



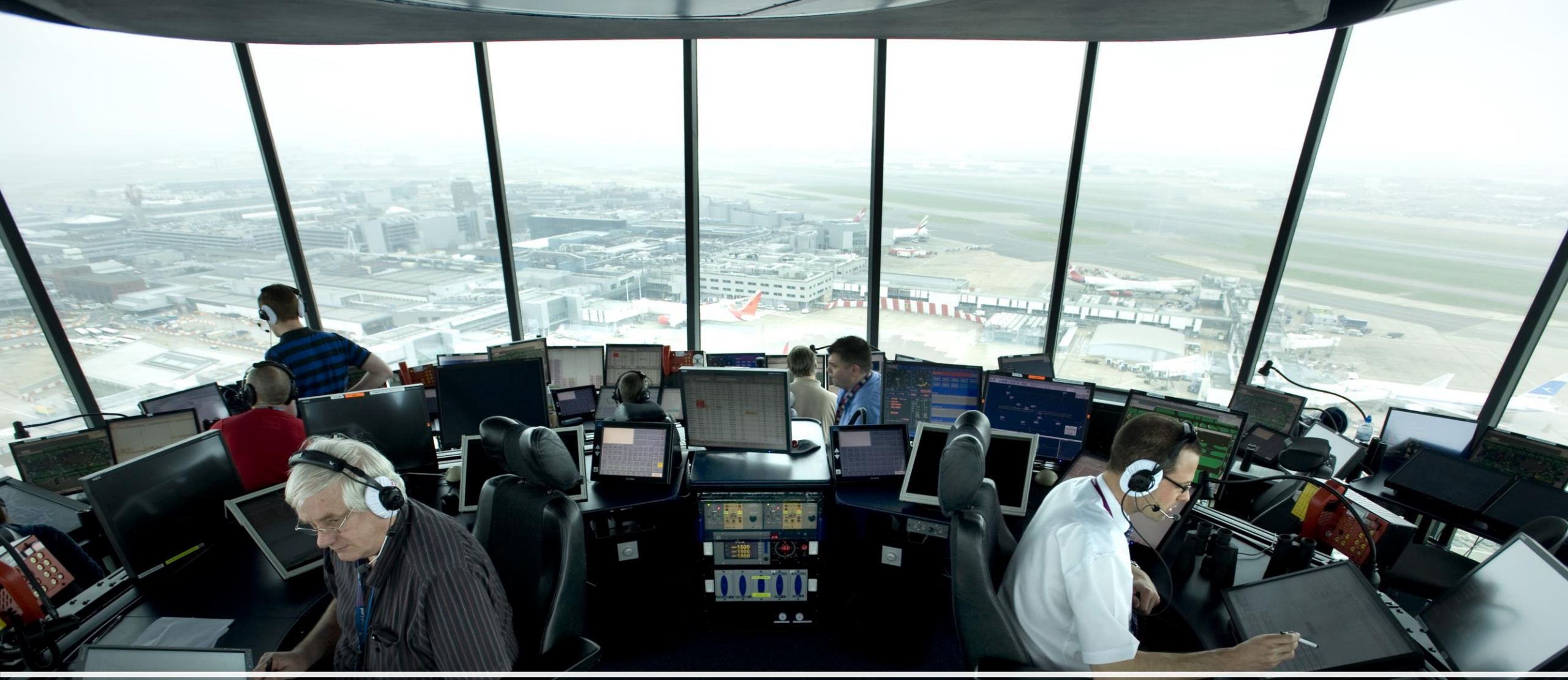
# Optimization in Aviation

Tekna Big Data webinar, 20th October 2021

Revenue management to the rescue

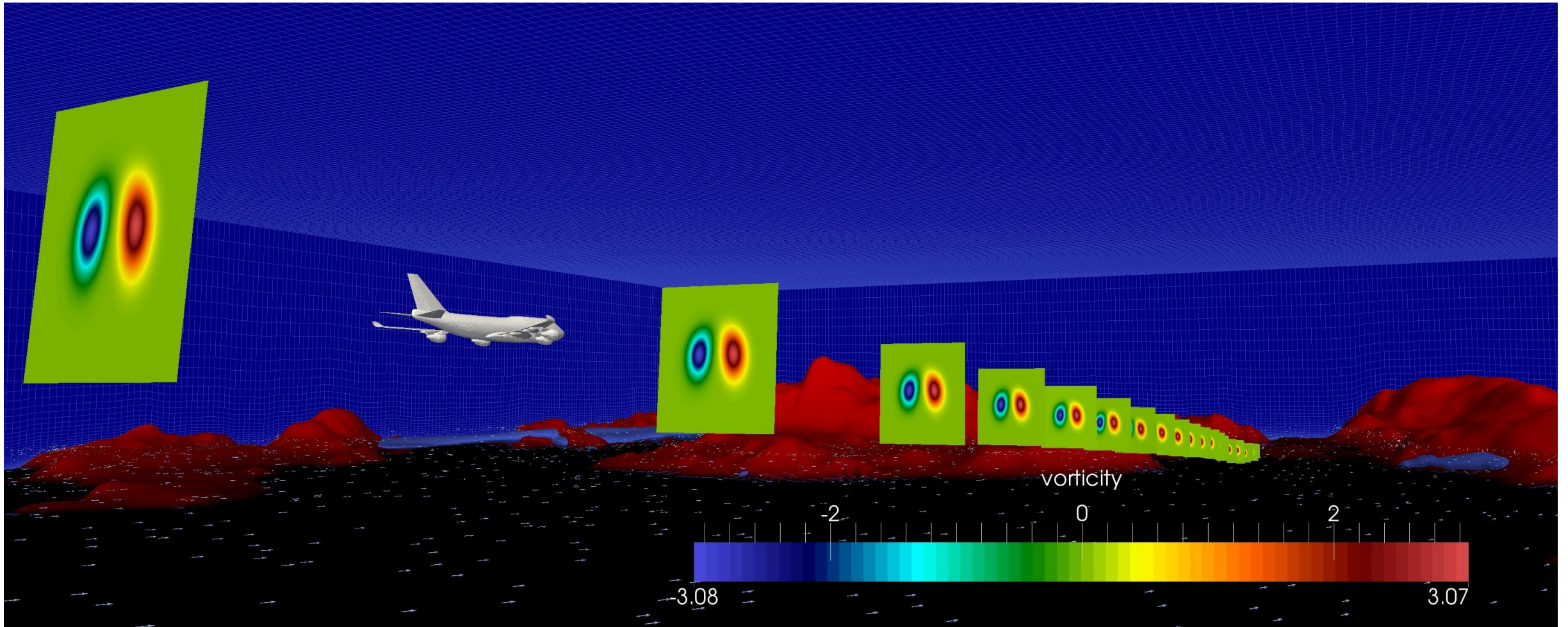
American Airlines





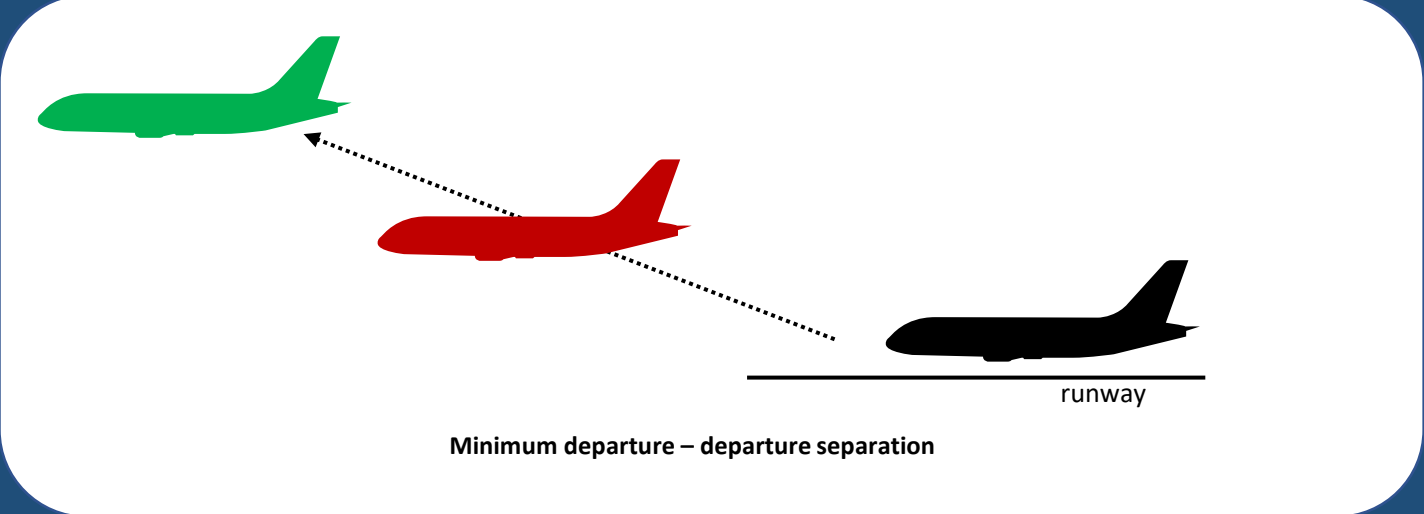
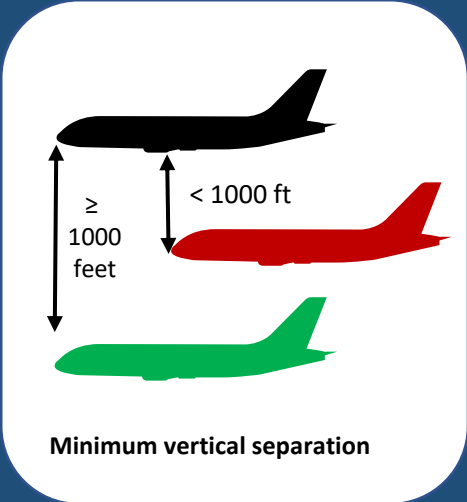
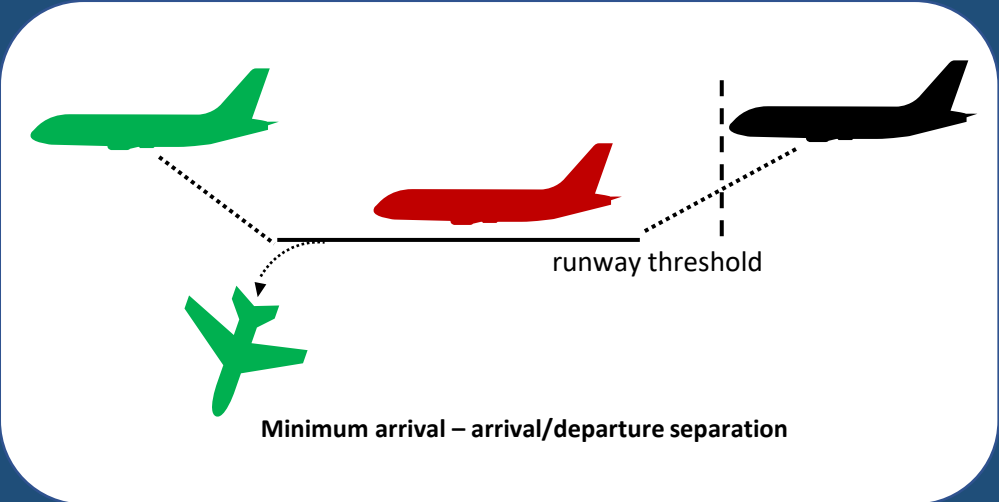
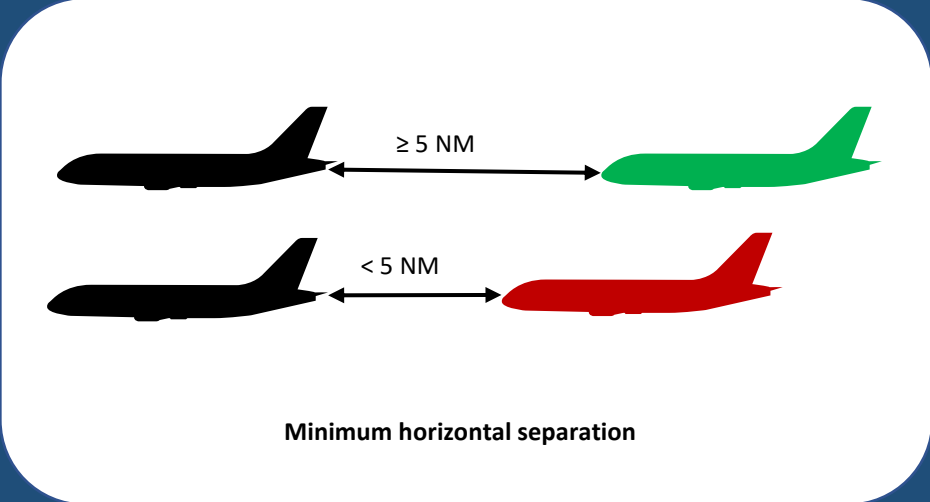
NATS, tower control at Heathrow, London

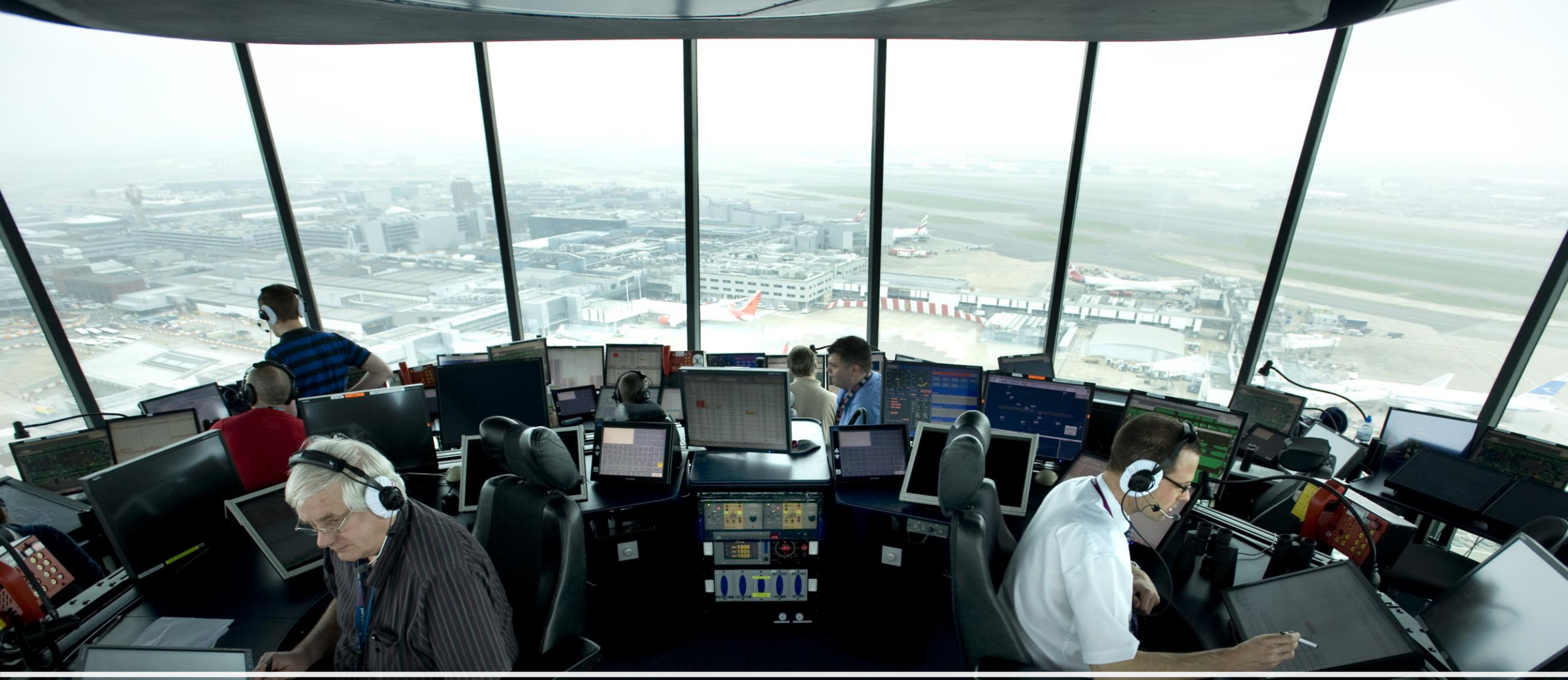
# Safe operations



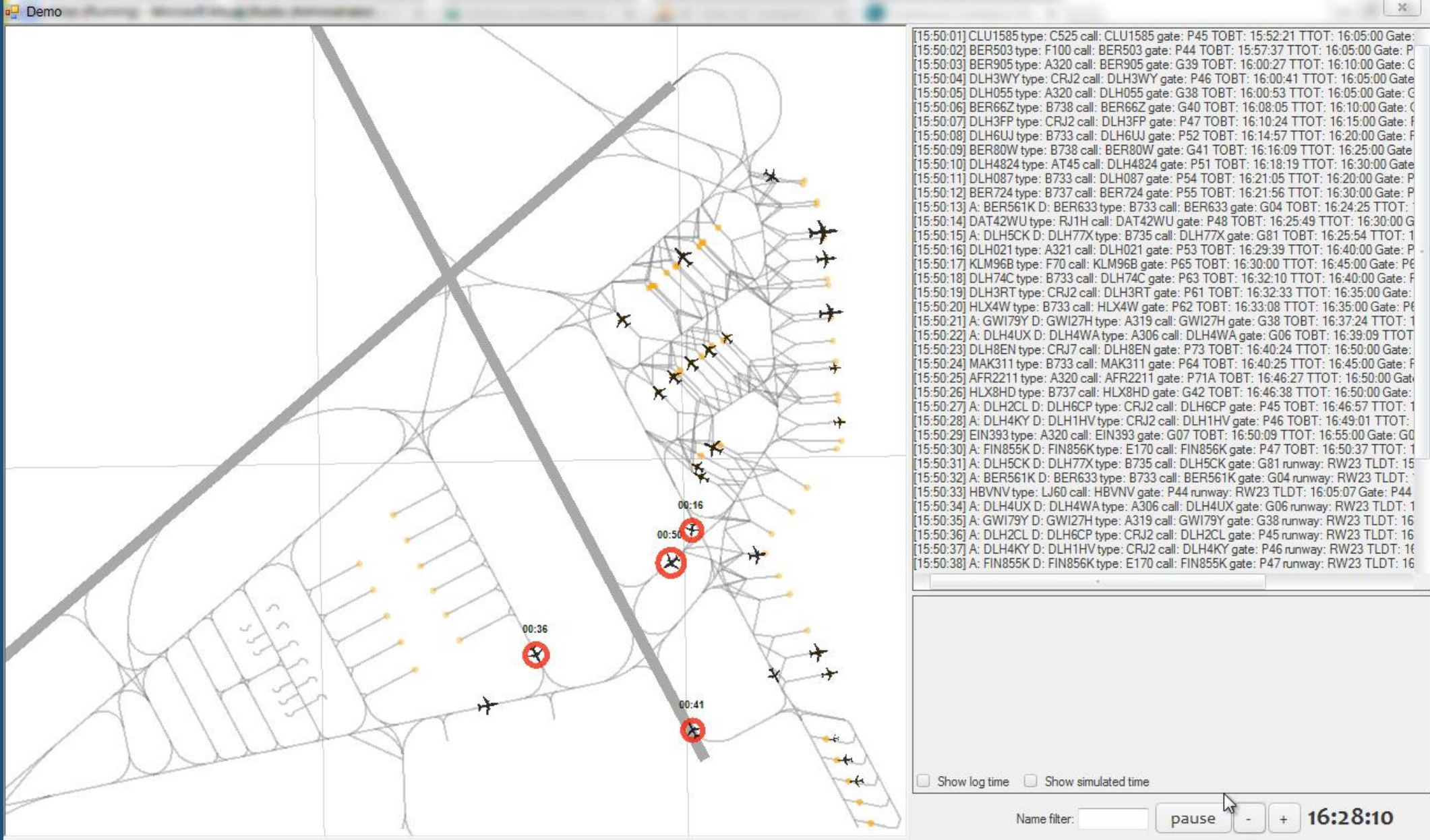
**Source:** Wake modeling in complex terrain using a hybrid Eulerian-Lagrangian Split Solver , Franz G. Fuchs et al 2016 J. Phys.: Conf. Ser. 753 082031, [online version](#)

# Safe operations

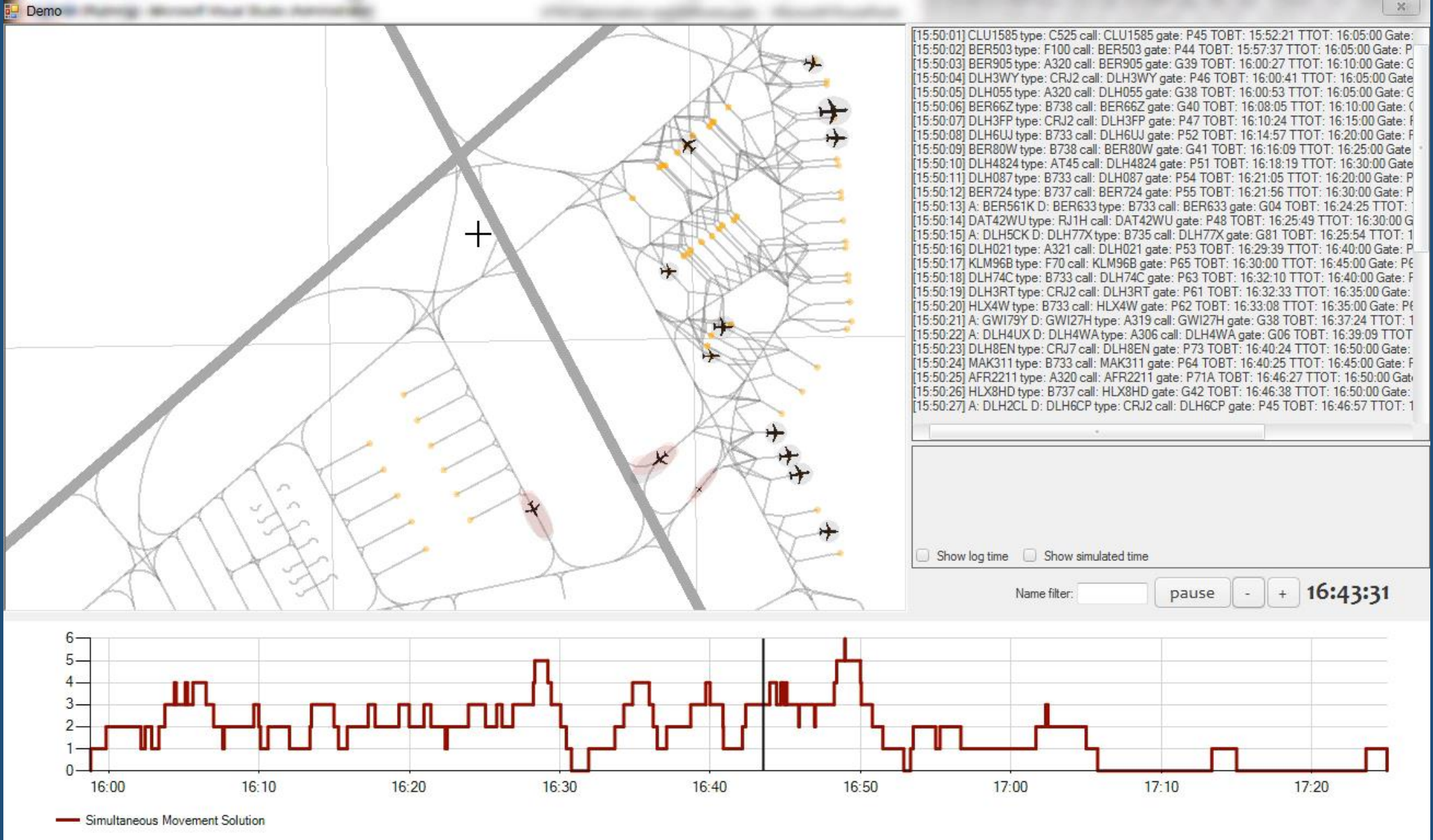




NATS, tower control at Heathrow, London



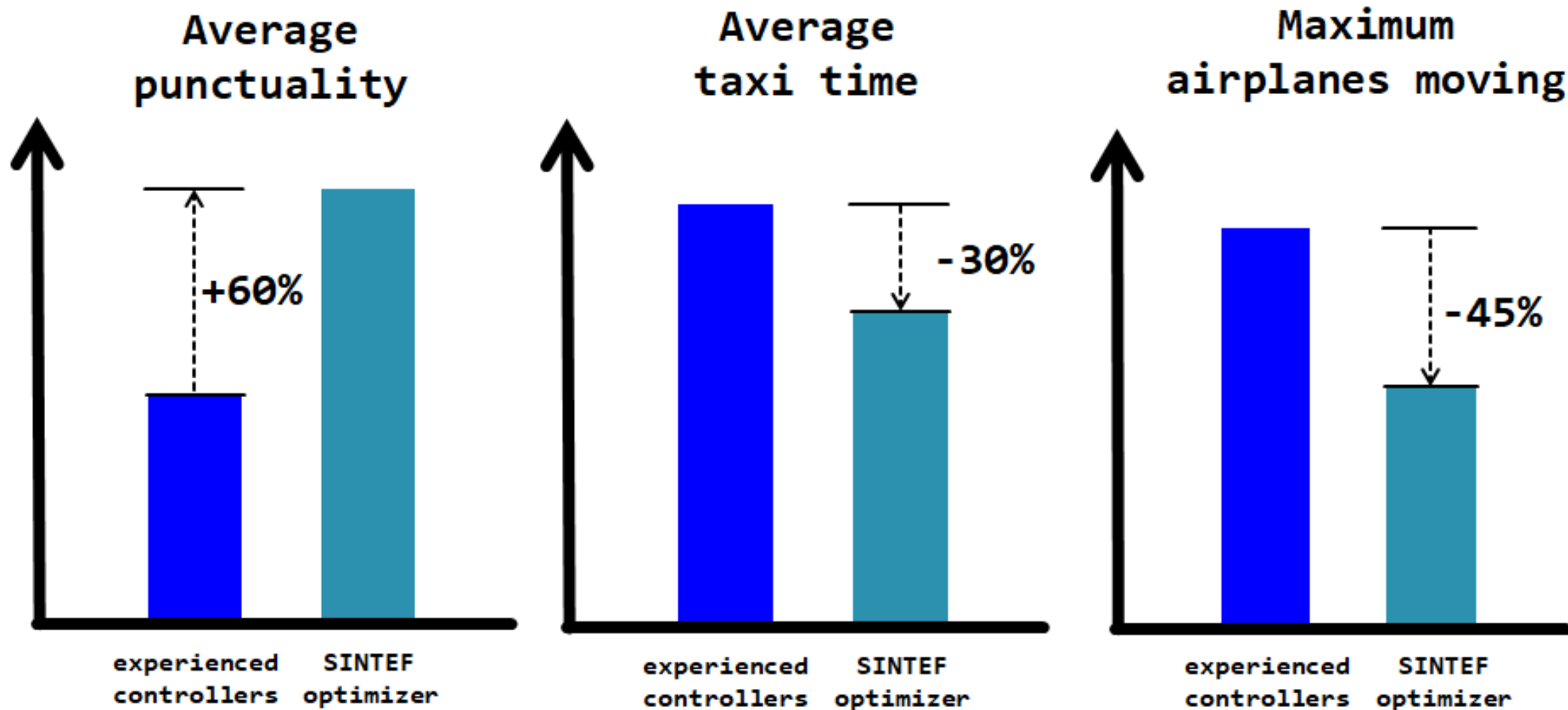
real-time simulation performed by air traffic controllers



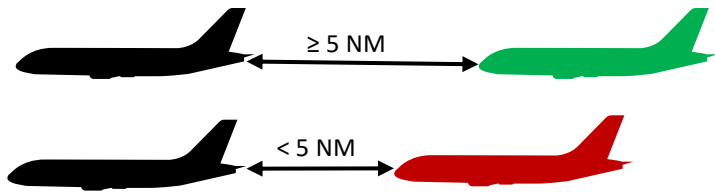
post-run simulation performed by math. optimization algorithm



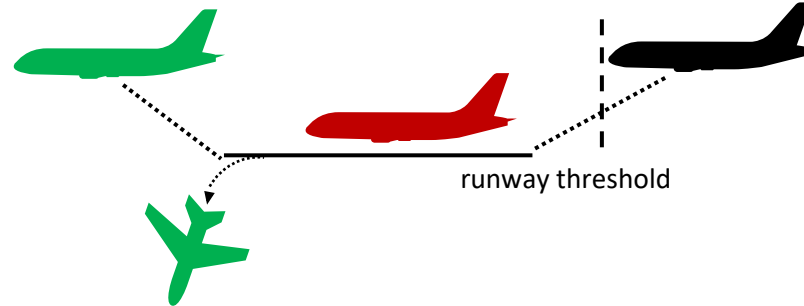
# What are the benefits?



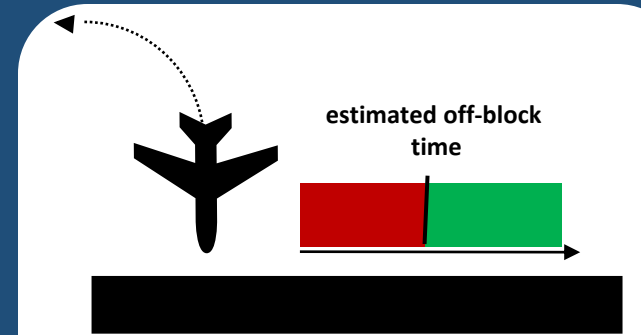
# Separation and time constraints



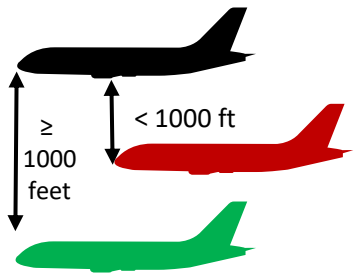
Minimum horizontal separation



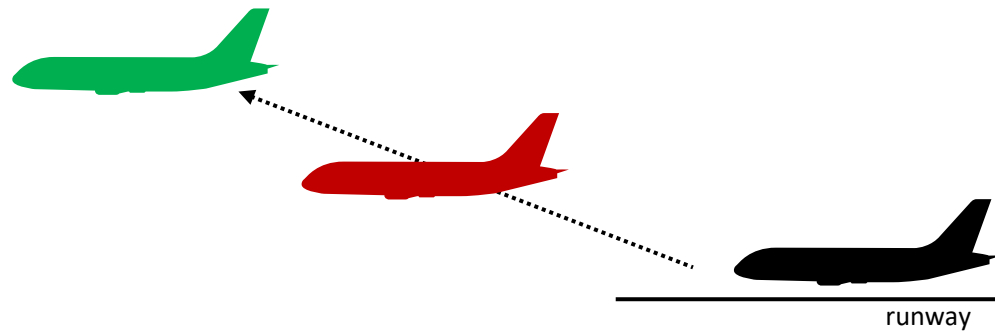
Minimum arrival - arrival/departure separation



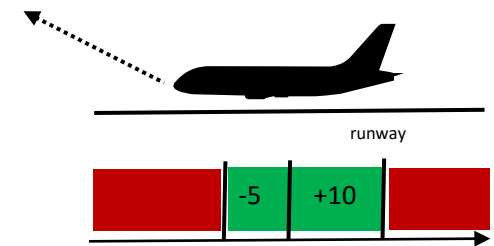
off-block time



Minimum vertical separation

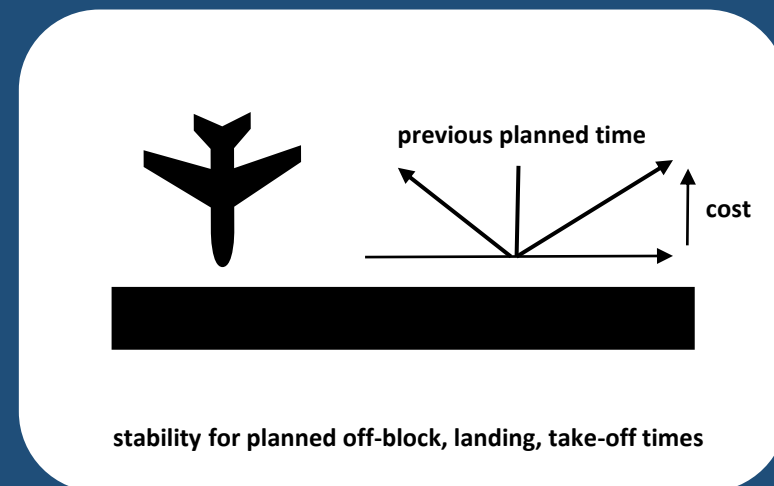
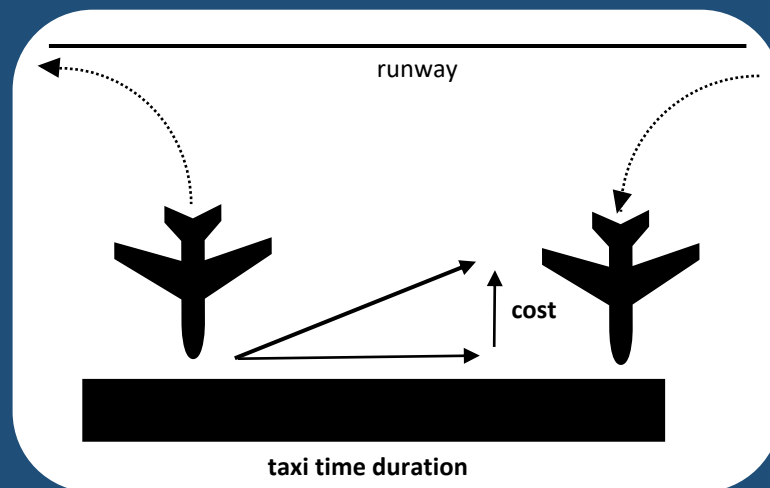
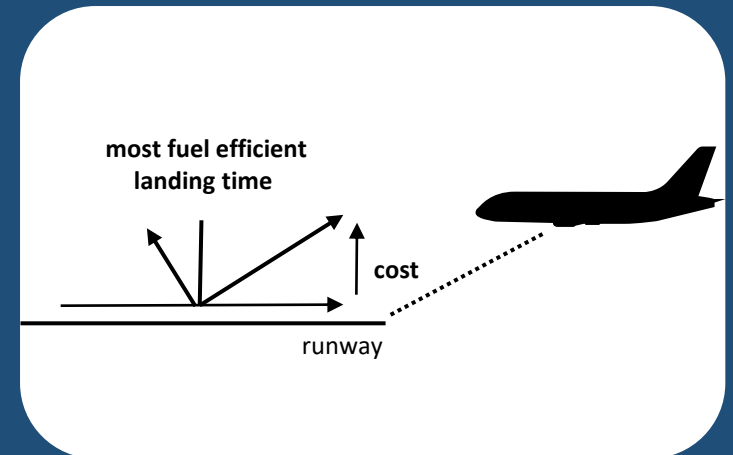
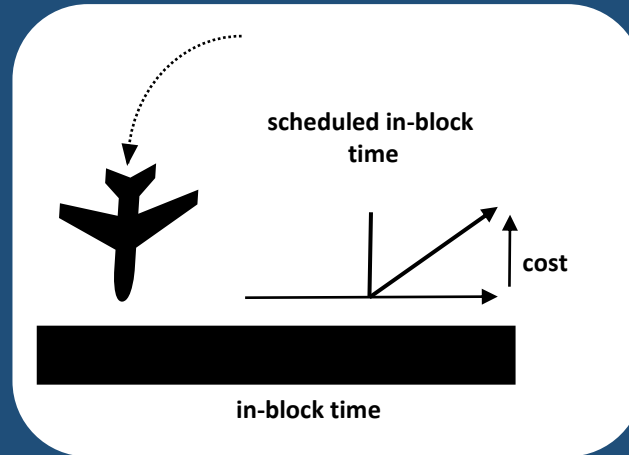
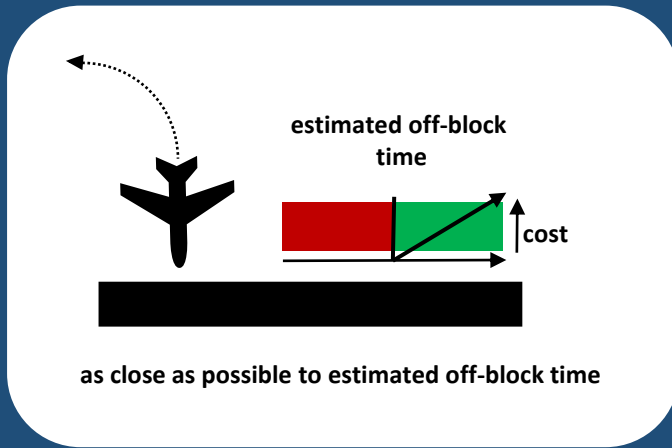


Minimum departure - departure separation



Calculated take-off time

# Objectives



Then the constraints can be written as follows:

- Each departure flight must be assigned a departure time or is dropped.

$$\sum_{t \in H_f} x_{ft} + y_f = 1 \quad \forall f \in D. \quad (1)$$

- A departure  $f$  cannot leave the gate before its off-block time  $\omega_f$ , so it cannot take-off before  $TX_f + \omega_f$ :

$$x_{ft} = 0 \quad f \in D, t \in H_f, t < TX_f + \omega_f \quad (2)$$

- The tardiness is defined by

$$d_f \geq (t - \delta_f)x_{ft} \quad \forall f \in D, t \in H_f. \quad (3)$$

- Similarly, earliness is defined by

$$e_f \geq (\delta_f - t)x_{ft} \quad \forall f \in D, t \in H_f. \quad (4)$$

- Constraints on the separation between departure flights become

$$x_{it} + \sum_{k \in [t, t + \tau_{ij}]} x_{jk} \leq 1 \quad \forall (i, j) \in D \times D, t \in T. \quad (5)$$

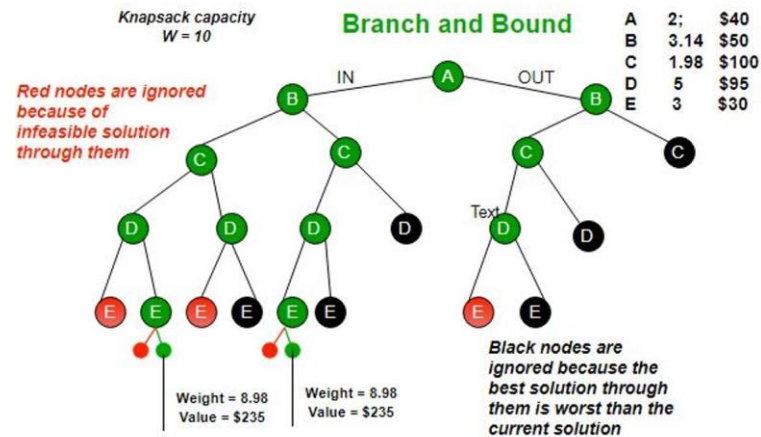
- Since arrival times are fixed, the separation between an arrival flight  $i$  and a departure flight  $j$  can be expressed as:

$$x_{jt} = 0 \quad \forall i \in L, j \in D, t \in [\lambda_i - \tau_{ij}, \lambda_i + \tau_{ji}]. \quad (6)$$

- Finally, the objective is to minimize the number of dropped flights. Ties are broken by minimizing the total deviation from the wanted departure times.

$$\sum_{f \in F} c_f y_f + \sum_{f \in D} (d_f + e_f) \quad (7)$$

where for all  $f \in D$ , we let  $c_f$  the cost of dropping flight  $f$ .



Source: <https://www.geeksforgeeks.org/branch-and-bound-algorithm/>

Exploiting proven mathematical properties makes your search much more efficient!

# Integrated runway sequencing





# Today's definition

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*"Determining the best possible timing (and sequence) of landings and take-offs on one or multiple runways in mixed-mode operations. Mixed-mode operations allow for landing and take-offs on the same runway."*

# Why integrated runway sequencing?

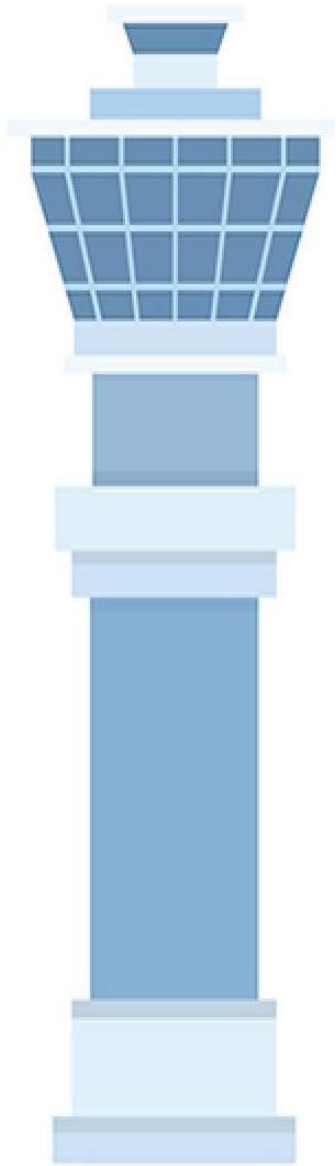
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Single runway airports

More efficient use of existing infrastructure

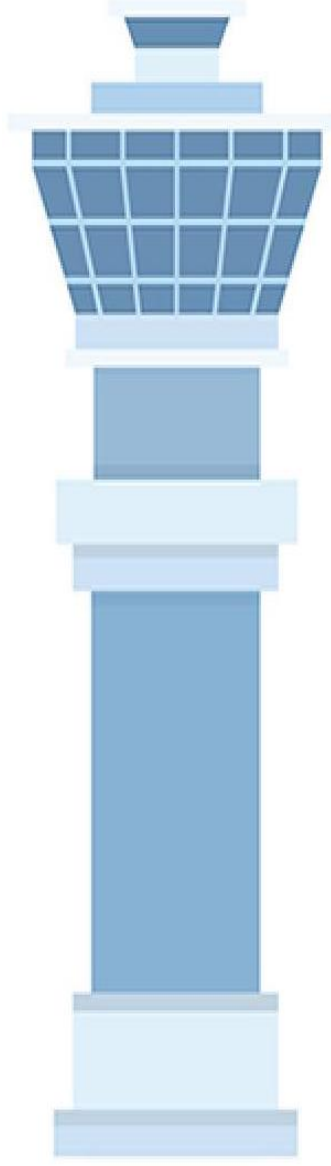
Postpone addition of new runway

**Approach**



**arrivals**

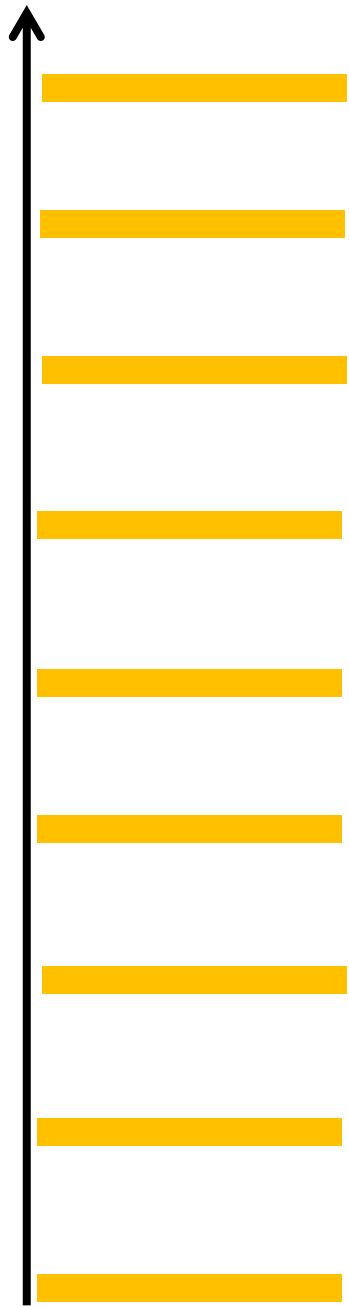
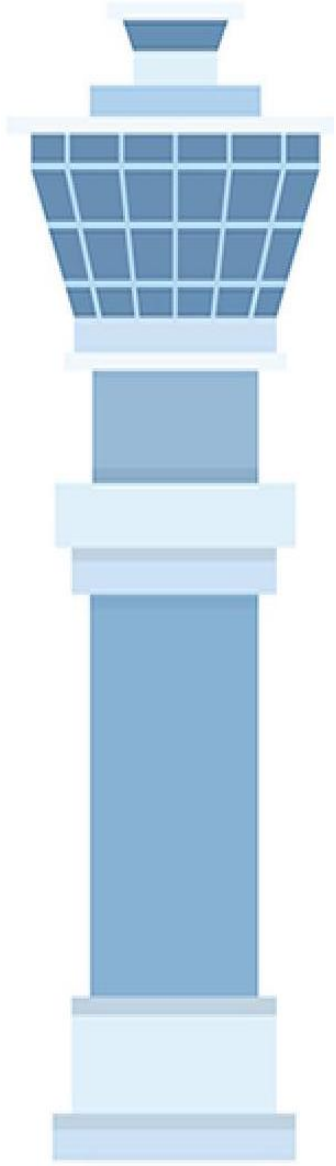
**Tower**



**departures**



**Approach**

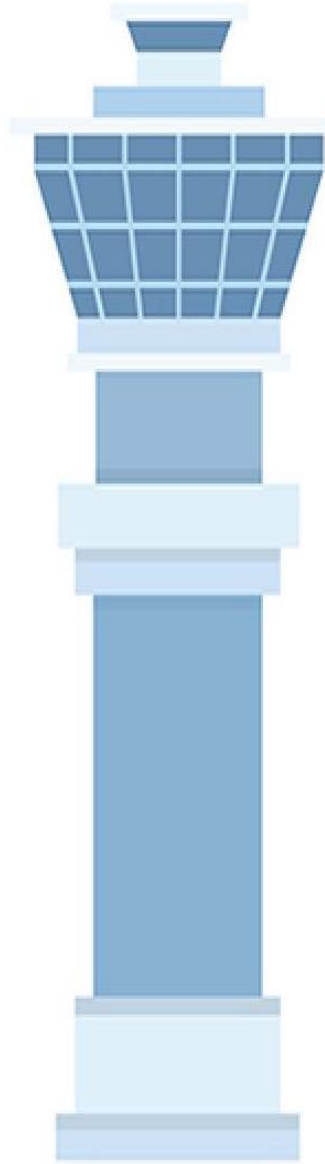


**arrivals**

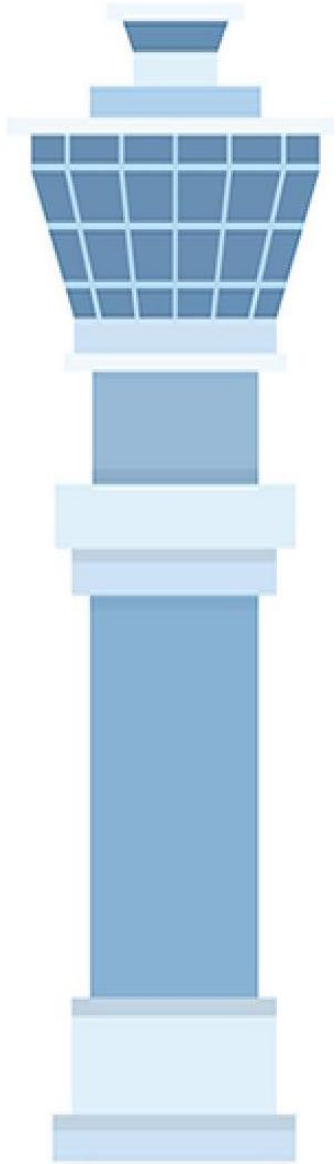


**departures**

**Tower**



Approach

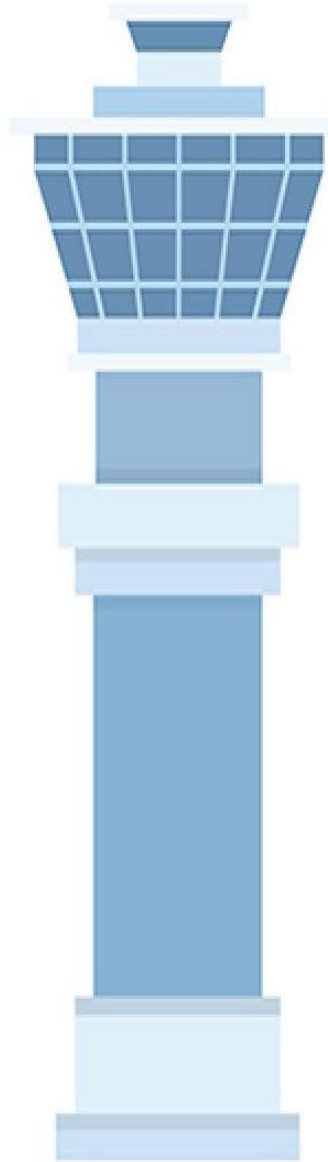


arrivals



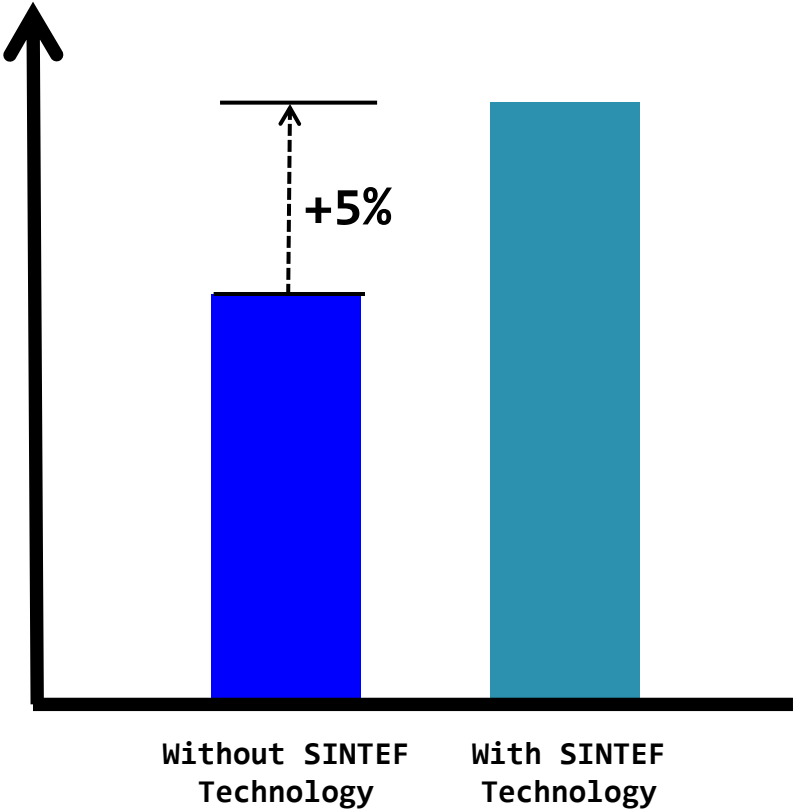
departures

Tower

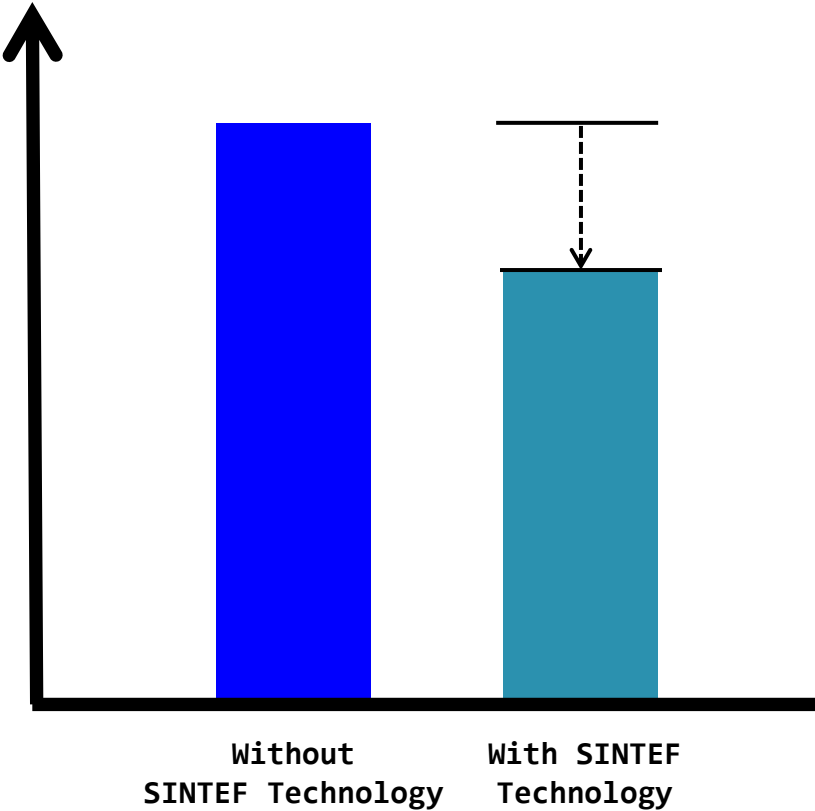


# What are the benefits?

### Peak throughput



### Controller Workload





AIR NAVIGATION SERVICES  
OF SWEDEN

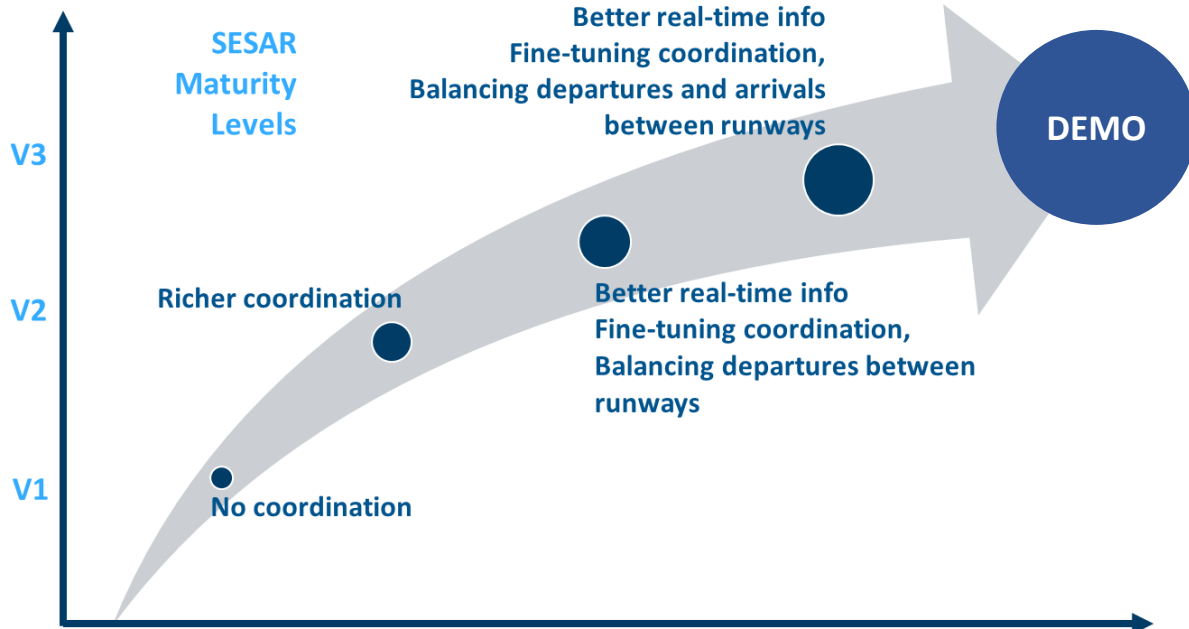


**swedavia**  
SWEDISH AIRPORTS

**THALES**



**SAAB**



SESAR 1 – P10.09.02.

SESAR 2020 – PJ02-08

SESAR VLD3 Very large scale demonstration



# EURO Working Group on the Practice of OR



- A network of practitioners of OR and analytics
  - A natural home for practitioners outside academia
  - A forum for
    - **sharing** experiences and solutions to the everyday challenges of OR practice
    - **learning** from each other to improve our own effectiveness
    - **building networks** for support and collaboration
    - **enjoying the opportunity** to meet, inspire and be inspired by like-minded people from across Europe
- [Membership is free: sign up or find out more: https://www.euro-online.org/websites/or-in-practice](https://www.euro-online.org/websites/or-in-practice)



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Teknologi for et bedre samfunn