Potential drop-in fuels benefits on Airport Air Quality

JETSCREEN Workshop: Maximizing sustainable aviation fuel benefits beyond CO2 reduction

Bruxelles – 26 Nov. 2019

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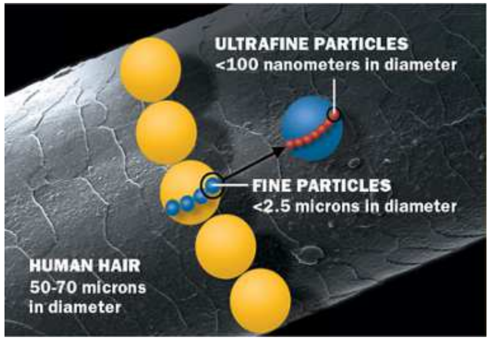
Air Quality at Airports

- Most important pollutants to focus on are nitrogen dioxide (NO_2), regional ozone (O_3) and particles;
- Particles: PM10, PM2.5 and ultra fine particles (UFPs) for which number concentration appears more relevant. SO2 from the aircraft engine may be important contributor to PM2.5.



- Additional emission species of interest are hazardous air pollutants (HAPs).

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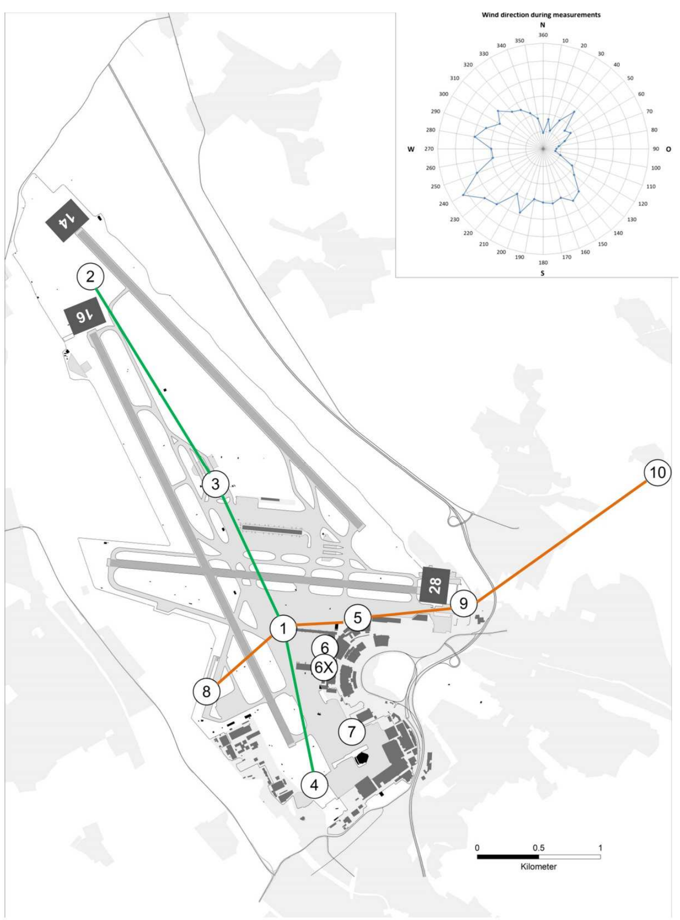
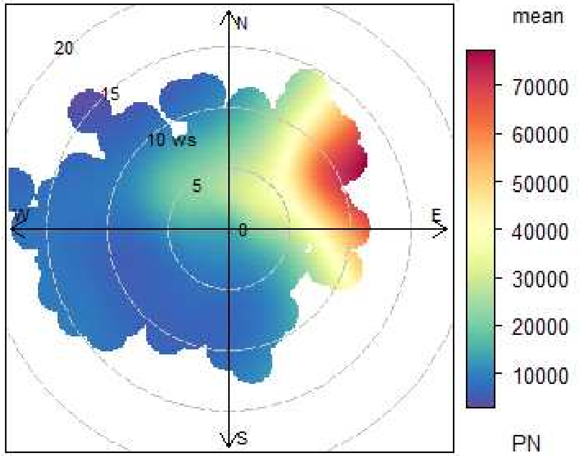
Air Quality at Airports – particles concern

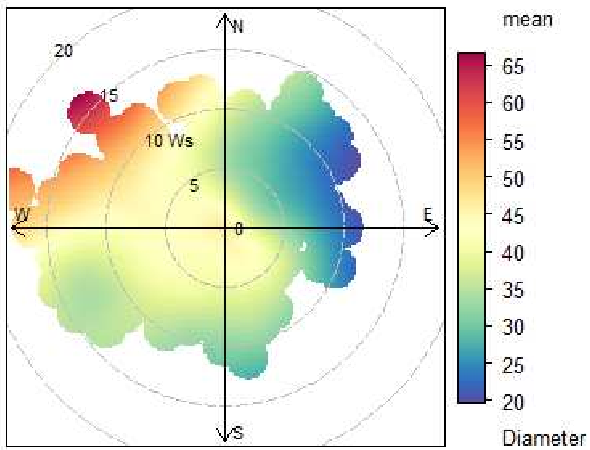
UFPs at Zurich airport



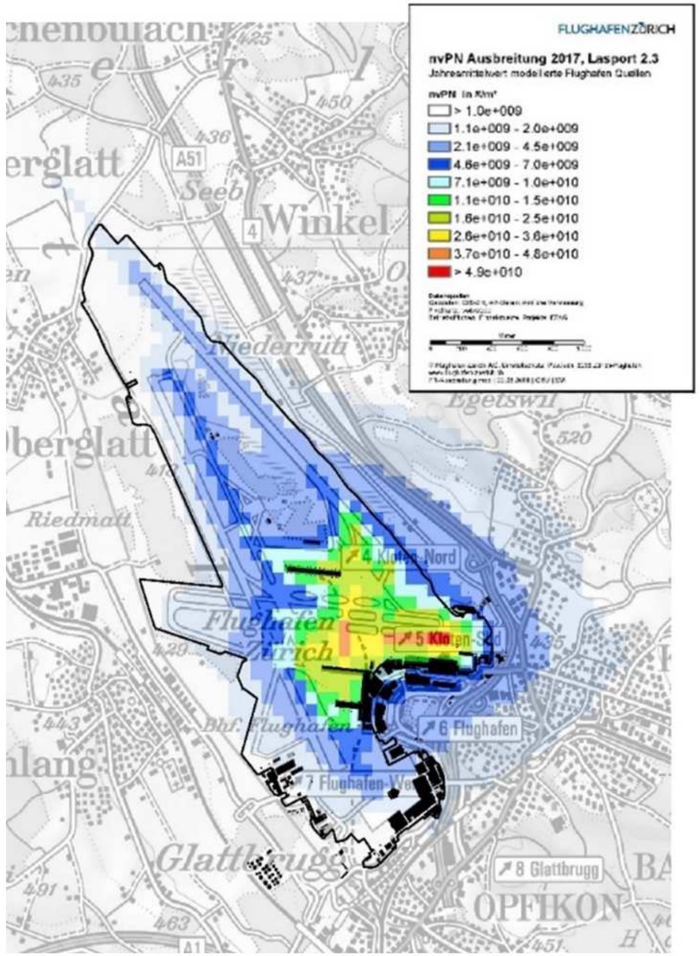
Zurich Airport layout with UFP monitoring stations and predominant wind field



Number of particles per cm^3



Size of particles in nm



nvPM number dispersion modelling with Lasport

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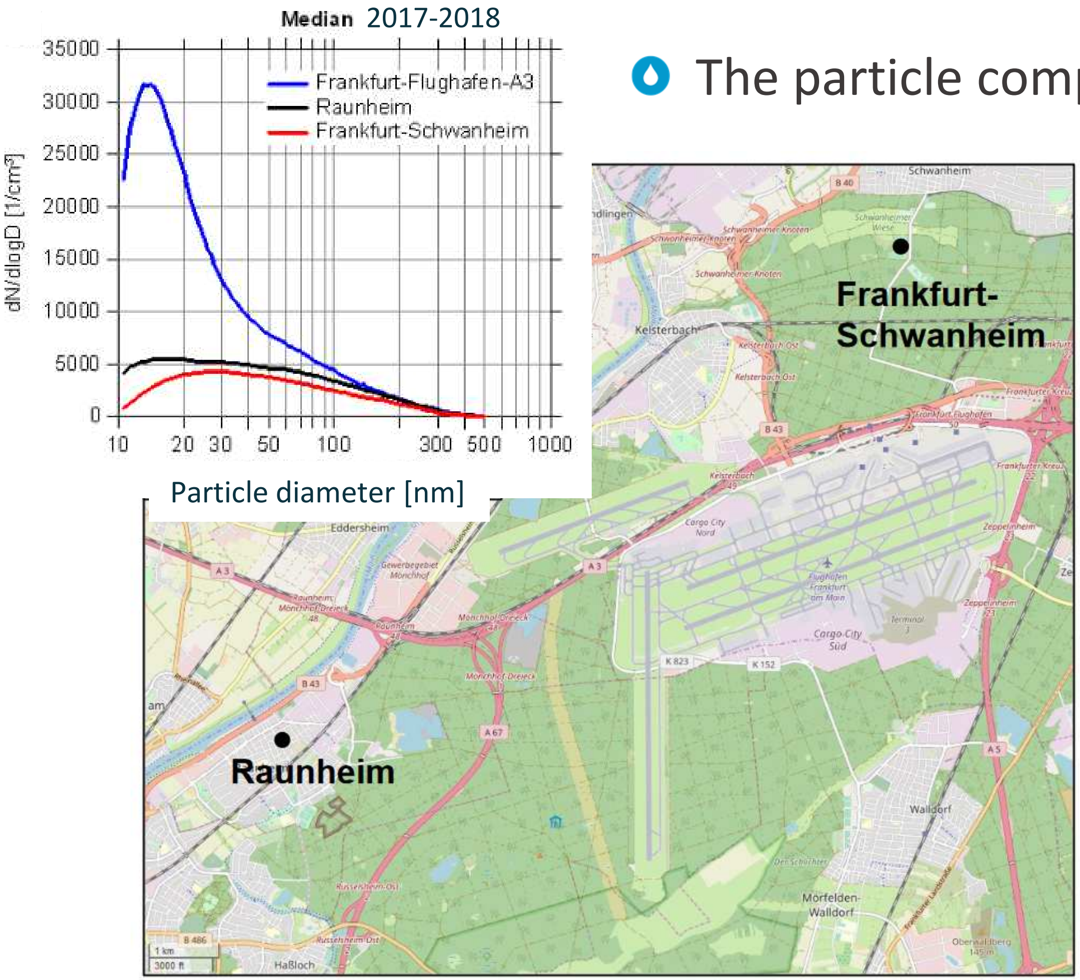
Air Quality at Airports – Particles concern

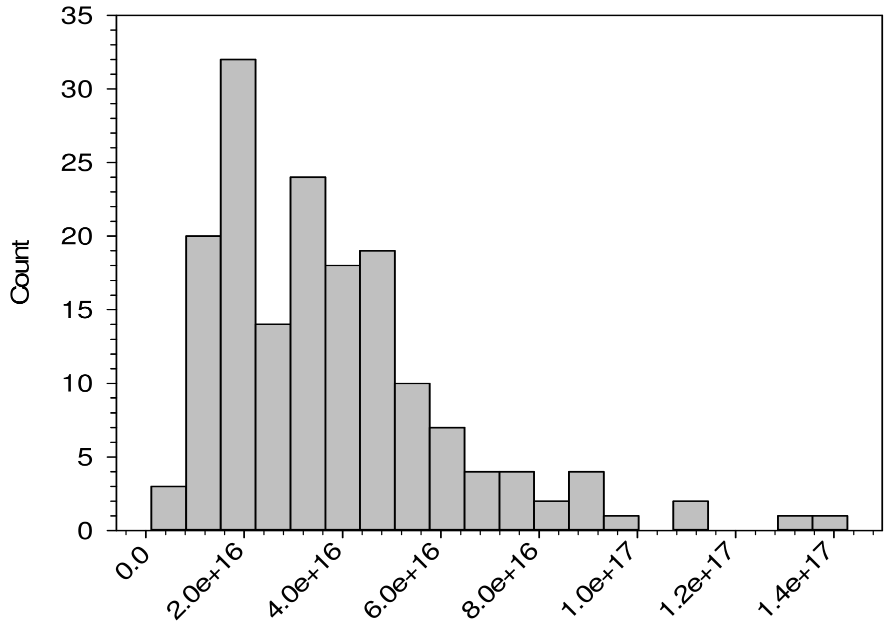
UFPs at Frankfurt Airport

- Airports are a source of UFPs that can be transported in the far surrounding



- The particle composition (e.g. nvPN fraction) is unknown

Histogram of 281 take-off events on 3 days (2015) at FraPort



Source: HLNUG, 2. Intermediate Report on Measurements of the regional air quality on UFP in the area of the Frankfurt Airport, 20.08.2019

Source: DLR

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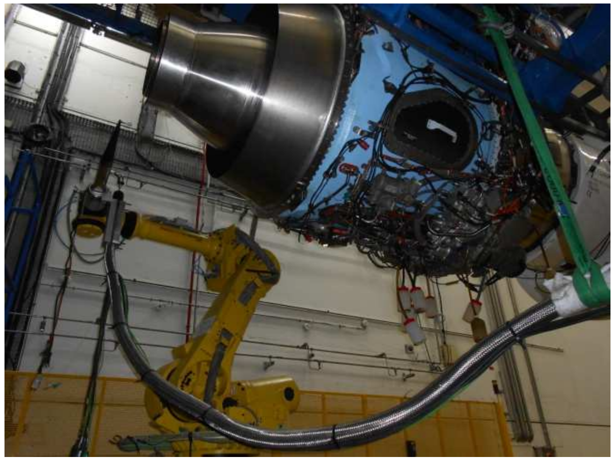
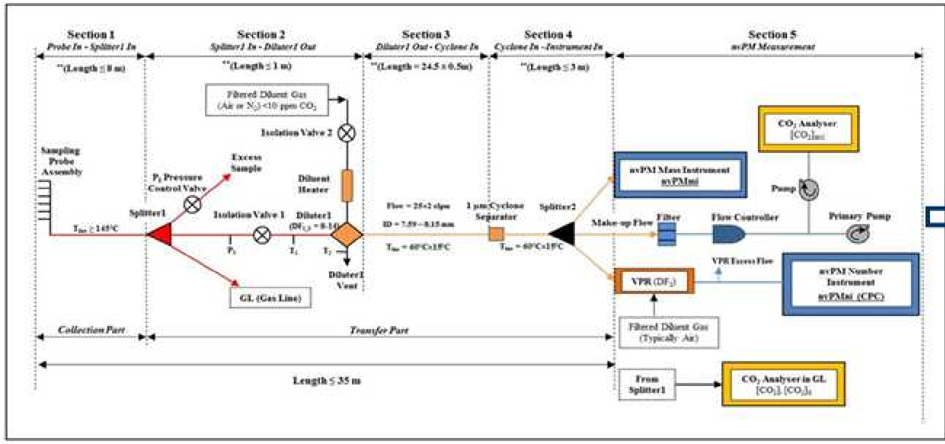
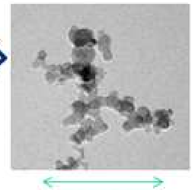
Ultra fine particles regulation: nvPM ICAO standards

- First standard based on mass concentration of non volatile particles (nvPM) ; will be applied to all in production engines >1/01/2020 with take-off thrust F00 > 26.7kN
- Second standard validated at CAEP11 (February 2019). Based on ICAO LTO cycle and on DP/F00=f(F00) type metric. Will apply to all new engines for which certification application date will be done > 1/01/2023. A relatively tolerant limit will apply also to all in production engines.
- nvPM are measured with a very strict protocol to guarantee minimum variability linked to measurement system and the way it is operated







$$nvPM\ mass\ concentration\ limit\ line\ [\mu g/m^3] = 10^{\{3+2.9 \times Foo^{-0.274}\}}$$

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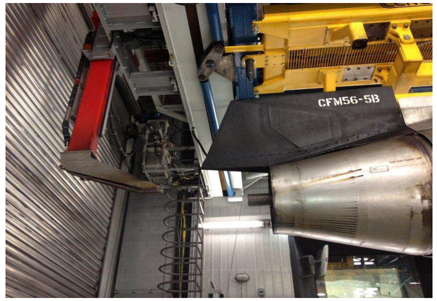
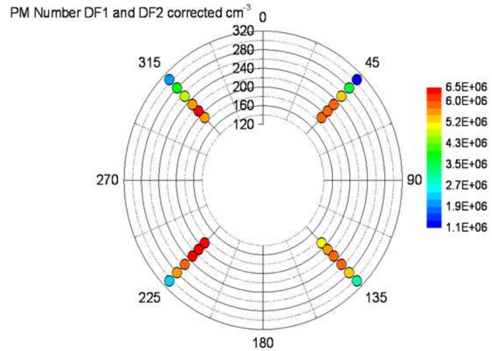
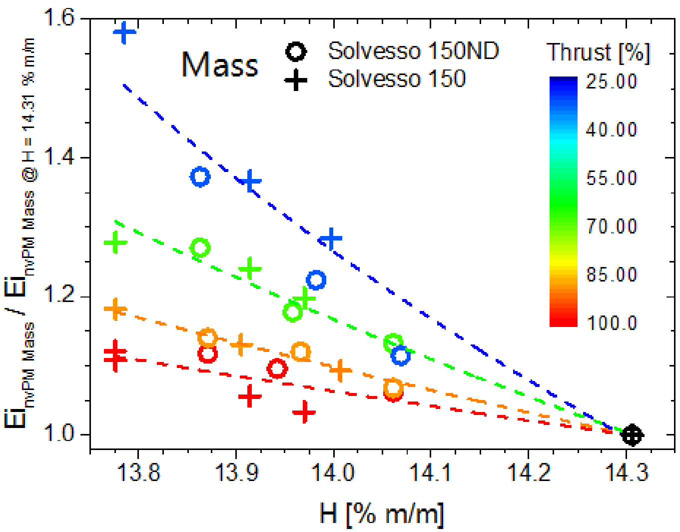
Fuel composition potential to reduce nvPM

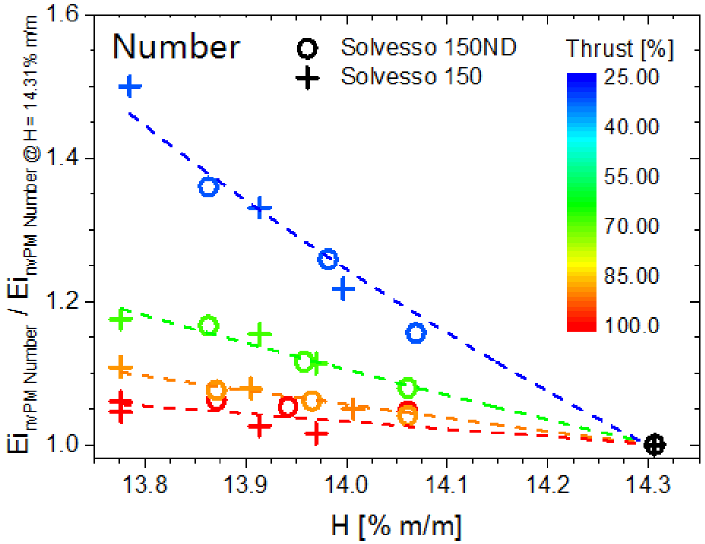
CFM56 results (A-PRIDE campaign)

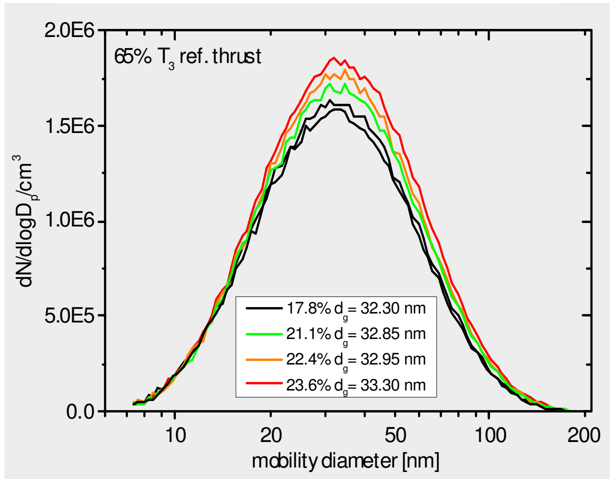
- FOCA funded campaign in Zurich, in 2015 on CFM56-7B23/3 engine (with Empa, ETH Zürich, SR Technics, GE, Safran-AE)
- Analysis of Fuel composition effect (aromatic content)











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Fuel composition potential to reduce nvPM

RR Generic Combustor Design with Air Blast Atomiser (Jetscreen)

JETSCREEN

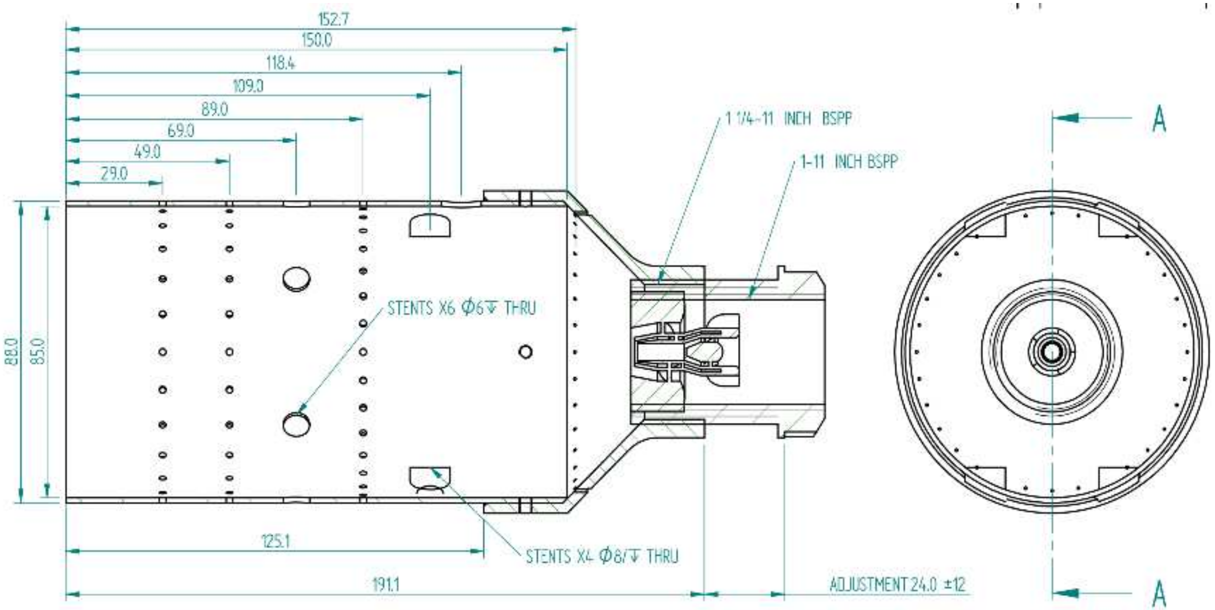
- Gas Turbine Research Centre (Port Talbot, UK)

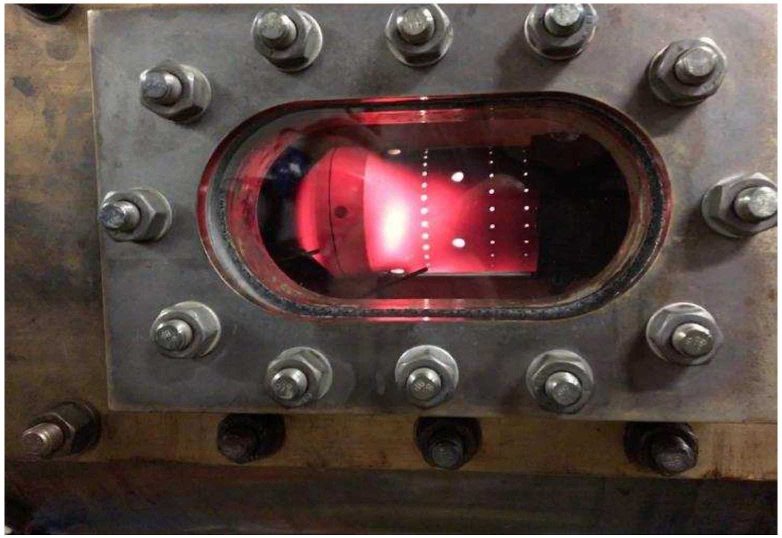
High Pressure Optical chamber

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

Rolls-Royce

Combustor design





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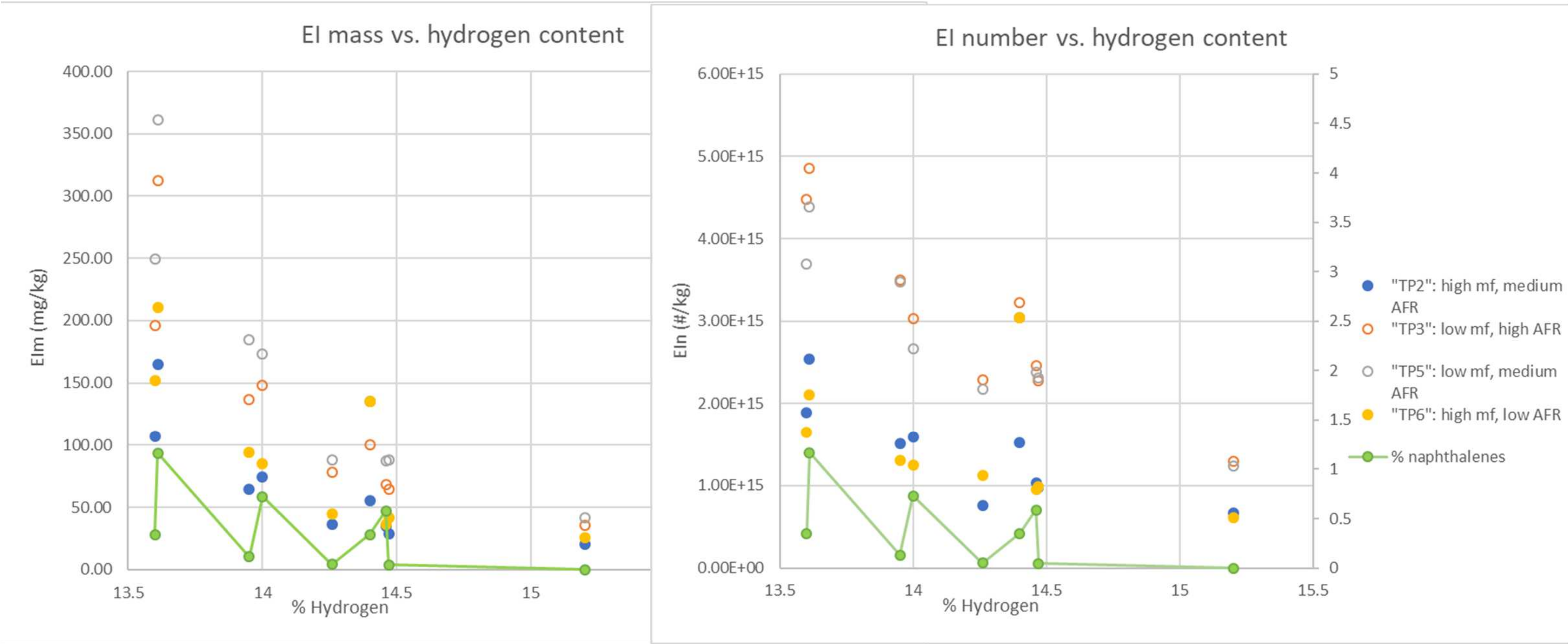
Fuel composition potential to reduce nvPM

RR Generic Combustor Design with Air Blast Atomiser (Jetscreen)

EI particle number/mass vs Hydrogen Content

(calculations fully corrected for fuel composition and sampling system particle losses)



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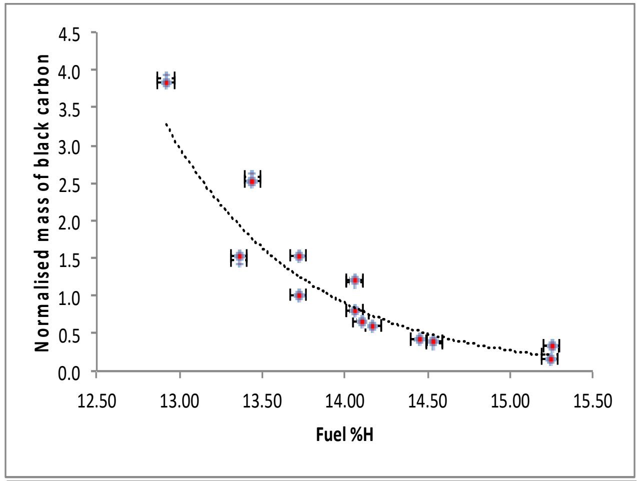
Fuel composition potential to reduce nvPM

Honeywell auxiliary Power Unit test results (Jetscreen)

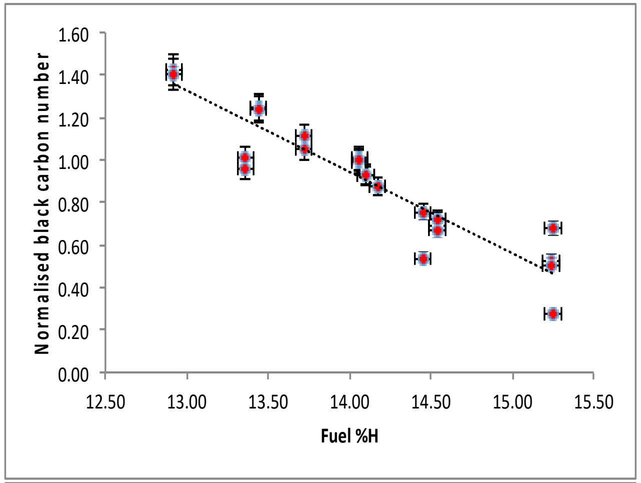
- Reverse flow single can combustor with OPR ≈ 5;
- Non-adiabatic constant pressure combustion;

The University Of Sheffield. Manchester Metropolitan University



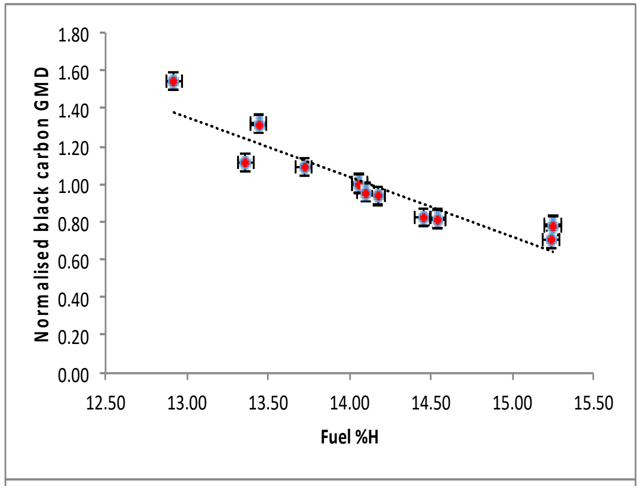
nvPM mass

➢ First order parameterization ($R^2 > 0.9$)



nvPM number

➢ First order parameterization ($R^2 > 0.85$)



nvPM size (GMD)

➢ First order parameterization ($R^2 > 0.85$)

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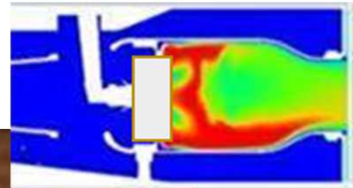
Fuel composition potential to reduce nvPM

Safran tubular combustor tested at Onera (Jetscreen)

- Representative of the business jet engine Silvercrest annular combustor
- Onera M1 rig (up to 25 bars) ; Measurements:
  - nvPM: mass, number, size ; vPM: size, number, chemical caracterisation
- Tests: 4 LTO cycle points + cruise point & **4 Fuels**
  - ref JetA1 (A1), desulf fuel (A1.2), 100%ATJ (B1), 70%/30% ATJ blend (E1)
- The campaign was completed on 25th Nov

Onera M1 high pressure test rig



Silvercrest representative tubular combustor (2019)

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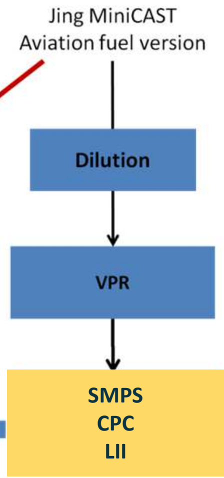
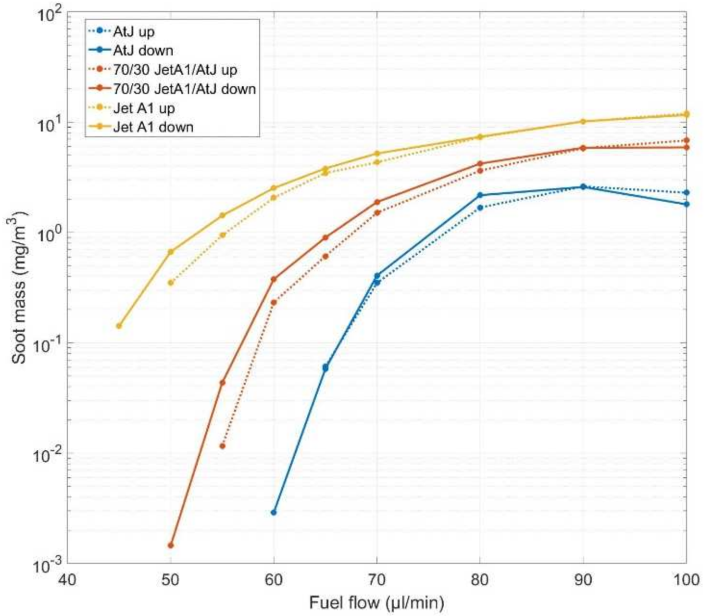
Fuel composition potential to reduce nvPM

Onera CAST results (Jetscreen)

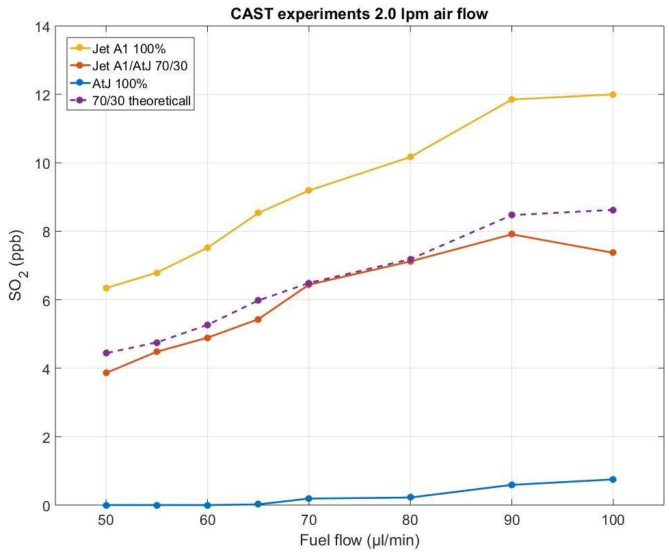


Effect of using different types of fuels on soot properties

- nvPM number concentration
- nvPM mass concentration
- Size distribution
- Estimation vPM number concentration



Fuel ID	Fuel Description
A1	Jet A-1 ASTM D7566
A1.1	Jet HT1
A1.2	Jet HT2
A1.3	Jet HT3
B1	ATJ-SPK
B2	HEFA
B3	CHCJ-ARA
C1	High aromatics, no S, low volatility (IBP>220 °C)
C2	Inter aromatics, no S
C3	Low aromatics, no S
C5	Inter volatility (200 °C<IBP<220 °C)
D2	100 s
E1	Jet A-1 + ATJ H/C=A1.1
E2	Jet A-1 + HEFA H/C=A1.1
E3	Jet A-1 + ATJ H/C=A1.4
E4	Jet A-1 + HEFA H/C=A1.4
E5	70 % Jet A-1 + 30 % ATJ-SPK (B1)
F1	ECLIF ref 3 (Jet A-1)
F2	ECLIF ref 4 (Jet A-1)
F3	Sustainable Alternative Jet Fuel 1: 51 % Ref 3 + 49 % HEFA
F4	Sustainable Alternative Jet Fuel 2: 70 % Ref 4 + 30 % HEFA
F5	Sustainable Alternative Jet Fuel 3: 49 % Ref 3 + 34 % Ref 4 + 17 % HEFA



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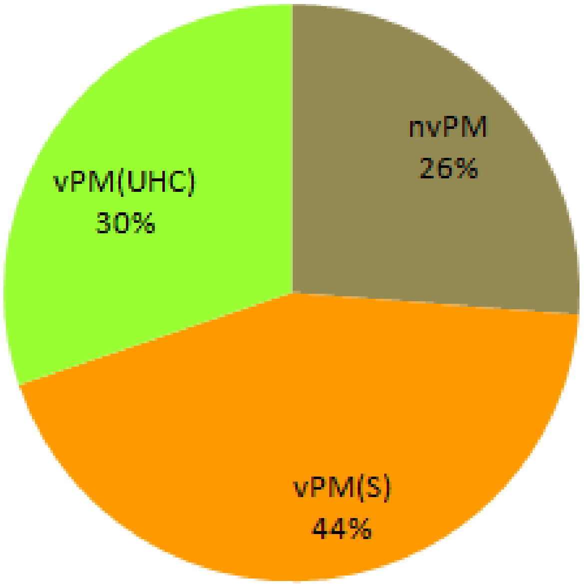
Fuel composition potential to reduce sulfur based aerosols:

Recall of FOA3 approach

- Reduction of sulfur content permits to reduce sulfur based volatile particles. Fuel sulfur content reduction is then naturally beneficial on PM2.5 reduction at airports.
- Using FOA3 (ICAO Doc 9889), Sulfur based volatile EI:
  - **EIvol(S)** = 3.3% * (M(SO4)/M(S)) * FSC ≈ **FSC** (EI expressed in g/kg ; FSC en%)
  - FSC = Fuel Sulfur Content ; FOA3 conservative value by default = 0.063%

PM2.5 contributions break-down using FOA3 applied to CFM56-5B family



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Conclusion

- Previous results, including recent ones from Jetscreen, confirm that removing aromatic content from fuel, and preferentially below current ASTM drop-in fuels 8% limit, permits important nvPM reduction (up to 1 order in the best situation)
- Results as well as simple FOA3 correlation, show proportionality of sulfur based aerosols emissions (contributing to vPM) to fuel sulfur content.
- Assuming that engine compatibility is fully verified (one of the focus of JETSCREEN), minimizing the aromatic or sulfur content in future drop-in fuels (respecting the current limit or even going beyond), could therefore have interesting air quality benefit at airports. This would be beneficial also for fossil kerosene.

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