NOSTROMO Project

NEXT-GENERATION OPEN-SOURCE TOOLS FOR ATM PERFORMANCE MODELLING AND OPTIMISATION

03/09/2021 – Engage KTN Workshop

TC2 ‘Machine Learning, AI and automation in ATM’

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NOSTROMO WP3 Leader, <Francisco Camara (DTU)>

Founding Members

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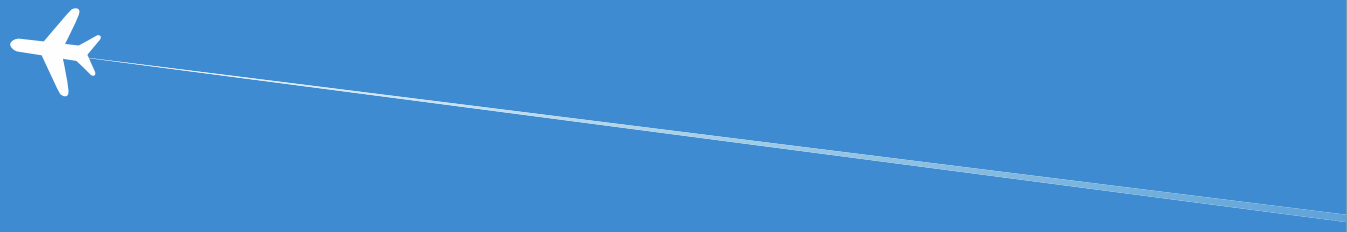
Introduction to NOSTROMO Project



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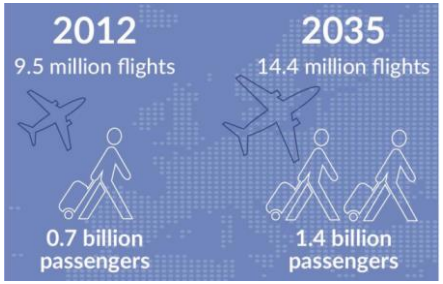
SESAR Programme: ATM MP Performance Ambitions



SESAR: A performance-driven programme

Technological pillar of SES

Key performance area	SES High-Level Goals vs. 2005	Key performance indicator	SESAR ambition vs. baseline 2012 — Absolute saving	SESAR ambition vs. baseline 2012 — Relative saving
Cost efficiency: ANS productivity	Reduce ATM services unit cost by 50% or more	• Gate-to-gate direct ANS cost per flight - Determined unit cost for en-route ANS* - Determined unit cost for terminal ANS*	EUR 290-380	30-40%
Operational efficiency	-	• Fuel burn per flight (tonne/flight) • Flight time per flight (min/flight)	4-8 min 0.25-0.5 tonne	3-6 % 5-10 %
Capacity	Enable 3-fold increase in ATM capacity	• Departure delay (min/dep) - En-route air traffic flow management delay* - Primary and reactionary delays all causes • Additional flights at congested airports (million) • Networkthroughput additional flights (million)	1-3 min 0.2-0.4 (million) 7.6-9.5 (million) Additional flights, not saving	10-30 % 5-10 %[1] 80-100 %[2]
Environment	Enable 10 % reduction in the effects flights have on the environment	• CO_2 emissions (tonne/flight) - Horizontal flight efficiency (actual trajectory)* - Vertical efficiency - Taxi-out phase	0.79-1.6 tonne	5-10 %
Safety	Improve safety by factor 10	• Accidents with ATM contribution	No increase in accidents	Improvement by a factor 3-4
Security	-	• ATM related security incidents resulting in traffic disruptions	No increase in incidents	

Metrics with monetary value in business view

* Targeted by the Performance Scheme

[1] Additional flights that can be accommodated at congested airports, representing 5-10 % of flights at congested airports (~31 % of14,4 (million) flights in 2035).
[2] Additional traffic accommodated in 2035 in comparison with 2012 and associated with ANSP productivity gains, enabled by SESAR. Note: Numbers are rounded.

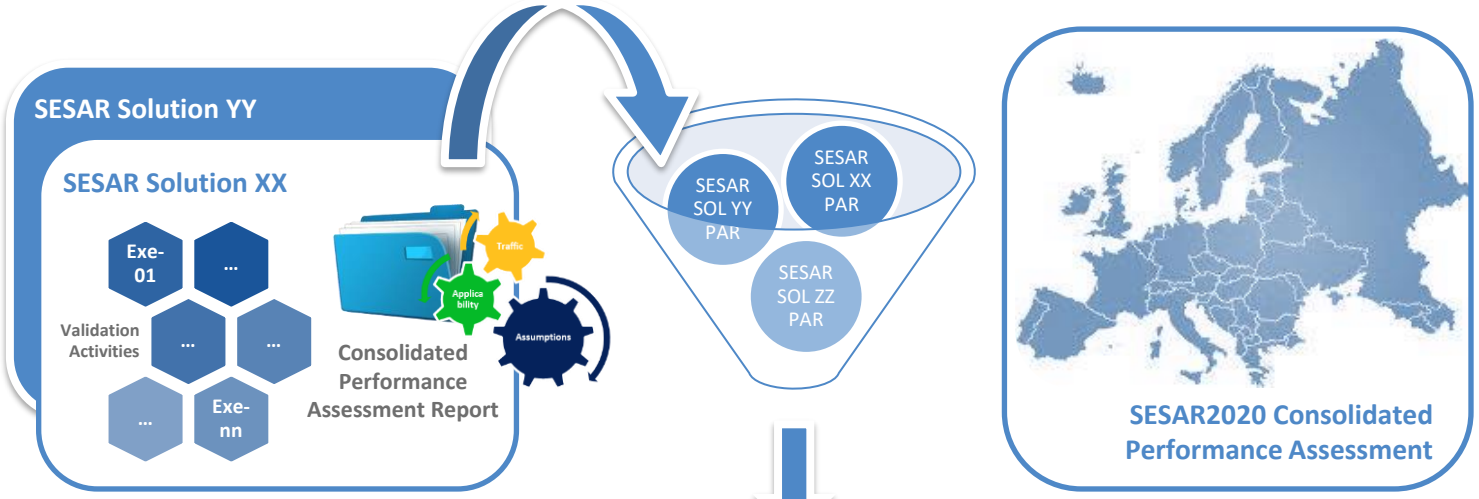
Why do we need Performance Assessment?

How can be known that a SESAR Solution will bring the expected benefits?

How can be justified that a SESAR Solution is ready for deployment and industrialisation?

How can be known if it is necessary to plan additional assessments or propose new concepts?

SESAR Performance Framework



A framework to support the goal of ensuring that the SESAR Programme develops the operational concept and technology needed to meet the performance ambitions described in the ATM Master Plan.

It provides a single, common reference and methodology to be applied consistently ensuring coherency of Performance results at programme level.

NOSTROMO Project: The Challenge

Evaluation of the impact of new ATM concepts and technologies at a system-wide level

Macroscopic Models

+ Easy to compute

+ Easy to explain and communicate results to decision makers

- No results on network effects

- Supported by expert judgement (no empirical evidence)

+ Realistic model of ATM components' behaviours and their interrelations due to new solutions

- High computational costs

- Complex results analysis and communication

Microscopic Models

NOSTROMO Project: Objectives

NOSTROMO project aims to develop, demonstrate and evaluate an innovative modelling approach for the assessment of the performance impact of future ATM concepts and solutions at ECAC network level, providing both a realistic representation of ATM system and model transparency, computational tractability and ease of use.

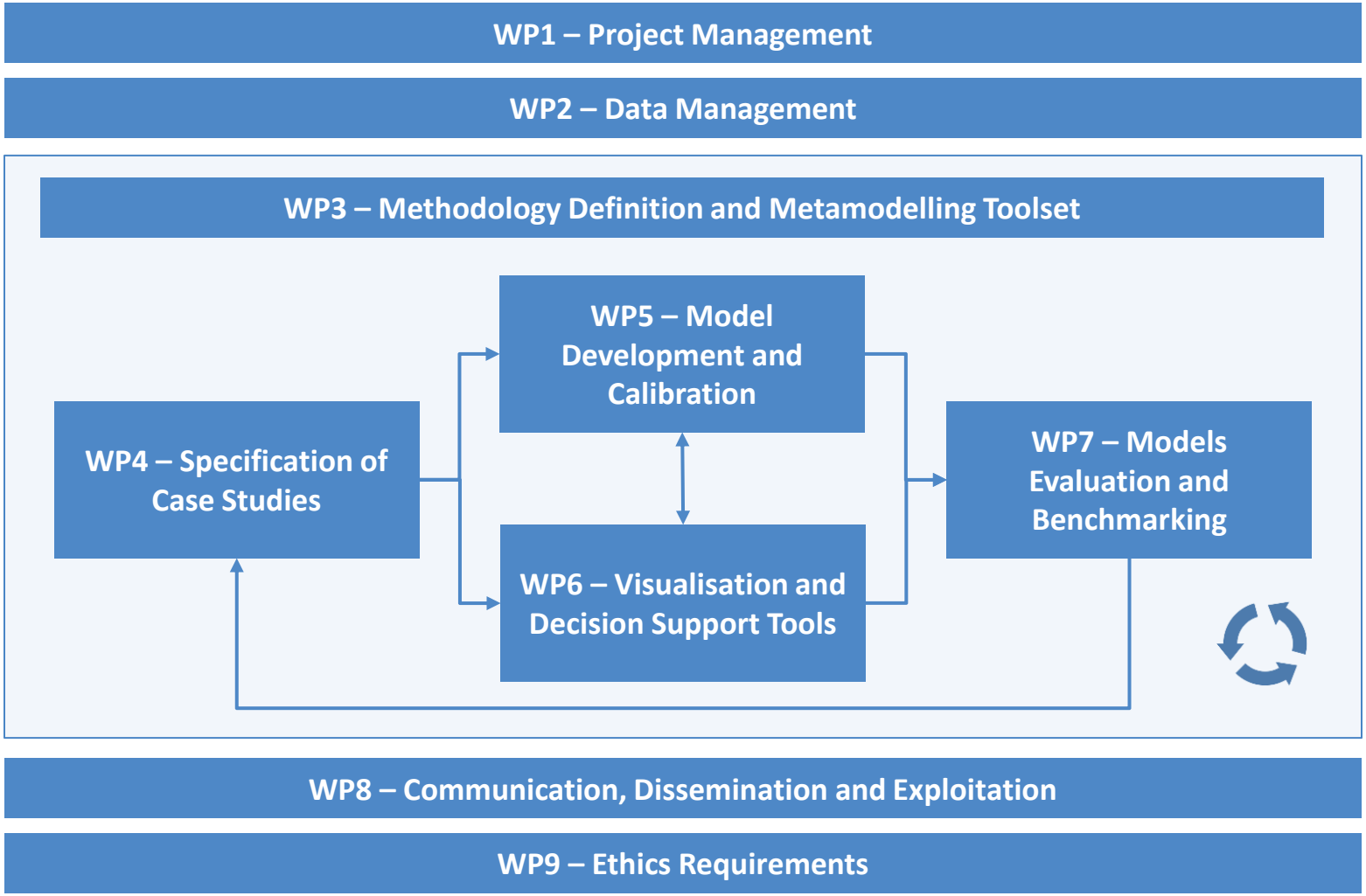
Develop a methodology for the construction of ATM performance metamodels, by exploiting recent advances in the field of active learning.

Implement the proposed metamodelling methodology by developing Open-Source metamodels of two state-of-the-art microsimulation tools (Mercury and FLITAN) able to reproduce ATM performance at ECAC level.

Develop a set of visualization and visual analytics tools that facilitate the analysis, interpretation and communication of the results of the new performance metamodels.

Demonstrate and evaluate the maturity of the NOSTROMO approach and the capabilities of the newly developed toolset through a set of case studies.

NOSTROMO Project: Work Breakdown Structure



NOSTROMO Project: Consortium

CRIDA

Performing validation activities (WP7)

NOMMON

Definition of visualisation and visual analytics tools (WP2 & 6)

UNIVERSITY OF WESTMINSTER

Development of micro-models (WP5)

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Application of e-OCVM (WP4)

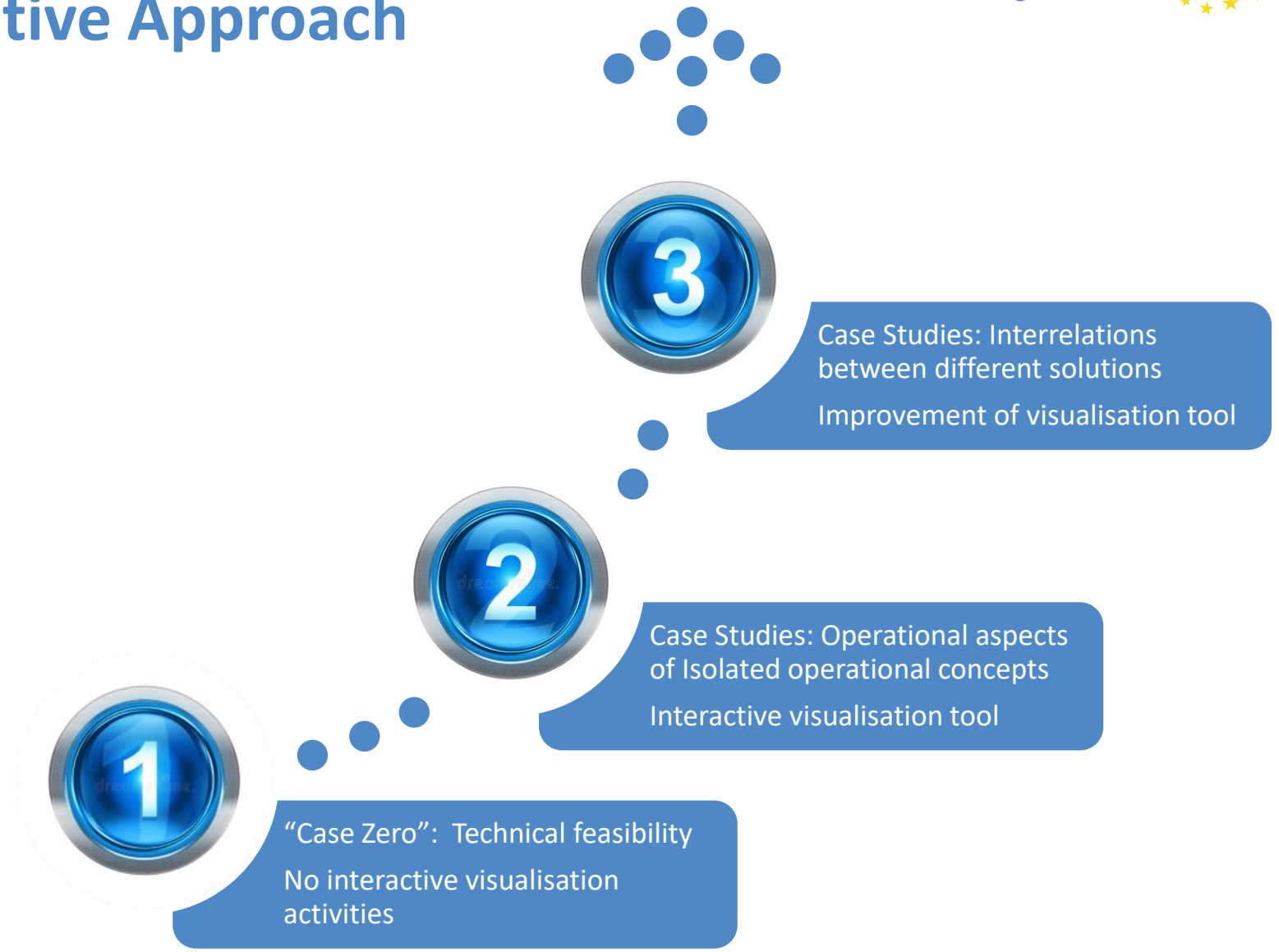
Technical University of Denmark DTU

Application of active learning Metamodelling techniques (WP3)

ISA Innovation for Sustainable Aviation

Development of micro-models

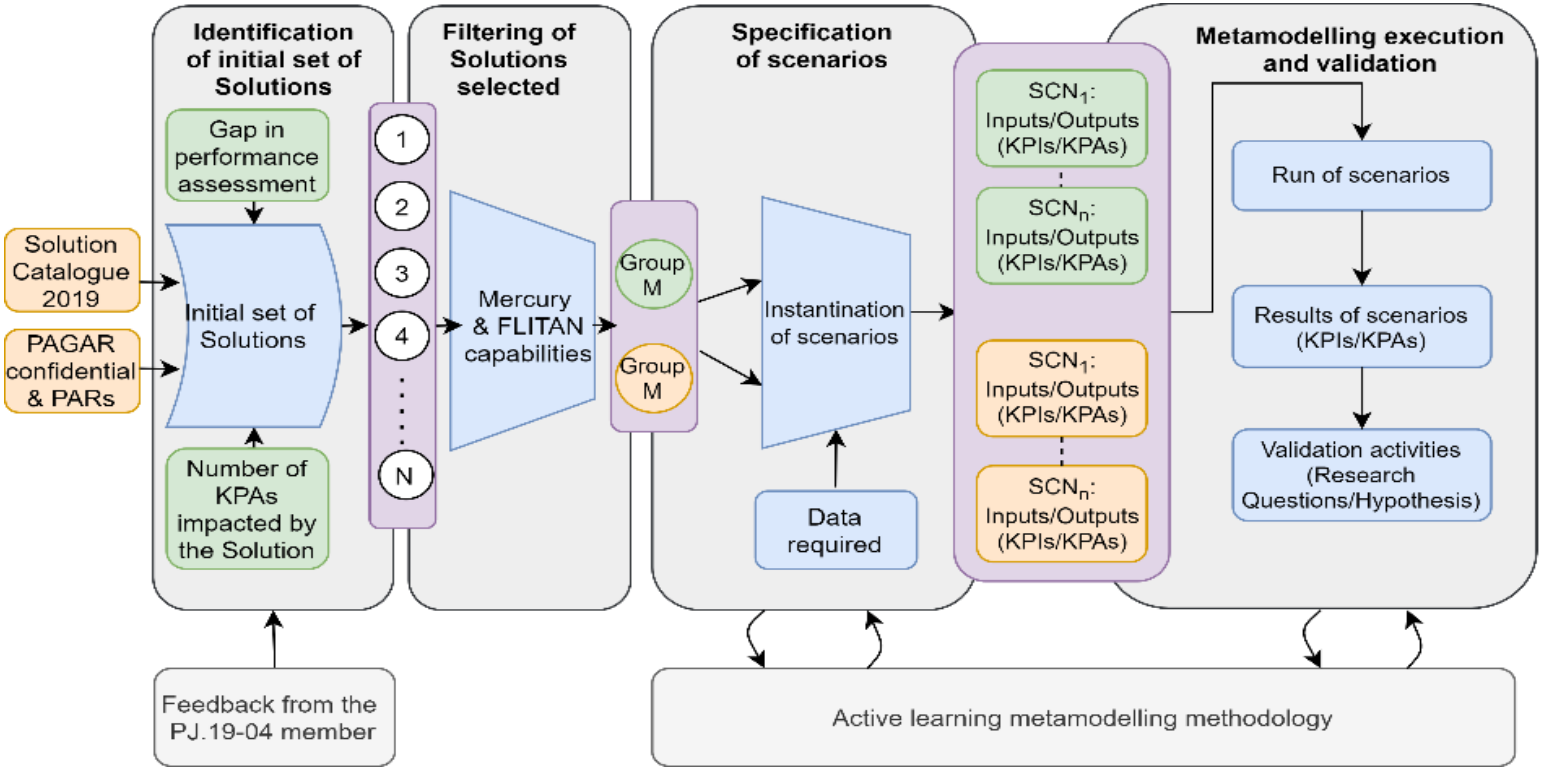
NOSTROMO Project: Incremental and Iterative Approach



Proposed Case Studies

Preliminary Specification of Cases Studies – General Approach

Top-down Approach



Bottom-up Approach

Preliminary Specification of Cases Studies – Top-down Approach

Solutions at V3 in SESAR 2020 Wave 1

Sol.	FEFF	APT CAP	TMA CAP	ENR CAP	PRD	PUN	ATCO	TECH	SAF	HP
PJ.01-06	ok								Yes	Yes
PJ.02-01	H-	H+			ok				Yes	Yes
PJ.02-02	ok	M-					ok		Yes	Yes
PJ.02-03	ok	H+					ok		Yes	Yes
PJ.02-05	ok				ok				Yes	Yes
PJ.02-08	ok	H+	H-		H-	ok			Yes	Yes
PJ.03a-04	ok				M-	M-	ok		No	Yes
PJ.03b-05									Yes	Yes
PJ.05-02							M+		Yes	Yes
PJ.06-01	H-				ok				Yes	Yes
PJ.10-01a	M-				ok		M-		Yes	Yes
PJ.10-02a	M-		ok	H+	ok		H-		Yes	Yes
PJ.11-A1									N/A	Yes
PJ.14-02-02									N/A	N/A
PJ.14-02-06									N/A	N/A
PJ.14-03-04									N/A	N/A
PJ.15-01								ok	N/A	N/A
PJ.15-02								ok	N/A	N/A
PJ.15-10								ok	N/A	N/A
PJ.15-11								ok	N/A	N/A
PJ.16-03								ok	N/A	N/A
PJ.17-01									N/A	N/A
PJ.18-02b	ok		M-	M-			ok		N/A	N/A
PJ.18-02c	ok		ok	M-	ok	ok	ok		Yes	N/A
18-04a					ok				N/A	N/A
8-04b	ok								N/A	N/A
06a	M-								N/A	N/A

Solutions non-fully V3

Sol.	FEFF	APT CAP	TMA CAP	ENR CAP	PRD	PUN	ATCO	TECH	SAF	HP
PJ.01-01	M-		H-		M-	M-			No	Yes
PJ.01-02	H-		H+		H-	H-	M-		Yes	Yes
PJ.01-03A			ok		ok		ok		Yes	Yes
PJ.01-03B	M-				ok		ok		N/A	Yes
PJ.01-03C							ok		N/A	No info
PJ.01-05	ok	M+	M+		M+		ok		N/A	Yes
PJ.01-07	ok								N/A	N/A
PJ.02-06	ok				ok				No	No info
PJ.02-11	ok		ok		M-		ok		Yes	Yes
PJ.03a-01	ok				M-		ok		Yes	Yes
PJ.03a-03	ok								N/A	N/A
PJ.03a-09									Yes	Yes
PJ.03b-01									Yes	Yes
PJ.03b-03									Yes	Yes
PJ.03b-06		ok							Yes	Yes
PJ.04-01	ok		ok		M-	ok			No	No info
PJ.04-02	ok				ok	H-			No	No info
PJ.05-03							M+	H-	Yes	Yes
PJ.05-05									N/A	N/A
PJ.06-02	ok				ok				Yes	Yes
PJ.07-01	M-				M-	ok			Yes	Yes
PJ.07-02						M-			Yes	Yes
PJ.07-03				ok	ok				Yes	Yes
PJ.08-01	ok			H+	ok		ok		Yes	Yes
PJ.08-02	ok			H+	ok		ok		N/A	N/A
PJ.09-01									Yes	No info
PJ.09-02	ok		M-	H+	M-	ok	M+		Yes	Yes
PJ.09-03	ok		H-	H+	M+	M+	M+		Yes	Yes
PJ.10-01b	M-		ok	M-	ok		H-		Yes	Yes
PJ.10-01c	H-				ok		ok		Yes	Yes
PJ.10-02b	ok		H+	H+	ok		M+		Yes	Yes
PJ.10-05									No	Yes
PJ.10-06							M+		Yes	Yes
PJ.11-A2									Yes	Yes
PJ.11-A3									N/A	Yes
PJ.11-A4									Yes	Yes
PJ.11-G1									Yes	Yes

The number of KPAs impacted by the specific solutions

The magnitude of remaining gap - the solutions classified as “H-“ and “M-“

Preliminary Selection of Case Studies: Bottom-up Approach

PJ.01-01	PJ.01-02	PJ.07-01	PJ.07-02
PJ.08-01	PJ.08-02	PJ.09-02	PJ.09-03
PJ.10-01b	PJ.02-08	PJ.06-01	PJ.10-02a
	Mercury Capabilities	FLITAN Capabilities	

Preliminary Selection of Case Studies: Bottom-up Approach

PJ.01-01	PJ.01-02	PJ.07-01	PJ.07-02
PJ.08-01	PJ.08-02	PJ.09-02	PJ.09-03
PJ.10-01b	PJ.02-08	PJ.06-01	PJ.10-02a
	Mercury Capabilities	FLITAN Capabilities	

Preliminary Selection of Case Studies: Bottom-up Approach

PJ.01-01	PJ.01-02	PJ.07-01	PJ.07-02
PJ.08-01	PJ.08-02	PJ.09-02	PJ.09-03
PJ.10-01b	PJ.02-08	PJ.06-01	PJ.10-02a
	Mercury Capabilities	FLITAN Capabilities	

Preliminary Selection of Case Studies

Mercury

- PJ01.01 'Extender Arrival Management (E-AMAN)'
- PJ07.02 'User Driven Prioritization Process (UDPP)'
- PJ09.03 'Collaborative Network Management'

Research Questions:

Test if unified constraint management, (constraints created by the UDPP slot allocation, by the E-AMAN tactical slot allocation etc) is more efficient than decentralised decision-making processes, when solutions like UDPP and E-AMAN are not synchronised (i.e. constraints are not shared).

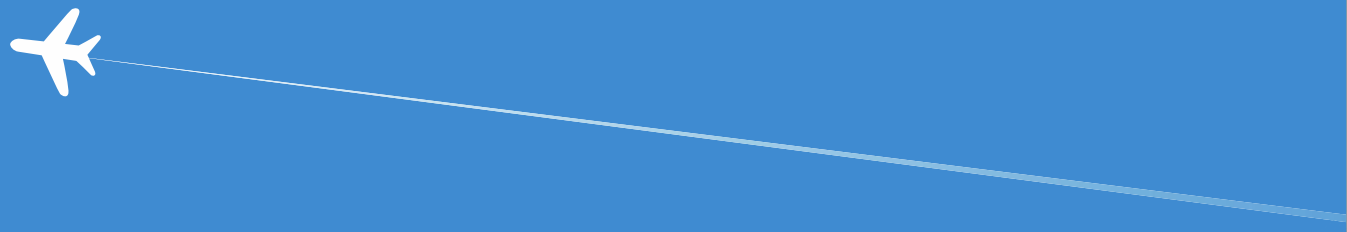
FLITAN

- PJ08.01 'Dynamic Airspace Configuration (DAC)'
- PJ02.08 'Traffic opt. on single and multiple runway a/p'

Research Questions:

What are the overall benefits in terms of capacity, flight efficiency and punctuality of a holistic integration of both en-route and airport operations?

Application of Active Learning: NOSTROMO Methodology



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Active Learning with Simulators

Main problem: **How can we use a simulator to search for policy-relevant values?**

- Systematic exploration is exhausting
- Computational hindrances strongly limit comprehensive scenario analysis

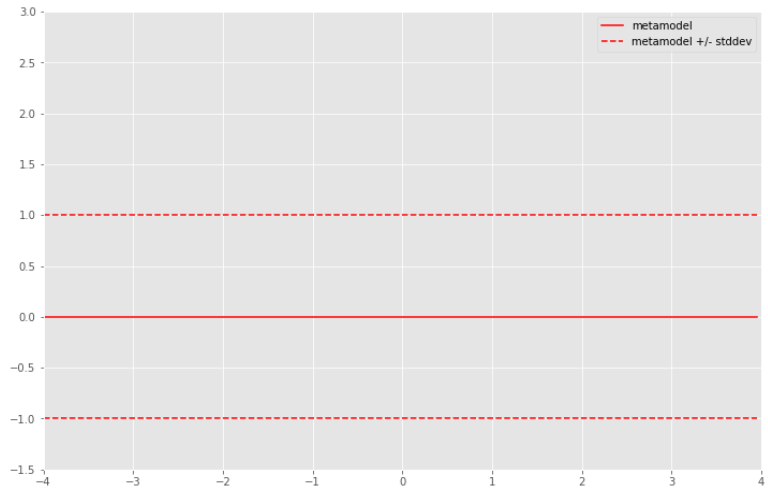
Aims:

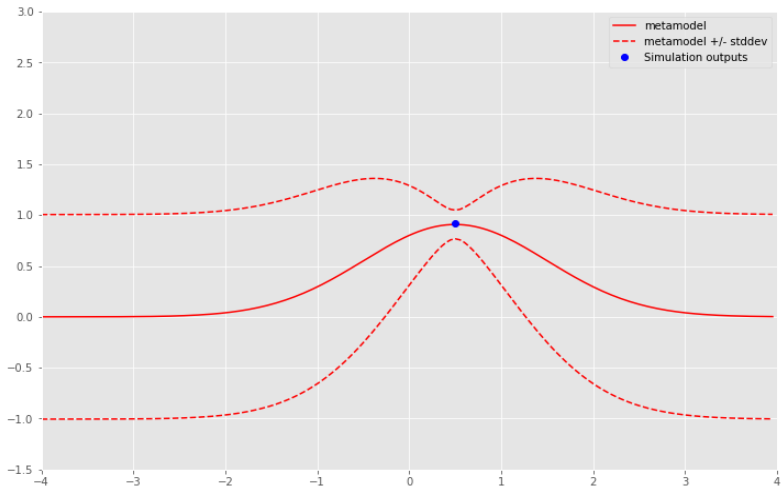
- Avoid redundant simulation runs
- Efficient guidance of simulation analysis
- Predict simulation output values given any input

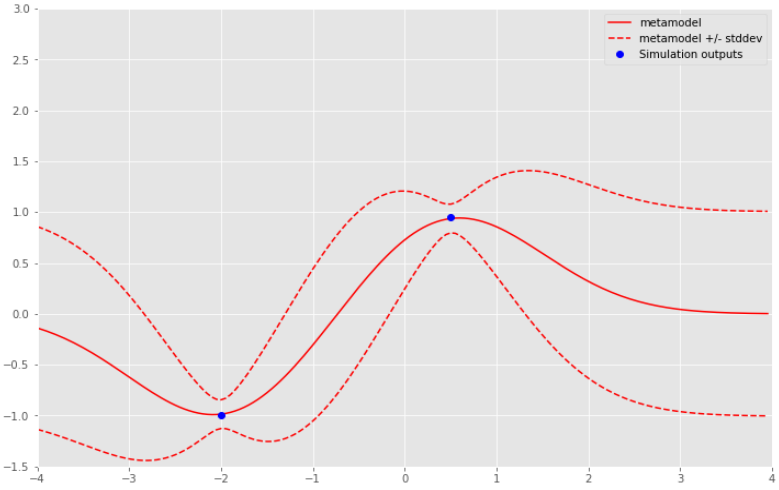
Proposed solution:

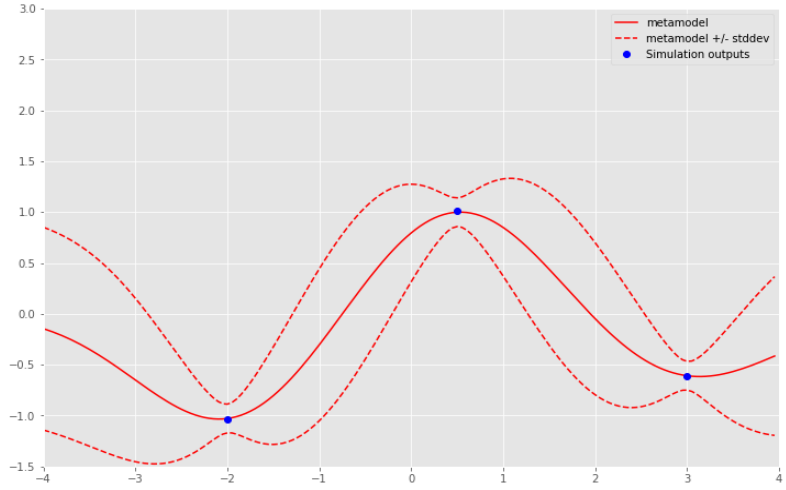
- Integration of active learning and simulation metamodeling
- Active learning → achieve greater performance with fewer data points
- Simulation Metamodeling → approximate the simulation model by a simpler and faster *black box*

Active Learning in general

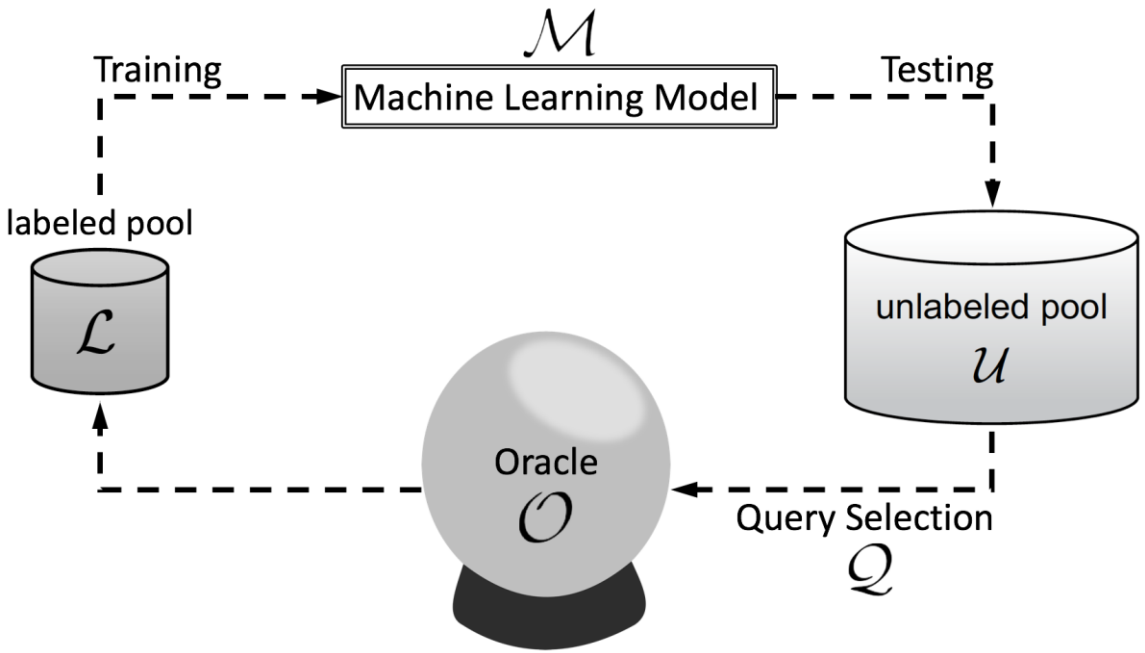








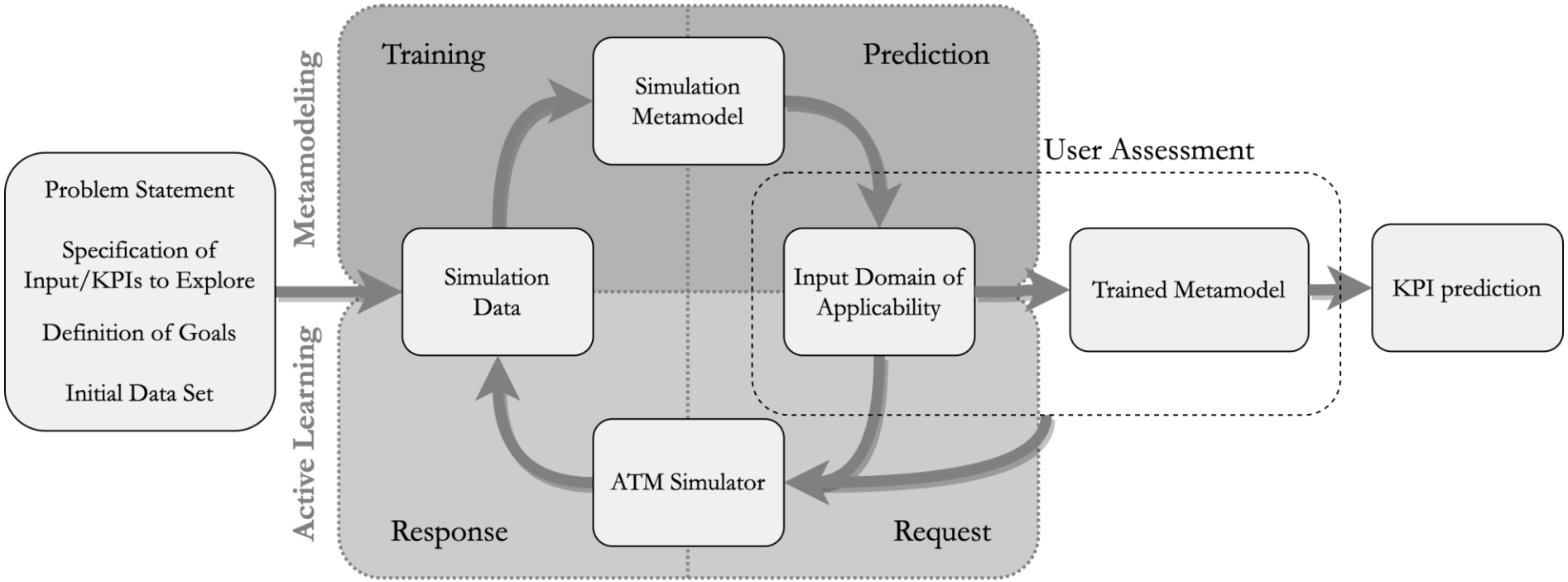
Active Learning in general



- High predictive performance with fewer data points; iterative training/learning process [Angluin (1988), Cohn et al. (1994), Freund (1997)].

- Gaussian Process (GP) framework [Rasmussen and Williams (2005)] allows for an intuitive way of developing active learning algorithms.

Active Learning in NOSTROMO



Active Learning: important notes

Initial data
Should be representative enough, thus initial simulation effort not entirely avoidable

Domain knowledge
Expertise supervision recommended

Retraining of metamodel
Might be required depending on expert's feedback

Trade-off speed VS accuracy
Trade-off constantly tracked and adjusted according to objectives

Approximate nature
Essential to keep in mind the approximate nature when drawing conclusions and improving model

Active Learning: latest results

Test case: Mercury with 1000 flights

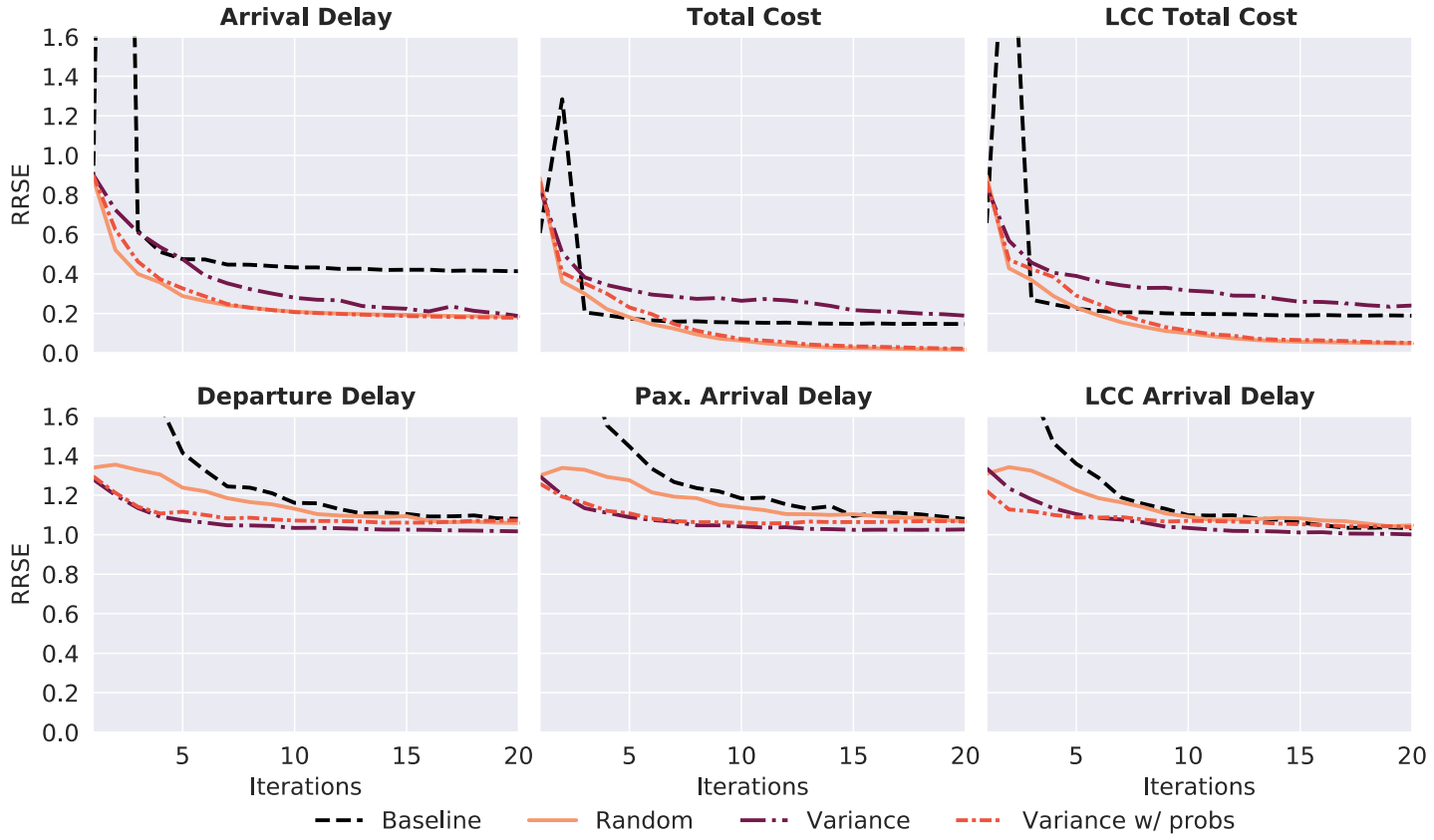
TABLE 1 Summary description of the Mercury input/output simulation variables used for metamodeling.

	var	name	description	values
Inputs	x_1	compensation_magnitude_long1	Compensation between first and second thresholds for long-haul passengers in euros (€)	[0, 500, 1000,..., 5000]
	x_2	first_compensation_threshold	Threshold of arrival time after which the passengers receive a compensation in minutes	[0, 60, 120,..., 480]
	x_3	fuel_price	Price per kilogram of fuel in euros (€)	[0, 0.5, 1,..., 5]
Outputs	y_1	arrival_delay_min_mean	Average arrival delay per flight in minutes	real-valued
	y_2	departure_delay_min_mean	Average departure delay per flight in minutes	real-valued
	y_3	total_cost_mean	Average total cost per flight operation in euros (€)	real-valued, positive
	y_4	pax_tot_arrival_delay_mean	Average total arrival delay per passenger in minutes	real-valued, positive
	y_5	lcc_arrival_delay_min_mean	Average arrival delay per flight for low cost carriers in minutes	real-valued
	y_6	lcc_total_cost_mean	Average total cost per flight for low cost carriers in euros (€)	real-value, positive

Active Learning: latest results

Baseline: Quadratic regression and static sampling (LHS)

Proposal: Active learning with Gaussian Process (3 different strategies)



Active Learning: latest results

Predictions for *arrival delay* after different number of iterations.

0 iterations:

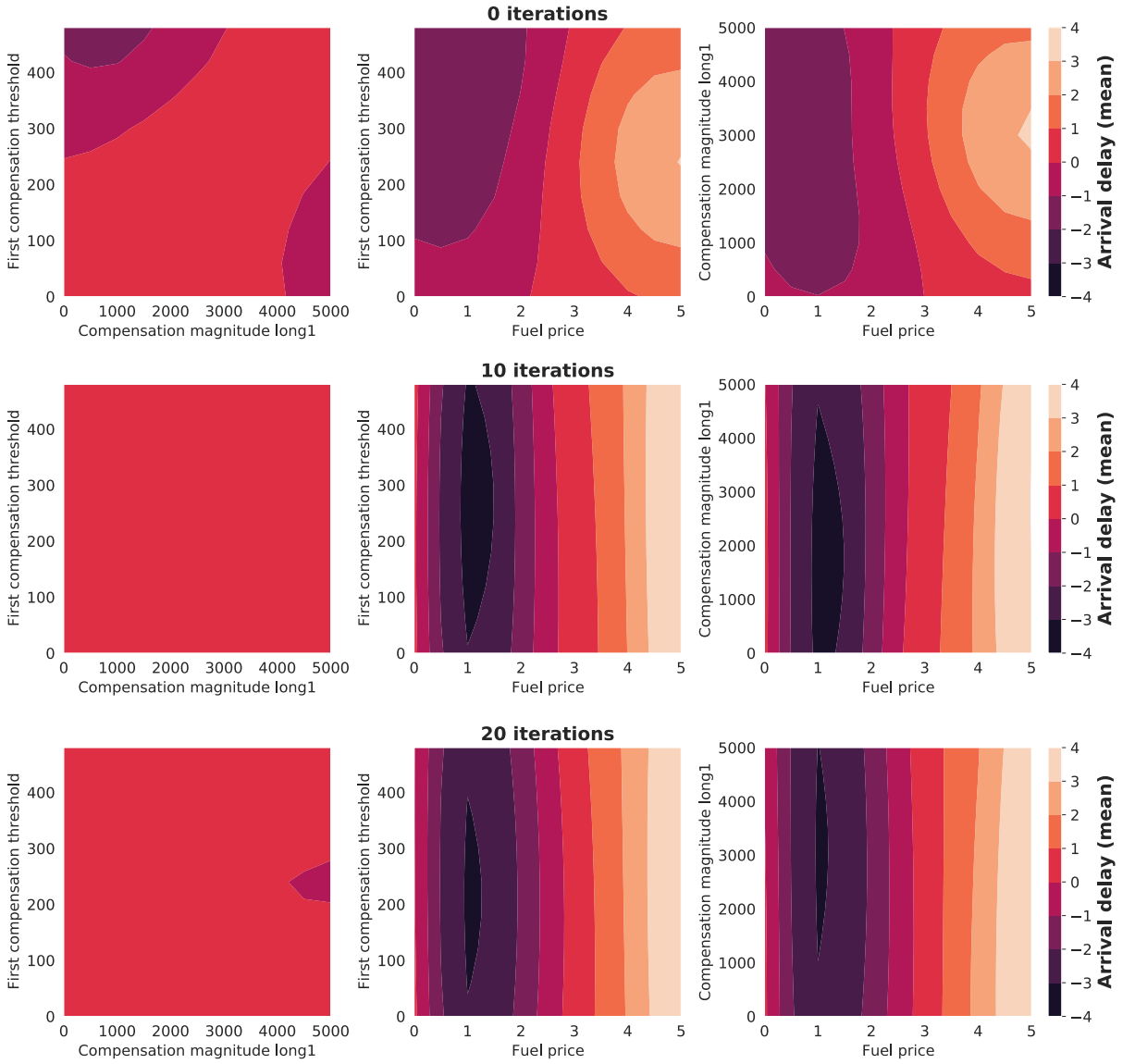
With the initial data, only a vague signal detected.

10 iterations:

Clear trend observed

20 iterations:

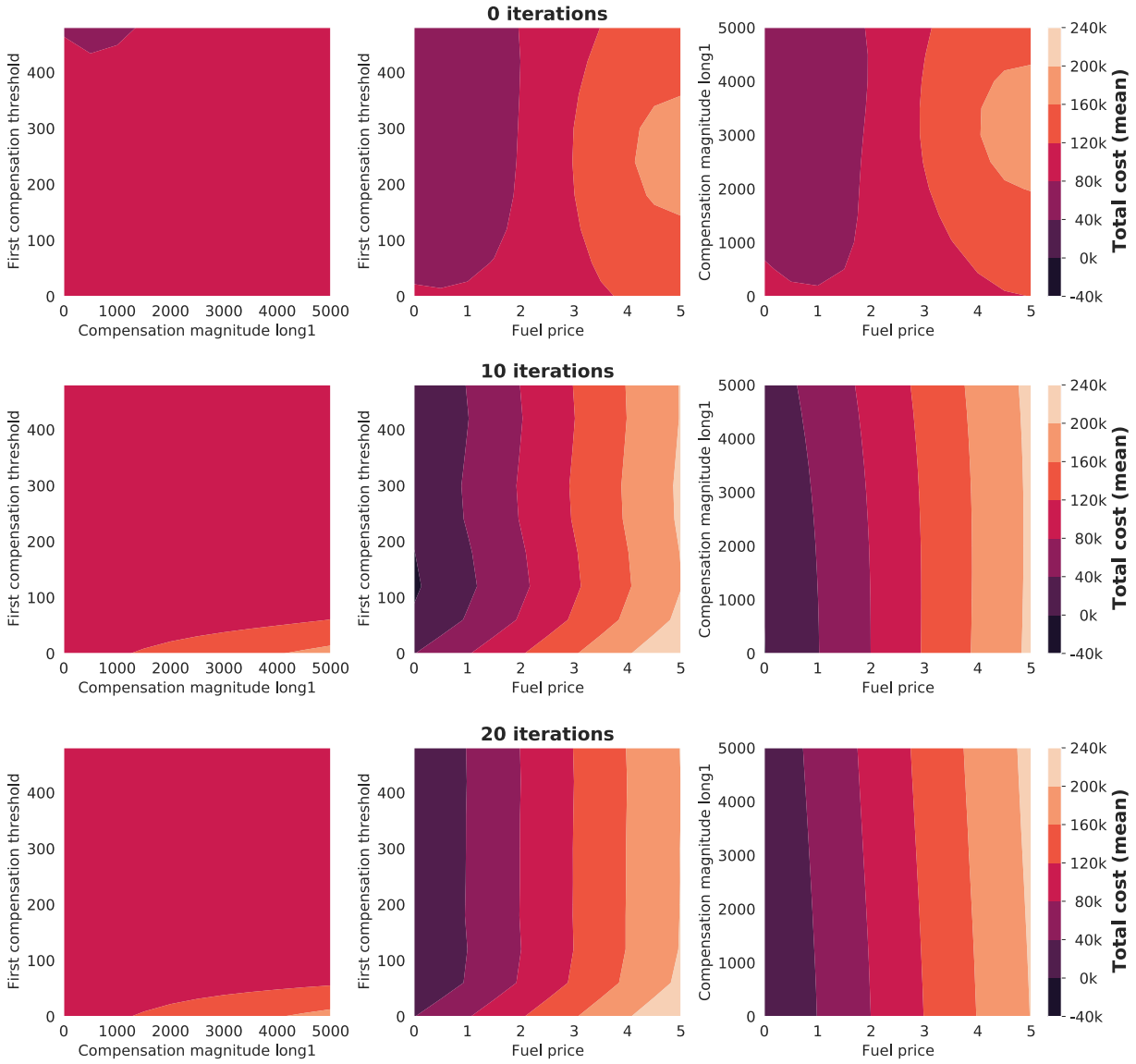
Only minor improvement with the extra iterations.



Active Learning: latest results

The predictions for *total cost* after different number of iterations.

Same conclusions as before.



Next Steps for NOSTROMO

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What are we going to get at the end of the Project?

OBJ#1 - Metamodeling Methodology

Methodology applied to the case studies and guidelines to apply it to other concepts.

OBJ#2 - Metamodels Implementation

Architecture to apply the methodology to the NOSTROMO case studies with the ability of integer new simulators to prove other concepts.

OBJ#3 - Visualisation

Visual dashboard to support the decision-making and to explore the trade-offs between KPAs/KPIs.

OBJ#4 - Evaluation and Benchmarking

Evidences of the methodology feasibility and a benchmark with existing ones.

New approach to ATM performance modelling

Foundation for SESAR 2020 PJ19.04 Wave3 project

Thank you very much for your attention!

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