SESAR JOINT UNDERTAKING

SafeOPS

SafeOPS
–
Evaluating an AI-based Decision Support for Go-around Handling

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RPAS and AI in Aviation

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EUROPEAN PARTNERSHIP

Co-funded by the European Union

Efficieny Resilience Trade-Off

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Efficiency Isn't the Only Economic Virtue

It often comes at the expense of resilience, as the new coronavirus is making clear.

Reference:
https://www.wsj.com/articles/efficiency-isnt-the-only-economic-virtue-11583873155

CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

COMMENTARY

Resilience vs. Efficiency

Reference:
https://www.csis.org/analysis/resilience-vs-efficiency

Efficiency:

- Optimizing a system/process in a known/defined environment.
- No unused resources

Resilience:

- Ability to absorb, adapt or recover from rare or unpredictable events and disturbances.
- Requires 'reserved capacity' / safety margins

Reference:
https://upload.wikimedia.org/wikipedia/commons/1/1f/Container_Ship_%27Ever_Given%27_stuck_in_the_Suez_Canal%2C_Egypt_-_March_24th%2C_2021_%2851070311183%29.jpg

European ATM Master Plan

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Goals that are hard to combine?

- Increase of capacity
  - + 60% IFR Network throughput
  - + 5-10% IFR movements at congested airports
- Increase ATM related safety by 100%

What is a good trade-off?

- When should we prioritize safety, when capacity?

Decision Intelligence:

- Provide ATCOs with real time / predictive risk information
- Use predictive information to support decision-making
- Increase safety and resilience

PERFORMANCE AMBITIONS FOR 2035 FOR CONTROLLED AIRSPACE

Key performance area	SES high-level goals 2005	Key performance indicator
Capacity	Enable 3-fold increase in ATM capacity	**Departure delay**[4],min/dep **IFR movements at most congested airports**[5], million **Network throughput IFR flights**[5], million **Network throughput IFR flight hours**[5], million
Cost efficiency	Reduced ATM services unit costs by 50% or more	**Gate-to-gate direct ANS cost per flight**[1], EUR(2012)
Operational efficiency		**Gate-to-gate fuel burn per flight**, kg/flight **Additional gate-to-gate flight time per flight**[2], min/ flight Within the: Gate-to-gate flight time per flight[3], min/flight
Environment	Enable 10% reduction in the effects flights have on the environment	**Gate-to-gate CO_2 emissions**, tonnes/flight
Safety	Improve safety by factor 10	**Accidents with direct ATM contribution**[6], #/year Includes in-flight accidents as well as accidents during surface movement (during taxi and on the runway)

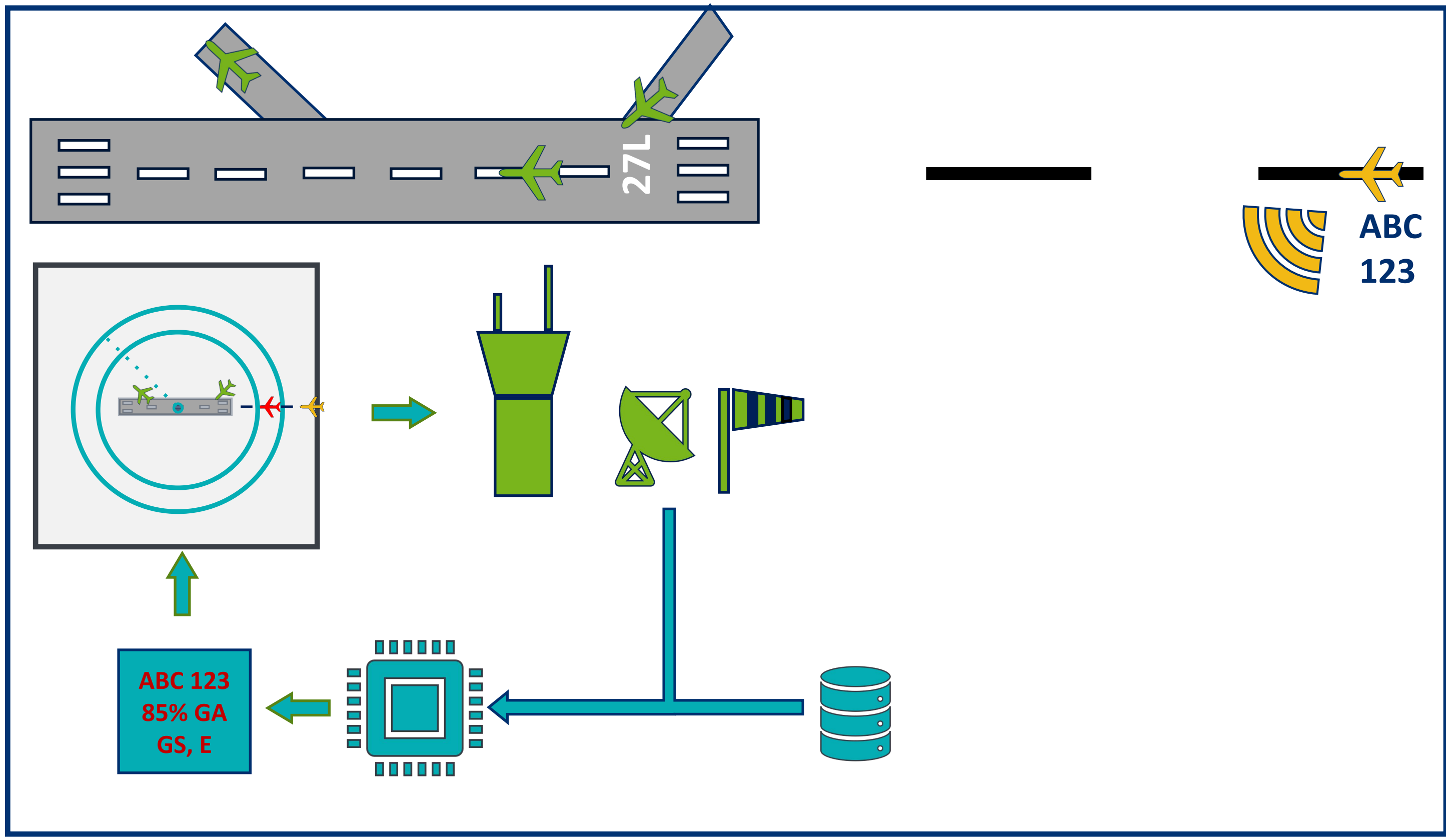
Reference:
https://www.atmmasterplan.eu/exec/overview/performance-ambitions

SafeOPS Concept

Approach and Departure Handling:
- Tower Controller realizes go-around through
  - Flight Crew's communication
  - Observation of flight (via radar)
- □ Reactive tactics to ensure safety

Predictive Analytics:
- Train an AI/ML model with historical performance and weather data
- Predict go-arounds ahead of time, using radar and weather data

Real Time Risk Information
- Provide the predictive information to ATCOs



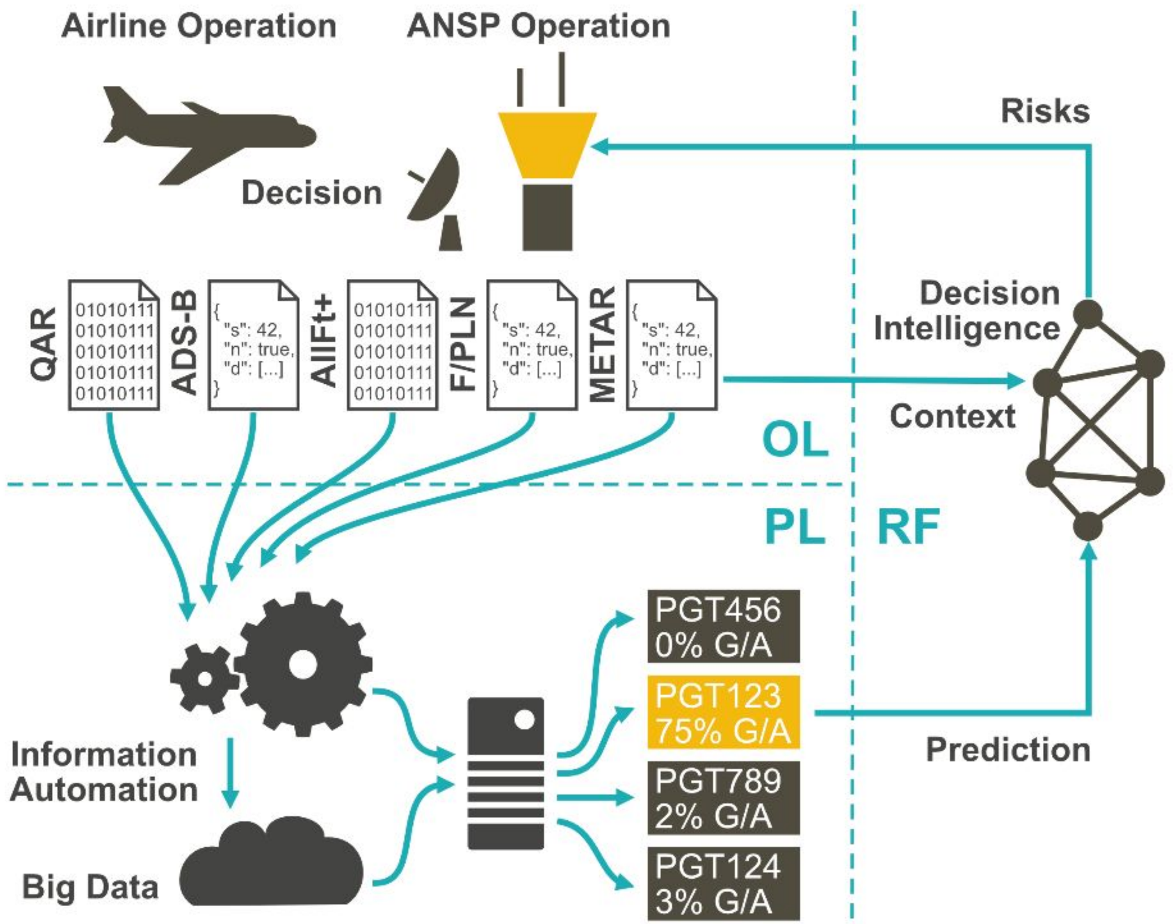
How does the predictive information impact decision-making, safety and resilience in the go-around scenario?

SafeOPS Structure

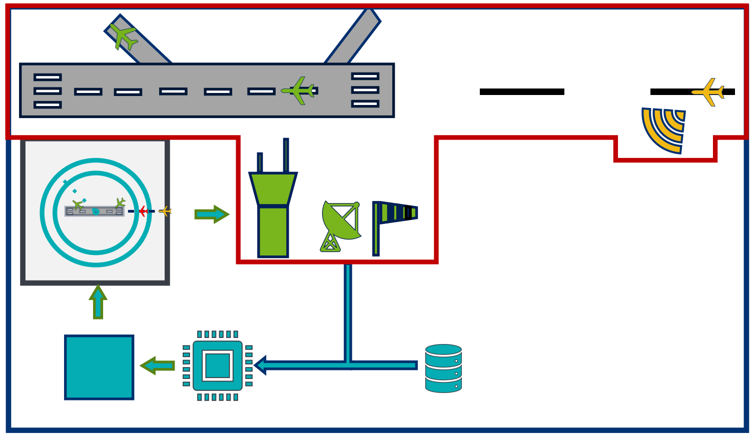
Operational Layer
Systems Engineering approach:
- Understand available procedures and technologies
- Define initial ConOps & requirements
- Evaluate impact of concept on safety and resilience

Risk Framework
Addresses the operational risks of the concept:
- Investigate provision of probabilistic information
- Human Performance/Integration of concept
- Initial safety assessment concept

Predictive Layer
Addresses big data related tasks:
- Data acquisition and pre-processing
- AI solution identification
- AI training



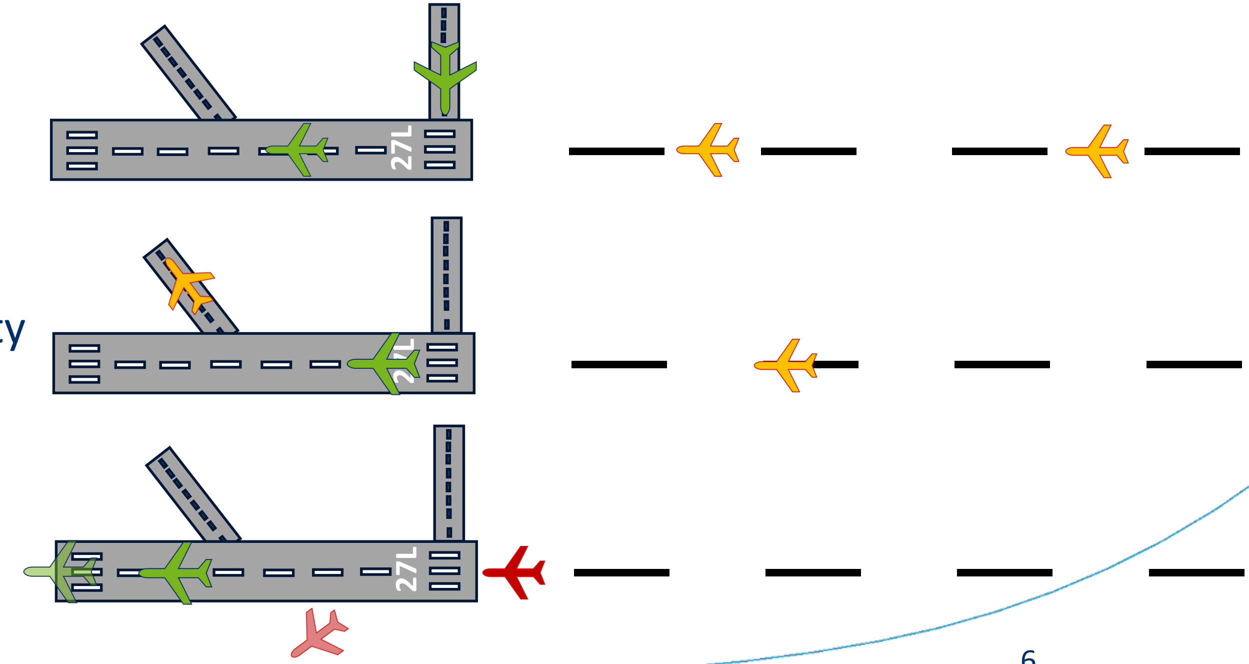
Investigated Scenario



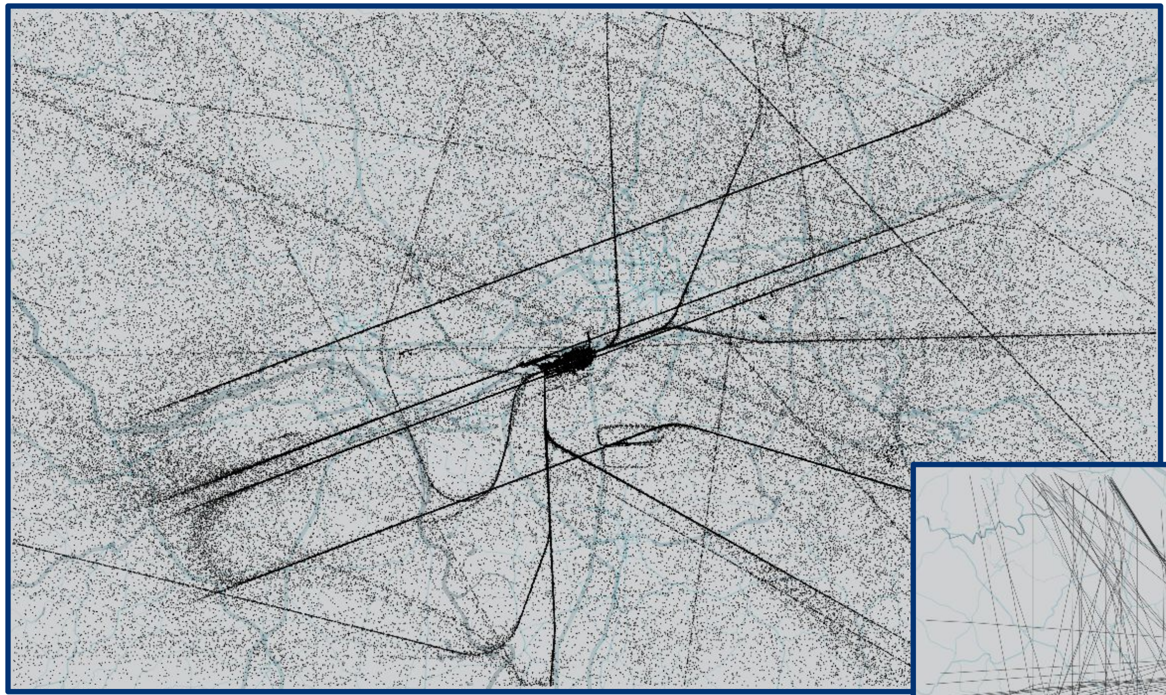
Go-Arounds:
- Go-arounds are standard procedures for ATCOs and Pilots
- On average 3 out of 1000 approaches result in a go-around

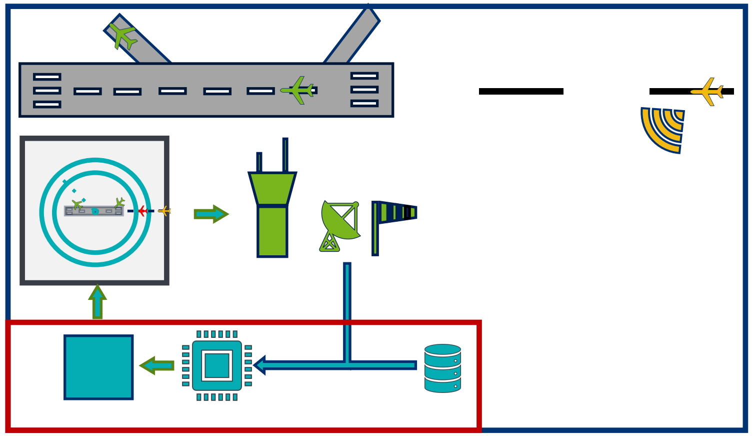
Under certain conditions, go-arounds can become complex:
- High congestion
- Conflicting departure and missed approach procedure

 Knock-on effects:
- Separation challenges
- Wake turbulence challenges
- High (peak) workload for ATCO and Pilots to ensure safety

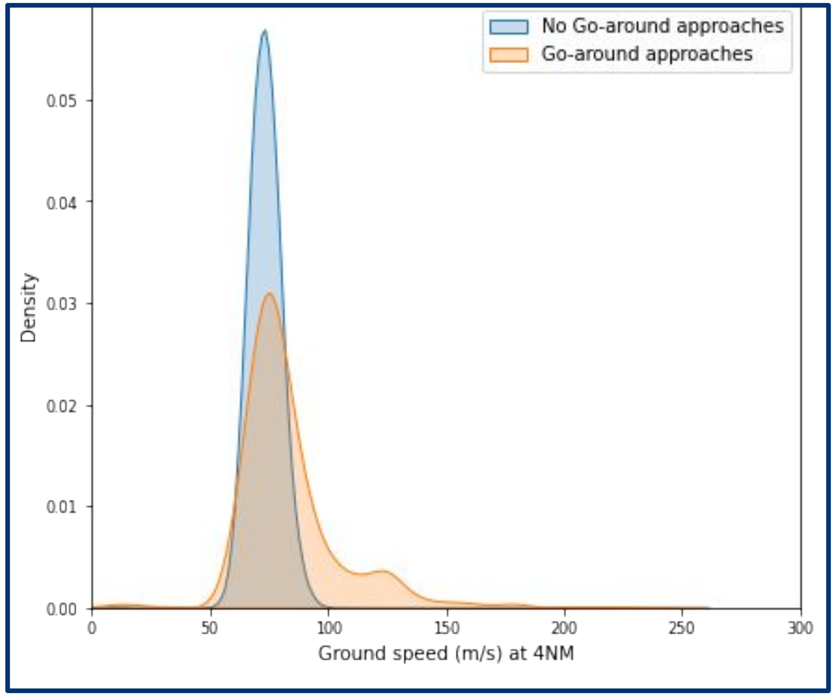


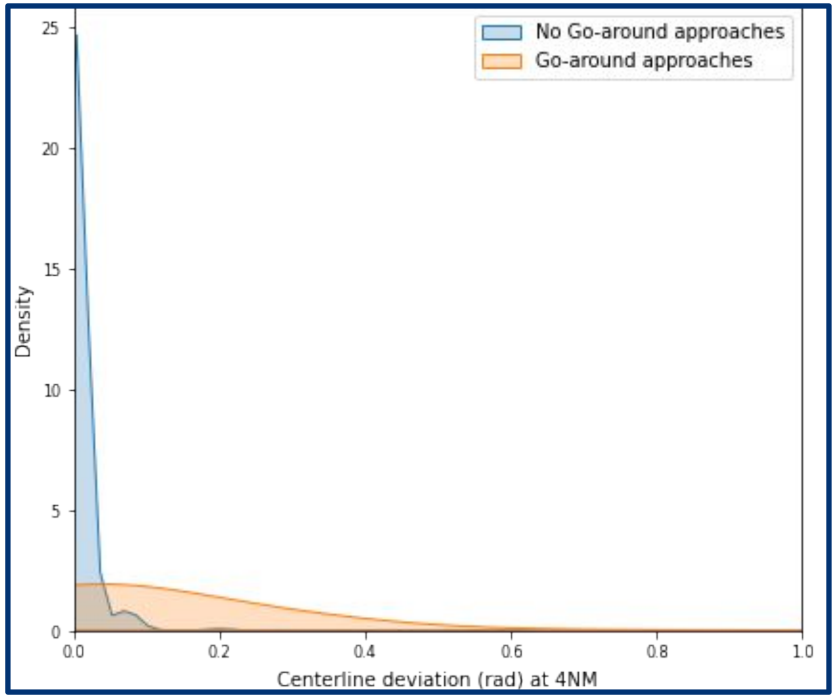
Ai/ML Prototype – Data Pipeline (1)

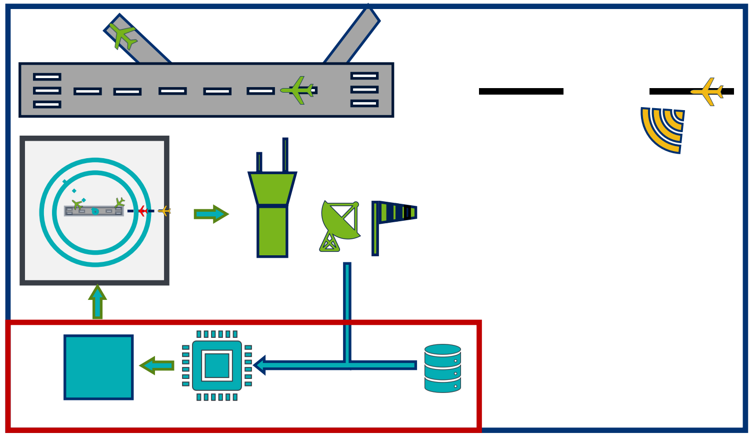




Ai/ML Prototype – Data Pipeline (2)







Training Data (D4.1/D4.2)

Nr. approaches	Nr. Go-arounds	GA/1000 approaches
227044	646	2.85

Ai/ML Prototype - Features

Feature type	Feature name
Flight information	Callsign
	ICAO24
	WTC
	Approach attempt
	Hour
	Day
	Week
Weather data	Wind speed
	Wind direction
	Temperature
	Visibility
	Approach type
	Dew point temperature
	Ceiling height
	Cross-wind
	Head/Tail-wind

Feature type	Feature name
Approach performance	Runway ID
	Specific energy level
	Ground speed
	Vertical speed
	Vertical speed variance
	Track
	Track variance
	Altitude
	Track/Runway Bearing deviation
	Centerline deviation
	Localizer ddm dev
	Glideslope ddm dev
Airport information	Total go-arounds
	Runway go-arounds
	Departures
	Arrivals
	Last departure time
	Last arrival time
	Last departure WTC
	Last arrival WTC
	Aircraft in front
	Closing time

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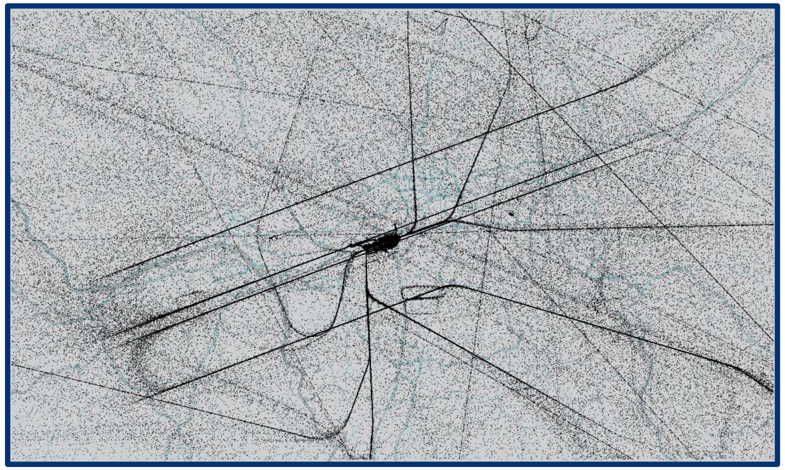
How many % of actual go-arounds are predicted by the AI prototype on average?

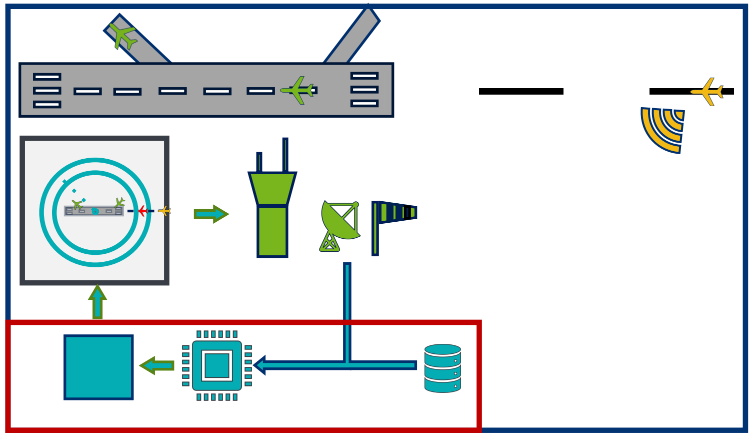
ⓘ Start presenting to display the poll results on this slide.

How many % of approaches that are predicted to become go-arounds, will on average perform a go-around?

ⓘ Start presenting to display the poll results on this slide.

Ai/ML Prototype





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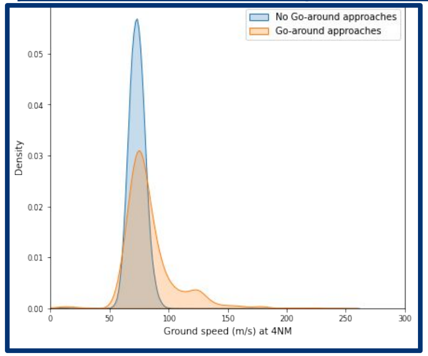

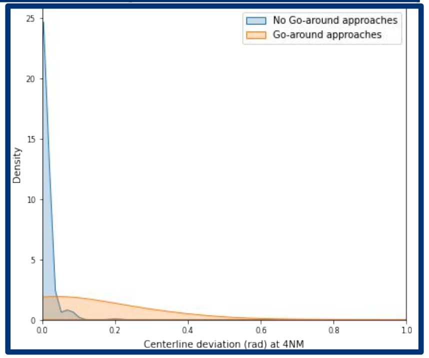

ML Results (D4.1/D4.2)

Prediction point	Go-around	Precision	Recall
2NM	True	0.8800	0.3411
	False	0.9981	0.9999
4NM	True	0.8710	0.2093
	False	0.9977	0.9999
6NM	True	0.9091	0.0775
	False	0.9974	0.9999

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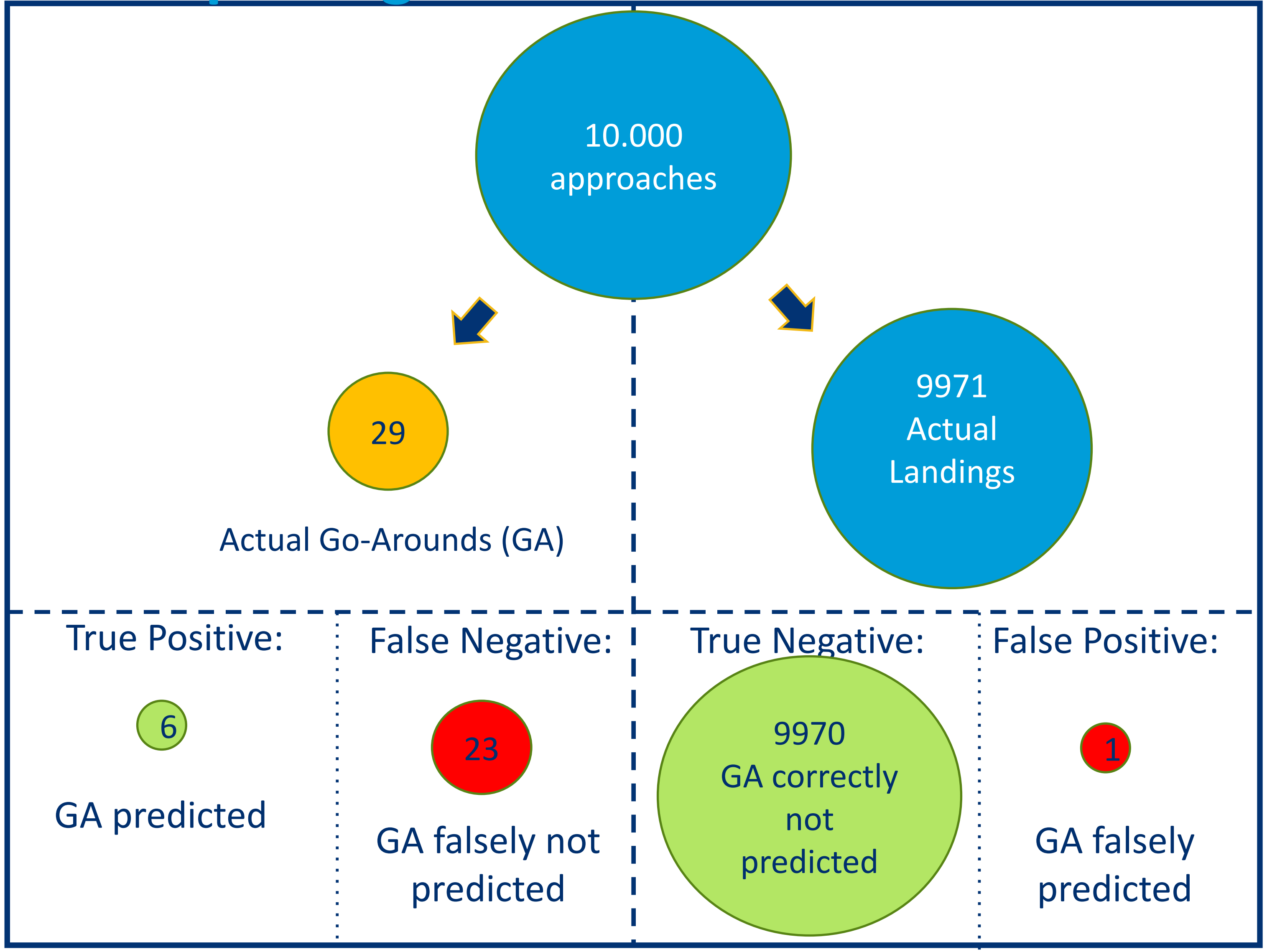
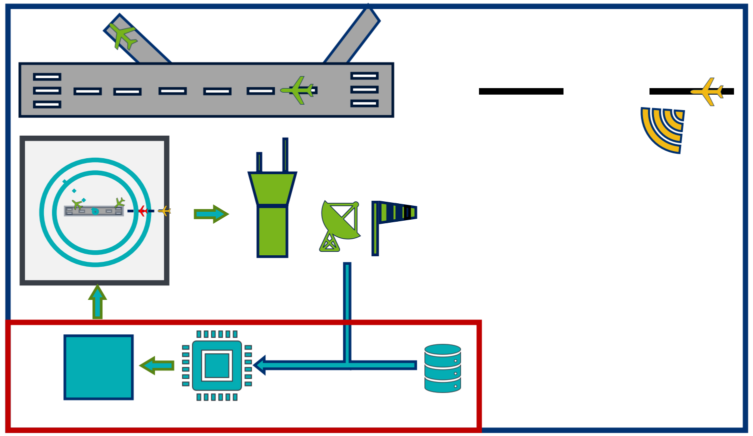
Do you think this Ai tool should be used as landing prediction, to enhance capacity?

ⓘ Start presenting to display the poll results on this slide.

Interpreting Results 4NM





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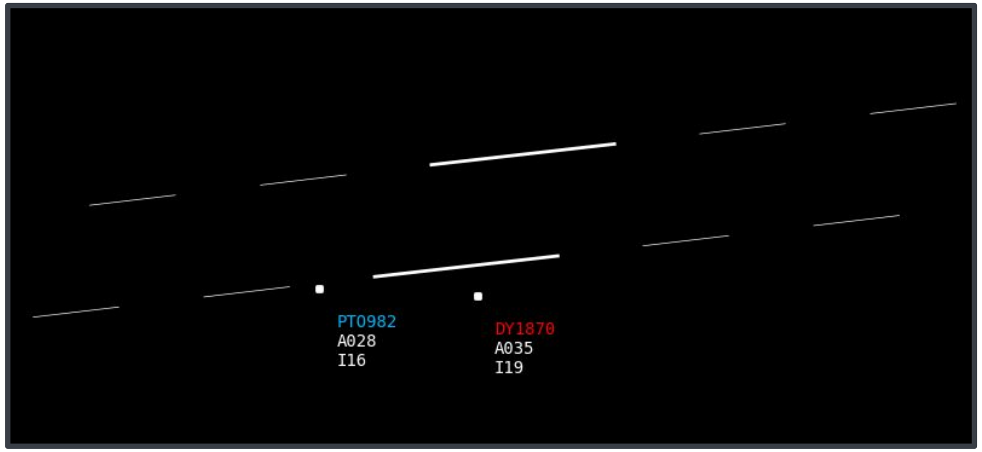
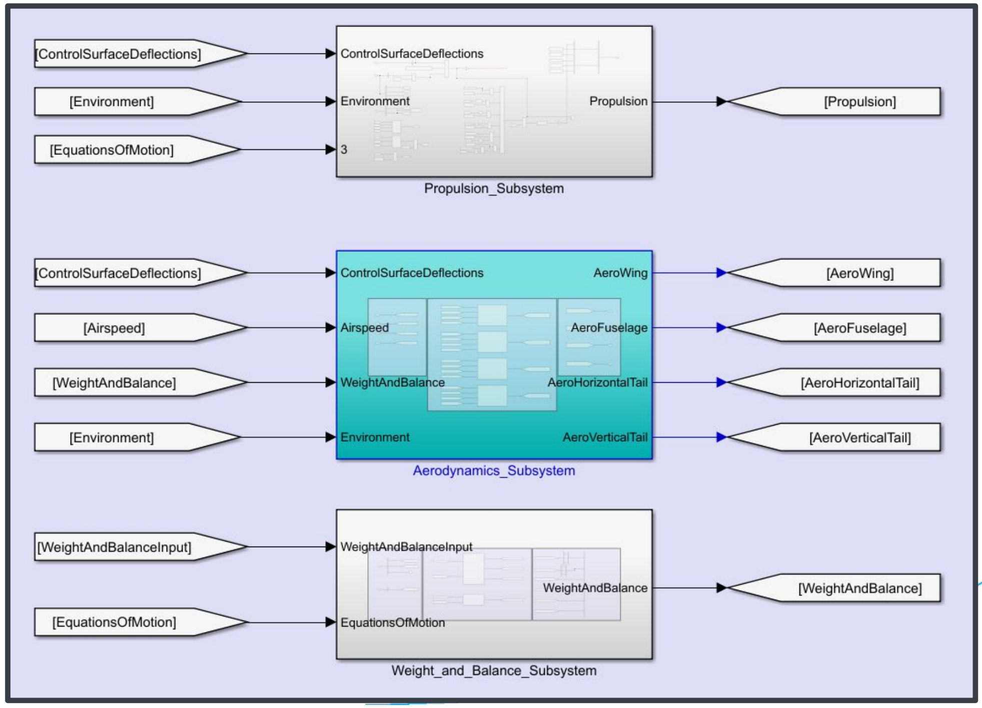
Low Fidelity Simulation Environment

Radar Screen Imitation
- Implemented in Python
- Easy manipulation of colors and information



Approach aircraft model
- Medium type, two-engine aircraft
- Performs approach automatically
- Performs standard missed approach procedure upon command
- Can be controlled according to ATCO’s commands



Departure aircraft model
- Variable WTC aircraft
- Automatically flies a Standard Instrument Departure Route
- Can be controlled according to ATCO’s command

SafeOPS

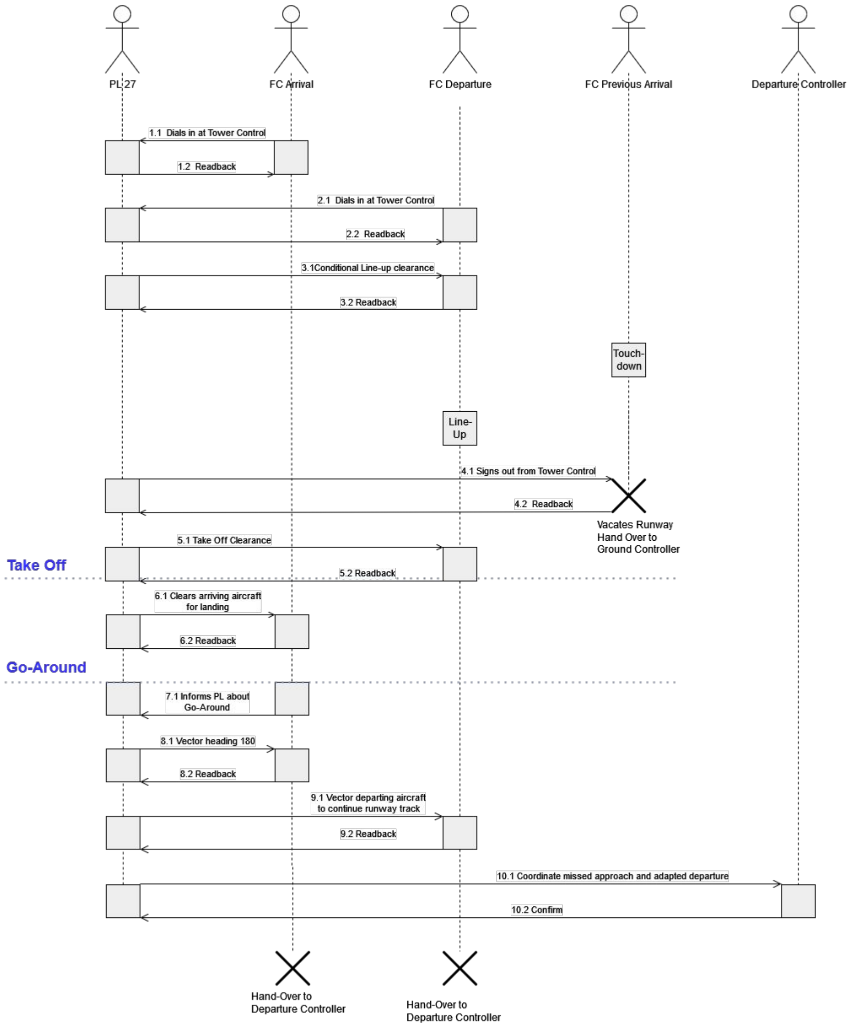
This is an example of the simulation exercises conducted for SafeOPS, where we investigate the effect of go-around forecasts on the approach and go-around handling of Air Traffic Control Officers (ATCOs)

SESAR JOINT UNDERTAKING

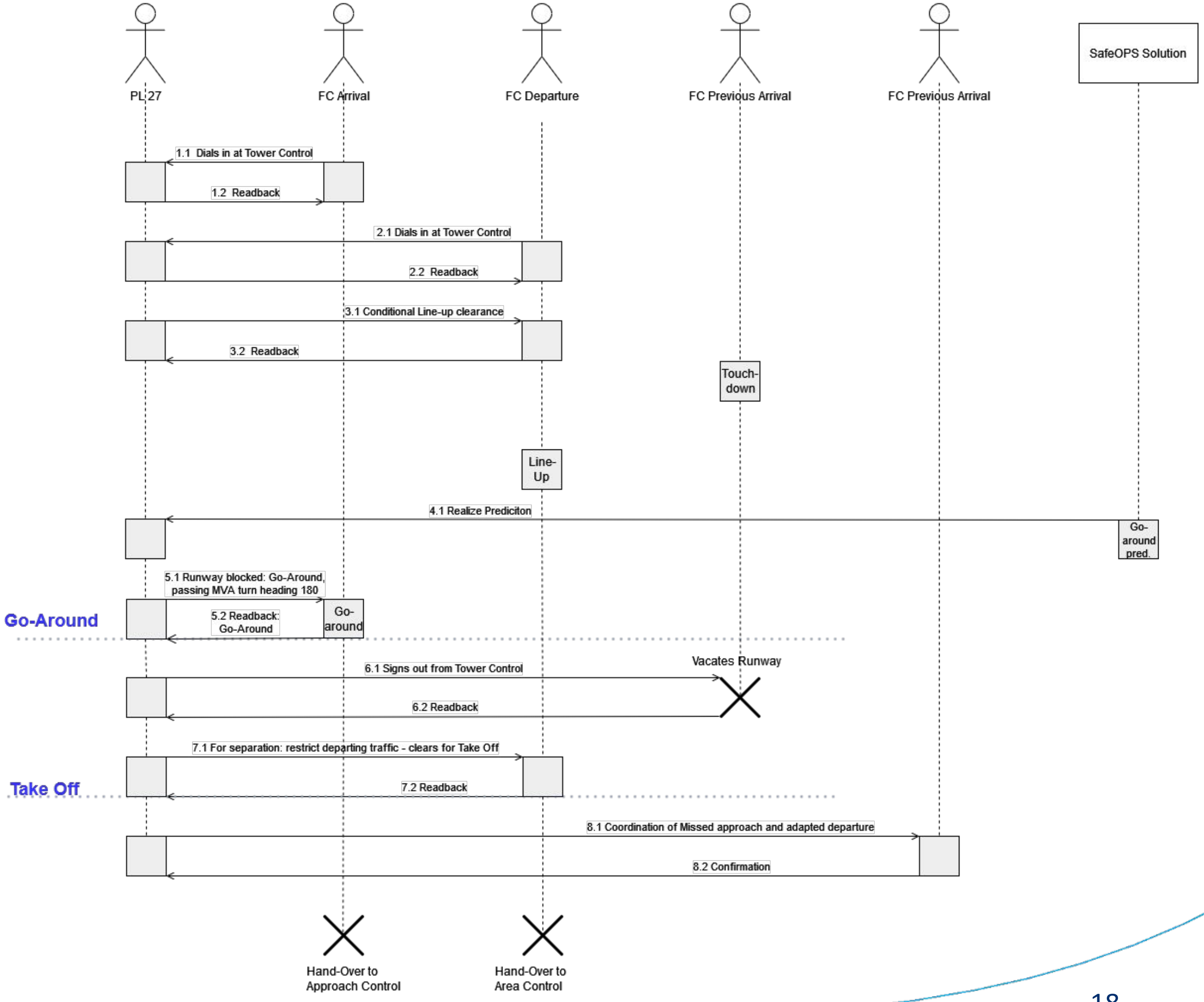
This project has received funding from the SESAR Joint Undertaking (JU) under grant agreement No 892919. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the SESAR JU members other than the Union

Simulation Output (1)

Sequence of Actions w/o Prediction

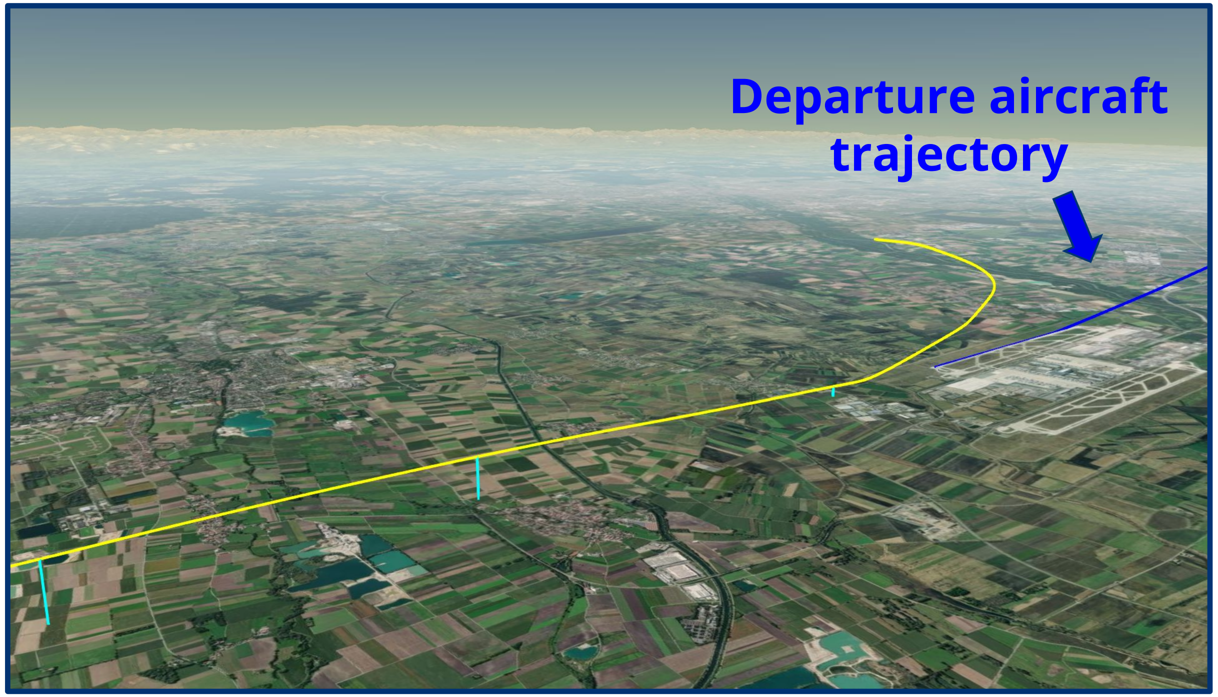


Sequence of Actions with Prediction

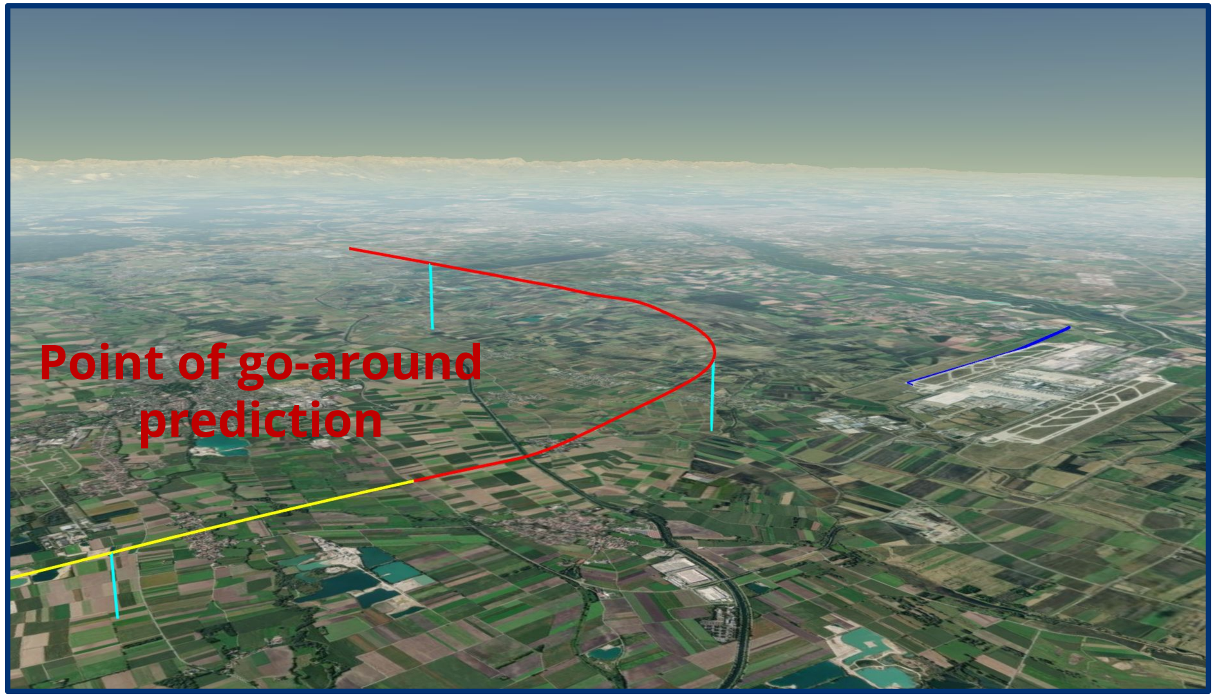


Simulation Output (2)

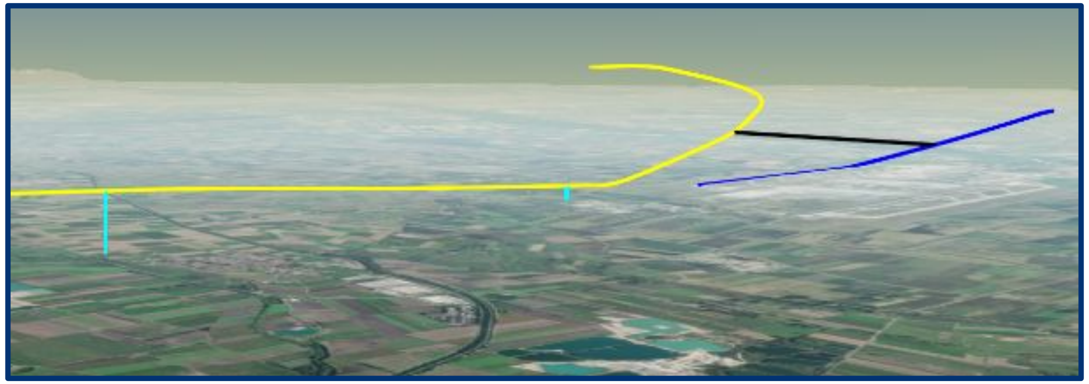
Trajectories of simulated aircraft without prediction



Trajectories of simulated aircraft with prediction



Simulation Metrics



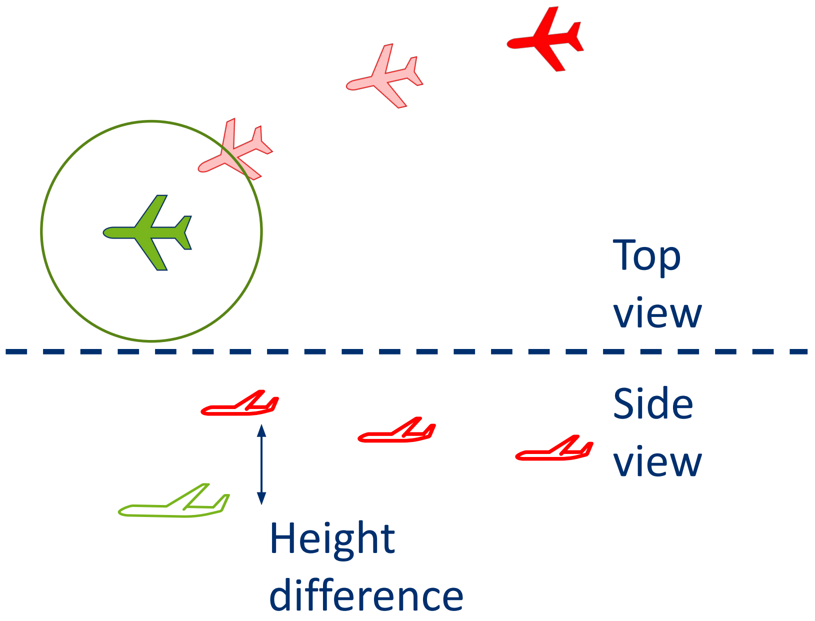
3 (5) Safety Metrics:

Radar separation:

- Horizontal distance if vertical distance is < 1000ft
- Vertical distance if horizontal distance is < 3NM
- Separation infringement (y/n)

Wake separation:

- Height difference, when in proximity of preceding aircraft
- Wake separation infringement (y/n)



3 Resilience Metrics

Workload overall coordinative tasks in the scenario

Peak workload coordinative tasks when both A/C are airborne

2 Capacity Metrics

- Successful Landing
- Successful Departure

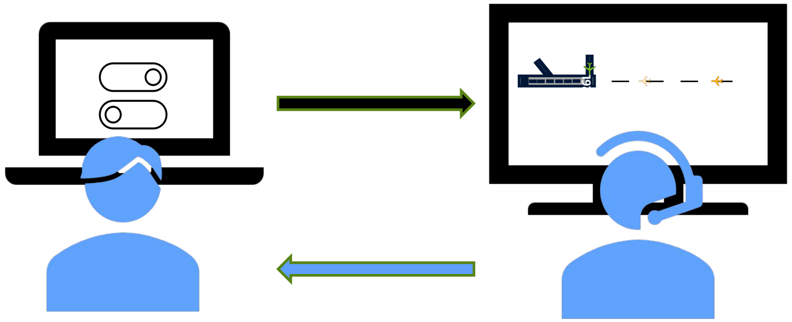
Simulation Exercises

True Positive Exercises:
- Compare state-of-the-art go-arounds with go-arounds including predictions

False Positive Exercises
- Compare false positive go-around prediction with landing scenario

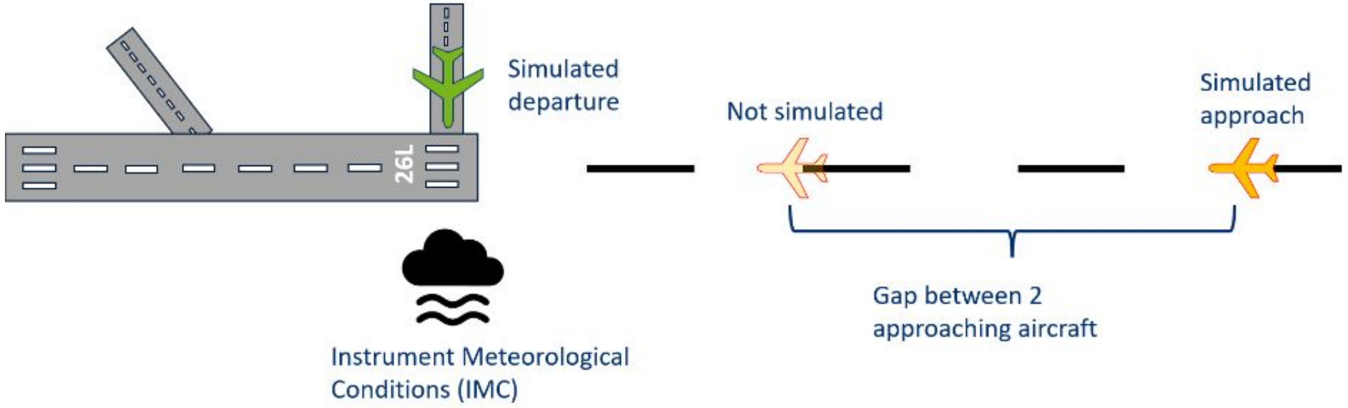
True Negative Exercises
- Compare state-of-the-art landings with correctly, not predicted go-around.

False Negative Exercises
- Compare state-of-the-art go-arounds with wrongly not predicted go-arounds



Simulation Participants:
- 5 ATCOs
- 2 Major European Airports

Simulation Configurations:
Only a few cases investigated:
- Fixed go-around initialization point
- 2 departure AC types
- Fixed approach performance
- No wind



Simulation Configuration Example

ID:	Dep.Cfg1		
Airport 2	**RWY (take-off)**	**SID**	**Gap between approaches**
	26L	S-SID	5NM
WX	IMC Conditions, no wind, ISA standard		

Aircraft Type	**V1**	**VR**	**V2**
Medium twin engine	142 kt	142 kt	150 kt

ID:	App.Cfg.1			
Airport 2	**IAP**	**Landing, if not commanded otherwise**	**MA init from RTH, if not requested from ATCO earlier.**	**Missed approach predicted at xxNM from RWY Threshold**
	ILS 26L	Yes	n.a.	n.a.
WX	IMC Conditions, no wind, ISA standard			

Aircraft Type	**VAPP**
Medium twin engine	135 kt

Simulation Exercises

Exercise ID:	Reference Scenarios			Solution Scenario		
	Scenario ID	Departure Configuration	Approach Configuration	Scenario ID	Departure Configuration	Approach Configuration
FP.1	RS.Landing.1	Dep.Cfg.1	App.Cfg.1	SS.FalsePositive.1	Dep.Cfg1	App.Cfg.6
FP.2				SS.FalsePositive.2		App.Cfg7
FP.3				SS.FalsePositive.3		App.Cfg.8
FP.4	RS.Landing.2	Dep.Cfg.2		SS.FalsePositive.4	Dep.Cfg2	App.Cfg.6
FP5				SS.FalsePositive.5		App.Cfg.7
FP.6				SS.FalsePositive.6		App.Cfg.8
TP.1	RS.GoAround.1	Dep.Cfg.1	App.Cfg2	SS.TruePositive.1	Dep.Cfg1	App.Cfg.3
TP.2				SS.TruePositive.2		App.Cfg4
TP.3				SS.TruePositive.3		App.Cfg.5
TP.4	RS.GoAround.2	Dep.Cfg.2		SS.TruePositive.4	Dep.Cfg2	App.Cfg.3
TP.5				SS.TruePositive.5		App.Cfg4
TP.6				SS.TruePositive.6		App.Cfg.5

Simulation Results

Summarizing results

True Positive				False Positive			
Prediction Point	Safety	Resilience	Capacity	Prediction Point	Safety	Resilience	Capacity
2NM	o	o	o	2NM	o	o	o
4NM	+	+	o	4NM	o	-	-
6NM	+	+	-	6NM	o	-	-

Conclusion

!

Simulation Exercise is limited through
- 2 aircraft types
- 1 fixed go-around initialization point

!

Monte Carlo based simulations needed
- To many variable parameters in the simulation
- Not possible to cover the complete operational context with humans in the loop

!

Use Case Frequency is relatively low:
- Go-arounds are ‘rare’
- Most relevant when conflicting SID and missed approach procedure
- Increase of use cases, in case ATM Master Plan ambitions will be (partially) achieved

!

Safety Capacity Trade-Off:
- Cost evaluation needed

 Define requirements for the minimum acceptable precision

Next Steps

Define the Operational Design Domain:
- Which types of aircraft are covered?
- Which performances are covered (swing overs)?
- Which weather conditions are covered?

Data Quality Requirements:
Objective DM-01[1]: The applicant should capture DQR for all data pertaining to the data management process…
 Avoid "Garbage In, Garbage Out"

Demonstrate real time capabilities:
- Pre-processing
- Feature computation

[1]https://www.easa.europa.eu/en/downloads/134357/en

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