Autum
School 2025

Models for flight operations

Examples of ML models and challenges
Pilot3 and Dispatcher3 projects

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Centre for ATM Research
University of Westminster
27 Oct 2025

Transportation
Research
Laboratory

Quintin Hogg
Trust

Pilot3

Transportation Research Laboratory

Pilot3

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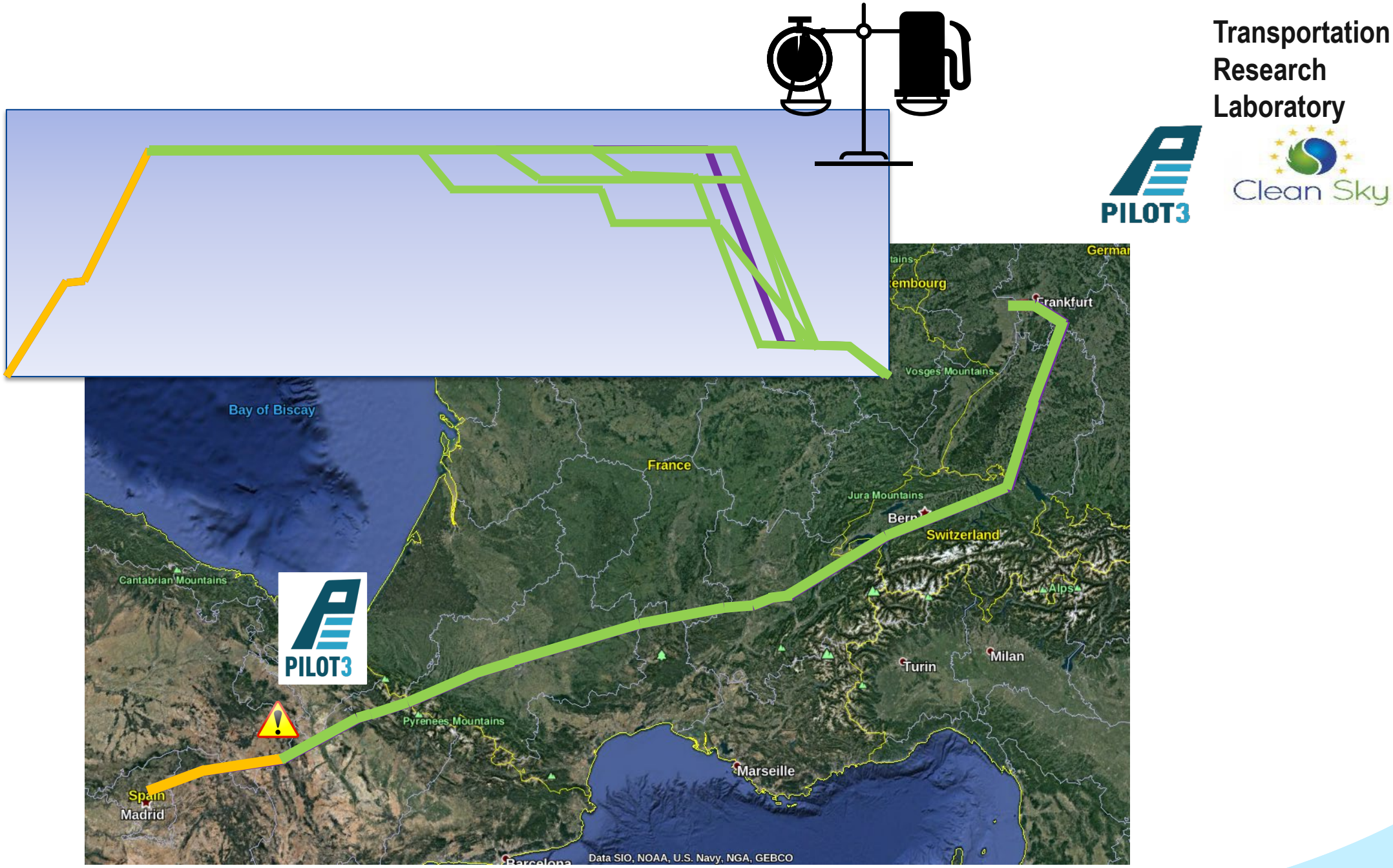

Pilot3

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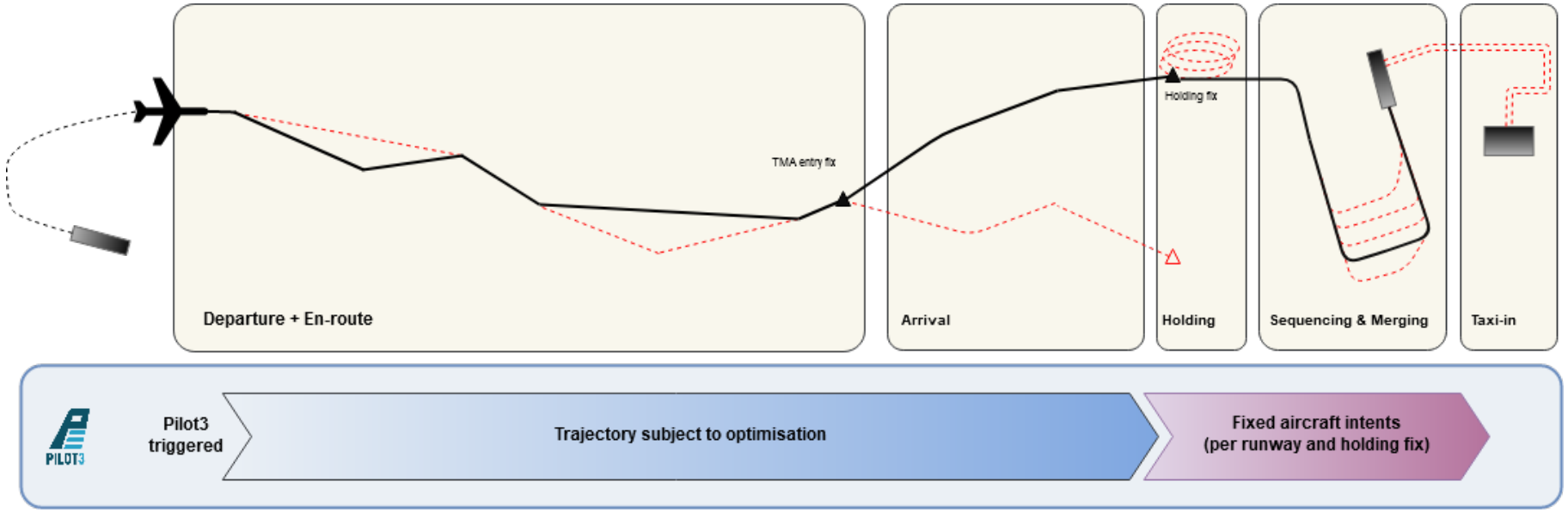

- Optimisation of vertical profile (from triggering point to FL100)

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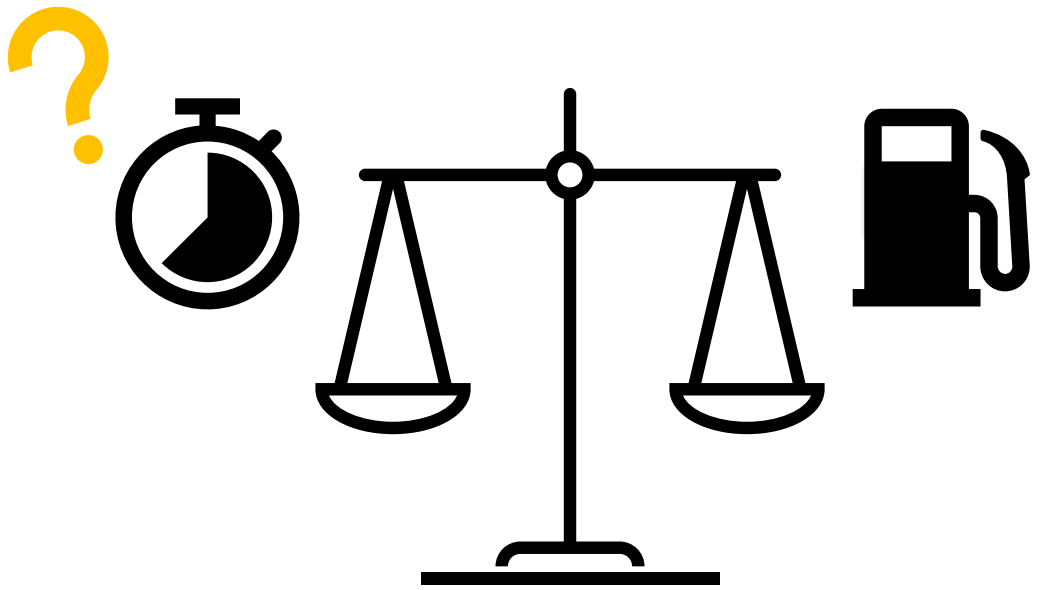
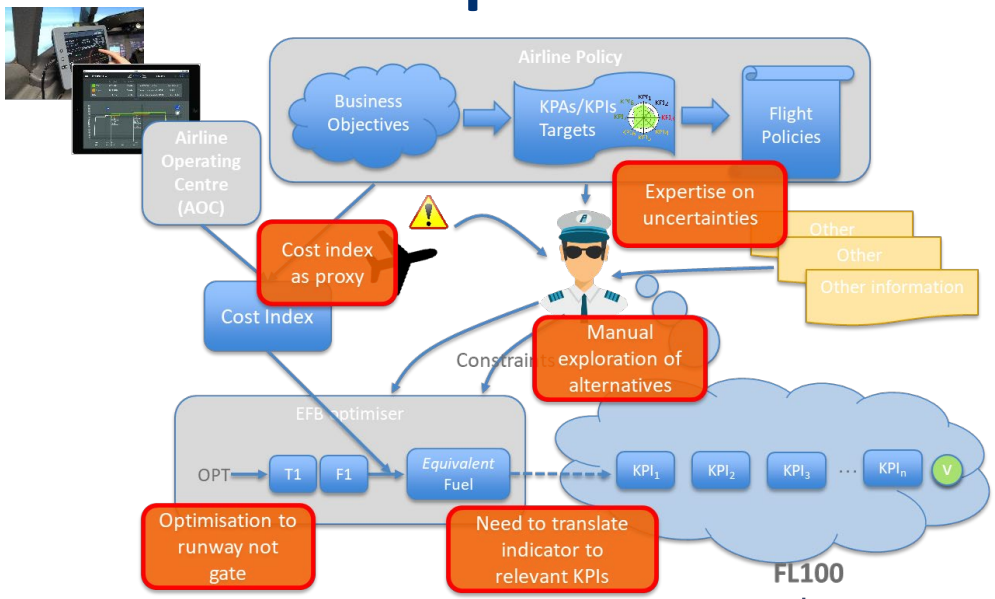
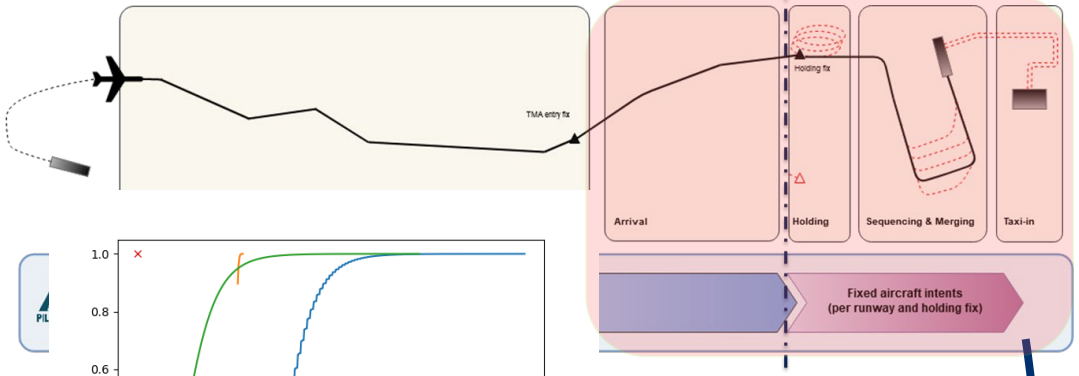


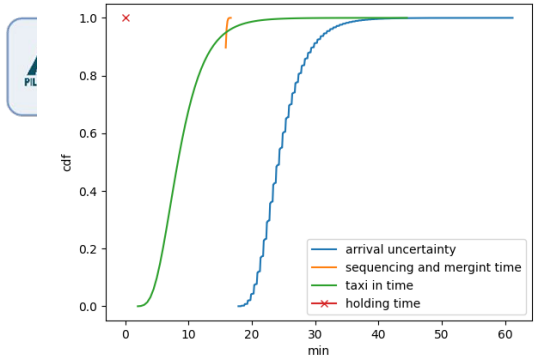
Cost Index

$$\frac{\text{Cost Time}}{\text{Cost Fuel}}$$

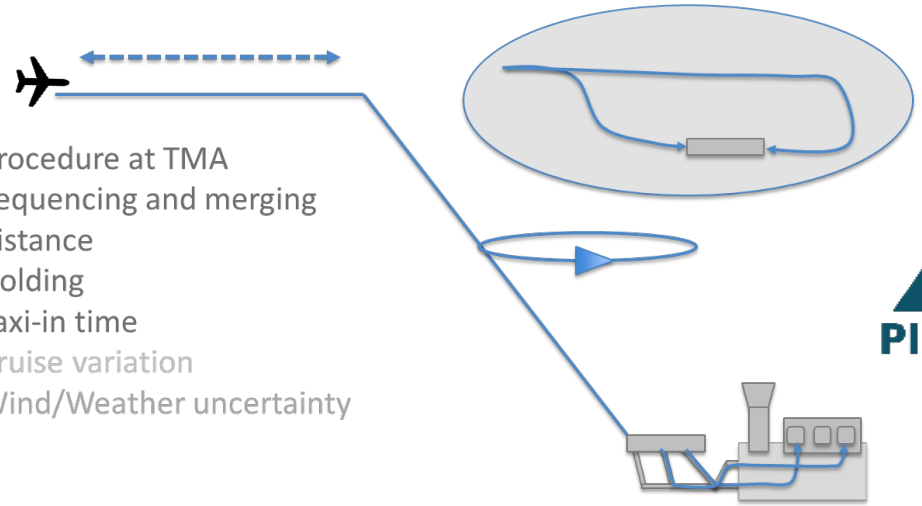
Pilot3 and Dispatcher3



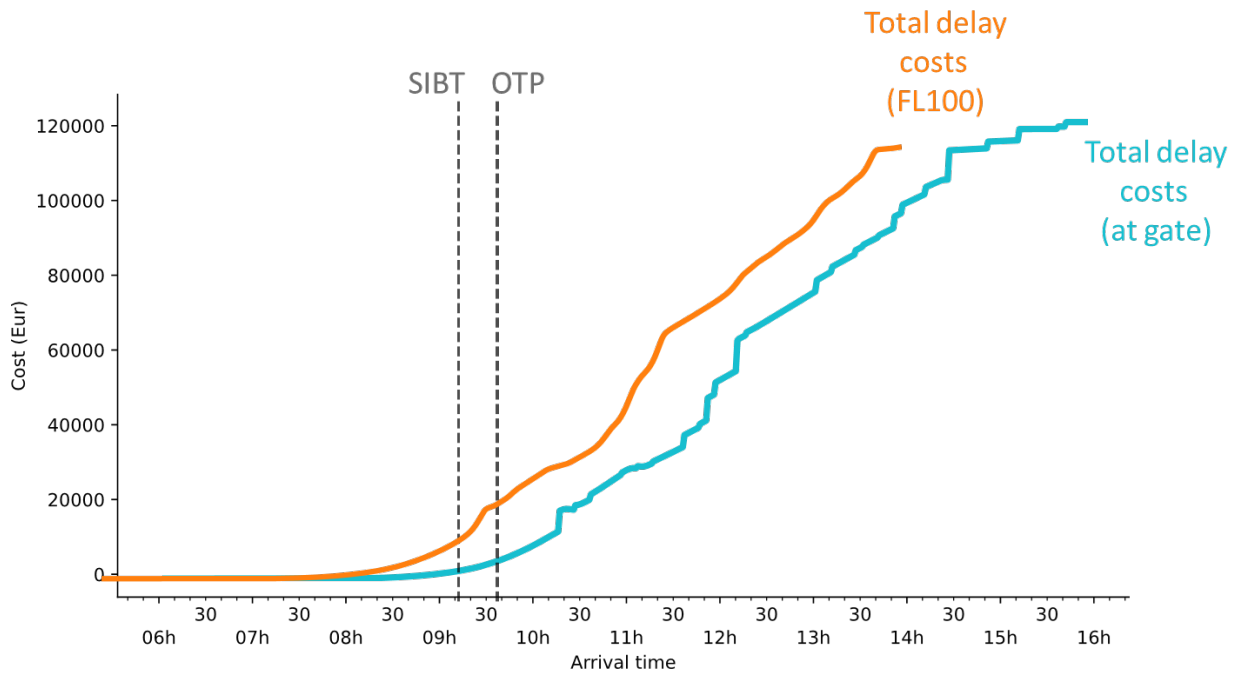




Arrival uncertainty



- Procedure at TMA
- Sequencing and merging distance
- Holding
- Taxi-in time
- Cruise variation
- Wind/Weather uncertainty



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PILOT3

Clean Sky

Pilot3

Multi-objective decision support system

PILOT3

HMI

Performance Indicators Estimator

Duty of Care Costs

Compensation Costs

Soft Costs

Cost Fuel

Transfer Costs

Non-connecting pax cost

Alternative itineraries

IROP Cost

Ground Time

Ground time heuristic

Minimum Connecting Time

Prob ATFM ML

Turnaround with delay ML

Ground time ML

Turnaround without delay ML

Missed connections

Connecting pax cost

Departure Time

Reactionary Delay

Reactionary Costs

Block Time

Block time heuristic

Reactionary cost

Other Costs

Reactionary Action

Rwy2Rwy time ML

Taxi in time

Block time ML

Taxi Out time

Non-passenger costs (Crew/Maintenance)

Non-passenger Costs

Alternatives Generator

Objective Function Estimator

Integrate uncertainty

Trajectory Optimiser

Optimiser

CI proxy

Simulated Annealing

Binary search

Cost function integrated

Grid-search

Trajectory Optimiser (DOC) Triggering point - FL100

Holding Seq.&merg. Taxi-in time and fuel dist.

Trajectory Predictor FL100 - runway

Performance Assessment Module

Performance Assessment

Sequencing and merging Distance

Between Waypoint Time

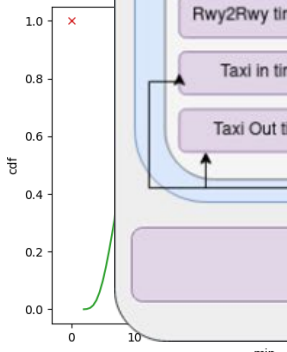
Taxi Time

Holding Time

TMA Distance

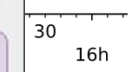
Operational ATM Estimator

Data Manager



Arrival uncertainty

Total delay costs (at gate)



Pilot3 – Machine learning models challenges

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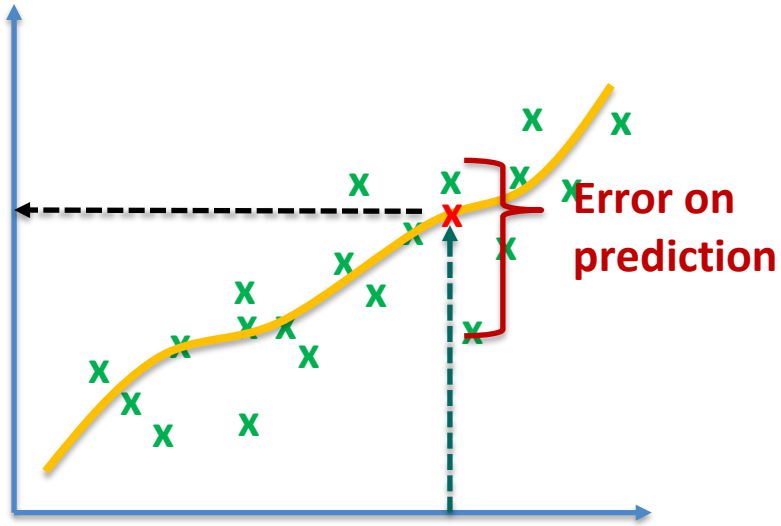
Challenges

1. Need of distribution not only average expected value



Pilot3 – Machine learning models challenges

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Challenges

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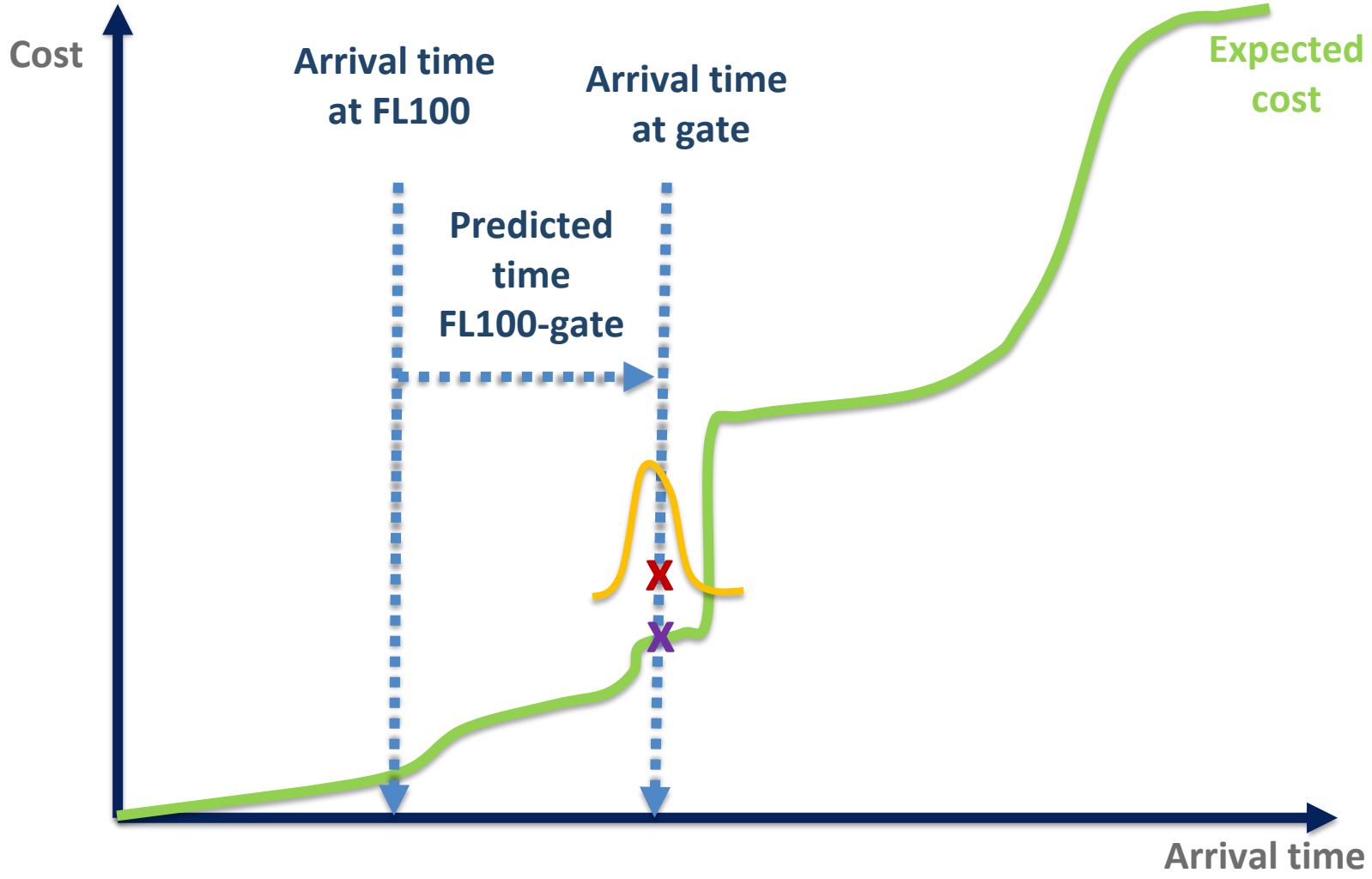

Pilot3 – Machine learning models challenges

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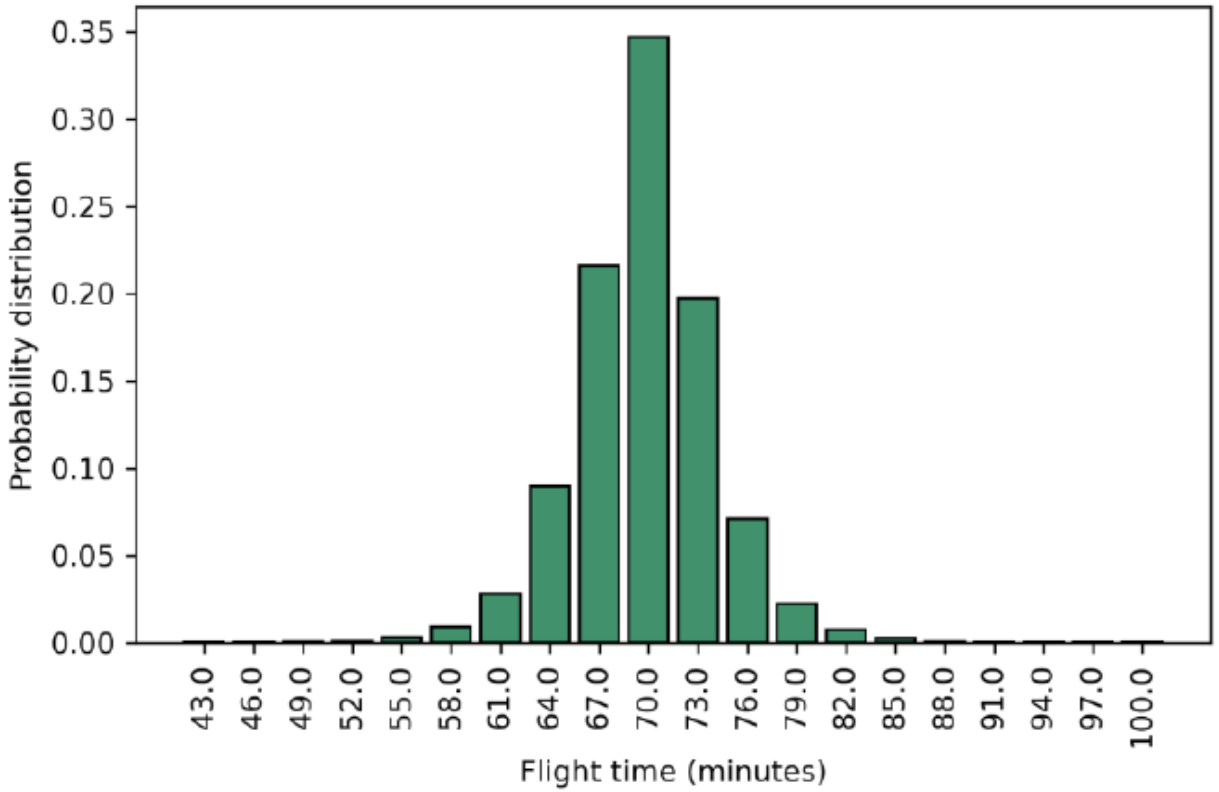

Pilot3 – Machine learning models challenges

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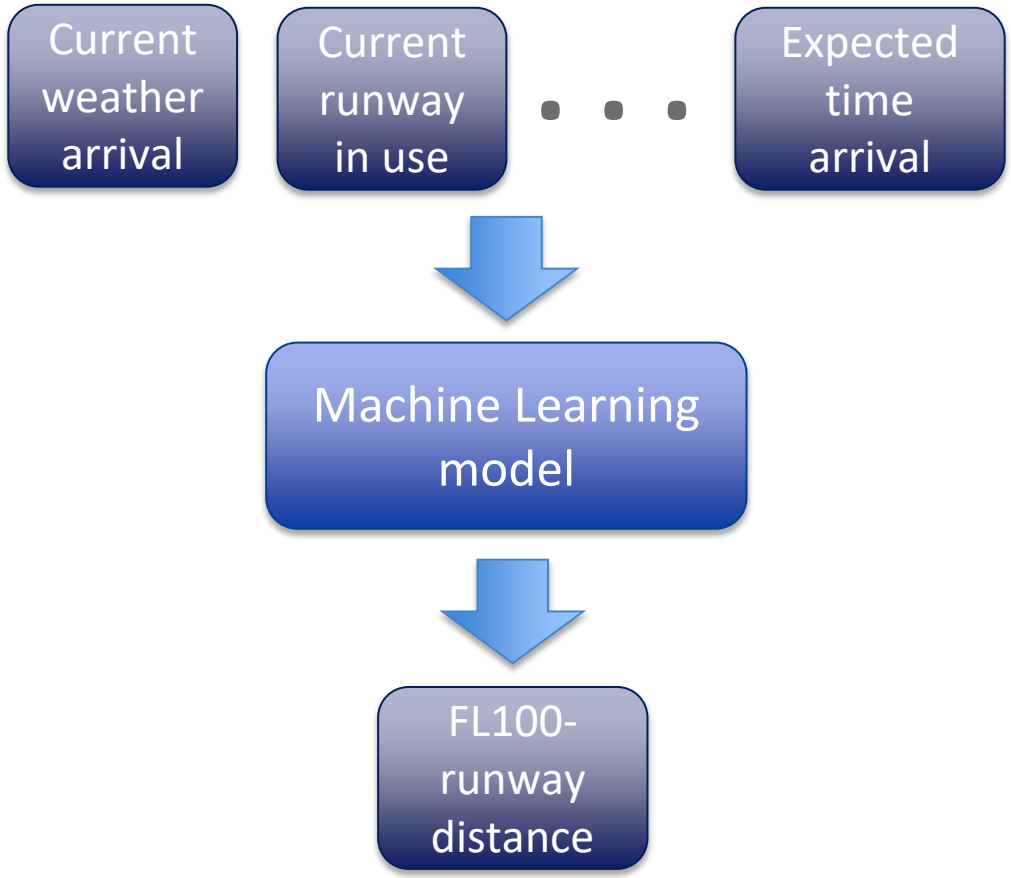
Challenges

2. Prediction horizon



Pilot3 – Machine learning models challenges

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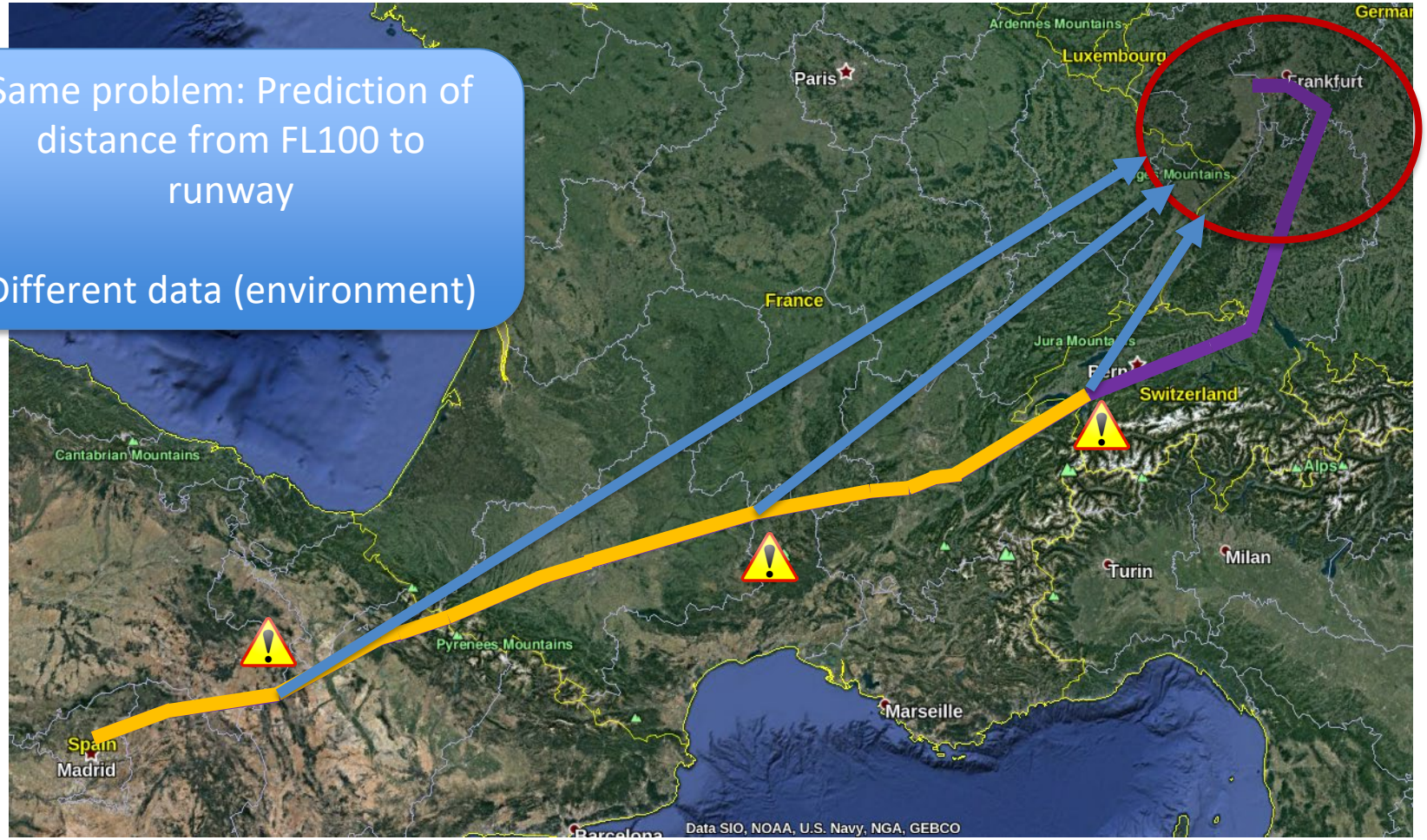
Challenges

2. Prediction horizon



Pilot3 – Machine learning models challenges

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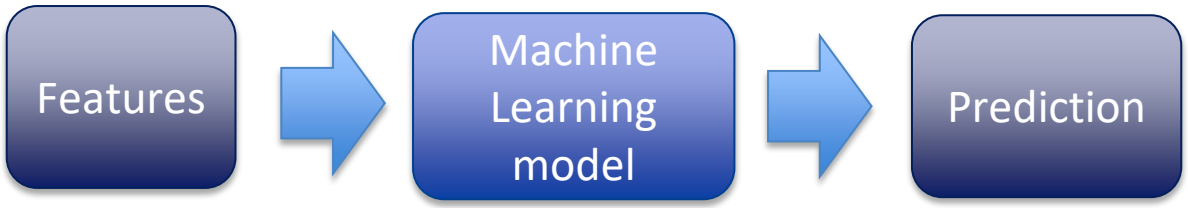
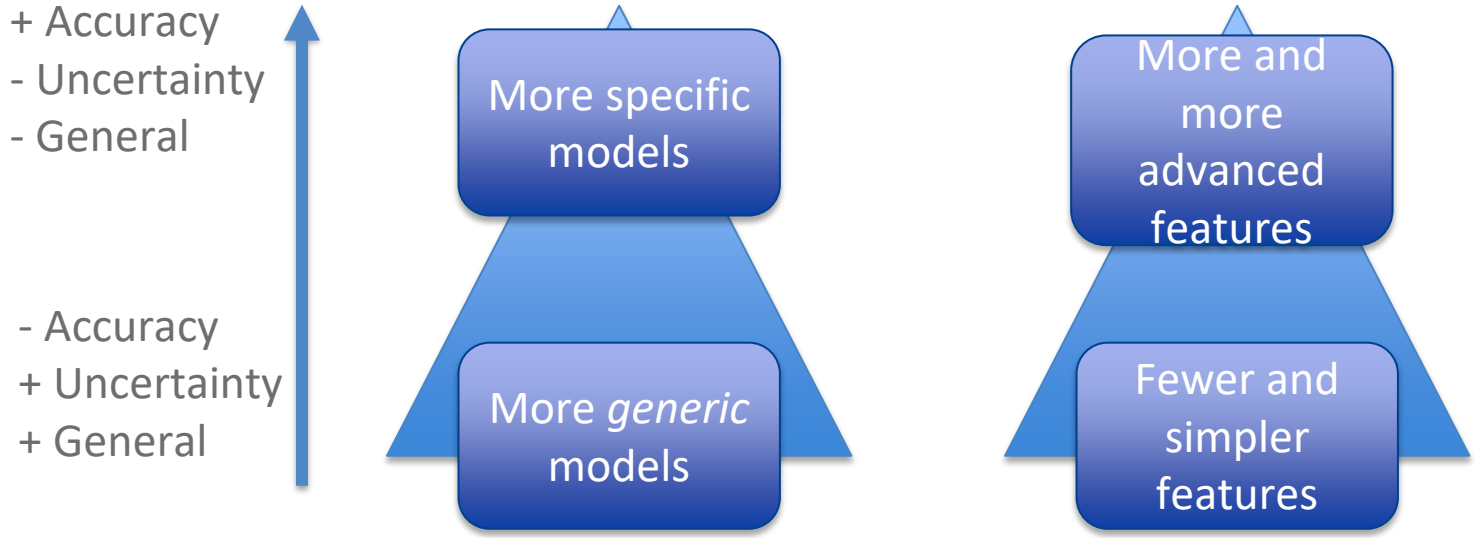
Challenges

3. Multi-model approach





Pilot3 – Machine learning models challenges

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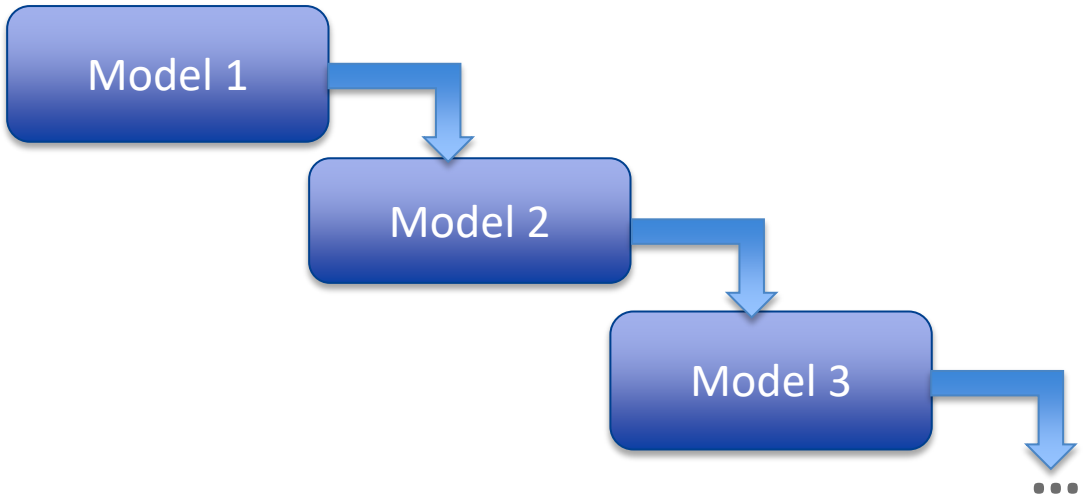
Challenges

3. Multi-model approach

Which model to use for a given prediction: trade-off accuracy/uncertainty/ genericity

Specific
More advanced features
Ground-updated data



Generic
Fewer features
Air-available data

Pilot3 – Machine learning models challenges

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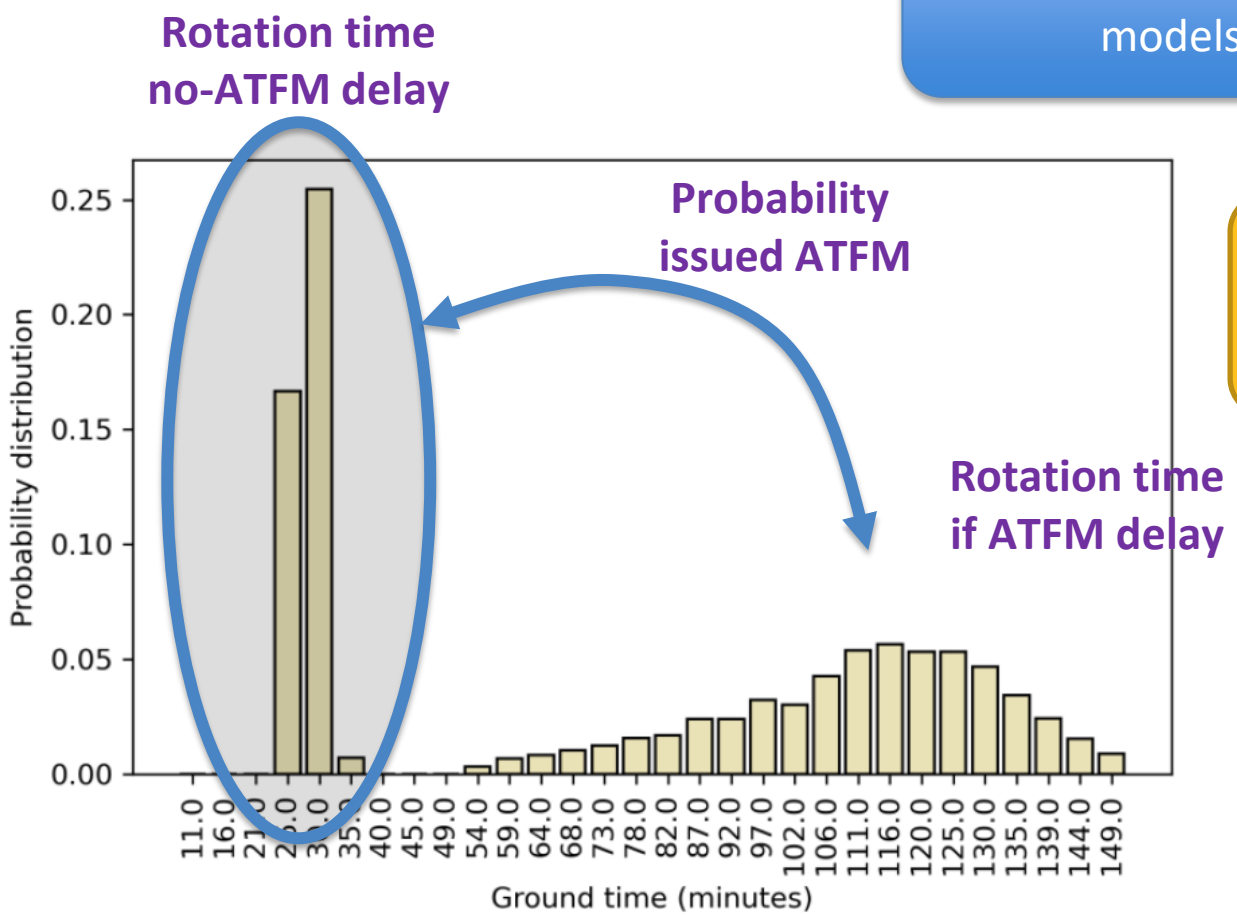
Challenges

3. Multi-model approach

Estimation of complex interactions integrating models



Propagation of errors across models?

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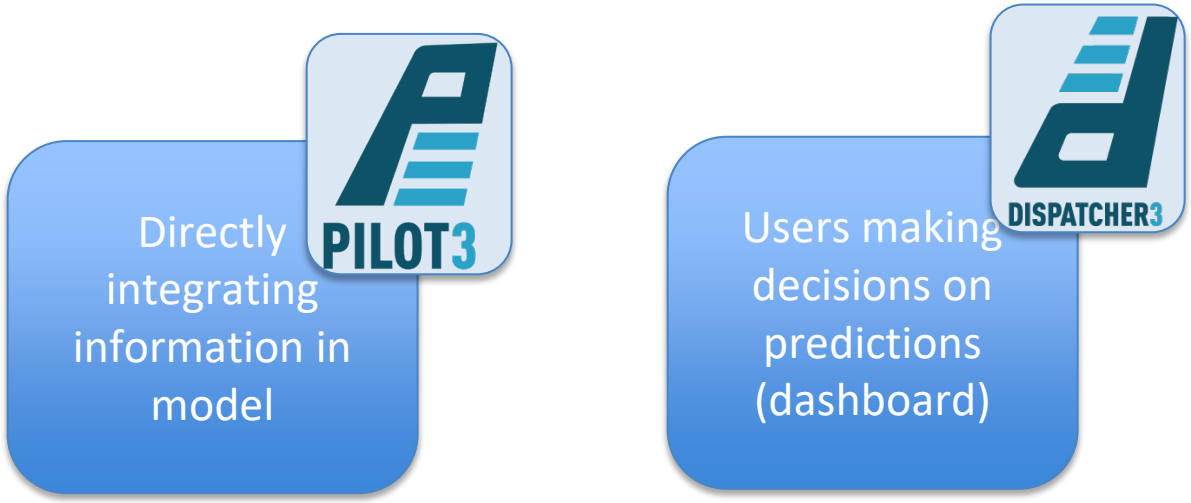
Challenges

4. Visualisation – interpretability

Using predictions with uncertainties → How to present the information to users?



Pilot3 – Machine learning models challenges

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Challenges

5. Data!

Pilot3 – Machine learning models challenges

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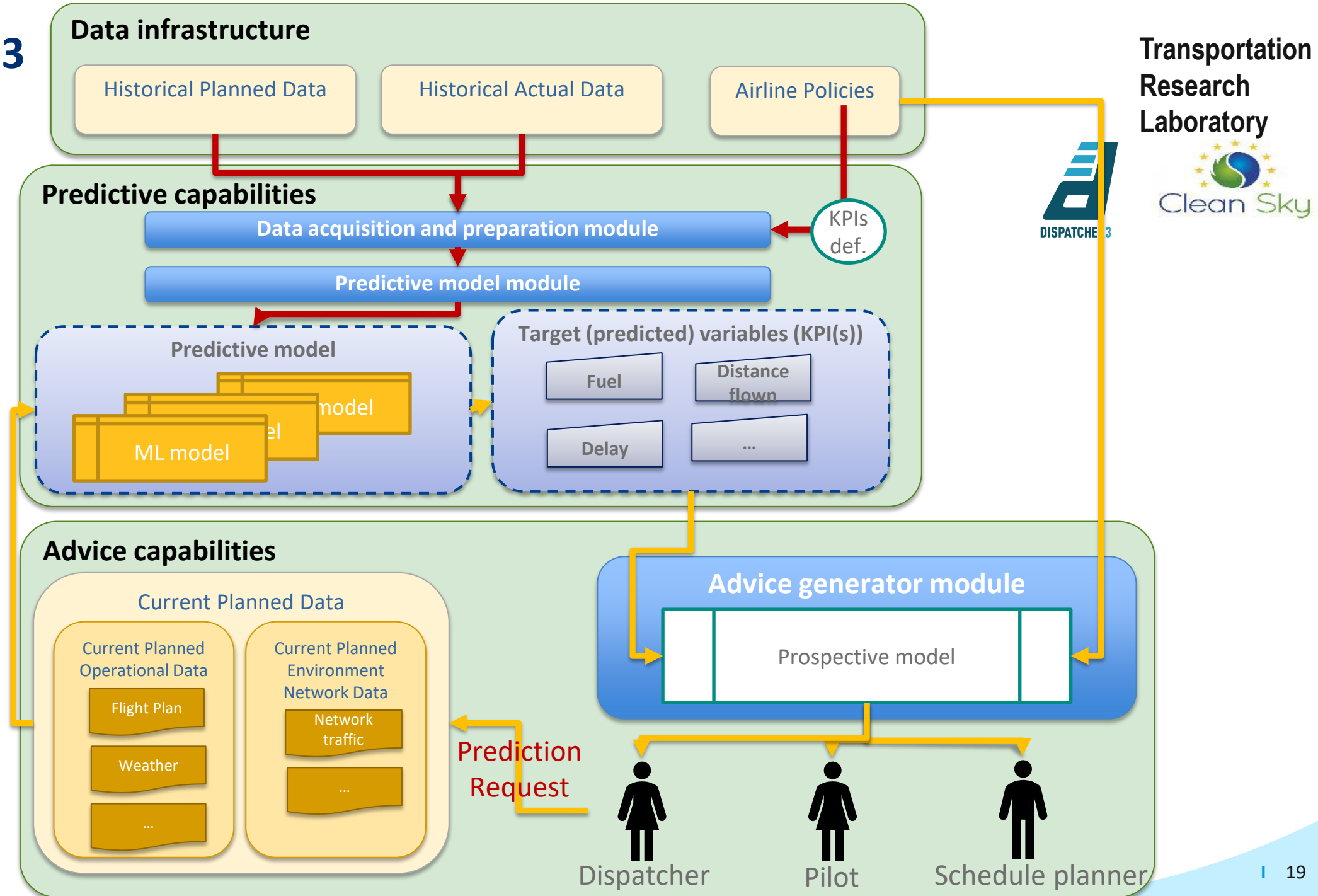
- **Machine learning models in Pilot3**
  - Used to compute cost function components
  - Used to estimate uncertainties that affect operations:
    - Distance at arrival (FL100-runway)
    - Taxi-in time
    - Reactionary delay
      - Block time
      - Rotation time
      - ATFM delay

- **Challenges (most of them applicable to ATM in general)**
  1. Need of distribution not only average expected value
  2. Prediction-horizon
  3. Multi-model approach
  4. Visualisation – interpretability
  5. Data!

Dispatcher3



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Dispatcher3 – Data sources

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#	Data source	Description	Used in
1	FDM provided by Vueling	Contains performance data and static data directly collected by the airlines	Fuel deviation (pre-departure)
2	ADS-B data by OpenSky	Radar data, contains trajectories	Holding scenarios (pre-departure)
3	METAR	Contains weather information at different European Airports	Pre-departure and pre-tactical scenarios
4	NOAA weather forecasts	GRIB file containing meteorological information in a 4D space (latitude, longitude, altitude and time)	Fuel deviation and runway in use (pre-departure)
5	ALLFT+	Network and flight plan and trajectories information from DDR2 by EUROCONTROL	Pre-departure and pre-tactical scenarios
6	ECTL R&D Archive	Network information and flight information provided by EUROCONTROL	Pre-departure scenarios
7	Vueling flight data and flight plans	Flight information and flight plans from Vueling flights.	Pre-departure and pre-tactical scenarios
8	Flight Plans by PREDICT	Simulated data using PREDICT software which estimates pre-tactical flight plans based on historical data (ALLFT+)	Pre-tactical scenarios

Dispatcher3

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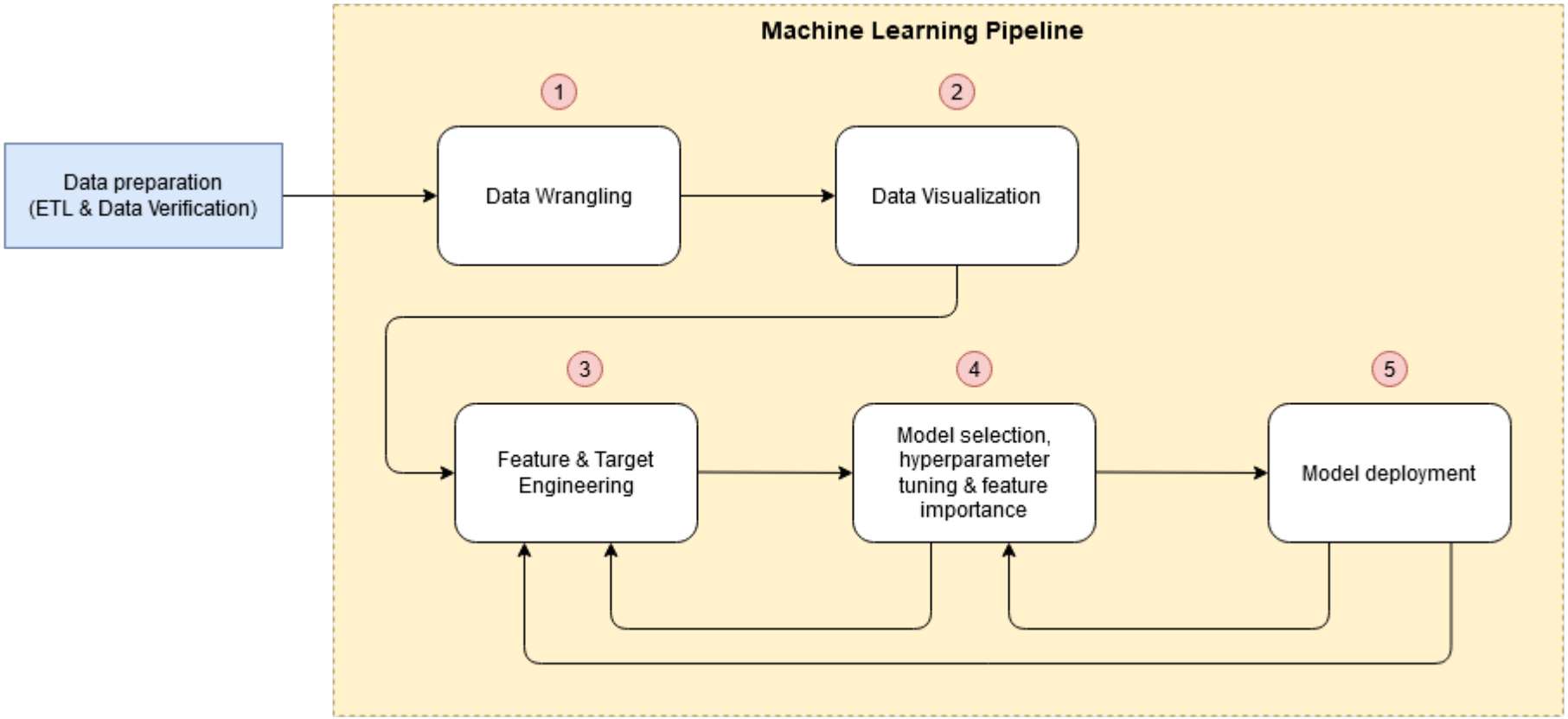

Dispatcher3

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Predictive capabilities

Pre-departure models (using data available 3h prior SOBT)

- Holdings at arrival at EGLL
- Fuel usage
- Runway at arrival at LEIB

Planned models (using data available at D-1)

- Probability being regulated by ATFM
- Location of regulation if flight regulated (airspace/airport)
- Probability regulated flight has zero minutes of delay assigned
- Distribution of delay if delay assigned is greater than zero

Advice capabilities

- Rotation / reactionary delay propagation
- Integrated interactive flight plan visualisation

Dispatcher3

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Static vs dynamic features

Static features

Operational time
Hour of departure
Day of the week
Month

Airport information
Size departure airport
Size arrival airport
Departure hub airline
Arrival hub airline

Dynamic features

Airport demand
Normalized num. departures
Normalized num. arrival

Network demand
Normalized OC
Normalized EC

Weather	
ATMAP score	METAR
Temperature	
Wind speed	
Visibility	
u/v wind	NOAA
Geopotential	
Relative humidity	
Ventilation rate	

Pilot3 and Dispatcher3

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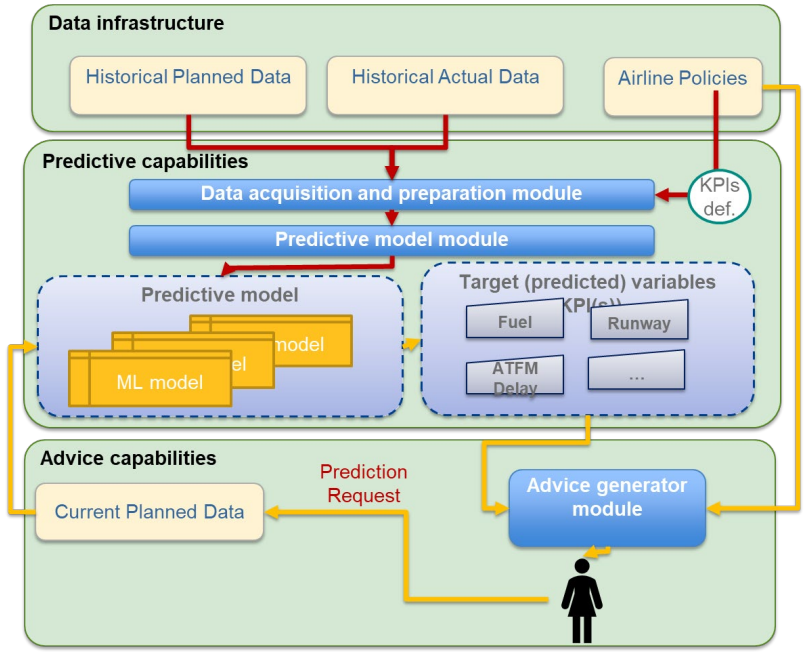

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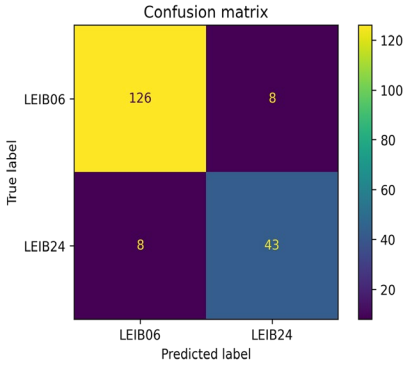

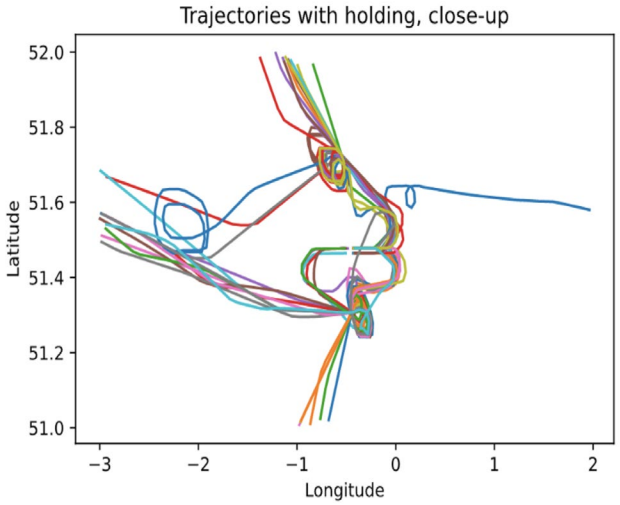

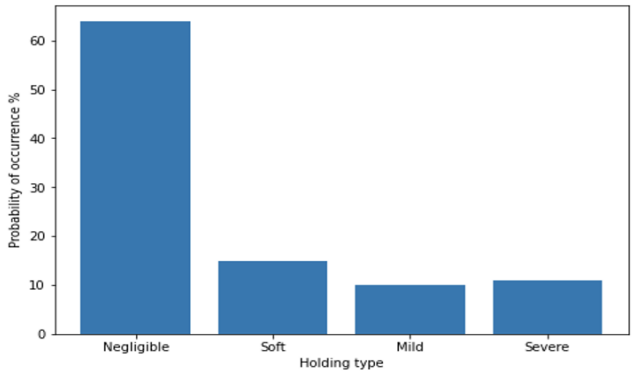

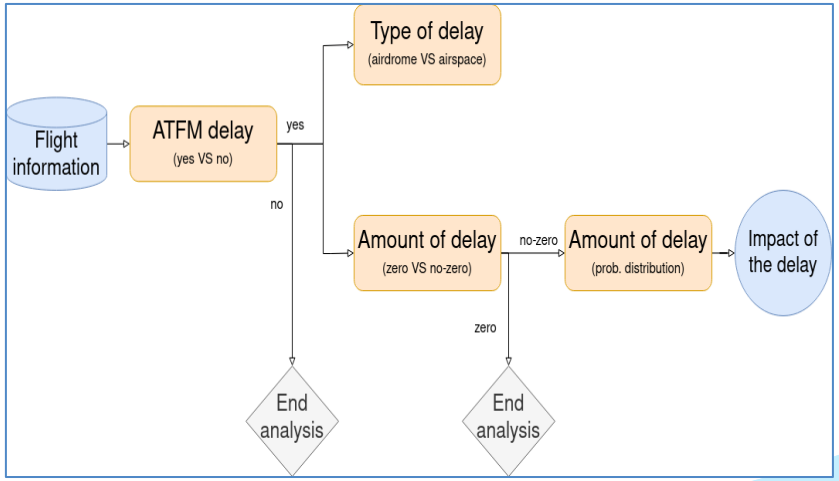

Pilot3 and Dispatcher3

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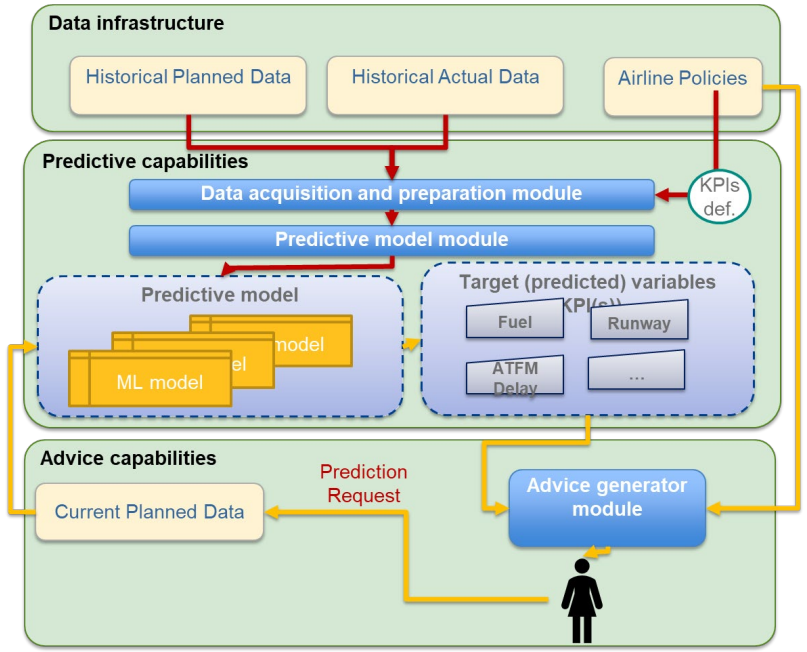

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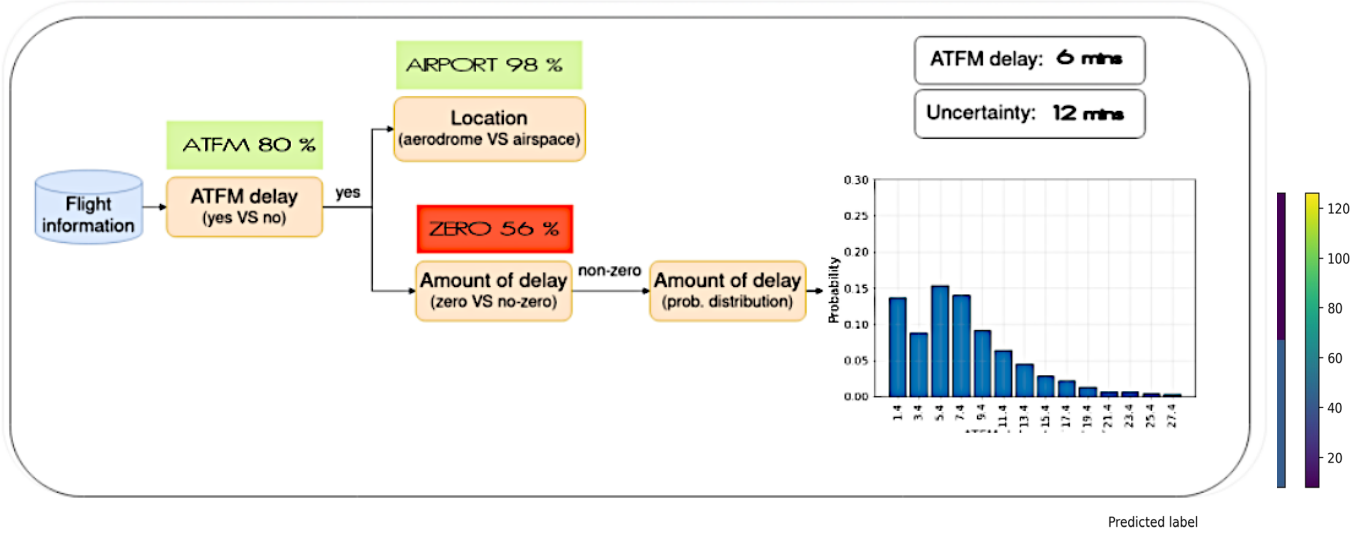
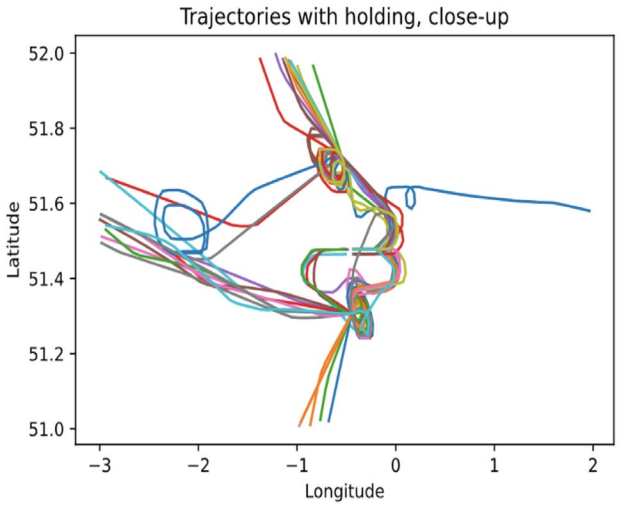
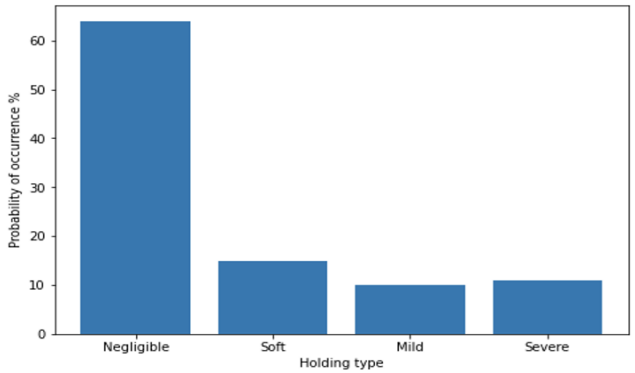
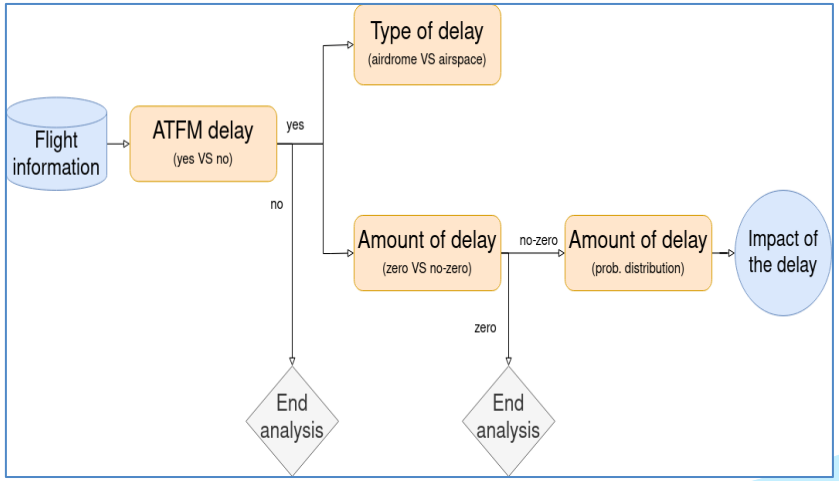
- Fuel usage



Adv







Pilot3 and Dispatcher3

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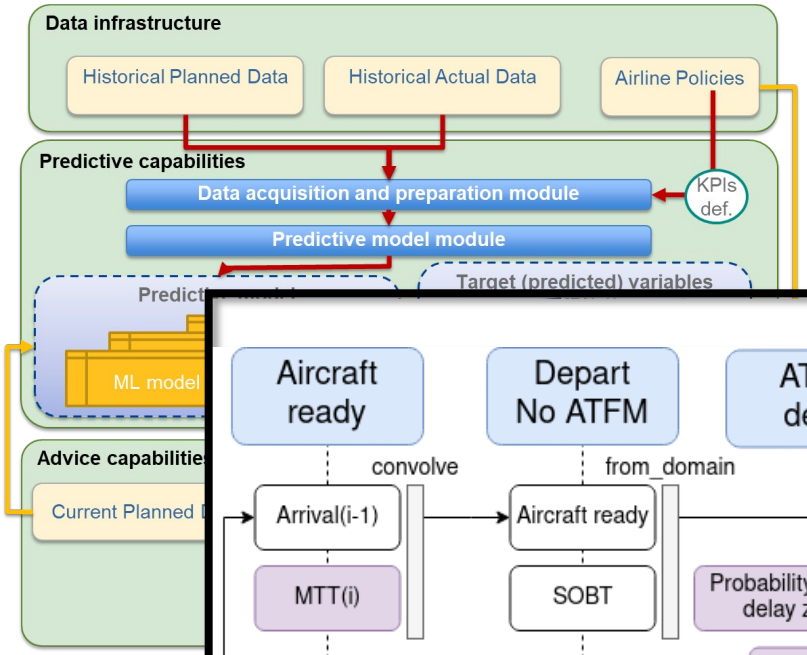
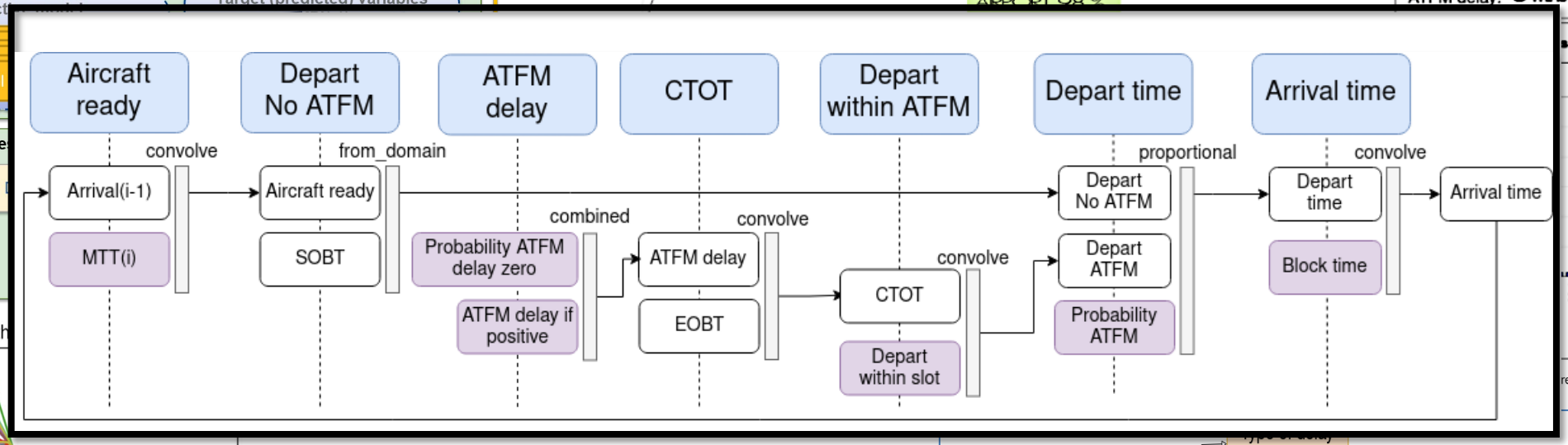
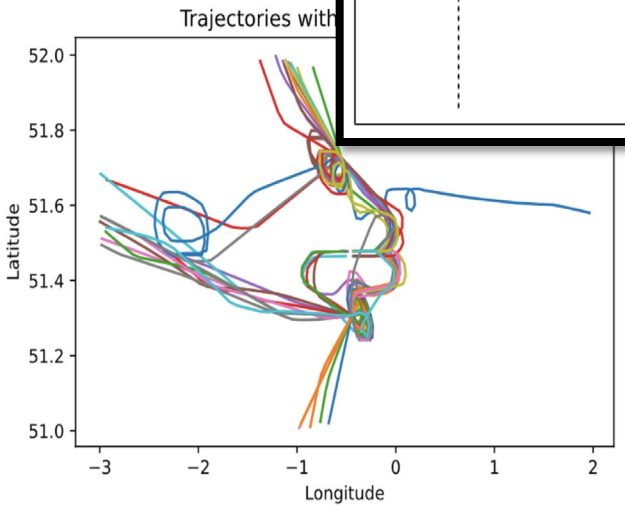


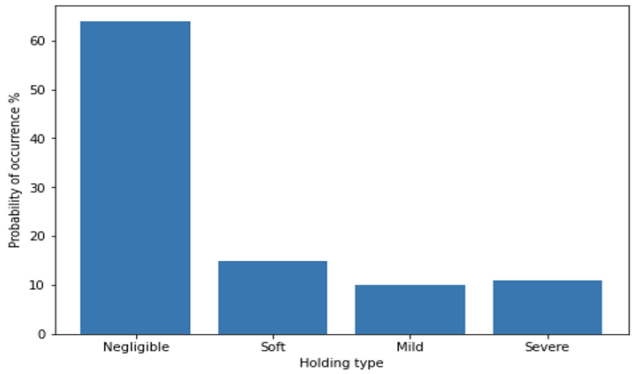
Predictive capabilities

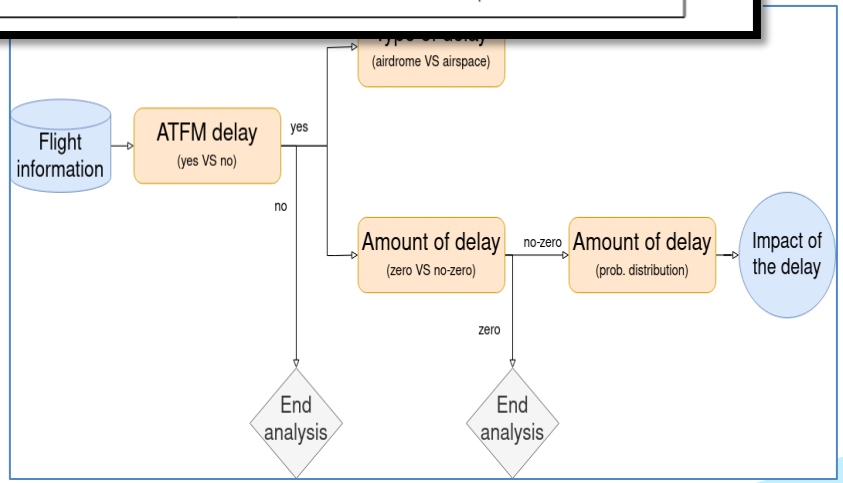
Pre-departure models (using data available 3h prior SOBT)

- Holdings at arrival at EGLL
- Fuel usage









Pilot3 and Dispatcher3

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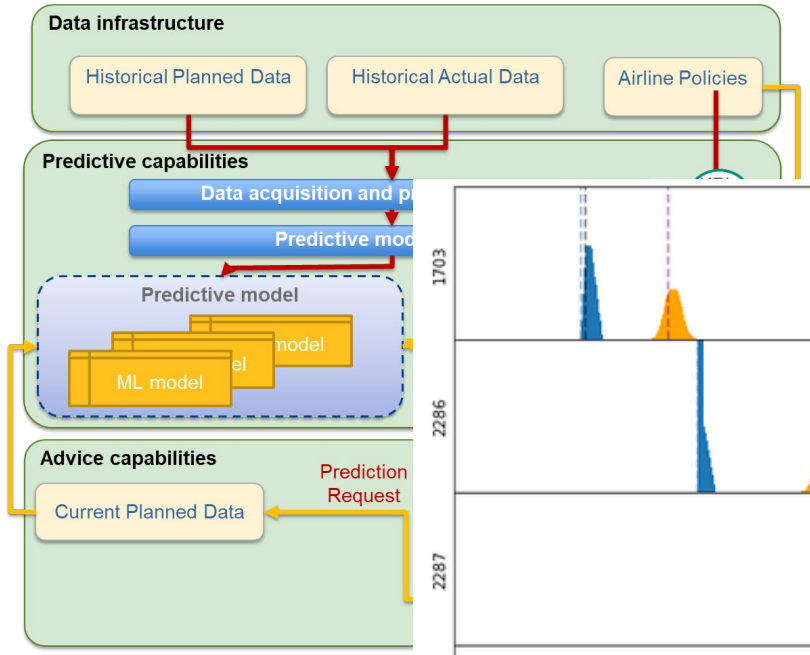
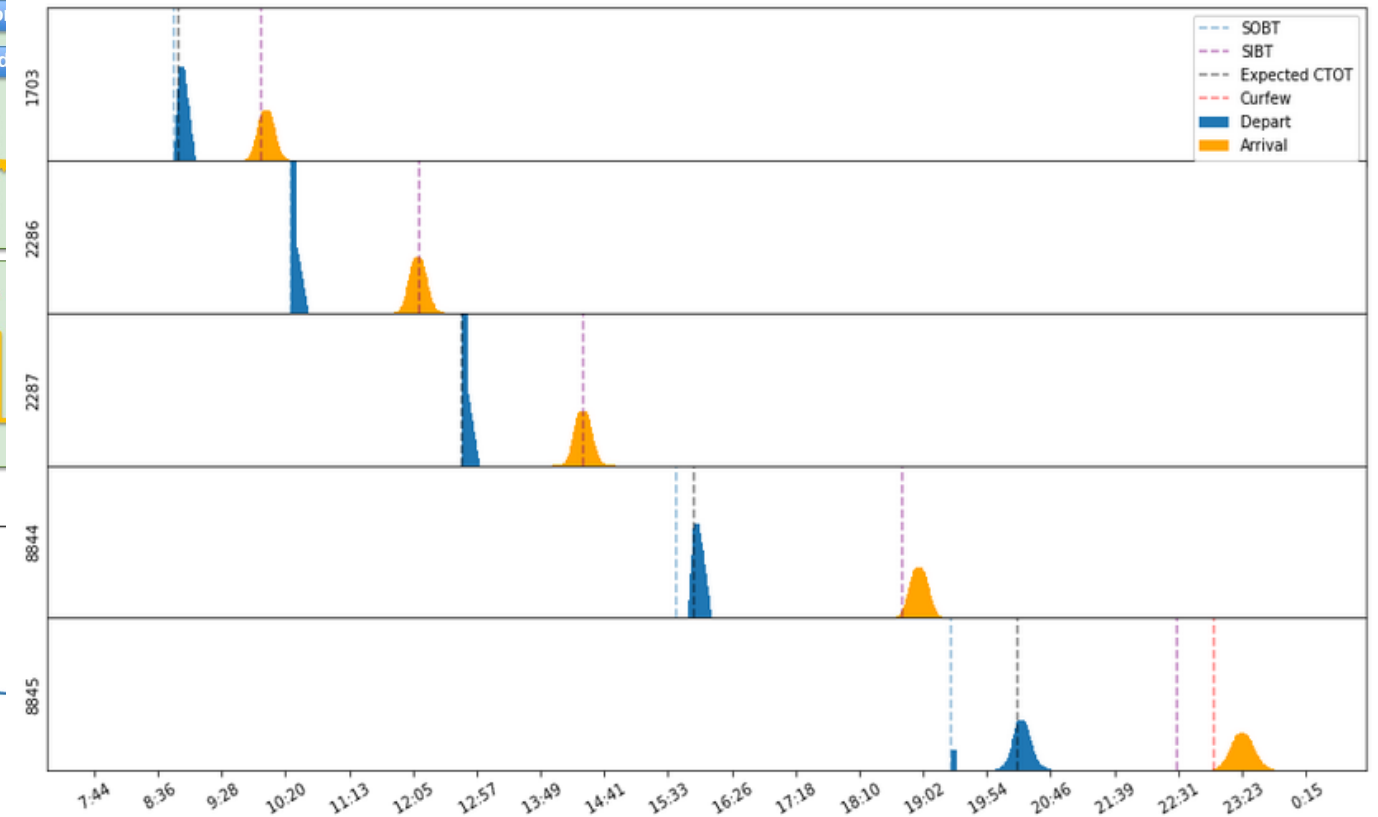
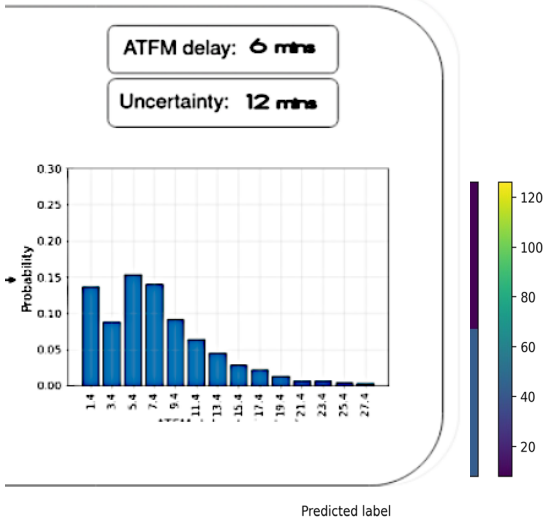


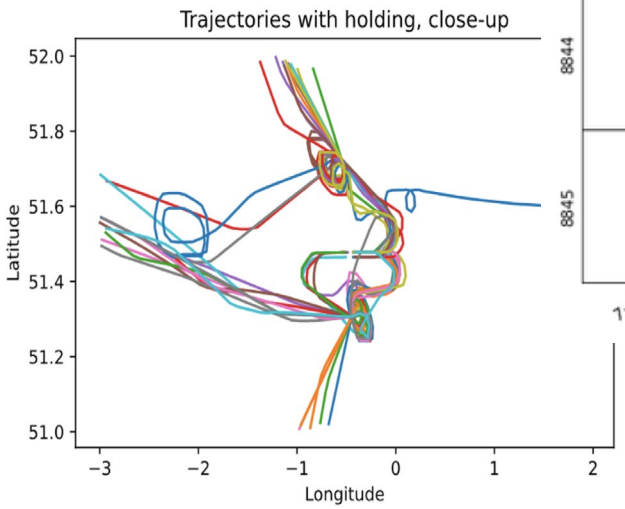
Predictive capabilities

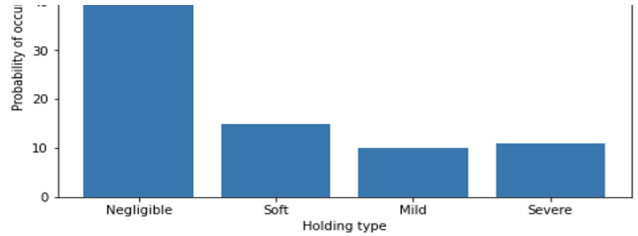
Pre-departure models (using data available 3h prior SOBT)

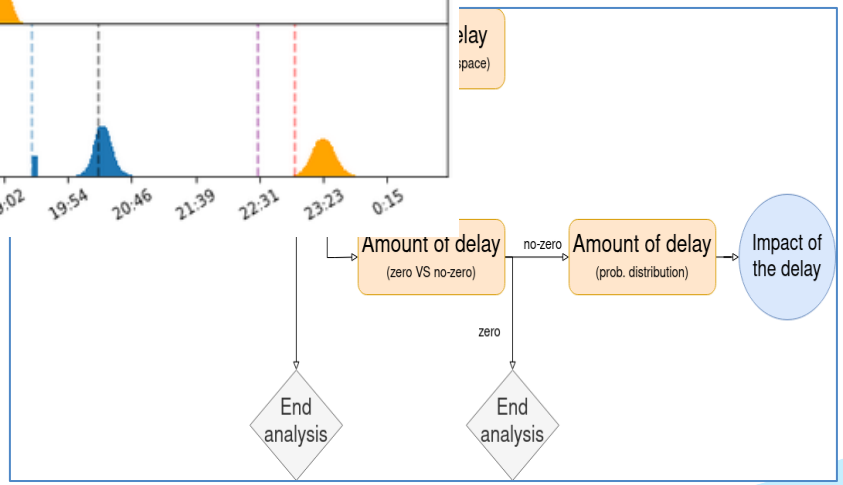
- Holdings at arrival at EGLL











Pilot3 and Dispatcher3

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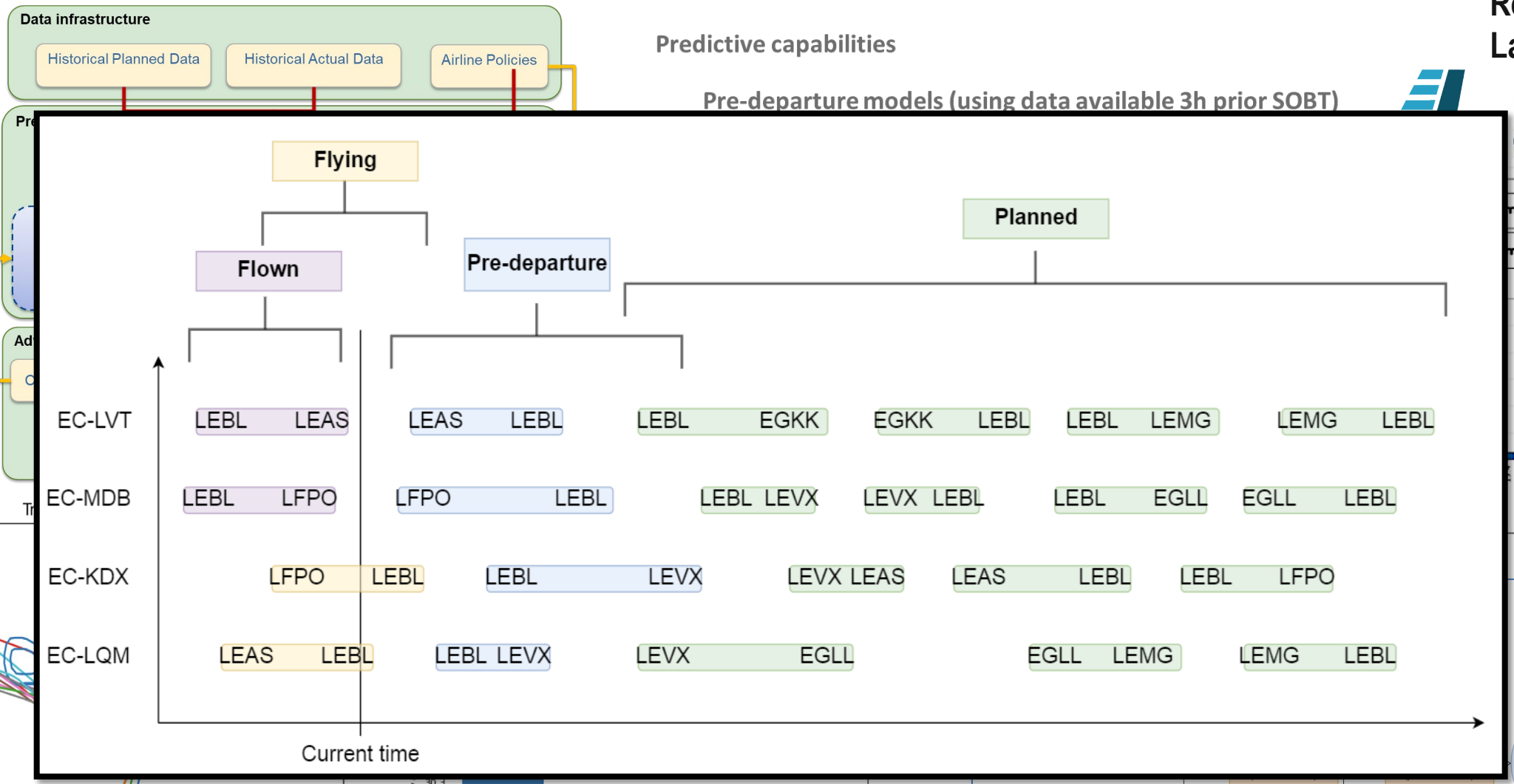
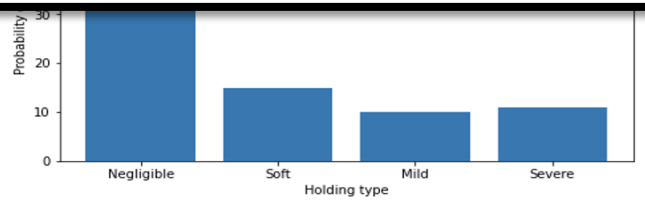
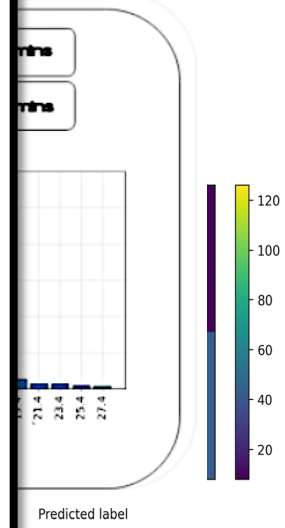
Clean Sky

Predictive capabilities

Pre-departure models (using data available 3h prior SOBT)







Conclusions

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Models are useful but not on their own

Consider data availability

Interpretability

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Thank you!

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