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European performance assessment – challenges and concepts

Prof Andrew Cook & Centre for Air Traffic Management Research team

FAA *New and Emerging Aviation Technologies* series; 14 November 2023

Overview

European performance assessment – challenges and concepts
—

- **Background and context**
  - team and core areas
  - SESAR context
  - recently completed projects

- **Key concepts** (on-going and prospective)
  - recently launched projects
  - thematic illustrations
    1. reference evaluation of the **cost of delay** to airlines
    2. Mercury: agent-based model for **ATM performance assessment**
    3. Engage 2: European **ATM knowledge transfer network**

- **Q&A and next steps**
  - Q&A (team opportunity)
  - Next steps (more targeted dialogues and exchanges)

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The team and core areas

Background and context

—

- **Centre for Air Traffic Management Research**
  - since 1999, various contexts, Centre *per se*
  - Andrew Cook, Luis Delgado (PRF)
  - Graham Tanner, Gérald Gurtner, Tatjana Bolić (SRF)
  - Elham Zareian, Majid Soolaki, Michal Weiszer (RF)
  - https://www.westminster.ac.uk/ (website & VRE)
- **Core group of strategic European partners (with refresh)**
- **Teaching and visiting students**
  - MSc Air Transport Planning & Management
    - *Air traffic management* (incl. future concepts & ENV impact)
    - *Air transport forecasting & market research*
  - visiting PhD students (France, Spain, India, China)
  - PhDs (internal cf. external)

(Engage 1)

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Background and context

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- **Specialisms of our Centre** (no implied order)
    - performance assessment (from fundamental to industrial)
    - economic analysis (incl. behavioural economics & conjoint)
    - modelling and simulation (incl. ABM, CNT, ML, metamodelling)
    - pax centricity, mobility, multimodality (SESAR award)
    - flight dynamics; flight prioritisation
    - data management
- **Applied research – main funders:**
    - SESAR & Clean Sky (both via Horizon); Horizon 2020/Europe directly ('Smart, green and integrated transport')
    - EUROCONTROL, ANSPs, airlines
    - with wide range of stakeholders, incl. airports, software/service providers; other research institutes
- **'Brexit'**
    - officially left EU January 2020; HE association bedding in (UK as eligible country count from 2024)
- **Major conferences: SIDs, Airspace World, ATM Seminar (FAA/ECTL), EASN; + multimodal, etc.**

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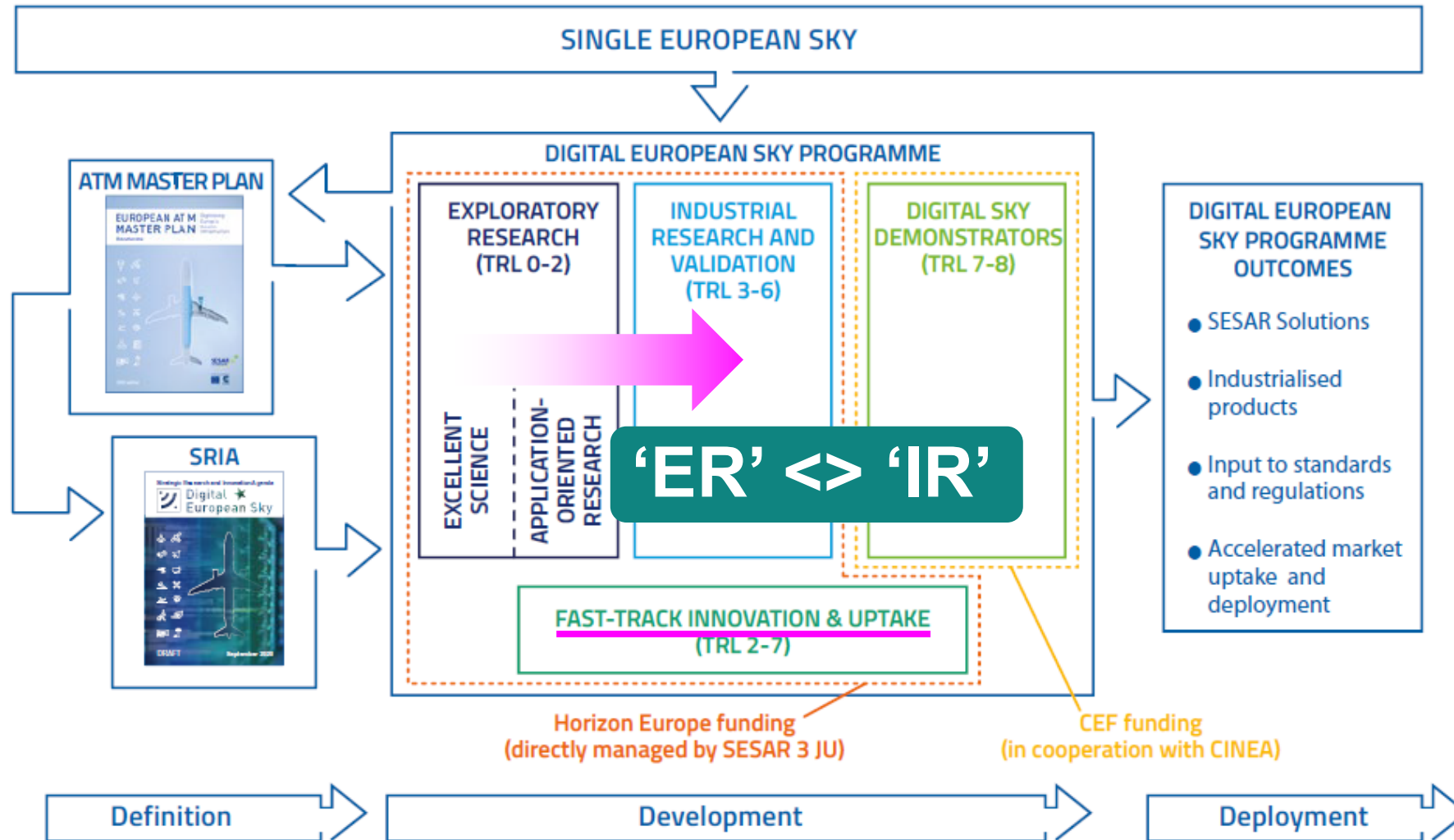
Background and context

Background and context

Digital European Sky

research and innovation portfolio

To deliver the Digital European Sky, the SESAR 3 JU has designed a portfolio of research and innovation activities for delivering solutions across nine flagships:

Connected and automated ATM

Air-ground integration and autonomy

Capacity-on-demand and dynamic airspace

U-space and urban air mobility

Virtualisation and cyber-secure data sharing

Multimodality and passenger experience

Aviation green deal

Artificial intelligence (AI) for aviation

Civil/Military interoperability and coordination

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Recently completed projects (1/2)

Background and context

—

- **Vista (€0.6m, SESAR) UoW lead**
  Strategic-tactical ABM, market forces: KPI trade-offs
  Innaxis, Belgocontrol, EUROCONTROL, Icelandair, Norwegian Air Shuttle, SWISS

- **Domino (€0.8m, SESAR) UoW lead**
  Platform to assess network coupling of ATM systems
  EUROCONTROL, Universita Degli Studi di Trieste, Università di Bologna, Innaxis

- **ADAPT (€1.0m, SESAR)**
  Tools to improve trajectory predictability
  Universita Degli Studi di Trieste, Technische Universiteit Delft, Deep Blue, Universita Degli Studi di Palermo

- **CAMERA (€1.4m, H2020 Smart, green and integrated transport)**
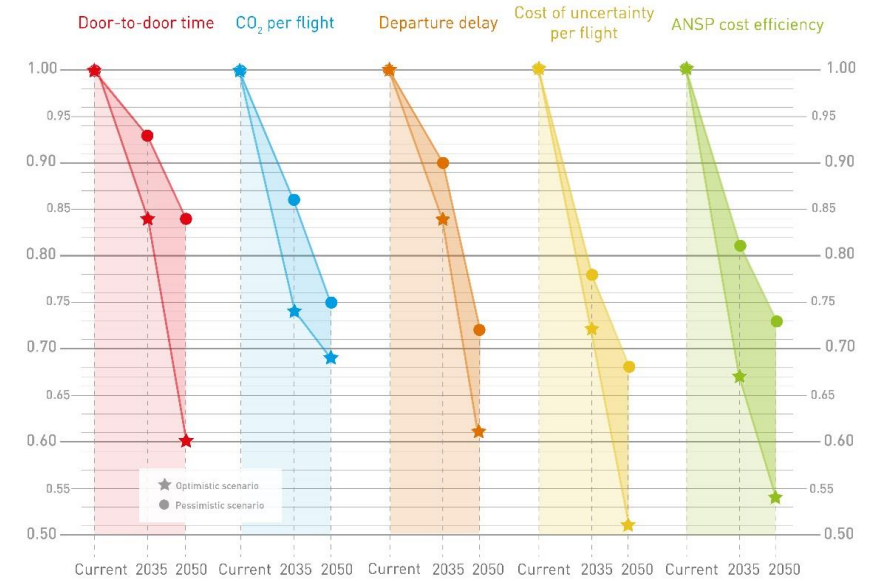 **ID gaps & innovation bottlenecks re. attaining EU mobility goals**
  Innaxis, EUROCONTROL, Bauhaus Luftfahrt, Deep Blue

- **Engage: European KTN (€4.0m, SESAR) UoW lead**
  Innaxis, Universita Degli Studi di Trieste, University of Belgrade, Technische Universiteit Delft, Frequentis, EUROCONTROL, EASA

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Recently completed projects (2/2)

Background and context

- **Pilot3 (€0.6m, H2020-Clean Sky 2)** UoW lead
  Trajectory alternatives software: multi-criteria business objectives
  Polytechnic University of Catalonia, PACE, Innaxis

- **Dispatcher3 (€0.6m, H2020-Clean Sky 2)** UoW lead
  ML models predict uncertainties impacting flight cost functions
  Innaxis, Polytechnic University of Catalonia, PACE, Vueling Airlines, Skeyes

- **Modus (€1.0m, SESAR)**
  Modelling & assessing the role of AT in an integrated, intermodal transport system
  Bauhaus Luftfahrt, Ecole Nationale de l'Aviation Civile, Innaxis, International Union of Railways, Skymantics Europe, EUROCONTROL

- **NOSTROMO (€1.8m, SESAR)**
  Next-generation open-source tools for ATM performance modelling & optimisation
  CRIDA*, Nommon, Polytechnic University of Catalonia, Technical University of Denmark, ISA Software
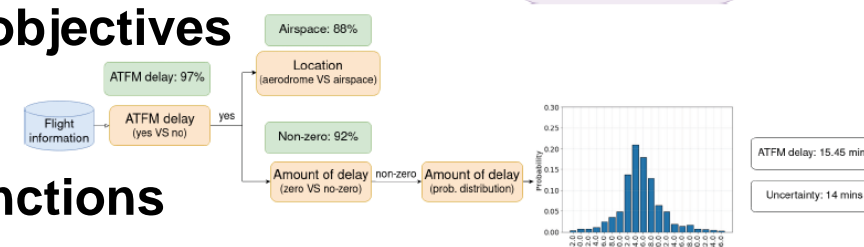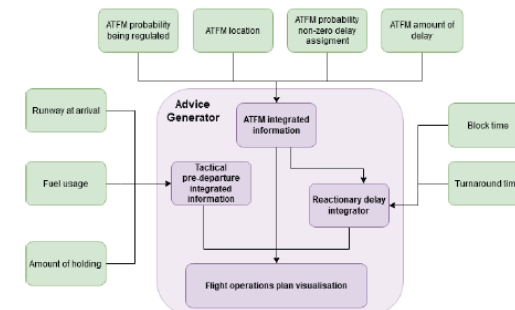
- **BEACON (€1.0m, SESAR)** UoW lead
  Behavioural economics for ATM concepts (UDPP extension, e.g. cost-based slot allocations)
  Nommon, EUROCONTROL, Salient Behavioural Consultants, University of Trieste, Swiss International Air Lines

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Recently launched projects

Key concepts (on-going and prospective)

- **MultiModX* (€1.8m, SESAR)** [JUL23, 2.5 years]

  Bauhaus Luftfahrt, Nommon, Airport Regions Council, Technische Uni. Dresden, Union Int. des Chemins de Fer

- **Green-GEAR (€2.0m, SESAR)** [SEP23, 2.5 years]

  DLR, EUROCONTROL, NATS (En Route), NLR, Universita Degli Studi di Trieste, Airbus

- **AMPLE3 (€'2.0'm, SESAR (IR))** [JUL23, 3 years]

  EUROCONTROL, +22 (mostly industry)

- **PEARL (€'2.0'm, SESAR (IR))** [SEP23, 3 years]

  ENAIRE (ANSP for Spain), +18 (mostly industry)

- **Engage 2* (€3.7m, SESAR)** [JUN23, 4 years]

  Deep Blue, Technische Universitaet Braunschweig, University of Belgrade, Innaxis, Frequentis, EASN, EUROCONTROL, Universita Degli Studi di Trieste

* Illustrated later

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Digital European Sky at a glance

Recently launched projects: Green-GEAR

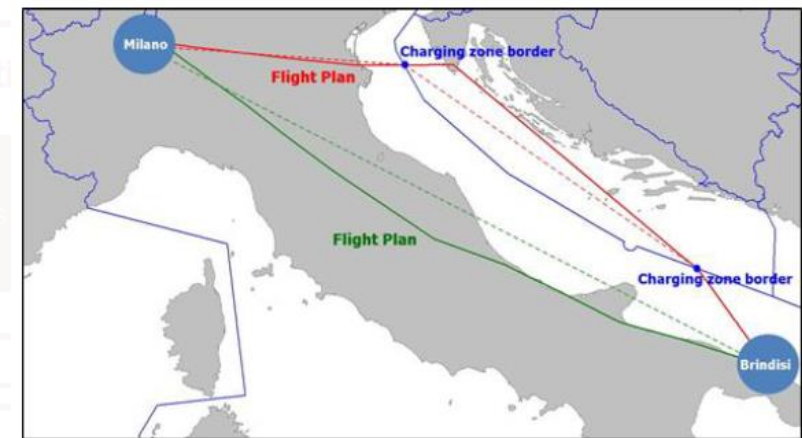# Key concepts (on-going and prospective)

—

- **WP5 context**
  - current European charging system has limited influence on ENV behaviour of AUs
  - within 'Green Deal' ambitions: urgent need to reinforce environmental dimension of route charging system and address its limitations

- **WP5 objectives**
  - develop 'green' route charging mechanisms that **incentivise AUs to reduce their ENV impact**
    - limited to en-route context
    - considering economic constraints (for ANSPs, AUs, network) – **full AU cost model**
    - considering capacity constraints
  - extend and adapt network models to simulate implementation of 'green' route charging mechanisms
    - develop a multi-agent reinforcement learning approach
    - linked to **stated preference survey** to capture AU preferences (utilities) – **first time (+ generic)**
  - develop 'Initial' (CO_2-only) and 'Full' (all emissions) Solutions

- **Coupled with geometric (cf. barometric) altimetry and 'RVSM2' (500ft minimum separation)**

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Recently launched projects: AMPLE3 & PEARL

Key concepts (on-going and prospective)

performance assessment

- **NOSTROMO API: efficient ATM simulation with active learning metamodeling**
   - a metamodel is a software approx. of a (simulation) model
    - it runs **much** faster than the original model (e.g. $>10^6$)
    - can be used for:
        - optimisation (e.g. find parameters that maximise a KPI)
        - portability (e.g. provide model to others, as a service)
        - accessibility (less expert knowledge needed)
        - exploring a much larger solution space
    - provides CIs (useful for stochastic models)
    - can drive a simulator automatically if it's programmable
    - often don't need to replicate every run (due to AL)
- **Multiple Solutions/models poss. if *a priori* compatible**
- **Watch this space in SESAR IR and ER2!**
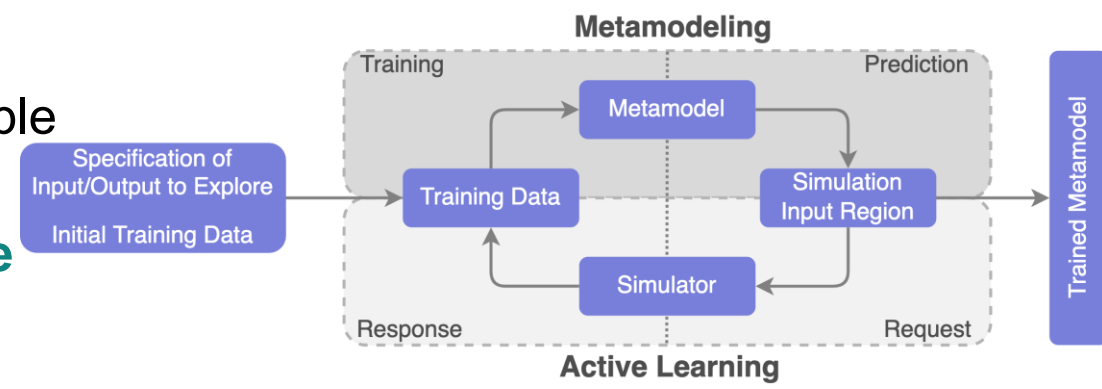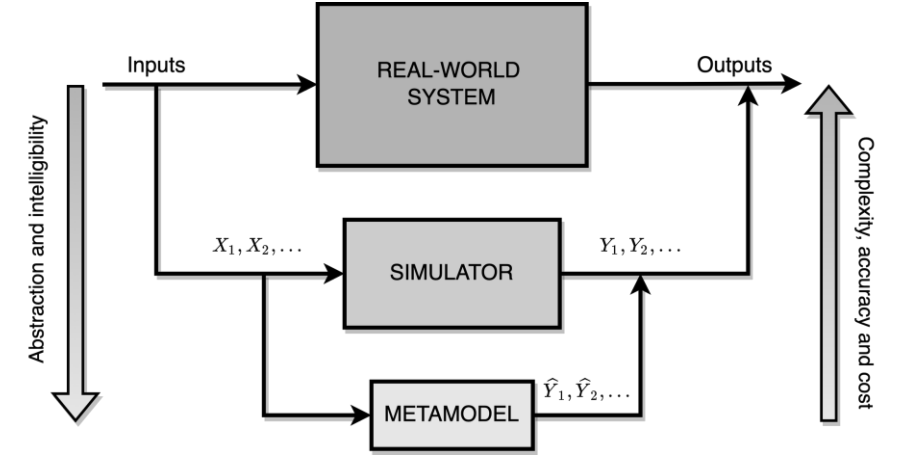
Thematic illustrations

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1. Reference evaluation of the cost of delay to airlines

Reference evaluation of the cost of delay to airlines

"The University of Westminster (UoW) report ... represents the most recent and comprehensive appraisal of the cost of delays in the air traffic management system in Europe"

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European airline delay cost reference values

24 December 2015

in Linkedin | 8+ Google | f Face

DOWNLOAD REPORT ⬇

This report, produced by the University of Westminster
European delay cost incurred by airlines, both at the s

It presents updated values for the cost of delay to Eur
The methodology is substantially unchanged compare
costs. Methodological points are only highlighted whe

Document
📄 European airline delay cost reference values rep

SES Performance Scheme – RP3 (2020-2024) dashboard

Capacity CKPI #1: En-route ATFM delay per flight [minutes per flight]

Period: January–February | [Download data] Source: PRU analysis; Network Manager | [Meta data]

FAB (based on ANSP)	Plan [2023]	Actual [2023]	[act. vs. plan]
Baltic FAB		0.02	
BLUE MED FAB		0.01	
DANUBE FAB		0.00	
DK-SE FAB		0.17	
FAB CE (SES RP2)		0.00	
FABEC		0.62	
NEFAB		0.00	
SW FAB		0.20	
UK-Ireland FAB		0.02	

Entity	Plan [2023]	Actual [2023]	[act. vs. plan]
LVNL		0.02	
Maastricht UAC		0.00	
MATS		0.00	
NAV Portugal		0.29	
NAVIAIR		0.28	
Oro navigacija		0.00	
PANSA		0.02	
ROMATSA		0.00	
skeyes		0.02	

Note 1. Various FAB and ANSP performance plans have different planned contributions to the EU target.
Note 2. PRB calculated that the economic optimum for delay was appx 0.35 min/flight (2010).

EUROCONTROL Standard Inputs for Economic Analyses

Edition number: 9.0
Edition date: December 2020

SUPPORTING EUROPEAN AVIATION

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Key features

Reference evaluation of the cost of delay to airlines

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- **Tactical cost of delay**
  - incurred on the day of operations, not planned in advance
  - e.g. aircraft waiting at-gate
  - mostly marginal costs

- **Strategic cost of delay (then a new concept)**
  - incurred in advance, often difficult to recover later ('sunk' cost)
  - e.g. schedule buffer ('opportunity' cost) & route extension
  - mostly unit costs

- **Passenger cost of delay**
  - 'hard' cost to airline
 - 'soft' cost to airline
  - ~~internalised costs~~

'hard' cost to airline   'soft' cost to airline

passenger 'value of time'
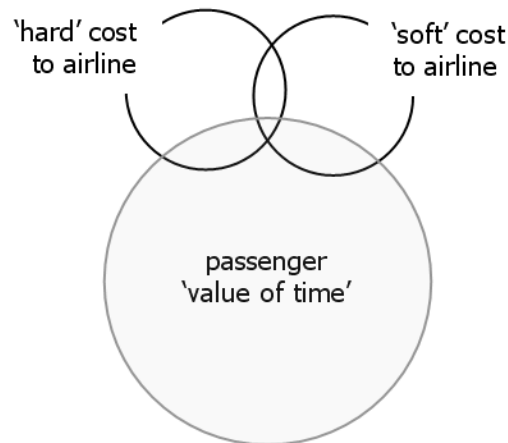
Reference evaluation of the cost of delay to airlines

2010 major updates

|	
Pax hard cost	Major update - full cost curves (power curve) derived as function of primary delay
Pax soft cost	Major update - full cost curves (logit curve) derived as function of primary delay; scalability now accounted for: small fraction of total now used in most contexts
Crew	Extensive new model addressing crew payment schemes and overtime rates; costs assigned to all delay magnitudes
Maintenance	Overheads fully assessed; cost base extended and re-calibrated on full ICAO data sets
Fleet	Cost base extended and re-calibrated on full ICAO data sets, supplemented with update from financial literature
Fuel	0.60 EUR/kg; carriage penalty now applied to arrival management
Reactionary	Extended model: multipliers fully quantified as function of primary delay magnitude, caps applied using new rotationary models

Table 26. AT-GATE / BASE / full tactical costs

Delay (mins)	5	15	30	60	90	120	180	240	300
B733	70	430	1 550	7 020	19 160	36 220	49 040	66 480	89 310
B734	80	480	1 740	7 930	21 690	40 960	55 340	74 780	100 040
B735	70	390	1 400	6 280	17 110	32 350	43 900	59 720	80 590
B738	90	540	1 940	8 860	24 270	45 750	61 740	83 220	110 920
B752	100	620	2 290	10 620	29 250	55 150	74 240	99 700	132 200
B763	170	900	3 200	14 780	39 960	85 300	121 880	152 860	191 990
B744	240	1 370	5 000	23 430	63 710	136 330	194 330	242 440	302 200
A319	70	440	1 600	7 320	20 040	37 850	51 240	69 420	93 180
A320	80	500	1						
A321	100	580	2						
AT43	30	180							
AT72	40	240							
DH8D	40	250							
E190	60	320	1						
A332	180	990	3						
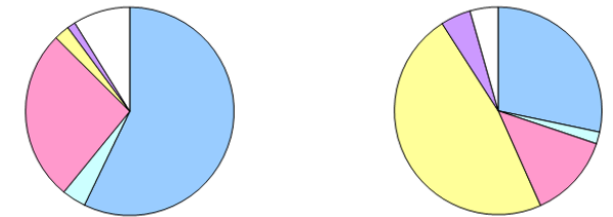
B738 at-gate (EUR 540)

B738 en-route (EUR 1 080)
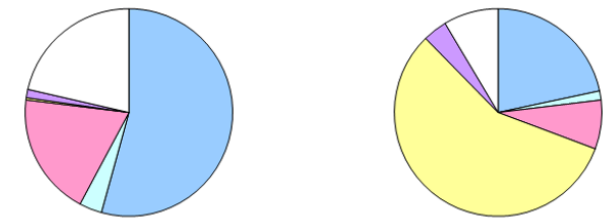
B744 at-gate (EUR 1 370)

B744 en-route (EUR 3 440)

| Pax hard | Pax soft | Crew | Fuel | Maintenance | Reactionary |
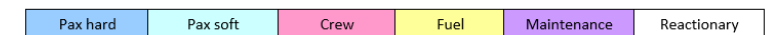
Reference evaluation of the cost of delay to airlines

—

- **Further research needed**
  - changing 3 of the 15 aircraft types (some data back-filling)
  - cheaper fuel (2019 cf. 2014) and very low inflation: no longer valid
  - pax hard costs: much higher claim rates; soft costs: more research (still) needed
  - curfews: quotas, surcharges, bans (may dominate costs, even at start of day)
  - *reactionary delay and propagation; crew; aircraft swaps; cancellation costs*

- **Applications**
  - *Standard Inputs for EUROCONTROL CBA* (etc.) – updated web tools?
  - integration with strategic and tactical tools
    - ANSP rostering – better predictions of airline demand w.r.t. route charges (e.g. Green-GEAR)
    - airlines – scheduling, routing choices, airborne delay recovery
    - SESAR Solutions – cost-saving evaluations, e.g. for flight prioritisation tools
 - EU policy – supporting evidence-led decisions for planned Reg. 261 changes

> - **Mercury + open source, user-defined, etc. (base year?)**
> - **Cost of delay to military stakeholders**

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Where next (2/2) – higher airspace operations (typically above FL550 / appx. 60 000 ft)

Reference evaluation of the cost of delay to airlines

—— **Enhancements needed in impact assessment (in addition to model geometries)**
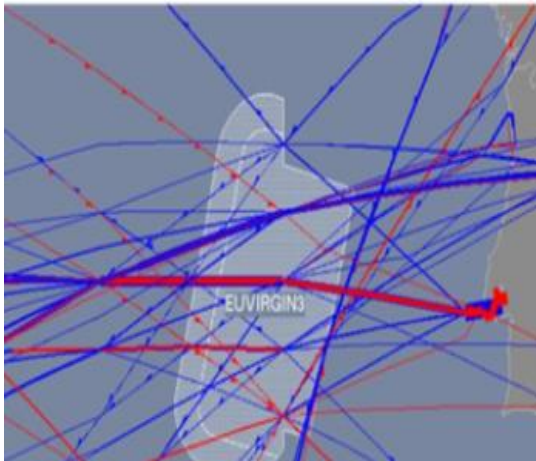
- **Regarding airline cost impact assessment**
  - enhance & update costings for commercial aviation (incl. dep. delays)
  - better alignment of costs to specific notification & response timing
    - e.g. if falls between our 'strategic' and 'tactical' cost points (similar for 'ADAPT' project)
    - potential changes to regulations (e.g. (EC) No 261/2004), whether airlines liable for delays etc.

- **Regarding other stakeholders**
  - cost impacts for ANSPs & Network Manager (e.g. ATCO provision, coord.)
  - impacts on military operations and cost impacts thereof
  - development, deployment & integration of (improved) sensors
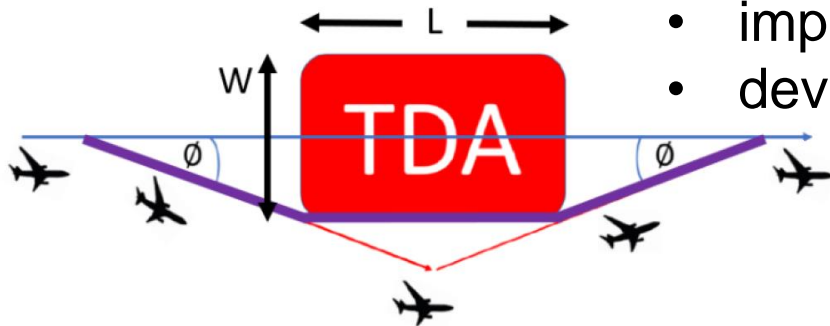
Thematic illustrations

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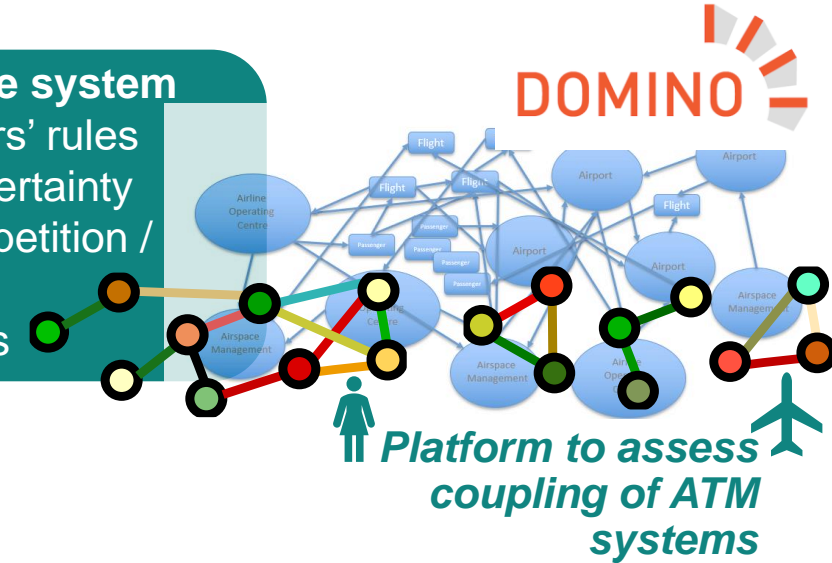2. Mercury: agent-based model for ATM performance assessment

**Provenance and range**

Mercury: agent-based model for ATM performance assessment
—

Changes in the system
- modify actors' rules
- change uncertainty
- modify competition / cooperation
- case studies

Platform to assess coupling of ATM systems

- **Background**
  - long-established passenger & social perspective
  - SESAR Outstanding Project Award 'POEM' (2015) (US analogues)
  - since developed over multiple projects (incl. DOMINO; ABM)
  - natural multimodal & wider context (e.g. PT, airport access)

- **On-going and prospective**
  - Modus → **MultiModX** (lessons & maturity)
  - D2D and *Flightpath 2050*
  - can be deployed flight-only
  - **only such simulator in Europe**
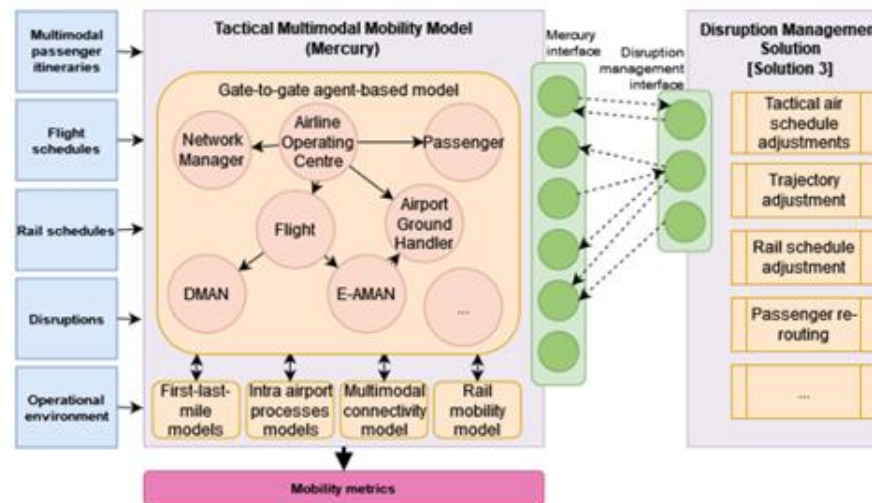
MultiModX: 3 Solutions

Performance Assessment
(multimodal performance framework)
Schedule Design
(integrated planning air-rail networks)
Disruption Management
(coordinated passenger reallocation)

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**Tactical air mobility evaluator**

Mercury: agent-based model for ATM performance assessment

—

Flight and passenger mobility model

- agent-based model
- describes main components of ATM system
- tracks **individual** flights and passengers
- multimodality and door-to-door estimation capabilities
- 1 day of operations at ECAC level (27k flights, 3M pax)
- open source (soon)

Event-driven simulator tracking main operational milestones:
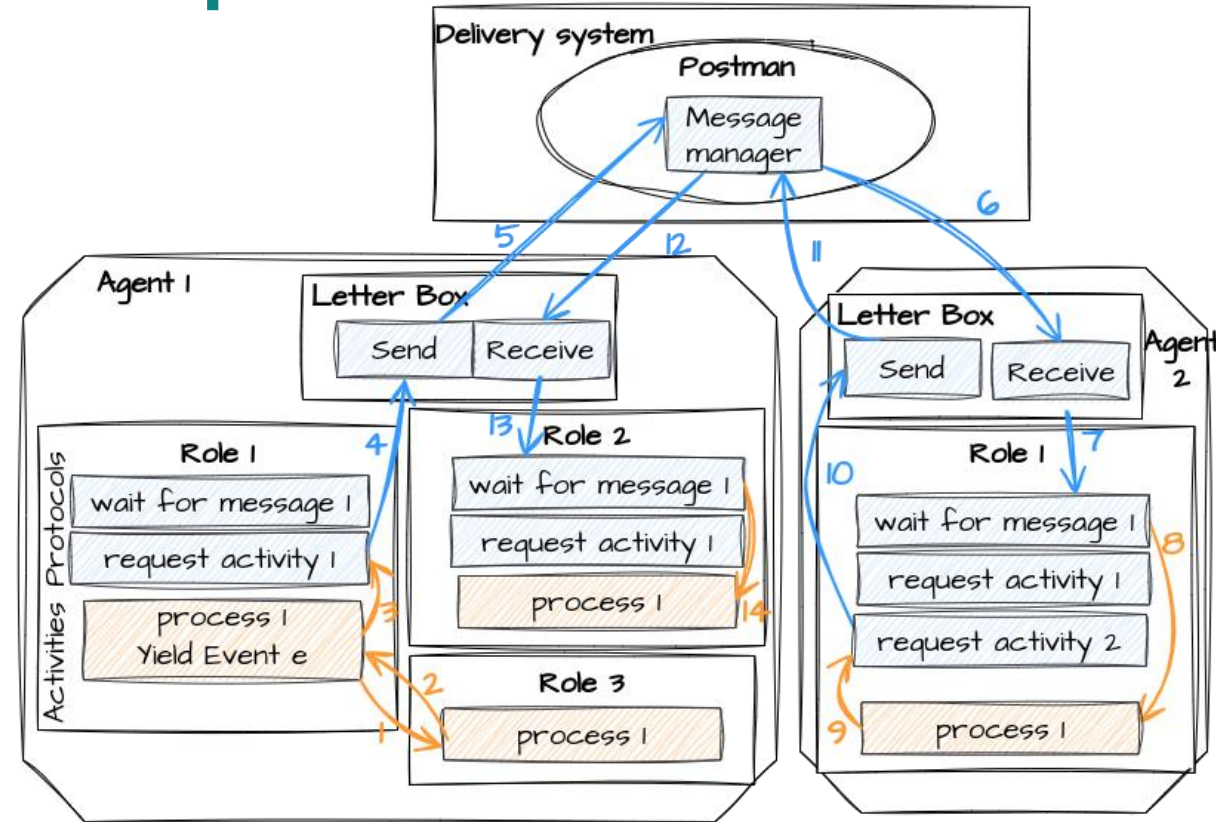
- flight plan submission, push-back ready, push-back, etc.

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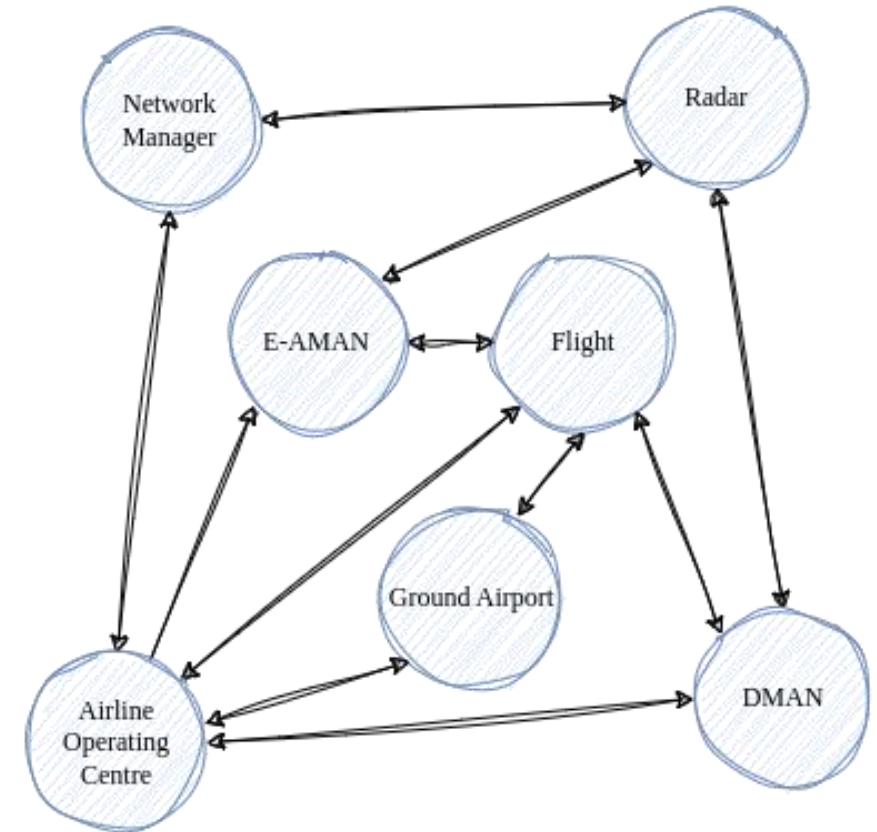
Mercury: agent-based model for ATM performance assessment

Agents encapsulate roles with functionalities. E.g.:

- Airline Operating Centre
  - fleet management
  - tactical reassignment of passengers
  - **cost modelling**
- Flight
 - flight plan adjustment
  - trajectory simulation

Roles: represent behaviour of agents and system rules

Activities: triggered by events and messages

Emergent behaviour and performance assessment

Mercury: agent-based model for ATM performance assessment

—

- Used to assess the impact of different changes:
  - ATM Solutions (e.g. E-AMAN, 4D-TBO, UDPP)
  - policies (e.g. pax compensation, ATC charges)
  - exogenous factors (e.g. cost of fuel)

- Low-level model, capture of emergent behaviours

- Performance indicators and associated distributions/errors (flight delay, CO_2, **costs**, etc.)

- Trade-offs between stakeholders
  - airlines / flights / airports / ANSPs / passengers / environment

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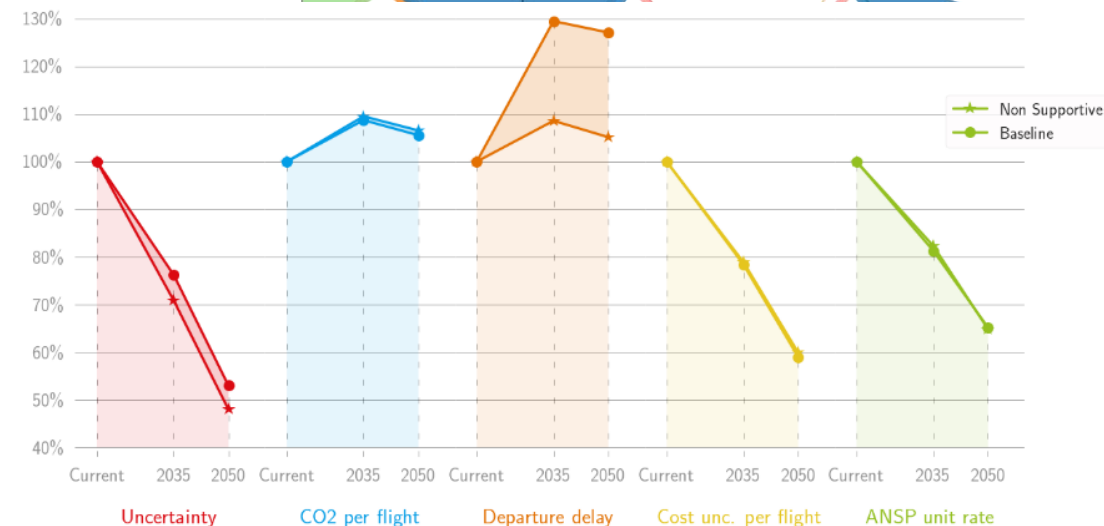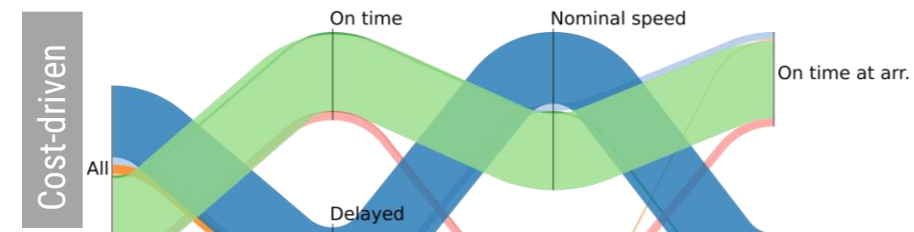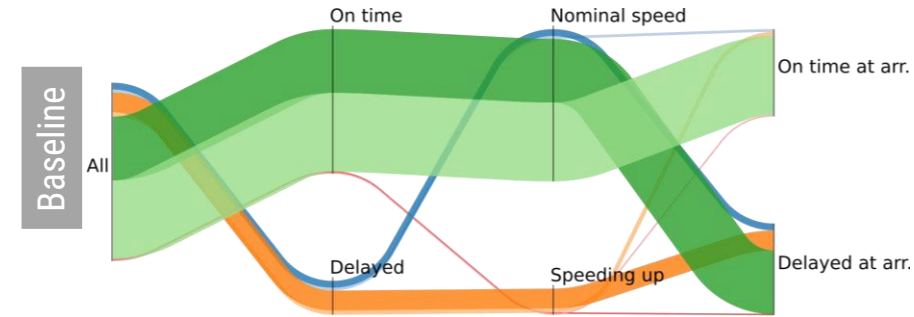
Open-source and modular simulator

Mercury: agent-based model for ATM performance assessment

—

Mercury is highly modular, with possibility to:

- modify existing roles easily

- add roles and include them in existing agents

- add entirely new events and agents

- plug external models live into Mercury

Mercury will be released as open source (under GPL licence) end of November 2023 at this address: https://github.com/UoW-ATM/Mercury

Thematic illustrations

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3. Engage 2: European ATM knowledge transfer network

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Engage 2: European ATM knowledge transfer network

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- Bridge gap between **industry** and **academia ('IR' & 'ER')**

- Investigate future ATM, including **required skills**

- Inspire and support **next generation of aviation professionals** in facing digital era

  Activities are focused on five main target groups:

  1. **Aviation academia and research**
  2. **ATM industry**
  3. **Policy and decision makers**
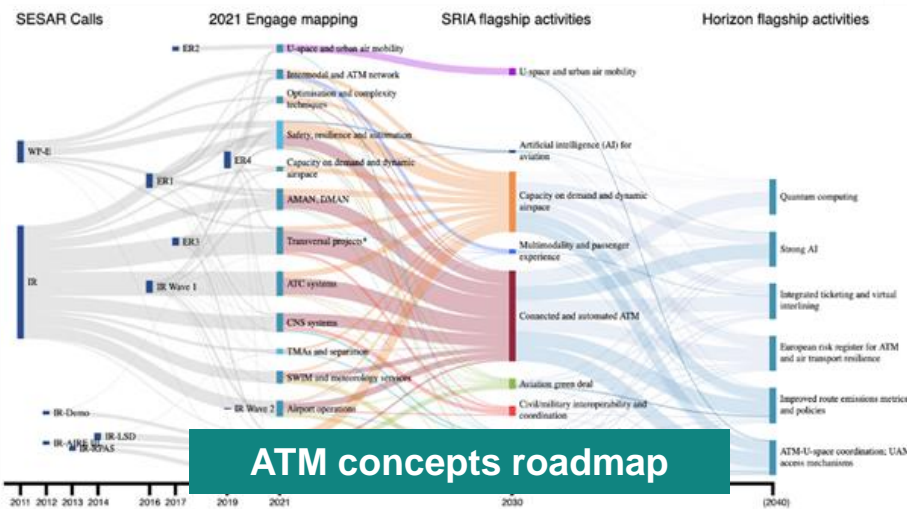 4. **Students**
  5. **General public**

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sesar JOINT UNDERTAKING

Co-funded by the European Union

Building on a number of firsts
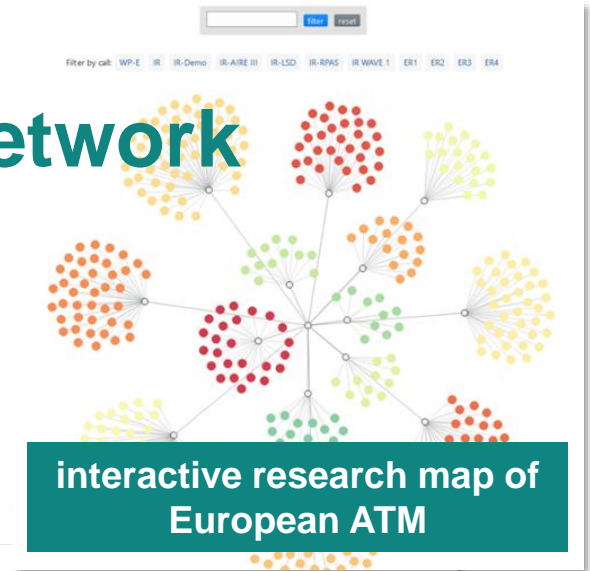
Engage 2: European ATM knowledge transfer network

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Updated version of the wiki (wikiengagektn.com/EngageWiki), incl.:

- **interactive research map of European ATM**

- **ATM concepts roadmap**

- **research repository**

- **European university programmes**

- **job opportunities**

concept (etc.) surveys underway with industry and academia!

interactive research map of European ATM

Research repository: Papers

« Search in Projects

Conference
☐ SESAR Innovation Days
☑ USA/Europe ATM R&D Seminar

Year
2011 · 201E · 2020

Project
Select a filter value

Theme
× ATM performance measurement and management

PaperID
Select a filter value

2015-370

A Framework for Assessing and Managing the Impact of ANSP Actions on Flight Efficiency

Conference: USA/Europe ATM R&D Seminar | Year: 2015

Theme: ATM performance measurement and management

2015-400

A Trajectory Optimization Based Analysis of the 3Di Flight Efficiency Metric

Conference: USA/Europe ATM R&D Seminar | Year: 2015

Theme: ATM performance measurement and management

2015-460

A New Method to Validate the Route Extension Metric against Fuel Efficiency

research repository

ATM concepts roadmap

For students – supporting study; supporting career pathways

Engage 2: European ATM knowledge transfer network

- financial support and mentoring for up to 10 PhD students (Call for PhDs opens NOV23)

- mentoring MSc students, including support for their Master theses

- 3 summer schools will be organised annually in Serbia (2024), Germany (2025) and Italy (2026)

- 2 hackathons; 24H coding events to solve ATM-related challenges

- 3 open days to attract, familiarise and inform students about ATM-related careers

- ATM job cards and videos will inform students in deciding their future career in ATM

- 'serious games' to support the orientation of students towards jobs in ATM

Engage KTN summer school 2019 (Belgrade, Serbia)

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sesar
JOINT UNDERTAKING

Co-funded by
the European Union

Thematic challenges underpin the network

Engage 2: European ATM knowledge transfer network

CNS vulnerability and security
Data-driven trajectory prediction
Efficient use of MET data
Novel market mechanisms in ATM

- **thematic challenges (3-5 novel concepts beyond SESAR 3) –** *now being decided*

- **'catalyst fund' projects** fast-track specific activities in support of developing solutions to **thematic challenges**; moving closer towards **industry goals/objectives** and higher TRLs

- financial support for **16 catalyst fund projects** through two Calls (in addition to PhD alignment)

- cross-fertilisation of knowledge from other disciplines to stimulate inputs from innovative, future-scoping and unconventional research into ATM

- series of **in-person and on-line workshops**

Engage KTN 'WIPA' project and its operational validation trial at Reims and Marseille ATC centres

Invitation!
- **join Industry Board**
- **(co-)mentor catalyst projects**
- **shape/align work**
- **participate in events (workshops)**
- **access concept (etc.) surveys**

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Thank you

- **Q&A**

- **Next steps** (cookaj@westminster.ac.uk)

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European performance assessment – challenges and concepts