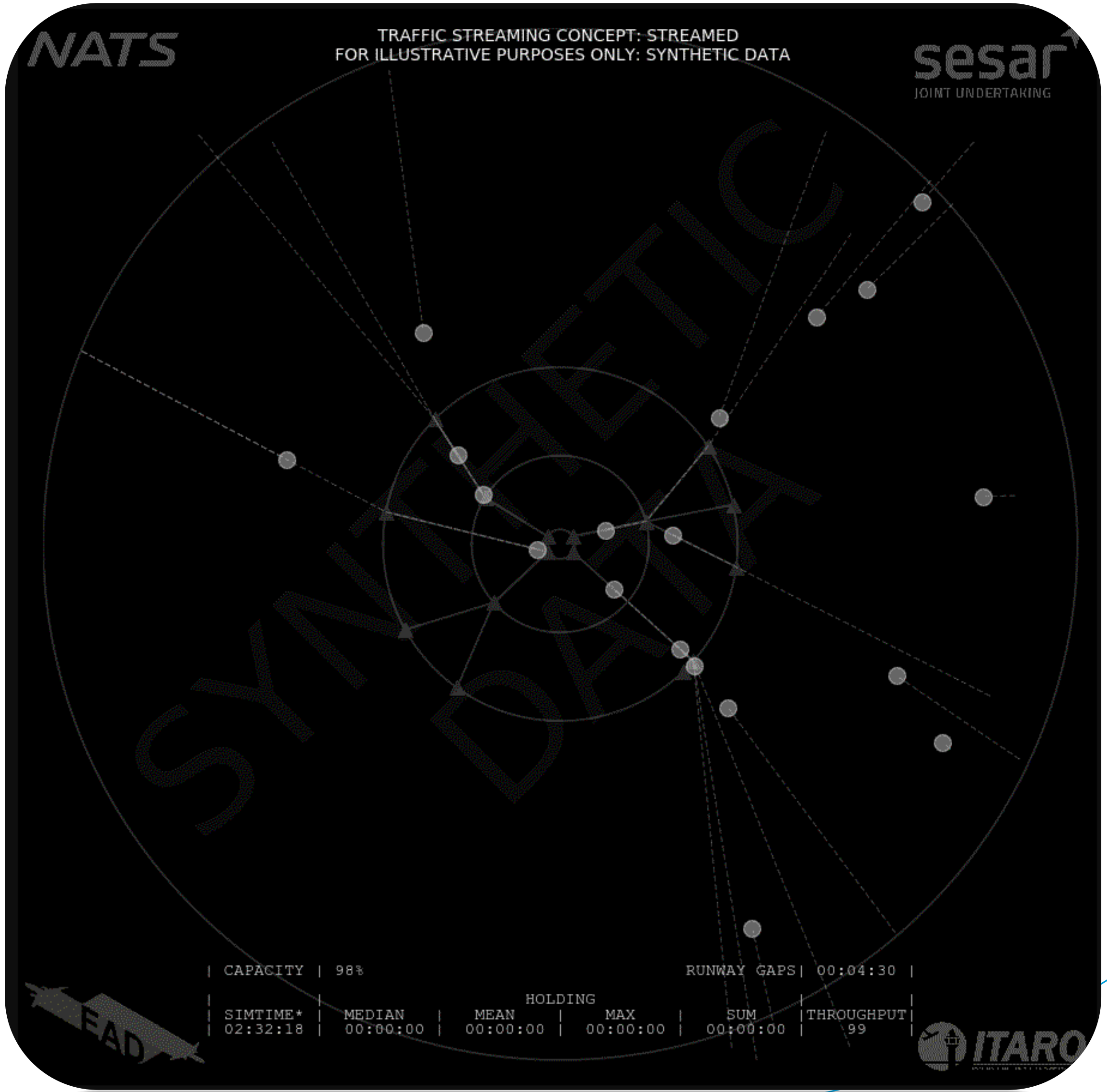
- Systemised Airspace Strategy
  - Future NERL airspace will be Free Route Airspace (FRA) at higher levels and ‘Systemised Airspace’ below, replacing current Enroute and terminal airspace.
  - Systemised Airspace will extend beyond current terminal airspace boundaries linking SIDs and STARs to Free Route Airspace.
  - Systemised Airspace is characterised by the existence of a structured route network utilising Performance Based Navigation (PBN). This structure is imposed to make conflicts more predictable and when combined with advanced ATM tools will <u>reduce controller intervention and therefore workload.</u>
- Environmental commitment
  - We prioritise working with our customers and partners to find more sustainable solutions, including providing efficient routings to <u>minimise the emissions of air traffic in our airspace.</u>

Approach to meeting strategic goals (relevant to this presentation)

- Development is required in airspace capacity and <u>queue management tools to improve the way traffic is delivered in and out of the airspace.</u>

Strategic Goal





Baseline


NATS
TRAFFIC STREAMING CONCEPT: UNSTREAMED
FOR ILLUSTRATIVE PURPOSES ONLY: SYNTHETIC DATA
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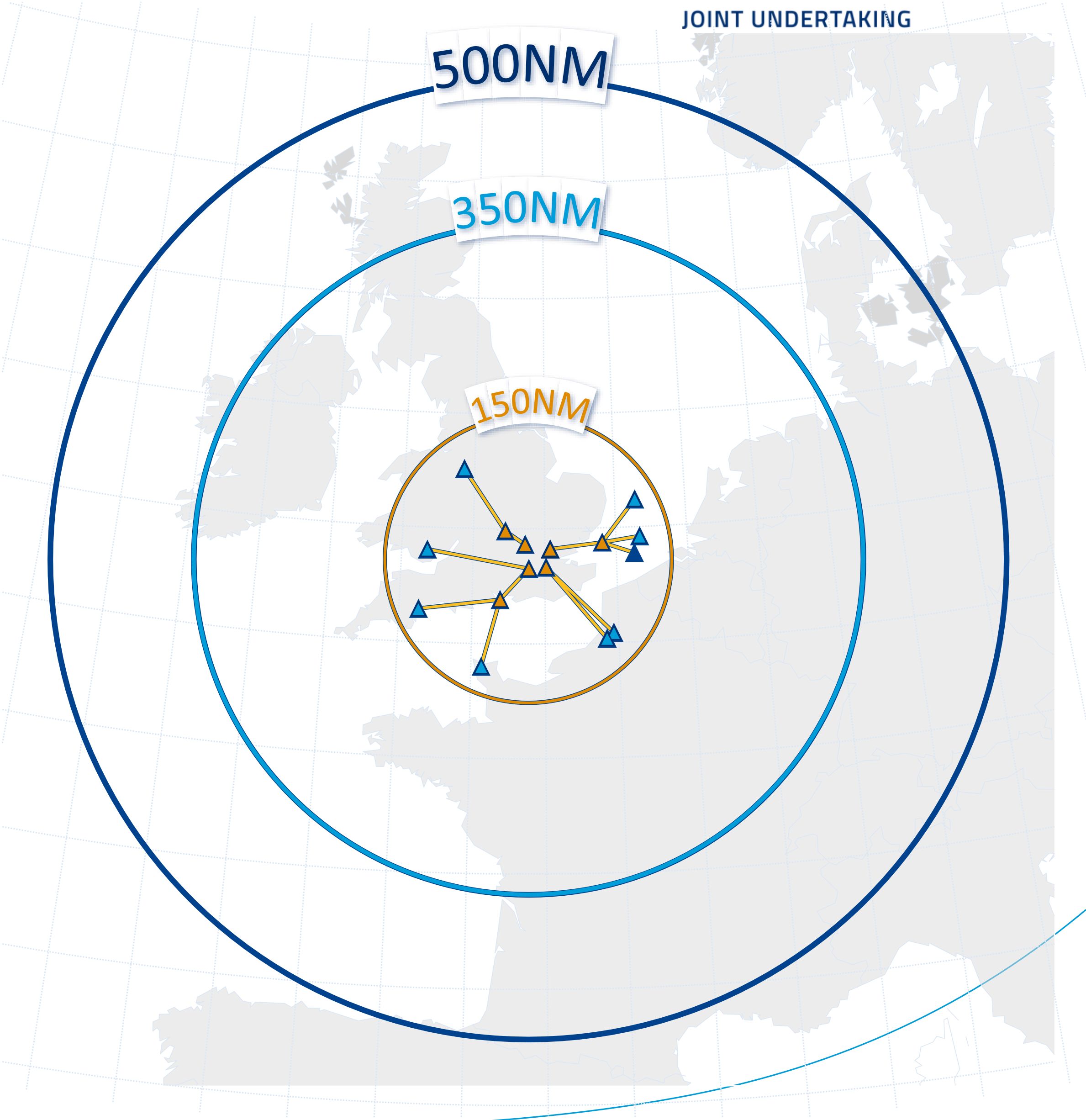
SYNTHETIC DATA
ITARO

Strategic Goal

Scope of SESAR PJ.01-08B1

- Using an enhanced version of the Heathrow AMAN to assign target times which are achievable through speed adjustment alone, starting from a 350NM horizon, separate arrival traffic by 90-seconds or greater within the systemised airspace (last ≈120NM of flight) to reduce or eliminate traffic bunching and stack holding
- Assess the concept and prototype in a shadow mode trial
- Explore the operational acceptability and feasibility of the solution in current operations with ATCOs through workshops
- Key Point – AMAN/airport centric arrival streaming does not consider other flights using the airspace
    - Assumption - FRA into Heathrow exclusive segregated systemised routes

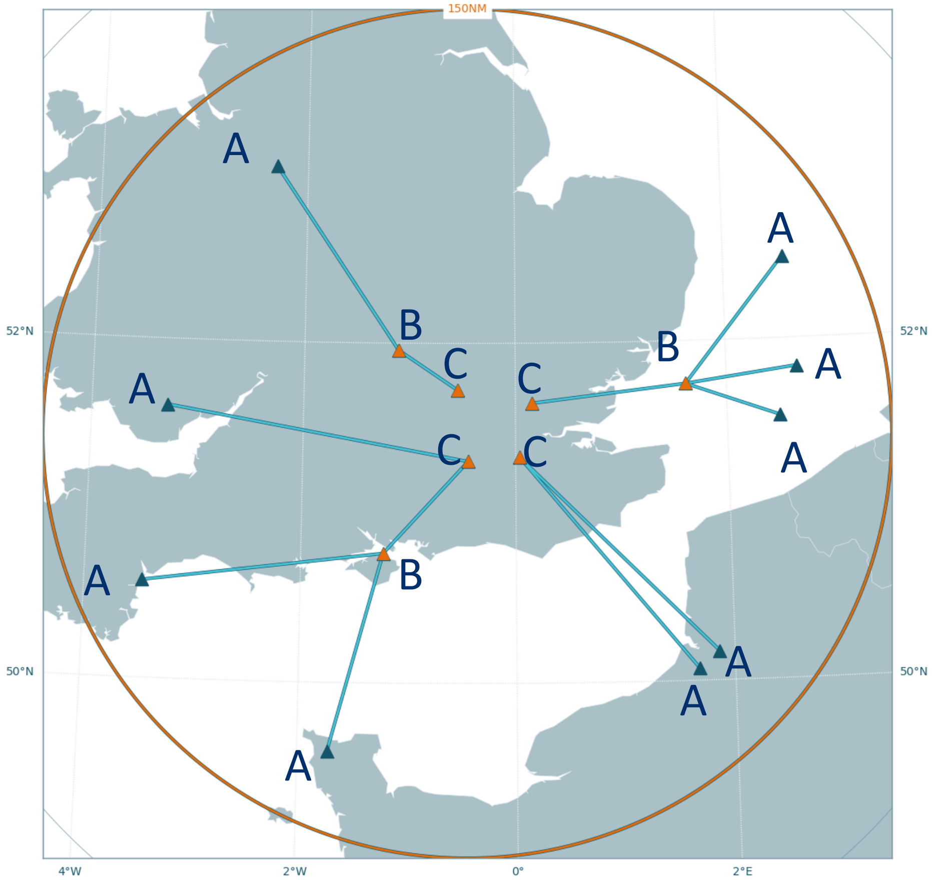


Concept Development – Foundations – AMAN and XMAN

- AMAN's main task is suggesting an optimised runway sequence and estimating delay
- XMAN aims to apportion excessive stack holding delay to the route
    - XMAN only targets stack-holding (not deconfliction)
    - Flight vs flight interactions are not considered (except at the runway)
    - Action is only taken where predicted IAF delay is above a threshold
        - High threshold accounts for expected error in long-range predictions
        - Slow down (best endeavours)
- Linked third party (LTP) Orthogon are the Heathrow AMAN/XMAN supplier
- Orthogon were a LTP in SESAR Wave-1 PJ.25
    - PJ.25 looked at metering a single flow through one waypoint near T.O.D.
        - Target times were planned, but plans were continually updated
        - Gaps were stacked up
- Technical limitations
    - AMAN/XMAN platform is a highly tuned, computationally complex and very secure
        - Not within scope to change core components – streaming algorithm was built on-top
        - Core functionality remained the same – runway sequencer and trajectory predictor modules

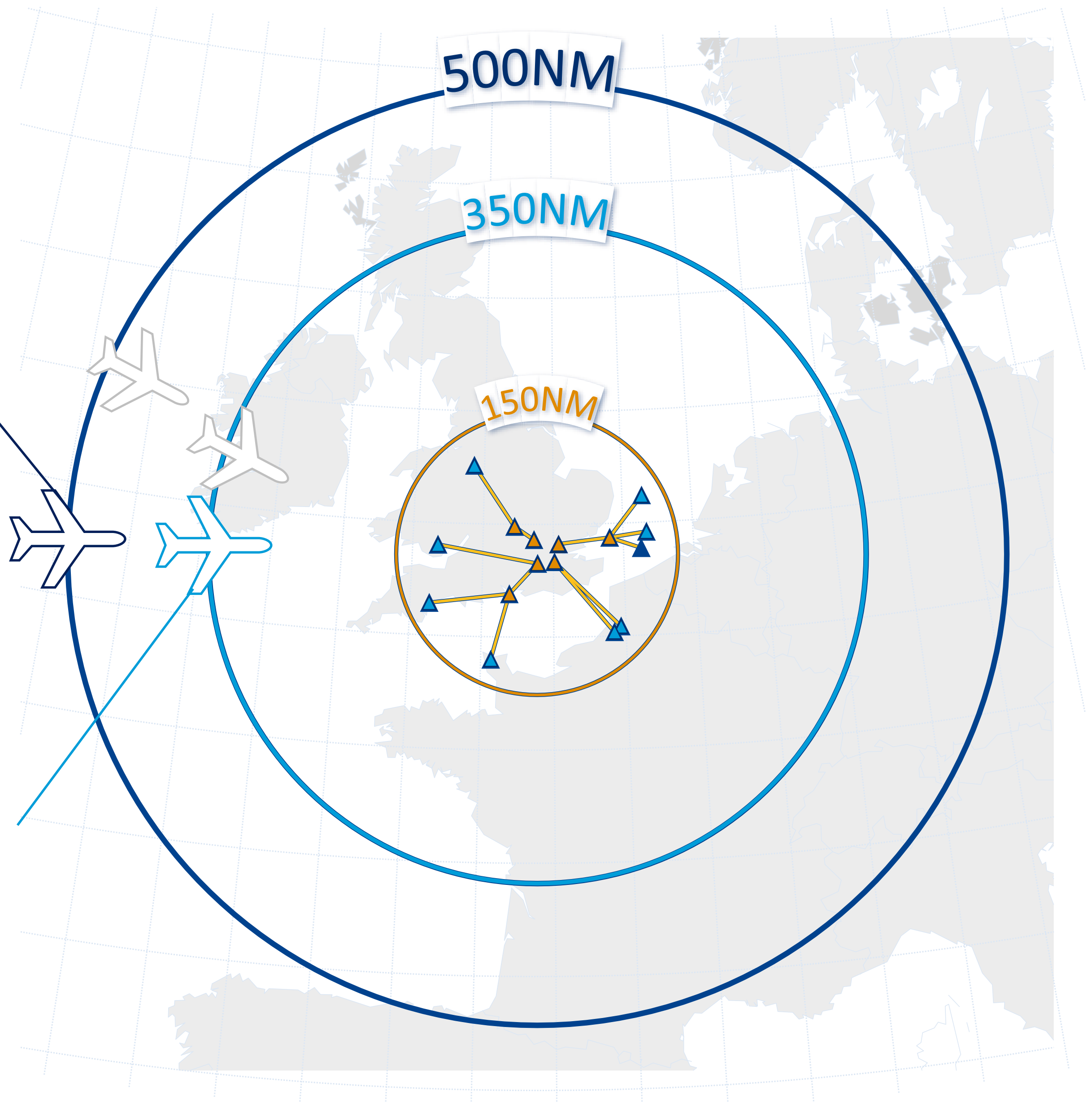
Concept Development – Problem setting

- NATS defined a simplified systemized airspace as a series of Time Assigned Points (TAPs) A, B & C
- Requirements
  - Use BADA model in AMAN to make sure trajectories are flyable (vs.PJ-25)
  - Aim for 90s separation at all points
  - Apportion predicted stack holding delay to the route
  - Avoid overtakes after TAP-A
  - The streamer must commit to decisions (vs.PJ-25)
- Technical approach
  - Orthogon built a planning component that worked with the output of the TP and sequencing components
  - Creates and logs streaming plans and freezes trajectories
    - assumes compliance [Shadow Mode]



Solution 1.0

AMAN building plan
Looking for conflicts and predicting holding



AMAN commits to entire trajectory
*constrained to shadow mode

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PJ.37-W3-03/PJ.01-W2-08B1 Arrival Streaming exercise results

James Daley – NATS 08B1 Technical Lead

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PJ.01-08B Thread B1 Recorded Data Trial - 2020

- The planned shadow mode trial was not possible due to the reduction in live traffic levels during the COVID-19 pandemic
- The assessment was conducted on the AMAN test-tool using recorded data
  - Like a shadow mode trial, the tracks would not react
- Findings:
  - Pop-up flights were a significant problem, disproportionately contributing to unresolved bunching
  - In order to effectively separate flights, action needs to be taken early even for the later internal points (TAPs B & C)
  - Shadowing not appropriate test
  - ETAs available from ETFMS EFDs, at the XMAN horizon were not reliable enough to predict bunching on a flight-to-flight separation resolution
  - BADA model provided only extreme speed range (RDT TTL was capped)

Solution 2.0

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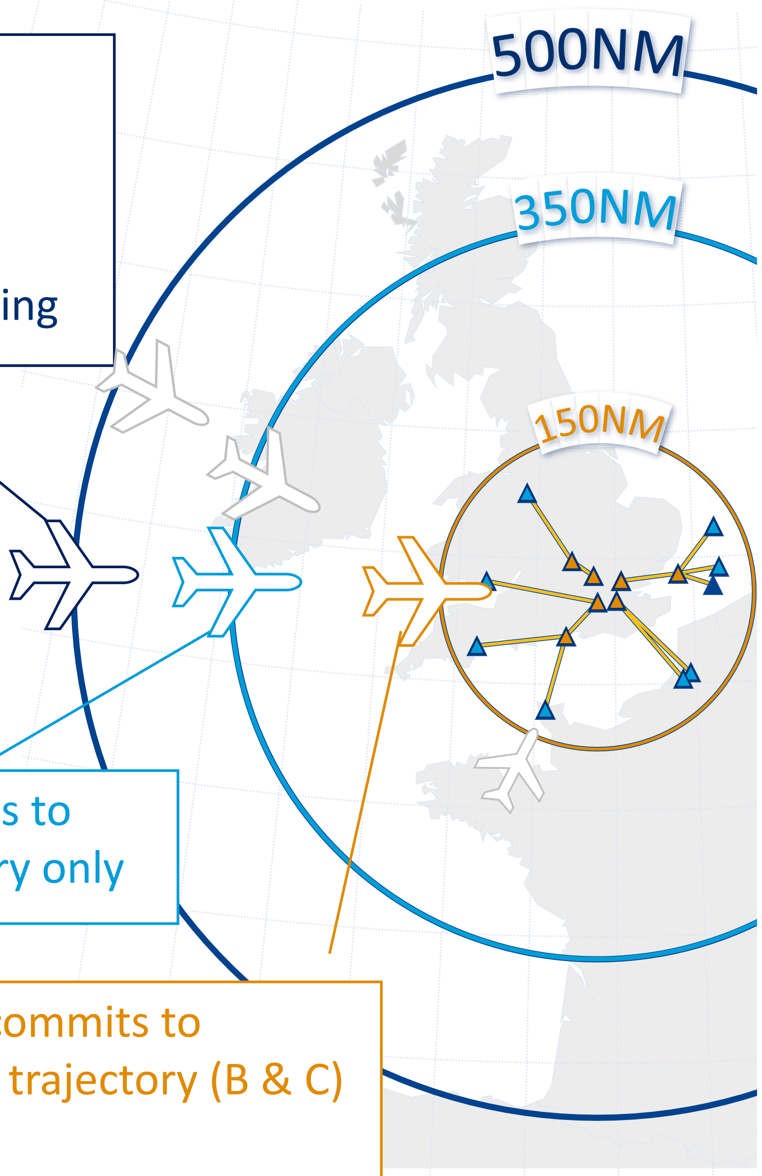
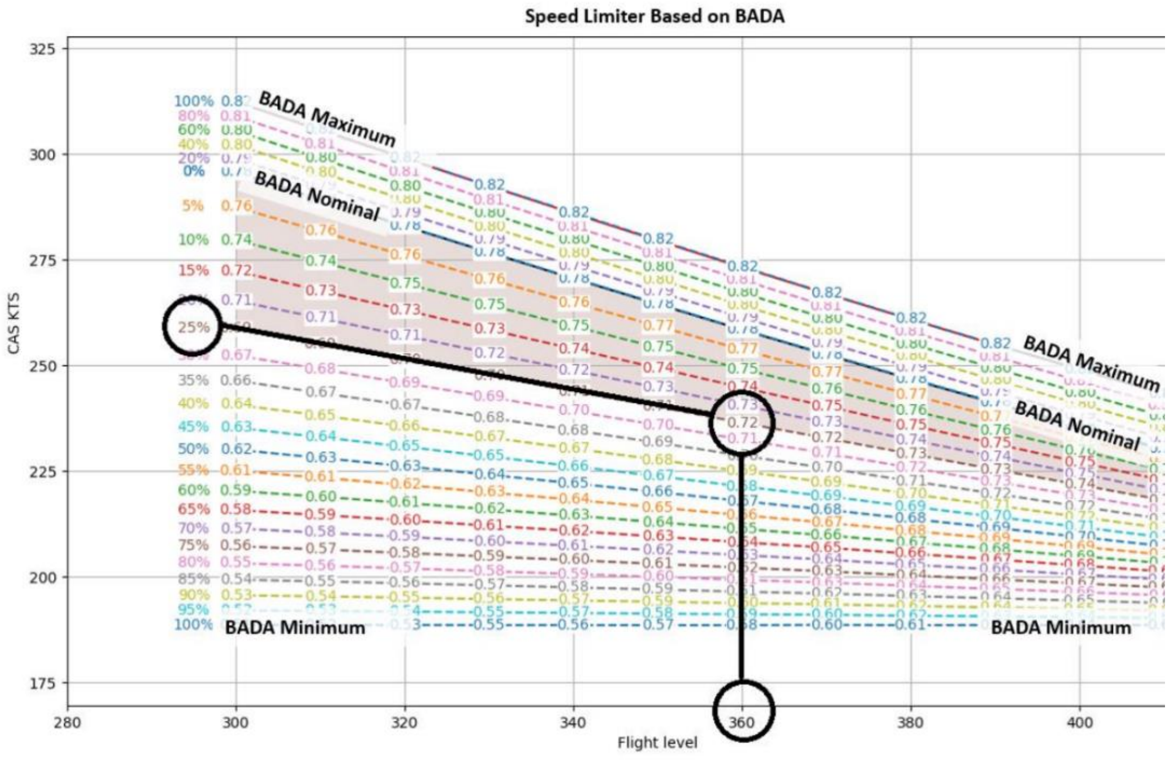
AMAN building plan
Looking for conflicts and predicting holding



AMAN commits to cruise trajectory only

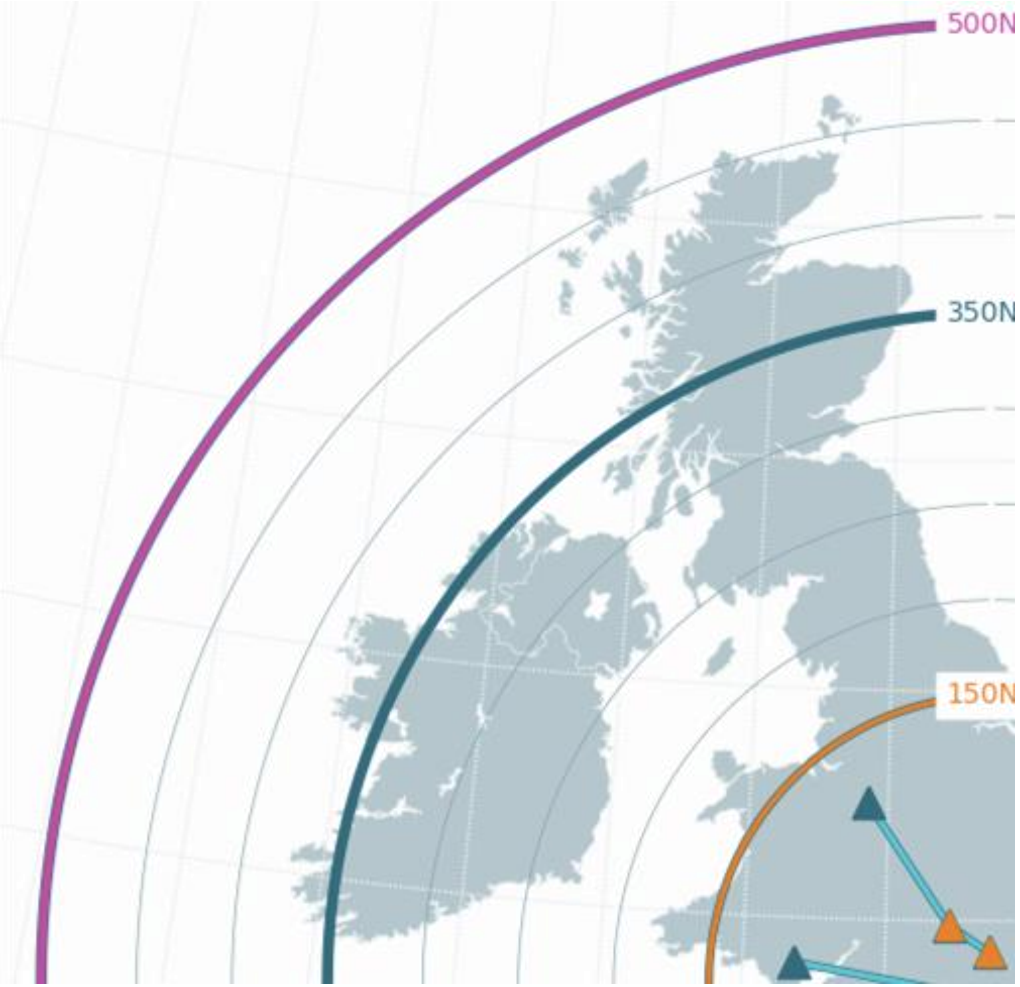
AMAN commits to descent trajectory (B & C)



PJ.37 Large Dataset Validation

- Concept was tweaked - NATS defined new rules to integrate pop-up traffic and developed a new speed model that would work with standard AMAN TP output (2.0)
- The streaming AMAN was updated and integrated into the Ace Simulator platform
- Bespoke simulator modules complied with AMAN instructions and conformed to an accuracy we would expect to see in the real-world (using FMS) creating a dynamic test environment
- The Large Dataset Validation was a highly controlled simulation which eliminated some real world variables (e.g., trajectory prediction reliability and compliance)
- The traffic samples were modelled on busy days from 2019
- >1000-hours of simulations were run with different streaming settings and traffic presentation variations
- LDV was intended to provide an indication of the upper-limits of the potential of the PJ-37 streaming solution (as executed by the AMAN prototype)
- Limitations – the baseline was uncontrolled (no system/actor is attempting to resolve bunching)

The LDV - illustration



LDV Results

- Solution runs had lower bunching and stack-holding than baseline runs
  - Approximately a 30% real-world reduction in bunching if upstream compliance is high
  - Approximately 20 to 25 seconds reduction in stack holding per flight averaged over the day (from ≈ 7-8 minute average)
  - Combined fuel saving from reduced holding and additional CDOs was estimated to be in the range 19-20 kg per flight on a busy summer day
  - This is based on the assumptions:
    - Accurate trajectory predictions are available
    - Upstream sectors/centres and airspace users comply with AMAN advice.

Moving in the right direction but have not yet met the strategic goal during this phase of research

Operational End-User Research – a few key findings

- Workshops and an extended demonstration allowed us to speak with over 60 controllers and other operational staff about the concept

- Controllers want the benefits that the concept is trying to achieve, fewer bunches and less holding. So the strategic aspirations are compatible with the operational need

- Controllers are not currently trained or equipped to separate/control using target times where the spacing is so tight (90s)
  - Giving a target time for a point up to 200+ miles is currently alien
  - Requested additional controller tools, conformance monitoring/what-if?
  - Time based control requires a "change of mindset"
  - RT capacity is limited and potentially complex target-times not seen as viable over RT (TOMs would need to be assessed by the pilot before accepting)
  - More receptive to speed requests and have the training and controller tools to currently support that

Operational End-User Research – a few key findings cont.

- Controllers did not generally consider target-times in descent to be practical where spacing was tight e.g., bunching situations
  - After ToD the practical order of flights would be clear to them and felt better equipped (than AMAN) to manage traffic from this point onwards
  - To ensure separation in bunching scenarios, aircraft would be *locked-on* specific speeds (controlling flights relative each other is priority, not an arrival tool target)

- Where the traffic situation allows, ATCOs would be receptive to a request to manually absorb various levels of delay in descent and would be receptive to descent speed suggestions from the streaming tool

- Where Streaming Tool requests were incompatible with the non-EGLL sector traffic, they would not necessarily get priority, as controllers have a duty to serve customers fairly

ETA accuracy

- AMAN/XMAN uses ETFMS EFDs outside of UK airspace
  - ETFMS is built for flow management purposes not flight-to-flight deconfliction
  - AMAN uses these predictions solely in time domain
  - AMAN calculated ETA_{min} to ETA_{max} are estimated using the EFD ETA and are based on a number assumptions (route, weather, current speed)
- AMAN has the ability to independently produce its own predicted trajectories if it knows the routes and is provided with surveillance (e.g. radar)
  - Orthogon tested extending its independent TP beyond the XMAN-horizon by using ADS-B data in place of Radar data
  - Scope limitations
    - direct routes were assumed beyond known/configured airspace
    - TP engine was not radically updated
  - Unfortunately, this simple approach showed no improvement over ETFMS

Research Output

Developed a fuller understanding of the problem space and identified the key variables in arrival streaming, amongst which are:

- **Ability of the streaming tool to reliably predict bunching** (ETO accuracy and reliability, required separation)
- **Ability of the streaming algorithm to solve the puzzle in an operationally acceptable way** (complex multi-factor decision making, balancing priorities)
- **Ability of aircraft to gain or lose time** (horizon distance, A/C performance, FL, C.I. etc.)
- **Traffic-mix** (Regional/Short/Long Haul)
- **Route structures and flow rates** (internal merging and distribution of traffic)
- **Ability of ATCOs (including upstream centres) to understand, prioritise and accommodate streaming tool targets** (other traffic, human capacity, support tools, type of target e.g. speed or time)
- **Streaming tool flexibility** (reacting to new information/pop-up flights/divergence from plan)
- **Independence of systemised routes** (streaming tools may need to consider multiple airports)
- **Streaming based on speed adjustment will have limits** – the rate at which aircraft enter the "horizon" determines holding/bunching at a macro level

Conclusions/Next Steps

- The initial PJ.01 idea was ambitious and appears to require a number of enablers which will become available as part of TBO (ADS-C, EPP, time based controller tools, what-if, conformance monitoring, CDM/planning tools, etc.)

- Devise an interim solution(s) targeting reductions in traffic bunching and excessive stack holding that would be implementable in the near-term, delivering benefit
- Current ideas
  - Develop a ground based proxy FMS with GE to model trajectories
    - current estimate (ETA), slowest (ETA_{max}) and fastest (ETA_{min})
  - Iteratively develop and test new and increasingly sophisticated de-bunching and delay absorption concepts/tools/algorithms in an agile manner
    - Consider the key findings of PJ.01/PJ.37
    - Scope - Targets likely actioned with speed advice communicated through SWIM portal
    - Test in combination with more other airspace/airport capacity management tools

Thank you for listening.

Any questions?

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PJ.37-W3-03/08B5
Reduced Arrival Airborne Holding Times - Overview and Results

Raphael Christien – EUROCONTROL 08B5 Technical Lead
Bruno Favennec – EUROCONTROL 08B5 Technical Lead

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Supporting
European
Aviation

EUROCONTROL

Reducing CO2 emissions of arrivals by acting on departure times

A perspective for 30 European airports

Raphaël Christien, Bruno Favennec and Karim Zeghal
EUROCONTROL Innovation Hub

PJ.01-W2-08B/PJ.37-W3-03/VLD3-WP2 Open Day

NATS CTC, Whiteley, 15th June 2023

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ITARO

CONSORTIUM COORDINATOR sesar DEPLOYMENT MANAGER

FOUNDING MEMBER sesar JOINT UNDERTAKING

NETWORK MANAGER

Context

- PJ37-W3-03 (ITARO) - Complement to NATS' B1 activity (PJ01-W2-08B)
- Investigate opportunities to control airborne delays by acting on departure times, relying on existing NM mechanisms - including a specific focus on London (EGLL/EGKK) with NATS

- Initial sensitivity analysis: (Q1'22 – Q3 '22)
  - Theoretical feasibility of controlling airborne delays to a target
  - Four European airports (EGLL, LEBL, LPPT and LSZH)

- Complementary analysis: (Q4'22 – Q1'23)
  - Exploring different airborne delay control mechanisms and introducing a ground delay capping
  - Optimising the reduction of airborne delays by considering weighted impacts for airborne, ground and extra delays
  - Extension to 'Top30' European airports(*) including EGLL and EGKK

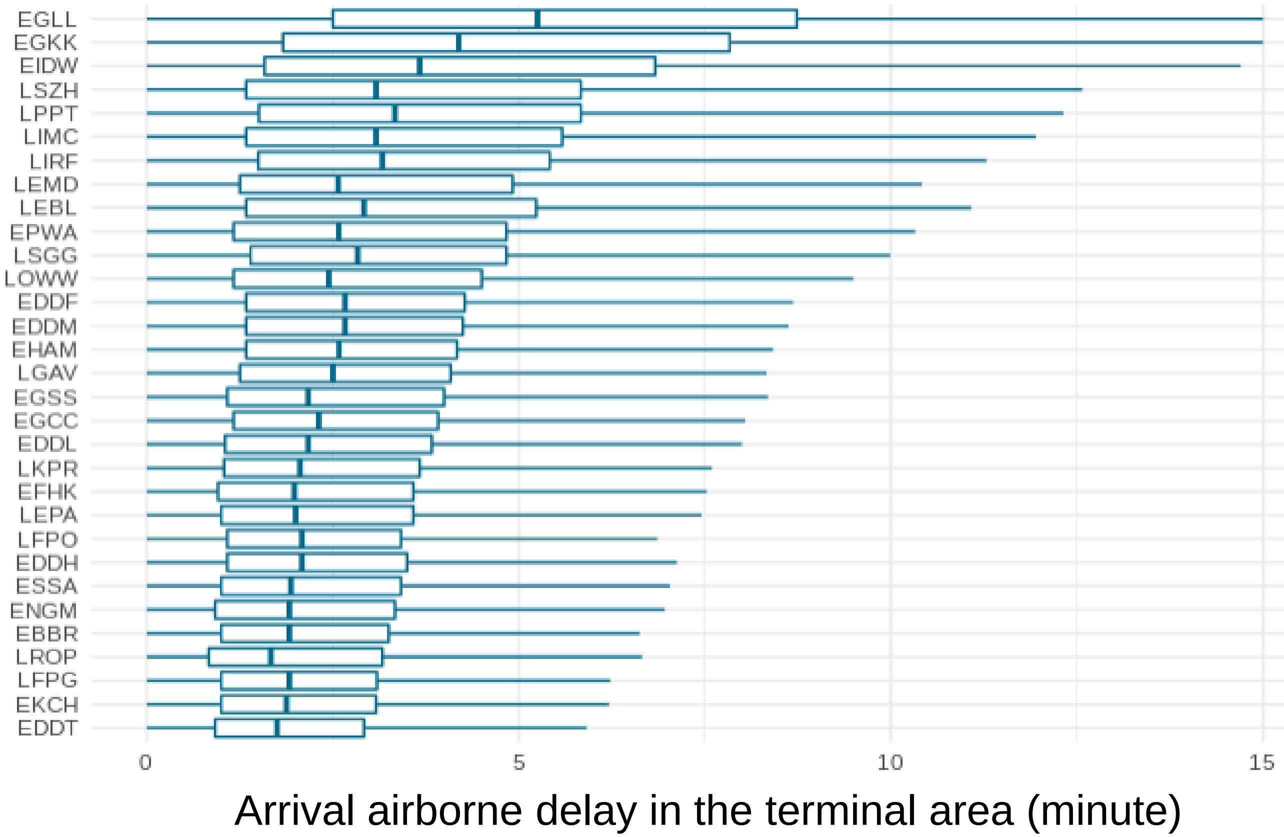
(*) no 2019 data available for Türkyie

Motivation

Arrival airborne **delays** generated by congestion in the terminal area at TOP30 European airports in 2019

⇒ **44,000hours (>5')**

⇒ **200,000 tons CO2**



25kg fuel burn / 75kg CO_2 per minute of airborne delay

A solution ?

Transfer **airborne** delay excess **to ground**
using current flow management regulation mechanisms

High airborne delay (double than ground delay) with current flow management measures

Related work

- Use of ground holding for airborne delay reduction, fuel conservation, and emissions reduction
  - Fuel Advisory Departure program, FAA, 1974
  - Airborne delay characteristics of flights controlled by ground holding at Tokyo Haneda, Tokyo ITPS, 2013
  - Operational Opportunities to Reduce Fuel Burn and Emissions, ICAO, 2014
  - "… reduce holding times at airports through a better support of the network .. ", EUROCONTROL PRR, 2017

- Bridging the gap between flow and arrival management
  - SESAR 2020 PJ24/NCM and PJ25/xStream – including Heathrow DCB trials, NATS, 2019

- Flow management and sustainability
  - Environmental impact of delay, EUROCONTROL, 2006

- Economical studies - cost of delays
  - Evaluating the true cost to airlines of one minute of airborne or ground delay, EUROCONTROL PRC, 2004
  - Estimating economic severity of Air Traffic Flow Management regulations, Univ. Westminster, 2021

- Airport capacity and delay predictions under uncertainties
  - Prediction of Airport Arrival Rates Using Data Mining Methods, Embry-Riddle Aeronautical University, 2018
  - Considering time uncertainties in ground holding for optimal traffic flow management, JAXA, 2018
  - Impact of departure time prediction errors on optimal traffic flow management; JAXA, 2022

Many challenges…

- Reducing TMA delay accurately by
  - Using departure slots in a -5’, +10’ window
  - Dealing with uncertainty
    - Predicting airborne delay few hours in advance
    - Being resilient to flight uncertainties
  - Acting only on a traffic subset
    - Non exempted flights still on ground

- Operational impact
  - Keep a high runway throughput
  - Contain overall ground + airborne delay
  - Contain maximum ground delay
  - Impact on departure airports (more congestion on the ground ?)
  - Impact on network (increased number of regulation, interaction with other regulations ?)

Scope

The question

Is reducing TMA delay by acting on departure times feasible under uncertainty ?

Technique

Macroscopic modelling using realistic traffic demand temporal uncertainty

Target environment

TOP30 European airports in 2019

Fair-weather days

2 millions flights

Model approach

Estimate

Time of arrival (ETA)

Schedule

Time of arrival (STA)

respecting separation

Distribute

delay (STA – ETA)

between air and ground

ETAs evolve as uncertainties unfold

- off-block time (AOBT different from EOBT)
- flight progress (faster/slower than expected)
- landing

First-Come First-Served,

with priority on exempted flights

Following control function parameters (target, time period, constraints)

e.g.

Maximum TMA delay ≤ target

Mean TMA delay per 30' ≤ target

Simulation : data

Traffic	Uncertainties	Required separation at destination
European airports with large TMA delays Flight plans 2019 Good weather days	Off-block time Flight duration	Calibrated constant (per destination)

Simulation : data

Uncertainties

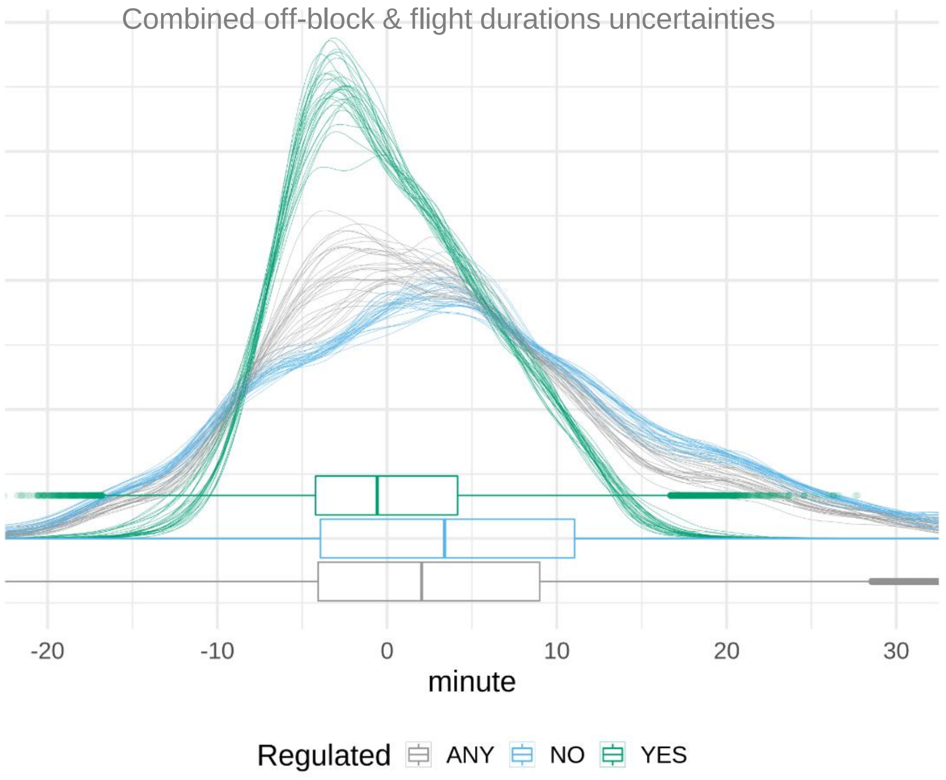
Off-block time

Sampled from actual data : AOBT - EOBT
- one sample for regulated flights
- one sample for non-regulated flights

Flight duration

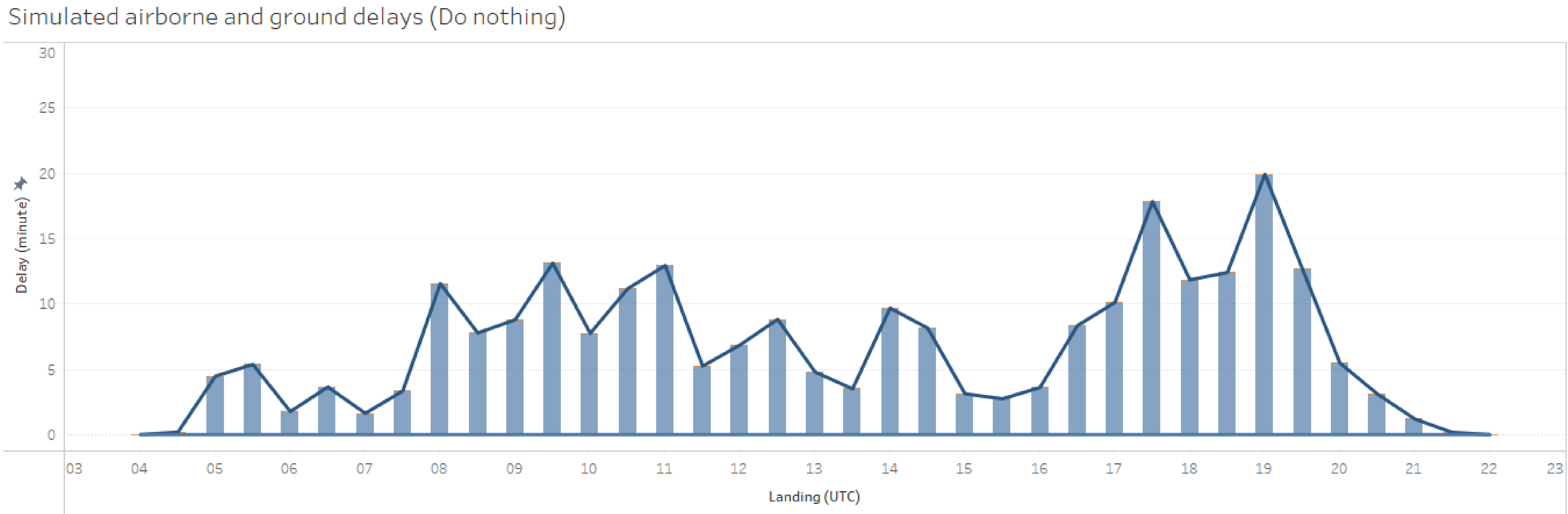
Proportional with time-to-go, following normal law, mean = 0, std.dev = 2%

Correlated deviations for flights with similar bearing and distance toward destination (mimic wind error effect)

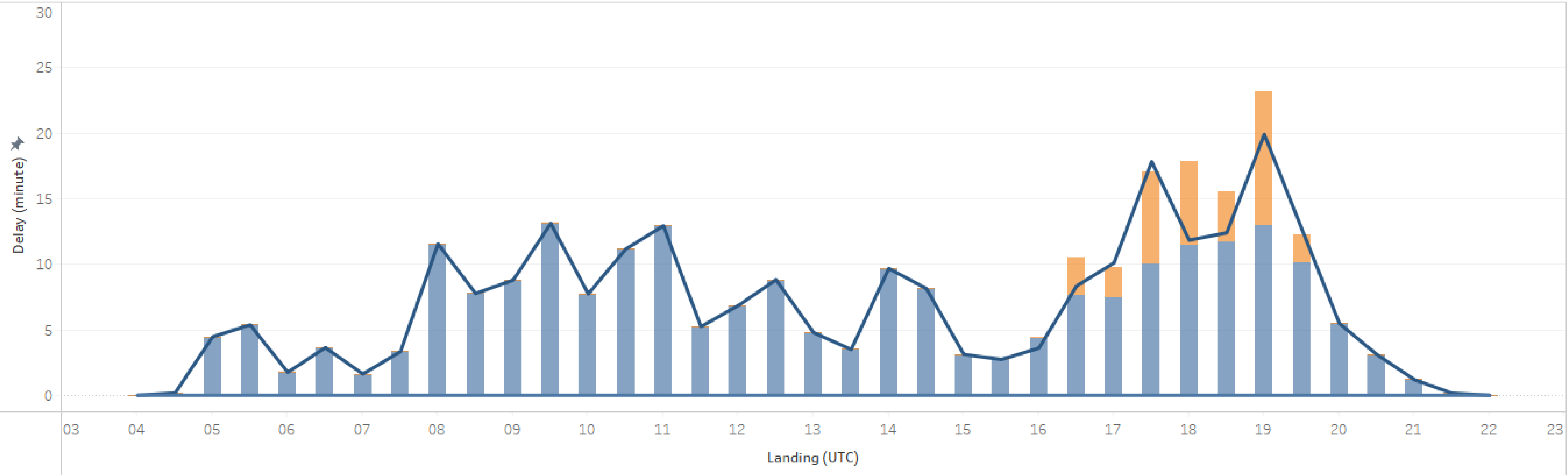


Experiments

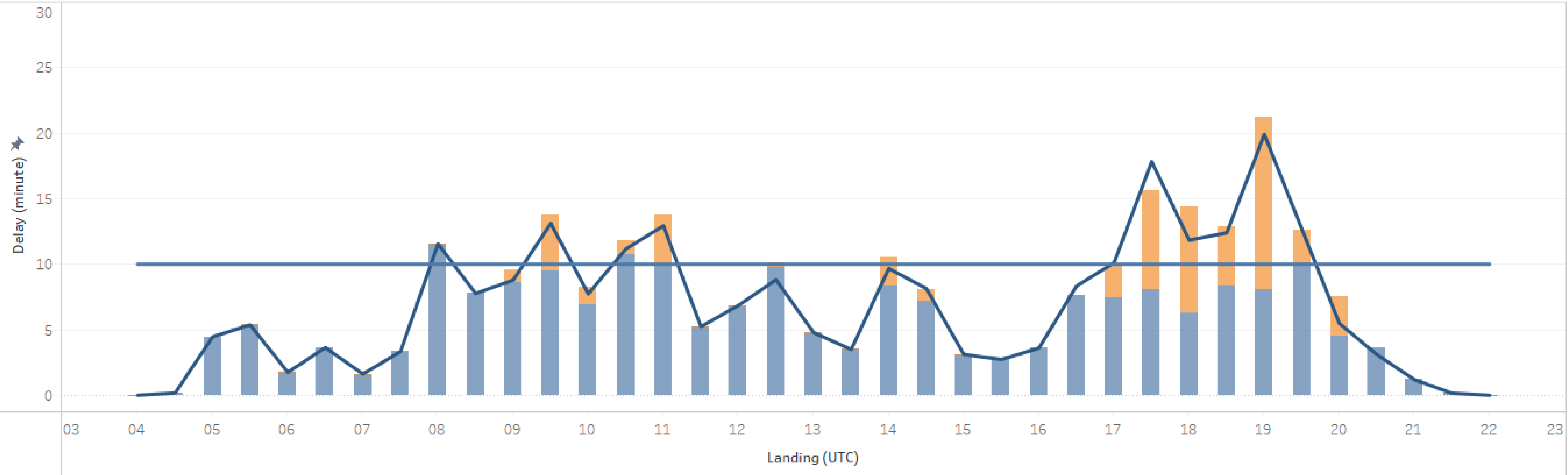
- For each destination and day, we simulate
  - Two baseline scenarios “Do nothing” and “Today”
  - Multiple delay control scenarios


Simulated airborne and ground delays (Do nothing)
Delay (minute)
30
25
20
15
10
5
0
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Landing (UTC)

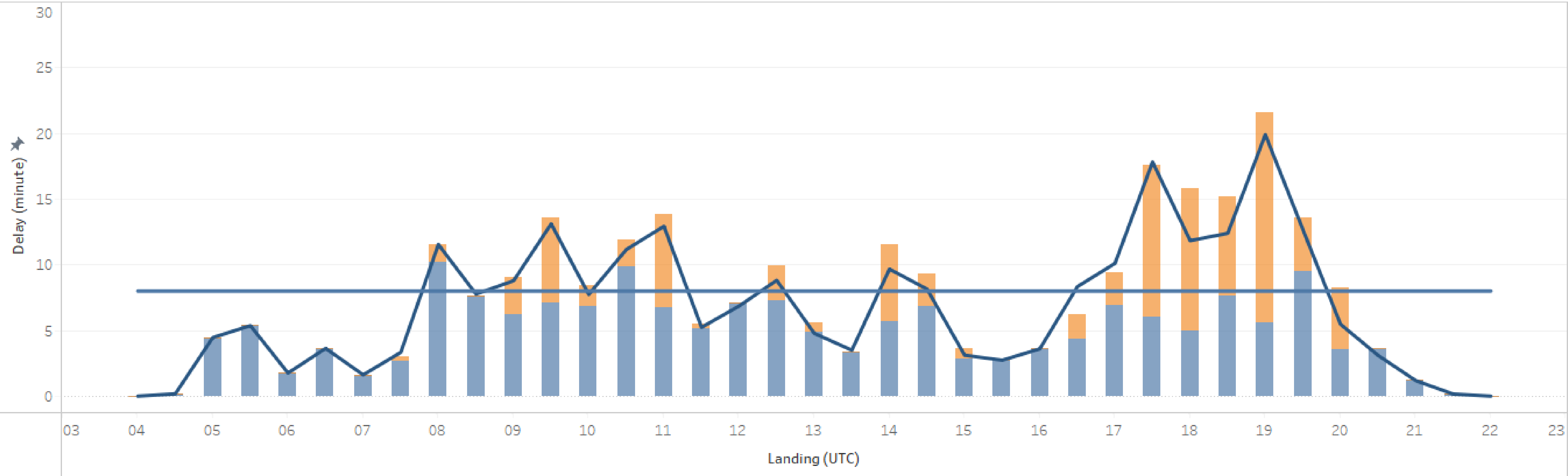
Simulated airborne and ground delays (Today)



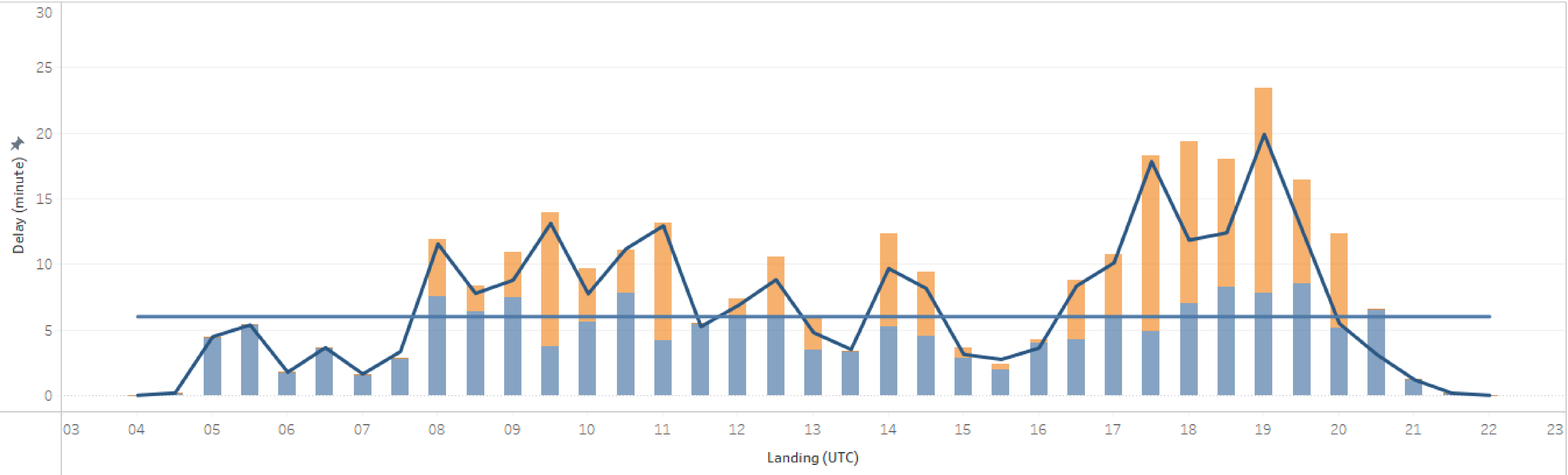
Simulated airborne and ground delays (10 min)



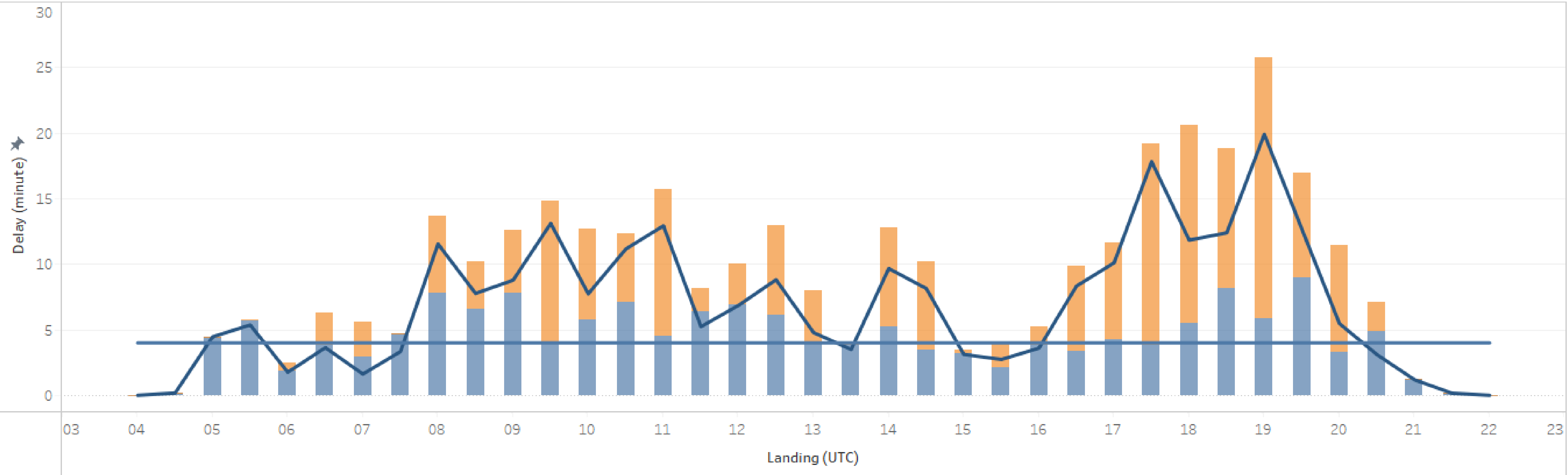
Simulated airborne and ground delays (8 min)



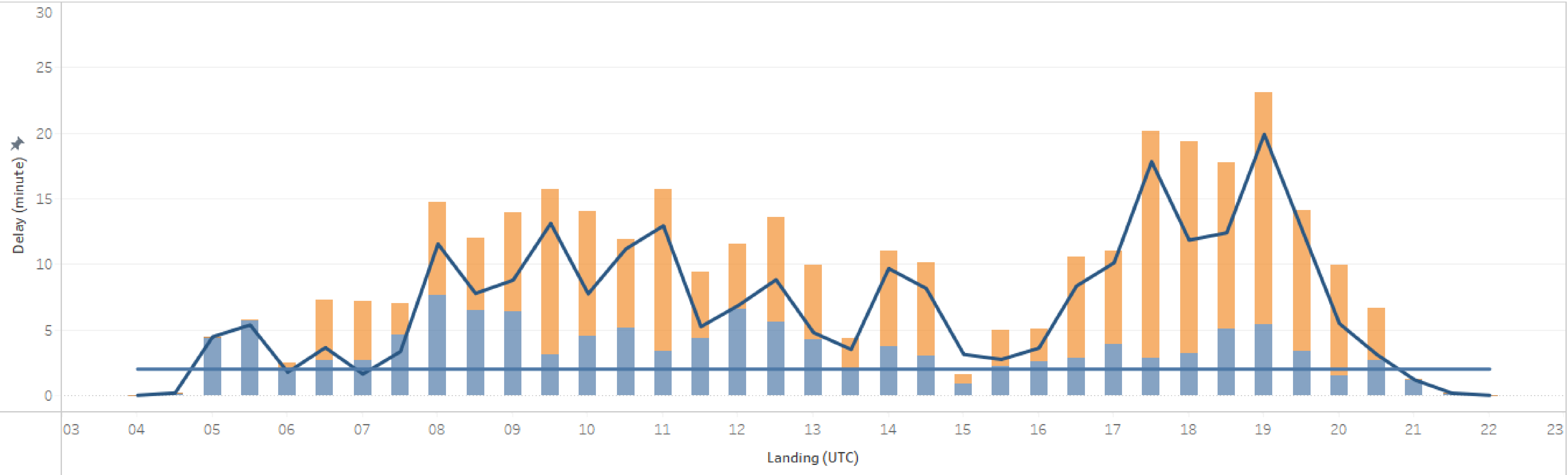
Simulated airborne and ground delays (6 min)



Simulated airborne and ground delays (4 min)



Simulated airborne and ground delays (2 min)



Results

- A sensitivity analysis to assess the effect of delay control parameters
- A trade-off assessment over TOP30 European airports for selected control parameters

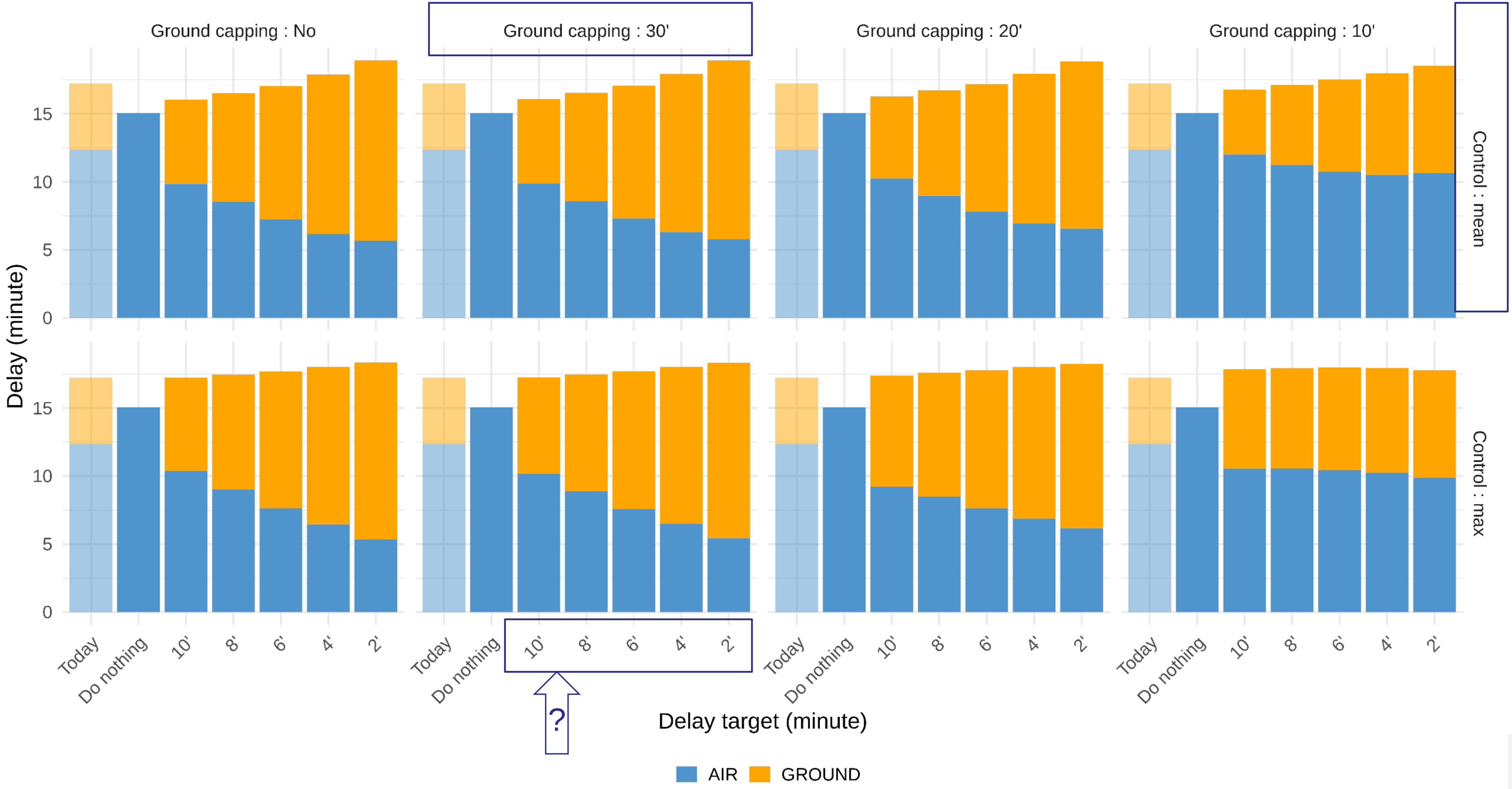
Delay control parameters: sensitivity analysis

- Goal : to assess the effect of the following parameters on ground and airborne delay
  - 2 **delay control functions**: maximum per flight or mean over 30 minutes
  - 5 **delay control targets** (2, 4, 6, 8 or 10 minutes)
  - 4 **ground delay capping** (10, 20, 30 minutes or none)

- Focus on peak periods
  - average airborne delay over 30’ period ≥ 10’ in “do nothing” scenario (empirical setting)

- Metrics: airborne, ground and total delay

Effect of control parameters on **mean** delays



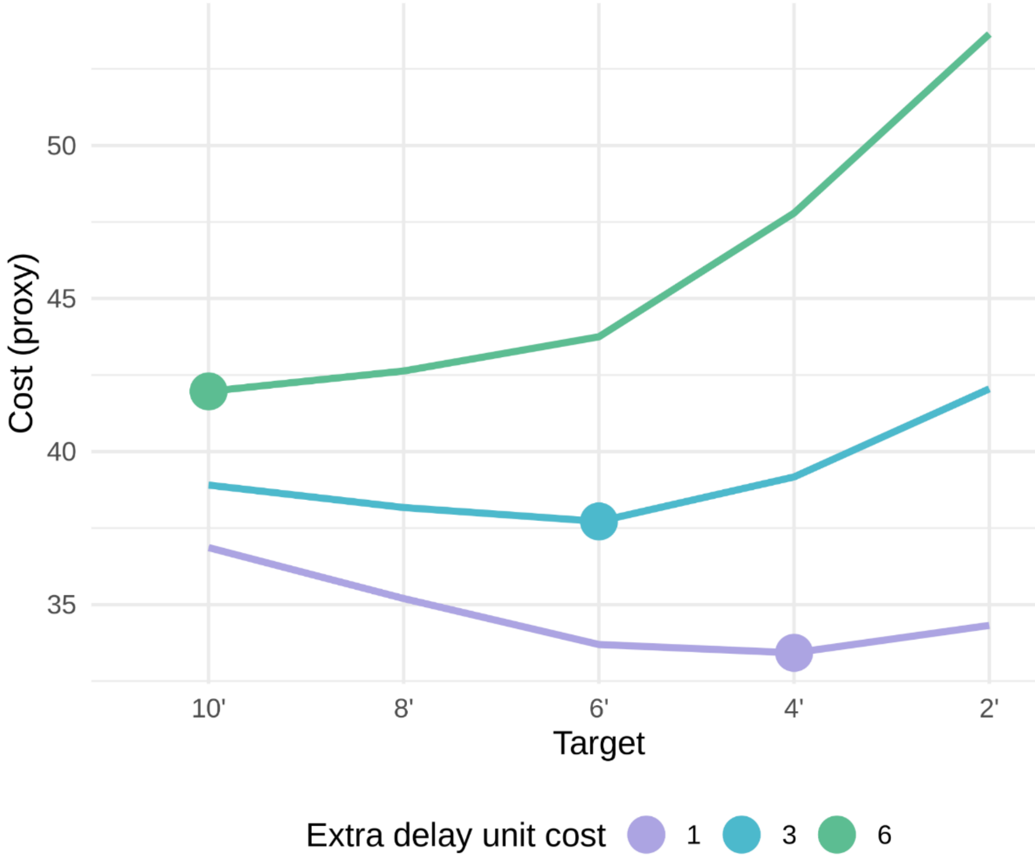
Trade-off assessment

- From sensitivity analysis, parameters selected:
  - mean function and 30’ ground delay capping
- Still need to select the delay target

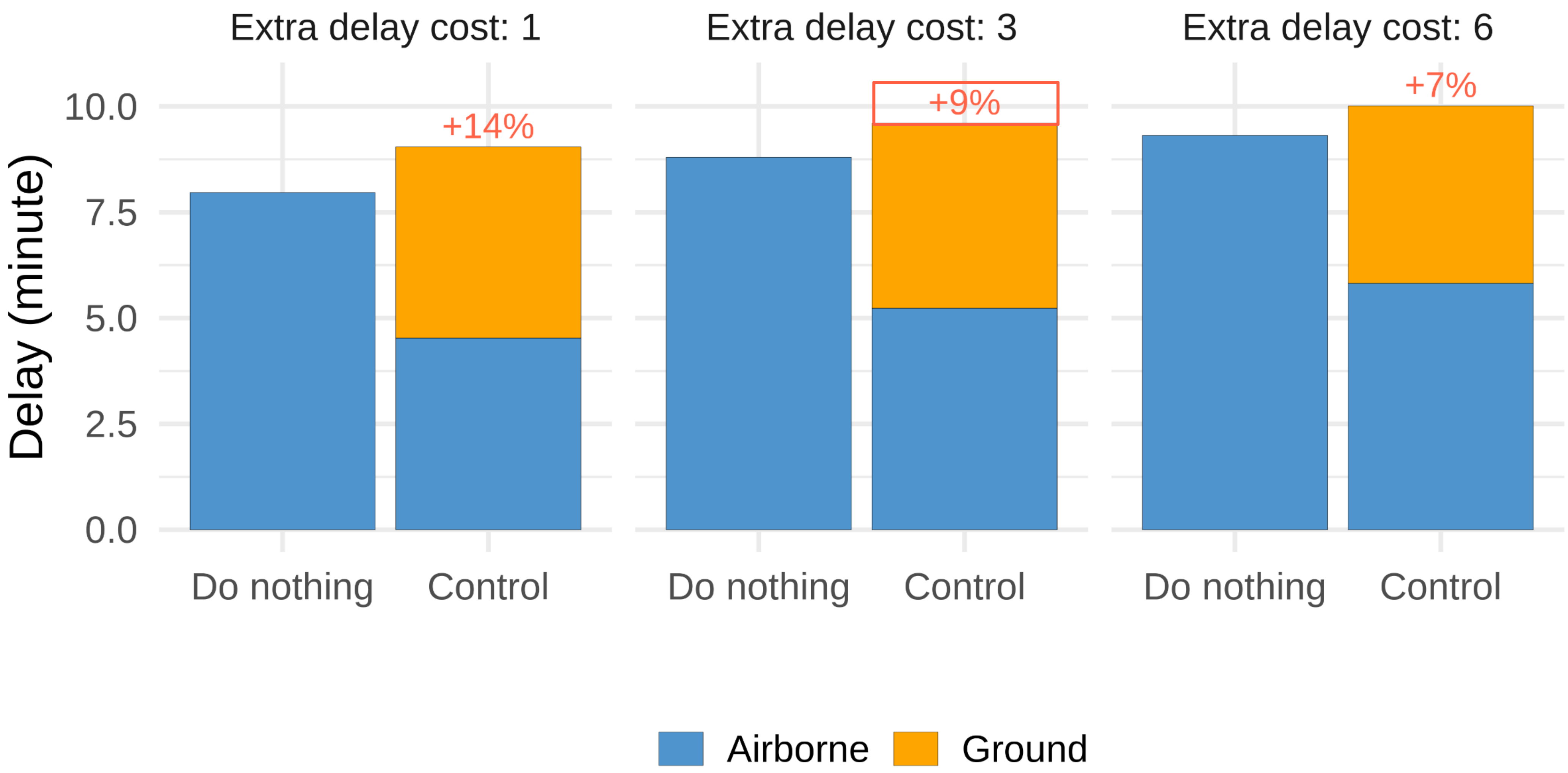
- Select one delay target per destination and day based on a minimum cost function

$$Cost = ground\ delay + 3\times\ airborne\ delay + n\times\ extra\ delay$$
$$with\ (n = 1, 3\ or\ 6)$$

- Metrics
  - Delays : airborne, ground, extra
  - CO_2
  - Runway throughput



Average ground, airborne and extra delays per flight during controlled periods

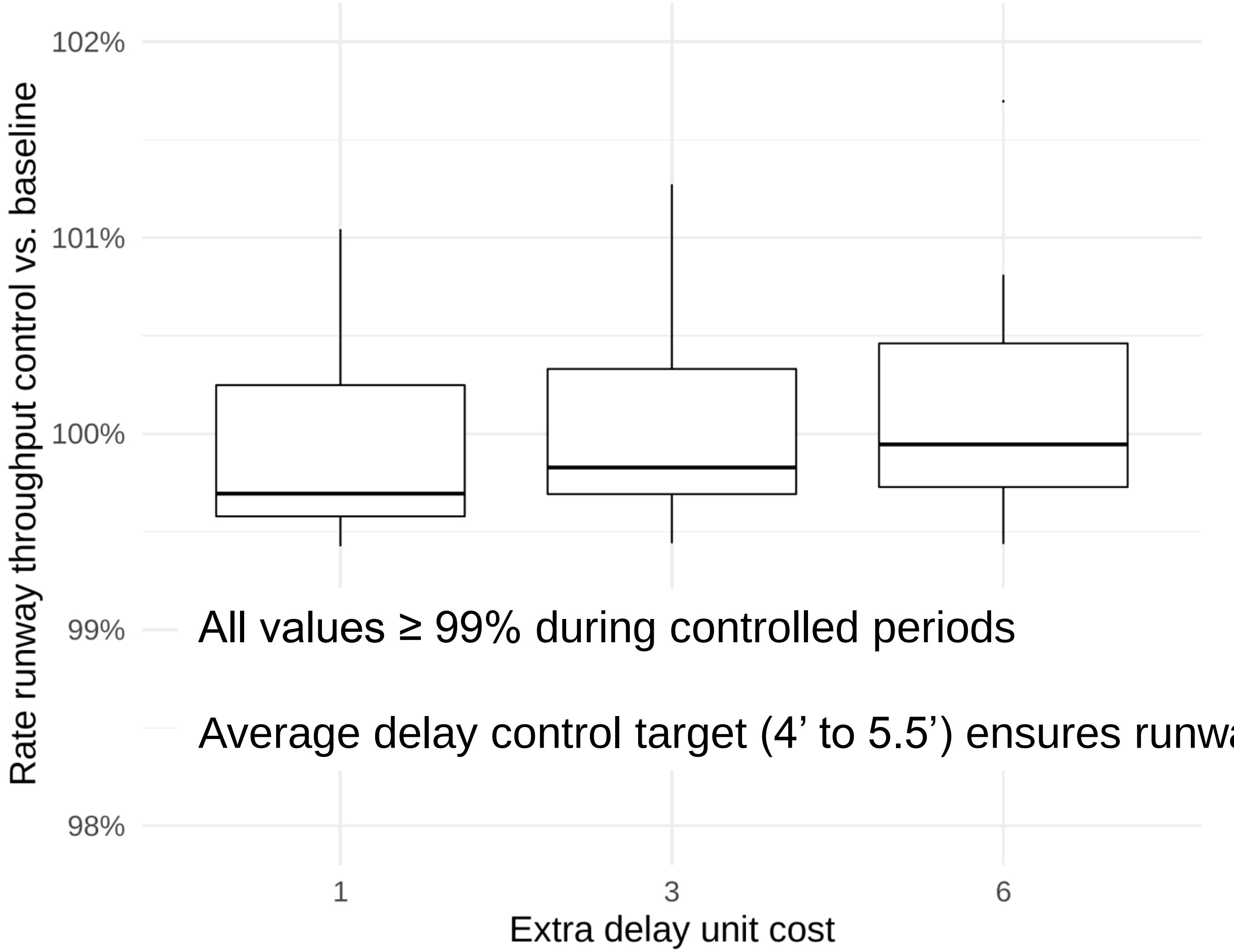


Average airborne delay and CO2 reduction per flight during 30' controlled periods: today vs. control

25kg fuel burn per minute of airborne delay ⇒
75kg CO2 per minute of airborne delay

Runway throughput

No significant impact



All values ≥ 99% during controlled periods

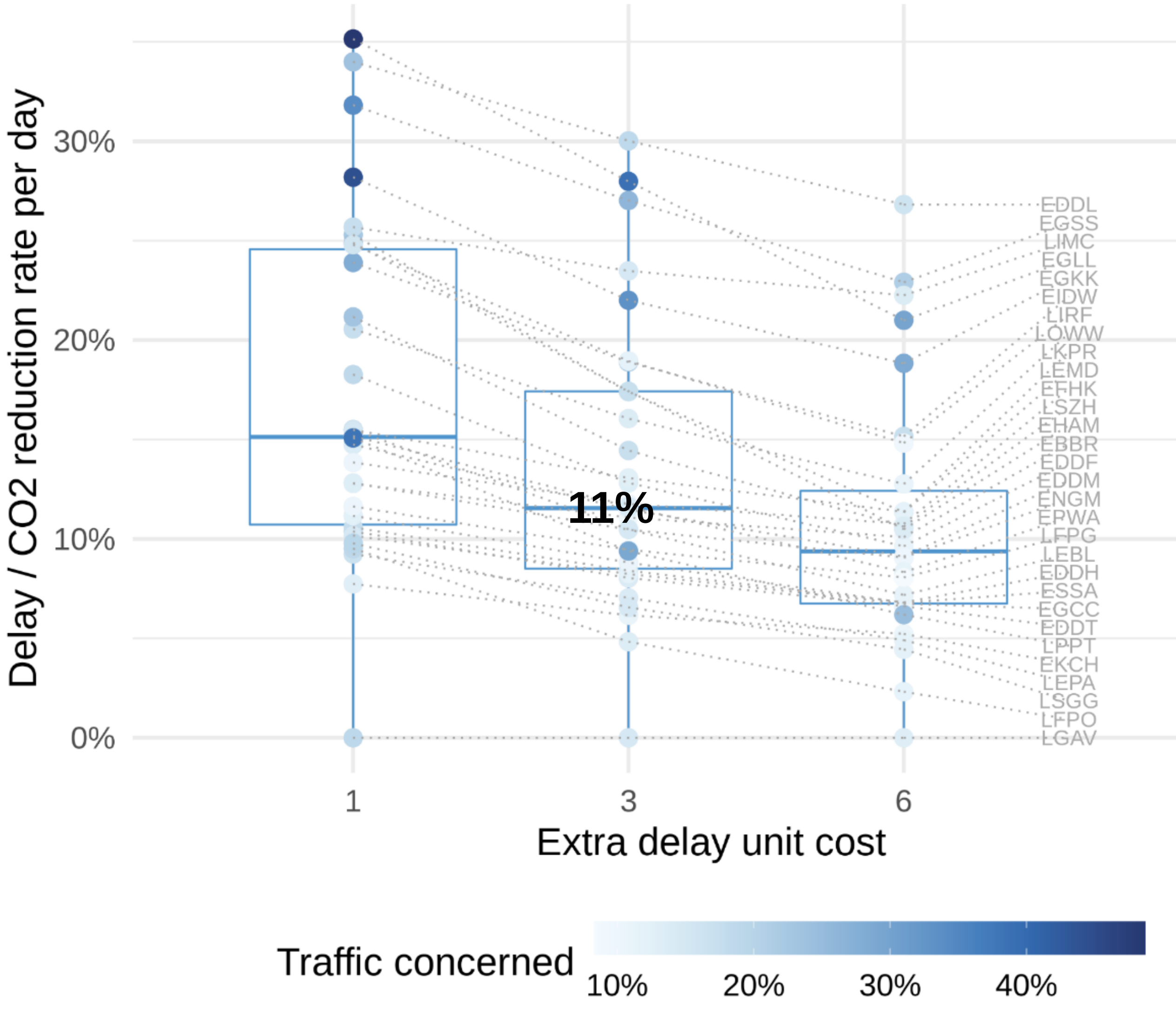
Average delay control target (4’ to 5.5’) ensures runway pressure

Airborne delay and CO2 reduction percentage per day

Compared to “Today” per destination

Median reduction vs. extra delay unit cost
10%, **11%** and 15%

Interquartile
10% to 25% reduction (1 extra delay unit cost cost)
7% to 12% for the higher (3 extra delay unit cost)

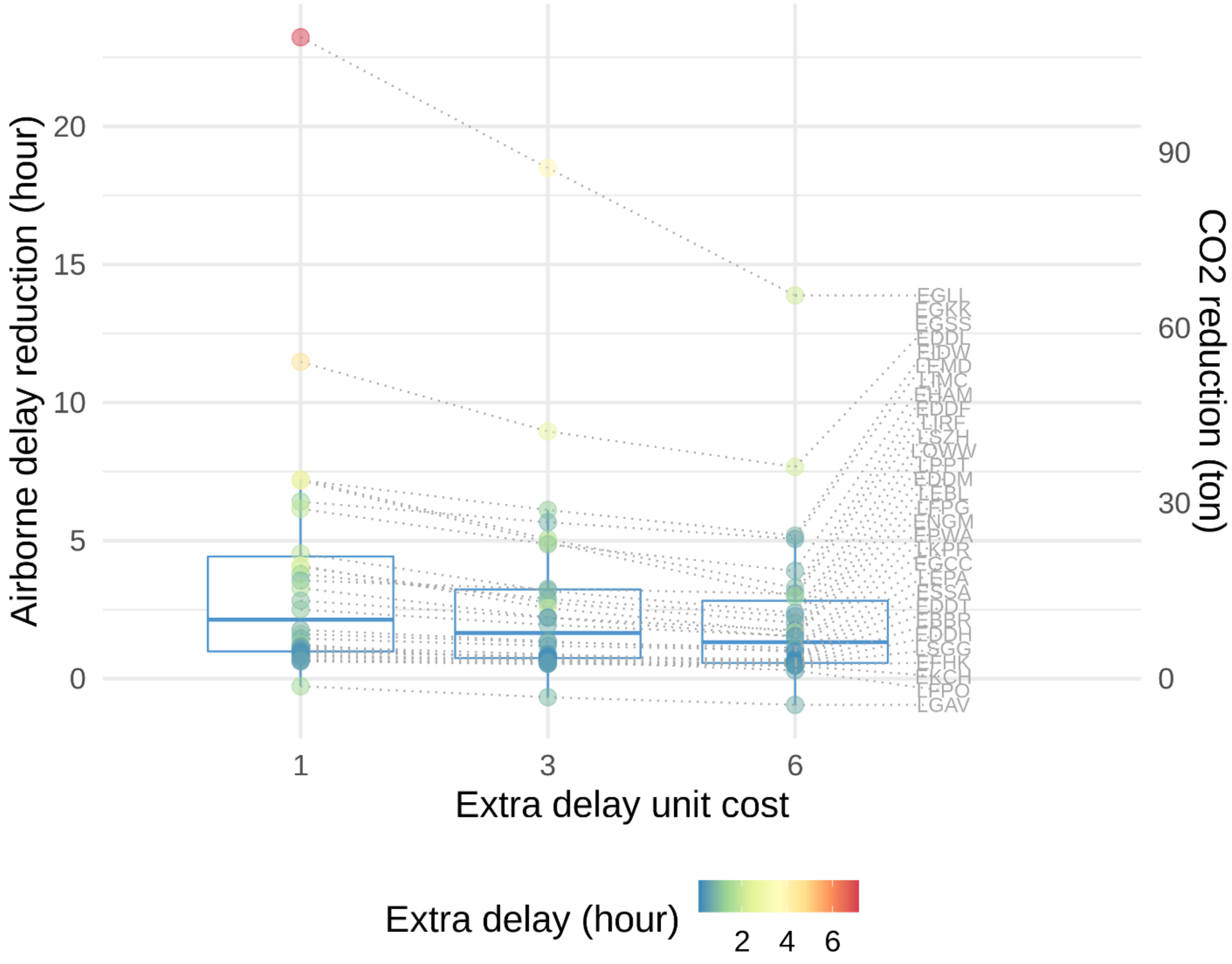


Average airborne delay and CO2 reduction per day

Medians

2 to 2.5 hours airborne delay daily reduction
(depending on extra cost)

9 to 11 tons CO2 reduction per day

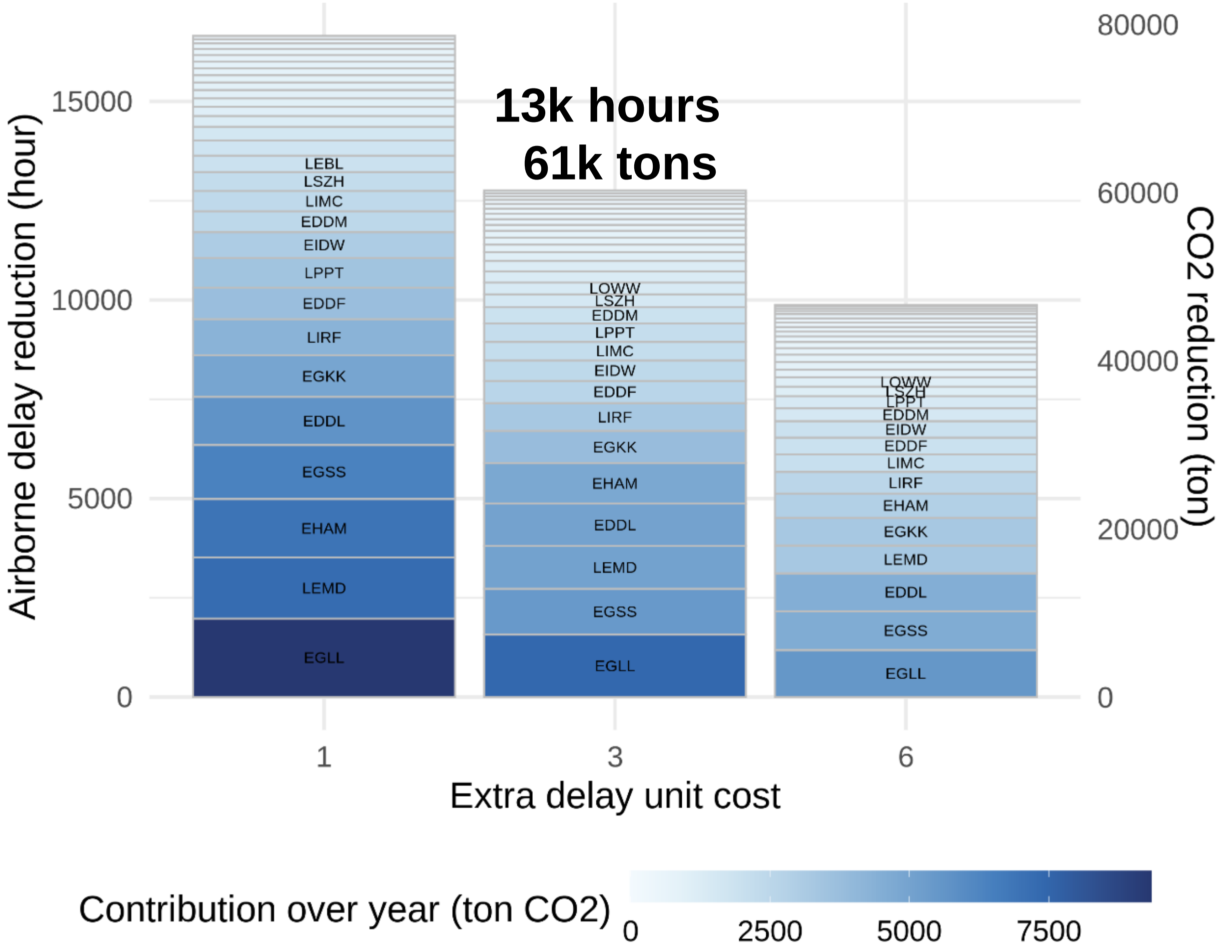


Cumulated reduction of airborne delays / CO2 emissions over all selected days

Fair weather days, stacked bars sorted by contribution

Destinations' contribution varies greatly

- 80% of reduction related to 14 destinations
- 50% of reduction related to 7 destinations



Conclusion

Medium cost scenario leads to

For delay-controlled periods

airborne delay : **-32%**

extra delay : **+9%**

Median airport airborne delays and CO2 reduction : **-11%**

Cumulated over all selected days : **13k** hours and **61k** tons reduction

No impact on runway throughput

50% of the gain with 7 airports, 80% with 14 airports

For more details

- Two scientific papers:
  - AIAA 2022 Aviation Forum

  https://www.researchgate.net/publication/361005587_Control_of_airborne_delays_by_adjusting_ground_delays_an_option_to_reduce_CO2_emissions

  - 2023 Eurocontrol/FAA ATM R&D Seminar

  https://www.researchgate.net/publication/371199346_Reducing_CO2_emissions_of_arrivals_by_acting_on_departure_times_-_A_perspective_for_30_European_airports

- Exploring the results
  - Dashboard visualisation
  - Dashboard access can be granted through a OneSky online account + direct request to EUROCONTROL team.

Perspectives

Model’s improvements

- impact on network, departure airports, airlines
- cost function improvement

Integration with existing approaches/measures ?

- strategic demand/capacity balancing
- tactical use of target-time of arrival

Increase maturity level, toward operations

- using current network management toolset
- getting accurate arrival delay estimates
- shadow mode, live trial

Work to be continued within SESAR 3 IR ISLAND project:

- EUROCONTROL further investigations (pan European perspective)
- NATS live trials (London Heathrow)

SUPPORTING EUROPEAN AVIATION

LUNCH

EUROCONTROL Dashboard demo

NATS Streaming Demo replay

Comms interviews

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SESAR JOINT UNDERTAKING

NATS

SORT
Safely Optimised Runway Throughput

VLD3 WP2 Pairwise Separation for Arrivals Overview and Results

Debbie Rushton – NATS Technical lead
Sarah Cavanagh – NATS Validation lead

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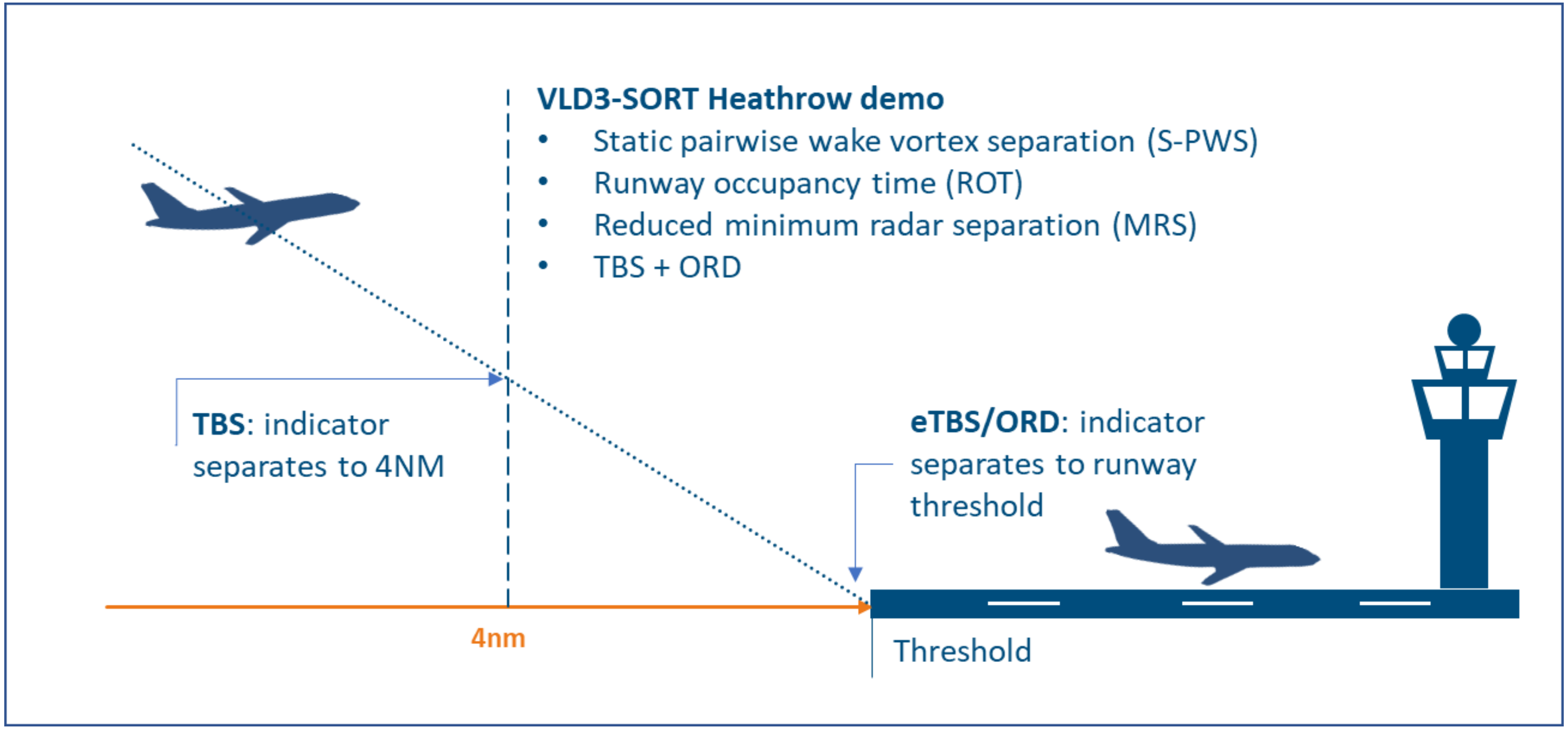
Pairwise separation for Arrivals - Heathrow



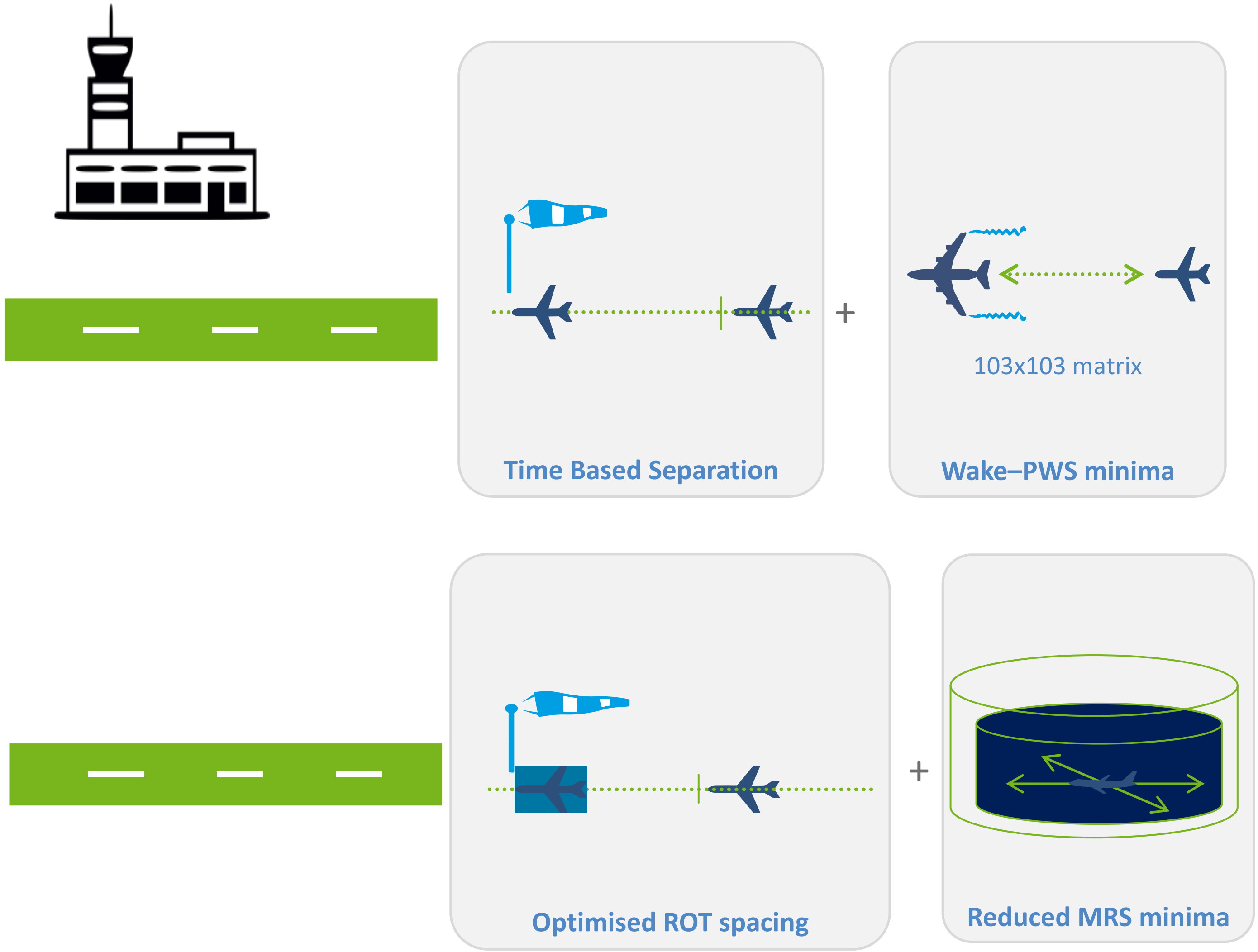
PJ.02-01-01 Optimised Runway Delivery (ORD) on Final Approach

PJ.02-03 Minimum-Pair separations based on Required Surveillance Performance (RSP)

PJ.02-01-04 Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics

PJ.02-08-03 Reduced separation based on local Runway Occupancy Time (ROT) characterisation

Demonstration for Heathrow Approach

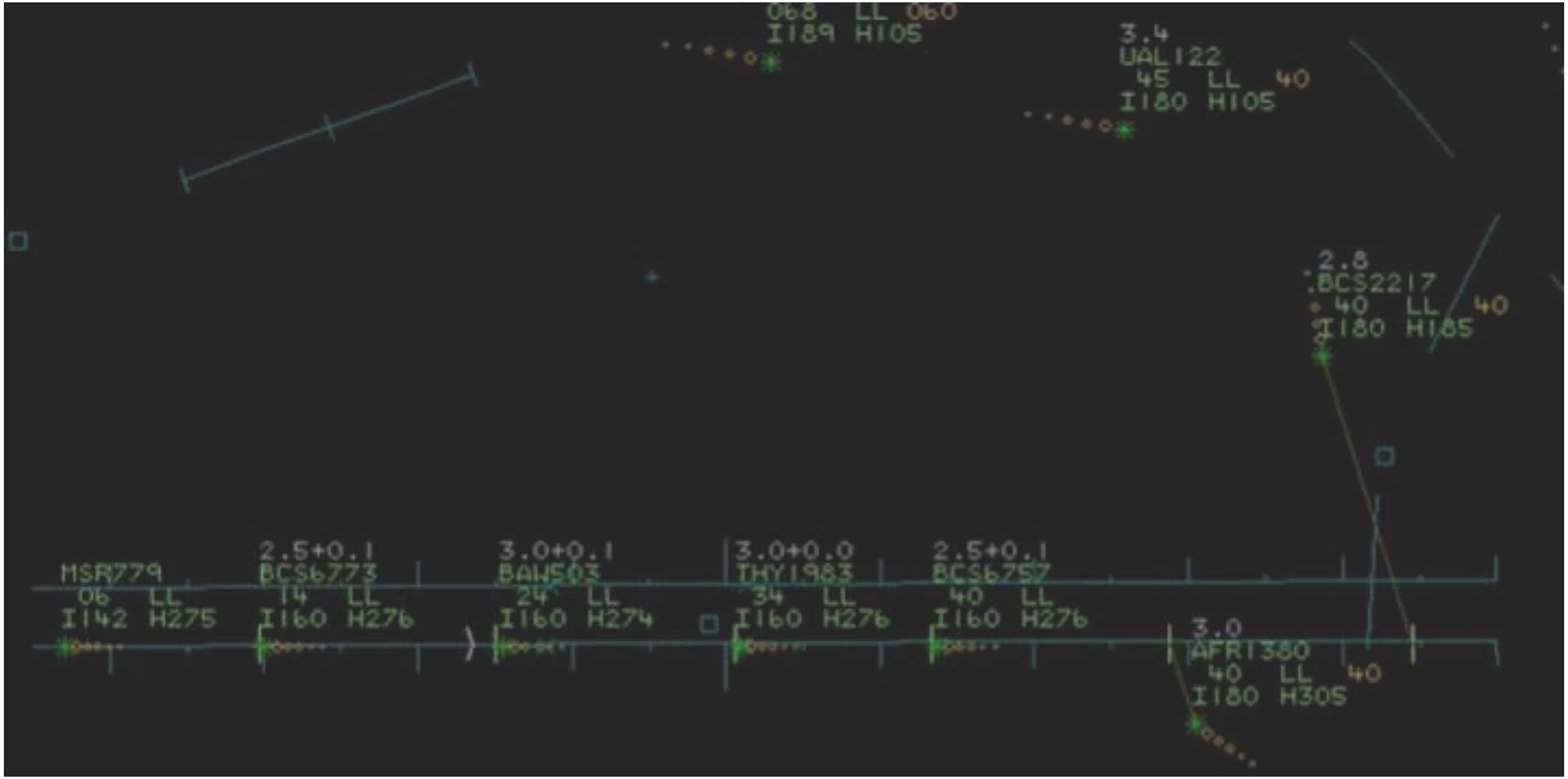


Further integrating RECAT-EU-PWS wake minima, reduced MRS and optimised ROT spacing

Supported by TBS-ORD

eTBS baseline

Intelligent Approach



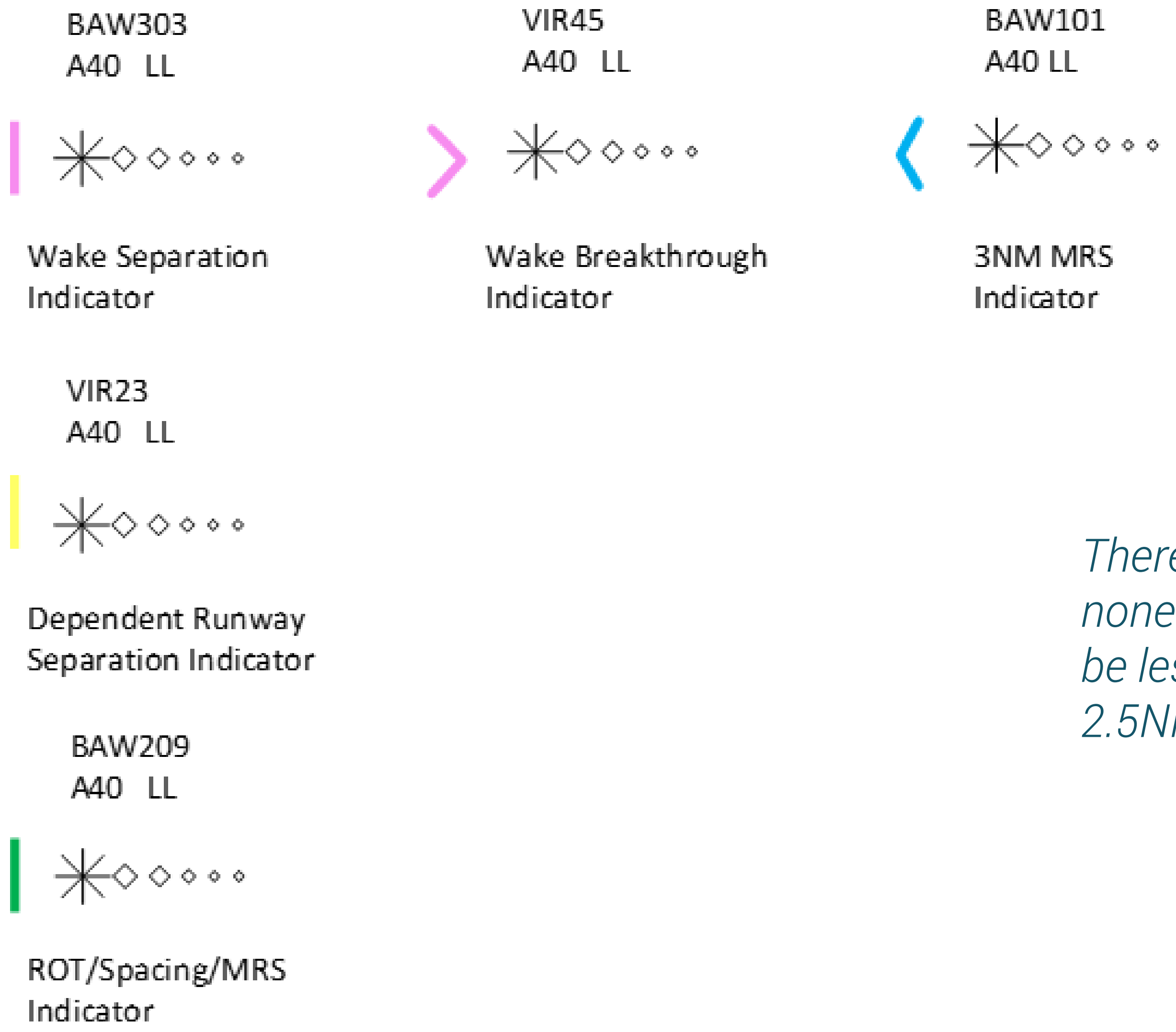
PWS Separation: In-trail

- Not less than 2.5NM minimum spacing to 4DME supported by a new 2NM Minimum Radar Separation (MRS) when both aircraft are established on final approach between threshold and 20DME in all VIS1 conditions without reliance on RSVA.
- The in-trail approach indicator including ORD is capped to be no lower than 2.5NM at 4DME.
- MRS will very rarely be the maximum threshold constraint. The majority of pairs will have a ROT or Wake constraint greater than 2NM at threshold. There will be very rare cases when MRS at threshold is the maximum constraint in strong headwinds. All Indicator types are capped to be no less than 2NM at threshold and therefore MRS is always protected.
- Earlier reduction to 2.5NM MRS applicable inside 20NM from threshold after the leader is established on a stable intercept heading (observed by the controller to be steady on the intercept track).

Separation & Spacing Standards

Constraint	Includes	Time or distance (normal operations)	Delivery Point
Wake	Wake Turbulence constraints	Time	Threshold
Dependent Runway	Dependent runway radar minimum constraints	Distance	Threshold
Minimum In-Trail (Non Wake)	Radar minimum constraints	Distance	Threshold
ROT	Runway Occupancy (ROT)	Time	Threshold
Spacing	Minimum spacing policy or an individual spacing between an aircraft pair.	Distance	Threshold

Indicator HMI Design



There is no separate MRS indicator as none of the displayed constraints will ever be less than MRS (2NM at threshold or 2.5NM before 4DME).

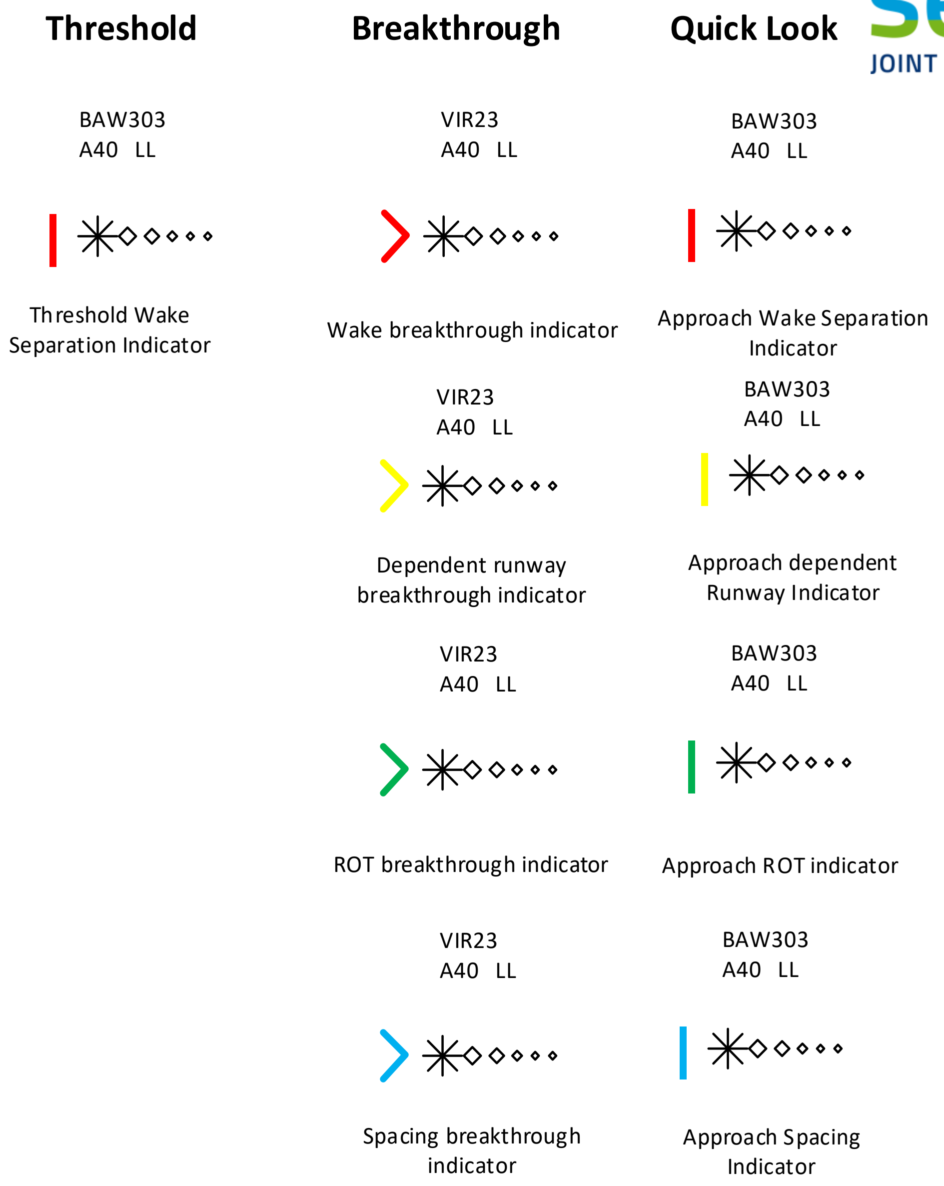
EXCDS Electronic Flight Strip Integration

The new interface between EXCDS and Intelligent Approach is required in order to:

- Introduce spacing management functionality (individual spacings & global spacing policy.) All spacing entered on EXCDS refers to the spacing required at Threshold.
- Use flight and runway data from EXCDS (including approach type, e.g. RNP and runway intent) as well as existing AMAN inputs.
- Allows the controller to directly input changes to the EXCDS strip to update IA.
- Access final approach sequence information from strip order in the FIN Live Bay to provide early notification (typically downwind rather than when aircraft turns on Baseleg as today) of required separation/spacing known as Early Line Zero (ELZ).

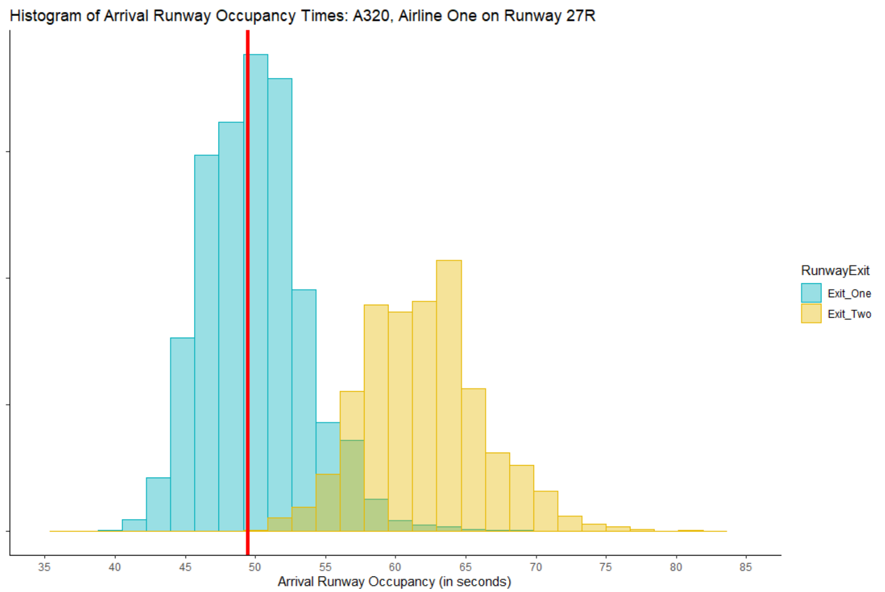
Tower Indicator HMI

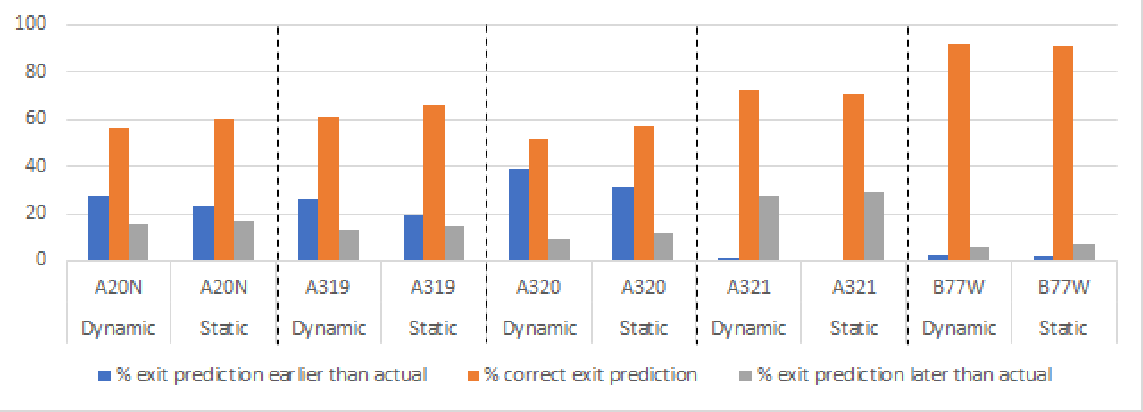
- The only Threshold indicator configured for display at Heathrow Tower is Wake.
- Indicators may also be displayed as ‘Breakthrough’ which indicates that the applicable approach constraint for the follower aircraft has been infringed.
- The breakthrough indicators configured for display at Heathrow Tower are Approach Wake, Approach Dependent runway, Approach ROT and Approach Spacing.

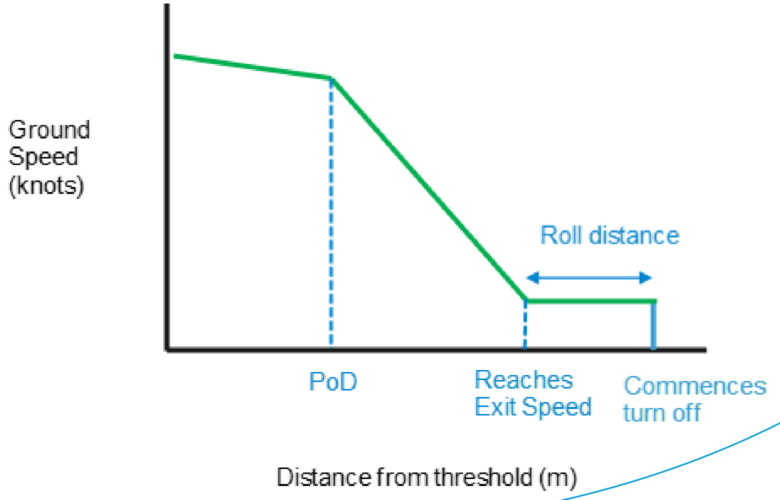


aROT Analysis

- Investigated possible modelling approaches and developed two
- Static and Dynamic approaches show similar levels of performance
    - Static: simple, at the same time scope limited for further improvement
    - Dynamic: potential for further refinement; more complex & requires careful calibration
- The aROT study led to the project using a Static approach for setting ROT spacing based on Runway and Wake plus Aircraft type and Airline information where appropriate







Project Definition Timeline – Concept Development

Q2 2021 **Q3 2021** **Q4 2021** **Q1 2022**

User Group Programme

Development Simulation #1

Baseline concept for the indicator support for all constraint types on final approach (Wake, ROT, Spacing, Dependent runway)

Development Simulation # 2

Entering individual spacings and global spacing policies into ExCDS, including different HMI options

Reliability of the IA sequencing tool and the display of Early line Zero

Indicator support for all constraint types following updates from Sim # 1

Development Simulation # 3

Further spacing scenarios

Refinements to ELZ functionality

Dependent RNP Approaches

Tower indicator display and HMI

Development Simulation # 4

Indicator support outside 20DME

Closed Runway Exit Spacing functionality

Updates to dependent indicators following sim #3

Refinements to ELZ functionality

ATC Procedures

Development Simulation # 5

Final review of simplified ELZ algorithm.

Assessment of the display of a blue chevron For indicators less than 3NM, if either the leader or the follower is more than 20NM from threshold.

Implementation Validation Simulation Timeline

Q1 2023 | Q2 2023 | Q3 2023 | Q4 2023

VLD3/Pairwise Demo Sim

To gather feedback from the User and gain confidence in the design of concept, functionality and procedures using the pre-FAT build of the operational software

To demonstrate the feasibility and benefits of implementing Pairwise, reduced MRS and improved ROT management at for Heathrow Approach

Validation Sim

To gather feedback on final IA software build post FAT/SAT

To assess acceptability of concept, functionality and procedures from the ATC users

To gather assurance evidence in terms of Human Factors and Safety data

VLD 3- Reference VS Solution Scenarios

Reference

- Current eTBS tool with RECAT-EU Wake Separation scheme
- Indicators for wake pairs only and for ROT pairs behind Upper, Heavy and Super aircraft where ROT is the largest constraint relative to the wake separation
- 3NM minimum spacing on final approach

Solution

- RECAT-EU-Pairwise Wake Separation Scheme
- Indicator support for all separation/spacing constraints
- Early indication of required separation/spacing in the form of Early Line Zero (ELZ)
- 2NM MRS on Final Approach
- Earlier reduction to 2.5NM on intermediate approach

Traffic Samples and Wind

- Traffic samples represented the change in aircraft fleet make up since the Covid 19 Pandemic and based on a future 2027 schedule at Heathrow Airport.
- Several traffic samples were created based on certain times of day, representing different mixes of wake categories:
  - 0600 - Early Morning Team – High proportion of Heavies
  - 1000 - Mix of Heavy and Medium aircraft
  - 2100 - High proportion of Mediums
  - 2200 - Light traffic levels to test Bandboxing and splitting
- A range of wind profiles were derived from Heathrow GWCS data and extrapolated above 3,000ft

RWY Direction	Wind Description
27	• Light Westerly • Strong Westerly • Northerly Crosswind at Altitude
09	• Light Easterly • Moderate North Easterly • Tailwind at altitude • Strong Easterly

Matched Runs and Experimental Design

- A fully matched comparative assessment approach was planned to be conducted, where conditions were kept constant, with the dependent variable being the tool in use - eTBS with RECAT-EU or Pairwise.

- ATCO rostering changes prior to the simulation prevented a fully matched assessment, introducing a degree of uncontrolled variability.

- 6 Matched Pairs conducted. Due to the small sample size, these should be treated as indicative results only.

- Other simulation days used to test the Pairwise tool under a wide range of operational scenarios.

Matched Runs

Date	Activity	Run #	Tool	Runway	Traffic Mix and Wind	Match ID
10/02/2023	Reference 1	1	eTBS	27	High Mediums, Light North-Westerly	1
		2		27	Mix Heavy/Medium, Light North-Westerly	2
		3		9	High Mediums, Light Easterly	3
		4		9	Mix Heavy/Medium, Light Easterly	4
11/02/2023	Reference 2	1	eTBS	27	High Mediums, Light North-Westerly	N/A
		2		9	High Mediums, Light Easterly	N/A
		3		9 (EMT)	High Heavies, Light Easterly	N/A
		4		27 (EMT)	High Heavies, Light Easterly	N/A
23/03/2023	PWS 1 (scenarios)	1	PWS	27	Mix Heavy/Medium, Strong Headwind	N/A
		2		09	High Mediums, Tailwind	N/A
		3		27 (EMT)	High Heavies, Strong Headwind	N/A
		4		27	High Mediums, Strong North-Easterly	N/A
24/03/2023	PWS 2 (scenarios)	1	PWS	27	High Mediums, Light North-Westerly	N/A
		2		9	Mix Heavy/Medium, Strong Easterly	N/A
		3		27	Mix Heavy/Medium, Strong Headwind	N/A
		4		9 (EMT)	High Heavies, Light Easterly	N/A
27/03/2023	PWS 3 (matched)	1	PWS	27	High Mediums, Light North-Westerly	1
		2		27	Mix Heavy/Medium, Light North-Westerly	2
		3		9	High Mediums, Light Easterly	3
		4		9	Mix Heavy/Medium, Moderate Headwind	5
28/03/2023	PWS 4 (matched) + Reference	1	PWS	27	High Mediums, Strong Headwind	6
		2	PWS	9	Mix Heavy/Medium, Light Easterly	4
		3	eTBS	27	High Mediums, Strong Headwind	6
		4	eTBS	9	Mix Heavy/Medium, Moderate Headwind	5

High Level Findings

OPERATIONAL FEASIBILITY:

- Pairwise considered to be acceptable under all runway configurations and wind conditions
- Indicator support for all constraints considered acceptable
- ELZ is useful and beneficial to the operation as information supports the controller in early decisions making and improves predictability.
- ExCDS Spacing functionality considered acceptable overall with some suggestions to improve HMI
- Reduction in MRS on final approach from 2.5NM to 2NM, and an earlier reduction from 3NM to 2.5NM in the RMA assessed as acceptable
- ATC Procedures considered acceptable

CAPACITY:

- Increase in arrival throughput in strong wind conditions
- Marginal benefits in moderate and light wind
- However, this depends on runway direction, traffic mix and results caveated with controllers' variation in delivery to indicator
- Feedback from controllers indicated Pairwise will bring about increased consistency in delivery with an indicator for all aircraft pairs

ENVIRONMENTAL:

- Fuel burn analysis indicates an average saving of 14.84kg per flight.
- This equates to an average CO_2 saving of 46.73kg per flight.

High Level Findings

SAFETY:

- Separation analysis indicated no losses of MRS during the PWS runs.
- Procedures considered ‘fail safe’ when transitioning from intermediate separation to final approach to avoid loss of separation
- Potential to reduce any safety incidents because the indicators and ELZ for all aircraft pairs allow the controller to acquire suitability of base-leg turn more quickly .

HUMAN FACTORS:

- The concept is feasible from a HF perspective, but requires further refinements being made to some components of the ATM system
- Controllers found the system and HMI intuitive and understood system behaviours.
- Full assessment on HP measures unable to be conducted due to some system limitations

JOINT UNDERTAKING

Safely Optimised Runway Throughput

VLD3 WP2 Pairwise Separation for Arrivals
Pairwise sim replay

Shona Chalmers – NATS ATC Expert
Norm Easter – NATS ATC Expert

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Next Steps

Ade Clark – NATS QM Benefits Delivery Manager
Bruno Favennec – EUROCONTROL 08B5 Technical Lead

Questions

JOINT UNDERTAKING

THANK YOU FOR YOUR ATTENTION

For further information visit:

- SESAR Joint Undertaking | Enhanced arrivals and departures (Wave 2) (sesarju.eu)
- SESAR Joint Undertaking | PJ37-W3 ITARO - INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS (sesarju.eu)
- SESAR Joint Undertaking | Improving runway throughput in one airport - SORT (Wave 2) (sesarju.eu)

or contact sian.andrews@nats.co.uk

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No 874520

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