Green-GEAR

Final Dissemination Workshop

SESAR Solution #0406 – Vertical Guidance using Geometric Altimetry

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Geometric Altimetry – Deliverables

		ERP	ERR	OSED	FRD	ECO-EVAL
Geo Alt	*Initial*			D3.1 / M10 ✓ NATS		
	Final	D3.2 / M12 ✓ NATS	D3.3 / M19 ✓ NATS	D3.5 / M20 ✓ NATS	D3.4 / M20 ✓ Airbus OPS	D3.6 / M21 ✓ DLR
SM	*Initial*			D4.1 / M10 ✓ NLR		
	Final	D4.2 / M11 ✓ DLR	D4.4 / M21 ✓ DLR	D4.6 / M20 ✓ NLR	D4.5 / M20 ✓ NLR	D4.7 / M21 ✓ DLR
Green RC	*Initial*		D5.3 / M14 ✓ UNITS	D5.1 / M10 ✓ EUROCONTROL		
	final	D5.2 / M11 ✓ UNITS	D5.7 / M22 ✓ UNITS	D5.4 / M22 ✓ EUROCONTROL	D5.5 / M22 ✓ NLR	D5.6 / M22+ ✓ UoW

Solution Data Pack (SDP) equivalent

Project Overview

- The Green-GEAR Project is part of SESAR’s innovation program, targeting sustainable and efficient airspace management.
- Solution ID: 0406 – Vertical Guidance using Geometric Altimetry.
- The consortium includes NATS (Solution lead), DLR (Project lead), AIRBUS, EUROCONTROL, the University of Trieste (UNITS), and the University of Westminster (UoW).
- Maturity Level: TRL2 (Technology Readiness Level 2 – concept formulation and proof of concept).

Background – Why This Matters

- Airspace is becoming increasingly crowded, not just with traditional aircraft but also with drones, Urban Air Mobility vehicles (eVTOL), and high-altitude operations.
- Current aviation systems rely on barometric altimetry, which uses atmospheric pressure to determine altitude.
- Barometric system requires pilots and controllers to make manual pressure adjustments (QNH/QFE) during flight.
- This complexity increases the risk of human error and operational inefficiency, especially as the number and variety of airspace users grows.

The Problem with Current Systems

- Barometric reference creates challenges:
  - Different users (aircraft, drones, balloons) use varying reference points.
  - Frequent manual changes during flight transitions (e.g., climbing or descending through transition altitudes).
  - Increased risk of miscommunication and error.
  - Limits the ability to safely integrate new types of airspace users.
  - Loss of flight levels due to the transition layer.
  - Inefficiency in approach procedures design to cope with temperature effect on barometric altitude

The Green-GEAR Solution

- Introduces geometric altimetry – using satellite navigation (GNSS) to determine altitude.
- Provides a single, unified altitude reference for all airspace users, regardless of vehicle type.
- Aims to simplify flight operations, reduce controller and pilot workload, and enable safe integration of new entrants.
- Makes it possible to manage 3D airspace more precisely, supporting innovations like dynamic separation and advanced approach procedures.

Two Proposed Methods for Implementation

1. **Defined Lateral Path with Altitude Constraints:**
    1. Aircraft follow specified horizontal paths with altitude restrictions.
    2. Fewer manual pressure adjustments needed, reducing workload and error.
    3. More consistent and predictable flying altitudes, improving safety and capacity.
    4. Requires changes in aircraft systems and architecture
2. **Defined Lateral and Vertical Path (Vertical Required Navigation Performance – V-RNP):**
    1. Aircraft follow a precise 3D flight path (both lateral and vertical).
    2. Allows for highly optimized routes and approaches, increasing efficiency and reducing fuel burn.
    3. Requires updates to Air Traffic Management (ATM) tools and ground-based safety systems.
    4. Requires significant changes in aircraft systems and architecture, with technical feasibility for departures still to be confirmed

Regulatory & Standardisation Challenges

- Transitioning to geometric altimetry requires new international and European standards.
- EUROCAE and RTCA are coordinating development of avionics and navigation standards for Flight Management Systems (FMS).
- GNSS resilience is a concern: systems must be robust to jamming and spoofing.
- Regulatory changes are needed to define how and when geometric altimetry can be used operationally.

How Did We Validate the Solution?

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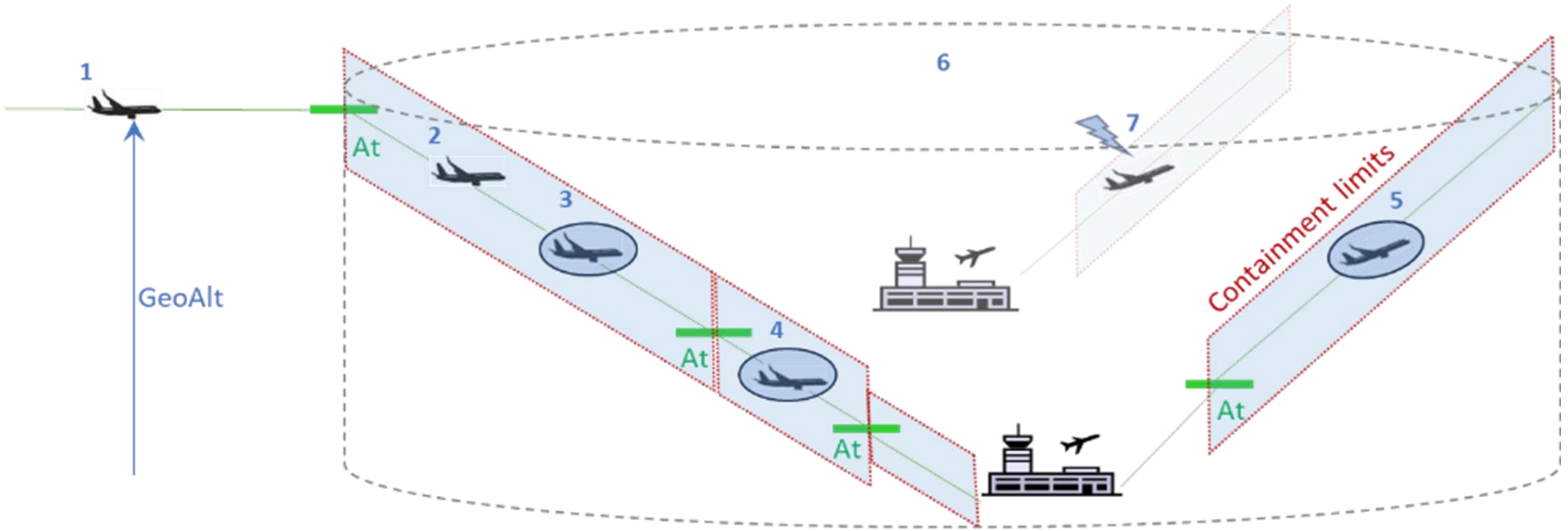

1. Ex.3 - Qualitative assessment of geometric cruise on aircraft functions, architecture and cockpit systems. Ex.4 – Quantitative assessment of geometric cruise versus barometric cruise through aircraft simulations.
2. Ex.4 - Quantitative assessment of geometric descent through aircraft simulations.
3. Ex.3 - Qualitative assessment of geometric descent on aircraft functions, architecture and cockpit systems.
4. Ex.3 - Qualitative assessment of geometric Initial Approach on aircraft functions, architecture and cockpit systems.
5. Ex.3 - Qualitative assessment of geometric climb on aircraft functions, architecture and cockpit systems.
6. A fully geometric TMA compared to a fully barometric TMA
    1. Ex.1 - Quantitative assessment through fast-time ATC simulations
    2. Ex.2 - Qualitative Safety and Human Performance assessment
7. Ex.2 - Qualitative Safety and Human Performance assessment of fallbacks due GNSS loss or spoofing.

Exercise 1: Fast-time Simulation (NATS)

Benefit Assessment of Fully Geometric TMA (TVAL.01.1)

- Fast-time simulation compared a fully geometric approach versus conventional barometric procedures in a Terminal Manoeuvring Area (TMA).
- Conducted at Whiteley, UK, between August and November 2024.
- Simulations examined airspace capacity, safety, and environmental impacts.
- Results showed significant potential for fuel savings, emission reductions, and maintaining or improving safety margins.
- Fast-time simulation of a fully geometric TMA compared with a fully barometric TMA to determine the relative benefits and disbenefits of geometrically-defined instrument flight procedures at a network level.

- Maturity: TRL 2
- Location: Whiteley, UK
- Start date: 01 Aug 24
- End date: 29 Nov 24

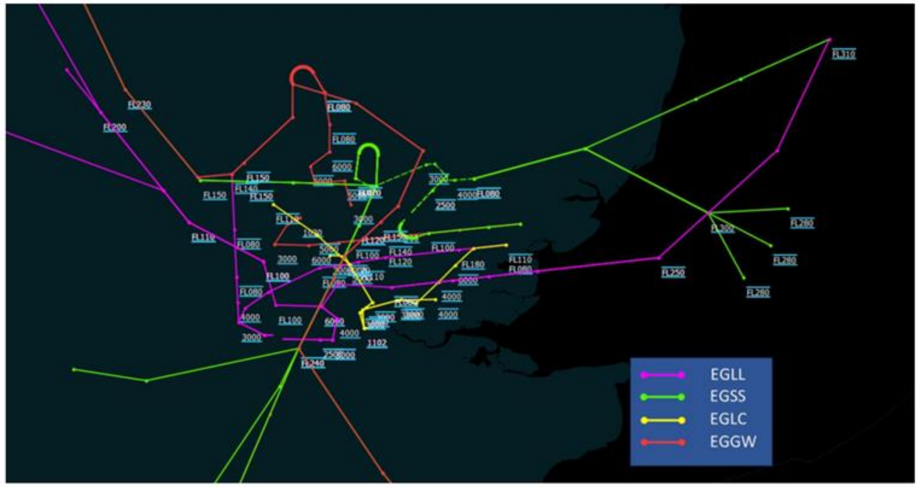

Figure 6: Reference Scenario - barometric altimetry with Altitude and Flight Level constraints at waypoints

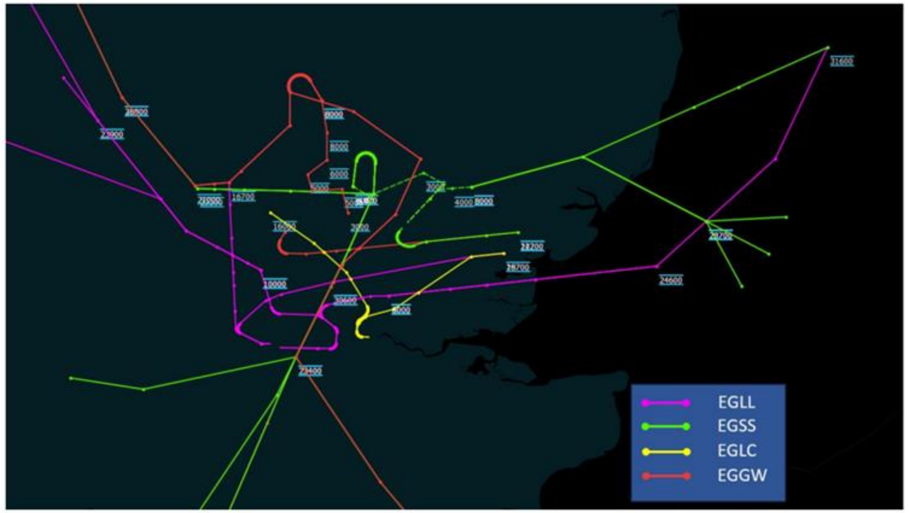

Figure 7: Solution Scenario - fixed climb/descent gradients based on geometric point-to-point vertical paths

Exercise 1: Fast-time Simulation (NATS) Results

DESCENT & APPROACH

Comparison of the descent results under Exercises #01 (this section) and #04 (see Appendix C) showed a reasonable correlation.

	2023 Arrivals		
	Fuel Burn (T)	CO2e (T)	%
EGLL	-1,394	-4,391	-0.9%
EGSS	-2,243	-7,065	-2.8%
EGGW	-1,196	-3,767	-2.1%
EGLC	-	-	-
Total	-4,833	-15,224	-1.6%
Per flight (kg)	-23.15	-72.91	-1.6%

Table 17: 2023 Fuel/CO_2e impacts on arrivals with the % change relative to overall fuel in UK FIR.

	2023 DEPARTURES		
	Fuel Burn (T)	CO2e (T)	%
EGLL	-3,870	-12,191	-2.6%
EGSS	4,126	12,998	2.5%
EGGW	-7	-22	-0.7%
EGLC	-580	-1,827	-2.9%
Total	-331	-1,042	-0.1%
Per flight (kg)	-2.12	-6.68	-0.1%

Table 19: Annual 2023 Fuel/CO_2e impacts on departures with the % change relative to overall fuel in UK FIR.

	2035 Arrivals		
	Fuel Burn (T)	CO2e (T)	%
EGLL	-1,447	-4,558	-1.0%
EGSS	-2,460	-7,749	-2.5%
EGGW	-2,042	-6,432	-2.7%
EGLC	-	-	-
Total	-5,949	-18,739	-1.8%
Per flight (kg)	-24.20	-76.22	-1.8%

Table 18: 2035 Fuel/CO_2e impacts on arrivals with the % change relative to overall fuel in UK FIR.

	2035 DEPARTURES		
	Fuel Burn (T)	CO2e (T)	%
EGLL	-3,870	-12,191	-2.6%
EGSS	4,905	15,451	2.4%
EGGW	-9	-28	-0.6%
EGLC	-724	-2,280	-2.4%
Total	302	952	0.1%
Per flight (kg)	1.66	5.23	0.1%

Table 20: Annual 2035 Fuel/CO_2e impacts on departures with the % change relative to overall fuel in UK FIR.

Exercise 2: Safety and Human Performance assessment (NATS)

- Held workshops to analyse safety and human factors with pilots, controllers, and engineers.
- No major human performance risks were identified, but this highlighted the need for robust procedures in the event of GNSS loss.
- Safety margins can be maintained or improved with proper training and fallback protocols.

Exercise 2: Key Outcomes

- **Capacity:** Removing the transition layer and using a unified altitude reference could increase efficiency and capacity.
- **Safety:** No evidence of increased risk for pilots or controllers, provided systems are robust.
- **Security:** Heavy reliance on GNSS requires contingency plans for signal loss or interference.

Exercise 3: Aircraft impact assessment (Airbus)

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- Judgement analysis conducted by Expert Group
- Addressing technical and operational feasibility considerations in the following areas:
    - Flight Management System (FMS) and Flight Performance
    - Navigation Systems (other than FMS)
    - Management of Jamming & Spoofing Threats
    - Compatibility with Surveillance Functions
    - Cockpit Systems and Flight Crew Operation

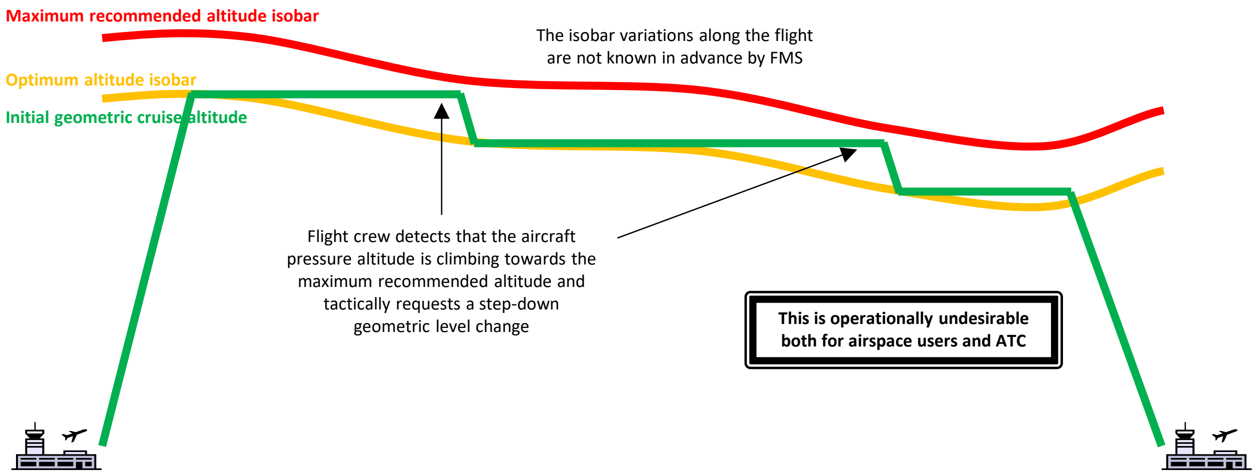
Exercise 3 main outcomes – TMA

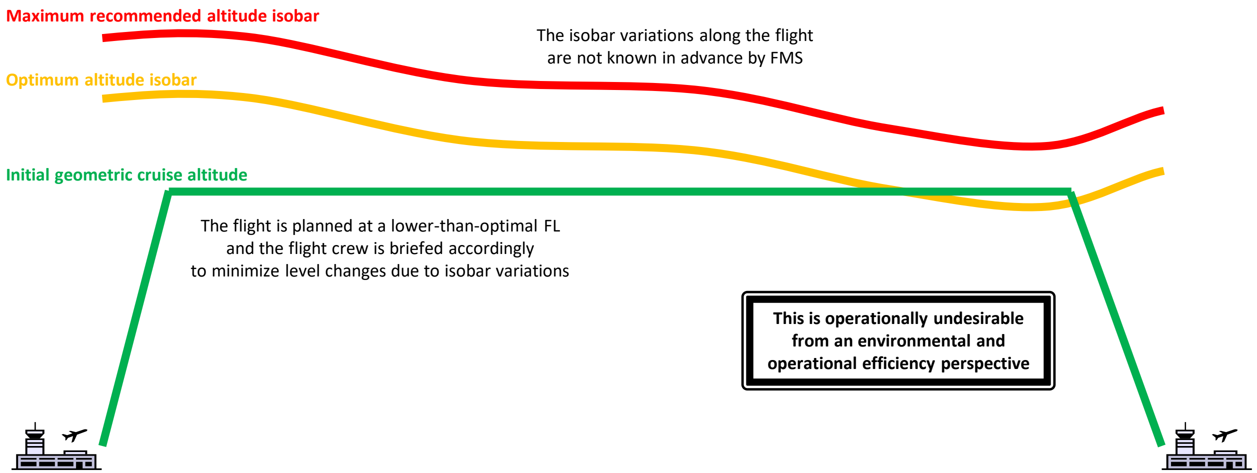
- **SOLUTION METHOD 1** (geometric instrument procedures with altitude constraints)
  - **Climb, Descent & Initial Approach:**
    - Found **technically feasible** with **open points** on **GNSS jamming&spoofing** and **FMS predictions**

- **SOLUTION METHOD 2** (geometric instrument procedures with prescribed vertical path)
  - **Descent & Initial Approach:**
    - Found **technically feasible** with **open points** on GNSS jamming&spoofing, FMS predictions and **speed management**
  - **Climb:**
    - **Major systems impact** and **significant operational hurdles** related to **vertical guidance** and **flight performance**
    - Also open points on GNSS jamming&spoofing and FMS predictions

Exercise 3 main outcomes – Cruise

- Found **technically feasible** with **open points on GNSS jamming&spoofing and FMS predictions**
- But **significant operational hurdles** related to **aircraft flight envelope and cruise altitude optimization**



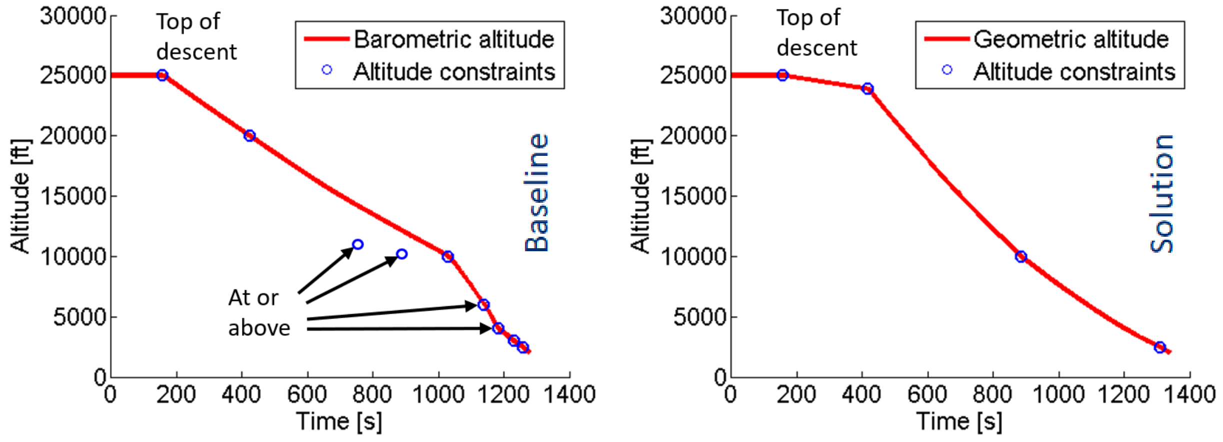


- **Detrimental for either AU/ATC operation (left case) or environment/flight efficiency (right case)**

Exercise 4 Results (1/2)

TMA

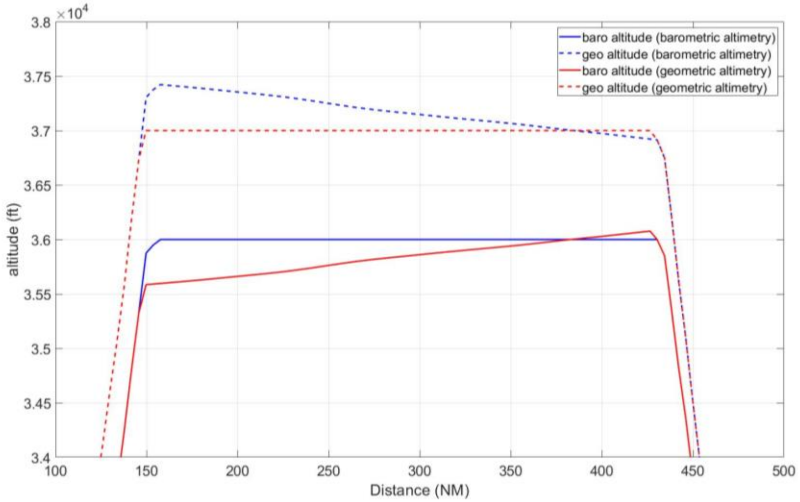
- general considerations:
  - Simulation model of DLR's research aircraft ATRA (A320) with very accurate flight dynamics based on data from real flight tests
  - FCS and FMS are of limited fidelity, simplified managed climb and descent modes have been implemented during Green-GEAR
  - fixed geometric starting/ending points for the descent/climb scenarios, irrespective of altimetry type, for comparability
  - several example scenarios for descent and climb
- example **descent** scenario NUGRA1H_BNN27L:
  - in the baseline scenario, baro vs. geo has a small +/- influence on fuel (depending on the QNH) but is close to zero on average
  - in the Solution scenario, always a positive influence because the aircraft is staying at a higher altitude for longer, average ∆fuel -23 kg (≈ -7%)
- example **climb** scenario WOBUN1F:
  - Solution scenario is nearly the same procedure but with fewer altitude constraints
  - in the baseline scenario, again baro vs. geo has a small +/- influence on fuel
  - **removal of level-off segments in the Solution scenario results a positive benefit**
  - **enforcing a fixed climb gradient results in a negative benefit**
  - *average* overall fuel savings of about -2 kg (≈ -0.25%); individual figures can become negative depending on QNH



Exercise 4 Results (2/2)

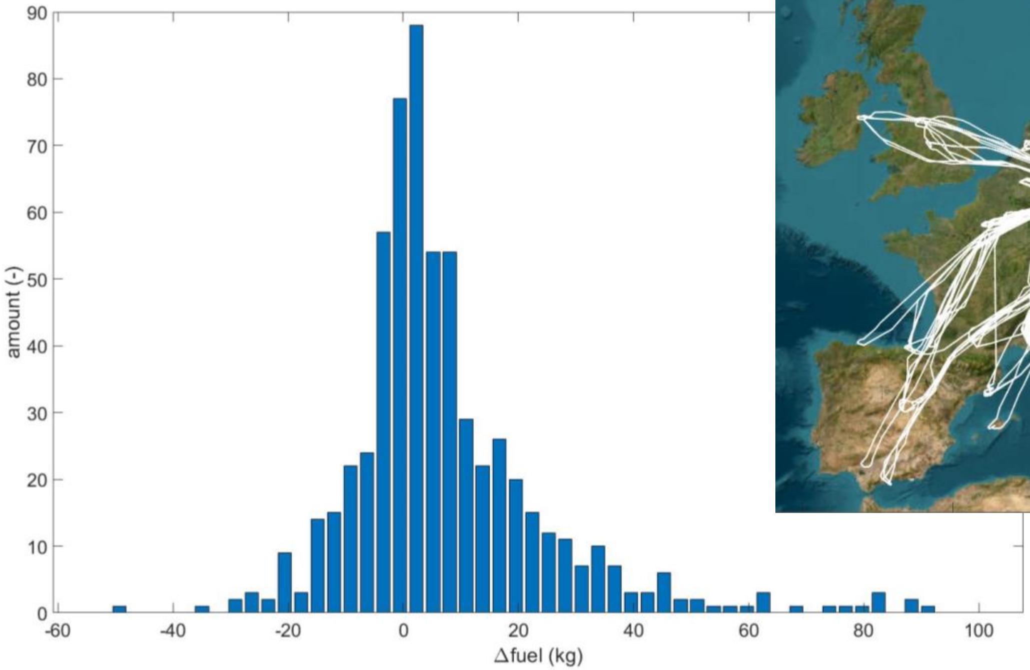
Cruise

- re-simulation of real flights through fast-time simulation, with ECMWF weather data, with barometric and geometric altimetry
- selection of geometric cruise altitude to best fit to flown trajectory (→ no real flight optimisation)



Flight profiles (baro and geo)

Delta fuel distribution



- 617 flights (between June and October 2024) of a single aircraft
- change of fuel consumption between -50.7 kg **(-2.3 % trip fuel)** and 89.8 kg **(+6.6 % trip fuel)**
- average change of fuel consumption is 5.9 kg **(+0.2 % trip fuel)**
- no significant influence on flight time observed

Recommendations for Next Steps

- Avoid large-scale deployment until GNSS jamming/spoofing risks are acceptably mitigated.
- Continue research and simulations to raise technology readiness (aim for TRL4).
- Collaborate with standards bodies and regulators to accelerate harmonisation.
- Invest in GNSS resilience and backup solutions.
- Next SESAR research programme – Project DYN-MAX (Solution 4 – Geometric Altimetry).

Project Conclusion

- Geometric altimetry is a promising solution for the future of airspace management.
- Potential to deliver safer, greener, and more efficient operations for all airspace users.
- Ongoing work focuses on regulatory frameworks, technical validation, and operational readiness.

Acknowledgments & Contributors

- The project is a collaboration between NATS, DLR, AIRBUS, EUROCONTROL, UNITS, and UoW.
- Supported by SESAR Joint Undertaking and project partners.
- Special thanks to the validation teams, workshop participants, and regulatory advisors.

Q&A and Discussion

- We welcome your questions and feedback.
- Open floor.

Thank you

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